(NASA-CR-170463) SKYMAP SYSTEM DESCRIPTION: STAR CATALOG DATA BASE GENERATION AND UTILIZATION (Computer Sciences Corp.) 663 p HC A99/MF A01 CSCL 03A

N83-17430

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G3/89 08310

CSC/SD-76/6041UD2

SKYMAP SYSTEM DESCRIPTION: STAR CATALOG DATA BASE GENERATION AND UTILIZATION

(REVISION 2)

Prepared For
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
Greenbelt, Maryland

CONTRACT NAS 5-24300
Task Assignment 84812

JUNE 1979

CSC

COMPUTER SCIENCES CORPORATION

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June 21, 1979

National Aeronautics and Space Administration
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Attention: Mr. R. Werking
Code 581.2
Bldg. 23, Room E-451

Subject: Contract NAS 5-24300
Task Assignment 84812
SKYMAP Maintenance

Dear Mr. Werking:

Submitted herewith is document CSC/SD-76/6041UD2, "SKYMAP System Description: Star Catalog Data Base Generation and Utilization (Revision 2)," which was prepared under task 84812. This document is a reissue and update incorporating corrections of minor typographical errors. The GSFC program library number associated with this document is G00606.

Yours truly,

M. Plett

Dr. M. E. Plett
Technical Area Manager
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SKYMAP SYSTEM DESCRIPTION: STAR CATALOG

DATA BASE GENERATION AND UTILIZATION

(REVISION 2)

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-24300
Task Assignment 83400

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PREFACE

This document is intended to serve as a specifications document, design document, system description, and user's manual. Because of the different uses intended, and because four different computer programs are involved, it has been written in modular form. Each section may be used independently, except that definitions given in Sections 1 and 2 are used throughout.

Section 1 is an introduction to the SKYMAP star catalog system and data base. Section 2 provides a system overview and specifies how each program fits into the system. Section 3 contains the scientific procedures used to gather and analyze the data that forms the primary data base. Section 4 is a description of the format of this data base and a definition of each data word. Sections 5 through 9 contain detailed software descriptions of each program in the system.

This revision incorporates minor changes necessitated by discovery of various errors or shortcomings in the SKYMAP system.

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ABSTRACT

This document details the specifications, design, software description, and use of the SKYMAP star catalog system. The SKYMAP system was developed to provide an accurate and complete catalog of all stars with blue or visual magnitudes brighter than 9.0 for use by attitude determination programs. Because of the large number of stars which are brighter than 9.0 magnitude, efficient techniques of manipulating and accessing the data were required. These techniques of staged distillation of data from a Master Catalog to a Core Catalog, and direct access of overlapping zone catalogs, form the basis of the SKYMAP system.

The collection and transformation of data required to produce the Master Catalog data base is described. The data flow through the main programs and levels of star catalogs is detailed. The mathematical and logical techniques for each program and the format of all catalogs are documented.

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SECTION 1 - INTRODUCTION

SKYMAP[1] is a collection of four computer programs leading to the creation, maintenance, and use of a series of star catalogs; these catalogs contain accurate positional and magnitude information suitable for use by attitude determination and analysis programs using star camera data. By "star camera," we refer to a nonintegrating scanning/tracking photometer. The star camera is used as an attitude determination sensor by comparing observed star positions with positions of real stars taken from a star catalog (see, for example, Reference 1). SKYMAP has been designed primarily to satisfy the requirements imposed by the Ball Brothers Research Corporation (BBRC) star camera (see Reference 2). Star catalogs used by previous missions such as the Small Astronomy Satellite-A and-B, the Orbiting Solar Observatory-I and H, and the Small Scientific Satellite are not adequate because they do not contain many of the relatively dim stars which are detectable by the BBRC instrument.

The only two existing catalogs which contain a large proportion of the required stars are the Henry Draper (HD) (Reference 3) and Smithsonian Astrophysical Observatory (SAO) (Reference 4) catalogs. Neither of these has star magnitudes sufficiently accurate for the purposes discussed below. Therefore, a new catalog had to be created by merging data from the HD, SAO, and other catalogs (see Section 3).

[1]The term "SKYMAP" will be used to refer to the entire collection of programs.

1.1 THE NEED FOR SKYMAP

Star cameras similar to the BBRC instrument are being used or are planned on a large number of spacecraft, including the following:

- Small Astronomy Satellite-C (SAS-C)
- High Energy Astronomy Observatory (HEAO-A, -B, and -C)
- International Ultraviolet Explorer (IUE)
- Multimission Modular Satellite (MMS) series, including AIRSAT, LANDSAT-D, STORMSAT, and the Gamma Ray Explorer (GRE)

For these spacecraft missions, fine attitude determination with an accuracy on the order of 1 arc-minute or better will be dependent upon star camera data. Except for SAS-C, rough attitude determination, with an accuracy on the order of 1 degree, will also primarily rely on star camera data.

To calculate an attitude from star camera data, one must be able to identify the stars which were observed by the camera. The basis of many star identification algorithms is some form of pattern matching. This technique may fail if there are insufficient star observations, if the reference star catalog does not contain stars which the camera observed, or if the reference star catalog contains too many stars not observable by the camera.

Star observations may be scarce because the period of analysis must be kept sufficiently small so that the spacecraft motion is known over the interval. For SAS-C, some analysis segments contain no more than five or six valid observed data points. Therefore, it is important that as few observed data points as possible be "lost" due to catalog incompleteness.

Ideally, the star catalog will contain all and only those stars that the camera might see. This avoids extraneous points in the reference pattern with which the observed pattern must be matched. In practice, it is impossible to reach this ideal.

Stars near the detection limit of the camera will not be observed consistently because of photon statistics and the slowly changing sensitivity of the camera. Therefore, the catalog must either (1) contain these stars, and hence contain stars which sometimes are not observable, or (2) not contain them, thereby lacking stars that sometimes are observable. If it is necessary to maximize the use of observed data, even stars with a low probability of detection must be included in the catalog.

An ideal star catalog would also contain exact magnitude information. However, brightness of the catalog stars is not precisely known. Star magnitudes are routinely measured on the Ultraviolet-Blue-Visual (UBV) system established by Johnson (see Reference 5). UBV magnitudes are not available for many of the dimmer stars detectable by the BBRC star camera. For these stars, the relatively inaccurate photovisual-photographic magnitudes reported in the HD and SAO catalogs must be used. However, the star camera sensitivity normally does not match exactly any of the filter-photometer combinations of these systems. Therefore, stellar magnitude data must be converted to the magnitude as seen by the star camera, called the "instrumental magnitude."

If the instrumental magnitudes in the star catalog are not precise, it is impossible to eliminate stars which are too faint to be detected by the camera without inadvertantly eliminating others which are sufficiently bright. Therefore, if the goal is catalog completeness, it is necessary to include more stars in the catalog than would otherwise be needed for a specific application. The instrumental magnitude must be determined with as much precision as is possible, so that the size of the catalog is minimized, thereby saving computing time and decreasing the probability of misidentifications.

1.2 REQUIREMENTS OF THE SKYMAP CATALOG

The SKYMAP catalog will be used by star identification routines and fine attitude determination routines. For the former, it must be complete to the camera's limiting magnitude, have accurate instrumental magnitudes and reasonably accurate positions; for the latter, it must contain accurate star positions. Other information, such as data on multiple stars or stars of variable brightness, should also be included so that analytical programs can avoid using such stars, if this is desirable.

In order to support the BBRC star camera, which will be used on the SAS-C and HEAO-A spacecraft, the following attributes are required for the SKYMAP catalog:

- It must contain all stars with either blue (B) or visual (V) magnitude brighter than 9.0.
- It must contain star positions (epoch 2000.0) accurate to 1 arc-second. Less accurately known positions must be flagged.
- It must contain proper motions to allow calculation of the star positions at epochs other than 2000.0 with minimum degradation of positional accuracy.
- It must contain observed or derived UBV magnitudes for all stars.
- It must contain information concerning the spectral energy distribution of the catalog stars in order to assist in accurate calculation of instrumental magnitudes.
- It must contain data concerning multiple star systems and stars of variable brightness for editing purposes.

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1.3 THE NEED FOR SEVERAL FORMS OF THE CATALOG

To fulfill the requirements of the SKYMAP catalog stated above, approximately 255,000 stars must be included in the catalog. With 540 bytes of data per star, this requires over 135 million bytes of storage.

Clearly, such a large catalog is not suitable for day-to-day operations. It may be too large to store conveniently on disk and would take too much time to access. On the other hand, fewer stars in the catalog or fewer data words per star would make it impossible to fulfill the completeness and accuracy requirements for the catalog.

The solution is the use of a hierarchy of three catalogs. The first is called the "Master Catalog". It contains all SKYMAP data (540 bytes) for all the stars within the 9.0 magnitude limit. Due to its size, the Master Catalog is normally stored on tape.

The second level is the "Mission Catalog", which contains that subset of Master Catalog data relevant to a particular spacecraft mission, and is created from the Master Catalog. When creating the Mission Catalog, unneeded parameters in the Master Catalog may be dropped, or a brighter limiting magnitude may be established. Parameters which will not change over long periods of time (for example, star positions at a selected epoch) may be calculated and stored in the Mission Catalog. The Mission Catalog will be much smaller than the Master Catalog. Because accessing the Master Catalog to create the Mission Catalog is time consuming, the Mission Catalog should contain enough data so that minor changes in star camera operational parameters during the course of mission support do not make it necessary to re-create it.

The Mission Catalog is optional. All SKYMAP programs that would read the Mission Catalog can read the Master Catalog instead. The advantage of using a Mission Catalog is the decreased computer time needed to read it. However, if it is not possible to define the parameters which will be required by a mission before program development, it may be impossible to define a Mission Catalog.

The third level in the catalog hierarchy is the "Run Catalog". The Run Catalog, used on a day-to-day basis by attitude determination programs, is created as a subset of the Mission Catalog. It contains the minimum data needed by attitude determination programs--the star number and the star position at a specific epoch. Up to four additional words of information may also be included; these may include, for example, instrumental magnitude, spectral type, position quality flag, or angular distance to the nearest neighboring star.

The Run Catalog contains the minimum number of stars allowable consistent with the limiting magnitude constraint. If any of the parameters in the Run Catalog must be updated during the mission, it is regenerated from the Mission or Master Catalog. For example, should the instrumental wavelength response of the star camera change, the Run Catalog would be re-created.

Therefore, the Run Catalog is as small as is operationally feasible. For SAS-C, it contains approximately 21,000 stars and 5 words of data per star. Because there is some data redundancy and a small amount of unused space required by the storage and retrieval techniques, estimates of how much disk storage is needed are deferred until Section 6.

Although the Run Catalog is as small as possible, it is still not efficient to have to read the entire catalog every time it is accessed. For this reason, the Run Catalog is presorted into zones. This scheme minimizes core storage and computer time requirements for programs which use the star catalog, at the expense of a modest amount of disk storage. A full description of zone definition is contained in Section 5.

The Run Catalog is output either as a direct-access disk file, or as a sequential tape file from which the disk file can be created. Analytical programs use this disk file in conjunction with an interface program to retrieve the star catalog data.

SKYMAP provides the software to read the Run Catalog and create a star catalog in computer core. This will be referred to as the "Core Catalog". Strictly speaking, it is not a member of the SKYMAP hierarchy of catalogs because it is not a permanent data set, but the Core Catalog will be discussed extensively in Sections 6 through 9.

1.4 GENERAL REQUIREMENTS FOR THE SKYMAP SYSTEM

The following SKYMAP capabilities provide for the creation, maintenance, and use of one or more of the star catalogs:

- Gathering, sorting, and analyzing the data necessary for the creation of the Master Catalog.
- Providing for selection of a subset of the Master Catalog to be included in the Mission Catalog. SKYMAP allows the user to generate secondary parameters based upon data contained in the Master Catalog (such as position at a specified epoch).
- Creating a sequential (tape) version of the Run Catalog.
- Providing for the transfer of the entire sequential Run Catalog, or any part thereof, to a direct-access (disk) file.
- Allowing for updating data in the Master and Mission Catalogs and adding new data as it becomes available.
- Providing routines for efficient interfacing of analytical routines with the star catalogs.

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SECTION 2 - SYSTEM OVERVIEW

SKYMAP can be visualized as both (1) a primary data base, called the Master Catalog, which contains data relevant to the calculation of stellar positions and magnitudes, and (2) a series of computer programs which prepare this data for use by attitude determination programs.

The Master Catalog was created by merging data from 11 star catalogs. Reference 44 summarizes the catalogs used. Based on the information contained in these catalogs, a number of additional parameters are computed and entered into the Master Catalog.

Given the existence of the Master Catalog, four SKYMAP programs provide efficient access to the data. Figure 2-1 shows the system data flow starting with the Master Catalog and ending with use of the data by the attitude determination programs.

Program UPDATE is used to select a subset of Master Catalog data needed by a specific mission, and also provides for the calculation of additional mission-dependent parameters based on Master Catalog data. The output from UPDATE is the Mission Catalog. UPDATE may also be used to correct Master Catalog data, add stars to or delete stars from the Master Catalog, and provide printed output of Master Catalog data.

The Mission Catalog (or the Master Catalog if no Mission Catalog is used) is sorted by program CAT into subcatalogs covering overlapping zones in the sky. Such presorting is required because the Mission Catalog is normally too large to be stored in core or to be sorted for each application.

The output from CAT is the Run Catalog, which can be in either sequential or direct-access format. If the direct-access output (on disk) is chosen, then the Run Catalog can be accessed directly. If sequential output (on tape) is chosen, program SWITCH must be used to read the entire Run Catalog, or any specified subset of it, and place it on direct-access disk file. Conservation of disk storage

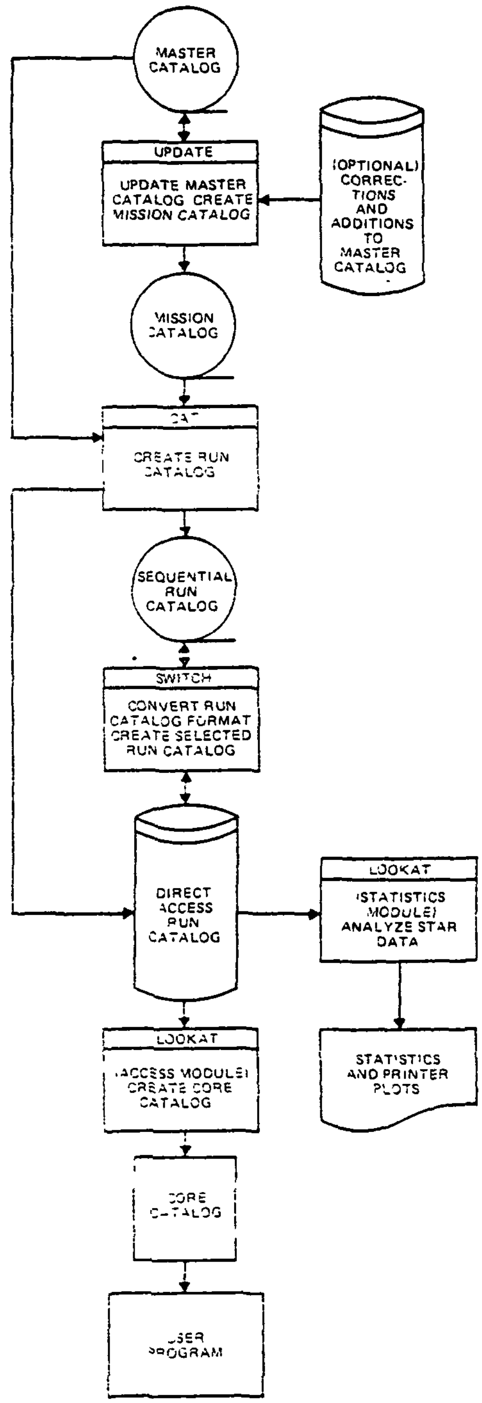

Figure 2-1. SKYMAP System Data Flow

is realized by using tape output from CAT and converting only that subset of the Run Catalog for which an immediate need is anticipated to direct-access format (using SWITCH).

Attitude determination programs access the Run Catalog by use of program LOOKAT, which requires a direct-access version of the Run Catalog as input. A call to a LOOKAT driver subroutine causes LOOKAT to read the Run Catalog and store the star data for the required part of the sky in the Core Catalog.

Using the Run Catalog as input, the statistics module of LOOKAT produces plots of stars in selected portions the sky and statistical information concerning star density. The remainder of this section is a more detailed discussion of the capabilities of each segment of SKYMAP.

2.1 THE MASTER CATALOG

The Master Catalog is a data base from which SKYMAP programs produce the Mission and Run Catalogs. It contains all the information necessary to compute stellar positions and instrumental magnitudes to as high a precision as possible. It also contains information on multiple and variable stars to be used for editing. The Master Catalog contains all known stars with either a B or V magnitude brighter than 9.0. The limiting magnitude has been chosen to ensure that all stars detectable by star cameras similar to the BBRC instrument are included in the Master Catalog. A technique for analyzing the completeness of a star catalog is given in Reference 45.

2.1.1 Types of Data Included in the Master Catalog

The Master Catalog contains data for the following four purposes:

- Cross-referencing the star to other catalogs
- Calculating the star's instrumental magnitude
- Calculating the star's position at any given epoch

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- Determining the star's positional error, distance from other stars, and magnitude variability for use by data editing algorithms

The main reference star number is the SKYMAP catalog number, assigned as specified in Section 3. Several other catalog numbers are available to assist in cross-referencing stars with other printed catalogs.

The calculation of the star's instrumental magnitude for inclusion in the Run Catalog usually requires detailed information on the spectral energy distribution of the star as seen from the Earth. The standard system of measuring stellar brightness is the UBV system (Reference 5). This system provides measurements taken with instrumental profiles of effective wavelength around 3500 Angstroms (Å) (Ultraviolet), 4400Å (Blue) and 5500Å (Visual) (i.e., UBV). The profile full widths at half maximum transmissivity (the "half widths") are about 900Å. Unfortunately, about half the stars in the Master Catalog had no observed UBV measurements. Therefore, it was necessary to convert the less accurate photographic and photovisual magnitudes from Reference 3 or Reference 4 into equivalent UBV magnitudes. This is accomplished by deducing the overall energy distribution from the existing magnitudes, the spectral type, and information on interstellar reddening. The interstellar reddening, in turn, is usually deduced from the distance of the star and its position in galactic coordinates. Section 3 and Reference 6 contain more detailed descriptions of how instrumental magnitudes can be calculated from information contained in the Master Catalog. To enable calculation of the instrument magnitude, the Master Catalog contains, when available, the following:

- HD photographic and photovisual magnitudes (one or the other is almost always available)
- HD spectral type (virtually always available)
- Spectral type and luminosity class on the modern Morgan-Keenan (MK) system (Reference 7)

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- UBV magnitudes
- Radial velocity (to help derive stellar distance)
- Heliocentric parallax (to help derive stellar distance)
- A derived stellar distance (to calculate the reddening index)
- A derived reddening index
- Derived values of the UBV magnitudes where no measurements exist
- Various data sources and quality flags

To calculate the star's position at a given epoch, the following are included:

- The right ascension and declination at epoch 2000.0
- The proper motion in the directions of right ascension and declination

Additionally, the Master Catalog contains information on stars having variable brightness and/or multiple stars to allow the user to identify and/or edit such stars from computations.

2.1.2 Generation of the Master Catalog

The Master Catalog is generated by combining the data from various existing catalogs. Because existing catalogs generally contain only one or two types of data, it is necessary to combine them before derived values of the distance, reddening index, and UBV magnitudes can be calculated. The process of gathering the data is described in Section 3; Section 3 also details how additional parameters have been computed from the basic data.

2.2 THE MISSION CATALOG

For a specific application, the Mission Catalog is smaller and more convenient to use than the Master Catalog. It is smaller because only those stars bright enough to be of interest to the mission are retained, and because much star data

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contained in the Master Catalog can be discarded or combined into more compact form once mission-dependent parameters are known. For example, positional and proper motion data in the Master Catalog are combined into position at the mission epoch in the Mission Catalog.

The Mission Catalog is not required because the Master Catalog can be substituted for it. This substitution, however, leads to increased computing time.

2.2.1 Variables Contained in the Mission Catalog

The Mission Catalog is complete down to a limiting magnitude specified by the user, but not to exceed that of the Master Catalog. The method of computation of the instrumental magnitude is also left to the user.

The Mission Catalog normally contains the following minimum data:

- HD number
- Position (right ascension and declination) at a user-specified epoch
- B and V magnitudes
- Reddening index
- Double star and variability flags

The user may specify additional words of output to be chosen from those available in the Master Catalog.

2.2.2 Program UPDATE

Program UPDATE generates the Mission Catalog from the Master Catalog. The following functions are performed by UPDATE:

- Calculation of derived parameters requested by the user
- Output of the Mission Catalog on a sequential file

- Printing of a summary of the Mission or Master Catalog upon request
- Providing a framework for altering, adding, or deleting data in the Master Catalog

2.3 THE RUN CATALOG

The Run Catalog is a presorted (possibly modified) version of the Mission Catalog. It is the catalog actually accessed by the mission's analytical programs. Section 6 gives a complete description of the Run Catalog, which is only briefly described in this section.

2.3.1 Organization and Content of the Run Catalog

The Run Catalog may be generated either in sequential or direct-access format. It contains sufficient data control records such that programs using the catalog may be run without additional user input describing the Run Catalog. The Run Catalog is complete to a user-specified limiting instrumental magnitude, not to exceed that of the Mission Catalog, and contains the following data:

- HD number
- Geocentric inertial coordinates of the star's unit vector at the user-specified epoch
- Up to four additional words of information at the discretion of the user, one of which is normally the instrumental magnitude

2.3.2 Program CAT

Program CAT generates the Run Catalog from the Mission Catalog (or optionally, from the Master Catalog). Functions performed by CAT are as follows:

- Calculates geocentric inertial coordinates (XYZ) from right ascension and declination (if necessary).

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- Defines overlapping zones that collectively cover the entire sky.
- Sorts the stars of the input catalog into subcatalogs, one subcatalog for each zone.
- Outputs the subcatalogs on a sequential or direct-access file.
- Outputs control word records describing the Run Catalog. Programs using the Run Catalog obtain all the information they need to access the subcatalogs from these control word records.
- Provides the user with the opportunity to alter the input data as desired.

2.3.3 Run Catalog Manipulation

The Run Catalog is normally generated by program CAT on a sequential (tape) file. It is transferred to a direct-access disk file by program SWITCH. If desired, only selected subcatalogs need be stored on disk. Program SWITCH allows the user to select which subcatalogs to store. Programs interface with the Run Catalog by using the "access module" of program LOOKAT, which is described in Section 2.3.4.

2.3.3.1 Program SWITCH

The functions performed by program SWITCH are as follows:

- Copies the Run Catalog, or portions of it, from one file to another.
- Converts the Run Catalog from sequential format to direct-access, or vice versa.
- Selects specified subcatalogs for copying to the output file.
- Prints a map of the portions of the celestial sphere covered by the selected subcatalogs.

- Rewrites the control word records of the Run Catalog to reflect the presence or absence of each subcatalog in the output file.
- Prints the contents of the subcatalogs.

2.3.3.2 Selection of Subcatalogs by SWITCH

Program CAT normally produces the Run Catalog on tape. Those portions of the Run Catalog which are needed by analytical programs are then copied onto disk storage. Program SWITCH performs this function.

If it is inconvenient to determine which parts of the sky will be observed by the star camera(s), or if disk storage is plentiful, the user can avoid having to rerun SWITCH periodically by placing the entire Run Catalog on disk using SWITCH. CAT can also generate the Run Catalog directly onto disk.

The user may wish to save disk space by using SWITCH to store only portions of the Run Catalog--namely, those portions it is anticipated will be used in the near future. This technique is especially useful when the star camera(s) will be pointing in nearly the same direction(s) for an extended period of time. In that case, only those subcatalogs which might fall within the range of the camera(s) are needed.

2.3.3.3 Interactive Capability in SWITCH

Program SWITCH can be run interactively on the IBM S/360-95 under the Time-Sharing Option (TSO), in the foreground mode. TSO output is confined to monitoring information reporting on the progress of the program. Error messages are sent to the TSO terminal if conditions within the program require an abnormal termination.

The advantages of running SWITCH interactively are as follows:

- It can be run in the foreground mode, thus decreasing turnaround time.

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- Internal error messages allow the user to correct errors in his NAMELIST or other input without waiting for printed output.

Both of these advantages may be critical when an operational support system has to reconfigure the Run Catalog quickly.

2.3.4 Using the Run Catalog--Program LOOKAT

Program LOOKAT is a modularized program performing several related functions. Its basic function is interfacing the Run Catalog with analytical programs. Secondary functions include creating various plots of the stars found in portions of the sky and performing statistical surveys over sections of the celestial sphere.

Because LOOKAT has been modularized, only those subroutines needed to perform a specific task have to be linked into the user program.

LOOKAT contains two basic modules to perform these duties. The Access Module is discussed in Section 2.3.4.1 and the Statistics Module is discussed in Section 2.3.4.2.

2.3.4.1 The Access Module

The Access Module of program LOOKAT is designed to allow interface with the Run Catalog with a minimum of effort. Basically, a program which needs star catalog information supplies LOOKAT with a star camera optical axis pointing or pointings. LOOKAT then loads the relevant subcatalog into calling sequence arrays. There are three ways to specify the region of interest, which will be described below.

Input to the Access Module consists of the Run Catalog, which must have been loaded onto disk in direct-access format, and calling sequence variables which instruct LOOKAT to load specified subcatalog(s) into arrays. All the information about the Run Catalog which LOOKAT needs is available in the control records of the Run Catalog. A call to LOOKAT's initialization subroutine at the

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start of the program causes LOOKAT to read these records and initialize appropriate internal arrays.

Because all necessary information concerning the Run Catalog exists within itself, the user program need only give LOOKAT sufficient information to determine which subcatalogs are needed. This may be done in the following three ways:

- First, the star camera optical axis pointing(s) may be input. LOOKAT then produces a "cap" catalog by loading into core the star information for all stars within a specified angular distance of the optical axis.
- Second, LOOKAT can produce a "band" around the celestial sphere corresponding to the path of the camera optical axis through the sky as the spacecraft spins. To do this, the spin axis pointing, and the angle at which the star camera is mounted relative to the spin axis, must be input.
- Third, LOOKAT can produce a "wedge" out of such a band by specifying the above and, in addition, specifying a starting (or central) optical axis pointing and the length of the desired "wedge."

For the second and the third methods, the Access Module of program LOOKAT also has the capability of sorting the stars in the output catalog by longitude. Stars dimmer than a specified limiting magnitude may be excluded from the output catalog.

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2.3.4.2 The Statistics Module

The Statistics Module of program LOOKAT provides statistical data about, and printer plots of, a region of the sky covered by a user-specified Core Catalog. The Statistics Module can perform the following:

- Call Access Module subroutines to produce a Core Catalog in either the cap, band, or wedge forms. This Core Catalog is then processed by the rest of the Statistics Module.
- Select stars from the Core Catalog for further processing on the basis of one of the star data words being within user-specified bounds.
- Compute right ascensions and declinations of Core Catalog stars.
- List the Run Catalog data control record parameters.
- List all the stars in user-specified Run Catalog zone subcatalogs.
- Sort the Core Catalog in either ascending or descending order of any star data word.
- List any user-specified subset of Core Catalog stars which are contiguous in either ascending or descending order of any star data word.
- Provide a count of stars in the Core Catalog which fall into each user-defined range of any star data word, and produce a histogram of these frequencies.
- Produce a printer plot of the Core Catalog stars.
- Correlate any two star data words for Core Catalog stars, using either a linear or quadratic fit, and generate a printer plot of the data and the resulting fitted curve.

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2.4 PROGRAM DESCRIPTION FORMATS

Each of the programs previously discussed in this section is fully described in one of the later sections of this document. The descriptions of each program adhere to the following format:

- Program requirements and interface with SKYMAP
- Capabilities and logical program flow
- Mathematical specifications
- Baseline diagram and unit descriptions
- Common area descriptions
- Operating guide

2.4.1 Unit Description Format

All unit descriptions in this document start the description on a new page, and all pages associated with a unit contain the unit name in the upper right-hand corner, which will aid in frequent reference to the subroutine. For each program described, the main routine is described first, followed by the subroutines in alphabetical order. Unit descriptions that appear in this document under the appropriate program description contain the following information.

DESCRIPTION: A brief statement of the unit's function and possibly a short narrative description of the unit flow is given.

CALLING SEQUENCE: SUBROUTINE OR FUNCTION. The name and argument list, if any, are supplied to indicate usage by the subprogram.

COMMON AREAS REFERENCED: The names of the COMMON areas referenced by the subprogram are listed in alphabetical order. The COMMON areas are described in the appropriate COMMON area description section.

EXTERNAL REFERENCES: All references to subprograms other than System 360 and FORTRAN library routines are listed in alphabetical order.
CALLED BY: Units that access this subprogram are listed in alphabetical order.

INPUT/OUTPUT DATA SETS: If this heading is present, a description of the type of input/output (e.g., diagnostic output or star catalog input) is given along with the data set reference numbers.

ERROR MESSAGES: A brief description of the cause of the error and the message that appears are given. If this heading is not present, no error messages are originated by the subprogram. More details concerning the cause of the error, the program action taken, and user response to be taken are given in the appropriate programs' User's Manual subsection.

The above information is presented on the first page(s) of the unit description. The succeeding pages of the description list, in tabular form, all the variables that interface with the unit through the calling sequence or COMMON blocks. The tables contain the following column headings:

- Name: The variable names are listed in their order of appearance in the calling sequence. Arrays are designated by their maximum dimensions.
- Symbol: If a symbol has been associated with the variable, it is listed in this column.
- I/O: The letter I indicates that the variable must be known under some or all circumstances before calling the unit; O indicates that the variable may have been modified prior to exiting the unit; and I/O indicates both conditions.
- Type: R*8 indicates that the variable is an 8-byte floating-point number and R*4 indicates a 4-byte floating-point number. I*4 indicates a 4-byte integer number and I*2, a 2-byte integer number. L*1 indicates a 1-byte logical variable. (Frequently, arrays of these variables are used to store literal information.)

- Interface: The letters C.S. indicate calling sequence interface; for other variables, the name of the COMMON block is given.

- Description: The variable is briefly described.

2.4.2 COMMON Area Description Format

All COMMON area descriptions in this document start the description on a new page and all pages associated with a COMMON area contain the COMMON name (e.g., /CATCOM/) in the upper right-hand corner. COMMON area descriptions that appear in this document under the appropriate program description contain the following information:

DESCRIPTION: A brief description of the contents of the COMMON area is given.

FORM: The variables appear in the order required for proper use of the COMMON area (i.e., COMMON/name/list).

REFERENCED BY: The names of subprograms in alphabetical order that reference the named COMMON area are given.

VARIABLES: The COMMON area variables are in tabular form, with the following headings:

- Name: Variable names are listed in the order in which they appear in the COMMON area. Arrays are designated by their maximum dimensions.

- Type: R*8 indicates that the variable is an 8-byte floating-point number and R*4 indicates a 4-byte floating-point number. I*4 indicates a 4-byte integer number and I*2, a 2-byte integer number. L*1 indicates a 1-byte logical variable.

- Description: The variable is briefly described.

2.4.3 NAMELIST Description Format

All NAMELIST descriptions in this document start the description on a new page and all pages associated with a particular NAMELIST contain the NAMELIST name (e.g., &CATIN) in the upper right-hand corner. NAMELISTs for each program are presented in alphabetical order. NAMELIST descriptions that appear in this document under the appropriate program description contain information under the following column headings for the NAMELIST variables:

- Name: Variable names are listed in the order in which they appear in the NAMELIST. Arrays are designated by their maximum dimensions.
- Type: R*4 indicates a 4-byte floating-point number and I*4 indicates a 4-byte integer number.
- Default: If the variable is set in BLOCK DATA or a DATA statement, its default value is given.
- Description: The variable is briefly described. The units and acceptable limits of the variable are also given.

SECTION 3 - MASTER CATALOG DATA

The Master Catalog is the data base for the SKYMAP system. It contains 540 bytes of data for each of approximately 255,000 stars.[1] The Master Catalog contains all known stars with either B or V magnitude brighter than 9.0.

This section describes the types of data included in the Master Catalog, the source for the data, and if derived, the procedure used in the derivation. Section 4 contains the details of the Master Catalog data organization.

3.1 STARS INCLUDED IN THE MASTER CATALOG

The basis for the Master Catalog is the Henry Draper (HD) catalog (Reference 3). As the HD is nearly complete to 9.0 visual magnitude, most stars bright enough to be included in the Master Catalog are HD stars. Additional stars were added from Blanco (Reference 8), the Smithsonian Astrophysical Observatory (SAO) star catalog (Reference 4), the AGK-3 star catalog (Reference 39), the Catalog of Visual Double Stars (Reference 33), and Kukarkin (Reference 9).

To determine which stars from the above references to include in the Master Catalog, the B and V magnitudes of each star were compared against a limiting value of 9.0 plus an allowance for the anticipated error in the star magnitude. The value for this anticipated error depended upon the method by which the B and V magnitudes were obtained.

For stars with measurements in the UBV system, the error allowance was taken to be 0.1 magnitude. Stars for which only photovisual and photographic magnitudes exist had these converted to B and V using the procedures given in Section 3.4.4. Error allowances for these stars varied according to the procedure used, which in turn depended on whether one or both of the photographic

[1]The number of stars in the Master Catalog will vary slightly as additions, corrections, and deletions are made to the data base.

and photovisual magnitudes existed. A discussion of this methodology is given in Section 3.4.2 (see Table 3-8).

3.2 STAR NUMBERS AND CROSS-REFERENCES

3.2.1 SKYMAP Number

A new numbering system has been introduced for all stars in the SKYMAP catalog. The system is open ended so that stars may be added to the catalog without renumbering the existing stars. Each SKYMAP star was assigned a number of the form XXYYZZZZ, where XX is the hours of right ascension, epoch 2000.0; YY is the minutes of right ascension, epoch 2000.0; and ZZ is a running index, starting at 0001. The advantage to this numbering system is that all SKYMAP stars have a SKYMAP number, whereas only a fraction of them have HD or SAO numbers.

3.2.2 HD Number

The star number from the HD catalog (Reference 3) is the basic number assigned to each Master Catalog star. For those few stars (approximately 1 percent) not having an HD number, numbers were assigned sequentially beginning at 500001.

3.2.3 Durchmusterung (DM) Number

The HD catalog also contains star numbers from the extensive Durchmusterung catalogs--the Bonner Durchmusterung (BD) (References 10 and 11), the Cordoba Durchmusterung (CD) (References 12 and 13), and the Cape Photographic Durchmusterung (CPD) (Reference 14).

Collectively, these catalogs cover the entire sky, with the BD extending from the North Pole to declination -23 degrees, the CD ranging from declination -23 degrees to -62 degrees, and the CPD covering the remainder of the sky. The Master Catalog contains BD numbers where available, then CD numbers, and CPD numbers if no others exist.

The Durchmusterung number consists of a zone number referring to the declination of the star at the epoch of the Durchmusterung (1855.0), and a sequential number within that zone. Therefore, star -2° 317 is the 317th star between declinations -2 degrees and -3 degrees. For ease in computation, these numbers have been converted into a single integer, defined as

$$D = \begin{cases} 100000\,(Z + 100) + N, & \text{for Z positive} \\ 100000\,(Z + 99) + N, & \text{for Z negative} \end{cases} \tag{3-1}$$

where D = converted Durchmusterung number

Z = zone number

N = sequential number

The difference in the formula for positive and negative Z is to allow for the existence of both a +0 degree zone (stars with declinations between 0 and +1 degrees) and a -0 degree zone (stars with declinations between 0 and -1 degrees).

3.2.4 SAO Number

The SAO number was obtained from the SAO catalog (Reference 4). Approximately 93 percent of the Master Catalog stars have SAO numbers.

3.2.5 Miscellaneous Identifiers

Several other star names and numbers have been included in the Master Catalog to permit easy cross-reference to printed star catalogs. They are

- The HR number from the Yale Catalog of Bright Stars (YBSC) (Reference 15). Only about 9100 of the brightest stars have HR numbers.
- The Flamsteed name, obtained from the YBSC (for example, alpha Orionis). Only about 1000 bright stars have Flamsteed names.

- The number from the Wilson Catalog of Radial Velocities (Reference 16).
- The number from the Aitken Double Star Catalog (ADS) (Reference 17).
- The sequence number from Kukarkin's General Catalog of Variable Stars (Reference 9).
- The star name from the General Catalog of Variable Stars (for example, BU Camelopardi).

3.2.6 Star Number Cross-Reference Tables

Because the various source catalogs have different star numbering systems, a cross-reference of the HD number, the SAO number, and the DM number was created. Right ascension and declination, epoch 2000.0, and visual magnitude are also cross-referenced for each star. The cross-reference was obtained by combining data from the SAO catalog (Reference 4), which gives the SAO and DM number, and the HD catalog (Reference 3), which gives the HD and DM number.

To create the first approximation to the cross-reference index, the SAO and the HD catalogs were sorted in order of DM number and then merged. The HD position, precessed to 1950.0, was checked against the SAO position for all stars that were matched with one another by the above procedure. Checks were also performed on the photovisual and photographic magnitudes and the spectral types. Tolerances of 120 arc-seconds were applied in right ascension and declination, 1.0 magnitude in magnitude, and 0 in spectral type. All stars failing one or more checks were examined manually, and the only entries accepted were those for which the discrepancy noted above could be explained (e.g., by an inadvertent inversion of magnitudes in one of the source catalogs), and for which the other parameters passed the stricter tests of tolerances--30 arc-seconds in right ascension and declination and 0.5 magnitude in magnitude.

All SAO stars not matched with HD stars by this method were then tested against all HD stars in an attempt to add entries to the cross-reference table. Entries were matched on the basis of position, magnitude, and spectral type. The tolerances were approximately 30 arc-seconds in right ascension and declination, 1.0 magnitude in magnitude, and 0 in spectral type. Each case was reviewed manually to remove spurious matches among members of multiple star systems. The resultant cross-reference table has over 320,000 entries, with each entry containing at least two of the three star numbers considered.

3.3 POSITIONAL DATA

Catalog star positions are given at the standard time (epoch), 2000.0. To determine a star's position at an epoch different from the catalog epoch, corrections must be made for precession of the Earth's axis and proper motion of the star across the sky. The Master Catalog provides this information.

3.3.1 Position at a Standard Epoch

The SAO catalog (Reference 4) is the primary source of star positions because it contains accurate data for a large number of stars. For those stars not in the SAO catalog, positions are taken (in order of preference) from the following: the AGK-3 catalog (Reference 39), the HD catalog (Reference 3), the HD Extension (Reference 40), Mermilliod (Reference 19), or Blanco (Reference 8). All positions are precessed from the catalog epoch to epoch 2000.0 using the precession correction noted in Section 3.3.3 and the proper motion (if known) discussed in Section 3.3.2.

To determine whether or not to substitute AGK-3 data for the SAO and HD positions already in SKYMAP, the accuracy and reliability of the AGK-3 catalog was evaluated and no evidence was found to dispute the accuracy estimates contained in either the SAO or AGK-3 catalogs. It is therefore concluded that the AGK-3 catalog is probably slightly more accurate than the SAO. However, a small number of large differences in AGK-3 and SAO positions and proper motions were found which are probably due to errors in the AGK-3 catalog. The accuracy of SKYMAP star positions taken from the SAO is adequate for analysis of star sensor data because the errors are typically less than 1 arc-second. Therefore, AGK-3 data, although slightly more accurate, is not substituted for SAO data. The accuracy of SKYMAP star positions taken from non-SAO sources is very poor, with typical errors of about 35 arc-seconds. Therefore, AGK-3 data was substituted for this data to improve accuracies, accepting the small number of errors so introduced. Reference 39 is a detailed report of this procedure.

Positions are reported as right ascension and declination at epoch 1950.0 and as a unit vector in a rectilinear coordinate system defined by

$$
\begin{aligned}
X &= \cos \delta \cos \alpha \\
Y &= \cos \delta \sin \alpha \qquad (3\text{-}2) \\
Z &= \sin \delta
\end{aligned}
$$

where α is right ascension, δ is declination, and (X, Y, Z) is the unit vector. The (X, Y, Z) coordinate system definition corresponds to the projection of the Earth's North Pole onto the celestial sphere as the Z-axis, and the vernal equinox as the X-axis, at epoch 2000.0. The Y-axis completes a right-handed orthonormal coordinate system such that $\hat{Z} = \hat{X} \times \hat{Y}$. Neglecting the effect of heliocentric parallax (always less than 1 arc-second), this coordinate system is identical to the Geocentric Inertial frame (G.I. frame) used repeatedly for attitude determination functions.

3.3.2 Proper Motion

The SAO proper motion in right ascension and in declination is reported in the Master Catalog for all SAO stars. Non-SAO stars have proper motions from the AGK-3 catalog (Reference 39), or have no observed proper motion. For lengths of time of up to several hundreds of years, proper motion corrections can be applied linearly, as follows:

$$
\begin{aligned}
\alpha_I &= \alpha_J + \mu_\alpha \Delta t \\
\delta_I &= \delta_J + \mu_\delta \Delta t
\end{aligned}
\qquad (3\text{-}3)
$$

where (α_I, δ_I) = right ascension and declination at epoch I

(α_J, δ_J) = right ascension and declination at standard catalog epoch J

(μ_α, μ_δ) = proper motion per year in right ascension and declination

Δt = the difference in years and fraction of a year between epoch I and epoch J

3.3.3 Precession

Because the Earth's spin axis precesses with a period of 26,000 years, star positions in the quasi-G.I. system defined above change slowly. This effect, known simply as "precession," was computed for each star using the following equations:

$$
(X'\ Y'\ Z') = \begin{bmatrix} \cos\zeta \cos\theta \cos Q - \sin\zeta \sin Q & -\sin\zeta \cos\theta \cos Q - \cos\zeta \sin Q & -\sin\theta \cos Q \\ \cos\zeta \cos\theta \sin Q + \sin\zeta \cos Q & -\sin\zeta \cos\theta \sin Q + \cos\zeta \cos Q & -\sin\theta \sin Q \\ \cos\zeta \sin\theta & -\sin\zeta \sin\theta & \cos\theta \end{bmatrix} \begin{pmatrix} X \\ Y \\ Z \end{pmatrix} \qquad (3\text{-}4)
$$

where $\zeta = 2305''.268$

$\theta = 2003''.787$

$Q = 2306''.060$

X, Y, Z = the star's geocentric inertial unit vector at the initial epoch

X', Y', Z' = the star's geocentric inertial unit vector 100 years later

The precession in right ascension (P_α) and declination (P_δ) per year is obtained by converting both unit vectors to right ascension (α) and declination (δ) by using

$$\alpha = \tan^{-1}(Y/X)$$

$$\delta = \sin^{-1}(Z)$$

$$\alpha' = \tan^{-1}(Y'/X')$$

$$\delta' = \sin^{-1}(Z')$$

and then differencing the results

$$P_\alpha = \alpha' - \alpha$$

$$P_\delta = \delta' - \delta$$

The precession correction, like proper motion, may be applied linearly over periods of several hundreds of years by substituting P_α and P_δ for μ_α and μ_δ, respectively, in Equation (3-3).

3.3.4 Accuracy of Star Positions

The accuracy of a star position at a given epoch (e.g., 1975.0) depends upon the accuracy of the catalog position at the standard epoch and of the corrections used to convert position to the desired epoch. The Master Catalog standard epoch is 2000.0. For SAO stars, the error in catalog right ascension and declination at epoch 2000.0 is usually less than 2 arc-seconds. AGK-3 stars have equally accurate positions (see Reference 41). Precession corrections are accurate to better than 0.001 arc-second per year. Stars not in the SAO or AGK-3 have positional errors of up to 2 arc-minutes at epoch 2000.0. Because no proper motions exist for these stars, additional errors build up at a maximum rate of about 1 arc-minute per 100 years for epochs after 2000.0.

However, most stars have proper motions an order of magnitude smaller than this. Conversion to earlier epochs decreases the error slightly up to about 1900.0, because proper motion errors resulting from the conversion of HD positions to epoch 2000.0 disappear. They begin to build up again at the stated rate for epochs prior to 1900.0.

3.4 SPECTRAL TYPE AND MAGNITUDE DATA

Star sensors will detect stars that are "sufficiently" bright on an "instrumental scale," where "sufficiently" and "instrumental scale" vary from sensor to sensor. Star catalogs report brightnesses as magnitudes defined by the logarithmic function

$$m \equiv -2.5 \log_{10} G + C \tag{3-5}$$

where m = star magnitude

G = star brightness

C = constant defined arbitrarily at the time the magnitude system is created

Therefore, higher magnitudes represent dimmer stars.

Because detector responses are based on the star brightness on an instrumental scale, the user may wish to compute the instrumental magnitude of catalog stars, defined by

$$m' = -2.5 \log_{10} \left\{ \int_0^\infty \frac{E(\lambda)}{r^2} [1 - I(\lambda)] \, P(\lambda) \, d\lambda \right\} + C \tag{3-6}$$

where λ = wavelength

$E(\lambda)$ = star energy flux as a function of wavelength at some standard distance

r = distance from the star to the Earth, in units of the standard distance

$I(\lambda)$ = interstellar absorption function as a function of wavelength, and is defined as the fraction of light of wavelength λ absorbed between the star and the Earth

$P(\lambda)$ = instrumental response as a function of wavelength, and is defined as the fraction of light incident on the sensor that produces an output signal, normalized to 1.0 at the wavelength of maximum response

$P(\lambda)$ is independent of which star is being observed, provided that the star is not so bright that it saturates the sensor. Consequently, it is a function of the detector used and does not appear in the Master Catalog. The constant, C, in Equation (3-6) is defined specifically for each system, and is discussed in Section 3.4.2.

The interstellar absorption function, $I(\lambda)$, can be deduced from the "interstellar absorption" discussed in Section 3.5.

The absolute stellar energy distribution, $E(\lambda)$, is given roughly at all wavelengths by the spectral type, discussed in Section 3.4.1. More precise but less comprehensive information on the apparent stellar energy distribution, $E(\lambda)/r^2$, is given by standard magnitudes, as discussed in Section 3.4.2.

The following quantities, available in the Master Catalog for each star, must be used to deduce instrumental magnitudes:

- Spectral class, luminosity class, and peculiarity code, collectively known as spectral type, either observed or converted from other variables
- Standard UBV magnitudes either observed or converted from other variables
- An interstellar absorption index as derived according to the procedures specified in Section 3.5

3.4.1 Spectral Type Data

The standard spectral type of the Master Catalog is the MK (Reference 7) spectral type, consisting of a spectral class, luminosity class, and peculiarity code. The spectral class is essentially a measure of stellar temperature; the luminosity class, of surface gravity; and the peculiarity code, of chemical composition, speed of rotation, and/or existence of an extended atmosphere. Collectively, these give an approximation to the absolute spectral energy distribution of the star. This approximation, however, becomes successively less accurate as one progresses towards wavelengths shorter than 4000 Å where the effects of variables other than those measured by spectral type become important.

MK spectral types were obtained from Jaschek (Reference 18) or, if not available there, from Blanco (Reference 8) and Mermilliod (Reference 19). Jaschek's catalog is a compendium of results from other observers and therefore sometimes contains more than one entry per star. Where different spectral types are listed for the same star, the one given most frequently has been adopted. If two or more were given with equal frequency, the first one listed was used. A similar procedure was followed for Blanco's and Mermilliod's catalogs.

Where no observed MK spectral type existed, the HD spectral class, as reported in the HD, SAO, or AGK-3 catalogs, was converted to an MK spectral type. The conversion was performed by obtaining tables of frequency of occurrence of MK spectral class, luminosity class, and peculiarity code for each HD spectral class, based on data for stars which had both HD and MK spectral types. The most frequently occurring values were adopted as the probable MK spectral type corresponding to the HD spectral class. Table 3-1 gives the result of this correlation. The converted peculiarity code is always taken to be zero (no peculiarities noted). The typical spread in MK spectral

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Table 3-1. SKYMAP Equivalent Spectral Types of HD Spectral Classes

HD SPECTRAL CLASS	SKYMAP SPECTRAL TYPE		NUMBER OF DATA POINTS
	SPECTRAL CLASS	LUMINOSITY CLASS	
Oa	B1*	–	2
Ob	B0*	–	1
Of	09.5	–	24
B0	B0.5	II	293
B1	B1	III	70
B2	B1	IV	267
B3	B3	V +	721
B5	B5	V +	606
B8	B8	V +	630
B9	B9	V +	849
B	B1	–	233
A0	A0	V +	2011
A2	A2	V +	940
A3	A3	V +	416
A5	A7	V +	381
A	A0	V +	151
F0	F0	V	612
F2	F2	V +	382
F5	F5	V +	845
F8	F8	V +	651
F	F0*	–	18
G0	G0	V +	1047
G5	G5	IV	1658
G	G0	V +	51
K0	K0	III +	2917
K2	K2	III +	750
K5	K5	III +	663
K	K1	III	30
Ma	M2	III +	328
Mb	M4	III +	136
Mc	M6*	III +	15
Md	M5*	III +	16

+MEANS THE LUMINOSITY CLASS NOTED WAS SHARED BY OVER HALF THE SAMPLE STARS.

*MEANS THE SPECTRAL CLASS CONVERSION IS VERY UNCERTAIN DUE TO SCARCITY OF DATA class for a given HD spectral class is about two-tenths of one class.[1] Results of a similar study of SAO and AGK-3 spectral types produced identical results except for M stars (see Table 3-2).

A similar study has been performed by the University of Michigan (Reference 20) based on their re-observation of all HD stars within approximately 37 degrees of the South Celestial Pole and with right ascension between 0 and 180 degrees. Their results tend to confirm those in Table 3-1. The Michigan study will be extended to cover the entire sky during the next several years. When complete, the results can be added to the Master Catalog, providing complete and uniform spectral classes for nearly all Master Catalog stars.

3.4.2 Magnitude Data

The standard magnitude system of the Master Catalog is the UBV system of Johnson (Reference 5). Figure 3-1 shows the spectral response curves for these magnitudes based on data from Reference 21.

The effective wavelengths of the U, B, and V magnitudes are approximately 3500 Å, 4400 Å and 5500 Å, respectively. Most star sensors in use are sensitive to wavelengths somewhere between these ranges. Occasionally, a sensor responds to shorter wavelengths down to about 2100 Å (e.g., the HEAO-A Experiment A-1 slit star sensor), for which no standard magnitudes exist.

Observed UBV data was primarily obtained from the compilations of Mermilliod (Reference 19) and secondarily from Blanco (Reference 8). Errors in measurement typically are 0.02 magnitude.

Whenever the Mermilliod catalog had more than one entry per star, the entries were averaged. The Blanco catalog also contained multiple entries for some stars. A study was performed paralleling that of Reference 22 to assess the

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[1] One spectral class is a whole "letter" difference, e.g., the difference between F5 and G5. A tenth of a spectral class is the difference, e.g., between G5 and G6.

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Table 3-2. SKYMAP Equivalent Spectral Types of SAO Spectral Class

SAO SPECTRAL CLASS	SKYMAP SPECTRAL TYPE		NUMBER OF DATA POINTS
	SPECTRAL CLASS	LUMINOSITY CLASS	
M0	M2	III +	411
M1	M3*	–	5
M2	M3*	–	7
M3	M4	III +	22
M4	M4	–	5

+MEANS THE LUMINOSITY CLASS NOTED WAS SHARED BY OVER HALF THE SAMPLE STARS

*MEANS THE SPECTRAL CLASS CONVERSION IS VERY UNCERTAIN DUE TO SCARCITY OF DATA.

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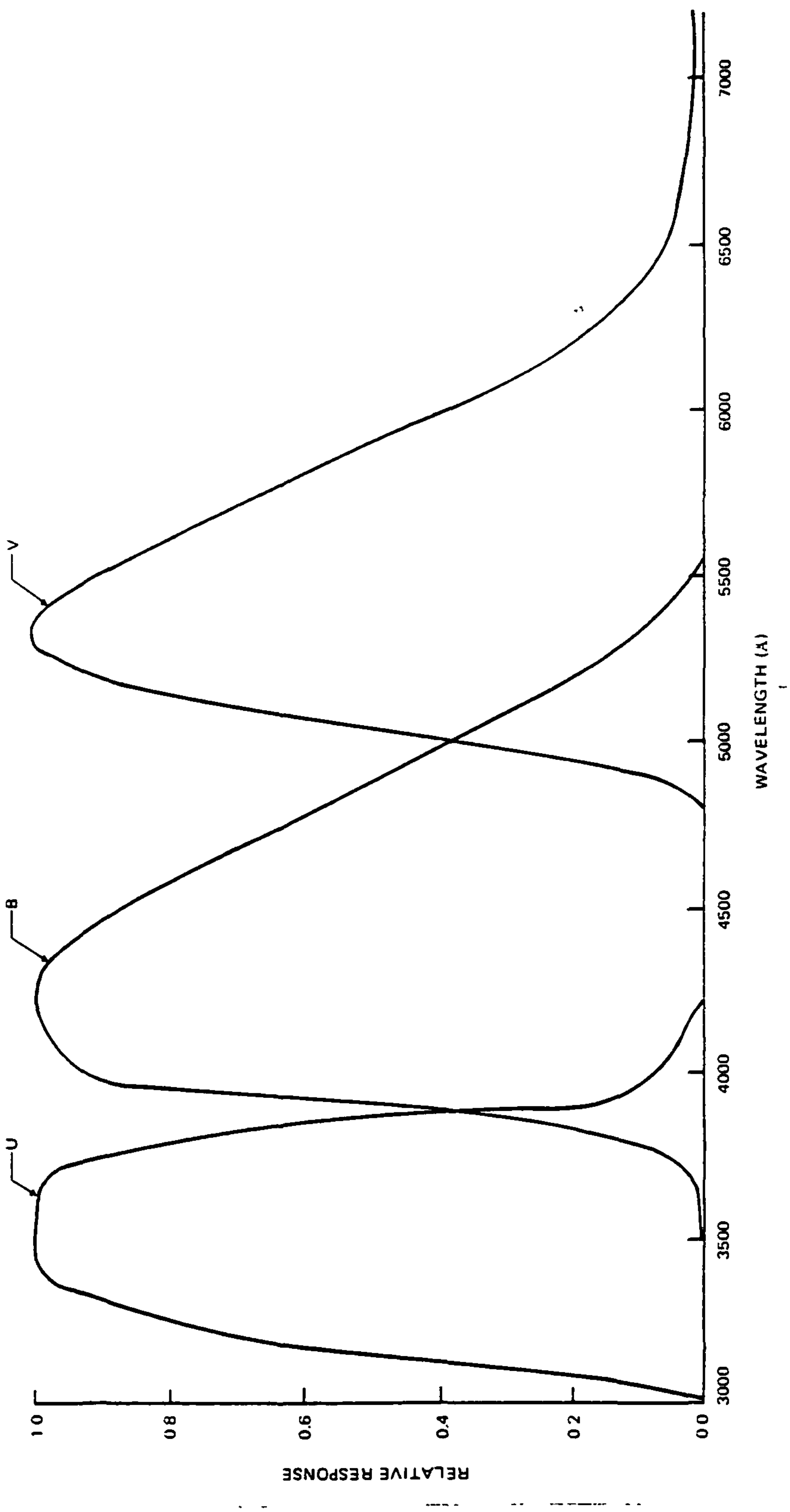

Figure 3-1. Relative Spectral Response Curves for U, B, and V Magnitudes

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reliability of each observer relative to the mean value of all observers. Mean errors were found to be 0.016 magnitude in V, 0.011 magnitude in the difference B-V, and 0.024 magnitude in the difference U-B. Observers having mean errors exceeding 0.03, 0.02, and 0.05 magnitudes for V, B-V, and U-B, respectively, were deemed to be less accurate than the norm, and their observations were given half weight in the subsequent averaging. A few observers who would have been down-weighted on the basis of this test were still accorded full weight if the results were based on fewer than 10 comparisons with other observers, or if the exclusion of a single data point brought the observer's mean error below the stated tolerances. The Master Catalog entry for Blanco magnitudes is a weighted average of all observations for the star. Each observation was given unit weight except those made by observers whose Blanco reference number is listed in Table 3-3. These were given a weight of 0.5.

Several highly discordant results were found between observers of the same star in the Blanco catalog. Whenever an individual observation deviated by more than 0.1 magnitude from the mean for that star, and when all other observations for the star agreed to within 0.1 magnitude, the deviant observation was deleted from consideration (given zero weight). Table 3-4 lists the observations which were deleted in their entirety because all data entries were discordant. Table 3-5 lists those for which portions of the observation were deleted.

For stars for which U magnitude data was not available, a conversion of other data to a U magnitude was performed (see Section 3.5). If B and V magnitudes were not available, they were derived from the HD, SAO, or AGK-3 photographic (ptg) and photovisual (ptv) magnitudes. The conversion equations were determined by a correlation of observed B and V magnitudes with ptg-ptv magnitudes for those stars having both types of magnitudes and also a spectral type.

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Table 3-3. Blanco (Reference 8) Observers Assigned Half Weight

	OBSERVATION		
	V	B–V	U–B
BLANCO OBSERVER REFERENCE NUMBERS	18 70 192 212	18 93 211 218 238 262	18

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Table 3-4. Blanco Data Points Deleted in Their Entirety

BLANCO STAR CATALOG NUMBER	BLANCO OBSERVER REFERENCE NUMBER
508	197
1771	12
1771	212
3039	405
4085	127
4262	122
4432	415
5237	197
8270	355
8908	44
9336	104
9336	355
9854	18
9854	34
12536	310
13272	378
14282	18
14520	34
14784	18
14784	34
16750	122
18764	84
18765	84
18765	211
19186	363

Table 3-5. Blanco Data Points Partially Deleted (1 of 2)

BLANCO STAR CATALOG NUMBER	DATA DELETED	BLANCO OBSERVER REFERENCE NUMBER
283	U–B	320
283	U–B	362
484	V	3
601	B–V	353
1161	B–V	75
1228	U–B	378
1320	V	197
2226	V	355
2341	B–V	373
2385	V	373
2385	U B	373
2444	V	83
2444	U–B	373
2449	V	83
2449	U–B	83
2530	V	10
2596	V	65
2596	V	84
3479	B–V	378
3479	B–V	379
3847	U–B	48
4127	U–B	116
4265	V	121
4265	V	127
4330	V	212
4632	U–B	3
4643	V	127
4643	V	355
5016	V	122
5384	V	78
5395	U–B	34
5513	U–B	60
5523	V	11
5526	B–V	234
5706	V	4
5832	V	223
6364	V	415
6967	V	378
7160	V	122
8401	U–B	18
8996	U–B	18
8996	U–B	34
9555	V	3
9669	U–B	18
10182	B–V	122
10413	V	33
10414	U–B	75
10675	U–B	422
11825	V	122
12102	B–V	122
12969	B–V	251
13042	V	34
13275	U–B	67
13275	U–B	362
13542	U–B	75
14217	V	362
14284	B–V	18
15299	V	212
15383	U–B	79
15383	U–B	88
15842	V	197
16324	U–B	296
16885	V	197
17026	U–B	79

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Table 3-5. Blanco Data Points Partially Deleted (2 of 2)

BLANCO STAR NUMBER	DATA DELETED	BLANCO OBSERVER REFERENCE NUMBER
17351	V	192
17597	V	119
17732	V	65
18081	V	378
18734	U–B	79
18909	B–V	25
18909	B–V	79
18909	U–B	79
18910	B–V	12

BLANCO STAR NUMBER	DATA DELETED	BLANCO OBSERVER REFERENCE NUMBER
18910	B–V	25
19011	U–B	34
19399	U–B	79
19726	B–V	120
19726	U–B	120
19855	B–V	251
19937	B–V	68
20036	B–V	121
21650	V	212

A magnitude-dependent correction factor was computed by averaging the quantity (V - ptv) for stars having both. The averaging was performed in V magnitude bins 0.5 magnitude in width and a smooth curve fit through the results (see Figure 3-2). A similar procedure was followed for (B - ptg) ; the results are given in Figure 3-3. The correction factors are given by

$$\begin{aligned} c_1 &= -0.24 + 0.03\ V \\ c_2 &= -0.161 + 0.0246\ B \end{aligned} \qquad (3\text{-}7)$$

This set of stars was then divided into subsets based upon spectral class as shown in Table 3-6. Linear least squares correlations of $(ptg + c_2)$ to B and V , $(ptv + c_1)$ to B and V , and both $(ptg + c_2)$ and $(ptv + c_1)$ to B and V were computed; however, it was found that the simpler relations given below resulted in correlations just as accurate.

For those stars having both ptv and ptg observed,

$$\begin{aligned} V &= ptv + a_1 + c_1 \\ B &= ptg + a_2 + c_2 \end{aligned} \qquad (3\text{-}8)$$

For those stars having only ptv observed,

$$\begin{aligned} V &= ptv \div a_1 + c_1 \\ B &= V + (B - V)^* \end{aligned} \qquad (3\text{-}9)$$

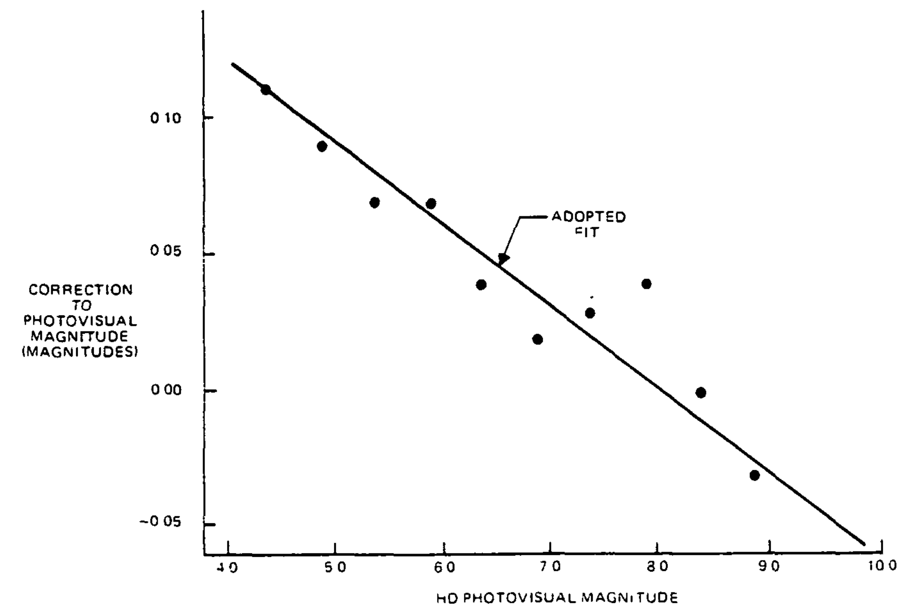

Figure 3-2. Correction to HD Photovisual Magnitude

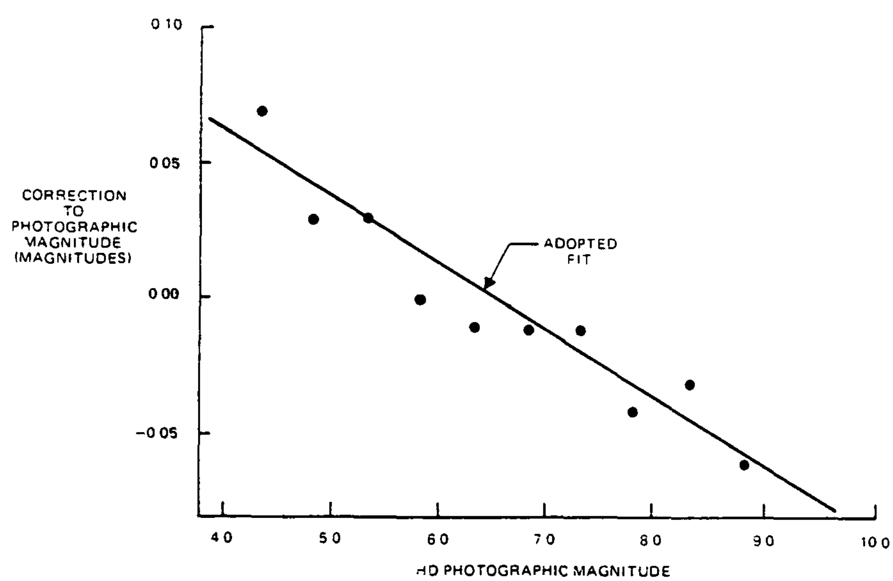

Figure 3-3. Correction to HD Photographic Magnitude

Table 3-6. Subsets of Spectral Class Used for Magnitude Conversion

CLASS NUMBER	RANGE OF MK SPECTRAL CLASS
1	O0–O9 5
2	B0–B3
3	B3.5–B7
4	B7 5–B9.5
5	A0–A3
6	A3.5–A7
7	A7.5–A9.5
8	F0–F3
9	F3.5–F7
10	F7.5–F9.5
11	G0–G3
12	G3.5–G7
13	G7.5–G9.5
14	K0–K3
15	K3.5–K7
16	K7.5–K9.5
17	M0–M3
18	M3.5–M9.5
19	R
20	N
21	C
22	S
23	WR, WC, WN

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For those stars having only ptg observed,

$$B = ptg + a_2 + c_2$$
$$V = B - (B - V)^* \qquad (3\text{-}10)$$

where $(B-V)^*$ is the mean difference of B and V magnitudes for the spectral class range.

Note that the values of $(B-V)^*$ do not correspond to intrinsic B-V values such as those reported in Reference 23. The latter are for stars having no interstellar reddening, whereas $(B-V)^*$ reflects the mean interstellar reddening of the subsets of stars analyzed.

The values of a_1, a_2, and $(B-V)^*$ which were obtained are listed in Table 3-7 for the appropriate spectral class ranges. The mean errors in converted B and V magnitudes were found to be about 0.1 magnitude in V and 0.15 in B. However, larger errors in B exist when B was obtained from Equation (3-9), and for V from Equation (3-10). The best estimates of these errors are shown in the form of error allowances presented in Table 3-8 for each configuration of methods for obtaining B and V. For purposes of this table, observed B and V magnitudes were assigned an error of 0.1 magnitude. The error allowance for source flags 3 through 11 are estimates of the error expected to be encountered when using these magnitude data.

The visual and photographic magnitudes given in the SAO catalog were converted to B and V by the technique used for the HD magnitudes. Figures 3-4 and 3-5 and Equations (3-11) and (3-12) give the correction factors as a function of magnitude (c_1 and c_2), and Table 3-9 gives the correction factors as a function of spectral type.

$$c_1 = \begin{cases} -0.199 + 0.023 \text{ ptv} & (\text{ptv} \le 7.75) \\ -0.64 + 0.08 \text{ ptv} & (\text{ptv} > 7.75) \end{cases} \qquad (3\text{-}11)$$

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Table 3-7. Correlation Results for Magnitude Conversion

SPECTRAL CLASS RANGE	a_1 (MAGNITUDES)	a_2 (MAGNITUDES)	(B–V)* (MAGNITUDES)
1	–0 20	+0.11	+0.25
2	+0.01	+0.08	+0 12
3	+0.03	+0.03	–0.03
4	+0 02	+0 02	–0.01
5	+0.06	+0.05	+0.11
6	+0.05	+0.07	+0.26
7	+0.05	+0.07	+0 29
8	+0.06	+0.03	+0.38
9	+0.06	+0.01	+0.47
10	+0.08	–0.02	+0 53
11	+0.05	+0.01	+0 64
12	+0 03	–0 03	+0.85
13	–0.01	–0.05	+0.93
14	–0.02	–0.02	+1 14
15	–0.04	+0.09	+1 40
16	+0.04	–0 07	–
17	–0.06	+0.02	+1 57
18	–0.06	0.00	+1 62
19	–0 12	+0.11	+1 25
20	–0.03	+0 11	–
21	–0.01	–0 01	–
22	–0 08	+0.06	–
23	+0.02	+0.05	+0 22

Table 3-8. Error Allowances for Various Methods of Obtaining B and V

MAGNITUDE SOURCE FLAG	MAGNITUDE SOURCE	ERROR ALLOWANCE (MAGNITUDES)
1	OBSERVED, REFERENCE 8 OR REFERENCE 19	0.1
2	OBSERVED, B OR V FROM REFERENCE 33; THE OTHER NOT GIVEN	0 1
3	CONVERTED HD OR SAO, USING EQ. (3–8)	0.4
4	CONVERTED HD OR SAO, USING EQ. (3–9)	0.5
5	CONVERTED HD OR SAO, USING EQ. (3–10)	0.7
6	UNCONVERTED HD (V=ptv, B=ptg), NOT CONVERTED BECAUSE SPECTRAL CLASS WAS UNAVAILABLE	0.8
7	SAME AS MAGNITUDE SOURCE FLAG 6, WHEN ONLY V = ptv WAS AVAILABLE	0.8
8	SAME AS MAGNITUDE SOURCE FLAG 6, WHEN ONLY B = ptg WAS AVAILABLE	1.0
9	B FROM REFERENCE 39; V FROM SPECTRAL TYPE IF AVAILABLE	0 8
10	V OBSERVED, REFERENCE 8 OR 19; B OBTAINED FROM EQ. (3–9)	0 1 (IN V) 0.3 (IN B)
11	SAME AS MAGNITUDE SOURCE FLAG 10 WHEN NO B COMPUTED DUE TO LACK OF SPECTRAL CLASS INFORMATION	0 1 (IN V)

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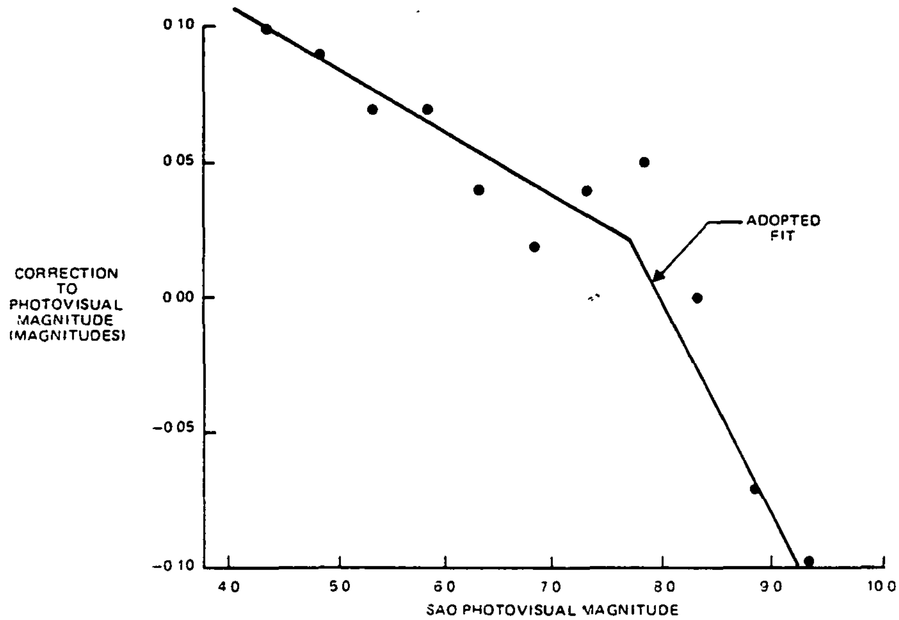

Figure 3-4. Correction to SAO Photovisual Magnitudes

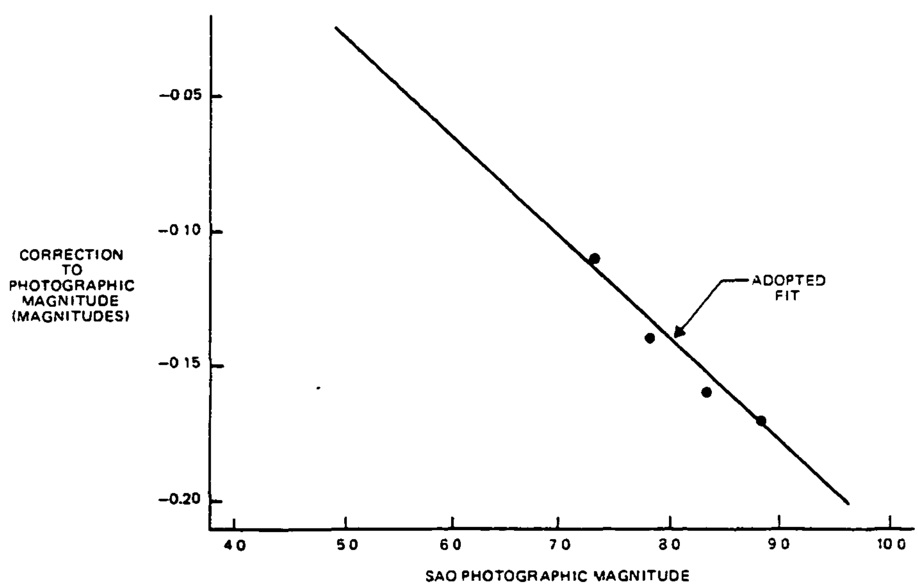

Figure 3-5. Correction to SAO Photographic Magnitude

Table 3-9. Spectral Type-Dependent Correction Factors for SAO Magnitudes

CLASS NUMBER	a_1	a_2
1	0.00	0.11
2	0.00	0.07
3	0.01	0.04
4	0.02	0 01
5	0.05	0.01
6	0.05	−0.01
7	0.04	0.03
8	0 05	0.04
9	0.05	0.06
10	0.08	0.03
11	0.05	0.05
12	0.04	0.03
13	0.01	0.03
14	0.00	−0 01
15	−0.02	0.01
16	0.04	−0.02
17	−0.05	0.13
18	−0.05	0.06
19	0.02	0.00
20	0.03	0.00
21	0.05	−0.13
22	−0.08	0.00
23	0.02	−0 02

$$c_2 = -0.161 + 0.0377 \text{ ptg} \quad (3\text{-}12)$$

3.5 INTERSTELLAR ABSORPTION COMPUTATION

The interstellar absorption function, $I(\lambda)$, which enters into the computation of instrumental magnitudes in Equation (3-6), has been repeatedly measured (see Reference 24). To good approximation, it can be thought of as a constant curve everywhere in space except for a scaling factor (amplitude). Figure 3-6, combined from References 25 and 26, gives the shape of this function. Note that absorption is very much higher in the ultraviolet regions of the spectrum (below 3500 Å) than in the visual or red regions. Consequently, a star affected by interstellar absorption will have its longer wavelength (red) photons absorbed to a lesser extent than its short wavelength (blue) photons, and will appear redder than its intrinsic color. This effect is called interstellar reddening.

The amplitude of the interstellar absorption function depends on the amount of gas and dust along the line of sight from the Earth to the star. For any given direction, it is a monotonically increasing function of distance. We have evaluated the absorption amplitude as a function of distance for various directions (see Section 3.5.2). Therefore, if the distance to a star is known, the interstellar absorption amplitude can be estimated. Section 3.5.1 deals with the evaluation of distances to stars. Section 3.5.2 discusses the computation of the interstellar absorption function from the UBV photometry or from the distance. Section 3.5.3 is an application of the absorption function to compute U magnitudes for stars not having an observed U magnitude.

3.5.1 Distance Calculations

Distances to stars are computed in a number of ways (see Reference 27); however, only three of these are applicable to sufficiently large numbers of Master Catalog stars to warrant their discussion here.

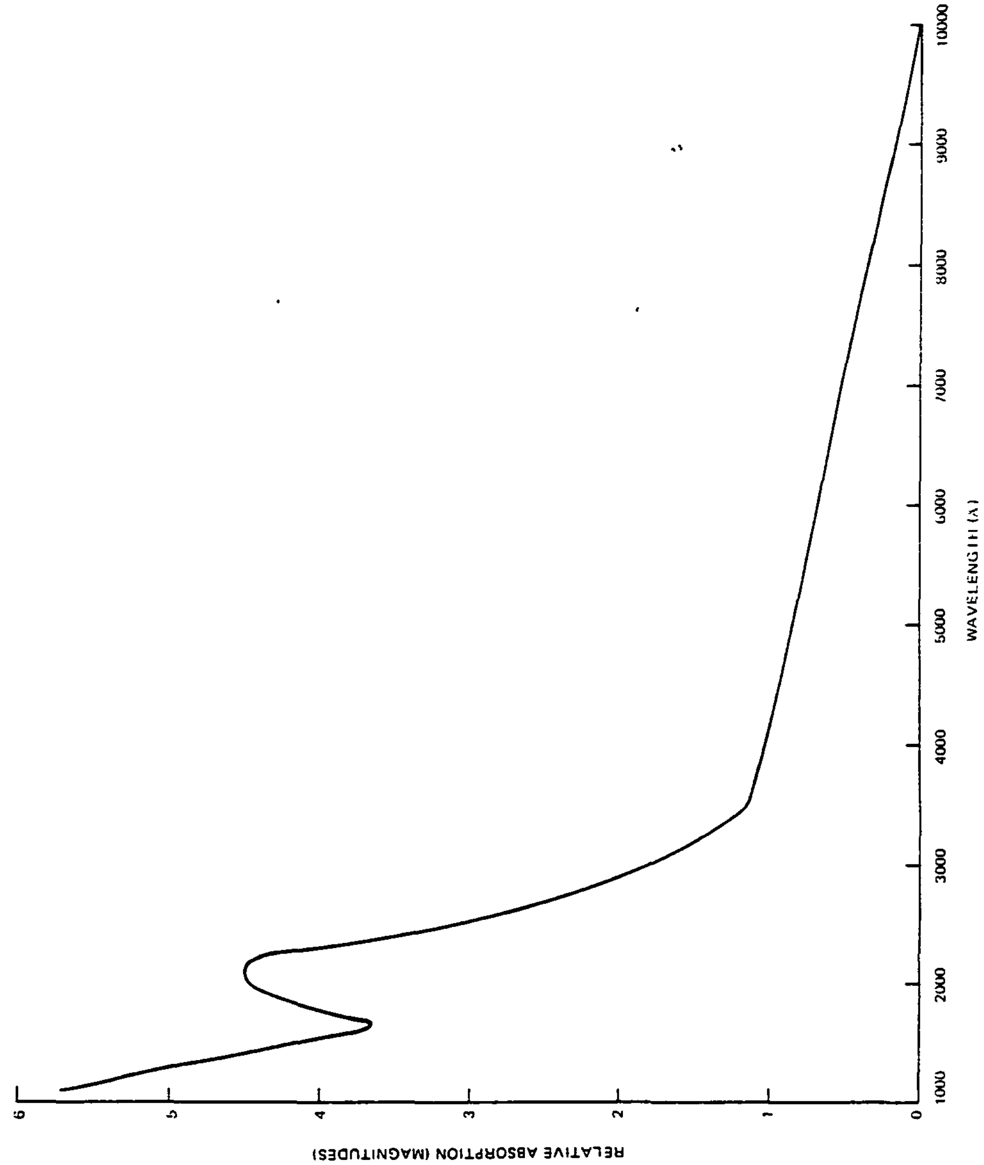

Figure 3-6. Relative Interstellar Absorption as a Function of Wavelength

3.5.1.1 Trigonometric Parallax

By observing a relatively nearby star against a background of distant objects at opposite ends of the Earth's orbit (6 months apart), a small trigonometric parallax can sometimes be seen (Figure 3-7). The size of this effect is always less than 1 arc-second. Knowing the trigonometric parallax angle in seconds of arc, p , as shown in Figure 3-7, the distance in parsecs, d , to the star (1 parsec = 3.085678×10^{16} m) , can be computed from

$$d = \frac{1}{p} \tag{3-13}$$

Trigonometric parallaxes from Reference 28 are available for about 5 percent of the Master Catalog stars, but the mean error in parallax, also given for each star in Reference 28, is often comparable to, or even greater than, the parallax.

Because the error quoted in Reference 28 is arrived at by comparison of multiple measurements of the same star, it does not take into account systematic errors which vary from observatory to observatory (Reference 29). A total error (one standard deviation) in the parallax equal to 0.007 arc-second or the catalog mean error in the parallax converted to a standard deviation by Equation (3-14), whichever is greater, has been conservatively assigned.

$$1 \text{ standard deviation} = 1.46 \times 1 \text{ mean error} \tag{3-14}$$

A very distant star may still have a positive parallax due to random observation errors. To avoid computing erroneous distances for cases such as this, no distance is calculated unless the parallax exceeds three times the measurement

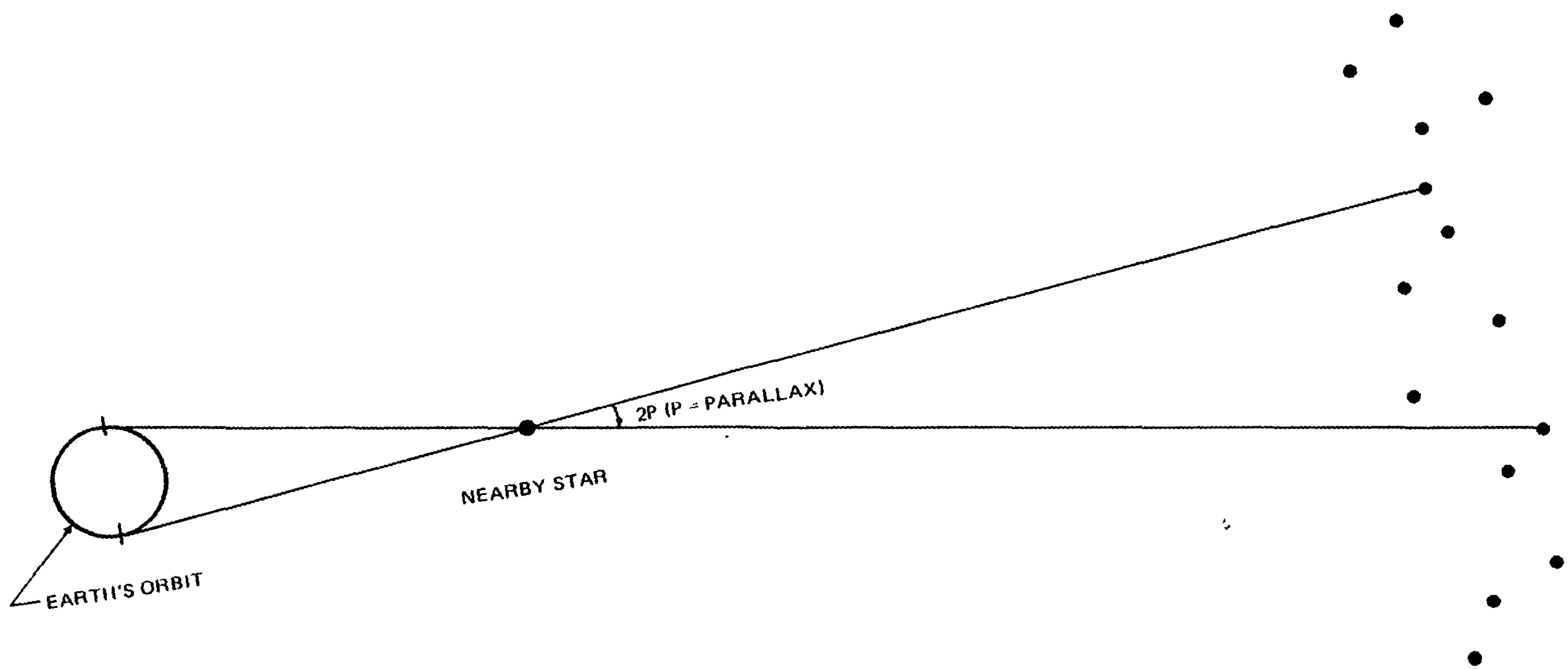

Figure 3-7. Schematic Representation of Stellar Trigonometric Parallax

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standard deviation by at least 0.005 arc-second. If it does, an expectation value of the distance is estimated from

$$d_p = \frac{\int_{p-3\epsilon_p}^{p+3\epsilon_p} \frac{1}{p_0}\, e^{-(p-p_0)^2/2\epsilon_p^2}\, dp_0}{\int_{p-3\epsilon_p}^{p+3\epsilon_p} e^{-(p-p_0)^2/2\epsilon_p^2}\, dp_0} \tag{3-15}$$

where p = measured parallax, in arc-seconds

ϵ_p = error in the parallax (1 standard deviation), in arc-seconds

d_p = distance in parsecs

The integration procedure is necessary because distance is not a linear function of parallax. Equation (3-15) was developed assuming that the errors in measured parallax follow a Gaussian distribution. The limits of the integral are taken to be three standard deviations from the measured parallax.

For stars with measured parallaxes that fail to exceed three measurement standard deviations by 0.005 arc-second (some may even be negative), it is still possible to derive a minimum distance to the star by assuming that the true parallax is no more than three standard deviations greater than the measured parallax. Thus, the minimum distance to the star is

$$d_{min} = \frac{1}{p + 3\epsilon_p} \tag{3-16}$$

To avoid computation of the integral in Equation (3-15), closed form approximations were developed. These formulae and regions of validity are given in Figure 3-8; they are everywhere accurate to better than 0.7 parsec.

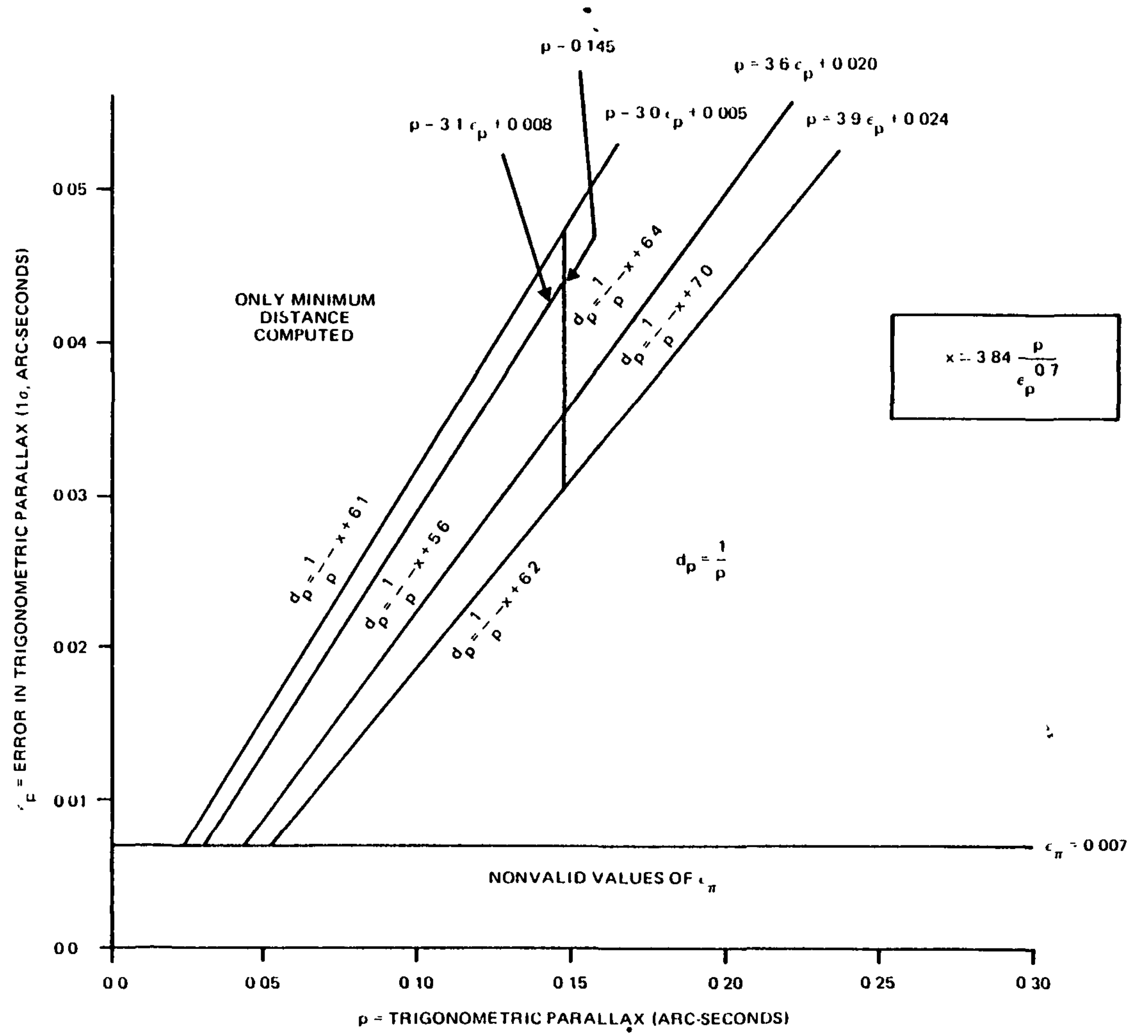

Figure 3-8. Formulae for Computation of Distance From Trigonometric Parallax

For stars with distances computed from Equation (3-15), the error in the distance, ϵ_x, is estimated from

$$\epsilon_x = \frac{1}{2}\left[\left|\frac{1}{p} - \frac{1}{p - \epsilon_p}\right| + \left|\frac{1}{p} - \frac{1}{p + \epsilon_p}\right|\right] \tag{3-17}$$

3.5.1.2 Spectroscopic Parallax

Because a star's spectral type gives a measure of the intrinsic (absolute) energy distribution (see Section 3.4.1), and the apparent magnitude gives a measure of its apparent brightness at the Earth, a comparison of the two can be used to compute the distance. This technique is known as spectroscopic parallax.

The apparent visual magnitude, V, is related to the absolute visual magnitude, M_v, by

$$V = M_v + 5 \log_{10} d_s - 5 + a_v \tag{3-18}$$

where M_v = absolute visual magnitude (apparent magnitude if the star were at a distance of 10 parsecs with no interstellar absorption)

d_s = distance to the star in parsecs

a_v = the amount of interstellar absorption at the visual (V) magnitude, in magnitudes

In Equation (3-18), only d_s is an unknown, although a_v is a function of distance. The absolute visual magnitude can be derived from the spectral type (see Reference 30 and Table 3-10). An iterative solution of Equation (3-18) was performed, starting with the estimate that $a_v = 0$. Using this assumption, a distance, d_s, was computed from Equation (3-18). A value of a_v was then obtained from the reddening versus distance study presented in Appendix B, and a new value of the distance computed. The procedure was repeated until

Table 3-10. Absolute Magnitude as a Function of Spectral Type

SPECTRAL CLASS	LUMINOSITY CLASS IA-O	IA	IAB	IB	II	III	IV	V
O6	-8.0	-6.2	-6.2	-6.1	****	****	****	-5.5
O7	-8.0	-6.2	-6.2	-6.1	****	****	****	-5.4
O8	-8.0	-6.2	-6.2	-6.1	****	****	****	-5.2
O9	-8.0	-6.2	-6.2	-6.1	****	-6.0	-5.4	-4.8
B0	-8.1	-6.2	-6.2	-5.8	-5.6	-5.0	-4.6	-4.1
B1	-8.2	-6.6	-6.2	-5.7	-5.1	-4.4	-3.9	-3.5
B2	-8.2	-6.8	-6.3	-5.7	-4.4	-3.6	-3.0	-2.5
B3	-8.3	-6.8	-6.3	-5.7	-3.9	-2.9	-2.3	-1.7
B4	-8.3	-6.9	-6.3	-5.7	-3.8	-2.6	-2.0	-1.4
B5	-8.3	-7.0	-6.3	-5.7	-3.7	-2.2	-1.6	-1.1
B6	-8.3	-7.1	-6.4	-5.7	-3.7	-1.9	-1.3	-0.9
B7	-8.3	-7.1	-6.4	-5.6	-3.6	-1.6	-1.0	-0.6
B8	-8.3	-7.1	-6.5	-5.6	-3.4	-1.2	-0.6	-0.2
B9	-8.4	-7.1	-6.5	-5.5	-3.1	-0.8	-0.3	0.2
A0	-8.4	-7.1	-6.6	-5.2	-2.8	-0.6	0.0	0.6
A1	-8.4	-7.3	-6.6	-5.1	-2.6	-0.4	0.3	1.2
A2	-8.5	-7.5	-6.7	-5.0	-2.4	-0.2	0.6	1.4
A3	-8.5	-7.6	-6.8	-4.8	-2.3	0.0	0.9	1.7
A4	-8.5	-7.7	-6.9	-4.9	-2.2	0.1	1.0	1.9
A5	-8.5	-7.7	-6.9	-4.8	-2.1	0.3	1.2	2.1
A6	-8.5	-7.9	-6.8	-4.9	-2.1	0.4	1.3	2.2
A7	-8.6	-8.0	-6.8	-4.9	-2.0	0.5	1.5	2.4
A8	-8.6	-8.2	-6.7	-4.9	-2.0	0.5	1.5	2.4
A9	-8.7	-8.3	-6.7	-4.9	-2.0	0.6	1.6	2.5
F0	-8.7	-8.5	-6.6	-4.7	-2.0	0.6	1.7	2.6
F1	-8.8	-8.5	-6.6	-4.7	-2.0	0.6	1.8	2.8
F2	-8.8	-8.4	-6.6	-4.6	-2.0	0.6	1.9	3.0
F3	-8.9	-8.3	-6.5	-4.6	-2.0	0.6	1.9	3.1
F4	-8.8	-8.3	-6.5	-4.6	-2.0	0.7	2.0	3.3
F5	-8.8	-8.2	-6.4	-4.6	-2.0	0.7	2.1	3.4
F6	-8.9	-8.1	-6.4	-4.6	-2.0	0.7	2.2	3.7
F7	-8.9	-8.1	-6.4	-4.6	-2.0	0.6	2.3	3.8
F8	-8.9	-8.0	-6.3	-4.6	-2.0	0.6	2.4	4.0
F9	-9.0	-8.0	-6.3	-4.6	-2.0	0.6	2.6	4.2
G0	-9.0	-8.0	-6.3	-4.5	-2.0	0.6	2.8	4.4
G1	-9.0	-8.0	-6.3	-4.5	-2.1	0.5	2.9	4.5
G2	-9.0	-8.0	-6.2	-4.5	-2.1	0.4	3.0	4.7
G3	****	-8.0	-6.2	-4.5	-2.1	0.4	3.0	4.9
G4	****	-8.0	-6.2	-4.5	-2.1	0.3	3.1	5.0
G5	****	-8.0	-6.2	-4.5	-2.1	0.3	3.2	5.2
G6	****	-8.0	-6.2	-4.5	-2.1	0.3	3.2	5.3
G7	****	-8.0	-6.1	-4.5	-2.1	0.3	3.2	5.5
G8	****	-8.0	-6.1	-4.5	-2.1	0.3	3.2	5.6
G9	****	-8.0	-6.1	-4.5	-2.1	0.2	3.2	5.7
K0	****	-8.0	-6.1	-4.4	-2.1	0.2	3.2	5.9
K1	****	-8.0	-6.1	-4.4	-2.2	-0.0	****	6.1
K2	****	-8.0	-6.0	-4.4	-2.2	-0.1	****	6.3
K3	****	-8.0	-6.0	-4.4	-2.3	-0.2	****	6.9
K4	****	-8.0	-5.9	-4.4	-2.3	-0.3	****	7.4
K5	****	-8.0	-5.9	-4.4	-2.3	-0.3	****	8.0
K6	****	-7.9	-5.9	-4.5	-2.3	-0.3	****	8.2
K7	****	-7.7	-5.9	-4.5	-2.3	-0.3	****	8.5
K8	****	-7.6	-5.8	-4.6	-2.4	-0.4	****	8.7
K9	****	-7.5	-5.8	-4.6	-2.4	-0.4	****	9.0
M0	****	-7.3	-5.7	-4.7	-2.4	-0.4	****	9.2
M1	****	-7.2	-5.7	-4.7	-2.4	-0.5	****	9.7
M2	****	-7.0	-5.6	-4.8	-2.4	-0.5	****	10.1
M3	****	-7.0	-5.6	-4.9	-2.4	-0.5	****	10.6
M4	****	****	****	****	-2.4	-0.5	****	11.3
M5	****	****	****	****	****	****	****	12.3
M6	****	****	****	****	****	****	****	13.4

values of a_v computed at successive steps differed by less than 0.01 magnitude.

To compute the expected error in this distance, Equation (3-18) is rewritten as

$$\log_{10} d_s = 0.2\ V - 0.2\ M_v + 1.0 - 0.2\ a_v \tag{3-19}$$

The anticipated error in V is computed according to the procedure used in calculating V (Section 3.4.2). The error in a_v is set such that the three standard deviation level in the absorption is equal to the full absorption. Thus, the error in a_v is equal to $a_v/3$.

The error in the absolute magnitude, M_v, comes from the following two sources:

- Error in the spectral type. For stars with observed MK types, this is assumed to be one-tenth of a spectral class and one-third of a luminosity class. For stars with only HD or SAO spectral types, this is taken as three-tenths of a spectral class and two-thirds of a luminosity class.

- Error in the conversion of spectral type to absolute magnitude. If the spectral type is well known, this error is probably quite small. It is assigned a value of 0.2 magnitude or one-half the difference between values for adjacent spectral class in tenths, whichever is the greater (see Reference 30).

The errors just discussed are used to compute the expected error, ϵ_ℓ, in $\log d_s$ by,

$$\epsilon_\ell = 0.2 \left[\epsilon_1^2 + \epsilon_2^2 + \epsilon_3^2 + \epsilon_4^2\right]^{1/2} \tag{3-20}$$

where ϵ_1 = error due to spectral type error

ϵ_2 = error due to the spectral type to absolute magnitude conversion

ϵ_3 = error due to apparent magnitude

ϵ_4 = error due to absorption

The error, ϵ_s (one standard deviation), in the distance obtained by spectroscopic parallax is then

$$\epsilon_s = \frac{1}{2}\left[10^{(\log_{10} d_s + \epsilon_\ell)} - 10^{(\log_{10} d_s - \epsilon_\ell)}\right] \tag{3-21}$$

3.5.1.3 Distance Limit Based on Space Velocity

It has been observed that star motions relative to the local standard of rest (LSR) are distributed approximately as a Gaussian distribution with a mean nearly equal to zero and standard deviation dependent on spectral type (Reference 27). The LSR is a nonrotating reference frame at the position of the Sun moving in a circular orbit about the galactic center with a velocity equal to the mean velocity for stars in the solar neighborhood at the Sun's distance from the galactic center.

The space velocity of a star relative to the LSR can be obtained from

$$\begin{aligned} \theta &= \theta^* + \theta' \\ \pi &= \pi^* + \pi' \\ z &= z^* \div z' \end{aligned} \tag{3-22}$$

where (θ^*, π^*, z^*) are the components of the space velocity of the star relative to the Sun in the coordinate system shown in Figure 3-9; (θ, π, z) are the components of the space velocity of the star relative to the LSR; and (θ', π', z') are the components of the Sun's velocity relative to the LSR, [-9, +11, +6 kilometers per second (km/sec)], respectively (Reference 27).

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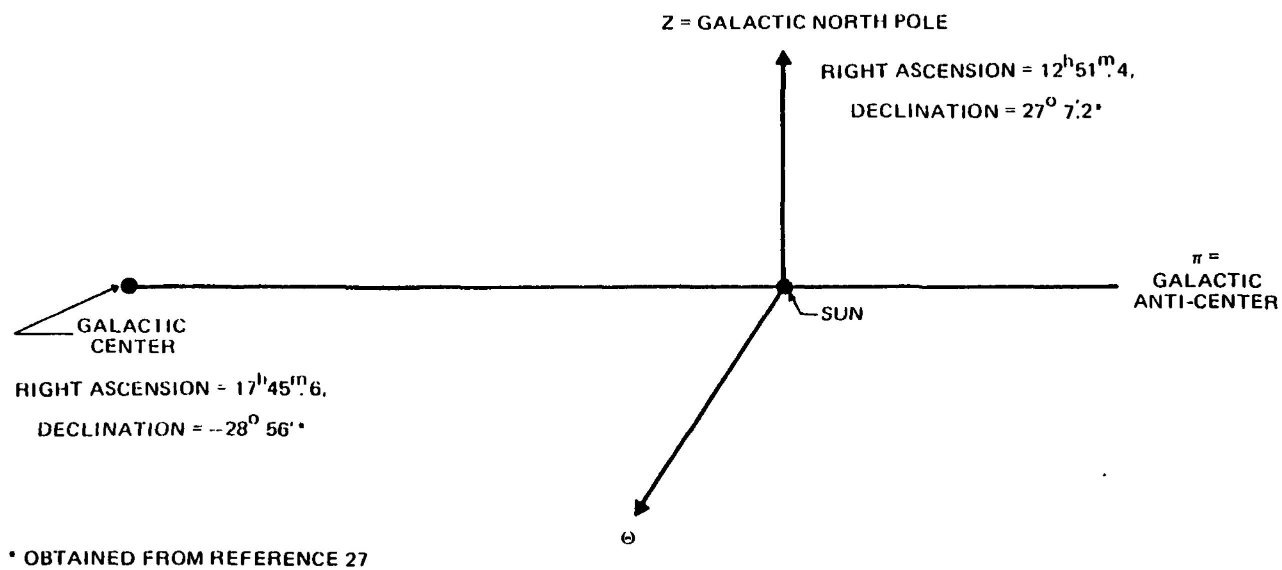

Figure 3-9. Coordinate System for Space Motions, Epoch 2000.0

The standard deviations in the stellar space velocity components $(\sigma_\theta, \sigma_\pi, \sigma_z)$ are given as a function of spectral type in Table 3-11, adapted from Reference 27.

The following is a discussion of the computation of a star's space velocity components (θ^*, π^*, z^*) relative to the Sun. This will be accomplished by first computing these components in G.I. coordinates and then transforming them to the rectilinear galactic coordinate frame defined above.

The computation of the space velocity components in G.I. coordinates requires known values of the position, distance, proper motion and radial velocity of the star. Distance is the variable which will eventually be solved for, and the position and proper motion are available in the Master Catalog. Radial velocities are, however, not included in the Master Catalog, pending the completion of a study being done at the University of Texas. Assuming that all stars have zero radial velocity relative to the LSR, the observed radial velocity is the negative of the Sun's motion in the direction of the star. This is computed from the space velocity of the Sun relative to the LSR (θ', π', z') and the galactic latitude and longitude of the star, which are computed from the G.I. unit vector of the star. The G.I. unit vector is given by

$$(X, Y, Z) = (\cos\delta \cos\alpha, \cos\delta \sin\alpha, \sin\delta) \qquad (3\text{-}23)$$

where (α, δ) are the right ascension and declination of the star, respectively.

The galactic latitude and longitude are obtained from

$$\begin{aligned} b &= \sin^{-1}(-0.8677\,X - 0.1981\,Y + 0.4559\,Z) \\ \ell &= \tan^{-1}\left(\frac{0.4940\,X - 0.4449\,Y + 0.7470\,Z}{-0.0549\,X - 0.8734\,Y - 0.4839\,Z}\right) \end{aligned} \qquad (3\text{-}24)$$

where (b, ℓ) are the galactic latitude and longitude, respectively.

Table 3-11. Standard Deviations of Space Velocity Components

	SPACE VELOCITY STANDARD DEVIATION (km/sec)		
SPECTRAL TYPES	σ_θ	σ_π	σ_z
O–A2 I–II	11	12	9
A3–M9 I–II	9	13	7
O–A9 III–IV	13	22	9
F0–F9 III–IV	15	28	9
G0–G9 III–IV	18	26	15
K0–K5 III–IV	21	31	17
K6–M9 III–IV	23	31	16
O–B5 V	9	10	6
B6–A2 V	9	15	9
A3–A9 V	9	20	9
F0–F7 V	17	27	17
F8–G0 V	18	26	20
G1–M9 V*	22	80	80

*THESE VALUES ARE FOR HIGH VELOCITY STARS, WHICH OCCUR OVER 20% OF THE TIME IN SPECTRAL TYPE G–M V, BUT RARELY FOR OTHER SPECTRAL TYPES

The coefficients in this equation come from the transformation matrix given below.

The value of the radial velocity of the star, R , is

$$R = [\pi' \cos b \cos \ell + \theta' \cos b \sin \ell + Z' \sin b] \tag{3-25}$$

The G.I. components of the space velocity of the star relative to the Sun are

$$\begin{aligned} v_x &= R \cos \delta \cos \alpha - \mu_\delta d \sin \delta \cos \alpha - \mu_\alpha d \cos \delta \sin \alpha \\ v_y &= R \cos \delta \sin \alpha - \mu_\delta d \sin \delta \sin \alpha + \mu_\alpha d \cos \delta \cos \alpha \\ v_z &= R \sin \delta + \mu_\delta d \cos \delta \end{aligned} \tag{3-26}$$

where $(\mu_\alpha , \mu_\delta)$ = the proper motion of the star in right ascension and declination, respectively

d = the distance to the star

The components of the space velocity in the rectilinear galactic frame are then

$$(\theta^*, \pi^*, z^*) = [M] \begin{pmatrix} v_x \\ v_y \\ v_z \end{pmatrix} \tag{3-27}$$

where the matrix [M] transforms a vector in the G.I. frame to the galactic frame. Its elements are the G.I. unit vectors of the three galactic frame axes shown in Figure 3-9, derived from the galactic pole and center given in Reference 27.

$$[M] = \begin{bmatrix} 0.4940 & -0.4449 & 0.7470 \\ 0.0549 & 0.8734 & 0.4839 \\ -0.8677 & -0.1981 & 0.4559 \end{bmatrix} \tag{3-28}$$

Assuming that the velocity components relative to the LSR do not exceed three times the standard deviations given in Table 3-11, a maximum distance can be computed as follows.

Invert Equations (3-26) and (3-27) to solve for d in terms of θ, as follows:

$$\begin{aligned} d = {} & (\theta - \theta' - 0.4940\, R \cos\delta \cos\alpha + 0.4449\, R \cos\delta \sin\alpha - 0.7470\, R \sin\delta)/ \\ & (-0.4940\, \mu_\delta \sin\delta \cos\alpha - 0.4940\, \mu_\alpha \cos\delta \sin\alpha + 0.4449\, \mu_\delta \sin\delta \sin\alpha \\ & -0.4449\, \mu_\alpha \cos\delta \cos\alpha + 0.7470\, \mu_\delta \cos\delta) \end{aligned} \tag{3-29}$$

If the denominator of Equation (3-29) is positive, d increases monotonically with increasing θ. In this case, set $\theta = 3\sigma_\theta$ and solve for d, calling the result d_1.

If the denominator is negative, d increases monotonically with decreasing θ. In this case, set $\theta = -3\sigma_\theta$, and solve for d, calling the result d_1. In either case, the solution for d_1 is as large as possible subject to the constraint that

$$|\theta| \le 3\sigma_\theta$$

which was the assumption made above.

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Next, invert Equations (3-26) and (3-27) in terms of π and z to get the following:

$$d = (\pi - \pi' - 0.0549\ R \cos\delta \cos\alpha - 0.8734\ R \cos\delta \sin\alpha - 0.4839\ R \sin\delta)/$$
$$(-0.0549\ \mu_\delta \sin\delta \cos\alpha - 0.0549\ \mu_\alpha \cos\delta \sin\alpha - 0.8734\ \mu_\delta \sin\delta \sin\alpha$$
$$+ 0.8734\ \mu_\alpha \cos\delta \cos\alpha + 0.4839\ \mu_\delta \cos\delta) \qquad (3\text{-}30)$$

$$d = (Z - Z' + 0.8677\ R \cos\delta \cos\alpha + 0.1981\ R \cos\delta \sin\alpha - 0.4559\ R \sin\delta)/$$
$$(0.8677\ \mu_\delta \sin\delta \cos\alpha + 0.8677\ \mu_\alpha \cos\delta \sin\alpha + 0.1981\ \mu_\delta \sin\delta \sin\alpha$$
$$- 0.1981\ \mu_\alpha \cos\delta \cos\alpha + 0.4559\ \mu_\delta \cos\delta) \qquad (3\text{-}31)$$

Solve Equations (3-30) and (3-31) as above for d, calling the results d_2 and d_3, respectively.

The maximum distance is then

$$d_{max} = \min(d_1, d_2, d_3) \qquad (3\text{-}32)$$

Observational imprecision in the proper motions is typically about 1.5×10^{-5} degrees per year (three standard deviations; Reference 31). Therefore, no maximum distance can be computed for stars where the absolute value of each proper motion is less than 1.5×10^{-5} degrees per year.

3.5.1.4 Computation of a Net Distance

If trigonometric parallax and spectroscopic distances are both available, they are combined to yield a net distance of

$$d = \frac{\dfrac{d_p}{\epsilon_x^2} + \dfrac{d_s}{\epsilon_s^2}}{\dfrac{1}{\epsilon_x^2} + \dfrac{1}{\epsilon_s^2}} \qquad (3\text{-}33)$$

where ϵ_x is the error (1 σ) in d_p and ϵ_s is the error (1 σ) in d_s. The net error, ϵ, in the distance is computed from

$$\frac{1}{\epsilon^2} = \frac{1}{\epsilon_x^2} + \frac{1}{\epsilon_s^2} . \qquad (3\text{-}34)$$

If only one distance estimate is available, it is used.

If d_{min} is available and the computed distance is less than d_{min}, it is set to d_{min}; if d_{max} is available and the computed distance is greater than d_{max}, it is set to d_{max}. If $d_{min} > d_{max}$, both are ignored. Whenever the best distance is set to d_{min} or d_{max}, the error is defined as equal to the distance.

3.5.2 The Interstellar Absorption Index

The amplitude of the interstellar absorption function, I, is obtained from either observed U, B, and V magnitudes or from the distance to the star using the model described below.

The interstellar absorption index, a_v , is defined as the amount of absorption in the V filter, expressed in magnitudes. The amount of absorption in any other bandpass can then be computed from

$$a_w = \frac{a_v \log_{10} \left[\left(\int_0^\infty W(\lambda)\ E(\lambda)(1 - I(\lambda))\ d\lambda \right) \Big/ \left(\int_0^\infty W(\lambda)\ E(\lambda)\ d\lambda \right) \right]}{\log_{10} \left[\left(\int_0^\infty V(\lambda)\ E(\lambda)(1 - I(\lambda))\ d\lambda \right) \Big/ \left(\int_0^\infty V(\lambda)\ E(\lambda)\ d\lambda \right) \right]} \tag{3-35}$$

where a_w = amount of absorption in the other bandpass, in magnitudes
$W(\lambda)$ = response in that bandpass as a function of wavelength

In general, a_w depends on the spectral energy distribution of the source, $E(\lambda)$, but for most star energy distributions and sensor bandpasses, the quantity in brackets is nearly constant (Reference 24).

3.5.2.1 Interstellar Absorption From BV Magnitudes

If observed B and V magnitudes exist, but U does not, the absorption in the V magnitude, a_v , can be computed directly from B and V alone.

The color excess, E_b , is first computed from

$$E_b = (B-V)_{observed} - (B-V)_{standard} \tag{3-36}$$

where $(B-V)_{standard}$ is given in Table 3-12 as a function of spectral type. The values in Table 3-12 were derived by first plotting, for various spectral classes and luminosity classes, observed B-V versus distance. Only those stars were plotted that had observed B and V magnitudes in the UBV system, an observed MK spectral type, no spectral peculiarity, and either a trigonometric or spectroscopic parallax yielding a distance less than 1000 parsecs. These plots are given in Appendix A.

Table 3-12. Smoothed Values of $(B-V)_{Standard}$ (1 of 2)

SPECTRAL CLASS	LUMINOSITY CLASS				
	I	II	III	IV	V
O9	−0.22	–	−0.25	–	−0.25
B0	−0.20	−0.22	−0.23	−0.25	−0 23
B1	−0.19	−0 19	−0.21	−0.23	−0.20
B2	−0.17	−0 17	−0 19	−0 20	−0.17
B3	−0.16	−0.14	−0.17	−0 17	−0.15
B4	−0.14	−0.12	−0 15	−0 14	−0.14
B5	−0.12	−0.09	−0.14	−0 12	−0.12
B6	−0.10	−0.06	−0.13	−0 10	−0.11
B7	−0.08	−0.03*	−0 11	−0.10	−0.09
B8	−0.05	−0.01*	−0.10	−0.09	−0.07
B9	−0.03	0.02*	−0.07	−0.05	−0.04
A0	−0 01	0.04*	−0.03	−0.02	−0 02
A1	0.01	0.06*	0.01	0.02	0.02
A2	0.04*	0.08*	0.05	0 05	0.05
A3	0.06*	0.10*	0 09	0.09	0.09
A4	0 08*	0.13*	0 12	0.12	0.13
A5	0.10*	0.16*	0.16	0 15	0.16
A6	0.13*	0.19	0.20	0.18	0.18
A7	0.16*	0.22	0.24	0 22	0.20
A8	0 19*	0.25	0.27	0 25	0.23
A9	0.24*	0.28	0.29	0.28	0.27
F0	0 30*	0.31	0.31	0.30	0.30
F1	0 35*	0.34	0 33	0.32	0 33
F2	0.40*	0.37	0.36	0 35	0.35
F3	0 45*	0.40	0.39	0 37	0 38
F4	0.50*	0.43	0.42	0.39	0.41
F5	0 56	0.46	0.46	0.41	0.44
F6	0.62	0.49	0.50*	0 45	0.47
F7	0 67	0.55	0.54*	0.48	0.49
F8	0.72	0 62	0.58*	0.52	0.52
F9	0.77	0.69	0.62*	0 55	0.55

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Table 3-12. Smoothed Values of $(B-V)_{Standard}$ (2 of 2)

SPECTRAL CLASS	LUMINOSITY CLASS				
	I	II	III	IV	V
G0	0.83	0.77	0.66	0 59	0.57
G1	0.88	0 84	0.71	0 62	0 59
G2	0 93	0.88	0.75	0.65	0 61
G3	0 98	0.93	0.79	0.68	0 63
G4	1.03	0.95	0.83	0.73	0 66
G5	1 08	0.97	0.88	0.77	0 68
G6	1.13*	1.00	0.92	0.82	0.70
G7	1.18*	1.03	0.94	0 85	0 73
G8	1.23*	1 07	0.95	0 88	0.76
G9	1.28*	1 12	0.97	0.93	0.80
K0	1.33*	1 17	1.00	0.96	0.85
K1	1.38*	1 23	1 10	1 00	0.88
K2	1 43*	1 35	1.17	–	0.93
K3	1 48	1 43	1.28	–	0.97
K4	1.53	1.52	1.42	–	1.05
K5	1.56	1.55	1 50	–	1 11
K6	1.57	1 58*	1.51*	–	1.16
K7	1.58	1.60*	1.52*	–	1.22
K8	1.59	1.62*	1.53*	–	1.28
K9	1.60	1 64*	1 54*	–	1 34
M0	1.60	1 65	1 55	–	1 39
M1	1.61	1 66	1 57	–	1 44
M2	1.62	1 67	1 59	–	1 48
M3	1.63*	1.68	1 61	–	1 53
M4	1 64*	1 69	1 64	–	1 57

*SIGNIFIES UNCERTAIN RESULTS DUE TO LACK OF DATA.

Some stars on the plot, especially those at larger distances, may show interstellar reddening; hence, they appear at redder values of B-V (higher on the plot) than they would if they were unreddened. Other sources of error are observational imprecision in the magnitude and in the spectral types. Due to these errors, some stars will have B-V values bluer (more negative) than the mean intrinsic B-V for the spectral class and luminosity class plotted. The best estimate of the intrinsic (standard) B-V is obtained by manual inspection of each plot.

For each luminosity class considered (I, II, III, IV, and V), a plot of observed intrinsic B-V versus spectral type was drawn (see Figure 3-10). A smooth curve was hand fit through the data points and adopted values of $(B-V)_{standard}$ read from the plot.

The absorption in V is then computed from

$$a_v = 3\ E_b \tag{3-37}$$

which can be obtained from Equation (3-35) using the transmission curves presented in Figure 3-1, or can be found in Reference 24.

