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MAGNETIC FIELD SATELLITE (MAGSAT) DATA PROCESSING SYSTEM SPECIFICATIONS

Prepared For

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
Goddard Space Flight Center
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Prepared for

GODDARD SPACE FLIGHT CENTER

By

COMPUTER SCIENCES CORPORATION

Under

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ABSTRACT

This document presents the software specifications for the MAGSAT data processing system (MDPS). The MDPS is divided functionally into preprocessing of primary input data, data management, chronicle processing, and postprocessing. Each of these is described in turn. Data organization and validity, and checks of spacecraft and instrumentation are discussed. Output products of the MDPS, including various plots and data tapes, are described. Formats for important tapes are presented in the appendices. Also included in the appendices are discussions and mathematical formulations for coordinate transformations and field model coefficients.

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SECTION 1 - INTRODUCTION

1.1 MISSION OBJECTIVES

The objectives of the Magnetic Field Satellite (MAGSAT) are

- To provide global vector magnetic field data to the United States Geological Survey (USGS) for use in the production of world-wide magnetic field charts for 1980.
- To provide magnetic field data for use in the location and analysis of large-scale magnetic anomalies on the Earth's crust so as to identify geological phenomena of importance in mineral research.
- To provide data to NASA/GSFC for updating mathematical models of the Earth's magnetic field.

1.2 INSTRUMENT ACCURACY SPECIFICATIONS

MAGSAT specifications call for a global survey of the three vector components of the Earth's magnetic field with each component determined to an accuracy of 6 gamma (γ) rms ($1\gamma = 10^{-5}$ gauss). Data will be acquired over a 4- to 8-month time period at the rate of 16 samples/second.

To achieve this accuracy, MAGSAT will use a highly accurate, ultra-stable, vector magnetometer with magnitude accuracy for each component better than 3γ rms and alignment stability better than 7 arc-seconds rms. A scalar magnetometer will also be flown for calibration and independent measurement of total field magnitude. Both the scalar and vector sensors will be mounted at the end of a 6-meter extendable boom to reduce spurious fields from the spacecraft electronics to less than 0.5γ (Reference 1).

1.3 DATA PROCESSING OBJECTIVES

The overall objective of the MAGSAT Data Processing System (MDPS) is to produce a series of data sets in a format useful to the principal investigators. These data sets will contain the magnetic field data (in gammas), computed from the raw magnetometer measurements (in counts). In addition, the data will be located in position and, in the case of vector data, also in orientation.

Secondary objectives include

- Generation of hardcopy and microfilm plots of the data.
- Generation of specialized investigator tapes that further reduce the amount of data and incorporate ancillary information.
- Generation of summary listings of processing statistics and data characteristics.
- Provision of a quicklook capability to process and display (on hardcopy plots) specialized early orbit data.

SECTION 2 - MAGSAT DATA PROCESSING SYSTEM SCOPE

2.1 MAGSAT DATA PROCESSING SYSTEM

The scope of the MAGSAT Data Processing System (MDPS) includes all processing from the receipt of orbit, attitude, and decom data tapes to the production of chronicle, investigator, and condensed orbit/attitude tapes, in addition to plots and printed processing statistics. This is illustrated in the top-level data flow diagram (Figure 2-1).

2.2 MDPS SPECIFICATIONS DOCUMENT

The MDPS specifications are conveniently divided into three parts: preprocessing, chronicle processing, and postprocessing. Preprocessing is discussed in Section 3, chronicle processing in Section 4, and postprocessing in Section 5. The data flow relationships among the three are shown in Figure 2-2. Tape formats and various related MDPS information are documented in Appendices A through N. A glossary is provided at the end of this document.

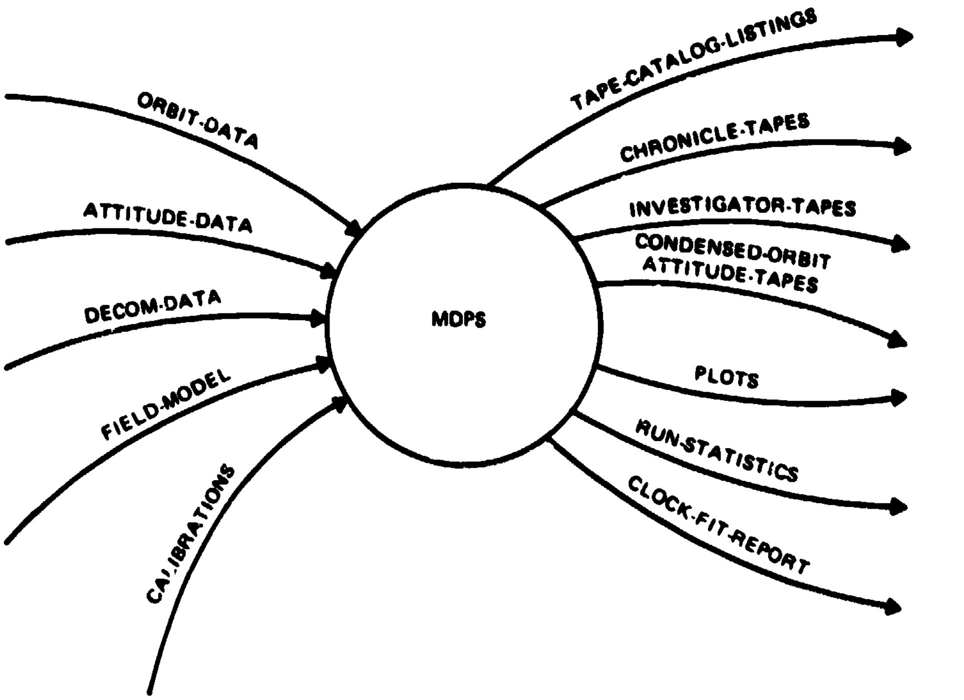

Figure 2-1 Top Level Data Flow Diagram

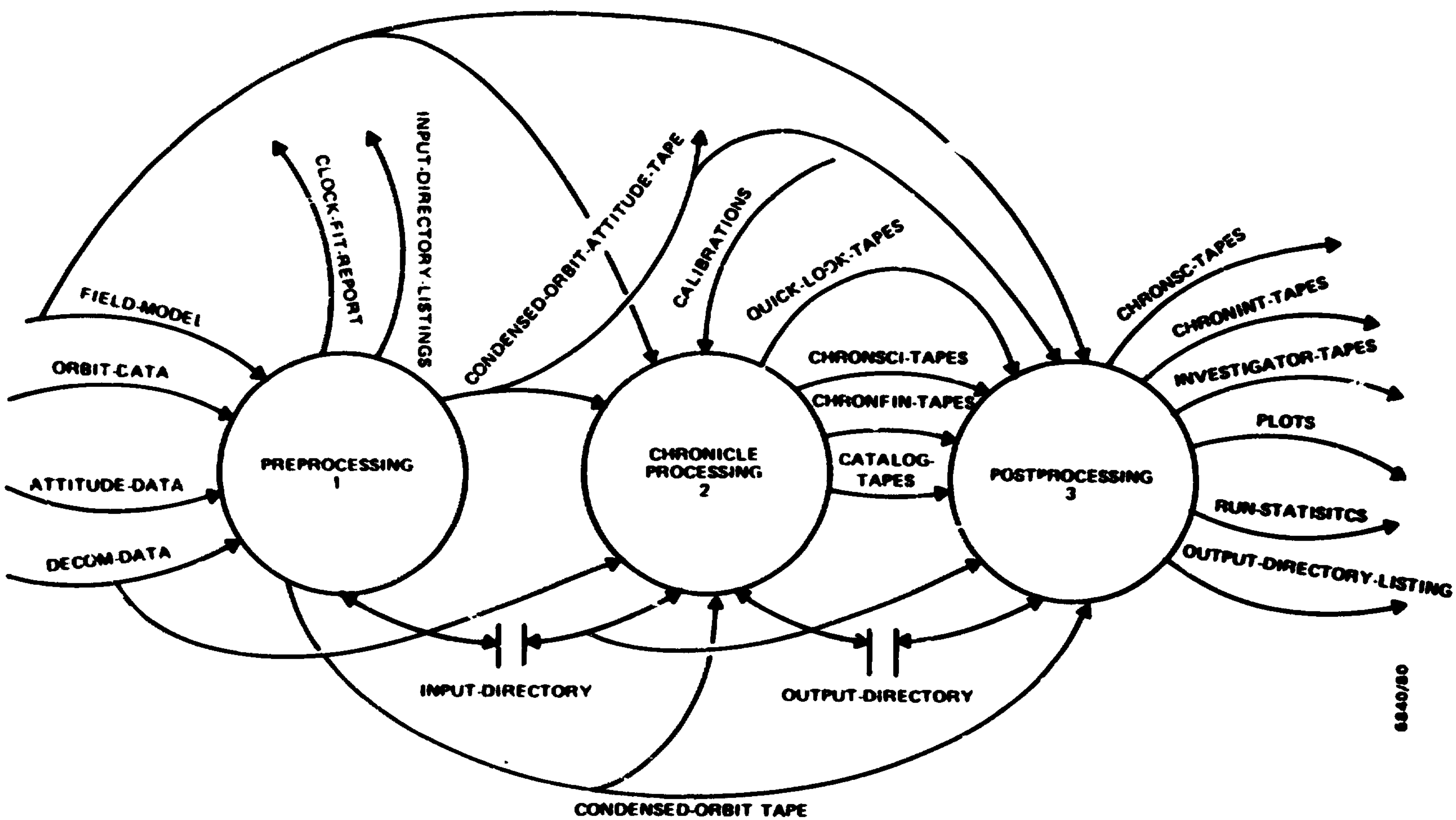

Figure 2-2 Second Level Data Flow Diagram

SECTION 3 - PREPROCESSING

Input preprocessing will perform all preliminary processing of the MDPS primary input data (decom, orbit, and attitude) in preparation for processing by the chronicle program (CRONICLE). This will include scanning the input tapes for errors and generating exception reports, compiling a catalog and listings of all input and output tapes handled by the preprocessing programs, creating a condensed orbit/attitude tape, and checking and preparing a report on the fit between clock coefficients. The data flow diagram for preprocessing appears in Figure 3-1. Requirements for each of the elements are discussed in the following sections.

3.1 DECOM PREPROCESSING

3.1.1 DECOM Data Organization

MAGSAT telemetry data received from the satellite tracking stations is decommutated and stored on DECOM tapes by GSFC's Information Processing Division (IPD).

A DECOM logical record is called a minor frame, which is a 960-bit subdivision of the telemetry (491.545 milliseconds of data per frame). Each minor frame contains eight readouts per component (A, B, and C) from the vector magnetometer and two readouts per side (A and B) from the scalar magnetometer; information on the status of various spacecraft functions; and two readouts from each axis of the major attitude systems; namely, the Sun sensors, the star cameras, and the attitude transfer system (see Figure 3-2).

The repetitive sampling cycles of the magnetometer and fine attitude systems are such that the effective time tags for the fine attitude observations are simultaneous with each other and with the effective time of every second scalar and every fourth vector magnetometer observation to within a a few milliseconds.

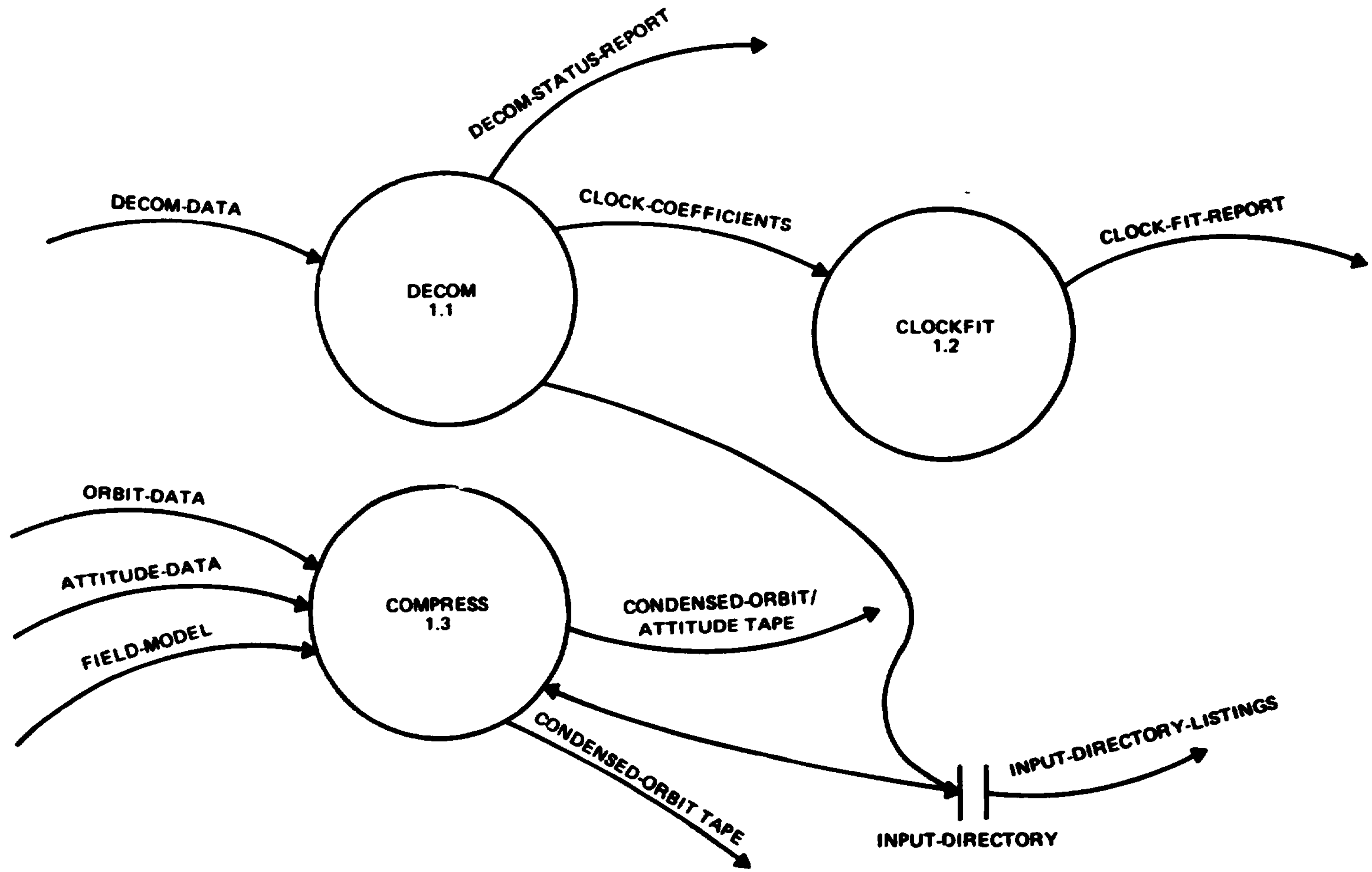

Figure 3-1 Preprocessing Data Flow Diagram

Bit	0	8	16	24	32
0	SYNC.	FMT. ID.*	PARITY		
40	FCTR *	VMAG. MSB A	VMAG. MSB B	VMAG. MSB C	ASCO
80	VMAG. LSB A	VMAG. LSB B	VMAG. LSB C	VMAG. LSB PAR	
120	SCALAR MAG 1	SCALAR MAG 2			
160	ATT. 0	ATS ROLL	ATS PITCH	ATS YAW	
200	VMAG. LSB A	VMAG. LSB B	VMAG. LSB C	VMAG. LSB PAR	
240	STAR CAMERA 1-A	STAR CAMERA 1-B	ATT 1		
280	STAR CAMERA 2-A	STAR CAMERA 2-B	ASC 1		
320	VMAG. LSB A	VMAG. LSB B	VMAG. LSB C	VMAG LSB PAR	
360	SUN SENSOR A	DSCO			
400	SUN SENSOR B	CMD 1	CMD 2		
440	VMAG. LSB A	VMAG LSB B	VMAG LSB C	VMAG LSB PAR	
480	GYRO 1	GYRO 2	TLM VFY		
520	TLM VFY	VMAG MSB A	VMAG MSB B	VMAG. MSB C	ASC 2
560	VMAG LSB A	VMAG. LSB B	VMAG. LSB C	VMAG. LSB PAR	
600	SCALAR MAG 1	SCALAR MAG 2			
640		ATS ROLL	ATS PITCH	ATS YAW	
680	VMAG. LSB A	VMAG LSB B	VMAG LSB C	VMAG LSB PAR	
720	STAR CAMERA 1-A	STAR CAMERA 1-B	SMAG HSKPG		
760	STAR CAMERA 2-A	STAR CAMERA 2-B	ASC 3		
800	VMAG. LSB A	VMAG LSB B	VMAG. LSB C	VMAG LSB PAR	
840	SUN SENSOR A	OSC 1			
880	SUN SENSOR B	XMAG.			
920	VMAG LSB A	VMAG. LSB B	VMAG. LSB C	VMAG LSB PAR	

*NOTE WHEN "FMT ID" = 0A, VMAG DATA ARE FROM VECTOR MAGNETOMETER A.
WHEN "FMT ID" = 0B, VMAG DATA ARE FROM VECTOR MAGNETOMETER B

Figure 3-2. Magsat Minor Frame of Telemetry Data (960 Bits)

A complete set of data relating the operating status of the spacecraft occurs every 16 minor frames and is called a digital subcommutator sequence. A complete set of analog readings indicating the scalar magnetometer operating status occurs every 32 minor frames and is called a scalar magnetometer (SMAG) sequence. A complete set of analog data indicating the vector magnetometer operating status occurs every 64 minor frames and is called a vector magnetometer (VMAG) sequence. Finally, a major frame is defined to be 256 minor frames (corresponding to approximately 2.1 minutes of data); this encompasses 16 digital, 8 SMAG, and 4 VMAG sequences.

A DECOM file consists of two title records followed by data records, with each data record corresponding to a minor frame. See Appendix A for the DECOM tape format and the time-tag of fields in the minor frame.

3.1.2 DECOM Preprocessing Specifications

Each DECOM tape (expected to contain about 1 day's data) received from IPD will be scanned to provide an initial assessment of the decom data. A report will be generated for examination to determine whether processing of particular files by the CRONICLE program is warranted. The report will contain distribution statistics related to the successful operation of the magnetometers. The report, provided on a major frame basis, will include

- Time reversals between minor frames
- Scalar and vector magnetometer status
- Heater and power status
- Star camera and Z-coil status
- Calibration status

A report listing all DECOM tapes received and their processing status will be generated once per month, and given to the Data Manager.

If no fatal errors (I/O error, invalid satellite ID, time reversal) are encountered in processing the DECOM file, a verification of the spacecraft clock coefficients provided on the DECOM title record will be performed. These coefficients are used to compute the universal time (UT) by fitting the spacecraft clock data to a polynomial. The coefficients will be archived on magnetic tape; each record will contain the UT and spacecraft clock start/stop values for the fit, and one set of coefficients. For non-identical sets of coefficients where there is an overlap in the spacecraft clock values, each fit is evaluated using a clock value in the overlap region. If the two agree within a tolerance of 6 milliseconds, processing will proceed. If the difference exceeds the tolerance, processing will halt and project management will be notified.

If the coefficients are not identical and there is no overlap in the spacecraft clock values, the fits will be extrapolated to a common point and checked as above.

A report on time coefficient quality will be furnished to the Data Manager once per month. See Appendix B for the clock coefficient tape format.

3.2 ORBIT/ATTITUDE PREPROCESSING

3.2.1 Orbit Data Organization

Estimates of MAGSAT position and velocity are supplied by the Johns Hopkins University Applied Physics Laboratory (APL) at 1-minute intervals on the minute for the life of the mission. One week's worth of orbit data will be stored on a 9-track, 1600-bpi tape using the GSFC standard EPHEM tape format with omission of selected fields. (See Appendix C for the EPHEM tape format.) The position estimates (X, Y, Z) will be in a geocentric inertial coordinate system referenced to the true-of-date equator, with X directed toward the vernal equinox, Y normal to X and in the plane of the equator, and Z normal to the X,Y plane so as to form a right-handed system. This system will be referred to as the celestial coordinate system.