3.5.2.2 Interstellar Absorption From UBV Magnitudes

If observed U, B, and V magnitudes are all available, the absorption computed from Equations (3-36) and (3-37) is still valid. However, the U magnitude is another piece of data which can be used to compute a_v. This is accomplished using the following equations (Reference 27):

$$E_u = (U-B)_{observed} - (U-B)_{standard}$$

$$E_b = \frac{-0.72 + (0.518 + 0.20\ E_u)^{1/2}}{0.10} \tag{3-38}$$

$$a_v = 3\ E_b$$

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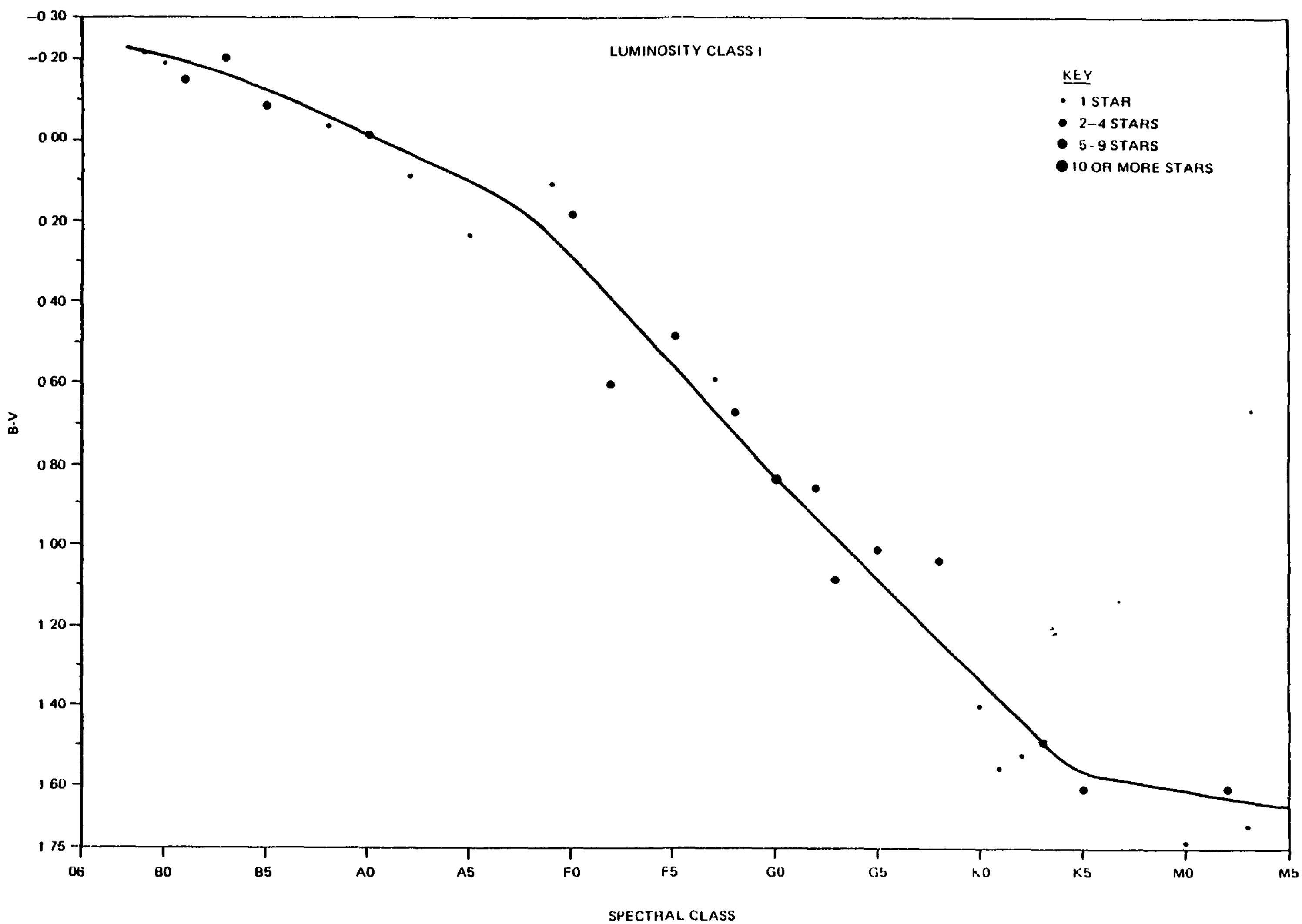

Figure 3-10. Estimated B-V Spectral Class Plots and Smoothed B-V Curve (1 of 5)

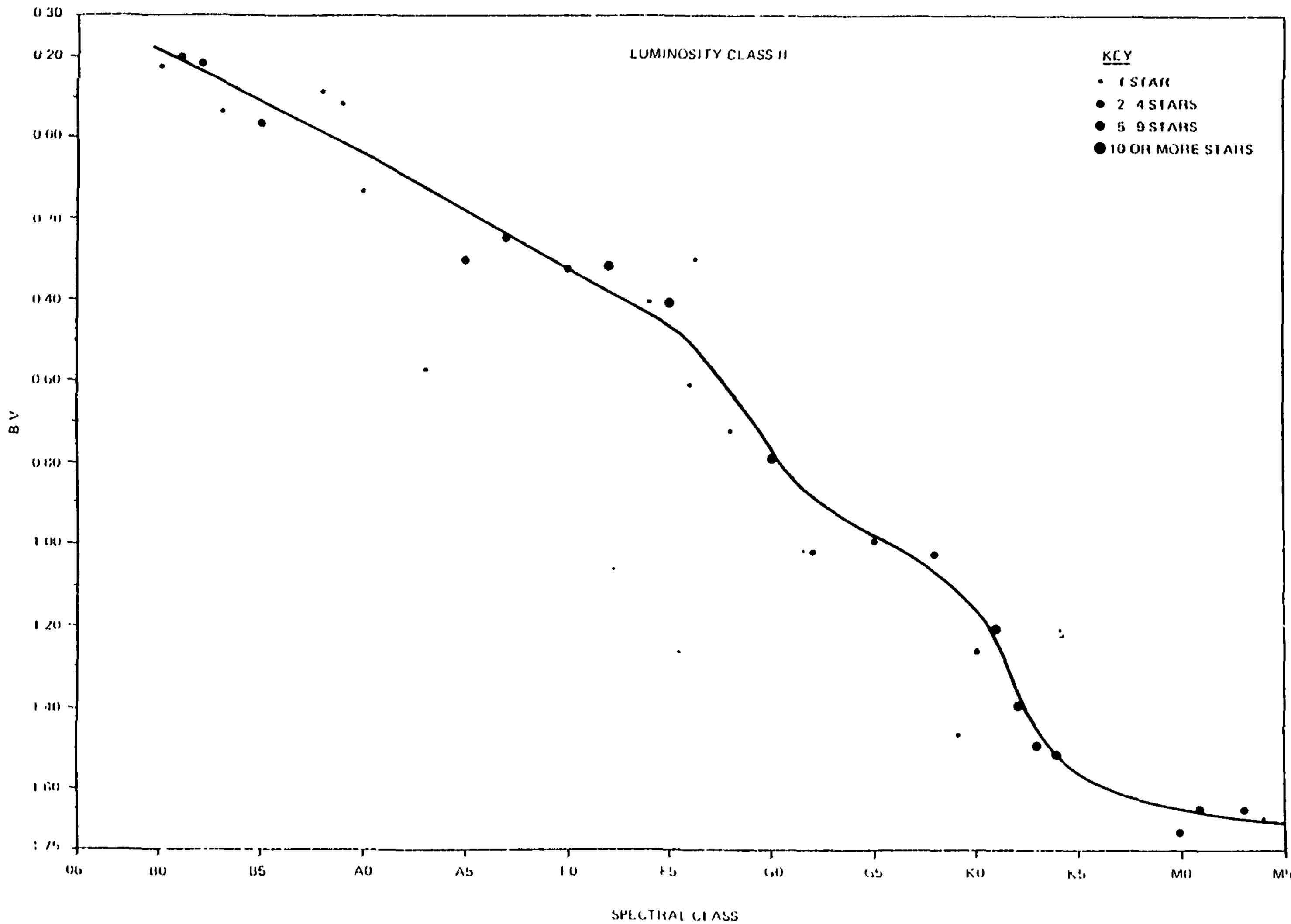

Figure 3-10. Estimated B-V Spectral Class Plots and Smoothed B-V Curve (2 of 5)

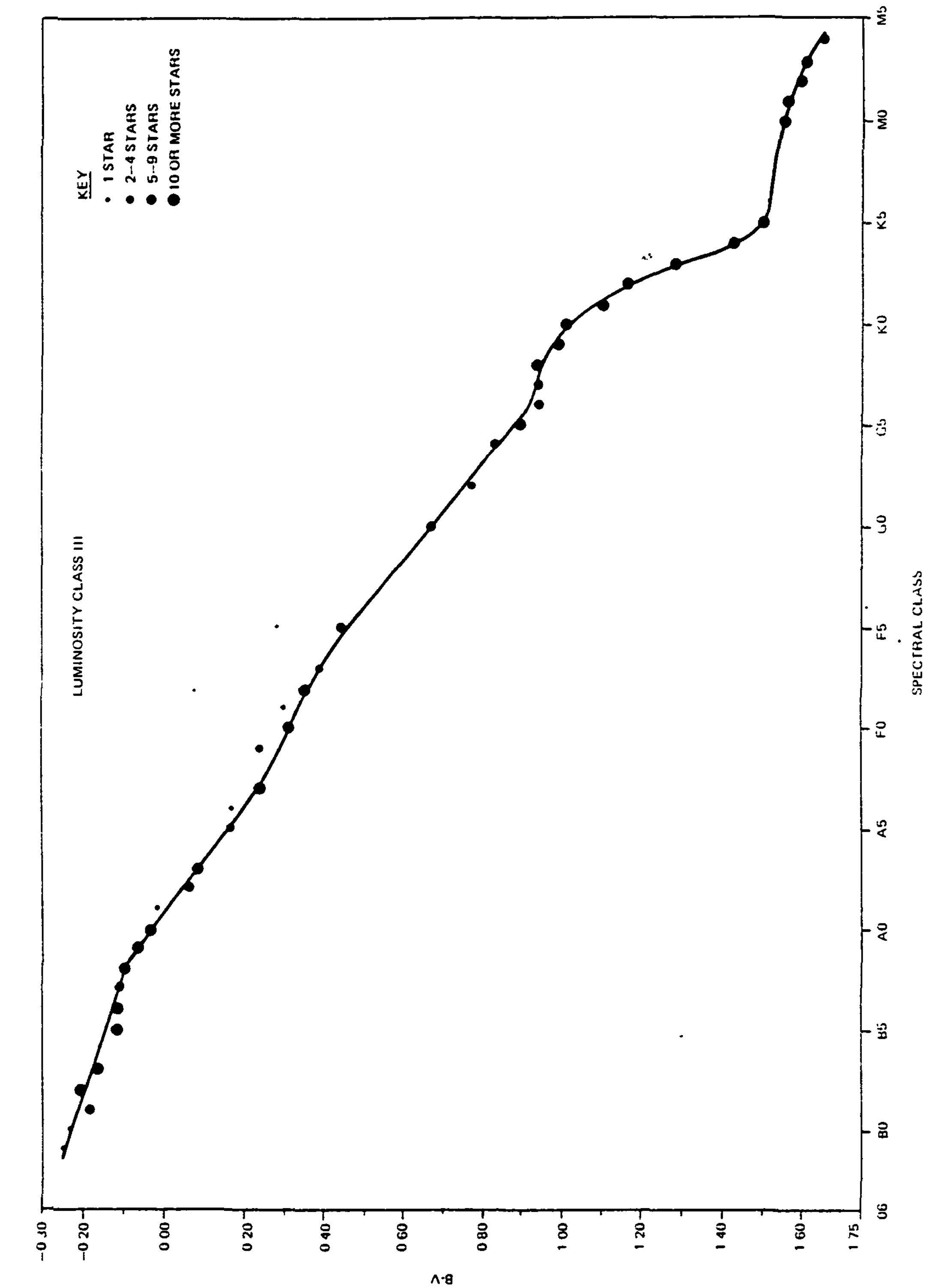

Figure 3-10. Estimated B–V Spectral Class Plots and Smoothed B–V Curve (3 of 5)

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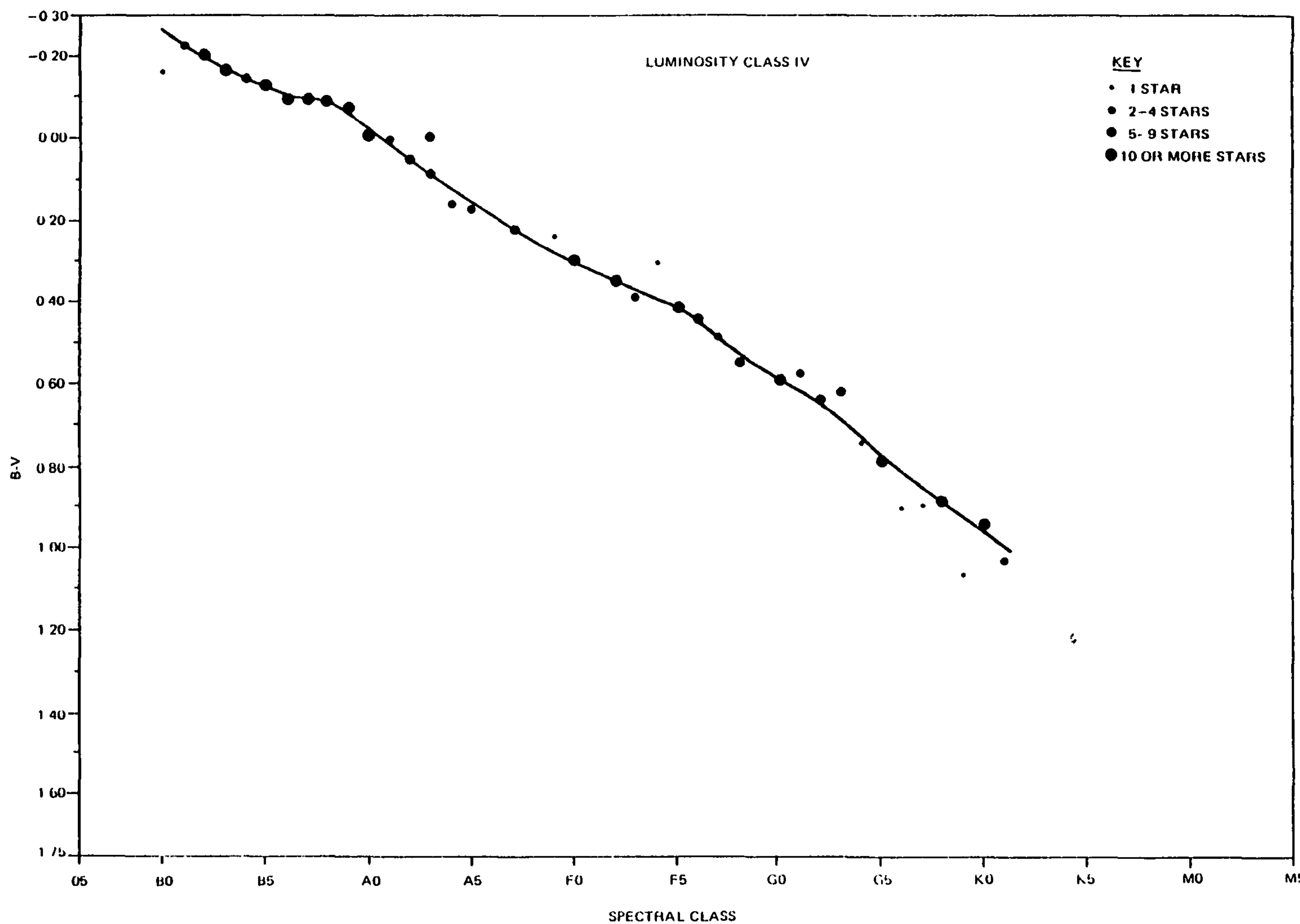

Figure 3-10. Estimated B-V Spectral Class Plots and Smoothed B-V Curve (4 of 5)

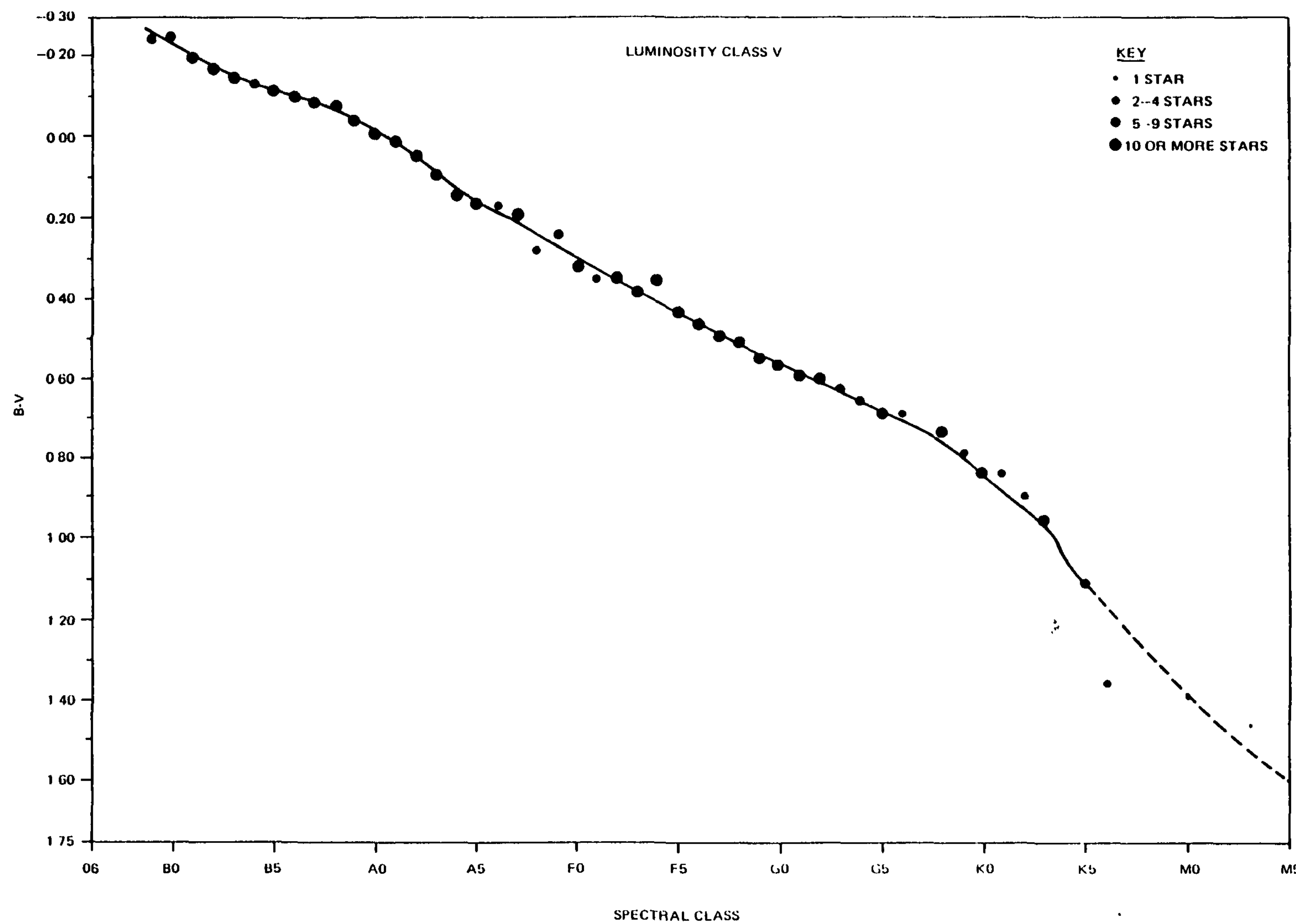

Figure 3-10. Estimated B-V Spectral Class Plots and Smoothed B-V Curve (5 of 5)

where E_u = the color excess in U-B, and $(U-B)_{standard}$ is found in Table 3-13 as a function of spectral type

$(U-B)_{standard}$ is derived in the same manner as $(B-V)_{standard}$. Plots of measured intrinsic U-B are given in Figure 3-11. Appendix A contains the distance versus U-B plots.

The adopted value of a_v is obtained by averaging the results of Equations (3-37) and (3-38), weighting the results of Equation (3-37) four times as heavily as those of Equation (3-38). This reflects the larger uncertainty in $(U-B)_{standard}$ due to the sensitivity of $(U-B)_{standard}$ to spectral type.

3.5.2.3 Interstellar Absorption as a Function of Distance

To compute the interstellar absorption in the V magnitude (a_v), a procedure identical to that of Reference 23 was used, using the SKYMAP Master Catalog data base as input data.

Only SKYMAP stars having the following data available were used in the study:

- Observed MK spectral type
- Observed B, V magnitudes

The sky was divided into 920 zones, overlapping 50 percent in both right ascension and declination. Color excess (E_b), distance plots were drawn for each zone. These are presented in Appendix B. A curve, consisting of one or two line segments, was then hand drawn through each plot.

The following rules were applied:

- The curve had to pass through the theoretically certain point $(E_b = 0$, distance $= 0)$.
- The curve had to be continuous.
- E_b could never decrease with increasing distance.

The slope of the lines is the amount of color excess per unit distance.

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Table 3-13. Smoothed Values of $(U-B)_{Standard}$ (1 of 2)

SPECTRAL CLASS	LUMINOSITY CLASS				
	I	II	III	IV	V
O9	−1 15	–	–	–	−1.07
B0	−1.06	−1.08	−0.99	−0.98*	−0.99
B1	−0.97	−0.96	−0.92	−0.90	−0.90
B2	−0 89	−0.85	−0.85	−0.80	−0 77
B3	−0 80	−0.74	−0.78	−0.71	−0.67
B4	−0.70	−0.62	−0.70	−0 63	−0.60
B5	−0.61	−0.51	−0.63	−0 54	−0 54
B6	−0.52	−0.40*	−0.57	−0.47	−0 48
B7	−0.44	−0.30*	−0.50	−0 40	−0.41
B8	−0.36	−0 19*	−0.40	−0.30	−0.30
B9	−0.27	−0.07*	−0.25	−0.20	−0 11
A0	−0.20	0.03*	−0.12	−0 10	−0.00
A1	−0.13*	0.15*	−0.01	0 00	0.03
A2	−0.09*	0.26*	0.06	0 06	0.06
A3	−0.06*	0.38*	0 12	0.09	0 08
A4	−0.05*	0.42*	0 12	0.10	0.10
A5	−0.04*	0.38	0.11	0 11	0.11
A6	−0.02*	0.32	0.10	0.11	0.11
A7	0.00*	0.28	0.10	0.10	0.10
A8	0.03*	0.24	0 10	0 10	0.10
A9	0.09*	0.21	0.10	0.09	0 07
F0	0.13*	0.18	0.09	0.08	0.04
F1	0.18*	0.16	0.08	0 06	0 02
F2	0 22*	0 17	0 07	0 04	0.01
F3	0.27*	0.19	0 06	0 02	0 00
F4	0.32*	0.21	0 05	0.00	0 00
F5	0.37*	0 24	0.04	0.00	−0 01
F6	0.41*	0.29	0.05	0 01	−0.01
F7	0.45	0.33	0.07*	0.04	0.00
F8	0.50	0.37	0.12*	0 10	0.02
F9	0 55	0.41	0 20*	0.15	0 04

Table 3-13. Smoothed Values of $(U-B)_{Standard}$ (2 of 2)

SPECTRAL CLASS	LUMINOSITY CLASS				
	I	II	III	IV	V
G0	0.60	0.44	0.26*	0.20	0.05
G1	0.63	0.50	0.33*	0.23	0.07
G2	0.66	0.55	0.40*	0.25	0.08
G3	0.70	0.60	0.47*	0.28	0.10
G4	0.73	0.64	0.53	0.32	0.15
G5	0.77	0.69	0.59	0.38	0.20
G6	0.80	0.73	0.62	0.43	0.25
G7	0.84	0.78	0.65	0.49	0.30
G8	0.88	0.83	0.68	0.53	0.35
G9	0.91	0.90	0.75	0.60	0.41
K0	0.94	1.09*	0.83	0.65	0.48
K1	0.98	1.23*	1.00	0.75*	0.53
K2	1.01	1.40*	1.20	–	0.60
K3	1.04	1.55	1.44	–	0.77
K4	1.06	1.68	1.67	–	0.95
K5	1.09*	1.70*	1.86	–	1.05
K6	1.11*	1.70*	1.91*	–	1.10
K7	1.13*	1.71*	1.93*	–	1.13
K8	1.15*	1.72*	1.95*	–	1.17
K9	1.17*	1.73*	1.95*	–	1.20
M0	1.19*	1.74*	1.94	–	1.23
M1	1.20*	1.75*	1.92	–	1.22
M2	1.22*	1.76	1.90	–	1.21
M3	1.24*	1.76	1.87	–	1.20
M4	–	1.77	1.80*	–	1.20

*SIGNIFIES UNCERTAIN RESULTS DUE TO LACK OF DATA.

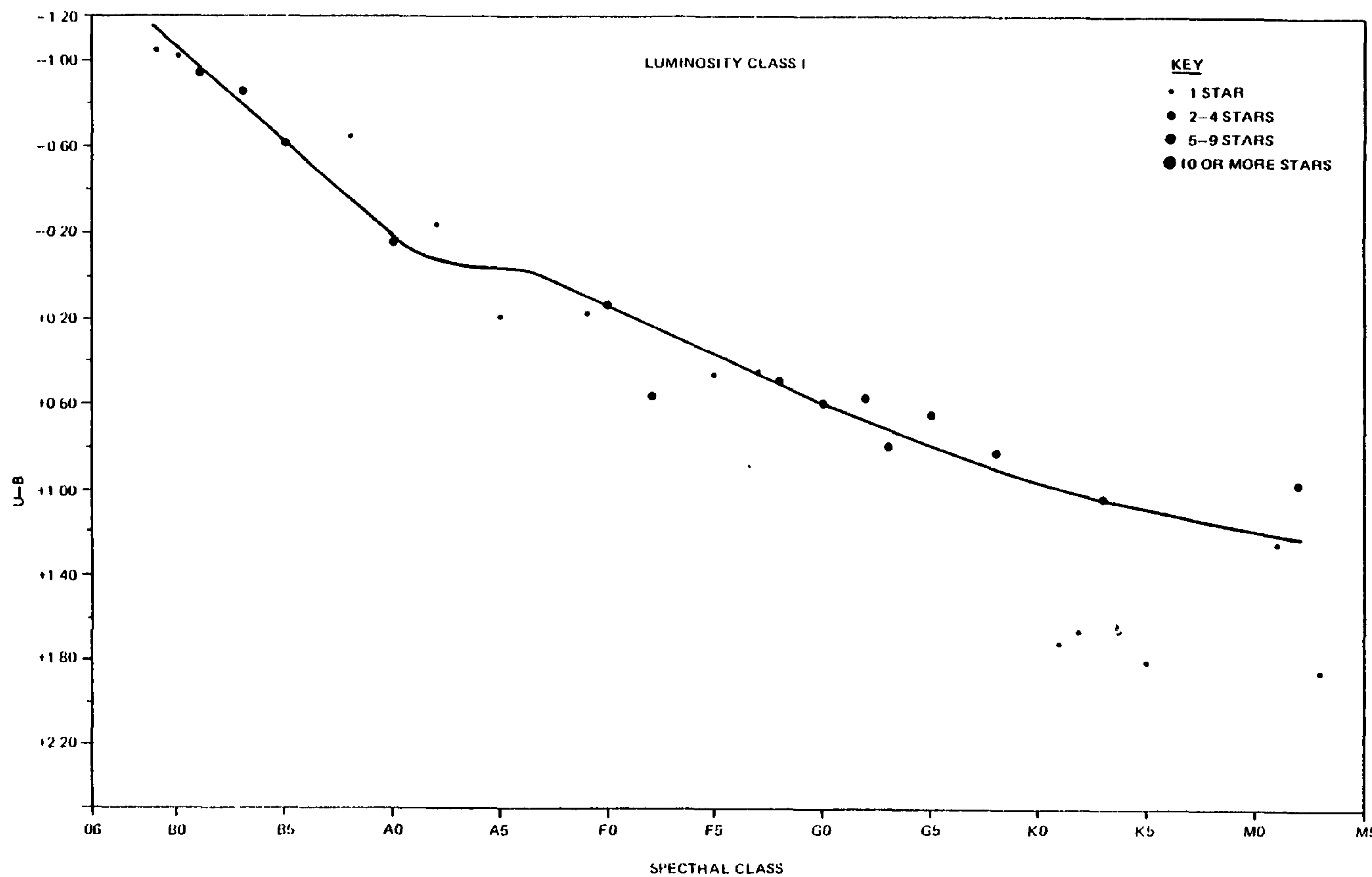

Figure 3-11. Estimated U-B Spectral Class Plot and Smoothed U-B Curve (1 of 5)

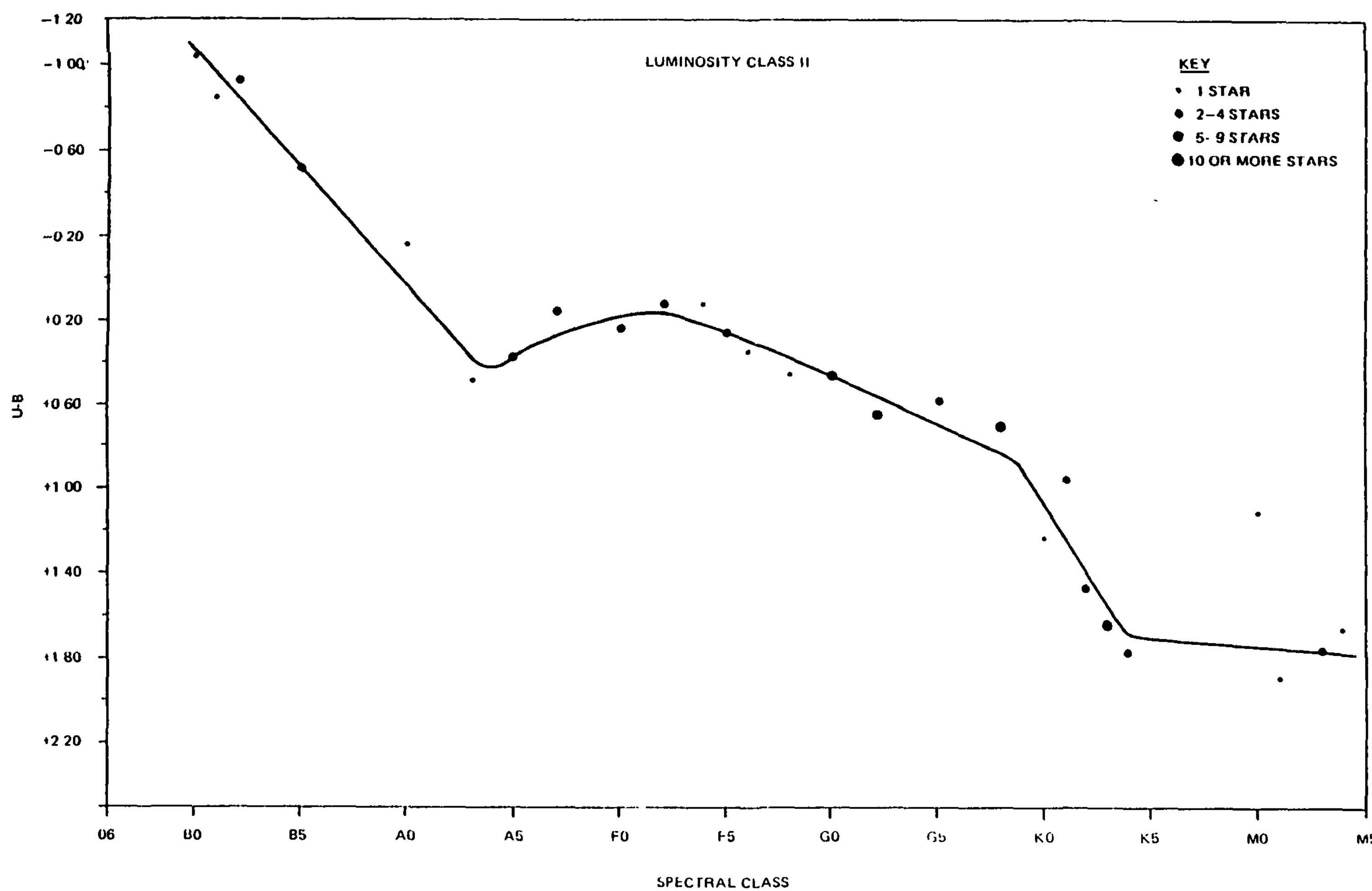

Figure 3-11. Estimated U-B Spectral Class Plot and Smoothed U-B Curve (2 of 5)

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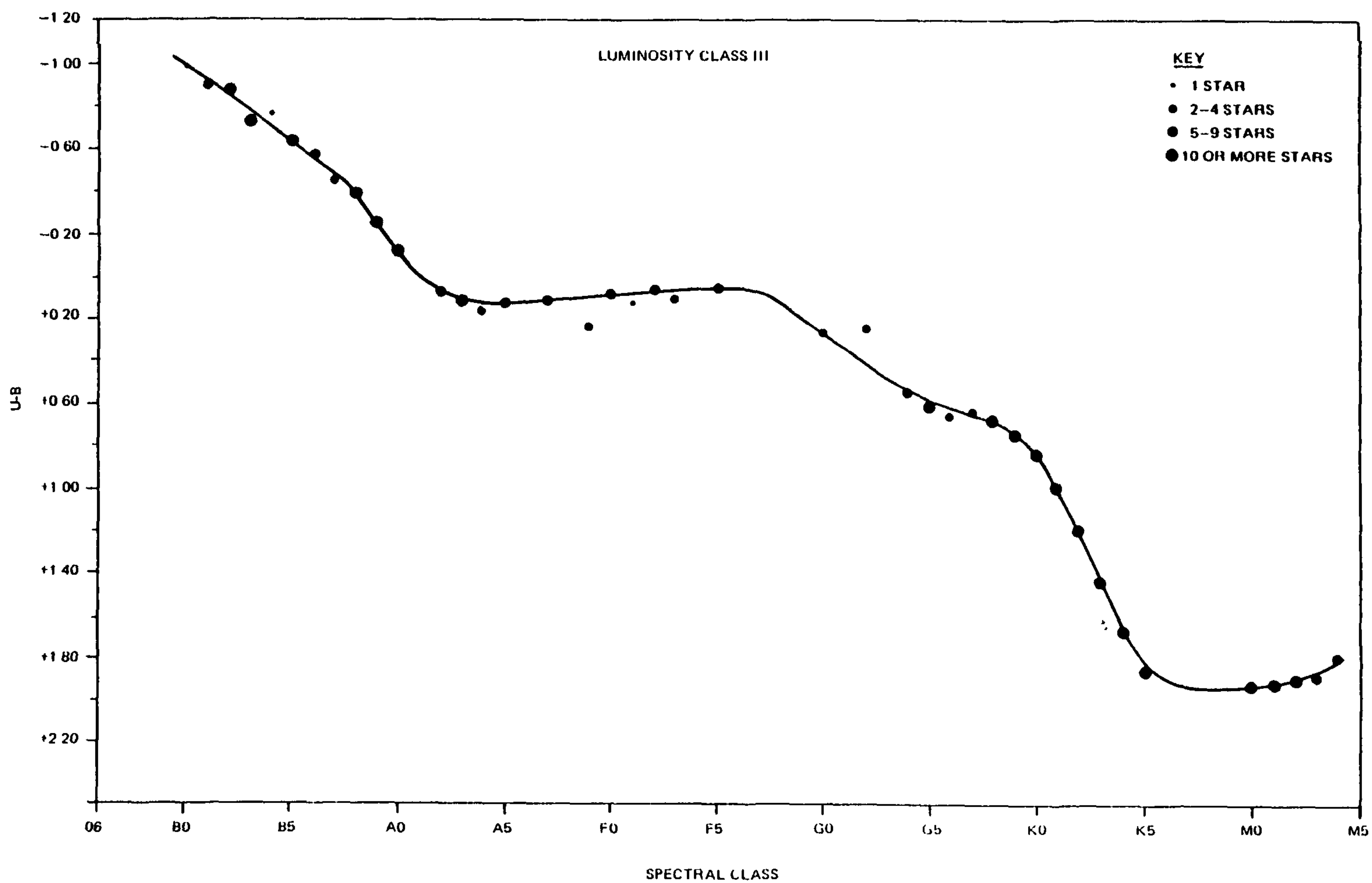

Figure 3-11. Estimated U-B Spectral Class Plot and Smoothed U-B Curve (3 of 5)

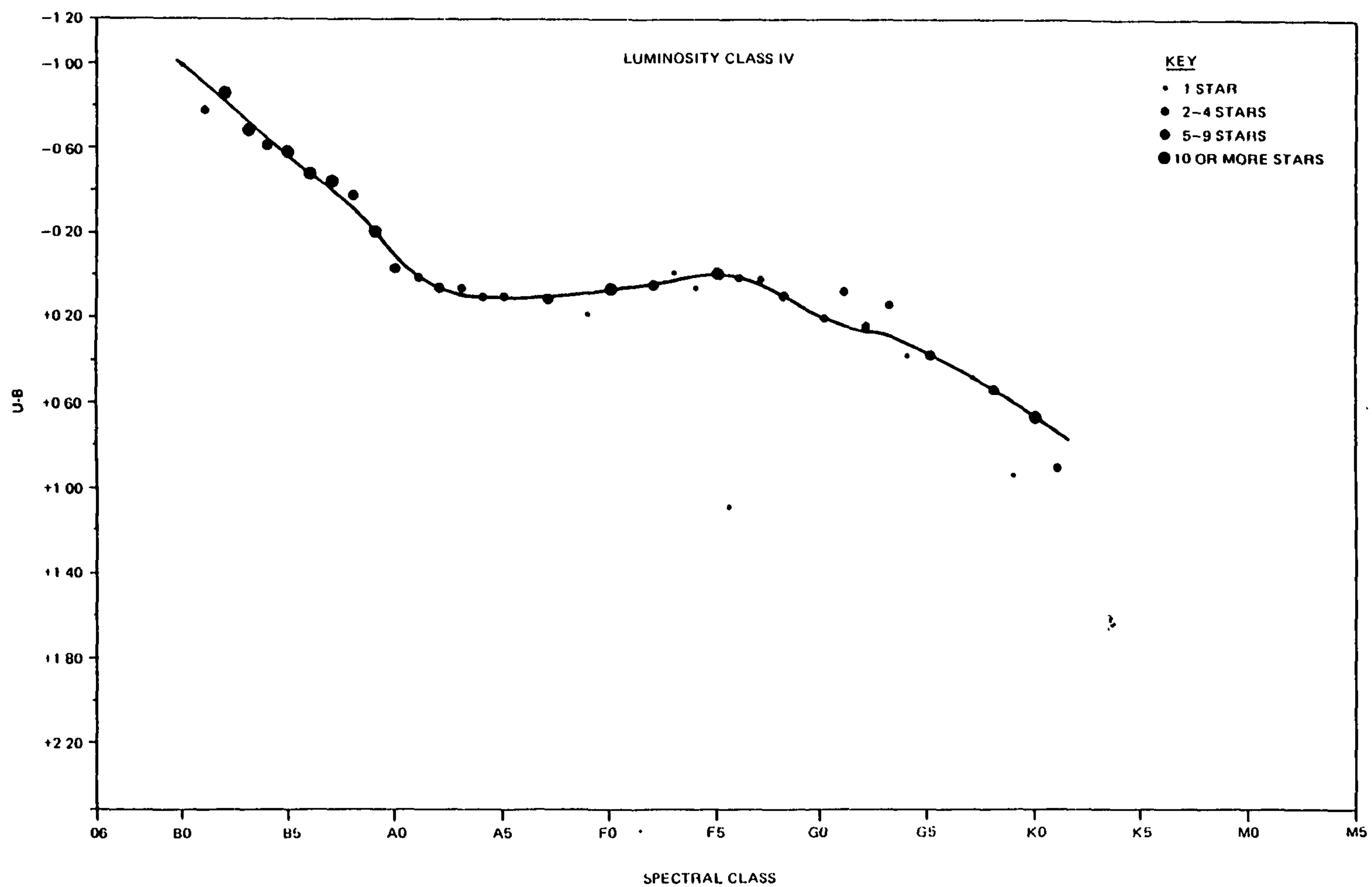

Figure 3-11. Estimated U-B Spectral Class Plot and Smoothed U-B Curve (4 of 5)

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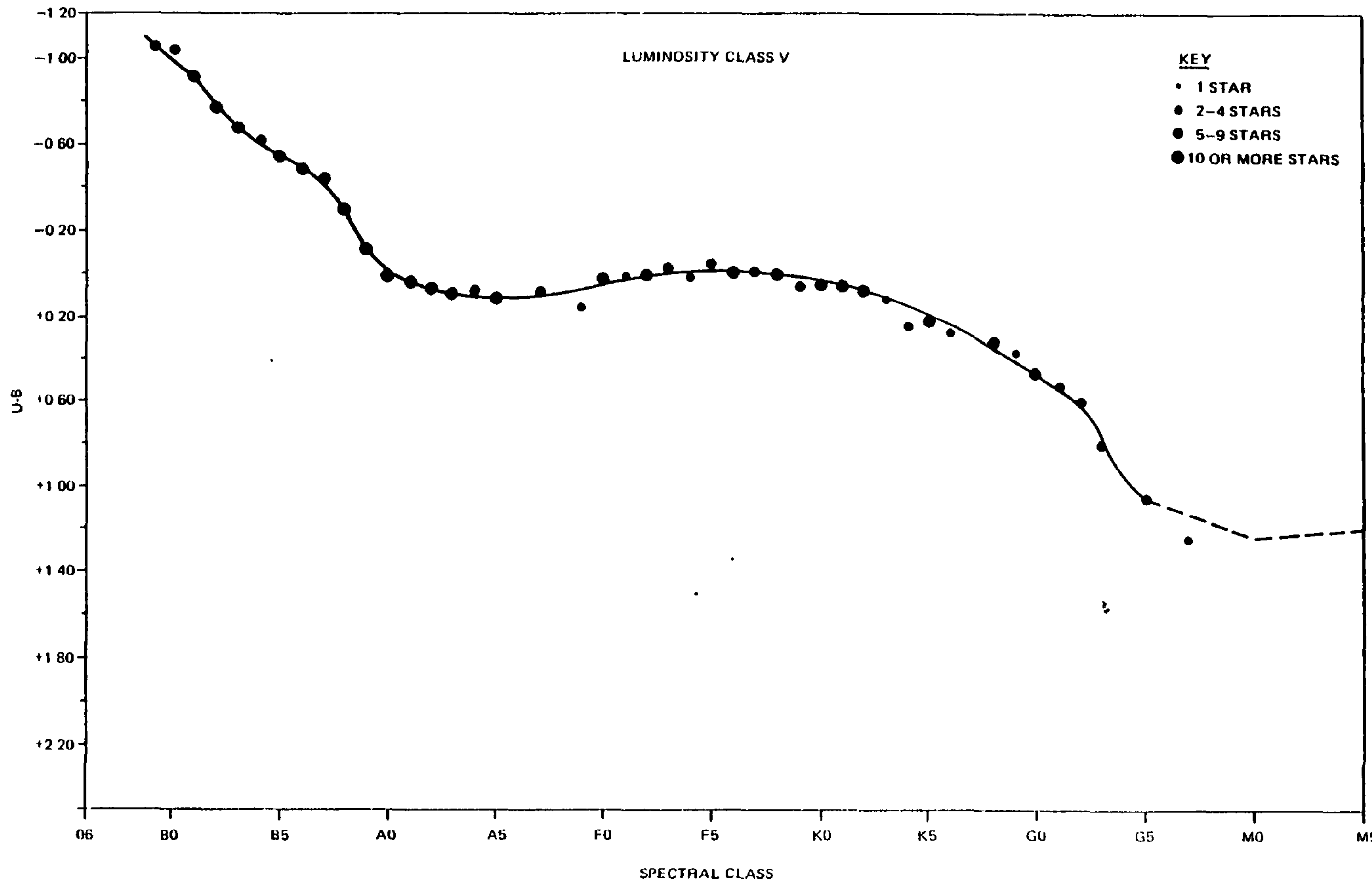

Figure 3-11. Estimated U-B Spectral Class Plot and Smoothed U-B Curve (5 of 5)

The results were then smoothed, and the relation $a_v = 3\ E_b$ applied to yield the adopted relationship of a_v to both distance and galactic coordinates. This is presented in Figure 3-12. For stars with galactic latitudes more than 20 degrees from the equator, a_v is assumed to be zero.

3.5.3 Computation of U Magnitudes

For stars not having measured U magnitudes, the following procedure was employed.

First, a correlation of observed U magnitude as a function of B and V magnitudes and spectral types was performed, using

$$U^o = \alpha + \beta B^o + (1 - \beta) V^o \tag{3-39}$$

where α and β are coefficients computed using a least squares algorithm for each range of spectral class and luminosity class given in Table 3-14; B^o and V^o are B and V magnitudes of the star with the interstellar absorption removed to yield intrinsic magnitudes; and the variable thereby computed, U^o, is the U magnitude of the star with the interstellar absorption ignored. The computed values of α, β and the standard deviation in U are given in Table 3-14.

The results of the correlation were then applied to all stars having B and V magnitudes, spectral types, and reddening indices to yield a U^o magnitude. Finally,

$$U = U^o + a_u \tag{3-40}$$

where A_u is the interstellar absorption in the U filter and is given in Reference 27 as

$$A_u = 1.57\ A_v + 0.006\ A_v^2 \tag{3-41}$$

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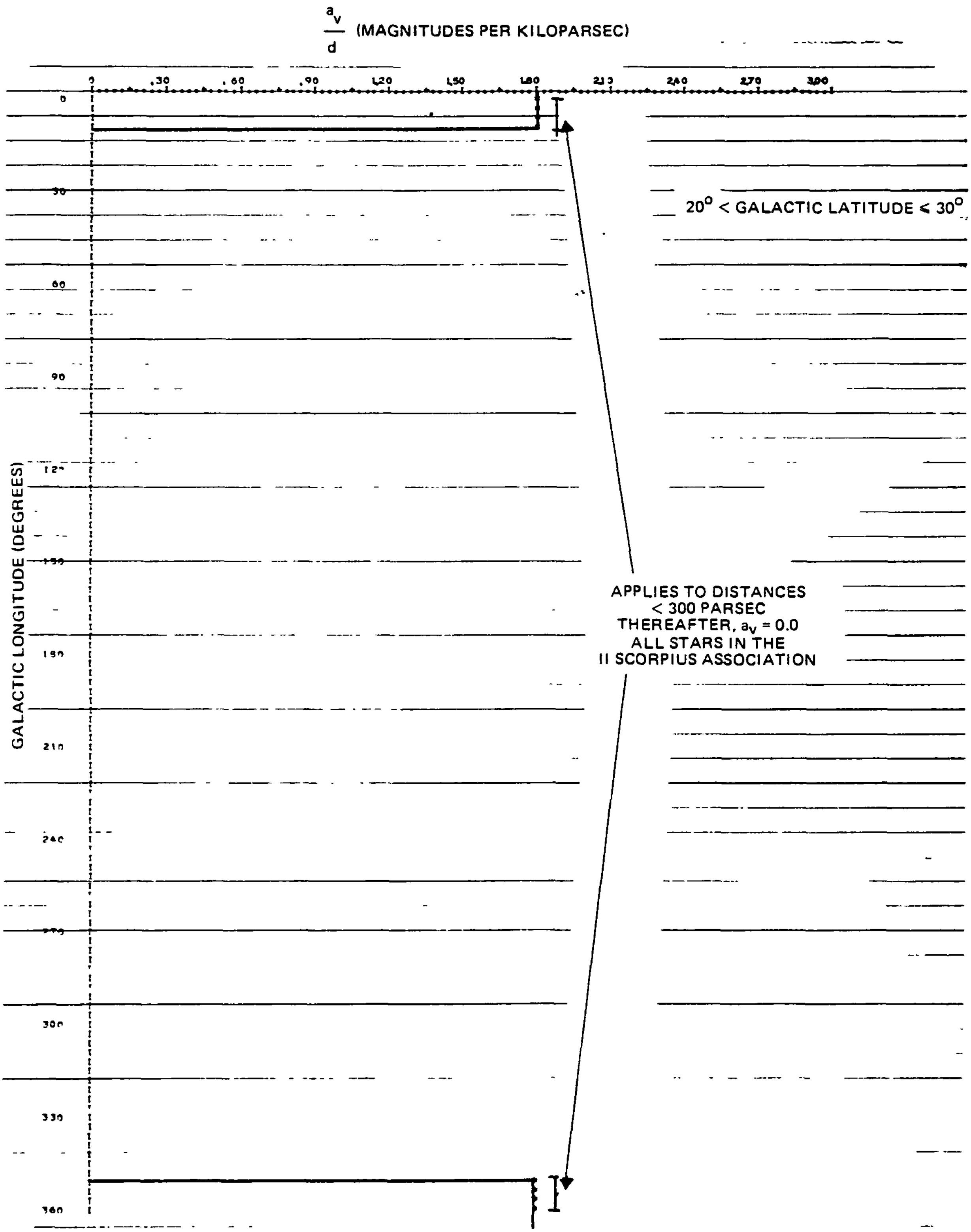

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (1 of 6)

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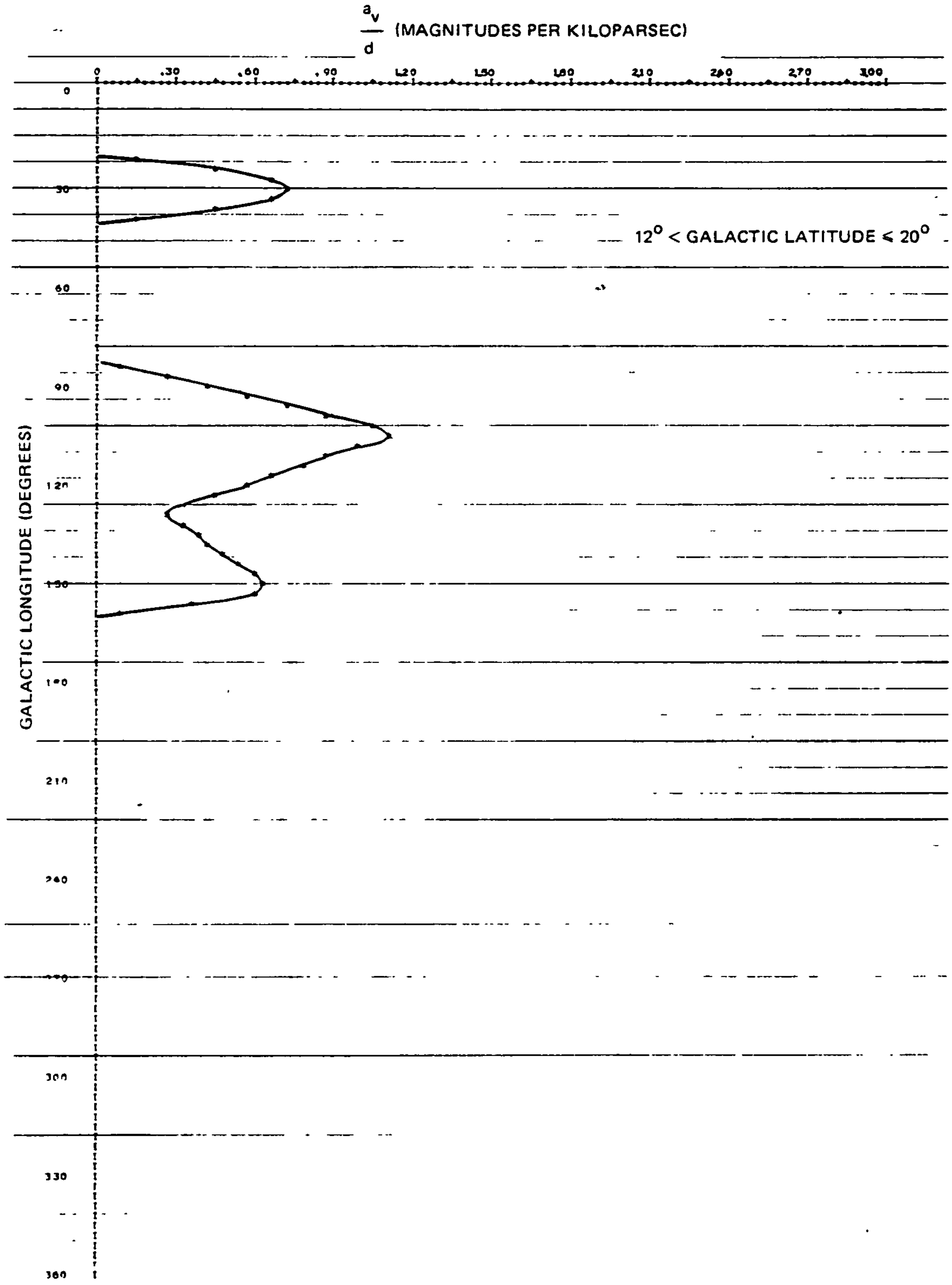

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (2 of 6)

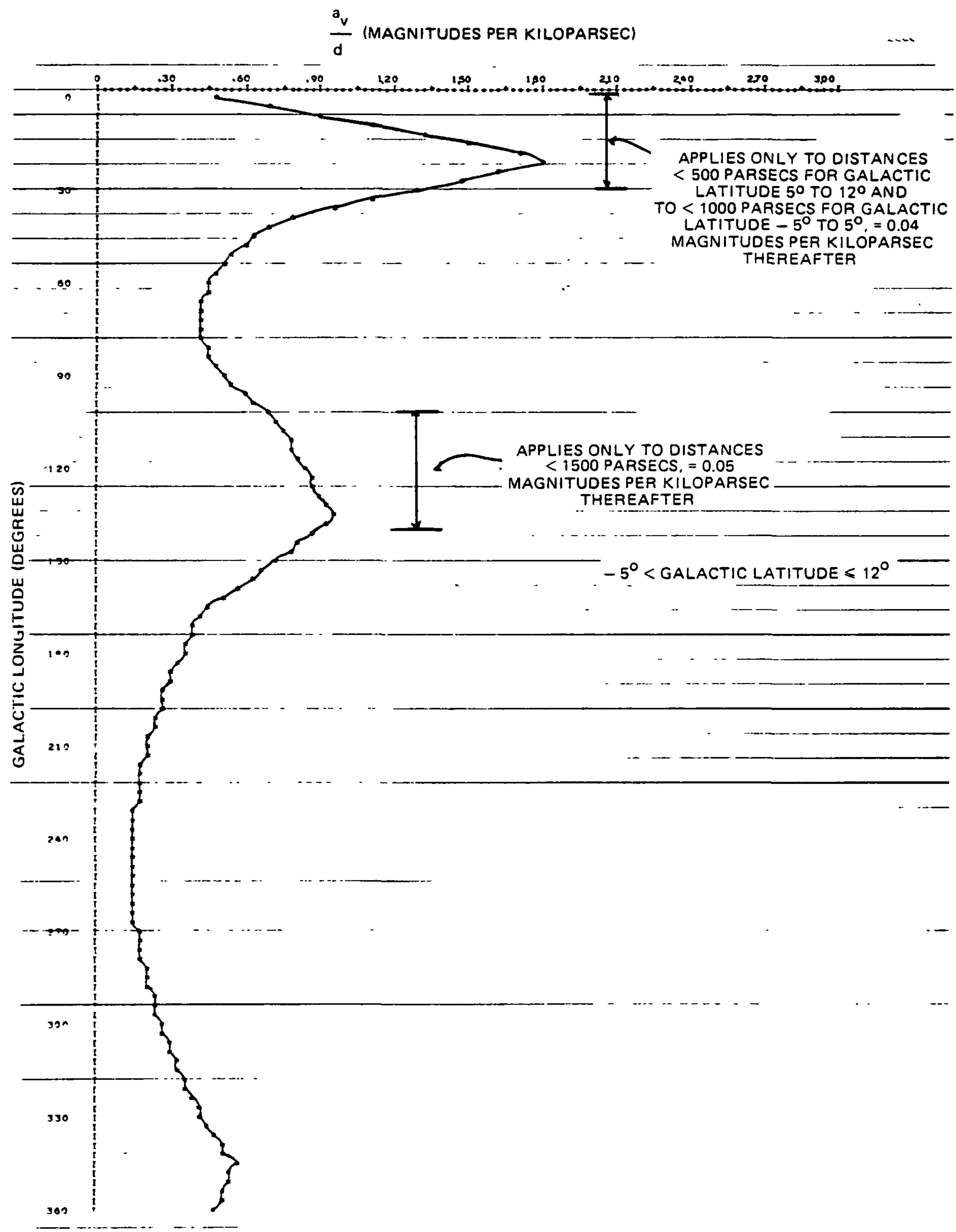

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (3 of 6)

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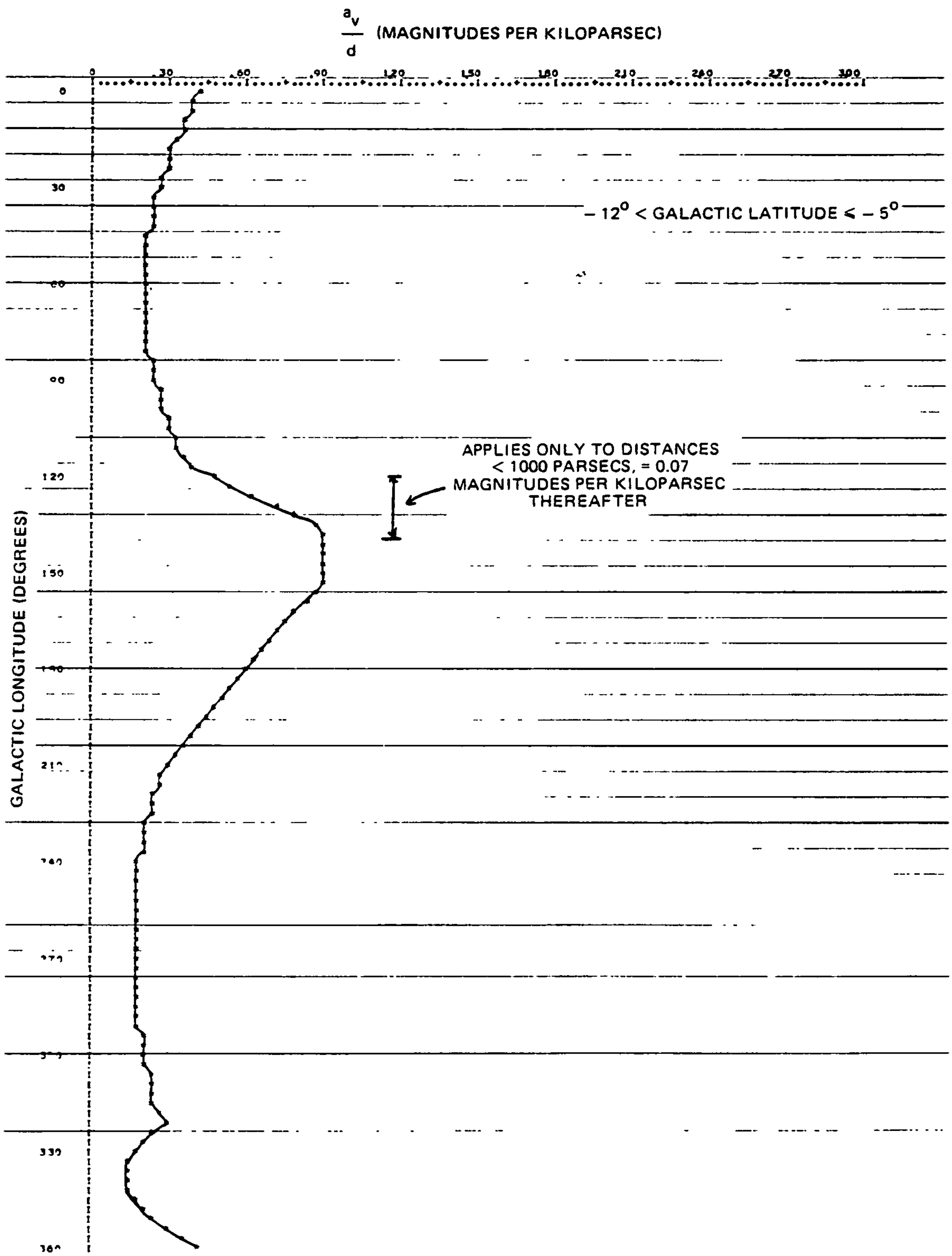

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (4 of 6)

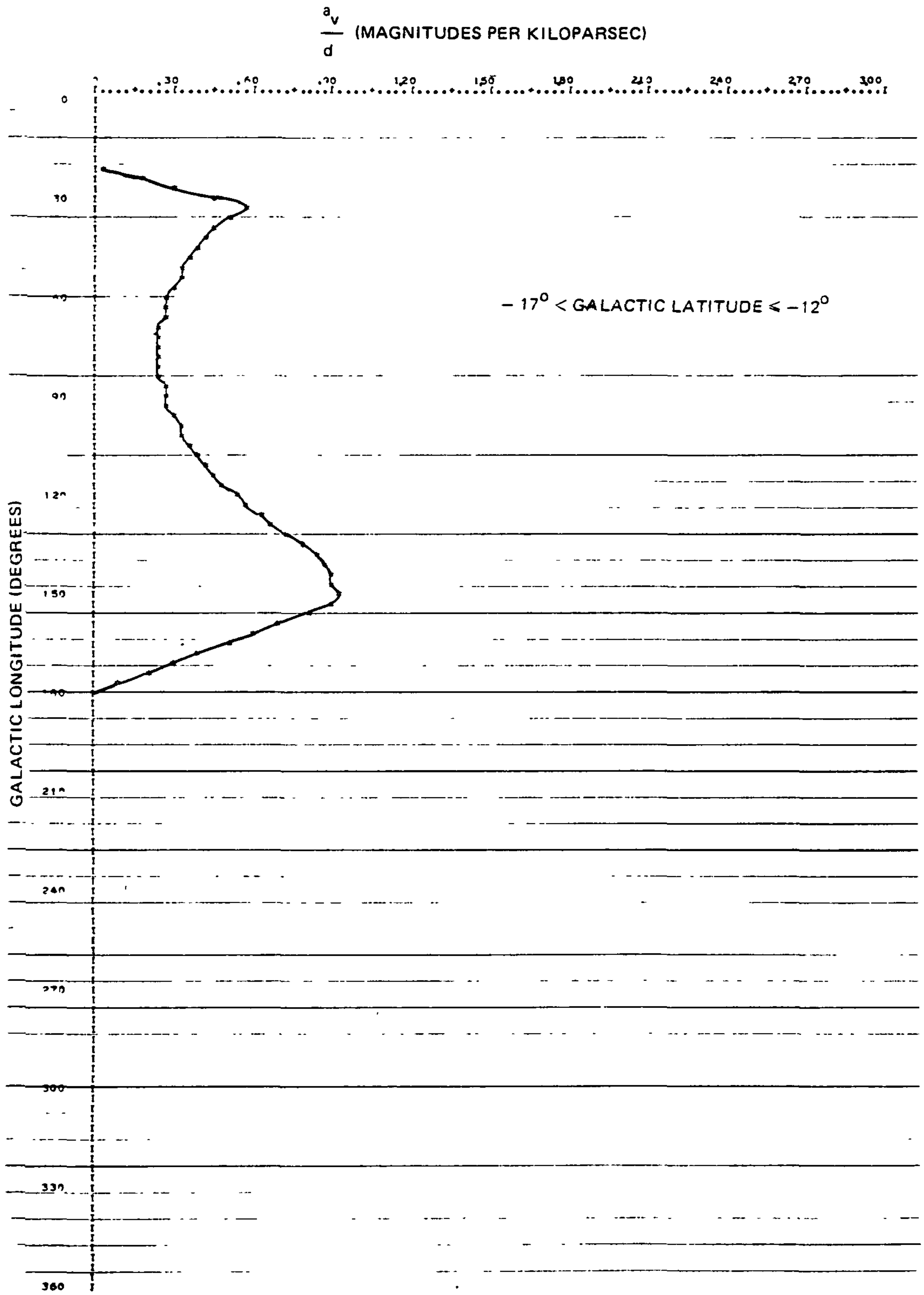

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (5 of 6)

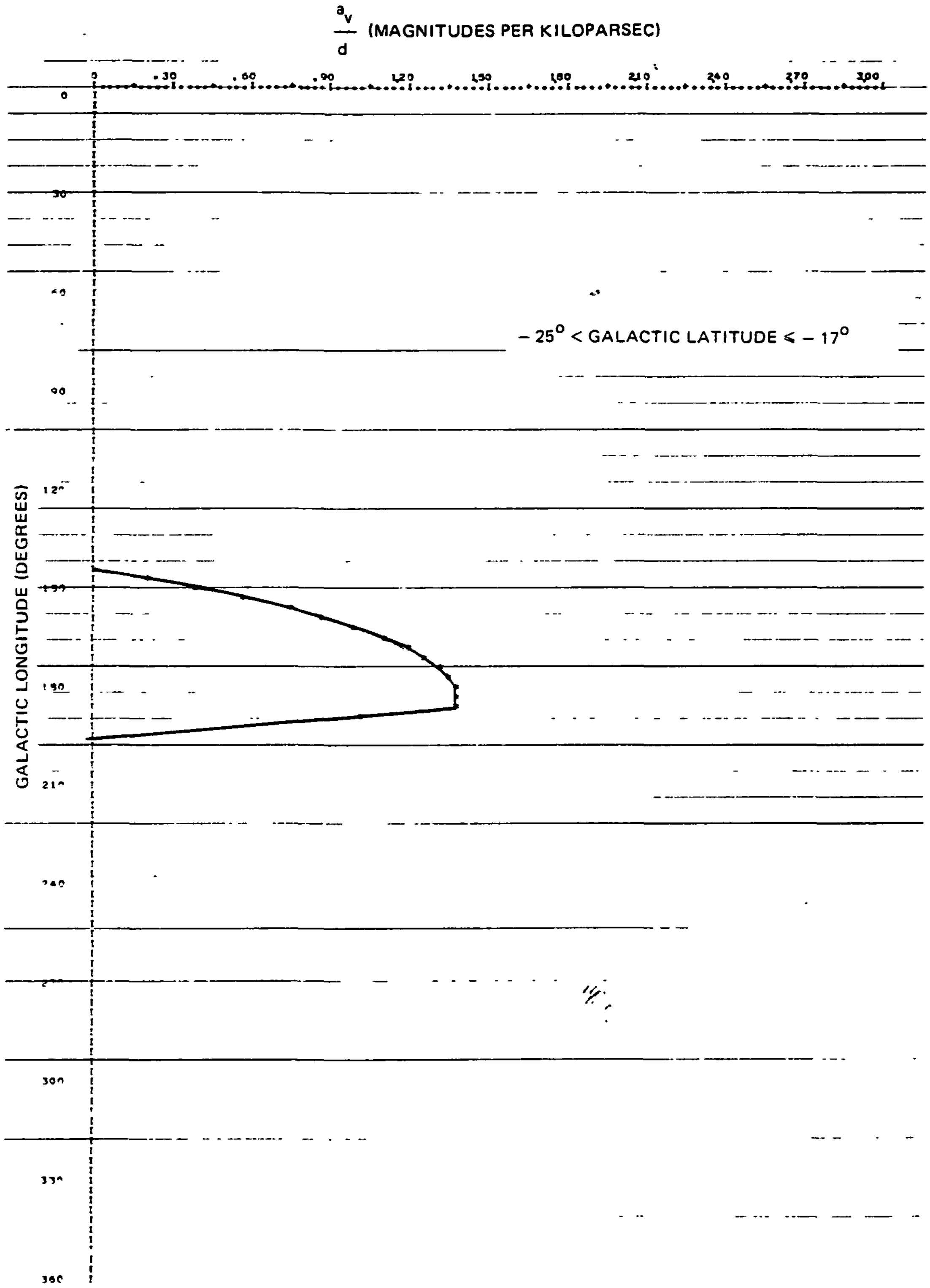

Figure 3-12. Adopted Relationship of a_V to Distance and Galactic Coordinates (6 of 6)

Table 3-14. Spectral Class/Luminosity Class Categories and Coefficients for Computation of U

NUMBER	SPECTRAL CLASSES	LUMINOSITY CLASSES	α	β	STANDARD DEVIATION IN U (MAGNITUDE)
1	O–B	I	−0.57	3.02	0.10
2	A–F	I	−0.26	2.13	0.19
3	G–M	I	−0.76	2 64	0 26
4	O–B	II	−0.45	3 35	0.14
5	A–F	II	0.12	1.17	0 10
6	G–M	II	−0.66	2.52	0.18
7	O–B	III	−0.38	2.72	0.22
8	A–G5	III	−0.07	1.67	0 15
9	G6–M	III	−0 86	2.75	0.15
10	O–A	IV	−0.23	3 63	0.15
11	F–K	IV	−0 37	2.09	0 16
12	O–B	V	−0.18	3 87	0.18
13	A–F	V	−0.01	1.06	0.10
14	G–M	V	−0.75	2.77	0.28

3.6 VARIABLE STAR DATA

Approximately 2 percent of the stars in the Master Catalog are known to have variable magnitudes. The cause of the variation may be changes in the star itself, such as pulsation, or physical blocking of the star by a companion (eclipse). The Master Catalog contains sufficient data about each variable star to determine its magnitude at any given time provided that the variations are regular.

The magnitude of a variable star is normally predictable and characterized by a functional form of given period and amplitude. Knowing the functional form (type of variation), period, amplitude (difference between brightest and dimmest magnitudes) and phase (current time minus epoch time), the magnitude at the current time is readily calculable from

$$m(t) = m' + A\nu\left[t - t_{epoch}\ (\text{modulo } P)\right] \tag{3-42}$$

where
m' = brightest magnitude
A = amplitude of variation
P = period of variation
t_{epoch} = epoch time
$\nu(t)$ = functional form of the variation

Because the meaning of epoch and the exact functional form of the variations differ by type of variable, one must refer to References 9 and 32 to make use of Equation (3-42). This function $\nu(t)$ is obtained by decoding a flag in the Master Catalog (see Section 4.5) which refers to the functional form in References 9 and 32. Stars listed as being irregular variables, semiregular variables or novae are unpredictable, and have no values of the epoch or period. Thus Equation (3-42) cannot be used. The minimum and maximum brightness provided in the Master Catalog do, however, provide limits on the magnitude.

3.7 MULTIPLE STAR DATA

Because analytical techniques to identify star sensor observations may confuse one star with a nearby companion or neighbor, it is often desirable to have information on the brightness of, and angular distance to, the next closest star. This is referred to below as "nearest neighbor" data. Stars brighter than 8.0 magnitude often do not have neighboring stars closer than 0.5 degree unless they are members of a multiple star system (one in which two or more stars are physically associated, i.e., gravitationally bound). Therefore, nearest neighbor data depends heavily on multiple star data.

The Master Catalog multiple star data obtained from Reference 33 consists of the difference in magnitude between the brightest and the second brightest star in the system, and the separation between them.

Since the measurement of separation was made at a specific time, typically 20 to 100 years ago, the separation may have changed due to the motion of the stars about one another. For virtually all stars with separations over 30 arc-seconds, however, the separation changes very slowly because the orbital periods are on the order of thousands of years.

For stars which are not members of multiple star systems, the distance to the nearest neighboring star in the Master Catalog, and the distance to the nearest neighboring star in the Master Catalog which met certain magnitude restrictions (see Section 4) were computed. This search was performed to a limit of 0.5 degree. Stars not having neighbors within this limit are shown as having no nearest neighbor. Reference 46 analyzes the accuracy of nearest neighbor data.

SECTION 4 - MASTER CATALOG FORMAT

This section is a description of the Master Catalog format, including a definition of each variable. Table 4-1 lists the Master Catalog data words for each star. All words are four bytes for ease in access. The column marked "IF NONE" gives the value stored in the position for the variable if that data is not valid. The source refers to whether the data was taken from an external source catalog, or was computed internally using SKYMAP software.

Each of the words of data listed in Table 4-1 is described below.

4.1 STAR NUMBERS AND NAMES

Star numbers and names are provided in the Master Catalog to allow easy cross-reference to printed star catalogs. The word number refers to that shown in Table 4-1.

4.1.1 Word 1

HD numbers are defined in Reference 8 in order of increasing right ascension, epoch 1900.0 (Word 23). Values range from 1 to 225300 for original HD stars, and from 225301 to approximately 280,000 for HD Extension stars.

4.1.2 Word 2

The SKYMAP number is a running index, as defined in Section 3.2.1. Numbers were assigned in catalog order; i.e., in order of increasing right ascension at the standard epoch (2000.0) (Word 13).

4.1.3 Word 3

The SAO number is a 6-digit integer used principally in the SAO catalog (Reference 4). These numbers are assigned sequentially within declination zones

Table 4-1. Master Catalog Format (1 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
STAR NUMBERS AND NAMES					
1	I*4	HD NUMBER	–	0	EXTERNAL
2	I*4	SKYMAP NUMBER	–	–	INTERNAL
3	I*4	SAO NUMBER	–	0	EXTERNAL
4	I*4	COMPOSITE DM NUMBER	–	0	EXTERNAL
5	I*4	HR NUMBER	–	0	EXTERNAL
6	I*4	ADS NUMBER	–	0	EXTERNAL
7	I*4	VARIABLE STAR CATALOG NUMBER	–	0	EXTERNAL
8–10	3(A*4)	STAR NAME	–	BLANK[1]	EXTERNAL
11–12	2(A*4)	VARIABLE NAME	–	BLANK	EXTERNAL
POSITIONS AND PROPER MOTIONS					
13	R*4	RIGHT ASCENSION, STANDARD EPOCH	DEGREES	–	INTERNAL & EXTERNAL
14	R*4	DECLINATION, STANDARD EPOCH	DEGREES	–	INTERNAL & EXTERNAL
15	R*4	ERROR IN STANDARD EPOCH POSITION	ARC-SECONDS	–	INTERNAL & EXTERNAL
16	R*4	GALACTIC LATITUDE	DEGREES	–	INTERNAL
17	R*4	GALACTIC LONGITUDE	DEGREES	–	INTERNAL
18–20	3(R*4)	UNIT VECTOR COMPONENTS, STANDARD EPOCH	–		INTERNAL
21	R*4	RIGHT ASCENSION, EPOCH 1950 0	DEGREES	0 0	EXTERNAL

[1]BLANK = 'bbbb'

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Table 4-1. Master Catalog Format (2 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
POSITIONS AND PROPER MOTIONS (CONT'D)					
22	R*4	DECLINATION, EPOCH 1950 0	DEGREES	0 0	EXTERNAL
23	R*4	RIGHT ASCENSION, EPOCH 1900 0	DEGREES	0 0	EXTERNAL
24	R*4	DECLINATION, EPOCH 1900.0	DEGREES	0.0	EXTERNAL
25	R*4	PROPER MOTION IN RIGHT ASCENSION	DEGREES/ YEAR	0 0	EXTERNAL
26	R*4	PROPER MOTION IN DECLINA- TION	DEGREES/ YEAR	0 0	EXTERNAL
27	R*4	PRECESSION IN RIGHT ASCEN- SION	DEGREES/ 100 YEARS	–	INTERNAL
28	R*4	PRECESSION IN DECLINATION	DEGREES/ 100 YEARS	–	INTERNAL
29	R*4	SUM OF PRECESSION AND PROPER MOTION IN RIGHT ASCENSION	DEGREES/ 100 YEARS	PRECESSION ONLY	INTERNAL
30	R*4	SUM OF PRECESSION AND PROPER MOTION IN DE- CLINATION	DEGREES/ 100 YEARS	PRECESSION ONLY	INTERNAL
MAGNITUDES AND SPECTRAL TYPES					
31	R*4	U MAGNITUDE, BEST VALUE	MAGNITUDES	-9.999	INTERNAL
32	I*4	U MAGNITUDE DERIVATION FLAG	-	-	INTERNAL
33	R*4	B MAGNITUDE, BEST VALUE	MAGNITUDES	–9 999	INTERNAL
34	R*4	V MAGNITUDE, BEST VALUE	MAGNITUDES	-9 999	INTERNAL
35	I*4	B, V MAGNITUDE DERIVATION FLAG	–	-	INTERNAL

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Table 4-1. Master Catalog Format (3 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
MAGNITUDES AND SPECTRAL TYPES (CONT'D)					
36	R*4	PHOTOVISUAL MAGNITUDE (ptv)	MAGNITUDES	0.0	EXTERNAL
37	R*4	PHOTOGRAPHIC MAGNITUDE (ptg)	MAGNITUDES	0.0	EXTERNAL
38	I*4	ptv–ptg PRESENCE FLAG	–	–	EXTERNAL
39	R*4	V MAGNITUDE, OBSERVATION	MAGNITUDES	–9.999	EXTERNAL
40	R*4	B–V COLOR, OBSERVATION	MAGNITUDES	–9.999	EXTERNAL
41	R*4	U–B COLOR, OBSERVATION	MAGNITUDES	–9.999	EXTERNAL
42	I*4	SPECTRAL CLASS, BEST VALUE	–	0	INTERNAL
43	I*4	LUMINOSITY CLASS, BEST VALUE	–	0	INTERNAL
44	I*4	PECULIARITY CODE, BEST VALUE	–	0	INTERNAL
45	I*4	SPECTRAL TYPE SOURCE FLAG	–	–	INTERNAL
46	I*4	HD SPECTRAL TYPE	–	0	EXTERNAL
47	I*4	SPECTRAL CLASS, MK, OBSERVED	–	0	EXTERNAL
48	I*4	LUMINOSITY CLASS, MK, OBSERVED	–	0	EXTERNAL
49	I*4	PECULIARITY CODE, MK, OBSERVED	–	0	EXTERNAL
50	I*4	SPECTRAL TYPE, MK, OBSERVED SOURCE FLAG	–	–	INTERNAL
DISTANCES AND INTERSTELLAR ABSORPTIONS					
51	R*4	TRIGONOMETRIC PARALLAX	ARC-SECONDS	–999.999	EXTERNAL
52	R*4	PROBABLE ERROR IN TRIGONOMETRIC PARALLAX	ARC-SECONDS	999.999	EXTERNAL

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Table 4-1. Master Catalog Format (4 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
DISTANCES AND INTERSTELLAR ABSORPTIONS (CONT'D)					
53	R*4	TRIGONOMETRIC PARALLAX DISTANCE	PARSECS	0.0	INTERNAL
54	R*4	ERROR IN TRIGONOMETRIC PARALLAX DISTANCE	PARSECS	0.0	INTERNAL
55	R*4	MINIMUM DISTANCE BASED ON TRIGONOMETRIC PARALLAX	PARSECS	0.0	INTERNAL
56	R*4	ABSOLUTE VISUAL MAGNITUDE	MAGNITUDES	-999.999	EXTERNAL
57	R*4	SPECTROSCOPIC DISTANCE	PARSECS	0.0	INTERNAL
58	R*4	ERROR IN SPECTROSCOPIC DISTANCE	PARSECS	0.0	INTERNAL
59	R*4	RADIAL VELOCITY	KM/SEC	-999.999	INTERNAL
60–62	3(R*4)	θ, π, z COMPONENTS OF THE SPACE VELOCITY RELATIVE TO THE LSR[1]	KM/SEC	-999.999	INTERNAL
63	R*4	MAXIMUM DISTANCE BASED ON SPACE MOTION	PARSECS	0.0	INTERNAL
64	R*4	BEST DISTANCE	PARSECS	0.0	INTERNAL
65	R*4	ERROR IN BEST DISTANCE	PARSECS	0.0	INTERNAL
66	I*4	DISTANCE DERIVATION FLAG		–	INTERNAL
67	R*4	INTERSTELLAR ABSORPTION IN V	MAGNITUDES	9.999	INTERNAL
68	R*4	COLOR EXCESS IN B - V		–	INTERNAL
69	I*4	SOURCE FLAG FOR INTERSTELLAR ABSORPTION		–	INTERNAL

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[1]LOCAL STANDARD OF REST

Table 4-1. Master Catalog Format (5 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
VARIABLE STAR DATA					
70	I*4	VARIABILITY TYPE CODE	—	0	EXTERNAL
71	I*4	QUESTIONABLE VARIABILITY FLAG	—	—	EXTERNAL
72	R*4	DIFFERENCE BETWEEN BRIGHT-EST AND DIMMEST MAGNITUDES	MAGNITUDES	-999 999	EXTERNAL
73	I*4	VARIABLE MAGNITUDE TYPE FLAG	—	—	EXTERNAL
74	R*4	EPOCH OF VARIATION	DAYS	0 0	EXTERNAL
75	R*4	PERIOD OF VARIATION	DAYS	0 0	EXTERNAL
MULTIPLE STAR DATA					
76	R*4	SEPARATION OF TWO BRIGHT-EST COMPONENTS OF PHYSICAL MULTIPLE STAR	ARC-SECONDS	0 0	EXTERNAL
77	R*4	DIFFERENCE IN BRIGHTNESS BETWEEN THE TWO BRIGHT-EST COMPONENTS	MAGNITUDES	-9 999	EXTERNAL
78	I*4	YEAR OF OBSERVATION	YEARS	1000	EXTERNAL
79	R*4	DISTANCE TO NEAREST NEIGHBORING STAR IN THE MASTER CATALOG	DEGREES	-9 999	INTERNAL
80	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 2" FROM THIS STAR	DEGREES	-9 999	INTERNAL
81	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 5" FROM THIS STAR	DEGREES	9 999	INTERNAL

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Table 4-1. Master Catalog Format (6 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
MULTIPLE STAR DATA (CONT'D)					
82	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 15" FROM THIS STAR	DEGREES	-9 999	INTERNAL
83	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 40" FROM THIS STAR	DEGREES	-9 999	INTERNAL
84	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 120" FROM THIS STAR	DEGREES	-9 999	INTERNAL
85	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR FURTHER THAN 300" FROM THIS STAR	DEGREES	9 999	INTERNAL
86	R*4	DISTANCE TO THE NEAREST NEIGHBORING MASTER CATALOG STAR NO MORE THAN TWO MAGNITUDES DIMMER THAN THIS STAR	DEGREES	-9 999	INTERNAL
87	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR NO MORE THAN TWO MAGNITUDES DIMMER THAN THIS STAR AND FURTHER THAN 5" FROM THIS STAR	DEGREES	-9 999	INTERNAL
88	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR NO MORE THAN TWO MAGNITUDES DIMMER THAN THIS STAR AND FURTHER THAN 40" FROM THIS STAR	DEGREES	-9 999	INTERNAL

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Table 4-1. Master Catalog Format (7 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
MULTIPLE STAR (CONT'D)					
89	R*4	DISTANCE TO THE NEAREST NEIGHBORING STAR NO MORE THAN TWO MAGNITUDES DIMMER THAN THIS STAR AND FURTHER THAN 300" FROM THIS STAR	DEGREES	-9 999	INTERNAL
90	I*4	SOURCE OF POSITION FLAG	--	0	INTERNAL
91	I*4	SOURCE OF RADIAL VELOCITY FLAG	--	0	INTERNAL
92	I*4	MULTIPLE STAR FLAG	--	0	INTERNAL
93	R*4	SYSTEMATIC ERROR IN RIGHT ASCENSION	ARC SEC	0	INTERNAL
94	R*4	SYSTEMATIC ERROR IN DECLINATION	ARC SEC	0	INTERNAL
95	I*4	WHEN SKYMAP STARS ARE IDENTIFIED AS DUPLICATE ENTRIES, THIS IS SKYMAP NUMBER OF LAST ENTRY MERGED WITH THIS STAR	---	0	INTERNAL
FORMATTED DATA					
96	A*4	DM NUMBER, +/- ZONE FLAG	---	BLANK	INTERNAL
97	A*4	DM ZONE		BLANK	INTERNAL
98 99	2(A*4)	DM SEQUENTIAL NUMBER	-	BLANK	INTERNAL
100	A*4	HOURS OF RIGHT ASCENSION, STANDARD EPOCH	HOURS	BLANK	INTERNAL
101	A*4	MINUTES OF RIGHT ASCENSION, STANDARD EPOCH	MINUTES (TIME)	BLANK	INTERNAL
102	A*4	SECONDS OF RIGHT ASCENSION, STANDARD EPOCH	SECONDS (TIME)	BLANK	INTERNAL
103	A*4	DECLINATION +/- FLAG, STANDARD EPOCH		BLANK	INTERNAL
104	A*4	DEGREES OF DECLINATION, STANDARD EPOCH	DEGREES	BLANK	INTERNAL

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Table 4-1. Master Catalog Format (8 of 8)

WORD NUMBER	TYPE	MEANING	UNITS	DEFAULT	SOURCE
FORMATTED DATA (CONT'D)					
105	A*4	MINUTES OF DECLINATION, STANDARD EPOCH	ARC-MINUTES	BLANK	INTERNAL
106	A*4	SECONDS OF DECLINATION, STANDARD EPOCH	ARC-SECONDS	BLANK	INTERNAL
107	A*4	SOURCE OF POSITION	---	--	INTERNAL
108	A*4	SUM OF PROPER MOTION AND PRECESSION IN RIGHT ASCENSION PER 100 YEARS	MINUTES (TIME)	BLANK	INTERNAL
109	A*4	SUM OF PROPER MOTION AND PRECESSION IN DECLINATION PER 100 YEARS	ARC-MINUTES	BLANK	INTERNAL
110	A*4	SOURCE OF U MAGNITUDE	--	---	INTERNAL
111	A*4	SOURCE OF B AND V MAGNITUDES	---	---	INTERNAL
112	A*4	SPECTRAL CLASS, OBSERVED, HD OR MK	---	BLANK	INTERNAL
113-114	2(A*4)	LUMINOSITY CLASS, OBSERVED, HD OR MK	--	BLANK	INTERNAL
115	A*4	PECULIARITY CODE, OBSERVED, HD OR MK	--	BLANK	INTERNAL
116	A*4	SPECTRAL TYPE SOURCE	---	--	INTERNAL
117	A*4	SOURCE OF DISTANCE	---	---	INTERNAL
118	A*4	SOURCE FOR INTERSTELLAR ABSORPTION	--	-	INTERNAL
119	A*4	B--V	MAGNITUDES	BLANK	INTERNAL
120	A*4	U-B	MAGNITUDES	BLANK	INTERNAL
121-122	2(A*4)	VARIABILITY TYPE	BLANK	BLANK	INTERNAL
123-135	4 BYTE	SPARES	---	--	---

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10 degrees wide, beginning at the North Celestial Pole. Therefore, increasing SAO numbers correspond approximately to decreasing declination, epoch 1950.0 (Word 22).

4.1.4 Word 4

The Durchmusterung number (DM number) is a coded composite of the DM zone and sequential index (see Section 3.2.2). It is an 8-digit integer, the first three digits of which represent the 1-degree-high declination zone (epoch 1855.0) into which the star falls, and the last five digits of which form a sequential index within that zone assigned in order of increasing right ascension (epoch 1855.0). Words 96 through 99 are a formatted equivalent of this word.

4.1.5 Word 5

The HR number, from the Yale Catalog of Bright Stars (Reference 15), is frequently cross-referenced in scientific literature. It is defined in order of increasing right ascension, epoch 1950.0, beginning with 1 and ending with 9110.

4.1.6 Word 6

The Aitken Double Star (ADS) number, originally defined in Reference 17, is a designation for multiple stars. It is a 5-digit integer, assigned in order of increasing right ascension, epoch 1900.0.

4.1.7 Word 7

The Variable Star Catalog sequence number (Reference 9) is given for all variable stars in the Master Catalog. It was originally defined in alphabetical order of constellation, and therefore bears no relation to the position of the star.

4.1.8 Words 8 Through 10

The star name (or Flamsteed name) is a Greek letter and/or Arabic number followed by the name of the constellation containing the star. It is encoded here as a formatted field with Greek letters represented by three character transliterations, and constellations as three character abbreviations. The star name is frequently used in the literature for stars brighter than 6.0 magnitude.

4.1.9 Words 11 and 12

The variable name consists of one or two letters and an abbreviation of the name of the constellation containing the star. Variable stars are frequently referred to by this name.

4.2 POSITIONS AND PROPER MOTIONS

The parameters presented in this section allow computation of the position of each star at any epoch. This is accomplished by adding corrections for proper motion and precession to the position given at a standard epoch (see Section 3.3).

4.2.1 Words 13 and 14

The basic position in the Master Catalog is the right ascension and declination at the standard epoch, which is 2000.0. These data come preferentially from the SAO (Reference 4) which contains all stars with accurately known positions and proper motions. Lacking SAO data, these words come from References 39, 8, 9, 33, 3, and 40.

Formatted equivalents of these data words appear in Words 100 to 106.

4.2.2 Word 15

The error in the standard epoch position is taken from the SAO catalog for SAO stars. For AGK-3 stars, it is set to 0.5 arc-second (see Reference 41). For HD or HDE positions it is 35 arc-seconds (see Reference 42), and for all others, it is 100 arc-seconds. The error in right ascension, ϵ_α, approximately equals the error in declination, ϵ_δ, and is given by:

$$\epsilon_\alpha \approx \epsilon_\delta \approx \epsilon_{TOT}/\sqrt{2} \qquad (4\text{-}1)$$

where ϵ_{TOT} = total error (Word 15)

4.2.3 Words 16 and 17

Galactic latitude and longitude are computed using Equation (3-21). Galactic latitude is referenced to the North Galactic Pole, which is at right ascension = $12^h51^m.4$ and declination = $+27^\circ7'.2$, epoch 2000.0. Galactic longitude is referenced to the zero point with right ascension = $17^h45^m.6$, and declination = $-28^\circ56'$, epoch 2000.0, which points to the galactic center (Reference 27).

4.2.4 Words 18 Through 20

Right ascension and declination at the standard epoch were converted to a G.I. (standard epoch) unit vector according to Equation (3-23).

4.2.5 Words 21 and 22

These right ascensions and declinations are taken, in order of preference, from Reference 4, 39, 8, 19, 18, or 33.

4.2.6 Words 23 and 24

These right ascensions and declinations are taken from the HD catalog, or its Extension, and are valid only for HD stars.

4.2.7 Words 25 and 26

Proper motion refers to the motion of the star across the sky due to the velocity of the star relative to the Sun. Equation (3-3) may be used to apply proper motion corrections from one epoch to another. The magnitude of the effect is usually less than 20 arc-seconds per hundred years, though occasionally it is as large as 1 arc-minute per hundred years. All stars with known proper motion are included in the SAO or AGK-3; therefore, the Master Catalog stars not in the SAO and AGK-3 do not have measured proper motions. These have been defaulted to 0.0. Lack of proper motion may lead to positional errors of up to 1 arc-minute per hundred years as the epoch is moved away from the epoch of measurement, 1900.0. These stars can be recognized as lacking proper motion data because their source of position (Word 90) will be different from 1 or 8.

4.2.8 Words 27 and 28

Precession is a correction in position due to the motion of the Earth's spin axis. The magnitude of the effect is approximately one-half degree in declination and 1 degree in right ascension per hundred years. It has been calculated for all Master Catalog stars using Equation (3-4).

4.2.9 Words 29 and 30

The total correction in position needed to transform from one epoch to another is the sum of proper motion (Words 25 and 26) and precession (Words 27 and 28). For convenience, these are summed and presented in Words 29 and 30. For those stars lacking proper motion data, these variables represent precession alone. Formatted equivalents of these words are given in Words 108 and 109.

4.3 MAGNITUDES AND SPECTRAL TYPES

The spectral energy distribution of a star as a function of wavelength is required to determine the instrumental magnitude of that star [see Equation (3-6)]. Precise observations of this distribution are available for only a handful of stars. However, two measures of spectral energy distribution are widely available--magnitudes within known bandpasses, and qualitative overall descriptions of the spectrum of the star (spectral type).

4.3.1 Word 31

The ultraviolet (U) magnitude of the UBV system (Reference 5) is centered at about 3500 Å and has an 800 Å half-width (see Figure 3-1). If observed values exist (from Words 39 through 41), they are used; if not, values are derived using the procedure given in Section 3.5.3. When the U magnitude has not been observed, and when one or more of the data words needed for its computation is not available, no U magnitude is computed.

4.3.2 Word 32

This flag gives the method by which the best value of the U magnitude (Word 31) was obtained. The meanings of each value are given below.

Value	Meaning
0	No U magnitude provided
1	U magnitude observed on UBV system
2	U magnitude computed by procedure given in Section 3.5.3
3	U-B observed and B computed from photovisual and/or photographic magnitudes

A formatted equivalent of this word is given in Word 110.

4.3.3 Words 33 and 34

The best values of the B (effective wavelength 4400 Å) and V (effective wavelength 5500 Å) magnitudes were obtained whenever possible from observed magnitudes (Words 39 and 40). When these were not available, they were derived according to the procedure given in Section 3.4.2. For variable stars, either B or V magnitude is listed (from Reference 9) and it refers to the brightest that the variable star will be. All Master Catalog stars have valid values of either V or B.

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4.3.4 Word 35

B and V magnitudes were calculated in various manners, as specified in Section 3.4.2. Anticipated errors associated with each method are given in Table 3-8. A formatted equivalent of this word is given in Word 111.

4.3.5 Words 36 and 37

These are the photovisual and photographic magnitudes from the HD catalog, or the SAO catalog for non-HD stars. They correspond approximately to V and B, respectively, but no spectral response curves are available for them.

4.3.6 Word 38

The validity flag for the photovisual and photographic magnitudes is defined below.

Value	Meaning
0	Neither photovisual nor photographic available
1	Both photovisual and photographic available from observations
2	Photovisual available from observation and photographic derived from photovisual and spectral type
3	Photographic available from observation and photovisual derived from photographic and spectral type
4	Photovisual available from observation; photographic not given
5	Photographic available from observation; photovisual not given

4.3.7 Words 39 Through 41

These are observed magnitudes on the system of Reference 5. B-V refers to the difference in B and V magnitude; U-B refers to the difference of U and B. Mean errors to be expected are 0.02 magnitude in V and B-V and 0.03 magnitude in U-B.

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4.3.8 Words 42 Through 44

The stars' spectral type is divided into spectral class, luminosity class, and peculiarity code. Spectral class (Word 42) is a measure of stellar temperature; the numerical code equivalents of the spectral classes are given in the table which follows. The spectral class code is a 4-digit integer.

The first two digits give the letter code.

First Two Digits	Letter Code
00	O
01	B
02	A
03	F
04	G
05	K
06	M
07	R
08	N
09	C
10	S
11	WR
12	WC
13	WN

The third digit is the number following the spectral type letter code; e.g., A8 becomes 0280. If no spectral type number is given, the third and fourth digits are 7. For example, A becomes 0277.

The fourth digit is 0 except for the case described above, for some O and M stars, and for stars with fractional spectral types. For O and M stars with small letters following the spectral type letter or number (e.g., O8f or Ma), the coding is:

Fourth digit	Meaning
1	a
2	b
3	c
4	d
6	e
8	f

For stars with a fractional spectral type, the fraction is encoded in the fourth digit. For example, B1.5 becomes 0115.

A few special codes appear, which are as follows:

Special Code	Meaning
0000	No spectral class available
0990	Peculiar
0991	S star, no further breakdown given

Luminosity class is a measure of stellar surface gravity, which affects the structure of the star's atmosphere and thus its spectral energy distribution. The codes for luminosity class are given below.

Code	Meaning
0	None
10	I
11	Ia-O
12	Ia
13	Ia-Iab
14	Iab

Code	Meaning
15	I-II
16	Iab-Ib
18	Ib
19	Ib-II
20	II
28	IIb
30	III
40	IV
50	V
60	VI
-10	c
-30	g
-50	d

Split classes are averaged; e.g., III-IV becomes 35.

The peculiarity code specifies anomalies in chemical composition of the star, its speed of rotation, or existence of an extended atmosphere. The coding for this variable is given below. This is a 2-digit code. The printout abbreviation refers to program UPDATE printed output (see Section 5).

The first digit is as follows:

Number	Meaning	Printout Abbreviation
1	Metallic	M
2	Very rapid rotator	NN
3	Weak lined	WL
4	Silicon	SI
5	Composite spectrum	COMP
6	Shell	SH

Number	Meaning	Printout Abbreviation
7	Variable	VAR
8	4670 star	4670
9	Star plus nebula	NEB

The second digit is a sum of any of the following that apply:

Number	Meaning	Printout Abbreviation
1	Peculiar	P
2	Rapid rotator	N
4	Emission star	E

The following special codes apply:

Special Codes	Meaning	Printout Abbreviation
00	No peculiarities noted	-
68	Calcium K-line star	K
69	EQ	EQ
78	S appended to spectral type (e.g., M2S)	S
79	Chromium star	CR
88	Horizontal branch star	HB
89	Helium star	HE
98	Strontium-chromium star	SRCR
99	Central star of a planetary nebula	PLAN

These spectral type words are based on the MK system of Reference 7. Stars for which MK spectral types (Words 47 through 49) have not been observed have had HD spectral types converted to the MK system using the procedure specified in Section 3.4.1. Formatted equivalents of these words are found in Words 112 through 115.

4.3.9 Word 45

This variable specifies the source for the spectral class, luminosity class, and peculiarity code given in Words 42 through 44, and are given below.

Value	Meaning
0	Spectral class, luminosity class, and peculiarity code not available
1,2,3	Spectral class, luminosity class, and peculiarity code observed in the MK system and reported in References 18, 19, or 8, respectively
4	Spectral class observed in the HD system and converted to spectral class and luminosity class in the MK system; the peculiarity code was set to 0
5	Same as 4 for SAO spectral types
6	Same as 4 for AGK-3 spectral types

A formatted equivalent of this word is found in Word 116.

4.3.10 Word 46

The spectral type in the HD system as given in References 3 and 4 consists of a spectral class only. The coding is the same as for the MK system spectral class shown in the table in Section 4.3.8, page 4-15.

4.3.11 Words 47 Through 49

These words are observed MK spectral class, luminosity class, and peculiarity code from References 18, 19, or 8 (listed in order of preference) and correspond to codes in the tables in Section 4.3.8.

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4.3.12 Word 50

This is the source flag for Words 47 through 49. The meanings of each flag are listed below:

Value	Meaning
0	None available
1	Taken from Reference 18
2	Taken from Reference 19
3	Taken from Reference 8

4.4 DISTANCES AND INTERSTELLAR ABSORPTIONS

The amount of interstellar absorption is a variable entering into the computation of instrumental magnitudes (Equation (3-6)). It, in turn, is derived from observed UBV magnitudes or from the star's distance and direction.

4.4.1 Word 51

Trigonometric parallax is the only direct measurement of distance available to astronomers for objects outside of the solar system. Section 3.5.1.1 discusses the definition of trigonometric parallax. Only a small fraction of Master Catalog stars have measured trigonometric parallaxes obtained from Reference 28. Over half of these have parallax errors sufficiently large compared to the parallax itself so that the parallax can be used to establish a minimum distance to the star.

4.4.2 Word 52

The probable error in the trigonometric parallax value given in Word 51 is also taken from Reference 28.

4.4.3 Words 53 Through 55

The distance derived from Words 51 and 52, the error in this distance (one standard deviation), and the minimum derived distance (if the parallax is too small compared to the error in parallax) are presented in these words. Section 3.5.1.1 details how these values are computed. All Master Catalog stars having valid values of Word 51 have valid values of either Words 53 and 54, or of Word 55.

4.4.4 Word 56

The absolute visual magnitude of a star is obtained from its spectral type, and is used in the computation of spectroscopic distance (Section 3.5.1.2). It is defined as what the observed (apparent) visual magnitude (V) would be if the star were at a distance of 10 parsecs and no intersellar absorption intervened. Absolute magnitudes are taken from Reference 30, except for those of supergiants, which are taken from Reference 34.

4.4.5 Words 57 and 58

The distance and error in distance to a star based on spectroscopic parallax (Section 3.5.1.2) are given in these words for all stars having valid values for Word 56.

4.4.6 Word 59

The radial velocity of a star is defined as its motion relative to the Sun in the direction directly towards (negative values) or away from (positive values) the Sun. Observed radial velocities are from Wilson (Reference 43). For stars not in Wilson, the inverse of the Sun's motion relative to the local standard of rest (LSR) in the direction of the star is taken as the radial velocity. This is statistically the most likely value. Section 3.5.1.3 details this calculation and defines LSR. The radial velocity flag (Word 91) specifies if the radial velocity is from Wilson or is calculated.

4.4.7 Words 60 Through 62

The θ, π, and z components of the stars' space velocity relative to the LSR are given in the coordinate system defined in Section 3.5.1.3 and computed according to the procedure defined in that section. These are compared to known dispersions of these velocity components given in Table 3-11 as a function of spectral type to yield a maximum distance to the star.

4.4.8 Word 63

The maximum distance to the star derived from Words 60 through 62 according to the procedure given in Section 3.5.1.3 is given in this word. All stars having valid values of Words 60 through 62 and a spectral type within the range specified in Table 3-9 have valid values for this word.

4.4.9 Words 64 and 65

The best available distance, Word 64, is computed from Words 53, 55, 57, and 63 according to the procedure given in Section 3.5.1.4; the error (one standard deviation) in this estimate, Word 65, is also computed as noted in that section.

4.4.10 Word 66

A flag is given which specifies how the distance presented in Word 64 was obtained. The flag value and its meanings are given below.

Value	Meaning
0	No distance given
1	Distance obtained from trigonometric parallax alone
2	Distance obtained from spectroscopic parallax alone
3	Distance obtained is a combination of trigonometric and spectroscopic parallax
4	Distance cited is a minimum distance computed from trigonometric parallax
5	Distance cited is a maximum distance computed from space velocities

A formatted equivalent of this word is given in Word 117.

4.4.11 Words 67 and 68

The amount of interstellar absorption, Word 67, at the V filter is computed according to the equations given in Section 3.5.2 for all stars with observed B and V magnitudes (Words 33 and 34) or a valid distance (Word 64). This can be readily converted into a color excess in B-V, Word 68, defined as the amount of increase in B-V due to interstellar absorption. Section 3.5.2 presents equations showing how this can be converted to absorptions in the B and U magnitudes.

4.4.12 Word 69

This flag indicates which method was used to obtain interstellar absorption. The flag values and its meanings are given below.

Value	Meaning
0	No absorption given
1	Absorption derived from B and V magnitudes alone
2	Absorption derived from U, B, and V magnitudes
3	Absorption derived from distance and direction to the star

A formatted equivalent of this word is given in Word 118.

4.5 VARIABLE STAR DATA

Stars with varying brightness (variable stars) may present a problem to mission planners and data analysts. If, for example, a sensor's limiting magnitude is 7.0, and a star varies in brightness between 6.0 and 8.0 magnitudes, then a data analysis program must include the star in its star catalog since it is sometimes sufficiently bright to be observed. On the other hand, mission planners cannot be sure it will be detectable, and so cannot plan on using it for control purposes unless they are able to predict its brightness as a function of time. The information contained in this section of the Master Catalog will allow the user to pick out variable stars, determine their brightest and dimmest magnitudes, and, for most stars, predict brightness as a function of time. Section 3.6 specifies how to predict the brightness of variable stars.

4.5.1 Word 70

The variability type code is a numerical code for the type of variability. Table 4-2 cross-references this code to the normal alphabetic code used in Reference 32 and gives a brief definition of the type of variation. The first digit of the 3-digit variability code gives the type of variable. If it is 1, the star is a pulsating variable; most of these stars have predictable variations. A 2 signifies an eruptive variable, usually having unpredictable variations. A 3 denotes an eclipsing variable, also usually having predictable variations.

The second digit of the code denotes the class of variable; for example, stars with 1 as the first digit and 2 as the second digit are all RR Lyrae type variables.

The third digit is the subclass of variable. A zero denotes that no subdivision exists for that type of variable or that the subdivision is unknown for that star.

4.5.2 Word 71

If the variability of a star is considered questionable, this flag is 1; otherwise, it is 0.

4.5.3 Words 72 and 73

For each regular variable and many well-observed irregular variables, the difference between the brightest and dimmest magnitudes possible for the star is given in Word 72. If Word 73 has a value of 1, the magnitude difference refers to the B or the photographic magnitude; if it is 2, Word 72 refers to the V magnitude.

4.5.4 Word 74

The epoch of a variable star is the time of a reference point in its light variation function, usually the time when the star is at its dimmest. It is expressed

Table 4-2. Variable Star Codes (1 of 2)

NUMERIC VARIABILITY CODE (WORD 70)	TYPE CODES ALPHAMERIC (WORDS 121, 122)	REFERENCE 32 CODE	NUMBER PRESENT IN MASTER CATALOG	TYPE OF VARIABLE	EXAMPLE
0	–	BLANK	–	NOT KNOWN TO BE VARIABLE	–
1	VARIABLE	BLANK OR V	52	UNCLASSIFIED VARIABLE	–
111	DEL CEP	C04	126	GALACTIC PLANE CEPHEID	β DOR
112	HALO CEP	CW	15	HALO CEPHEID	α UMI
120	RR LYRAE	RR	4	RR LYRAE TYPE	AI VEL
121	RR LYRA	RRA	22	RR LYRAE TYPE WITH ASYMMETRIC LIGHT CURVE	RX ERI
122	RR LYR C	RRC	3	RR LYRAE TYPE WITH SINE CURVE LIGHT CURVE	V703 SCO
130	RV TAURI	RV	4	RV TAURI TYPE	SS GEM
131	RV TAU A	RVA	5	SUPERGIANT WITH DOUBLE WAVE VARIATION, ALTERNATING PRIMARY AND SECONDARY MAXIMA, AND A CONSTANT MEAN MAGNITUDE	R SCT
132	RV TAU B	RVB	5	SAME AS 131 WITH A VARIABLE MEAN MAGNITUDE	U MON
140	BETA CEP	02C	17	BETA CANUS MAJORIS TYPE WITH LOW AMPLITUDE VARIATIONS	β CRU
150	DELT SCU	04SC	5	DELTA SCUTI TYPE WITH LOW AMPLITUDE	ρ PUP
160	ALP CNV	01CV	10	MAGNETIC VARIABLE	ϵ UMA
171	IRR LATE	IB	109	SLOW IRREGULAR VARIABLE OF LATE SPECTRAL TYPE[1]	β PEG
172	IRR SPGT	IC	12	IRREGULAR SUPERGIANT	RW CEP
180	MIRA	M	282	MIRA TYPE VARIABLE OF LONG PERIOD AND LARGE AMPLITUDE	o CET

[1] "LATE" SPECTRAL TYPE REFERS TO RELATIVE COOL STARS, SUCH AS THOSE WITH SPECTRAL CLASS K, M, R, N, S, OR C.

Table 4-2. Variable Star Codes (2 of 2)

NUMERIC VARIABILITY CODE (WORD 70)	TYPE CODES ALPHAMERIC (WORDS 121, 122)	REFERENCE 32 CODE	NUMBER PRESENT IN MASTER CATALOG	TYPE OF VARIABLE	EXAMPLE
190	SEMIREG	SR	66	SEMIREGULAR VARIABLE	VZ CAM
191	SEMIRG A	SRA	51	SEMIREGULAR GIANT OF LATE SPECTRAL TYPE	T CEN
192	SEMIRG C	SRC	17	SEMIREGULAR SUPER GIANT NEAR THE GALACTIC PLANE	α ORI
193	SEMIRG D	SRD	14	SEMIREGULAR GIANT OR SUPERGIANT OF SPECTRAL TYPE F, G, OR K	89 HER
194	RR CRB	SRB	142	SEMIREGULAR GIANT OF LATE SPECTRAL TYPE AND ALMOST REGULAR VARIATION	ρ PER
195	RR CRB E	SRBE	1	SAME AS 194 WITH EMISSION LINES IN THE SPECTRUM	η GEM
200	ERUPTIVE	IA	18	IRREGULAR VARIABLE OF EARLY SPECTRAL TYPE, SUBJECT TO ERUPTIONS	MU CEN
210	RW AUR	RW, RWN	22	IRREGULAR, LARGE AMPLITUDE	X PER
230	R CORBOR	RCRB	5	IRREGULAR, R CORONA BOREALIS TYPE	R CRB
261	NOVA RAP	NA	3	RAPIDLY DEVELOPING NOVA	V720 SCO
262	NOVA SLW	NB	1	SLOWLY DEVELOPING NOVA	X CIR
263	NOVA REC	ND	1	RECURRENT NOVA	T CRB
264	P CYGNI	NE	10	P CYGNI, NOVA-LIKE VARIABLE	γ CAS
270	IRR	I	19	RAPID IRREGULAR VARIABLE	VW DRA
300	ECLIPSE	E	15	ECLIPSING BINARY	ER VUL
310	ALGOL	EA	307	ALGOL TYPE ECLIPSING BINARY	α VIR
320	BETA LYR	EB	83	BETA LYRAE TYPE ECLIPSING BINARY	μ^1 SCO
330	CONTACT	EW	27	CONTACT TYPE ECLIPSING BINARY	ι BOO
340	ELLIPSDL	ELL	6	ELLIPSOIDAL TYPE ECLIPSING BINARY	π^5 ORI

1 "LATE" SPECTRAL TYPE REFERS TO RELATIVE COOL STARS, SUCH AS THOSE WITH SPECTRAL CLASS K, M, R, N, S, OR C.

in Julian days minus 2,400,000. Reference 32 must be consulted for more detailed information on the meaning of epoch for each type of variable. Irregular and most semiregular variables do not have meaningful epochs because their variations are too unpredictable.

4.5.5 Word 75

The period of a regular variable star is the duration of one cycle in its light variation function. Irregular and most semiregular variables do not have meaningful periods because their variations are too unpredictable.

4.6 MULTIPLE STAR DATA

Whenever two stars brighter than the sensor limiting magnitude are situated close together in the sky, data reduction programs may have difficulty determining which was observed by the sensor. Therefore, these programs may wish to avoid stars having nearby companions. Control programs will also want to avoid selecting these stars as control or guide stars. A star may have a close companion if it is a physical multiple star, or if it is part of an optical double--two stars which are not physically associated but which appear near one another in the sky.

Physical double stars may be recognized as having valid entries in Words 76 and 77 of the Master Catalog. Optical doubles to a distance of 0.5 degree are included, along with physical doubles, in the nearest neighbor computations (Words 79 through 83).

4.6.1 Word 76

The separation of the two brightest components of a physical multiple star is given in this word. The observation referred to in Word 76 was made in the year noted in Word 78. If the observation of a star occurred more than a few years from the epoch of interest, the stars of the multiple star system may have moved significantly relative to one another. Thus, the separation may no longer be valid. As a general rule, if a separation is greater than approximately 30 arc-seconds, it will change only very slowly. This is because, at the distances of virtually all stars, a 30-arc-second separation implies that the stars are orbiting each other at such large distances that the period of the orbit is thousands of years or longer. Stars with smaller separations are either (1) located very near to one another, in which case the separation will vary rapidly but will always be small, or (2) located at a great distance from one another but, by chance, are now aligned nearby along the line of sight from the Earth. In the latter case, the stars are moving very slowly relative to one another, and therefore the separation between them will remain small for a long period of time. Therefore, stars with separations over 30 arc-seconds may be considered to always have separations equal to the value given, and stars with smaller separations can always be assumed to have separations smaller than 30 arc-seconds.

4.6.2 Word 77

The difference in brightness between the two brightest components is given in Word 77.

4.6.3 Word 78

The year in which the separation observation (Word 76) was made can be used to determine the validity of the assumption that the separation is still valid (see Section 4.6.1). All stars having a valid value of Word 76 also have a valid value in Word 78.

4.6.4 Word 79

The distance to the nearest Master Catalog star is given in Word 79. If the distance is more than 0.5 degree, it is coded as 360.0. If the nearest neighbor is a member of a physical multiple star system with this star, Word 79 is made negative (hence, -0.01 means that the nearest star to this star is 0.01 degree away and is part of a multiple star system).

4.6.5 Words 80 Through 89

These words are the same as Word 79, except that for Words 80 through 85, the restriction was also imposed that the neighbor must be further than the star in question than 5, 15, 30, 60, 120, and 300 arc-seconds, respectively. Words 86, 87, 88, and 89 are identical to Words 79, 81, 83, and 85, respectively, with the additional restriction that the neighbor must be no more than 2 visual magnitudes dimmer than the star in question.

4.7 MISCELLANEOUS DATA

Six data words not required by earlier versions of the catalog have been inserted into these previously unused positions.

4.7.1 Word 90

This flag gives the source of the star's position.

Value	Source of Position	Reference Number
1	SAO	4
2	HD or HD Extension	3, 40
3	Blanco	8
4	Jaschek	18
5	Multiple star catalog	33
6	Parallax catalog	28
7	Wilson	43
8	AGK-3 catalog	39
9	Variable star catalog	9

4.7.2 Word 91

This flag gives the source of the star's radial velocity. If it is 0, the radial velocity quoted is the inverse of the Sun's motion; if it is 1, the radial velocity is from Wilson (Reference 43).

4.7.3 Word 92

This word gives the source of multiple star data.

Value	Meaning
0	No multiple star data given
1	Multiple star data from Reference 33
2 - 23599999	Two or more source catalog stars within 1 arc-minute of one another were combined. Word 92 gives the SKYMAP number of the secondary
99999999	Two or more source catalog stars within 1 arc-minute of one another were combined. The secondary had no HD number

4.7.4 Words 93 and 94

Word 93 is the systematic error in right ascension and Word 94 is the systematic error in declination for HD stars in the region of the sky including this star. See Reference 42 for details. The correction must be added to the HD position to correct the systematic error. Words 93 and 94 are valid only for stars whose position comes from the HD or HDE catalogs (Word 90 is equal to 2).

4.7.5 Word 95

Some stars have duplicate entries in SKYMAP because of inadequate cross-referencing between source catalogs. When duplicate entries are discovered and merged, the SKYMAP number of the entry that was merged into this entry is saved in Word 95. The SKYMAP number of a merged entry will not be used for any other star.

4.8 FORMATTED DATA

A number of coded data words have been converted into an alphameric format for convenience in printing.

4.8.1 Words 96 Through 99

The DM number (Word 4) is decoded as a plus or minus sign for the zone, the zone number, and the sequence number within the zone, and are placed respectively into Words 96, 97, and 98 and 99 (combined).

4.8.2 Words 100 Through 106

The right ascension and declination at the standard epoch (Words 13 and 14) are decoded into hours, minutes, and seconds of time, and into degrees, minutes, and seconds of arc, respectively.

4.8.3 Word 107

The source of the position at the standard epoch is encoded in this variable by an examination of Word 3. If Word 3 is zero (no SAO number), the position was obtained from either the HD (Reference 3), if Words 23 and 24 are nonzero, or otherwise from Reference 8 or 9. This word is encoded as follows:

Value	Meaning
SAO	Position came from the SAO catalog (Reference 4)
HD	Position came from the HD catalog (Reference 3) or its Extension (Reference 40)
BLAN	Position came from Blanco (Reference 8)
JAS	Position came from Jaschek (Reference 18)
MULT	Position came from Multiple Star Catalog (Reference 33)
PAR	Position came from Parallax catalog (Reference 28)
WIL	Position came from Wilson (Reference 43)
AGK3	Position came from AGK3 catalog (Reference 39)
VAR	Position came from Variable Star Catalog (Reference 9)

4.8.4 Words 108 and 109

The sum of the proper motion and precession (Words 29 and 30) is given in minutes of time and minutes of arc for right ascension and declination, respectively.

4.8.5 Word 110

The source of the U magnitude quoted in Word 32 is encoded as follows:

Value	Meaning
(blank)	U magnitude observed on the UBV system or none given in Word 31
*	U magnitude computed as noted under Word 32

4.8.6 Word 111

The source of the V and B magnitudes given in Words 33 and 34 is encoded as follows:

Value	Meaning
(blank)	B and V both observed
C	Converted HD or SAO magnitudes as noted in Word 35
H	Unconverted HD or SAO magnitudes
*	V observed in UBV system; B computed from V and the spectral type or not given in Word 33

4.8.7 Words 112 Through 115

The spectral type codes have been decoded to the standard formats given in Section 4.3.8.

4.8.8 Word 116

The source of the spectral type information given in Words 112 through 115 is encoded as follows:

Value	Meaning
(blank)	Observed on the MK system or not given
H	Converted from the HD system

4.8.9 Word 117

The method by which the distance (Word 64) was derived is encoded as follows:

Value	Meaning
(blank)	No distance given
T	Distance from trigonometric parallax
S	Distance from spectroscopic parallax
S, T	Distance is a combination of trigonometric and spectroscopic parallax
MIN	Distance is a minimum distance from trigonometric parallax
MAX	Distance is a maximum distance from space velocities

4.8.10 Word 118

The source of the interstellar absorption amplitude (Word 67) is encoded as follows:

Value	Meaning
(blank)	None given
BV	Derived from B and V
UBV	Derived from U, B and V
*	Derived from distance and direction

4.8.11 Words 119 and 120

The difference between B and V and between U and B magnitudes (Words 31, 33, and 34) is given in these words.

4.8.12 Words 121 and 122

An 8-character description of the type of variability is given in this word. Table 4-2 provides an interpretation of these codes, and a cross-reference to the numerical codes of Word 70.

REFERENCES

1. Computer Sciences Corporation, CSC/SD-76/6001, High Energy Astronomy Observatory (HEAO-A) Attitude Determination System Specifications and Requirements, C. M. Gray et al., February 1976

2. Ball Brothers Research Corporation, 40781, Configuration Item Specification - Stellar Aspect Sensor, R. L., Cleavinger, 1973

3. A. J. Cannon and E. C. Pickering, Harvard Annals, vol. 91-99, 1918-1924, Cambridge, Massachusetts: Harvard University

4. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV. Washington, D.C.: Smithsonian Institute, 1971

5. H. L. Johnson and W. W. Morgan, Astrophysical Journal, 1953, vol. 117, p. 313

6. Computer Sciences Corporation, Analysis of Small Astronomy Satellite-C (SAS-C) Y-Axis Star Tracker Data, D. M. Gottlieb (to be published)

7. W. W. Morgan, P. C. Keenan, and E. Kellman, An Atlas of Stellar Spectra. Chicago: University of Chicago Press, 1953

8. V. M. Blanco, S. Dermers, G. G. Douglass and M. P. Fitzgerald, Publ. U. S. Naval Obs., 2nd series, vol. 21, 1968

9. B. V. Kukarkin, P. P. Parenego, Yu. I. Efremov, and P. N. Kholopov, General Catalog of Variable Stars, third edition. Moscow: Publishing House of the Academy of Sciences of the U.S.S.R., 1968

10. F. W. A. Argelander, "Bonner Sternverzeichness," Sections 1-3, Astron. Beob. Sternwarte Konigl. Rhein, vols. 3-5, Bonn: Friedrich-Wilhelms University, 1859-1862

11. E. Schonfeld, "Bonner Sternverzeichness," Section 4, Astron. Beob. Sternwarte Konigl. Rhein, vol. 8, Bonn: Friedrich-Wilhelms University, 1886

12. J. M. Thome, "Cordoba Durchmusterung," Parts I-IV, Resultados Obs. Nacional Argentino, vols. 16-19, 1892-1914

13. C. D. Perrine, "Cordoba Durchmusterung," Part V, Resultados Obs. Nacional Argentino, vol. 21, 1932

14. D. Gill and J. C. Kapteyn, "Cape Photographic Durchmusterung," Parts I-III, Ann. Cape Obs., vols. 3-5, 1896-1900

15. D. Hoffleit, Catalog of Bright Stars. New Haven, Connecticut: Yale University Observatory, 1964

16. R. E. Wilson, General Catalog of Stellar Radial Velocities. Washington, D.C.: Carnegie Institute of Washington, 1953

17. R. G. Aitken, New General Catalog of Double Stars Within 120° of the North Pole, vols. 1 and 2. Washington, D.C.: Carnegie Institute of Washington, 1932

18. C. Jaschek, H. Conde, and A. C. de Sierra, Publ. La Plata Obs. Ser. Astron., vol. 28, 1964

19. J. Mermilliod, Bulletin D'Information du Centre de Donnees Stellaires de Strasbourg, 1973 (unpublished letter)

20. N. Houk and A. Cowley, "Spectral Classification and Multicolor Photometry," ed. C. Fehrenback and B. E. Westerlund, International Astronomical Union Symposium No. 50, 1973

21. T. A. Matthews and A. R. Sandage, "Optical Identification of 3C48, 3C196, and 3C286 with Stellar Objects," Astrophysical Journal, 1963, vol. 138, p. 30

22. M. P. Fitzgerald, Astronomy and Astrophysical Supplement, 1973, vol. 9, p. 297

23. D. M. Gottlieb and W. L. Upson III, "Local Interstellar Reddening," Astrophysical Journal, 1969, vol. 157, p. 611

24. S. Sharpless, Interstellar Reddening in Basic Astronomical Data, ed. K. A. Strand. Chicago: University of Chicago Press, 1963

25. A. E. Whitford, "The Law of Interstellar Reddening," Astronomical Journal, 1958, vol. 63, p. 201

26. T. P. Stecher, "Interstellar Extinction in the Ultraviolet II," Astrophysical Journal Letters, 1969, vol. 157, p. L125

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27. D. Mihalas, Galactic Astronomy. San Francisco: W. H. Freeman and Company, 1968

28. L. F. Jenkins, General Catalog of Trigonometric Stellar Parallaxes. New Haven: Yale University Observatory, 1952

29. K. Aa. Strand, Trigonometric Stellar Parallaxes in Basic Astronomical Data, ed. K. Aa. Strand. Chicago: University of Chicago Press, 1963

30. P. C. Keenan, Classification of Stellar Spectra in Basic Astronomical Data, ed. K. Aa. Strand. Chicago: University of Chicago Press, 1963

31. W. Dieckvoss, Photographic Proper Motions in Basic Astronomical Data, ed. K. Aa. Strand. Chicago: University of Chicago Press, 1963

32. B. V. Kukarkin and P. P. Parenago, Surveys and Observations of Physical and Eclipsing Variable Stars in Basic Astronomical Data, ed. K. Aa. Strand. Chicago: University of Chicago Press, 1963

33. United States Naval Observatory, Index Catalog of Visual Double Stars, 1974-75 (magnetic tape)

34. A. Blaauw, The Calibration of Luminosity Criteria in Basic Astronomical Data, ed. K. Aa. Strand. Chicago: University of Chicago Press, 1963

35. Goddard Space Flight Center, Mission and Data Operations IBM 360 User's Guide, July 1973

36. Computer Sciences Corporation, CSC/TM-76/6106, User's Interface to the SKYMAP Program LOOKAT/FETCH Subroutines, D. M. Gottlieb, May 1976

37. --, CSC/TM-76/6055, User's Interface to the SKYMAP Program LOOKAT/BAND Subroutines, D. M. Gottlieb, March 1976

38. --, CSC/TM-76/6101, User's Interface to the SKYMAP Program LOOKAT/SLICE Subroutines, D. M. Gottlieb, April 1976

39. Astronomisches Rechen Institut, Dritter Katalog der Astronomischen Gesellschaft, Heidelberg, Germany, 1975

40. A. J. Cannon and M. W. Mayall, Harvard Annals, vol. 112, 1949, Cambridge, Massachusetts: Harvard University

41. Computer Sciences Corporation, CSC/TM-77/6181, A Comparison Between AGK-3 and Smithsonian Astrophysical Observatory (SAO) Star Catalogs, C. Y. Yang and D. M. Gottlieb, July 1977

42. --, CSC/TM-77/6009, The Accuracy of SKYMAP Star Positions, D. M. Gottlieb, February 1977

43. R. E. Wilson, General Catalog of Stellar Radial Velocities, Washington, D. C.: Carnegie Institute of Washington, 1953

44. Computer Sciences Corporation, CSC/TM-77/6118, Source Catalogs for SKYMAP Data, D. M. Gottlieb, April 1977

45. --, CSC/TM-77/6066, The Completeness of Star Catalogs, C. Y. Yang, March 1977

46. --, CSC/TM-76/6232, Accuracy of SKYMAP Nearest-Neighbor Data, D. M. Gottlieb, December 1976

SECTION 5 - UPDATING THE MASTER CATALOG

Whenever it is necessary to add data to, delete data from, or change data in the Master Catalog, care must be exercised to avoid errors that would affect existing Master Catalog data. Accordingly, program UPDATE has been written to provide a structure within which modifications can be made. Program UPDATE can do the following:

- Add stars to the Master Catalog
- Delete stars from the Master Catalog
- Add, delete, or change data for stars in the Master Catalog
- Compute those variables marked "Internal" in Table 4-1 from existing Master Catalog data
- Output a subset of Master Catalog data (the Mission Catalog)
- Print part or all of the Master Catalog data

5.1 PROGRAM UPDATE OVERVIEW

Figure 5-1 shows the logical flow for program UPDATE. UPDATE begins by reading NAMELIST/FILES/, which contains flags directing the basic program flow. Subroutine CONTRL is then called to read NAMELIST/INSTR/, which contains detailed instructions for the sections of UPDATE which add and delete data.

Data for a single star is read from the input Master Catalog. If data for the star is to be deleted in its entirety, the data for the next star is read. If not, data for the star is deleted and/or added as directed by user-input instructions. If requested, user-written subroutine(s) which modify the star data are now called. These calls may be skipped if a user-specified Master Catalog data word falls outside of user-specified limits.

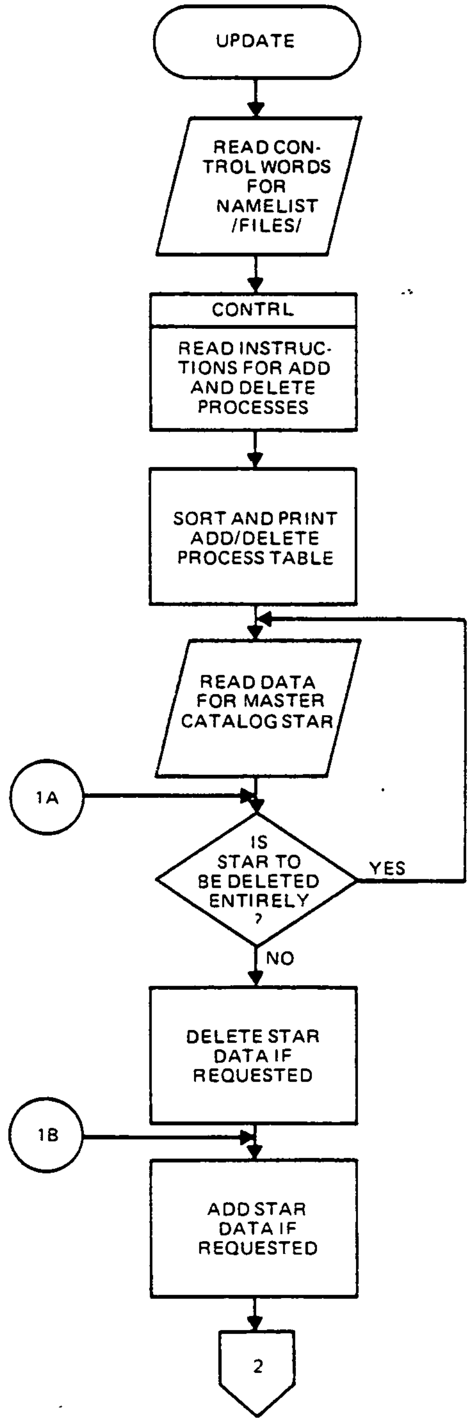

Figure 5-1. Logical Flow for Program UPDATE (1 of 3)

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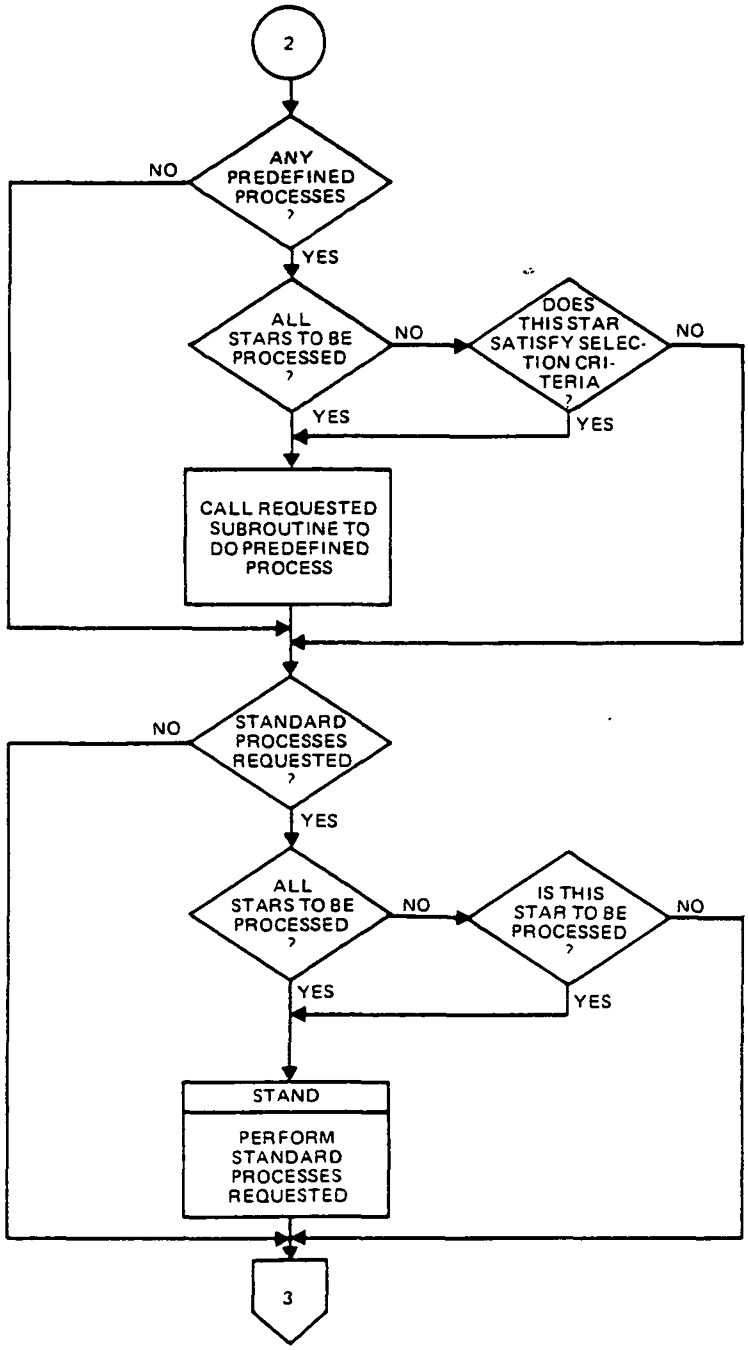

Figure 5-1. Logical Flow for Program UPDATE (2 of 3)

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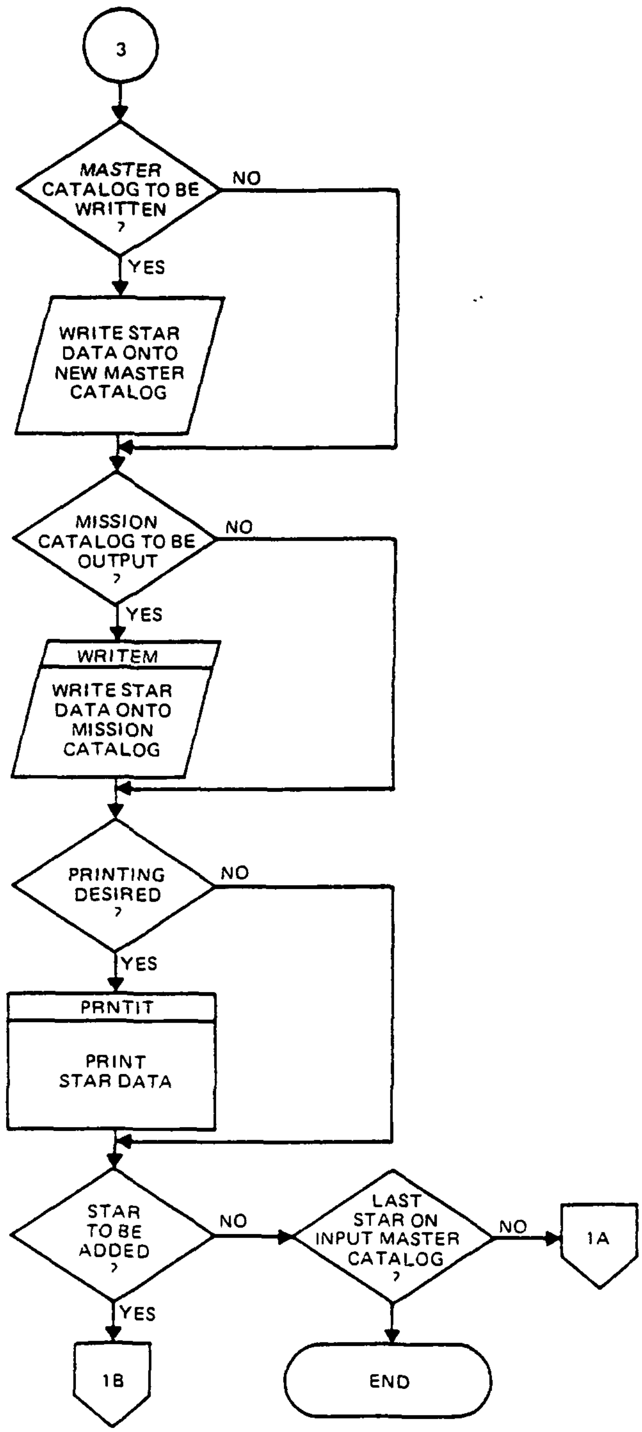

Figure 5-1. Logical Flow for Program UPDATE (3 of 3)

Each of the words listed as "Internal" in Table 4-1 can be computed by UPDATE. The user specifies which words are to be computed. The calculations are performed for (1) all stars, (2) for only those stars added to the Master Catalog during the runs, or (3) for all stars added or having data added during the run, in accordance with a user-input parameters.

If a Master Catalog output tape is desired, the star data is written. Similarly, if requested, a call to the user-written subroutine WRITEM outputs the Mission Catalog. If desired, the star data is printed in either a summary format or a full scientific format.

If a star is to be added after the star just processed, it is inserted into the program flow at this point. UPDATE allows data to be added for this star and allows predefined and/or standard processes to be performed before outputting the data on the Master Catalog, Mission Catalog, and/or printer data set.

Each star on the input Master Catalog is processed in turn until an end of file is encountered. UPDATE then prints a terminating message and stops.

5.2 MATHEMATICAL SPECIFICATIONS

All of the mathematical specifications for UPDATE are given in Section 3.

5.3 BASELINE DIAGRAM AND UNIT DESCRIPTIONS

5.3.1 Baseline Diagram

Figure 5-2 is a baseline diagram for program UPDATE.

5.3.2 Unit Descriptions

A unit description of program UPDATE and each subroutine is presented in Sections 5.3.2.1 through 5.3.2.30. An explanation of the tabular formats used in these sections is given in Section 2.4.1. Appendix C is a FORTRAN compiler listing of UPDATE.

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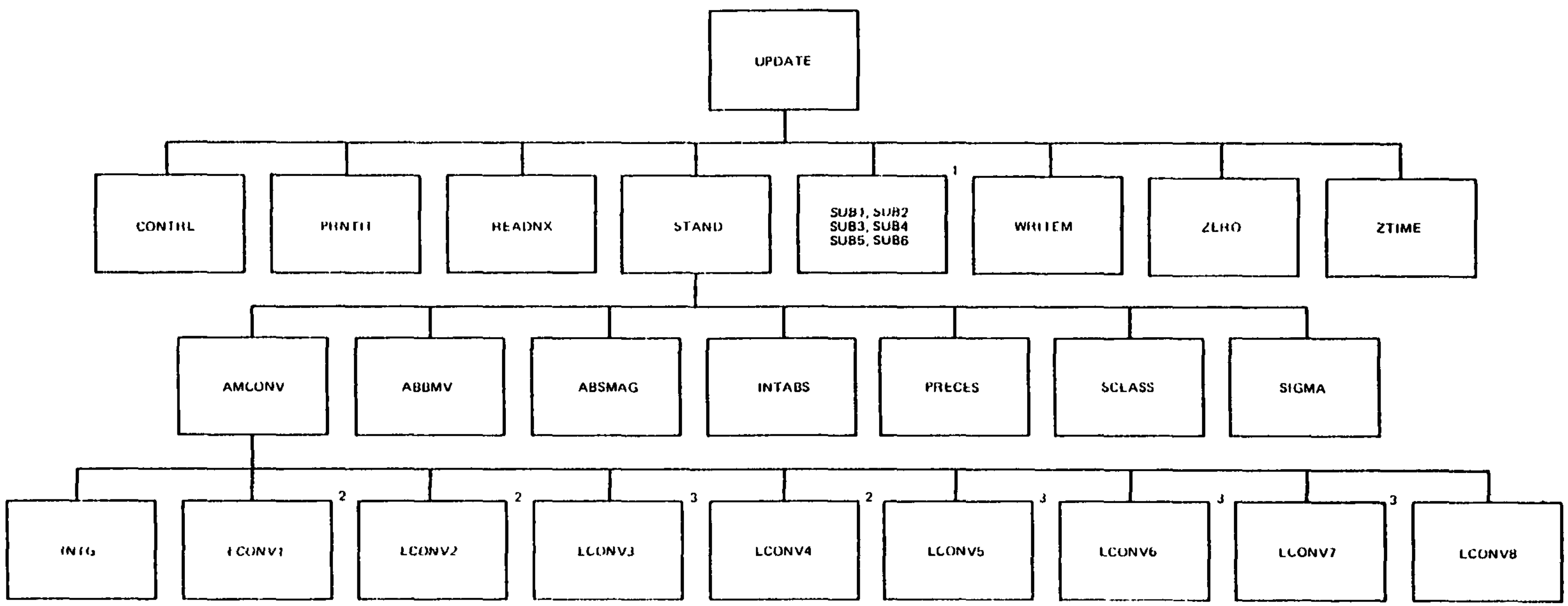

[1] THESE ARE USER WRITTEN SUBROUTINES
[2] THESE SUBROUTINES REFERENCE UPDATE SUBROUTINES IDIGIT AND INTG
[3] THESE SUBROUTINES REFERENCE UPDATE SUBROUTINE INTG

Figure 5-2. Baseline Diagram for Program UPDATE

The following is an index to all program UPDATE modules.

5.3.2.1 Program UPDATE

DESCRIPTION: UPDATE calls subroutines to read input Master Catalog data, adds and deletes stars or data for an existing Master Catalog star, and calls subroutines to perform computations with star data, to output the Master and Mission Catalogs, and to produce printed output of star data.

CALLING SEQUENCE: None. (UPDATE is the main program.)

COMMON AREAS REFERENCED: ABBLK, ABSBLK, ADDBLK, CNTBLK, FLBLK, PRCBLK, PRTBLK, SIGBLK, STDBLK

EXTERNAL REFERENCES: CONTRL, PRNTIT, READNX, STAND, SUB1, SUB2, SUB3, SUB4, SUB5, SUB6, WRITEM, ZERO, ZTIME

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number 5 is NAMELIST/FILES/ input. FORTRAN data set reference number IFILE(22) is error message and trace message printed output. FORTRAN data set reference number ICNT(2, I) is star data input for the Ith add/delete process. FORTRAN data set reference number IFILE(24) is Master Catalog input. FORTRAN data set reference number IFILE(26) is log printed output. FORTRAN data set reference number IFILE(25) is Master Catalog output.

ERROR MESSAGES:

'END OF FILE ON NAMELIST FILE 5'--No NAMELIST/FILES/was found on unit 5. One must be supplied.

'WARNING--FOR THE xxTH PROCESS, THE INPUT DATA SET FILE NUMBER yy IS EMPTY.'--The data set (on file number yy) for the xxth add/delete process was empty. UPDATE ignores this add/delete instruction.

'WARNING--FOR THE xxTH PROCESS, A STAR TO BE DELETED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star to be deleted. UPDATE ignores this delete instruction. Note that delete records not being in numerical order of SKYMAP number may cause this error.

'WARNING--FOR THE xxTH PROCESS, A STAR WITH DATA TO BE DELETED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star with data to be deleted. UPDATE ignores this delete data instruction. Note that delete data records not being in numerical order by SKYMAP number may cause this error.

'WARNING--FOR THE xxTH PROCESS, A STAR WITH DATA TO BE ADDED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star with data to be deleted. UPDATE ignores this delete data instruction. Note that delete data records not being in numerical order by SKYMAP number may cause this error.

'WARNING--FOR THE xxTH PROCESS, A STAR WITH DATA TO BE ADDED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star with data to be added. UPDATE ignores this add data instructions. Note that add data records not being in numerical order of SKYMAP number may cause this error.

5.3.2.2 Subroutine ABBMV

DESCRIPTION: ABBMV computes the mean B-V and the HD magnitude to UBV magnitude conversion coefficients for the input spectral class.

CALLING SEQUENCE: Subroutine ABBMV (ISTC, A, B, BMV, IFLAG, FMAG, GMAG)

COMMON AREAS REFERENCED: ABBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE ABBMV

Name	Symbol	I/O	Type	Interface	Description
ISTC		I	I*4	C.S.	Spectral class code
A, B, BMV		O	R*4	C.S.	Parameters for conversion of HD magnitudes to UBV magnitudes for a star of spectral class ISTC A refers to A1 of Table 3-7; B, to A2; and BMV, to (B-V)*
IFLAG		I	I*4	C.S.	Data source flag = 1, data is from the HD catalog = 2, data is from the SAO catalog
FMAG		I	R*4	C.S.	V magnitude for use in computation of A
GMAG		I	R*4	C.S.	B magnitude for use in computation of B
AXX(23), BXX(23), BMVXX(23)		I	R*4	/ABBLK/	AXX(I), BXX(I), BMVXX(I) Parameters for conversion of HD magnitudes to UBV magnitudes for a star of spectral class range I of Table 3-6. AXX refers to A1 of Table 3-7; BXX, to A2; and BMVXX, to (B-V)*
AYY(23), BYY(23)		I	R*4	/ABBLK/	Same as AXX and BXX for SAO stars

5.3.2.3 Subroutine ABSMAG

DESCRIPTION: ABSMAG calculates the absolute magnitude of a star of spectral type and luminosity class represented by IST, ILEFT, and ILC.

CALLING SEQUENCE: Subroutine ABSMAG (IST,ILEFT,ILC,A)

COMMON AREAS REFERENCED: ABSBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE ABSMAG

Name	Symbol	I/O	Type	Interface	Description
IST		I	I*4	C.S.	Spectral class code divided by 10 and truncated to an integer
ILEFT		I	I*4	C.S.	Fractional spectral class code = 0, spectral class is not fractional = 1, spectral class is one-twentieth of a spectral class later than indicated by IST (e.g., B1.5)
ILC		I	I*4	C.S.	Luminosity class code
A	M_V	O	R*4	C.S.	Absolute visual magnitude for a star of spectral type given by IST, ILEFT, ILC
AMAG(61,8)	M_V	I	R*4	/ABSBLK/	AMAG(I,J) = the absolute visual magnitude for a star of spectral type code between I*10 and I*10 + 9, and luminosity class given by J — Luminosity Class 1 — Ia-O 2 — Ia 3 — Iab or I 4 — Ib 5 — II 6 — III 7 — IV 8 — V

5.3.2.4 Subroutine AMCONV

DESCRIPTION: AMCONV converts Master Catalog data to the alphameric Master Catalog words indicated as being "Internal" in Table 4-1.

CALLING SEQUENCE: Subroutine AMCONV (X, IX)

COMMON AREAS REFERENCED: FLBLK, PRCBLK

EXTERNAL REFERENCES: INTG, LCONV1, LCONV2, LCONV3, LCONV4, LCONV5, LCONV6, LCONV7, LCONV8

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE AMCONV

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. Descriptions are found in Table 4-1
X(135)		I/O	I*4	C.S.	Master Catalog data for a star. Descriptions are found in Table 4-1
IPROC(100)		I	I*4	/PRCBLK/	Standard process execution flag If IPROC(I) = 0, the Ith standard process is not to be performed If IPROC(I) $\neq$ 0, the Ith standard process is to be performed See the NAMELIST/PROCS/ description in Section 5.5.1.1.3 for a definition of each process
IPART(10)		I	I*4	/PRCBLK/	Standard process group flag If IPART(I) = 0, no standard processes in group I are to be performed If IPART(I) = 1, one or more standard processes in group I is to be performed I = 1 refers to IPROC(J), $1 \le J \le 6$ I = 2 refers to IPROC(J), $11 \le J \le 12$ I = 3 refers to IPROC(J), $21 \le J \le 29$ I = 4 refers to IPROC(J), $31 \le J \le 41$

5.3.2.5 Subroutine CONTRL

DESCRIPTION: CONTRL reads NAMELIST/INSTR/ which contains detailed instructions for the add/delete processes. CONTRL also checks these input variables to ensure that they are within the allowed range.

CALLING SEQUENCE: Subroutine CONTRL(IC)

COMMON AREAS REFERENCED: CNTBLK, FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IC is NAMELIST/INSTR/ input. FORTRAN data set reference number IFILE(22) is error message output.

ERROR MESSAGES:

'WARNING--ITY INDICATES A NULL PROCESS OR AN UNDEFINED PROCESS. ITY = xxx.' where ITY = xxx . Only values between 1 and 6 are meaningful. UPDATE ignores this add/delete process.

'ERROR--FOR THE xxTH PROCESS, THE FILE DEFINED yy IS ALREADY IN USE.' The input file (yy) for the xxth add/delete process was previously defined as a NAMELIST read, printed output or Master Catalog input file, or as an input file for a previous add/delete process. The user should change the duplicated file number. UPDATE stops.

'WARNING--FOR THE xxTH PROCESS--A DELETE DATA PROCESS, NDEL (yyyyyyyy) WAS NOT POSITIVE.' For add/delete process number xx, the number of data words to be deleted (yyyyyyyy) was not positive. UPDATE ignores this process.

'ERROR--FOR THE xxTH PROCESS, NDEL (yyyyyyyy) WAS LARGER THAN THE LIMIT, 20.' For add/delete process number xx, the number of data words to be deleted was greater than the maximum allowed, 20. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE yyTH WORD TO BE DELETED IS AN ILLEGAL VALUE--zzzz.' For add/delete process number xx, the yyth word to be deleted lies outside of the limits 1 ≤ zzzz ≤ 131. UPDATE stops.

'WARNING--FOR THE xxTH PROCESS, AN ADD DATA PROCESS, NADD (yyyyyyyy) WAS NOT POSITIVE.' For add/delete process number xx, the number of words of data to be added, yyyyyyyy, was not positive. UPDATE ignores this add/delete process.

'ERROR--FOR THE xxTH PROCESS, NADD (yyyyyyyy) WAS LARGER THAN THE LIMIT, 20.' For add/delete process number xx, the number of data words to be added was greater than the maximum allowed, 20. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE yyTH WORD TO BE ADDED IS AN ILLEGAL VALUE--zzzz.' For add/delete process number xx, the yyth word to be added lies outside of the limits 1 ≤ zzzz ≤ 131. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE SUBROUTINE NUMBER SPECIFIED (yyyyyyyy) IS AN ILLEGAL VALUE.' For add/delete process xx, the subroutine number to be called must be 1 ≤ yyyyyyyy ≤ 6. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE CONDITIONAL VARIABLE, IVARTS, IS yyyyyyyy, AN ILLEGAL VALUE.' For add/delete process number xx, the variable to be tested for conditional application of the process is not within the allowed range 1 ≤ yyyyyyyy ≤ 131. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, ITSTYP = yyyyyyyy WHICH DOES NOT AGREE WITH THE FORMAT OF MASTER CATALOG WORD zzzz.' For add/delete process number xx, the type of the conditional variable was yyyyyyyy, which does not agree with the Master Catalog data type for word zzzz. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, ITSTYP = yyyyyyyy, AN ILLEGAL VALUE.' For add/delete process number xx, the type of conditional variable was yyyyyyyy, which is outside of the allowed range: 1 ≤ yyyyyyyy ≤ 2. UPDATE stops.

'WARNING--OVER 20 PROCESSES CALLED FOR.' Only 20 add/delete processes are allowed. More than that are ignored.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE CONTRL

Name	Symbol	I/O	Type	Interface	Description
IC		I	I*4	C.S.	File number for NAMELIST/INSTR/ input
ICNT(49,20)		O	I*4	/CNTBLK/	For the Jth add/delete process ICNT(1,J) = NAMELIST/INSTR/ parameter ITY ICNT(2,J) = NAMELIST/INSTR/ parameter IFL ICNT(3,J) = NAMELIST/INSTR/ parameter NDEL ICNT(4,J), ..., ICNT(23,J) = NAMELIST/INSTR/ parameters IDEL(1), ... IDEL(20), respectively ICNT(24,J) = NAMELIST/INSTR/ parameter NADD ICNT(25,J), ..., ITCNT(44,J) = NAMELIST/INSTR/ parameters IADD(1), ... IADD(20), respectively ICNT(45,J) = NAMELIST/INSTR/ parameter ISUB ICNT(46,J) = NAMELIST/INSTR/ parameter IVARTS ICNT(47,J) = NAMELIST/INSTR/ parameter ITSTYP ICNT(48,J) = NAMELIST/INSTR/ parameter ILIMA ICNT(49,J) = NAMELIST/INSTR/ parameter ILIMB For a description of NAMELIST/INSTR/ parameters, see Section 5.5.1.1.2
FCNT		O	R*4	/CNTBLK/	For the Jth add/delete process FCNT(1,J) = NAMELIST/INSTR/ parameter FLIMA FCNT(2,J) = NAMELIST/INSTR/ parameter FLIMB For a description of NAMELIST/INSTR/ parameters, see Section 5.5.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE CONTRL

Name	Symbol	I/O	Type	Interface	Description
NCNT		O	I*4	/CNTBLK/	Number of add/delete processes called for
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) is error message output

5.3.2.6 Subroutine IDIGIT

DESCRIPTION: Subroutine IDIGIT converts a 4-digit integer into four 1-digit integers.

CALLING SEQUENCE: Subroutine IDIGIT (I,N,JA,JB,JC,JD)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE IDIGIT

Name	Symbol	I/O	Type	Interface	Description
I		I	I*4	C.S.	Any integer such that $0 \le I \le 9999$
N		I	I*4	C.S.	Number of digits in I
JA, JB, JC, JD		O	I*4	C.S.	Single digit integers such that JA = I if N = 1 10(JA) + JB = I if N = 2 100(JA) + 10(JB) + JC = I if N = 3 1000(JA) + 100(JB) + 10(JC) + JD = I if N = 4

5.3.2.7 Subroutine INTABS

DESCRIPTION: Subroutine INTABS computes the interstellar absorption for a given direction and distance from the Sun.

CALLING SEQUENCE: Subroutine INTABS (DIST,B,EL,ABSORB)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE INTABS

Name	Symbol	I/O	Type	Interface	Description
DIST	d	I	R*4	C.S.	Distance from the Sun (parsecs)
B	b	I	R*4	C.S.	Galactic latitude (degrees)
EL	ℓ	I	R*4	C.S.	Galactic longitude (degrees)
ABSORB	A_V	O	R*4	C.S.	Interstellar absorption in the V magnitude (magnitudes)

5.3.2.8 Subroutine INTG

DESCRIPTION: Subroutine INTG converts four A1 variables into the equivalent A4 variables.

CALLING SEQUENCE: Subroutine INTG (IA,IB,IC,ID,IRES)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE INTG

Name	Symbol	I/O	Type	Interface	Description
IA,IB,IC,ID		I	I*4	C.S.	Four integers, each equivalent to a single alphanumeric character
IRES		O	I*4	C.S.	An integer equivalent to the conjunction of the four characters represented by IA,IB,IC, and ID, such that IRES = UUWWXXYY (hexadecimal) if IA = UU, IB = WW, IC = XX and ID = YY (hexadecimal)

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5.3.2.9 Function LCONV1

DESCRIPTION: LCONV1 converts a 2-digit integer into the 4-byte alphameric equivalent, left justified and filled with two blanks. The first digit, if zero, is set to a blank.

CALLING SEQUENCE: Function LCONV1(I)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: IDIGIT, INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV1

Name	Symbol	I/O	Type	Interface	Description
I		I	I*4	C.S.	Integer; $0 \leq I \leq 99$
LCONV1		O	I*4	C.S.	Four-byte alphameric equivalent of I, left justified. Two blanks inserted in the rightmost two bytes. If the first byte is a 0, it is converted to a blank

5.3.2.10 Function LCONV2

DESCRIPTION: LCONV2 converts a 4-digit positive integer to its 4-byte alphameric equivalent.

CALLING SEQUENCE: Function LCONV2(I)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: IDIGIT, INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV2

Name	Symbol	I/O	Type	Interface	Description
I		I	I*4	C.S.	Integer; $0 \le I \le 9999$
LCONV2		O	I*4	C.S.	Four-byte alphameric equivalent of I. The first $N(N \le 3)$ zeros are converted to blanks

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5.3.2.11 Function LCONV3

DESCRIPTION: LCONV3 converts a 1-digit positive integer to its alphameric equivalent, left justified and blank filled.

CALLING SEQUENCE: Function LCONV3(I)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV3

Name	Symbol	I/O	Type	Interface	Description
I		I	I*4	C.S.	Integer; $0 \leq I \leq 9$
LCONV3		O	I*4	C.S.	Four-byte alphameric equivalent of I, left justified. The last three bytes are blanks

5.3.2.12 Function LCONV4

DESCRIPTION: LCONV4 converts a floating point number, F, such that $F \geq 0.0$, into a 4-byte alphameric equivalent in the format XX.X, where X is a digit.

CALLING SEQUENCE: Function LCONV4(F)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: IDIGIT, INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV4

Name	Symbol	I/O	Type	Interface	Description
F		I	R*4	C.S.	Floating point number such that F ≥ 0.0
LCONV4		O	I*4	C.S.	Four-byte alphameric equivalent of F in the format XX.X where X is a digit. If the first X is a zero, it is converted into a blank

5.3.2.13 Function LCONV5

DESCRIPTION: LCONV5 converts a floating point number, F, such that $|F| \leq 9.949$, into a 4-byte alphameric equivalent in the format ±X.X, where X is a digit and ± is a plus or a minus sign.

CALLING SEQUENCE: Function LCONV5(F)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV5

Name	Symbol	I/O	Type	Interface	Description
F		I	R*4	C.S.	Floating point number such that $\|F\| \leq 9.949$
LCONV5		O	I*4	C.S.	Four-byte alphameric equivalent of F in the format ±X.X, where X is a digit and ± is a plus or a minus sign

5.3.2.14 Function LCONV6

DESCRIPTION: LCONV6 converts a floating point number, F, such that $|F| \leq 99.49$, into a 4-byte alphameric equivalent in the format ±XX., where X is a digit and ± is a plus or a minus sign.

CALLING SEQUENCE: Function LCONV6(F)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV6

Name	Symbol	I/O	Type	Interface	Description
F		I	R*4	C.S.	Floating point number such that $\lvert F \rvert \leq 99.49$
LCONV6		O	I*4	C.S.	Four-byte alphameric equivalent of F in the format ±XX., where X is a digit and ± is a plus or a minus sign. If the first X is a zero, it is converted into a blank

5.3.2.15 Function LCONV7

DESCRIPTION: LCONV7 converts a floating point number, F, such that $|F| \leq 99.49$, into a 4-byte alphameric equivalent in the format ±b̸XX, where X is a digit, b̸ is a blank, and ± is a plus or a minus sign.

CALLING SEQUENCE: Function LCONV(F)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV7

Name	Symbol	I/O	Type	Interface	Description
F		I	R*4	C.S.	Floating point number such that $\lvert F \rvert \leq 99.49$
LCONV7		O	I*4	C.S.	Four-byte alphameric equivalent of F in the format ±b̸XX, where X is a digit, b̸ is a blank and ± is a plus or a minus sign. If the first X is a zero, it is converted to a blank

5.3.2.16 Function LCONV8

DESCRIPTION: LCONV8 converts a floating point number, F, such that $-0.9949 \le F \le 9.949$, into a 4-byte alphameric equivalent in the format X.XX, where X is a digit if $F \ge 0.00$ and -.XX is $F \le 0.0$.

CALLING SEQUENCE: Function LCONV(F)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: IDIGIT, INTG

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR FUNCTION LCONV8

Name	Symbol	I/O	Type	Interface	Description
F		I	R*4	C.S.	Floating point number such that $-0.9949 \le F \le 9.949$
LCONV8		O	I*4	C.S.	Four-byte alphameric equivalent of F in the format X.XX, where X is a digit if $F \ge 0.0$. If the first X is 0, it is converted to a blank. If $F < 0$, the format is -.XX

5.3.2.17 Subroutine PRECES

DESCRIPTION: Subroutine PRECES precesses star coordinates from one epoch to another.

CALLING SEQUENCE: Subroutine PRECES (DX, APRE, EPOCHA, EPOCHB, EPREA, EPRED)

COMMON AREAS REFERENCED: PRCBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PRECES

Name	Symbol	I/O	Type	Interface	Description
DX(2)		I/O	R*8	C.S.	DX(1) and DX(2) are star right ascension and declination, respectively. When input, they are epoch EPOCHA; when output, EPOCHB
APRE(3, 3)		I/O	R*8	C.S.	Rotation matrix for computation of precession. Output if IFAPRE = 0; input otherwise
EPOCHA		I	R*4	C.S.	Original epoch of DX(1) and DX(2)
EPOCHB		I	R*4	C.S.	Final epoch of DX(1) and DX(2)
EPREA		O	R*4	C.S.	Proper motion in right ascension (degrees)
EPRED		O	R*4	C.S.	Proper motion in declination (degrees)
IFAPRE		I	I*4	/PRCBLK/	APRE computation flag = 0, compute APRE = 1, use input APRE

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5.3.2.18 Subroutine PRNTIT

DESCRIPTION: Subroutine PRNTIT produces printed output of Master Catalog data.

CALLING SEQUENCE: Subroutine PRNTIT (IFPRNT, X, IX)

COMMON AREAS REFERENCED: FLBLK, PRTBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IFILE(26) is log printed output. FORTRAN data set reference number IFILE(22) is error message printed output. FORTRAN data set reference number IFILE(27) is NAMELIST/XPRINT/ input. FORTRAN data set reference numbers IFLPRT(I), I = 1, ..., 10 are printed output.

ERROR MESSAGES:

'ERROR--AN END OF FILE WAS ENCOUNTERED ON THE NAMELIST/ XPRINT/ FILE. PRINTOUT IS CANCELLED.' File IFILE(27) does not contain NAMELIST/XPRINT/. No printout is generated.

'ERROR--THE CONDITIONAL PRINT VARIABLE, ICOND, HAS AN ILLEGAL VALUE (xxxxxx). PRINTOUT IS CANCELLED.' The first conditional print variable must be a Master Catalog word. Accordingly, it must satisfy /xxxxxx/ ≤ 131 or 1001 ≤ xxxxxx ≤ 1004. No printout is produced.

'ERROR--THE CONDITIONAL PRINT VARIABLE, ICOND2, HAS AN ILLEGAL VALUE (xxxxxx). PRINTOUT IS CANCELLED.' The second conditional print variable must be a Master Catalog word. Accordingly, it must satisfy /xxxxxx/ ≤ 131 or 1001 ≤ xxxxxx ≤ 1004. No printout is produced.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PRNTIT

Name	Symbol	I/O	Type	Interface	Description
X(135)		I	R*4	C.S.	Master Catalog Data for a star. Definitions are given in Table 4-1
IX(135)		I	I*4	C.S.	Master Catalog data for a star. Definitions are given in Table 4-1
IFPRNT		O	I*4	C.S.	Printout control word = 0, no printout produced. If an error is encountered in reading or interpreting NAMELIST/XPRINT/, this word is set to 0 ≠ 0, printout is produced
IFST		I/O	I*4	/PRTBLK/	First call flag. If IFST≠0, this is the first call to PRNTIT. PRNTIT then reads NAMELIST/XPRINT/ and sets IFST=0. If IFST=0, this is not the first call to PRNTIT
IWRT		I	I*4	/PRTBLK/	File number for printed output
ICTY		I	I*4	/PRTBLK/	Master Catalog word number of the first conditional variable
ICTY2		I	I*4	/PRTBLK/	Master Catalog word number of the second conditional variable
ITYPRT		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word ITYPRT*
IFLPRT(10)		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ words JFLPRT*
ICOND		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word JCOND*

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PRNTIT

Name	Symbol	I/O	Type	Interface	Description
ICMN		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word JCMN*
ICMX		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word JCMX*
FCMN		I/O	R*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word GCMN*
FCMX		I/O	R*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word GCMX*
ICOND2		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word JCOND2*
ICMN2		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word JCMN2*
ICMX2		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word ICMX2*
FCMN2		I/O	R*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word GCMN2*
FCMX2		I/O	R*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word GCMX2*
LINES		I/O	I*4	/PRTBLK/	Same as NAMELIST/XPRINT/ word LINESX*
ILNTOT(100)		I/O	I*4	/PRTBLK/	ILNTOT(I) = Total number of lines output to FORTRAN data set reference number I
ILNMLT(100)		I/O	I*4	/PRTBLK/	ILNMLT(I) = Number of lines of data per star output to FORTRAN data set reference number I
IUNIQ(100)		I/O	I*4	/PRTBLK/	IUNIQ(I), the unit uniqueness flag = 0, IFLPRT(I) = IFLPRT(J) for J < I = 1, IFLPRT(I) ≠ IFLPRT(J) for any J < I
					*See Section 5.5.1.1.4 for a description of NAMELIST/XPRINT/ variables

5.3.2.19 Subroutine READNX

DESCRIPTION: Subroutine READNX reads a record from an add/delete process input file.

CALLING SEQUENCE: Subroutine READNX(IPR)

COMMON AREAS REFERENCED: ADDBLK, FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IFILE (IPR) is add/delete process input.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE READNX

Name	Symbol	I/O	Type	Interface	Description
IPR		I	I*4	C.S.	Add/delete process file number for which a record is to be read
DTADD(20,20)		O	R*4	/ADDBLK/	For add/delete process number IPR, DTADD(I,IPR) = the value of the Ith data word to be added ($1 \le I \le 20$)
NDTADD(20)		O	I*4	/ADDBLK/	For add/delete process IPR, NDTADD(IPR) = the SKYMAP number of the star for which data is to be added/deleted
IFILE(30)		I	I*4	/FLBLK/	File IFILE(IPR) is the add/delete input data set ($1 \le IPR \le 20$)

5.3.2.20 Subroutine SCLASS

DESCRIPTION: Subroutine SCLASS converts a spectral class code to a class number, as defined in Table 3-6.

CALLING SEQUENCE: Subroutine SCLASS(ISTC)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SCLASS

Name	Symbol	I/O	Type	Interface	Description
ISTC		I/O	I*4	C.S.	When input, the spectral class code When output, the class for that spectral class code, as defined in Table 3-6

5.3.2.21 Subroutine SIGMA

DESCRIPTION: Subroutine SIGMA computes the mean standard deviations for the three galactic velocity components as a function of spectral class and luminosity class. Table 3-11 gives the values that are output.

CALLING SEQUENCE: Subroutine SIGMA (ISPT, ILC, SIGTHT, SIGPI, SIGZ)

COMMON AREAS REFERENCED: SIGBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SIGMA

Name	Symbol	I/O	Type	Interface	Description
ISPT		I	I*4	C.S.	Spectral class code
ILC		I	I*4	C.S.	Luminosity class code
SIGTHT, SIGPI, SIGZ	σ_θ, σ_π, σ_z	O	R*4	C.S.	Mean standard deviation for the θ, π, and z space velocity components for spectral class ISPT and luminosity class ILC in kilometers per second. If the spectral class or luminosity class is not in the range presented in Tables 3-11, SIGTHT = -999.999.
SIG1(13), SIG2(13), SIG3(13)	σ_θ, σ_π σ_z	I	R*4	/SIGBLK/	SIG1(I), SIG2(I), SIG3(I) = the mean standard deviation in kilometers per second for the θ, π, and z space velocity components, respectively, for the range of spectral class and luminosity class given in column 1 of Table 3-11.

5.3.2.22 Subroutine STAND

DESCRIPTION: STAND computes the numerical variables noted as "Internal" in Table 4-1.

CALLING SEQUENCE: Subroutine STAND (X, IX, ISTFST)

COMMON AREAS REFERENCED: ERRBLK, FLBLK, PRCBLK, STDBLK

EXTERNAL REFERENCES: ABBMV, ABSMAG, AMCONV, INTABS, PRECES, SCLASS, SIGMA

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IFILE(29) is NAMELIST /PROCS/ input. FORTRAN data set reference number IFILE(22) is error message output.

ERROR MESSAGES:

'ERROR--UNEXPECTED END OF FILE ON SUBROUTINE STAND NAMELIST.' File IFILE(29) did not contain NAMELIST /PROCS/. UPDATE stops.

'ERROR--SPECTROSCOPIC PARALLAX NON-CONVERGENCE FOR STAR HD xxxxxxx = SKYMAP yyyyyyy . LAST DISTANCE WAS zzzzzzzz.z PARSECS.' Irrecoverable error in the spectroscopic parallax routine. Master Catalog Words 57 and 58 are set to zero for star HD xxxxxxx = SKYMAP number yyyyyyy. The best estimate for the distance is zzzzzzzz.z.

'ERROR--SPECTROSCOPIC PARALLAX ERROR COULD NOT BE COMPUTED FOR STAR HD xxxxxxx = SKYMAP yyyyyyy.' The error in the spectroscopic parallax was set to 0.0 for star HD xxxxxxx = SKYMAP number yyyyyyy. The error is irrecoverable.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STAND

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. Descriptions are found in Table 4-1
IX(135)		I/O	I*4	C.S.	
ISTFST		I/O	I*4	C.S.	STAND initial call flag = 0, this is not the initial call to STAND = 1, this is the initial call to STAND. ISTFST is set = 0 following execution of STAND
RAERR(18, 8), DCERR(18, 8)		I	R*4	/ERRBLK/	Systematic errors in right ascension and declination, respectively. The subscripts (I, J) refer to region of the sky as defined in Section 4.7
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) is error message output. File IFILE(29) is NAMELIST /PROCS/ input
IPROC(100)		O	I*4	/PRCBLK/	Standard process execution flag. If IPROC(I) = 0, the ith standard process is not to be performed If IPROC(I) ≠ 0, the ith standard process is to be performed See Section 5.5 for a definition of each process
IPART(10)		O	I*4	/PRCBLK/	Standard process group flag. If IPART(I) = 0, no standard processes in group I are to be performed If IPART(I) = 1, one or more standard processes in group I is to be performed I = 1 refers to IPROC(J), 1 ≤ J ≤ 6. I = 2 refers to IPROC(J), 11 ≤ J ≤ 1.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STAND

Name	Symbol	I/O	Type	Interface	Description
IPART(10) (cont'd)					I = 3 refers to IPROC(J), $21 \le J \le 29$. I = 4 refers to IPROC(J), $31 \le J \le 41$.

5.3.2.23 Subroutine SUB1

DESCRIPTION: SUB1 is a user-supplied subroutine to perform add/delete date functions. It is called only if ICNT(2, J) = 1 for some J, such that $1 \leq J \leq$ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT.

CALLING SEQUENCE: Subroutine SUB1(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB1

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

5.3.2.24 Subroutine SUB2

DESCRIPTION: SUB2 is a user-supplied subroutine to perform add/delete data functions. It is called only if ICNT(2, J) = 2 for some J, such that $1 \le J \le$ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT.

CALLING SEQUENCE: Subroutine SUB2(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB2

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

5.3.2.25 Subroutine SUB3

DESCRIPTION: SUB3 is a user-supplied subroutine to perform add/delete data functions. It is called only if ICNT(2, J) = 3 for some J, such that $1 \leq J \leq$ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT.

CALLING SEQUENCE: Subroutine SUB3(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB3

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

5.3.2.26 Subroutine SUB4

DESCRIPTION: SUB4 is a user-supplied subroutine to perform add/delete data functions. It is called only if ICNT(2, J) = 4 for some J, such that 1 ≤ J ≤ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT

CALLING SEQUENCE: Subroutine SUB4(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB4

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	
IFILE (30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

5.3.2.27 Subroutine SUB5

DESCRIPTION: SUB5 is a user-supplied subroutine to perform add/delete data functions. It is called only if ICNT(2, J) = 5 for some J, such that $1 \leq J \leq$ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT.

CALLING SEQUENCE: Subroutine SUB5(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB5

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

5.3.2.28 Subroutine SUB6

DESCRIPTION: SUB6 is a user-supplied subroutine to perform add/delete data functions. It is called only if ICNT(2, J) = 6 for some J, such that $1 \leq J \leq$ NCNT. See subroutine CONTRL description (Section 5.3.2.5) for a definition of ICNT and NCNT.

CALLING SEQUENCE: Subroutine SUB6(X, IX)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SUB6

Name	Symbol	I/O	Type	Interface	Description
X(135)		I/O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions
IX(135)		I/O	I*4	C.S.	
IFILE(30)		I	I*4	/FLBLK/	File IFILE(22) can be used for error message printed output. File IFILE(26) can be used for log printed output

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5.3.2.29 Subroutine WRITEM

DESCRIPTION: Subroutine WRITEM is a user-written subroutine to write a Mission Catalog.

CALLING SEQUENCE: Subroutine WRITEM (X, IX, IKNT)

COMMON AREAS REFERENCED: FLBLK

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IFILE(28) is Mission Catalog output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE WRITEM

Name	Symbol	I/O	Type	Interface	Description
X(135)		I	R*4	C.S.	Master Catalog data for star. See Table 4-1 for definitions
IX(135)		I	I*4	C.S.	
IKNT		I/O	I*4	C.S.	Mission Catalog output counter, equal to the number of records written on IFILE(28)
IFILE(30)		I	I*4	/FLBLK/	IFILE(28) is the file number for Mission Catalog output

5.3.2.30 Subroutine ZERO

DESCRIPTION: Subroutine ZERO sets Master Catalog words to their default values.

CALLING SEQUENCE: Subroutine ZERO (IDO, IWORD, X, IX)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE ZERO

Name	Symbol	I/O	Type	Interface	Description
IDO		I	I*4	C.S.	Zero all words flag = 1, zero only word number IWORD $\neq$ 1, zero all words
IWORD		I	I*4	C.S.	Word number to be zeroed (IDO = 1 only)
X(135)		O	R*4	C.S.	Master Catalog data for a star. See Table 4-1 for definitions and default values
IX(135)		O	I*4	C.S.	

5.4 COMMON AREA DESCRIPTIONS

5.4.1 COMMON /ABBLK/

DESCRIPTION: /ABBLK/ contains the coefficients used to convert HD magnitudes to the UBV system (see Section 3.4.2)

FORM: COMMON /ABBLK/ AXX(23), BXX(23), BMVXX(23), AYY(23), BYY(23)

REFERENCED BY: ABBMV, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
AXX(23), BXX(23), UBVXX(23)	R*4	AXX(I), BXX(I), BMVXX(I): Parameters for conversion of HD magnitudes to UBV magnitudes according to the formulae of Section 3.4.2. I refers to the spectral class range from Table 3-6. AXX is A1 of Table 3-7, BXX is A2, and BMVXX is (B-V)*
AYY(23), BYY(23)	R*4	Same as AXX, BXX for SAO stars

5.4.2 COMMON /ABSBLK/

DESCRIPTION: /ABSBLK/ contains absolute visual magnitudes of stars as a function of spectral type.

FORM: COMMON /ABSBLK/ AMAG(61, 8)

REFERENCED BY: ABSMAG, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
AMAG(61, 8)	R*4	AMAG(I, J) = the absolute visual magnitude for a star of spectral type code between I*10 and I*10+9, inclusive, and luminosity class given by:

J	Luminosity Class
1	Ia-O
2	Ia
3	Iab or I
4	Ib
5	II
6	III
7	IV
8	V

5.4.3 COMMON /ADDBLK/

DESCRIPTION: /ADDBLK/ contains star data to be added to, or deleted from, the Master Catalog.

FORM: COMMON /ADDBLK/ DTADD(20,20), NDTADD(20)

REFERENCED BY: READNX, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
DTADD(20,20)	R*4	For add/delete process number J, DTADD(I,J) is the value of the Ith data word to be added ($1 \le I \le 20$)
NDTADD(20)	I*4	For add/delete process J, NDTADD(J) is the SKYMAP number of the star for which data is to be added or deleted

5.4.4 COMMON /CNTBLK/

DESCRIPTION: /CNTBLK/ contains parameters defining the add/delete data processes to be performed by UPDATE.

FORM: COMMON /CNTBLK/ ICNT(49, 20), FCNT(2, 20), NCNT

REFERENCED BY: CONTRL, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
ICNT(49, 20)	I*4	For the Jth add/delete process: ICNT(1, J) = NAMELIST /INSTR/ parameter ITY ICNT(2, J) = NAMELIST /INSTR/ parameter IFL ICNT(3, J) = NAMELIST /INSTR/ parameter NDEL ICNT(4, J), ..., ICNT(23, J) = NAMELIST /INSTR/ parameters IDEL(1) ... IDEL(20), respectively ICNT(24, J) = NAMELIST /INSTR/ parameter NADD ICNT(25, J) ..., ICNT(44, J) = NAMELIST /INSTR/ parameters IADD(1), ... IADD(20), respectively ICNT(45, J) = NAMELIST /INSTR/ parameter ISUB ICNT(46, J) = NAMELIST /INSTR/ parameter IVARTS ICNT(47, J) = NAMELIST /INSTR/ parameter ITSTYP ICNT(48, J) = NAMELIST /INSTR/ parameter ILIMA ICNT(49, J) = NAMELIST /INSTR/ parameter ILIMB For a description of NAMELIST /INSTR/ parameters, see Section 5.5.1.1.2

Name	Type	Description
FCNT(2,20)	R*4	For the Jth add/delete process: FCNT(1,J) = NAMELIST /INSTR/ parameter FLIMA FCNT(2,J) = NAMELIST /INSTR/ parameter FLIMB For a description of NAMELIST /INSTR/ parameters, see Section 5.5.1.1.2
NCNT	I*4	Number of add/delete processes called for

5.4.5 COMMON /ERRBLK/

DESCRIPTION: /ERRBLK/ contains systematic errors in HD star positions

FORM: COMMON /ERRBLK/ RAERR(18,8),DCERR(18,8)

REFERENCED BY: BLOCK DATA, STAND

DEFINITION OF VARIABLES:

Name	Type	Description
RAERR(18,8), DCERR(18,8)	R*4	Systematic errors in right ascension and declination, respectively, for HD stars. The subscripts (I,J) refer to a region of the sky as defined in Section 4.7.

5.4.6 COMMON /FLBLK/

DESCRIPTION: /FLBLK/ contains the FORTRAN data set reference numbers for UPDATE input/output data sets.

FORM: COMMON /FLBLK/ IFILE(30)

REFERENCED BY: AMCONV, CONTRL, PRNTIT, READNX, STAND, SUB1, SUB2, SUB3, SUB4, SUB5, SUB6, UPDATE, WRITEM

DEFINITION OF VARIABLES:

Name	Type	Description
IFILE(30)	I*4	IFILE(I) = NAMELIST /FILES/ parameter IFILEX(I). See Section 5.5.1.1.1 for a description of IFILEX.

5.4.7 COMMON /PRCBLK/

DESCRIPTION: /PRCBLK/ contains the flags directing execution of UPDATE standard processes.

FORM: COMMON /PRCBLK/ IPROC(100), IPART(10)

REFERENCED BY: AMCONV, STAND, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
IPROC(100)	I*4	Standard process execution flag. If IPROC(I) = 0, the Ith standard process is not to be performed If IPROC(I) ≠ 0, the Ith standard process is to be performed See the NAMELIST/PROCS, description in Section 5.5.1.1.3 for a definition of each process
IPART(10)	I*4	Standard process group flag. If IPART(I) = 0, no standard processes in group I are to be performed If IPART(I) = 1, one or more standard processes in group I are to be performed I = 1 refers to IPROC(J), $1 \le J \le 6$. I = 2 refers to IPROC(J), $11 \le J \le 12$. I = 3 refers to IPROC(J), $21 \le J \le 29$. I = 4 refers to IPROC(J), $31 \le J \le 41$. I = 5, ..., 10 are not used

5.4.8 COMMON /PRTBLK/

DESCRIPTION: /PRTBLK/ contains the instructions to UPDATE which control printed output.

FORM: COMMON /PRTBLK/ IFST,IWRT,ICTY,ICTY2,ITYPRT,IFLPRT(10), ICOND,ICMN,ICMX, FCMN, FCMX,ICOND2,ICMN2,ICMX2, FCMN2, FCMX2, LINES,ILNTOT(100),ILNMLT(100),IUNIQ(10)

REFERENCED BY: PRNTIT, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
IFST	I*4	First call flag. If IFST ≠ 0, this is the first call to PRNTIT. PRNTIT then reads NAMELIST /XPRINT/ and sets IFST = 0. If IFST = 0, this is not the first call to PRNTIT
IWRT	I*4	File number for printed output
ICTY	I*4	Master Catalog word number of the first conditional variable
ICTY2	I*4	Master Catalog word number of the second conditional variable
ITYPRT	I*4	Same as NAMELIST /XPRINT/ word JTYPRT[1]
IFLPRT(10)	I*4	Same as NAMELIST /XPRINT/ words JFLPRT[1]
ICOND	I*4	Same as NAMELIST /XPRINT/ word JCOND[1]
ICMN	I*4	Same as NAMELIST /XPRINT/ word JCMN[1]
ICMX	I*4	Same as NAMELIST /XPRINT/ word JCMX[1]
FCMN	R*4	Same as NAMELIST /XPRINT/ word GCMN[1]

[1] See Section 5.5.1.1.4 for a definition of NAMELIST /XPRINT/ variables.

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Name	Type	Description
FCMX	R*4	Same as NAMELIST /XPRINT/ word GCMX[1]
ICOND2	I*4	Same as NAMELIST /XPRINT/ word JCOND2[1]
ICMN2	I*4	Same as NAMELIST /XPRINT/ word JCMN2[1]
ICMX2	I*4	Same as NAMELIST /XPRINT/ word JCMX2[1]
FCMN2	R*4	Same as NAMELIST /XPRINT/ word GCMN2[1]
FCMX2	R*4	Same as NAMELIST /XPRINT/ word GCMX2[1]
LINES	I*4	Same as NAMELIST /XPRINT/ word LINESX[1]
ILNTOT(100)	I*4	ILNTOT(I) = total number of lines output to FORTRAN data set reference number I
ILNMLT(100)	I*4	ILNMLT(I) = number of lines of data per star output to FORTRAN data set reference number I
IUNIQ(10)	I*4	The unit uniqueness flag: IUNIQ(I) = 0, IFLPRT(I) = IFLPRT(J) for $J < I$ IUNIQ(I) = 1, IFLPRT(I) $\neq$ IFLPRT(J) for any $J < I$

[1] See Section 5.5.1.1.4 for a definition of NAMELIST /IXPRINT variables.

5.4.9 COMMON /SIGBLK/

DESCRIPTION: /SIGBLK/ contains the mean standard deviation in stellar space velocity components as a function of spectral type.

FORM: COMMON /SIGBLK/ SIG1(13), SIG2(13), SIG3(13)

REFERENCED BY: SIGMA, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
SIG1(13), SIG2(13), SIG3(13)	R*4	SIG1(I), SIG2(I), SIG3(I) = the mean standard deviation for the θ, π, and z space velocity components, respectively, for the range of spectral class and luminosity class given in column 1 of Table 3-9

5.4.10 COMMON /STDBLK/

DESCRIPTION: /STDBLK/ contains the standard intrinsic B-V and U-B colors as a function of spectral class and luminosity class.

FORM: COMMON /STDBLK/BMVSTD(66, 5), UMBSTD(66, 5)

REFERENCED BY: STAND, UPDATE

DEFINITION OF VARIABLES:

Name	Type	Description
BMVSTD(66, 5) UMBSTD(66, 5)	R*4	BMVSTD(I, J), UMBSTD(I, J) = standard unreddened B-V and U-B color, respectively, for a star of spectral class code 10*I and luminosity class code 10*J

5.5 USER'S MANUAL

This subsection will enable the user to create the proper NAMELIST and data set input, write selected code to handle special cases, interpret the resulting output, and formulate the appropriate Job Control Language (JCL) for program UPDATE.

5.5.1 Input to Program Update

Input to UPDATE consists of several NAMELISTs, optional data sets, and optionally one or more user-written subroutines.

5.5.1.1 NAMELIST Input

The user may code input data into program UPDATE via NAMELISTs FILES, INSTR, PROCS, and XPRINT. The NAMELIST parameters are presented below in the format stated in Section 2.4.3.

FILES is always read first from FORTRAN data set reference number 5. INSTR is always read next from FORTRAN data set reference number IFILE(23). INSTR is read repeatedly until an end of file is encountered. If standard processes are to be performed, PROCS is read next from FORTRAN data set number IFILE(29). If printed output is to be generated, XPRINT is then read from FORTRAN data set reference number IFILE(27). Except for INSTR, multiple NAMELISTs are not processed by UPDATE.

5.5.1.1.1 NAMELIST /FILES/

Name	Type	Default	Description
IFILEX(30)	I*4	10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26, 27, 28, 29, 5, 6, 4, 40, 50, 60, 35, 70, 3, 0	IFILEX(I), 1 ≤ I ≤ 20 = file number for the I^{th} add/delete data set IFILEX(21) = not used IFILEX(22) = file number for error message and program trace printed output IFILEX(23) = file number for NAMELIST /INSTR/ input IFILEX(24) = file number for Master Catalog input IFILEX(25) = file number for Master Catalog output IFILEX(26) = file number for printed log output IFILEX(27) = file number for NAMELIST /XPRINT/ input. IFILEX(28) = file number for Mission Catalog output IFILEX(29) = file number for NAMELIST /PROCS/ input IFILEX(30) = not used
IFPRNT	I*4	0	Print flag = 0, do not print star data = 1, print star data
IFMAST	I*4	0	Master Catalog output flag = 0, do not output Master Catalog = 1, output Master Catalog
IFMISS	I*4	0	Mission Catalog output flag = 0, do not call subroutine WRITEM to output Mission Catalog = 1, call subroutine WRITEM to output Mission Catalog

Name	Type	Default	Description
IFSTND	I*4	0	Standard processes call flag = 0, do not perform standard processes = 1, perform requested standard processes only for stars added to the Master Catalog during the current run = 2, perform requested standard processes only for stars added to the Master Catalog, and for stars with data added during the current run = 3, perform requested standard processes for all Master Catalog stars

5.5.1.1.2 NAMELIST /INSTR/

Name	Type	Default	Description
ITY	I*4	0	Type of process to be performed = 0, none = 1, add stars = 2, delete stars = 3, delete data for a star = 4, add data for a star = 5, predefined process for all stars = 6, predefined process for stars stars passing conditional test only
IFL	I*4	0	Input file number for add/delete process data
NDEL	I*4	0	Number of words of data to be deleted (ITY = 3 only)
IDEL(20)	I*4	20*0	Master Catalog word numbers of words of data to be deleted (ITY = 3 only)
NADD	I*4	0	Number of words of data to be added (ITY = 1 or 4 only)
IADD(20)	I*4	20*0	Master Catalog word numbers of words of data to be added (ITY = 1 or 4 only)
ISUB	I*4	1	Call subroutine SUBX, where X is replaced by the value of ISUB to be called (ITY = 5 or 6 only)
IVARTS	I*4	0	Master Catalog variable number of the conditional variable (ITY = 6 only)
ITSTYP	I*4	1	Type of conditional variable = 1, conditional variable is I*4 = 2, conditional variable is R*4 (ITY = 6 only)

Name	Type	Default	Description
ILIMA, ILIMB	I*4	0, 0	Limits for conditional variable. Perform predefined process only if the value of Master Catalog word IVARTS is greater than or equal to ILIMA and less than or equal to ILIMB (ITY = 6 and ITSTYP = 1 only)
FLIMA, FLIMB	R*4	0.0, 0.0	Limits for conditional variable. Perform predefined process only if the value of Master Catalog word IVARTS is greater than or equal to FLIMA and less than or equal to FLIMB (ITY = 6 and ITSTYP = 2 only)

5.5.1.1.3 NAMELIST /PROCS/

Name	Type	Default	Description
JPROC(100)	I*4	100*0	Standard process flags JPROC(I) = 0, do not perform the Ith standard process JPROC(I) ≠ 0, perform the Ith standard process

Table 5-1 summarizes the standard processes.

Table 5-1. Summary of Standard Processes (1 of 2)

NUMBER	MASTER CATALOG WORD NUMBERS (WORDS COMPUTED)	DEFINITION OF WORDS COMPUTED	SECTION IN WHICH COMPUTATIONAL PROCEDURE DEFINED	MASTER CATALOG WORD NUMBERS (WORDS NEEDED FOR COMPUTATION)
1	13, 14	RIGHT ASCENSION, DECLINATION AT INPUT EPOCH	3 3 1	3, 21, 22, 23, 24
2	15	ERROR IN STANDARD EPOCH POSITION	3 3 1	3
3	16, 17	GALACTIC LATITUDE AND LONGITUDE	3 5 1 3	18, 19, 20
4	18, 19, 20	G I UNIT VECTOR COMPONENTS	3 5 1 3	13, 14
5	27, 28	PRECESSION IN RIGHT ASCENSION AND IN DECLINATION	3 3 3	13, 14
6	29, 30	TOTAL MOTION IN RIGHT ASCENSION AND IN DECLINATION	3 3 2, 3 3 3	25, 26, 27, 28
7	93, 94	SYSTEMATIC ERRORS IN POSITION	4 7	13, 14, 90
11	42, 43, 44, 45	BEST VALUE OF SPECTRAL TYPE AND SOURCE FLAG	3 4 1	46 - 50
12	33, 34, 35	BEST VALUE OF B, V MAGNITUDES AND SOURCE FLAG	3 4 2	36 40, 42
21	53 - 55	TRIGONOMETRIC PARALLAX DISTANCE AND ERROR	3 5 1 1	51, 52
22	56	ABSOLUTE VISUAL MAGNITUDE	3 5 1 2	42, 43
23	57 58	SPECTROSCOPIC DISTANCE AND ERROR	3 5 1 2	16, 17, 34, 35, 42, 43, 45 56, 67, 69
24	59	RADIAL VELOCITY	3 5 1 3	16, 17
25	63	MAXIMUM DISTANCE BASED ON SPACE MOTION	3 5 1 3	13, 14, 25, 26, 42, 43, 59

Table 5-1. Summary of Standard Processes (2 of 2)

NUMBER	MASTER CATALOG WORD NUMBERS (WORDS COMPUTED)	DEFINITION OF WORDS COMPUTED	SECTION IN WHICH COMPUTATIONAL PROCEDURE DEFINED	MASTER CATALOG WORD NUMBERS (WORDS NEEDED FOR COMPUTATION)
26	64–66	BEST DISTANCE, ERROR AND DERIVATION FLAG	3 5 1 4	53–55, 57, 58, 63
27	60–62	COMPONENTS OF SPACE VELOCITY	3.5.1.3	13, 14, 25, 26, 59,64, 66
28	67–69	INTERSTELLAR AB-SORPTION AND SOURCE FLAG	3 5 2	16, 17, 31, 33, 34, 42–44, 64
29	31–32	BEST VALUE OF U MAG-NITUDE AND DERIVA-TION FLAG	3 5 3	33, 34, 42–44, 67, 68
31	96–99	DM NUMBER	*	4
32	100–102	RIGHT ASCENSION	*	13
33	103–106	DECLINATION	*	14
34	107	SOURCE OF POSITION	*	1, 3
35	108, 109	MOTION IN RIGHT AS-CENSION AND IN DE-CLINATION	*	29, 30
36	110	U MAGNITUDE SOURCE	*	32
37	111	B, V MAGNITUDE SOURCE	*	35
38	112–116	SPECTRAL TYPE AND SOURCE	*	42–45
39	117	DISTANCE SOURCE	*	66
40	118	INTERSTELLAR AB-SORPTION SOURCE	*	69
41	119–120	B–V, U–B	*	31, 33, 34

*THESE WORDS ARE ALPHAMERIC EQUIVALENTS OF THOSE INDICATED IN THE LAST COLUMN

5.5.1.1.4 NAMELIST /XPRINT/

Name	Type	Default	Description
JTYPRT	I*4	1	Type of printed output = 1, one page summary = 2, full scientific See Section 5.5.2.3.3 for a description of these outputs
JFLPRT(10)	I*4	10*0	JFLPRT(I) = file number for the Ith page of printed output
JCOND, JCOND2	I*4	0, 0	Master Catalog word number for the first and second conditional variables. If = 0, not processed
JCMN, JCMX, JCMN2, JCMX2	I*4	0, 0, 0, 0	Minimum and maximum values of the first and second conditional variables, respectively, that result in data from the star being printed (JCOND and/or JCOND2 $\neq$ 0 and Master Catalog word JCOND and/or JCOND2 being I*4 only)
GCMN, GCMX, GCMN2, GCMX2	R*4	0.0, 0.0 0.0, 0.0	Minimum and maximum values of the first and second conditional variables, respectively, that result in data from the star being printed (JCOND and/or JCOND2 $\neq$ 0 and Master Catalog word JCOND and/or JCOND2 being R*4 only)
LINESX	I*4	80	Maximum number of lines of output to be printed on one page

5.5.1.2 Data Set Input

All or selected star data words may be added to, or deleted from, the Master Catalog using the add/delete processes. NAMELIST /INSTR/ contains the control parameters defining the flow of this segment of UPDATE (see Section tion 5.5.1.1.2). The star data to be added and the star numbers for deleting data or stars are read from data sets. For the Ith add/delete process, the associated data set is on file ICNT(2,I) in COMMON /CNTBLK/.

The format of the input data sets is the same for all processes and consists of one 4-byte integer followed by twenty 4-byte floating point words per logical record. The integer is the SKYMAP number of the star to be processed, except for add star processes, when it is the SKYMAP number of the star following which the new star is to be added. For add star or add data processes, the next floating point NADD (a NAMELIST /INSTR/ parameter) words are the values for Master Catalog word numbers IADD(J), J = 1, ..., NADD (IADD is also a NAMELIST /INSTR/ parameter). For delete star or delete data processes, the floating point words are meaningless.

Each input data set must be ordered by increasing SKYMAP number. Failure to do so may result in some stars not being processed.

For add star processes, the SKYMAP number of the star must be one of the Master Catalog data words added. Any data word not specifically added will be set to its default value (see Table 4-1).

5.5.1.3 User-Written Subroutines

5.5.1.3.1 Subroutines SUB1, SUB2, SUB3, SUB4, SUB5, and SUB6

The user may code up to six subroutines to perform predefined processes. These subroutines are called subject to logic provided in the add/delete process NAMELIST /INSTR/ (see Section 5.5.1.1.2). Whenever indicated by ITY (a NAMELIST /INSTR/ parameter), SUB1, SUB2, SUB3, SUB4, SUB5, or SUB6 is called.

Dummy versions of these subroutines are provided in UPDATE. These are all of the following form:

```
SUBROUTINE SUBy (X, IX)
COMMON /FLBLK/ IFILE(30)
DIMENSION X(135), IX(135)
RETURN
END
```

where y is an integer between 1 and 6. X, IX, and IFILE are defined in Sections 5.3.2.23 to 5.3.2.28.

5.5.1.3.2 Subroutine WRITEM

The user may code subroutine WRITEM to output a Mission Catalog in any format he desires. The Mission Catalog output must always be to file IFILE(28) (a COMMON /FLBLK/ parameter). A dummy version of this routine is provided in UPDATE as follows:

```
SUBROUTINE WRITEM (X, IX, IKNT)
DIMENSION X(135), IX(135), DX4
COMMON /FLBLK/ IFILE(30)
IKNT = IKNT + 1
RETURN
END
```

X, IX, and IFILE are defined in Section 5.3.2.29. IKNT is an output record counter whose value is set to 0 at the start of execution.

5.5.2 <u>Output From Program UPDATE</u>

5.5.2.1 Output Master Catalog

Whenver the NAMELIST /FILES/ parameter IFMAST is not equal to zero, a Master Catalog is output on file IFILE(25) (a COMMON /FLBLK/ parameter).

The format of the output Master Catalog is identical to that of the input Master Catalog (see Section 4). All additions, deletions, and changes of data accomplished by UPDATE are present on the output Master Catalog. Because of this, there is no guarantee that the output Master Catalog will be in order by SKYMAP number. If it is not, subsequent executions of UPDATE may not accomplish the desired results.

5.5.2.2 Mission Catalog

Whenever the NAMELIST /FILES/ parameter IFMISS is not equal to zero, user-written subroutine WRITEM is called in which the user may code the output of a Mission Catalog on file IFILE(28). (IFILE is a COMMON /FLBLK/ parameter.)

5.5.2.3 Printed Output

Trace message and error message output appear on file IFILE(22) (IFILE is a COMMON /FLBLK/ parameter); log output is written to file IFILE(26); and a printed version of the catalog is output on files JFLPRT(1), ..., JFLPRT(k), where JFLPRT is a NAMELIST /XPRINT/ parameter and k depends on the value of JTYPRT (also a NAMELIST /XPRINT/ parameter). For JTYPRT = 1, k = 1; and for JTYPRT = 2, k = 6.

5.5.2.3.1 Trace Message Output

UPDATE produces a small amount of trace message output to inform the user of progress through the program. No user action is necessary based on this output, but it can be used to assist in tracking down problems encountered with UPDATE.

5.5.2.3.2 Error Message Output

UPDATE produces error message output for a number of anomalous situations. These are listed below, together with an explanation of the cause of the message and what user action is indicated. Each error message is preceded by either the word "ERROR" or "WARNING." Messages preceded by "ERROR" cause a stop to be executed. Messages preceded by "WARNING" cause the action specified to be taken, but execution continues.

- Error Messages From UPDATE

  'END OF FILE ON NAMELIST FILE 5.' No NAMELIST/FILES/ was found on unit 5. One must be supplied.

  'WARNING--FOR THE xxTH PROCESS, THE INPUT DATA SET FILE NUMBER yy is EMPTY.' The data set (on file number yy) for the xxth add/delete process was empty. UPDATE ignores this add/delete instruction.

  'WARNING--FOR THE xxTH PROCESS, A STAR TO BE DELETED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star to be deleted. UPDATE ignores this delete instruction. Note that delete records not being in numerical order of SKYMAP number may cause this error.

  'WARNING--FOR THE xxTH PROCESS, A STAR WITH DATA TO BE DELETED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star with data to be deleted. UPDATE ignores this delete data instruction. Note that delete data records not being in numerical order of SKYMAP number may cause this error.

  'WARNING--FOR THE xxTH PROCESS, A STAR WITH DATA TO BE ADDED (yyyyyy) IS NOT IN THE MASTER CATALOG' where xx is the number of the add/delete process and yyyyyy is the SKYMAP number of the star with data to be added. UPDATE ignores this add data instruction. Note that add data records not being in numerical order of SKYMAP number may cause this error.

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- Error Messages From Subroutine CONTRL

'WARNING--ITY INDICATES A NULL PROCESS OR AN UNDEFINED PROCESS. ITY = xxx.' ITY was equal to xxx. Only values between 1 and 6 are meaningful. UPDATE ignores this add/delete process.

'ERROR--FOR THE xxTH PROCESS, THE FILE DEFINED yy IS ALREADY IN USE.' The input file (yy) for the xxth add/delete process was previously defined as a NAMELIST read, printed output or Master Catalog input file, or as an input file for a previous add/delete process. Change the duplicated file number. UPDATE stops.

'WARNING--FOR THE xxTH PROCESS--A DELETE DATA PROCESS, NDEL (yyyyyyyy) WAS NOT POSITIVE.' For add/delete process number xx, the number of data words to be deleted (yyyyyyyy) was not positive. UPDATE ignores this process.

'ERROR--FOR THE xxTH PROCESS, NDEL (yyyyyyyy) WAS LARGER THAN THE LIMIT, 20.' For add/delete process number xx, the number of data words to be deleted was greater than the maximum allowed, 20. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE yyTH WORD TO BE DELETED IS AN ILLEGAL VALUE--zzzz' For add/delete process number xx, the yyth word to be deleted lies outside of the limits $1 \leq zzzz \leq 131$. UPDATE stops.

'WARNING--FOR THE xxTH PROCESS, AN ADD DATA PROCESS, NADD (yyyyyyyy) WAS NOT POSITIVE.' For add/delete process number xx, the number of words of data to be added, yyyyyyyy, was not positive. UPDATE ignores this add/delete process.

'ERROR--FOR THE xxTH PROCESS, NADD (yyyyyyyy) WAS LARGER THAN THE LIMIT, 20.' For add/delete process number xx, the number of data words to be added was greater than the maximum allowed, 20. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE yyTH WORD TO BE ADDED IS AN ILLEGAL VALUE--zzzz' For add/delete process number xx, the yyth word to be added lies outside of the limits $1 \leq$ zzzz ≤ 131. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE SUBROUTINE NUMBER SPECIFIED (yyyyyyyy) IS AN ILLEGAL VALUE.' For add/delete process xx, the subroutine number to be called must be $1 \leq$ yyyyyyyy ≤ 6. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, THE CONDITIONAL VARIABLE, IVARTS, IS yyyyyyyy, AN ILLEGAL VALUE.' For add/delete process number xx, the variable to be tested for conditional application of the process is not within the allowed range $1 \leq$ yyyyyyyy ≤ 131. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, ITSTYP = yyyyyyyy, WHICH DOES NOT AGREE WITH THE FORMAT OF MASTER CATALOG WORD zzzz.' For add/delete process number xx, the type of the conditional variable was yyyyyyyy, which does not agree with the Master Catalog data type for word zzzz. UPDATE stops.

'ERROR--FOR THE xxTH PROCESS, ITSTYP = yyyyyyyy, AN ILLEGAL VALUE.' For add/delete process number xx, the type of conditional variable was yyyyyyyy, which is outside of the allowed range $1 \leq$ yyyyyyyy ≤ 2. UPDATE stops.

'WARNING--OVER 20 PROCESSES CALLED FOR.' Only 20 add/delete processes are allowed. Any over that amount are ignored.

- Error Messages From Subroutine PRNTIT

'ERROR--AN END OF FILE WAS ENCOUNTERED ON THE NAMELIST/XPRINT/FILE. PRINTOUT IS CANCELED.' File IFILE(27) does not contain NAMELIST/XPRINT/. No printout is generated.

'ERROR--THE CONDITIONAL PRINT VARIABLE, ICOND, HAS AN ILLEGAL VALUE (xxxxxx). PRINTOUT IS CANCELED.' The first conditional print variable must be a Master Catalog word. Accordingly, it must satisfy the conditions $/xxxxxx/ \leq 131$ or $1001 \leq xxxxxx \leq 1004$. No printout is produced.

'ERROR--THE CONDITIONAL PRINT VARIABLE, ICOND2, HAS AN ILLEGAL VALUE (xxxxxx). PRINTOUT IS CANCELED.' The second conditional print variable must be a Master Catalog word. Accordingly, it must satisfy the conditions $/xxxxxx/ \leq 131$ or $1001 \leq xxxxxx \leq 1004$. No printout is produced.

- Error Messages From Subroutine STAND

'ERROR--UNEXPECTED END OF FILE ON SUBROUTINE STAND NAMELIST.' File IFILE(29) did not contain NAMELIST/PROCS/. UPDATE stops.

'ERROR--SPECTROSCOPIC PARALLAX NON-CONVERGENCE FOR STAR HO xxxxxxx = SKYMAP yyyyyyy. LAST DISTANCE WAS zzzzzzzz.z PARSECS.' Irrecoverable error in the spectroscopic parallax routine. Master Catalog words 57 and 58 are set to zero for star HO xxxxxxx = SKYMAP number yyyyyyy. The best estimate for the distance is zzzzzzzz.z.

'ERROR--SPECTROSCOPIC PARALLAX ERROR COULD NOT BE COMPUTED FOR STAR HD xxxxxxx = SKYMAP yyyyyyy.' The error in the spectroscopic parallax was set to 0.0 for star HD xxxxxxx = SKYMAP number yyyyyyy. The error is irrecoverable.

5.5.2.3.3 Printed Catalog Output

Whenever NAMELIST /FILES/ parameter IFPRNT is not equal to zero, a printed version of Master Catalog data is generated in accordance with the instructions given in NAMELIST /XPRINT/. Two standard formats are available: a one-page summary (Figure 5-3) or a six-page full scientific output (Figure 5-4).

5.5.3 Job Control Language

UPDATE may be run from a FORTRAN source or a load module. The JCL shown in Figure 5-5 assumes that UPDATE is being run from a cataloged source data set named UPDATE.FORT. The input Master Catalog is assumed to be on tape. All file numbers are assigned their default values.

5.5.4 Overlay Considerations

Most of the core storage required by UPDATE is for input/output buffers and for a few large subroutines which are called repeatedly by UPDATE. Therefore, overlay procedures would be unable to substantially reduce core requirements.

5.5.5 System Resources

UPDATE requires 300K bytes of core storage for the compile step and 390K bytes for execution. Tape and data set requirements vary according to the function to be performed; however, the input Master Catalog always requires one nine-track tape drive.

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SKYMAP	HD	RIGHT ASC HH MM SS S	DECLINATION DD MM SS S	POS	MOVEMENT R A	MOVEMENT DEC	V	B V	U-B	SPECTRAL TYPE		VARIABLE	HD	SKYMAP
1	3	0 2 35 0	+41 57 3 7	SAO	+5 1	+ 34	6 59	07 C	01	A0 V	H		3	1
2	6	0 2 29 9	0 46 50 6	SAO	+5 1	+ 34	6 29	1 10	1 02	G9 G			6	2
3	14	0 2 42 9	+18 36 22 3	SAO	+5 2	+ 34	6 85	03 C		B9 V	H		14	3
4	17	0 2 38 5	+35 17 26 4	SAO	+5 1	+ 34	6 87	16	04	A3 III			17	4
5	21	0 2 37 5	32 44 46 6	SAO	+5 1	+ 34	7 12	1 05 C	1 09	K0 V	H		21	5
6	23	0 2 35 8	52 25 42 1	SAO	+5 1	+ 34	7 02	58 C	28	G1 V	H		23	6
7	24	0 2 37 9	63 7 26 0	SAO	+5 1	+ 34	7 96	64 C	38	G1 V	H		24	7
8	25	0 2 47 3	+[illegible] 29 33 0	SAO	+5 2	+ 34	7 15	38 C	02	F1 V	H		25	8
9	28	0 2 46 5	5 59 14 0	SAO	+5 1	+ 34	4 61	1 04	87	K1 III			28	9
10	31	0 2 45 7	2[illegible] 34 59 4	HD	+5 1	+ 34	8 38	06		B5 V	N		31	10
11	32	0 2 46 6	7[illegible] 8 9 5	SAO	+5 1	+ 34	6 95	51 C	18	G7 IV	H		32	11
12	39	0 2 54 5	+33 49 37 2	SAO	+5 1	+ 34	7 76	53 C	02	F8 V	H		39	12
13	43	0 2 48 5	+ 1 19 40 6	SAO	+5 1	+ 34	6 84	90 C	61	G7 IV	H		43	13
14	53	0 2 49 5	57 14 2 3	SAO	+5 1	+ 34	7 26	03 C	02	A0 V	H		53	14
15	58	0 2 59 1	+52 53 36 2	SAO	+5 2	+ 34	7 24	1 07 C	1 14	K0 V	H		58	15
16	63	0 2 57 3	9 53 40 7	SAO	+5 1	+ 34	7 53	47 C	02	F5 V	H		63	16
17	68	0 2 55 9	+[illegible] 14 16 5	SAO	+5 1	+ 34	6 85	1 02 C	1 06	K0 V	H		68	17
18	71	0 3 4 0	+[illegible]5 25 54 5	SAO	+5 2	+ 34	7 55	1 07 C	1 14	K0 V	H		71	18
19	72	0 3 5 8	+14 11 25 2	SAO	+5 2	+ 34	7 68	0[illegible] C	01	A0 V	H		72	19
20	73	0 3 2 0	+15 7 23 4	SAO	+5 2	+ 34	8 11	10 C	04	B1 5 IV			73	20
21	79	0 3 3 5	51 31 59 4	HD	+5 1	+ 34	7 33	63 C	24	K3 III	H		79	21
22	80	0 3 4 3	1 35 19 0	SAO	+5 1	+ 34	7 35	90 C	61	G7 IV	H		80	22
23	83	0 3 12 3	+ 6 48 32 9	SAO	+5 2	+ 34	8 38	07 C	03	A0 V	H		83	23
24	85	0 3 10 0	17 55 41 2	SAO	+5 1	+ 34	7 61	30 C	01	F2 V	H		85	24
25	87	0 3 7 8	+13 7 5 4	SAO	+5 1	+ 34	5 51	90	81	K0 V	H		87	25
26	98	0 3 21 7	+40 20 38 6	SAO	+5 2	+ 34	7 41	26 C	02	A5 V	H		98	26
27	99	0 3 23 1	+41 27 30 4	SAO	+5 2	+ 34	7 81	26 C	01	A5 V	H		99	27
28	100	0 3 22 2	+2[illegible] 17 27 2	SAO	+5 1	+ 34	7 00	1 40 C	1 59	K5 III	H		100	28
29	101	0 3 21 1	+17 57 31 2	SAO	+5 1	+ 34	7 66	53 C	02	F8 V	H		101	29
30	105	0 3 19 [illegible]	[illegible] 1 50 2	SAO	+5 1	+ 34	7 52	60	31	G0 V			105	30
31	109	0 3 26 [illegible]	[illegible] 23 6 1	SAO	5 2	+ 34	7 [illegible]	16		08 B	P		109	31
32	110	0 3 23 [illegible]	[illegible] 8 21 8	SAO	+5 2	+ 34	6 66	96 C	61	G7 IV	H		110	32
33	111	0 3 26 1	[illegible] 59 [illegible]5 9	SAO	+5 1	+ 34	6 6[illegible]	1 30 C	1 59	K5 III			111	33
34	112	0 3 28 [illegible]	+2[illegible] 38 18 4	SAO	+5 1	+ 34	7 40	1 07 C	1 14	K0 V	H		112	34
35	123	0 3 38 2	+55 9 28 7	SAO	+5 2	+ 34	5 98	67	36	G7 IV	H		123	35
36	126	0 3 33 [illegible]	+ 9 26 12 1	SAO	+5 1	+ 34	7 66	47 C	02	F5 V	H		126	36
37	135	0 3 43 5	+3[illegible] 10 4[illegible] 2	SAO	+5 2	+ 34	7 05	21	02	F1 V	H		135	37
38	141	0 3 36 1	2 25 47 7	SAO	+5 1	+ 34	7 8[illegible]	05		A0 V	N		141	38
39	142	0 3 44 1	49 21 10 8	SAO	+5 2	+ 34	5 70	52	03	G1 IV			142	39
40	144	0 3 49 [illegible]	[illegible] 55 4 6	SAO	+5 2	+ 34	5 56	02	48	B8 III			144	40
41	145	0 3 44 6	+4 37 13 1	SAO	+5 2	+ 34	6 9	1 07 C	1 14	K0 V	H		145	41
42	156	0 3 51 [illegible]	10 18 55 6	SAO	+5 1	+ 34	7 13	38 C	01	F1 V	H		156	42
43	164	0 3 59 7	+[illegible] 14 11 1	SAO	+5 2	+ 34	7 88	07 C	02	A0 V	H		164	43
44	166	0 4 6 7	+26 14 44 2	SAO	+5 2	+ 34	6 14	75	33	K0 V			166	44
45	167	0 4 0 9	+20 16 31 4	SAO	+5 1	+ 34	6 71	1 00 C	89	G9 III			167	45
46	171	0 4 11 [illegible]	+[illegible] 7 25 7	SAO	+5 6	+ 34	8 15	26 C		A5 V	H		174	46
47	175	0 4 5 [illegible]	+[illegible] 2 47 1	SAO	+5 2	+ 34	8 27	01 C	- 21	B9 V	H		175	47
48	192	0 4 17 8	+[illegible] 9 1 1	SAO	+5 2	+ 34	7 95	38 C	03	F1 V	H		192	48
49	193	0 4 18 3	+[illegible]5 3 3 1	SAO	+5 2	+ 34	7 68	0[illegible] C	05	A0 V	H		193	49
50	191	0 4 13 7	+[illegible]8 20 49 2	SAO	+5 2	+ 34	8 12	18 C	00	A3 V	H		191	50
51	203	0 4 16 7	[illegible] 23 6 9	SAO	+5 1	+ 34	6 18	38	02	A7 V			203	51
52	201	0 4 29 6	+7[illegible] 29 48 5	SAO	+5 3	+ 34	7 75	26 C	03	A5 V	H		204	52
53	211	0 4 20 [illegible]	3[illegible] 9 22 7	SAO	+5 1	+ 34	6 88	1 19 C	1 22	K0 V	H		211	53
54	219	0 4 33 9	+72 55 55 9	SAO	+5 3	+ 34	7 94	40 C	03	F2 V	H		219	54
55	222	0 4 27 5	+[illegible]2 37 59 2	SAO	+5 1	+ 34	7 85	38 C	01	F1 V	H		222	55
56	228	0 5 27 1	[illegible] 34 1 2	SAO	+5 1	+ 34	7 51	85 C	55	G7 IV	H		228	56
57	231	0 4 30 [illegible]	+ 6 35 51 0	SAO	+5 1	+ 34	7 77	28 C	01	A7 V	H		231	57
58	249	0 4 47 4	+[illegible]6 10 26 4	SAO	+5 2	+ 34	7 2[illegible]	1 14 C		K1 IV			249	58

Figure 5-3. Printed One-Page Summary Output From Program UPDATE

ORIGINAL PAGE IS
OF POOR QUALITY

SKYMAP	HD	SAO	DM	M	ADS	VSC	STAR NAME	VAR NAME	RIGHT ASC. HH MM SS.S	DECLINATION DD MM SS.S	MOVEMENT R.A. DEC.	V	B-V	U-B
1	3	36042	+44 4550	1	46	0			0 2 35.0	+44 57 3.7	+5.1 + 34	6.39	.07	.01
2	6	128565	- 1 4525	2	0	0			0 2 29.9	- 0 46 50.6	+5.1 + 34	6.29	1.10	1.02
3	14	10965	+63 1426	0	0	0			0 2 42.9	+69 36 22.3	+5.2 + 34	6.85	.03	
4	17	53630	+34 5061	0	0	0			0 2 38.5	+35 17 36.4	+5.1 + 34	6.87	.16	.04
5	21	192359	-3316936	0	0	0			0 2 37.5	-32 44 46.6	+5.1 + 34	7.12	1.05	1.09
6	22	231020	-5212251	0	0	0			0 2 35.8	-52 25 42.1	+5.1 + 34	7.02	.58	.28
7	24	248112	-63 4949	0	0	0			0 2 37.9	-63 7 26.0	+5.1 + 34	7.96	.64	.38
8	25	36044	+48 4241	0	0	0			0 2 47.3	+49 29 33.0	+5.2 + 34	7.49	.38	.02
9	28	128572	- 6 6357	3	0	0	33	PSC	0 2 46.5	- 5 59 14.0	+5.1 + 34	4.61	1.04	.87
10	31	0	-22 6257	0	0	0			0 2 45.7	-21 34 59.4	+5.1 + 34	8.38	-.06	
11	32	192351	-3915250	0	0	0			0 2 46.6	-39 8 9.5	+5.1 + 34	6.95	.51	.18
12	39	53635	+33 4812	0	51	0			0 2 54.5	+33 49 37.2	+5.1 + 34	7.76	.53	.02
13	43	109004	+ 2 4752	0	0	0			0 2 48.5	+ 3 19 40.6	+5.1 + 34	6.84	.90	.61
14	53	231922	-5710426	0	0	0			0 2 49.5	-57 14 2.3	+5.1 + 34	7.26	.03	.02
15	58	21074	+52 3538	0	0	0			0 2 59.4	+52 53 36.2	+5.2 + 34	7.24	1.07	1.14
16	63	128577	-10 6227	0	0	0			0 2 57.3	- 9 53 40.7	+5.1 + 34	7.03	.47	.02
17	68	248114	-63 3548	0	0	0			0 2 55.9	-68 14 18.5	+5.1 + 34	6.85	1.02	1.06
18	71	21076	+54 3139	0	0	0			0 3 4.0	+55 25 54.5	+5.2 + 34	7.05	1.07	1.14
19	72	36049	+43 4627	0	0	0			0 3 5.8	+44 11 25.2	+5.2 + 34	7.88	.07	-.01
20	73	36047	+42 4831	0	0	0			0 3 2.0	+43 7 23.4	+5.2 + 34	8.44	.10	.04
21	79	0	-5113763	0	0	0			0 3 3.5	-51 31 59.4	+5.1 + 34	7.33	.63	.24
22	80	248116	-62 6468	0	0	0			0 3 4.3	-61 35 19.0	+5.1 + 34	7.35	.90	.61
23	83	36051	+46 4254	0	0	0			0 3 12.3	+46 49 32.9	+5.2 + 34	8.38	.07	.03
24	85	91703	+17 5032	0	56	0			0 3 10.0	+17 33 43.2	+5.1 + 34	7.84	.40	.01
25	87	91701	+12 5063	4	0	0	86	PEG	0 3 7.8	+13 7 5.4	+5.1 + 34	5.51	.90	.94
26	98	36054	+48 4244	0	59	0			0 3 21.7	+49 20 38.6	+5.2 + 34	7.41	.26	.02
27	99	36056	+43 4629	0	0	0			0 3 23.1	+44 27 39.4	+5.2 + 34	7.81	.26	.01
28	100	73737	+23 4853	0	0	0			0 3 22.2	+24 17 27.2	+5.1 + 34	7.06	1.40	1.59
29	101	91706	+17 5035	0	0	0			0 3 21.1	+17 57 31.2	+5.1 + 34	7.66	.53	.02
30	105	214961	-4216587	0	0	0			0 3 19.6	-42 1 50.2	+5.1 + 34	7.52	.60	.31
31	108	10973	+62 2363	0	0	0			0 3 26.9	+63 24 6.1	+5.2 + 34	7.38	.16	
32	110	36057	+39 5219	0	0	0			0 3 29.4	+40 8 24.8	+5.2 + 34	6.66	.90	.61
33	111	73736	+27 4674	0	0	0			0 3 26.1	+27 59 55.9	+5.1 + 34	6.87	1.40	1.59
34	112	73739	+24 4883	0	0	0			0 3 28.6	+24 38 18.4	+5.1 + 34	7.40	1.07	1.14
35	123	21089	+57 2365	5	61	0			0 3 38.2	+58 9 28.7	+5.2 + 34	5.98	.67	.36
36	126	109006	+ 8 5172	0	0	0			0 3 33.9	+ 9 26 12.1	+5.1 + 34	7.66	.47	.02
37	135	10977	+59 2829	0	0	0			0 3 43.5	+60 10 43.2	+5.2 + 34	7.95	.24	.02
38	141	166043	-2918964	0	0	0			0 3 36.1	-29 25 47.7	+5.1 + 34	7.89	-.03	
39	142	214963	-4914337	6	0	0			0 3 44.1	-49 21 10.8	+5.2 + 34	5.70	.52	.03
40	144	10978	+63 2107	7	0	0	10	CAS	0 3 49.7	+63 55 4.6	+5.2 + 34	5.56	-.02	-.48
41	145	36061	+40 5233	0	0	0			0 3 44.8	+40 37 11.1	+5.2 + 34	6.96	1.07	1.14
42	156	147084	-18 6426	0	0	0			0 3 51.7	-18 18 59.6	+5.1 + 34	7.43	.38	.01
43	164	21088	+55 3087	0	0	0			0 3 59.7	+56 14 11.1	+5.2 + 34	7.88	.07	.02
44	166	73743	+28 4704	8	60	0			0 4 0.7	+28 44 44.2	+5.2 + 34	6.14	.75	.33
45	167	73744	+27 4676	0	0	0			0 4 0.9	+28 16 31.4	+5.1 + 34	6.73	1.00	.89
46	174	17	+84 546	0	0	0			0 4 11.4	+85 7 35.7	+5.6 + 34	8.15	.26	
47	179	21091	+55 3088	0	0	0			0 4 5.7	+56 2 47.1	+5.2 + 34	8.27	.03	-.21
48	192	10981	+65 2001	0	0	0			0 4 17.8	+66 9 1.1	+5.2 + 34	7.95	.38	.03
49	193	10982	+64 1900	0	0	0			0 4 18.3	+65 3 3.1	+5.2 + 34	7.88	.07	.05
50	194	53646	+37 4936	0	0	0			0 4 13.7	+38 20 49.2	+5.2 + 34	8.12	.18	.00
51	203	166053	-23 04	9	0	0			0 4 16.7	-23 23 6.9	+5.1 + 34	6.18	.38	.02
52	204	4037	+71 1250	0	0	0			0 4 29.6	+72 29 48.5	+5.3 + 34	7.75	.26	.03
53	213	192399	-39 04	0	0	0			0 4 20.9	-39 9 22.7	+5.1 + 34	6.88	1.19	1.22
54	219	4038	+72 1140	0	0	0			0 4 33.9	+72 55 55.9	+5.3 + 34	7.94	.40	.03
55	222	73750	+22 4955	0	0	0			0 4 27.5	+22 33 59.2	+5.1 + 34	7.85	.38	.01
56	228	214979	-44 05	0	0	0			0 5 27.1	-43 44 1.2	+5.1 + 34	7.51	.85	.55
57	231	109014	+ 6 5242	0	0	0			0 4 30.3	+ 6 35 51.0	+5.1 + 34	7.77	.28	.01
58	249	73758	+25 5073	0	0	0			0 4 47.4	+26 10 26.4	+5.2 + 34	7.23	1.14	
59	251	109019	+ 6 5243	0	0	0			0 4 44.4	+ 7 25 31.4	+5.1 + 34	7.92	.47	.02
60	256	147090	-13 6428	10	0	0			0 4 45.1	-17 39 55.0	+5.1 + 34	6.19	.13	.09
61	267	147092	-12 6617	0	0	0			0 4 49.8	-11 53 27.2	+5.1 + 34	7.62	.18	.00
62	268	166063	-26 08	0	0	0			0 4 48.9	-25 37 58.5	+5.1 + 34	7.05	.45	-.01
63	273	231930	-57 06	0	0	0			0 4 51.0	-57 6 53.6	+5.1 + 34	7.30	1.27	1.36
64	276	258832	-77 01	0	0	0			0 4 46.2	-77 0 32.4	+4. + 34	7.54	.41	.08
65	278	21108	+51 02	0	81	0			0 5 1.3	+52 29 41.3	+5.2 + 34	7.55	.90	.61
66	281	53659	+30 01	0	33	0			0 5 0.2	+31 23 27.3	+5.2 + 34	6.96	.90	.61
67	285	231932	-56 10	0	0	0			0 4 56.6	-56 17 24.2	+5.1 + 34	7.32	.19	.00
68	290	53661	+39 03	0	82	0			0 5 2.8	+39 52 12.8	+5.2 + 34	6.82	.90	.61
69	292	53669	+36 01	0	96	0			0 5 7.8	+36 54 27.4	+5.2 + 34	7.47	.47	.02
70	294	109023	+ 3 03	0	0	0			0 5 6.2	+ 0 48 58.2	+5.1 + 34	7.98	.07	-.01
71	299	21114	+54 01	0	0	0			0 5 14.3	+55 17 55.3	+5.2 + 34	7.75	.64	.38
72	309	248119	-61 01	0	0	0			0 5 4.0	-60 55 10.4	+5.0 + 34	8.25	.11	-.25
73	313	53668	+37 03	0	0	0			0 5 15.7	+38 26 37.2	+5.2 + 34	7.66	.16	-.00

Figure 5-4. Printed Full Scientific Output From Program UPDATE (1 of 6)

SKYMAP	HD	R.A. DEGS.	DECL. DEGS.	POS ERR ARC SEC	SRCE	G. I. UNIT VECTOR X	Y	Z	GALACTIC COORDS LAT DEGS.	LONG DEGS.	PROP. MOTION R.A. DEG/100 YRS	DEC.	PRECESSION R.A. DEG/100 YRS	DEC.	MOVEMENT R.A. DEG/100 YRS	DEC.
1	3	0.646	44.951	0.240	SAO	0.7077	0.0080	0.7065	-16.878	114.509	-0.0005	-0.0004	1.287	0.567	1.287	0.567
2	6	0.625	-0.781	0.200	SAO	0.9998	0.0109	-0.0136	-61.139	98.505	0.0012	-0.0015	1.281	0.567	1.282	0.565
3	14	0.679	63.606	0.370	SAO	0.3648	0.0043	0.9311	6.365	118.814	0.0032	0.0006	1.298	0.567	1.301	0.568
4	17	0.660	35.293	0.370	SAO	0.8161	0.0094	0.5778	-26.358	112.533	0.0006	-0.0004	1.285	0.567	1.286	0.567
5	21	0.656	-32.746	0.650	SAO	0.8410	0.0096	-0.5409	-78.641	2.189	-0.0021	-0.0018	1.277	0.567	1.274	0.565
6	23	0.643	-52.428	0.540	SAO	0.6097	0.0069	-0.7926	-63.513	318.905	-0.0052	-0.0037	1.272	0.567	1.267	0.563
7	24	0.658	-63.124	0.140	SAO	0.4520	0.0052	-0.8920	-53.480	311.750	0.0047	0.0006	1.268	0.567	1.273	0.568
8	25	0.657	49.492	0.470	SAO	0.6495	0.0079	0.7603	-12.421	115.404	-0.0011	-0.0018	1.289	0.567	1.288	0.565
9	28	0.694	-5.987	0.050	SAO	0.9945	0.0120	-0.1043	-65.334	93.964	-0.0003	0.0026	1.280	0.567	1.280	0.570
10	31	0.690	-21.583	120.000	HD	0.9298	0.0112	-0.3679	-77.988	59.794	0.0	0.0	1.281	0.567	1.281	0.567
11	32	0.694	-39.136	0.720	SAO	0.7756	0.0094	-0.6312	-74.826	339.367	0.0012	0.0011	1.275	0.567	1.276	0.568
12	39	0.727	33.827	0.260	SAO	0.8307	0.0105	0.5567	-27.806	112.267	-0.0008	0.0008	1.286	0.567	1.285	0.568
13	43	0.702	3.328	0.550	SAO	0.9982	0.0122	0.0581	-57.316	101.437	-0.0004	0.0004	1.281	0.567	1.281	0.567
14	53	0.706	-57.234	0.490	SAO	0.5412	0.0067	-0.8409	-59.065	315.119	0.0012	-0.0004	1.270	0.567	1.271	0.567
15	58	0.747	52.893	0.380	SAO	0.6032	0.0079	0.7975	-9.082	116.056	0.0003	0.0001	1.290	0.567	1.291	0.567
16	63	0.739	-9.895	0.470	SAO	0.9850	0.0127	-0.1718	-69.406	83.263	0.0025	-0.0016	1.279	0.567	1.282	0.565
17	68	0.733	-68.238	0.620	SAO	0.3707	0.0047	-0.9287	-48.584	309.404	0.0011	-0.0002	1.263	0.567	1.264	0.567
18	71	0.767	55.432	0.490	SAO	0.5673	0.0076	0.8235	-6.586	116.522	-0.0003	0.0004	1.292	0.567	1.291	0.567
19	72	0.774	44.190	0.330	SAO	0.7170	0.0097	0.6970	-17.643	114.456	0.0000	-0.0003	1.288	0.567	1.288	0.567
20	73	0.758	43.123	0.420	SAO	0.7298	0.0097	0.6836	-18.689	114.236	0.0007	-0.0003	1.288	0.567	1.288	0.567
21	79	0.765	-51.533	120.000	HD	0.6220	0.0083	-0.7830	-64.361	319.579	0.0	0.0	1.279	0.567	1.279	0.567
22	80	0.768	-61.589	0.340	SAO	0.4753	0.0064	-0.8796	-54.959	312.461	0.0009	0.0001	1.267	0.567	1.268	0.567
23	83	0.801	46.809	0.460	SAO	0.6844	0.0096	0.7291	-15.072	114.974	-0.0001	0.0005	1.289	0.567	1.289	0.567
24	85	0.792	17.562	0.370	SAO	0.9533	0.0132	0.3017	-43.686	107.928	0.0016	-0.0006	1.283	0.567	1.285	0.566
25	87	0.782	13.118	0.200	SAO	0.9738	0.0133	0.2270	-47.982	106.309	0.0013	0.0001	1.283	0.567	1.284	0.567
26	98	0.841	49.344	0.470	SAO	0.6514	0.0096	0.7586	-12.564	115.470	-0.0000	0.0003	1.290	0.567	1.290	0.567
27	99	0.846	44.461	0.460	SAO	0.7137	0.0105	0.7004	-17.396	114.561	-0.0011	-0.0008	1.289	0.567	1.288	0.566
28	100	0.842	24.291	0.610	SAO	0.9114	0.0134	0.4114	-37.151	110.024	0.0007	-0.0004	1.284	0.567	1.285	0.567
29	101	0.838	17.959	0.350	SAO	0.9512	0.0139	0.3083	-43.312	108.119	-0.0040	-0.0041	1.283	0.567	1.279	0.563
30	105	0.832	-42.031	0.380	SAO	0.7427	0.0108	-0.6695	-72.654	332.490	0.0040	-0.0024	1.273	0.567	1.277	0.565
31	106	0.862	63.402	0.380	SAO	0.4477	0.0067	0.8942	1.250	117.969	-0.0009	0.0005	1.298	0.567	1.297	0.567
32	110	0.872	40.140	0.360	SAO	0.7644	0.0116	0.6447	-21.635	113.734	0.0005	-0.0000	1.288	0.567	1.289	0.567
33	111	0.859	27.999	0.600	SAO	0.8829	0.0132	0.4695	-33.533	111.013	0.0004	0.0003	1.285	0.567	1.286	0.567
34	112	0.869	24.638	0.480	SAO	0.9099	0.0138	0.4169	-36.817	110.149	0.0028	-0.0005	1.285	0.567	1.287	0.566
35	123	0.909	58.159	0.200	SAO	0.5275	0.0084	0.8495	-3.917	117.079	0.0138	0.0010	1.295	0.567	1.309	0.568
36	126	0.951	9.437	0.220	SAO	0.9863	0.0153	0.1640	-51.554	104.927	0.0002	-0.0005	1.282	0.567	1.282	0.566
37	135	0.931	60.179	0.140	SAO	0.4972	0.0081	0.8676	-1.929	117.441	0.0011	-0.0004	1.297	0.567	1.298	0.566
38	141	0.900	-29.430	0.250	SAO	0.8708	0.0137	-0.4914	-79.818	13.023	0.0011	-0.0002	1.276	0.567	1.277	0.567
39	142	0.934	-49.353	0.380	SAO	0.6513	0.0106	-0.7587	-66.383	321.546	0.0241	-0.0009	1.270	0.567	1.294	0.566
40	144	0.957	63.918	0.230	SAO	0.4396	0.0073	0.8982	1.751	118.100	0.0006	0.0001	1.300	0.567	1.301	0.567
41	145	0.937	40.620	0.510	SAO	0.7589	0.0124	0.6510	-21.173	113.881	0.0029	0.0003	1.289	0.567	1.292	0.567
42	150	0.965	-18.317	0.330	SAO	0.9492	0.0160	-0.3143	-76.207	72.148	0.0006	0.0003	1.278	0.567	1.278	0.567
43	164	0.999	56.216	0.140	SAO	0.5557	0.0097	0.8313	-5.817	116.793	-0.0000	0.0002	1.295	0.567	1.295	0.567
44	166	1.003	28.746	0.150	SAO	0.8766	0.0153	0.4809	-32.829	111.346	0.0120	-0.0049	1.286	0.567	1.298	0.562
45	167	1.004	28.275	0.630	SAO	0.8805	0.0154	0.4737	-33.289	111.232	-0.0011	-0.0004	1.286	0.567	1.285	0.567
46	174	1.047	85.127	0.130	SAO	0.0849	0.0016	0.9964	22.616	121.993	0.0094	0.0005	1.402	0.567	1.412	0.567
47	175	1.024	56.046	0.140	SAO	0.5584	0.0100	0.8295	-6.007	116.774	-0.0012	-0.0001	1.296	0.567	1.295	0.567
48	192	1.074	66.150	0.300	SAO	0.4043	0.0076	0.9146	3.941	118.534	-0.0006	0.0003	1.305	0.567	1.304	0.567
49	193	1.076	65.051	0.410	SAO	0.4217	0.0079	0.9067	2.858	118.346	-0.0009	0.0005	1.304	0.567	1.303	0.567
50	194	1.057	38.347	0.240	SAO	0.7841	0.0145	0.6204	-23.423	113.523	-0.0001	-0.0006	1.289	0.567	1.289	0.566
51	203	1.069	-23.385	0.390	SAO	0.9177	0.0171	-0.3969	-79.137	52.565	0.0030	-0.0011	1.276	0.567	1.279	0.566
52	204	1.123	72.457	0.350	SAO	0.3007	0.0059	0.9537	10.189	119.651	-0.0000	-0.0013	1.316	0.567	1.316	0.566
53	213	1.087	-39.156	0.540	SAO	0.7753	0.0147	-0.6314	-75.016	338.441	-0.0001	0.0000	1.272	0.567	1.272	0.567
54	219	1.141	72.932	0.320	SAO	0.2934	0.0058	0.9560	10.617	119.733	0.0035	-0.0002	1.317	0.567	1.321	0.567
55	222	1.115	22.566	0.230	SAO	0.9233	0.0180	0.3838	-38.888	109.855	0.0002	-0.0001	1.285	0.567	1.286	0.567
56	228	1.163	-43.734	0.710	SAO	0.7224	0.0172	-0.6913	-71.459	328.345	-0.0013	-0.0004	1.268	0.567	1.266	0.566
57	231	1.126	6.597	0.220	SAO	0.9932	0.0195	0.1149	-54.340	103.952	-0.0014	-0.0008	1.282	0.567	1.281	0.566
58	249	1.198	26.174	0.260	SAO	0.8973	0.0188	0.4411	-35.381	110.911	0.0038	-0.0029	1.287	0.567	1.290	0.564
59	251	1.185	7.425	0.220	SAO	0.9914	0.0205	0.1292	-53.565	104.452	-0.0002	-0.0004	1.282	0.567	1.282	0.567
60	256	1.188	-17.665	0.650	SAO	0.9526	0.0198	-0.3035	-75.902	74.690	-0.0006	0.0011	1.277	0.567	1.276	0.568
61	267	1.208	-11.891	0.310	SAO	0.9783	0.0206	-0.2060	-71.352	87.380	-0.0005	0.0008	1.278	0.567	1.278	0.568
62	268	1.204	-25.633	0.610	SAO	0.9014	0.0189	-0.4326	-79.963	40.961	0.0070	-0.0032	1.275	0.567	1.282	0.564
63	273	1.212	-57.115	0.440	SAO	0.5428	0.0115	-0.8398	-59.270	314.693	0.0010	-0.0004	1.262	0.567	1.263	0.566
64	276	1.193	-77.009	0.630	SAO	0.2247	0.0047	-0.9744	-40.113	306.225	0.0110	0.0004	1.230	0.567	1.241	0.567
65	278	1.255	52.495	0.140	SAO	0.6087	0.0133	0.7933	-9.528	116.293	-0.0002	-0.0001	1.297	0.567	1.297	0.567
66	281	1.251	31.391	0.670	SAO	0.8534	0.0186	0.5209	-30.281	112.213	0.0002	-0.0008	1.288	0.567	1.288	0.566
67	285	1.236	-56.290	0.610	SAO	0.5549	0.0120	-0.8319	-60.051	315.217	0.0034	0.0011	1.262	0.567	1.266	0.568
68	290	1.262	39.870	0.360	SAO	0.7673	0.0169	0.6411	-21.956	113.996	-0.0008	-0.0002	1.291	0.567	1.290	0.567
69	292	1.283	36.908	0.270	SAO	0.7994	0.0179	0.6005	-24.871	113.423	-0.0000	0.0000	1.290	0.567	1.290	0.567
70	294	1.276	0.816	0.220	SAO	0.9997	0.0223	0.0142	-59.875	100.882	-0.0003	-0.0005	1.281	0.567	1.281	0.566
71	299	1.310	55.299	0.140	SAO	0.5691	0.0130	0.8221	-6.771	116.805	0.0098	0.0004	1.299	0.567	1.309	0.567
72	309	1.267	-60.920	0.140	SAO	0.4859	0.0107	-0.8739	-55.669	312.414	0.0033	-0.0013	1.258	0.567	1.261	0.566
73	313	1.315	38.444	0.310	SAO	0.7830	0.0180	0.6217	-23.366	113.759	-0.0009	-0.0011	1.291	0.567	1.290	0.566

Figure 5-4. Printed Full Scientific Output From Program UPDATE (2 of 6)

SKYMAP	HD	V	B-V		U-B	B	U	PTV	PTG		SPECTRAL CLASSIFIC S.T.	L.C.	PEC.		SP. CL. CODE S.T.	L.C.	PEC	HD S.T.
1	3	6.35	.07	C	.01	6.46	6.47	6.51	6.51	2	A0	V		H	200	50	0	200
2	6	6.29	1.10		1.02	7.39	8.41	6.28	7.28	2	G9	G			490	-30	0	500
3	14	6.85	.03	C		6.88	****	6.98	6.98	2	B9	V		H	190	50	0	190
4	17	6.87	.16		.04	7.03	7.07	6.80	6.86	2	A3	III			230	30	0	220
5	21	7.12	1.05	C	1.09	8.17	9.25	7.18	8.30	1	K0	V		H	500	50	0	500
6	23	7.02	.58	C	.28	7.60	7.88	7.10	7.60	1	G1	V		H	410	50	0	400
7	24	7.96	.64	C	.38	8.60	8.98	8.00	8.60	3	G1	V		H	410	50	0	400
8	25	7.49	.38	C	.02	7.87	7.89	7.54	7.82	2	F1	V		H	310	50	0	300
9	28	4.61	1.04		.87	5.65	6.53	4.68	5.68	2	K1	III			510	30	0	500
10	31	8.38	-.06			8.32	****	8.04	8.20	1	B9	V	N		190	50	2	200
11	32	6.95	.51	C	.18	7.45	7.64	7.00	7.60	1	G7	IV		H	470	40	0	450
12	37	7.76	.53	C	.02	8.29	8.31	7.80	8.30	2	F8	V		H	380	50	0	380
13	43	6.84	.90	C	.61	7.74	8.35	6.89	7.67	2	G7	IV		H	470	40	0	450
14	53	7.26	.03	C	.02	7.30	7.32	7.38	7.40	1	A0	V		H	200	50	0	200
15	58	7.24	1.07	C	1.14	8.31	9.45	7.30	8.30	2	K0	V		H	500	50	0	500
16	63	7.03	.47	C	.02	7.50	7.52	7.11	7.53	2	F5	V		H	350	50	0	350
17	68	6.65	1.02	C	1.06	7.67	8.92	6.91	8.30	1	K0	V		H	500	50	0	500
18	71	7.05	1.07	C	1.14	8.12	9.26	7.11	8.11	2	K0	V		H	500	50	0	500
19	72	7.68	.07	C	-.01	7.55	7.95	8.00	8.00	2	A0	V		H	200	50	0	200
20	73	8.44	.10	C	.04	8.54	8.58	8.60	8.40	2	B1.5	IV			115	40	0	120
21	77	7.33	.63	C	.24	7.96	8.21	7.40	8.10	1	K3	III		H	530	30	0	520
22	80	7.35	.90	C	.61	8.25	8.87	7.60	8.40	3	G7	IV		H	470	40	0	450
23	83	8.38	.07	C	.03	8.45	8.48	8.50	8.50	2	A0	V		H	200	50	0	200
24	85	7.84	.40	C	.01	8.24	8.26	7.90	8.20	2	F2	V		H	320	50	0	320
25	87	5.51	.90		.84	6.41	7.25	5.66	6.66	2	K0	V		H	500	50	0	500
26	98	7.41	.26	C	.02	7.67	7.69	7.46	7.54	2	A5	V		H	250	50	0	230
27	99	7.81	.26	C	.01	8.07	8.08	7.86	7.94	2	A5	V		H	250	50	0	230
28	100	7.06	1.40	C	1.59	8.46	****	7.12	9.30	2	K5	III		H	550	30	0	550
29	101	7.66	.53	C	.02	8.19	8.21	7.70	9.20	2	F8	V		H	380	50	0	380
30	105	7.52	.60		.31	8.12	8.43	7.80	8.10	1	G0	V			400	50	0	400
31	108	7.38	.16			7.53	****	7.36	7.12	2	O8.3		P		88	0	1	177
32	110	6.66	.90	C	.61	7.56	8.17	6.71	7.49	2	G7	IV		H	470	40	0	450
33	111	6.87	1.40	C	1.59	8.27	9.86	6.93	8.00	2	K5	III			550	30	0	520
34	112	7.40	1.07	C	1.14	8.47	9.61	7.46	8.46	2	K0	V		H	500	50	0	500
35	123	5.98	.67		.36	6.65	7.01	6.10	6.88	2	G7	IV		H	470	40	0	450
36	126	7.66	.47	C	.02	8.13	8.15	7.74	8.16	2	F5	V		H	350	50	0	350
37	135	7.95	.24		.02	8.19	8.21	9.50	8.80	2	F1	V		H	310	50	0	300
38	141	7.89	-.03			7.87	****	7.82	8.00	1	A0	V	N		200	50	2	200
39	142	5.70	.52		.03	6.22	6.25	5.77	6.30	1	G1	IV			410	40	0	400
40	144	5.56	-.02		-.48	5.54	5.06	5.49	5.44	2	B8	III			180	30	0	180
41	145	6.96	1.07	C	1.14	8.03	9.17	7.02	8.02	2	K0	V		H	500	50	0	500
42	156	7.43	.38	C	.01	7.81	7.82	7.48	7.76	2	F1	V		H	310	50	0	300
43	164	7.88	.07	C	.02	7.95	7.97	8.00	8.00	2	A0	V		H	200	50	0	200
44	166	6.14	.75		.33	6.89	7.22	6.20	7.20	2	K0	V			500	50	0	500
45	167	6.73	1.00	C	.89	7.73	8.62	6.79	7.79	2	G9	III			490	30	0	500
46	174	8.15	.26	C		8.41	****	8.20	8.30	2	A5	V		H	250	50	0	230
47	175	8.27	.03	C	-.21	8.30	8.09	8.40	8.40	2	B9	V		H	190	50	0	190
48	192	7.95	.38	C	.03	8.33	8.36	8.00	8.30	2	F1	V		H	310	50	0	300
49	193	7.68	.07	C	.05	7.55	8.00	8.00	8.00	2	A0	V		H	200	50	0	200
50	194	8.12	.18	C	.00	8.31	8.31	8.20	8.30	2	A3	V		H	230	50	0	220
51	203	6.18	.38		.02	6.56	6.58	6.06	6.40	1	A7	V			270	50	0	300
52	204	7.75	.26	C	.03	8.01	8.04	7.80	7.90	2	A5	V		H	250	50	0	230
53	213	6.88	1.19	C	1.22	8.07	9.28	6.94	8.20	1	K0	V		H	500	50	0	500
54	219	7.94	.40	C	.03	8.34	8.38	8.00	8.30	2	F2	V		H	320	50	0	320
55	222	7.85	.38	C	.01	8.23	8.24	7.90	8.20	2	F1	V		H	310	50	0	300
56	228	7.51	.85	C	.55	8.35	8.91	7.56	8.50	1	G7	IV		H	470	40	0	450
57	231	7.77	.28	C	.01	8.05	8.06	7.80	7.90	2	A7	V		H	270	50	0	250
58	243	7.23	1.14	C		8.37	****	7.30	8.30	2	K1	IV			510	40	0	500
59	251	7.92	.47	C	.02	8.39	8.41	8.00	8.40	2	F5	V		H	350	50	0	350
60	256	6.19	.13		.09	6.32	6.41	6.18	6.26	2	A3	V			230	50	0	230
61	267	7.62	.18	C	.00	7.81	7.81	7.70	7.80	2	A3	V		H	230	50	0	220
62	268	7.05	.45		-.01	7.50	7.49	6.89	7.60	1	F5	V		H	350	50	0	350
63	273	7.30	1.27	C	1.36	8.56	9.93	7.60	8.70	3	K3	III		H	530	30	0	520
64	276	7.54	.41		.08	7.95	8.03	7.90	8.20	3	F5	IV-V			350	45	0	300
65	278	7.55	.90	C	.61	8.45	9.06	7.60	8.40	2	G7	IV		H	470	40	0	450
66	281	6.96	.90	C	.61	7.86	8.47	7.01	7.79	2	G7	IV		H	470	40	0	450
67	285	7.32	.19	C	.00	7.51	7.51	7.40	7.60	1	F5	V		H	350	50	0	350
68	290	6.82	.90	C	.61	7.72	8.33	6.87	7.65	2	G7	IV		H	470	40	0	450
69	292	7.47	.47	C	.02	7.94	7.96	7.55	7.97	2	F5	V		H	350	50	0	360
70	294	7.98	.07	C	-.01	8.05	8.05	8.10	8.10	2	A0	V		H	200	50	0	200
71	299	7.75	.64	C	.38	8.39	8.77	7.83	8.39	2	G1	V		H	410	50	0	400
72	309	8.25	.11	C	-.25	8.35	8.10	8.30	8.50	1	G7	IV		H	470	40	0	450
73	313	7.66	.16		-.00	7.82	7.82	7.90	8.30	2	A5	V			250	50	0	230