The Greenwich Hour Angle (GHA) is provided on each EPHEM tape for an epoch which coincides with the orbit data start-time. The GHA is later used in the coordinate rotations from inertial or celestial coordinates to Earth-fixed coordinates. (See Appendix K.)

A copy of each EPHEM tape will be made and delivered to the MAGSAT Data Manager or to a GSFC location designated by him. A report listing all EPHEM tapes received and their processing status will be prepared and delivered to the Data Manager once per month.

3.2.2 Attitude Data Organization

MAGSAT attitude estimates are computed by the Mission Support Computing and Analysis Division (MSC&AD) and forwarded by IPD on 9-track, 1600-bpi tapes. Estimates will be in the form of Euler symmetric parameters expressed as quaternions and will be used to transform vector magnetometer measurements from the coordinate system of the vector instrument to the celestial coordinate system. Appendix D contains the attitude tape format.

Data will be stored in 12-hour files starting at either 0Z or 12Z, and may contain overlap into each adjacent file by as much as 5 minutes. Attitude results will be computed by MSC&AD using one of three different modes: quicklook, intermediate, or fine.

Quicklook results will be essentially the same as intermediate except that the operational GSFC orbit rather than the definitive APL orbit will be used in the computation.

Intermediate results will be computed using data from the infrared horizon scanner and the two coarse Sun sensors with the definitive orbit, but will not make use of the attitude transfer system (ATS) which relates movements of the boom on which the magnetometers are located to the spacecraft body. Fine results are computed using data from the two star cameras, the fine Sun sensor, and the ATS with the definitive orbit.

Each data record contains 128 sets of attitude results with the frequency of attitude determination differing between intermediate attitude and fine attitude determination. Intermediate attitude is output at a frequency of approximately once per 2 seconds to approximately once per 32 seconds (the time increment will be a power of 2) and is synchronized with the minor frame rate and, hence, the magnetometer readings. The optimal frequency of attitude determination for intermediate attitude cannot be determined until the dynamic characteristics of the spacecraft are known (the initial value is once every 4 minor frames or about once every 2 seconds).

The fine attitude determination is output at a frequency of from twice per minor frame or about once every 246 milliseconds (nominal, assuming a telemetry minor frame duration of 492 milliseconds) to once per 64 minor frames (about once per 32 seconds), the time increment being a power of 2. The output frequency will be twice per minor frame, i.e. once every 246 milliseconds unless a different frequency is agreed upon by MSC&AD and the Project Scientist. The frequency of attitude results within a 12-hour file will not vary either for intermediate or fine attitude. If it is not possible to compute attitude at any given time within a data record, the quaternion components that transform from the vector magnetometer to celestial coordinates will contain the values -9.999 (Reference 2). A report listing all attitude tapes received and their processing status will be prepared and delivered to the Data Manager once per month.

Post-launch specifications include the following:

- A modification to work around an error on the fine attitude tapes. The end time of a file in the header record is always incorrect. An approximate time calculated from another word in the header will be used instead.

- An investigation of the GSFC-supplied B & L package to calculate the invariant latitude. The old OGO-F package will be used as a check (Reference 3).

3.2.3 Condensed Orbit/Attitude Tapes

Orbit data for the entire mission will be stored in condensed form on a single 9-track, 6250-bpi, condensed orbit (CORB) tape. EPHEM records, which contain 50 sets of position estimates, will be condensed to generate orbit records containing 128 sets of position estimates. On the CORB tape, the entire mission is divided into 128-minute records with the start time of any record being displaced from the time of the first ephemeris data for the mission by a multiple of 128 minutes.

The CORB tape shall also contain the satellite position in the so-called dipole or geomagnetic coordinate system. This system is based on the centered dipole which most nearly approximates the main field. The north geomagnetic pole has a geographic co-latitude, θ_o, of 11.4° and a geographic east longitude, λ_o, of 290.24°. The geomagnetic co-latitude, Θ, and east longitude, ϕ, are given by

$$\cos\Theta = \cos\theta\cos\theta_o + \sin\theta\sin\theta_o\cos(\lambda-\lambda_o)$$

$$\sin\phi = \sin\theta\sin(\lambda-\lambda_o)/\sin\Theta$$

where θ and λ are the geographic co-latitude and east longitude, respectively.

The geomagnetic local time (MLT) is also provided. MLT is defined relative to the dipole coordinate system. Geomagnetic noon at a location, P, occurs when the sub-solar point is on the geomagnetic meridian of P, and the MLT for P is defined (in degrees) as $180° + \phi_p - \phi_s$, where ϕ_p and ϕ_s are the geomagnetic longitudes of P and of the sub-solar point, respectively.

Also, a parameter called the invariant latitude, Λ, will be supplied. By definition, $\Lambda = \cos^{-1} (1/L^{1/2})$ where L is the McIlwain magnetic shell parameter. For a rigorous definition, the reader should refer to McIlwain's paper (Reference 4). A non-mathematical definition is that L is the distance in the geomagnetic equatorial plane (in Earth radii) to the field line in an appropriate model having its intercept with the Earth's surface at Λ.

Attitude data will be merged with the condensed orbit data to form a condensed orbit/attitude (CO/A) tape. CO/A orbit records will be identical to CORB records, and will contain 128 position estimates at 1-minute intervals. CO/A attitude records will contain a maximum of 240 attitude estimates and span between 1 and 128 minutes, approximately, depending upon the frequency of attitude determination. If attitude data is not available at any given time within the record, the quaternion components will contain the value -9.999. The general organization of the CO/A tape will consist of sets of 128 minutes worth of orbit data followed by condensed attitude records covering the same time span. Attitude data is condensed only for those time intervals for which there is orbit data. This requires time-tagging each set of quaternions and verifying that they fall within the previous condensed orbit record's time span. It should be noted that there may be orbit data for which there is no corresponding attitude data. Appendix E gives the format of the condensed orbit and orbit/attitude tapes.

On both the CORB and CO/A tapes, the GHA (t) from the EPHEM tape is rotated to the appropriate GHA (o) for an epoch at $0^h0^m0^s$ UTC of the EPHEM epoch day. An Earth rotation rate of 6.3003881 radians/day is used.

A catalog of all created condensed orbit and condensed orbit/attitude tapes will be maintained. A list of these tapes will be made available to the Project Scientist and Data Manager once each week.

3.3 PREPROCESSING DATA MANAGEMENT

In order to allow for easy access to the status of data processing, an input directory will be constructed. This will be a disk data set containing identification and quality information for all external (DECOM, EPHEM, and attitude) and internal (CORB, CO/A, and clock) tapes processed by MDPS.

Entries containing pertinent details (such as volume serial and file numbers, and data time span and quality) will be made by the preprocessing software and will be accessed and updated by the CRONICLE program.

The organization of the input directory and the formats of the input directory records are described in Appendix F.

DECOM and attitude records are linked within the directory by tape type and start day (in terms of days since launch), while all other entries are linked by tape type only. This means that each decom and attitude entry contains the record number of the next entry made in the input directory for that tape type and day, while all other entries contain the record number of the next entry made in the directory for that tape type.

Interface software will be designed to access entries in the input directory by volume, tape type, or time interval and type. This allows MDPS users to access the correct input tapes by specifying a processing time interval and tape type.

A backup of the input directory will be created on tape every 2 weeks. In this 2-week period, records for each entry inserted, updated, or deleted are kept on a temporary disk directory. If the input directory is destroyed for some reason, it can be restored by merging the backup on tape with the temporary directory.

SECTION 4 - CHRONICLE PROCESSING

4.1 INTRODUCTION

The CRONICLE program will process MAGSAT telemetry (decom) data and store scalar and vector magnetometer measurements on tape for subsequent use by the scientific community. The program will access data records from a decom tape, perform basic input/output and data validity tests, verify time continuity and consistency throughout the transmission, and establish the operating status of the spacecraft's magnetometers. Based on these preliminary tests, quality checks will be performed on the magnetometer data with erroneous data being rejected and flagged in diagnostic printouts. Data that is not rejected will be converted to gammas, transformed to the North-East-Vertical (NEV) coordinate system, and archived on data tapes and catalogs. A data flowchart for the CRONICLE program is presented in Figure 4-1.

4.2 PRELIMINARY DECOM DATA QUALITY VERIFICATION

Decom data checks will be divided into several categories, as follows:

- Performing selected data validity checks.
- Verifying that the telemetry transmission is continuous in time.
- Verifying the consistency of the spacecraft clock with the universal time clock (UTC).
- Checking that the magnetometers are working within specified operating limits.

Each of these functions is addressed in the following sections.

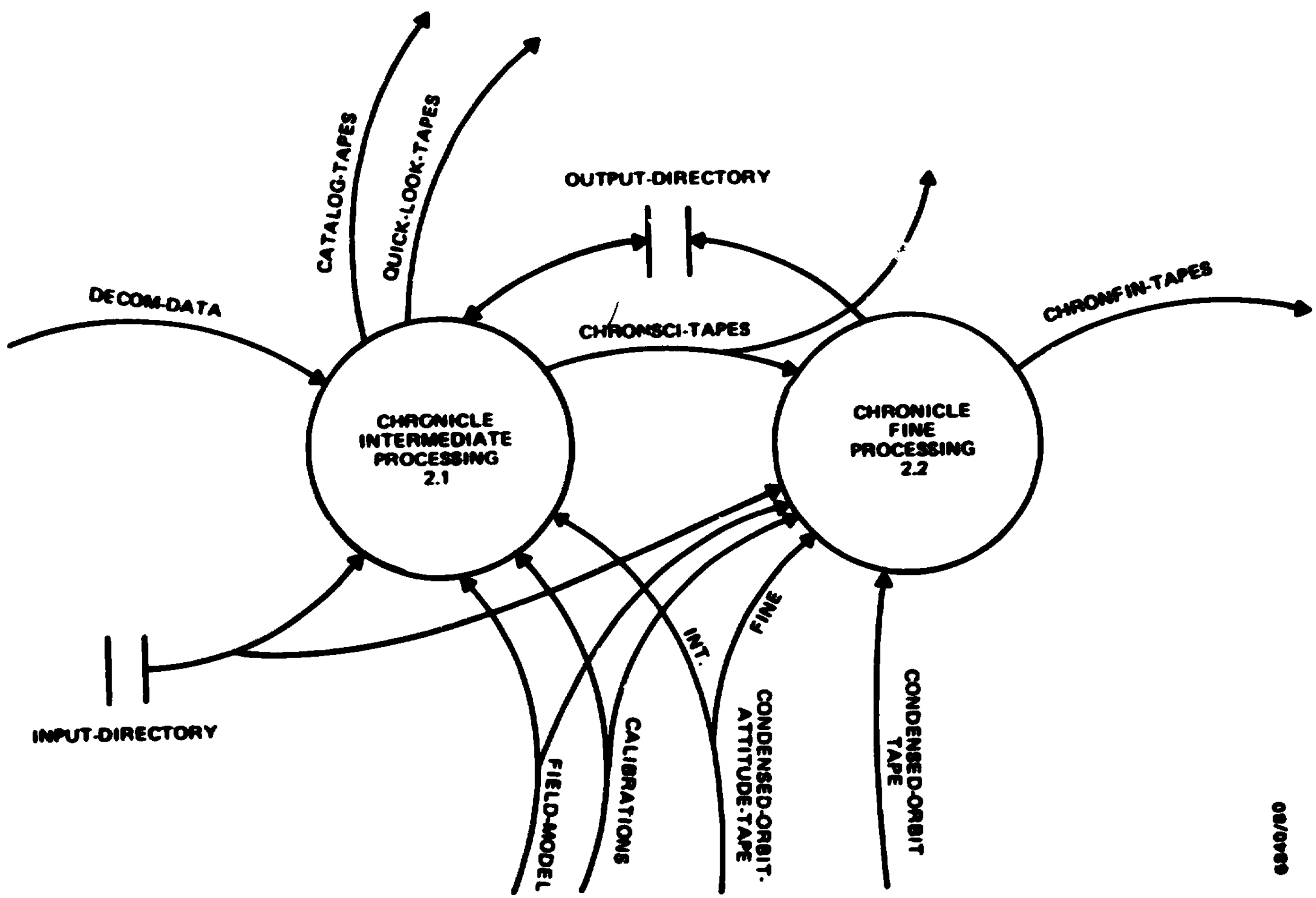

Figure 4-1 Chronicle Data Flow Diagram

4.2.1 DECOM Input/Output (I/O) and Data Validity Checks

The DECOM tape is made up of files which consist of two title records followed by data records. The title records will be read and pertinent file constants checked for validity and compatibility with the user-specified program options. The international code, data type, and experiment ID will be tested for pre-established values; the tape serial number and file start/stop times will be checked for agreement with those specified on card input.

4.2.2 DECOM Time Continuity Checks

Frame time updates will be checked for agreement with the frame time duration (stored in the DECOM file header records) to within a 2-millisecond tolerance. Time backups within a DECOM file, jumps greater than 5 hours, or jumps inconsistent with the telemetry data rate (jumps which are not multiples of the frame time duration) will cause processing to be terminated for that file.

4.2.3 DECOM Time-Consistency Checks

The spacecraft clock, which is used to compute UT, is defined for each minor frame by concatenating the minor frame counter (byte 19 of the data record on the DECOM tape--see Appendix A) with the major frame counter (located in the first three frames of the digital subcommutator sequence--see Section 3.1.1). If the major frame counter is not available in an SMAG sequence, due to data gaps, the entire sequence is padded.

The UT value associated with the frame will be computed from a polynomial derived from the spacecraft clock time coefficients found in the DECOM file title record. This computed time will be checked for agreement with the frame time within a user-specified tolerance (the default value is 2 milliseconds). Data will be rejected if frame times are not within tolerance.

4.2.4 Scalar Magnetometer Data Quality Checks

The following is a list of data checks which will provide summary information concerning scalar data quality:

- The commanded accumulation time for sides A and B will be checked and noted in output summaries when a change from the previous values is detected. In the event of a change, processing was to be terminated for the DECOM file unless the program was run in quicklook mode.

  (Post launch note: However, due to bit errors encountered in telemetry, which occasionally indicated that the commanded accumulation time has changed, when in fact it has not changed for the entire mission, file processing is not terminated. Instead, telemetry data associated with non-standard commanded accumulation times is skipped and processing continues.)

- The tracking filter lock for sides A and B will be checked. If it is not in lock status, data will be rejected on option and noted in output summaries.

- The lamp brightness status for sides A and B will be checked. If both sides are bad, data will be rejected on option and noted in output summaries.

- The signal amplitude status and range for sides A and B will be checked. If both are bad or out of range, data will be rejected on option and noted in output summaries.

4.2.5 Scalar Magnetometer Power Checks

The following checks on spacecraft equipment power status will be made:

- Sensor power (A and B) will be checked. Data will be rejected when both are off.

- Power converter status for each side will be checked. Data will be rejected when both are on or off.
- Lamp status will be checked and data rejected if off for both sides.
- Cell photocurrents A1/A2 and B1/B2 will be checked and noted in output summaries if either pair is out of range.
- Heater status for sides A and B and for the sensor base-plate will be checked for the purpose of computing heater duty cycles.

4.2.6 Scalar Magnetometer Temperature Checks

The following temperature measurements of key spacecraft equipment will be checked:

- Cell temperatures (A1/A2 and B1/B2) will be checked and noted in output summaries if either pair is out of range.
- Lamp temperatures for sides A and B will be checked and noted in output summaries if out of range.

4.2.7 Scalar Parity and Data Quality Checks

Before converting the scalar measurements to gammas, the scalar parity and data quality will be checked. The rightmost 2 bits of the 20-bit raw count scalar measurements will be used as data quality and parity flags, respectively. The parity flag (bit 20) should be set so that the total number of bits set to 1 in each 20-bit word is odd. Otherwise, the data point will be rejected. If the data quality flag (bit 19) is set to 1, the tracking filter is in unlock status or the lamp brightness or signal amplitude have dropped below predetermined thresholds, in which case the data point will be rejected.

4.2.8 Vector Magnetometer Power Checks

The following checks on the spacecraft equipment power status will be made:

- VMAG power will be checked and data rejected when off.
- VMAG voltage monitors (± 12V) will be checked and data rejected when they vary by more than specifications (the default value is 5 percent).

4.2.9 Vector Magnetometer Temperature Checks

VMAG sensor (A/B) and platform temperatures (A/B) will be checked and noted in output summaries if they are out of range or if they vary by more than specifications (the default value is 5° C). Data will be rejected on option in these instances.

4.2.10 Vector Readout Description

Vector measurements are sampled approximately eight times each half-second (decom minor frame) for each axis (A, B, and C). Each observation consists of an 8-bit coarse count readout for each axis (two readouts per half-second) and a 12-bit fine count readout for each axis (eight readouts per half-second), which will be combined in the process of computing component values. Associated with each set of fine readouts is a coarse status word which contains the least significant bit of the coarse counter between coarse readouts. This status word is used to update the coarse count value between coarse readouts when necessary (see Section 4.2.12).

Figure 4-2 shows the vector magnetometer readouts for a half minor frame (0.25 second).

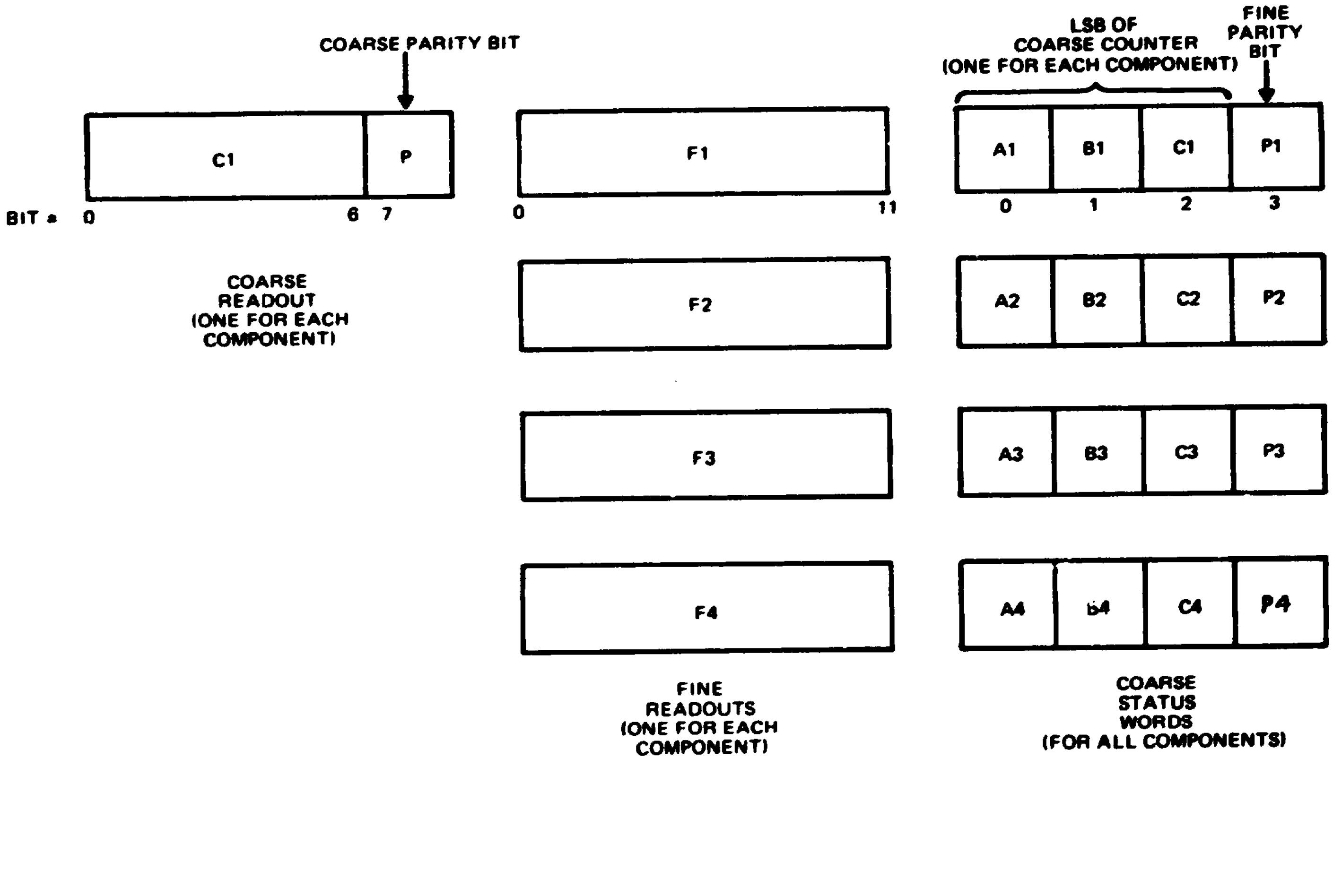

Figure 4-2 Vector Magnetometer Readouts to 1/2 Minor Frame

4.2.11 Vector Parity Checks

After proper operating conditions are verified for the vector magnetometer (Sections 4.2.8 and 4.2.9) and before computing component values, parity checks will be performed on the coarse and fine count readouts for each axis. The parity bit of the 8-bit coarse count readout is the rightmost bit (see Figure 4-2). Only one parity bit, associated with each 36-bit group of fine count readouts (12 bits per axis), is contained in the coarse status word. Parity checking involves checking the parity bit and the other bits associated with the parity bit and verifying that the total number set to 1 is odd. Failure of the test is cause for rejection of the measurement, since one or more of the measurement bits have been erroneously changed in state.

4.2.12 Vector Coarse Counter Change Check

Updates to the coarse count value must be made prior to computing the field value whenever the coarse counter changes value between coarse count readouts. Such a change in value is denoted by a change in the bit state of bits 0, 1, and 2 of the coarse status word (associated with each set of fine count measurements as shown in Figure 4-2) for components A, B, and C, respectively. This change in bit state indicates that the coarse count value associated with the fine count should be incremented or decremented by 1 depending on whether the subsequent coarse readout is greater or less than the previous readout.

In addition, a switching transient due to a change in the value of the coarse counter introduces an error in the corresponding fine counter measurement for each axis. The vector measurement will be rejected at the time of the change and for several measurements thereafter (the default value is 3).

4.2.13 Other Spacecraft Checks

The status of various spacecraft instruments which indirectly affect the SMAG and VMAG readings are checked. These include the X-, Y-, and Z-coils, star camera, electronic flip, and vector calibration status. SMAG and VMAG data will be flagged when any of these instruments is on. In these instances, separate data records containing a flag describing instrument status will be output to a chronicle tape (see chronicle tape format, Appendix G).

4.2.14 Data Processing Status Flags

Preliminary DECOM data checks performed by the CRONICLE program will be summarized and coded on a set of status flags. These flags will be stored on the quality catalog tape described in Sections 4.6.2 and 4.6.4. There are three types of status flags which will be generated by the CRONICLE program during preliminary DECOM data checks.

The following is a list of codes for each type of status flag. If the code is a positive number, each bit in the flag which is set to 1 denotes a particular diagnostic related to the spacecraft for a given set of 32 DECOM minor frames of an SMAG sequence. If scalar and/or vector data for the entire SMAG sequence was rejected due to preliminary DECOM checks, the scalar processing flag (SPF) and/or vector processing flag (VPF) code will be set to a negative value specifying the reason for rejection.

- Scalar Processing Status Flag (SPF) - A 32-bit word for each SMAG sequence which will summarize telemetry data related to the scalar magnetometer status for that sequence. The flag will also contain SMAG sequence rejection codes for both general telemetry errors (see Sections 4.2.1 through 4.2.3) and faulty scalar magnetometer status (see Sections 4.2.4 through 4.2.6).

- **Vector Processing Status Flag (VPF) - A 16-bit word for each SMAG sequence which will summarize telemetry data related to vector magnetometer status for that sequence. The flag will also contain SMAG sequence rejection codes for faulty vector magnetometer status (see Sections 4.2.8 and 4.2.9).**
- **Spacecraft Status Flag (GPF) - An 8-bit word for each SMAG sequence which will summarize telemetry data related to general spacecraft status for that sequence (see Section 4.2.13).**

For each SMAG sequence processed, various telemetry data will be flagged by setting certain bits of the appropriate status flags for that seque·.e. At the end of the preliminary processing of a decom file, the arrays of status flags generated will be scanned for the purpose of removing spurious inconsistencies in the telemetry data and the summary statistics for the file.

These status flags will also be saved on quicklook tapes and on the quality data catalog (Appendices H and I, respectively).

The following is a list of codes for each type of status flag. In the case of the SPF and VPF status flags, negative codes specify reasons for rejecting either scalar or vector data for a given SMAG sequence.

Positive SPF Codes

Bit	Definition
1	If set, see negative codes.
2	---
3	Tracking filter A unlock
4	Tracking filter B unlock
5	Lamp brightness status (A and B) bad
6	Lamp brightness A and B out of range

Bit	Definition
7	Signal amplitude A bad
8	Signal amplitude B bad
9	Power converter A off
10	Power converter B off
11	Lamps A and B off
12	Cell photocurrent A off
13	Cell photocurrent B off
14	Heater A1 on
15	Heater A2 on
16	Heater A3 on
17	Heater B1 on
18	Heater B2 on
19	Heater B3 on
20	Sensor baseplate heater on
21	Cell temperature A bad
22	Cell temperature B bad
23	Lamp temperature A bad
24	Lamp temperature B bad
25	Scalar power A off
26	Scalar power B off
27	Scalar data quality A bad
28	Scalar data quality B bad
29 - 32	---

Negative SPF Codes

Code	Definition
-3	SMAG sequence padded
-4	50 percent or more of sequence with bad frame count
-5	Less than two non-padded minor frames in sequence or frame times inconsistent
-6	Duplicate sequence

Code	Definition
-7	Major frame counter not found
-8	Spacecraft clock error
-11*	Both tracking filters in unlock status
-12	Accumulation time not found
-13*	Lamp brightness A and B bad
-14*	Signal amplitude A and B bad
-15	Lamps A and B off
-16*	Cell photocurrents A and B out of range
-18*	Lamp temperatures A and B out of range
-20*	Cell temperatures A and B out of range
-22	Power converters A and B off
-23	Power converters A and B on
-24	Scalar power A and B off

*Rejection option specified by user; the default is no rejection.

Positive VPF Codes

Bit Set	Definition
1	---
2	Power off
3	Platform heater B select
4	Digital B, power B select
5	Analog B select
6	Electronic zero offset on
7	Calibration on
8	+12V bias variance out of range
9	-12V bias variance out of range
10	Optical bench temperature low
11	Sensor temperature variance out of range
12	Platform temperature variance out of range
13 - 16	---

Negative VPF Codes

Code	Definition
-1	Power off
-2	-12V variance out of range
-3	+12V variance out of range
-4*	Sensor temperature bad
-5*	Platform temperature bad
-6*	Optical bench temperature low

*Rejection option specified by user; the default is no rejection.

GPF Codes

Bit Set	Definition
1 - 3	---
4	Star camera 1 on
5	Star camera 2 on
6	X-coil on
7	Y-coil on
8	Z-coil on

4.3 DATA COMPUTATION

When timing errors, faulty instrument operating status, and parity have been detected and flagged, the CRONICLE program will compute magnetic field values from raw count data of the scalar and vector magnetometer, edit data of dubious quality, and archive the data on chronicle and data catalog tapes.

Data computation procedures are described below.

4.3.1 Scalar Computation

Scalar measurements for sides A and B are stored on a DECOM record in the form of raw counts of the oscillation of the sensor's cesium electrons over a given time period. The larmor oscillation frequency is directly proportional to the amplitude of the local magnetic field (3.49847 Hz/gamma).

The oscillation time period (commanded accumulation time) for side x (x = A or B) is first computed as

$$Tx = 2 \quad (Nx + 1) \ T \text{ seconds}$$

where Nx = the command word associated with the accumulator for side x read every 16 DECOM minor frames (default value is 29)

T = the bit period of $0.5120256 \ 10^{-3}$ seconds [computed by dividing the second clock coefficient (i.e., the duration of a telemetry minor frame) by 960 bits/frame]

A prescale factor is necessary for computing scalar measurements and is derived from the corresponding command word Nx. The prescale value, Ax, is shown below.

Value of Nx	Ax
0 - 63	1
64 - 127	2
128 - 255	4

Scalar frequency measurements, fx, for side x are then computed as follows:

$$fx = Ax \left(\frac{ISCLRx}{16\ Tx}\right) \quad Hz$$

where ISCLRx is the raw count scalar reading for side x (parity and data quality bits shifted out).

It should be noted that the tracking filter (phase locked loop) causes the 16th harmonic of the larmor frequency to be counted by the accumulator for the purpose of providing the desired measurement resolution.

Scalar measurements in terms of gammas, Fx, for side x are computed as

$$Fx = \frac{fx}{3.49847} \text{ gammas}$$

4.3.2 Vector Computation

After checking vector parity and making appropriate adjustments to coarse count readouts, vector measurements are computed.

The 12-bit fine count measurement (F) for each sensor axis will be converted to gammas by using a scale factor (S) and the current zero value (Z) which may be different for each axis and for each digital system (A and B).

The coarse count (C) for each axis will be scaled by 1000γ for a total range of $\pm 64{,}000\gamma$. The actual value of each count (in gammas) will be determined from table lookup. Usually there are six such tables (one for each axis for either digital system, A or B, selected). The total component of the magnetic field (V) along each axis will be computed as follows:

$$V = C_{(gammas)} + S\ (F - Z)$$

Calibration constants S and Z and coarse count conversion tables will initially be supplied by the instrument sponsor and subsequently computed in offline calibration of magnetometer data processed throughout the mission. (See Appendix N.)

4.3.3 Vector Orthogonalization and Rotation to Sensor Platform Coordinates

In general, the sensor axes will not be exactly orthogonal. To orthogonalize the sensor output (A_R, B_R, C_R), the transformation shown below will be used.

$$\begin{pmatrix} A \\ B \\ C \end{pmatrix}_{\text{Sensor Platform Coordinate}} = M_2 \, M_1^{-1} \begin{pmatrix} A \\ B \\ C \end{pmatrix}_R$$

The orthogonalization matrix M_1 will be a function of the sensor output and alignment constants; M_2 will be a rotation matrix to sensor platform coordinates. In this coordinate system, A is normal to the surface of the primary optical reference cube of the vector magnetometer.

Both alignment constants and M_2 will be determined during ground tests of the vector magnetometer and the spacecraft. Alignment constants will be subsequently updated in offline calibration of magnetometer data throughout the mission. (See Appendix N.)

4.3.4 Attitude Bias Correction

MAGSAT intermediate and fine attitude data will be adjusted, on option, for biases in roll pitch and yaw before vector coordinate transformations are performed. Biases will be determined from offline calibration analysis of attitude data. See Appendix J for details in the bias correction used.

4.3.5 Vector Coordinate Transformation

Vector magnetometer measurements derived from DECOM data are in vector magnetometer ABC coordinates and must be converted to NEV coordinates for the data editing by the CRONICLE program and for experimental use. This conversion or transformation of coordinates depends on the satellite attitude and orbit information stored on the condensed orbit/attitude tape described in Section 3.2.3. Attitude information (with bias corrections described in Section 4.3.4) is used to convert measurements from vector magnetometer ABC to celestial coordinates XYZ (Appendix J). A conversion of measurements from celestial XYZ to NEV coordinates is then made using orbit information (Appendix K). Vector data is rejected if either orbit or attitude data is not available.

4.4 DATA EDITING

Before magnetometer data is stored on output tape by the CRONICLE program, several tests will be performed for the purpose of data editing and providing data quality statistics. These tests are described in the following sections.

4.4.1 Scalar/Vector Comparison

The three-axis (orthogonal) vector data, converted to gammas but still in terms of sensor platform coordinates, will be tested for consistency with the scalar measurements. The total field values derived from the vector components will be compared to the scalar readings with which they are synchronized. If the difference of these two values exceeds 3γ (default), all three components of the vector measurements and the corresponding scalar readings will be tallied for diagnostic summaries. Vector data will not be rejected during this test.

4.4.2 Scalar Reference Test

Scalar magnetometer measurements will be compared with corresponding theoretical magnetic field estimates to screen clearly erroneous values. In order to derive theoretical estimates, orbit data is required. If orbit data is not available, scalar data will be rejected. Measurements which deviate significantly from these estimates will be deleted. Reference error tolerances will be made more stringent when scalar amplitude falls in a specified null region. Appendix L describes the theoretical field.

4.4.3 Vector Reference Test (Post-Launch Requirement)

The total field value derived from vector magnetometer measurements will be compared with corresponding theoretical field estimates. If total field values differ significantly from these estimates, all three component measurements will be deleted.

4.4.4 Outlier Tests

Magnetometer measurements will be deleted if their differences from corresponding field estimates show up as spikes or significant outliers. Separate outlier tests will be performed on scalar measurements and on each vector component value. (Note: Post-launch requirement specified performing an outlier test on the total field values derived from vector measurements.)

Outlier test tolerances F4, F5, and F6 will be specified separately for each scalar and vector component measurement. The test will proceed as follows for each measurement type:

- A line will be fit to the differences (over 32 minor decom frames) with respect to time using the least-squares technique.
- The rms deviation from the fit will be computed.
- All points deviating from the fit by more than F4* rms or by more than F5 will be rejected. If any points are rejected, the entire test will be repeated (this iterative procedure will be cut off after about 15 iterations) using only data passing the test just completed. If at the end of the test the final rms is greater than F6, the entire data batch will be deleted.

4.4.5 Overlap Data Tests

A decom tape will contain a combination of playback files (data stored on tape recorders and played back during transmission to ground stations) and real-time files (data transmitted to ground stations in real time).

As a result, decom files may overlap in time and redundant data may exist. Overlap data will be processed by the CRONICLE program and appropriate statistics computed. If measurement differences for overlap data exceed 5 gammas or if time differences exceed 50 milliseconds, the latter data will be deleted.

Optionally, magnetometer data which passes all the data edit tests in this section will be output to a chronicle and/or a quicklook tape.

4.5 FINE ATTITUDE UPDATE PROCEDURE

The FINEUP program is a specialized version of the CRONICLE program which will be used to update the chronicle tapes. FINEUP will use fine attitude data and better estimates of vector calibration and sensor alignment constants. Preliminary processing, as described in Section 4.2, will be bypassed since chronicle data tapes instead of decom data will be used as input.

The fine attitude update process is outlined below.

4.5.1 Vector Data Computation

Only vector data will be computed in the fine attitude update process. Scalar magnetometer data is independent of spacecraft attitude and therefore needs only to be copied from chronicle tape input.

Raw counts of the vector magnetometer data, stored on chronicle tape input, will be converted into gammas, as described in Section 4.3.2. Better estimates of vector calibration constants computed in offline calibration analysis of data generated by the CRONICLE program will be used. Parity and coarse counter checks need not be performed since this was done previously by the CRONICLE program.

Vector orthogonalization and rotation to sensor coordinates ABC will be performed, using better estimates of sensor alignment constants as described in Section 4.3.3.

Finally, fine attitude data will be adjusted due to biases in spacecraft roll, pitch, and yaw before coordinate transformations are made to the vector data as described in Sections 4.3.4 and 4.3.5.

4.5.2 Data Editing (Post-Launch Requirement)

Only the reference and outlier tests (Sections 4.4.3 and 4.4.4) will be performed and these tests will be applied only to the vector data.

4.6 CRONICLE PROGRAM OUTPUT PRODUCTS

The absolute file number will be used as a key to reference all MDPS output products associated with a given set of processed decom data. This number will be incremented by 1 whenever one or more of the following conditions are encountered in processing (or reprocessing) decom data:

- A new file is accessed
- A 5-minute (or greater) time gap occurs in the data
- A change occurs in the day of year of the data

Output products generated by the CRONICLE program will, on option, include

- A printed summary of scalar, vector, and related engineering data quality statistics from each run including a complete summary of all reasons for data rejection.

- A quicklook format tape of processed scalar, vector, and engineering data to be input to the quicklook plot program.
- A CRONICLE format tape of edited scalar and vector data processed by the CRONICLE program.
- Amplitude and quality catalog tapes of MAGSAT engineering data and CRONICLE program processing statistics.
- A MDPS run-history (disk data set).

A detailed description of this output follows.

4.6.1 CRONICLE Printout

The CRONICLE printout will contain processing statistics on the extent and quality of DECOM data processed. At the user's option, statistics can be reported every 512 minor DECOM frames (4-minute section), and summarized for each file of DECOM data.

4.6.1.1 Four-Minute Summary Statistics

Statistics on scalar, vector, and related engineering data quality will be listed, at user option, every two DECOM major frames (512 minor frames, or approximately 4.2 minutes of data processed by the CRONICLE program). This information will be included in the quality catalog described in Section 4.6.4. The 4-minute statistics will include

- Start time of section.
- Satellite position
- Total scalar analog subcom sequences (SMAG sequence of 32 minor frames) accepted.
- Total SMAG sequences rejected and reasons for rejection (see Appendix I).

- Total scalar and vector measurements accepted.
- Total scalar and vector measurements rejected and reasons for rejection (see Appendix I).
- Spacecraft instrument analog readouts (minimum, maximum, and average).
- Spacecraft instrument status and heater duty cycles.

4.6.1.2 Absolute File Summary Statistics

An absolute file of processed DECOM data will correspond to a set of records within a given DECOM file with the same day of year and with time gaps no greater than 5 minutes. Duplicate DECOM data or DECOM data reprocessed by the CRONICLE program causing data overlap will be designated as a separate new absolute file.

Summaries of the 4-minute statistics (Section 4.6.1.1) will be included in the absolute file summary statistics.

The following information will also be listed:

- Start/stop time of absolute file.
- Date of CRONICLE run.
- DECOM file description (extracted from DECOM file header records).
- Reason for file rejection (if rejected; see Appendix I).
- Minimum and maximum spacecraft clock fit errors.
- Commanded accumulation time for scalar magnetometer for each side.
- Number of scalar and vector measurements not computed due to missing orbit or attitude data.

- Scalar/vector compare exceptions.
- Frequency distribution chart of overlap data with respect to time and measurement differences with old data.

CRONICLE run listings [processing and job control language (JCL) messages] will be recorded and archived on microfilm.

4.6.2 Quicklook Tape

Formatted dumps of scalar and vector measurements and related engineering data will be stored on tape at user option for subsequent quicklook processing. (See Appendix H for the quick-look tape format.) Plots of the data on this tape will be generated by the output postprocessing software (see Section 5).

4.6.3 Chronicle Tapes

There are two types of chronicle tapes generated in the chronicle processing stage: CHRONSCI and CHRONFIN tapes. Scalar and vector data from DECOM tapes will be edited and archived on CHRONSCI tapes by the CRONICLE program. CHRONSCI tapes will be updated with fine attitude data and stored on CHRONFIN tapes by the FINEUP program.

Data for more than 1 day may be stored on either tape. There will be separate records for scalar and vector data, each containing up to 1 minute's worth of data. Time increments between data points within a record will be fixed and the records will be stored on tape in time order. Pad data points will be denoted by the value 99999.0. Separate records will be allocated for data processed during commanded calibration and when the spacecraft X-, Y-, or Z-coil is on.