Figure 5-4. Printed Full Scientific Output From Program UPDATE (3 of 6)

SKYMAP	HD	VSC	VAR NAME	VARIABLE	TYPE CODE	BRIGHT MAG	DIFF MAG	EPOCH DAYS	PERIOD DAYS	ADS	SEPAR. ARCSEC	DIFF MAG	YEAR	NEAREST NEIGH IN MC DEG	NEAREST NEIGH 2 MAG DEG
1	3	0			0	6.39 V	0.0	0.0	0.0	46	12.900	7.00	1925	-0.004	0.450
2	6	C			0	6.29 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
3	14	0			0	6.85 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
4	17	0			0	6.87 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
5	21	C			0	7.12 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
6	23	C			0	7.02 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
7	24	C			0	7.96 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
8	25	C			0	7.49 V	0.0	0.0	0.0	0	0.0	0.0	0	0.176	0.176
9	28	C			0	4.61 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
10	31	C			0	8.38 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
11	32	C			0	6.95 V	0.0	0.0	0.0	0	0.0	0.0	0	0.305	0.305
12	39	0			0	7.76 V	0.0	0.0	0.0	51	0.200	1.40	1960	-0.000	-0.000
13	43	0			0	6.84 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
14	53	C			0	7.26 V	0.0	0.0	0.0	0	0.0	0.0	0	0.301	0.301
15	58	0			0	7.24 V	0.0	0.0	0.0	0	0.0	0.0	0	0.348	0.348
16	63	C			0	7.33 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
17	68	C			0	6.35 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
18	71	0			0	7.05 V	0.0	0.0	0.0	0	0.0	0.0	0	0.339	0.339
19	72	0			0	7.88 V	0.0	0.0	0.0	0	0.0	0.0	0	0.276	0.276
20	73	C			0	8.44 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
21	79	0			0	7.33 V	0.0	0.0	0.0	0	0.0	0.0	0	0.362	0.362
22	80	C			0	7.35 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
23	83	C			0	8.38 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
24	85	0			0	7.84 V	0.0	0.0	0.0	56	7.700	0.0	1956	-0.002	-0.002
25	87	0			0	5.51 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
26	98	0			0	7.41 V	0.0	0.0	0.0	59	2.400	3.30	1935	-0.001	0.176
27	99	0			0	7.81 V	0.0	0.0	0.0	0	0.0	0.0	0	0.276	0.276
28	100	C			0	7.06 V	0.0	0.0	0.0	0	0.0	0.0	0	0.349	0.349
29	101	0			0	7.66 V	0.0	0.0	0.0	0	0.0	0.0	0	0.399	0.399
30	105	0			0	7.52 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
31	108	0			0	7.38 V	0.0	0.0	0.0	0	0.0	0.0	0	0.295	0.295
32	110	C			0	6.66 V	0.0	0.0	0.0	0	0.0	0.0	0	0.403	0.403
33	111	0			0	6.87 V	0.0	0.0	0.0	0	0.0	0.0	0	0.306	0.306
34	112	C			0	7.40 V	0.0	0.0	0.0	0	0.0	0.0	0	0.349	0.349
35	123	C			0	5.38 V	0.0	0.0	0.0	61	0.0	1.10	1960	0.201	0.201
36	126	0			0	7.66 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
37	135	C			0	7.95 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
38	141	C			0	7.89 V	0.0	0.0	0.0	0	34.000	12.10	1954	-0.009	0.414
39	142	C			0	5.70 V	0.0	0.0	0.0	0	5.400	5.70	1928	-0.001	-0.500
40	144	C			0	5.56 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
41	145	C			0	6.96 V	0.0	0.0	0.0	0	0.0	0.0	0	0.483	0.493
42	156	C			0	7.43 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
43	164	C			0	7.88 V	0.0	0.0	0.0	0	0.0	0.0	0	0.194	0.194
44	166	C			0	6.14 V	0.0	0.0	0.0	65	53.200	3.60	1909	-0.015	0.397
45	167	C			0	6.73 V	0.0	0.0	0.0	0	0.0	0.0	0	0.306	0.306
46	174	C			0	8.15 V	0.0	0.0	0.0	0	0.0	0.0	0	0.496	0.496
47	175	C			0	8.27 V	0.0	0.0	0.0	0	0.0	0.0	0	0.194	0.194
48	192	C			0	7.95 V	0.0	0.0	0.0	0	0.200	0.0	1970	-0.000	-0.000
49	193	C			0	7.88 V	0.0	0.0	0.0	0	0.0	0.0	0	0.360	0.360
50	194	C			0	8.12 V	0.0	0.0	0.0	0	0.0	0.0	0	0.226	0.226
51	203	C			0	6.18 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
52	204	C			0	7.75 V	0.0	0.0	0.0	0	0.0	0.0	0	0.436	0.436
53	213	C			0	6.88 V	0.0	0.0	0.0	0	0.0	0.0	0	0.305	0.305
54	219	C			0	7.94 V	0.0	0.0	0.0	0	0.0	0.0	0	0.279	0.279
55	222	C			0	7.95 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
56	228	C			0	7.51 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
57	231	C			0	7.77 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
58	249	C			0	7.23 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
59	251	0			0	7.92 V	0.0	0.0	0.0	0	0.0	0.0	0	0.490	0.490
60	256	0			0	6.19 V	0.0	0.0	0.0	0	0.0	0.0	0	0.354	0.354
61	267	C			0	7.62 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
62	268	0			0	7.05 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
63	273	C			0	7.30 V	0.0	0.0	0.0	0	0.0	0.0	0	0.301	0.301
64	276	0			0	7.54 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
65	278	C			0	7.55 V	0.0	0.0	0.0	81	3.000	5.10	1943	-0.001	0.458
66	281	C			0	6.96 V	0.0	0.0	0.0	83	1.500	5.50	1955	-0.000	0.295
67	285	C			0	7.32 V	0.0	0.0	0.0	0	0.0	0.0	0	-0.500	-0.500
68	290	C			0	6.82 V	0.0	0.0	0.0	82	24.800	3.00	1955	-0.007	0.403
69	292	0			0	7.47 V	0.0	0.0	0.0	86	1.100	5.00	1959	-0.000	0.500
70	294	C			0	7.98 V	0.0	0.0	0.0	0	0.0	0.0	0	0.474	0.474
71	299	0			0	7.75 V	0.0	0.0	0.0	0	0.0	0.0	0	0.339	0.339
72	309	C			0	8.25 V	0.0	0.0	0.0	0	5.400	2.70	1926	-0.001	-0.500
73	313	C			0	7.66 V	0.0	0.0	0.0	0	0.0	0.0	0	0.226	0.226

Figure 5-4. Printed Full Scientific Output From Program UPDATE (4 of 6)

SKYMAP	HD	TRIGONOMETRIC PARALLAX PARALLAX ARC SEC	+/- ARC SEC	DIST. PC	+/- PC	MIN DST PC	SPECTROSCOPIC PARALLAX ABS V	DIST. PC	+/- PC	DYNAMIC PARALLAX R.V. K/S	THET K/S	PI K/S	Z K/S	MAX DST PC	BEST DISTANCE DIST. PC	+/- PC	
1	3	********	********	0.0	0.0	0.0	0.60	144.1	77.7	-4.	-8.	10.	-1.	0.0	144.1	77.7	S
2	6	********	********	0.0	0.0	0.0	0.20	165.2	77.5	1.	-26.	-38.	-7.	0.0	165.2	77.5	S
3	14	********	********	0.0	0.0	0.0	0.20	213.5	108.1	-6.	*****	*****	*****	118.2	118.2	118.2	MAX
4	17	********	********	0.0	0.0	0.0	0.0	236.6	92.3	-3.	-7.	-0.	-3.	0.0	236.6	92.3	S
5	21	********	********	0.0	0.0	0.0	5.90	17.5	9.9	4.	-16.	13.	1.	430.3	17.5	9.9	S
6	23	********	********	0.0	0.0	0.0	4.50	31.9	12.3	6.	-35.	17.	6.	197.1	31.9	12.3	S
7	24	********	********	0.0	0.0	0.0	4.50	49.2	23.5	6.	0.	-5.	2.	664.8	49.2	23.5	S
8	25	********	********	0.0	0.0	0.0	2.80	86.7	31.5	-5.	-21.	12.	-21.	209.8	86.7	31.5	S
9	28	0.0060	0.0100	0.0	0.0	18.9	0.0	83.5	13.8	1.	19.	33.	18.	190.2	83.5	13.8	S
10	31	********	********	0.0	0.0	0.0	0.20	432.5	102.4	3.	-8.	11.	3.	0.0	432.5	102.4	S
11	32	********	********	0.0	0.0	0.0	3.20	56.1	36.4	5.	8.	6.	2.	0.0	56.1	36.4	S
12	39	********	********	0.0	0.0	0.0	4.00	56.5	23.1	-3.	-11.	20.	14.	0.0	56.5	23.1	S
13	43	********	********	0.0	0.0	0.0	3.20	53.4	35.6	0.	-8.	16.	7.	0.0	53.4	35.6	S
14	53	********	********	0.0	0.0	0.0	0.60	215.1	111.4	6.	-8.	-38.	12.	0.0	215.1	111.4	S
15	58	********	********	0.0	0.0	0.0	5.90	18.5	10.8	-5.	-14.	8.	9.	0.0	18.5	10.8	S
16	63	********	********	0.0	0.0	0.0	3.40	53.2	21.0	2.	-10.	-16.	4.	101.1	53.2	21.0	S
17	68	********	********	0.0	0.0	0.0	5.90	15.5	8.7	6.	-10.	6.	-1.	0.0	15.5	8.7	S
18	71	********	********	0.0	0.0	0.0	5.90	17.0	9.9	-5.	-15.	10.	10.	0.0	17.0	9.9	S
19	72	********	********	0.0	0.0	0.0	0.60	286.2	154.3	-4.	-19.	1.	-9.	0.0	286.2	154.3	S
20	73	********	********	0.0	0.0	0.0	-3.45	2385.1	1105.7	-4.	54.	-249.	-80.	0.0	2385.1	1105.7	S
21	79	********	********	0.0	0.0	0.0	-0.20	321.4	107.6	6.	-10.	9.	-1.	0.0	321.4	107.6	S
22	80	********	********	0.0	0.0	0.0	3.20	67.6	48.3	6.	-4.	1.	-0.	0.0	67.6	48.3	S
23	83	********	********	0.0	0.0	0.0	0.60	360.3	194.3	-4.	-6.	27.	37.	0.0	360.3	194.3	S
24	85	********	********	0.0	0.0	0.0	3.00	93.0	34.5	-1.	-4.	-14.	6.	236.9	93.0	34.5	S
25	87	********	********	0.0	0.0	0.0	5.90	8.4	4.4	-1.	-9.	9.	7.	0.0	8.4	4.4	S
26	98	********	********	0.0	0.0	0.0	2.10	115.3	46.0	-5.	-12.	12.	15.	0.0	115.3	46.0	S
27	99	********	********	0.0	0.0	0.0	2.10	138.7	55.3	-4.	-31.	23.	-17.	0.0	138.7	55.3	S
28	100	********	********	0.0	0.0	0.0	-0.30	296.5	130.7	-2.	-5.	-29.	-2.	0.0	296.5	130.7	S
29	101	********	********	0.0	0.0	0.0	4.00	54.0	22.0	-1.	-47.	25.	-27.	102.2	54.0	22.0	S
30	105	********	********	0.0	0.0	0.0	4.40	42.1	7.1	5.	-15.	-16.	10.	75.3	42.1	7.1	S
31	108	********	********	0.0	0.0	0.0	*******	0.0	0.0	-6.	*****	*****	*****	0.0	0.0	0.0	
32	110	********	********	0.0	0.0	0.0	3.20	49.1	32.8	-4.	-11.	7.	8.	0.0	49.1	32.8	S
33	111	********	********	0.0	0.0	0.0	-0.30	271.6	82.5	-3.	-0.	4.	21.	0.0	271.6	82.5	S
34	112	********	********	0.0	0.0	0.0	5.90	19.9	11.7	-2.	-8.	2.	8.	225.0	19.9	11.7	S
35	123	0.0430	0.0040	24.3	3.9	0.0	3.20	36.0	22.2	-5.	-0.	-17.	17.	62.3	24.7	3.8	S.T
36	126	********	********	0.0	0.0	0.0	3.40	71.1	28.1	-0.	-10.	8.	4.	0.0	71.1	28.1	S
37	135	********	********	0.0	0.0	0.0	2.80	107.2	29.8	-5.	-9.	-2.	0.	0.0	107.2	29.8	S
38	141	********	********	0.0	0.0	0.0	0.60	287.7	90.7	4.	-2.	-17.	11.	0.0	287.7	90.7	S
39	142	0.0430	0.0070	25.6	5.9	0.0	2.90	36.3	9.0	5.	20.	-60.	18.	30.2	28.8	4.9	S.T
40	144	********	********	0.0	0.0	0.0	-1.20	225.4	58.0	-6.	-8.	-3.	16.	0.0	225.4	58.0	S
41	145	********	********	0.0	0.0	0.0	5.90	16.3	9.5	-4.	-9.	4.	9.	333.0	16.3	9.5	S
42	156	********	********	0.0	0.0	0.0	2.80	84.3	30.6	3.	-3.	7.	6.	0.0	84.3	30.6	S
43	164	********	********	0.0	0.0	0.0	0.60	286.2	154.3	-5.	-13.	12.	15.	0.0	286.2	154.3	S
44	166	0.0650	0.0050	14.5	1.6	0.0	5.90	11.2	2.7	-3.	-5.	-16.	3.	46.6	13.6	1.3	S.T
45	167	********	********	0.0	0.0	0.0	0.20	202.6	67.7	-3.	-28.	38.	-3.	0.0	202.6	67.7	S
46	174	********	********	0.0	0.0	0.0	2.10	162.2	64.6	-7.	*****	*****	*****	135.4	135.4	135.4	MAX
47	175	********	********	0.0	0.0	0.0	0.20	410.5	207.8	-5.	-14.	15.	-1.	0.0	410.5	207.8	S
48	192	********	********	0.0	0.0	0.0	2.80	107.2	38.9	-6.	-16.	9.	8.	0.0	107.2	38.9	S
49	193	********	********	0.0	0.0	0.0	0.60	286.2	154.3	-6.	-24.	11.	23.	0.0	286.2	154.3	S
50	194	********	********	0.0	0.0	0.0	1.70	192.8	77.4	-4.	-6.	10.	-7.	0.0	192.8	77.4	S
51	203	********	********	0.0	0.0	0.0	2.40	57.0	8.8	3.	*****	*****	*****	49.0	49.0	49.0	MAX
52	204	********	********	0.0	0.0	0.0	2.10	134.9	53.8	-6.	-23.	-3.	-30.	0.0	134.9	53.8	S
53	213	********	********	0.0	0.0	0.0	5.90	15.7	8.9	5.	-9.	10.	1.	0.0	15.7	8.9	S
54	219	********	********	0.0	0.0	0.0	3.00	97.4	36.1	-6.	-6.	-7.	5.	483.9	97.4	36.1	S
55	222	********	********	0.0	0.0	0.0	2.80	102.3	37.1	-2.	-9.	9.	5.	0.0	102.3	37.1	S
56	228	********	********	0.0	0.0	0.0	3.20	72.7	47.1	5.	-15.	13.	4.	0.0	72.7	47.1	S
57	231	********	********	0.0	0.0	0.0	2.40	118.6	46.8	-0.	-15.	16.	0.	0.0	118.6	46.8	S
58	249	********	********	0.0	0.0	0.0	*******	0.0	0.0	-2.	*****	*****	*****	105.9	105.9	105.9	MAX
59	251	********	********	0.0	0.0	0.0	3.40	80.2	31.6	-0.	-13.	11.	3.	0.0	80.2	31.6	S
60	256	********	********	0.0	0.0	0.0	1.70	79.0	25.7	3.	0.	24.	4.	0.0	79.0	25.7	S
61	267	********	********	0.0	0.0	0.0	1.70	153.1	61.5	2.	3.	30.	7.	0.0	153.1	61.5	S
62	268	********	********	0.0	0.0	0.0	3.40	53.7	17.0	3.	*****	*****	*****	43.6	43.6	43.6	MAX
63	273	********	********	0.0	0.0	0.0	-0.20	315.5	137.2	6.	-12.	-44.	16.	0.0	315.5	137.2	S
64	276	********	********	0.0	0.0	0.0	2.75	90.8	13.6	7.	8.	-24.	4.	198.9	90.8	13.6	S
65	278	********	********	0.0	0.0	0.0	3.20	74.0	49.3	-5.	-12.	10.	4.	0.0	74.0	49.3	S
66	281	********	********	0.0	0.0	0.0	3.20	56.4	37.6	-3.	-10.	9.	2.	0.0	56.4	37.6	S
67	285	********	********	0.0	0.0	0.0	3.40	60.8	22.3	6.	7.	-4.	-0.	209.6	60.8	22.3	S
68	290	********	********	0.0	0.0	0.0	3.20	52.9	35.3	-4.	-14.	13.	5.	0.0	52.9	35.3	S
69	292	********	********	0.0	0.0	0.0	3.40	65.2	25.7	-3.	-11.	10.	7.	0.0	65.2	25.7	S
70	294	********	********	0.0	0.0	0.0	0.60	299.7	161.6	1.	-23.	10.	-3.	0.0	299.7	161.6	S
71	299	********	********	0.0	0.0	0.0	4.50	44.7	18.4	-5.	5.	-28.	19.	120.5	44.7	18.4	S
72	309	********	********	0.0	0.0	0.0	3.20	102.2	66.2	6.	-17.	-23.	19.	141.3	102.2	66.2	S
73	313	********	********	0.0	0.0	0.0	2.10	129.4	41.7	-4.	-17.	14.	-13.	0.0	129.4	41.7	S

Figure 5-4. Printed Full Scientific Output From Program UPDATE (5 of 6)

SKYMAP	HD	BEST DISTANCE DIST. PC	+/- PC		INTERSTELLAR ABS. V MAG	E(B-V) MAG	
1	3	144.1	77.7	S	0.07	0.02	*
2	6	165.2	77.5	S	0.53	0.18	UBV
3	14	116.2	118.2	MAX	****	****	
4	17	236.6	92.3	S	0.0	0.0	*
5	21	17.5	9.9	S	0.06	0.02	UBV
6	23	31.9	12.3	S	0.0	0.0	UBV
7	24	45.2	23.5	S	0.0	0.0	*
8	25	86.7	31.5	S	0.04	0.01	*
9	28	63.6	13.8	S	0.0	0.0	UBV
10	31	432.5	102.4	S	0.0	0.0	*
11	32	56.1	36.4	S	0.0	0.0	UBV
12	39	56.5	23.1	S	0.0	0.0	*
13	43	53.4	35.6	S	0.0	0.0	*
14	53	215.1	111.4	S	0.13	0.04	UBV
15	58	16.5	10.8	S	0.01	0.00	*
16	63	53.2	21.0	S	0.0	0.0	*
17	68	15.5	8.7	S	0.0	0.0	UBV
18	71	17.0	9.9	S	0.01	0.00	*
19	72	266.2	154.3	S	0.0	0.0	*
20	73	2385.1	1105.7	S	0.0	0.0	*
21	79	321.4	107.6	S	0.0	0.0	UBV
22	80	67.6	48.3	S	0.0	0.0	*
23	83	360.3	194.3	S	0.17	0.06	*
24	85	93.0	34.5	S	0.0	0.0	*
25	87	6.4	4.4	S	0.0	0.0	UBV
26	98	115.3	46.0	S	0.05	0.02	*
27	99	136.7	55.3	S	0.0	0.0	*
28	100	296.5	130.7	S	0.0	0.0	*
29	101	54.0	22.0	S	0.0	0.0	*
30	105	42.1	7.1	S	0.0	0.0	*
31	108	0.0	0.0		****	****	
32	110	45.1	32.8	S	0.0	0.0	*
33	111	271.6	82.5	S	0.0	0.0	*
34	112	19.9	11.7	S	0.0	0.0	*
35	123	24.7	3.8	S,T	0.02	0.01	*
36	126	71.1	28.1	S	0.0	0.0	*
37	135	107.2	29.8	S	0.09	0.03	*
38	141	287.7	90.7	S	0.0	0.0	*
39	142	28.8	4.9	S,T	0.0	0.0	UBV
40	144	225.4	58.0	S	0.19	0.06	*
41	145	14.3	9.5	S	0.0	0.0	*
42	156	64.3	30.6	S	0.0	0.0	*
43	164	286.2	154.3	S	0.11	0.04	*
44	166	13.6	1.3	S,T	0.0	0.0	UBV
45	167	202.6	67.7	S	0.0	0.0	*
46	174	135.4	135.4	MAX	****	****	
47	175	410.5	207.8	S	0.16	0.05	*
48	192	107.2	38.9	S	0.09	0.03	*
49	193	286.2	154.3	S	0.24	0.08	*
50	194	192.8	77.4	S	0.0	0.0	*
51	203	49.0	49.0	MAX	0.36	0.12	UBV
52	204	134.9	53.8	S	0.11	0.04	*
53	213	15.7	8.9	S	0.39	0.13	UBV
54	219	97.4	36.1	S	0.08	0.03	*
55	222	102.3	37.1	S	0.0	0.0	*
56	228	72.7	47.1	S	0.0	0.0	UBV
57	231	116.6	46.8	S	0.0	0.0	*
58	249	105.9	105.9	MAX	****	****	
59	251	80.2	31.6	S	0.0	0.0	*
60	256	79.0	25.7	S	0.10	0.03	UBV
61	267	153.1	61.5	S	0.0	0.0	*
62	268	43.6	43.6	MAX	0.02	0.01	UBV
63	273	315.5	137.2	S	0.0	0.0	*
64	276	90.8	13.6	S	0.0	0.0	*
65	278	74.0	49.3	S	0.03	0.01	*
66	281	54.4	37.6	S	0.0	0.0	*
67	285	60.8	22.3	S	0.0	0.0	UBV
68	290	52.9	35.3	S	0.0	0.0	*
69	292	65.2	25.7	S	0.0	0.0	*
70	294	259.7	161.6	S	0.0	0.0	*
71	299	44.7	18.4	S	0.02	0.01	*
72	309	102.2	66.2	S	0.0	0.0	UBV
73	313	129.4	41.7	S	0.0	0.0	*

Figure 5-4. Printed Full Scientific Output From Program UPDATE (6 of 6)

```
  // EXEC FORTRANH,REGION=300K
  //SYSIN DD DSN=UPDATE.FORT,DISP=SHR
  // EXEC LOADER,REGION=390K,PARM='SIZE=350000'
  //FT03F001 DD DSN=NAMELIST.PROCS.CNTL,DISP=SHR
                  NAMELIST/PROCS/ DATA CARDS GO HERE
  //FT04F001 DD DSN=NAMELIST.INSTR.CNTL,DISP=SHR
                  NAMELIST/INSTR/ DATA CARDS GO HERE
1 //FT10F001 DD DSN=ADD.DATA,DISP=SHR
2 //FT11F001 DD DSN=DELETE.DATA,DISP=SHR
  //FT35F001 DD DSN=NAMELIST.XPRINT.CNTL,DISP=SHR
                  NAMELIST/XPRINT/ DATA CARDS GO HERE
3 //FT40F001 DD UNIT=2400-9,VOL=SER=XXXXX,DISP=(OLD,KEEP),
  //   LABEL=(1,BLP),DCB=(RECFM=FB,LRECL=540,BLKSIZE=27000)
4 //FT50F001 DD UNIT=2400-9,VOL=SER=YYYYY,DISP=(NEW,KEEP),
  //   LABEL=(1,BLP),DCB=(RECFM=FB,LRECL=540,BLKSIZE=27000)
  //FT60F001 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=1922,BUFNO=1)
5 //FT70F001 DD UNIT=2400-9,VOL=SER=ZZZZZ,DISP=(NEW,KEEP),
6 //   LABEL=(1,BLP),DCB=(RECFM=FB,LRECL=50,BLKSIZE=5000)
  //FT90F001 DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=1922,BUFNO=1)
  //DATA5 DD *

                NAMELIST/FILES/ DATA CARDS GO HERE

  /*
```

NOTES

1 - ADD DATA IS A PREVIOUSLY EXISTING DATA SET OF DCB = (RECFM = FB, LRECL = 88, BLKSIZE = uuuu), WHERE uuuu IS A MULTIPLE OF 88 AND ≤ 7294 ADD DATA CONTAINS DATA FOR AN ADD/DELETE PROCESS
2 DELETE DATA IS A PREVIOUSLY EXISTING DATA SET SIMILAR TO ADD DATA.
3 xxxxx IS THE TAPE NUMBER OF THE INPUT MASTER CATALOG.
4 yyyyy IS THE TAPE NUMBER FOR THE OUTPUT MASTER CATALOG .
5 – zzzzz IS THE TAPE NUMBER FOR THE MISSION CATALOG
6 – THIS DATA MAY BE ALTERED TO SUIT THE USER'S PURPOSE, BUT LRECL MUST AGREE WITH THE MISSION CATALOG WRITE STATEMENT IN THE USER-SUPPLIED SUBROUTINE WRITEM.

Figure 5-5. Sample JCL for Program UPDATE

5.5.6 Execution Time Estimates

Because of the wide variety of functions performed by UPDATE, it is impossible to give accurate execution time estimates. Normally, however, UPDATE is Central Processing Unit (CPU) bound. For example, a job which writes an output Master Catalog and prints Master Catalog data in the full scientific format will require approximately 2 minutes CPU and 0.5 minute I/O on the S/360-95 computer per 10,000 stars processed.

SECTION 6 - THE RUN CATALOG

The Run Catalog is the interface star catalog used by attitude determination programs. It is created by program CAT, usually on tape in sequential format, using the Mission Catalog (or Master Catalog, if necessary) as input. It is transferred to direct-access disk storage for use by attitude determination programs by program SWITCH. The Run Catalog may also be created as a direct-access disk data set by CAT, thereby bypassing SWITCH. This section discusses the generation of the Run Catalog by program CAT.

6.1 RUN CATALOG REQUIREMENTS

This section discusses the requirements placed upon the Run Catalog by the programs that will use it.

The minimum data required for each star are the star number (for identification), and its position as a geocentric inertial unit vector. Although not explicitly required by SKYMAP programs or subroutines, an instrumental magnitude is also normally included.

6.1.1 Data Quality

The position accuracy which is specified for Run Catalog data is dependent on both the required accuracy and the available accuracy of the current data. The available accuracy of 0.5 arc-second for most stars (see Section 3) is also the limiting accuracy of a 4-byte word. Double precision position data would increase disk and core storage requirements by as much as 75 percent without substantially increasing accuracy. Therefore, 0.5 arc-second has been chosen as the goal for the Run Catalog. Approximately 1 percent of the Master Catalog stars have positions with inaccuracies of about 1 arc-minute. These stars are flagged in the Master Catalog so that they can be eliminated from consideration if the user chooses to do so.

Like positional accuracy, the specified accuracy of the instrumental magnitude depends both on what is desirable from the user's point of view and what is attainable. The accuracy of the available data leads to instrumental magnitudes, for BBRC-type star cameras, with mean errors of about ±0.1 for 50 percent of the stars in the Master Catalog, and approximately ±0.3 magnitude for the rest (see Section 3).

The user's accuracy requirements result from the difficulty of identifying observed stars with their catalog counterparts. This problem in pattern matching is made more difficult if the star catalog contains more candidate stars than the camera is capable of detecting. The excess stars increase the number of mismatches while not increasing the number of true matches.

Stars may be eliminated from consideration by pattern matching routines if their instrumental magnitudes are dimmer than the instrument threshold magnitude. The number of excess stars in the catalog is a function of the magnitude tolerance that must be applied to account for errors in catalog magnitudes and the instrumental threshold. Because in-flight calibration may reduce instrumental threshold errors to below 0.1 magnitude (Reference 1), catalog errors of no more than ±0.1 magnitude are desirable. The full attainable accuracy of 0.1 magnitude is therefore the goal for the Run Catalog. Whenever more accurate data are available, the high accuracy is retained. When only lesser quality data exist, it is used but the results are flagged in the Master Catalog.

Incompleteness in the catalog means that some stars observed by the star camera will not be identifiable with catalog stars; this also makes star identification more difficult. Therefore, a further requirement placed on the Run Catalog data is that it be as complete as possible down to a specified instrumental magnitude limit.

6.1.2 Data Organization

The requirements on the Run Catalog discussed so far concern the nature of the data it contains. Since the Run Catalog obtains its data from the Mission or

Master Catalog (or a user-input catalog), these requirements do not affect program CAT, except that CAT must do nothing to degrade the data beyond the specified limits. The following requirements on the Run Catalog deal with the format of the catalog, which does directly affect the design of CAT.

The major requirement of the Run Catalog format is that it allow access by attitude determination programs with minimum use of computer time and core storage. Disk storage requirements should also be minimized.

In addition, to provide the flexibility needed to analyze data across a spacecraft slew, or when the motion of the spin axis is large or unpredictable, the Run Catalog is designed so that programs can function properly even if the attitude of the spacecraft changes substantially during a single computer run.

For a typical BBRC camera, the total Run Catalog will contain approximately 21,000 stars. For most applications, programs will require at least 20 bytes of data per star (star number, the three components of the star unit vector in geocentric inertial coordinates, and a star magnitude). Thus, 420,000 bytes of storage will be needed. Clearly, the entire catalog cannot be stored in core, and some kind of "presorting" is necessary. One solution to this problem is to presort the catalog prior to each program run, retaining only those stars in the region of the sky which will be scanned by a camera during one spacecraft rotation. This procedure assumes that the spacecraft spin axis attitude will change by only a small amount during the period of interest.

For a camera located along the spin axis (or for a pointed satellite), this band degenerates into a circular cap. This technique works well for a cap, since the portion of the sky which must be considered is small. However, for a camera located with its optical axis perpendicular to the spin axis, the presorting technique just described has some disadvantages.

The major difficulty is that even the reduced catalog is large, requires significant core storage, and requires still further sorting inside the user's program.

Presorting the full catalog into a band is very time consuming for a catalog the size of the SAS-C and HEAO-A catalogs (21,000 stars). Furthermore, this method requires that the entire input catalog be "resorted" if the spin axis attitude changes substantially.

Because of this difficulty, the band technique was rejected in favor of the subcatalog technique. A method is desired whereby, given any camera optical axis pointing, presorted subcatalog(s) can be read into core which will contain data for all stars visible to the camera. This goal is achieved by dividing the entire sky into zones. The zones overlap in declination to ease the task of determining which zones are needed to cover the desired region of the sky (see Section 6.3.2.1).

Once the zones are defined, the catalog is sorted into subcatalogs, one for each zone, and stored on disk in a direct-access file. Whenever a camera optical axis pointing is supplied, the requisite subcatalog(s) can easily be identified by searching a matrix describing the zones, and the needed stars read into core.

Programs which require a presorted band can simply and efficiently obtain the band by combining subcatalogs using program LOOKAT, described in Section 8.

The subcatalog technique satisfies all the requirements imposed above. In addition, it is highly efficient, because the costly sorting is performed by program CAT only once, and not for each run of the user's program.

6.2 PROGRAM CAT OVERVIEW

Program CAT sorts an input star catalog into a number of overlapping subcatalogs. The input catalog is usually the Mission Catalog and will be referred to as such in this section, but it could also be the Master Catalog or a user-supplied catalog.

6.2.1 Capabilities of Program CAT

In order to fulfill the above requirements, program CAT performs the following functions:

- Divides the sky into overlapping zones.
- Converts star geocentric inertial unit vectors to right ascension and declination, or vice versa (if needed, or if requested by the user).
- Rejects stars if they are dimmer than a user-specified limiting magnitude (optional).
- Sorts Mission Catalog star data into the zones if in the catalog generation mode. Star data consists of one 4-byte integer and up to seven 4-byte floating point words.
- Outputs the Run Catalog in either sequential or direct-access format.
- Writes control records on the output file giving programs accessing the Run Catalog all the information needed to read the data records.
- Counts how many stars would fall into each zone, if in the star counting mode.
- Provides the user the opportunity to modify the input data before sorting.
- Prints the output subcatalogs (optional).

6.2.2 Program CAT Logical Flow

Figure 6-1 is a flowchart for program CAT. CAT begins with the input of the NAMELIST data which defines the system flow. This is performed by subroutine CONTRL, which reads the NAMELIST and checks the input values to

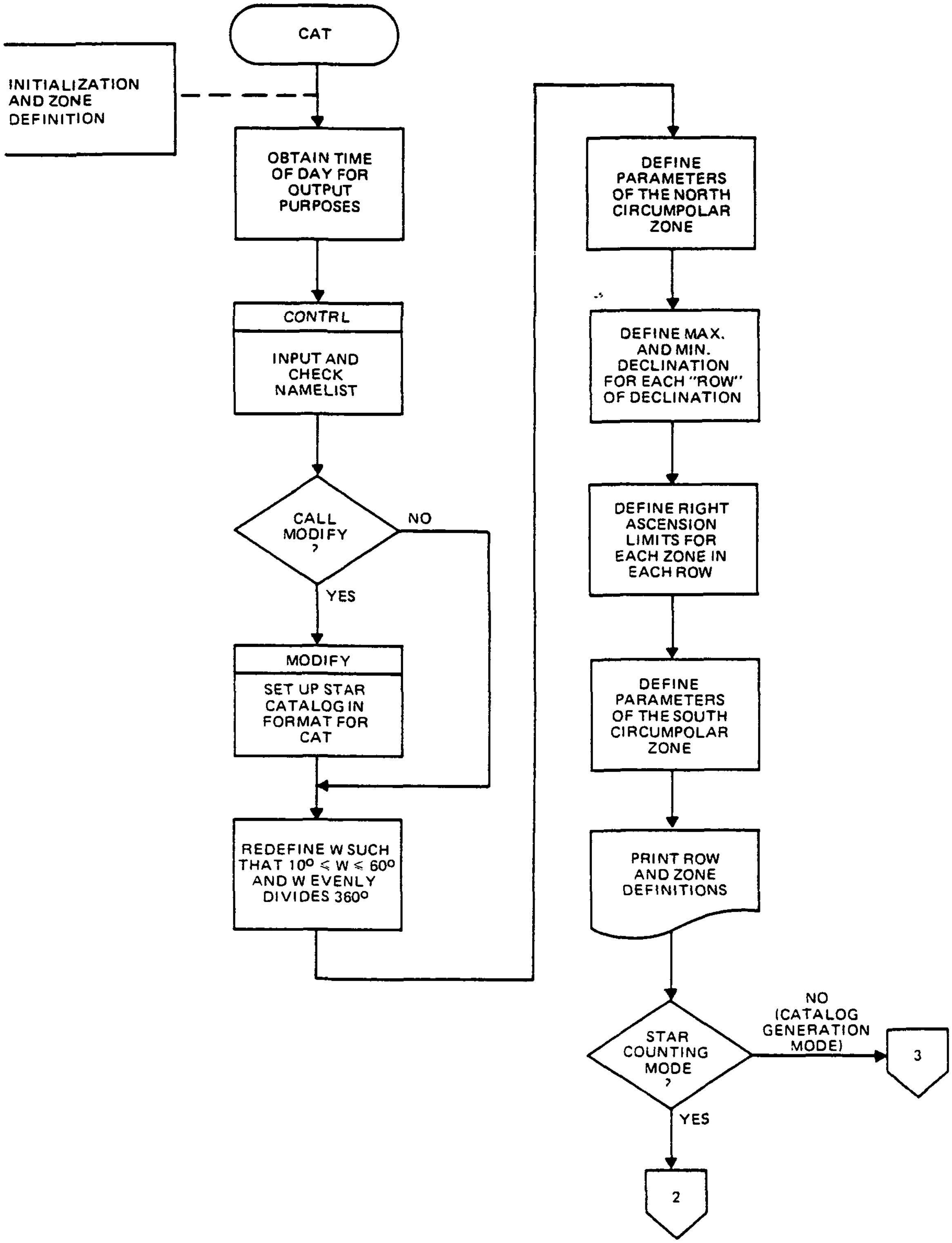

Figure 6-1. Program CAT Logical Flow (1 of 6)

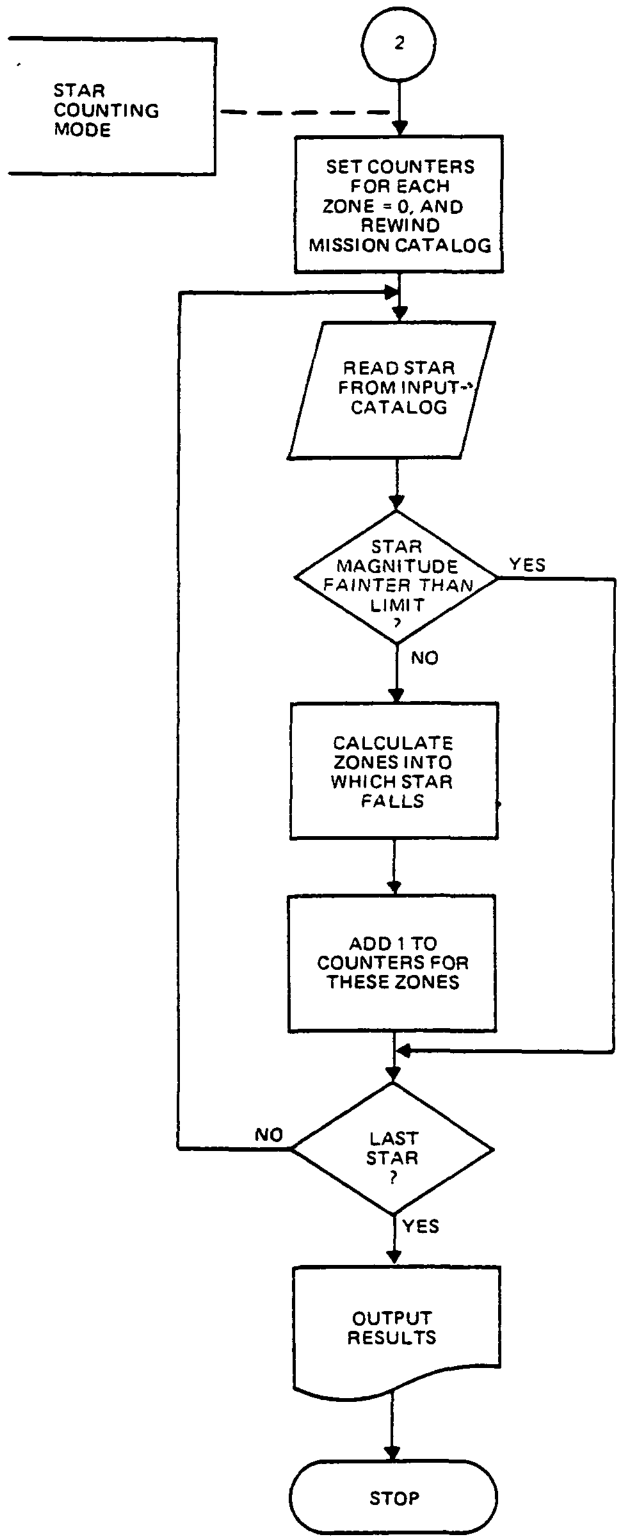

Figure 6-1. Program CAT Logical Flow (2 of 6)

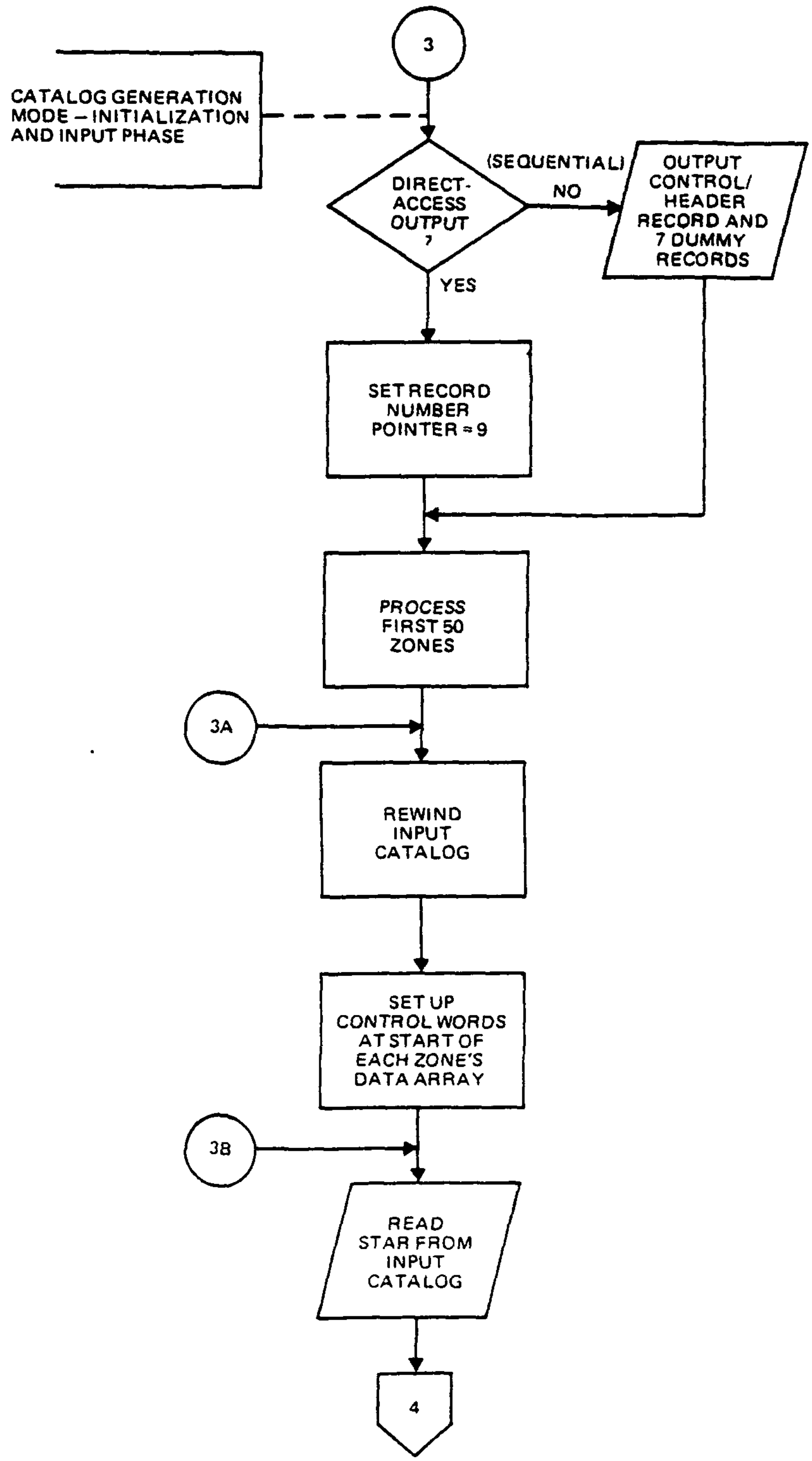

Figure 6-1. Program CAT Logical Flow (3 of 6)

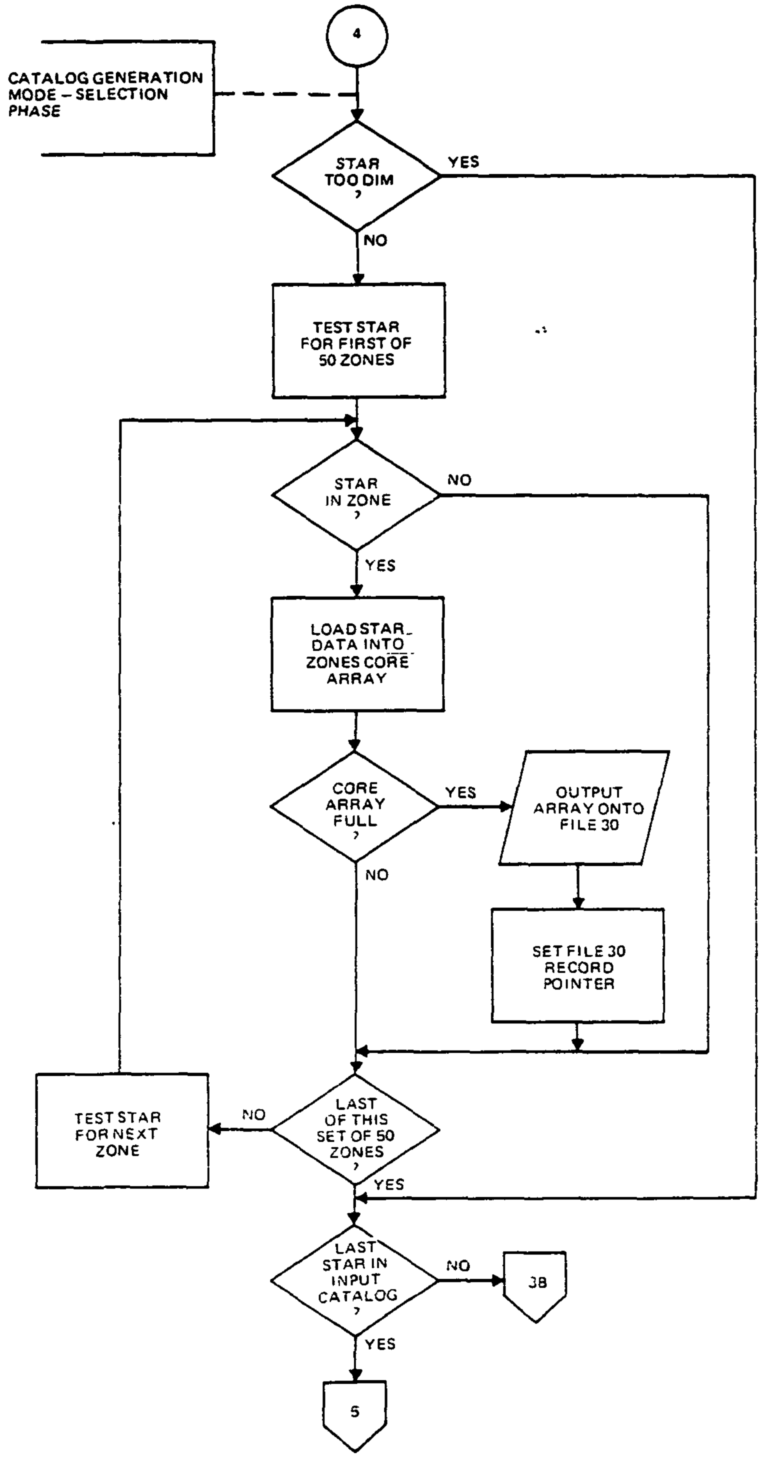

Figure 6-1. Program CAT Logical Flow (4 of 6)

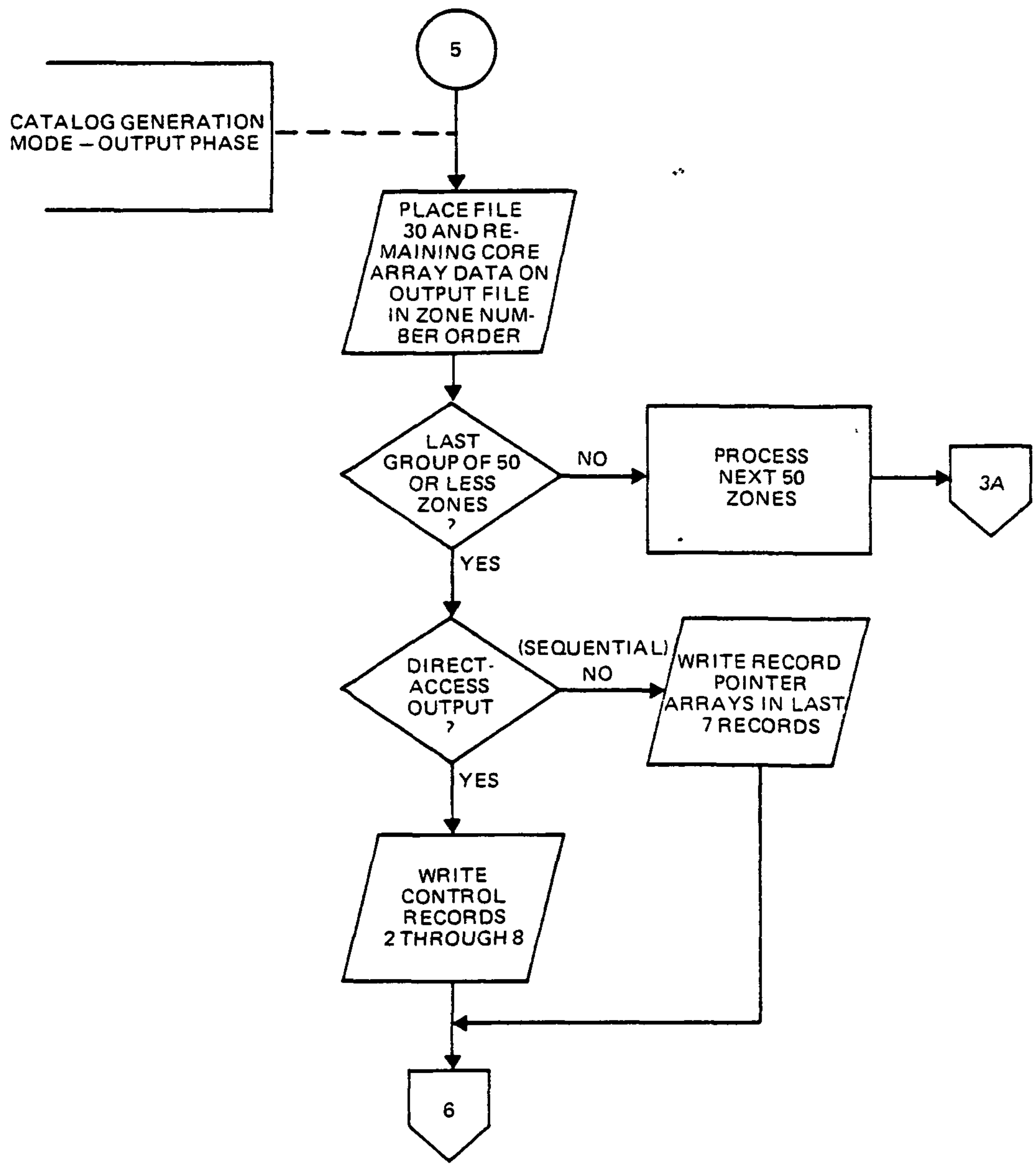

Figure 6-1. Program CAT Logical Flow (5 of 6)

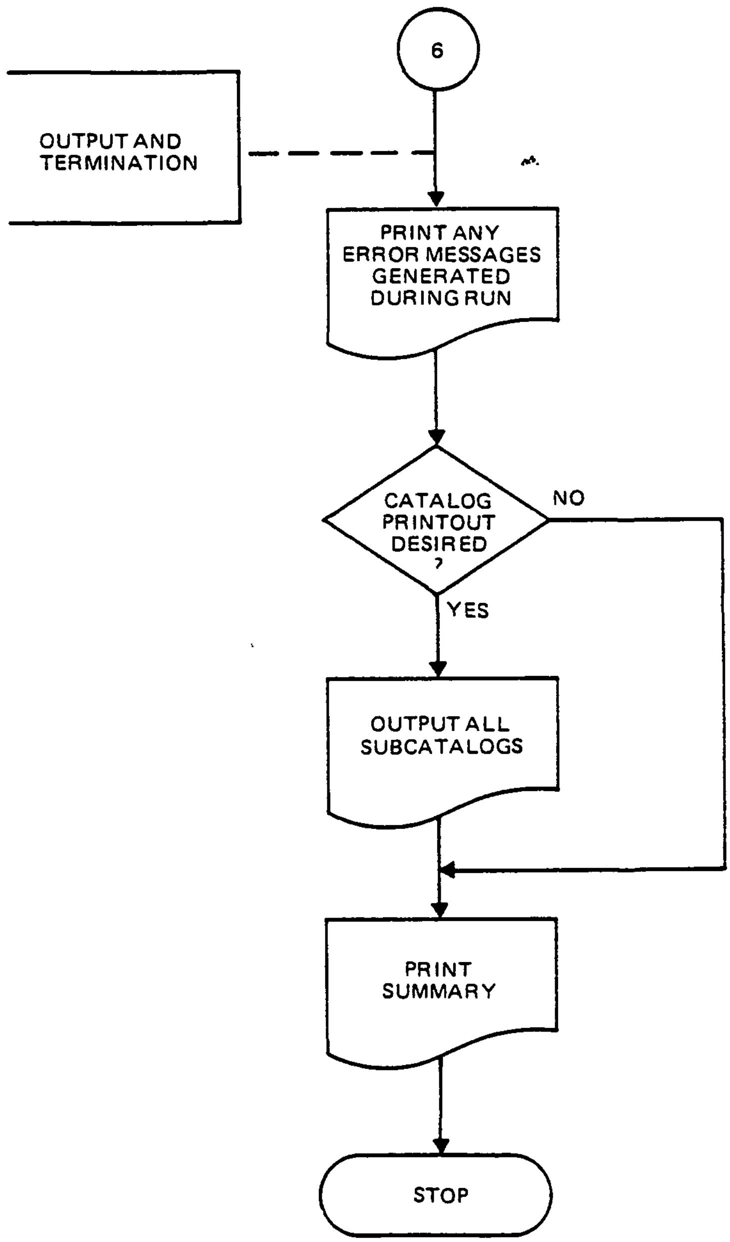

Figure 6-1. Program CAT Logical Flow (6 of 6)

be sure they lie within prescribed limits. If they do not, an error message is written, and the job terminates.

The Mission Catalog provides the input data for program CAT. Right ascension and declination are always required by CAT to assign stars to appropriate zones. Geocentric inertial unit vectors are needed as output in catalog generation mode. However, only one or the other might be present in the Mission Catalog. If the user indicates that only geocentric inertial (G.I.) unit vectors are present, CAT converts them to right ascension and declination in subroutine MODIFY. If only right ascension and declination are present, and if CAT is in catalog generation mode (or if the user requests it), G. I. unit vectors are calculated in MODIFY.

6.2.2.1 Zone Definition

CAT divides the sky into overlapping zones of user-specified size. The input zone size defines the declination range (height) of the zones. The zone height is increased, if necessary, to ensure that the resultant zones are symmetric about the equator.

CAT performs zone definition by calculating zone right ascension and declination limits. The first zone defined is a circumpolar zone about the North Celestial Pole.

As will be explained in Section 6.3.2.1, the zones overlap in declination by 50 percent. Consequently, the next "row" of zones overlaps the north circumpolar zone such that if, for example, the zone height is 30 degrees, the row of zones directly below the north circumpolar zone has declination limits of + 45 and + 75 degrees. Figure 6-2 depicts sample zone overlap.

The zones within a row are assigned a right ascension range (width) such that:

- Each zone is always at least half as wide, in arc-length, as it is high.

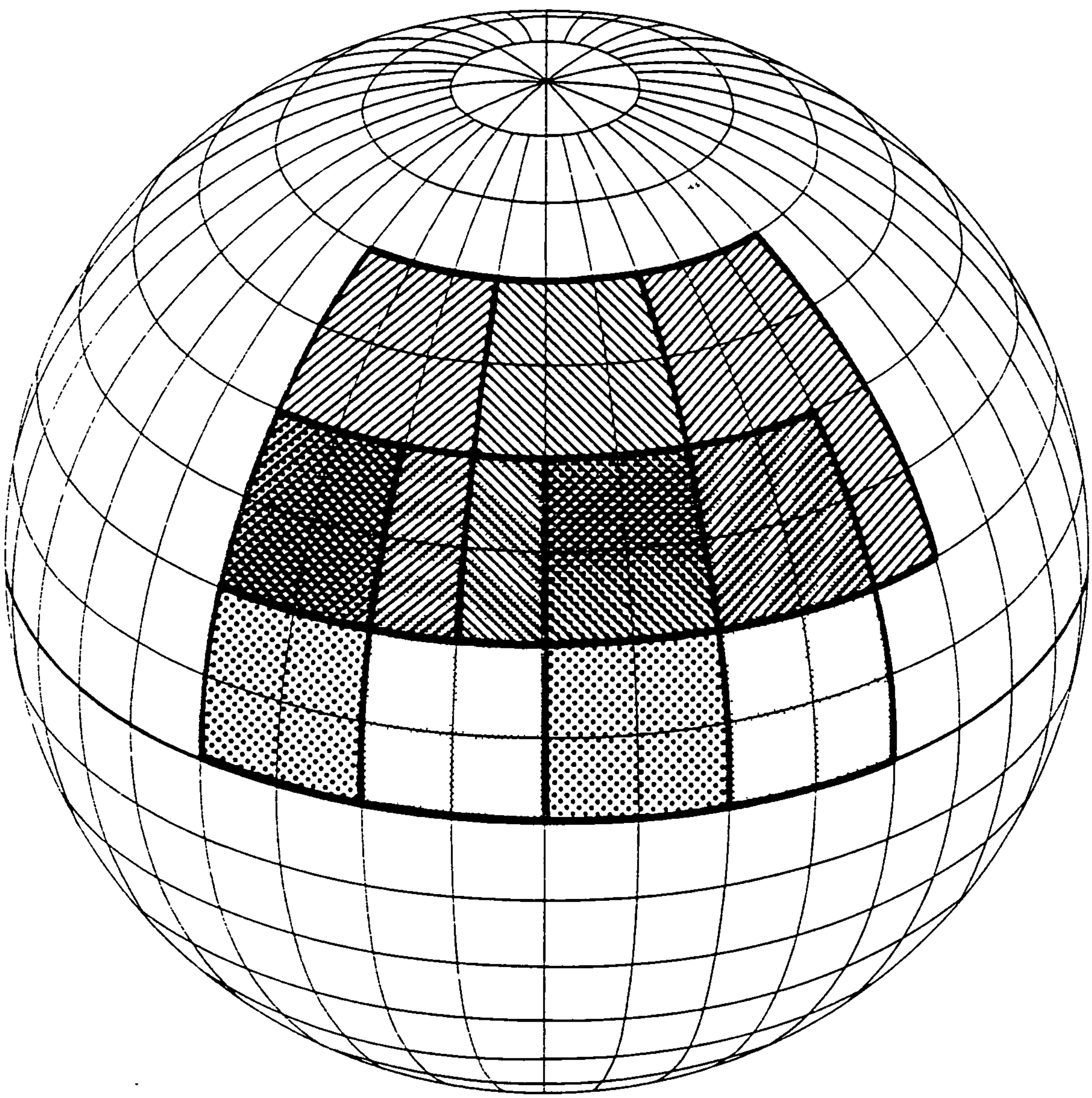

Figure 6-2. Example of 50 Percent Zone Overlap

- The first zone in a row starts at 0 degrees right ascension and the last one ends exactly at 360 degrees right ascension.

Because of the 50 percent zone overlap in declination, every star except those near the poles appears in two zones. This increases the size of the Run Catalog nearly two-fold from what it would be without such redundancy.

Elimination of "declination redundancy" has not been done, however, because to do so would greatly complicate the problem of determining the zones needed to cover a specified region of the sky. This is because the right ascension boundaries of two zones adjacent in declination are not necessarily in line with each other.

After each zone in a row is defined, CAT proceeds to the next row. Finally, a south circumpolar zone is defined.

6.2.2.2 Star Counting Mode

CAT has both a catalog generation mode (see Section 6.2.2.3) and a star counting mode. In star counting mode, each star is read from the Mission Catalog and its magnitude is checked against the user-defined magnitude limit. If the star is too dim, it is rejected and CAT reads the data for the next star. If it is sufficiently bright, the zones that would contain the star are determined and their zone counters incremented. Normally, a star falls in two zones, one in each of two partially overlapping declination rows. The exceptions are stars near the celestial poles, which occur only in a circumpolar zone.

When all stars have been processed, the results are printed.

6.2.2.3 Catalog Generation Mode

In catalog generation mode, CAT begins by writing a control/header record on the output file. This record contains the following:

- The number of zones
- The number of rows

- The number of words of data per star
- For each row, five variables defining the row: maximum and minimum row declination, right ascension width of the zones within the row, number of the first zone in the row, and number of zones in the row
- The NAMELIST parameters used to create the catalog, including a user-input 80-character title
- The time and date of catalog generation

If the output file is to be sequential, seven dummy records are written; this maintains similarity between direct-access and sequential file formats.

Next, CAT sorts the Mission Catalog stars into zones. Fifty zones are processed at one time. The Mission Catalog is read and stars dimmer than the user-defined limit are rejected. The data for each remaining star are stored in the appropriate core arrays for the zone. When the core array for a zone is filled, it is output onto temporary direct-access disk storage (file 30). A directory array is loaded with the zone number such that the ith record on the temporary disk file corresponds to the zone number for which data are stored in the ith position in the directory.

When an end of file is encountered on the input file, the temporary disk file directory is interrogated for each zone number in turn. Appropriate records are transferred to the permanent output file, and any data remaining in core are also transferred. A pointer array is loaded such that the ith value of the pointer array is the logical record number of the first Run Catalog record for the ith subcatalog. CAT then rewinds the Mission Catalog and processes the next fifty zones.

When all zones have been processed, CAT loads the pointer array into records two through eight of a direct-access file, or into the last seven records of a sequential file.

CAT concludes by printing the subcatalogs (if requested by the user) and by printing a summary of the zones. The summary includes right ascension and declination of the zone center, right ascension and declination of the zone limits, the number of stars in the zone, and the number of the first logical record in the Run Catalog for the zone.

Since the subcatalog printout is achieved by rewinding the output Run Catalog which CAT has just written and then reading it back into core as needed, this option checks the readability of the output catalog.

6.3 MATHEMATICAL SPECIFICATIONS

6.3.1 Conversion Between Right Ascension, Declination and Geocentric Inertial Unit Vector

Subroutine MODIFY may be called to convert right ascension and declination to a G. I. vector, or vice versa, using the following equations:

$$\begin{aligned} \alpha &= \tan^{-1} (Y/X) \\ \delta &= \sin^{-1} (Z) \end{aligned} \tag{6-1}$$

or

$$\begin{aligned} X &= \cos\alpha \cos\delta \\ Y &= \sin\alpha \cos\delta \\ Z &= \sin\delta \end{aligned} \tag{6-2}$$

where α = right ascension

δ = declination

(X, Y, Z) = unit vector in G. I. coordinates

Once the preliminary zone width, $\Delta\alpha^*$, is calculated, it is increased such that the final zone width, $\Delta\alpha$, is an integer which evenly divides 720. This procedure assures regular zones, with one beginning and another ending at 0 degrees.

6.3.2.2 Calculating the Zone Number and Zone Definition Parameters

Zone numbering is important because the routines that read the Run Catalog select a subcatalog by specifying its zone number. The zone number is derived, when accessing the Run Catalog, from a camera optical axis pointing and zone description arrays. Zone 1 is the north circumpolar zone, which has a minimum declination of 90-W degrees. Subsequent declination rows are defined by maximum and minimum declinations. The row immediately to the south of the north circumpolar zone extends from a declination of 90-W/2 degrees to a declination of 90-3W/2 degrees.

Within a declination row, the first zone begins at 0 degrees right ascension and ends at $\Delta\alpha$ degrees; the second begins at $\Delta\alpha$ and ends at $2\Delta\alpha$, and so on. Zones are numbered consecutively in order of increasing right ascension. The last zone in a row ends at 360 degrees.

The final zone is a south circumpolar zone, analogous to zone 1, with maximum declination of -90+W degrees.

6.3.3 Sorting Stars into Zones

Most stars in the mission catalog fall into one zone in each of two overlapping declination rows. The exceptions are stars within W/2 degrees of a celestial pole which fall only in a circumpolar zone.

A star falls within a row provided that

$$\delta_{min} < \delta \leq \delta_{max} \qquad (6-5)$$

where δ is the star declination.

Pages 6-17 and 6-18 are blank.

It is in a specific zone within that row if

$$\alpha_{min} < \alpha \leq \alpha_{max} \tag{6-6}$$

where α is the star right ascension.

The lack of the equal sign attached to the first "less than" sign in Equation (6-6) prevents a single star from being in both of two adjacent zones within a row.

6.4 BASELINE DIAGRAM AND UNIT DESCRIPTIONS

6.4.1 Baseline Diagram

Figure 6-3 is a baseline diagram for Program CAT.

6.4.2 Unit Descriptions

A unit description of program CAT and each subroutine is presented in Sections 6.4.2.1 through 6.4.2.6. An explanation of the tabular formats used in these subsections is given in Section 2.4.1. Appendix D is a FORTRAN compiler listing of CAT.

The following is an index to all program CAT modules.

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OF POOR QUALITY

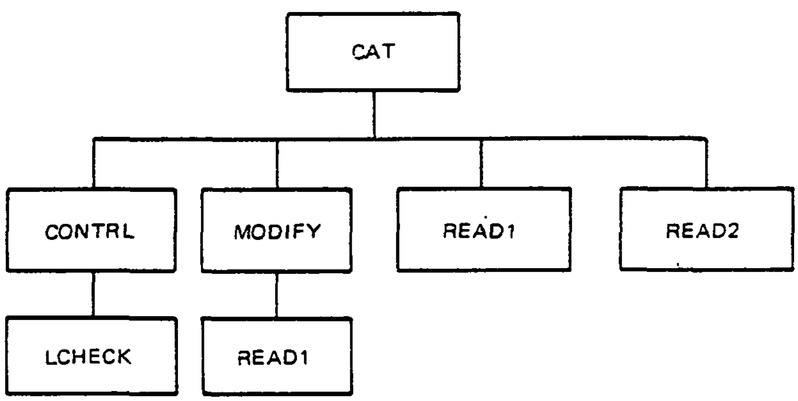

Figure 6-3. Program CAT Baseline Diagram

6.4.2.1 Program CAT

DESCRIPTION: CAT converts an input star catalog into the Run Catalog format. The user has the option of selecting and modifying the input data in subroutine READ1. The output catalog contains star number, G.I. unit vector, and user-specified data for each star.

CALLING SEQUENCE: None (CAT is the main program)

COMMON AREAS REFERENCED: CATCOM

EXTERNAL REFERENCES: CONTRL, MODIFY, READ1, READ2

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output; 30 is temporary internal direct-access storage; 50 is temporary sequential storage; 80 is the output catalog file (sequential output only); and 90 is the output catalog file (direct-access output only). I6 is defaulted to 6 in CAT.

ERROR MESSAGES:

'EXECUTION TERMINATING DUE TO OVERFLOW IN FILE 30'--Temporary storage file 30 is too small. Enlarge it by altering the DEFINE FILE 30 statement, the DATA statement containing the variable NLRECS and the DIMENSION statement for the IWHO array. See Section 6.6.1.3.3 and the listing of CAT in Appendix D.

'ZONE xxx HAD yyyyyy STARS IN IT. THE MAXIMUM DESIRED ACCORDING TO YOUR NAMELIST PARAMETER (NMAX) IS zzzzz'--This is a warning only. CAT takes no action, and the subcatalog contains all relevant stars found in the Mission Catalog.

'ERROR--NSTARS EXCEEDS xxx'--This message is found in the zone summary and occurs when the number of stars in a single subcatalog exceeds the maximum number desired according to the NAMELIST parameter NMAX. CAT takes no action, and the subcatalog contains all relevant stars found in the Mission Catalog.

6.4.2.2 Subroutine CONTRL

DESCRIPTION: CONTRL reads the control parameter NAMELIST, &CATIN, checks values against the permissible range of values, and outputs error messages as needed.

CALLING SEQUENCE: Subroutine CONTRL (no calling sequence)

COMMON AREAS REFERENCED: CATCOM

EXTERNAL REFERENCES: LCHECK

CALLED BY: CAT

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 is NAMELIST input; I6 is printed output. I5 is defaulted to 5 and I6 to 6 in CONTRL.

ERROR MESSAGES:

'WARNING ONLY--MAGNITUDE LIMIT xxxx.xxx MAY BE TOO BRIGHT.' A warning is printed when the magnitude limit is less than 3.0. CAT takes no abnormal action.

'FATAL ERROR--INPUT FILE SPECIFIED IS A PROGRAM CAT FILE.' CAT terminates execution. Files I5, I6, 30, 50, 80, and 90 are system files not available for input (see NAMELIST parameter IFILE).

'NO MODIFICATION SPECIFIED BUT ICNVRT NOT =7. CAT WILL EXECUTE MODIFY TO CALCULATE ALPHA-DELTA OR XYZ, WHICHEVER IS NOT PRESENT ON THE INPUT FILE.' Right ascension and declination are not available on the input catalog, or, if the program is in catalog generation mode, G.I. coordinates are not present on the input catalog. MODIFY is called to calculate the required parameters.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE CONTRL

Name	Symbol	I/O	Type	Interface	Description
IMODE		O	I*4	/CATCOM/	Program mode flag: = 0, CAT produces Run Catalog = 1, CAT only counts stars that would be put into the zones
ICNVRT		O	I*4	/CATCOM/	Coordinate conversion flag: = 1, (α , δ) input and output = 2, (α , δ) input; G.I. coordinates output = 3, (α , δ) input; both output = 4, G.I. coordinates input; (α , δ) output = 5, G.I. coordinates input and output = 6, G.I. coordinate input; both output = 7, both input and output
IFILE		O	I*4	/CATCOM/	Input catalog file number
W	W	O	R*4	/CATCOM/	Desired declination width of the zones in degrees; converted in MAIN to the actual declination width
ISEQ		O	I*4	/CATCOM/	Output file organization: = 1, sequential file = 2, direct-access file
FMAG		O	R*4	/CATCOM/	Limiting magnitude for the catalog
IFCAT		O	I*4	/CATCOM/	Printout flag: = 0, print summary only = 1, print catalog
NMAX		O	I*4	/CATCOM/	Maximum number of stars desired in a subcatalog
NWORDS		O	I*4	/CATCOM/	Number of output words per star

INPUT/OUTPUT VARIABLES FOR SUBROUTINE CONTRL

Name	Symbol	I/O	Type	Interface	Description
IFMDFY		O	I*4	/CATCOM/	Subroutine MODIFY call flag: = 0, do not call MODIFY = 1, call MODIFY
TITLE(20)		O	R*4	/CATCOM/	Alphameric title, 80 characters long
I5		I	I*4	/FILES/	FORTRAN file reference number for NAMELIST input
I6		I	I*4	/FILES/	FORTRAN file reference number for printed output

6.4.2.3 Subroutine LCHECK

DESCRIPTION: LCHECK tests the values of the NAMELIST parameters to ensure that they fall within the allowed range.

CALLING SEQUENCE: Subroutine LCHECK (WORD, FVAL, IVAL, IA, IB, FA, FB, ITY)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

CALLED BY: CONTRL

INPUT/OUTPUT DATA SETS: File I6 is printed output. I6 is defaulted to 6 in LCHECK.

ERROR MESSAGES:

'NAMELIST ERROR-VALUE OUT OF ALLOWED RANGE. NAME = xx (ALLOWED) yy - zz.', where NAME is the variable name, xx is the NAMELIST value for the variable, and yy and zz are the minimum and maximum values permitted. The NAMELIST parameter was not within the permitted range. This is a fatal error.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE LCHECK

Name	Symbol	I/O	Type	Interface	Description
WORD		I	R*8	C.S.	Descriptive name of variable (alphameric)
FVAL		I	R*4	C.S.	Value of R*4 variable to be checked (if ITY=2)
IVAL		I	I*4	C.S.	Value of I*4 variable to be checked (if ITY=1)
IA		I	I*4	C.S.	Minimum permissible value of IVAL
IB		I	I*4	C.S.	Maximum permissible value of IVAL
FA		I	R*4	C.S.	Minimum permissible value of FVAL
FB		I	R*4	C.S.	Maximum permissible value of FVAL
ITY		I	I*4	C.S.	Data type flag: = 1, variable to be checked is I*4 = 2, variable to be checked is R*4
I6		I	I*4	/FILES/	FORTRAN data set reference number for printed output

6.4.2.4 Subroutine MODIFY

DESCRIPTION: MODIFY calculates the G. I. unit vector, given right ascension and declination, or vice versa.

CALLING SEQUENCE: Subroutine MODIFY (no calling sequence)

COMMON AREAS REFERENCED: CATCOM

EXTERNAL REFERENCES: READ1

CALLED BY: CAT

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number 50 is temporary sequential output of the modified input catalog. FORTRAN data set reference number I6 is printed output. I6 is defaulted to 6 in MODIFY.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE MODIFY

Name	Symbol	I/O	Type	Interface	Description
IMODE		I	I*4	/CATCOM/	Program mode flag: = 0, CAT produces Run Catalog = 1, CAT only count stars that would be put into the zones
ICNVRT		I	I*4	/CATCOM/	Coordinate conversion flag: = 1, (α , δ) input and output = 2, (α , δ) input; G.I. coordinates output = 3, (α , δ) input; both output = 4, G.I. coordinates input; (α , δ) output = 5, G.I. coordinates input and output = 6, G.I. coordinate input; both output = 7, both input and output
ISTDAT		I/O	I*4	/CATCOM/	First data word of star data from input catalog
FSTDAT(9)		I/O	R*4	/CATCOM/	Remaining nine data words of star data from input catalog or subroutine MODIFY. Note that FSTDAT is used both as an internal and an output variable; only the last seven words of FSTDAT are output (see Table 6-2)
IEOF		I	I*4	/CATCOM/	End-of-file flag for Mission Catalog. When subroutines READ1 and READ2 return to MAIN: = 0, no EOF encountered on Mission Catalog file = 1, EOF encountered When subroutines READ1 and READ2 are called from MAIN: = 1, rewind unit and return data for a star = -1, return data for a star

INPUT/OUTPUT VARIABLES FOR SUBROUTINE MODIFY

Name	Symbol	I/O	Type	Interface	Description
I6		I	I*4	/FILES/	FORTRAN data set reference number for printed output

Table 6-2. Star Data Storage Variables

VARIABLE	MEANING	OUTPUT WORD NUMBER RELATIVE TO START OF STAR DATA SEGMENT
ISTDAT	STAR NUMBER	1
FSTDAT(1)	RIGHT ASCENSION	NOT OUTPUT
FSTDAT(2)	DECLINATION	NOT OUTPUT
FSTDAT(3)		2
FSTDAT(4)	COMPONENTS OF G.I. UNIT VECTOR	3
FSTDAT(5)		4
FSTDAT(6)	USUALLY STAR MAGNITUDE	5
FSTDAT(7)	OPTIONAL DATA	6
FSTDAT(8)	OPTIONAL DATA	7
FSTDAT(9)	OPTIONAL DATA	8

6.4.2.5 Subroutine READ1

DESCRIPTION: READ1 is a user-written subroutine which reads the input star catalog. The user may insert code to modify input star catalog variables. A listing of the existing READ1 subroutine is contained in Appendix D.

CALLING SEQUENCE: Subroutine READ1 (no calling sequence)

COMMON AREAS REFERENCED: CATCOM

EXTERNAL REFERENCES: None

CALLED BY: CAT, CONTRL

INPUT/OUTPUT DATA SETS: The user-defined file, IFILE, in COMMON/CATCOM/, is used for catalog input.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE READ1

Name	Symbol	I/O	Type	Interface	Description
IEOF		I/O	I*4	/CATCOM/	End-of-file flag for Mission Catalog. When subroutines READ1 and READ2 return to MAIN: = 0, no EOF encountered on Mission Catalog file = 1, EOF encountered When subroutines READ1 and READ2 are called from MAIN: = 1, rewind unit and return data for a star = -1, return data for a star
IFILE		I	I*4	/CATCOM/	Input catalog file number
ISTDAT		O	I*4	/CATCOM/	First data word of star data to be placed on output catalog
FSTDAT(9)		O	R*4	/CATCOM/	Remaining nine data words of star data

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6.4.2.6 Subroutine READ2

DESCRIPTION: READ2 reads the star catalog which has been modified by subroutine MODIFY.

CALLING SEQUENCE: Subroutine READ2 (no calling sequence)

COMMON AREAS REFERENCED: CATCOM

EXTERNAL REFERENCES: None

CALLED BY: CAT

INPUT/OUTPUT DATA SETS: File 50 (disk) is used as input.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE READ2

Name	Symbol	I/O	Type	Interface	Description
ISTDAT		O	I*4	/CATCOM/	First data word of star data from input catalog
FSTDAT(9)		O	R*4	/CATCOM/	Remaining nine data words of star data from input catalog or subroutine MODIFY. Note that FSTDAT is used both as an internal and an output variable; only the last seven words of FSTDAT are output (see Table 6-2)
IEOF		I/O	I*4	/CATCOM/	End-of-file flag for Mission Catalog. When subroutines READ1 and READ2 return to MAIN: = 0, no EOF encountered on Mission Catalog file = 1, EOF encountered When subroutines READ1 and READ2 are called from MAIN: = 1, rewind unit and return data for a star = -1, return data for a star

6.5 COMMON AREA DESCRIPTION (CATCOM)

NAME: CATCOM

DESCRIPTION: CATCOM contains the input/output control words needed by program CAT and its subroutines.

FORM: COMMON/CATCOM/IMODE, ICNVRT, IFILE, W, ISEQ, FMAG, IFCAT, NMAX, NWORDS, IFMDFY, TITLE(20), ISTDAT, FSTDAT(9), IEOF

REFERENCED BY: CAT, CONTRL, MODIFY, READ1, READ2

DEFINITION OF VARIABLES:

Name	Type	Description
IMODE	I*4	Program mode flag: = 0, CAT produces Run Catalog = 1, CAT only counts stars that would be put into the zones
ICNVRT	I*4	Coordinate conversion flag: = 1, (α , δ) input and output = 2, (α , δ) input; G.I. coordinates output = 3, (α , δ) input; both output = 4, G.I. coordinates input; (α , δ) output = 5, G.I. coordinates input and output = 6, G.I. coordinate input; both output = 7, both input and output
IFILE	I*4	Input catalog file number
W	R*4	Desired declination width of the zones in degrees; converted in MAIN to the actual declination width
ISEQ	I*4	Output file organization: = 0, direct access file = 1, sequential file
FMAG	R*4	Limiting magnitude for the catalog

Name	Type	Description
IFCAT	I*4	Printout flag: = 0, print summary only = 1, print catalog
NMAX	I*4	Maximum number of stars desired in a subcatalog
NWORDS	I*4	Number of output words per star
IFMDFY	I*4	Subroutine MODIFY call flag: = 0, do not call MODIFY = 1, call MODIFY
TITLE(20)	R*4	Alphameric title, 80 characters long
ISTDAT	I*4	First data word of star data from input catalog
FSTDAT(9)	R*4	Remaining nine data words of star data from input catalog or subroutine MODIFY. Note that FSTDAT is used both as an internal and an output variable; only the last seven words of FSTDAT are output (see Table 6-2)
IEOF	I*4	End-of-file flag for Mission Catalog. When subroutines READ1 and READ2 return to MAIN: = 0, no EOF encountered on Mission Catalog file = 1, EOF encountered When subroutines READ1 and READ2 are called from MAIN: = 1, rewind unit and return data for a star = -1, return data for a star

6.6 USER'S MANUAL

This subsection will enable the user to create the proper NAMELIST input, modify selected code to handle special cases, interpret the output resulting from program CAT, and formulate the appropriate Job Control Language (JCL).

6.6.1 Input to Program CAT

Input to CAT consists of a NAMELIST, an input star catalog, and a user-written or modified subroutine, READ1.

6.6.1.1 NAMELIST & CATIN

The user may code input data into program CAT via NAMELIST &CATIN. The NAMELIST parameters, together with their default values, are presented in the following list, which adheres to the format stated in Section 2.4.3. Multiple NAMELISTs cannot be used in program CAT.

Name	Type	Default	Description
IMODE	I*4	0	Program mode flag: = 0, CAT produces Run Catalog = 1, CAT only counts stars that would be put into the zones
ICNVA	I*4	1	Star coordinate input control flag: = 1, right ascension and declination input = 2, G.I. unit vector input = 3, both input
ICNVB	I*4	2	Star coordinate output control flag: = 1, right ascension and declination output = 2, G.I. coordinates output = 3, both output
IFILE	I*4	52	Input catalog file number. Valid range: 1 ≤ IFILE ≤ 99, but not 30, 50, 80, 90 or I5, I6 (defaulted to 5 and 6, respectively)
W	R*4	30.0	Desired declination width of the zones (degrees). Valid values are shown in Table 6-1
ISEQ	I*4	1	Output file format flag: = 1, sequential file = 2, direct-access file
FMAG	R*4	9.99	Limiting magnitude for the catalog. Restrictions explained in Section 6.6.1.3.1.

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Name	Type	Default	Description
IFCAT	I*4	0	Printout flag: = 0, summary printout only = 1, full catalog printout
NMAX	I*4	9999	Maximum number of stars desired in a subcatalog
NWORDS	I*4	8	Number of output words per star. Valid range: 4 ≤ NWORDS ≤ 8
IFMDFY	I*4	0	Subroutine MODIFY call flag: = 0, do not call MODIFY = 1, call MODIFY
TITLE(20)	R*4	20*'bbbb'	User input title (80 characters)

6.6.1.2 Input Star Catalog

The input catalog must contain star numbers and positions. Usually, it will also contain an instrumental magnitude, or an approximation to one, such as the stellar magnitude in a standard system.

The input star catalog must reside on the file designated by the NAMELIST parameter IFILE. IFILE may be any number from 1 through 99 except 30, 50, 80, 90, or I5, I6 (defaulted to 5 and 6 respectively). The SKYMAP Mission Catalog is usually the input catalog to program CAT. If a Mission Catalog is not created, the Master Catalog can be used, as can any other catalog supplied by the user which contains the necessary data. Subroutine READ1, which is user supplied, reads the input catalog. The output required by CAT from READ1 is discussed below.

6.6.1.3 Source Code User Modifications

The user may need to alter subroutine READ1 and the MAIN routine.

6.6.1.3.1 Subroutine READ1

The user must supply subroutine READ1 to read the input star catalog. A default version of READ1 has been provided which reads the Master Catalog and outputs star number (HD number), geocentric inertial unit vector components and instrumental magnitude. A listing of the current READ1 subroutine is shown in Appendix D along with the listing of program CAT.

READ1 communicates with CAT via COMMON/CATCOM/. The star data which READ1 must place in CATCOM are as follows:

ISTDAT	Integer output word, usually the star number
FSTDAT(1)	Right ascension (if given)
FSTDAT(2)	Declination (if given)
FSTDAT(3)	X-coordinate in G.I. coordinates (if given)
FSTDAT(4)	Y-coordinate in G.I. coordinates (if given)
FSTDAT(5)	Z-coordinate in G.I. coordinates (if given)
FSTDAT(6)	Star magnitude (optional)
FSTDAT(7)	Extra floating point output word (optional)
FSTDAT(8)	Extra floating point output word (optional)
FSTDAT(9)	Extra floating point output word (optional)
IEOF	= 0, if no end of file was encountered on the input file = 1, if an end of file was encountered on the input file

If IEOF = -1 when READ1 is called, the unit should be rewound (if applicable). FSTDAT(6) should be set to 0.0 if star magnitudes are not going to be output because FSTDAT(6) is always checked in CAT agains the NAMELIST parameter FMAG to determine if the star is bright enough to be included in the catalog. If information other than magnitude is stored in FSTDAT(6), ensure that FMAG is large enough to avoid rejection of data.

6.6.1.3.2 The MAIN Routine

It is envisioned that the only changes the user will want to make to MAIN are to alter the size of the direct-access data sets (files 30 and 90) referenced by CAT. File 30 is always required, and file 90 is needed when CAT is to produce a direct-access run catalog. If the size of these files is too small, a user SD37 ABEND will occur. If they are too large, excess disk storage and I/O time will be used.

To determine the proper sizes for files 30 and 90, CAT should be run in star counting mode. The numbers of logical records needed for each are printed at the end of the output.

To alter the size of file 30, change the statement at sequence number 00008300 in the MAIN program:

```
DEFINE FILE 30 (2000, 410, U, NEXT)
```

The first parameter in parentheses should be set to the number of logical records desired for that file. The JCL DD statement for FT30F001 must also agree with this DEFINE FILE.

To alter the size of file 90, change the statement at sequence number 00008400 and 00008401 in the MAIN program:

```
DEFINE FILE 90 (2000, 410, U, NEXTFN)
DATA NLRECS/2000/
```

The first parameter in parentheses in the DEFINE FILE 90 statement should be set to the number of logical records desired for that file. The value for NLRECS in the DATA statement should also be set to this value. The JCL DD statement for FT90F001 must also agree with this DEFINE FILE.

6.6.2 Output From Program CAT

6.6.2.1 Run Catalog

CAT will create either a sequential or a direct-access Run Catalog. The program that reads the Run Catalog, LOOKAT, can only use the direct-access version. However, the user may wish to store the Run Catalog on tape and only unload it onto disk when it is needed. In that case, CAT should be used to create a sequential Run Catalog on tape, and program SWITCH should be used to load it onto disk in direct-access format (see Section 7).

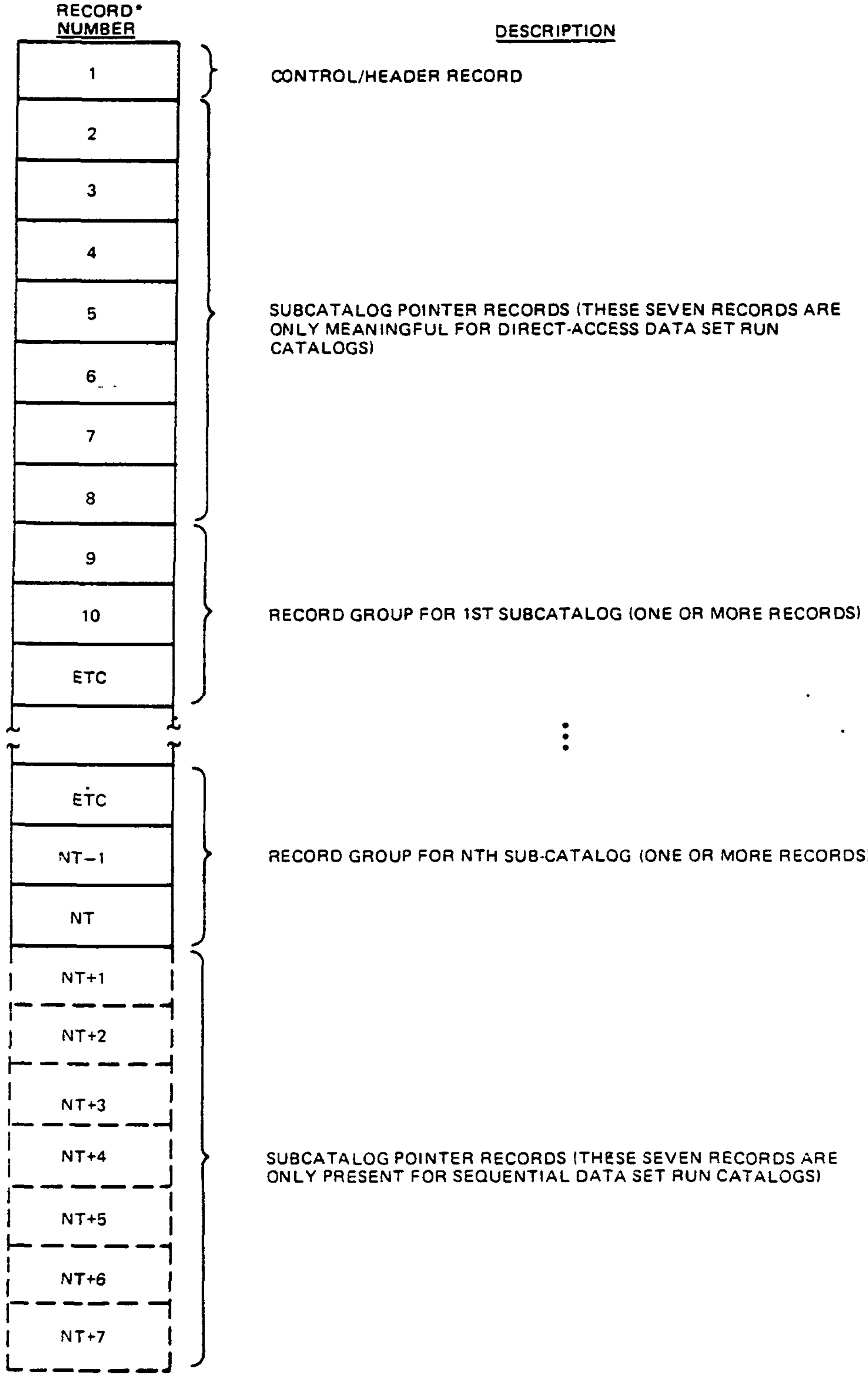
6.6.2.1.1 Run Catalog Organization

The organization of the sequential and direct-access versions of the Run Catalog, shown in Figure 6-4, are identical up through the last data record, NT, of the last subcatalog, N. The direct-access version of the Run Catalog is written on FORTRAN data set reference number 90 using an unformatted FORTRAN write statement and a DEFINE FILE statement. The record length is 1640 bytes (410 4-byte words per record). The sequential version has a fixed block format, a logical record length of 1640 bytes, and a block size of 6560 bytes.

6.6.2.1.2 Catalog Structure

The first eight (logical) records of the direct-access Run Catalog and the first one and last seven records of the sequential Run Catalog contain data needed by the access module of program LOOKAT, which reads the catalog.

The second through eighth records of the direct-access version and the last seven records of the sequential version contain pointers corresponding to the first logical record of data pertaining to each of the subcatalogs. Some of the data needed for these records is not available until the sorting is complete, which creates a problem if output is sequential. To keep the direct-access and sequential versions as similar as possible, records two through eight in the sequential file are filled with dummy data. At the end of the catalog generation,



*LENGTH OF ALL RECORDS IS 1640 BYTES = 410 4-BYTE WORDS

Figure 6-4. Run Catalog Structure

the data contained in the second through eighth records of the direct-access version are written as the last seven records in the sequential version. The final seven records of the sequential catalog can be easily recognized, as they contain the integer constant 987654 as the 401st through 410th word.

For either version, the star data subcatalogs start at the ninth logical record as shown in Figure 6-4. Subsection 6.6.2.1.4 details the format of the subcatalogs.

6.6.2.1.3 Format of the Control/Header Record and Pointer Records

The first record of data on the Run Catalog contains the sub-catalog control words and header information. Table 6-3 defines the data found in this record.

The second through eighth record of the direct-access catalog, and the last seven records of the sequential catalog, contain the I*4 record pointers. The pointers are written 400 to a record, plus 10 dummy words at the end containing the integer 987654. The ith pointer in this group of seven records is the record number corresponding to the first record for the ith subcatalog. Those pointers which are not used if there are fewer than 2800 subcatalogs are set to 0.0.

The control/header record and pointer records are read automatically by program LOOKAT which provides the interface between the Run Catalog and attitude determination programs.

6.6.2.1.4 Subcatalog Format

A subcatalog consists of one or more consecutive 410 word logical records. The logical records are constructed of segments NWORDS long, where NWORDS is a NAMELIST parameter whose value must be $4 \leq$ NWORDS ≤ 8. The organization of these records is shown in Figure 6-5.

The first two segments of the first logical record for a subcatalog contain control words which are described in Table 6-4. Each following segment

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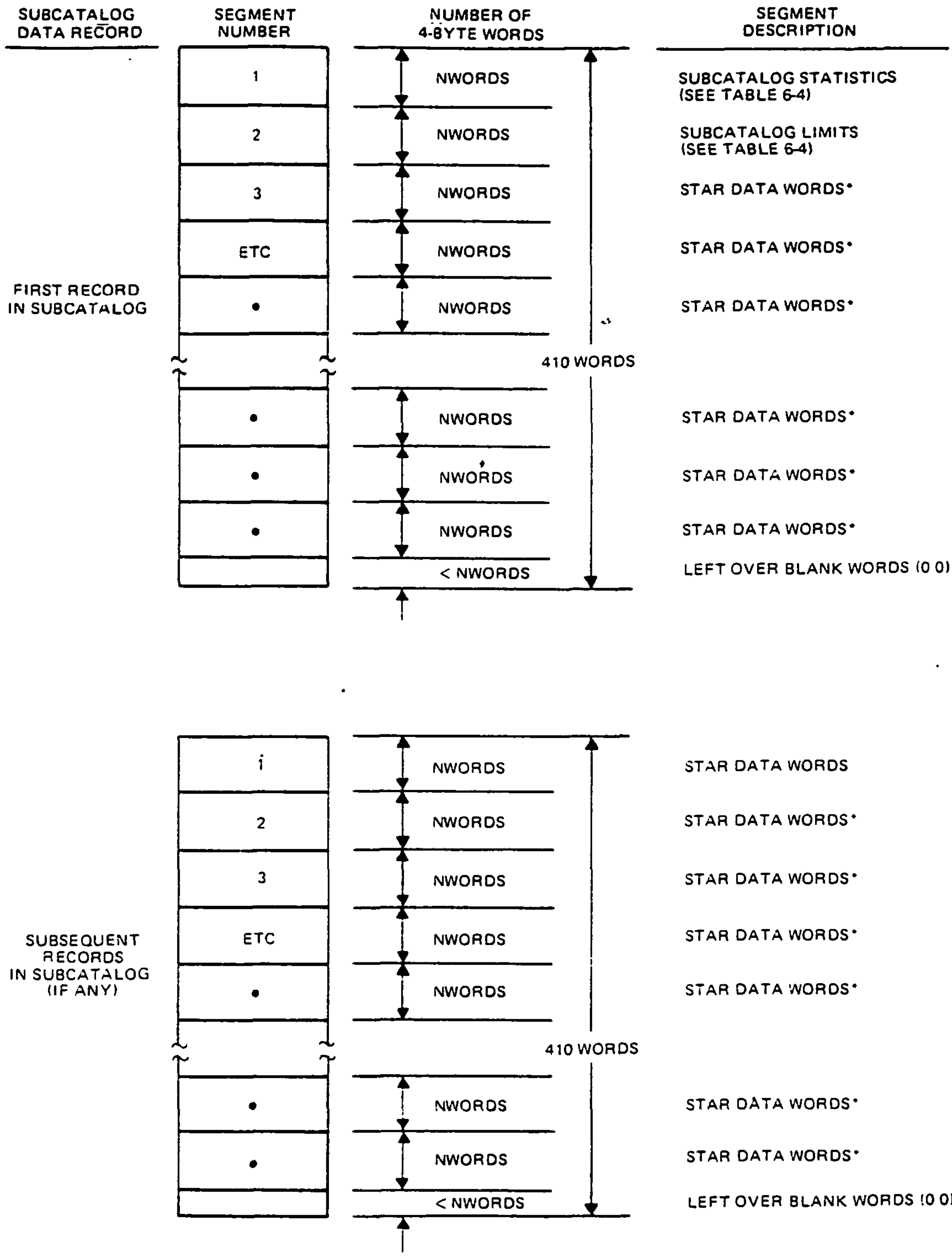
Table 6-3. Data Words in the Control/Header Record of the Run Catalog

WORD POSITION IN RECORD	FORMAT	DESCRIPTION
1	I*4	NUMBER OF SUBCATALOGS
2–201		FOR EACH DECLINATION ROW OF ZONES, UP TO A MAXIMUM OF 40 ROWS, FIVE WORDS DEFINING
	R*4	• MAXIMUM ROW DECLINATION
	R*4	• MINIMUM ROW DECLINATION
	R*4	• RIGHT ASCENSION WIDTH OF THE ZONES IN THE ROW
	I*4	• NUMBER OF THE FIRST ZONE IN THE ROW
	I*4	• TOTAL NUMBER OF ZONES IN THE ROW
		THE FIRST FIVE WORDS REFER TO ROW 1, THE NEXT FIVE TO ROW 2, ETC. WORDS WHICH ARE NOT USED BECAUSE THERE ARE FEWER THAN 40 ROWS ARE MEANINGLESS.
202	I*4	NUMBER OF ROWS
203	I*4	NUMBER OF WORDS OF DATA PER STAR
204	I*4	COMMON/CATCOM/PARAMETER ICNVRT
205	I*4	NAMELIST PARAMETER IFILE
206	R*4	NAMELIST PARAMETER W
207	I*4	NAMELIST PARAMETER ISEQ
208	R*4	NAMELIST PARAMETER FMAG
209	I*4	NAMELIST PARAMETER NMAX
210	I*4	NAMELIST PARAMETER IFMDFY
211–230	R*4	NAMELIST PARAMETER TITLE
231–237	R*4	TIME OF DAY AND DATE WHEN CAT WAS RUN TO GENERATE THE RUN CATALOG
238–410	–	MEANINGLESS



*WORDS IN THE REMAINDER OF THE RECORD AFTER THE LAST STAR DATA ENTRY IN THE SUB-CATALOG ARE SET TO 0.0

Figure 6-5. Run Catalog Subcatalog Data Record Organization

Table 6-4. Contents of First Two Segments of First Record in a Run Catalog Subcatalog

SEGMENT NUMBER	WORD POSITION IN SEGMENT	FORMAT	DESCRIPTION
1	1	I*4	SUBCATALOG NUMBER
	2	R*4	RIGHT ASCENSION OF THE ZONE CENTER (DEGREES)
	3	R*4	DECLINATION OF THE ZONE CENTER (DEGREES)
	4	I*4	NUMBER OF STARS IN THE SUB-CATALOG
	5 THROUGH NWORDS	–	IF THESE WORDS ARE PRESENT (I.E., $4 < \mathrm{NWORDS} \leq 8$), THEY ARE MEANINGLESS
2	1	R*4	MAXIMUM RIGHT ASCENSION OF THE ZONE (DEGREES)
	2	R*4	MINIMUM RIGHT ASCENSION OF THE ZONE (DEGREES)
	3	R*4	MAXIMUM DECLINATION OF THE ZONE (DEGREES)
	4	R*4	MINIMUM DECLINATION OF THE ZONE (DEGREES)
	5 THROUGH NWORDS	–	IF THESE WORDS ARE PRESENT (I.E., $4 < \mathrm{NWORDS} \leq 8$), THEY ARE MEANINGLESS

contains data for a single star. The words within a star data segment are given in Table 6-5. Stars are ordered in the Run Catalog in the order they appear in the input catalog.

In program CAT segments of data are first stored in a core array. When a total count of (410-NWORDS) words is exceeded in the core array, the complete segment is stored, and the array is written on a temporary output file. The limit was chosen to ensure that sufficient space was left in the 410 word core array to finish storing the data for the final star. Any unfilled words at the end of a partial record are left blank.

6.6.2.2 Printed Output from CAT

CAT produces the following printed output to assist in evaluating the program performance:

- A table of NAMELIST parameters, the values assigned to them, and a description of their meaning (Figure 6-6)
- A series of self-explanatory error messages concerning NAMELIST parameter values. Some are fatal. If the program printout ends here, correct the indicated error and rerun the job. The meaning of each error message is given in Table 6-6.
- If MODIFY has been called, a statement that MODIFY is finished, the number of stars it output, and the number of the last star (Figure 6-7)
- The parameters defining the rows (Figure 6-8)
- The parameters defining the zones (Figure 6-9)

When exercising the star counting mode, the following is printed:

- A table of the number of stars in a zone, including zone number, maximum and minimum zone declination, maximum and minimum

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Table 6-5. Data Words in a Run Catalog
Star Data Segment

RELATIVE POSITION	FORMAT	DESCRIPTION
1	I*4	USUALLY THE STAR NUMBER
2–4	R*4	THE STAR'S GEOCENTRIC INERTIAL UNIT VECTOR AT A SPECIFIED EPOCH (X, Y, Z)
5*	R*4	SIXTH FLOATING POINT WORD OUTPUT BY READ1 OR READ2 THIS SHOULD BE THE STELLAR INSTRUMENTAL MAGNITUDE, IF PRESENT
6*	R*4	SEVENTH FLOATING POINT WORD OUTPUT BY READ1 OR READ2
7*	R*4	EIGHTH FLOATING POINT WORD OUTPUT BY READ1 OR READ2
8*	R*4	NINTH FLOATING POINT WORD OUTPUT BY READ1 OR READ2

*OPTIONAL WORDS

```
TIME AND DATE OF RUN -- 13.28.04.CE FRI APR 04,1975

TITLE -- TEST CATALOG GENERATED BY D. GOTTLIEB ON APRIL 3
INSTRUCTIONS TO CAT ARE --

NAME            VALUE       MEANING

IMODE              0        MODE OF OPERATION FLAG --
                                 0= NORMAL MODE (PRODUCES CATALOG)
                                 1= ONLY COUNTS STARS

W               30.0        DESIRED DECLINATION WIDTH OF THE ZONES

IFILE             52        INPUT FILE NUMBER

ISEQ               0        TYPE OF OUTPUT FILE --
                                 0= SEQUENTIAL
                                 1= DIRECT ACCESS

FMAG            9.59        LIMITING MAGNITUDE FOR THE CATALOGUE

IFCAT              1        FLAG FOR PRINTOUT OF CATALOGUE --
                                 0= SUPPRESS PRINTING
                                 1= ALLOW PRINTING

NMAX             100        MAXIMUM NUMBER OF STARS DESIRED IN A SUB-CATALOGUE

NWORDS             6        NUMBER OF OUTPUT WORDS PER STAR

ICNVRT             2        INPUT-OUTPUT POSITIONAL DATA FLAG --
                                 1= ALPHA-DELTA IN ... ALPHA-DELTA OUT
                                 2= ALPHA-DELTA IN ... XYZ OUT
                                 3= ALPHA-DELTA IN ... BOTH OUT
                                 4= XYZ IN ... ALPHA-DELTA OUT
                                 5= XYZ IN ... XYZ OUT
                                 6= XYZ IN ... BOTH OUT
                                 7= BOTH IN ... BOTH OUT

IFMDFY             0        SUBROUTINE MODIFY CALL FLAG --
                                 0= DO NOT CALL MODIFY
                                 1= CALL MODIFY
```

Figure 6-6. Sample Output From CAT, NAMELIST Summary

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Table 6-6. Program CAT Error Messages

FROM MAIN	'EXECUTION TERMINATING DUE TO OVERFLOW IN FILE 30' – TEMPORARY DIRECT-ACCESS STORAGE FILE IS TOO SMALL. ENLARGE IT BY ALTERING THE DEFINE FILE STATEMENT, THE DATA STATEMENT CONTAINING THE VARIABLE NLRECS AND THE DIMENSION STATEMENT FOR THE IWHO ARRAY IN THE MAIN PROGRAM 'ZONE xxxx HAD yyyyyy STARS IN IT THE MAXIMUM DESIRED ACCORDING TO YOUR NAMELIST PARAMETER (NMAX) IS zzzzz' – WARNING ONLY CAT TAKES NO ACTION, AND YOUR FULL CATALOG IS STORED ON THE OUTPUT FILE. 'ERROR – NSTARS EXCEEDS xxx' – FOUND IN THE ZONE SUMMARY. THIS MESSAGE OCCURS WHEN THE NUMBER OF STARS IN A SINGLE SUB-CATALOG EXCEEDS THE MAXIMUM NUMBER DESIRED ACCORDING TO THE NAMELIST PARAMETER NMAX. CAT TAKES NO ACTION, AND YOUR FULL SUB-CATALOG IS ON THE OUTPUT FILE.
FROM CONTRL:	'WARNING ONLY – MAGNITUDE LIMIT xxxx.xxx MAY BE TOO BRIGHT.' WARNING IS PRINTED WHEN LIMITING MAGNITUDE IS < 3.0, CAT TAKES NO ACTION. 'FATAL ERROR – INPUT FILE SPECIFIED IS A PROGRAM CAT FILE.' CAT TERMINATES EXECUTION. FILES 15,16,30,50,80 AND 90 ARE SYSTEM FILES NOT AVAILABLE FOR INPUT (SEE NAMELIST PARAMETER IFILE). 'NO MODIFICATION SPECIFIED BUT ICNVRT NOT =7. CAT WILL EXECUTE MODIFY TO CALCULATE ALPHA-DELTA OR XYZ, WHICHEVER IS NOT PRESENT ON THE INPUT FILE.' RIGHT ASCENSION AND DECLINATION ARE NOT AVAILABLE ON THE INPUT CATALOG, OR (DURING CATALOG GENERATION MODE ONLY) GEOCENTRIC INERTIAL COORDINATES ARE NOT PRESENT ON THE INPUT CATALOG THEY ARE NEEDED, SO MODIFY IS CALLED TO CALCULATE THEM
FROM LCHECK.	'NAMELIST ERROR – VALUE OUT OF ALLOWED RANGE. NAME = xx (ALLOWED) yy – zz ' FATAL ERROR THE NAMELIST PARAMETER WAS NOT WITHIN THE PERMITTED RANGE.

```
MODIFY IS FINISHED
     6480 STARS OUTPUT
LAST STAR NUMBER IS        6480
```

Figure 6-7. Sample Output From CAT, MODIFY Trace Message

ROW DEFINITION

NUMBER	MAX. DECL.	MIN. DECL.	R.A. WIDTH	NO. FIRST ZONE	NUM. ZONES
1	90.00	60.00	360.00	1	1
2	75.00	45.00	60.00	2	6
3	60.00	30.00	30.00	8	12
4	45.00	15.00	22.50	20	16
5	30.00	0.0	18.00	36	20
6	15.00	-15.00	18.00	56	20
7	0.0	-30.00	18.00	76	20
8	-15.00	-45.00	22.50	96	16
9	-30.00	-60.00	30.00	112	12
10	-45.00	-75.00	60.00	124	6
11	-60.00	-90.00	360.00	130	1

Figure 6-8. Sample Output From CAT, Row Definition

ZONE DEFINITION

NUMBER	DECLINATIONS MIN.	DECLINATIONS MAX.	RIGHT ASCENSIONS MIN.	RIGHT ASCENSIONS MAX.
1	60.000	90.000	0.0	360.000
2	45.000	75.000	0.0	60.000
3	45.000	75.000	60.000	120.000
4	45.000	75.000	120.000	180.000
5	45.000	75.000	180.000	240.000
6	45.000	75.000	240.000	300.000
7	45.000	75.000	300.000	360.000
8	30.000	60.000	0.0	30.000
9	30.000	60.000	30.000	60.000
10	30.000	60.000	60.000	90.000
11	30.000	60.000	90.000	120.000
12	30.000	60.000	120.000	150.000
13	30.000	60.000	150.000	180.000
14	30.000	60.000	180.000	210.000
15	30.000	60.000	210.000	240.000
16	30.000	60.000	240.000	270.000
17	30.000	60.000	270.000	300.000
18	30.000	60.000	300.000	330.000
19	30.000	60.000	330.000	360.000
20	15.000	45.000	0.0	22.500
21	15.000	45.000	22.500	45.000
22	15.000	45.000	45.000	67.500
23	15.000	45.000	67.500	90.000
24	15.000	45.000	90.000	112.500
25	15.000	45.000	112.500	135.000
26	15.000	45.000	135.000	157.500
27	15.000	45.000	157.500	180.000
28	15.000	45.000	180.000	202.500
29	15.000	45.000	202.500	225.000
30	15.000	45.000	225.000	247.500
31	15.000	45.000	247.500	270.000
32	15.000	45.000	270.000	292.500
33	15.000	45.000	292.500	315.000
34	15.000	45.000	315.000	337.500
35	15.000	45.000	337.500	360.000
36	0.0	30.000	0.0	18.000
37	0.0	30.000	18.000	36.000
38	0.0	30.000	36.000	54.000
39	0.0	30.000	54.000	72.000
40	0.0	30.000	72.000	90.000
41	0.0	30.000	90.000	108.000
42	0.0	30.000	108.000	126.000
43	0.0	30.000	126.000	144.000
44	0.0	30.000	144.000	162.000
45	0.0	30.000	162.000	180.000
46	0.0	30.000	180.000	198.000
47	0.0	30.000	198.000	216.000
48	0.0	30.000	216.000	234.000
49	0.0	30.000	234.000	252.000
50	0.0	30.000	252.000	270.000
51	0.0	30.000	270.000	288.000
52	0.0	30.000	288.000	306.000
53	0.0	30.000	306.000	324.000
54	0.0	30.000	324.000	342.000
55	0.0	30.000	342.000	360.000
56	-15.000	15.000	0.0	18.000
57	-15.000	15.000	18.000	36.000
58	-15.000	15.000	36.000	54.000
59	-15.000	15.000	54.000	72.000
60	-15.000	15.000	72.000	90.000
61	-15.000	15.000	90.000	108.000
62	-15.000	15.000	108.000	126.000
63	-15.000	15.000	126.000	144.000
64	-15.000	15.000	144.000	162.000
65	-15.000	15.000	162.000	180.000
66	-15.000	15.000	180.000	198.000
67	-15.000	15.000	198.000	216.000
68	-15.000	15.000	216.000	234.000
69	-15.000	15.000	234.000	252.000
70	-15.000	15.000	252.000	270.000

Figure 6-9. Sample Output From CAT, Zone Definition

zone right ascension and the number of stars in the zone (Figure 6-10)

- Total number of stars included in one or more zones; total number of entries, and the actual redundancy factor (average number of entries per star) (Figure 6-11)

When in the catalog generation mode, the following is printed:

- A summary of errors occurring during catalog sorting, if any. The errors and actions that must be taken to correct them are discussed in Table 6-6.
- If the job terminates properly, the statement "END OF CATALOG" is printed.

When a full catalog printout has been requested (IFCAT=1), the contents of each subcatalog is printed, including the following:

- Star number
- G.I. unit vector
- Up to four other data words (Figure 6-12)

The last printed output from CAT is a summary of the parameters describing the zones. The summary, shown in Figure 6-13, includes the zone number, the coordinates of the zone center, the coordinates of the zone limits, the number of stars in the zone, and the output file record number for the first record of the subcatalog corresponding to the zone. Any zones containing more stars than indicated by NAMELIST parameter NMAX are flagged. A final sentence gives the maximum number of stars in any one zone.

6.6.3 Job Control Language

CAT may be run from a FORTRAN source or a load module. The JCL shown in Figure 6-14 assumes CAT is being run from a cataloged source data set named CAT.FORT, and that the input Mission Catalog is on a cataloged data set named INPUTCAT.DATA.