A more detailed description of the CHRONSCI and CHRONFIN tapes is given below.

- **CHRONSCI Tape**
  This tape contains scalar and vector measurements edited and archived by the CRONICLE program. Vector magnetometer measurements will be stored on a CHRONSCI tape in two forms: Components will be in raw count form and given in the sensor platform coordinate system as received on the DECOM tape. They will also be converted to gammas and transformed to the NEV coordinate system using the transformations given in Section 4.3.3, 4.3.4, and 4.3.5, with the intermediate quality attitude data derived from the infrared horizon scanner and the two coarse Sun sensors.

- CHRONFIN Tape
  This tape is similar in content to the CHRONSCI tape in that it contains both scalar and vector measurements. Vector components will be in gammas and transformed to the NEV coordinate system using fine attitude data derived from the fine Sun sensor, two star cameras, and the ATS of the spacecraft. Data records containing vector measurements will be immediately followed by attitude quality flags derived from attitude tape input. Vector data in raw count form will not be stored on this tape. The CHRONFIN tape will also contain MAGSAT ephemeris data records for the time span of magnetometer data stored on tape.

No ephemeris or attitude data quality records are included on a CHRONSCI tape.

Appendix G contains a general chronicle tape format description which contains all record types and their organization on the tape.

CHRONSCI and CHRONFIN tapes will be updated with new data in subsequent CRONICLE or FINEUP runs, as described in Sections 4.7.1 and 4.7.2.

4.6.4 Engineering Data Catalogs

DECOM engineering data processed by the CRONICLE program and the resulting processing statistics will be compiled on data catalogs which will be stored on tape. Two data catalogs (quality and amplitude) will be generated or updated whenever a chronicle tape is generated from DECOM data. Data will be archived on an absolute file basis; data records for the file will be headed by an absolute file title record. Archiving and management of these catalogs will be done by the CRONICLE program as described in Section 4.7.3.

Engineering and quality data will be archived on the quality catalog tape on an absolute file basis. Quality data records for the absolute file will be headed by an absolute file title record which contains

- Absolute file start/end times
- DECOM file label contents for the absolute file.
- Absolute file summary statistics (see Section 4.6.1.2).
- CRONICLE program run constants used to generate the absolute file.

Quality data records will contain engineering information from two major frames (see Section 3.1.1) or approximately 4.2 minutes worth of decom data processed by the CRONICLE program. Each record will contain a start time, satellite position estimates, and 4-minute section statistics described in Section 4.6.1.1. Quality data records will also contain data processing statistics on a 16-second, 32 minor frame (post-launch requirement) and 2 major frame basis. The record formats are shown in Appendix I. The output postprocessing software will generate listings of the quality catalog data (see Section 5).

Scalar amplitude data will be extracted from DECOM records and archived on an absolute file basis on the amplitude catalog tape. The record's start time will be synchronized with the quality catalog data records. Contents of an amplitude catalog record will include the record start time and associated satellite position, and up to 16 samples of signal amplitude data for each side (A and B) of the scalar magnetometer. Appendix M contains the amplitude catalog record formats. The output post-processing software will generate plots and listings of the data (see Section 5).

4.6.5 MDPS Run History

At the conclusion of MDPS CRONICLE processing, a one-line job status summary will be added onto a disk data set which is a complete log of all MDPS processing. The record format is given below.

Displacement (Bytes)	Parameter	Type	Units
0	Job name	R*8 (EBCDIC)	
8	Program name	R*8 (EBCDIC)	
16	Date of run	I*4	YYDDD
20	Start time	I*4	Seconds of day
24	Elapsed wall clock time	I*4	Seconds
28	CPU time used	I*4	Seconds
32	I/O time used	I*4	Seconds
36	Program completion codes (three fields)	I*4 (each)	
48	Job priority (0-255)	L*1	
49	Parameter field from execute card (parameters and comments, 51 EBCDIC characters)	L*1 (each)	

4.7 CRONICLE PROGRAM DATA MANAGEMENT

This section describes how the CRONICLE program will update and manage the MDPS output data base. The output data base will consist of the following:

- CHRONSCI tapes (described in Section 4.6.3)
- CHRONFIN tapes (described in Section 4.6.3)
- Engineering Data Catalogs (described in Section 4.6.4)
- Output directory
  The CRONICLE program will store entries on disk of all the CHRONSCI, CHRONFIN, and data catalog tapes generated. The MDPS output directory will serve as a reference for automatically managing, updating, and archiving output by the CRONICLE program.

Chronicle tape data management and data catalog management are described below.

4.7.1 CHRONSCI Tape Data Management

CHRONSCI tapes will be generated by the CRONICLE program which processes DECOM input. Up to 4 days of processed telemetry data will be stored on one tape. The output directory will be accessed to determine whether an old CHRONSCI tape is to be appended with new data or a new tape is to be generated.
DECOM data may be reprocessed by the CRONICLE program. Reprocessed data will replace corresponding data already on a CHRONSCI tape only if overlap data tests (described in Section 4.4.5) are passed; that is, if overlap measurements and time differences are within 5 gammas and 50 milliseconds, respectively.

4.7.2 CHRONFIN Data Management

With the receipt of better estimates of vector sensor calibration, alignment constants, and fine attitude data, the CHRONSCI data will be updated by the FINEUP program (as shown in Section 4.5) and written to a CHRONFIN tape. Preliminary processing described in Section 4.3 will be bypassed since CHRONSCI data instead of DECOM data will be used as input.

There will be a one-to-one correspondence between CHRONSCI and CHRONFIN tapes. Up to 4 days of CHRONFIN data will be stored on one tape with the tape time span being identical to the updated CHRONSCI tape (referenced in the output directory).

CHRONFIN data may be reprocessed by the FINEUP program; in which case, old CHRONFIN data will be replaced with reprocessed data.

Upon receipt of all available intermediate and fine attitude tape input, the scalar and vector data records (NEV format only) from the CHRONSCI tapes will be merged onto respective CHRONFIN tapes for time periods where no fine attitude data was available. Intermediate and fine vector data records will be distinguished by data flags. (See Appendix G.)

4.7.3 Data Catalog Management

Quality and amplitude data catalogs will be generated and/or updated whenever a CHRONSCI tape is generated by the CRONICLE program using DECOM input.

DECOM data and processing statistics will be stored in time order in these catalogs. The output directory will be accessed to locate the correct catalog reel for updating purposes and for the purpose of generating data overlap statistics if data is reprocessed.

The absolute file number will be used as a key to reference all MDPS cataloged output products associated with a given set of processed decom data. This number will be incremented by 1 whenever chronicle tapes and the respective data catalogs are generated and when one or more of the following conditions are encountered in processing (or reprocessing) decom data:

- A new file is accessed
- A 5-minute (or greater) time gap occurs in the data
- A change occurs in the day of year of the data

Groups of records on the data catalog corresponding to an absolute file of data processed by the CRONICLE program will be headed by an absolute file title record. If a given set of decom data is reprocessed, the resultant group of quality or amplitude catalog records generated will be merged into the data base with old catalog records by time sequence of decom data--not by absolute file number.

SECTION 5 - POSTPROCESSING

5.1 INTRODUCTION

Postprocessing output products for MAGSAT will include plots of telemetry data in various formats, copies of the chronicle tapes containing only selected data record tapes, investigator tapes in two formats, and listings of the statistical catalogs in various formats. Figure 5-1 is a data flow diagram showing these processes. The following sections define each of the products.

5.2 PLOTS

Four types of hardcopy data plots will be generated: quicklook, amplitude, latitude, and polar plots. Any of these can be plotted on either a CalComp pen plotter or a Stromberg Data Graphics microfilm recorder.

5.2.1 Quicklook Plots

Throughout the MAGSAT mission and especially during the early orbits, subsets of the DECOM data will be processed through the system on a priority basis. To allow the Project Scientist to see the data for rapid evaluation, specialized plotting programs (QL4060 and AMPLOT) will be developed to display magnetometer and signal amplitude data.

5.2.1.1 Scalar and Vector Magnetometer Quicklook Plots

The QL4060 program will input specialized quicklook tapes (see Appendix H) generated by the CRONICLE program, and output plots with the following attributes:

- All data is plotted versus time.
- Variable time intervals are selected by users.
- Only every nth point is plotted, where n can be user-selected.

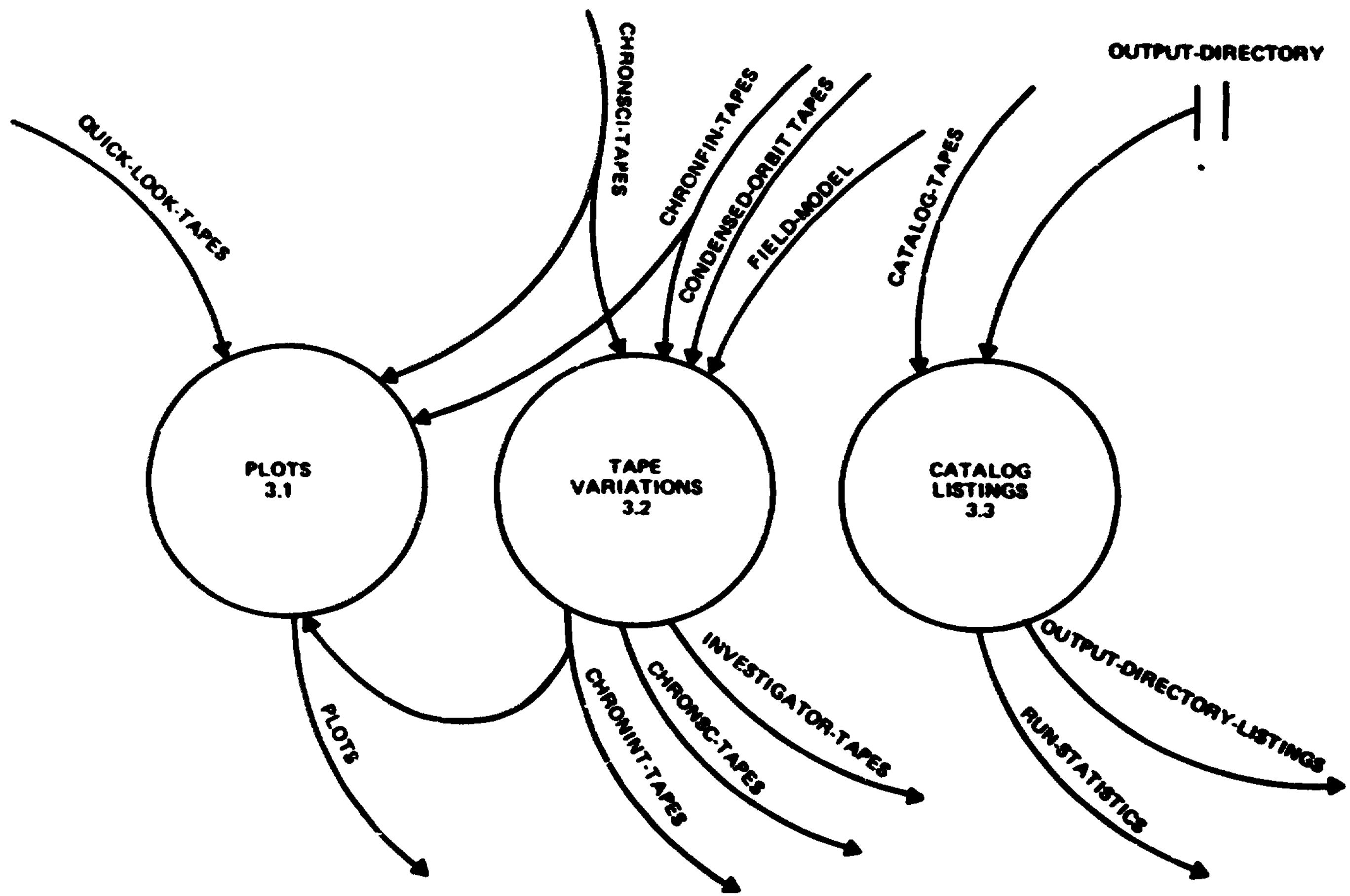

Figure 5-1 Postprocessing Data Flow Diagram

- Plots will be in sets of four.
- One set will include scalar magnitude, X-magnitude, Y-magnitude, and Z-magnitude.
- A second set of plots will include differences from a field model of scalar magnitude and the X, Y, and Z (NEV) components of the vector data.
- The vertical scale will be automatically chosen to fit the data.

NOTE: The following are post-launch requirements.

- An option to plot the scalar-vector differences.
- An option to use the scalar value of the vector data in place of the scalar data for difference plots.

5.2.1.2 Signal Amplitude Quicklook Plots

The AMPLOT program will process signal amplitude data stored on quicklook tapes and generate plots of amplitude versus time. Program features and options will include the following:

- Plots of signal amplitude may be generated for either or both sides A and B.
- Time intervals are variable, and selected by the user.
- The program will select a suitable scale for the ordinate (amplitude), depending on the data values to be plotted.

5.2.2 Plotting by Latitude Region

A program (called LATPLT) will be developed to plot the processed data with latitude as the abscissa and either the magnitude of the data or the difference between the data and a user-supplied field model as the ordinate. The latitude scale will be continuous with the location of the satellite; that is, there will be no gaps in the data as the satellite turns from north to south or south to north. Each plot will cover exactly one orbit starting at the northbound equatorial crossing. The ordinate scale will be automatically adjusted to best fit the data for each orbit.

Appropriate lables, grid lines, and tic marks will be provided, including time, longitude, and altitude at each latitude grid line.

Additions to LATPLT requested after launch include the addition of identification labels, labeling of every grid line instead of every other grid line, and an option to fix the ordinate axis across all plots.

5.2.3 Plotting by Polar Region

A program (called POLPLT) will be developed to plot the processed data along the satellite track plotted on a polar grid. Program POLPLT reads scalar and vector magnetometer data from chronicle or investigator tapes and produces plots of the polar regions. The plots show the path of the satellite with the deviation between the magnetometer data and a field model superimposed. Scale lines are drawn periodically along the satellite track and labeled with a scale value (in gammas) corresponding to the length of the scale line. The altitude (in kilometers) and the time of day (in hours and hundredths of hours) are also plotted.

Either of two coordinate systems may be selected: geographic (latitude versus longitude) or geomagnetic (invariant latitude versus geomagnetic local time). A time span, the desired polar region (North, South, or both), and a latitude limit are specified by the user through card input. For each passage of the satellite through the specified polar region within the specified time span, four plot frames are produced representing the scalar data and the X, Y, and Z components of the vector data.

Additions to POLPLT requested after launch include the addition of the terminator line on each plot and the ability to plot vector data (two dimensions only) using directed line segments.

5.3 CHRONICLE TAPE VARIATIONS

Chronicle (CHRONSCI) tapes generated by the CRONICLE program contain data in both spacecraft and NEV coordinate systems. Scientific investigators may be interested in vector data in only spacecraft or NEV coordinates. In order to reduce the bulk of data distribution to the investigators, two versions of chronicle tapes will be generated from CHRONSCI tapes.

- CHRONINT - Scalar and vector magnetometer measurements (in gammas) will be stored on this tape. Vector measurements will be in the NEV coordinate system derived from intermediate attitude data.
- CHRONSC - Scalar measurements (in gammas) and vector measurements (raw count form) in the spacecraft coordinate system (prior to the orthogonalization and other rotations described in Sections 4.3.3, 4.3.4, and 4.3.5) will be stored on this tape.

Up to 8 days of data will be contained on either tape. In addition, these tapes will contain orbit records formatted such that the orbit data can be interpolated for every data point contained in the data records which follow. Appendix G provides a general format description for chronicle tapes.

5.4 INVESTIGATOR TAPES

A separate document describing the investigator tapes will be prepared (see Reference 5).

5.5 CATALOG LISTINGS

Data catalogs generated by the CRONICLE program will be listed by the CATLST program.

There are two types of data catalogs:

- Quality Catalog - Summaries of digital and analog engineering data extracted for every 512 minor frames (4.2 minutes) of telemetry data. Associated scalar and vector magnetometer data quality and edit statistics will also be stored.
- Amplitude Catalog - Analog readings of signal amplitude for every 512 minor frames of telemetry data (in sync with quality catalog).

Quality catalog data for an absolute file is summarized and stored on each catalog as a separate title record which will preface each set of quality and amplitude data for an absolute file.

The CATLST program will provide one-line summaries of digital engineering data and data quality statistics for each catalog data record. Similar one-line summaries will also be listed for the absolute file title records.

Engineering summaries will include the following:

1. Start time of record.
2. Position (for quality or amplitude data record).
3. Total SMAG sequences accepted.
4. Total sequences rejected and reasons for rejection (see Appendix I).
5. Percent of total sequences with spacecraft star cameras and X-, Y-, and Z-coils on.
6. Total sequences where scalar or vector data was rejected and reasons for rejection (see Appendix I).

7. Percent of scalar data quality errors.

8. Percent of vector data rejected due to parity errors and changes in the coarse counter.

9. Percent of total sequences with scalar power converters and sensors on.

10. Percent of total sequences with vector digital/analog and calibration on.

11. Average vector sensor and platform temperature readings.

12. Total number of significant scalar/vector comparison exceptions (see Section 4.4.1).

One-line data quality summaries will include items 3, 4, 6, 7, 8, 10, and 12 of the engineering summaries as well as

- Total scalar and vector data points accepted.
- Total scalar and vector data points rejected and reasons for rejection (see Appendix H).

Complete detailed listings for each catalog, including a list of analog engineering data readouts, will also be generated by the CATLST program and stored on microfilm.

5.6 TIME-LINE PLOTS (POST-LAUNCH REQUIREMENT)

The data catalog will be used to generate CalComp time-line graphs depicting scalar and vector data availability.

APPENDIX A - DECOM TAPE FORMAT

This appendix defines the format and epoch time of MAGSAT telemetry data of interest. Each file consists of two title records, one or more data records, and a sentinel record. The nine-track, 1600-bpi tape has the following attributes: RECEM = FB, LRECL = 144, BLKSIZE = 14400, DEN = 3. All bytes are 8-bit; there is zero fill between data entries.

The record format is as follows:

FILE TITLE RECORD 1:

Displacement (bytes)	Parameter	Type
0	International Code (7912301 for MAGSAT (EBCDIC)	R*8
8	First Frame Quality Word of File	I*4
12	Station (tracking station receiving this pass of data)(EBCDIC)	I*4
16	Tape Serial Number (XYYDDD, which is any character plus year and day of data) (EBCDIC)	R*8
24	Year of Pass (last two digits)	I*4
28	Start Time (DDDHHMMSS)	I*4
32	Stop Time (DDDHHMMSS)	I*4
36	Date of Tape Generation (YYMMDD)	I*4
40	Edit Version Number (YYMMDD)	I*4
44	DECOM Version Number (YYMMDD)	I*4
48	File Number	I*2
50	Reel Number	I*2
52	Experimenter ID	I*2
54	Number of Clock Fits in this File	I*2
56	Value of spacecraft clock at beginning of this fit interval	I*4

Displacement (bytes)	Parameter	Type
60	Value of spacecraft clock at end of this fit interval	I*4
64	First coefficient of this clock fit	R*8
72	Second coefficient of this clock fit	R*8
80	Third coefficient of this clock fit	R*8
88	Same as bytes 56-87 for second clock fit if needed	
120	Spares	

FILE TITLE RECORD 2:

Displacement (bytes)	Parameter	Type
0	Same as bytes 56-87 (first record) for third clock fit if needed	--
32	Spares	--

DATA RECORD:

Displacement (bytes)	Parameter		Type
0	Frame Quality Word		I*4
	BIT 0 = 1,	Time gap to previous frame	
	BIT 1 = 1,	Time overlap with previous file	
	BIT 2* = 1,	S/C clock time gap to previous file	
	BIT 3* = 1,	UTC time gap to previous file	
	BITS 4 and 5	Binary count of bit errors in frame synchronization word	
	BIT 8 = 1,	Questionable frame count value	
	BIT 9 = 1,	New time line used	
	BIT 11 = 1,	UTC corrected by more than 15 ms	
	BIT 12 = 1,	S/C clock jump	

*Significant only on first frame within the file

Displacement (bytes)	Parameter			Type
4	Synchronization Word	Reference Frame Time (RFT) is at trailing edge of bit 23 of the telemetry minor frame (TMF) which is the last bit of the sync word		R*4
8	TLM VFY			I*2
10	Day of Year	RFT for next TMF (RFT for this TMF is found by subtracting 960 bits or 491.5446 ms)		I*2
12	Milliseconds of day			I*4
17	VMAG ID			L*1
19	Frame Counter			L*1
21	Frame Parity			L*1
		Relative Time[1] (Bits)	(MS)	
23	SMAG Housekeeping Sub-Com (32 channels)	164.50	84.23	L*1
25	ASC0 (64 ch.)	18.00	9.22	L*1
27	ASC1 (64 ch.)	258.00	132.10	L*1
29	ASC2 (64 ch.)	498.00	254.99	L*1
31	ASC3 (4 ch.)	738.00	377.87	L*1
33	DSC0 (16 ch.)	366.00	187.91	L*1
35	DSC1 (16 ch.)	864.00	433.69	L*1
48	SCALAR MAG A	-418.00	-214.03	I*4
52	SCALAR MAG B	-658.00	-336.91	I*4
57	MSB-A	-59.60	-30.52	L*1
59	MSB-B			L*1
61	MSB-C			L*1
64	LSB-A[2]	-181.94	-93.16	I*2
66	LSB-B[2]	-179.60	-91.96	I*2
68	LSB-C[2]	-177.26	-90.76	I*2
71	LSB-Parity			L*1

Displacement (bytes)	Parameter	Relative Time[1] (Bits)	(MS)	Type
72	LSB-A			
74	LSB-B	-59.60	-30.52	I*2
76	LSB-C			
79	LSB Parity			L*1
80	LSB-A			
82	LSB-B	60.40	30.93	I*2
84	LSB-C			
87	LSB Parity			L*1
88	LSB-A			
90	LSB-B	180.40	92.37	I*2
92	LSB-C			
95	LSB Parity			L*1
96	SCALAR MAG A	62.00	31.75	I*4
100	SCALAR MAG B	-178.00	-91.14	I*4
105	MSB-A			
107	MSB-B	420.40	215.26	L*1
109	MSB-C			
112	LSB-A			
114	LSB-B	300.40	153.81	I*2
116	LSB-C			
119	LSB Parity			L*1
120	LSB-A			
122	LSB-B	420.40	215.26	I*2
124	LSB-C			
127	LSB Parity			L*1
128	LSB-A			
130	LSB-B	540.40	276.70	I*2
132	LSB-C			
135	LSB Parity			L*1
136	LSB-A			
138	LSB-B	660.40	338.14	I*2
140	LSB-C			
143	LSB Parity			L*1

End of Record

Footnotes

1. Relative time is the correction applied in the MAGSAT data processing to the reference frame time (RFT) for the current telemetry minor frame (TMF) in order to obtain the time-tag for each data parameter. (Post-launch note: the RFT for each TMF is found by subtracting the duration of one TMF from the day/time given in bytes 10-16 of the decom data record for that TMF.) The duration of one TMF is 960 bits times the current bit duration obtained from the clock coefficients. Nominally, one bit duration is 0.5120256 ms so that one TMF duration is 491.5446 ms.

   Time-tags for scalar and vector magnetometer measurements for a given TMF are computed as follows:

   $$t = RFT + RELATIVE\ TIME$$

   where RFT is computed as described above and is associated with the trailing edge of the last bit (bit 23) of the 24-bit synchronization word from the previous TMF. Relative time is $(\Delta TM - \Delta TR - 1)T$.

   ΔTM is the number of bits between bit 23 of the synchronization word and the first bit of the measurement reading in the same TMF.

   ΔTR is the number of bits between real or effective aperture center and the first bit of the measurement reading.

   For the scalar magnetometer, ΔTR is a function of the command word associated with the accumulation time for the cycle counter.

   Thus for SMAG A, $\Delta TR = \Delta TRA + 30 - (NA + 1)$
   and for SMAG B, $\Delta TR = \Delta TRB + 30 - (NB + 1)$

where ΔTRA = 513.0 bits

ΔTRB = 773.0 bits

30 bits = half width of instrument aperture for default accumulation time

NA,NB= command words for accumulation times (default NA = NB = 29). For the lifetime of MAGSAT, the SMAG accumulation times were kept at the default values of NA = NB = 29).

T is the duration of one telemetry bit. (Nominally, the telemetry bit rate is 1953.02734375 Hz so that T = 0.5120256 ms). Reference Applied Physics Laboratory Document #7249-9047 "Design Specification for Magsat Spacecraft Telemetry Subsystem" Issue A, April 21, 1978.

2. The time-tags for the vector magnetometer data from axes A, B, C are always such that the time-tag for axis A is 2.34 bits or 1.20 ms earlier than that for axis B. Similarly, the time-tag for axis B is 2.34 bits or 1.20 ms earlier than that for axis C. An example is given for the first readout of LSB A, B, C in the TMF. However, in the MDPS the time-tag for axis B was applied in all cases to axes A and C, since the resulting simplification was considered worth the loss in accuracy of ± 1.2 ms for the time-tags of axes A and C.

APPENDIX B - CLOCK COEFFICIENT TAPE FORMAT

This appendix defines the record format of the clock coefficient tape, 9-track, 6250-bpi tape with the following attributes: RECFM = FB, LRECL = 44, BLKSIZE = 2240, DEN = 4.

Displacement (bytes)	Parameter	Type
0	Value of the spacecraft clock at the beginning of the fit inverval	R*8
8	Value of the spacecraft clock at the end of the fit interval	R*8
16	First coefficient of the clock fit	R*8
24	Second coefficient of the clock fit	R*8
32	Third coefficient of the clock fit	R*8
40	Start day of fit	I*4

APPENDIX C - ORBIT (EPHEM) TAPE FORMAT

This appendix defines the record format for the 9-track, 1600-bpi EPHEM tapes which contain MAGSAT ephemeris (orbit) data. There is exactly one file per tape. The file consists of a file title record, data records, and a sentinel record. The attributes of the tape are RECFM = VBS, LRECL = 2804, BLKSIZE = 2808, DEN = 3.

The record formats are as follows:

FILE TITLE RECORD:

Displacement (bytes)	Parameter	Type	Units
0	Not used	--	--
	The next three items give the start time of the ephemeris.		
24	Date	R*8	YYMMDD
32	Day count of year	R*8	Days from Jan 0
40	Seconds of day	R*8	Seconds
	The next three items give the end time of the ephemeris.		
48	Date	R*8	YYMMDD
56	Day count of year	R*8	Days from Jan 0
64	Seconds of day	R*8	Seconds
72	Δt, interval between data points	R*8	Seconds
80	Not used	--	--
	The next six items give the initial conditions (elements epoch).		
344	Year (last two digits)	R*8	YY
352	Month	R*8	Months

Displacement (bytes)	Parameter	Type	Units
360	Day	R*8	Days
368	Hour	R*8	Hours
376	Minutes	R*8	Minutes
384	Seconds x 1000	R*8	Seconds
392	Not used	--	--
1568	Greenwich hour angle at epoch given in Bytes 24, 32, 40.	R*8	Radians
1576	Not used	--	--

DATA RECORD FORMAT

Displacement (bytes)	Parameter	Type	Units
	The first three items give the time, t, of the first ephemeris point.		
0	Date	R*8	YYMMDD
8	Day count of year	R*8	Days from Jan 0
16	Seconds of day	R*8	Seconds
24	Δt, interval between data points	R*8	Seconds
32	X } Position vector components at time t	R*8	DUL
40	Y } Position vector components at time t	R*8	DUL
48	Z } Position vector components at time t	R*8	DUL
56	$\dot{X}$ } Velocity vector components at time t	R*8	DUL/DUT
64	$\dot{Y}$ } Velocity vector components at time t	R*8	DUL/DUT
72	$\dot{Z}$ } Velocity vector components at time t	R*8	DUL/DUT
80	49 sets of position and velocity vector components at times $t + \Delta t$, $t + 2\Delta t$, ..., $t + 49\Delta t$ (48 bytes per set)	R*8	DUL, DUL/DUT

Displacement (bytes)	Parameter	Type	Units
2432	Time, t, of first ephemeris point in DUT	R*8	DUT
2440	Δt, interval between data points in DUT	R*8	DUT
2448	Zeros (not used)	--	--

NOTE: DODS = Definitive Orbit Determination System

DUL = DODS Units of Length = Decamegameter = 10,000 km

DUT = DODS Units of TIME = $\frac{1}{100}$ day = 864 seconds

SENTINEL RECORD FORMAT:

Displacement (bytes)	Parameter	Type	Units
0	Sentinel indicator (0.99999999999999999D16)	R*8	--
80	Not used	--	--

APPENDIX D - ATTITUDE TAPE FORMAT

This appendix defines the record formats for the MAGSAT 9-track, 1600-bpi attitude tape provi^d^d by IPD. Each tape will contain 24 hours worth of data in files spanning 12 hours. The file consists of a single file title record followed by data records. The attributes of the tape are RECFM = F, LRECL = 3492, BLKSIZE = 3492, DEN = 3.

File Title Record Format:

Displacement (bytes)	Parameter	Default	Type	Units
0	Spacecraft identification	E8	L*1	--
1	Data mode (1 = intermediate; 2 = fine; 3 = quicklook	1	L*1	--
2	Data type	2	L*1	--
3	Running number of records in a block	0	I*2	--
5	Zero fill	0	--	--
8	Running number of records in a transmission	0	I*2	--
10	Zero fill	0	--	--
12	Date processed and number of times reprocessed, right justified	0	I*4	YYDDDHHNN
16	Start time of data in a block	0	I*4	YYDDDHHMM
20	Stop time of data in a block	0	I*4	YYDDDHHMM

Displacement (bytes)	Parameter	Default	Type	Units
24	Day of year of the start time of the first valid data point written in this transmission	0	I*2	Days from Jan 0
26	Msec of day of the start time of the first valid data point written in this transmission	0	I*4	Milliseconds
30	Data set type	99	I*2	--
32	Zero fill	0	--	--
34[1]	Day of year of the stop time of the last valid data point written in this transmission	0	I*2	Days from Jan 0
36[1]	Msec of day of the stop time of the last valid data point written in this transmission	0	I*4	Milliseconds
40	Attitude type flag =1, intermediate =2, fine =3, quicklook	1	I*4	--
44	Zero fill	0	--	--

DATA RECORD FORMAT:

Displacement (bytes)	Parameter	Default	Type	Units
0	Same as title record			
12	Date processed and number of times reprocessed	0	I*4	YYDDDHHNN

[1] These values are incorrect on early fine attitude tapes.

Displacement (bytes)	Parameter	Default	Type	Units
16	Start time of data in a block	0	I*4	YYDDDHHMM
20	Stop time of data in a block	0	I*4	YYDDDHHMM
24	Day of year of first valid data point in record	0	I*2	Day count from Jan 0
26[1]	Msec of day of first valid data point in record, t	0	I*4	Milliseconds
30	Data set type	98	I*2	--
32	Interval between data points, Δt		R*4	Milliseconds
36	Zero fill	0	--	--
38	Day of year of last valid data point of record	0	I*2	Days from Jan 0
40	Msec of day of last valid data point of record	0	I*4	Milliseconds
44	Processing flags for each of the 128 data points contained in the record (for fine attitude only; for definition of the flag, see page D-5)	--	I*2	--
300[2]	For time=start time, first component of the quaternion which transforms from sensor platform (A_v, B_v, C_v) to celestial coordinates (true of date), subject to the constraint that the fourth component be positive	-9.999	R*4	--

Displacement (bytes)	Parameter	Default	Type	Units
304	Second component of the quaternion	-9.999	R*4	--
308	Third component of the quaternion	-9.999	R*4	--
312	First component of the quaternion which transforms from optical bench to sensor platform coordinates, subject to the constraint that the fourth component be positive	-9.999	R*4	--
316	Second component of the quaternion	-9.999	R*4	--
320	Third component of the quaternion	-9.999	R*4	--
324	127 sets of quaternions (same as bytes 300-323) for time t + Δt, t + 2Δt, . . . , t + 127Δt (48 bytes per set)	-9.999	R*4	--
3372	Zero fill	--	--	--

Post-launch notes:

[1] For intermediate quaternions, time-tags were in error by 461 milliseconds.

[2] In order to maintain fourth quaternion precision for fine attitude data, all four quaternion elements were packed in 12-byte fields (e.g., for first quaternion set--bytes 300 to 311).

PROCESSING FLAG DEFINITION

A five-digit processing flag, ±abcde, is defined as follows:

Character	Description
a	Smoothing character (level of smoothing of final attitude): = 0, no smoothing = 1, linear smoothing = 2, nonlinear smoothing
b	Residual character: = 0, all residuals within boundaries = 1, QUEST[1] residual and SC1 acceptable, SC2 bad = 2, QUEST residual acceptable, SC1 bad, SC2 acceptable = 3, QUEST residual acceptable, SC1 and SC2 bad = 4, QUEST residual bad, SC1 and SC2 acceptable = 5, QUEST residual bad, SC1 acceptable, SC2 bad = 6, QUEST residual and SC1 bad, SC2 acceptable = 7, QUEST residual SC1, and SC2 bad
c	Gyro and ATS character: = 0, observed gyro point, observed ATS point = 1, observed gyro point, interpolated ATS point = 2, observed gyro point, default ATS value = 3, interpolated gyro data, observed ATS point = 4, interpolated gyro data, interpolated ATS point = 5, interpolated gyro data, default ATS value = 6, gyro data point invalid, observed ATS point = 7, gyro data point invalid, interpolated ATS point = 8, gyro data point invalid, default ATS value
d	Attitude computation character (method of final attitude computation): = 0, with QUEST, using three vectors = 1, with QUEST, using SC1 and SC2 = 2, with QUEST, using SC1 and FSS = 3, with QUEST, using SC2 and FSS = 4, using SC1 and gyro = 5, using SC2 and gyro = 6, using FSS and gyro = 7, not computed

[1]QUEST refers to the attitude determination least-squares program.

Character	Description
e	Pattern matching character: = 0, SC1 and SC2 valid, identified = 1, SC1 valid, identified; SC2 valid, not identified = 2, SC1 valid, identified; SC2 not valid = 3, SC1 valid, not identified; SC2 valid, identified = 4, SC1 valid, not identified; SC2 valid, not identified = 5, SC1 valid, not identified; SC2 not valid = 6, SC1 not valid; SC2 valid, identified = 7, SC1 not valid; SC2 valid, not identified = 8, SC1 not valid; SC2 not valid

APPENDIX E - CONDENSED ORBIT AND CONDENSED ORBIT/ ATTITUDE TAPE FORMAT

This appendix defines the record formats for the condensed orbit and condensed orbit/attitude tapes. The condensed orbit tape is a 9-track, 6250-bpi tape with the following attributes: RECFM = FB, LRECL = 3906, BLKSIZE = 15480, DEN = 4. It is made up of orbit records only. The condensed orbit/attitude tape is a 9-track, 6250-bpi tape with the following attributes: RECFM = VBS, LRECL = 3388, BLKSIZE = 16944, DEN = 4.

Record formats are as follows:

ORBIT RECORD:

Displacement (bytes)	Parameter	Type	Units
0	Zero fill	I*4	
4	Modified Julian Day of first data value	I*4	MJD (See Glossary)
8	Milliseconds of day of first data value	I*4	Milliseconds
12	Time increment between observations	R*4	Milliseconds
16	Reference time of coordinate system (epoch) for GHA corresponding to date in byte 24, page C-1.	R*4	MJD at $0^h 0^m 0^s$ UTC
20	Greenwich hour angle (GHA) at epoch	R*4	Radians
24	Position vector X (128 values)	R*4	km
536	Position vector Y (128 values)	R*4	km
1048	Position vector Z (128 values)	R*4	km
1560	Invariant latitude (128 values)	R*4	Degrees

Displacement (bytes)	Parameter	Type	Units
2072	Geomagnetic time (128 values)	R*4	Hours
2584	Dip latitude (128 values)	R*4	Degrees

ATTITUDE RECORD:

Displacement (bytes)	Parameter	Type	Units
0	Attitude quality indicator = 1, intermediate = 2, fine = 3, quicklook	I*4	--
4	Modified Julian Day of first observation	I*4	MJD (See Glossary)
8	Milliseconds of day of first observation	I*4	Milliseconds
12	Time increment between observations	R*4	Milliseconds
16	Date data was processed and number of times reprocessed	I*4	YYDDDHHNN
20	Number of sets of quaternions in the data record	I*4	
[1] 24	First component of quaternion that transforms from sensor platform (A_v, B_v, C_v) coordinates to celestial true-of-date geocentric coordinates (CC) at start time (240 values)	R*4	--
[1] 984	Second component of the quaternion defined above (240 values)	R*4	--
[1] 1944	Third component of the quaternion defined above (240 values)	R*4	--

Displacement (bytes)	Parameter	Type	Units
2904	Attitude quality flags (240 values; see page D-5)	I*2	--

[1]In order to maintain fourth quaternion precision for fine attitude data (byte 0=2), all four components of a quaternion set are packed in 12-byte fields. The 12-byte field is defined by concatenating those bytes designated for the three components for a given quaternion set, (e.g., the first set is packed in bytes 24, 984, and 1944; the second set in bytes 28, 988, and 1948).

APPENDIX F - INPUT DIRECTORY DESCRIPTION

Figure F-1 is a synoptic view of input directory record organization, and Figure F-2 is a detailed description of record organization.

Record 1	Housekeeping Parameters
Record 2	Record numbers for first and last entries for CLOCK, EPHEM, CORB, CO/A
Record 3	Record numbers for first and last entries for ATTITUDE (Days 1-18)
Record 4	Record numbers for first and last entries for ATTITUDE (Days 19-36)
	≈
Record 16	Record numbers for first and last entries for ATTITUDE (Days 235-252)
Record 17	Record numbers for first and last entries for DECOM (Days 1-18)
Record 18	Record numbers for first and last entries for DECOM (Days 19-36)
	≈
Record 30	Record numbers for first and last entries for DECOM (Days 235-252)
Record 31	Pool of Blank Tapes (1-9)
Record 32	Pool of Blank Tapes (10-18)
Record 33	Input Entry
	≈
Record 3200	Input Entry

Figure F-1. Synoptic View of Input Directory Record Organization

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RECORD 1

Displacement (bytes)	Description	Type
0	Program name for last update (EBCDIC)[1]	R*8
8	Date of first update (YYDDD)[2]	I*2
10	Date of last update (YYDDD)[2]	I*2
12	Number of logical records allocated	I*2
14	Last logical record used	I*2
16	Number of entries deleted	I*2
18	Number of logical records reused	I*2
20	Number of clock entries	I*2
22	Number of EPHEM entries	I*2
24	Number of condensed orbit (CORB) entries	I*2
26	Number of condensed orbit/attitude (CO/A) entries	I*2
28	Number of attitude entries	I*2
30	Number of DECOM entries	I*2
32	Volume serial of first CORB backup (EBCDIC)[1]	R*8
40	Volume serial of second CORB backup (EBCDIC)[1]	R*8
48	Spare	R*8

RECORD 2

Displacement (bytes)	Description	Type
0	Record number for first clock entry	I*2
2	Record number for last clock entry	I*2
4	Record number for first EPHEM entry	I*2
6	Record number for last EPHEM entry	I*2
8	Record number for first CORB entry	I*2
10	Record number for last CORB entry	I*2

Figure F-2. Detailed Description of Record Organization (1 of 4)

RECORD 2 (Continued)

Displacement (bytes)	Description	Type
12	Record number for first CO/A entry	I*2
14	Record number for last CO/A entry	I*2
16	Spare	

RECORD 3

0	Record number for first attitude entry for Day 1	I*2
2	Record number for last attitude entry for Day 1	I*2
4	Record number for first attitude entry for Day 2	I*2
6	Record number for last attitude entry for Day 2	I*2
...	...	
68	Record number for first attitude entry for Day 18	I*2
70	Record number for last attitude entry for Day 18	I*2

...