ORIGINAL PAGE IS
OF POOR QUALITY

ZONE COUNTS

ZONE	DECLINATIONS		RIGHT ASCENSIONS		NO. STARS
1	60.00	90.00	0.0	360.00	1080
2	45.00	75.00	0.0	60.00	180
3	45.00	75.00	60.00	120.00	180
4	45.00	75.00	120.00	180.00	180
5	45.00	75.00	180.00	240.00	180
6	45.00	75.00	240.00	300.00	180
7	45.00	75.00	300.00	360.00	180
8	30.00	60.00	0.0	30.00	90
9	30.00	60.00	30.00	60.00	90
10	30.00	60.00	60.00	90.00	90
11	30.00	60.00	90.00	120.00	90
12	30.00	60.00	120.00	150.00	90
13	30.00	60.00	150.00	180.00	90
14	30.00	60.00	180.00	210.00	90
15	30.00	60.00	210.00	240.00	90
16	30.00	60.00	240.00	270.00	90
17	30.00	60.00	270.00	300.00	90
18	30.00	60.00	300.00	330.00	90
19	30.00	60.00	330.00	360.00	90
20	15.00	45.00	0.0	22.50	90
21	15.00	45.00	22.50	45.00	60
22	15.00	45.00	45.00	67.50	60
23	15.00	45.00	67.50	90.00	60
24	15.00	45.00	90.00	112.50	90
25	15.00	45.00	112.50	135.00	60
26	15.00	45.00	135.00	157.50	60
27	15.00	45.00	157.50	180.00	60
28	15.00	45.00	180.00	202.50	90
29	15.00	45.00	202.50	225.00	60
30	15.00	45.00	225.00	247.50	60
31	15.00	45.00	247.50	270.00	60
32	15.00	45.00	270.00	292.50	90
33	15.00	45.00	292.50	315.00	60
34	15.00	45.00	315.00	337.50	60
35	15.00	45.00	337.50	360.00	60
36	0.0	30.00	0.0	18.00	60
37	0.0	30.00	18.00	36.00	60
38	0.0	30.00	36.00	54.00	60
39	0.0	30.00	54.00	72.00	60
40	0.0	30.00	72.00	90.00	30
41	0.0	30.00	90.00	108.00	60
42	0.0	30.00	108.00	126.00	60
43	0.0	30.00	126.00	144.00	60
44	0.0	30.00	144.00	162.00	60
45	0.0	30.00	162.00	180.00	30
46	0.0	30.00	180.00	198.00	60
47	0.0	30.00	198.00	216.00	60
48	0.0	30.00	216.00	234.00	60
49	0.0	30.00	234.00	252.00	60
50	0.0	30.00	252.00	270.00	30
51	0.0	30.00	270.00	288.00	60
52	0.0	30.00	288.00	306.00	60
53	0.0	30.00	306.00	324.00	60
54	0.0	30.00	324.00	342.00	60
55	0.0	30.00	342.00	360.00	30
56	-15.00	15.00	0.0	18.00	60
57	-15.00	15.00	18.00	36.00	60
58	-15.00	15.00	36.00	54.00	60
59	-15.00	15.00	54.00	72.00	60
60	-15.00	15.00	72.00	90.00	30
61	-15.00	15.00	90.00	108.00	60
62	-15.00	15.00	108.00	126.00	60
63	-15.00	15.00	126.00	144.00	60
64	-15.00	15.00	144.00	162.00	60
65	-15.00	15.00	162.00	180.00	30
66	-15.00	15.00	180.00	198.00	60
67	-15.00	15.00	198.00	216.00	60
68	-15.00	15.00	216.00	234.00	60
69	-15.00	15.00	234.00	252.00	60
70	-15.00	15.00	252.00	270.00	30
71	-15.00	15.00	270.00	288.00	60
72	-15.00	15.00	288.00	306.00	60
73	-15.00	15.00	306.00	324.00	60
74	-15.00	15.00	324.00	342.00	60
75	-15.00	15.00	342.00	360.00	30
76	-30.00	0.0	0.0	18.00	60
77	-30.00	0.0	18.00	36.00	60
78	-30.00	0.0	36.00	54.00	60
79	-30.00	0.0	54.00	72.00	60
80	-30.00	0.0	72.00	90.00	30
81	-30.00	0.0	90.00	108.00	60
82	-30.00	0.0	108.00	126.00	60

Figure 6-10. Sample Output From CAT, Zone Count Summary

ORIGINAL PAGE IS
OF POOR QUALITY

```
NUMBER OF STARS =       6480
TOTAL COUNTS =     11880
REDUNDANCY FACTOR =       1.8333

IF YOU STORE 6 WORDS OF DATA PER STAR,
  YOU WILL NEED      93 LOGICAL RECORDS ON FILE 30.

IF YOU OUTPUT A STAR CATALOG IN DIRECT-ACCESS FORMAT, IT WILL R EQUIRE    225 LOGICAL RECORDS ON FILE 90.
```

Figure 6-11. Sample Output From CAT, Star Count Predictions

ORIGINAL PAGE IS OF POOR QUALITY

ZONE 1 BEGINS AT RECORD 5

THIS ZONE IS A NORTH CIRCUMPOLAR ZONE WITH MINIMUM DECLINATION 60.00
NUMBER OF STARS IN ZONE = 1080

STAR NUMBER	X	Y	Z	OTHER DATA	
151	0.49240	0.00430	0.87040	2.61000	161.00000
152	0.47710	0.00420	0.87980	2.62000	162.00000
153	0.46170	0.00400	0.88700	2.63000	163.00000
154	0.44620	0.00390	0.89490	2.64000	164.00000
155	0.43050	0.00380	0.90260	2.65000	165.00000
156	0.41470	0.00360	0.91000	2.66000	166.00000
157	0.39870	0.00350	0.91710	2.67000	167.00000
158	0.38270	0.00330	0.92390	2.68000	168.00000
159	0.36650	0.00320	0.93040	2.69000	169.00000
160	0.35020	0.00310	0.93670	2.70000	170.00000
161	0.33380	0.00290	0.94260	2.71000	171.00000
162	0.31730	0.00280	0.94830	2.72000	172.00000
163	0.30070	0.00260	0.95370	2.73000	173.00000
164	0.28400	0.00250	0.95880	2.74000	174.00000
165	0.26720	0.00230	0.96360	2.75000	175.00000
166	0.25040	0.00220	0.96810	2.76000	176.00000
167	0.23340	0.00200	0.97240	2.77000	177.00000
168	0.21640	0.00190	0.97630	2.78000	178.00000
169	0.19940	0.00170	0.97990	2.79000	179.00000
170	0.18220	0.00160	0.98330	2.80000	180.00000
171	0.16500	0.00140	0.98630	2.81000	181.00000
172	0.14730	0.00130	0.98900	2.82000	182.00000
173	0.13050	0.00110	0.99140	2.83000	183.00000
174	0.11320	0.00100	0.99360	2.84000	184.00000
175	0.09590	0.00080	0.99540	2.85000	185.00000
176	0.07850	0.00070	0.99690	2.86000	186.00000
177	0.06100	0.00050	0.99810	2.87000	187.00000
178	0.04360	0.00040	0.99900	2.88000	188.00000
179	0.02620	0.00020	0.99970	2.89000	189.00000
180	0.00870	0.00010	1.00000	2.90000	190.00000
331	0.43420	0.08970	0.87040	2.71000	171.00000
332	0.45920	0.08700	0.87980	2.72000	172.00000
333	0.45410	0.08410	0.88700	2.73000	173.00000
334	0.43470	0.08130	0.89490	2.74000	174.00000
335	0.42330	0.07850	0.90260	2.75000	175.00000
336	0.40770	0.07560	0.91000	2.76000	176.00000
337	0.39210	0.07270	0.91710	2.77000	177.00000
338	0.37630	0.06970	0.92390	2.78000	178.00000
339	0.36040	0.06680	0.93040	2.79000	179.00000
340	0.34430	0.06380	0.93670	2.80000	180.00000
341	0.32820	0.06080	0.94260	2.81000	181.00000
342	0.31200	0.05780	0.94830	2.82000	182.00000
343	0.29570	0.05480	0.95370	2.83000	183.00000
344	0.27930	0.05180	0.95880	2.84000	184.00000
345	0.26280	0.04870	0.96360	2.85000	185.00000
346	0.24620	0.04560	0.96810	2.86000	186.00000
347	0.22950	0.04250	0.97240	2.87000	187.00000
348	0.21280	0.03940	0.97630	2.88000	188.00000
349	0.19600	0.03630	0.97990	2.89000	189.00000
350	0.17920	0.03320	0.98330	2.90000	190.00000
351	0.16230	0.03010	0.98630	2.91000	191.00000
352	0.14530	0.02690	0.98900	2.92000	192.00000
353	0.12830	0.02380	0.99140	2.93000	193.00000
354	0.11130	0.02060	0.99360	2.94000	194.00000
355	0.09420	0.01750	0.99540	2.95000	195.00000
356	0.07710	0.01430	0.99690	2.96000	196.00000
357	0.06000	0.01110	0.99810	2.97000	197.00000
358	0.04290	0.00790	0.99900	2.98000	198.00000
359	0.02570	0.00480	0.99970	2.99000	199.00000
360	0.00860	0.00160	1.00000	3.00000	200.00000
511	0.46120	0.17250	0.87040	2.81000	181.00000
512	0.44690	0.16710	0.87880	2.82000	182.00000
513	0.43250	0.16170	0.88700	2.83000	183.00000
514	0.41790	0.15630	0.89490	2.84000	184.00000
515	0.40320	0.15080	0.90260	2.85000	185.00000
516	0.38840	0.14520	0.91000	2.86000	186.00000
517	0.37350	0.13960	0.91710	2.87000	187.00000
518	0.35840	0.13400	0.92390	2.88000	188.00000
519	0.34330	0.12840	0.93040	2.89000	189.00000
520	0.32800	0.12260	0.93670	2.90000	190.00000
521	0.31270	0.11690	0.94260	2.91000	191.00000
522	0.29720	0.11110	0.94830	2.92000	192.00000
523	0.28170	0.10530	0.95370	2.93000	193.00000
524	0.26600	0.09950	0.95880	2.94000	194.00000
525	0.25030	0.09360	0.96360	2.95000	195.00000
526	0.23450	0.08770	0.96810	2.96000	196.00000
527	0.21870	0.08180	0.97240	2.97000	197.00000

Figure 6-12. Truncated Sample Output From CAT, Run Catalog Subcatalog Contents

SUMMARY

ZONE	ZONE CENTER R.A.	ZONE CENTER DECL.	R.A. ZONE LIMITS MIN.	R.A. ZONE LIMITS MAX.	DECL. ZONE LIMITS MAX.	DECL. ZONE LIMITS MIN.	STARS IN ZONE	FIRST RECORD
1	180.000	75.000	0.0	360.000	90.000	60.000	1080	9
2	30.000	60.000	0.0	60.000	75.000	45.000	180	25
3	90.000	60.000	60.000	120.000	75.000	45.000	180	28
4	150.000	60.000	120.000	180.000	75.000	45.000	180	31
5	210.000	60.000	180.000	240.000	75.000	45.000	180	34
6	270.000	60.000	240.000	300.000	75.000	45.000	180	37
7	330.000	60.000	300.000	360.000	75.000	45.000	180	40
8	15.000	45.000	0.0	30.000	60.000	30.000	90	43
9	45.000	45.000	30.000	60.000	60.000	30.000	90	45
10	75.000	45.000	60.000	90.000	60.000	30.000	90	47
11	105.000	45.000	90.000	120.000	60.000	30.000	90	49
12	135.000	45.000	120.000	150.000	60.000	30.000	90	51
13	165.000	45.000	150.000	180.000	60.000	30.000	90	53
14	195.000	45.000	180.000	210.000	60.000	30.000	90	55
15	225.000	45.000	210.000	240.000	60.000	30.000	90	57
16	255.000	45.000	240.000	270.000	60.000	30.000	90	59
17	285.000	45.000	270.000	300.000	60.000	30.000	90	61
18	315.000	45.000	300.000	330.000	60.000	30.000	90	63
19	345.000	45.000	330.000	360.000	60.000	30.000	90	65
20	11.250	30.000	0.0	22.500	45.000	15.000	90	67
21	33.750	30.000	22.500	45.000	45.000	15.000	60	69
22	56.250	30.000	45.000	67.500	45.000	15.000	60	70
23	78.750	30.000	67.500	90.000	45.000	15.000	60	71
24	101.250	30.000	90.000	112.500	45.000	15.000	90	72
25	123.750	30.000	112.500	135.000	45.000	15.000	60	74
26	146.250	30.000	135.000	157.500	45.000	15.000	60	75
27	168.750	30.000	157.500	180.000	45.000	15.000	60	76
28	191.250	30.000	180.000	202.500	45.000	15.000	90	77
29	213.750	30.000	202.500	225.000	45.000	15.000	60	79
30	236.250	30.000	225.000	247.500	45.000	15.000	60	80
31	258.750	30.000	247.500	270.000	45.000	15.000	60	81
32	281.250	30.000	270.000	292.500	45.000	15.000	90	82
33	303.750	30.000	292.500	315.000	45.000	15.000	60	84
34	326.250	30.000	315.000	337.500	45.000	15.000	60	85
35	348.750	30.000	337.500	360.000	45.000	15.000	60	86
36	9.000	15.000	0.0	18.000	30.000	0.0	60	87
37	27.000	15.000	18.000	36.000	30.000	0.0	60	88
38	45.000	15.000	36.000	54.000	30.000	0.0	60	89
39	63.000	15.000	54.000	72.000	30.000	0.0	60	90
40	81.000	15.000	72.000	90.000	30.000	0.0	30	91
41	99.000	15.000	90.000	108.000	30.000	0.0	60	92
42	117.000	15.000	108.000	126.000	30.000	0.0	60	93
43	135.000	15.000	126.000	144.000	30.000	0.0	60	94
44	153.000	15.000	144.000	162.000	30.000	0.0	60	95
45	171.000	15.000	162.000	180.000	30.000	0.0	30	96
46	189.000	15.000	180.000	198.000	30.000	0.0	60	97
47	207.000	15.000	198.000	216.000	30.000	0.0	60	98
48	225.000	15.000	216.000	234.000	30.000	0.0	60	99
49	243.000	15.000	234.000	252.000	30.000	0.0	60	100
50	261.000	15.000	252.000	270.000	30.000	0.0	30	101
51	279.000	15.000	270.000	288.000	30.000	0.0	60	102
52	297.000	15.000	288.000	306.000	30.000	0.0	60	103
53	315.000	15.000	306.000	324.000	30.000	0.0	60	104
54	333.000	15.000	324.000	342.000	30.000	0.0	60	105
55	351.000	15.000	342.000	360.000	30.000	0.0	30	106
56	9.000	0.0	0.0	18.000	15.000	-15.000	60	107
57	27.000	0.0	18.000	36.000	15.000	-15.000	60	108
58	45.000	0.0	36.000	54.000	15.000	-15.000	60	109
59	63.000	0.0	54.000	72.000	15.000	-15.000	60	110
60	81.000	0.0	72.000	90.000	15.000	-15.000	30	111
61	99.000	0.0	90.000	108.000	15.000	-15.000	60	112
62	117.000	0.0	108.000	126.000	15.000	-15.000	60	113
63	135.000	0.0	126.000	144.000	15.000	-15.000	60	114
64	153.000	0.0	144.000	162.000	15.000	-15.000	60	115
65	171.000	0.0	162.000	180.000	15.000	-15.000	30	116
66	189.000	0.0	180.000	198.000	15.000	-15.000	60	117
67	207.000	0.0	198.000	216.000	15.000	-15.000	60	118
68	225.000	0.0	216.000	234.000	15.000	-15.000	60	119
69	243.000	0.0	234.000	252.000	15.000	-15.000	60	120

ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
~~ERROR -- NSTARS EXCEEDS 100~~

Figure 6-13. Sample Output From CAT, Run Catalog Summary (1 of 2)

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SUMMARY

ZONE	ZONE CENTER R.A.	ZONE CENTER DECL.	R.A. ZONE LIMITS MIN.	R.A. ZONE LIMITS MAX.	DECL. ZONE LIMITS MAX.	DECL. ZONE LIMITS MIN.	STARS IN ZONE	FIRST RECORD
70	261.000	0.0	252.000	270.000	15.000	-15.000	30	121
71	279.000	0.0	270.000	288.000	15.000	-15.000	60	122
72	297.000	0.0	288.000	306.000	15.000	-15.000	60	123
73	315.000	0.0	306.000	324.000	15.000	-15.000	60	124
74	333.000	0.0	324.000	342.000	15.000	-15.000	60	125
75	351.000	0.0	342.000	360.000	15.000	-15.000	30	126
76	9.000	-15.000	0.0	18.000	0.0	-30.000	60	127
77	27.000	-15.000	18.000	36.000	0.0	-30.000	60	128
78	45.000	-15.000	36.000	54.000	0.0	-30.000	60	129
79	63.000	-15.000	54.000	72.000	0.0	-30.000	60	130
80	81.000	-15.000	72.000	90.000	0.0	-30.000	30	131
81	99.000	-15.000	90.000	108.000	0.0	-30.000	60	132
82	117.000	-15.000	108.000	126.000	0.0	-30.000	60	133
83	135.000	-15.000	126.000	144.000	0.0	-30.000	60	134
84	153.000	-15.000	144.000	162.000	0.0	-30.000	60	135
85	171.000	-15.000	162.000	180.000	0.0	-30.000	30	136
86	189.000	-15.000	180.000	198.000	0.0	-30.000	60	137
87	207.000	-15.000	198.000	216.000	0.0	-30.000	60	138
88	225.000	-15.000	216.000	234.000	0.0	-30.000	60	139
89	243.000	-15.000	234.000	252.000	0.0	-30.000	60	140
90	261.000	-15.000	252.000	270.000	0.0	-30.000	30	141
91	279.000	-15.000	270.000	288.000	0.0	-30.000	60	142
92	297.000	-15.000	288.000	306.000	0.0	-30.000	60	143
93	315.000	-15.000	306.000	324.000	0.0	-30.000	60	144
94	333.000	-15.000	324.000	342.000	0.0	-30.000	60	145
95	351.000	-15.000	342.000	360.000	0.0	-30.000	30	146
96	11.250	-30.000	0.0	22.500	-15.000	-45.000	90	147
97	33.750	-30.000	22.500	45.000	-15.000	-45.000	60	149
98	56.250	-30.000	45.000	67.500	-15.000	-45.000	60	150
99	78.750	-30.000	67.500	90.000	-15.000	-45.000	60	151
100	101.250	-30.000	90.000	112.500	-15.000	-45.000	90	152
101	123.750	-30.000	112.500	135.000	-15.000	-45.000	60	154
102	146.250	-30.000	135.000	157.500	-15.000	-45.000	60	155
103	168.750	-30.000	157.500	180.000	-15.000	-45.000	60	156
104	191.250	-30.000	180.000	202.500	-15.000	-45.000	90	157
105	213.750	-30.000	202.500	225.000	-15.000	-45.000	60	159
106	236.250	-30.000	225.000	247.500	-15.000	-45.000	60	160
107	258.750	-30.000	247.500	270.000	-15.000	-45.000	60	161
108	281.250	-30.000	270.000	292.500	-15.000	-45.000	90	162
109	303.750	-30.000	292.500	315.000	-15.000	-45.000	60	164
110	326.250	-30.000	315.000	337.500	-15.000	-45.000	60	165
111	348.750	-30.000	337.500	360.000	-15.000	-45.000	60	166
112	15.000	-45.000	0.0	30.000	-30.000	-60.000	90	167
113	45.000	-45.000	30.000	60.000	-30.000	-60.000	90	169
114	75.000	-45.000	60.000	90.000	-30.000	-60.000	90	171
115	105.000	-45.000	90.000	120.000	-30.000	-60.000	90	173
116	135.000	-45.000	120.000	150.000	-30.000	-60.000	90	175
117	165.000	-45.000	150.000	180.000	-30.000	-60.000	90	177
118	195.000	-45.000	180.000	210.000	-30.000	-60.000	90	179
119	225.000	-45.000	210.000	240.000	-30.000	-60.000	90	181
120	255.000	-45.000	240.000	270.000	-30.000	-60.000	90	183
121	285.000	-45.000	270.000	300.000	-30.000	-60.000	90	185
122	315.000	-45.000	300.000	330.000	-30.000	-60.000	90	187
123	345.000	-45.000	330.000	360.000	-30.000	-60.000	90	189
124	30.000	-60.000	0.0	60.000	-45.000	-75.000	180	191
125	90.000	-60.000	60.000	120.000	-45.000	-75.000	180	194
126	150.000	-60.000	120.000	180.000	-45.000	-75.000	180	197
127	210.000	-60.000	180.000	240.000	-45.000	-75.000	180	200
128	270.000	-60.000	240.000	300.000	-45.000	-75.000	180	203
129	330.000	-60.000	300.000	360.000	-45.000	-75.000	180	206
130	180.000	-75.000	0.0	360.000	-60.000	-90.000	1080	209

ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100
ERROR -- NSTARS EXCEEDS 100

MAXIMUM NUMBER OF STARS IN ANY ZONE = 1080
MAXIMUM DESIRED WAS = 100

Figure 6-13. Sample Output From CAT, Run Catalog Summary (2 of 2)

```
//            JOB CARD GOES HERE
//ƀEXECƀFORTRANH,REGION=330K
//SYSINƀ DDƀ DSN=CAT.FORT,DISP=SHR
/*
//ƀEXECƀLOADER,REGION=350K,PARM='SIZE=350000'
//FT30F001ƀ DDƀ DSN=&&SCR1,UNIT=DISK,
1
//ƀƀSPACE=(1640,2000),DISP=(NEW,PASS),DCB=(DSORB=DA)
2 //FT50F001 ƀ DD ƀDSN=&&SCR2,UNIT=DISK,
//ƀƀSPACE=(TRK,100),DCB=(RECFM=FB,LRECL=80,BLKSIZE=7280),
3
//ƀƀDISP=(NEW,PASS)
4
//FT52F001ƀ DD ƀ DSN=INPUTCAT.DATA,DISP=SHR
5 //FT80F001ƀ DD ƀ UNIT=2400-9,VOL=SER=XXXXXX,
6
//ƀƀLABEL=(1,BLP),DISP=(NEW,KEEP),
7
//ƀƀDCB=(RECFM=FB,LRECL=1640,BLKSIZE=6560)
8 //FT90F001ƀ DD ƀDSN=CATFINAL.DATA,DISP=SHR
9
/*
//
```

NOTES

1 – THE 2000 REFERS TO THE NUMBER OF LOGICAL RECORDS IN THE FILE. IT MUST BE AT LEAST AS LARGE AS THE NUMBER OF LOGICAL RECORDS ASSIGNED TO FILE 30 IN THE DEFINE FILE STATEMENT IN THE MAIN PROGRAM (SEE SECTION 6.6.1.3.3)

2 – THIS FILE IS INCLUDED ONLY IF MODIFY WILL BE EXECUTED

3 – THE NUMBER OF TRACKS REQUIRED FOR FILE 50 IS EQUAL TO THE NUMBER OF STARS IN THE INPUT CATALOG DIVIDED BY 91

4 – THE FILE NUMBER FOR THIS FILE MUST EQUAL THE NAMELIST PARAMETER IFILE THE DEFAULT VALUE OF 52 IS SHOWN.

5 – THIS FILE IS INCLUDED ONLY IF OUTPUT IS SEQUENTIAL IT IS NOT NEEDED IN STAR COUNTING MODE. THIS DD STATEMENT IS FOR A TAPE, BUT SEQUENTIAL DISK OUTPUT IS ALSO POSSIBLE.

6 – xxxxxx IS REPLACED BY A TAPE NUMBER.

7 – THIS INDICATES OUTPUT ON THE FIRST FILE OF THE TAPE. ALTER THIS NUMBER AS NEEDED.

8 – THIS FILE IS INCLUDED FOR DIRECT-ACCESS OUTPUT ONLY IT IS NOT NEEDED IN STAR COUNTING MODE.

9 – THIS DATASET NAME MAY BE REPLACED AS NEEDED IT IS ASSUMED TO BE A PREVIOUSLY CATALOGED DATA SET OF DCB=(DSORG=DA) AND SPACE=(1640,xxxx), WHERE xxxx IS AT LEAST AS LARGE AS THE NUMBER OF LOGICAL RECORDS ALLOCATED TO FILE 90 IN THE DEFINE FILE STATEMENT IN THE MAIN PROGRAM. (SEE SECTION 6 6 1 3 3)

Figure 6-14. JCL To Execute Program CAT From Source Library

6.6.4 Overlay Considerations

Overlay is not useful within CAT because there are no major subroutines.

6.6.5 System Resources

CAT is designed to run on the IBM S/360-95 computer under OS/HASP or OS/MVT. CAT requires 330K bytes of main storage for the FORTRAN H compiler and 350K bytes for LOADER.

Temporary disk storage is needed for files 30 and 50. File 30 requires N/4 tracks, where N is the number of logical records allocated file 30 in the DEFINE FILE statement in the MAIN program. This file holds the sorted data overflowing from core arrays during the sorting process and therefore must contain enough room for all star data for 50 zones. File 50 is needed only if MODIFY is to be called. It requires M/91 tracks of temporary disk storage where M is the number of stars in the input catalog.

If output is direct-access, an additional data set is required for file 90. The data set requires L/4 tracks of disk storage, where L = the number of logical records allocated file 90 in the DEFINE FILE statement in the MAIN program. L can be determined by running CAT in star count mode (Sections 6.2.2.2 and 6.6.2.2).

6.6.6 Execution Time Estimates

The central processing unit (CPU) and input/output (I/O) execution times required to run program CAT have been investigated for the following situation.

An input star catalog on disk with DCB=(RECFM=FB, LRECL=80, BLKSIZE=7280) was used. CAT was executed in catalog generation mode, with the limited printout option (IFCAT=0) and MODIFY was executed to convert right ascension and declination to the G. I. unit vector.

The CPU and I/O times required for direct-access (disk) output under OS/HASP can be approximated by

$$\text{CPU} = \frac{S}{10000}(0.84 + 0.007Z) \qquad \text{Seconds}$$

$$\text{I/O} = 3.30 + 1.17 \times \frac{S}{10000} \qquad \text{Seconds}$$

where CPU = CPU time in seconds for low speed core

I/O = I/O time in seconds

S = number of stars in input catalog

Z = number of zones generated (see Table 6-1)

For sequential (tape) output,

$$\text{CPU} = \frac{S}{10000}(0.69 + 0.0080Z) \qquad \text{Seconds}$$

$$\text{I/O} = 2.00 + 0.37 \times \frac{S}{10000} \qquad \text{Seconds}$$

For both direct-access and sequential (tape) output, the I/O time is only a weak function of the number of zones. Neither CPU nor I/O time is significantly dependent on the number of words of data per star.

Printout of the entire catalog (IFCAT=1) requires approximately 0.5 minute more CPU and 0.3 minute more I/O per 10,000 stars in the input catalog.

Star counting mode uses about one-fourth the CPU and approximately the same I/O as sequential (tape) output catalog generation jobs.

SECTION 7 - RUN CATALOG DATA MANAGEMENT

Routines using the Run Catalog, specifically program LOOKAT, reference it by reading a direct-access (disk) version of the Run Catalog.

When the Run Catalog is created by program CAT, it may be in either sequential (tape or disk) or direct-access format. The normal mode of operation creates the Run Catalog on tape in sequential format. The entire Run Catalog, or those portions which the user anticipates needing (which may be referred to as the "selected" Run Catalog), are then loaded onto a direct-access disk file by program SWITCH. This procedure provides a tape backup for the disk file and allows saving of disk storage when only portions of the Run Catalog will be needed.

7.1 CAPABILITIES OF PROGRAM SWITCH

Program SWITCH has two basic functions, as follows:

- Copying the Run Catalog, or portions of the Run Catalog, from one file to another, simultaneously converting it between sequential and direct-access file format, if desired
- Selecting portions of the Run Catalog for transfer to an output file

In addition, SWITCH permits the following:

- Execution in foreground mode under timesharing option (TSO), with monitoring messages output to the TSO terminal. This is possible only when no tapes are involved.
- Simultaneous processing of up to six camera mounting positions on the spacecraft.

- Specification of Run Catalog zones to be transferred to the output file by any of the following methods:
  - Specification of the zone numbers to be transferred;
  - Specification of an array of camera optical axis pointings; or,
  - Specification of the spin axis pointing and camera elevation angle and field of view; this results in all zones along the path taken by the camera optical axis during one spacecraft rotation being selected.
- Printout of the entire (selected) Run Catalog.

7.2 PROGRAM SWITCH LOGICAL FLOW

Figure 7-1 is a logical flow chart for program SWITCH.

NAMELIST parameters which control program flow are read from an input file. The NAMELIST record images are printed to provide the user with a convenient means of checking his input. Since some input files cannot be rewound, the NAMELIST card images are simultaneously written on a temporary disk file. This file is then rewound and a regular NAMELIST read performed. NAMELIST parameter values are checked to ensure that they are within permissible limits. If they are not, an error message is printed and SWITCH stops. A formatted output of all relevant NAMELIST parameters is printed.

Next, the first record of the input file (Run Catalog) is read. This record contains control words describing the format of the Run Catalog. It also contains the user-input title, time, and NAMELIST parameter values that were used by program CAT to generate the full Run Catalog. This information is printed so that the user can determine if the correct input catalog is being used. The control record formats are discussed in Section 6.6.2.1.3.

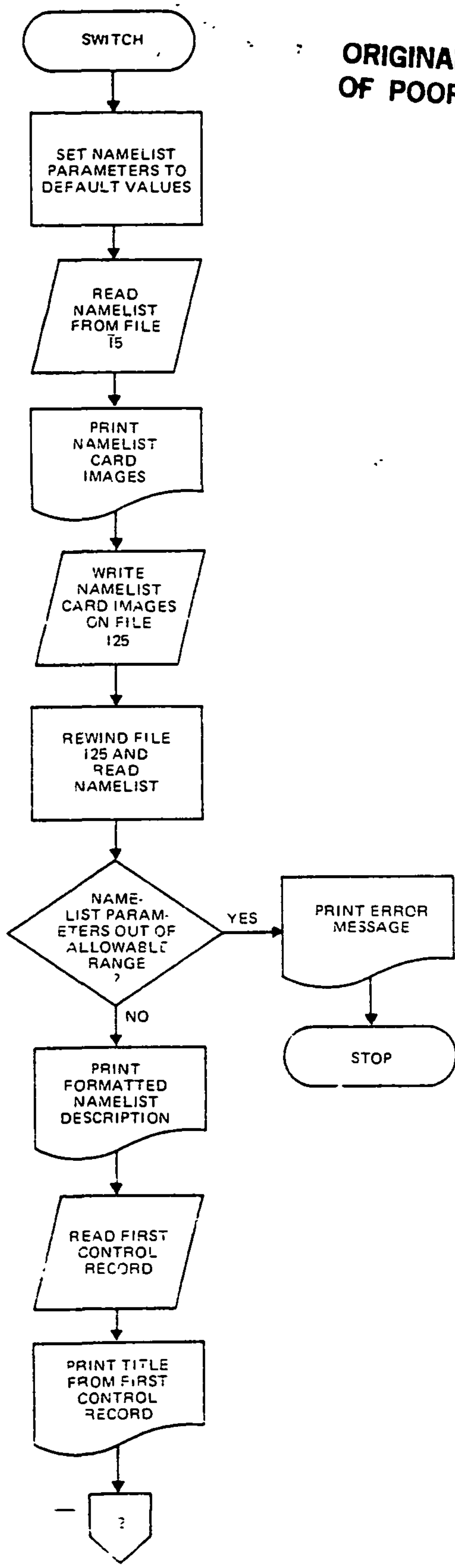

Figure 7-1. Logical Data Flow for Program SWITCH (1 of 4)

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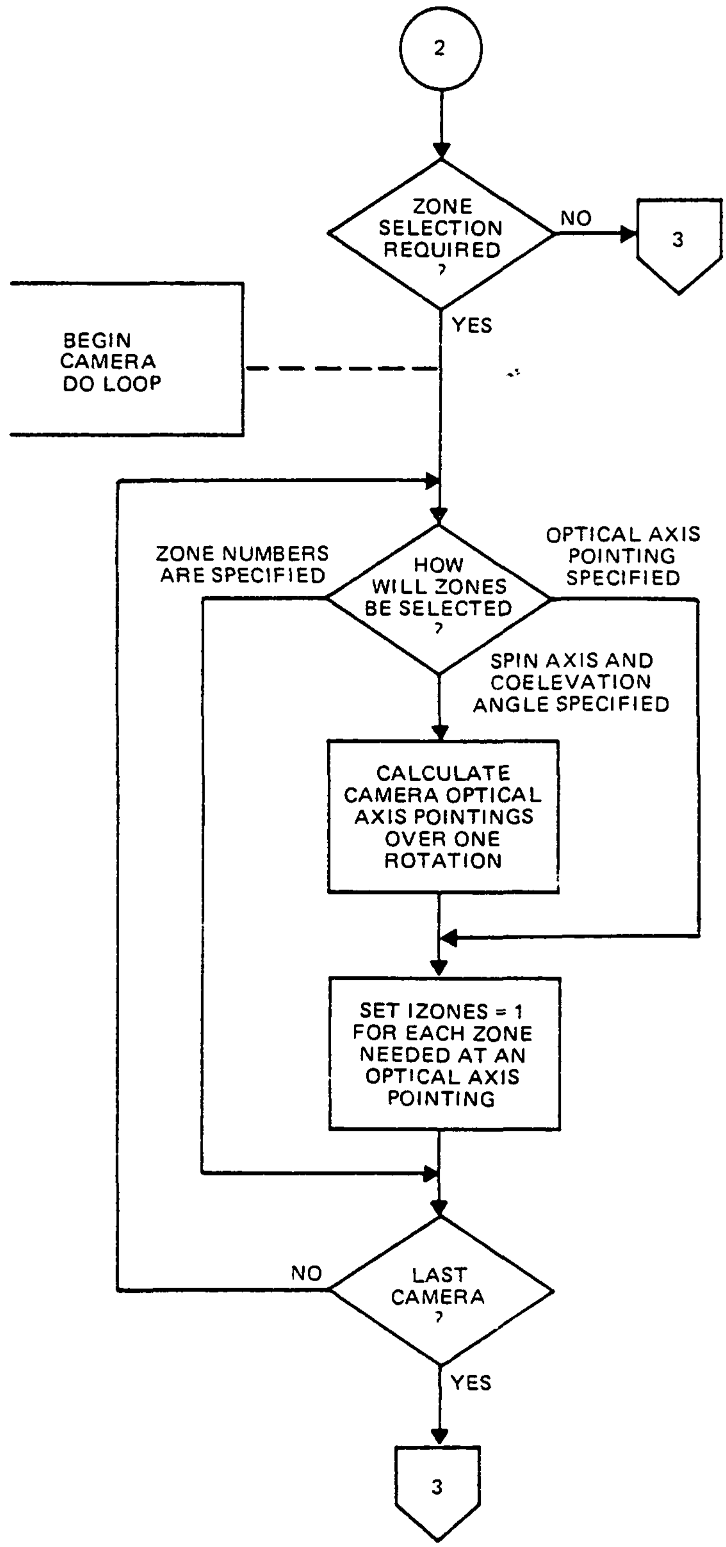

Figure 7-1. Logical Data Flow for Program SWITCH (2 of 4)

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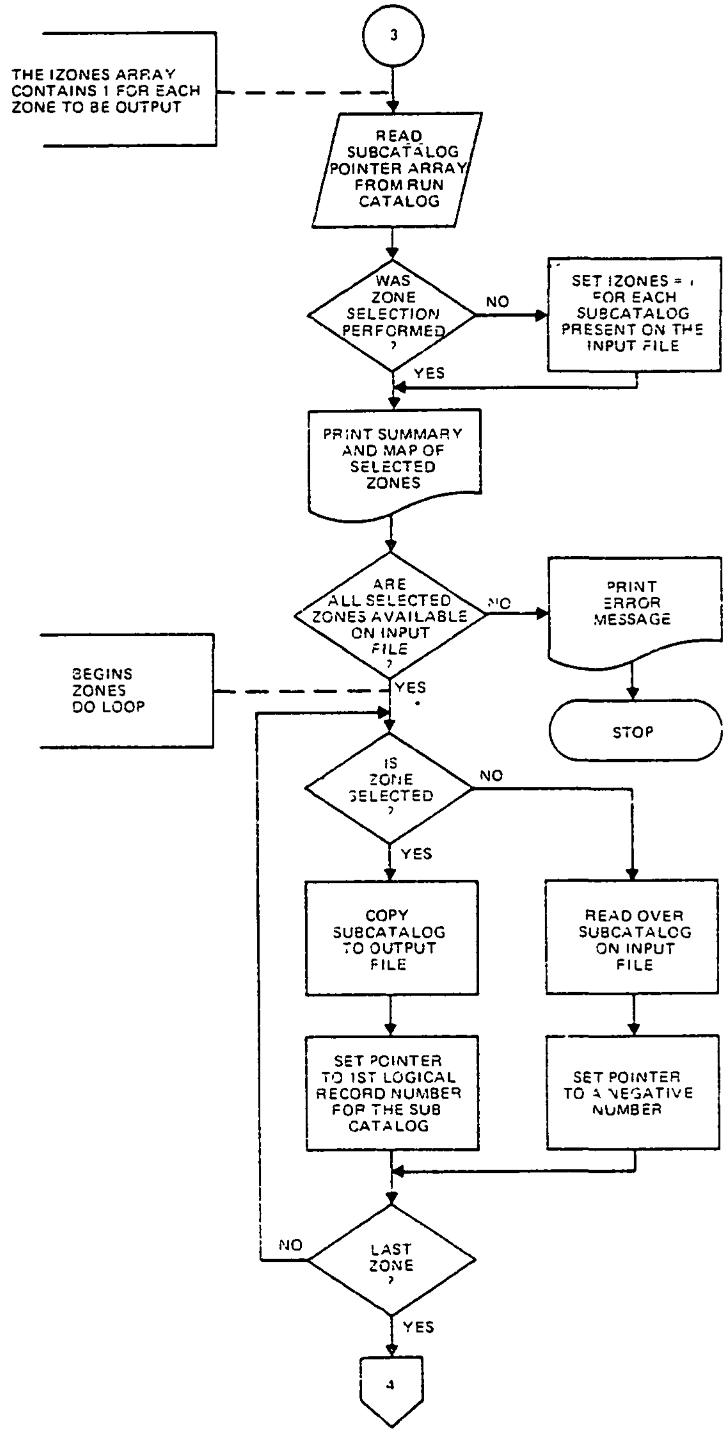

Figure 7-1. Logical Data Flow for Program SWITCH (3 of 4)

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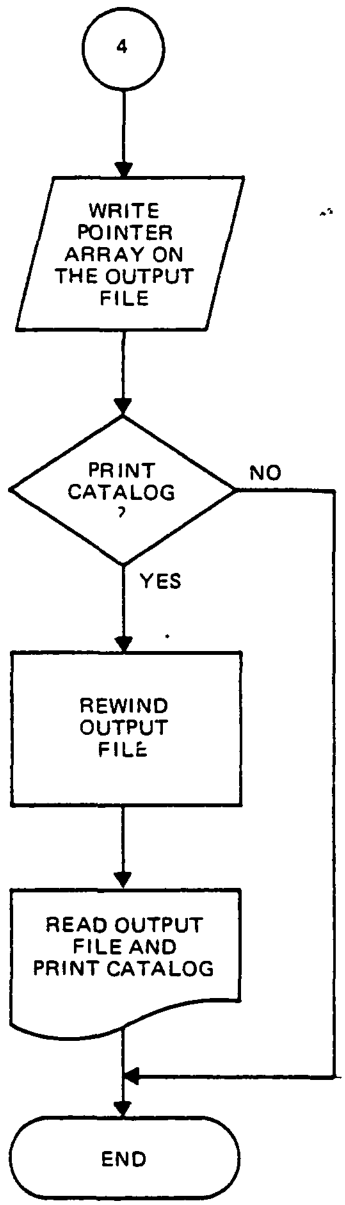


Figure 7-1. Logical Data Flow for Program SWITCH (4 of 4)

7.2.1 Zone Selection

SWITCH determines which subcatalogs to write on the output file by computing the IZONES array, which contains the zone selection flags. IZONES(I) = 1 if subcatalog number I is to be written on the output file. If it is not, IZONES(I) = 0 .

If the entire Run Catalog is to be output, IZONES(I) is set to 1 for all subcatalogs. If only portions of the Run Catalog are to be output, zone selection is performed for each of up to six camera/spin axis combinations. The zones required for each camera are flagged with a 1 in the IZONES array.

For each camera, the required zones may be selected in one of three ways.

- Case 1: The user determines which zones will be needed by some manual technique and inputs the number of these zones.
- Case 2: The user specifies a spin axis pointing, an angle between the spin axis and camera optical axis (coelevation angle), and a field-of-view factor as defined in Section 7.3. SWITCH selects the zones necessary for all camera optical axis pointings within the path taken by the camera optical axis during a complete spacecraft rotation.
- Case 3: The user specifies an array of optical axis pointings. SWITCH selects the zones necessary for each pointing in the array, and for a user input field of view about the pointing.

Zone selection is now complete.

The subcatalog pointer array defined in Section 6.6.2.1.3 is read from the input file. For each subcatalog in the input file, the array IPOINT contains the number of the first logical record of that subcatalog. A negative value in IPOINT means the subcatalog is not available on the input file.

If zone selection was performed, the IZONES array now contains a 1 for each subcatalog to be transferred to the output catalog. If selection was not performed, IZONES is set to 1 for every subcatalog available on the input file and is set to 0 for the unavailable subcatalogs. A summary of the selected zones is printed and a right ascension/declination plot showing the portion of the sky they cover is generated.

SWITCH ensures that every zone selected for output is available on the input file. If one or more is not, an error message is printed and SWITCH stops.

7.2.2 Creation of the Output Catalog

SWITCH creates the output Run Catalog by transferring each selected subcatalog from the input file to the output file.

An index keeps track of the logical record number being written on the output file. The pointer array, IPOINT, is set to the output file logical record number for the first subcatalog record.

If the zone is not to be output, but is present on the input file, the subcatalog is read from the input file without being written on the output file. This positions the input device to the start of the next subcatalog. In this case, the IPOINT array value is set to the negative of the next output record number, thereby indicating that the zone is not present.

When all zones have been processed, the IPOINT array is written on the second through eighth records of a direct-access output file, or as the last seven records of a sequential file.

If requested, the output file is rewound, read, and a printed output produced. The message "END OF CATALOG" is printed and SWITCH stops.

7.3 MATHEMATICAL SPECIFICATIONS

7.3.1 Calculating Optical Axis Pointings

The zones that SWITCH transfers to the output file are selected from a set of zone numbers directly, or from optical axis pointings. The pointings, in turn, can be specified in either of two ways, defined in Section 7.2.1 as Case 2 and Case 3. Case 3 degenerates to Case 2 with a coelevation angle of 0.0 degrees. Therefore, this section shows only how the optical axis pointings are generated for Case 2.

The camera optical axis path is calculated at small discrete intervals as it sweeps out a path about the spin axis. Additional paths are computed at intervals of half the zone height until limits are reached. The limits are computed from

$$\text{limits} = \theta = \text{FOV} \qquad (7\text{-}1)$$

where θ = angle between the spin axis and the camera optical axis
FOV = radius of the field of view (NAMELIST parameter FOV)

The following procedure is used to calculate the discrete camera optical axis pointings in G.I. coordinates for a band with coelevation angle θ. Each additional band is computed the same way, with θ appropriately altered.

Let α, δ = spin axis right ascension and declination, respectively
θ = angle between the spin axis and the camera optical axis
β = angular separation between the discrete optical axis points to be calculated

Define a coordinate system such that the z'-axis is the spin axis. The x'- and y'-axes are arbitrary subject to the constraints that the coordinate system be right-handed and orthonomal, as shown in Figure 7-2.

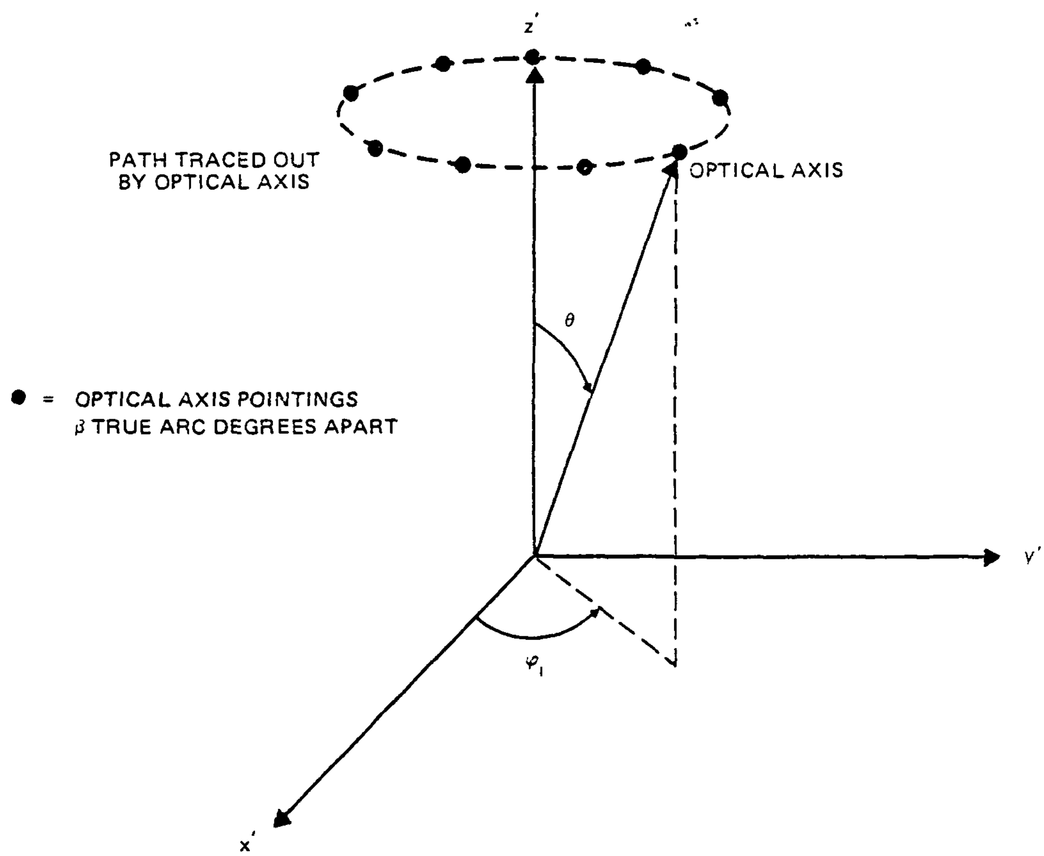


Figure 7-2. Spin Axis Coordinate System

Consider a set of optical axis pointings in this coordinate system:

$$\left.\begin{aligned} x_i' &= \cos\varphi_i \sin\theta \\ y_i' &= \sin\varphi_i \sin\theta \\ z_i' &= \cos\theta \end{aligned}\right\} i = 1, \ldots, N \qquad (7\text{-}2)$$

where

$$\varphi_i = (i - 1)\frac{\beta}{\sin\theta} \qquad i = 1, \ldots, N \qquad (7\text{-}3)$$

This yields a set of points in the x', y', z' coordinate system (the spin axis coordinate system) with angular separation β . Define N such that

$$N = \frac{2\pi \sin\theta}{\beta} \qquad (7\text{-}4)$$

Round N up to the next highest integer and ensure that $\sin\theta$ in Equations (7-3) and (7-4) is set to 0.01 if it is actually less than that. N is now the number of pointings needed for one complete spacecraft rotation, and (x_i', y_i', z_i') , for $i = 1, \ldots, N$, are the required pointings in the spin axis frame. Define A as the matrix that transforms a vector from the spin axis coordinate system to the G.I. system.

$$A = \begin{bmatrix} \cos\alpha \sin\delta & -\sin\alpha & \cos\alpha \cos\delta \\ \sin\alpha \sin\delta & \cos\alpha & \sin\alpha \cos\delta \\ -\cos\delta & 0 & \sin\delta \end{bmatrix} \qquad (7\text{-}5)$$

where α = spin axis right ascension

δ = spin axis declination

Then:

$$[x\ y\ z]_i = [A]\begin{bmatrix} x' \\ y' \\ z' \end{bmatrix}_i \qquad i = 1, \ldots, N \tag{7-6}$$

where $[x, y, z]_i$ are the required optical axis pointings in the G.I. frame.

7.3.2 Zone Number Calculation

Given an optical axis pointing, SWITCH determines the number of the zones needed to access stars in its vicinity.

Recall that the sky was divided into overlapping rows defined by a range of declination (Section 6.3.2). A star is in row j provided that

$$\delta_j - W \leq \delta^* \leq \delta_j \tag{7-7}$$

where δ^* = declination of the star in degrees

δ_j = northern limiting declination of the jth row in degrees, obtained from the Run Catalog header records (see Section 6.6.2.1)

W = declination zone height

Each row is divided into zones. The arc-width of the zones in each row is defined in the Run Catalog header records.

Zones are numbered sequentially starting at row 1, and within a row, sequentially in order of increasing right ascension. The zone number, Z, for a particular optical axis pointing α_0, δ_0 is,

$$Z = N_j + (\alpha_0/\Delta A_j) \tag{7-8}$$

truncated to an integer

where α_0 = right ascension of the optical axis in degrees

ΔA_j = the right ascension width of the zones in the jth row, in degrees and obtained from the Run Catalog header records (see Section 6.6.2.1)

j = the row number, which is given by

$$j = \left(0.5 + \frac{2.0\ (90.0 - \delta_0)}{W} \right) \tag{7-9}$$

where $(\ldots)$ = the greatest integer contained in the expression

W = the zone height, in degrees, also obtained from the Run Catalog header records

Z is the number of the zone whose center is nearest the optical axis pointing. Except for circumpolar zones, two zones adjacent in right ascension are combined to form a region whose right ascension arc-width at least equals its height. To calculate the number of the remaining (adjacent) zone, the central right ascension of zone number Z is computed from

$$C = (Z - N_j)\ \Delta A_j + 0.5\ \Delta A_j \tag{7-10}$$

If $\alpha_0 < C$, the remaining zone is the one adjacent to zone number Z on the side of decreasing right ascension. If $\alpha_0 \geq C$, the remaining zone is on the side of increasing right ascension.

7.4 BASELINE DIAGRAM AND UNIT DESCRIPTION

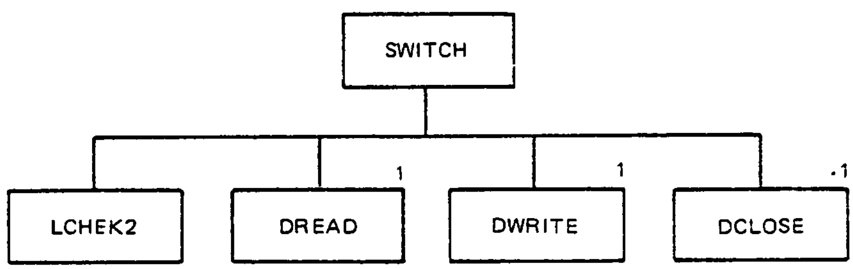
7.4.1 Baseline Diagram

Figure 7-3 is a baseline diagram of program SWITCH.

7.4.2 Unit Descriptions

Unit descriptions of programs SWITCH and LCHEK2 are presented in Sections 7.4.2.1 and 7.4.2.2, respectively. An explanation of the tabular formats used in these sections is given in Section 2.4.1. Appendix E is a FORTRAN compiler listing of SWITCH.

The following is an index to all program SWITCH modules.



[1] THESE ARE DIRECT-ACCESS INPUT/OUTPUT ROUTINES. SEE REFERENCE 35 FOR A DESCRIPTION.

Figure 7-3. Baseline Diagram of Program SWITCH

7.4.2.1 Program SWITCH

DESCRIPTION: SWITCH copies a Run Catalog from one file to another. Conversion between sequential and direct-access file organization may be performed during the copy. SWITCH allows the copying of only selected subcatalogs as specified by NAMELIST parameters.

CALLING SEQUENCE: None (SWITCH is the main program)

COMMON AREAS REFERENCED: FERMSG

EXTERNAL REFERENCES: DCLOSE, DREAD, DWRITE, LCHEK2

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 is NAMELIST input; I6 is printed output; I25 is temporary internal storage; INFILE is the input Run Catalog file; IOUTFL is the output Run Catalog file; and ITSOFL is an optional file for TSO monitoring if SWITCH is operated in TSO foreground mode. I5, I6, and I25 are defined in a DATA statement to be 5, 6, and 25, respectively. INFILE, IOUTFL, and ITSOFL are NAMELIST parameters with default values of 40, 41, and 16, respectively.

ERROR MESSAGES:

'NAMELIST ERROR - IZONES (xxxx) = yyyyyy (ONLY 0 OR 1 IS ALLOWED)'--The IZONES array determines which subcatalogs will be output. IZONES(I) = 0 means that the ith subcatalog will not be output; IZONES(I) = 1 means that it will be output. Other values are illegal. The user should check NAMELIST input values for IZONES. SWITCH terminates execution.

'NAMELIST ERROR - CAMALP (xxxx, y) = zzzzzz.zzzzz (ALLOWED RANGE IS 0.0 TO 360.0)'.

'NAMELIST ERROR - CAMDEL (xxxx, y) = zzzzzz.zzzzz (ALLOWED RANGE IS -90.0 TO -90.0)'--The camera optical axis right ascension and declinations may be input via NAMELIST into the CAMALP and CAMDEL arrays. The units are degrees. Only values between the limits stated are valid. The user should check NAMELIST input. SWITCH terminates execution.

'NAMELIST ERROR - INFILE = xxxx WHICH IS A SYSTEM FILE'.

'NAMELIST ERROR - IOUTFL = xxxx WHICH IS A SYSTEM FILE'.

'NAMELIST ERROR - ITSOFL = xxxx WHICH IS A SYSTEM FILE'.

'NAMELIST ERROR - INFLIE = IOUTFL'.

'NAMELIST ERROR - INFILE = ITSOFL'.

'NAMELIST ERROR - IOUTFL = ITSOFL'--The FORTRAN files INFILE, IOUTFL, and ITSOFL must all be different and must also differ from files I5, I6, and I25. The user should check NAMELIST input for INFILE, IOUTFL, and ITSOFL and the DATA statement for I5, I6, and I25. SWITCH terminates execution.

'FATAL ERROR - OVERFLOW OF THE CAMALP AND CAMDEL ARRAYS'--The arrays are dimensioned for 1100. During calculation of the optical axis pointings, more than 1100 were generated. The NAMELIST parameter TOLER, which controls the spacing of these points, is too small. SWITCH terminates execution.

'FATAL ERROR - ONE OR MORE SUBCATALOGS NEEDED FOR OUTPUT WAS NOT AVAILABLE IN THE INPUT CATALOG'--The required subcatalog(s) which are misssing from the input file are flagged in a zone summary printout on FORTRAN data set I6 by '**********ERROR**********' as the last field. The user should respecify the output zones or obtain a more complete input catalog. SWITCH terminates execution.

'READ ERROR OCCURRED ON A DIRECT-ACCESS FILE. THE FOLLOWING IS THE DATA ERROR MESSAGE BLOCK.

ZZZZZZZZ	IIIII	AAAAAAAA
AAAAAAAA	ZZZZZZZZ	ZZZZZZZZ
ZZZZZZZZ	ZZZZZZZZ'	

The Z, I, and A fields indicated are hexadecimal, integer, and alphameric information, respectively, from the Direct Access Input/Output (DAIO) error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take the appropriate action.

7.4.2.2 Subroutine LCHEK2

DESCRIPTION: LCHEK2 checks values of NAMELIST parameters against their permissible range.

CALLING SEQUENCE: Subroutine LCHEK2 (WORD,FVAL,IVAL,IA,IB,FA,
FB,ITY,IFTSO,ITSOFL)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

CALLED BY: SWITCH

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output. ITSOFL is optional TSO terminal output if the program is run in TSO foreground mode.

ERROR MESSAGES:

'NAMELIST ERROR - VALUE OUT OF ALLOWED RANGE xxxxxx = yyyyyy (ALLOWED) zzzzzz - wwwwww'--NAMELIST variables must be within the specified limits. A STOP is executed within subroutine LCHEK2.

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE LCHEK2

Name	Symbol	I/O	Type	Interface	Description
WORD		I	R*8	C.S.	Descriptive name of variable (alphameric)
FVAL		I	R*4	C.S.	Value of R*4 variable to be checked (if ITY = 2)
IVAL		I	I*4	C.S.	Value of I*4 variable to be checked (if ITY = 1)
IA		I	I*4	C.S.	Minimum permissible value of IVAL
IB		I	I*4	C.S.	Maximum permissible value of IVAL
FA		I	R*4	C.S.	Minimum permissible value of FVAL
FB		I	R*4	C.S.	Maximum permissible value of FVAL
ITY		I	I*4	C.S.	Data type flag: = 1, variable to be checked is I*4 = 2, variable to be checked is R*4
IFTSO		I	I*4	C.S.	If IFTSO $\neq$ 0, write any NAMELIST error message on file ITSOFL
ITSOFL		I	I*4	C.S.	TSO output file number

7.5 COMMON AREA DESCRIPTIONS

The only COMMON area used by program SWITCH or its subroutines is /FERMSG/ which is described below.

NAME: FERMSG

DESCRIPTION: FERMSG contains the error return fields from the DAIO read routine, DREAD.

FORM: COMMON /FERMSG/ IMES(26)

REFERENCED BY: DREAD, SWITCH

DEFINITION OF VARIABLES:

Name	Type	Description
IMES(1)	4-byte hexadecimal	DAIO error return field (see Reference 35)
IMES(2)	I*4	DAIO error return field (see Reference 35)
IMES(3)	4-byte alphameric	DAIO error return field (see Reference 35)
.	.	.
.	.	.
.	.	.
IMES(22)	4-byte alphameric	DAIO error return field (see Reference 35)
IMES(23)	4-byte hexadecimal	DAIO error return field (see Reference 35)
.	.	.
.	.	.
.	.	.
IMES(26)	4-byte hexadecimal	DAIO error return field (see Reference 35)

7.6 USER'S MANUAL

This subsection will enable the user to create the proper NAMELIST input, interpret the resulting output from program SWITCH, and formulate the appropriate Job Control Language (JCL).

7.6.1 Input to Program SWITCH

Input to SWITCH consists of a NAMELIST and an input Run Catalog. In addition, the user may have to modify one statement in the main routine.

7.6.1.1 NAMELIST &SWITIN

The NAMELIST parameters in &SWITIN and their default values are presented in the following list which adheres to the format stated in Section 2.4.3. Multiple NAMELISTs cannot be used in program SWITCH.

Name	Type	Default	Description
IMODE	I*4	2	File data organization flag: = 1, input and output are sequential = 2, input sequential, output direct-access = 3, input direct-access, output sequential = 4, input and output are both direct-access
IFSLCT	I*4	0	Subcatalog selection flag: = 0, copy the entire input catalog onto the output file. This overrides the other NAMELIST parameters that specify which subcatalogs are to be transferred = 1, use selection logic to determine which subcatalogs to put on the output file
IFTSO	I*4	0	Interactive capability flag: = 0, interactive capability OFF = 1, interactive capability ON
IFPRNT	I*4	0	Print flag: = 0, do not print full output catalog = 1, print full output catalog
INFILE	I*4	0	Input file number
IOUTFL	I*4	0	Output file number
ITSOFL	I*4	16	Interactive file number for monitoring messages (when IFTSO = 1 only)

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Name	Type	Default	Description
TOLER[1]	R*4	1.0	Arc distance in degrees between camera optical axis pointings (for IFSLCT = 1 only)
NCAMPT(6)[1]	I*4	6*1	NCAMPT(I)--for the ith camera, number of valid points being stored in the CAMALP and CAMDEL arrays (for ISLFLG = 3 only)
FOV(6)[1]	R*4	6*0.0	FOV(I)--for the ith camera, the total height of the band to be selected in degrees. This should be the sum of the field-of-view radius, and the maximum anticipated precession, nutation and secular motion of and uncertainty in the spin axis position (for ISLFLG = 2 or 3 only)
ISLFLG(6)[1]	I*4	6*2	ISLFLG(I)--selection mode flag for the ith camera = 1, the required subcatalogs are flagged in the NAMELIST array IZONES = 2, the path of the camera optical axis is determined from the spin axis position and the angle between the spin axis and the camera optical axis = 3, the path of the camera optical axis is specified in the NAMELIST arrays CAMALP and CAMDEL
IZONES(2800)[1]	I*4	2800*0	IZONES(I)--subcatalog selection flag for the ith subcatalog (ISLFLG = 1 only) = 0, do not copy subcatalog to output file = 1, copy subcatalog to output file

[1]Required when IFSLCT = 1.

Name	Type	Default	Description
SPINAL(6)[1]	R*4	6*0.0	SPINAL(I)--right ascension of the spin axis of the ith camera in degrees (ISLFLG = 2 only)
SPINDL(6)[1]	R*4	6*90.0	SPINDL(I)--declination of the spin axis of the ith camera in degrees (ISLFLG = 2 only)
COELEV(6)[1]	R*4	6*90.0	COELEV(I)--angle between the spin axis and the ith camera optical axis in degrees (ISLFLG = 2 only)
CAMALP (1100,6)[1]	R*4	6600*0.0	CAMALP(J,I)--jth right ascension of the optical axis for the ith camera, in degrees (ISLFLG = 3 only)
CAMDEL (1100,6)[1]	R*4	6600*0.0	CAMDEL(J,I)--jth declination of the optical axis for the ith camera, in degrees (ISLFLG = 3 only)
NCAM[1]	I*4	1	Number of cameras to be considered (1 ≤ NCAM ≤ 6)

7.6.1.2 Input Run Catalog

SWITCH requires an input Run Catalog generated either by program CAT or by a previous execution of program SWITCH. The Run Catalog may be in either sequential or direct-access format. The format of the Run Catalog is presented in Section 6.6.2.1.

7.6.1.3 Modifications to SWITCH

It is envisioned that the user may wish to alter SWITCH to reset the DATA statement defining file numbers for NAMELIST input, printed output, and temporary storage.

To alter the file numbers, the following statement (sequence number 00005900) may be changed:

```
DATA I5,I6,I25/5,6,25/
```

[1]Required when IFSLCT = 1.

7.6.2 Output From Program SWITCH

SWITCH produces a sequential or direct-access output Run Catalog and printed output.

7.6.2.1 Output Run Catalog

SWITCH will produce a Run Catalog that is structurally the same as that produced by CAT (see Section 6.6.2.1). However, it may contain only a portion of the subcatalogs present on the input Run Catalog. Missing subcatalogs are flagged in the pointer array (see IPOINT, in Section 6.6.2.1.3) by having the number of their first logical record set to the negative of what it would have been were the subcatalog present.

All control records and the subcatalog internal format are the same as the output Run Catalog from program CAT (Section 6.6.2.1.3). The catalog may be either sequential or direct access.

7.6.2.2 Printed Output From SWITCH

SWITCH produces the following printed output to assist in evaluating the program performance:

- A listing of NAMELIST card images.
- A formatted listing of the NAMELIST parameters.
- A series of self-explanatory error messages concerning NAMELIST parameter values. If the printout ends here, correct the indicated error and rerun the job. The meaning of each error is given in the unit descriptions, Sections 7.4.2.1 and 7.4.2.2.
- The title and NAMELIST parameters which were used by program CAT to create the original run catalog.
- A summary of the zones including zone number, limiting right ascensions and declinations, the number of the first logical record on the

input file for that zone, and the "YES/NO" comments indicating if the subcatalog was present on the input file and if it will be written on the output file.

- An error message if a subcatalog requested for output is not available on the input file. If this occurs, the printout will end here. Change either the input file or the requested output.
- A right ascension/declination plot of the zones selected for output.
- A printout of the entire output Run Catalog, if requested, including row definition parameters, the pointer array and the catalog data for each star in each zone.
- If the program terminates normally, the message "END OF CATALOG."

7.6.3 Job Control Language

SWITCH may be run from a FORTRAN source or a load module. Figure 7-4 presents the JCL needed to compile and execute SWITCH.

7.6.4 Overlay Considerations

Program SWITCH cannot be overlaid.

7.6.5 System Resources Needed

SWITCH requires 325K bytes of core storage for a FORTRAN-H compile and 300K bytes in the GO step.

Two tracks of temporary disk storage are required for file I25.

CPU times required for executions are less than one-half minute for catalogs containing 50,000 stars or less. I/O times required for execution are approximately the same as those needed by program CAT (see Section 6.6.5).

```
  // . . . JOB CARD GOES HERE . . .
  // EXEC FORTRANH, REGION=325K,PARM='XREF'
1 //SYSIN DD DSN = &&SWITCH , DISP=(OLD,PASS), UNIT=DISK
  // DCB=(RECFM=FB,LRECL=80, BLKSIZE=7280)
  /*
  //EXEC LOADER, REGION=300K,PARM='SIZE=300000'
  //FT25F001 DD DSN=&&SCR,DCB=(RECFM=FB,LRECL=100,BLKSIZE=300),
  // UNIT=DISK,SPACE=(TRK,2),DISP=(NEW,PASS)
2 //FT41F001 DD DSN= XXXXXXXX , SPACE=(1640, 400),
3
4 // DISP=( NEW,CATALOG ), DCB=(DSORG=DA), UNIT=DISK
5 //FT42F001 DD UNIT=2400-9, VOL=SER=XXXXXX, LABEL=(1,BLP),
6
  // DISP = (OLD,KEEP),DCB=(RECFM=FB,LRECL=1640,BLKSIZE=6560)
  //DATA5 DD*
    &SWITIN
7   IMODE=2,
5   INFILE=42,
8   IFSLCT=0,
9   IFPRNT=0
   END
  /*
```

NOTES

1 – DATA SET NAME FOR PROGRAM SOURCE
2 – OUTPUT RUN CATALOG DATA SET NAME
3 – NUMBER OF LOGICAL RECORDS
4 – IF THE DATA SET IS OLD, MAKE THIS PARAMETER 'OLD, KEEP'.
NOTE DIRECT-ACCESS DATA SETS MUST ALWAYS BE NEW
5 – INPUT FILE HAS BEEN RESET TO 42 FROM THE DEFAULT VALUE OF 40
6 – OUTPUT IS ON TAPE. DISK IS ALSO PERMISSABLE
7 – INPUT IS SEQUENTIAL. OUTPUT IS DIRECT-ACCESS
8 – SWITCH WILL SELECT ALL ZONES IN THE INPUT CATALOG
9 – DO NOT PRINT AN OUTPUT CATALOG

Figure 7-4. Job Control Language for Program SWITCH

SECTION 8 - ACCESSING THE RUN CATALOG

The user interfaces with the complete or selected SKYMAP Run Catalog by using the subroutines of program LOOKAT.

LOOKAT performs two functions--accessing the Run Catalog, and statistical analysis of the Run Catalog. The groups of subroutines used for these purposes are called the Access Module and the Statistics Module, respectively.

This section discusses the Access Module of LOOKAT; Section 9 presents information on the additional subroutines of the Statistics Module.

8.1 ACCESS MODULE CAPABILITIES

The capabilities of the LOOKAT Access Module are as follows:

- It obtains star data from a direct-access Run Catalog created by program CAT (or program SWITCH).
- It creates a star catalog in core (the Core Catalog) from this data according to user specification.
- It creates Core Catalogs covering any of the following:
    - A circular region of the sky ("cap") of any user-specified radius about any designated pointing.
    - A "band" of the sky of any user-specified height about any great or small circle.
    - A "wedge" of the sky of any user-specified height about any arc of any great or small circle (i.e., a slice of the band).

  Figures 8-1, 8-2, and 8-3 depict areas covered by typical cap, band, and wedge Core Catalogs, respectively.
- Optionally, it excludes stars from the Core Catalog if they are dimmer than any user-specified limit.

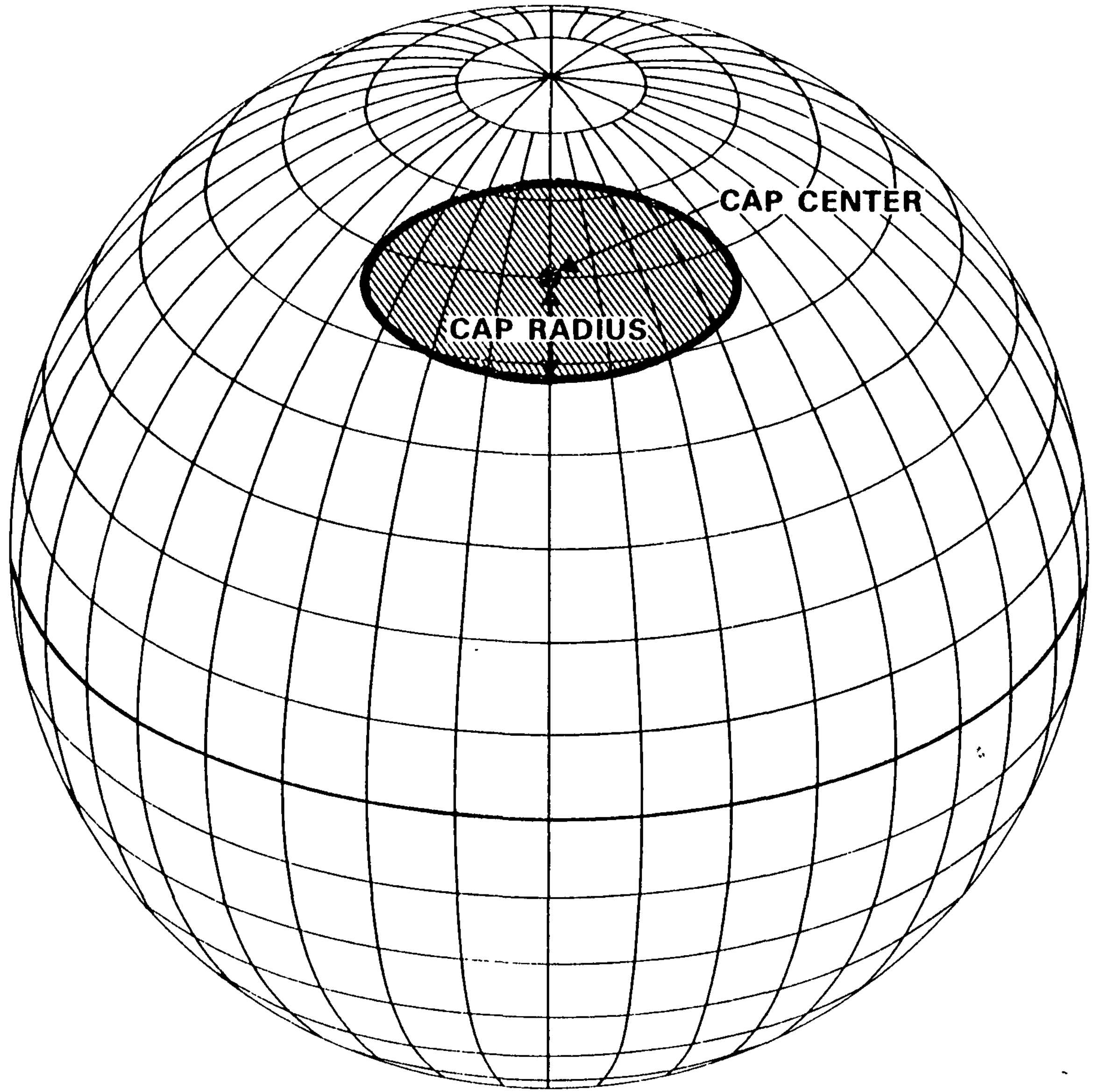

Figure 8-1. Region Covered by a Typical Cap Core Catalog

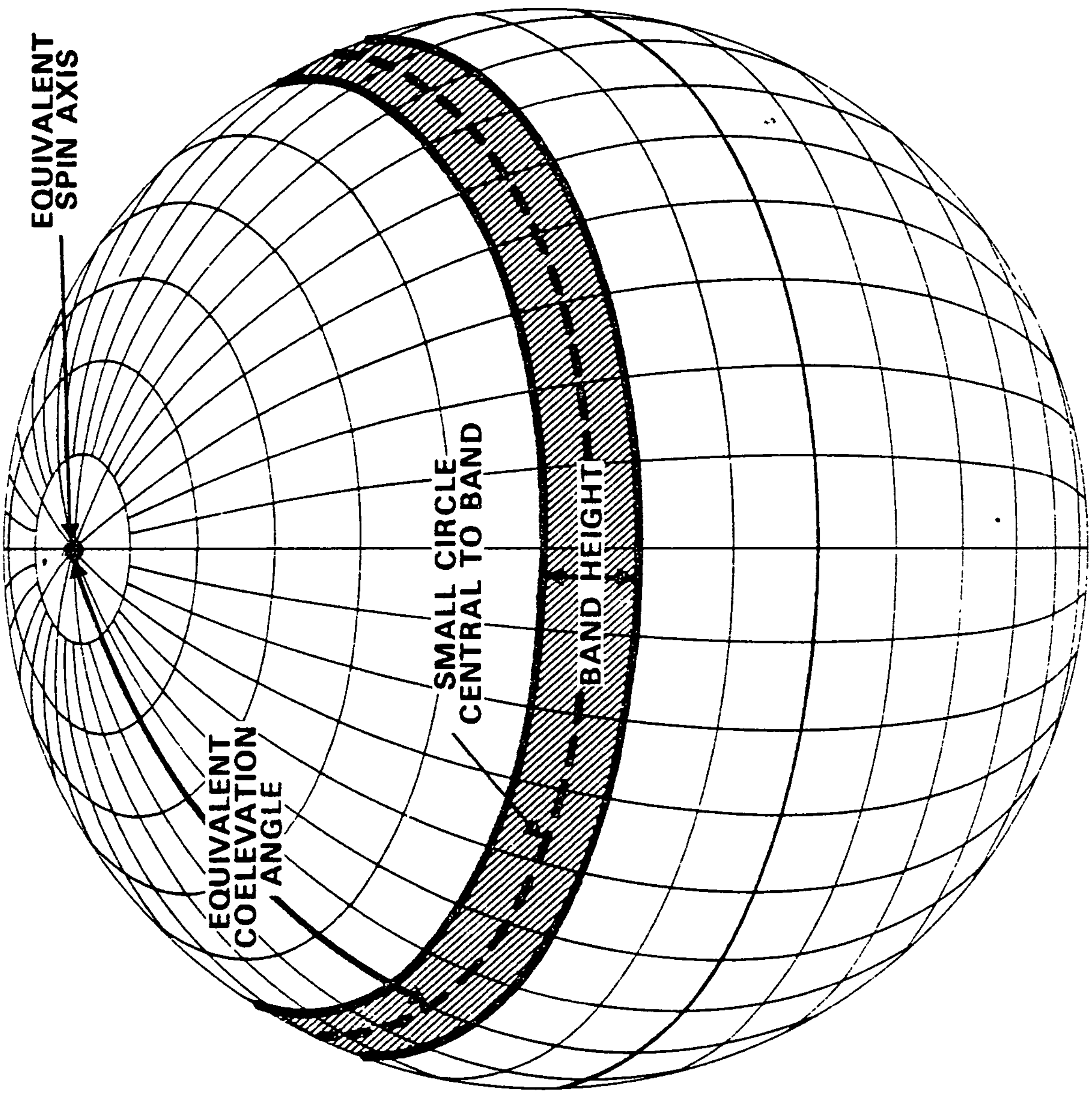

Figure 8-2. Region Covered by a Typical Band Core Catalog

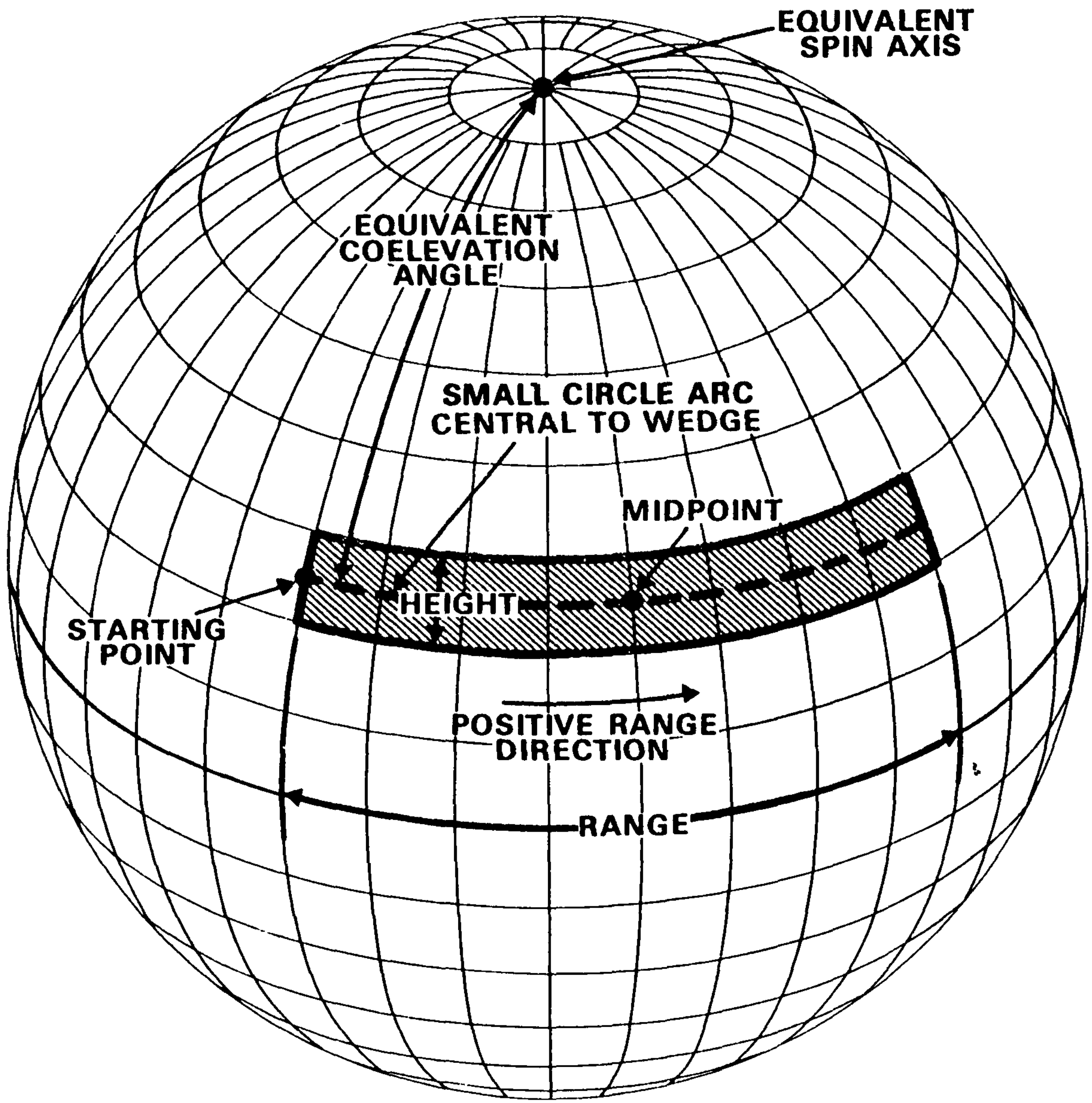

Figure 8-3. Region Covered by a Typical Wedge Core Catalog

- Optionally, it computes azimuths in a spacecraft coordinate system ("longitudes") for all band or wedge Core Catalog stars.

- Optionally, it sorts band or wedge Core Catalog stars in order of increasing longitude.

- It obtains all information from the Run Catalog header records necessary to read the Run Catalog (see Section 6.6.2.1.3).

- It allows specification of the great or small circles used to define the region of the sky covered by band and wedge Core Catalogs by user input of
  - A spin axis
  - The angle between the spin axis and the desired great or small circle (coelevation angles)
  - The size of the sensor field of view

- It allows specification of the desired arc of the great or small circle referred to above in connection with the definition of the wedge Core Catalog by user input of
  - A starting or central pointing anywhere on the desired great or small circle
  - The difference in longitude between the desired starting and final pointings on the great or small circle (the "range")

8.2 ACCESS MODULE LOGICAL FLOW

The Access Module does not have a main routine. Three of its subroutines are intended to be used as driver routines for the rest of the LOOKAT subroutines. These three subroutines--FETCH, BAND, and SLICE--are intended to be inserted in the user's program as CALL statements.

Besides an initialization subroutine, there are three types of subroutines in program LOOKAT--drivers, workers, and utilities. The driver subroutines are designed to create Core Catalogs for the three shape regions noted in Section 8.1. The worker subroutines each perform one specific function, and are called by the driver subroutines. The utility subroutines are called by worker and driver subroutines to perform very small standard functions, such as conversion of a position from right ascension/declination form to G.I. unit vector form.

8.2.1 The Driver Subroutines

The Access Module has three driver subroutines--FETCH, BAND, and SLICE. Subroutine FETCH produces a cap Core Catalog centered at a user-input pointing and with user-defined radius (see Figure 8-1). Optionally, stars fainter than an input limiting magnitude are excluded from the Core Catalog. Figure 8-4 is a logical flow diagram for FETCH.

Subroutine BAND produces a band Core Catalog of user-specified height centered around the path swept out by a vector located a given angular distance from a given spin axis (see Figure 8-2). Optionally, stars fainter than an input limiting magnitude are excluded from the Core Catalog. If desired, star longitudes are calculated as defined in Section 8.3.7. If longitudes are calculated, the output catalog stars are sorted in order of ascending longitude. Figure 8-5 is a logical flow diagram for BAND.

Subroutine SLICE produces a wedge Core Catalog of user-specified height and range centered around the path swept out by a vector located a given angular distance from a given spin axis (see Figure 8-3). Figure 8-6 is a logical flow diagram for SLICE.

8.2.2 The Worker Subroutines

Most of the worker subroutines are simple enough so that the descriptions given in Sections 8.3 and 8.5 are sufficient. Subroutine STORE, however, is described

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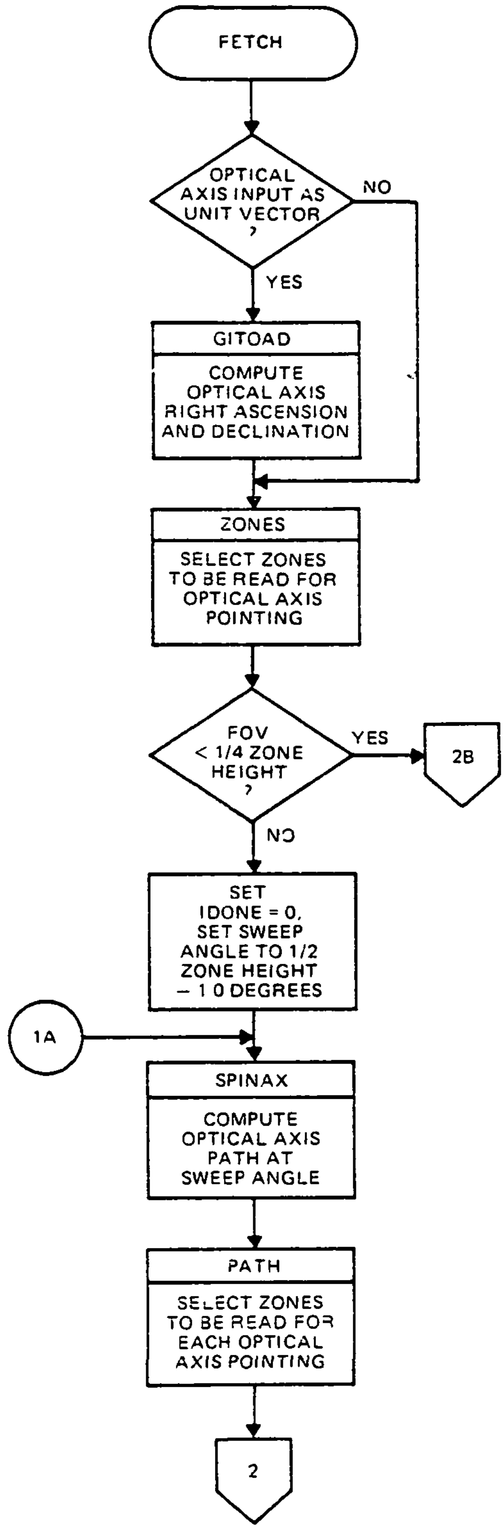

Figure 8-4. Subroutine FETCH Logical Flow (1 of 2)

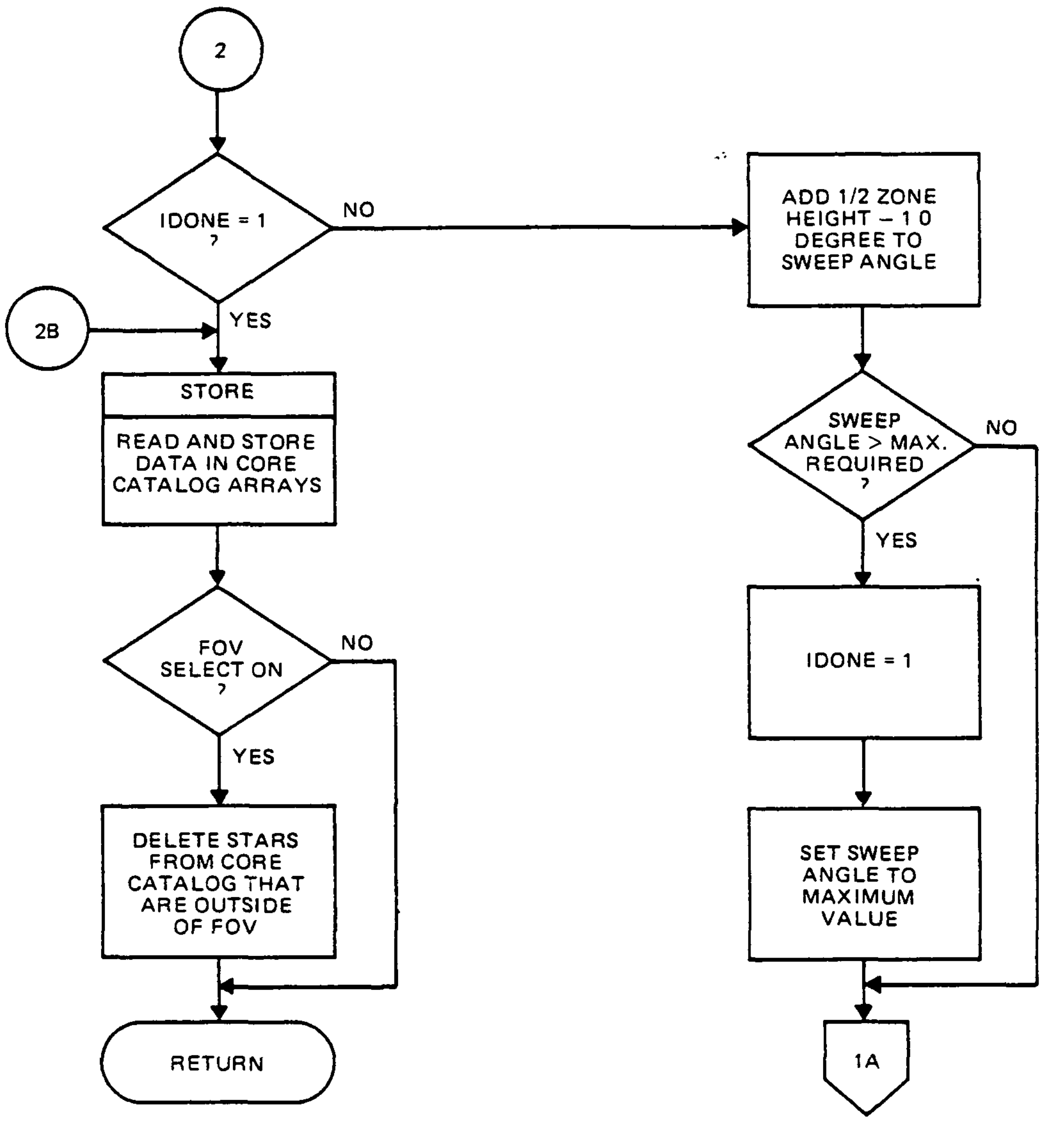

Figure 8-4. Subroutine FETCH Logical Flow (2 of 2)

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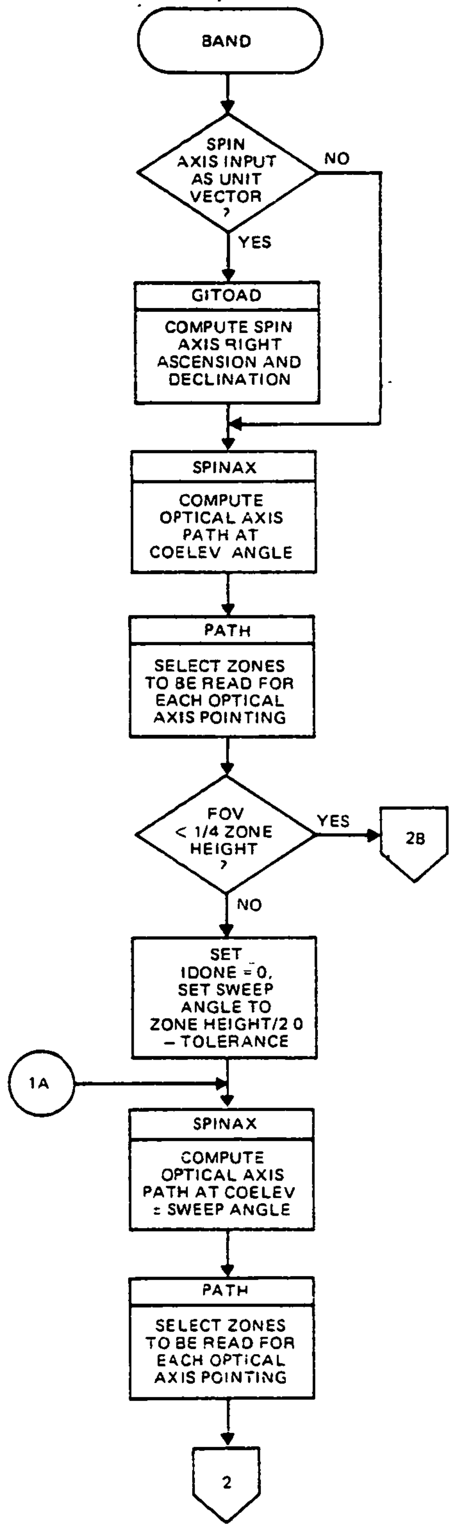

Figure 8-5. Subroutine BAND Logical Flow (1 of 2)

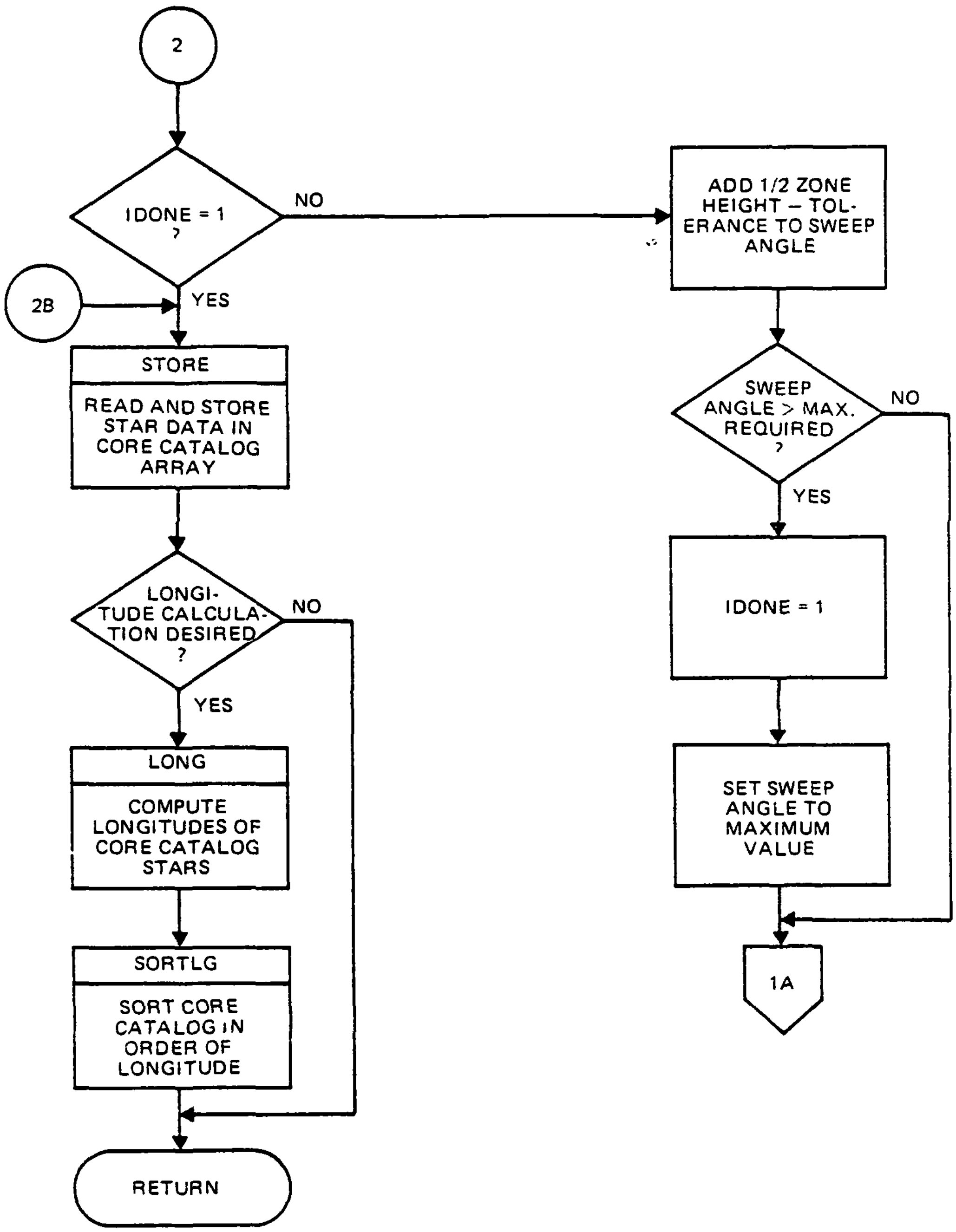

Figure 8-5. Subroutine BAND Logical Flow (2 of 2)

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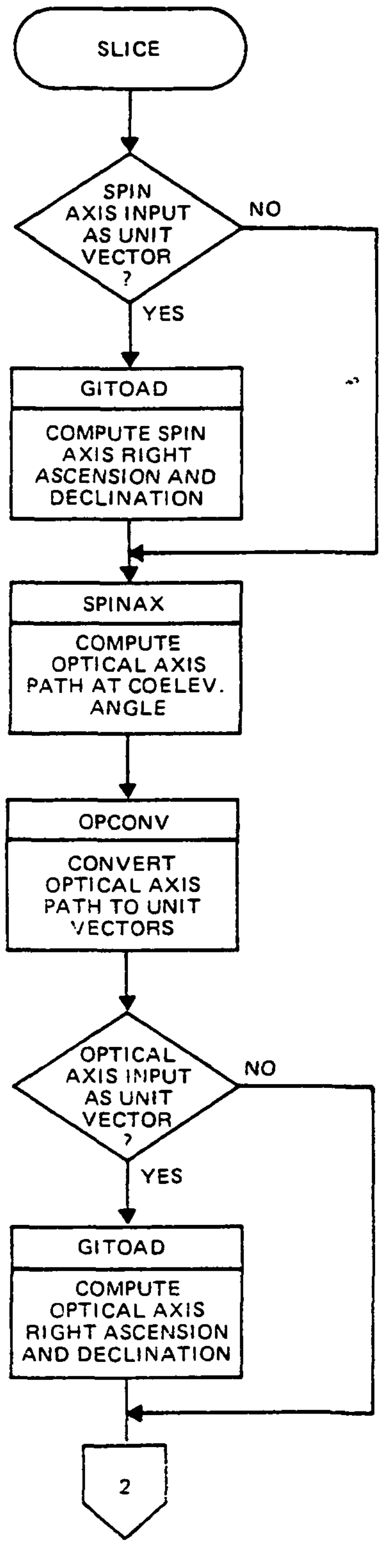

Figure 8-6. Subroutine SLICE Logical Flow (1 of 4)

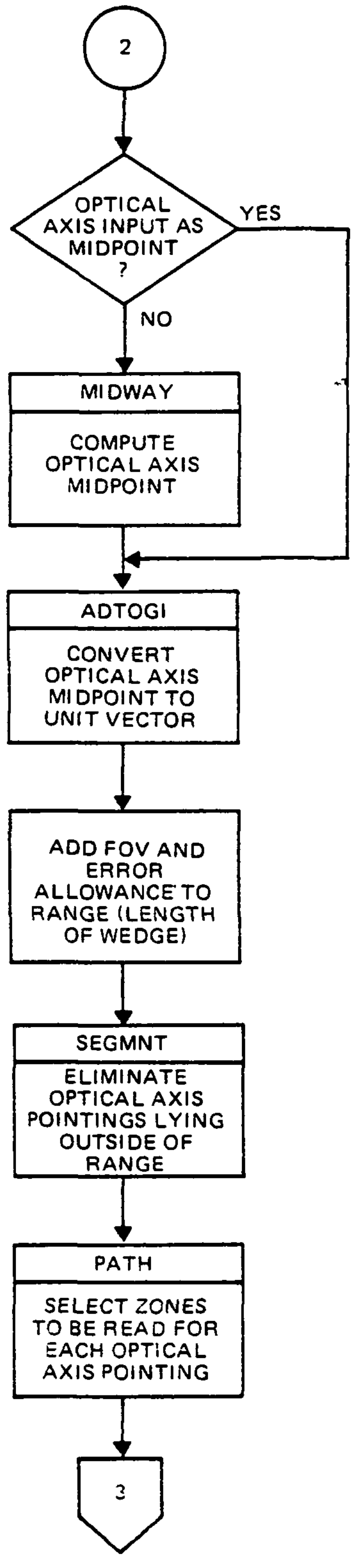

Figure 8-6. Subroutine SLICE Logical Flow (2 of 4)

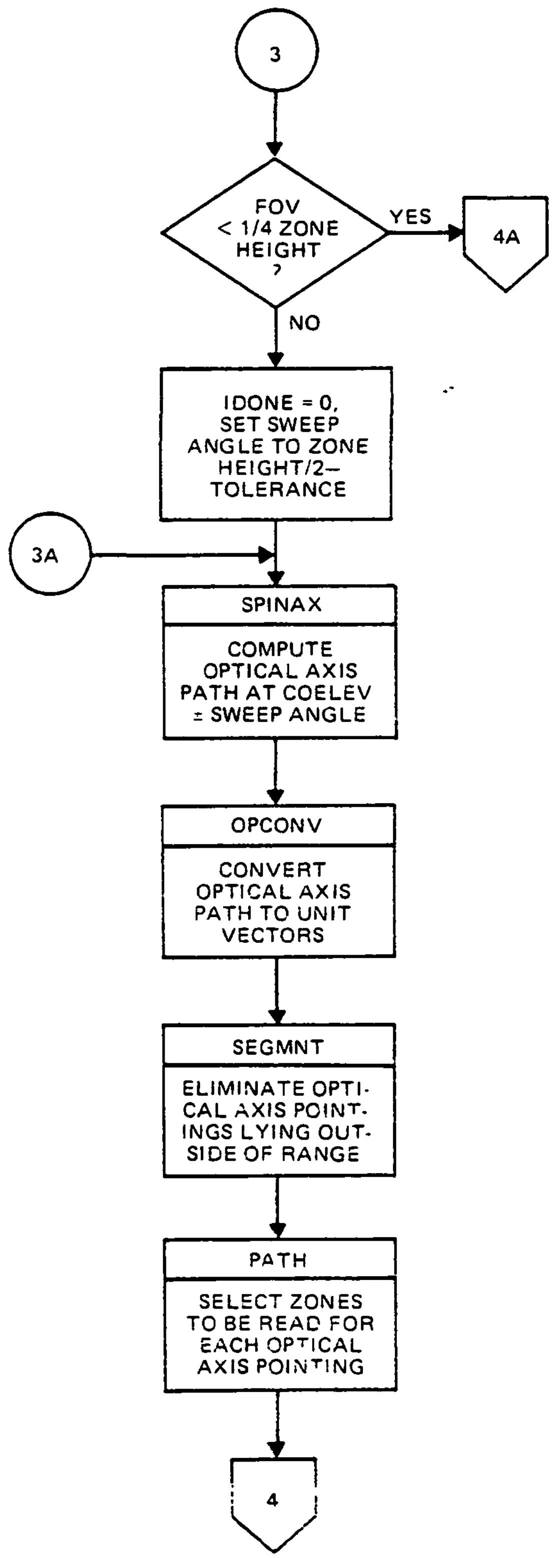

Figure 8-6. Subroutine SLICE Logical Flow (3 of 4)

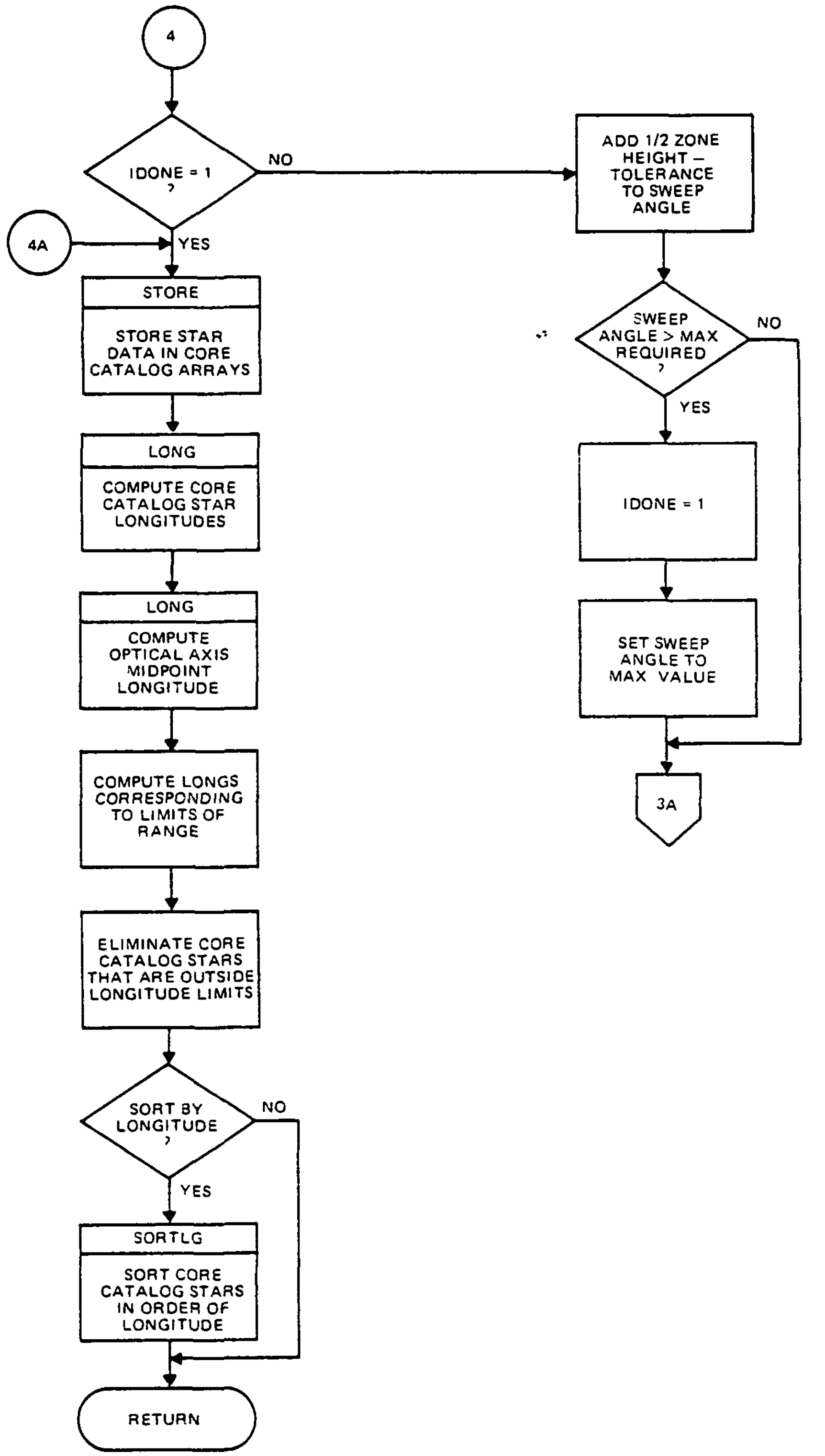

Figure 8-6. Subroutine SLICE Logical Flow (4 of 4)

here. STORE is the subroutine which stores data in the Core Catalog. Elsewhere in LOOKAT, an array is computed specifying which zones may contain stars needed in the Core Catalog. STORE reads each specified subcatalog from the direct-access Run Catalog. For each star, the catalog data is stored in the output arrays provided that it lies within the region of the sky to be covered by the Core Catalog and is brighter than a user-specified magnitude. Either or both of these tests may be "turned off" by the user by setting appropriate flags in the driver subroutine calling sequence.

Subroutine NODUPE is called by STORE to determine if the star has already been stored in the output catalog. This may occur because zones overlap 50 percent in declination. Because STORE processes zones starting with the northernmost and working southwards, only stars in the northern half of a zone can possibly be duplicates. NODUPE first determines if a star is in the northern half of its zone. If it is, the star number is checked against those of stars already in the Core Catalog. If this star is not a duplicate, the Core Catalog array index is incremented by one, and data from the next star is stored. If the star is a duplicate, the index is not incremented so that the next star's data overwrites it.

STORE returns the Core Catalog and a parameter giving the number of valid stars in the catalog.

8.2.3 Utility Subroutines

The utility subroutines are limited in scope and the descriptions given in Sections 8.3 and 8.4 are sufficient.

8.2.4 Initialization Subroutine

Subroutine INITSK is used to read the first eight Run Catalog records which contain data describing the Run Catalog structure (Section 6.6.2.1.3). It must be executed before calls to any of the driver subroutines, FETCH, BAND, or SLICE. Figure 8-7 is a logical flow diagram for INITSK.

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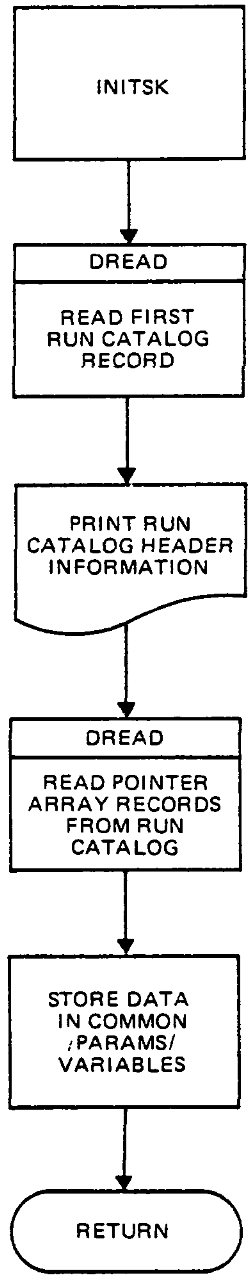

Figure 8-7. Subroutine INITSK Logical Flow

8.3 MATHEMATICAL AND LOGICAL TECHNIQUES

8.3.1 Determining the Zone Number Corresponding to a Pointing

The LOOKAT subroutines determine which Run Catalog zones must be read by computing an array of pointings, representing the path taken by a sensor optical axis during some interval of time (see Section 8.3.4). Given the right ascension and declination of one of these pointings, subroutine ZONES determines which two subcatalogs are required using the equations presented in Section 7.3.2. Two subcatalogs adjacent in right ascension are required because, in general, the zone's right ascension width is only half the arc distance of its declination height. This technique was used to provide the required 50-percent zone overlap in declination. LOOKAT subroutines, however, assume the zones are "square."

8.3.2 Conversion Between Right Ascension, Declination, and Geocentric Inertial Coordinates

Subroutine GITOAD converts a G.I. unit vector to right ascension and declination. Subroutine ADTOGI computes the reverse. The equations used were given in Section 6.3.1.

8.3.3 Determination of Whether a Star Is Within the Field of View

8.3.3.1 Subroutine FETCH

Given a single optical axis pointing, as with subroutine FETCH, a star is within a circular field of view centered at that point provided that

$$\overleftarrow{S}_{GI} \cdot \overleftarrow{O}_{GI} \geq \cos r \tag{8-1}$$

where $\overleftarrow{S}_{GI}$ = star unit vector in G.I. coordinates

$\overleftarrow{O}_{GI}$ = optical axis unit vector in G.I. coordinates

r = half-cone angle of the field of view

8.3.3.2 Subroutine BAND

For subroutine BAND, a star is within the field of view if it is within the specified distance from any point on the patch swept out by the optical axis during one rotation about the spin axis. This occurs if

$$C_A \leq \overleftarrow{S}_{GI} \cdot \overleftarrow{A}_{GI} \leq C_B \tag{8-2}$$

where $C_A = \cos\left(\min(\theta - r,\ 180^\circ)\right)$

$C_B = \cos\left(\max(\theta - r,\ 0^\circ)\right)$

$\overleftarrow{A}_{GI}$ = spin axis unit vector in G.I. coordinates

θ = angle between the spin axis and the optical axis of the sensor (coelevation angle)

8.3.3.3 Subroutine SLICE

For subroutine SLICE, a star is within the field of view if it passes the test of Equation (8-2) and if

$$L_{min} \leq L_o \leq L_{max} \text{ (module } 360^\circ) \tag{8-3}$$

where L_o is the star longitude (see Section 8.3.7), and L_{min} and L_{max} are the minimum and maximum permitted longitudes as described in Section 8.3.6.

8.3.4 Calculation of the Optical Axis Path

For a spinning spacecraft, a sensor optical axis sweeps out a circle on the celestial sphere during one spacecraft rotation. Subroutines BAND and SLICE specify the zones that must be read to generate the appropriate Core Catalog by first calculating this optical axis (pointing) at discrete intervals; the zones required are then determined for each pointing. If the distance between computed pointings is small compared to the zone size, no zones will be missed by using this procedure. Appendix F discusses the sizing of the discrete steps.

The required optical axis path is calculated using the equation presented in Section 7.3.1. Additional paths parallel to the optical axis path are computed whenever the sum of the field-of-view size and the anticipated spin axis motion/uncertainty is too large relative to the Run Catalog zone size. Failure to do so would lead to some zones being "skipped over" and thus an incomplete Core Catalog. Figure 8-8 shows the various sweeps necessary to cover a specified region of the sky. The variables defined below are also shown on this figure.

If F is the radius of a circle circumscribed about the field of view; ϵ is the maximum angular distance the spin axis is allowed to move away from the axis used to create the Core Catalog before a new Core Catalog must be generated; and τ is the maximum arc distance along a great circle between two consecutive computed optical axis points, the additional sweeps are made at

$$\theta \pm \varphi, \ \theta \pm 2\varphi, \ldots, \ \theta \pm n\varphi, \ \theta \pm \psi \tag{8-4}$$

where θ is the nominal coelevation angle,

$$\varphi = \frac{W}{2} - \tau \tag{8-5}$$

where W = zone height,

$$\psi = F + \epsilon + \tau - \left(\frac{W}{4} - \frac{\tau}{2}\right) \tag{8-6}$$

and n is an integer ≥ 1 chosen such that

$$0.0 \leq \psi - n\varphi \leq \varphi \tag{8-7}$$

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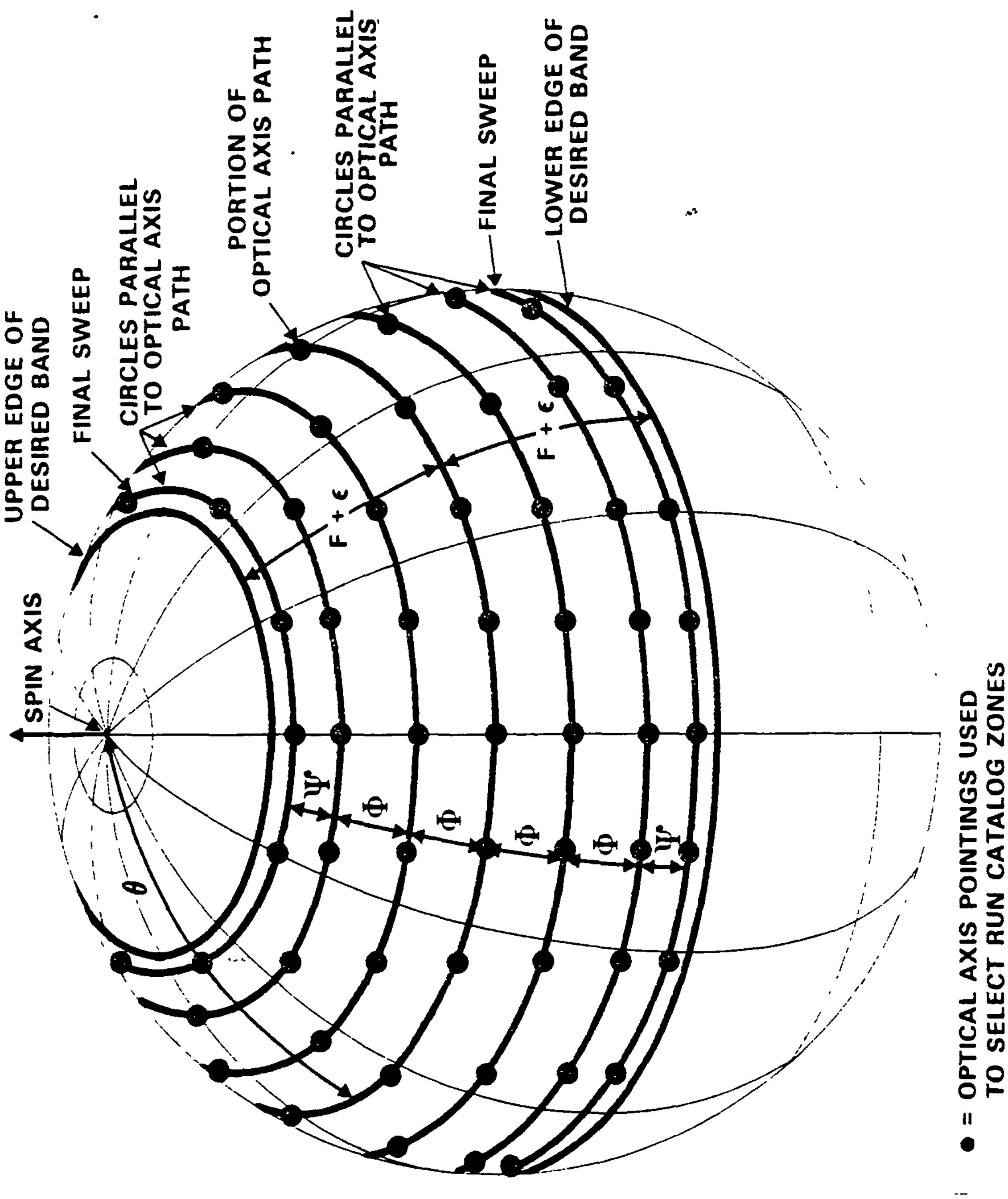


Figure 8-8. Multiple Sweeps Made To Cover a Region of the Sky

The additional sweeps specified in Equation (8-4) are made for band and wedge Core Catalogs whenever

$$F + \epsilon + \tau > W/4 \tag{8-8}$$

For cap Core Catalogs where

$$F > W/4 \tag{8-9}$$

a similar technique is used with

$$\begin{aligned} \theta &= 0 \\ \tau &= 1.0 \text{ degree} \\ \epsilon &= 0 \end{aligned} \tag{8-10}$$

Appendix F contains a mathematical proof that this procedure specifies all zones required to ensure a complete Core Catalog. The derivations of Equations (8-5) and (8-6), which serve to define ϕ and ψ, are also presented in Appendix F.

8.3.5 Calculation of a Segment of the Optical Axis Path

If, during the interval of analysis, the spacecraft rotates less than one complete rotation, the optical axis path sweeps out only a segment of the band described in Section 8.3.4. Subroutine SLICE takes the array of camera optical axis pointings specified in Section 8.3.4 and selects those within a given number of degrees of a given "central" optical axis pointing.

Three optical axis sweeps are processed at once. If there are a total of N_O optical axis pointings generated, the first $N' = N_O/3$ of them correspond to one sweep, the next third to another sweep, and the final third to yet another sweep. Referring to the first N' points in the optical axis array, a segment of the band R degrees wide requires that I_R points on either side of the central pointing be selected, where

$$I_R = \left(1 + \frac{0.5\,R}{360/N'} \right) \tag{8-11}$$

where ( ) means the greatest integer less than or equal to the expression and R is the sum of the desired width of the wedge plus twice the FOV radius and error allowance.

The central optical axis pointing will not, in general, be one of the points in the camera optical axis array. Therefore, we define the central optical axis pointing as that value , $\hat{O}*$, such that

$$f = \hat{O}* \cdot \hat{O}_{MID}$$

is a maximum, where

$\hat{O}_{MID}$ = central optical axis pointing input to the subroutine

The pointings to be selected, therefore, are I_R pointings on either side of $\hat{O}*$, plus the corresponding pointings in the second and third N' points.

8.3.6 Calculation of the Midpoint of the Optical Axis Path

Subroutine SEGMNT requires that the central pointing of the optical axis path be specified. Sometimes it is more convenient to specify the starting optical axis point, $\hat{O}_{start}$, and the range, R . Subroutine MIDWAY calculates the central pointing,

$$\hat{O}_{MID} = (O_{MID,x} , O_{MID,y} , O_{MID,z}) \tag{8-12}$$

from

$$O_{MID,x} = C_x \sin\theta + A_x \cos\theta$$
$$O_{MID,y} = C_y \sin\theta + A_y \cos\theta \qquad (8\text{-}13)$$
$$O_{MID,z} = C_z \sin\theta + A_z \cos\theta$$

where

$$C_x = B_x \cos\left(\frac{R}{2}\right) + (A_y B_z - A_z B_y) \sin\left(\frac{R}{2}\right)$$
$$C_y = B_y \cos\left(\frac{R}{2}\right) + (A_z B_x - A_x B_z) \sin\left(\frac{R}{2}\right) \qquad (8\text{-}14)$$
$$C_z = B_z \cos\left(\frac{R}{2}\right) + (A_x B_y - A_y B_x) \sin\left(\frac{R}{2}\right)$$

$$B_x = \frac{O_{START,x} - A_x (\hat{A}\cdot\hat{O}_{START})}{|B|}$$
$$B_y = \frac{O_{START,y} - A_y (\hat{A}\cdot\hat{O}_{START})}{|B|} \qquad (8\text{-}15)$$
$$B_z = \frac{O_{START,z} - A_z (\hat{A}\cdot\hat{O}_{START})}{|B|}$$

where $|B| = (B_x^2 + B_y^2 + B_z^2)^{1/2}$ is determined from the numerator portion of Equation (8-15) before normalization

$A = (A_x, A_y, A_z)$ = spin axis

R = the angle of rotation about the spin axis during the interval

θ = coelevation angle between the spin and optical axes

8.3.7 Calculation of Star Longitudes

The longitude of a star is defined as the angle made by the projection of the star unit vector onto the spacecraft equatorial plane, and measured from a reference axis. The reference axis is defined as the intersection of the spacecraft equatorial plane with the plane containing the spacecraft spin axis and the vector in the direction of the vernal equinox.

The longitude is given by

$$L = \tan^{-1} (x_2/x_1) \tag{8-16}$$

where

$$\begin{aligned} x_2 &= \hat{S} \cdot \hat{P} \\ x_1 &= \hat{S} \cdot \hat{P}' \end{aligned} \tag{8-17}$$

$$\begin{aligned} \hat{P} &= (\hat{A} \times \hat{V})/|\hat{A} \times \hat{V}| \\ \hat{P}' &= (\hat{P} \times \hat{A})/|\hat{P} \times \hat{A}| \end{aligned} \tag{8-18}$$

and where L = star longitude
$\hat{S}$ = star unit vector in G.I. coordinates
$\hat{A}$ = spin axis unit vector in G.I. coordinates
$\hat{V}$ = vernal equinox vector in G.I. coordinates = (1, 0, 0)

A singularity in the longitude equations occurs when the spin axis is parallel to the vernal equinox vector. This problem has been avoided by a small offset in the spin axis. Whenever the spin axis is closer than 10^{-2} degrees from the plus (respectively, minus) vernal equinox, the spin axis declination used to compute longitude is -10^{-2} (respectively, $+10^{-2}$) degrees for the parallel (respectively, antiparallel) case.

8.4 BASELINE DIAGRAM AND UNIT DESCRIPTIONS

8.4.1 Baseline Diagram

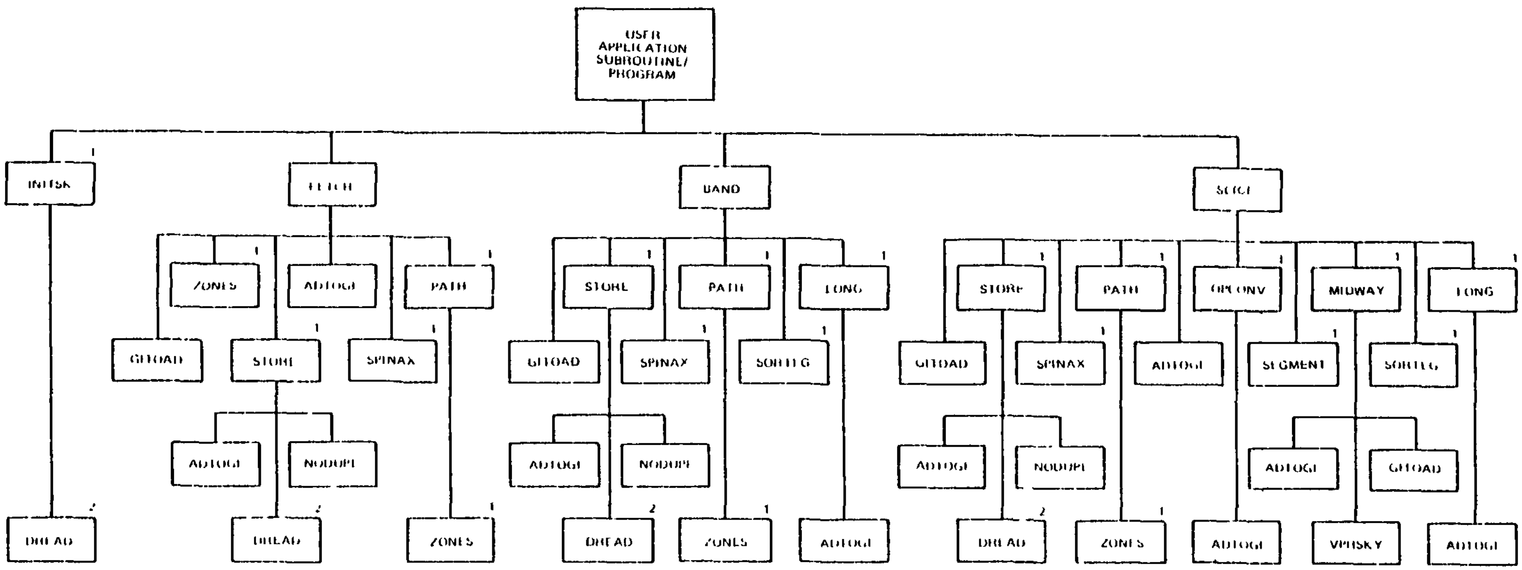
Figure 8-9 is a baseline diagram for the Access Module of program LOOKAT.

8.4.2 Unit Descriptions

A unit description of each subroutine of the Access Module of program LOOKAT is presented in Sections 8.4.2.1 through 8.4.2.19. An explanation of the tabular formats used in these subsections is given in Section 2.4.1. Appendix G is a FORTRAN compiler listing of LOOKAT.