RECORD 16 - has attitude information for Days 235-252

RECORD 17 - has DECOM information for Days 1-18

...

RECORD 30 - has DECOM information for Days 235-252

RECORD 31-32 - contains volume serial numbers for 18 blank tapes (8 bytes per tape)

RECORD 33-3200 - INPUT entries described on the next page

Figure F-2. Detailed Description of Record Organization (2 of 4)

INPUT ENTRY FORMAT

Displacement (bytes)	Description	Type
0	Program name making entry (EBCDIC)[1]	R*8
8	Volume serial number of input tape (EBCDIC)[1]	R*8
16	Record number for the next entry in the link	I*2
18	= True, record available for reuse = False, record occupied	L*1
19	= True, input tape in box storage or other = False, input tape in data base	L*1
20	Number of times entry updated	I*2
22	=0, Intermediate =1, Fine =2, Quicklook } for attitude only	L*1
23	Type of input 1 = Clock 2 = EPHEM 3 = CORB 4 = CO/A 5 = Attitude 6 = DECOM	L*1
24	Date of entry in directory (YYDDD)[2]	I*2
26	File number	L*1
27	Input Preprocessing Status Flag (details to be determined)	L*1
28	Start day (relative to launch)	I*2
30	End day (relative to launch)	I*2
32	Start time (milliseconds of day)	I*4
36	End time (milliseconds of day)	I*4
40	Edit version number (DECOM only, see Appendix A)	I*2

Figure F-2. Detailed Description of Record Organization (3 of 4)

Input Entry Format (Continued)

Displacement (bytes)	Description	Type
42	Feet of tape used	I*2
44	Number of SMAG sequences for DECOM number of records for EPHEM and attitude	I*2
46	Date of processing by CRONICLE - DECOM only (YYDDD)[2]	I*2
48	Percent pad for DECOM and EPHEM; percent pad and/or missing time for attitude	L*1
49	Percent time continuity errors for DECOM	L*1
50	Percent time consistency errors for DECOM	L*1
51	CRONICLE program status flag (see Section 4.2.14)	L*1
52	Comments (EBCDIC)	--
62	Spare	--

NOTES: 1. All EBCDIC entries are left justified and padded with blanks on right, if necessary.

2. YY = years since 1979.

Figure F-2. Detailed Description of Record Organization (4 of 4)

APPENDIX G - CHRONICLE TAPE FORMAT

This appendix ccntains the record formats for the chronicle tape generated by the MDPS CRONICLE program. The DCB for this 9-track, 6250-bpi tape will be RECFM = VBS, LRECL = 4126, BLKSIZE = 28886, DEN = 4. Up to nine types of records will be merged in time order on this tape: one orbit and one scalar data record, three vector component records (in units of counts, spacecraft coordinates), three vector component records (in units of gammas, NEV coordinates), and one corresponding record for attitude quality.

An orbit data record will precede a group of scalar, vector, and attitude quality data records which lie within the orbit time interval (128 minutes). Scalar and vector data records will also be time ordered. A scalar data record will be followed by a set of vector component data records if each is available within the time span of the orbit record. A chronicle tape may contain vector component records in either or both coordinate systems. Vector component records in NEV coordinates generated from fine attitude data will be immediately followed by an attitude quality record which will describe the accuracy of the attitude data used in transforming the vector component data to topocentric coordinates.

The orbit data record format is as follows:

Displacement (bytes)	Parameter	Type
0	Data type = 0, indicating satellite position data	L*1
1	Data type of next record (on investigator copy only)	L*1
2	Spare	
4	MJD of first observation (See Glossary)	I*4
8	Milliseconds of day for first observation (ms)	I*4
12	Time increment between observations	I*4
16	Reference time of coordinate system (epoch) for GHA (MJD at $0^h 0^m 0^s$ UTC)	R*4
20	Greenwich hour angle at epoch (radians)	R*4
24	X inertial coordinate (km, 128 values)	R*4
536	Y inertial coordinate (km, 128 values)	R*4
1048	Z inertial coordinate (km, 128 values)	R*4
1560	Invariant latitude (degrees, 128 values)	R*4
2072	Geomagnetic time (hours, 128 values)	R*4
2584	Dip latitude (degrees, 128 values)	R*4

The CRONICLE scalar data record format is as follows:

Displacement (bytes)	Parameter	Type
0	Data type = 1, indicating scalar observations	L*1
1	Data type of next record (on investigator copy only)	L*1
2	Spacecraft status (five-digit integer - abcde) a = 1, calibration on b = 1, electronic flip on c = 1, x-coil on d = 1, y-coil on e = 1, z-coil on	I*2
4	MJD of first observation (See Glossary)	I*4
8	Milliseconds of day of first observation (ms)	I*4
12	Time increment between observation (ms)	R*4
16	[1]Time offset (ms - correction to measurement time)	R*4
20	Spare	I*4
24	Scalar observations (gammas - 512 values)	R*4
2072	Number of points in this record which fall into the time span of the next scalar record	I*2

The vector data (sensor platform coordinates) CRONICLE record format I follows:

Displacement (bytes)	Parameter	Type
0	Data type = 2, 3, 4, indicating vector a, b, or c observations, respectively	L*1
1	Data type of next record (on investigator copy only)	L*1
2	Spacecraft status (five-digit integer - abcde)	I*2
	a = 1, calibration on	
	b = 1, electronic flip on	
	c = 1, x-coil on	
	d = 1, y-coil on	
	e = 1, z-coil on	
4	MJD of first observation (See Glossary)	I*4
8	Milliseconds of day of first observation (ms)	I*4
12	Time increment between observations (ms)	R*4
16	[1]Time offset (ms - correction to measurement time)	R*4
20	Spares	I*4
24	Fine counts (1024 values, pad = 9999)	I*2
2072	Coarse counts (1024 values, pad = 255)	L*1
3096	Number of points in this record which falls into the time span of the next record of this type	

The vector data (NEV coordinates) CRONICLE record format is as follows:

Displacement (bytes)	Parameter	Type
0	Data type: = 5, 6, 7, indicating vector x, y, or z (i.e., NEV) observations, respectively, generated from intermediate attitude data; = 8, 9, 10, for data generated from fine attitude data	L*1
1	Data type of next record	L*1
2	Spacecraft status (see record types 2-4)	I*2
4	MJD of first observation (See Glossary)	I*4
8	Milliseconds of day of first observation (ms)	I*4
12	Time increment between observations (ms)	R*4
16	[1]Time offset (ms - correction to measurement time)	R*4
20	Spare	
24	Vector component observations (gammas; 1024 values, pad = 99999.0)	R*4
4120	Number of points in this record which fall into the time span of the next record of this type	I*2

The attitude quality CRONICLE record format is as follows:

Displacement (bytes)	Parameters	Type
0	Data type = 16, indicating attitude quality data	L*1
1	Data type of next record (on investigator copy only)	L*1
2	Spare	I*2
4	MJD of first observation (See Glossary)	I*4
8	Milliseconds of day of first observation (ms)	I*4
12	Time increment between observations (ms)	R*4
16	[2]Time offset (ms - correction to measurement time)	R*4
20	Spare	I*4
24	Attitude processing flags, 256 values, synchronized with every fourth vector observation starting with first observation of vector record; see page D-5 for flag definition	I*2

[1]The "time offset" for scalar and vector records represents the amount of time subtracted from the scalar magnetometer time-tags so as to adjust these to be identical to the nearly simultaneous vector magnetometer time-tags. Adding the value of the time offset to the scalar magnetometer time-tags would reproduce the time-tags as they appear after the "relative time" corrections. The observation times for the scalar magnetometer actually occur 0.8 ms after those for the vector magnetometer. The time offset values for the scalar magnetometer of 0, +1, or +2 ms represent the 0.8 ms true offset. In addition, for both scalar and vector, the time offset represents fluctuations due to roundoff to the nearest millisecond in the IPD-provided times and to other factors.

[2]For the attitude quality records, the time offset represents the amount subtracted from attitude processing flag time-tags in order to make vector and attitude quality record time (byte 8) identical.

APPENDIX H - QUICKLOOK TAPE FORMAT

This appendix contains the record formats for the 9-track, 16000-bpi quicklook tape generated by the CRONICLE program. The DCB of the tape will be RECFM = VBS, LRECL = 468, BLKSIZE = 31828, DEN = 3.

Quicklook data will be stored on tape on an absolute file basis. There will be three types of records. The first record will be an absolute file title record summarizing the data content for the absolute file.

Displacement (bytes)	Parameter	Type
0	MJD of absolute file (See Glossary)	I*4
4	Start milliseconds of absolute file	I*4
8	End milliseconds of absolute file	I*4
12	DECOM minor frame rate (milliseconds)	R*4
16	Station number	I*4
20	Absolute file number	I*2
22	DECOM run number	I*2
24	DECOM reel number	I*2
26	DECOM file number	I*2
28	Year (YY) of quicklook run	I*2
30	Day of year (DDD) of quicklook run	I*2
32	DECOM tape serial number (EBCDIC)	R*8

The second type of quicklook record will contain engineering data for a scalar analog subcom sequence of 32 DECOM minor frames or records. This record will precede a group of records of type 3 containing quicklook scalar or vector measurements. The record format for type 2 is given below.

Displacement (bytes)	Parameter	Type
0	Milliseconds of day	I*4
4	CRONICLE program scalar data status flag (summary of preliminary data checks)	I*4
8	CRONICLE program vector data status flag (summary of preliminary data checks)	I*2
10	Scalar subcom[1] (32 values)	L*1
42	Analog subcom[1] (32 values)	L*1
74	Analog subcom[1] (32 values)	L*1
106	Analog subcom[1] (32 values)	L*1
138	Analog subcom[1] (32 values)	L*1
170	Digital subcom[1] (32 values)	L*1
202	Digital subcom[1] (32 values)	L*1
234	Spacecraft clock value	I*4

The third type of quicklook record will contain either scalar or vector data. Two scalar measurements (one from each side) or three vector components and their differences from theoretical values are contained in each record whose format is given below. Padded or rejected measurements are set to 9999.0.

[1]Subcom data are 8-bit words, stored on DECOM tape, which provide digital and analog data concerning spacecraft status. Thirty-two words will be stored for each subcom.

The scalar data quicklook record format is as follows:

Displacement (bytes)	Parameter	Type
0	Set to 1	I*4
4	Milliseconds of day	I*4
8	Scalar A value	R*4
12	Scalar A difference from theoretical value	R*4
16	Scalar B value	R*4
20	Scalar B difference from theoretical value	R*4

The vector data quicklook record format is as follows:

Displacement (bytes)	Parameter	Type
0	Set to 2	I*4
4	Milliseconds of day	I*4
8	X component value	R*4
12	X difference from theoretical field	R*4
16	Y component value	R*4
20	Y difference from theoretical field	R*4
24	Z component value	R*4
28	Z difference from theoretical field	R*4

When all of the data for an absolute file has been written onto the tape, an "end-of-absolute-file" marker will be written. This will be a scalar/vector data record with the value -999 contained in the first four bytes.

Record Number	Type	Description
1	1	File title
2	2	Engineering data
3 to N	3	Quicklook scalar/vector data
N + 1	delimiter	(Zero fill data record)
N + 2	2	Engineering data
N + 3 to M	3	Quicklook scalar/vector data
M + 1	delimiter	(Zero fill)

⋮

End of Absolute File (first 4-byte word = -999)

APPENDIX I - QUALITY CATALOG FORMAT

MAGSAT satellite engineering data and CRONICLE program data processing statistics will be stored on a quality catalog tape (9-track, 6250-bpi).

There will be two types of records on a quality catalog tape: an absolute file title record followed by a set of quality data records corresponding to the absolute file referenced in the title record. Each quality data record consists of engineering data and processing statistics related to two major frames of telemetry (Decom) 4.2-min data.

The DCB of the tape will be RECFM = VBS, LRECL = 774, BLKSIZE = 30964, DEN = 4.

The data record formats are shown below.

ABSOLUTE FILE TITLE RECORD FORMAT

Bytes 0 to 57 contain header information, bytes 58 to 163 contain summary statistics, bytes 164 to 387 contain scalar data summary, bytes 388 to 523 contain vector data summary, and bytes 524 to the end contain CRONICLE run parameters.

Displacement (bytes)	Parameter	Type
0	Start MILS	I*4
4	Stop MILS	I*4
8	Start MJD (see Glossary)	I*4
12	MJD of CRONICLE run (see Glossary)	I*4
16	DECOM minor frame rate	R*4
20	Absolute file number	I*2
22	Number of quality records	I*2
24	Number of amplitude records	I*2
	4 bytes spare	---

Displacement (bytes)	Parameter	Type
30	DECOM data overlap flag: 0 - no overlap 1 - overlap	I*2
32	Attitude type used in run: 0 - intermediate 1 - fine	I*2
34	DECOM run number	I*2
36	DECOM file number	I*2
38	DECOM reel number	I*2
40	DECOM tape label	R*8
48	Station ID (EBCDIC)	I*4
52	DECOM generation ID	I*2
54	DECOM edit ID	I*2
56	DECOM version number	I*2
58	[1]Total SMAG sequences in file	I*2
60	Total SMAG sequences accepted	I*2
62	2 bytes spare	
64	[2]Total SMAG sequences rejected	I*2
66	Total SMAG sequences of scalar data edited (see Sections 4.3 and 4.4)	I*2
68	Total SMAG sequences of vector data edited	I*2

[1]SMAG sequence - 32 DECOM minor frames containing both scalar and vector data.

[2]A distribution of rejected sequences for each type of rejection is given in bytes 70-82. This list is inclusive except for the number of sequences rejected due to both scalar and vector data edited (Sections 4.3 and 4.4).

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
	Total SMAG sequences rejected due to	
70	Pad sequence (see Section 4.2.3)	I*2
72	Bad frame count (see Appendix A, page A-2, frame quality word)	I*2
74	No start time for sequence	I*2
76	Duplicate sequence	I*2
78	No major frame found	I*2
80	S/C clock error (see Section 4.2.3)	I*2
82	Scalar and vector data rejected in telemetry checks (see Section 4.2)	I*2
84	2-byte spare	--
86	Total DECOM frames padded	I*2
88	[1]Total number of scalar/vector differences (absolute value) >0 and ≤ SV3	I*4
92	Total number . . . >SV3 and ≤ SV3 + 3	I*4
96	Total number . . . >SV3 + and ≤ SV3 + 10	I*4
100	Total number >SV3 + 10	I*4
	Percent of total sequences with	
104	Star camera 1 on	I*2
106	Star camera 2 on	I*2

[1]SV3 - scalar/vector compare tolerance (default = 3 gammas). See Section 4.4.1.

ABSOLUTE FILE TITLE RECCRD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
108	x-coil on	I*2
110	y-coil on	I*2
112	z-coil on	I*2
114	2-byte spare	I*2
	Analog Subcom:	
116, 118, 120	Minimum x-, y-, z-coil currents	3(I*2)
122, 124, 126	Maximum x-, y-, z-coil currents	3(I*2)
128	Minimum clock fit error	I*2
130	Maximum clock fit error	I*2
132	[1]Total vector points rejected (before outlier test) where only one or two components accepted	I*4
	Sum of the squares (SOS) of residuals of data compared to field model:	
136	Scalar A (total points used in byte 192)	R*4
140	Scalar B (total points used in byte 196)	R*4
144	Vector x (total points used in byte 408)	R*4
148	Vector y (total points used in byte 412)	R*4
152	Vector z (total points used in byte 416)	R*4
156	Number of vector points rejected due to missing ephemeris data	I*4
160	Number of vector points rejected due to missing attitude data	I*4

[1]If any component is rejected due to parity errors or course counter change (Sections 4.2.11, 4.2.12), the entire measurement is rejected since all three components are necessary for the vector coordinate transformations (Sections 4.3.3, 4.3.5).

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
164	Total number of sequences where scalar data accepted	I*2
166	[1]Total number of sequences where scalar data rejected	I*2
	Total number of sequences where scalar data rejected due to	
168	No accumulation time found	I*2
170	Tracking files unlock	I*2
172	Lamp brightness bad	I*2
174	Amplitude bad	I*2
176	Cell photocurrent bad	I*2
178	Lamp temperature bad	I*2
180	Cell temperature bad	I*2
182	Scalar power off	I*2
184	Both power converters off	I*2
186	Both power converters on	I*2
188	Lamps off	I*2
190	No data in sequence	I*2
192	Total scalar A points accepted	I*4
196	Total scalar B points accepted	I*4
200	[2]Total scalar A points rejected	I*4
204	Total scalar B points rejected	I*4

[1]Total includes bytes 168 thru 190, and byte 66.

[2]Total includes bytes 208 thru 220, bytes 70 thru 82 times 64 (64 scalar A points to a sequence), bytes 168 thru 190 times 64, byte 86 times 2 (two scalar A points to a minor frame), and the total number of scalar A points rejected due to missing ephemeris.

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
	Total scalar points rejected (side A) due to	
208	Parity (Section 4.2.7)	I*4
212	Data quality (bit 19, Section 4.2.7)	I*4
216	Reference (Section 4.4.2)	I*4
220	Outlier (Section 4.4.4)	I*4
224-236	Points rejected (side B) due to parity, etc. (see side A)	4(I*4)
	Percent of total sequences with	
240	Sensor baseplate heater on	I*2
242	Heater A1 on	I*2
244	Heater A2 on	I*2
246	Heater A3 on	I*2
248	Heater B1 on	I*2
250	Heater B2 on	I*2
252	Heater B3 on	I*2
254	Power converter A on	I*2
256	Power converter B on	I*2
258	Scalar power A on	I*2
260	Scalar power B on	I*2
262	Tracking filter A on	I*2
264	Tracking filter B on	I*2

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
266	Lamp A on	I*2
268	Lamp B on	I*2
	Scalar analog suboom (minimum, raw count form)	
270	Lamp RF A	I*2
272	Lamp RF B	I*2
274	Voltage monitor 1	I*2
276	Voltage monitor 2	I*2
278	Voltage monitor 3	I*2
280	Coil photocurrent A1	I*2
282	Coil photocurrent A2	I*2
284	Coil photocurrent B1	I*2
286	Coil photocurrent B2	I*2
288	Cell temperature A1	I*2
290	Cell temperature A2	I*2
292	Cell temperature B1	I*2
294	Cell temperature B2	I*2
296	Lamp temperature A	I*2
298	Lamp temperature B	I*2
300	Lamp brightness A	I*2
302	Lamp brightness B	I*2

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
304	Signal amplitude A	I*2
306	Signal amplitude B	I*2
308-344	Scalar analog subcom (maximum) of Lamp RF A, etc. (see minimum)	19(I*2)
346-382	Scalar analog subcom (average) of Lamp RF A, etc. (see minimum)	19(I*2)
384	Command word for scalar A accumulation time (NA) (see Section 4.3.1)	I*2
386		I*2
388	Command word for scalar B accumulation time (NB) (see Section 4.3.1)	
		I*2
390	Total number of sequences where vector data accepted	
		I*2
	[1]Total number of sequences where vector data rejected	
392	Total number of sequences where vector data rejected due to	I*2
394	Vector power off	I*2
396	-12 voltage bad	I*2
398	+12 voltage bad	I*2
400	Optical bench temperature low	I*2
402	Sensor temperature A bad	I*2
404	Platform temperature A bad	I*2
406	Sensor temperature B bad	I*2
	Platform temperature B bad	

[1]Total includes bytes 393 thru 406 and byte 68.

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
408	Total vector x accepted	I*4
412	Total vectory y accepted	I*4
416	Total vector z accepted	I*4
420	[1]Total vector x rejected	I*4
424	Total vector y rejected	I*4
428	Total vector z rejected	I*4
	Total vector x rejected due to	
432	Parity (Section 4.2.11)	I*4
436	Coarse count change (Section 4.2.12)	I*4
440	Outlier (Section 4.4.4)	I*4
444-452	Total vector y rejected (see vector x)	3(I*4)
456-464	Total vector z rejected (see vector x)	3(I*4)
	Percent of total sequences with	
468	2-byte spare	---
470	2-byte spare	---
472	Platform heater A on	I*2
474	Platform heater B on	I*2
476	Digital A on	I*2
478	Digital B on	I*2
480	Analog A on	I*2

[1]Total includes bytes 432 thru 440, bytes 70 thru 80 times 256 (256 vector points per sequence), bytes 392 thru 406 times 256, byte 86 times 8 (8 vector points per minor frame), bytes 156 and 160.

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (byte)	Parameter	Type
482	Analog B on	I*2
484	Electronic flip (reverse mode)	I*2
486	Calibration mode	I*2
	Vector analog subcom (minimum, in raw count form)	
488	+12 voltage monitor	I*2
490	-12 voltage monitor	I*2
492	Sensor temperature A	I*2
494	Sensor temperature B	I*2
496	Platform temperature A	I*2
498	Platform temperature B	I*2
500-510	Vector analog subcom (maximum - see minimum values)	6 (I*2)
512-522	Vector analog subcom (average - see minimum values)	6 (I*2)
	CRONICLE Program Run Parameters	
524	Calibration data set (EBCDIC, Appendix N)	R*8
532	Time tolerance for S/C clock check (Section 4.2.3)	I*4
536	Scalar reference test tolerances: E1, E2, E3 (2) (Section 4.4.2)	4 (R*4)
	E1 - Upper limit for low amplitude condition in reference test (default = 1)	

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
	E2 - Adjustment to reference error tolerance during low amplitude condition (default = 1.8)	
	E3(1) - Reference error tolerance for side A; maximum allowable deviation of scalar measurement from theoretical field (default = 500 gammas)	
	E3(2) - E3 value for side B	
552	8-byte spare	--
560	Scalar/Vector outlier tolerances: F4(5), F5(5), F6(5) (one for each data type: scalar A, B and vector X, Y, Z - see Section 4.4.4)	15(R*4)
620	S/V compare tolerance: SV3 (Section 4.4.1)	
624	Vector voltage variance tolerance: VARP (Section 4.2.8)	R*4
628	Vector temperature variance tolerance: VART (Section 4.2.9)	R*4
632	Vector fine counter variance tolerance: FRATE (during electronic flip calibration cycle, vector fine count data are flagged in printout summaries if variance exceeds FRATE, Section 4.2.13)	R*4
636	Valid ranges for accepting scalar data referenced by REJSA: LIMSA (I, J) (Sections 4.2.4 - 4.2.6)	10(R*4)

	Default low/high
I = 1, low	
I = 2, high	
J = 1, cell photocurrent A	0./10. ma
= 2, cell temperature A	48.1/56.° C
= 3, lamp temperature A	36. /60.° C
= 4, signal amplitude A	0. / 5. v
= 5, lamp brightness A	0. /50. ma

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter		Type
676	Same as LIMSA for side B	See LIMSA defaults	10(R*4)
716	Valid data ranges for accepting vector data referenced by REJVA: LIMVA (2,2) (Sections 4.2.8 - 4.2.9) I = 1, low I = 2, high J = 1, VMAG temp. = 2, Platform temp.	 defaults 23. /27. °C 23.3/26.5°C	4*(R*4)
732	Same as LIMVA for system B: LIMVB (2,2)	See LIMVA defaults	4*(R*4)
748	Number of vector points to reject at coarse count change: ICCREJ (Section 4.2.12)		I*4
752	Scalar data rejection flags set to true or false to optionally reject bad or out-of-range data (side A): REJSA(J) (default = false; no data rejected) J = 1, cell photocurrent A = 2, cell temperature A = 3, lamp temperature A = 4, signal amplitude A = 5, lamp brightness A = 6, tracking filter A (unlock status)		6(L*1)
758	Scalar data rejection flags for bad or out-of-range data (side B): REJSB(J). same as for REJSA (side A)		6(L*1)
764	Vector data rejection flags for bad or out-of-range data (system A, voltage): REJVA(J) (default - no data rejected) J = 1, sensor temperature A = 2, platform temperature A = 3, ± 12 voltage monitors		3(L*1)

ABSOLUTE FILE TITLE RECORD FORMAT (CONT'D.)

Displacement (byte)	Parameter	Type
767	Vector data rejection flags for bad or out-of-range data for system B and optical bench REJVB(J) J = 1, 2 (See REJVA) = 3, optical bench temperature low	3(L*1)

QUALITY DATA RECORD FORMAT

Each record contains statistics for two major frames of DECOM data (512 minor frames ~ 4.2 minutes). Bytes 0 to 18 contain the header information, bytes 19 to 43 describe the summary statistics, bytes 44 to 144 contain the scalar data summary, and bytes 145 to 660 contain the vector data summary.

Displacement (bytes)	Parameter	Type
0	Latitude (degrees)	R*4
4	Longitude (degrees)	R*4
8	Altitude (km)	R*4
12	Start time (milliseconds of day)	I*4
16	Absolute file number	I*2
18	Spare byte	---
	Note: Fields in bytes 19-27 are packed - 5 bits to a field.	
19	[1]Total SMAG sequences	
	Total SMAG sequences accepted	

[1]SMAG sequence - 32 DECOM minor frames containing both scalar and vector data.

QUALITY DATA RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
	5-bit spare	
	Total SMAG sequences rejected (see note for byte 64 of file title record)	
	Total SMAG sequences of scalar data edited (see Sections 4.3 and 4.4)	
	Total SMAG sequences of vector data edited (see Sections 4.3 and 4.4)	
	Total SMAG sequences rejected due to	
	Pad sequence (Section 4.2.3)	
	Bad frame count (frame quality word, Appendix A, page A-2)	
	No start time for sequence	
	Duplicate sequence	
	No major frame found	
	S/C clock error (Section 4.2.3)	
	Scalar and vector data rejected in telemetry checks (Section 4.2)	
	5-bit spare	
28	Total DECOM frames padded	I*2
30	Total number scalar/vector differences (absolute values) > SV3 + 10 gammas (see Section 4.4.1)	
	Percent of total sequence with	
32	Star camera 1 on	L*1
33	Star camera 2 on	L*1

QUALITY DATA RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
34	x-coil on	L*1
35	y-coil on	L*1
36	z-coil on	L*1
37	Spare byte	
	Analog subcom (minimum)	
38	x-coil current	L*1
39	y-coil current	L*1
40	z-coil current	L*1
41-43	Analog subcom (maximum); (see minimum values, in the form of raw counts)	3(L*1)
	Note: Fields in bytes 44-52 are packed - 5 bits to a field.	
44	Total number of sequences where scalar data accepted	
	Total number of sequences where scalar data rejected	
	[1]Total number of sequences where scalar data rejected due to	
	No accumulation time found	
	Tracking filter unlock	
	Lamp brightness bad	
	Amplitude bad	
	Cell photocurrent bad	

[1]See note for byte 166 of file title record.

QUALITY DATA RECORD FORMAT (CONT'D.)

Displacement (bytes)	Parameter	Type
	Lamp temperature bad	
	Cell temperature bad	
	Sensor power off	
	Both power converters off	
	Both power converters on	
	Lamps off	
	No data in sequences	
53	Total scalar A points accepted	I*2
55	Total scalar B points accepted	I*2
57	[1]Total scalar A points rejected	I*2
59	Total scalar B points rejected	I*2
	Note: Fields in bytes 61-72 are packed - 12 bits to a field.	
	Total scalar points rejected due to (side A)	
61	Parity (Section 4.2.7)	
	Data quality (bit 19) (Section 4.2.7)	
	Reference (Section 4.4.2)	
	Outlier (Section 4.4.4)	
	Total scalar points rejected due to parity, ... (side B)	
	Percent of total sequence with	
73	Sensor baseplate heater on	L*1

[1]See note for byte 200 of file title record

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
74	Heater A1 on	L*1
75	Heater A2 on	L*1
76	Heater A3 on	L*1
77	Heater B1 on	L*1
78	Heater B2 on	L*1
79	Heater B3 on	L*1
80	Power converter A on	L*1
81	Power converter B on	L*1
82	Scalar power A on	L*1
83	Scalar power B on	L*1
84	Tracking filter A on	L*1
85	Tracking filter B on	L*1
86	Lamp A on	L*1
87	Lamp B on	L*1
	Scalar analog subcom (minimum in raw count form)	
88	Lamp RF A	L*1
89	Lamp RF B	L*1
90	Voltage monitor 1	L*1
91	Voltage monitor 2	L*1
92	Voltage monitor 3	L*1

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Paramter	Type
93	Cell photocurrent A1	L*1
94	Cell photocurrent A2	L*1
95	Cell photocurrent B1	L*1
96	Cell photocurrent B2	L*1
97	Cell temperature A1	L*1
98	Cell temperature A2	L*1
99	Cell temperature B1	L*1
100	Cell temperature B2	L*1
101	Lamp temperature A	L*1
102	Lamp temperature B	L*1
103	Lamp brightness A	L*1
104	Lamp brightness B	L*1
105	Signal amplitude A	L*1
106	Signal amplitude B	L*1
107-125	Scalar analog subcom (maximum; see minimum values)	19(L*1)
126-144	Scalar analog subcom (average; see minimum values)	19(L*1)
	Note: Fields in bytes 145-151 are packed - 5 bits to a field.	
145	Total number of sequences where vector data accepted	
	[1]Total number of sequences where vector data rejected	

[1]See note for byte 390 for file title record.

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
	Total number of sequences where vector data rejected due to	
	Vector power off	
	-12 voltage bad	
	+12 voltage bad	
	Optical bench temperature low	
	Sensor temperature A bad	
	Platform temperature A bad	
	Sensor temperature B bad	
	Platform temperature B bad	
152	Total vector x accepted	I*2
154	Total vector y accepted	I*2
156	Total vector z accepted	I*2
158	[1]Total vector x rejected	I*2
160	Total vector y rejected	I*2
162	Total vector z rejected	I*2
	Total vector x data rejected due to	
164	Parity (Section 4.2.11)	I*2
166	Coarse count change (Section 4.2.12)	I*2
168	Outlier (Section 4.4.4)	I*2
170-174	Total vector y rejected (see vector x)	3(I*2)

[1]See note for byte 420 for file title record.

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
176-180	Total vector z rejected (see vector x)	3(I*2)
	Percent of total sequence with	
182	2-byte spare	--
184	Platform heater A on	L*1
185	Platform heater B on	L*1
186	Digital A on	L*1
187	Digital B on	L*1
188	Analog A on	L*1
189	Analog B on	L*1
190	Electronic flip (reverse mode)	L*1
191	Calibration mode	L*1
	Vector analog subcom (minimum in raw count form):	
192	+12 voltage monitor	L*1
193	-12 voltage monitor	L*1
194	Sensor temperature A	L*1
195	Sensor temperature B	L*1
196	Platform temperature A	L*1
197	Platform temperature B	L*1
198-203	Vector analog subcom (maximum; see minimum values)	6(L*1)
204-209	Vector analog subcom (average; see minimum values)	6(L*1)

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
210	Spacecraft data status flags (preliminary data checks - 16 values - one for each SMAG sequence, Section 4.2.14)	16(L*1)
226	[1]Number of scalar vector differences SV3 (16 values - one for each sequence)	
242	Scalar data status flags (preliminary data checks - 16 values - one for each sequence, Section 4.2.14)	16(I*4)
306	Total scalar points accepted in first sequence	L*1
307	[2]Total scalar points rejected in first sequence	L*1
	Total scalar points rejected in first sequence due to	
308	Parity	L*1
309	Data quality	L*1
310	Reference test	L*1
311	Outlier test	L*1
312	Scalar point distribution for second sequence (see bytes 306-311)	6(L*1)
318,324	Scalar point distribution for third, fourth, . . sequence	13(6(L*1))
395	Scalar point distribution for 16th sequence (see bytes 306-311)	6(L*1)
402	Vector data status flags (preliminary data checks - 16 values - one for each sequence, Section 4.2.14)	16(I*2)
	Total vector points accepted for first sequence:	
434	x component	L*1

[1]SV3 - Scalar/vector compare tolerance (default = 3 gammas). See Section 4.4.1
[2]See note for byte 200 for file title record.

QUALITY DATA RECORD FORMAT (CONT'D)

Displacement (bytes)	Parameter	Type
435	y component	L*1
436	z component	L*1
437-439	[1]Total vector points (per component) rejected in first sequence	3(L*1)
	Total vector points (per component) rejected in first sequence due to	
440-442	Parity	3(L*1)
443-445	Coarse count change	3(L*1)
446-448	Outlier	3(L*1)
449-463	Vector point distribution for second sequence (see bytes 434-448)	15(L*1)
464,479	Vector point distribution for third, fourth,... sequence	13(15(L*1))
660	Vector point distribution for 16th sequence see bytes 434-448)	15(L*1)

[1]See note for byte 420 for file title record.

APPENDIX J - APPLICATION OF ATTITUDE DATA TO VECTOR PROCESSING

J.1 INTRODUCTION

This section describes the application of attitude observations to the coordinate transformations necessary for vector processing. Attitude data are received in quaternion form from IPD.

Vector magnetometer measurements derived from DECOM data are converted to gammas (Section 4.3.2), orthogonalized, and rotated to the vector magnetometer ABC coordinates (see Section 4.3.3), and then converted to NEV coordinates for the reference test and experimental use. This conversion or transformation of coordinates depends on the satellite attitude and orbit information stored on the condensed orbit/attitude tape described in Section 3.2.3. Attitude information is first used in converting vector measurements from vector magnetometer ABC to celestial coordinates XYZ. A conversion of measurements from celestial XYZ to NEV coordinates is then made using orbit information (Section K.3).

J.2 SPACECRAFT TO CELESTIAL COORDINATE TRANSFORMATION

Attitude quaternions used in the transformation are nearly simultaneous with every fourth vector measurement. Quaternions will be estimated for the times of the vector measurements by a fourth-order Stirling interpolation formula.

J.2.1 Quaternion Notation

The quaternion notation describes, in general, the coordinates of the spacecraft after rotation by angle ψ about a line which has direction cosine angles i, j, and k, with respect to the celestial coordinate system. The four components of the quaternion $\vec{Q}$ for this case are

$$Q_1 = \cos i \sin \psi/2$$

$$Q_2 = \cos j \sin \psi/2$$

$$Q_3 = \cos k \sin \psi/2$$

$$Q_4 = \cos \psi/2$$

These quaternion elements satisfy the relation

$$Q_1^2 + Q_2^2 + Q_3^2 + Q_4^2 = 1 \tag{J-1}$$

The direction cosine rotation matrix with elements formed from quaternions is written as

$$[A(\vec{Q})] = \begin{bmatrix} Q_1^2 - Q_2^2 - Q_3^2 + Q_4^2 & 2(Q_1Q_2 + Q_3Q_4) & 2(Q_1Q_3 - Q_2Q_4) \\ 2(Q_1Q_2 - Q_3Q_4) & -Q_1^2 + Q_2^2 - Q_3^2 + Q_4^2 & 2(Q_2Q_3 + Q_1Q_4) \\ 2(Q_1Q_3 + Q_2Q_4) & 2(Q_2Q_3 - Q_1Q_4) & -Q_1^2 - Q_2^2 + Q_3^2 + Q_4^2 \end{bmatrix} \tag{J-2}$$

The vector magnetometer observations can be considered as components of a vector in the ABC coordinate system. Thus

$$\vec{B}_s = B_a \hat{e}_a + B_b \hat{e}_b + B_c \hat{e}_c \tag{J-3}$$

where $\hat{e}_a$, $\hat{e}_b$, $\hat{e}_c$ are unit vectors of the ABC system.

To obtain $\vec{B}_C$ in the geocentric celestial system, the following transformation may be used (assuming no errors in the attitude quaternions):

$$\vec{B}_C = \begin{bmatrix} B_X \\ B_Y \\ B_Z \end{bmatrix} = \left[A(\vec{Q})\right] \vec{B}_S = \left[A(\vec{Q})\right] \begin{bmatrix} B_A \\ B_B \\ B_C \end{bmatrix} \qquad \text{(J-4)}$$

J.3 ATTITUDE BIAS CORRECTION

Errors in the attitude quaternion set $\vec{Q}$ were discovered after launch due to biases in roll (R), yaw (Y), and pitch (P) for the magnetometer ABC axes. An in-orbit dynamic determination of these biases resulted in the follwing correction rotation matrix for the magnetometer axes:

$$T(R, Y, P) = \begin{pmatrix} \cos P & 0 & \sin P \\ 0 & 1 & 0 \\ -\sin P & 0 & \cos P \end{pmatrix} \begin{pmatrix} \cos Y & \sin Y & 0 \\ -\sin Y & \cos Y & 0 \\ 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 & 0 & 0 \\ 0 & \cos R & -\sin R \\ 0 & \sin R & \cos R \end{pmatrix}$$

$$= \begin{pmatrix} \cos P \cos Y & \cos P \sin Y \cos R + \sin P \sin R & -\cos P \sin Y \sin R + \sin P \cos R \\ -\sin Y & \cos Y \cos R & -\cos Y \sin R \\ -\sin P \cos Y & -\sin P \sin Y \cos R + \cos P \sin R & \sin P \sin Y \sin R + \cos P \cos R \end{pmatrix}$$

The equivalent correction rotation is represented in quaternion notation by

$$\vec{Q}^1(R, Y, P) = \vec{q}(R)\,\vec{q}(Y)\,\vec{q}(P)$$

$$\text{where } \vec{q}(R) = \begin{bmatrix} -\sin R/2 \\ 0 \\ 0 \\ \cos R/2 \end{bmatrix} \quad ; \vec{q}(Y) = \begin{bmatrix} 0 \\ 0 \\ \sin Y/2 \\ \cos Y/2 \end{bmatrix} \quad ; \vec{q}(P) = \begin{bmatrix} 0 \\ -\sin P/2 \\ 0 \\ \cos P/2 \end{bmatrix}$$

The rule for quaternion multiplication states that the quaternion product

$$\vec{q}'' = \vec{q}\,\vec{q}'$$

may be expressed in matrix form as

$$\begin{bmatrix} q_1'' \\ q_2'' \\ q_3'' \\ q_4'' \end{bmatrix} = \begin{bmatrix} q_4 & q_3 & -q_2 & q_1 \\ -q_3 & q_4 & q_1 & q_2 \\ q_2 & -q_1 & q_4 & q_3 \\ -q_1 & -q_2 & -q_3 & q_4 \end{bmatrix} \begin{bmatrix} q_1' \\ q_2' \\ q_3' \\ q_4' \end{bmatrix}$$

Using this rule, we obtain for the quaternion representing the correction rotation

$$\vec{Q}(R, Y, P) = \begin{bmatrix} -\cos\frac{P}{2}\cos\frac{Y}{2}\sin\frac{R}{2} + \sin\frac{P}{2}\sin\frac{Y}{2}\cos\frac{R}{2} \\ \cos\frac{P}{2}\sin\frac{Y}{2}\sin\frac{R}{2} - \sin\frac{P}{2}\cos\frac{Y}{2}\cos\frac{R}{2} \\ \sin\frac{P}{2}\cos\frac{Y}{2}\sin\frac{R}{2} + \cos\frac{P}{2}\sin\frac{Y}{2}\cos\frac{R}{2} \\ \sin\frac{P}{2}\sin\frac{Y}{2}\sin\frac{R}{2} + \cos\frac{P}{2}\cos\frac{Y}{2}\cos\frac{R}{2} \end{bmatrix} \begin{bmatrix} Q_1' \\ Q_2' \\ Q_3' \\ Q_4' \end{bmatrix}$$

The original attitude quaternions $\vec{Q}$ may be transformed to a corrected set $\vec{Q}''$ by multiplying by the correction rotation quaternion $\vec{Q}'(R, Y, P)$.