The following is an index to all program LOOKAT Access Module subroutines and functions.

Module	Reference Page
SPINAX	8-66
STORE	8-68
VPHSKY	8-73
ZONES	8-75



[1] SUBROUTINE USES SKYMAP SUBROUTINES DIAG AND DIAG2 WHICH HAVE BEEN OMITTED FOR CLARITY

[2] DREAD IS AN S/360 DAIO SYSTEM ROUTINE (REFERENCE 35)

Figure 8-9. Access Module of Program LOOKAT Baseline Diagram

8.4.2.1 Subroutine ADTOGI

DESCRIPTION: Subroutine ADTOGI converts a vector in right ascension and declination to a G.I. unit vector.

CALLING SEQUENCE: Subroutine ADTOGI (ALPHA, DELTA, X, Y, Z)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

CALLED BY: FETCH, LONG, MIDWAY, OPCONV, SLICE, STORE

INPUT/OUTPUT VARIABLES FOR SUBROUTINE ADTOGI

Name	Symbol	I/O	Type	Interface	Description
ALPHA, DELTA	α , δ	I	R*4	C.S.	Right ascension and declination of a vector (degrees)
X, Y, Z	X,Y,Z	O	R*4	C.S.	Components of the geocentric inertial unit vector corresponding to ALPHA, DELTA

8.4.2.2 Subroutine BAND

DESCRIPTION: Subroutine BAND produces a catalog in ISTDAT and FSTDAT, given a spin axis and coelevation.

CALLING SEQUENCE: Subroutine BAND (ITYPE, A, B, C, COELEV, TOLER, SLOP, IFMAG, FMAGLM, IFFOV, FOV IFLONG, ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, OPAXIS, OPGI, PARAMS, POINT

EXTERNAL REFERENCES: GITOAD, LONG, PATH, SORTLG, SPINAX, STORE

CALLED BY: User program

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is error message printed output.

ERROR MESSAGES:

'BAND...ERROR OCCURRED IN SUBROUTINE xxxxxxxx... PROGRAM RETURNS.' This is accompanied by a message from subroutine (xxxxxxxx).

INPUT/OUTPUT VARIABLES FOR SUBROUTINE BAND

Name	Symbol	I/O	Type	Interface	Description
ITYPE		I	I*4	C.S.	Spin axis coordinate type flag – = 1, geocentric inertial unit vector input = 2, right ascension, declination input
A, B, C		I	R*4	C.S.	If ITYPE = 1, components of the spin axis geocentric inertial unit vector If ITYPE = 2, right ascension and declination of the spin axis (degrees) and zero, respectively
COELEV	θ	I	R*4	C.S.	Angle between the optical axis and the spin axis (degrees)
TOLER	τ	I	R*4	C.S.	Angular separation between the desired points calculated for the optical axis pointings (degrees)
SLOP	ϵ	I	R*4	C.S.	Error factor = sum of the maximum error expected in the spin axis position, and the maximum expected precession and nutation angle (degrees)
IFMAG		I	I*4	C.S.	Magnitude reject flag – = 0, do not reject stars fainter than FMAGLM = 1, reject stars fainter than FMAGLM
FMAGLM		I	R*4	C.S.	Limiting magnitude (IFMAG = 1 only)
IFFOV		I	I*4	C.S.	Field of view reject flag – = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
FOV	r	I	R*4	C.S.	Radius of circular FOV (degrees), FOV must be provided even when IFFOV = 0

INPUT/OUTPUT VARIABLES FOR SUBROUTINE BAND

Name	Symbol	I/O	Type	Interface	Description
IFLONG		I	I*4	C.S.	Longitude calculation flag - = 0, do not calculate star longitudes = 1, calculate star longitudes
ISTDAT (NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector x-component FSTDAT(I, 2) = G.I unit vector y-component FSTDAT(I, 3) = G.I unit vector z-component FSTDAT(I, 4) = normally, star magnitude FSTDAT(I, 5), FSTDAT(I, 6), FSTDAT(I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment (See Section 6.6.2.1.4)
STLONG(NDIM1)		O	R*4	C.S.	Star longitude, as computed in Section 8.3.7
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars

INPUT/OUTPUT VARIABLES FOR SUBROUTINE BAND

Name	Symbol	I/O	Type	Interface	Description
I6		I	I*4	/FILES/	Error message output file number
IFOPGI		O	I*4	/OPGI/	OPCONV call flag - = 0, OPCONV has not been called = 1, OPCONV has been called
W		I	I*4	/PARAMS/	Declination height of the rows (degrees)

8.4.2.3 Subroutine DIAG

DESCRIPTION: Subroutine DIAG prints the leading diagnostic message, and returns the level of diagnostic output flag (IFDIAG) and the number of the diagnostic output file (IDFL).

CALLING SEQUENCE: Subroutine DIAG (TITLE, IFDIAG, IDFL)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: None

CALLED BY: INITSK, LONG, MIDWAY, OPCONV, PATH, SEGMNT, SORTLG, SPINAX, STORE, ZONES

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is printed diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE DIAG

Name	Symbol	I/O	Type	Interface	Description
TITLE		I	R*8	C.S.	Eight-character alphameric word identical to the name of the calling subroutine (left justified)
IFDIAG		O	I*4	C.S.	Level for diagnostic printout. 0 gives no diagnostic printout. 1, 2, 3, 4, and 5 give successively more
IDFLX		O	I*4	C.S.	FORTRAN file number for diagnostic printout
IFDG		I	I*4	/FILES/	Diagnostic control flag - = 0, no diagnostics = 1, 2, 3, 4, 5, successively more diagnostics printed
IDFL		O	I*4	/FILES/	Diagnostic output file number. FORTRAN file number for diagnostic printout

8.4.2.4 Subroutine DIAG2

DESCRIPTION: Subroutine DIAG2 prints the trailing diagnostic message.

CALLING SEQUENCE: SUBROUTINE DIAG2 (TITLE)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: NONE

CALLED BY: INITSK, LONG, MIDWAY, OPCONV, PATH, SEGMNT, SORTLG, SPINAX, STORE, ZONES

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is printed diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE DIAG2

Name	Symbol	I/O	Type	Interface	Description
TITLE		I	R*8		Eight-character alphameric word identical to the name of the calling sequence (left justified)
IFDG		I	I*4	/FILES/	Diagnostic control flag - = 0, no diagnostics = 1, 2, 3, 4, 5, successively more diagnostics printed
IDFL		I	I*4	/FILES/	Diagnostic output file number

8.4.2.5 Subroutine FETCH

DESCRIPTION: Subroutine FETCH is a driver routine that produces a "cap" Core Catalog for a given optical axis pointing.

CALLING SEQUENCE: Subroutine FETCH(ITYPE, A, B, C, IFMAG, FMAGLM,
IFFOV, FOV, ISTDAT, FSTDAT,
NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, PARAMS, POINT, OPAXIS

EXTERNAL REFERENCES: ADTOGI, GITOAD, PATH, SPINAX, STORE, ZONES

CALLED BY: User program

INPUT/OUTPUT DATA SETS: FORTRAN data sets reference number 16 is error message output.

ERROR MESSAGES:

'FETCH ... ZONE REQUESTED NOT AVAILABLE ... PROGRAM RETURNS.' The zone requested by FETCH was not present on the input Run Catalog.

'FETCH ... ERROR OCCURRED IN SUBROUTINE STORE ... PROGRAM RETURNS'--Some fatal error occurred in subroutine STORE. This is accompanied by a specific error message from STORE.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE FETCH

Name	Symbol	I/O	Type	Interface	Description
ITYPE		I	I*4	C.S.	Optical axis coordinate type flag - = 1, optical axis given as a geocentric inertial unit vector = 2, optical axis given as right ascension and declination
A, B, C		I	R*4	C.S.	When ITYPE = 1, the components of the optical axis unit vector in geocentric inertial coordinates When ITYPE = 2, the right ascension and declination of the optical axis, in degrees, followed by a blank word
IFMAG		I	I*4	C.S	= 0, do not reject stars fainter than FMAGLM = 1, reject stars fainter than FMAGLM
FMAGLM		I	R*4	C.S.	Limiting magnitude (required for IFMAG=1 only)
IFFOV		I	I*4	C.S.	Field of view select flag - = 0, do not reject stars outside the FOV = 1, reject stars outside the FOV
FOV	r	I	R*4	C.S.	Half cone angle of the FOV (degrees) FOV must be provided even when IFFOV=0.
ISTDAT(NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT(NDIM1, NDIM2)		O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, and i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector of the x-component FSTDAT(I, 2) = G.I unit vector of the y-component FSTDAT(I, 3) = G.I unit vector of the z-component

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE FETCH

Name	Symbol	I/O	Type	Interface	Description
FSTDAT (NDIM1, NDIM2) (Cont'd)					FSTDAT(I,4) = normally, star magnitude FSTDAT(I,5), FSTDAT(I,6), FSTDAT(I,7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment (See Section 6.6.2.1.4)
NDIM1		I	I*4	C.S.	Dynamic dimension for the ISTDAT and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Error message output file number
NZONES		I	I*4	/PARAMS/	Number of zones
W		I	I*4	/PARAMS/	Declination height of the rows (degrees)
IZONES(2800)		O	I*4	/POINT/	Zone output flag - IZONES(I) = 0, do not output data from zone I = 1, output data from zone I Valid for I = 1, . . . , number of zones

8.4.2.6 Subroutine GITOAD

DESCRIPTION: Subroutine GITOAD converts a geocentric inertial unit vector (X, Y, Z) to right ascension and declination.

CALLING SEQUENCE: Subroutine GITOAD(X, Y, Z, ALPHA, DELTA)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

CALLED BY: BAND, FETCH, MIDWAY, SLICE

INPUT/OUTPUT VARIABLES FOR SUBROUTINE GITOAD

Name	Symbol	I/O	Type	Interface	Description
X, Y, Z	X, Y, Z	I	R*4	C.S.	Components of a geocentric inertial unit vector
ALPHA, DELTA	α, δ	O	R*4	C.S.	Right ascension and declination of the unit vector (degrees)

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8.4.2.7 Subroutine INITSK

DESCRIPTION: Subroutine INITSK initializes various variables in COMMON /PARAMS/ by reading the first eight records of INFILE.

CALLING SEQUENCE: SUBROUTINE INITSK (no calling sequence)

COMMON AREAS REFERENCED: FERMSG, FILES, PARAMS, POINT

EXTERNAL REFERENCES: DIAG, DIAG2, DREAD

CALLED BY: User program

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number INFILE is a direct-access Run Catalog. FORTRAN data set reference number IDFL is printed diagnostic output.

ERROR MESSAGES:

'INITSK ... READ ERROR ON RUN CATALOG FILE ... PROGRAM STOPS. DAIO ERROR MESSAGE FIELD IS

ZZZZZZZZIIIIIIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAZZZZZZZZ ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ'

The Z, I, and A fields indicated are hexadecimal, integer, and alphameric information, respectively, from the DAIO error return fields. The user must determine what error occurred by consulting "Data Management Techniques" in Reference 35 and take appropriate action.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE INITSK

Name	Symbol	I/O	Type	Interface	Description
I6		I/O	I*4	/FILES/	Error message output file number
INFILE		I/O	I*4	/FILES/	Direct-access Run Catalog file number
IDFL		I	I*4	/FILES/	Diagnostic output file number
NZONES		I/O	I*4	/PARAMS/	Number of zones
ROWMAX(40)		I/O	R*4	/PARAMS/	Maximum row declination for the Ith row (1 ≤ I ≤ NROWS) (degrees)
ROWMIN(40)		I/O	R*4	/PARAMS/	Minimum row declination for the Ith row (1 ≤ I ≤ NROWS) (degrees)
ROWWID(40)		I/O	R*4	/PARAMS/	Right ascension width of the zones in the Ith row (1 ≤ I ≤ NROWS) (degrees)
NROWST(40)		I/O	I*4	/PARAMS/	Number of the first zone in the Ith row (1 ≤ I ≤ NROWS)
NUMROW(40)		I/O	I*4	/PARAMS/	Total number of zones in the Ith row (1 ≤ I ≤ NROWS)
NROWS		I/O	I*4	/PARAMS/	Number of rows
NWORDS		I/O	I*4	/PARAMS/	Number of words of data per star
NPER		I/O	I*4	/PARAMS/	Number of data segments in one logical record (see Section 6.6.2.1.4)
W	W	I/O	I*4	/PARAMS/	Declination height of the rows (degrees)
IZROW(2800)		I/O	I*4	/PARAMS/	Row number for the Ith zone (1 ≤ I ≤ NZONES)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE INITSK

Name	Symbol	I/O	Type	Interface	Description
IPOINT(2800)		I/O	I*4	/POINT/	IPOINT(I) = record number of the first logical record in the Run Catalog for zone I. If IPOINT(I) is negative, zone I is not present. Valid for I = 1, ..., number of zones

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8.4.2.8 Subroutine LONG

DESCRIPTION: Subroutine LONG calculates longitudes of stars in the ISTDAT and FSTDAT arrays. The longitudes, relative to a great circle intersecting the vernal equinox and the spin axis, are stored in STLONG.

CALLING SEQUENCE: SUBROUTINE LONG (SPINAL, SPINDL, COELEV,
ISTDAT, FSTDAT, STLONG, NDIM1,
NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: ADTOGI, DIAG, DIAG2

CALLED BY: BAND, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is printed diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE LONG

Name	Symbol	I/O	Type	Interface	Description
SPINAL, SPINDL		I	R*4	C.S.	Right ascension and declination of the spin axis (degrees)
COELEV	θ	I	R*4	C.S.	Angle between the spin axis and the optical axis (degrees)
ISTDAT(NDIM1)		I	I*4	C.S.	Core Catalog array normally containing star numbers
FSTDAT(NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I,1) = G.I unit vector x-component FSTDAT(I,2) = G.I unit vector y-component FSTDAT(I,3) = G.I unit vector z-component FSTDAT(I,4) = normally, star magnitude FSTDAT(I,5), FSTDAT(I,6), FSTDAT(I,7) = star data corresponding to the sixth, seventh, and eighth words of data in the Run Catalog star data segment (see Section 6.6.2.1.4)
STLONG(NDIM1)		O	R*4	C.S.	Star longitude, as computed in Section 8.3.7.
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog.
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars

8.4.2.9 Subroutine MIDWAY

DESCRIPTION: Subroutine MIDWAY calculates the middle of a range of optical axis pointings, given the initial optical axis pointing, the spin axis pointing, and the range over which the spacecraft spins.

CALLING SEQUENCE: SUBROUTINE MIDWAY (SPINAL, SPINDL, COELEV,
OAALP, OADEL, RANGE,
ALPMID, DELMID, XMID,
YMID, ZMID)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: ADTOGI, DIAG, DIAG2, GITOAD, VPHSKY

CALLED BY: SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE MIDWAY

Name	Symbol	I/O	Type	Interface	Description
SPINAL, SPINDL		I	R*4	C.S.	Right ascension and declination of the spin axis (degrees)
COELEV	θ	I	R*4	C.S.	Angle between the spin axis and camera optical axis (degrees)
OAALP, OADEL	α_o , δ_o	I	R*4	C.S.	Camera optical axis at the start of the interval (degrees)
RANGE	R	I	R*4	C.S.	Amount of spin during the interval (degrees)
ALPMID, DELMID	α_{MID}, δ_{MID}	O	R*4	C.S.	Right ascension and declination of the optical axis at the midpoint of the interval
XMID, YMID, ZMID	X_{MID}, Y_{MID}, Z_{MID}	O	R*4	C.S.	Geocentric inertial unit vector components of the optical axis at the midpoint of the interval

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8.4.2.10 Subroutine NODUPE

DESCRIPTION: Subroutine NODUPE ensures that no duplicate stars are loaded into the ISTDAT and FSTDAT arrays. It increments the place-keeping index, IPLACE, for these arrays only if the current candidate star is not already in the catalog, and if it is brighter than the specified magnitude limit if there is one.

CALLING SEQUENCE: SUBROUTINE NODUPE (IPLACE, NMAX, IROWHR, I, ZLIM, IERRA, IERRB, IFMAG, FMAGLM, ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, PARAMS, POINT

EXTERNAL REFERENCES: None

CALLED BY: STORE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed error message output.

ERROR MESSAGES:

'NODUPE ... OVERFLOW IN THE ISTDAT AND FSTDAT ARRAYS AT STAR NUMBER xxxxxxxx IN ZONE NUMBER yyyyy ... SUBROUTINE RETURNS TO DRIVER SUBROUTINE THROUGH SUBROUTINE STORE.'

INPUT/OUTPUT VARIABLES FOR SUBROUTINE NODUPE

Name	Symbol	I/O	Type	Interface	Description
IPLACE		I/O	I*4	C.S.	Input: Position in the FSTDAT and ISTDAT arrays where data was just stored Output: Storage location in the FSTDAT and ISTDAT arrays where the next star data should be stored
NMAX		I	I*4	C.S.	Maximum number of stars allowed in arrays
IROWHR		I	I*4	C.S.	Row number of first row from which a subcatalog was selected for storage
I		I	I*4	C.S.	Zone number
ZLIM		I	R*4	C.S.	Sine of the declination midpoint of zone I
IERRA, IERRB		O	I*4	C.S.	Error return flags (alphameric) = blanks, no error occurred = anything else, error occurred in the subroutine spelled out by IERRA, IERRB
IFMAG		I	I*4	C.S.	Magnitude sorting flag - = 0, do not reject stars fainter than FMAGLM = 1, reject stars fainter than FMAGLM
FMAGLM		I	R*4	C.S.	Limiting magnitude (used for IFMAG=1 only)
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog array containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector x-component FSTDAT(I, 2) = G.I unit vector y-component

INPUT/OUTPUT VARIABLES FOR SUBROUTINE NODUPE

Name	Symbol	I/O	Type	Interface	Description
FSTDAT (NDIM1, NDIM2) (Cont'd)					FSTDAT(I, 3) = G.I. unit vector z-component FSTDAT(I, 4) = normally, star magnitude FSTDAT(I, 5), FSTDAT(I, 6), FSTDAT(I, 7) = star data corresponding to the sixth, seventh, and eighth words of data in a Run Catalog star data segment (see Section 6.6.2.1.4)
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I/O	I*4	C.S.	Number of valid Core Catalog stars; increment by one on output if the last star loaded is to be kept
I6		I	I*4	/FILES/	Error message output file number
IZROW(2800)		I	I*4	/PARAMS/	Row number for the Ith zone ($1 \le I \le NZONES$)

8.4.2.11 Subroutine OPCONV

DESCRIPTION: Subroutine OPCONV converts the CAMALP, CAMDEL arrays into geocentric inertial coordinates and stores the results in CAMX, CAMY and CAMZ.

CALLING SEQUENCE: Subroutine OPCONV (no calling sequence)

COMMON AREAS REFERENCED: FILES, OPAXIS, OPGI

EXTERNAL REFERENCES: ADTOGI, DIAG, DIAG2

CALLED BY: SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is for diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE OPCONV

Name	Symbol	I/O	Type	Interface	Description
IDFL		I	I*4	/FILES/	Diagnostic output file number
CAMALP(1100), CAMDEL(1100)		I	R*4	/OPAXIS/	Right ascension and declination of the discrete optical axis pointings calculated for a spinning spacecraft (degrees)
NCAMPT		I	I*4	/OPAXIS/	Number of valid points in the CAMALP and CAMDEL arrays
CAMX(1100), CAMY(1100), CAMZ(1100)		O	R*4	/OPGI/	X, Y, and Z components of the optical axis pointings in COMMON /OPAXIS/
IFOPGI		O	I*4	/OPGI/	OPCONV call flag - = 0, OPCONV has not been called = 1, OPCONV has been called

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8.4.2.12 Subroutine PATH

DESCRIPTION: Subroutine PATH determines which zones are required, given the path of the optical axis (CAMALP, CAMDEL).

CALLING SEQUENCE: SUBROUTINE PATH (IFZERO)

COMMON AREAS REFERENCED: FILES, OPAXIS, PARAMS, POINT

EXTERNAL REFERENCES: DIAG, DIAG2, ZONES

CALLED BY: BAND, FETCH, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PATH

Name	Symbol	I/O	Type	Interface	Description
IFZERO		I	I*4	C.S.	IZONES array zero flag: = 0, do not zero IZONES array = 1, zero IZONES array before computation of zones required
IDFL			I*4	/FILES/	Diagnostic output file number
CAMALP(1100) CAMDEL(1100)		I	R*4	/OPAXIS/	Right ascension and declination of the discrete optical axis pointings calculated for a spinning spacecraft (degrees)
NCAMPT		I	I*4	/OPAXIS/	Number of valid points in the CAMALP and CAMDEL arrays
IZONES(2800)		O	I*4	/POINT/	Zone output flag - IZONES(I) = 0, do not output data from zone I = 1, output data from zone I Valid for I = 1, ..., number of zones
NZONES		I	I*4	/PARAMS/	Number of zones

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8.4.2.13 Subroutine SEGMNT

DESCRIPTION: Subroutine SEGMNT alters the CAMALP, CAMDEL arrays so that they contain only those points within RANGE/2 degrees from the point (ALPMID, DELMID).

CALLING SEQUENCE: Subroutine SEGMNT(ALPMID,DELMID,XMID,YMID,
ZMID,RANGE)

COMMON AREAS REFERENCED: FILES,OPAXIS,OPGI

EXTERNAL REFERENCES: DIAG,DIAG2

CALLED BY: SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is diagnostic printed output. FORTRAN data set reference number I6 is error message printed output.

ERROR MESSAGES:

'SEGMNT ... SEGMNT WAS CALLED BEFORE OPCONV ... EXECUTION CONTINUES'--The CAMX, CAMY, and CAMZ arrays may not have been calculated; the resultant catalog may be incorrect. This error occurs only when SEGMNT is called by the user independently of the LOOKAT driver subroutines.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SEGMNT

Name	Symbol	I/O	Type	Interface	Description
ALPMID, DELMID	α_{MID}, δ_{MID}	I	R*4	C.S.	Right ascension and declination of the optical axis at the midpoint of the interval (degrees)
XMID, YMID, ZMID	X_{MID}, Y_{MID}, Z_{MID}	I	R*4	C.S.	Components of geocentric inertial unit vector corresponding to ALPMID, DELMID
RANGE	R	I	R*4	C.S.	Amount of spin during the interval (degrees)
I6		I	I*4	/FILES/	Error message output file number
IDFL		I	I*4	/FILES/	Diagnostic output file number
CAMALP(1100), CAMDEL(1100)		O	R*4	/OPAXIS/	Right ascension and declination of the discrete optical axis pointings calculated for a spinning spacecraft (degrees)
NCAMPT		I/O	I*4	/OPAXIS/	Number of valid points in the CAMALP and CAMDEL arrays
CAMX(1100), CAMY(1100), CAMZ(1100)		I/O	R*4	/OPGI/	X, Y, and Z components of the optical axis pointings in COMMON /OPAXIS/
IFOPGI		I	I*4	/OPGI/	OPCONV call flag – = 0, OPCONV has not been called = 1, OPCONV has been called

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8.4.2.14 Subroutine SLICE

DESCRIPTION: Subroutine SLICE produces a catalog in ISTDAT and FSTDAT, given a spin axis, coelevation angle, starting or central optical axis and range. The catalog represents a portion of a spin-band catalog.

CALLING SEQUENCE: SUBROUTINE SLICE(ITYPE, A, B, C, COELEV, TOLER, SLOP, IOABEG, IOATYP, OA, OB, OC, RANGE, IFMAG, FMAGLM, IFFOV, FOV, IFLONG, ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, OPAXIS, OPGI, PARAMS, POINT

EXTERNAL REFERENCES: ADTOGI, GITOAD, LONG, MIDWAY, OPCONV, PATH, SEGMNT, SORTLG, SPINAX, STORE

CALLED BY: User program

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is error message printed output.

ERROR MESSAGES:

'SLICE ... ERROR OCCURRED IN SUBROUTINE xxxxxxxx ... PROGRAM STOPS'--This is accompanied by message from subroutine (xxxxxxxx).

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SLICE

Name	Symbol	I/O	Type	Interface	Description
ITYPE		I	I*4	C.S.	Spin axis coordinate type flag - = 1, geocentric inertial unit vector is input = 2, right ascension and declination are input
A, B, C		I	R*4	C.S.	If ITYPE = 1, components of the spin axis geocentric inertial unit vector If ITYPE = 2, right ascension and declination of the spin axis (degrees). C is zero
COELEV	θ	I	R*4	C.S.	Angle between the optical axis and the spin axis (degrees)
TOLER	τ	I	R*4	C.S.	Angular separation between the desired points calculated for the optical axis pointings (degrees)
SLOP	ϵ	I	R*4	C.S.	Error factor = sum of the maximum error expected in the spin axis position, and the maximum expected precession and nutation angle (degrees)
IOABEG		I	I*4	C.S.	Optical axis start or midpoint flag = 1, optical axis input is the start of the interval = 2, optical axis input is the midpoint of the interval
IOATYP		I	I*4	C.S.	Optical axis coordinate type flag - = 1, geocentric inertial unit vector is input = 2, right ascension and declination are input
OA, OB, OC		I	R*4	C.S.	If IOATYP = 1, components of the optical axis geocentric inertial unit vector If IOATYP = 2, right ascension and declination of the optical axis (degrees). C is zero

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SLICE

Name	Symbol	I/O	Type	Interface	Description
RANGE	R	I	R*4	C.S.	Amount of spin during the interval (degrees)
IFMAG		I	I*4	C.S.	Magnitude reject flag - = 0, do not reject stars fainter than FMAGLM = 1, reject stars fainter than FMAGLM
FMAGLM		I	R*4	C.S.	Limiting magnitude (IFMAG = 1 only)
IFFOV		I	I*4	C.S.	Field of view reject flag - = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
FOV	r	I	R*4	C.S.	Radius of circular FOV (degrees). FOV must be provided even if IFFOV = 0
IFLONG		I	I*4	C.S.	Longitude sort flag - = 0, do not sort stars by longitudes = 1, sort stars in order of increasing longitude
ISTDAT(NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT(NDIM1, NDIM2)		O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector X-component FSTDAT(I, 2) = G.I unit vector Y-component FSTDAT(I, 3) = G.I unit vector Z-component FSTDAT(I, 4) = normally, star magnitude

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SLICE

Name	Symbol	I/O	Type	Interface	Description
FSTDAT(NDIM1, NDIM2) (Cont'd)					FSTDAT(I, 5), FSTDAT(I, 6), FSTDAT(I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment (See Section 6.6.2.1.4)
STLONG(NDM1)		O	R*4	C.S.	Star longitude, as defined in Section 8.3.7. STLONG is computed if IFLONG = 1
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Error message output file number
IFOPGI		O	I*4	/OPGI/	OPCONV call flag - = 0, OPCONV has not been called = 1, OPCONV has been called
W		I	I*4	/PARAMS/	Declination height of the rows (degrees)

8.4.2.15 Subroutine SORTLG

DESCRIPTION: Subroutine SORTLG sorts the stars in the ISTDAT, FSTDAT, and STLONG arrays in order of increasing longitude (STLONG).

CALLING SEQUENCE: SUBROUTINE SORTLG (ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, PARAMS

EXTERNAL REFERENCES: DIAG, DIAG2

CALLED BY: BAND, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is printed diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SORTLG

Name	Symbol	I/O	Type	Interface	Description
ISTDAT(NDIM1)		I/O	I*4	C.S.	Core Catalog array normally containing star numbers. On output, this array is sorted in order of increasing longitude.
FSTDAT(NDIM1, NDIM2)		I/O	R*4	C.S.	Core Catalog array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector x-component FSTDAT(I, 2) = G.I unit vector y-component FSTDAT(I, 3) = G.I unit vector z-component FSTDAT(I, 4) = normally, star magnitude FSTDAT(I, 5), FSTDAT(I, 6), FSTDAT(I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment (See Section 6.6.2.1.4) On output this array is sorted in order of increasing longitude
STLONG(NDIM1)		I/O	R*4	C.S.	Star longitude, as computed in Section 8.3.7. On output, this array is sorted in order of increasing longitude
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SORTLG

Name	Symbol	I/O	Type	Interface	Description
IDFL		I	I*4	/FILES/	Diagnostic output file number
NWORDS		I	I*4	/PARAMS/	Number of words of data per star

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8.4.2.16 Subroutine SPINAX

DESCRIPTION: Subroutine SPINAX calculates the path taken by the optical axis of a camera at discrete (TOLER) intervals over one rotation.

CALLING SEQUENCE: SUBROUTINE SPINAX (SPINAL, SPINDL, COELEV, TOLER, SLOP, IERRA, IERRB)

COMMON AREAS REFERENCED: FILES, OPAXIS, PARAMS

EXTERNAL REFERENCES: DIAG, DIAG2

CALLED BY: BAND, FETCH, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed error message output. FORTRAN data set reference number IDFL is printed diagnostic output.

ERROR MESSAGES:

'SPINAX ... OVERFLOW OF THE CAMALP AND CAMDEL ARRAYS ... SUBROUTINE RETURNS.'--More than 1100 optical axis printings were generated. Increase the size of TOLER.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE SPINAX

Name	Symbol	I/O	Type	Interface	Description
SPINAL, SPINDL		I	R*4	C.S.	Right ascension and declination of the spin axis (degrees)
COELEV	θ	I	R*4	C.S.	Angle between the spin axis and camera optical axis (degrees)
TOLER	τ	I	R*4	C.S.	Angular separation between the desired points calculated for the optical axis pointings (degrees)
SLOP	ϵ	I	R*4	C.S.	Error factor which equals the sum of the maximum error expected in the spin axis position, and the maximum expected precession and nutation angle (degrees)
IERRA, IERRB		O	I*4	C.S.	Error return flags (alphameric) = blank, no error occurred = anything else, error occurred in the subroutine spelled out by IERRA, IERRB
16		I	I*4	/FILES/	Error message output file number
IDFL		I	I*4	/FILES/	Diagnostic output file number
CAMALP(1100) CAMDEL(1100)		O	R*4	/OPAXIS/	Right ascension and declination of the discrete optical axis pointings calculated for a spinning spacecraft (degrees)
NCAMPT		O	I*4	/OPAXIS/	Number of valid points in the CAMALP and CAMDEL arrays

8.4.2.17 Subroutine STORE

DESCRIPTION: Subroutine STORE creates a catalog in the ISTDAT and FSTDAT arrays covering the zones requested in the array IZONES using input file INFILE. Redundant stars are eliminated.

CALLING SEQUENCE: SUBROUTINE STORE (IERRA, IERRB, IFMAG, FMAGLM, FOV, SLOP, IFFOV, SPINAL, SPINDL, COELEV, ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FERMSG, FILES, PARAMS, POINT

EXTERNAL REFERENCES: ADTOGI, DIAG, DIAG2, DREAD, NODUPE

CALLED BY: BAND, FETCH, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed error message output. FORTRAN data set reference number INFILE is a direct-access Run Catalog. FORTRAN data set reference number IDFL is printed diagnostic output.

ERROR MESSAGES:

'STORE ... ZONE xxxx NOT IN INPUT CATALOG ... SUBROUTINE RETURNS.'

'STORE ... READ ERROR ON RUN CATALOG FILE ... PROGRAM RETURNS.'
DAIO ERROR MESSAGE FIELD IS

ZZZZZZZZ IIIII AAAAAAAA AAAAAAAA AAAAAAAA
AAAAAAAA AAAAAAAA AAAAAAAA AAAAAAAA AAAAAAAA
AAAAAAAA AAAAAAAA ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ
ZZZZZZZZ'

The Z, I, and A fields indicated are hexadecimal, integer and alphameric information, respectively, from the DAIO error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take appropriate action.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STORE

Name	Symbol	I/O	Type	Interface	Description
IERRA, IERRB		O	I*4	C.S.	Error return flags (alphameric) = blanks, no error occurred = anything else, an error occurred in the subroutine spelled out by IERRA, IERRB
IFMAG		I	I*4	C.S.	Magnitude sorting flag - = 0, do not reject stars fainter than FMAGLM = 1, reject stars fainter than FMAGLM
FMAGLM		I	R*4	C.S.	Limiting magnitude (used for IFMAG=1 only)
FOV	r	I	R*4	C.S.	Half cone angle of the FOV (degrees, IFFOV=1 only)
SLOP	ϵ	I	R*4	C.S.	Error factor = sum of the maximum error expected in the spin axis position, and the maximum expected precession and nutation angle (degrees)
IFFOV		I	I*4	C.S.	Field of view select flag - = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
SPINAL, SPINDL		I	R*4	C.S.	Right ascension and declination of the spin axis, respectively (degrees, IFFOV = 1 only)
ISTDAT (NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT(NDIM1, NDIM2)		O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT(I, 1) = G.I unit vector x-component FSTDAT(I, 2) = G.I unit vector y-component

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STORE

Name	Symbol	I/O	Type	Interface	Description
FSTDAT(NDIM1, NDIM2) (Cont'd)					FSTDAT(I, 3) = G. I unit vector z-component FSTDAT(I, 4) = normally, star magnitude FSTDAT(I, 5), FSTDAT(I, 6), FSTDAT(I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment (See Section 6.6.2.1.4)
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Error message output file number
INFILE		I	I*4	/FILES/	Direct-access input Run Catalog file number
INREC		O	I*4	/FILES/	Associated variable for INFILE
IDFL		I	I*4	/FILES/	Diagnostic output file number
NZONES		I	I*4	/PARAMS/	Number of zones
ROWMAX(40)		I	R*4	/PARAMS/	Maximum row declination for the Ith row $(1 \le I \le NROWS)$ (degrees)
ROWMIN(40)		I	R*4	/PARAMS/	Minimum row declination for the Ith row $(1 \le I \le NROWS)$ (degrees)

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE STORE

Name	Symbol	I/O	Type	Interface	Description
NWORDS		I	I*4	/PARAMS/	Number of words of data per star
NPER		I	I*4	/PARAMS/	Number of data segments in one logical record (see Section 6.6.2.1.4)
IZROW(2800)		I	I*4	/PARAMS/	Row number for the Ith zone (1 ≤ I ≤ NZONES)
IZONES(2800)		I	I*4	/POINT/	Zone output flag - IZONES(I) = 0, do not output data from zone I IZONES(I) = 1, output data from zone I Valid for I = 1, ..., number of zones
IPOINT(2800)		I	I*4	/POINT/	IPOINT(I) = record number of the first logical record in the Run Catalog for Zone I. If IPOINT(I) is negative, Zone I is not present. Valid for I = 1, ..., number of zones

8.4.2.18 Subroutine VPHSKY

DESCRIPTION: Subroutine VPHSKY computes the unit vector corresponding to a given rotation angle and a given angular separation.

CALLING SEQUENCE: SUBROUTINE VPHSKY (A, B, PHI, COSCON, SINCON, C)

COMMON AREAS REFERENCED: None

EXTERNAL REFERENCES: None

CALLED BY: MIDWAY

INPUT/OUTPUT VARIABLES FOR SUBROUTINE VPHSKY

Name	Symbol	I/O	Type	Interface	Description
A(3), B(3)		I	R*4	C.S.	Unit vectors partially defining the dihedral angle
PHI		I	R*4	C.S.	Rotation angle (radians)
COSCON, SINCON		I	R*4	C.S.	Cosine and sine of the angle separating A and C
C(3)		O	R*4	C.S.	Unit vector such that the dihedral angle from the A, B plane to the A, C plane is PHI, and the angle between A and C is the cone angle. If A is parallel or anti-parallel to B, the solution is undefined and C(1) = 2.0

8.4.2.19 Subroutine ZONES

DESCRIPTION: Subroutine ZONES calculates the zone numbers (LZA, LZB) required for a given pointing (OAALP, OADEL).

CALLING SEQUENCE: SUBROUTINE ZONES(OAALP, OADEL, LZA, LZB)

COMMON AREAS REFERENCED: FILES, PARAMS

EXTERNAL REFERENCES: DIAG, DIAG2

CALLED BY: BAND, FETCH, PATH

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number IDFL is printed diagnostic output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE ZONES

Name	Symbol	I/O	Type	Interface	Description
OAALP, OADEL		I	R*4	C.S.	Right ascension and declination of the optical axis, respectively (degrees)
LZA, LZB		O	I*4	C.S.	Zone numbers required for the given optical axis pointing
IDFL		I	I*4	/FILES/	Diagnostic output file number
ROWWID(40)		I	R*4	/PARAMS/	Right ascension width of the zones in the Ith row (1 ≤ I ≤ NROWS) (degrees)
NROWST(40)		I	I*4	/PARAMS/	Number of the first zone in the Ith row (1 ≤ I ≤ NROWS)
NROWS		I	I*4	/PARAMS/	Number of rows
W		I	I*4	/PARAMS/	Declination height of the rows (degrees)

8.5 COMMON AREA DESCRIPTIONS

8.5.1 COMMON /FERMSG/

DESCRIPTION: COMMON /FERMSG/ contains the DAIO error message fields.

FORM: COMMON /FERMSG/ IMES(26)

REFERENCED BY: INITSK, STORE

DEFINITION OF VARIABLES:

Name	Type	Description
IMES(26)	4-byte hexadecimal, integer and alphameric	DAIO error message fields--see Reference 35

8.5.2 COMMON /FILES/

DESCRIPTION: COMMON /FILES/ contains parameters defining program files.

FORM: COMMON /FILES/I5, I6, INFILE, INREC, IFDG, IDFL

REFERENCED BY: BAND, DIAG, DIAG2, FETCH, INITSK, LONG, MIDWAY, NODUPE, OPCONV, PATH, SEGMNT, SLICE, SORTLG, SPINAX, STORE, ZONES

DEFINITION OF VARIABLES:

Name	Type	Description
I5	I*4	Card input file number
I6	I*4	Error message output file number
INFILE	I*4	Direct-access input Run Catalog file number
INREC	I*4	Associated variable for INFILE
IFDG	I*4	Diagnostic control flag - = 0, no diagnostics = 1, 2, 3, 4, 5, successively more diagnostics printed
IDFL	I*4	Diagnostic output file number

8.5.3 COMMON /OPAXIS/

DESCRIPTION: COMMON /OPAXIS/ contains the optical axis pointing calculated for a spinning spacecraft.

FORM: COMMON /OPAXIS/ CAMALP(1100),CAMDEL(1100),NCAMPT

REFERENCED BY: BAND, FETCH, OPCONV, PATH, SEGMNT, SLICE, SPINAX

DEFINITION OF VARIABLES:

Name	Type	Description
CAMALP(1100) CAMDEL(1100)	R*4	Right ascension and declination of the discrete optical axis pointings calculated for a spinning spacecraft (degrees)
NCAMPT	I*4	Number of valid points in the CAMALP and CAMDEL arrays

8.5.4 COMMON /OPGI/

DESCRIPTION: OPGI contains the geocentric inertial unit vectors corresponding to the optical axis pointing in COMMON /OPAXIS/.

FORM: COMMON /OPGI/ CAMX(1100),CAMY(1100),CAMZ(1100),IFOPGI

REFERENCED BY: BAND,OPCONV,SEGMNT,SLICE

DEFINITION OF VARIABLES:

Name	Type	Description
CAMX, CAMY, CAMZ	R*4	X, Y, and Z components of the optical axis pointings in COMMON /OPAXIS/
IFOPGI	I*4	OPCONV call flag - = 0, OPCONV has not been called = 1, OPCONV has been called

8.5.5 COMMON /PARAMS/

DESCRIPTION: PARAMS contains control words and arrays which define the structure of the Run Catalog.

FORM: COMMON /PARAMS/ NZONES, ROWMAX(40), ROWMIN(40), ROWWID(40), NROWST(40), NUMROW(40), NROWS, NWORDS, NPER, W, IZROW(2800)

REFERENCED BY: BAND, FETCH, INITSK, NODUPE, PATH, SLICE, SORTLG, SPINAX, STORE, ZONES

DEFINITION OF VARIABLES:

Name	Type	Description
NZONES	I*4	Number of zones
ROWMAX(40)	R*4	Maximum row declination for the Ith row (1 ≤ I ≤ NROWS) (degrees)
ROWMIN(40)	R*4	Minimum row declination for the Ith row (1 ≤ I ≤ NROWS) (degrees)
ROWWID(40)	R*4	Right ascension width of the zones in the Ith row (1 ≤ I ≤ NROWS) (degrees)
NROWST(40)	I*4	Number of the first zone in the Ith row (1 ≤ I ≤ NROWS)
NUMROW(40)	I*4	Total number of zones in the Ith row (1 ≤ I ≤ NROWS)
NROWS	I*4	Number of rows
NWORDS	I*4	Number of words of data per star
NPER	I*4	Number of data segments in one logical record (see Section 6.6.2.1.4)
W	I*4	Declination height of the rows (degrees)
IZROW(2800)	I*4	Row number for the ith zone (1 ≤ I ≤ NZONES)

8.5.6 COMMON /POINT/

DESCRIPTION: POINT contains arrays describing which zones are available on the input Run Catalog and which are requested on the output catalog.

FORM: COMMON /POINT/IZONES(2800), IPOINT(2800)

REFERENCED BY: BAND, FETCH, INITSK, NODUPE, PATH, SLICE, STORE

DEFINITION OF VARIABLES:

Name	Type	Description
IZONES(2800)	I*4	Zone output flag - IZONES(I) = 0, do not output data from zone I = 1, output data from zone zone I Valid for I = 1, ..., number of zones
IPOINT(2800)	I*4	IPOINT(I) = record number of the first logical record in the Run Catalog for Zone I. If IPOINT(I) is negative, Zone I is not present. Valid for I = 1, ..., number of zones

8.6 USER'S MANUAL

This section will permit the user to formulate code to generate Core Catalogs using Access Module driver subroutines.

8.6.1 Using Existing Driver Subroutines

The Access Module contains three driver subroutines which may be called by user programs to create Core Catalogs.

The three driver subroutines are FETCH, BAND, and SLICE. Each is described in detail in Section 8.6.2. The following steps must be taken to use any Access Module driver subroutine:

- LOOKAT uses dynamic dimensioning for the Core Catalog output arrays. In the main routine, dimension statements must be hard coded for the ISTDAT, FSTDAT, and STLONG arrays. ISTDAT and STLONG must be dimensioned to the value of NDIM1 used in the driver subroutine calling sequence. FSTDAT must be doubly dimensioned; the first dimension is NDIM1 and the second is NDIM2, as used in the driver subroutine calling sequence. NDIM1 is the maximum number of stars anticipated in the Core Catalog; NDIM2 is the number of floating point words of data per star to be output in the Core Catalog.

- The following parameters in COMMON /FILES/ must be set: I6, INFILE, and IFDG. If IFDG $\neq$ 0, IDFL must also be set. Default values are not provided by LOOKAT. The remaining parameters--I5 and INREC--are not used by the Access Module. Section 8.5.2 defines these parameters. It should be noted that INFILE must be a one- or two-digit positive integer, must not equal I6 or IDFL, and must agree with the JCL DD statement for the input Run Catalog.

- Call SUBROUTINE INITSK before calls are made to any other LOOKAT subroutines. Repeated calls to INITSK use computer time, but do not otherwise affect performance of LOOKAT subroutines.

- Code CALL statements to the driver subroutines with all input calling sequence variables defined. When the driver returns control to the user program, the requested Core Catalog will exist in core, provided no error conditions described below are encountered.

8.6.2 The Driver Subroutines

8.6.2.1 Subroutine FETCH

FETCH produces a Core Catalog containing all the stars within a specified half-cone angle whose axis is centered on a user-specified pointing. Reference 36 is a convenient small document describing the user's interface with FETCH.

8.6.2.2 Subroutine BAND

BAND produces a Core Catalog containing all the stars located in a band of user-input width about the path taken by the optical axis of a spinning sensor. Reference 37 is a convenient small document describing the user's interface with BAND.

8.6.2.3 Subroutine SLICE

SLICE produces a Core Catalog containing all the stars in a user-specified subset of a band catalog, defined by minimum and maximum longitudes, relative to a spin inertial frame. Reference 38 is a convenient small document describing the user interface with SLICE.

8.6.3 Input to the Access Module

Input to the Access Module, other than calling sequence variables, consists of a direct-access disk Run Catalog (created by program CAT) or selected Run Catalog (created by program SWITCH).

LOOKAT has no NAMELISTs; user entry of data into the Access Module is accomplished by calling sequences and COMMON blocks.

8.6.4 Output From the Access Module

Output from the Access Module is limited to error messages, diagnostic printed output, and the Core Catalog.

8.6.4.1 Error Message Output

Program contingencies cause error message output on FORTRAN data set reference number I6 (a COMMON /FILES/ variable). A complete listing of these messages, together with brief explanations where necessary, is given below.

'BAND ... ERROR OCCURRED IN SUBROUTINE xxxxxxxx ... PROGRAM RETURNS'--This is accompanied by a message from the subroutine stated.

'FETCH ... ZONE REQUESTED NOT AVAILABLE ... PROGRAM STOPS.'
A zone requested by FETCH was not present on the input Run Catalog. This is accompanied by an error message from subroutine AVAIL.

'FETCH ... ERROR OCCURRED IN SUBROUTINE STORE ... PROGRAM RETURNS'--Some fatal error occurred in subroutine STORE. This is accompanied by a specific error message from STORE.

'INITSK ... READ ERROR ON RUN CATALOG FILE ... PROGRAM STOPS. DAIO ERROR MESSAGE FIELD IS

ZZZZZZZZIIIIIIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAZZZZZZZZ ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ'

The Z, I, and A fields indicated are hexidecimal, integer, and alphameric information, respectively, from the DAIO error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take appropriate action.

'NODUPE ... OVERFLOW IN THE ISTDAT AND FSTDAT ARRAYS AT STAR NUMBER xxxxxxxx IN ZONE NUMBER yyyyy ... SUBROUTINE RETURNS TO DRIVER SUBROUTINE THROUGH SUBROUTINE STORE.'

'SEGMNT ... SEGMNT WAS CALLED BEFORE OPCONV ... EXECUTION CONTINUES'--The CAMX, CAMY, and CAMZ arrays may not have been calculated; the resultant catalog may be incorrect.

'SLICE ... ERROR OCCURRED IN SUBROUTINE xxxxxxxx ... PROGRAM RETURNS'--This is accompanied by a message from the indicated subroutine.

'SPINAX ... OVERFLOW OF THE CAMALP AND CAMDEL ARRAYS ... SUBROUTINE RETURNS.'--More than 1100 optical axis pointings were generated. Increase the size of TOLER.

'STORE ... ZONE xxxx NOT IN INPUT CATALOG ... SUBROUTINE RETURNS.'

'STORE ... READ ERROR ON RUN CATALOG FILE ... PROGRAM RETURNS. DAIO ERROR MESSAGE FIELD IS

ZZZZZZZZIIIIIIAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAZZZZZZZZ ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ'

The Z, I, and A fields indicated are hexidecimal, integer, and alphameric information, respectively, from the DAIO error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take appropriate action.

8.6.4.2 Diagnostic Output

Diagnostic output may be requested by the user; it is written on FORTRAN data set reference number IDFL, provided IFDG > 0 (both are COMMON /FILES/ parameters). Diagnostic output consists of trace messages delineating the entry and exit of each major subroutine, plus selected variables. Values of IFDG of 1, 2, 3, 4, and 5 produce successively more output. Level 1 produces little more than trace messages. Level 2 writes major input/output variables. Level 3 writes larger input/output arrays and some calculated variables. Level 4 includes large calculated arrays, and level 5 includes many variables produced inside of DO loops.

8.6.4.3 Core Catalog

The Core Catalog contains precisely the same data as the input Run Catalog (see Table 6-4).

8.6.5 Job Control Language

The GO step of any job using the Access Module must contain a DD statement defining the star catalog. The form of this statement is

```
//FTxxF001 DD DSN=ATTIT.CAMERA.SKYMAP.DATA,DISP=SHR
```

where xx is replaced by the file number assigned to the Run Catalog, and must equal COMMON /FILES/ parameter INFILE.

DD statements must also be provided for files I6 and IDFL if these are not directed to defaulted SYSOUT files.

LOOKAT subroutines are available in nonexecutable load module form and may be referenced by including the following in the GO step JCL:

```
//SYSLIB DD DSN=ATTIT.SKYMAP.LOOKAT.OBJ,DISP=SHR
```

8.6.6 Overlay Considerations

Various portions of the Access Module can be overlaid. We recommend against overlay of COMMON /FILES/ and COMMON /PARAMS/ unless no further calls to LOOKAT subroutines are anticipated. If these are overlaid, COMMON /FILES/ must be reset by the user program and COMMON /PARAMS/ by a call to subroutine INITSK. All subroutines can be overlaid without harm, but care should be taken to keep all subroutines within a working segment (defined as a driver and its attendant structure; see Figure 8-9) in a single leg.

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8.6.7 System Resources Needed

LOOKAT is designed to run on the IBM S/360-95 computer under OS/HASP or OS/MVT.

Disk storage is required for the input Run Catalog. The amount of storage needed depends on the size of the input Run Catalog (see Sections 6.6.5 and 7.6.5).

Storage required for the GO step depends on which subroutines are to be used. Table 8-1 presents the size of each subroutine as compiled under FORTRANH, option 2. Table 8-2 presents the sizes of the various COMMON blocks.

The total storage needed is the sum of that required for the chosen subroutines and all the COMMON blocks plus up to 20K bytes for input/output buffers.

8.6.8 Execution Time Estimates

Because of the large variety of options available in LOOKAT, we have not attempted to estimate execution times. For a limiting magnitude of 7.5, Core Catalogs have been generated containing up to 3000 stars in less than 0.25 minute each for CPU and I/O time.

Table 8-1. Subroutine Sizes for the Access Module

SUBROUTINE NAME	SIZE (DECIMAL BYTES)
ADTOGI	526
BAND	1758
DIAG	408
DIAG2	316
FETCH	1786
GITOAD	480
INITSK	4026
LONG	1914
MIDWAY	1506
NODUPE	932
OPCONV	692
PATH	834
SEGMNT	3236
SLICE	2952
SORTLG	2030
SPINAX	2066
STORE	4128
VPHSKY	810
ZONES	962

Table 8-2. COMMON Block Sizes for the Access Module

COMMON AREA NAME	SIZE (DECIMAL BYTES)
FERMSG	104
FILES	24
OPAXIS	8804
OPGI	13204
PARAMS	12020
POINT	22400

SECTION 9 - ANALYZING THE RUN CATALOG

Statistical analysis of the Run Catalog is performed by the Statistics Module of program LOOKAT. Using the subroutines of the Statistics Module, the user can obtain information about the star distribution in the sky which may aid him in specifying and developing software.

This section discusses the subroutines of the Statistics Module. Access Module subroutines referenced by the Statistic Module are detailed in Section 8.

9.1 STATISTICS MODULE CAPABILITIES

The capabilities of the Statistics Module of program LOOKAT are:

- List the contents of any or all subcatalogs.
- Generate a Core Catalog by referencing any of the Access Module drivers--FETCH, BAND, or SLICE.
- Select stars from the Core Catalog for further analysis on the basis of any Core Catalog star data word being within user-specified bounds.
- Calculate right ascensions and declinations of the Core Catalog stars from the G.I. unit vector. Store these in any specified locations of the Core Catalog arrays.
- List the parameters used by program CAT to create the Run Catalog.
- Sort the Core Catalog into either ascending or descending order of any specified Core Catalog data word.
- List the Core Catalog star data or a user-specified subset of the Core Catalog.
- Count the number of stars falling into user-specified bins defined by reference to any specified Core Catalog star data word; present the results in tabular and histogram form.

The histogram has an automatic scaling feature to assure that data will not have to be truncated. Counts above or below the bin limits are given on separate lines of the histogram.

- Define "bins" for any given star data word based upon user-specified zero point and scale factor, or a zero point and scale factor derived from a user-specified member of bins and the extreme values for the star data word.
- Produce right ascension versus declination printer plots for the Core Catalog stars on either a whole-sky plot or a plot scaled to allow maximum resolution.
- Correlate any two specified Core Catalog star data words using either least-squares linear or quadratic fits; and present data in tabular and/or printer plot form.
- Calculate mean errors before and after the correlation.
- Provide a printer plot of the correlation variables. Optionally, add the correlation curve to this plot.

9.2 STATISTICS MODULE OVERVIEW

The Statistics Module produces statistical information and plots of the Run Catalog data, using as input a direct-access Run Catalog created directly by program CAT or loaded to disk subsequently by program SWITCH. The Access Module of program LOOKAT is used to create Core Catalogs, which are used in the statistical analysis. An input data set and a statistics driver routine direct SWITCH Program flow.

9.2.1 Statistics Module Logical Flow

A baseline diagram of the Statistics Module, STATS, is given in Figure 9-1 and a logical flow diagram of STATS is presented in Figure 9-2. The Statistics Module is entered by a call to its driver subroutine, STATS. A NAMELIST is

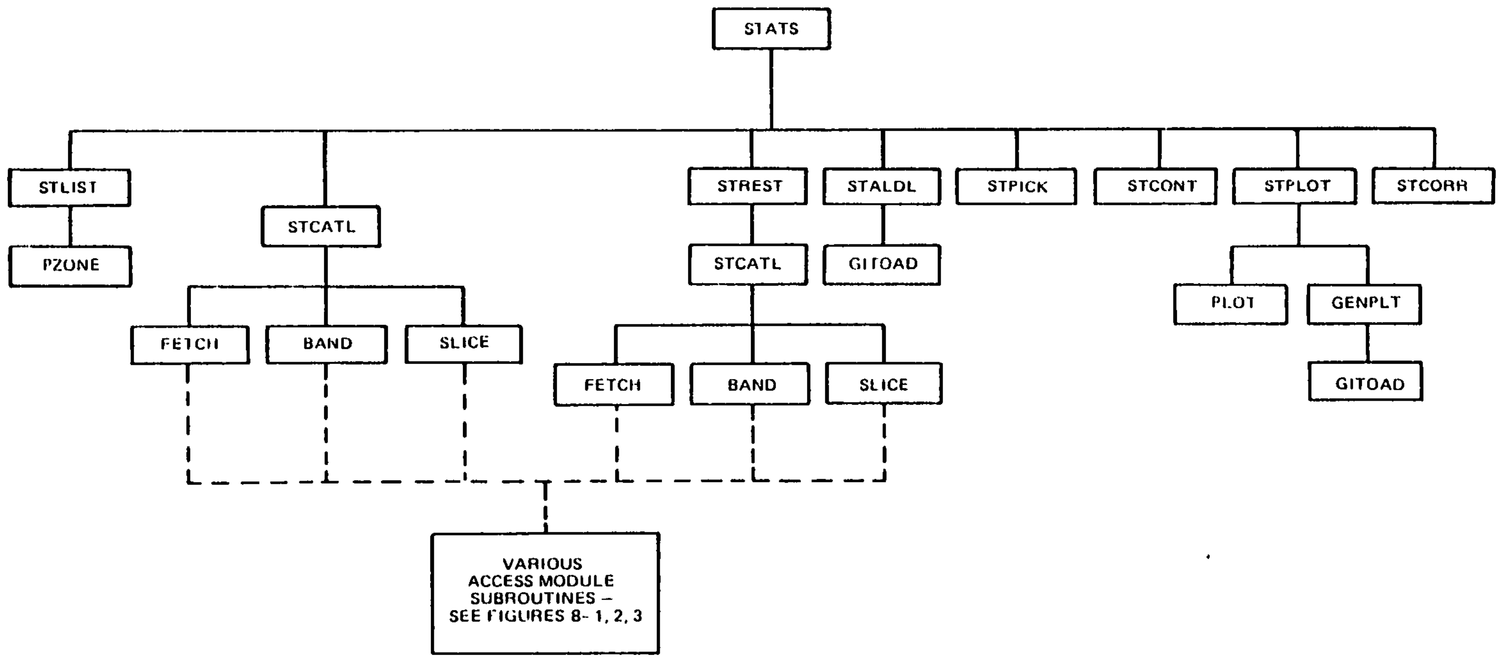

Figure 9-1. Baseline Diagram of Subroutine STATS

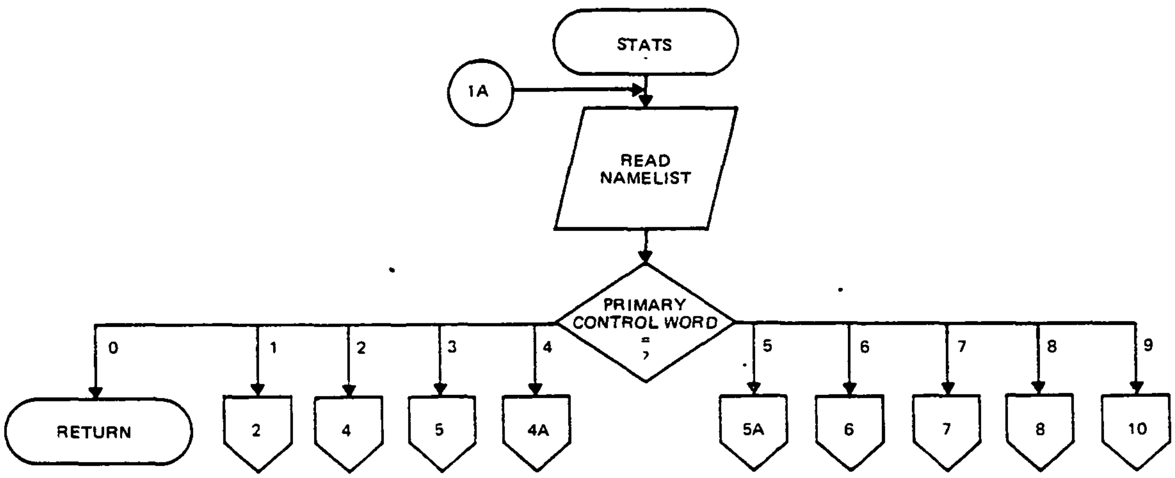

Figure 9-2. Logical Flow of the Statistics Module (1 of 10)

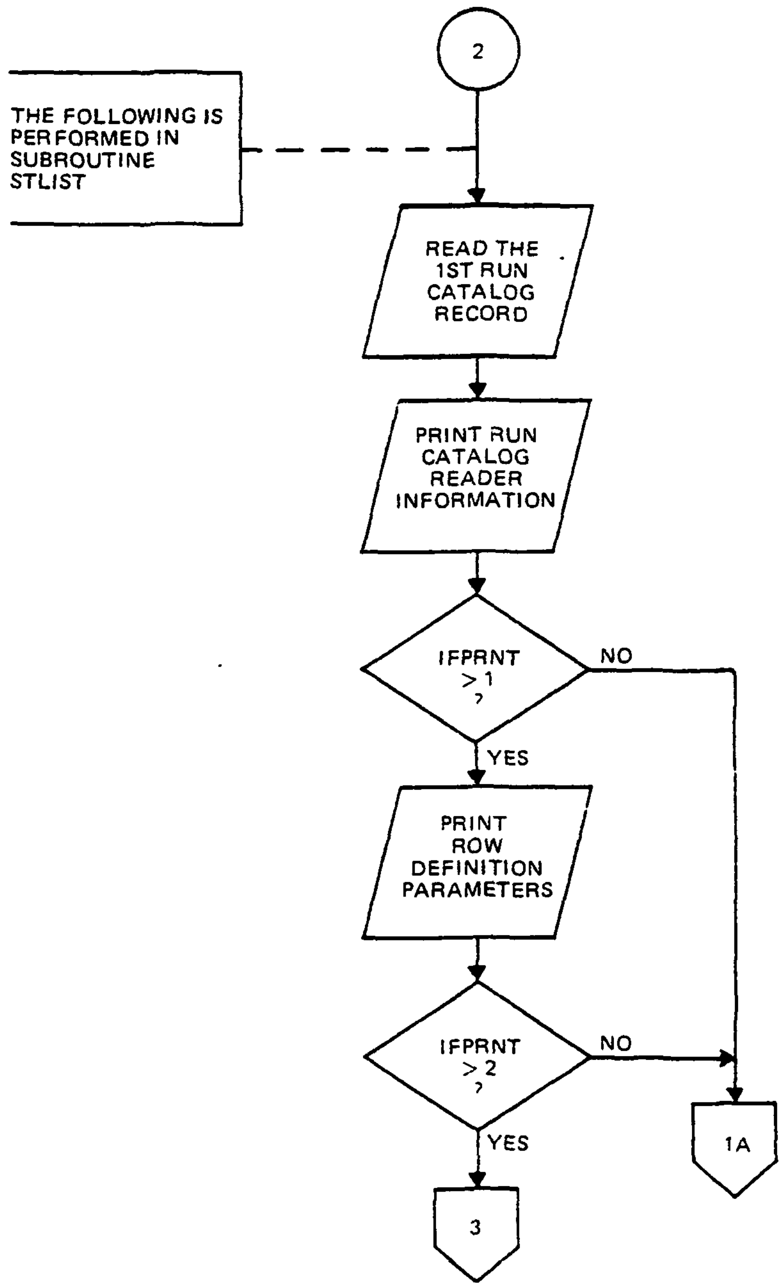

Figure 9-2. Logical Flow of the Statistics Module (2 of 10)

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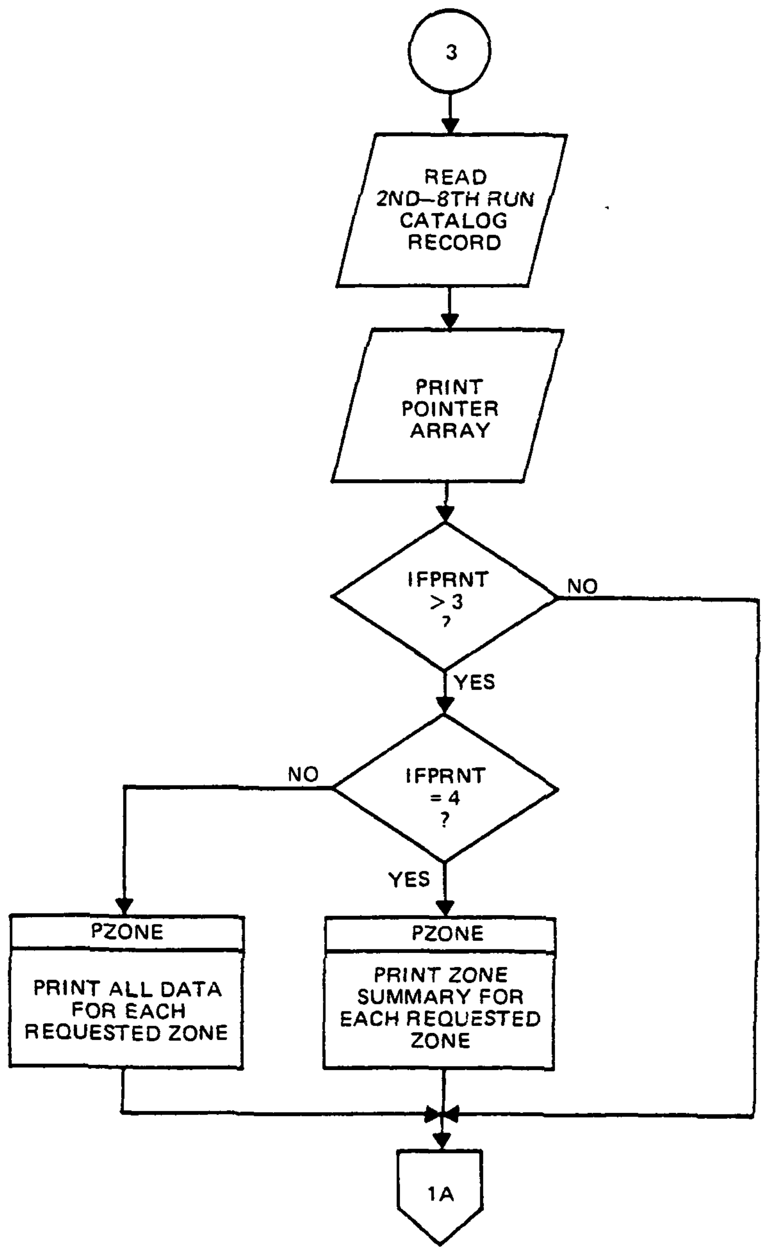

Figure 9-2. Logical Flow of the Statistics Module (3 of 10)

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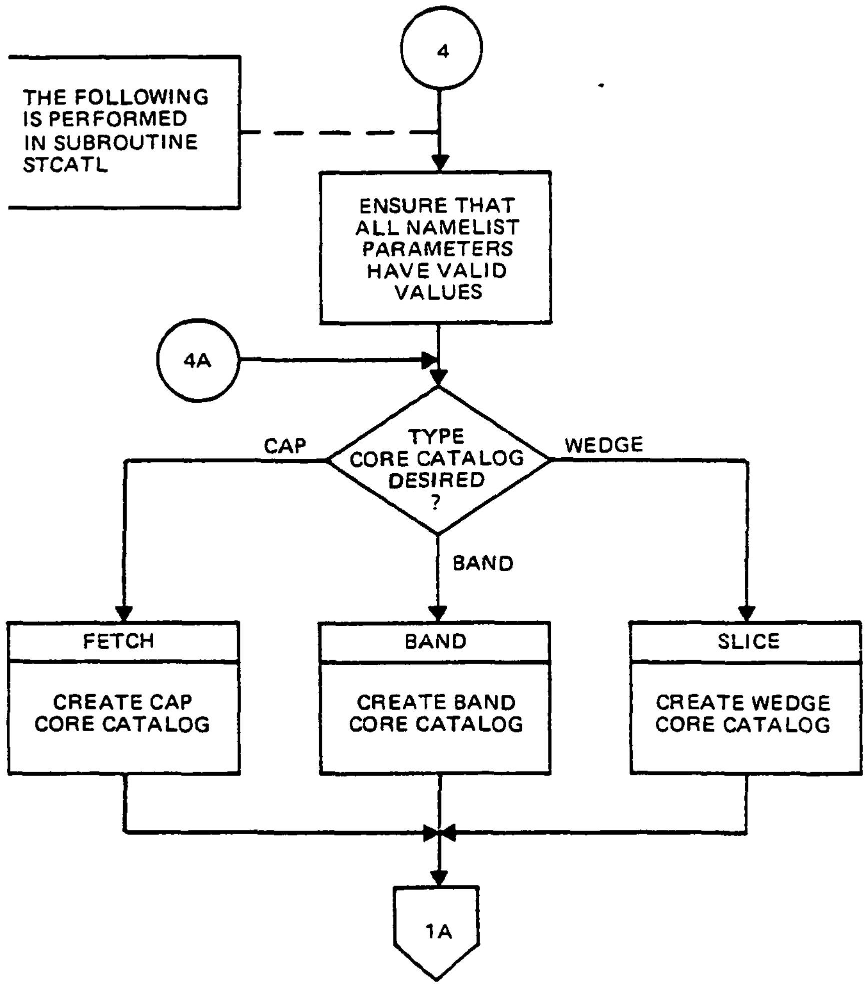

Figure 9-2. Logical Flow of the Statistics Module (4 of 10)

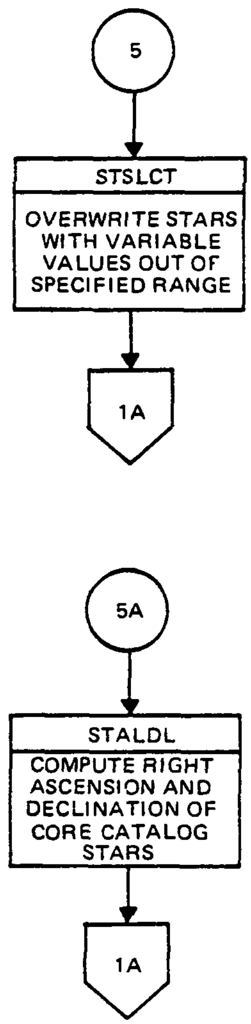

Figure 9-2. Logical Flow of the Statistics Module (5 of 10)

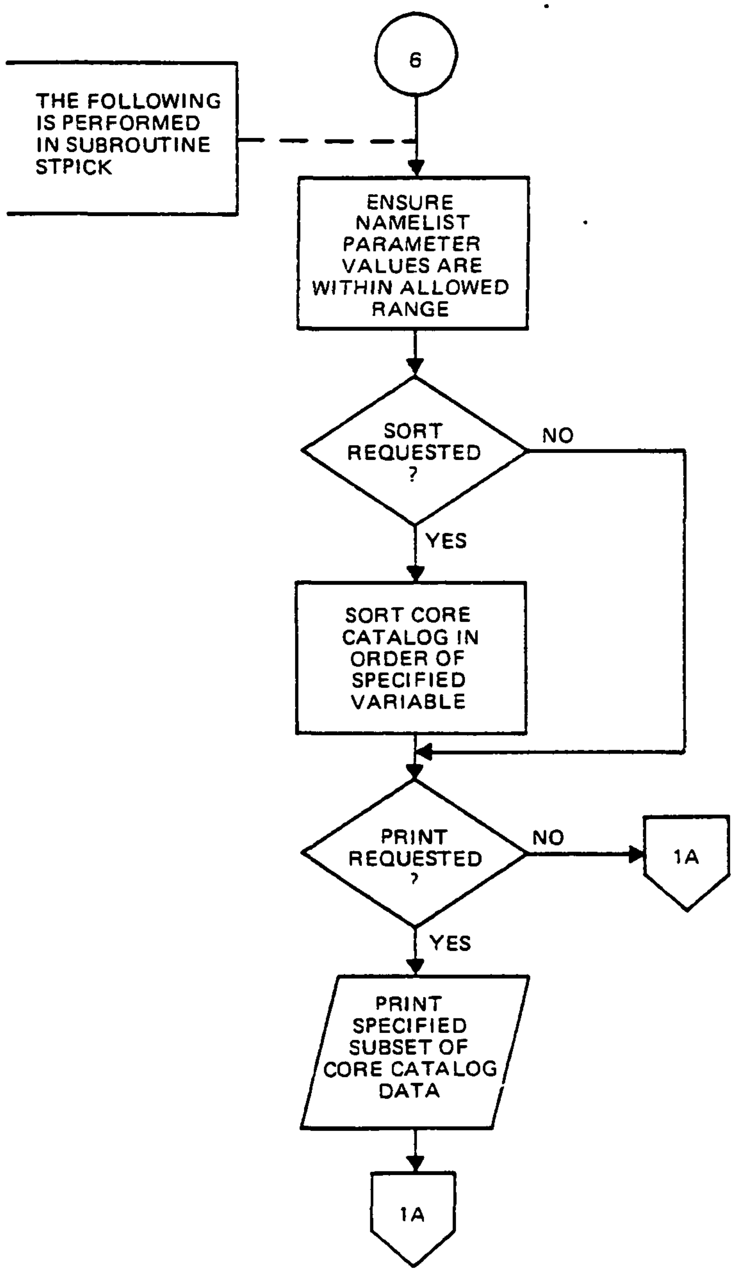

Figure 9-2. Logical Flow of the Statistics Module (6 of 10)

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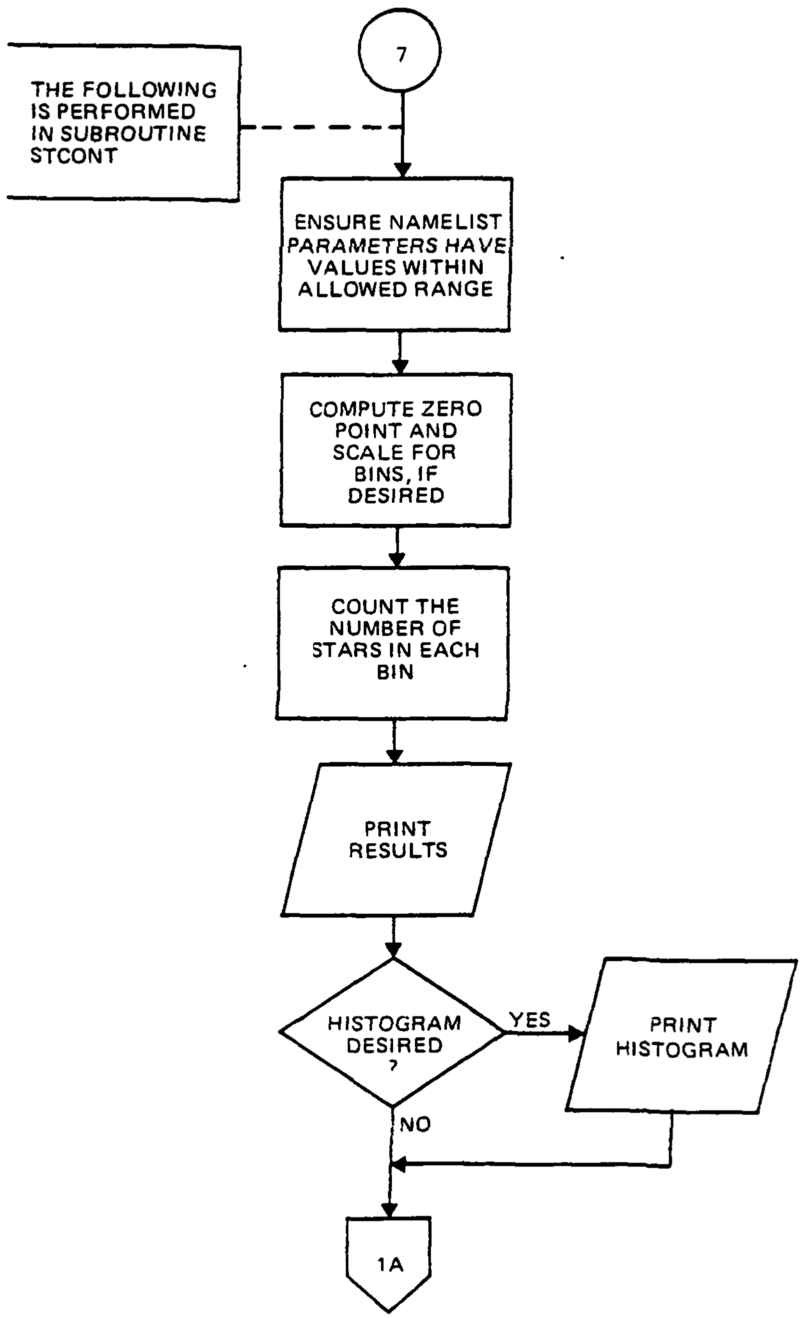

Figure 9-2. Logical Flow of the Statistics Module (7 of 10)

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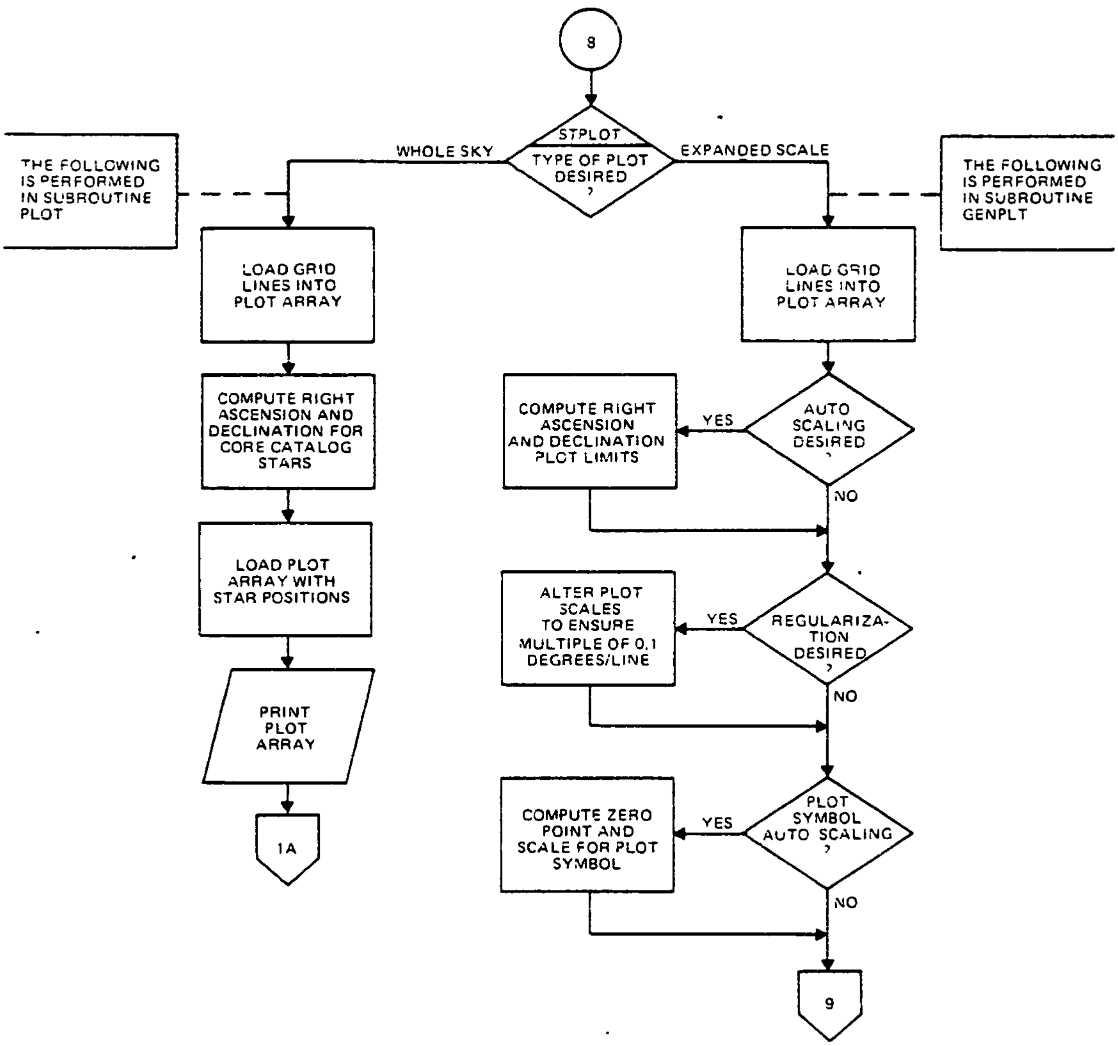

Figure 9-2. Logical Flow of the Statistics Module (8 of 10)

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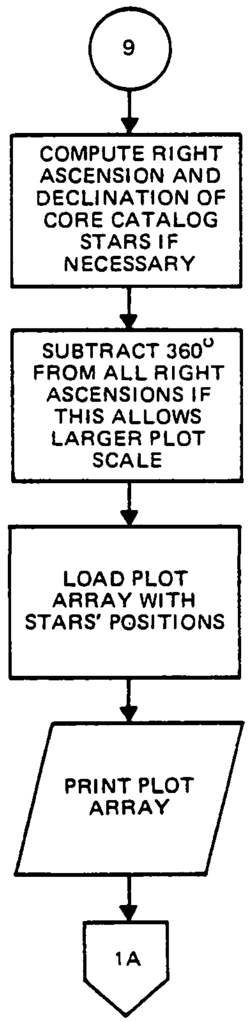

Figure 9-2. Logical Flow of the Statistics Module (9 of 10)

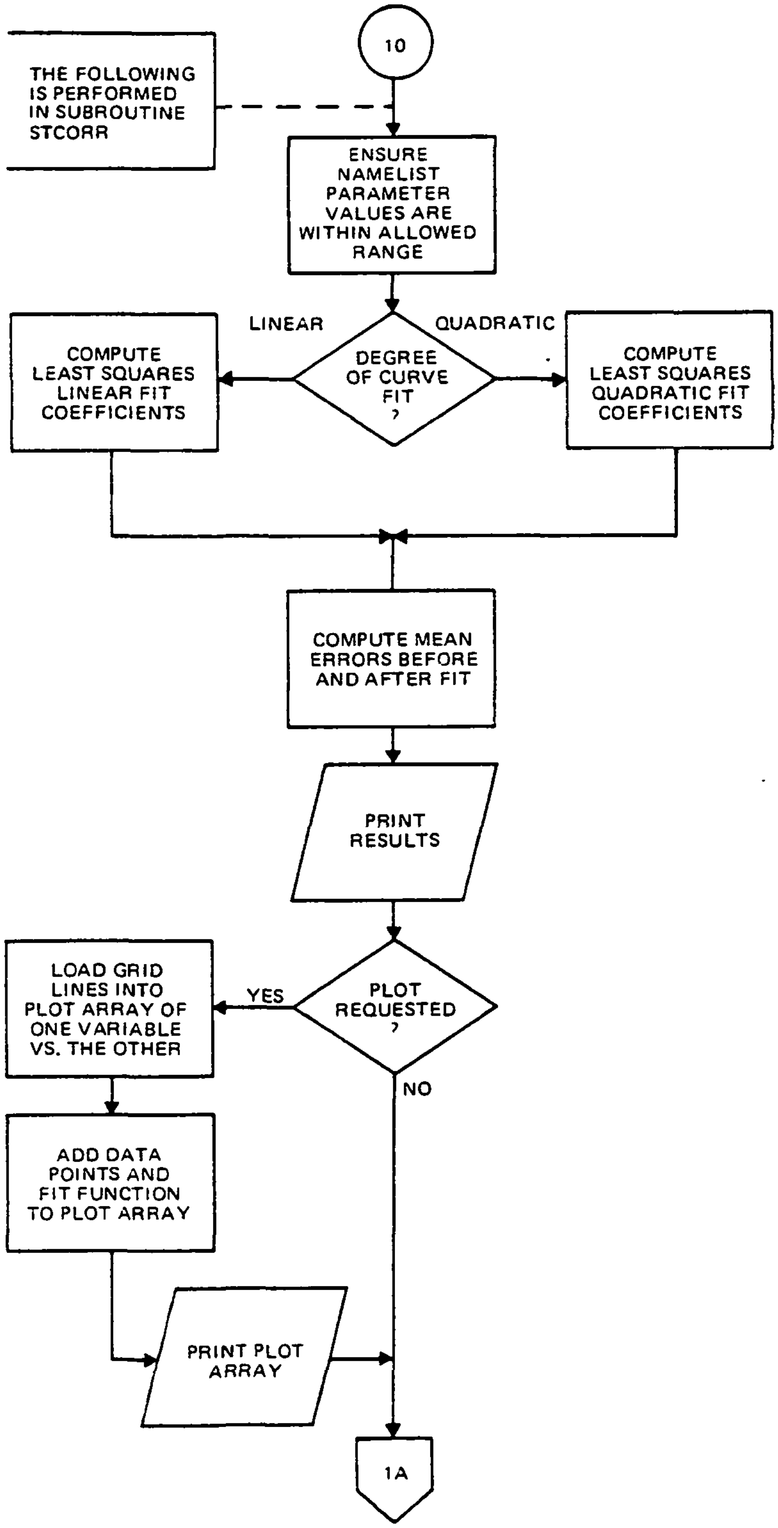

Figure 9-2. Logical Flow of the Statistics Module (10 of 10)

read from data set FORTRAN reference number I5. Program flow is directed to one of the worker subroutines based on the value of the NAMELIST primary control word ISTAT. Table 9-1 lists the values the primary control word, the name of the subroutine to which they direct program flow, and a brief description of that subroutine.

The Secondary Control Words, which were read from the same NAMELIST as the primary control word, control the program flow within the worker subroutine. After the worker subroutine completes its function, it returns to STATS, which reads another NAMELIST from file I5. The program continues until

- A value of zero is read for the primary control word (STATS returns).
- An I/O error is encountered reading the Run Catalog (program STOPS).
- An end of file is encountered on file I5 (STATS returns).

The logical program flow for four of the most involved of the Statistics Module subroutines is discussed below. The other subroutines are described only functionally in Section 9.6.

9.2.2 Subroutine STPICK

STPICK begins by checking the value of the secondary control words against a set of allowed values.

The user specifies which star data word is to be the sorting variable. This can be ISTDAT or any of the eight FSTDAT words. A value of zero for this control word permits the user to skip the sorting phase of STPICK.

The sort is accomplished in either ascending or descending order (user-specified) and control then passes to the printing phase of STPICK.

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Table 9-1. Primary Control Word Values and Meanings

VALUE	SUBROUTINE CALLED	FUNCTION PERFORMED
0	NONE	STATS RETURNS
1	STLIST	LISTS PARTS OR ALL OF RUN CATALOG
2	STCATL	PRODUCES CORE CATALOG
3	STSLCT	SELECTS A SUBSET OF THE CORE CATALOG BASED ON THE VALUE OF A SPECIFIED CORE CATALOG DATA WORD
4	STREST	RESETS CORE CATALOG TO WHAT IS WAS PRIOR TO STSLCT EXECUTIONS
5	STALDL	CALCULATES AND STORES RIGHT ASCENSION AND DECLINATION
6	STPICK	SORTS CORE CATALOG ON A SPECIFIED VARIABLE AND PRINTS ALL OR SPECIFIED PARTS OF THE CORE CATALOG DATA
7	STCONT	COUNTS THE NUMBER OF CORE CATALOG STARS HAVING THE VALUE OF A GIVEN DATA WORD IN EACH OF A NUMBER OF SPECIFIED INTERVALS
8	STPLOT	PRODUCES A RIGHT ASCENSION VERSUS DECLINATION PLOT OF CORE CATALOG STARS
9	STCORR	CORRELATES ONE CORE CATALOG DATA WORD WITH ANOTHER, AND PLOTS THE RESULTS

The user may skip the printing phase, or he may instruct STPICK to print a subset of Core Catalog data. The possible subsets are

- All data
- All data words up through a given FSTDAT location (for all stars)
- The relative array location, ISTDAT and sorting variable (if other than ISTDAT) for any given range of relative array locations

9.2.3 Subroutine STCONT

STCONT begins by checking the values of the secondary control words against a set of allowed values. STCONT then defines the bins into which Core Catalog stars will be counted. The bins are defined by a zero point, a bin size, and the total number of bins. These parameters are derived by one of the following methods:

- The user specifies the zero, scale and number of bins.
- The user specifies the number of bins and STCONT calculates a zero and scale which assure that all stars will fall within one of the bins.

Once the bins are defined, STCONT counts the number of Core Catalog stars with the user-specified data word value within each bin limit. The number of stars having values below the lowest bin and above the highest, if any, are also counted.

STCONT presents the results in tabular and, optionally, histogram form. The scales are printed in either decimal or exponential format depending on the magnitude of the values to be printed and the interval between them. Decimal notation is used unless four or more characters before the decimal point are required for at least one value to be printed, or if the scale is less than 0.01.

9.2.4 Subroutine GENPLT

The plotting subroutine, STPLOT, calls either subroutine PLOT or subroutine GENPLT to perform the plotting function. PLOT is relatively simple; it produces a full-sky right ascension versus declination plot of the Core Catalog. GENPLT is more complex and is described below. When called by STPLOT, GENPLT has many of its capabilities turned off by hard-coded calling sequence variables.

Since the user may wish to call GENPLT directly, we describe here the full capabilities of the subroutine.

GENPLT begins by blanking out the plotting array, LL, and then setting up grid lines every tenth row and column. A whole sky plot may be generated, or the user may specify automatic scaling. The automatic scaling feature of GENPLT expands the scale to as high a resolution as possible while still assuring that all stars fall within the bounds of the plot.

Optionally, the zero points and scale factors are slightly altered to ensure that the grid points fall on even multiples of 0.1 degrees.

The user has the option of specifying character discrimination. If this option is not used, stars are printed as asterisks. If it is used, stars are printed as single digit integers from one to nine. The value plotted is determined from the value of a user-specified star data word. The zero point and scale factor for character choice may be user-specified or automatically calculated, as for right ascension and declination.

Once the character for a star is chosen, it is entered into the plot array at the appropriate row and column. If a star is already plotted there, an asterisk replaces the earlier character. When all stars in the Core Catalog have been processed, the LL array is printed.

9.2.5 Subroutine STCORR

STCORR begins by checking the values of the secondary control words against a set of allowed values. The two star data words to be correlated are specified in these control words. The user has also specified that either a linear or a quadratic least-squares fit is to be attempted.

STCORR calculates the coefficients of this fit and prints them. It then calculates and prints the mean deviation of the first correlation parameter from its norm before the correlation and its mean residual after the correlation.

Optionally, a printer plot of one variable against the other is generated. This is accomplished by blanking out a plotting array, putting in grid lines at every tenth row and column, entering a character for each star, and (optionally) entering the correlation curve across the width of the plot. The plot array is then printed.

9.3 MATHEMATICAL SPECIFICATIONS

9.3.1 Conversion of Star Geocentric Inertial Unit Vectors to Right Ascension, Declination

Conversion of the Star Geocentric Inertial unit vector (always present on the Run Catalog) to right ascension and declination is accomplished in subroutine STALDL using the utility subroutine GITOAD. The relevant equations are the same as those presented in Section 6.3.1.

9.3.2 Calculating Bin Zero Point and Scale Factor

When employing subroutine STCONT to count the number of stars with specified Core Catalog data word values within various intervals, the user has the option of specifying only the total number of bins he desires. The Core Catalog data word values are then examined to establish a zero point and scaling factor such that all data falls within the bins and the resolution is as high as possible.

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The following formulae are used:

$$Z = V_{min}$$
$$S = (V_{max} - V_{min})/N_{bins} \qquad (9\text{-}1)$$

where Z = the zero point

S = the scale factor

N_{bins} = user-input number of bins

$V_{min} = \min(V_1, \ldots, V_n)$

$V_{max} = \max(V_1, \ldots, V_n)$

V_i = data word value for the ith star in the Core Catalog

n = number of stars in the Core Catalog

The ith star is counted as being in the jth bin provided that:

$$Z + S(j - 1) < V_i \leq Z + S_j \qquad (9\text{-}2)$$

9.3.3 Determining the Zero Point and Scale Factor for a Right Ascension Declination Plot

If the automatic scaling capability of subroutine GENPLT is used to expand the right ascension, declination plotting scale, then the two zero points and scale factors must be determined. This is accomplished in a procedure completely analogous to that described in Section 9.3.2, with one exception concerning the right ascension scale. Because right ascension may take any value between 0 and 360 degrees, and because it is a continuous variable (i.e., 0 degree = 360 degrees), it is desirable to be able to expand a plot containing points at right ascensions near, but on both sides of, 0 degree. For example, if five data points are to be plotted, with right ascensions 4, 7, 2, 358, and 353 degrees, the normal technique of scaling would yield a zero point of 2 degrees and a scale of (358 degrees - 2 degrees)/119 $\cong$ 3.0, where 119 is the number of columns in the plot. Clearly a plot centered around 0 degree would present a better scale. This is accomplished by subtracting 360 degrees from all right ascensions greater than 180 degrees. Then, the calculated zero would be, for our example, -7 degrees and the scale would be just over 0.1 degree, an increase of a factor of 30 in resolution.

In GENPLT, both methods are used to calculate the zero point and scale factor. Whichever method yields a higher resolution is used for the plot.

9.3.4 Calculating the Correlation Curve Between Two Variables

In subroutine STCORR, least-squares curve fits of two specified star data words are calculated. The user may specify a linear or quadratic fit.

9.3.4.1 Linear Fit

If the correlation curve is to be

$$x = \alpha + \beta y \tag{9-3}$$

where x, y are the variables to be correlated, then

$$\begin{aligned} \alpha &= \left(\sum_{i=1}^{n} x_i - \beta \sum_{i=1}^{n} y_i \right) / n \\ \beta &= \left(\sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i / n \right) \Big/ \left(\sum_{i=1}^{n} y_i y_i - \sum_{i=1}^{n} y_i \quad \sum_{i=1}^{n} y_i \right) / n \Big) \end{aligned} \tag{9-4}$$

where x_i, y_i = the ith data point

n = the number of stars in the Core Catalog

9.3.4.2 Quadratic Fit

If the correlation curve is to be

$$x = \alpha + \beta y + \gamma y^2 \tag{9-5}$$

then

$$\alpha = \left(\sum_{i=1}^{n} x_i - \beta \sum_{i=1}^{n} y_i - \gamma \sum_{i=1}^{n} y_i^2\right) / n$$

$$\beta = (C + \gamma D)/E$$

$$\gamma = \left[\sum_{i=1}^{n} x_i y_i^2 - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i^2/n + \frac{C}{E}\left(\sum_{i=1}^{n} y_i^2 \sum_{i=1}^{n} y_i/n - \sum_{i=1}^{n} y_i^3\right)\right] \Bigg/$$

$$\left[\frac{D}{E}\left(\sum_{i=1}^{n} y_i^3 - \sum_{i=1}^{n} y_i^2 \sum_{i=1}^{n} y_i/n\right) + \sum_{i=1}^{n} y_i^4 - \sum_{i=1}^{n} y_i^2 \sum_{i=1}^{n} y_i^2/n\right] \tag{9-6}$$

$$C = \sum_{i=1}^{n} x_i y_i - \sum_{i=1}^{n} x_i \sum_{i=1}^{n} y_i/n$$

$$D = \sum_{i=1}^{n} y_i^2 \sum_{i=1}^{n} y_i/n - \sum_{i=1}^{n} y_i^3$$

$$E = \sum_{i=1}^{n} y_i^2 - \sum_{i=1}^{n} y_i \sum_{i=1}^{n} y_i/n$$

9.4 BASELINE DIAGRAM AND UNIT DESCRIPTIONS

9.4.1 Baseline Diagram

Figure 9-1 presented earlier is the baseline diagram for the Statistics Module driver, STATS.

9.4.2 Unit Descriptions

A unit description of each subroutine in the Statistics Module is given in Sections 9.4.2.1 through 9.4.2.13. An explanation of the tabular formats used in these sections is given in Section 2.4.1.

The following is an index to all program LOOKAT Statistics Module subroutines and functions.

9.4.2.1 Subroutine STATS

DESCRIPTION: Subroutine STATS is the driver for the statistics module. A card read from file I5 determines which statistics module subroutine is to be called.

CALLING SEQUENCE: Subroutine STATS (ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STINST

EXTERNAL REFERENCES: STALDL, STCATL, STCONT, STCORR, STLIST, STPICK, STPLOT, STREST, STSLCT

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input. FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STATS

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core catalog output array. For the ith Core Catalog star, with I ≤ NUMCAT, FSTDAT (I,1) = G.I. unit vector x-component FSTDAT (I,2) = G.I. unit vector y-component FSTDAT (I,3) = G.I. unit vector z-component FSTDAT (I,4) = normally star magnitude FSTDAT (I,5), FSTDAT (I,6), FSTDAT (I,7) star data corresponding to the sixth, seventh and eighth words of data in the Run catalog star data segment
STLONG (NDM1)		I	R*4	C.S.	Star longitude, as computed in Section 8.3.7
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the core catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
ISTDAT		O	I*4	STINIST	Primary control word, directs program flow to a worker subroutine = 0, returns to calling routine = 1, calls STLIST = 2, calls STCATL = 3, calls STSLCT

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE STATS

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (Cont'd)					= 4, calls STREST = 5, calls STALDL = 6, calls STPICK = 7, calls STCONT = 8, calls STPLOT = 9, calls STCORR
ITYCAT		O	I*4	/STINST/	Catalog type flag - catalog generated by Subroutine - = 1, FETCH = 2, BAND = 3, SLICE
SPINRA, SPINDC		O	R*4	/STINST/	Spin axis right ascension and declination in degrees (ITYCAT = 2 or 3 only)
OPAXRA, OPAXDC		O	R*4	/STINST/	Sensor optical axis right ascension and declination in degrees (ITYCAT = 1 or 3 only)
IOPTYP		O	I*4	/STINST/	Optical axis flag 1, optical axis input is its starting point = 2, optical axis input is its midpoint (ITYCAT = 3 only)
RANGE	R	O	R*4	/STINST/	Optical axis scan range in degrees (ITYCAT = 3 only)
COELEV	θ	O	R*4	/STINST/	Coelevation angle between the spin axis and optical axis, in degrees (ITYCAT = 2 or 3 only)
TOLER	τ	O	R*4	/STINST/	Angular separation between successive optical axis sample points, in degrees (ITYCAT = 2 or 3 only)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STATS

Name	Symbol	I/O	Type	Interface	Description
SLOP	ϵ	O	R*4	/STINST/	Error factor in the spin axis position, including secular motion, precession and nutation, in degrees (ITYCAT = 2 or 3 only)
IFMAG		O	I*4	/STINST/	Magnitude sort flag = 0, do not reject stars fainter than the limiting magnitude = 1, reject star fainter than the limiting magnitude
FMAGLM		O	R*4	/STINST/	Limiting magnitude
IFFOV		O	I*4	/STINST/	Field-of-view select flag = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
FOV		O	R*4	/STINST/	Radius of a circular field-of-view or half side length of a square field-of-view, in degrees
IFPRNT		O	I*4	/STINST/	Function flag = 1, print only Run Catalog title and header = 2, also print row definition parameters = 3, also print pointer array = 4, also print zone definition parameters = 5, print all Run Catalog data
IFPALL		O	I*4	/STINST/	(Valid for IFPRNT = 4 or 5 only) = 1, print data for all zones available in the run catalog = 2, print data for zones listed on the following records only.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STATS

Name	Symbol	I/O	Type	Interface	Description
IZONEP (100)		O	I*4	/STINST/	Zone numbers to be printed (IFPALL = 2 only)
ISELCT		O	I*4	/STINST/	Variable on which selection test is to be performed = 0, no selection to be done = 1-8, selection done on FSTDAT (*, ISELCT) = 9, selection done on ISTDAT
SELMIN, SELMAX		O	R*4	/STINST/	Selection limits - stars selected must have FSTDAT (*, ISELCT) greater than SELMIN and less than SELMAX (ISELCT = 1-8 only)
ISLMIN, ISLMAX		O	I*4	/STINST/	Selection limits - stars selected must have ISTDAT greater than ISLMIN and less than ISLMAX (ISELCT = 9 only)
IRAPUT, IDCPUT		O	I*4	/STINST/	Locations in the FSTDAT array where right ascension and declination, respectively, are to be stored. (Must be 4, 5, 6, 7 or 8, and IRAPUT ≠ IDCPUT).
ISORT		O	I*4	/STINST/	Sort variable flag = 0, do not sort = 1-8, sort on FSTDAT (*, ISORT) = 9, sort on ISTDAT
IORDER		O	I*4	/STINST/	Sort order flag = 1, sort in ascending order = 2, sort in descending order

INPUT/OUTPUT VARIABLES FOR SUBROUTINE

Name	Symbol	I/O	Type	Interface	Description
ISRTPR		O	I*4	/STINST/	Print flag = 0, print nothing = 1, for all stars, print ISTDAT and FSTDAT (*, ISORT) = 2, print ISTDAT and FSTDAT (*, ISORT) for stars located in relative positions IPRBEG to IPREND of the Core Catalog arrays only = 3-8, print ISTDAT, and FSTDAT (*, 1) through FSTDAT (*, ISRTPR) for all stars
IPRBEG, IPREND		O	I*4	/STINST/	First and last positions in the catalog arrays to be printed (ISRTPR = 2 only)
ICOUNT		O	I*4	/STINST/	Count variable indicator = 0 or 9, do nothing (return) = 1-8, count variable is FSTDAT (*, ICOUNT)
NBINS		O	I*4	/STINST/	Number of bins into which stars are sorted
ZERO		O	R*4	/STINST/	Zero point for bin definition, i.e., lower limit of lowest bin
SCALE		O	R*4	/STINST/	Scaling for bin definition. If SCALE = 0.0, STCONT uses automatic scaling (see Section 9.3.2)
IFHIST		O	I*4	/STINST/	Histogram print flag = 0, do not print histogram of the results = 1, print histogram of the results
ITYPLT		O	I*4	/STINST/	Type plot to be generated = 1, whole sky plot (uses subroutine PLOT)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STATS

Name	Symbol	I/O	Type	Interface	Description
ITYPLT (Cont'd)					= 2, amplified scale plot, plotting only that part of sky covered by the Core Catalog (uses Subroutine GENPLT)
IPLTVR		O	I*4	/STINST/	Plot character determined from the value of the variable = 0, 9 none (use *) = 1-8, FSTDAT (*, IPLTVR)
ICORRA, ICORRB		O	I*4	/STINST/	Correlation variables, correlate FSTDAT (*, ICORRA) versus FSTDAT (*, ICORRB). If either ICORRA or ICORRB = 0 or 9, STCORR returns.
ICRDEG		O	I*4	/STINST/	Type of correlation = 0, none = 1, least squares linear fit (ICORRA = $\alpha + \beta$ (ICORRB) = 2, least squares quadratic fit (ICORRA) $\alpha + \beta$ (ICORRB) + γ (ICORRB)^2
ICRPCT		O	I*4	/STINST/	Plot flag = 0, do not plot = 1, plot ICORRA versus ICORRB = 2, plot ICORRA versus ICORRB including the correlation curve

9.4.2.2 Subroutine GENPLT

DESCRIPTION: Subroutine GENPLT creates a plot of the star catalog using as large a scale as possible. If desired, one variable may be chosen for plot character discrimination. Automatic scaling is available, but not mandatory.

CALLING SEQUENCE: Subroutine GENPLT (IPLTFL, IFRADC, IFAUTO, ALPZ, ALPSC, DECZ, DECSC, ICHARV, IFCAUT, CHARZ, CHARSC, IFREG, ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, PARAMS

EXTERNAL REFERENCES: GITOAD

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output. FORTRAN data set reference number IPLTFL is printed plot output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE GENPLT

Name	Symbol	I/O	Type	Interface	Description
IPLTFL		I	I*4	C.S.	File number for plot output
IFRADC		I	I*4	C.S.	Right ascension/declination availability flag = 0, not available = 1, exist in FSTDAT (*, 5) and FSTDAT (*, 6)
IFAUTO		I	I*4	C.S.	Automatic scaling flag for X and Y coordinates = 0, do not use automatic scaling = 1, use automatic scaling
ALPZ, ALPSC		I	R*4	C.S.	Right ascension (X axis) zero point and interval (IFAUTO = 0 only)
DECZ, DECSC		I	R*4	C.S.	Declination (Y axis) zero point and interval (IFAUTO = 0 only, degrees)
ICHARV		I	I*4	C.S.	Plot symbol flag = 0, plot all stars as asterisks = 1 to 8, the row of the FSTDAT (*, ICHARV) array to be used for discrimination
IFCAUT		I	I*4	C.S.	Character automatic scaling flag = 0, do not use automatic scaling on character = 1, use automatic scaling for plot character
CHARZ, CHARSC		I	R*4	C.S.	Plot character zero and interval (IFCAUT = 0 only)
IFREG		I	I*4	C.S.	Regularization flag = 0, leave scales as calculated = 1, round X and Y scales so as to be in even tenths of a degree

INPUT/OUTPUT VARIABLES FOR SUBROUTINE GENPLT

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I. unit vector X-component FSTDAT (I, 2) = G.I. unit vector Y-component FSTDAT (I, 3) = G.I. unit vector Z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in Run Catalog star data segment
STLONG (NDM1)		I	I*4	C.S.	Star longitude, as computed in Section 8.3.7.
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
W	W	I	I*4	/PARAMS/	Declination height of the rows (degrees)

9.4.2.3 Subroutine PLOT

DESCRIPTION: Subroutine PLOT produces a printer plot of the stars in the Core Catalog.

CALLING SEQUENCE: Subroutine PLOT (IPLTFL,IFRADC,ISTDAT,FSTDAT, NDIM1,NDIM2,NUMCAT)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: GITOAD

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output. FORTRAN data set reference number IPLTFL is printed plot output.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PLOT

Name	Symbol	I/O	Type	Interface	Description
IPLTFL		I	I*4	C.S.	File number of plot output
IFRADC		I	I*4	C.S.	Right ascension/declination availability flag = 0, not available = 1, exist in FSTDAT (*, 5) and FSTDAT (*, 6)
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I. unit vector X-component FSTDAT (I, 2) = G.I. unit vector Y-component FSTDAT (I, 3) = G.I. unit vector Z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars

9.4.2.4 Subroutine PZONE

DESCRIPTION: Subroutine PZONE prints either a summary of the data concerning a zone, or all data for the zone.

CALLING SEQUENCE: Subroutine PZONE (IP,IA)

COMMON AREAS REFERENCED: FERMSG,FILES,PARAMS,POINT

EXTERNAL REFERENCES: DREAD

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES:

'READ ERROR ON RUN CATALOG FILE... PROGRAM STOPS. DAIO ERROR MESSAGE FIELD IS ZZZZZZZZ IIIII AAAAAAAAAAAAAAAAAAAAAAAAAA AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA AA ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ'. The Z,I and A fields indicated are hexidecimal, integer and alphameric information, respectively from the DAIO error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take appropriate action.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE PZONE

Name	Symbol	I/O	Type	Interface	Description
IP		I	I*4	C.S.	Zone number to be printed
IA		I	I*4	C.S.	Printout flag = 4, print only summary data = 5, print all zone data
I6		I	I*4	/FILES/	Printed output file number
INFILE		I	I*4	/FILES/	Direct-access input Run Catalog file number
NWORDS		I	I*4	/PARAMS/	Number of words of data per star
NPER		I	I*4	/PARAMS/	Number of data segments in one logical record (See Section 6.6.2.1.4)
IPOINT(2800)		I	I*4	/POINT/	IPOINT (I) = record number of the first logical record in the Run Catalog for Zone I. If IPOINT (I) is negative, Zone I is not present. Valid for I=1, ..., number of zones

9.4.2.5 Subroutine STALDL

DESCRIPTION: Subroutine STALDL calculates right ascensions and declinations of the catalog stars, and stores them in user specified positions of the FSTDAT array.

CALLING SEQUENCE: Subroutine STALDL (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: GITOAD

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES:

'AN ILLEGAL VALVE FOR THE FSTDAT POSITION WAS INPUT. RIGHT ASCENSION AND DECLINATION ARE STORED IN POSITIONS 7 AND 8 RESPECTIVELY.' The user is only allowed to store right ascension and declination in positions 4, 5, 6, 7 or 8 of FSTDAT.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STALDL

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with $i \le$ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
I6			I*4	/FILES/	Printed output file number
NCAT			I*4	/STCOM/	Number of stars in the Core Catalog after selection by subroutine STSLCT
IRAPUT, IDCPUT		I	I*4	/STINST/	Locations in the FSTDAT array where right ascension and declination, respectively, are to be stored. (Must be 4, 5, 6, 7 or 8, and IRAPUT $\neq$ IDCPUT)

9.4.2.6 Subroutine STCATL

DESCRIPTION: Subroutine STCATL generates a star catalog in the ISTDAT and FSTDAT arrays. In accordance with instructions read from file 15, and by using access module driver subroutines.

CALLING SEQUENCE: Subroutine STCATL (IFRST, ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, PARAMS, STCOM, STINST

EXTERNAL REFERENCES: BAND, FETCH, SLICE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number 16 is printed output.

ERROR MESSAGES: None .

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCATL

Name	Symbol	I/O	Type	Interface	Description
IFRST		I	I*4	C.S.	Reset flag - = 0, read catalog specifications from file I5 = 1, use catalog specifications read last time
ISTDAT (NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		O	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with $i \leq$ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
STLONG (NDM1)		O	R*4	C.S.	Star longitude, as computed in Section 8.3.7.
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCATL

Name	Symbol	I/O	Type	Interface	Description
W		I	I*4	/PARAMS/	Declination height of the rows (degrees)
NCAT		I	I*4	/STCOM/	Number of stars in the Core Catalog after selection in subroutine STSLCT
ITYCAT		I/O	I*4	/STINST/	Catalog type flag--catalog generated by Subroutine = 1, FETCH = 2, BAND = 3, SLICE
SPINRA, SPINDC		I/O	R*4	/STINST/	Spin axis right ascension and declination in degrees (ITYCAT = 2 or 3 only)
OPAXRA, OPAXDC		I/O	R*4	/STINST/	Sensor optical axis right ascension and declination in degrees (ITYCAT = 1 or 3 only)
IOPTYP		I/O	I*4	/STINST/	Optical axis flag = 1, optical axis input is its starting point = 2, optical axis input is its midpoint (ITYCAT = 3 only)
RANGE	R	I/O	R*4	/STINST/	Optical axis scan range in degrees (ITYCAT = 3 only)
COELEV	θ	I/O	R*4	/STINST/	Coelevation angle between the spin axis and optical axis, in degrees (ITYCAT = 2 or 3 only)
TOLER	τ	I/O	R*4	/STINST/	Angular separation between successive optical axis sample points, in degrees (ITYCAT = 2 or 3 only)
SLOP	ϵ	I/O	R*4	/STINST/	Error factor in the spin axis position, including secular motion, precession and nutation, in degrees (ITYCAT = 2 or 3 only)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCATL

Name	Symbol	I/O	Type	Interface	Description
IFMAG		I/O	I*4	/STINST/	Magnitude sort flag - = 0, do not reject stars fainter than the limiting magnitude = 1, reject stars fainter than the limiting magnitude
FMAGLM		I/O	R*4	/STINST/	
IFFOV		I/O	I*4	/STINST/	Field-of-view select flag - = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
FOV		I/O	R*4	/STINST/	Radius of a circular field-of-view or half side length of a square field-of-view, in degrees

9.4.2.7 Subroutine STCONT

DESCRIPTION: Subroutine STCONT counts how many stars fall into each bin. Bins are defined in a user-specified manner for a user-specified variable. Optionally, a histogram is printed.

CALLING SEQUENCE: Subroutine STCONT (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCONT

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with $i \leq$ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog.
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number
NCAT			I*4	/STCOM/	Number of Core Catalog stars after selection is subroutine STSLCT
ICOUNT		I	I*4	/STINST/	Count variable indicator - = 0 or 9, do nothing (return) = 1 - 8, count variable is FSTDAT (*,ICOUNT)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCONT

Name	Symbol	I/O	Type	Interface	Description
NBINS		I/O	I*4	/STINST/	Number of bins into which stars are sorted
ZERO		I/O	R*4	/STINST/	Zero point for bin definition - i.e., lower limit of lowest bin
SCALE		I/O	R*4	/STINST/	Scaling for bin definition. If SCALE = 0.0, STCONT uses automatic scaling (see Section 9.3.2)
IFHIST		I	I*4	/STINST/	Histogram print flag - = 0, do not print histogram of the results = 1, print histogram of the results

9.4.2.8 Subroutine STCORR

DESCRIPTION: Subroutine STCORR correlates any two star catalog variables. Either a least squares linear or quadratic fit is used. A plot of one variable against the other, and the correlation curve, is given.

CALLING SEQUENCE: Subroutine STCORR (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input. FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES: None

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCORR

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)			R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog.
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT			I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number
NCAT		I	I*4	/STCOM/	Number of Core Catalog stars after selection in subroutine STSLCT
ICORRA, ICORRB		I	I*4	/STINST/	Correlation variables, correlate FSTDAT (*, ICORRA) versus FSTDAT (*, ICORRB). If either ICORRA or ICORRB = 0 or 9, STCORR returns.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STCORR

Name	Symbol	I/O	Type	Interface	Description
ICRDEG		I	I*4	/STINST/	Type of correlation = 0, none = 1, least squares linear fit (ICORRA) = $\alpha + \beta$ (ICORRB) = 2, least squares quadratic fit (ICORRA) = $\alpha + \beta$ (ICORRB) + γ (ICORRB)^2
ICRPLT		I	I*4	/STINST/	Plot flag - = 0, do not plot = 1, plot ICORRA vs. ICORRB = 2, plot ICORRA vs. ICORRB including correlation curve

9.4.2.9 Subroutine STLIST

DESCRIPTION: Subroutine STLIST produces a listing of star catalog definitional parameters contained in the first eight logical records of the Run Catalog. Through subroutine PZONE, it can also cause subcatalogs to be entirely printed .

CALLING SEQUENCE: Subroutine STLIST (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FERMS G, FILES, PARAMS, POINT, STINST

EXTERNAL REFERENCES: DREAD, PZONE

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input. FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES:

'RUN CATALOG READ ERROR IN STLIST. THE FOLLOWING IS THE DAIO ERROR BLOCK

ZZZZZZZZ IIIII AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA
AAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAAA

ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ ZZZZZZZZ'

The Z, I, and A fields indicated are hexadecimal, integer and alphameric information, respectively, from the DAIO error return fields. The user must determine what error occurred by consulting Reference 35 under "Data Management Techniques" and take appropriate action.

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STLIST

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with $i \le$ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog.
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
16		I	I*4	/FILES/	Printed output file number
INFILE		I	I*4	/FILES/	Direct-access input Run Catalog file number
NZONES		I	I*4	/PARAMS/	Number of zones
ROWMAX(40)		I	R*4	/PARAMS/	Maximum row declination for the Ith row ($1 \le I \le$ NROWS) (degrees)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STLIST

Name	Symbol	I/O	Type	Interface	Description
ROWMIN(40)		I	R*4	/PARAMS/	Minimum row declination for the Ith row (1 ≤ I ≤ NROWS) (degrees)
ROWWID(40)		I	R*4	/PARAMS/	Right ascension width of the zones in the Ith row (1 ≤ I ≤ NROWS) (degrees)
NROWST(40)		I	I*4	/PARAMS/	Number of the first zone in the Ith row (1 ≤ I ≤ NROWS)
NUMROW(40)		I	I*4	/PARAMS/	Total number of zones in the Ith row (1 ≤ I ≤ NROWS)
NROWS		I	I*4	/PARAMS/	Number of rows
IPOINT(2800)		I	I*4	/POINT/	IPOINT(I) = record number of the first logical record in the Run Catalog for Zone I. If IPOINT(I) is negative, Zone I is not present. Valid for I=1, ..., number of zones.
IFPRNT		I	I*4	/STINST/	Function flag – = 1, print only Run Catalog title and header = 2, also print row definition parameters = 3, also print pointer array = 4, also print zone definition parameters = 5, print all Run Catalog data
IFPALL		I	I*4	/STINST/	(Valid for IFPRNT = 4 or 5 only) = 1, print data for all zones available in the Run Catalog = 2, print data for zones listed on the following records only.
IZONEP(100)		I	I*4	/STINST/	Zone numbers to be printed (IFPALL – 2 only)

9.4.2.10 Subroutine STPICK

DESCRIPTION: Subroutine STPICK sorts the Core Catalog in either ascending or descending order of a star data word. Additionally, it lists all or part of the star data in sorted order.

CALLING SEQUENCE: Subroutine STPICK (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input. FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES: None

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INPUT/OUTPUT VARIABLES FOR SUBROUTINE STPICK

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog.
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog.
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number
NCAT		I	I*4	/STCOM/	Number of Core Catalog stars after selection in subroutine STSLCT
ISORT		I	I*4	/STINST/	Sort variable flag - = 0, do not sort = 1-8, sort on FSTDAT (*, ISORT) = 9, sort on ISTDAT

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STPICK

Name	Symbol	I/O	Type	Interface	Description
IORDER		I	I*4	/STINST/	Sort order flag - = 1, sort in ascending order = 2, sort in descending order
ISRTPR		I	I*4	/STINST/	Print flag - = 0, print nothing = 1, for all stars print ISTDAT and FSTDAT (*, ISORT) = 2, print ISTDAT and FSTDAT (*, ISORT) for stars located in relative positions IPRBEG to IPREND of the Core Catalog arrays only. = 3-8, print ISTDAT, and FSTDAT (*,1) through FSTDAT (*,ISRTPR) for all stars
IPRBEG, IPREND		I	I*4	/STINST/	First and last positions in the catalog arrays to be printed (ISRTPR = 2 only).

9.4.2.11 Subroutine STPLOT

DESCRIPTION: Subroutine STPLOT produces a plot of the star catalog using the plot and GENPLT routines.

CALLING SEQUENCE: Subroutine STPLOT (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: GENPLT, PLOT

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input.

ERROR MESSAGES: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STPLOT

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I	R*4	C.S.	Core Catalog output array. For the i^{th} Core Catalog star, with $i \leq$ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words of floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number
NCAT		I	I*4	/STCOM/	Number of Core Catalog stars after selection by subroutine STSLCT
ITYPLT		I	I*4	/STINST/	Type plot to be generated - = 1, whole sky plot (uses subroutine PLOT) = 2, amplified scale plot, plotting only that part of sky covered by the Core Catalog (uses subroutine GENPLT)

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STPLOT

Name	Symbol	I/O	Type	Interface	Description
IPLTVR		I	I*4	/STINST/	Plot character determined from the value of the variable = 0, 9 none (use *) = 1-8, FSTDAT (*, IPLTVR)

9.4.2.12 Subroutine STREST

DESCRIPTION: Subroutine STREST causes the Core Catalog to be reset to what it was the last time STCATL was called.

CALLING SEQUENCE: Subroutine STREST (ISTDAT, FSTDAT, STLONG, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES

EXTERNAL REFERENCES: STCATL

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number 16 is printed output.

ERROR MESSAGES: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STREST

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2		O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
STLONG (NDM1)		O	R*4	C.S.	Star longitude, as computed in Section 8.3.7
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, FSTDAT and STLONG arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words or floating point data per star in the Core Catalog
NUMCAT		O	I*4	C.S.	Number of valid Core Catalog stars
I6		I	I*4	/FILES/	Printed output file number

9.4.2.13 Subroutine STSLCT

DESCRIPTION: Subroutine STSLCT selects stars from the Core Catalog for further processing on the basis of one of the star data words being within user-specified bounds. Overwriting of the ISTDAT and FSTDAT arrays occurs, so that previously stored data is lost.

CALLING SEQUENCE: Subroutine STSLCT (ISTDAT, FSTDAT, NDIM1, NDIM2, NUMCAT)

COMMON AREAS REFERENCED: FILES, STCOM, STINST

EXTERNAL REFERENCES: None

INPUT/OUTPUT DATA SETS: FORTRAN data set reference number I5 contains control card input. FORTRAN data set reference number I6 is printed output.

ERROR MESSAGES: None

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STSLCT

Name	Symbol	I/O	Type	Interface	Description
ISTDAT (NDIM1)		I/O	I*4	C.S.	Core Catalog output array normally containing star numbers
FSTDAT (NDIM1, NDIM2)		I/O	R*4	C.S.	Core Catalog output array. For the ith Core Catalog star, with i ≤ NUMCAT, FSTDAT (I, 1) = G.I unit vector x-component FSTDAT (I, 2) = G.I unit vector y-component FSTDAT (I, 3) = G.I unit vector z-component FSTDAT (I, 4) = normally, star magnitude FSTDAT (I, 5), FSTDAT (I, 6), FSTDAT (I, 7) = star data corresponding to the sixth, seventh and eighth words of data in a Run Catalog star data segment
NDIM1		I	I*4	C.S.	Dynamic dimension size for the ISTDAT, and FSTDAT arrays, corresponding to the maximum number of stars anticipated in the Core Catalog
NDIM2		I	I*4	C.S.	Dynamic dimension for the FSTDAT array, corresponding to the number of words or floating point data per star in the Core Catalog
NUMCAT		I	I*4	C.S.	Number of valid Core Catalog stars

INPUT/OUTPUT VARIABLES FOR SUBROUTINE STSLCT

Name	Symbol	I/O	Type	Interface	Description
I6		I	I*4	/FILES/	Printed output file number
NCAT		I/O	I*4	/STCOM/	Number of Core Catalog stars after selection
ISELCT		I	I*4	/STINST/	Variable on which selection test is to be performed - = 0, no selection to be done = 1 through 8, selection done on FSTDAT (*,ISELCT) = 9, selection done on ISTDAT
SELMIN, SELMAX		I	R*4	/STINST/	Selection limits--stars selected must have selection data variable values greater than SELMIN and less than SELMAX (ISELCT = 1 through 8 only)
ISLMIN, ISLMAX		I	I*4	/STINST/	Selection limits--stars selected must have selection data variable values greater than ISLMIN and less than ISLMAX (ISELCT = 9 only)

9.5 COMMON AREA DESCRIPTIONS

In this section, we present descriptions of the COMMON areas peculiar to the Statistics Module of LOOKAT. These COMMON blocks also appearing in the Access Module are described in Section 8.5.

9.5.1 COMMON/STCOM/

DESCRIPTION: STCOM contains the word giving the number of stars remaining in the Core Catalog after selection has taken place in subroutine STSLCT.

FORM: COMMON/STCOM/NCAT

REFERENCED BY: STALDL, STCATL, STCONT, STCORR, STPICK, STPLOT, STSLCT

DEFINITION OF VARIABLES:

Name	Type	Description
NCAT	I*4	Number of stars in the Core Catalog after selection

9.5.2 COMMON/STINST/

DESCRIPTION: STINST contains the primary and secondary control words which direct Statistics Module execution.

FORM: COMMON/STINST/ISTAT, ITYCAT, SPINRA, SPINDC, OPAXRA, OPAXDC, IOPTYP, RANGE, COELEV, TOLER, SLOP, IFMAG, FMAGLM, IFFOV, FOV, IFPRNT, IFPALL, IZONEP, ISELCT, SELMIN, SELMAX, ISLMIN, ISLMAX, IRAPUT, IDCPUT, ISORT, IORDER, ISRTPR, IPRBEG, IPREND, ICOUNT, NBINS, ZERO, SCALE, IFHIST, ITYPLT, IPLTVR, ICORRA, ICORRB, ICRDEG, ICRPLT

REFERENCED BY: STALDL, STATS, STCATL, STCONT, STCORR, STLIST, STPICK, STPLOT, STSLCT

DEFINITION OF VARIABLES: The variables in COMMON/STINST/ are identical to those of NAMELIST/STAT/. See Section 9.6.1.1 for a description of each variable.

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9.6 USER'S MANUAL

This section will enable the user to formulate the appropriate Job Control Language (JCL), create the proper input NAMELIST and interpret the resulting output from the Statistics Module of program LOOKAT.

9.6.1 Input to the Statistics Module

Input to the Statistics Module consists of a direct-access Run Catalog created by program CAT and loaded onto disk by program CAT or program SWITCH, and a data file of NAMELISTs read from FORTRAN data set reference number I5. The Run Catalog is the same as that used for the Access Module (see Section 8.6.1). The NAMELIST data set is described in Section 9.6.1.1. Modifications to the code to run the Statistics Module as a stand-alone program are presented in Section 9.6.1.2.

9.6.1.1 The NAMELIST Data Set

Program flow through the Statistics Module is directed by control words read from NAMELIST/STAT/ on FORTRAN data set reference number I5 (a COMMON/FILES/ parameter). The driver routine, STATS, reads a NAMELIST containing the primary control word and secondary control words. The following table describes each NAMELIST/STAT/ variable. These are identical to the variables in COMMON/STINST/.

FORM: NAMELIST/STAT/ISTAT, ITYCAT, SPINRA, SPINDC, OPAXRA, OPAXDC, IOPTYP, RANGE, COELEV, TOLER, SLOP, IFMAG, FMAGLM, IFFOV, FOV, IFPRNT, IFPALL, IZONEP, ISELCT, SELMIN, SELMAX, ISLMIN, ISLMAX, IRAPUT, IDCPUT, ISORT, IORDER, ISRTPR, IPRBEG, IPREND, ICOUNT, NBINS, ZERO, SCALE, IFHIST, ITYPLT, IPLTVR, ICORRA, ICORRB, ICRDEG, ICRPLT

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Name	Type	Default	Subroutines Using Variable	Description
ISTAT	I*4	0	STATS	Primary control word, directs program flow to a worker subroutine. = 0, returns to calling routine = 1, calls STLIST = 2, calls STCATL = 3, calls STSLCT = 4, calls STREST = 5, calls STALDL = 6, calls STPICK = 7, calls STCONT = 8, calls STPLOT = 9, calls STCORR
ITYCAT	I*4	1	STCATL	Catalog type flag--catalog generated by subroutine = 1, FETCH = 2, BAND = 3, SLICE
SPINRA, SPINDC	R*4	0.0, 0.0	STCATL	Spin axis right ascension and declination in degrees (ITYCAT = 2 or 3 only)
OPAXRA, OPAXDC	R*4	0.0, 0.0	STCATL	Sensor optical axis right ascension and declination in degrees (ITYCAT = 1 or 3 only)
IOPTYP	I*4	1	STCATL	Optical axis flag = 1, optical axis input is its starting point = 2, optical axis input is its midpoint (ITYCAT = 3 only)
RANGE	R*4	360.0	STCATL	Optical axis scan range in degrees (ITYCAT = 3 only)
COELEV	R*4	0.0	STCATL	Coelevation angle between the spin axis and optical axis, in degrees (ITYCAT = 2 or 3 only)
TOLER	R*4	1.0	STCATL	Angular separation between successive optical axis sample points, in degrees (ITYCAT = 2 or 3 only)

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Name	Type	Default	Subroutines Using Variable	Description
SLOP	R*4	0.0	STCATL	Error factor in the spin axis position, including secular motion, precession and nutation, in degrees (ITYCAT = 2 or 3 only)
IFMAG	I*4	0	STCATL	Magnitude sort flag - = 0, do not reject stars fainter than the limiting magnitude = 1, reject stars fainter than the limiting magnitude
FMAGLM	R*4	9.9×10^{10}	STCATL	Limiting magnitude
IFFOV	I*4	0	STCATL	Field-of-view select flag - = 0, do not reject stars outside of the FOV = 1, reject stars outside of the FOV
FOV	R*4	180.0	STCATL	Radius of a circular field-of-view or half side length of a square field-of-view, in degrees
IFPRNT	I*4	1	STLIST	Function flag - = 1, print only Run Catalog title and header = 2, also print row definition parameters = 3, also print pointer array = 4, also print zone definition parameters = 5, print all Run Catalog data
IFPALL	I*4	1	STLIST	(Valid for IFPRNT = 4 or 5 only) = 1, print data for all zones available in the Run Catalog

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Name	Type	Default	Subroutines Using Variable	Description
				= 2, print data for zones listed on the following records only.
IZONEP(100)	I*4	100*0	STLIST	Zone numbers to be printed (IFPALL = 2 only)
ISELCT	I*4	0	STSLCT	Variable on which selection test is to be performed - = 0, no selection to be done = 1 through 8, selection done on FSTDAT (*, ISELCT) = 9, selection done on ISTDAT
SELMIN, SELMAX	R*4	0.0, 0.0	STSLCT	Selection limits--stars selected must have selection data variable values greater than SELMIN and less than SELMAX (ISELCT = 1 through 8 only)
ISLMIN, ISLMAX	I*4	0, 0	STSLCT	Selection limits--stars selected must have selection data variable values greater than ISLMIN and less than ISLMAX (ISELCT = 9 only)
IRAPUT, IDCPUT	I*4	7, 8	STALDL	Locations in the FSTDAT array where right ascension and declination, respectively, are to be stored. (Must be 4, 5, 6, 7 or 8, and IRAPUT ≠ IDCPUT)
ISORT	I*4	0	STPICK	Sort variable flag - = 0, do not sort = 1 through 8, sort on FSTDAT (*, ISORT) = 9, sort on ISTDAT
IORDER	I*4	1	STPICK	Sort order flag - = 1, sort in ascending order = 2, sort in descending order

Name	Type	Default	Subroutines Using Variable	Description
ISRTPR	I*4	0	STPICK	Print flag - = 0, print nothing = 1, for all stars print ISTDAT and FSTDAT (*, ISORT) = 2, print ISTDAT and FSTDAT (*, ISORT) of stars located in relative positions IPRBEG to IPREND of the Core Catalog arrays only = 3 through 8, print ISTDAT, and FSTDAT (*, 1) through FSTDAT (*, ISRTPR) for all stars
IPRBEG, IPREND	I*4	1, NCAT*	STPICK	First and last positions in the catalog arrays to be printed (ISRTPR = 2 only)
ICOUNT	I*4	0	STCONT	Count variable indicator - = 0 or 9, do nothing (return) = 1 through 8, count variable is FSTDAT (*, ICOUNT)
NBINS	I*4	10	STCONT	Number of bins into which stars are sorted
ZERO	I*4	0.0	STCONT	Zero point for bin definition--i.e., lower limit of lower bin
SCALE	R*4	Automatic Scaling	STCONT	Scale for bin definition. If SCALE = 0.0, STCONT uses automatic scaling (see Section 9.3.2)
IFHIST	I*4	0	STCONT	Histogram print flag - = 0, do not print histogram of the results = 1, print histogram of the results

*NCAT--The number of stars in the Core Catalog.

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Name	Type	Default	Subroutines Using Variable	Description
ITYPLT	I*4	1	STPLOT	Type plot to be generated - = 1, whole sky plot (uses subroutine PLOT) = 2, amplified scale plot, ploting only that part of sky covered by the Core Catalog (uses subroutine GENPLT).
IPLTVR	I*4	0	STPLOT	Plot character determined from the value of the variable - = 0, 9 none (use *) = 1 through 8, FSTDAT (*, IPLTVR)
ICORRA, ICORRB	I*4	0, 0	STCORR	Correlation variable, correlate FSTDAT (*, ICORRA) versus FSTDAT (*, ICORRB). If either ICORRA or ICORRB = 0 or 9, STCORR returns
ICRDEG	I*4	0	STCORR	Type of correlation = 0, none = 1, least squares linear fit (ICORRA) = $\alpha + \beta$ (ICORRB) = 2, least squares quadratic fit (ICORRA) = $\alpha + \beta$ (ICORRB) + γ (ICORRB)^2
ICRPLT	I*4	0	STCORR	Plot flag - = 0, do not plot = 1, plot ICORRA versus ICORRB = 2, plot ICORRA versus ICORRB including the correlation curve

Figure 9-3 is a sample set of NAMELISTs. The primary control word directs STATS to call a specific worker subroutine.

The secondary control words provide the instructions necessary for the subroutine called by STATS.

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INPUT	NAMELIST
&STAT ISTAT=1,IFPRNT=3, &END	A
&STAT ISTAT=1,IFPRNT=4,IFPALL=1, &END	B
&STAT ISTAT=1,IFPRNT=5,IFPALL=2,IZONEP(1)=2,3,5,97*0 &END	C
&STAT ISTAT=2,ITYCAT=1,OPAXRA=100.0,OPAXDC=30.0,FOV=4.0, &END	D
&STAT ISTAT=6,ISORT=0,IORDER=0,ISRTPR=3, &END	E
&STAT ISTAT=3,ISELCT=4,SELMIN=-9.9E10,SELMAX=5.0, &END	F
&STAT ISTAT=6,ISORT=0,IORDER=0,ISRTPR=3, &END	G
&STAT ISTAT=4, &END	H
&STAT ISTAT=6,ISORT=0,IORDER=0,ISRTPR=3, &END	I
&STAT ISTAT=5,IRAPUT=7,IDCPUT=8, &END	J
&STAT ISTAT=6,ISORT=0,IORDER=0,ISRTPR=3, &END	K
&STAT ISTAT=6,ISORT=4,IORDER=1,ISRTPR=1, &END	L
&STAT ISTAT=6,ISORT=9,IORDER=2,ISRTPR=2,IPRBEG=3,IPREND=23, &END	M
&STAT ISTAT=7,ICOUNT=4,NBINS=10,IFHIST=0, &END	N
&STAT ISTAT=7,ICOUNT=4,NBINS=0,ZERO=3.2,SCALE=1.0,IFHIST=1, &END	O
&STAT ISTAT=7,ICOUNT=4,NBINS=50,IFHIST=0, &END	P
&STAT ISTAT=8,ITYPLT=1,IPLTVR=0, &END	Q
&STAT ISTAT=8,ITYPLT=2,IPLTVR=-, &END	R
&STAT ISTAT=9,ICORRA=3,ICORRB=8,ICRDEG=1,ICRPLT=0, &END	S
&STAT ISTAT=9,ICORRA=3,ICORRB=8,ICRDEG=2,ICRPLT=2, &END	T
&STAT ISTAT=0, &END	U

Figure 9-3. NAMELIST Input to the Statistics Module (Corresponding Output in Figures 9-5 to 9-15)

When the worker subroutine completes its function, control is returned to subroutine STATS, which reads another NAMELIST/STAT/ and calls the worker subroutine indicated. This process continues until an end of file is encountered on file I5, or a value of zero is read for the primary control word.

Default values for all NAMELIST parameters are set prior to the first NAMELIST read. Explicit coding of any NAMELIST parameter to 0 or 0.0 results in the default value of that parameter being used.

NAMELIST reads alter only those parameters which appear explicitly in the NAMELIST. Additionally, each NAMELIST variable is used by only one subroutine. Therefore, if, for example, the same function is to be performed several different times during one run, all NAMELISTs calling for this function after the first, need only contain the value for the primary control word.

9.6.1.2 User Source Code Modifications

The Statistics Module is a collection of subroutines, used together with Access Module subroutines. There is no main routine. However, if the Statistics Module is to be used in a stand-alone capacity, subroutine STATS can easily be converted to a main routine. Figure 9-4 is a listing of subroutine STATS which indicates how this is accomplished.

9.6.2 Output From the Statistics Module

Output from the Statistics Module consists of printed output on FORTRAN data set reference numbers I6 and IPLTFL (plot output). Error messages and diagnostic output may be generated by Access Module subroutines used in connection with the Statistics Module (see Sections 8.6.4.1 and 8.6.4.2) on FORTRAN data set reference number IDFL.

A sample output has been generated to demonstrate the major capabilities of the output module.

```
      SUBROUTINE STATS(ISTDAT,FSTDAT,STLONG,NDIM1,NDIM2,NUMCAT)          35000000  1
C                                                                        35000100
C ***********************************************************************35000200
C                                                                        35000300
C          SUBROUTINE STATS IS THE DRIVER FOR THE STATISTICS             35000400
C            MODULE.  A CARD READ FROM FILE I5 DETERMINES                35000500
C            WHICH STATISTICS MODULE SUBROUTINE IS TO BE CALLED.         35000600
C                                                                        35000700
C          AUTHOR.  DAVID M. GOTTLIEB. COMPUTER SCIENCES CORP.           35000800
C          WRITTEN.  AUGUST 1, 1975.                                     35000900
C                                                                        35001000
C          EXTERNAL REFERENCES ... STLIST, STCATL, STSLCT,               35001100
C            STREST, STALDL, STPICK, STCONT, STPLOT, STCORR              35001200
C                                                                        35001300
C ***********************************************************************35001400
C                                                                        35001500
      COMMON/FILES/I5,I6,INFILE,INREC,IEDC,IDEL                          35001600
      DIMENSION ISTDAT(NDIM1),FSTDAT(NDIM1,NDIM2),STLONG(NDIM1)          35001700  2
      NAMELIST/STAT/ISTAT,ITYCAT,SPINRA,SPINDC,OPAXRA,OPAXDC,IOPTYP,     35001705
     * RANGE,CCELEV,TOLER,SLOP,IFMAG,FMAGLM,IFFOV,FOV,IFPRNT,IFPALL,     35001710
     * IZONEP,ISELCT,SELMIN,SELMAX,ISLMIN,ISLMAX,IRAPUT,IDCPUT,ISORT,    35001715
     * IORDER,ISRTPR,IPRBEG,IPREND,ICOUNT,NBINS,ZERO,SCALE,IFHIST,       35001720
     * ITYPLT,IPLTVR,ICORRA,ICORRB,ICRDEG,ICRPLT                         35001725
      DIMENSION IZONEP(100)                                              35001730
      COMMON/STINST/ISTAT,ITYCAT,SPINRA,SPINDC,OPAXRA,                   35001731
     * OPAXDC,IOPTYP,RANGE,CCELEV,TOLER,SLOP,IFMAG,                      35001732
     * FMAGLM,IFFOV,FOV,IFPRNT,IFPALL,IZONEP,ISELCT,SELMIN,              35001733
     * SELMAX,ISLMIN,ISLMAX,IRAPUT,IDCPUT,ISORT,IORDER,                  35001734
     * ISRTPR,IPRBEG,IPREND,ICOUNT,NBINS,ZERO,SCALE,                     35001735
     * IFHIST,ITYPLT,IPLTVR,ICORRA,ICORRB,ICRDEG,ICRPLT                  35001736
      WRITE(I6,1)                                                        35001900
C          PRIMARY CONTROL WORD                                          35001902
      ISTAT=0                                                            35001903
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STCATL                 35001905
      ITYCAT=1                                                           35001906
      SPINRA=0.0                                                         35001909
      SPINDC=0.0                                                         35001912
      OPAXRA=0.0                                                         35001915
      OPAXDC=0.0                                                         35001918
      IOPTYP=1                                                           35001921
      RANGE=360.0                                                        35001924
      CCELEV=0.0                                                         35001927
      TOLER=1.0                                                          35001930
      SLOP=0.0                                                           35001933
      IFMAG=0                                                            35001936
      FMAGLM=9.9E+10                                                     35001939
      IFFOV=0                                                            35001942
      FOV=180.0                                                          35001945
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STLIST                 35001947
      IFPRNT=1                                                           35001949
      IFPALL=1                                                           35001951
      DO 333 JJJ=1,100                                                   35001954
  333 IZONEP(JJJ)=0                                                      35001957
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STSLCT                 35001959
      ISELCT=0                                                           35001960
      SELMIN=0.0                                                         35001963
      SELMAX=0.0                                                         35001966
      ISLMIN=0                                                           35001969
      ISLMAX=0                                                           35001972
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STALDL                 35001974
      IRAPUT=7                                                           35001975
      IDCPUT=8                                                           35001978
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STPICK                 35001980
      ISORT=0                                                            35001981
      IORDER=1                                                           35001984
      ISRTPR=0                                                           35001987
      IPRBEG=1                                                           35001990
      IPREND=NCAT                                                        35001993
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STCONT                 35001995
      ICOUNT=0                                                           35001996
      NBINS=10                                                           35001999
      ZERO=0.0                                                           35002002
      SCALE=0.0                                                          35002005
      IFHIST=0                                                           35002008
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STPLCT                 35002010
      ITYPLT=1                                                           35002011
      IPLTVR=0                                                           35002014
C          SECONDARY CONTROL WORDS FOR SUBROUTINE STCORR                 35002016
```

Figure 9-4. Places Where Source for STATS Is Modified To Convert It to a Main Routine (1 of 2)

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```
      ICORRA=0                                                   35002017
      ICORRB=0                                                   35002020
      ICRDEG=0                                                   35002023
      ICRPLT=0                                                   35002026
  100 CONTINUE                                                   35002029
    1 FORMAT('ISTATISTICS MODULE ENTERED')                       35002100
      READ(I5,STAT,END=199)                                      35002300
    2 FORMAT(I1)                                                 35002400
      IF(ISTAT.EQ.0) RETURN                                      35002500
      GO TO (101,102,103,104,105,106,107,108,109),ISTAT          35002600
  101 CALL STLIST(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35002700
      GO TO 100                                                  35002800
  102 CALL STCATL(0,ISTDAT,FSTDAT,STLONG,NDIM1,NDIM2,NUMCAT)     35002900
      GO TO 100                                                  35003000
  103 CALL STSLCT(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35003100
      GO TO 100                                                  35003200
  104 CALL STREST(ISTDAT,FSTDAT,STLONG,NDIM1,NDIM2,NUMCAT)       35003300
      GO TO 100                                                  35003400
  105 CALL STALCL(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35003500
      GO TO 100                                                  35003600
  106 CALL STPICK(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35003700
      GO TO 100                                                  35003800
  107 CALL STCCNT(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35003900
      GO TO 100                                                  35004000
  108 CALL STPLOT(ISTDAT,FSTDAT,STLONG,NDIM1,NDIM2,NUMCAT)       35004100
      GO TO 100                                                  35004200
  109 CALL STCORR(ISTDAT,FSTDAT,NDIM1,NDIM2,NUMCAT)              35004300
      GO TO 100                                                  35004400
  199 WRITE(I6,3)                                                35004500
    3 FORMAT(' EOF ON FILE I5')                                  35004600
      RETURN                                                     35004700  3
      END                                                        35004800
```

1. – DELETE THIS STATEMENT.

2. – DELETE THIS CARD AND INSERT THE FOLLOWING (ALL BEGIN IN COLUMN 7):

```
DIMENSION ISTDAT(AAAA),FSTDAT(AAAA,B),STLONG(AAAA)
IFDG = U
IDFL = VV
I5 = XX
I6 = YY
INFILE = ZZ
NDIM1 = AAAA
NDIM2 = B
CALL INITSK
```

WHERE XX, YY AND ZZ ARE THE REFERENCE NUMBERS FOR THE CONTROL INPUT DATA SET, PRINTED OUTPUT DATA SET AND RUN CATALOG DATA SET, RESPECTIVELY. U IS THE DIAGNOSTIC LEVEL FLAG (SEE SECTION 8 5 2) VV IS THE DIAGNOSTIC OUTPUT FILE NUMBER (U = 0 ONLY) AAAA IS THE MAXIMUM NUMBER OF CORE CATALOG STARS EXPECTED, AND B IS THE NUMBER OF FLOATING POINT WORDS OF DATA PER STAR

3. – REPLACE THIS STATEMENT WITH THE FOLLOWING.

```
STOP
```

Figure 9-4. Places Where Source for STATS Is Modified To Convert It to a Main Routine (2 of 2)

Figure 9-3 gave the NAMELIST input used. Each complete NAMELIST is delineated with a heavy horizontal line and assigned a reference letter (on the right).

The following table interprets these sample NAMELISTs in words. Figures 9-5a to 9-24a present the resultant printed output for a Run Catalog generated by the SKYMAP system to a limiting magnitude of 7.6.

Reference Letter	Subroutine Called Due to Primary Control	Secondary Control Card Meaning
A	STLIST	List header, row, definition and printer arrays
B	STLIST	Also list zone definition parameter. List data for all zones
C	STLIST	Also list star data. List only those zones specified (numbers 2, 3, and 5)
D	STCATL	Generate a Core Catalog using subroutine FETCH. The optical axis right ascension and declination are 180 degrees and 30 degrees, respectively
E	STPICK	Do not sort. List all eight data words
F	STSLCT	Pick out all stars with FSTDAT (*, 4) between -9.999×10^{10} and 5.0
G	STPICK	Do not sort. List all eight data words
H	STREST	Reset catalog as it was before STSLCT
I	STPICK	Do not sort. List all eight data words
J	STALDL	Calculate star right ascensions and declinations. Store in FSTDAT (*, 7) and FSTDAT (*, 8), respectively

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Reference Letter	Subroutine Called Due to Primary Control	Secondary Control Card Meaning
K	STPICK	Do not sort. List all eight data words
L	STPICK	Sort Core Catalog on FSTDAT (*, 4). Sort in ascending order. List data for all stars
M	STPICK	Sort Core Catalog on ISTDAT. Sort in descending order. List only the 3rd through 28th positions in the Core Catalog arrays
N	STCONT	Count the stars in reference to FSTDAT (*, 4). Count into 10 bins (automatic scaling)
O	STCONT	Count the stars in reference to FSTDAT (*, 4). Define the bins to have a zero of 3.2 and a scale factor of 1.0. Produce a histogram of the results
P	STCONT	Count the stars in reference to FSTDAT (*, 4). Count into 50 bins (automatic scaling)
Q	STPLOT	Plot the Core Catalog on full-sky plot
R	STPLOT	Plot the Core Catalog on an amplified sky scale. The symbol is defined in reference to FSTDAT (*, 4)
S	STCORR	Correlate FSTDAT (*, 3) against FSTDAT (*, 8). Use a linear fit. Do not plot the results
T	STCORR	Correlate FSTDAT (*, 3) against FSTDAT (*, 8). Use a quadratic fit. Plot the results
U	STSLCT	Select all stars with FSTDAT (*, 3) between 0.0 and 0.5
V	STPICK	Do not sort. List all eight data words
W		Return to calling routine

```
THE RUN CATALOG WAS ORIGINALLY GENERATED BY CAT ON 01.12.35.85 WED MAR 03.1976

  TITLE -- SAS-C CATALOG WITH MAG = 0.4B + 0.6V

  NAMELIST PARAMETERS --
         NWORDS = 5
         ICNVRT = 2
         IFILE  = 52
         W      = 30.0
         ISEQ   = 0
         FMAG   =    9.99
         NMAX   =   9999
         IFMDFY = 0
```

Figure 9-5. Statistics Module Output for NAMELIST A (1 of 3)

ROW DEFINITION --

NUMBER	DECLINATION LIMITS (DEGREES)			R.A. WIDTH (DEGREES	NUMBER OF FIRST ZONE	NO. ZONES IN ROW
1	60.000	TO	90.000	360.000	1	1
2	45.000	TO	75.000	60.000	2	6
3	30.000	TO	60.000	30.000	8	12
4	15.000	TO	45.000	22.500	20	16
5	0.0	TO	30.000	18.000	36	20
6	-15.000	TO	15.000	18.000	56	20
7	-30.000	TO	0.0	18.000	76	20
8	-45.000	TO	-15.000	22.500	96	16
9	-60.000	TO	-30.000	30.000	112	12
10	-75.000	TO	-45.000	60.000	124	6
11	-90.000	TO	-60.000	360.000	130	1

Figure 9-5. Statistics Module Output for NAMELIST A (2 of 3)

```
PCINTER ARRAY --
```

ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER
1	9	2	33	3	45	4	53	5	59
6	84	7	72	8	85	9	92	10	99
11	106	12	112	13	116	14	120	15	123
16	127	17	132	18	141	19	151	20	159
21	164	22	169	23	175	24	182	25	189
26	194	27	197	28	200	29	204	30	207
31	211	32	216	33	224	34	234	35	240
36	245	37	248	38	251	39	255	40	260
41	266	42	273	43	278	44	282	45	285
46	288	47	291	48	294	49	297	50	300
51	305	52	311	53	318	54	323	55	327
56	330	57	333	58	336	59	339	60	343
61	350	62	358	63	364	64	368	65	371
66	374	67	377	68	380	69	383	70	387
71	391	72	397	73	402	74	406	75	409
76	412	77	415	78	418	79	421	80	425
81	431	82	438	83	445	84	450	85	454
86	457	87	460	88	463	89	467	90	471
91	475	92	481	93	486	94	491	95	495
96	498	97	501	98	505	99	509	100	514
101	523	102	533	103	539	104	544	105	548
106	553	107	560	108	568	109	576	110	581
111	585	112	589	113	593	114	597	115	602
116	612	117	624	118	632	119	639	120	647
121	657	122	665	123	670	124	675	125	681
126	690	127	707	128	720	129	731	130	738

Figure 9-5. Statistics Module Output for NAMELIST A (3 of 3)

```
THE RUN CATALOG WAS ORIGINALLY GENERATED BY CAT ON 01.12.35.85 WED MAR 03.1976
  TITLE -- SAS-C CATALOG WITH MAG = 0.4B + 0.6V
  NAMELIST PARAMETERS --
          NWORDS  = 5
          ICNVRT  = 2
          IFILE   = 52
          W       = 30.0
          ISEQ    = 0
          FMAG    =   9.99
          NMAX    =  9999
          IFMDFY  = 0
```

Figure 9-6. Statistics Module Output for NAMELIST B (1 of 5)

ROW DEFINITION --

NUMBER	DECLINATION LIMITS (DEGREES))			R.A. WIDTH (DEGREES	NUMBER OF FIRST ZONE	NO. ZONES IN ROW
1	60.000	TO	90.000	360.000	1	1
2	45.000	TO	75.000	60.000	2	5
3	30.000	TO	60.000	30.000	8	12
4	15.000	TO	45.000	22.500	20	16
5	0.0	TO	30.000	18.000	36	20
6	-15.000	TO	15.000	18.000	56	20
7	-30.000	TO	0.0	18.000	76	20
8	-45.000	TO	-15.000	22.500	96	16
9	-60.000	TO	-30.000	30.000	112	12
10	-75.000	TO	-45.000	60.000	124	6
11	-90.000	TO	-60.000	360.000	130	1

Figure 9-6. Statistics Module Output for NAMELIST B (2 of 5)

POINTER ARRAY --

ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER
1	[illegible]	2	33	3	45	4	53	5	59
6	64	7	72	8	85	9	92	10	99
11	105	12	112	13	116	14	120	15	123
16	127	17	132	18	141	19	151	20	159
21	164	22	169	23	175	24	182	25	189
26	194	27	197	28	200	29	204	30	207
31	211	32	216	33	224	34	234	35	240
36	245	37	248	38	251	39	255	40	260
41	266	42	273	43	278	44	282	45	285
46	288	47	291	48	294	49	297	50	300
51	305	52	311	53	318	54	323	55	327
56	330	57	333	58	336	59	339	60	343
61	350	62	356	63	364	64	368	65	371
66	374	67	377	68	380	69	383	70	387
71	391	72	397	73	402	74	406	75	409
76	412	77	415	78	418	79	421	80	425
81	431	82	438	83	445	84	450	85	454
86	457	87	460	88	463	89	467	90	471
91	475	92	481	93	486	94	491	95	495
96	493	97	501	98	505	99	509	100	514
101	523	102	533	103	539	104	544	105	548
106	553	107	560	108	568	109	576	110	581
111	585	112	589	113	593	114	597	115	602
116	612	117	624	118	632	119	639	120	647
121	657	122	665	123	670	124	675	125	681
126	690	127	707	128	720	129	731	130	738

Figure 9-6. Statistics Module Output for NAMELIST B (3 of 5)

ZONE DEFINITION --

NUMBER	RIGHT ASCENSION LIMITS (DEGREES)			DECLINATION LIMITS (DEGREES)			ZONE CENTER (DEGREES) RIGHT ASC.	DECL IN.	NUMBER OF STARS	NO. FIRST FIRST REC.
1	0.0	TO	360.000	60.000	TO	90.000	180.000	75.000	1000	9
2	0.0	TO	60.000	45.000	TO	75.000	30.000	60.000	894	33
3	60.000	TO	120.000	45.000	TO	75.000	90.000	60.000	574	45
4	120.000	TO	180.000	45.000	TO	75.000	150.000	60.000	431	53
5	180.000	TO	240.000	45.000	TO	75.000	210.000	60.000	403	59
6	240.000	TO	300.000	45.000	TO	75.000	270.000	60.000	678	64
7	300.000	TO	360.000	45.000	TO	75.000	330.000	60.000	1010	72
8	0.0	TO	30.000	30.000	TO	60.000	15.000	45.000	537	85
9	30.000	TO	60.000	30.000	TO	60.000	45.000	45.000	503	92
10	60.000	TO	90.000	30.000	TO	60.000	75.000	45.000	515	99
11	90.000	TO	120.000	30.000	TO	60.000	105.000	45.000	453	106
12	120.000	TO	150.000	30.000	TO	60.000	135.000	45.000	317	112
13	150.000	TO	180.000	30.000	TO	60.000	165.000	45.000	276	116
14	180.000	TO	210.000	30.000	TO	60.000	195.000	45.000	229	120
15	210.000	TO	240.000	30.000	TO	60.000	225.000	45.000	300	123
16	240.000	TO	270.000	30.000	TO	60.000	255.000	45.000	339	127
17	270.000	TO	300.000	30.000	TO	60.000	285.000	45.000	695	132
18	300.000	TO	330.000	30.000	TO	60.000	315.000	45.000	803	141
19	330.000	TO	360.000	30.000	TO	60.000	345.000	45.000	597	151
20	0.0	TO	22.500	15.000	TO	45.000	11.250	30.000	325	159
21	22.500	TO	45.000	15.000	TO	45.000	33.750	30.000	344	164
22	45.000	TO	67.500	15.000	TO	45.000	56.250	30.000	460	166
23	67.500	TO	90.000	15.000	TO	45.000	78.750	30.000	511	175
24	90.000	TO	112.500	15.000	TO	45.000	101.250	30.000	528	182
25	112.500	TO	135.000	15.000	TO	45.000	123.750	30.000	359	189
26	135.000	TO	157.500	15.000	TO	45.000	146.250	30.000	238	194
27	157.500	TO	180.000	15.000	TO	45.000	168.750	30.000	212	197
28	180.000	TO	202.500	15.000	TO	45.000	191.250	30.000	249	200
29	202.500	TO	225.000	15.000	TO	45.000	213.750	30.000	239	204
30	225.000	TO	247.500	15.000	TO	45.000	236.250	30.000	267	207
31	247.500	TO	270.000	15.000	TO	45.000	258.750	30.000	333	211
32	270.000	TO	292.500	15.000	TO	45.000	281.250	30.000	584	216
33	292.500	TO	315.000	15.000	TO	45.000	303.750	30.000	765	224
34	315.000	TO	337.500	15.000	TO	45.000	326.250	30.000	431	234
35	337.500	TO	360.000	15.000	TO	45.000	348.750	30.000	376	240
36	0.0	TO	18.000	0.0	TO	30.000	9.000	15.000	218	245
37	18.000	TO	36.000	0.0	TO	30.000	27.000	15.000	212	248
38	36.000	TO	54.000	0.0	TO	30.000	45.000	15.000	244	251
39	54.000	TO	72.000	0.0	TO	30.000	63.000	15.000	365	255
40	72.000	TO	90.000	0.0	TO	30.000	81.000	15.000	477	260
41	90.000	TO	108.000	0.0	TO	30.000	99.000	15.000	562	266
42	108.000	TO	126.000	0.0	TO	30.000	117.000	15.000	386	273
43	126.000	TO	144.000	0.0	TO	30.000	135.000	15.000	267	278
44	144.000	TO	162.000	0.0	TO	30.000	153.000	15.000	197	282
45	162.000	TO	180.000	0.0	TO	30.000	171.000	15.000	165	285
46	180.000	TO	198.000	0.0	TO	30.000	189.000	15.000	212	288
47	198.000	TO	216.000	0.0	TO	30.000	207.000	15.000	198	291
48	216.000	TO	234.000	0.0	TO	30.000	225.000	15.000	210	294
49	234.000	TO	252.000	0.0	TO	30.000	243.000	15.000	239	297
50	252.000	TO	270.000	0.0	TO	30.000	261.000	15.000	333	300
51	270.000	TO	288.000	0.0	TO	30.000	279.000	15.000	460	305
52	288.000	TO	306.000	0.0	TO	30.000	297.000	15.000	534	311
53	306.000	TO	324.000	0.0	TO	30.000	315.000	15.000	350	318
54	324.000	TO	342.000	0.0	TO	30.000	333.000	15.000	248	323
55	342.000	TO	360.000	0.0	TO	30.000	351.000	15.000	237	327
56	0.0	TO	18.000	-15.000	TO	15.000	9.000	0.0	202	330
57	18.000	TO	36.000	-15.000	TO	15.000	27.000	0.0	203	333
58	36.000	TO	54.000	-15.000	TO	15.000	45.000	0.0	233	336
59	54.000	TO	72.000	-15.000	TO	15.000	63.000	0.0	282	339
60	72.000	TO	90.000	-15.000	TO	15.000	81.000	0.0	531	343
61	90.000	TO	108.000	-15.000	TO	15.000	99.000	0.0	571	350
62	108.000	TO	126.000	-15.000	TO	15.000	117.000	0.0	421	358
63	126.000	TO	144.000	-15.000	TO	15.000	135.000	0.0	311	364
64	144.000	TO	162.000	-15.000	TO	15.000	153.000	0.0	236	368
65	162.000	TO	180.000	-15.000	TO	15.000	171.000	0.0	189	371
66	180.000	TO	198.000	-15.000	TO	15.000	189.000	0.0	194	374
67	198.000	TO	216.000	-15.000	TO	15.000	207.000	0.0	209	377
68	216.000	TO	234.000	-15.000	TO	15.000	225.000	0.0	211	380
69	234.000	TO	252.000	-15.000	TO	15.000	243.000	0.0	250	383
70	252.000	TO	270.000	-15.000	TO	15.000	261.000	0.0	285	387
71	270.000	TO	288.000	-15.000	TO	15.000	279.000	0.0	418	391
72	288.000	TO	306.000	-15.000	TO	15.000	297.000	0.0	392	397
73	306.000	TO	324.000	-15.000	TO	15.000	315.000	0.0	306	402
74	324.000	TO	342.000	-15.000	TO	15.000	333.000	0.0	238	406
75	342.000	TO	360.000	-15.000	TO	15.000	351.000	0.0	231	409
76	0.0	TO	18.000	-30.000	TO	0.0	9.000	-15.000	215	412
77	18.000	TO	36.000	-30.000	TO	0.0	27.000	-15.000	201	415
78	36.000	TO	54.000	-30.000	TO	0.0	45.000	-15.000	222	418
79	54.000	TO	72.000	-30.000	TO	0.0	63.000	-15.000	251	421
80	72.000	TO	90.000	-30.000	TO	0.0	81.000	-15.000	419	425

Figure 9-6. Statistics Module Output for NAMELIST B (4 of 5)

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OF POOR QUALITY

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81	90.000	TO	108.000	-30.000	TO	0.0	99.000	-15.000	550	431
82	108.000	TO	126.000	-30.000	TO	0.0	117.000	-15.000	489	438
83	126.000	TO	144.000	-30.000	TO	0.0	135.000	-15.000	360	445
84	144.000	TO	162.000	-30.000	TO	0.0	153.000	-15.000	269	450
85	162.000	TO	180.000	-30.000	TO	0.0	171.000	-15.000	214	454
86	180.000	TO	198.000	-30.000	TO	0.0	189.000	-15.000	231	457
87	198.000	TO	216.000	-30.000	TO	0.0	207.000	-15.000	221	460
88	216.000	TO	234.000	-30.000	TO	0.0	225.000	-15.000	254	463
89	234.000	TO	252.000	-30.000	TO	0.0	243.000	-15.000	304	467
90	252.000	TO	270.000	-30.000	TO	0.0	261.000	-15.000	300	471
91	270.000	TO	288.000	-30.000	TO	0.0	279.000	-15.000	444	475
92	288.000	TO	306.000	-30.000	TO	0.0	297.000	-15.000	325	481
93	306.000	TO	324.000	-30.000	TO	0.0	315.000	-15.000	323	486
94	324.000	TO	342.000	-30.000	TO	0.0	333.000	-15.000	252	491
95	342.000	TO	360.000	-30.000	TO	0.0	351.000	-15.000	231	495
96	0.0	TO	22.500	-45.000	TO	-15.000	11.250	-30.000	229	498
97	22.500	TO	45.000	-45.000	TO	-15.000	33.750	-30.000	250	501
98	45.000	TO	67.500	-45.000	TO	-15.000	56.250	-30.000	294	505
99	67.500	TO	90.000	-45.000	TO	-15.000	78.750	-30.000	346	509
100	90.000	TO	112.500	-45.000	TO	-15.000	101.250	-30.000	688	514
101	112.500	TO	135.000	-45.000	TO	-15.000	123.750	-30.000	759	523
102	135.000	TO	157.500	-45.000	TO	-15.000	146.250	-30.000	450	533
103	157.500	TO	180.000	-45.000	TO	-15.000	168.750	-30.000	337	539
104	180.000	TO	202.500	-45.000	TO	-15.000	191.250	-30.000	314	544
105	202.500	TO	225.000	-45.000	TO	-15.000	213.750	-30.000	387	548
106	225.000	TO	247.500	-45.000	TO	-15.000	236.250	-30.000	493	553
107	247.500	TO	270.000	-45.000	TO	-15.000	258.750	-30.000	617	560
108	270.000	TO	292.500	-45.000	TO	-15.000	281.250	-30.000	601	568
109	292.500	TO	315.000	-45.000	TO	-15.000	303.750	-30.000	369	576
110	315.000	TO	337.500	-45.000	TO	-15.000	326.250	-30.000	320	581
111	337.500	TO	360.000	-45.000	TO	-15.000	348.750	-30.000	256	585
112	0.0	TO	30.000	-60.000	TO	-30.000	15.000	-45.000	265	589
113	30.000	TO	60.000	-60.000	TO	-30.000	45.000	-45.000	294	593
114	60.000	TO	90.000	-60.000	TO	-30.000	75.000	-45.000	387	597
115	90.000	TO	120.000	-60.000	TO	-30.000	105.000	-45.000	801	602
116	120.000	TO	150.000	-60.000	TO	-30.000	135.000	-45.000	925	612
117	150.000	TO	180.000	-60.000	TO	-30.000	165.000	-45.000	638	624
118	180.000	TO	210.000	-60.000	TO	-30.000	195.000	-45.000	543	632
119	210.000	TO	240.000	-60.000	TO	-30.000	225.000	-45.000	609	639
120	240.000	TO	270.000	-60.000	TO	-30.000	255.000	-45.000	800	647
121	270.000	TO	300.000	-60.000	TO	-30.000	285.000	-45.000	585	657
122	300.000	TO	330.000	-60.000	TO	-30.000	315.000	-45.000	361	665
123	330.000	TO	360.000	-60.000	TO	-30.000	345.000	-45.000	323	670
124	0.0	TO	60.000	-75.000	TO	-45.000	30.000	-60.000	438	675
125	60.000	TO	120.000	-75.000	TO	-45.000	90.000	-60.000	694	681
126	120.000	TO	180.000	-75.000	TO	-45.000	150.000	-60.000	1326	690
127	180.000	TO	240.000	-75.000	TO	-45.000	210.000	-60.000	1017	707
128	240.000	TO	300.000	-75.000	TO	-45.000	270.000	-60.000	853	720
129	300.000	TO	360.000	-75.000	TO	-45.000	330.000	-60.000	519	731
130	0.0	TO	360.000	-90.000	TO	-50.000	180.000	-75.000	2321	738

Figure 9-6. Statistics Module Output for NAMELIST B (5 of 5)

ORIGINAL PAGE IS
OF POOR QUALITY

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THE RUN CATALOG WAS ORIGINALLY GENERATED BY CAT CN 01.12.35.85 WED MAR 03,1976

  TITLE -- SAS-C CATALOG WITH MAG = 0.4B + 0.6V

  NAMELIST PARAMETERS --
           NWORDS  = 5
           ICNVRT  = 2
           IFILE   = 62
           W       = 30.0
           ISEQ    = 0
           FMAG    =    9.99
           NMAX    =   9999
           IFMDFY  = 0
```

Figure 9-7. Statistics Module Output for NAMELIST C (1 of 6)

ROW DEFINITION --

NUMBER	DECLINATION LIMITS (DEGREES))			R.A.WIDTH (DEGREES	NUMBER OF FIRST ZONE	NO. ZONES IN ROW
1	60.000	TO	90.000	360.000	1	1
2	45.000	TO	75.000	60.000	2	6
3	30.000	TO	60.000	30.000	8	12
4	15.000	TO	45.000	22.500	20	16
5	0.0	TO	30.000	18.000	36	20
6	-15.000	TO	15.000	18.000	56	20
7	-30.000	TO	0.0	18.000	76	20
8	-45.000	TO	-15.000	22.500	96	16
9	-60.000	TO	-30.000	30.000	112	12
10	-75.000	TO	-45.000	60.000	124	6
11	-90.000	TO	-60.000	360.000	130	1

Figure 9-7. Statistics Module Output for NAMELIST C (2 of 6)

POINTER ARRAY --

ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER	ZONE	POINTER
1	9	2	33	3	45	4	53	5	59
6	54	7	72	8	85	9	92	10	99
11	100	12	112	13	116	14	120	15	123
16	127	17	132	18	141	19	151	20	159
21	164	22	169	23	175	24	182	25	189
26	194	27	197	28	200	29	204	30	207
31	211	32	216	33	224	34	234	35	240
36	245	37	248	38	251	39	255	40	260
41	266	42	273	43	278	44	282	45	285
46	288	47	291	48	294	49	297	50	300
51	305	52	311	53	318	54	323	55	327
56	330	57	333	58	336	59	339	60	343
61	350	62	358	63	364	64	368	65	371
66	374	67	377	68	380	69	383	70	387
71	391	72	397	73	402	74	406	75	409
76	412	77	415	78	416	79	421	80	425
81	431	82	438	83	443	84	450	85	458
86	457	87	460	88	463	89	467	90	471
91	475	92	481	93	486	94	491	95	495
96	499	97	501	98	505	99	509	100	514
101	523	102	533	103	539	104	544	105	548
106	553	107	560	108	568	109	576	110	581
111	585	112	589	113	593	114	597	115	602
116	612	117	624	118	632	119	639	120	647
121	657	122	665	123	670	124	675	125	681
126	690	127	707	128	720	129	731	130	738

Figure 9-7. Statistics Module Output for NAMELIST C (3 of 6)

ZONE NUMBER 2

THIS ZONE IS CENTERED AT RIGHT ASCENSION 30.00 (LIMITS -- 0.0 TO 60.00)
DECLINATION 60.00 (LIMITS -- 45.00 TO 75.00)
NUMBER OF STARS IN ZONE = 894

STAR NUMBER	X	Y	Z	OTHER DATA (MAGNITUDE)
14	0.36475	0.00832	0.93109	6.85866
25	0.64950	0.00790	0.76032	7.64200
58	0.60325	0.00787	0.79751	7.66466
71	0.56734	0.00759	0.82345	7.47466
88	0.65145	0.00956	0.75864	7.51400
109	0.44768	0.00873	0.89417	7.43900
123	0.52751	0.00837	0.84951	6.24800
144	0.41960	0.00734	0.87816	5.55580
370	0.27661	0.00729	0.96096	7.33133
371	0.45499	0.01174	0.89042	6.82500
432	0.51671	0.01465	0.85603	2.40371
433	0.64814	0.01809	0.76131	7.75400
443	0.42572	0.01332	0.90477	7.37800
487	0.69297	0.02073	0.72067	6.07856
556	0.69208	0.02754	0.72070	7.75400
567	0.61563	0.02057	0.78776	7.00866
571	0.69684	0.02346	0.71684	5.19435
584	0.54596	0.01974	0.83760	6.39666
593	0.50881	0.01763	0.86070	6.71800
630	0.65915	0.02156	0.75164	7.71866
663	0.53973	0.02002	0.84160	7.07466
679	0.27158	0.01083	0.96225	7.46466
698	0.53049	0.02079	0.84744	7.17200
709	0.56333	0.02716	0.82594	7.26666
727	0.40883	0.01635	0.91247	7.06133
725	0.54431	0.02164	0.83861	7.37500
743	0.67020	0.02738	0.74168	6.74440
761	0.59647	0.02473	0.90225	7.00000
763	0.67869	0.02913	0.73389	7.76466
818	0.69626	0.03093	0.71713	6.74350
849	0.64681	0.02938	0.76209	7.01900
861	0.47262	0.02173	0.88100	6.71600
883	0.64946	0.03037	0.75979	6.95133
915	0.50359	0.02478	0.86359	7.32800
1026	0.46014	0.02437	0.88751	7.33133
1045	0.60578	0.03307	0.79188	7.47866
1142	0.48823	0.02921	0.87226	6.76600
1198	0.49139	0.03596	0.88560	7.66800
1210	0.58128	0.03562	0.81292	7.52400
1239	0.47997	0.02988	0.87677	6.09200
1240	0.65237	0.04062	0.75681	7.39300
1241	0.68909	0.04281	0.72341	7.65800
1254	0.54893	0.03454	0.83516	7.23133
1255	0.60111	0.03766	0.79827	7.67866
1278	0.57664	0.03676	0.81617	7.61866
1279	0.67285	0.04259	0.73928	5.85400
1314	0.51719	0.03422	0.85518	7.69400
1317	0.62586	0.04117	0.77865	5.97840
1360	0.29721	0.02003	0.95460	7.55400
1374	0.69186	0.04701	0.71857	7.37466
1383	0.47683	0.03246	0.87840	7.73800
1447	0.45269	0.03207	0.89109	7.68200
1457	0.29419	0.02116	0.95551	7.70466
1496	0.51575	0.03742	0.85592	7.30800
1559	0.36430	0.02797	0.93086	7.74350
1561	0.65956	0.05023	0.74997	6.18133
1598	0.55346	0.04322	0.83176	7.09800
1601	0.65812	0.05134	0.75116	6.81600
1614	0.70209	0.05491	0.70997	7.12800
1659	0.39380	0.03199	0.91864	7.23400
1695	0.380[illegible]	0.03147	0.92419	7.10466
1697	0.47683	0.03948	0.87811	7.44600
1727	0.53262	0.04457	0.84518	7.71133
1732	0.40237	0.03404	0.91485	7.78200
1811	0.58034	0.05100	0.81278	7.60800
1842	0.41574	0.03767	0.90666	7.49200
1844	0.49861	0.04493	0.86566	7.74000
1917	0.48751	0.04509	0.87195	6.72400
1950	0.49514	0.04565	0.86756	7.64000
1966	0.59156	0.05573	0.80433	7.55800
1976	0.61645	0.05815	0.78524	5.51680
2011	0.47413	0.04569	0.87927	5.40000
2054	0.60213	0.05901	0.79621	5.59866
2057	0.66888	0.06568	0.74046	7.78200
2083	0.31522	0.03165	0.94849	6.90200
2110	0.41880	0.04226	0.90710	7.42866
2112	0.57471	0.05778	0.81631	7.36300

OUTPUT CONTINUES

Figure 9-7. Statistics Module Output for NAMELIST C (4 of 6)

ZONE NUMBER 3

THIS ZONE IS CENTERED AT RIGHT ASCENSION 90.00 (LIMITS -- 60.00 TO 120.00)
DECLINATION 60.00 (LIMITS -- 45.00 TO 75.00)
NUMBER OF STARS IN ZONE = 574

STAR NUMBER	X	Y	Z	OTHER DATA (MAGNITUDE)
25213	0.13226	0.23215	0.96364	7.22466
25225	0.13765	0.24139	0.96062	7.08456
25274	0.18150	0.31757	0.93070	6.48180
25290	0.23245	0.40458	0.88447	7.79800
25291	0.25685	0.44610	0.85734	5.24920
25362	0.29585	0.49842	0.81840	6.72350
25425	0.20517	0.36245	0.90914	6.06900
25427	0.23568	0.41493	0.87880	7.63133
25443	0.21190	0.40979	0.88268	6.87200
25473	0.13873	0.24302	0.95851	6.98800
25528	0.15664	0.28142	0.94671	7.36866
25602	0.28873	0.51400	0.80774	6.69560
25616	0.33602	0.59552	0.72887	6.62900
25638	0.22714	0.40739	0.88455	6.92533
25639	0.22718	0.40732	0.88458	6.95166
25642	0.31301	0.55908	0.76848	4.28004
25734	0.23676	0.42753	0.87245	7.33866
25765	0.17830	0.32499	0.92876	7.42200
25787	0.30308	0.54557	0.78065	7.35800
25877	0.24171	0.44154	0.86407	6.73600
25878	0.28846	0.52453	0.80103	7.43466
25889	0.30466	0.59359	0.77508	7.95566
25906	0.25133	0.45929	0.85199	7.12200
25929	0.30660	0.56781	0.76682	6.89133
25940	0.32419	0.59142	0.73823	4.02550
25948	0.27704	0.50714	0.81613	6.38800
25987	0.33268	0.60943	0.72051	6.98133
26076	0.14493	0.27294	0.95105	6.43880
26101	0.17331	0.32527	0.92960	6.79320
26111	0.21483	0.40148	0.89032	7.72800
26232	0.16375	0.11176	0.93594	7.53456
26482	0.30318	0.58228	0.75434	7.50900
26512	0.26786	0.51586	0.81308	7.01133
26551	0.24731	0.47773	0.84184	6.08300
26630	0.30413	0.59187	0.74646	4.51969
26669	0.17622	0.34934	0.92028	6.79666
26670	0.21418	0.42749	0.88070	5.48500
26755	0.24029	0.47665	0.84502	6.14320
26764	0.26825	0.53108	0.80374	5.21080
26792	0.24395	0.48562	0.83944	6.42566
26801	0.21137	0.42280	0.88123	7.74000
26824	0.30860	0.61310	0.72723	7.77866
26839	0.23259	0.46507	0.85417	6.82133
26857	0.28379	0.56559	0.77432	7.32300
26882	0.22006	0.44268	0.86926	7.28866
26907	0.31010	0.62023	0.72049	7.16900
26951	0.28458	0.57375	0.76800	4.63960
27022	0.18520	0.37951	0.90646	5.59400
27084	0.28356	0.57792	0.76525	5.62200
27132	0.27608	0.56852	0.77496	5.54743
27245	0.21231	0.44229	0.87138	5.99060
27322	0.23879	0.49941	0.83281	5.89900
27332	0.30451	0.63343	0.71137	7.53133
27399	0.27722	0.58116	0.76512	7.94800
27396	0.29719	0.62255	0.72395	4.83520
27402	0.21714	0.45874	0.86163	6.06133
27493	0.19950	0.42618	0.88227	7.04200
27546	0.13116	0.28586	0.94925	7.37666
27569	0.25172	0.54078	0.80262	7.11200
27635	0.26029	0.56062	0.78610	6.82900
27673	0.25564	0.57452	0.77418	6.98350
27795	0.28828	0.63160	0.71971	7.03500
27855	0.22116	0.49010	0.84314	6.14133
27856	0.23307	0.51573	0.82444	7.36200
27921	0.25753	0.57281	0.77818	7.77866
27932	0.14314	0.32174	0.93525	7.38466
28005	0.27938	0.62570	0.72832	6.88600
28134	0.24643	0.55999	0.79100	7.47800
28204	0.11837	0.27780	0.95332	6.03200
28280	0.27453	0.63357	0.72334	7.71133
28342	0.14927	0.35191	0.92405	6.83900
28401	0.16502	0.39107	0.90545	7.50800
28433	0.16979	0.40107	0.89928	7.33800
28446	0.23060	0.54166	0.80701	5.30533
28579	0.21934	0.52442	0.82272	7.78200
28734	0.20467	0.49968	0.84169	6.80200
28747	0.26678	0.64773	0.71364	7.59866

OUTPUT CONTINUES

Figure 9-7. Statistics Module Output for NAMELIST C (5 of 6)

ZONE NUMBER 5

THIS ZONE IS CENTERED AT RIGHT ASCENSION 210.00 (LIMITS -- 180.00 TO 240.00)
DECLINATION 60.00 (LIMITS -- 45.00 TO 75.00)
NUMBER OF STARS IN ZONE = 403

STAR NUMBER	X	Y	Z	OTHER DATA (MAGNITUDE)
104725	-0.35349	-0.00164	0.93544	7.54300
104905	-0.52404	-0.00530	0.85168	5.62000
105031	-0.61272	-0.00812	0.79026	7.32200
105043	-0.45064	-0.00619	0.89268	6.19800
105122	-0.35869	-0.00552	0.93344	7.30600
~~105197~~	~~-0.53162~~	~~-0.00980~~	~~0.84693~~	~~7.30200~~
105421	-0.56274	-0.01379	0.82652	7.48780
105584	-0.59211	-0.01764	0.80566	7.65350
105678	-0.25971	-0.00836	0.96565	6.55000
106002	-0.53932	-0.02181	0.84182	7.03000
106150	-0.61204	-0.02745	0.79035	7.61400
106381	-0.40004	-0.02040	0.91627	7.14466
106478	-0.59099	-0.03162	0.80606	6.57680
~~106574~~	-0.33365	-0.01861	0.94251	~~6.18540~~
106591	-0.53923	-0.03052	0.84161	3.34187
106677	-0.29472	-0.01720	0.95543	6.74960
106813	-0.54999	-0.03459	0.83446	7.66300
106884	-0.59397	-0.03902	0.80354	6.33040
107273	-0.45833	-0.03462	0.88811	7.77400
107274	-0.65074	-0.04937	0.75770	5.94640
107379	-0.39483	-0.03113	0.91823	7.03133
~~107414~~	-0.43780	-0.03489	0.89839	~~7.67800~~
107465	-0.52611	-0.04240	0.84936	6.11640
107610	-0.67367	-0.05742	0.73680	6.79400
107670	-0.46975	-0.04046	0.88187	7.15800
107740	-0.65838	-0.05791	0.75046	7.21400
107950	-0.61513	-0.05315	0.78528	5.14800
108134	-0.48282	-0.04801	0.87440	7.58466
108135	-0.54118	-0.05371	0.83919	6.45900
~~108150~~	~~-0.43497~~	~~-0.04338~~	~~0.89940~~	~~6.68220~~
108346	-0.56418	-0.05969	0.92349	6.95133
108399	-0.30387	-0.03226	0.95217	6.80466

Figure 9-7. Statistics Module Output for NAMELIST C (6 of 6)

```
CATALOG GENERATED BY FETCH --
OPTICAL AXIS RIGHT ASCENSION AND DECLINATION --   100.000     30.000 MAGNITUDE SORT FLAG AND LIMITING MAGNITUDE -- 0 999999992320.000
FCV SORT FLAG AND FOV --  0      4.000

NUMBER OF STARS IN THE FULL CATALOG --       1039
```

Figure 9-8. Statistics Module Output for NAMELIST D

MEANINGLESS WORDS, NOT IN RUN CATALOG

	STAR NO.	G I UNIT VECTOR X	Y	Z	MAGNITUDE				
INDEX	ISTDAT	FSTDAT(*,1)	FSTDAT(*,2)	FSTDAT(*,3)	FSTDAT(*,4)	FSTDAT(*,5)	FSTDAT(*,6)	FSTDAT(*,7)	FSTDAT(*,8)
1	28782	0.278E 00	0.677E 00	0.682E 00	0.778E 01	0.149E-79	0.362E 00	0.880E 00	0.308E 00
2	28857	0.362E 00	0.880E 00	0.308E 00	0.612E 01	0.149E-79	0.364E 00	0.888E 00	0.279E 00
3	28879	0.364E 00	0.888E 00	0.279E 00	0.661E 01	0.149E-79	0.330E 00	0.811E 00	0.483E 00
4	28929	0.330E 00	0.811E 00	0.483E 00	0.557E 01	0.149E-79	0.347E 00	0.856E 00	0.384E 00
5	28976	0.347E 00	0.856E 00	0.384E 00	0.691E 01	0.149E-79	0.313E 00	0.776E 00	0.547E 00
6	29022	0.313E 00	0.776E 00	0.547E 00	0.760E 01	0.149E-79	0.356E 00	0.880E 00	0.314E 00
7	29023	0.356E 00	0.880E 00	0.314E 00	0.751E 01	0.149E-79	0.315E 00	0.783E 00	0.537E 00
8	29037	0.315E 00	0.783E 00	0.537E 00	0.777E 01	0.150E-79	0.357E 00	0.886E 00	0.294E 00
9	29051	0.357E 00	0.886E 00	0.294E 00	0.762E 01	0.150E-79	0.278E 00	0.699E 00	0.658E 00
10	29094	0.278E 00	0.699E 00	0.658E 00	0.476E 01	0.150E-79	0.278E 00	0.699E 00	0.658E 00
11	29095	0.278E 00	0.699E 00	0.658E 00	0.451E 01	0.150E-79	0.279E 00	0.701E 00	0.656E 00
12	29096	0.279E 00	0.701E 00	0.656E 00	0.780E 01	0.150E-79	0.350E 00	0.873E 00	0.340E 00
13	29103	0.350E 00	0.873E 00	0.340E 00	0.742E 01	0.150E-79	0.350E 00	0.874E 00	0.338E 00
14	29104	0.350E 00	0.874E 00	0.338E 00	0.673E 01	0.150E-79	0.296E 00	0.744E 00	0.600E 00
15	29122	0.296E 00	0.744E 00	0.600E 00	0.711E 01	0.150E-79	0.293E 00	0.739E 00	0.607E 00
16	29132	0.293E 00	0.739E 00	0.607E 00	0.765E 01	0.150E-79	0.355E 00	0.891E 00	0.283E 00
17	29139	0.355E 00	0.891E 00	0.283E 00	0.149E 01	0.150E-79	0.344E 00	0.865E 00	0.365E 00
18	29150	0.344E 00	0.865E 00	0.365E 00	0.773E 01	0.150E-79	0.339E 00	0.854E 00	0.395E 00
19	29169	0.339E 00	0.854E 00	0.395E 00	0.617E 01	0.150E-79	0.349E 00	0.881E 00	0.318E 00
20	29181	0.349E 00	0.881E 00	0.318E 00	0.780E 01	0.150E-79	0.346E 00	0.876E 00	0.336E 00
21	29193	0.346E 00	0.876E 00	0.336E 00	0.740E 01	0.150E-79	0.324E 00	0.823E 00	0.467E 00
22	29224	0.324E 00	0.823E 00	0.467E 00	0.729E 01	0.150E-79	0.353E 00	0.895E 00	0.272E 00
23	29225	0.353E 00	0.895E 00	0.272E 00	0.682E 01	0.150E-79	0.270E 00	0.692E 00	0.669E 00
24	29235	0.270E 00	0.692E 00	0.669E 00	0.761E 01	0.151E-79	0.353E 00	0.898E 00	0.262E 00
25	29247	0.353E 00	0.898E 00	0.262E 00	0.747E 01	0.151E-79	0.268E 00	0.692E 00	0.671E 00
26	29297	0.268E 00	0.692E 00	0.671E 00	0.737E 01	0.151E-79	0.283E 00	0.731E 00	0.620E 00
27	29308	0.283E 00	0.731E 00	0.620E 00	0.756E 01	0.151E-79	0.308E 00	0.791E 00	0.528E 00
28	29309	0.308E 00	0.791E 00	0.528E 00	0.696E 01	0.151E-79	0.351E 00	0.900E 00	0.260E 00
29	29310	0.351E 00	0.900E 00	0.260E 00	0.779E 01	0.151E-79	0.289E 00	0.751E 00	0.594E 00
30	29363	0.289E 00	0.751E 00	0.594E 00	0.766E 01	0.151E-79	0.322E 00	0.832E 00	0.452E 00
31	29364	0.322E 00	0.832E 00	0.452E 00	0.659E 01	0.151E-79	0.338E 00	0.873E 00	0.352E 00
32	29365	0.338E 00	0.873E 00	0.352E 00	0.538E 01	0.151E-79	0.347E 00	0.897E 00	0.275E 00
33	29375	0.347E 00	0.897E 00	0.275E 00	0.591E 01	0.151E-79	0.290E 00	0.757E 00	0.586E 00
34	29409	0.290E 00	0.757E 00	0.586E 00	0.757E 01	0.151E-79	0.330E 00	0.859E 00	0.392E 00
35	29419	0.330E 00	0.859E 00	0.392E 00	0.776E 01	0.152E-79	0.269E 00	0.709E 00	0.652E 00
36	29457	0.269E 00	0.709E 00	0.652E 00	0.676E 01	0.152E-79	0.323E 00	0.846E 00	0.425E 00
37	29459	0.323E 00	0.846E 00	0.425E 00	0.632E 01	0.152E-79	0.344E 00	0.899E 00	0.271E 00
38	29479	0.344E 00	0.899E 00	0.271E 00	0.513E 01	0.152E-79	0.255E 00	0.673E 00	0.695E 00
39	29487	0.255E 00	0.673E 00	0.695E 00	0.717E 01	0.152E-79	0.343E 00	0.899E 00	0.273E 00
40	29488	0.343E 00	0.899E 00	0.273E 00	0.475E 01	0.152E-79	0.306E 00	0.811E 00	0.498E 00
41	29537	0.306E 00	0.811E 00	0.498E 00	0.702E 01	0.152E-79	0.260E 00	0.696E 00	0.670E 00
42	29587	0.260E 00	0.696E 00	0.670E 00	0.750E 01	0.153E-79	0.274E 00	0.737E 00	0.618E 00
43	29645	0.274E 00	0.737E 00	0.618E 00	0.523E 01	0.153E-79	0.307E 00	0.823E 00	0.477E 00
44	29646	0.307E 00	0.823E 00	0.477E 00	0.570E 01	0.153E-79	0.251E 00	0.683E 00	0.685E 00
45	29722	0.251E 00	0.683E 00	0.685E 00	0.530E 01	0.153E-79	0.270E 00	0.736E 00	0.620E 00

OUTPUT CONTINUES

Figure 9-9. Statistics Module Output for NAMELIST E

```
STARS SELECTED HAVE              -0.990E 11  .GT.  FSTDAT(*,4)  .LT.  0.300E 01
NUMBER OF STARS SELECTED --          34
```

Figure 9-10. Statistics Module Output for NAMELIST F

INDEX	ISTDAT	FSTDAT(*,1)	FSTDAT(*,2)	FSTDAT(*,3)	FSTDAT(*,4)	FSTDAT(*,5)	FSTDAT(*,6)	FSTDAT(*,7)	FSTDAT(*,8)
1	29094	0.278E 00	0.699E 00	0.658E 00	0.476E 01	0.150E-79	0.278E 00	0.699E 00	0.558E 00
2	29095	0.278E 00	0.699E 00	0.658E 00	0.451E 01	0.150E-79	0.279E 00	0.701E 00	0.656E 00
3	29139	0.355E 00	0.991E 00	0.283E 00	0.149E 01	0.150E-79	0.344E 00	0.865E 00	0.355E 00
4	29488	0.343E 00	0.899E 00	0.273E 00	0.475E 01	0.152E-79	0.306E 00	0.811E 00	0.498E 00
5	29763	0.318E 00	0.865E 00	0.389E 00	0.422E 01	0.154E-79	0.251E 00	0.695E 00	0.673E 00
6	31398	0.239E 00	0.803E 00	0.546E 00	0.330E 01	0.162E-79	0.215E 00	0.735E 00	0.643E 00
7	31647	0.218E 00	0.759E 00	0.613E 00	0.497E 01	0.163E-79	0.241E 00	0.834E 00	0.496E 00
8	31954	0.192E 00	0.596E 00	0.692E 00	0.321E 01	0.165E-79	0.238E 00	0.863E 00	0.445E 00
9	32068	0.198E 00	0.728E 00	0.656E 00	0.424E 01	0.165E-79	0.199E 00	0.728E 00	0.656E 00
10	32069	0.199E 00	0.728E 00	0.656E 00	0.382E 01	0.165E-79	0.237E 00	0.862E 00	0.448E 00
11	32301	0.240E 00	0.899E 00	0.367E 00	0.470E 01	0.166E-79	0.184E 00	0.700E 00	0.590E 00
12	32549	0.243E 00	0.933E 00	0.264E 00	0.456E 01	0.168E-79	0.238E 00	0.920E 00	0.312E 00
13	32630	0.185E 00	0.730E 00	0.658E 00	0.310E 01	0.168E-79	0.189E 00	0.743E 00	0.642E 00
14	33276	0.222E 00	0.938E 00	0.268E 00	0.493E 01	0.172E-79	0.166E 00	0.716E 00	0.573E 00
15	335[illegible]	0.170E 00	0.765E 00	0.622E 00	0.495E 01	0.173E-79	0.171E 00	0.780E 00	0.601E 00
16	34[illegible]	0.147E 00	0.751E 00	0.644E 00	0.497E 01	0.177E-79	0.156E 00	0.792E 00	0.590E 00
17	354[illegible]	0.141E 00	0.867E 00	0.478E 00	0.160E 01	0.183E-79	0.129E 00	0.805E 00	0.579E 00
18	35706	0.143E 00	0.917E 00	0.373E 00	0.482E 01	0.184E-79	0.125E 00	0.813E 00	0.559E 00
19	36371	0.112E 00	0.839E 00	0.532E 00	0.498E 01	0.187E-79	0.119E 00	0.883E 00	0.453E 00
20	37202	0.103E 00	0.927E 00	0.360E 00	0.291E 01	0.192E-79	0.798E-01	0.747E 00	0.650E 00
21	37711	0.902E-01	0.955E 00	0.284E 00	0.481E 01	0.194E-79	0.639E-01	0.706E 00	0.705E 00
22	38656	0.483E-01	0.774E 00	0.632E 00	0.489E 01	0.199E-79	0.595E-01	0.933E 00	0.355E 00
23	39003	0.405E-01	0.775E 00	0.631E 00	0.442E 01	0.201E-79	0.469E-01	0.882E 00	0.459E 00
24	39357	0.379E-01	0.885E 00	0.463E 00	0.458E 01	0.203E-79	0.408E-01	0.934E 00	0.355E 00
25	39587	0.351E-01	0.937E 00	0.346E 00	0.465E 01	0.204E-79	0.353E-01	0.945E 00	0.324E 00
26	40111	0.200E-01	0.899E 00	0.438E 00	0.480E 01	0.207E-79	0.182E-01	0.869E 00	0.494E 00
27	40183	0.128E-01	0.708E 00	0.706E 00	0.191E 01	0.207E-79	0.141E-01	0.766E 00	0.543E 00
28	40312	0.128E-01	0.796E 00	0.605E 00	0.259E 01	0.208E-79	0.177E-01	0.958E 00	0.286E 00
29	41116	-0.433E-02	0.919E 00	0.395E 00	0.450E 01	0.212E-79	-0.389E-02	0.939E 00	0.344E 00
30	41117	-0.389E-02	0.939E 00	0.344E 00	0.474E 01	0.212E-79	-0.387E-02	0.958E 00	0.288E 00
31	42545	-0.384E-01	0.960E 00	0.278E 00	0.490E 01	0.219E-79	-0.331E-01	0.746E 00	0.565E 00
32	42995	-0.477E-01	0.922E 00	0.383E 00	0.392E 01	0.221E-79	-0.432E-01	0.806E 00	0.590E 00
33	43039	-0.463E-01	0.869E 00	0.493E 00	0.475E 01	0.222E-79	-0.490E-01	0.943E 00	0.329E 00
34	44478	-0.802E-01	0.920E 00	0.383E 00	0.352E 01	0.229E-79	-0.656E-01	0.725E 00	0.685E 00
35	45542	-0.106E 00	0.932E 00	0.346E 00	0.410E 01	0.235E-79	-0.108E 00	0.946E 00	0.305E 00
36	47105	-0.145E 00	0.948E 00	0.283E 00	0.192E 01	0.0	0.277E-79	0.0	0.838E-43
37	48329	-0.160E 00	0.891E 00	0.426E 00	0.354E 01	0.249E-79	-0.140E 00	0.760E 00	0.535E 00
38	50019	-0.178E 00	0.810E 00	0.560E 00	0.304E 01	0.0	0.277E-79	0.0	0.938E-43
39	52973	-0.247E 00	0.903E 00	0.353E 00	0.432E 01	0.273E-79	-0.250E 00	0.913E 00	0.321E 00
40	54719	-0.252E 00	0.825E 00	0.505E 00	0.492E 01	0.282E-79	-0.262E 00	0.852E 00	0.453E 00
41	56537	-0.309E 00	0.907E 00	0.286E 00	0.362E 01	0.291E-79	-0.265E 00	0.772E 00	0.577E 00
42	56986	-0.306E 00	0.875E 00	0.376E 00	0.367E 01	0.293E-79	-0.311E 00	0.889E 00	0.335E 00
43	58207	-0.312E 00	0.827E 00	0.468E 00	0.421E 01	0.300E-79	-0.300E 00	0.793E 00	0.530E 00
44	58946	-0.311E 00	0.790E 00	0.528E 00	0.431E 01	0.304E-79	-0.300E 00	0.759E 00	0.577E 00

Figure 9-11. Statistics Module Output for NAMELIST G

ORIGINAL PAGE IS
OF POOR QUALITY

```
CATALOG RESET
```

Figure 9-12. Statistics Module Output for NAMELIST II (1 of 2)

```
CATALOG GENERATED BY FETCH --
OPTICAL AXIS RIGHT ASCENSION AND DECLINATION --    100.000    30.000 MAGNITUDE SORT FLAG AND LIMITING MAGNITUDE -- 0 9.9999992320.000
FOV SORT FLAG AND FOV -- , 0      4.000
NUMBER OF STARS IN THE FULL CATALOG --       1039
```

Figure 9-12. Statistics Module Output for NAMELIST II (2 of 2)

ORIGINAL PAGE IS
OF POOR QUALITY

INDEX	ISTDAT	FSTDAT(*,1)	FSTDAT(*,2)	FSTDAT(*,3)	FSTDAT(*,4)	FSTDAT(*,5)	FSTDAT(*,6)	FSTDAT(*,7)	FSTDAT(*,8)
1	28782	0.278E 00	0.677E 00	0.682E 00	0.778E 01	0.149E-79	0.362E 00	0.880E 00	0.308E 00
2	28867	0.362E 00	0.880E 00	0.308E 00	0.612E 01	0.149E-79	0.364E 00	0.888E 00	0.279E 00
3	28879	0.364E 00	0.888E 00	0.279E 00	0.661E 01	0.149E-79	0.330E 00	0.811E 00	0.483E 00
4	28929	0.330E 00	0.811E 00	0.483E 00	0.557E 01	0.149E-79	0.347E 00	0.856E 00	0.384E 00
5	28975	0.347E 00	0.856E 00	0.384E 00	0.691E 01	0.149E-79	0.313E 00	0.776E 00	0.547E 00
6	29022	0.313E 00	0.776E 00	0.547E 00	0.760E 01	0.149E-79	0.356E 00	0.880E 00	0.314E 00
7	29023	0.356E 00	0.880E 00	0.314E 00	0.751E 01	0.149E-79	0.315E 00	0.783E 00	0.537E 00
8	29037	0.315E 00	0.783E 00	0.537E 00	0.777E 01	0.150E-79	0.357E 00	0.886E 00	0.294E 00
9	29051	0.357E 00	0.886E 00	0.294E 00	0.762E 01	0.150E-79	0.278E 00	0.699E 00	0.658E 00
10	29090	0.278E 00	0.699E 00	0.658E 00	0.476E 01	0.150E-79	0.278E 00	0.699E 00	0.559E 00
11	29095	0.278E 00	0.699E 00	0.658E 00	0.451E 01	0.150E-79	0.279E 00	0.701E 00	0.656E 00
12	29096	0.279E 00	0.701E 00	0.656E 00	0.780E 01	0.150E-79	0.350E 00	0.873E 00	0.340E 00
13	29103	0.350E 00	0.873E 00	0.340E 00	0.742E 01	0.150E-79	0.350E 00	0.874E 00	0.338E 00
14	29104	0.350E 00	0.874E 00	0.338E 00	0.673E 01	0.150E-79	0.296E 00	0.744E 00	0.500E 00
15	29122	0.296E 00	0.744E 00	0.600E 00	0.711E 01	0.150E-79	0.293E 00	0.739E 00	0.507E 00
16	29132	0.293E 00	0.739E 00	0.607E 00	0.765E 01	0.150E-79	0.355E 00	0.891E 00	0.283E 00
17	29139	0.355E 00	0.891E 00	0.283E 00	0.149E 01	0.150E-79	0.344E 00	0.865E 00	0.355E 00
18	29150	0.344E 00	0.865E 00	0.365E 00	0.773E 01	0.150E-79	0.339E 00	0.854E 00	0.395E 00
19	29169	0.339E 00	0.854E 00	0.395E 00	0.617E 01	0.150E-79	0.349E 00	0.881E 00	0.318E 00
20	29181	0.349E 00	0.881E 00	0.318E 00	0.780E 01	0.150E-79	0.346E 00	0.876E 00	0.335E 00
21	29193	0.346E 00	0.876E 00	0.336E 00	0.740E 01	0.150E-79	0.324E 00	0.823E 00	0.467E 00
22	29224	0.324E 00	0.823E 00	0.467E 00	0.729E 01	0.150E-79	0.353E 00	0.895E 00	0.272E 00
23	29225	0.353E 00	0.895E 00	0.272E 00	0.682E 01	0.150E-79	0.270E 00	0.692E 00	0.569E 00
24	29235	0.270E 00	0.692E 00	0.669E 00	0.761E 01	0.151E-79	0.353E 00	0.898E 00	0.262E 00
25	29247	0.353E 00	0.898E 00	0.262E 00	0.747E 01	0.151E-79	0.268E 00	0.692E 00	0.571E 00
26	29297	0.268E 00	0.692E 00	0.671E 00	0.737E 01	0.151E-79	0.283E 00	0.731E 00	0.520E 00
27	29308	0.283E 00	0.731E 00	0.620E 00	0.756E 01	0.151E-79	0.308E 00	0.791E 00	0.528E 00
28	29309	0.308E 00	0.791E 00	0.528E 00	0.696E 01	0.151E-79	0.351E 00	0.900E 00	0.250E 00
29	29310	0.351E 00	0.900E 00	0.260E 00	0.779E 01	0.151E-79	0.289E 00	0.751E 00	0.594E 00
30	29343	0.289E 00	0.751E 00	0.594E 00	0.766E 01	0.151E-79	0.322E 00	0.832E 00	0.452E 00
31	29364	0.322E 00	0.832E 00	0.452E 00	0.659E 01	0.151E-79	0.338E 00	0.873E 00	0.352E 00
32	29365	0.338E 00	0.873E 00	0.352E 00	0.558E 01	0.151E-79	0.347E 00	0.897E 00	0.273E 00
33	29375	0.347E 00	0.897E 00	0.275E 00	0.591E 01	0.151E-79	0.290E 00	0.757E 00	0.586E 00
34	29409	0.290E 00	0.757E 00	0.586E 00	0.757E 01	0.151E-79	0.330E 00	0.859E 00	0.392E 00
35	29419	0.330E 00	0.859E 00	0.392E 00	0.776E 01	0.152E-79	0.269E 00	0.709E 00	0.532E 00
36	29457	0.269E 00	0.709E 00	0.652E 00	0.676E 01	0.152E-79	0.323E 00	0.846E 00	0.425E 00
37	29459	0.323E 00	0.846E 00	0.425E 00	0.632E 01	0.152E-79	0.344E 00	0.899E 00	0.271E 00
38	29479	0.344E 00	0.899E 00	0.271E 00	0.513E 01	0.152E-79	0.255E 00	0.673E 00	0.595E 00
39	29497	0.255E 00	0.673E 00	0.695E 00	0.717E 01	0.152E-79	0.343E 00	0.899E 00	0.273E 00
40	29498	0.343E 00	0.899E 00	0.273E 00	0.475E 01	0.152E-79	0.306E 00	0.811E 00	0.498E 00
41	29537	0.306E 00	0.811E 00	0.498E 00	0.702E 01	0.152E-79	0.260E 00	0.696E 00	0.670E 00
42	29587	0.260E 00	0.696E 00	0.670E 00	0.760E 01	0.153E-79	0.274E 00	0.737E 00	0.618E 00
43	29645	0.274E 00	0.737E 00	0.618E 00	0.623E 01	0.153E-79	0.307E 00	0.823E 00	0.477E 00
44	29646	0.307E 00	0.823E 00	0.477E 00	0.570E 01	0.153E-79	0.251E 00	0.683E 00	0.585E 00
45	29722	0.251E 00	0.683E 00	0.685E 00	0.530E 01	0.153E-79	0.270E 00	0.736E 00	0.620E 00
46	29742	0.270E 00	0.736E 00	0.620E 00	0.680E 01	0.153E-79	0.278E 00	0.757E 00	0.591E 00
47	29743	0.278E 00	0.757E 00	0.591E 00	0.763E 01	0.153E-79	0.316E 00	0.858E 00	0.405E 00
48	29745	0.316E 00	0.858E 00	0.405E 00	0.713E 01	0.153E-79	0.318E 00	0.865E 00	0.389E 00
49	29753	0.316E 00	0.865E 00	0.389E 00	0.422E 01	0.154E-79	0.251E 00	0.695E 00	0.573E 00
50	29833	0.251E 00	0.695E 00	0.673E 00	0.728E 01	0.154E-79	0.324E 00	0.890E 00	0.319E 00
51	29836	0.324E 00	0.890E 00	0.319E 00	0.743E 01	0.154E-79	0.312E 00	0.859E 00	0.407E 00
52	29859	0.312E 00	0.859E 00	0.407E 00	0.636E 01	0.154E-79	0.257E 00	0.713E 00	0.552E 00
53	29856	0.257E 00	0.713E 00	0.652E 00	0.611E 01	0.154E-79	0.286E 00	0.791E 00	0.541E 00
54	29857	0.286E 00	0.791E 00	0.541E 00	0.650E 01	0.154E-79	0.265E 00	0.740E 00	0.618E 00
55	29923	0.265E 00	0.740E 00	0.618E 00	0.698E 01	0.155E-79	0.244E 00	0.699E 00	0.572E 00
56	30090	0.244E 00	0.699E 00	0.672E 00	0.683E 01	0.155E-79	0.291E 00	0.829E 00	0.478E 00
57	30111	0.291E 00	0.829E 00	0.478E 00	0.734E 01	0.155E-79	0.303E 00	0.865E 00	0.399E 00
58	30122	0.303E 00	0.865E 00	0.399E 00	0.605E 01	0.155E-79	0.251E 00	0.721E 00	0.546E 00
59	30138	0.251E 00	0.721E 00	0.646E 00	0.634E 01	0.155E-79	0.246E 00	0.711E 00	0.659E 00
60	30152	0.246E 00	0.711E 00	0.659E 00	0.693E 01	0.155E-79	0.296E 00	0.849E 00	0.438E 00
61	30168	0.296E 00	0.849E 00	0.438E 00	0.739E 01	0.155E-79	0.311E 00	0.895E 00	0.320E 00
62	30197	0.311E 00	0.895E 00	0.320E 00	0.649E 01	0.156E-79	0.278E 00	0.823E 00	0.495E 00
63	30178	0.278E 00	0.823E 00	0.495E 00	0.742E 01	0.156E-79	0.280E 00	0.827E 00	0.487E 00
64	30179	0.280E 00	0.827E 00	0.487E 00	0.712E 01	0.157E-79	0.267E 00	0.800E 00	0.537E 00
65	30453	0.267E 00	0.800E 00	0.537E 00	0.599E 01	0.157E-79	0.271E 00	0.810E 00	0.520E 00
66	30454	0.271E 00	0.810E 00	0.520E 00	0.603E 01	0.157E-79	0.302E 00	0.898E 00	0.319E 00
67	30455	0.302E 00	0.898E 00	0.319E 00	0.721E 01	0.157E-79	0.276E 00	0.826E 00	0.492E 00

OUTPUT CONTINUES

Figure 9-13. Statistics Module Output for NAMELIST I

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STAR RIGHT ASCENSIONS AND DECLINATIONS ARE STORED IN FSTDAT POSITIONS        7        8 ,RESPECTIVELY
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Figure 9-14. Statistics Module Output for NAMELIST J

INDEX	ISTDAT	FSTDAT(*,1)	FSTDAT(*,2)	FSTDAT(*,3)	FSTDAT(*,4)	FSTDAT(*,5)	FSTDAT(*,6)	Right Ascension FSTDAT(*,7)	Declination FSTDAT(*,8)
1	28782	0.278E 00	0.677E 00	0.682E 00	0.778E 01	0.149E-79	0.362E 00	0.676E 02	0.430E 02
2	28867	0.362E 00	0.880E 00	0.308E 00	0.612E 01	0.149E-79	0.364E 00	0.677E 02	0.179E 02
3	28879	0.364E 00	0.888E 00	0.279E 00	0.661E 01	0.149E-79	0.330E 00	0.677E 02	0.152E 02
4	28929	0.330E 00	0.811E 00	0.483E 00	0.557E 01	0.149E-79	0.347E 00	0.679E 02	0.289E 02
5	28976	0.347E 00	0.856E 00	0.384E 00	0.691E 01	0.149E-79	0.313E 00	0.679E 02	0.225E 02
6	29022	0.313E 00	0.776E 00	0.547E 00	0.760E 01	0.149E-79	0.356E 00	0.681E 02	0.332E 02
7	29023	0.356E 00	0.880E 00	0.314E 00	0.751E 01	0.149E-79	0.315E 00	0.680E 02	0.193E 02
8	29037	0.315E 00	0.783E 00	0.537E 00	0.777E 01	0.150E-79	0.357E 00	0.681E 02	0.325E 02
9	29051	0.357E 00	0.886E 00	0.294E 00	0.762E 01	0.150E-79	0.278E 00	0.680E 02	0.171E 02
10	29094	0.278E 00	0.699E 00	0.658E 00	0.476E 01	0.150E-79	0.278E 00	0.683E 02	0.412E 02
11	29095	0.278E 00	0.699E 00	0.658E 00	0.451E 01	0.150E-79	0.279E 00	0.683E 02	0.412E 02
12	29096	0.279E 00	0.701E 00	0.656E 00	0.780E 01	0.150E-79	0.350E 00	0.683E 02	0.410E 02
13	29103	0.350E 00	0.873E 00	0.340E 00	0.742E 01	0.150E-79	0.350E 00	0.682E 02	0.199E 02
14	29104	0.350E 00	0.874E 00	0.338E 00	0.673E 01	0.150E-79	0.296E 00	0.682E 02	0.199E 02
15	29122	0.296E 00	0.744E 00	0.600E 00	0.711E 01	0.150E-79	0.293E 00	0.683E 02	0.369E 02
16	29132	0.293E 00	0.739E 00	0.607E 00	0.765E 01	0.150E-79	0.355E 00	0.684E 02	0.373E 02
17	29139	0.355E 00	0.891E 00	0.283E 00	0.149E 01	0.150E-79	0.344E 00	0.683E 02	0.154E 02
18	29150	0.344E 00	0.865E 00	0.365E 00	0.773E 01	0.150E-79	0.339E 00	0.683E 02	0.214E 02
19	29169	0.339E 00	0.854E 00	0.395E 00	0.617E 01	0.150E-79	0.349E 00	0.684E 02	0.232E 02
20	29181	0.349E 00	0.881E 00	0.318E 00	0.780E 01	0.150E-79	0.346E 00	0.684E 02	0.136E 02
21	29193	0.346E 00	0.876E 00	0.336E 00	0.740E 01	0.150E-79	0.324E 00	0.684E 02	0.197E 02
22	29224	0.324E 00	0.823E 00	0.467E 00	0.729E 01	0.150E-79	0.353E 00	0.685E 02	0.273E 02
23	29225	0.353E 00	0.895E 00	0.272E 00	0.692E 01	0.150E-79	0.270E 00	0.685E 02	0.158E 02
24	29235	0.270E 00	0.692E 00	0.669E 00	0.761E 01	0.151E-79	0.353E 00	0.687E 02	0.420E 02
25	29247	0.353E 00	0.898E 00	0.262E 00	0.747E 01	0.151E-79	0.268E 00	0.685E 02	0.132E 02
26	29257	0.268E 00	0.692E 00	0.671E 00	0.737E 01	0.151E-79	0.283E 00	0.688E 02	0.421E 02
27	29308	0.283E 00	0.731E 00	0.620E 00	0.756E 01	0.151E-79	0.308E 00	0.688E 02	0.334E 02
28	29309	0.308E 00	0.791E 00	0.528E 00	0.696E 01	0.151E-79	0.351E 00	0.688E 02	0.319E 02
29	29310	0.351E 00	0.900E 00	0.260E 00	0.779E 01	0.151E-79	0.289E 00	0.687E 02	0.130E 02
30	29363	0.289E 00	0.751E 00	0.594E 00	0.766E 01	0.151E-79	0.322E 00	0.689E 02	0.364E 02
31	29364	0.322E 00	0.832E 00	0.452E 00	0.659E 01	0.151E-79	0.338E 00	0.688E 02	0.253E 02
32	29365	0.338E 00	0.873E 00	0.352E 00	0.558E 01	0.151E-79	0.347E 00	0.688E 02	0.205E 02
33	29375	0.347E 00	0.897E 00	0.275E 00	0.591E 01	0.151E-79	0.290E 00	0.688E 02	0.139E 02
34	29409	0.290E 00	0.757E 00	0.586E 00	0.767E 01	0.151E-79	0.330E 00	0.690E 02	0.359E 02
35	29419	0.330E 00	0.859E 00	0.392E 00	0.776E 01	0.152E-79	0.269E 00	0.690E 02	0.231E 02
36	29457	0.269E 00	0.709E 00	0.652E 00	0.676E 01	0.152E-79	0.323E 00	0.692E 02	0.407E 02
37	29459	0.323E 00	0.846E 00	0.425E 00	0.632E 01	0.152E-79	0.344E 00	0.691E 02	0.251E 02
38	29479	0.344E 00	0.899E 00	0.271E 00	0.513E 01	0.152E-79	0.255E 00	0.691E 02	0.157E 02
39	29487	0.255E 00	0.673E 00	0.695E 00	0.717E 01	0.152E-79	0.343E 00	0.693E 02	0.440E 02
40	29488	0.343E 00	0.899E 00	0.273E 00	0.475E 01	0.152E-79	0.306E 00	0.691E 02	0.158E 02
41	29537	0.306E 00	0.811E 00	0.498E 00	0.702E 01	0.152E-79	0.260E 00	0.693E 02	0.299E 02
42	29587	0.260E 00	0.696E 00	0.670E 00	0.760E 01	0.153E-79	0.274E 00	0.695E 02	0.420E 02
43	29645	0.274E 00	0.737E 00	0.618E 00	0.523E 01	0.153E-79	0.307E 00	0.696E 02	0.382E 02
44	29646	0.307E 00	0.823E 00	0.477E 00	0.570E 01	0.153E-79	0.251E 00	0.695E 02	0.235E 02
45	29722	0.251E 00	0.683E 00	0.685E 00	0.530E 01	0.153E-79	0.270E 00	0.698E 02	0.433E 02
46	29742	0.270E 00	0.736E 00	0.620E 00	0.690E 01	0.153E-79	0.278E 00	0.699E 02	0.383E 02
47	29743	0.278E 00	0.757E 00	0.591E 00	0.763E 01	0.153E-79	0.316E 00	0.698E 02	0.362E 02
48	29745	0.316E 00	0.858E 00	0.405E 00	0.713E 01	0.153E-79	0.318E 00	0.698E 02	0.239E 02
49	29763	0.318E 00	0.865E 00	0.389E 00	0.422E 01	0.154E-79	0.251E 00	0.698E 02	0.229E 02
50	29833	0.251E 00	0.695E 00	0.673E 00	0.728E 01	0.154E-79	0.324E 00	0.701E 02	0.423E 02
51	29836	0.324E 00	0.890E 00	0.319E 00	0.743E 01	0.154E-79	0.312E 00	0.700E 02	0.186E 02
52	29859	0.312E 00	0.859E 00	0.407E 00	0.636E 01	0.154E-79	0.257E 00	0.700E 02	0.240E 02
53	29866	0.257E 00	0.713E 00	0.652E 00	0.611E 01	0.154E-79	0.286E 00	0.702E 02	0.407E 02
54	29867	0.286E 00	0.791E 00	0.541E 00	0.650E 01	0.154E-79	0.265E 00	0.701E 02	0.328E 02
55	29923	0.265E 00	0.740E 00	0.618E 00	0.698E 01	0.155E-79	0.244E 00	0.703E 02	0.382E 02
56	30090	0.244E 00	0.699E 00	0.672E 00	0.683E 01	0.155E-79	0.291E 00	0.707E 02	0.423E 02
57	30111	0.291E 00	0.829E 00	0.478E 00	0.734E 01	0.155E-79	0.303E 00	0.707E 02	0.236E 02

OUTPUT CONTINUES

Figure 9-15. Statistics Module Output for NAMELIST K

ORIGINAL PAGE IS OF POOR QUALITY

ORIGINAL PAGE IS
OF POOR QUALITY

SORT COMPLETE ON FSTCAT(*,4)
ASCENDING ORDER

POSITION	STAR NUMBER	VALUE	POSITION	STAR NUMBER	VALUE	POSITION	STAR NUMBER	VALUE
1	29139	0.149E 01	2	35497	0.160E 01	3	40183	0.191E 01
4	47105	0.192E 01	5	40312	0.259E 01	6	37202	0.291E 01
7	32630	0.310E 01	8	31964	0.321E 01	9	31398	0.330E 01
10	44478	0.352E 01	11	48329	0.354E 01	12	56537	0.362E 01
13	50019	0.364E 01	14	55986	0.357E 01	15	32069	0.382E 01
16	42995	0.392E 01	17	45542	0.410E 01	18	58207	0.421E 01
19	29763	0.422E 01	20	32068	0.424E 01	21	58946	0.431E 01
22	52973	0.432E 01	23	39003	0.442E 01	24	41116	0.450E 01
25	29095	0.451E 01	26	39357	0.458E 01	27	39587	0.465E 01
28	32549	0.466E 01	29	32301	0.470E 01	30	41117	0.474E 01
31	29388	0.475E 01	32	43039	0.475E 01	33	29094	0.476E 01
34	40111	0.480E 01	35	37711	0.481E 01	36	35708	0.482E 01
37	36371	0.488E 01	38	38656	0.489E 01	39	42545	0.490E 01
40	54719	0.492E 01	41	33276	0.493E 01	42	33641	0.495E 01
43	34411	0.497E 01	44	31647	0.497E 01	45	34334	0.505E 01
46	59037	0.508E 01	47	41040	0.510E 01	48	37436	0.511E 01
49	29679	0.513E 01	50	34578	0.514E 01	51	46553	0.515E 01
52	33959	0.515E 01	53	34759	0.516E 01	54	47100	0.517E 01
55	36389	0.517E 01	56	48097	0.518E 01	57	35296	0.519E 01
58	30780	0.519E 01	59	49908	0.523E 01	60	43153	0.524E 01
61	38751	0.526E 01	62	32923	0.527E 01	63	47174	0.528E 01
64	34452	0.529E 01	65	34559	0.530E 01	66	29722	0.530E 01
67	35943	0.532E 01	68	30834	0.533E 01	69	36819	0.534E 01
70	32977	0.534E 01	71	36408	0.535E 01	72	43042	0.537E 01
73	35571	0.538E 01	74	57727	0.539E 01	75	38944	0.539E 01
76	45770	0.539E 01	77	56728	0.539E 01	78	41357	0.544E 01
79	59149	0.545E 01	80	30504	0.546E 01	81	48682	0.546E 01
82	54715	0.549E 01	83	34557	0.551E 01	84	32990	0.552E 01
85	49520	0.553E 01	86	49606	0.554E 01	87	31592	0.554E 01
88	37098	0.555E 01	89	52497	0.555E 01	90	57264	0.555E 01
91	35185	0.556E 01	92	28929	0.557E 01	93	29365	0.558E 01
94	37269	0.558E 01	95	42509	0.559E 01	96	47914	0.561E 01
97	34904	0.562E 01	98	54801	0.563E 01	99	37147	0.563E 01
100	35620	0.564E 01	101	38558	0.564E 01	102	42954	0.565E 01
103	34790	0.569E 01	104	57669	0.569E 01	105	29646	0.570E 01
106	47395	0.571E 01	107	57423	0.571E 01	108	36576	0.572E 01
109	30823	0.576E 01	110	38478	0.577E 01	111	35600	0.577E 01
112	33554	0.578E 01	113	36162	0.578E 01	114	47152	0.579E 01
115	55221	0.580E 01	116	53257	0.580E 01	117	42087	0.584E 01
118	39658	0.585E 01	119	54131	0.586E 01	120	55383	0.586E 01
121	39546	0.586E 01	122	57927	0.587E 01	123	59686	0.587E 01
124	29266	0.588E 01	125	29375	0.591E 01	126	53329	0.591E 01
127	38570	0.591E 01	128	40588	0.592E 01	129	44927	0.593E 01
130	37546	0.595E 01	131	39004	0.595E 01	132	35239	0.596E 01
133	36589	0.595E 01	134	57744	0.596E 01	135	45412	0.597E 01
136	30592	0.597E 01	137	41269	0.598E 01	138	32991	0.599E 01
139	30453	0.599E 01	140	35520	0.600E 01	141	55052	0.600E 01
142	46136	0.600E 01	143	41074	0.601E 01	144	31539	0.601E 01
145	37367	0.602E 01	146	48450	0.602E 01	147	30454	0.603E 01
148	33204	0.603E 01	149	58579	0.604E 01	150	34078	0.605E 01
151	30122	0.605E 01	152	42784	0.606E 01	153	37519	0.606E 01
154	35189	0.606E 01	155	46052	0.606E 01	156	43819	0.606E 01

OUTPUT CONTINUES

Figure 9-16. Statistics Module Output for NAMELIST L

SORT COMPLETE ON ISTDAT
DESCENDING ORDER

POSITION	STAR NUMBER	VALUE	POSITION	STAR NUMBER	VALUE	POSITION	STAR NUMBER	VALUE
3	59828	0.0	4	59798	0.0	5	59686	0.0
6	59557	0.0	7	59507	0.0	8	59430	0.0
9	59350	0.0	10	59333	0.0	11	59292	0.0
12	59203	0.0	13	59173	0.0	14	59149	0.0
15	59148	0.0	16	59106	0.0	17	59084	0.0
18	59059	0.0	19	59037	0.0	20	59014	0.0
21	58946	0.0	22	58919	0.0	23	58899	0.0
24	58898	0.0	25	58829	0.0	26	58781	0.0
27	58747	0.0	28	58746	0.0			

Figure 9-17. Statistics Module Output for NAMELIST M

COUNT PERFORMED ON FSTDAT(*,4)

NUMBER OF BINS -- 10
ZERO AND SCALE -- 0.1487E-01 -- 0.6313E 00

NUMBER	VARIABLE VALUE FROM	TO	FREQUENCY
LESS THAN		1.487	0
1	1.487	2.118	4
2	2.118	2.749	1
3	2.749	3.381	1
4	3.381	4.012	7
5	4.012	4.643	10
6	4.643	5.274	35
7	5.274	5.906	62
8	5.905	6.537	125
9	6.537	7.168	283
10	7.168	7.800	505
OVER	7.800		0

TOTAL NUMBER OF POINTS -- 1039

Figure 9-18. Statistics Module Output for NAMELIST N

ORIGINAL PAGE IS
OF POOR QUALITY

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COUNT PERFORMED ON FSTDAT(*,4)

 NUMBER OF BINS --          10
 ZERO AND SCALE --    0.3200E 01    0.1000E 01

NUMBER         VARIABLE VALUE                FREQUENCY
               FROM        TO
LESS THAN                 3.200                 7
    1          3.200      4.200                10
    2          4.200      5.200                41
    3          5.200      6.200               121
    4          6.200      7.200               372
    5          7.200      8.200               488
    6          8.200      9.200                 0
    7          9.200     10.200                 0
    8         10.200     11.200                 0
    9         11.200     12.200                 0
   10         12.200     13.200                 0
OVER          13.200                            0

TOTAL NUMBER OF POINTS --        1039


HISTOGRAM FOR FSTDAT(*,4)

 TOTAL NUMBER OF POINTS --       1039

  FROM          TO              1         2         3         4         5         6         7         8         9    FREQ.
                        0       0         0         0         0         0         0         0         0         0
  MORE THAN    13.200                                                                                                 0
 12.200  TO    13.200                                                                                                 0
 11.200  TO    12.200                                                                                                 0
 10.200  TO    11.200                                                                                                 0
  9.200  TO    10.200                                                                                                 0
  8.200  TO     9.200                                                                                                 0
  7.200  TO     8.200   **********************************************************************************          488
  6.200  TO     7.200   **************************************************************                              372
  5.200  TO     6.200   *********************                                                                       121
  4.200  TO     5.200   *******                                                                                      41
  3.200  TO     4.200   **                                                                                           10
  LESS THAN     3.200   **                                                                                            7

EACH * REPRESENTS     6 DATA POINTS (ROUNDED UP)
```

Figure 9-19. Statistics Module Output for NAMELIST O

```
COUNT PERFORMED ON FSTDAT(*,4)

NUMBER OF BINS --            50
ZERO AND SCALE --   0.3200E 01   0.1000E 01
```

NUMBER	VARIABLE VALUE FROM	VARIABLE VALUE TO	FREQUENCY
LESS THAN		3.200	7
1	3.200	4.200	10
2	4.200	5.200	41
3	5.200	6.200	121
4	6.200	7.200	372
5	7.200	8.200	488
6	8.200	9.200	0
7	9.200	10.200	0
8	10.200	11.200	0
9	11.200	12.200	0
10	12.200	13.200	0
11	13.200	14.200	0
12	14.200	15.200	0
13	15.200	16.200	0
14	16.200	17.200	0
15	17.200	18.200	0
16	18.200	19.200	0
17	19.200	20.200	0
18	20.200	21.200	0
19	21.200	22.200	0
20	22.200	23.200	0
21	23.200	24.200	0
22	24.200	25.200	0
23	25.200	26.200	0
24	26.200	27.200	0
25	27.200	28.200	0
26	28.200	29.200	0
27	29.200	30.200	0
28	30.200	31.200	0
29	31.200	32.200	0
30	32.200	33.200	0
31	33.200	34.200	0
32	34.200	35.200	0
33	35.200	36.200	0
34	36.200	37.200	0
35	37.200	38.200	0
36	38.200	39.200	0
37	39.200	40.200	0
38	40.200	41.200	0
39	41.200	42.200	0
40	42.200	43.200	0
41	43.200	44.200	0
42	44.200	45.200	0
43	45.200	46.200	0
44	46.200	47.200	0
45	47.200	48.200	0
46	48.200	49.200	0
47	49.200	50.200	0
48	50.200	51.200	0
49	51.200	52.200	0
50	52.200	53.200	0
OVER	53.200		0

```
TOTAL NUMBER OF POINTS --      1039
```

Figure 9-20. Statistics Module Output for NAMELIST P

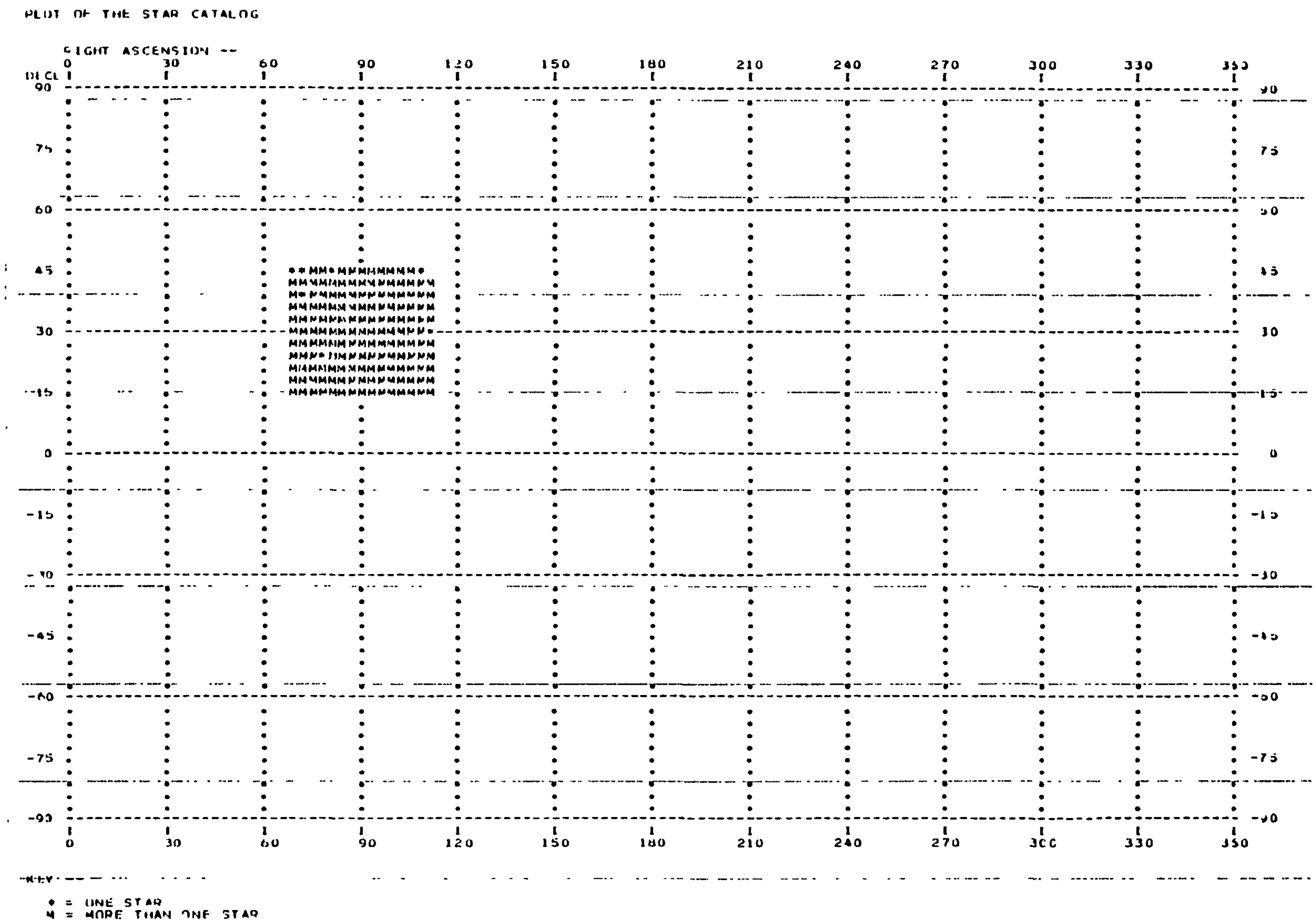

Figure 9-21. Statistics Module Output for NAMELIST Q

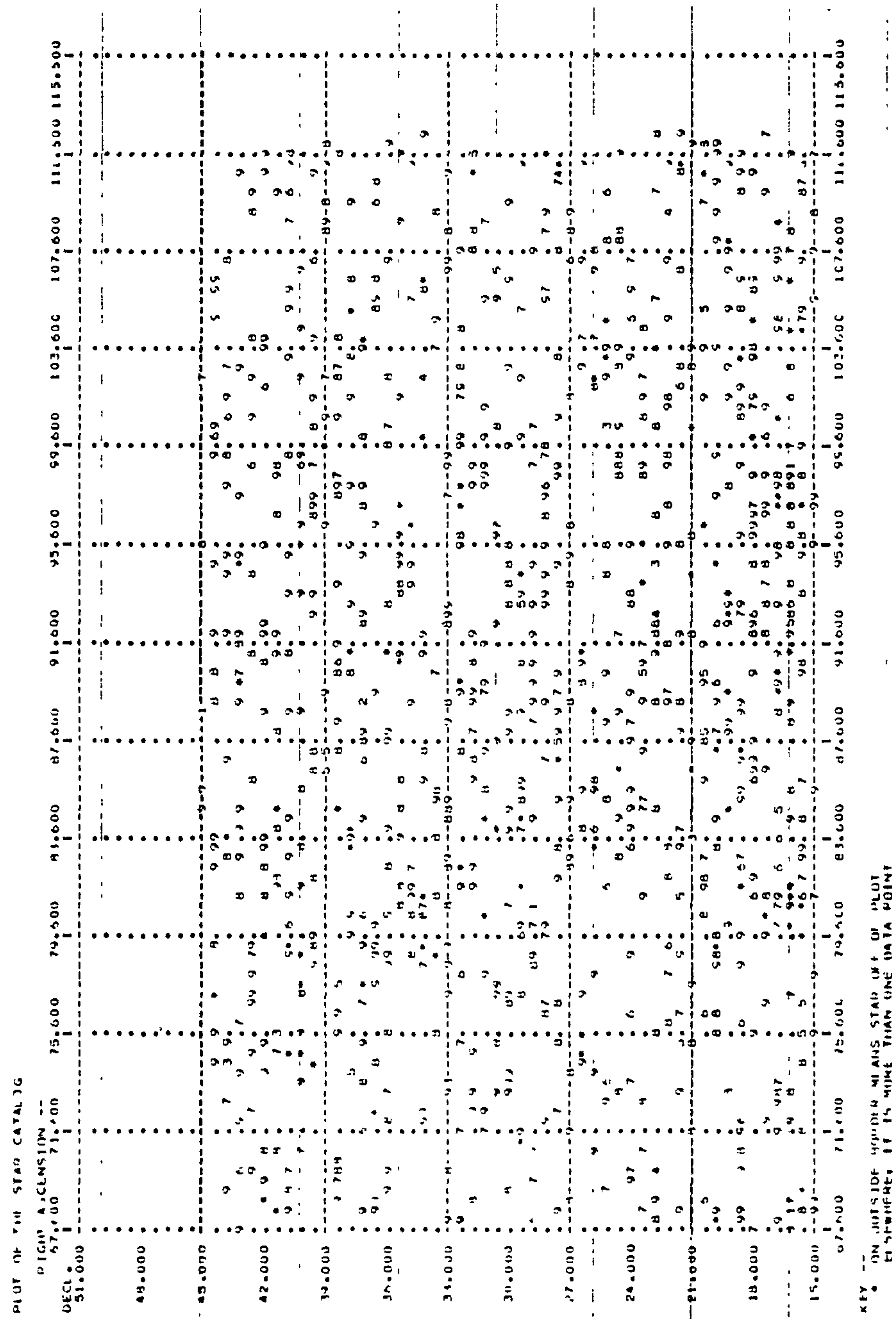

Figure 9-22. Statistics Module Output for NAMELIST R

```
LEAST-SQUARES FIT TO THE EQUATION FSTDAT(*,3)  =  ALPHA  +  BETA  *  FSTDAT(*,8)  --
ALPHA =    0.4048E-01
BETA  =    0.1511E-01
NUMBER OF DATA POINTS =    1039
MEAN DEVIATION OF FSTDAT(*,3) FROM THE NORM (   0.4769E 00)  =   0.1365E 00
MEAN ERROR AFTER CORRELATION =    0.5127E-02
```

Figure 9-23. Statistics Module Output for NAMELIST S

```
LEAST-SQUARES FIT TO THE EQUATION FSTDAT(*,3) = ALPHA + BETA * FSTDAT(*,8) + GAMMA * FSTDAT(*,8) ** 2 --
ALPHA =  -0.4573E-02
BETA  =   0.1851E-01
GAMMA =  -0.5807E-04
NUMBER OF DATA POINTS =    1039
MEAN DEVIATION OF FSTDAT(*,3) FROM THE NORM (  0.4769E 00)  =   0.1365E 00
MEAN ERROR AFTER CORRELATION =    0.1214E-02
```

Figure 9-24. Statistics Module Output for NAMELIST T (1 of 2)

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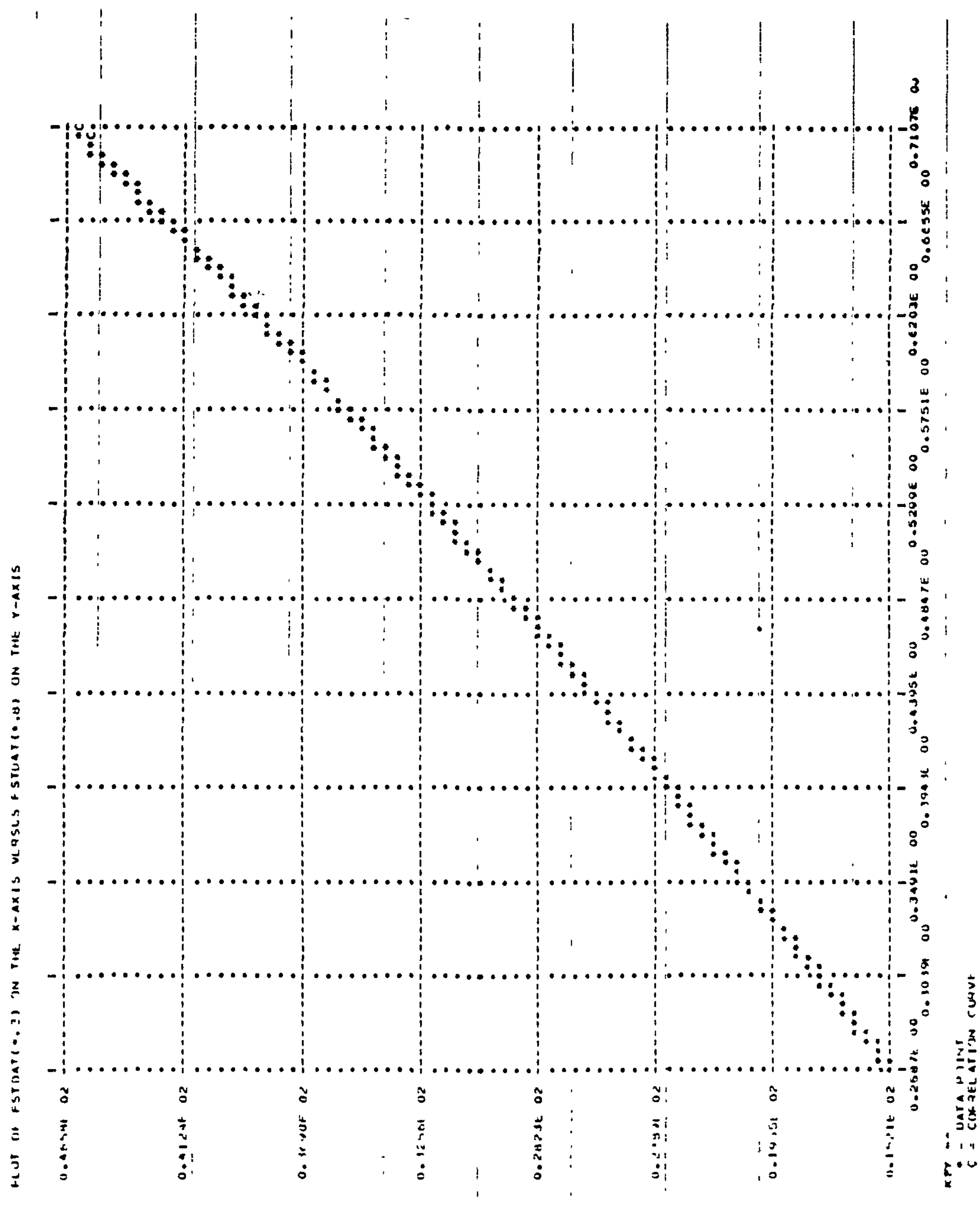

Figure 9-24. Statistics Module Output for NAMELIST T (2 of 2)

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9.6.3 Job Control Language

The Statistics Module subroutines may be incorporated into any desired program. To run them, define FORTRAN data sets for the following reference numbers in the GO step: I5, I6, IPLTFL, INFILE.

I5 is used for NAMELIST input; I6 is for printed output; IPLTFL, for printer plot output; and INFILE for the input direct-access Run Catalog. If diagnostic output is to be generated (IFDG ≠ 0), a FORTRAN data set for reference number IDFL must also be defined. Table 9-4 gives the DCB characteristics required of each data set.

The source code for LOOKAT and nonexecutable object module members are available. Names and locations of these data sets are available from the attitude determination program maintenance functional group of GSFC, code 581.

9.6.4 Overlay Considerations

The Statistics Module subroutines may be placed, as a unit, in an overlay structure. Within the Statistics Module, any subroutine may be overlaid as a separate unit with these restrictions:

- STLIST and PZONE must be in the same unit.
- STPLOT, PLOT, and GENPLT must be in the same unit.
- STATS and GITOAD and COMMON/STINST/ must be in the root.
- STCATL and STREST require Access Module subroutines. The Access Module subroutines have overlay considerations as given in Section 8.6.4. No additional restrictions are posed by STCATL and STREST, which may be overlaid separately from the Access Module subroutines they reference.

Table 9-2. DCB for Statistics Module Data Sets

DATA SET REFERENCE NUMBER	BLOCKING	LOGICAL RECORD LENGTH	BLOCKSIZE
I5	FB	80	7280
I6[1]	VBA	137	1922
IPLTFL[1]	VBA	137	1922
INFILE	FB	1640	1640
IDFL[1]	VBA	137	1922

[1]THESE ARE NORMALLY SYSOUT = A DATA SETS.

9.6.5 System Resources Needed

The Statistics Module subroutines core storage requirements are given in the following table:

Subroutine	Size (Bytes)
GENPLT	11836
PLOT	9250
PZONE	4336
STALDL	934
STATS	1888
STCATL	2260
STCONT	3682
STCORR	11194
STLIST	3892
STPICK	2102
STPLOT	640
STREST	466
STSLCT	1062

Larger storage requirements that these are imposed by the Access Module subroutines referenced by the Statistics Module (see Section 8.6.5).

9.6.6 Execution Time Estimates

Because of the large variety of functions performed by the Statistics Module, we have not attempted to estimate execution times.

APPENDIX A - B-V AND U-B VERSUS DISTANCE PLOTS

This appendix is published separately.

APPENDIX B - COLOR EXCESS VERSUS DISTANCE PLOTS

This appendix is published separately.

APPENDIX C - FORTRAN COMPILER LISTING OF PROGRAM UPDATE

This appendix is published separately.

APPENDIX D - FORTRAN COMPILER LISTING OF PROGRAM CAT

This appendix is published separately.

APPENDIX E - FORTRAN COMPILER LISTING OF PROGRAM SWITCH

This appendix is published separately.

APPENDIX F - ZONE SELECTION TECHNIQUES

This appendix contains a mathematical proof that the techniques for selecting the zones that subroutine STORE reads to generate a Core Catalog (Section 8.3) will always contain all Run Catalog stars within the specified region of the sky.

Because several different techniques are used for zone selection, the proof is divided into three cases. Before these are discussed, however, two theorems that will be used repeatedly will be proved.

- Definition: Let X and Y be any points on the unit sphere. d(X, Y) is defined as the smallest angular distance between X and Y along a great circle. d(X, Y) is always taken as positive.

- Theorem 1: If X , Y , and Z are three points on the unit sphere, such that d(X, Y) , d(X, Z) , and d(Y, Z) are each ≤90 degrees, then

$$d(X, Y) + d(Y, Z) \geq d(X, Z)$$

- Proof: This is a formulation of the Schwartz inequality. Let XYZ be the spherical triangle defined by points X , Y , and Z ; let ζ be the angle opposite side XZ .

Then, by the law of cosines

$$\begin{aligned} \cos [d(X, Z)] = \cos [d(X, Y)] \cos [d(Y, Z)] \\ - \sin [d(X, Y)] \sin [d(Y, Z)] \cos \zeta \end{aligned} \qquad \text{(F-1)}$$

Since $\cos \zeta \geq -1$ for any value of ζ , Equation (F-1) becomes:

$$\begin{aligned} \cos [d(X, Z)] \geq \cos [d(X, Y)] \cos [d(Y, Z)] \\ - \sin [d(X, Y)] \sin [d(Y, Z)] \end{aligned} \qquad \text{(F-2)}$$

Thus,

$$\cos [d(X, Z)] \geq \cos [d(X, Y) + d(Y, Z)] \tag{F-3}$$

Since 0 degree $\leq d(X, Z) \leq 180$ degrees , and 0 degree $\leq d(X, Y) + d(Y, Z) \leq$ 180 degrees , Equation (F-3) implies

$$d(X, Z) \leq d(X, Y) + d(Y, Z) \tag{F-4}$$

- Definition: For any given point on the unit sphere, such as an optical axis pointing, subroutine ZONES selects one zone for subroutine STORE to read. This is called the selected zone.

Zones are defined by program CAT as the area between two pairs of parallel circles on the unit sphere (see Section 6.3.2). One pair of circles are great circles (called right ascension), which intersect at the poles of the unit sphere. The other pair (called declination) are parallel to the equator of the unit sphere. The zone height is the distance between the two declination circles. The zone width[1] was computed to be greater than or equal to the minimum distance between the circles of right ascension for any declination between the two declination circles (see Figure F-1).

Therefore, the zone width is greater than or equal to $W/\cos \delta'$ where W is the zone height and δ' is the declination within the zone of largest absolute value. Mathematically, a pointing in the zone provided that

$$\begin{aligned} |\alpha_c - \alpha_o| &\leq \frac{W}{2 \cos \delta'} \\ |\delta_c - \delta_o| &\leq \frac{W}{2} \end{aligned} \tag{F-5}$$

[1] By "zone" we refer to a combination of two adjacent half-zones so as to create a "whole" zone meeting this requirement.

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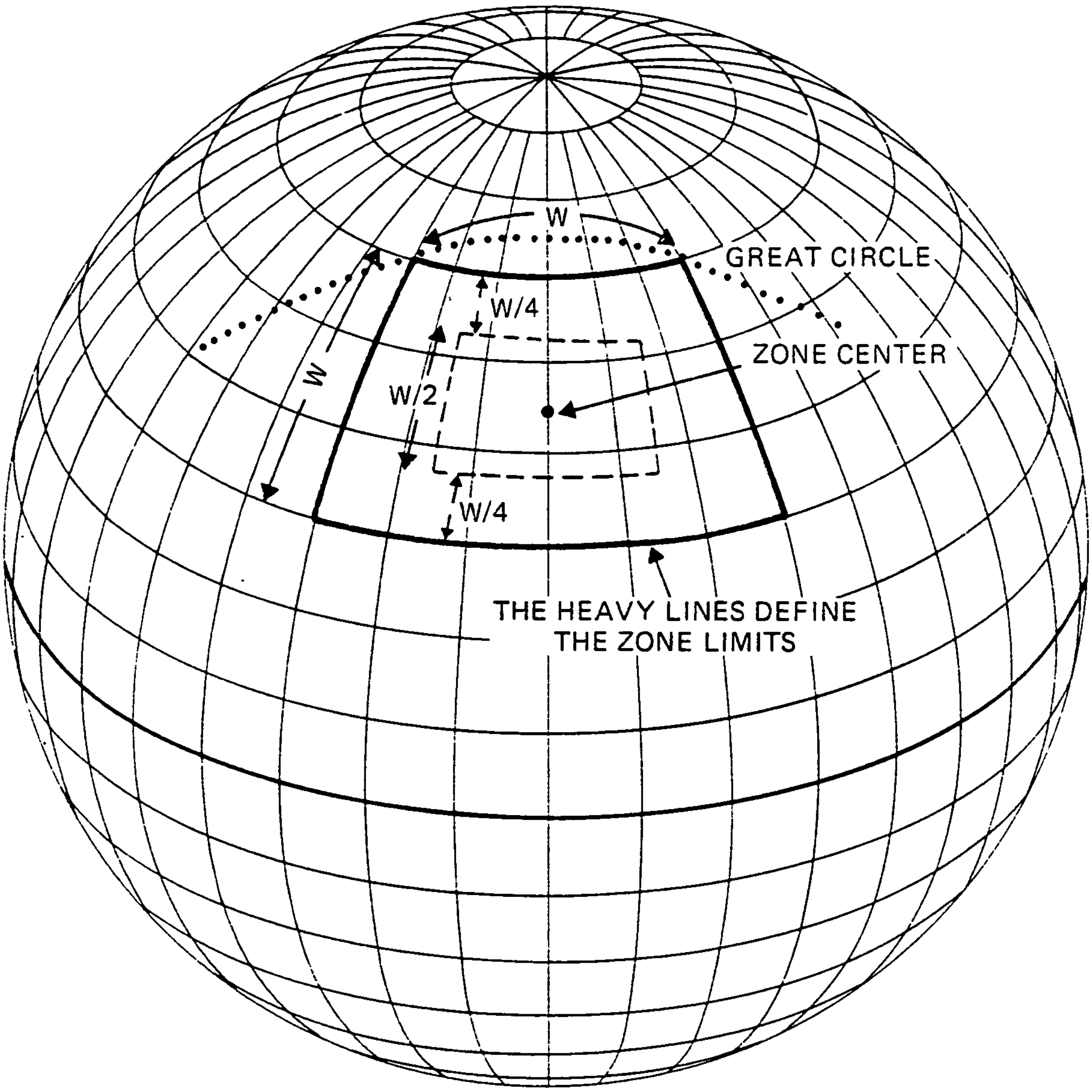

Figure F-1. Definition of Zone Limits

where (α_c, δ_c) are the right ascension and declination of the zone center and (α_o, δ_o) are the right ascension and declination of the pointing.

Because zones overlap by 50 percent on all sides (Figure 6-2), the selected zone for a given pointing is computed by LOOKAT as the one which satisfies

$$|\alpha_o - \alpha_c| \cos \delta_o \le \frac{W}{4}$$

and (F-6)

$$|\delta_o - \delta_c| \le \frac{W}{4}$$

In Figure F-1, the dotted lines enclose the region of the sky in which a pointing will cause the zone to be selected.

- <u>Theorem 2:</u> If a pointing X causes a zone to be selected, all points Y such that $d(X, Y) \le W/4$ will lie within the selected zone.

- <u>Proof</u>: Let (α_x, δ_x) be the right ascension and declination of the pointing X. Let (α_c, δ_c) be the right ascension and declination of the center of the zone (C) selected for X. Let (α_y, δ_y) be the right ascension and declination of any pointing Y such that $d(x, y) \le W/4$. We must prove that Y is in Zone C.

First,

$$|\alpha_y - \alpha_c| = |\alpha_y - \alpha_x + \alpha_x - \alpha_c| \le |\alpha_y - \alpha_x| + |\alpha_x - \alpha_c| \qquad \text{(F-7)}$$

Similarly,

$$|\delta_y - \delta_c| \le |\delta_y - \delta_x| + |\delta_x - \delta_c| \tag{F-8}$$

Using Equation (F-6), Equations (F-7) and (F-8) become

$$\begin{aligned} |\alpha_y - \alpha_c| &\le \frac{W}{4} (\cos \delta_x)^{-1} + |\alpha_y - \alpha_x| \\ |\delta_y - \delta_c| &\le \frac{W}{4} + |\delta_y - \delta_x| \end{aligned} \tag{F-9}$$

Let P be the point at right ascension α_y and declination δ_x. Then

$$d(P, Y) = |\delta_y - \delta_x|$$

and (F-10)

$$d(P, X) = |\alpha_y - \alpha_x| \cos \delta_x$$

But PXY is a right spherical triangle; hence

$$d(P, Y) \le d(X, Y)$$

and (F-11)

$$d(P, X) \le d(X, Y)$$

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By assumption, $d(X, Y) \le W/4$; therefore,

$$d(P, Y) \le \frac{W}{4}$$

and (F-12)

$$d(P, X) \le \frac{W}{4}$$

Combining Equations (F-10) and (F-12)

$$|\alpha_y - \alpha_x| \le \cos \delta_x \frac{W}{4}$$

$$|\delta_y - \delta_x| \le \frac{W}{4} \qquad \text{(F-13)}$$

Substituting this result in Equation (F-9), and noting that $\cos \delta_x$ is always positive since $-\pi/2 \le \delta_x \le \pi/2$:

$$|\alpha_y - \alpha_c| \le \frac{W}{4} (\cos \delta_x)^{-1} + \frac{W}{4} (\cos \delta_x)^{-1} \le \frac{W}{2 \cos \delta_x} \le \frac{W}{2 \cos \delta'}$$

$$|\delta_y - \delta_c| \le \frac{W}{4} + \frac{W}{4} \le \frac{W}{2} \qquad \text{(F-14)}$$

where δ' is the declination of greatest absolute value within the zone. Equation (F-14) is precisely the condition stated in Equation (F-5) for a pointing being within the zone.

We now are ready to prove that each of LOOKAT's zone selection techniques selects the zones necessary to create a Core Catalog containing all stars within the specified region of the sky.

- Definition: $F \equiv$ the half-cone angle of a circular field of view or the half-side length of a square field of view. $\epsilon \equiv$ an error allowance (LOOKAT NAMELIST parameter SLOP), which is added to F to determine the desired height of a band or wedge Core Catalog. $\bar{\tau} \equiv$ the angular distance between computed optical axis pointings (LOOKAT NAMELIST parameter TOLER; see Section 8.3.4).

- Case I: For a cap Core Catalog when $F \le W/4$, there is only one selected zone--the one for the user-defined optical axis. By theorem 2, all stars within W/4 degrees of this pointing are in the selected zone. Therefore, the selected zone is the only one required to ensure that all Run Catalog stars within the cap are in a selected zone.

- Case II: For a band catalog when

$$F + \epsilon + \dot{\tau} \le \frac{W}{4} \quad . \tag{F-15}$$

the Core Catalog must contain all stars within $(F + \epsilon)$ of the path taken by the optical axis during one rotation about the spin axis.

For a wedge catalog for which the condition of Equation (F-15) is met, the Core Catalog must contain a subset of those stars in the band defined by longitude limits (see Section 8.3.5). In this appendix, it is assumed that the longitude selection is done properly, and only the question of proper selection of zones for that band of which the wedge is a subset is addressed.

When the condition of Equation (F-15) is met, LOOKAT creates a series of optical axis pointings (see Section 8.3.4), $\left(\alpha_i^O, \delta_i^O\right)$, $i = 1, N^O$ where $\left(\alpha_i^O, \delta_i^O\right)$ are the right ascension and declination of the ith pointing, and N^O is the number of pointings.

The pointings are created such that

$$d\left[\left(\alpha_i^o, \delta_i^o\right), \left(\alpha_{i+1}^o, \delta_{i+1}^o\right)\right] \le \tau \qquad i = 1; N^o - 1$$

and (F-16)

$$d\left[\left(\alpha_1^o, \delta_1^o\right), \left(\alpha_{N^o}^o, \delta_{N^o}^o\right)\right] \le \tau$$

It is now to be demonstrated that any star within the band of height $2(F + \epsilon)$ centered on the optical axis path is in the zone selected for $\left(\alpha_i^o, \delta_i^o\right)$ for some i .

- Proof: Figure F-2 depicts the situation. Y is any arbitrary point (star) in the band defined above. The arc YZ is constructed perpendicular to the optical axis path and along a great circle. Let the computed optical axis points on either side of Z have right ascension and declination $\left(\alpha_k^o, \delta_k^o\right)$ and $\left(\alpha_{k+1}^o, \delta_{k+1}^o\right)$, respectively. Call the points O_k and O_{k+1} . From Theorem 1:

$$d(Y, O_k) \le d(Y, Z) + d(Z, O_k) \tag{F-17}$$

Because YZ is an arc of a great circle perpendicular to the optical axis path,

$$d(Y, Z) \le F + \epsilon \tag{F-18}$$

Because Z is intermediate to O_k and O_{k+1} and lies on the same circle as these two points,

$$d(O_k, Z) \le d(O_k, O_{k+1}) \tag{F-19}$$

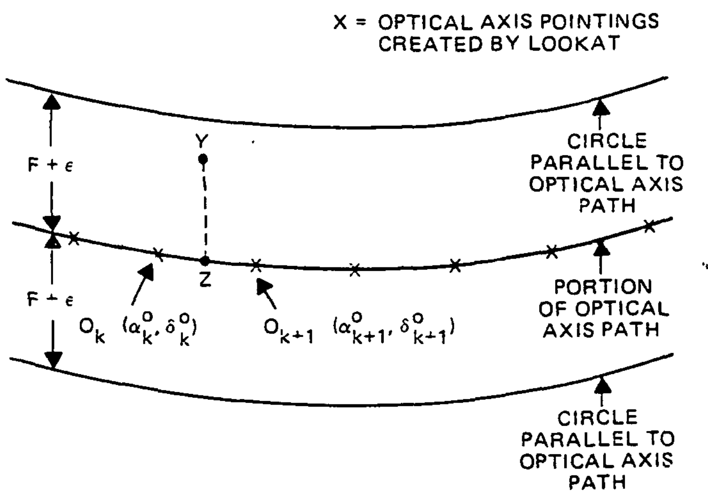

Figure F-2. Schematic Representation of Case II

By Equation (F-16), $d(O_k, O_{k+1}) \le \tau$, so

$$d(O_k, Z) \le \tau \qquad \text{(F-20)}$$

Substituting Equations (F-18) and (F-20) in Equation (F-17)

$$d(Y, O_k) \le F + \epsilon + \tau$$

Using Equation (F-15)

$$d(Y, O_k) \le \frac{W}{4} \qquad \text{(F-21)}$$

Because O_k is one of the optical axis points computed by LOOKAT, the zone for O_k is selected. By theorem 2, Equation (F-21) implies that Y is in that zone. Hence, Y is in one of the zones selected, namely that for pointing O_k .

- Case III: For a band catalog with $F + \epsilon + \tau > W/4$, the Core Catalog must contain all stars within $(F + \epsilon)$ of the path taken during one rotation about the spin axis. For a similar wedge catalog, a subset of these stars is required, as for Case II.

In addition, a cap catalog with $F > W/4$ is treated by LOOKAT in the same way, with $\epsilon = 0$ and τ set by LOOKAT. The coelevation angle is taken as 0.0, thus effectively placing the optical axis at the center of the cap.

The technique used by LOOKAT to select zones in this case is the same technique used for Case II, except that additional sweeps are taken along circles parallel to the optical axis path and located at distances $\pm\omega$, $\pm 2\omega$, . . . , $\pm n\omega$, $\pm\psi$ from the optical axis path, with $|\psi - n\omega| \le \omega$.

- Proof: Call the sweeps at $\pm\psi$ from the optical axis path the "final sweeps." Let Y be an arbitrary point (star) lying within $(F + \epsilon)$ of the optical axis path. It must be proved that Y lies within one of the selected zones.

- Case IIIa: Y lies inside the final sweeps. Figure F-3 depicts the situation. The arc Z_1Z_2 is a part of a great circle perpendicular to the circles shown and passing through point Y. O_1, O_2, O_3, and O_4 are the four optical axis points created by LOOKAT surrounding Z_1 and Z_2.

Note that $d(Z_1, Z_2) \leq \varphi$.

Because Y, Z_1 and Z_2 lie on the same great circle

$$d(Y, Z_1) + d(Y, Z_2) = d(Z_1, Z_2) \leq \varphi \tag{F-22}$$

Therefore, either

$$d(Y, Z_1) \leq \frac{\varphi}{2}$$

or (F-23)

$$d(Y, Z_2) \leq \frac{\varphi}{2}$$

Without loss of generality, let $d(Y, Z_1) \leq \varphi/2$.

By Equation (F-16),

$$d(O_1, O_2) \leq \tau \tag{F-24}$$

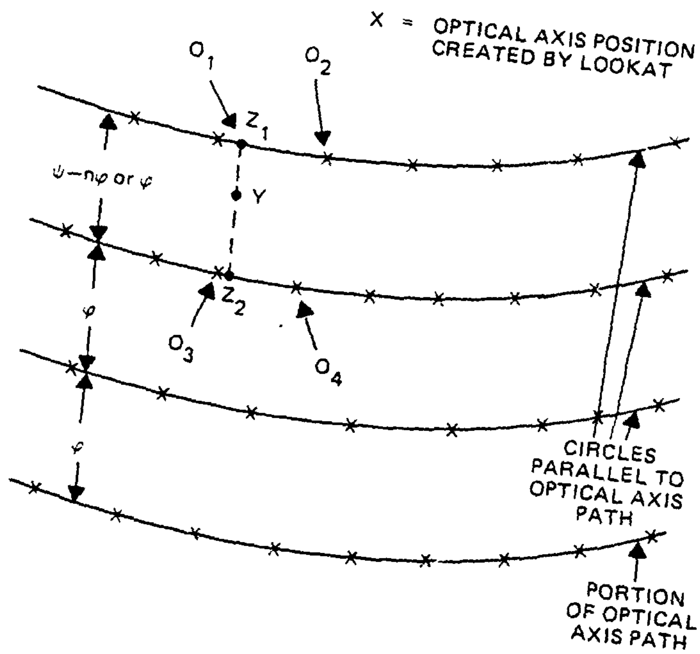

Figure F-3. Schematic Representation for Case IIIa

Because O_1, Z_1, and O_2 lie on a circle, either

$$d(O_1, Z_1) \le \frac{\tau}{2}$$

or (F-25)

$$d(O_2, Z_1) \le \frac{\tau}{2}$$

Without loss of generality, let $d(O_1, Z_1) \le \tau/2$.

Combining Equations (F-23) and (F-25) and theorem 1,

$$\begin{aligned} d(Y, O_1) &\le d(Y, Z_1) + d(O_1, Z_1) \\ &\le \frac{\omega}{2} + \frac{\tau}{2} \end{aligned} \tag{F-26}$$

If the restriction is imposed that

$$\frac{\omega}{2} + \frac{\tau}{2} \le \frac{W}{4} \tag{F-27}$$

then, using Equations (F-26) and (F-27),

$$d(Y, O_1) \le \frac{W}{4} \tag{F-28}$$

By theorem 2, Y lies in the selected zone for O_1 provided Equation (F-27) is satisfied. Rewriting Equation (F-27),

$$\omega \le \frac{W}{2} - \tau \qquad \text{(F-29)}$$

In LOOKAT, $\omega = (W/2) - \tau$.

Hence, Equation (F-28) holds.

- Case IIIb: Y lies outside the final sweeps. Figure F-4 depicts the situation. The arc YZ is part of a great circle perpendicular to the circles shown and passing through Y . O_1 and O_2 are the optical axis points surrounding Z . Note that

$$d(Y, Z) \le \chi - (\psi - n\varphi) \qquad \text{(F-30)}$$

Also, by Equation (F-16)

$$d(O_1, O_2) \le \tau$$

and since O_1 , Z , and O_2 lie on a circle, either

$$d(O_1, Z) \le \frac{\tau}{2}$$

or (F-31)

$$d(O_2, Z) \le \frac{\tau}{2}$$

Without loss of generality, let $d(O_1, Z) \le \tau/2$.

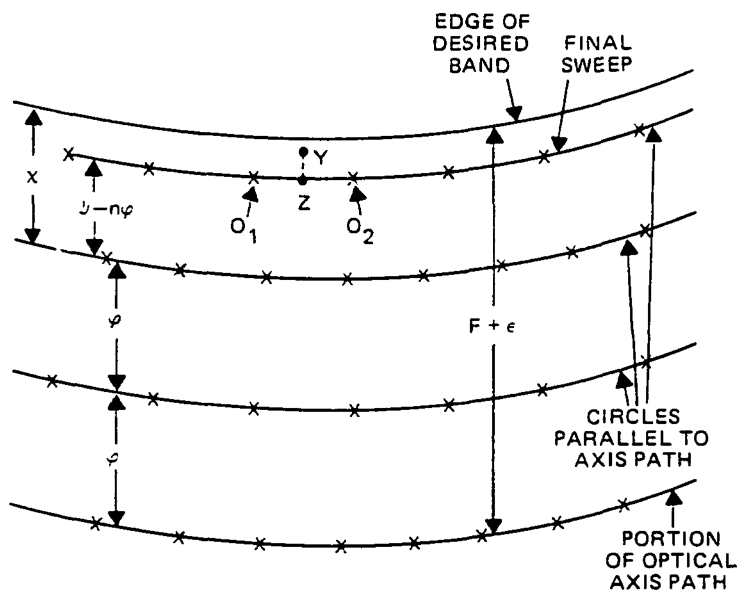

Figure F-4. Schematic Representation of Case IIIb

By theorem 1,

$$d(Y, O_1) \le d(Y, Z) + d(O_1, Z) \tag{F-32}$$

Substituting the results of Equations (F-30) and (F-31),

$$d(Y, O_1) \le \chi - (\psi - n\varphi) + \frac{\tau}{2} \tag{F-33}$$

Therefore, provided that

$$\chi - (\psi - n\varphi) + \frac{\tau}{2} \le \frac{W}{4} \tag{F-34}$$

$$d(Y, O_1) \le \frac{W}{4} \tag{F-35}$$

which by theorem 2 proves that Y is in the selected zone for O_1. Rewriting Equation (F-34), $\chi - (\psi - n\varphi) \le (W/4) - (\tau/2)$.

In LOOKAT, $\chi - (\psi - n\varphi) = (W/4) - (\tau/2)$; hence, Equation (F-34) is satisfied and Equation (F-35) holds.

All cases have now been covered and the proof is complete.

REFERENCES

1. W. M. Smart, Spherical Astronomy, Fifth Edition, Cambridge, England: Cambridge University Press, 1962

APPENDIX G - FORTRAN COMPILER LISTING OF PROGRAM LOOKAT

This appendix is published separately.

APPENDIX H - ACCURACY OF SKYMAP NEAREST NEIGHBOR DATA

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ACCURACY OF SKYMAP NEAREST-NEIGHBOR DATA

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-11999
Task Assignment 790

Prepared by:

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ABSTRACT

The SKYMAP Master Catalog nearest-neighbor parameters are being revised in accordance with the results of this study on the accuracy of multiple star separations. Additional parameters are being added of the form: "nearest neighboring star more than X arc-seconds distant," where X takes on discreet values from 2 to 300.

SECTION 1 - INTRODUCTION

The distance between a star and its nearest neighboring star (at some magnitude limit) can be an important parameter for star identification and attitude determination algorithms. Such algorithms may exclude an identification from attitude computation if the catalog star has a neighbor within the identification error window (possible misidentification). The SKYMAP Master Catalog has the distance to the nearest neighboring Master Catalog star as one of its data words (Reference 1).

For some applications, stars separated by less than some given angular distance may be acceptable for attitude computation. For example, if the required attitude accuracy is 1 arc-minute it makes no difference which of two stars (separated by 5 arc-seconds) the sensor actually tracked. Therefore, the Master Catalog nearest-neighbor data words have been recomputed to exclued successively larger values of the minimum distance a star must be from a catalog star to be considered its neighbor. Specifically, the Master Catalog contains the following nearest-neighbor data words:

- Nearest neighbor in the Master Catalog, including members of multiple systems (no minimum separation).
- Nearest neighbor in the Master Catalog, including members of 2 arc-seconds, 5 arc-seconds, 15 arc-seconds, 40 arc-seconds, 120 arc-seconds, or 300 arc-seconds.

The choice of 2 arc-seconds as the smallest separation is based on an analysis of the accuracy of the known star positions and multiple star separation (see Secion 2).

A near-neighbor to a star may be another star that is physically associated with it (members of a multiple star system) or a star that lies in nearly the same direction relative to the Earth (optical double). Both possibilities are considered in the SKYMAP nearest-neighbor computation.

SECTION 2 - ACCURACY OF THE NEAREST-NEIGHBOR PARAMETER

The accuracy of the nearest-neighbor computation depends on the following factors:

- The accuracy of Master Catalog star positions (for optical doubles only).
- The accuracy of Master Catalog multiple star separations (Reference 2) for physical doubles only.
- The motion of the members of multiple star systems relative to one another since the time of measurement of their separation.

Over 90 percent of Master Catalog stars have positions from the Smithsonian Astrophysical Observatory (SAO) catalog (Reference 3). These positions are accurate to < 1 arc-second (one standard deviation). The multiple star separations are believed to be as accurate at the epoch of their observation.

The third factor listed above as contributing to the error remains to be evaluated. To do so, a model of the relative motion of members of multiple star systems has been developed to yield the distribution of angular separations of two multiple star members as a function of the interval since measurement of the separation, and as a function of the angular separation at the time.

The basic parameters of the model are presented in Figures 2-1 and 2-2. Figure 2-1 shows the relationship of the distance to the star (ℓ), its angular separation (θ) and its physical separation (r). The two stars orbit their common center-of-mass, but we simplify the problem by referencing our calculations to the primary.

Figure 2-2 shows the relationship of the orbital radius (r) assuming a circular orbit, the angular separation (θ) at phase (ϕ) on the orbit, and the maximum angular separation (θ_{max}, at phase 0^{o}).

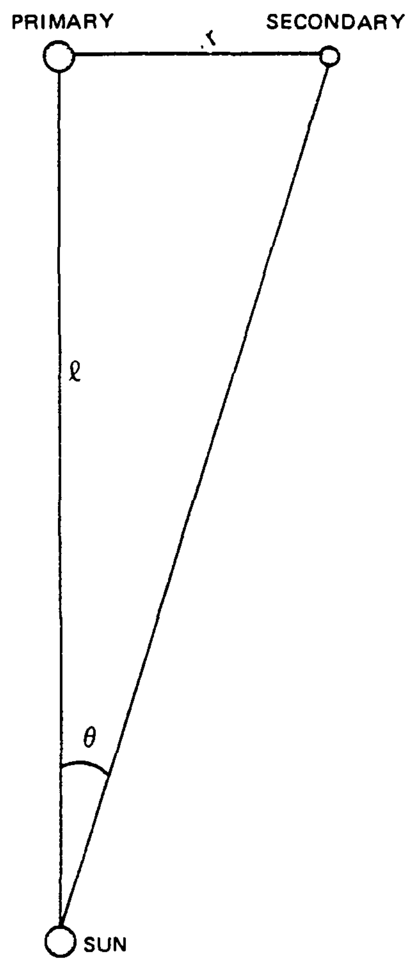

Figure 2-1. Physical and Angular Separation for a Star

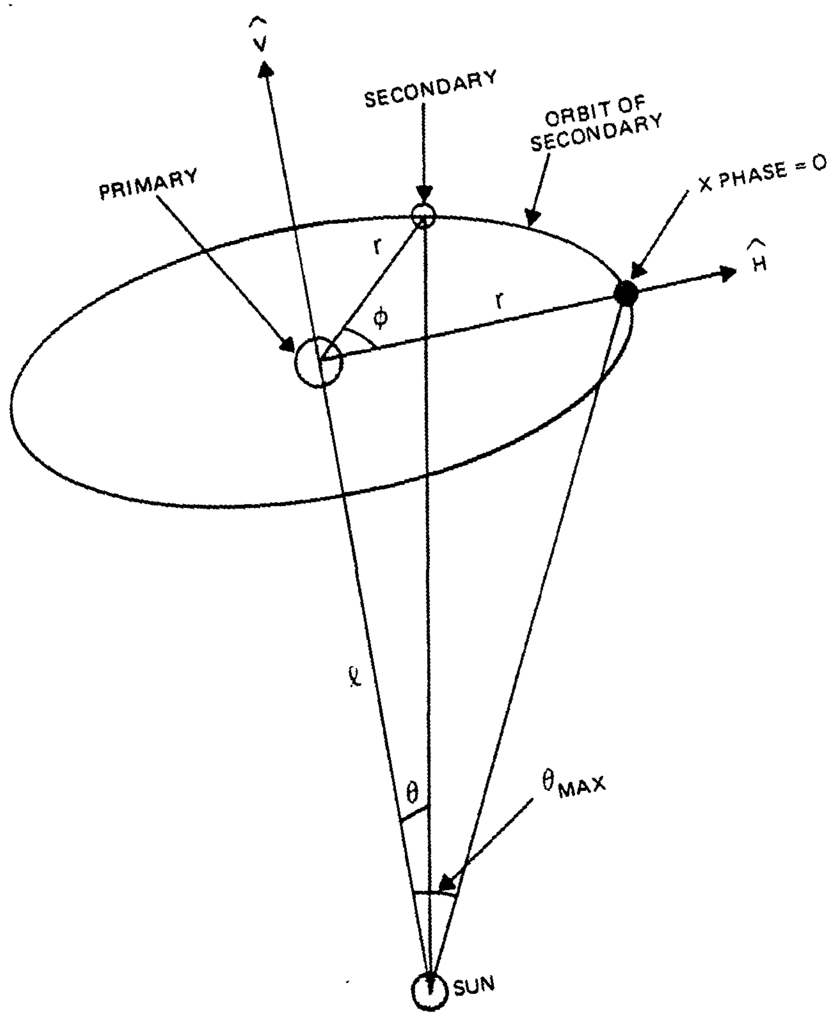

Figure 2-2. Angular Separation as a Function of Phase

Considering first the component of separation in the horizontal direction ($\hat{H}$) in Figure 2-2, then the component of separation in the vertical direction ($\hat{V}$), and finally summing them (using the square root of the sum of the squares since the great distance to the stars allows planar treatment of the problem)

$$\theta_{max} = \frac{\theta}{\sqrt{\cos^2 \phi + \sin^2 \phi \sin^2 i}} \qquad (2-1)$$

where i is the inclination of the orbital plane to the Earth-star line.

When the star is at maximum separation, the orbital radius is given by:

$$r = \ell \theta_{max} \qquad (2-2)$$

where θ_{max} is in radians.

To address the problem of how much the angular separation changes in a given time interval, T, let ϕ_1 be the phase at the beginning of the interval, and ϕ_2 the phase at the end of the interval.

Thus,

$$\phi_2 - \phi_1 = T/P \qquad (2-3)$$

where P is the orbital period.

Using Equation (2-1) to compute θ_1 and θ_2, the angular separations at these two phases,

$$\theta_2 = \frac{\left(\sqrt{\cos^2 \phi_2 + \sin^2 \phi_2 \sin^2 i}\right)}{\left(\sqrt{\cos^2 \phi_1 + \sin^2 \phi_1 \sin^2 i}\right)} \theta_1 \qquad (2-4)$$

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By Kepler's law,

$$P = K\,r^{3/2} \tag{2-5}$$

where P is the period and K is a constant. K = 1 if P is written in years and r in astronomical units (the mean distance from the Earth to the Sun).

Using ϕ_1 as the phase at the epoch of observation, Equations (2-1) and (2-5) yield:

$$P = \frac{K\ell^{3/2}\,\theta_1^{3/2}}{\left(\cos^2\phi_1 + \sin^2\phi_1\,\sin^2 i\right)^{3/4}} \tag{2-6}$$

Equations (2-3), (2-4) and (2-6), taken together, can be used to evaluate the distribution of θ_2 after a period of T years.

The various parameters that enter with computation of the distribution of θ_2 are defined in Table 2-1.

The approximation has been made that the distribution of distances, ℓ, for all Master Catalog stars (Table 2-2), is also valid for multiple stars. Further, it is assumed that the distribution of ℓ is equally valid for all observed values of the separation, θ_1. Actually, large values of θ_1 generally correspond to relatively nearby stars. However, the distribution of distances shown in Table 2-2 is sufficiently concentrated (95 percent of the stars are closer then 500 parsecs) that this approximation is considered satisfactory.

The distribution of θ_2 has been obtained by integrating Equation (2-4) with Equations (2-3) and (2-6), and using ϕ_i, i, and ℓ as variables of integration (see Table 2-1). The results are presented in Table 2-3.

Table 2-1. Parameters Needed To Evaluate the Distribution of θ_2

PARAMETER	HOW OBTAINED
T	STUDY PARAMETER WITH RESULTS PRESENTED AS A FUNCTION OF T
θ_1	STUDY PARAMETER WITH RESULTS PRESENTED AS A FUNCTION OF θ_1
ϕ_1	VARIABLE OF INTEGRATION (VARIED UNIFORMLY BETWEEN 0° AND 360°)
ι	VARIABLE OF INTEGRATION (VARIED UNIFORMLY BETWEEN 0° AND 90°)
K	= 1 BECAUSE P IS WRITTEN IN PARSECS AND r IN ASTRONOMICAL UNITS
ℓ	VARIABLE OF INTEGRATION (DISTRIBUTION GIVEN IN TABLE 2-2)
ϕ_2	EVALUATED FROM EQUATION (2-3)
P	EVALUATED FROM EQUATION (2-6)

Table 2-2. Distribution of Distances

DISTANCE RANGE (PARSECS)	NUMBER IN MASTER CATALOG	FRACTION OF TOTAL
0–10	258	0.006
10–20	3433	0.085
20–30	1266	0.031
30–40	1314	0.032
40–50	1813	0.045
50–60	2217	0.055
60–70	2016	0.050
70–80	1848	0.046
80–90	1774	0.044
90–100	1355	0.033
100–200	8909	0.220
200–300	6197	0.153
300–400	4477	0.110
400–500	1353	0.033
500–600	585	0.014
600–700	395	0.010
700–800	173	0.004
800–900	144	0.004
900–1000	153	0.004
1000–2000	425	0.010
2000–3000	163	0.004
3000–4000	96	0.002
4000–5000	92	0.002
5000–6000	46	0.001
6000–7000	31	0 001
7000–8000	10	0.0002
8000–9000	10	0.0002
9000–10000	4	0.0001
OVER 10000	4	0.0001

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Table 2-3. Angular Separation Distribution as a Function of Time From Observation Epoch and Initial Separation

TIME INTERVAL = 30 YEARS		
INITIAL SEPARATION (ARC SECONDS)	99% PROBABILITY INTERVAL (ARC SECONDS)	99.9% PROBABILITY INTERVAL (ARC SECONDS)
1.5	0.0– 3.0	0.0– 4 0
2.5	0.5– 4.0	0.0– 5.0
3.5	2.5– 5.0	1 0– 6.0
4.5	3.0– 6.0	2.0– 7.0
7.5	7.0– 8.0	5.0– 9.5
12.5	12.0–13.0	10.0–15.0
TIME INTERVAL = 75 YEARS		
1.5	0.0– 3.5	0.0– 5.0
2.5	0.5– 4.5	0.0– 6.0
3.5	1.0– 5.0	0.0– 7 0
4.5	2.0– 6.0	0.5– 8.0
7.5	6.0– 8.5	4.0–11.0
12.5	11.0–13.5	8.0–16.0

SECTION 3 - CONCLUSIONS

From the results given in Table 2-3 and the distributions of angular separation and epoch of observation given in Tables 3-1 and 3-2 (based on the stars contained in the SKYMAP catalog, the limiting magnitude of which is 8.0 visual and blue) the following statements are justified at the 99.9 percent probability level:

- The component of nearest-neighbor angular separation error attributable to relative motion of the components is less than 3 arc-seconds for stars with measured separations of less than 5 arc-seconds and less than 2 arc-seconds for those with measured separations greater than 5 arc-seconds.
- The probability that a nearest-neighbor computation of 2 arc-seconds or less is actually greater than 2 arc-seconds is about 0.05.
- The probability that a nearest-neighbor computation of 5 arc-seconds or less is actually greater than 5 arc-seconds is less than 0.01.

These results refer to the component of error due to motion of the multiple star components relative to one another. The error in the observation of the separation is another component of the total error (believed to be less than 1 arc-second, one standard deviation) which somewhat increases the total error.

This result should serve as a cautionary flag to persons using the Master Catalog word: nearest-neighbor in the Master Catalog greater than 2 arc-seconds. Approximately 5 percent of these stars may actually have a neighbor 2 to 5 arc-seconds distant that was not considered in the computation.

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Table 3-1. Distribution of Multiple Star Separations

SEPARATION (ARC-SEC)	NUMBER OF MASTER CATALOG STARS	CUMULATIVE FRACTION OF TOTAL MASTER CATALOG STARS
0–1	1395	0.031
1–2	837	0.050
2–3	544	0.062
3–4	402	0.071
4–5	299	0.078
5–6	278	0.084
6–7	187	0.088
7–8	176	0.092
8–9	171	0.096
9–10	133	0.099
10–15	605	0.113
15–20	423	0.122
20–25	355	0.130
25–30	286	0.136
30–35	206	0.141
35–40	160	0.144
40–45	129	0.147
45–50	113	0.150
50–55	98	0.152
55–60	84	0.154
60–65	67	0.155
65–70	70	0.157
70–75	53	0.159
75–80	52	0.160
80–85	41	0 161
85–90	44	0.162
OVER 90	81	0 164
TOTAL KNOWN MULTIPLE STARS IN THE MASTER CATALOG	7289	0 164
TOTAL STARS IN THE MASTER CATALOG	44571	

Table 3-2. Epoch of Observation of Master Catalog Multiple Stars

YEARS	NUMBERS OF STARS
1850–1859	3
1860–1869	1
1870–1879	9
1880–1889	12
1890–1899	106
1900–1909	473
1910–1919	815
1920–1929	964
1930–1939	1166
1940–1949	1006
1950–1959	2304
1960–1969	499
1970–1976	62

REFERENCES

1. Computer Sciences Corporation, SD-76/6041, SKYMAP System Description: Star Catalog Data Base Generation and Utilization, D. M. Gottlieb and C. M. Gray, 1976.

2. United States Naval Observatory, Index Catalog of Visual Double Stars, 1974-1975.

3. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV. Smithsonian Institute, Washington, D.C., 1971.

APPENDIX I - THE ACCURACY OF SKYMAP STAR POSITIONS

CSC/TM-77/6009

THE ACCURACY OF SKYMAP STAR POSITIONS

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-11999
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ABSTRACT

The accuracy of the SKYMAP star position data has been investigated by comparing positions in two different source catalogs. Systematic errors in one of these have been discovered and evaluated. A method for computing the total error in position as a function of visual magnitude and star position is presented, along with recommendations to improve some SKYMAP positions.

SECTION 1 - INTRODUCTION

This report examines the accuracy of the star positions given in the SKYMAP Master Catalog (see Reference 1 for a description of SKYMAP). Knowledge of the accuracy of the SKYMAP positional data is vital when using the SKYMAP catalog, for two reasons. First, in star identification routines, an observed star is identified with a catalog star only if the positions of the two agree to within a given tolerance. When calculating this tolerance, allowance must be made for the anticipated error in the star catalog positions as well as for the errors in the observed star positions. Finally, once observed stars are identified with catalog stars, an attitude is computed by forcing the observations to fall as closely as possible on the catalog star positions. It may be desirable to edit out catalog stars with large positional uncertainties before an attitude is computed, to avoid large errors in the solutions.

The errors in SKYMAP positions have been studied to place reliable estimates on the positional errors, and to discover ways to improve the star positions whenever possible.

SECTION 2 - METHODOLOGY

SKYMAP star positions come from the Smithsonian Astrophysical Observatory Star Catalog (SAO, Reference 2), and the Henry Draper Catalog (HD, Reference 3). The SAO positions were used for all SAO stars in SKYMAP. Since both SAO and SKYMAP are in epoch 1950.0, no adjustments to the SAO position were required. For stars not in the SAO (about 5 percent of SKYMAP stars to 8.0 visual magnitude, but about 20 percent of SKYMAP stars to 9.0 visual magnitude), the positions given in the HD at epoch 1900.0 were precessed to 1950.0 and then adopted as SKYMAP positions.

Errors in the SAO positions are given in the SAO catalog itself, and are also reported in the SKYMAP positional error word. These are usually less than 1 arc-second, and always less than 3 arc-seconds (one standard deviation). Errors in these SKYMAP positions that originated in the HD catalog are much larger.

To evaluate the size of the errors in position for SKYMAP stars not in the SAO, a comparison was made of SAO positions with HD positions precessed to 1950.0, using positions of SKYMAP stars contained in both the HD and the SAO as data. Slightly more than 41,000 stars were used in this study.

Differences in the SAO positions and the precessed HD positions are due to a combination of the following effects:

- Errors in the positions reported in the HD
- Errors in the precession model used to precess the HD positions to epoch 1950.0
- Proper motion of the stars from 1900.0 to 1950.0
- Errors in the positions reported in the SAO.

The first source of error was found to be the dominant one. To demonstrate this point the other sources of error are discussed briefly.

The precession model was tested by precessing a grid of stars from the Fourth Fundamental Catalog (FK4, Reference 4) from epoch 1950.0 to 1975.0. The FK4 positions are extremely precise (errors less than 0.01 arc-seconds) and are given in both of these epochs. Therefore, the differences in the FK4 positions for epoch 1975.0, and the FK4 positions for 1950.0 precessed to 1975.0 using our model, give an estimate of the imprecision of the model.

In no case did the precession model introduce more than 0.5 arc-seconds per century of error. The precession needed to advance HD positions to the SKYMAP epoch is from 1900.0 to 1950.0, and the test was performed on epochs 1950.0 to 1975.0. However, no significant additional uncertainty due to the earlier epochs is anticipated.

Proper motions of the stars during the interval 1900.0 to 1950.0 contribute to the total error. However, proper motions of more than 2 arc-seconds per 50 years are rare.

Errors in the reported SAO positions, as noted above, are almost always less than 1 arc-second.

Because the mean difference in the SAO position and the precessed HD position exceeded 20 arc-seconds in declination and 20 arc-seconds in right ascension, the three other sources of error discussed above can be ignored. In the following, the entire difference is referred to as error in the HD position, although a small fraction of this error is actually due to precession, proper motion, and SAO position error.

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To evaluate the size of the HD-position errors, the following four measures were computed for each star:

- The error in right ascension:

$$\Delta\alpha = (\alpha_{SAO} - \alpha^*_{HD}) \cos \delta_{SAO} \qquad (2\text{-}1)$$

  where α_{SAO} is the SAO right ascension, α^*_{HD} is the HD right ascension precessed to epoch 1950.0, and δ_{SAO} is the SAO declination. The cos δ_{SAO} term is employed to convert an angle in right ascension to an angular distance (along a great circle).

- The error in declination

$$\Delta\delta = (\delta_{SAO} - \delta^*_{HD}) \qquad (2\text{-}2)$$

  where δ^*_{HD} is the HD declination precessed to epoch 1950.0.

- The absolute error in right ascension

$$|\Delta\alpha| = |\alpha_{SAO} - \alpha^*_{HD}| \cos \delta_{SAO} \qquad (2\text{-}3)$$

- The absolute error in declination

$$|\Delta\delta| = |\delta_{SAO} - \delta^*_{HD}| \qquad (2\text{-}4)$$

These four quantities were analyzed as a function of position in the sky and star magnitude. The results are presented in Section 3.

SECTION 3 - RESULTS

The results from this study are presented in the following three parts:

- Discussion of the absolute value of the errors in right ascension and declination as a function of region of the sky
- Report of systematic errors in right ascension and declination as a function of region of the sky
- Analysis of these errors as a function of star magnitude

For purposes of this study, the sky was divided into 144 regions, defined as follows. Region (I, J) contained all stars such that:

$$(J - 1)\ 45^{\circ} \leq \alpha_{SAO} < (J)\ 45^{\circ} \qquad 1 \leq J \leq 8$$

and (3-1)

$$90^{\circ} - 10^{\circ}\ (I) \leq \delta_{SAO} < 100^{\circ} - 10^{\circ}\ (I) \qquad 1 \leq I \leq 18$$

where α_{SAO} is the SAO right ascension of the star (in degrees), and δ_{SAO} is its declination.

The source catalogs from which the SAO and HD were compiled were usually limited to certain declinations. Variations between catalogs show up most strongly as a variation of the position errors as a function of declination. Therefore, the regions were made smaller in declination than in right ascension to more precisely delineate error variations.

To determine if more significant results could be obtained by choosing regions of more limited right ascension, the study was repeated with regions offset 22.5 degrees in right ascension from that of the original study. No significant differences were noted between the two studies. It is therefore concluded that the division of the sky which was used satisfactorily defined the variation in position errors.

3.1 ABSOLUTE POSITION ERRORS AS A FUNCTION OF REGION OF THE SKY

The quantities $|\Delta\alpha|$ and $|\Delta\delta|$ from Equations (2-3) and (2-4) are the absolute errors in right ascension and declination, respectively. They represent the total error in the positions taken from the HD catalog and precessed to the SKYMAP epoch, 1950.0. They include random errors, i.e., those due to the round-off in the HD catalog positions; and systematic errors, traceable either to the source catalogs from which the HD was produced or to the method of reduction of source catalog data by the HD compilers.

The results for the absolute error in right ascension are given in Table 3-1. Here the mean absolute error is written in seconds of arc, and is presented as a function of right ascension (J) and declination (I), where J and I are defined in Equation 3-1. The rightmost column and the bottom row are the means for all stars in that declination or right ascension region, respectively. The value in the lower right corner is the mean for the entire sky.

The results for absolute error in declination are given in the same format in Table 3-2.

The standard deviations in the absolute error in right ascension are given in Table 3-3, and those for declination are given in Table 3-4. These quantities are important because they are an estimate of how accurate the HD positions can become if they are corrected for systematic effects. For example, for the region $I = 1$, $J = 4$, the mean absolute error in right ascension is 65.0 arc-seconds. The standard deviation in the absolute error in right ascension, however, is only 24.6 arc-seconds; converted to an equivalent mean error, that is about 20 arc-seconds. The fact that the standard deviation is substantially less than the mean absolute error implies that the mean error

Table 3-1. Mean Absolute Errors in Right Ascension

I = \ J =	1	2	3	4	5	6	7	8	ALL
1	55.0	60.5	52.2	65.0	34.6	56.5	50.3	37.7	48.0
2	36.7	34.6	34.5	38.2	26.1	27.3	27.1	24.8	31.0
3	26.8	25.2	24.7	21.1	22.1	22.7	23.2	21.8	23.6
4	22.1	23.2	20.2	24.8	20.6	21.1	20.8	22.8	22.2
5	21.8	22.3	21.7	20.5	19.7	19.6	20.9	20.5	21.1
6	21.4	19.3	19.5	17.8	19.3	19.8	19.1	18.2	19.3
7	20.4	18.8	17.5	20.6	20.3	20.4	18.6	19.9	19.2
8	18.5	20.6	18.6	20.7	19.9	20.7	19.3	21.0	19.8
9	19.6	19.9	23.0	19.4	23.6	23.2	19.2	20.8	21.1
10	20.9	20.1	20.6	20.6	19.5	19.8	19.1	17.7	19.9
11	20.0	20.7	19.0	19.0	19.2	18.9	19.2	19.0	19.3
12	17.7	18.3	18.6	17.8	18.1	17.7	17.6	19.3	18.2
13	19.7	19.7	20.1	18.1	19.4	19.1	16.4	17.2	18.8
14	19.8	20.8	19.5	20.7	18.2	21.4	20.6	19.5	20.1
15	20.8	19.6	20.4	20.7	23.6	21.4	20.9	21.4	21.2
16	19.1	20.3	19.9	21.2	28.1	26.0	27.5	29.2	24.1
17	27.5	25.3	23.1	21.6	43.2	36.6	37.0	44.8	32.1
18	34.1	50.9	41.0	41.2	56.9	57.4	56.2	64.6	48.1
ALL	21.9	21.1	20.4	20.7	22.3	21.3	20.2	21.3	21.0

Table 3-2. Mean Absolute Errors in Declination

I \ J =	1	2	3	4	5	6	7	8	ALL
1	13.8	41.4	49.0	19.5	15.0	19.7	26.8	17.7	24.1
2	28.5	31.3	36.8	24.7	26.9	27.5	28.1	25.2	28.7
3	26.2	31.7	32.4	30.4	29.1	31.6	27.0	27.5	28.9
4	24.1	33.3	33.6	34.4	26.6	26.7	27.4	23.8	27.7
5	29.4	28.9	33.2	30.9	27.6	30.1	26.9	24.2	28.7
6	30.9	27.3	31.9	32.3	33.1	29.5	23.4	31.2	26.7
7	30.8	28.5	26.6	29.5	29.9	34.3	23.3	32.1	26.3
8	28.7	31.4	26.6	28.6	30.2	34.3	28.3	31.3	29.6
9	26.1	27.3	28.5	25.9	28.7	30.3	25.6	29.8	27.7
10	21.7	24.5	23.4	23.0	21.4	24.4	25.6	19.7	23.4
11	21.0	22.5	22.2	21.5	22.5	24.5	24.2	21.9	22.7
12	21.1	22.9	23.2	21.9	22.6	25.1	23.0	20.2	22.8
13	19.6	23.1	24.0	22.0	21.7	25.5	24.0	21.2	23.3
14	21.2	20.4	21.8	21.2	21.8	24.1	25.0	20.2	22.2
15	20.0	21.7	21.7	20.3	22.5	24.0	26.3	20.9	22.1
16	19.8	22.0	21.1	20.3	23.1	23.8	25.1	22.8	22.2
17	18.2	21.4	20.4	22.2	20.9	26.6	29.7	23.0	22.9
18	21.8	20.1	25.3	22.6	18.5	39.0	40.6	20.7	25.8
ALL	25.3	26.9	25.7	24.1	24.8	27.5	29.4	25.3	25.7

Table 3-3. Standard Deviations in the Absolute Error in Right Ascension

I \ J =	1	2	3	4	5	6	7	8	ALL
1	33.5	35.1	38.2	24.6	28.4	40.9	32.1	38.9	36.2
2	30.5	28.0	31.3	28.0	23.6	25.0	25.2	24.3	27.7
3	24.6	23.1	22.4	19.5	21.1	21.6	20.7	19.0	21.7
4	22.6	22.5	20.1	20.7	21.4	18.9	19.1	20.8	21.0
5	20.5	21.4	19.9	19.1	16.3	18.8	18.8	18.8	19.6
6	19.1	16.6	17.6	17.0	18.7	18.8	17.9	18.0	17.9
7	19.1	17.3	17.6	19.5	18.8	19.5	17.5	18.8	18.3
8	16.6	18.1	17.7	17.8	18.6	17.9	17.5	20.6	18.0
9	18.0	18.2	20.0	17.7	20.8	21.0	18.6	17.9	19.2
10	19.8	18.4	19.7	19.0	17.2	19.4	17.8	16.6	18.6
11	17.8	17.4	17.2	18.3	17.6	16.7	17.8	15.9	17.4
12	17.7	16.9	17.5	17.5	17.2	17.0	17.3	18.9	17.5
13	17.9	17.4	18.9	17.7	18.4	18.1	16.1	16.2	17.9
14	19.0	18.3	17.8	19.1	17.0	19.5	18.2	17.7	18.4
15	20.0	19.2	18.7	18.7	20.8	19.2	18.9	19.4	19.3
16	17.8	18.3	18.2	19.6	24.0	23.1	25.6	23.9	22.0
17	23.5	25.6	25.0	18.8	32.5	33.3	31.0	31.5	24.3
18	33.6	27.7	34.1	32.8	35.0	29.1	25.1	32.0	33.0
ALL	20.9	19.6	19.3	19.3	21.1	20.3	19.2	20.2	19.9

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Table 3-4. Standard Deviations in the Absolute Error in Declination

I = \ J =	1	2	3	4	5	6	7	8	ALL
1	12.9	16.8	13.7	7.8	9.9	14.0	19.7	8.7	17.5
2	25.7	23.2	26.4	17.1	23.1	23.2	20.8	21.3	23.2
3	21.2	27.0	26.3	26.5	23.2	25.2	22.4	22.9	24.1
4	19.4	26.6	27.5	26.3	22.5	22.3	21.3	19.8	22.9
5	23.1	22.2	24.1	23.8	21.7	26.4	21.7	19.5	22.6
6	24.2	21.2	24.3	24.7	23.5	23.3	17.8	24.0	22.5
7	23.2	22.0	21.0	23.9	23.3	26.1	17.6	24.7	22.3
8	22.1	24.4	21.1	22.5	22.8	25.1	23.7	23.9	23.3
9	20.7	21.5	20.8	20.1	21.6	21.6	19.3	24.8	21.2
10	16.1	19.0	16.8	17.0	16.0	18.8	18.8	15.5	17.6
11	15.4	16.2	16.2	15.6	16.7	17.8	17.3	15.9	16.5
12	15.6	18.4	17.7	16.3	17.1	18.2	17.0	15.7	17.3
13	14.7	17.3	17.0	16.5	16.0	18.5	17.7	15.1	17.1
14	15.3	14.9	16.2	15.1	16.2	17.7	17.2	13.5	16.1
15	14.4	15.7	15.0	14.0	16.0	16.9	18.3	14.4	15.6
16	13.8	14.8	15.2	14.7	15.5	17.9	19.3	14.7	15.9
17	13.3	15.0	15.3	13.4	15.7	19.4	20.8	14.7	16.6
18	15.8	18.0	18.6	16.0	15.2	23.7	29.6	14.1	20.8
ALL	20.4	21.3	19.9	18.8	19.1	21.0	19.6	20.4	20.1

differs notably from zero, and that the mean absolute error could be reduced by correcting the HD positions in a systematic way. In fact, as noted below, the mean (systematic) error in right ascension was 44 arc-seconds for this region.

Table 3-5 presents the number of data points (stars) in each region of the sky. Because some regions have relatively few stars, statistical imprecision cannot be ignored. To obtain more insight into which variations in the mean absolute errors were statistically significant, the z-scores of the means (i.e., the number of standard deviations from the whole sky mean) were computed from the following formula:

$$Z_{ij} = (\mu_{ij} - \mu)/(\sigma^*_{ij}) \qquad (3\text{-}2)$$

where Z_{ij} = the z-score for the region (I, J)

μ_{ij} = the mean for the region (I, J)

μ = the whole-sky mean (21.0 arc-seconds for right ascension and 25.7 arc-seconds for declination), and

σ^*_{ij} = the standard deviation in the mean for region (I, J) as computed from Equation 3-3:

$$\sigma^*_{ij} = \sigma_{ij}/\sqrt{N_{ij}} \qquad (3\text{-}3)$$

where σ_{ij} = the standard deviation of the data from the mean for region (I, J), and

N_{ij} = the number of data points in region (I, J).

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Table 3-5. Number of Data Points in Each Region in the Sky

J = / I =	1	2	3	4	5	6	7	8	ALL
1	11.0	17.0	9.0	7.0	20.0	11.0	24.0	32.0	131.0
2	132.0	118.0	104.0	72.0	73.0	88.0	103.0	152.0	842.0
3	282.0	220.0	137.0	126.0	123.0	153.0	197.0	368.0	1606.0
4	488.0	310.0	245.0	162.0	148.0	160.0	372.0	520.0	2405.0
5	501.0	526.0	351.0	190.0	154.0	223.0	626.0	617.0	3188.0
6	381.0	518.0	415.0	199.0	192.0	257.0	764.0	435.0	3161.0
7	294.0	478.0	424.0	214.0	215.0	253.0	701.0	346.0	2925.0
8	250.0	559.0	659.0	243.0	249.0	372.0	734.0	288.0	3354.0
9	242.0	522.0	748.0	254.0	224.0	325.0	558.0	287.0	3160.0
10	238.0	529.0	715.0	276.0	244.0	278.0	459.0	282.0	3021.0
11	202.0	352.0	685.0	317.0	266.0	350.0	532.0	265.0	2969.0
12	211.0	259.0	664.0	285.0	274.0	445.0	413.0	267.0	2817.0
13	198.0	280.0	739.0	358.0	362.0	655.0	442.0	218.0	3293.0
14	156.0	188.0	427.0	311.0	285.0	380.0	240.0	180.0	2173.0
15	136.0	174.0	468.0	673.0	405.0	447.0	236.0	196.0	2735.0
16	164.0	157.0	266.0	510.0	448.0	304.0	228.0	168.0	2245.0
17	87.0	83.0	123.0	160.0	138.0	128.0	112.0	86.0	917.0
18	19.0	17.0	12.0	26.0	11.0	13.0	11.0	11.0	120.0
ALL	3992.0	5306.0	7191.0	4423.0	3832.0	4842.0	6758.0	4718.0	41062.0

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The z-scores for absolute error in right ascension are presented in Figure 3-1 and the same scores for absolute error in declination are shown in Figure 3-2. Lines are drawn around those parts of the sky where the z-score exceeds +3 (solid lines) or is less than -3 (dashed lines).

The analysis of covariance, which is a rigorous statistical test (see Reference 5) was applied to the data to answer the following questions:

- Is there any significant variation in the mean absolute errors as a function of right ascension within the declination areas?
- Is there any significant variation as a function of declination within the right ascension areas?

The F-ratio statistic showed significant variations within each right ascension region for the absolute mean errors in both right ascension and declination. The results showed significant variation within declination regions for only one region of right ascension for the mean absolute error in right ascension, and for only two regions for the mean absolute error in declination. It can be concluded that the mean absolute errors in both right ascension and declination can be adequately represented as a function of declination alone.

Table 3-6 is a convenient summary of these results and is adapted from the data presented in Tables 3-1 and 3-2.

Table 3-6 shows that the mean absolute error in right ascension is constant at a value of about 20 arc-seconds for stars with declinations between +60 and -60 degrees. The table also shows that for other declinations, the mean error increases approximately as the function:

$$\bar{\epsilon}_{|\Delta\alpha|} = -109.6 - 4.64\ |\delta_{SAO}| + 0.04\ |\delta_{SAO}|^2 \qquad (3\text{-}4)$$

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I \ J	1	2	3	4	5	6	7	8
1	-3.1	3.9	5.1	-2.1	-4.8	-1.4	0.3	-5.2
2	1.3	2.7	4.3	-0.5	0.4	0.7	1.2	-0.3
3	0.4	3.3	3.0	2.0	1.6	2.9	0.8	1.5
4	-1.8	5.1	4.5	4.2	0.5	0.6	1.5	-2.2
5	3.6	3.3	5.8	3.0	1.1	5.9	1.5	-1.8
6	4.2	1.7	4.9	3.8	4.4	2.6	-3.5	4.9
7	3.8	2.8	0.9	2.4	2.7	5.3	-3.6	4.9
8	2.2	5.5	1.1	2.2	3.2	6.7	3.0	4.0
9	0.3	1.7	3.7	0.2	2.1	3.8	-0.0	2.8
10	-3.8	-1.4	-3.6	-2.6	-4.1	-1.1	-0.1	-6.4
11	-4.3	-3.7	-5.6	-4.7	-3.0	-1.2	-2.0	-3.9
12	-4.2	-2.4	-3.5	-3.9	-2.9	-0.7	-3.2	-5.7
13	-5.8	-2.5	-2.6	-4.4	-4.7	-0.2	-2.0	-4.4
14	-3.6	-4.8	-4.9	-5.2	-4.0	-1.8	-0.6	-5.4
15	-4.6	-3.4	-5.7	-9.9	-4.0	-2.1	0.5	-4.7
16	-5.4	-3.1	-4.9	-8.2	-3.5	-1.8	-0.4	-2.6
17	-5.2	-2.6	-3.8	-3.3	-3.5	0.6	2.1	-1.7
18	-1.1	-1.3	-0.1	-1.0	-1.6	2.0	2.3	-1.2

Figure 3-2. Z-Scores for the Mean Absolute Error in Declination

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Table 3-6. Mean Absolute Errors as a Function of Declination

DECLINATION REGION (DEGREES)	MEAN ABSOLUTE ERROR IN RIGHT ASCENSION (ARC SECONDS)	MEAN ABSOLUTE ERROR IN DECLINATION (ARC SECONDS)
+90 TO +80	48	24
+80 TO +70	31	29
+70 TO +60	24	29
+60 TO +50	22	28
+50 TO +40	21	29
+40 TO +30	19	29
+30 TO +20	19	28
+20 TO +10	20	30
+10 TO 0	21	28
0 TO -10	20	23
-10 TO -20	19	23
-20 TO -30	18	23
-30 TO -40	19	23
-40 TO -50	20	22
-50 TO -60	21	22
-60 TO -70	24	22
-70 TO -80	32	23
-80 TO -90	48	26
WHOLE SKY	21	26

where δ_{SAO} is the declination in degrees, and $\bar{\epsilon}_{|\Delta\alpha|}$ is the mean absolute error in right ascension in arc-seconds.

The mean absolute error in declination can be represented as a constant (29 arc-seconds) for stars with positive declinations, and another constant (23 arc-seconds) for stars with negative declinations.

3.2 SYSTEMATIC POSITION ERRORS AS A FUNCTION OF POSITION IN THE SKY

The quantities Δ_α and Δ_δ from Equations (2-1) and (2-2) are the (signed) errors in the right ascension and declination, respectively. When averaged over the regions of the sky defined above, they represent systematic errors in the star positions. These systematic errors can be corrected, thereby reducing the total error in position.

Tables 3-7 and 3-8 present the mean error in right ascension and declination as a function of region of the sky. J and I define the regions as in Equation (3-1). The format of the tables is the same as that of Table 3-1.

Since some regions had very few stars (see Table 3-5), a z-score was computed to specify where deviations from zero systematic error were statistically significant:

$$z_{ij} = u_{ij}/\sigma^*_{ij} \tag{3-5}$$

where z_{ij} = the z-score for the region (I, J)

u_{ij} = the mean error for the region (I, J), and,

σ^*_{ij} = the standard deviation in the mean error for region (I, J), as defined in Equation (3-6):

$$\sigma^*_{ij} = \sigma_{ij}/\sqrt{N_{ij}} \tag{3-6}$$

Table 3-7. Mean Errors in Right Ascension

J =	1	2	3	4	5	6	7	8	ALL
I =									
1	-40.8	-17.0	33.1	43.8	9.9	-53.5	22.5	19.2	4.8
2	7.0	8.0	-6.3	-4.6	-3.7	5.0	-2.1	-7.4	-0.3
3	-1.1	-4.2	-1.5	1.3	-3.4	-1.1	2.2	0.0	-0.9
4	-0.1	2.0	-0.1	0.1	0.6	-0.2	-1.9	-1.8	-0.4
5	1.4	-0.5	2.3	0.5	0.4	-1.1	1.0	1.2	0.8
6	-0.7	-2.1	-2.6	-0.4	-2.8	-4.1	-0.1	-0.6	-1.4
7	2.2	-2.1	-2.7	2.8	2.0	-0.8	0.4	2.0	0.1
8	0.7	3.9	4.0	-0.7	-2.2	-3.2	-2.7	2.8	0.6
9	-1.3	3.9	9.6	-2.6	2.8	0.4	3.2	1.6	3.6
10	3.4	-0.9	3.4	6.0	-3.1	4.5	4.8	-4.9	1.9
11	-2.0	-8.4	-4.8	0.2	-2.2	0.1	1.5	1.3	-2.0
12	-0.5	0.5	2.7	-1.3	3.3	3.8	6.1	-1.2	2.2
13	-1.0	-0.3	-4.1	-3.6	-2.9	1.4	1.0	1.1	-1.3
14	1.4	2.5	-0.1	3.4	1.7	1.5	3.2	-1.1	1.5
15	-0.9	0.9	0.8	0.9	1.4	0.4	-4.1	-4.7	-0.1
16	2.6	-2.6	1.2	-1.1	-4.1	-3.0	7.7	5.2	-0.2
17	6.1	10.4	-4.1	3.5	16.4	15.0	-18.0	-16.7	2.4
18	-15.8	-29.4	27.1	14.7	-27.6	-8.0	8.6	23.1	-1.3
ALL	0.5	-0.1	0.9	0.4	-0.2	0.5	0.9	-0.3	0.4

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Table 3-8. Mean Errors in Declination

J = / I =	1	2	3	4	5	6	7	8	ALL
1	11.0	41.4	49.0	6.3	-0.7	18.7	22.4	1.8	10.1
2	9.5	18.9	17.0	-1.8	1.8	5.6	10.4	-3.7	7.4
3	6.1	15.3	20.3	11.3	-6.2	4.9	-1.1	0.1	5.7
4	3.6	14.9	15.7	-1.3	7.3	-5.9	-2.3	-2.8	3.2
5	0.6	7.5	5.3	0.1	-5.2	-5.2	-0.6	-5.2	0.2
6	-3.6	6.1	3.9	-1.8	-6.1	-5.1	-2.6	-2.6	-0.8
7	-3.8	-1.2	2.5	-4.3	-4.9	-11.9	-4.3	-9.8	-4.1
8	-5.5	8.0	6.0	-1.5	-10.2	-16.8	-10.1	-10.7	-3.8
9	2.0	3.3	7.4	1.3	-2.8	-10.5	-8.3	-6.3	-0.8
10	1.2	6.7	3.8	2.1	-7.1	-10.7	-13.9	-4.6	-1.8
11	-2.8	1.3	2.9	0.2	-11.3	-13.8	-13.8	-8.4	-5.2
12	5.1	4.3	6.1	-0.8	-11.1	-12.2	-11.1	-0.8	-2.6
13	5.1	9.0	7.3	-2.0	-7.1	-14.9	-13.6	-5.0	-3.4
14	8.3	4.4	6.0	0.7	-7.3	-12.9	-16.0	-2.0	-3.0
15	7.1	3.6	4.0	-1.0	-11.8	-13.0	-18.9	1.1	-4.6
16	7.8	5.0	0.2	-5.6	-13.8	-15.4	-18.9	0.9	-7.0
17	3.3	-4.3	-0.8	-2.9	-14.6	-20.7	-26.2	-3.1	-5.3
18	5.5	-6.4	-16.0	-6.8	-14.5	-39.0	-40.5	-10.6	-13.9
ALL	1.9	6.2	5.7	-1.1	-8.2	-11.6	-8.5	-4.2	-2.1

where σ_{ij} = the standard deviation of the data from the mean for region (I, J), and

N_{ij} = the number of data points in region (I, J).

Figures 3-3 and 3-4 present the z-scores for the mean errors in right ascension and declination, respectively. Again, solid and dashed lines enclose the regions which deviate more than three standard deviations from zero-mean error in the positive and negative directions, respectively.

An analysis of convariance on the errors in right ascension showed no significant deviations from a mean error of zero as a function of either right ascension or declination. Furthermore, an inspection of Figure 3-3 shows no large scale positive or negative features. It can be concluded that there are no significant systematic errors in right ascension.

The analysis of covariance on the errors in declination revealed significant deviations from a mean error of zero as a function of right ascension for each declination region, and as a function of declination for each right ascension region. Additional analysis of covariance statistics were obtained for selected groups of regions in an attempt to isolate areas of the sky where the mean error in declination was constant to within statistical precision. However, only very small areas could be found.

Therefore, the individual values given in Table 3-8 have been adopted as the best values for the systematic error in declination.

3.3 ABSOLUTE POSITION ERRORS AS A FUNCTION OF VISUAL MAGNITUDE

All stars in the study were divided into five groups based upon visual magnitude defined in the following tabulation:

Group Number	Visual Magnitude	Number in Group
1	Less than 5.0	1,568
2	5.0 to 6.0	3,468
3	6.0 to 7.0	10,465

J =	1	2	3	4	5	6	7	8
I =								
1	-2.7	-1.0	1.8	2.2	1.0	-4.0	2.0	2.1
2	1.7	2.0	-1.4	-0.8	-0.9	1.3	-0.6	-2.7
3	-0.5	-1.8	-0.5	0.5	-1.3	-0.4	1.0	0.0
4	-0.1	1.1	-0.1	0.1	0.2	-0.1	-1.3	-1.4
5	1.0	-0.4	1.5	0.2	0.2	-0.6	0.9	1.0
6	-0.5	-1.9	-2.0	-0.2	-1.5	-2.4	-0.1	-0.5
7	1.3	-1.8	-2.2	1.4	1.1	-0.5	0.4	1.3
8	0.4	3.4	4.1	-0.4	-1.3	-2.3	-2.8	1.6
9	-0.8	3.3	9.1	-1.6	1.3	0.2	2.8	1.0
10	1.8	-0.7	3.2	3.6	-1.9	2.7	4.0	-3.4
11	-1.1	-6.1	-5.0	0.2	-1.4	0.1	1.4	0.8
12	-0.3	0.3	2.8	-0.9	2.2	3.3	5.2	-0.7
13	-0.5	-0.2	-4.1	-2.9	-2.0	1.4	0.9	0.7
14	0.6	1.2	-0.1	2.1	1.2	1.0	1.9	-0.6
15	-0.4	0.4	0.6	0.8	0.9	0.3	-2.3	-2.3
16	1.3	-1.2	0.7	-0.8	-2.4	-1.5	3.2	1.8
17	1.6	2.7	-1.3	1.5	3.7	3.6	-4.2	-3.0
18	-1.5	-2.4	2.0	1.5	-1.5	-0.5	0.5	1.1

Figure 3-3. Z-Scores for the Mean Error in Right Ascension

J = / I =	1	2	3	4	5	6	7	8
1	2.4	10.1	10.8	1.1	-0.2	4.1	4.5	0.5
2	2.9	6.0	4.1	-0.5	0.4	1.5	3.1	-1.4
3	3.1	5.9	6.5	3.3	-1.9	1.5	-0.4	0.1
4	2.6	6.6	6.1	-0.4	2.6	-2.2	-1.3	-2.1
5	0.4	4.8	2.5	0.0	-1.8	-1.8	-0.4	-4.2
6	-1.8	4.1	2.0	-0.6	-2.1	-2.2	-2.5	-1.4
7	-1.7	-0.7	1.5	-1.7	-1.9	-4.6	-3.9	-4.6
8	-2.4	4.8	4.6	-0.6	-4.4	-8.3	-7.7	-4.8
9	0.9	2.2	5.9	0.6	-1.2	-5.3	-6.3	-2.8
10	0.7	5.1	3.5	1.2	-4.3	-6.2	-10.4	-3.2
11	-1.5	0.9	2.8	0.1	-7.2	-9.6	-12.1	-5.3
12	2.9	2.4	5.5	-0.5	-7.1	-9.0	-8.6	-0.5
13	3.0	5.5	6.9	-1.5	-5.2	-13.7	-10.7	-2.9
14	4.2	2.4	4.7	0.1	-4.7	-9.3	-9.8	-1.1
15	3.5	1.8	3.3	-1.7	-9.5	-11.1	-11.2	0.6
16	4.4	2.4	0.1	-5.2	-12.0	-10.5	-11.2	0.4
17	1.4	-1.5	-0.4	-1.4	-7.9	-9.1	-11.1	-1.0
18	0.9	-1.0	-2.1	-1.3	-2.5	-5.9	-5.2	-1.6

Figure 3-4. Z-Scores for the Mean Error in Declination

Group Number	Visual Magnitude	Number in Group
4	7.0 to 8.0	19,033
5	8.0 to 9.0*	6,528

The mean absolute error in right ascension and declination was computed for each group. The results are presented in Table 3-9. Analyses of covariance performed on this data revealed that the mean absolute error in right ascension was constant to within statistical precision for stars of visual magnitude 5.0 and brighter. However, all groups differed significantly from one another in the mean absolute error in declination, except for groups 4 and 5.

3.4 POSITION ERRORS AS A FUNCTION OF VISUAL MAGNITUDE

No significant differences (at the 95 percent confidence level) were found between magnitude groups in either the mean error in right ascension or the mean error in declination.

*Most are between 8.0 and 8.3.

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Table 3-9. Mean Absolute Errors in Position as a Function of Visual Magnitude

MAGNITUDE	RIGHT ASCENSION MEAN ABSOLUTE ERROR (ARC SECONDS)	S.D.* (ARC SECONDS)	DECLINATION MEAN ABSOLUTE ERROR (ARC SECONDS)	S.D.* (ARC SECONDS)
LESS THAN 5.0	18.3	0.6	19.2	0.6
5.0 TO 6.0	20.2	0.5	22.1	0.5
6.0 TO 7.0	21.1	0.3	25.0	0.3
7.0 TO 8.0	21.3	0.2	26.9	0.2
8.0 TO 9.0	21.2	0.4	26.6	0.4
ALL STARS	21.0	0.14	25.7	0.16

*STANDARD DEVIATION IN THE MEAN

SECTION 4 - DISCUSSION

4.1 THE SIZE OF THE ERRORS IN POSITION

This subsection presents a summary of the results presented in Section 3. For stars appearing in the SAO, errors in position are less than 1 arc-second for most stars, and are always less than 3 arc-seconds.

For stars not appearing in the SAO, the precessed HD positions have positional uncertainties (as presented in Tables 3-1 and 3-2). These uncertainties are a function of declination, but not of right ascension, as noted in Table 3-6. The mean error in the absolute value of the right ascension can be taken as 20 arc-seconds for stars with declinations between +60 and -60 degrees, and is given by Equation (3-4) for stars with other declinations. The mean absolute error in declination is 29 arc-seconds for stars with positive declinations and 23 arc-seconds for stars with negative declinations.

A slight adjustment based on visual magnitude is made by subtracting 2.7 arc-seconds from the mean absolute error in right ascension for stars brighter than 5.0 magnitude. Similarly, the mean absolute error in declination is decreased by 6.5 arc-seconds for stars with magnitudes brighter than 5.0; by 3.6 arc-seconds for stars with visual magnitudes between 5.0 and 6.0; and is increased by 1.0 arc-seconds for stars dimmer than 7.0 magnitude.

Systematic errors in position were found only for the error in declination (see Table 3-8) and were usually of about 10 to 20 arc-seconds amplitude.

4.2 IMPROVING THE POSITIONS

HD declinations can be improved by subtracting the systematic errors (noted in Table 3-8) from the declinations of the individual stars. This should decrease the mean errors in declination to values of approximately the standard deviations given in Table 3-4.

An even greater improvement in SKYMAP positions can be realized by adopting the positions available in the Catalog der Astronomischen Gesellschaft-3 (AGK-3, Reference 6). The SAO catalog was compiled using positional data from various source catalogs, including the Catalog der Astronomischen Gesellschaft-2 (AGK-2, Reference 7), the predecessor of the AGK-3. The AGK-3 positions are slightly more accurate than those of the AGK-2; furthermore, a large number of additional stars, especially in the Southern Hemisphere, are included in the AGK-3.

It is not known at this time how many SKYMAP stars not in the SAO catalog are in the AGK-3. Using the AGK-3 positions, however, would decrease the number of stars for which HD positions (with their large attendant uncertainties) would have to be adopted.

4.3 A FUNDAMENTAL LIMIT TO THE ACCURACY OF HD POSITIONS

No amount of analysis will be able to reduce the HD positional uncertainties below those imposed by the round-off of the positions reported in the HD catalog. The HD gives declinations to the nearest arc-minute, resulting in a mean absolute error in declination of 15 arc-seconds. Because the mean absolute error noted in Table 3-2 is 25.7 arc-seconds, and because several arc-seconds of that may be due to precession model inaccuracies, proper motion, and errors in the SAO position, only a very limited reduction in the mean absolute error in declination can be achieved. Most (if not all) of that reduction will be achieved by subtracting the systematic error in declination reported in Section 3-2, leaving a mean absolute error of approximately 2- arc-seconds (see Table 3-4).

In right ascension, the situation is more complex. The HD reports right ascensions to 0.1 minute of time, which is equivalent to 90 cos δ (arc-seconds) where δ is the star declination.

The mean absolute error in right ascension, therefore, will always be at least 22.5 cos δ arc-seconds. Table 4-1 gives the mean absolute error in right ascension for each declination interval studied, including (for comparison) the minimum error as computed from the above formula.

For most of the stars in the study, the mean absolute error in right ascension is slightly below the lower limit imposed by round-off. We have no explanation for this phenomenon, except that, statistically, it is only marginally significant.

Significant reductions in the mean absolute error can theoretically be attained only for those stars with declinations north of +40 degrees or south of -40 degrees. Correlation of error in right ascension has not been found with any other variable; therefore, no action can be taken to reduce these errors at this time.

Table 4-1. Mean Absolute Error in Right Ascension and its Lower Limit

DECLINATION (DEGREES)	MEAN ABSOLUTE ERROR (ARC SECONDS)	LOWER LIMIT (ARC SECONDS)
+90 TO +80	48.0	2.8
+80 TO +70	31.0	6.6
+70 TO +60	23.6	10.7
+60 TO +50	22.2	13.5
+50 TO +40	21.1	15.3
+40 TO +30	19.3	18.6
+30 TO +20	19.2	20.6
+20 TO +10	19.8	21.7
0 TO +10	21.1	22.3
-10 TO 0	19.9	22.3
-20 TO -10	19.3	21.7
-30 TO -20	18.2	20.6
-40 TO -30	18.8	18.6
-50 TO -40	20.1	15.3
-60 TO -50	21.2	13.5
-70 TO -60	24.1	10.7
-80 TO -70	32.1	6.6
-90 TO -80	48.1	2.8

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REFERENCES

1. Computer Sciences Corporation, SD-76/6041, SKYMAP System Description: Star Catalog Data Base Generation and Utilization, D. M. Gottlieb and C. M. Gray, November 1976

2. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV, Washington, D.C.: Smithsonian Institute, 1971

3. A. J. Cannon and E. C. Pickering, Harvard Annals, vols. 91-99, Cambridge, Massachusetts: Harvard University, 1918-1924

4. Fricke, W. and Kopff, A., Fourth Fundamental Catalog, Veroffentlichungen des Astronomischen Rechen-Instituts Heidelberg, No. 10, 1963

5. Hays, William L., Statistics. New York: Holt, Rinehart, and Winston, 1973

6. Catalog der Astronomischen Gesellschaft - 3

7. Schorr, R. and A. Kohlschütter, Zweiter Katalog der Astronomischen Gesellschaft, fuer das Aequinoktium 1950, vols. 1-15, Hamburger Sternwarte and Universitaetssternwarte Bonn, 1951-1958

APPENDIX J - THE COMPLETENESS OF STAR CATALOGS

CSC/TM-77/6066

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THE COMPLETENESS OF STAR CATALOGS

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-11999
Task Assignment 82006

Prepared by:

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ABSTRACT

The completeness of two star catalogs which are the source of most SKYMAP stars has been studied by means of star counts. The projected completeness of the SKYMAP Star Catalog at various limiting magnitudes is inferred.

TABLE OF CONTENTS

SECTION 1 - INTRODUCTION

The SKYMAP Star Catalog (Reference 1) was compiled from several source catalogs, primarily the Henry Draper catalog (HD, Reference 2) and the Smithsonian Astrophysical Observatory catalog (SAO, Reference 3). To determine the projected completeness level of the 9.0-magnitude SKYMAP catalog now being compiled, the completeness of the HD and the SAO star catalogs by means of star counts was investigated. The technique is described in Section 2. The SKYMAP star catalog will be at least as complete as any one of the source catalogs.

The investigation discussed in Sections 2 and 3 shows that SKYMAP will be at least 93-percent complete at 8.0 visual magnitude, 77-percent complete at 9.0, and about 45- to 50-percent complete at 10.0 (if extended that far).

In terms of blue magnitude, it will be 100-percent complete at 8.0 blue magnitude, and at least 98-percent complete at 9.0 blue magnitude. If some of the stars missing from the HD catalog are in the SAO catalog, the completeness levels of the SKYMAP catalog will be higher than these minimum estimates.

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SECTION 2 - TECHNIQUES

2.1 DIRECT COMPARISONS

One method to check the completeness of a star catalog is to observe all stars within a certain range of magnitude in a certain region of the sky and then determine what fraction of these stars are in the catalog. Such a task would be formidable for the whole sky. For certain types of stars, a few regions of the sky have been extensively observed (References 4 and 5). These may be used to spot check the completeness level of the catalog. Unfortunately, the samples available for comparison using this method are so small that they are statistically insignificant.

2.2 STAR COUNT METHOD

Another method used to estimate completeness is the star count method. Assume that stars are uniformly distributed in space. Then the number of stars, $N(r)$, located within a distance, r , would be proportional to the cube of the distance

$$N(r) = cr^3 \tag{2-1}$$

where c is a proportionality constant.

The apparent magnitude, m , and the absolute magnitude, M , are related by the equation

$$m - M \equiv 5 \log r - 5 \tag{2-2}$$

which is equivalent to

$$r = 10^{0.2(m-M)+1} \tag{2-3}$$

Assuming that stars are distributed uniformly in an infinite space, and that all stars have the same intrinsic brightness (absolute magnitude), and combining Equations (2-1) and (2-3),

$$N(m) = c(10^{0.6m+K}) \tag{2-4}$$

or

$$\log N(m) = 0.6m + K' \tag{2-5}$$

where K and K' are empirical constants. The spatial distribution of stars is not uniform, and stars do not all have the same absolute magnitude, so the relationship described in Equation (2-5) is not always valid. However, there is empirical evidence (Reference 6) that the plot of $\log N(m)$ versus m does show a linear relationship for stars brighter than 10.0 magnitude, although the slope is smaller than 0.6.

Mihalas (Reference 4) quotes empirical results which yield a slope of approximately 0.47 for stars brighter than about 10th visual magnitude.

For both the HD and the SAO, the number of stars $N(m)$ over the whole sky within apparent magnitude intervals 0.1-magnitude wide was counted. Then $\log N(m)$ versus m was plotted. The range of apparent magnitude for which a linear function appeared on the plot defines the range of completeness of the catalogs. Section 3 describes these results in detail.

SECTION 3 - RESULTS

3.1 HENRY DRAPER CATALOG

Figure 3-1 is the plot of log N(m) versus m for the HD photovisual magnitudes. The equation of the line is $\log N = 0.50m + 0.715$. The linear relation extends to visual magnitude 7.2. It is concluded that the HD is complete to an approximate visual magnitude of 7.2.

Similarly, Figure 3-2 shows a linear relationship in the plot of HD photographic magnitudes to 8.7 magnitude. The equation of the line is $\log N = 0.48m + 0.618$.

By extrapolating the linear portion of the log N(m) versus m plots, the completeness level of the HD star catalog as a function of magnitude is computed. Tables 3-1 and 3-2 give the completeness level of the HD in terms of photovisual and photographic magnitudes, respectively.

3.2 SMITHSONIAN ASTROPHYSICAL OBSERVATORY CATALOG

Figure 3-3 is a log N(m) versus m plot for the SAO star catalog photovisual magnitudes, indicating completeness to 7.3 magnitude. The equation of the line is $\log N = 0.50m + 0.718$. Above 7.3 magnitude the plot is erratic due to the low quality of SAO magnitudes. Consequently, no reliable estimate of completeness can be made.

However, the procedure outlined for HD produced completeness estimates that are best described as upper limits to the true completeness. Table 3-3 presents these estimates. These figures indicate true completeness of the SAO not exceeding 85 percent at 8.0 magnitude, 70 percent at 9.0 magnitude, and 49 percent at 10.0 magnitude.

Because more than 49 percent of the stars in the SAO catalog do not have photographic magnitudes, no inference can be drawn about the SAO star catalog in terms of photographic magnitude.

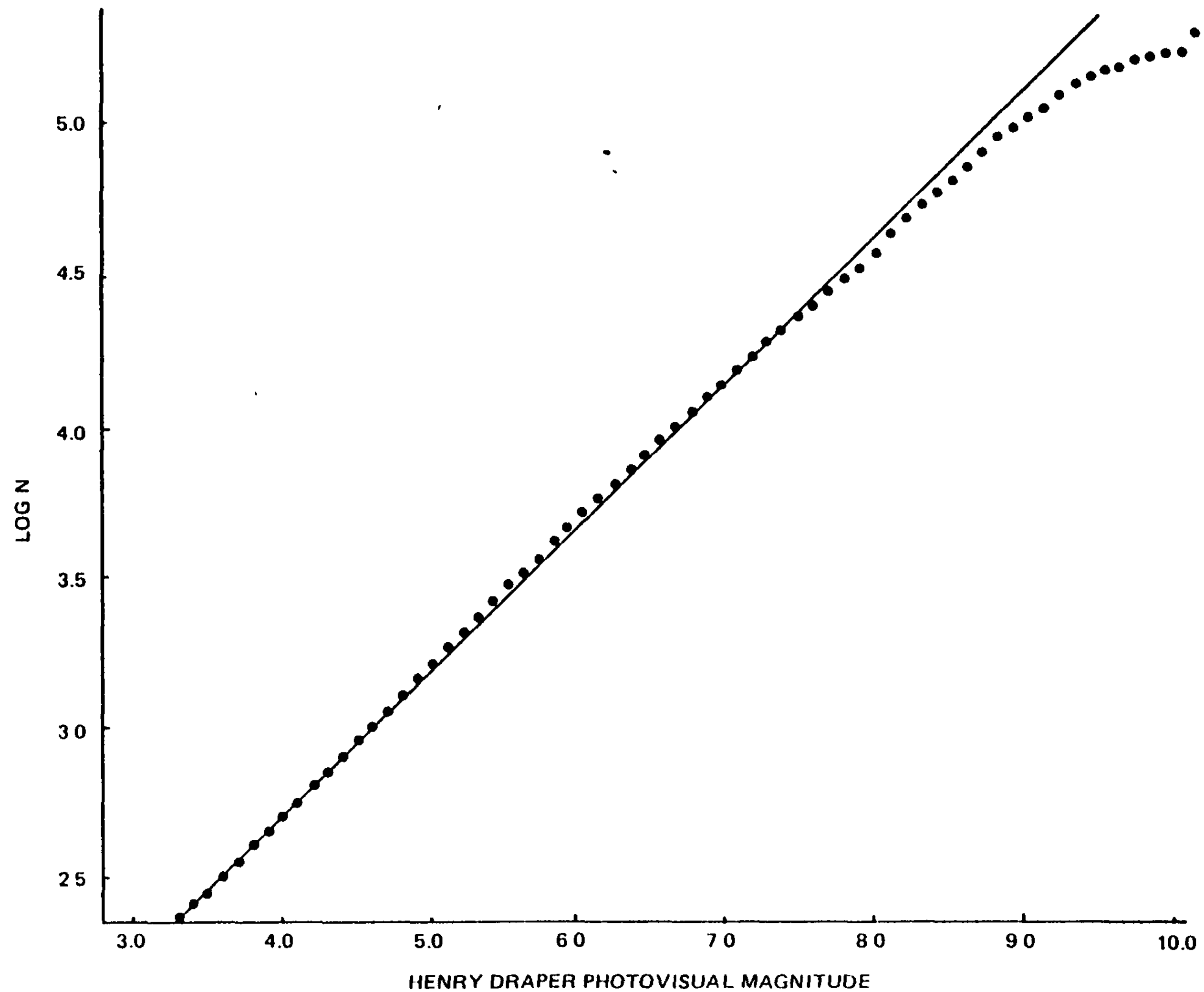

Figure 3-1. Plot of log N(m) Versus m for the HD Photovisual Magnitudes

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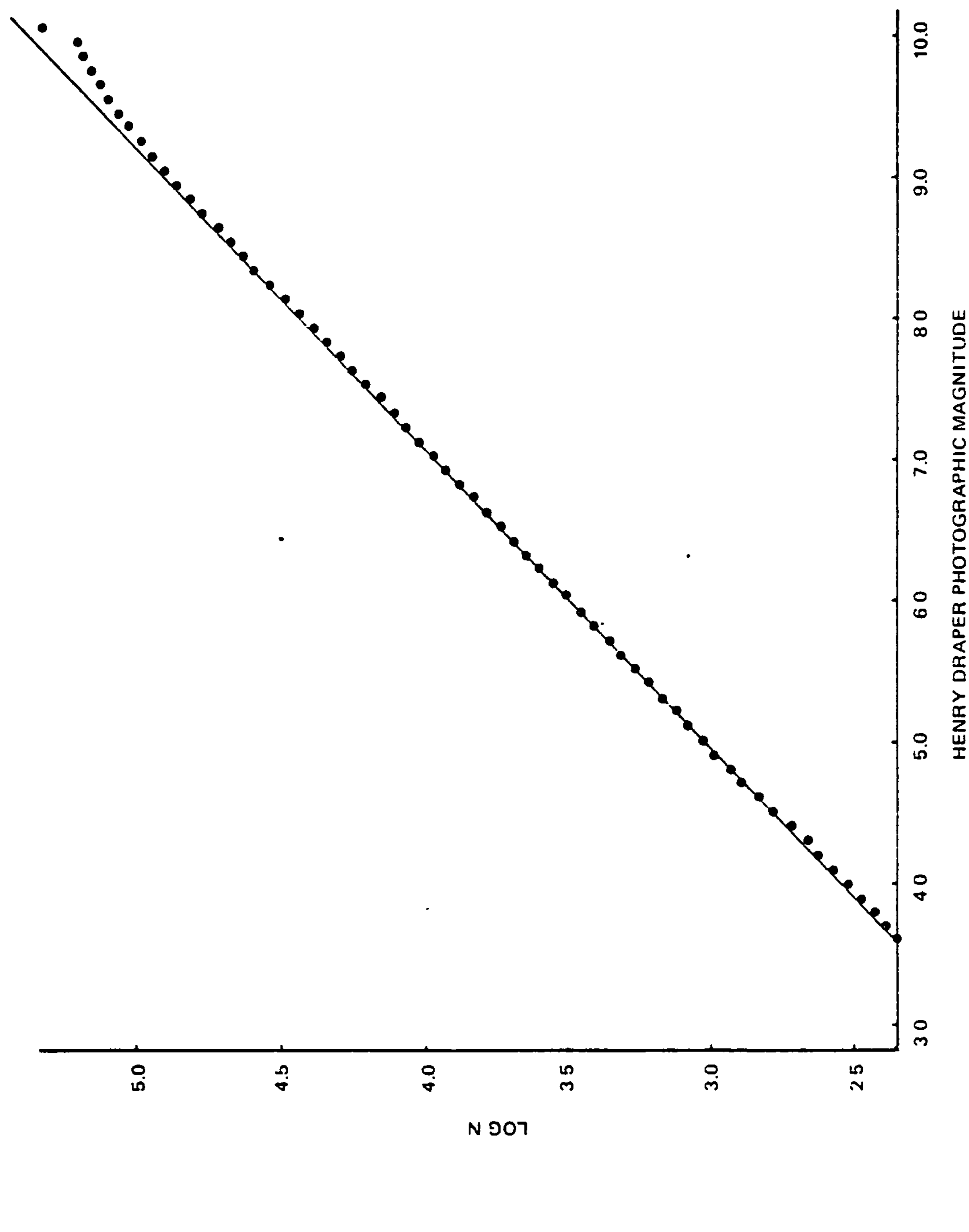

Figure 3-2. Plot of log N(m) Versus m for the HD Photographic Magnitudes

Table 3-1. Completeness Level of the HD Catalog in Terms of Photovisual Magnitudes

m	COMPLETENESS (IN PERCENT)
≤ 7.2	100.0
7.3	97.1
7.4	95.5
7.5	93.5
7.6	91.8
7.7	91.2
7.8	90.2
7.9	91.0
8.0	92.7
8.1	92.9
8.2	91.8
8.3	89.9
8.4	87.7
8.5	87.1
8.6	86.7
8.7	85.7
8.8	82.6
8.9	80.5
9.0	77.4
9.1	74.6
9.2	71.8
9.3	67.9
9.4	63.4
9.5	59.2
9.6	54.8
9.7	50.5
9.8	46.5
9.9	42.4

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Table 3-2. Completeness Level of the HD Catalog in Terms of Photographic Magnitudes

m	COMPLETENESS (IN PERCENT)
< 8.7	100.0
8.8	99.3
8.9	99.1
9.0	97.9
9.1	96.4
9.2	95.5
9.3	92.9
9.4	89.9
9.5	87.1
9.6	83.4
9.7	80.0
9.8	76.2
9.9	71.8

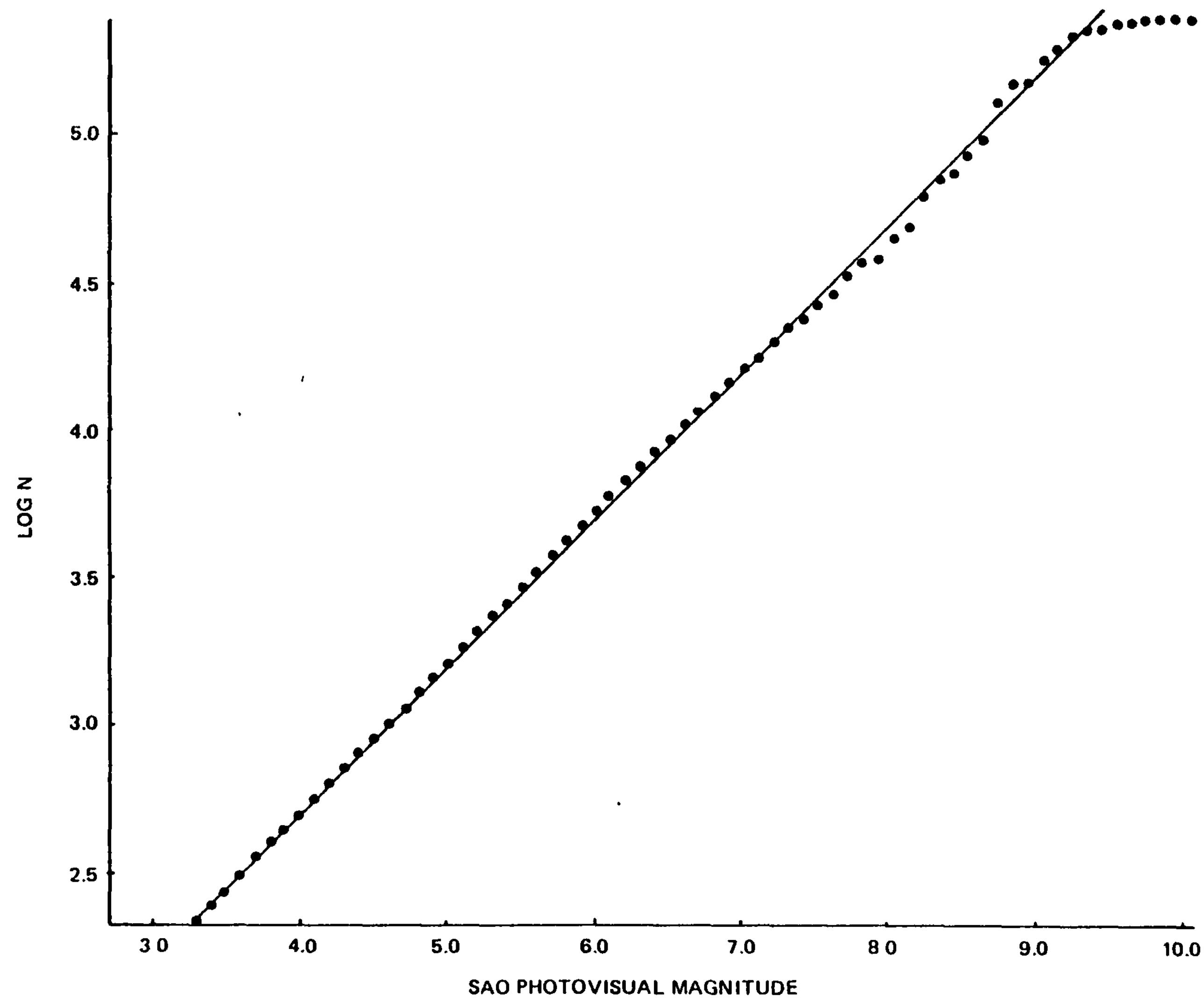

Figure 3-3. Plot of log N(m) Versus m for the SAO Photovisual Magnitudes

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Table 3-3. Upper Limit to the Completeness Level of the SAO Catalog in Terms of Photovisual Magnitudes

m	COMPLETENESS (IN PERCENT)
≤ 7.3	100.0
7.4	91.6
7.5	91.4
7.6	88.9
7.7	94.2
7.8	92.7
7.9	84.7
8.0	88.9
8.1	87.5
8.2	97.9
8.3	99.3
8.4	89.9
8.5	95.1
8.6	97.7
8.7	114.0
8.8	115.1
8.9	103.7
9.0	109.9
9.1	106.9
9.2	106.9
9.3	99.3
9.4	88.9
9.5	88.2
9.6	74.5
9.7	67.6
9.8	60.7
9.9	54.2
10.0	49.1

REFERENCES

1. Computer Sciences Corporation, CSC/SD-76/6041, SKYMAP System Description: Star Catalog Data Base Generation and Utilization, D. M. Gottlieb and C. M. Gray, 1976

2. A. J. Cannon and E. C. Pickering, Harvard Annals, 1918-1924, vols. 91-99, Cambridge, Massachusetts: Harvard University

3. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV, 1971, Smithsonian Institute, Washington, D.C.

4. J. J. Nassau and W. W. Morgan, Astrophysical Journal, 1952, vol. 115, pp. 475

5. A. Slettebak and R. V. Brundage, Astronomical Journal, 1971, vol. 76, pp. 338

6. D. Mihalas, Galactic Astronomy. San Francisco: W. H. Freeman and Company, 1968

APPENDIX K - SOURCE CATALOGS FOR SKYMAP DATA

CSC/TM-77/6118

SOURCE CATALOGS FOR SKYMAP DATA

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-11999
Task Assignment 82006

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ABSTRACT

This document describes the source catalogs from which SKYMAP data was compiled. The variables obtained from each catalog are enumerated. Several potential source catalogs not used in creating SKYMAP are also described, and reasons are presented for not using the data they contain.

TABLE OF CONTENTS

SECTION 1 - INTRODUCTION

SKYMAP (Reference 1) is a compendium of stellar data specifically designed for analysis of star sensor data for attitude determination. Most of the data in SKYMAP comes directly from 1 of 10 star catalogs. Each of these "source" star catalogs contains some, but not all, of the data needed for some of the stars included in SKYMAP. By combining the data of the source catalogs, a data base was formed from which the final SKYMAP catalog was generated.

This report describes each of the star catalogs considered for use as a source catalog for SKYMAP, regardless of whether the catalog was eventually used or not. Within each catalog description is a definition of data taken from that catalog and whether it was a primary or secondary source of that data. Included are explanations for the rejection of some catalog data. The most recently issued catalog is the primary data source unless an earlier issue was considered to be more accurate or more reliable. When this occurs, reasons are included for choosing the earlier catalog. Catalogs in this document are referred to by a short descriptive name. Table 1-1 gives the complete name of the catalog, the short name, and the reference number for each of the catalogs referred to.

FULL NAME	PRIMARY TYPE OF DATA	SHORT NAME	BIBLIOGRAPHY NUMBER
HENRY DRAPER CATALOG	SPECTRAL TYPES	HD	2
HENRY DRAPER EXTENSION	SPECTRAL TYPES	HDE	3
SMITHSONIAN ASTROPHYSICAL OBSERVATORY STAR CATALOG	POSITIONS	SAO	4
BONNER DURCHMUSTERUNG	POSITIONS	BD	5, 6
CORDOBA DURCHMUSTERUNG	POSITIONS	CD	7, 8
CAPE PHOTOGRAPHIC DURCHMUSTERUNG	POSITIONS	CPD	9
ASTRONOMISCHE GESELLSCHAFT KATALOG–3	POSITIONS	AGK–3	10
UNITED STATES NAVAL OBSERVATORY PHOTOMETRY CATALOG	PHOTOMETRY	BLANCO	11
STRASBOURG PHOTOMETRY CATALOG	PHOTOMETRY	MERMILLIOD	12
JASCHEK SPECTRAL TYPE CATALOG	SPECTRAL TYPES	JASCHEK	13
MICHIGAN SPECTRAL TYPE CATALOG	SPECTRAL TYPES	MICHIGAN	14
GENERAL CATALOG OF TRIGONOMETRIC STELLER PARALLAXES	PARALLAXES	JENKINS	15
CATALOG OF RADIAL VELOCITIES	RADIAL VELOCITIES	WILSON	16
EVANS RADIAL VELOCITY CATALOG	RADIAL VELOCITIES	EVANS	17
INDEX CATALOG TO VISUAL DOUBLE STARS	MULTIPLE STAR DATA	MULTIPLE STAR CATALOG	18
GENERAL CATALOG OF VARIABLE STARS	VARIABLE STAR DATA	KUKARKIN	19
CATALOG OF BRIGHT STARS	MANY	YBSC	20

Table 1-1. Catalogs Considered as Sources of SKYMAP Data

SECTION 2 - SOURCE CATALOG DESCRIPTIONS

2.1 HENRY DRAPER CATALOG

The Henry Draper Catalog (HD) is the primary source for star numbers and a secondary source for positions (behind the Smithsonian Astrophysical Observatory Catalog, SAO), spectral types (behind the Jascheck, Mermilliod, and Blanco catalogs), and magnitudes (behind the Mermilliod, Blanco, Jaschek, and Kukarkin catalogs). The Durchmusterung number (DM number) from the HD is also used by SKYMAP. Disagreements between DM numbers found in both the HD and SAO were resolved manually on a case-by-case basis.

2.2 HENRY DRAPER EXTENSION (HDE)

The HDE is an extension of the HD to dimmer stars for limited regions of the sky. The data taken from the HDE is the same as the data taken from the HD.

2.3 SMITHSONIAN ASTROPHYSICAL OBSERVATORY (SAO) STAR CATALOG

The SAO is the primary source of positions, position errors, and proper motions. Only the Astronomische Gesellschaft Katalog-3 (AGK-3) is newer than the SAO; it is not used because its reliability has not yet been verified. The SAO is a secondary source for spectral types (behind Jaschek, Mermilliod, Blanco, the HD, and the HDE catalogs), and for magnitudes (behind Mermilliod, Blanco, Jaschek, Kukarkin, the HD, and the HDE catalogs). Durchmusterung numbers for stars not in the HD come from the SAO. For stars in both the HD and SAO, DM numbers not identical in the two catalogs were resolved manually on a case-by-case basis.

2.4 BONNER DURCHMUSTERUNG (BD)/CORDOBA DURCHMUSTERUNG(CD)/ CAPE PHOTOGRAPHIC DURCHMUSTERUNG (CPD)

The BD/CD/CPD catalogs are old positional catalogs. Collectively, they cover the entire sky, and contain more stars than any of the other source catalogs. However, they are only incompletely available on magnetic tape; even those portions that are on tape are generally not quality-assured. The SAO and AGK-3 catalogs are compiled from these and similar catalogs, with appropriate data reduction procedures applied. Therefore, the BD/CD/CPD catalogs are not used as source material for SKYMAP.

2.5 ASTRONOMISCHE GESELLSCHAFT KATALOG-3

The AGK-3 is the most modern catalog of stellar positions for stars north of declination -2 degrees. Stars south of this declination are not contained in the AGK-3. Positions and proper motions available in the AGK-3 are probably the most accurate extant. However, the tape version of the catalog has not been quality-assured. Preliminary inspection indicates the existance of a small number of typographical errors. The difference in positions given in the AGK-3 and in the SAO (currently the primary source of positions) is under study at this time. Until the AGK-3 is sufficiently quality-assured, however, it will not be used as a source of SKYMAP data.

2.6 UNITED STATES NAVAL OBSERVATORY PHOTOMETRY CATALOG

Blanco is a secondary source of star magnitudes (behind Mermilliod). It is a compendium of most Ultraviolet-Blue-Visual photometry (UBV) done before 1967. Blanco also serves as a secondary source of spectral types (behind Jaschek and Mermilliod).

2.7 STRASBOURG PHOTOMETRY CATALOG

Mermilliod is a compendium of UBV photometry made available after the publication of Blanco and before 1975 (approximately). The intent of the issuers is to keep it current by the addition of new data as it becomes available to them. Mermilliod is the primary source of UBV photometry and a secondary source of spectral types (behind Jaschek).

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2.8 JASCHEK SPECTRAL TYPE CATALOG

Jaschek is a collection of spectral types reported prior to 1964. It is the primary source of spectral types, and a secondary source of UBV photometry (behind Mermilliod and Blanco).

2.9 MICHIGAN SPECTRAL TYPE CATALOG

A project at the University of Michigan to observe new spectral types for all HD stars is currently in progress, but only about one-fourth of the results are available. This catalog will eventually become the best source of spectral types. However, it is still only partially complete and has not been quality-assured. Therefore, it is not currently used as a source of SKYMAP data.

2.10 GENERAL CATALOG OF TRIGONOMETRIC STELLAR PARALLAXES

Jenskins is a compilation of stellar parallax data. Although it is about 25 years old, very little additional data has become available since its publication. It is this study's only source of trigonometric parallax and error in trigonometric parallax data.

2.11 CATALOG OF RADIAL VELOCITIES

Wilson is a compendium of radial velocities over 10 years old. It is not a source of SKYMAP data because a new catalog (Evans) is almost ready for use and because radial velocities are not a crucial parameter for attitude determination.

2.12 EVANS RADIAL VELOCITY CATALOG

Evans is available in printed form, but not on magnetic tape. It is recommended that the relevant portions of the catalog be card-punched and put on tape for inclusion in SKYMAP. However, at this time, it is not a source of SKYMAP data.

2.13 INDEX CATALOG TO VISUAL DOUBLE STARS

The Multiple Star Catalog is the most modern available collection of multiple star data, and is the only source of multiple star data for SKYMAP.

2.14 GENERAL CATALOG OF VARIABLE STARS

Kukarkin is the most modern available compilation of variable star data, and is the only source of variable star data for SKYMAP.

2.15 CATALOG OF BRIGHT STARS

The YBSC is a compendium of stellar data similar to SKYMAP but limited to the 9100 brightest stars in the sky (about 6.2 magnitude). It is used as a primary source for star names, which are assigned only to the brighter stars. All other data contained in the YBSC is available in one or more of the other source catalogs, and thus is not taken from the YBSC.

BIBLIOGRAPHY

1. Computer Sciences Corporation, CSC/SD-76/6041, SKYMAP System Description: Star Catalog Data Base Generation and Utilization, D. M. Gottlieb and C. M. Gray, November, 1976

2. Cannon, A. J., and E. C. Pickering, Harvard Annals, 1918-1924, vols. 91-100, Cambridge, Massachusetts: Harvard University

3. Cannon, A. J., and M. W. Mayall, Harvard Annals, 1949, vol. 112, Cambridge, Massachusetts: Harvard University

4. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV, 1971, Smithsonian Institute, Washington, D. C.

5. Argelander, F. W. A., "Bonner Sternverzeichness," Sections 1-3, Astron. Beob. Sternwarte Konigl. Rhein, vols. 3-5, Bonn: Freidrich-Wilhelms University, 1859-1862

6. Schonfeld, E., "Bonner Sternverzeichness," Section 4, Astron. Beob. Sternwarte Konigl. Rhein, vol. 8, Bonn: Friedrich-Wilhelms University, 1886

7. Thome, J. M., "Cordoba Durchmusterung," Parts I-IV, Resultados Obs. Nacional Argentina, vols. 16-19, 1892-1914

8. Perrine, C. C., "Cordoba Durchmusterung," Part V, Resultados Obs. Nacional Argentina, vol. 21, 1932

9. Gill, D., and J. C. Kapteyn, "Cape Photographic Durchmusterung," Parts I-III, Ann. Cape Obs., vols. 3-5, 1896-1900

10. Astronomische Gesellschaft Katalog-3, Clayton Smith, United States Naval Observatory (private communication), 1977

11. Blanco, V. M., S. Dermers, G. G. Douglass, and M. P. Fitzgerald, Publ. U.S. Naval Obs., 2nd series, vol. 21, 1968

12. Mermilliod, J., Bulletin D'Information du Centre de Donnees Stellaires de Strasbourg (unpublished letter), 1973

13. Jaschek, C., H. Conde, and A. C. de Sierra, Publ. La Plata Obs. Ser. Astron., vol. 28, 1964

BIBLIOGRAPHY (Cont'd)

14. Cowley, A. (private communication), 1976

15. Jenkins, L. F., General Catalog of Trigonometric Stellar Parallaxes. New Haven: Yale University Observatory, 1952

16. Wilson, R. E., General Catalog of Stellar Radial Velocities. Washington, D. C.: Carnegie Institute of Washington, 1953

17. Evans, D. (private communication), 1976

18. Index Catalog of Visual Double Stars, United States Naval Observatory magnetic tape (1974-75)

19. Kukarkin, B. V., P. P. Parnego, Yu. I. Efremov, and P. N. Kholopov, General Catalog of Variable Stars, second edition. Moscow: Publishing House of the *Academy of Sciences of the U. S. S. R.*, 1958

20. Hoffleit, D., Catalog of Bright Stars. New Haven, Connecticut: Yale University Observatory, 1964

APPENDIX L - A COMPARISON BETWEEN AGK-3 AND SMITHSONIAN ASTROPHYSICAL OBSERVATORY (SAO) STAR CATALOGS

A COMPARISON BETWEEN AGK-3 AND SMITHSONIAN ASTROPHYSICAL OBSERVATORY (SAO) STAR CATALOGS

Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

Contract NAS 5-11999
Task Assignment 82006

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Technical Area Manager

ABSTRACT

This document describes a comparison of star positions and proper motions between the Smithsonian Astrophysical Observatory (SAO) Star Catalog and the Dritter Katalog der Astronomischen Gesellschaft (AGK-3) Star Catalog. No evidence was found to dispute the accuracies in position and proper motion quoted in the two catalogs. A small fraction of stars showed large discrepancies in position or proper motion. The reasons for these apparent errors were investigated. Based on the results of this study, it is recommended that AGK-3 positions be substituted for Henry Draper positions in SKYMAP, but not for SAO positions. It is also recommended that approximately 2000 "new" stars found in the AGK-3 be included in SKYMAP.

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SECTION 1 - INTRODUCTION

SKYMAP (Reference 1) star positions and proper motions are obtained primarily from the Smithsonian Astrophysical Observatory (SAO) star catalog (Reference 2). However, about 25 percent of SKYMAP stars are not in the SAO catalog; for these stars, positions have been obtained from the Henry Draper (HD) catalog (Reference 3) and their proper motions have been defaulted to zero. The SAO positions are accurate to better than 1 arc-second, and the proper motions are accurate to about 1.5 arc-seconds per century. However, the HD positional accuracy is only about 35 arc-seconds. Because typical star camera accuracies are between 2 and 10 arc-seconds, the SAO positions and proper motions are adequate for the analysis of star camera data. The HD positions, however, have such large errors that catalog accuracy often limits the attainable attitude accuracy.

To resolve this problem, an attempt was made to improve the positions of those SKYMAP stars not having SAO positions by obtaining positional data from the new AGK-3 catalog (Reference 4). The AGK-3 is a recent (1974-1976) revision of the AGK-2 catalog (Reference 5), from which many SAO positions were taken. AGK-3 is reported to be more accurate than the SAO in both position and proper motion (Reference 6). Furthermore, the AGK-3 contains a number of stars not in the SAO catalog. However, this catalog has never been fully quality-assured. To determine the reliability and accuracy of the AGK-3, a study was made of the differences in position and proper motion for those stars listed in both the SAO and the AGK-3.

SECTION 2 - COMPARISON OF SAO AND AGK-3 CATALOGS

2.1 TECHNIQUE

Because the SAO does not contain AGK-3 numbers and the AGK-3 does not quote SAO numbers, stars in the two catalogs had to be identified with one another through their Durchmusterung (DM) numbers. Approximately 70 percent of AGK-3 stars were thereby identified with about 45 percent of SAO stars. For stars which could be identified in this manner, the difference in positions was formulated:

$$\Delta\delta = |\delta_{SAO} - \delta_{AGK-3}|$$
$$\Delta\alpha = |\alpha_{SAO} - \alpha_{AGK-3}| / \cos(\delta_{SAO}) \qquad (2-1)$$

where δ_{SAO} = declination in the SAO,
δ_{AGK-3} = declination in the AGK-3,
α_{SAO} = right ascension in the SAO, and
α_{AGK-3} = right ascension in the AGK-3.

The difference in proper motion was similarly computed. The results are presented in Tables 2-1 and 2-2.

2.2 ACCURACY OF STAR POSITIONS

The estimated error in SAO positions is typically 0.5 arc-second (Reference 2); for the AGK-3 it is 0.2 arc-second (Reference 6). Therefore, the distribution of $\Delta\delta$ and $\Delta\alpha$ as defined in Equation (2-1) should be a Gaussian with standard deviation

$$\sqrt{(0.5)^2 + (0.2)^2} \approx 0.55 \text{ arc-seconds} \qquad (2-2)$$

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Table 2-1. Distribution of Differences in SAO and AGK-3 Star Positions

DIFFERENCE IN POSITION	NUMBER OF STARS	
	RIGHT ASCENSION	DECLINATION
$\leq$ 0.5 ARC–SECONDS	91,708	108,226
0.5 – 1.0 ARC–SECONDS	32,934	18,788
1.0 – 1.5 ARC–SECONDS	2,951	1,863
1.5 – 2.0 ARC–SECONDS	1,344	262
2.0 – 2.5 ARC–SECONDS	174	73
2.5 – 3.0 ARC–SECONDS	111	48
3.0 – 3.5 ARC–SECONDS	69	43
3.5 – 4.0 ARC–SECONDS	37	27
4.0 – 4.5 ARC–SECONDS	46	35
> 4.5 ARC–SECONDS	1,532	1,541
TOTAL TESTED	130,906	130,906

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Table 2-2. Distribution of Differences in SAO and AGK-3 Proper Motions

DIFFERENCE IN PROPER MOTION		NUMBER OF STARS	
DEGREE/YEAR	ARC-SECONDS/100 YEARS	RIGHT ASCENSION	DECLINATION
< 0.00001	< 3.6	124,535	125,458
0.00001 – 0.00002	3.6 – 7.2	5,842	5,103
0.00002 – 0.00003	7.2 – 10.8	268	145
0.00003 – 0.00004	10.8 – 14.4	70	33
0.00004 – 0.00005	14.4 – 18.0	38	34
0.00005 – 0.00006	18.0 – 21.6	23	15
0.00006 – 0.00007	21.6 – 25.2	19	11
0.00007 – 0.00008	25.2 – 28.8	10	10
0.00008 – 0.00009	28.8 – 32.4	10	12
> 0.00009	> 32.4	91	85
TOTAL		130,906	130,906

The distribution presented in Table 2-1 is consistent with this result, except for a small fraction of stars having large errors. The large errors are relevant to a discussion of catalog reliability, but not to a study of accuracy. No evidence was found to dispute the quoted star position accuracies of the SAO and AGK-3 catalogs; neither can this study confirm the quoted accuracies, because the data on which the SAO and AGK-3 are based is not entirely independent (both catalogs depend partially on the AGK-2 catalog).

The large errors (> 4.5 arc-seconds) were further investigated by studying a random sample of 100 cases. In 63 percent of these cases, there was an apparent error in the DM number used to identify an SAO star with an AGK-3 star. The error could be in the AGK-3 or the SAO, but in either case it led to an erroneous identification, and therefore to a large position error. The remaining 37 percent of the differences are unexplained.

A summary of the percentage occurrence results from comparison of AGK-3 and SAO star positions is as follows: the difference consistent with quoted errors was 98 percent, the difference due to DM number error was 1.2 percent, and the difference greater than 4.5 arc-seconds and unexplained was 0.8 percent.

2.3 ACCURACY OF PROPER MOTIONS

The quoted error for proper motions in the SAO catalog is typically about 1.5 arc-seconds per 100 years (Reference 2); for the AGK-3 it is 0.8 arc-seconds per 100 years (Reference 6). Using an argument similar to the one employed for position errors, it is projected that the difference in proper motions would follow a Gaussian with standard deviation of about 1.7 arc-seconds.

The distribution presented in Table 2-2 is consistent with this result except for a very few large errors. No evidence was found to contradict the errors quoted in the SAO and AGK-3 catalog for proper motions. Once again, these error estimates cannot be verified because the data presented in the two catalogs are not totally independent.

A random sample of 100 proper motions errors greater than 32.4 arc-seconds per hundred years was investigated. Nineteen percent of these were found to be due to a mispunch in the most significant column of the AGK-3 catalog proper motion, leading to enormous proper motions. The others are unexplained, but could be the tail of the Gaussian distributions.

A summary of the percentage occurrence results from comparison of AGK-3 and SAO proper motions is as follows: the difference consistent with quoted errors was 99.8 percent, the difference due to AGK-3 mispunch was less than 0.1 percent, and the difference greater than 32.4 arc-seconds per 100 years and unexplained was 0.2 percent.

2.4 NEW STARS FOUND IN THE AGK-3 CATALOG

Of the 183,145 AKG-3 stars, 48,638 were found in neither the SAO or HD catalogs, or could not be cross-referenced to these catalogs due to DM number errors. A breakdown of this number by photographic magnitude includes 856 stars brighter than 9.0, 8,710 stars with magnitudes ranging from 9.0 to 10.0, and 39,072 stars dimmer than 10.0.

About 2000 of these start are brighter than the limiting magnitude of SKYMAP. Including them in SKYMAP would increase its completeness by between 1 and 2 percent at the 9.0-magnitude level.

SECTION 3 - CONCLUSIONS AND RECOMMENDATIONS

It is recommended that the AGK-3 positions and proper motions be substituted for those SKYMAP positions currently derived from HD data. The risk of large error is about 2 percent, but most of these "large" errors are still smaller than the current 35-arc-second uncertainties.

It is also recommended that the AGK-3 positions and proper motions not be substituted for those SKYMAP positions currently derived from SAO data. The current accuracy of SAO positions is sufficient for all applications currently projected. Substituting AGK-3 data would introduce about 2 percent large errors without counterbalancing benefit.

Finally, this study concludes that the AGK-3 stars not found in the SAO and the HD be added to SKYMAP. This will increase the completeness of SKYMAP by between 1 and 2 percent at 9.0 magnitude. Less than 1 percent of the stars so introduced will have position errors greater than 4.5 arc-seconds. Another 1 percent will have correct positions but incorrect DM numbers. This risk seems acceptable in the view of the additional completeness gained.

REFERENCES

1. Computer Sciences Corporation, CSC/SD-76/6041, SKYMAP System Description: Star Catalog Data Base Generation and Utilization, D. M. Gottlieb and, C. M. Gray, November 1976

2. Smithsonian Institute Staff, Smithsonian Astrophysical Observatory Star Catalog, Parts I-IV, Washington, D. C.: Smithsonian Institute, 1971

3. A. J. Cannon and E. C. Pickering, Harvard Annals, vols. 91-99, Cambridge, Massachusetts: Harvard University, 1918-1924

4. Dritter Katalog der Astronomischen Gessellschaft, Astronomisches Rechen Institut, Heidelberg, Germany, 1975

5. Schorr, R. and A. Kohlschutter, Zweiter Katalog der Astronomischen Gessellschaft, fuer das Aequinoktium 1950, vols. 1-15, Hamburger Sternwarte and Universitaetssternwarte Bonn, 1951-1958

6. Clayton Smith, United States Naval Observatory Staff, Private Communication, 1977