Thus

$$\vec{Q}'' = \vec{Q}'\,\vec{Q}$$

In matrix form

$$\vec{Q}'' = \begin{bmatrix} Q_1'' \\ Q_2'' \\ Q_3'' \\ Q_4'' \end{bmatrix} = \begin{bmatrix} Q_4 & Q_3 & -Q_2 & Q_1 \\ -Q_3 & Q_4 & Q_1 & Q_2 \\ Q_2 & -Q_1 & Q_4 & Q_3 \\ -Q_1 & -Q_2 & -Q_3 & Q_4 \end{bmatrix} \begin{bmatrix} Q_1' \\ Q_2' \\ Q_3' \\ Q_4' \end{bmatrix} \qquad \text{(J-5)}$$

Then the rotation matrix for transforming from the vector magnetometer axes to the celestial coordinate system including roll, yaw, and pitch bias corrections is written as A $(\vec{Q}'')$ in Equation J-2, where the uncorrected attitude quaternions $\vec{Q}$ are replaced by the corrected quaternions $\vec{Q}''$ from Equation J-5.

J.4 SPACECRAFT TO NEV COORDINATE TRANSFORMATION

If A $(\vec{Q}'')$ is the rotation matrix from the MAGSAT vector magnetometer ABC module axes to the true-of-date geocentric celestial coordinate system, including roll, yaw, and pitch bias corrections (see Equations J-2 and J-5), and $T(\vec{r})$ is the rotation matrix from the true-of-date geocentric celestial system to the NEV topocentric coordinate system (see Equation K-5), then the rotation matrix $R(\vec{r}, \vec{Q}'')$ from ABC to NEV coordinates is

$$R(\vec{r}, \vec{Q}'') = \left[T(\vec{r})\right] \left[A(\vec{Q}'')\right] \qquad \text{(J-6)}$$

Thus, $\vec{B}_T$ in the topocentric system is given by

$$\vec{B}_T = \begin{bmatrix} B_N \\ B_E \\ B_V \end{bmatrix} = \left[R(\vec{r}, \vec{Q}'')\right] \vec{B}_S$$

$$= \left[T(\vec{r})\right] \left[A(\vec{Q}'')\right] \begin{bmatrix} B_A \\ B_B \\ B_C \end{bmatrix} = \left[T(\vec{r})\right] \begin{bmatrix} B_X \\ B_Y \\ B_Z \end{bmatrix}$$

APPENDIX K - APPLICATION OF ORBIT DATA TO MDPS PROCESSING

K.1 INTRODUCTION

The satellite's position at the time of each scalar and vector magnetometer measurement is necessary in performing the reference tests. This orbit data is used in computing the field model values corresponding to each measurement once every 30 seconds and in defining the vector component transformation from the true-of-date geocentric inertial coordinates [called celestial coordinates, (CC)] to topocentric (NEV) coordinates (Figure K-1) at every vector magnetometer data point.

A satellite position, stored on tape by the MDPS COMPRS program, occurs once every minute. Scalar measurements occur four times per DECOM minor frame (about eight times per second) or twice each side (A or B). Vector measurements occur eight times per DECOM minor frame or every 61 milliseconds per component.

A fourth-order Stirling interpolation formula will be used to achieve the desired 10-meter accuracy for interpolated orbit values at the time of each DECOM measurement. This formula will also be used for interpolating the associated invariant latitude, geomagnetic time, and dipole latitude stored on the condensed orbit tape.

K.2 ORBIT COMPUTATION (CELESTIAL COORDINATES)

The interpolated satellite position (x, y, z) must be converted from CC to geocentric Earth-fixed coordinates (latitude, longitude, and radius). The rotation of the Earth since the reference time of the coordinate system is first computed as

$$L = \text{DFRADY} * 6.3003881 + \text{DELTDY} * .01720279 + \text{SIDTM} \qquad \text{(K-1)}$$

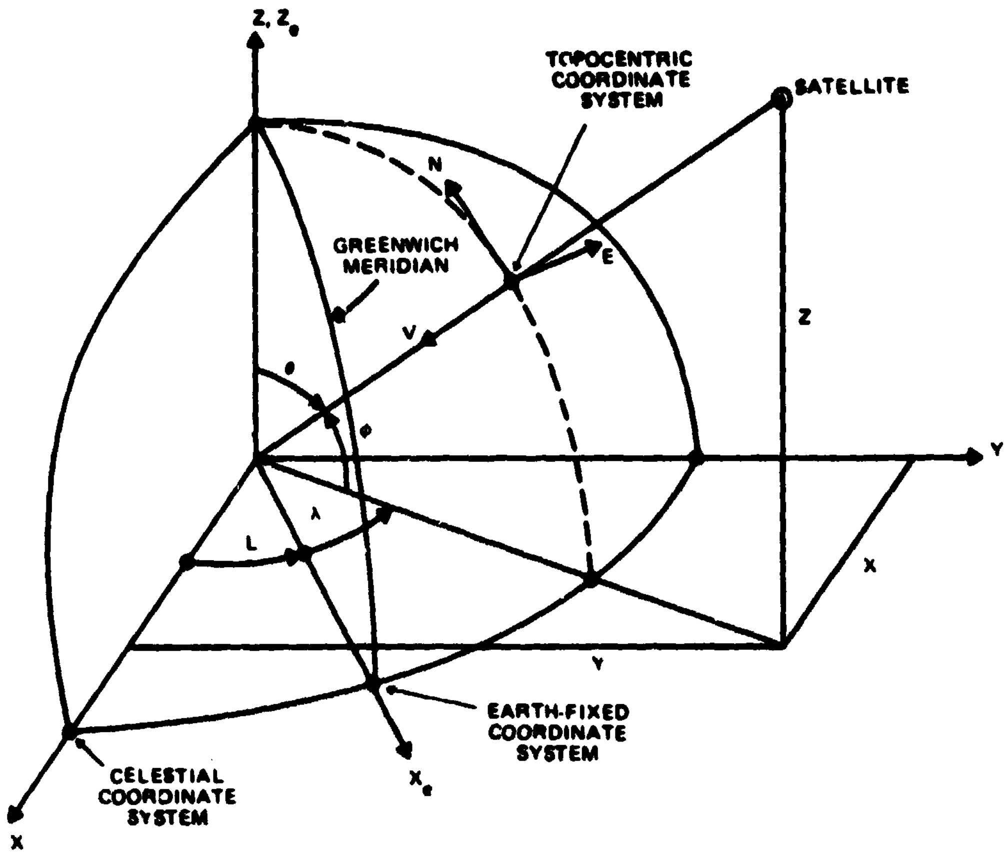

Figure K-1. Coordinate System Geometry

where DELTDY is the number of days since the reference time of the coordinate system, DFRADY is the fraction of day, and SIDTM is the hour-angle of Greenwich (GHA, i.e., angle L in Figure K-1) at the reference time.[1]

The Earth-fixed coordinates, x_e, y_e and z_e, where x_e is along the Greenwich meridian, are computed next by the following rotation formulas:

$$\begin{aligned} x_e &= x \cos L + y \sin L \\ y_e &= -x \sin L + y \cos L \end{aligned} \tag{K-2}$$

Finally, geocentric coordinates [colatitude (θ), longitude (λ), and geocentric radius (R)] are computed as

$$\begin{aligned} R &= \left[x_e^2 + y_e^2 + z_e^2\right]^{1/2} \\ \theta &= \frac{\pi}{2} - \phi \end{aligned} \tag{K-3}$$

where

$$\phi = \sin^{-1}\left(\frac{z_e}{R}\right)$$

$$\lambda = \tan^{-1}\left(\frac{y_e}{x_e}\right)$$

---

[1] See condensed orbit tape format (Appendix E and Section 3.2.3).

ϕ, λ and R are required for computing reference field measurements every 30 seconds (Appendix L).

K.3 CELESTIAL TO TOPOCENTRIC COORDINATE TRANSFORMATION

The transformation from the celestial coordinate (CC) system to the topocentric NEV may be derived in terms of the angles λ, L, and φ computed in Section K.2 where λ is about the Z (spin)-axis of the CC system and φ is about the negative Y-axis of the CC system after rotation through $\lambda + L$ (Figure K-1).

The transformation matrix, $T(\lambda + L, \varphi)$, for these two rotations may be written as

$$T(\lambda + L, \varphi) = \begin{bmatrix} \cos\left(\phi + \Pi/2\right) & 0 & \sin\left(\phi + \Pi/2\right) \\ 0 & 1 & 0 \\ -\sin\left(\phi + \Pi/2\right) & 0 & \cos\left(\phi + \Pi/2\right) \end{bmatrix} \begin{bmatrix} \cos(\lambda + L) & \sin(\lambda + L) & 0 \\ -\sin(\lambda + L) & \cos(\lambda + L) & 0 \\ 0 & 0 & 1 \end{bmatrix} \tag{K-4}$$

$$= \begin{bmatrix} -\sin\phi\cos(\lambda + L) & -\sin\phi\sin(\lambda + L) & \cos\phi \\ -\sin(\lambda + L) & \cos(\lambda + L) & 0 \\ -\cos\phi\cos(\lambda + L) & -\cos\phi\sin(\lambda + L) & -\sin\phi \end{bmatrix}$$

where the leftmost rotation by $\phi + \Pi/_2$ is necessary to relate the axes x to N, y to E, and z to V (Figure K-1).

By using the identities

$$\sin\phi = \frac{z}{R} \qquad \sin(\lambda + L) = \frac{y}{\sqrt{x^2 + y^2}}$$

$$\cos\phi = \frac{\sqrt{x^2 + y^2}}{R} \qquad \cos(\lambda + L) = \frac{x}{\sqrt{x^2 + y^2}}$$

$T(\lambda + L, \varphi)$ may be expressed directly in terms of the celestial coordinates x, y, z as

$$T(x,y,z) = T(\vec{r}) = \frac{1}{R\sqrt{x^2 + y^2}} \begin{bmatrix} -zx & -zy & x^2 + y^2 \\ -yR & xR & 0 \\ -x\sqrt{x^2 + y^2} & -y\sqrt{x^2 + y^2} & -z\sqrt{x^2 + y^2} \end{bmatrix} \qquad \text{(K-5)}$$

APPENDIX L - THEORETICAL MAGNETIC FIELD

The vector components of the Earth's magnetic field are approximated via a linear expansion of spherical harmonics with respect to a given satellite position (ϕ, λ, R) for use as reference field data by the CRONICLE program and the plotting software. Spherical harmonic coefficients are stored on disk in card form and are accessed by the CRONICLE program for computing vector component and total field (scalar) model estimates at a given point of the MAGSAT ephemeris. The extent of the magnetic field model (number of coefficients) is determined by the maximum degree NMAX and order m(m≤NMAX) of the spherical harmonic approximation used. It is expected for MAGSAT processing that NMAX will be less than 18. Coefficient values (g_n^m, h_n^m), for a particular term of degree n and order m, and their secular change ($\dot{g}_n^m$, $\dot{h}_n^m$) and acceleration ($\ddot{g}_n^m$, $\ddot{h}_n^m$) values for a given epoch are stored on one card in the format given below.

Column	Format	Description
1-3	I3	Degree of coefficient (n)
4-6	I3	Order of coefficient (m)
7-17	F11.4	g_n^m (gammas)
18-28	F11.4	h_n^m (gammas)
29-39	F11.4	$\dot{g}_n^m$ (gammas/sec)
40-50	F11.4	$\dot{h}_n^m$ (gammas/sec)
51-61	F11.4	$\ddot{g}_n^m$ (gammas/sec/sec)
62-72	F11.4	$\ddot{h}_n^m$ (gammas/sec/sec)

Theoretical field components (V_x, V_y, V_z) are computed using the field model coefficients and the FIELD subroutine package supplied for OGO-6 processing (Reference 3), or as modified and supplied by the Data Manager or Project Scientist.

APPENDIX M - AMPLITUDE CATALOG FORMAT

Signal amplitude data will be archived on an absolute file basis in the amplitude catalog tape (9-track, 6250 bpi). The DCB of the tape will be RECFM = VBS, CRECL = 774, BLKSIZE = 30964, DEN = 4. As on the quality catalog, an absolute file of data will consist of a file title record followed by data records. The format of the file title record can be found in Appendix I. Each data record will contain signal amplitude (A and B) data for two major frames of DECOM data. The data record format is shown below.

Amplitude Catalog Data Record Format

Displacement (bytes)	Parameter	Type
0	Latitude (degrees)	R*4
4	Longitude (degrees)	R*4
8	Altitude (km)	R*4
12	Start time (milliseconds of day)	I*4
16	Absolute file number	I*2
18	Spares	---

Amplitude Data

Up to 16 samples of signal amplitude for each side will be contained in an amplitude data record (1 byte per sample) which spans two DECOM major frames (512 minor frames). Readouts are in raw count form (0-255). To convert to volts, the readouts should be multiplied by the constant 0.025.

Displacement (bytes)	Parameter	Type
20	Signal amplitude A (16 samples)	L*1
36	Signal amplitude B (16 samples)	L*1

APPENDIX N - VECTOR CALIBRATION CONSTANTS

This appendix contains the record formats for the disk data set which contains vector calibration constants. The constants will be used to convert vector magnetometer measurements from raw-count form (as stored on a DECOM tape) to gammas and, subsequently, to align measurements to the orthogonal sensor platform coordinate system ABC.

More than one set of constants will be stored on disk. The first set will be determined from preflight ground calibration of the spacecraft. Subsequent sets will be determined from offline calibration analysis of data stored on chronicle tapes (see Appendix G). Calibrations may change as a function of spacecraft lifetime due to drift in sensor and platform electronics. Each set of calibration constants is denoted by a unique six-digit ID (YYMMDD) which denotes the year, month, and day when the constants were generated. The CRONICLE and FINEUP programs will access a given calibration set by referencing a particular ID in the program control input.

The DCB for the disk data set of calibration constants will be RECFM = FB, LRECL = 80, BLKSIZE = 3520. Constants are stored on 80-character card images. Record (card) formats are given in Table N-1. Due to the length and complexity of the footnotes used in this table, the footnotes appear on page N-4.

Table N-1. Vector Calibration Record Format (1 of 2)

Column Number	Format	Parameter
1 - 6	A6	Calibration ID (YYMMDD)
8	I1	[1]Vector digital system select: If = 1, digital A; If = 2, digital B
9	I1	Vector analog system select: If = 1, analog A; If = 2, analog B
10	A1	Type of calibration constant: If = S, fine count scale factor (Section 4.3.2) If = Z, fine count zero offset (Section 4.3.2) If = V, nominal change in vector measurements during vector calibration cycle (not used) [2]If = W, coarse counter calibration constants used to generate coarse count table (Section 4.3.2) [3]If = A, sensor alignment constants used to orthogonalize measurements (Section 4.3.3)
11 - 40	3F10.2	Calibration constants for types S, Z, and V (three values; one for each component of vector measurement)
11 - 70	6F10.2	Sensor alignment constants for type A (six values).
		Coarse count calibration constants (type W) stored on six consecutive cards, two cards per component of vector measurement.
11 - 80 (first card)	7F10.2	Coarse count calibration constants for x component (nine values).
11 - 40 (second card)	2E15.8	

Table N-1. Vector Calibration Record Format (2 of 2)

Column Number	Format	Parameter
11 - 80 (third card)	7F10.2	Coarse count calibration constants for y component (nine values).
11 - 40 (fourth card)	2E15.8	
11 - 80 (fifth card)	7F10.2	Coarse count calibration constants for z component (nine values).
11 - 40 (sixth card)	2E15.8	

Footnotes to Table N-1

[1]Usually, for each calibration set, there are four groups of calibration constants--one for each configuration of vector magnetometer electronics: digital A/analog A, digital A/analog B, etc.

For the lifetime of the MAGSAT mission, digital A/analog A was the only configuration used, with the exception of the period of January 25 to 28, 1980, where digital B/analog B was used.

[2]For each component, coarse counts are converted to gammas via table lookup. An entry in the table (C_i) for coarse count i (i = 0 to 127) for a given component is computed as follows:

$$C_i = w_0(1-b_{i0}) - (w_1 b_{i1} + w_2 b_{i2} + \dots + w_6 b_{i6})$$

$$+ w_7(64 - i)^3 + w_8(64 - i)^5 \text{ gammas}$$

where w_k, k = 0,1,...,8 are the coarse calibration constants

b_{ik} is the kth bit of the coarse count i (set either to 0 or 1; bit 0 is the leftmost bit)

[3]Vector measurement readouts, converted to gammas (A_R, B_R, C_R) will be orthogonalized as shown in Section 4.3.3. The orthogonal transformation matrix, M_1, will be a function of the measurements and sensor alignment calibration constants $\alpha_0, \alpha_1, \dots, \alpha_5$. The matrix M_1 is computed as follows:

$$M_1 = \begin{bmatrix} (1-\alpha_0^2-\alpha_1^2)^{\frac{1}{2}} & \frac{f(A_R)}{B_R} \sin \frac{\alpha_0 B_R}{f(A_R)} & \alpha_1 \\ \frac{f(B_R)}{A_R} \sin \frac{\alpha_2 A_R}{f(B_R)} & (1-\alpha_2^2 - \alpha_3^2)^{\frac{1}{2}} & \alpha_3 \\ \alpha_4 & \frac{f(C_R)}{B_R} \sin \frac{\alpha_5 B_R}{f(C_R)} & (1-\alpha_4^2-\alpha_5^2)^{\frac{1}{2}} \end{bmatrix}$$

The alignment constants, α, and functions $f(A_R)$, $f(B_R)$, and $f(C_R)$ were determined during ground tests of the vector magnetometer and the MAGSAT spacecraft. Alignment constants may be modified by in-flight calibrations.

GLOSSARY

ABC	Sensor platform coordinates of the vector magnetometer.
Amplitude catalog	Contains analog readings of signal amplitude in sync with the quality catalog (see Section 5.3).
APL	Applied Physics Laboratory of Johns Hopkins University.
ASC0, 1, 2, 3	Analog subcom 0, 1, 2, 3.
ATS	Attitude Transfer System.
Attitude tapes	S/C attitude information provided by MSC&AD in three forms: intermediate, fine, and quicklook (see Section 3.2.2 and Appendix D). Each form is on a separate tape.
B	Earth's magnetic field flux.
B&L package	Part of the OGO-F software system. It computes the invariant latitude.
CATLST	Program which outputs formatted listings of the quality and amplitude catalogs.
CC	Celestial coordinates (see Figure K-1).
CHRONFIN	A tape which is similar in content to the CHRONSCI tape. It is produced by the FINEUP program which incorporates fine attitude data into the calculations. See Sections 4.6.3 and 4.7.2.
CHRONINT, CHRONSC	Each tape contains a subset of the data available on the CHRONSCI tape. Each is produced from the CHRONSCI tape. See Section 5.3.
CHRONSCI	A tape which contains scalar and vector measurements edited and archived by the CRONICLE program. See Section 4.6.3 and Appendix G.

Clock tape	Contains spacecraft clock coefficients.
CO/A	Condensed orbit/attitude tape.
CORB	Condensed orbit tape.
CRONICLE	Main driver program for MDPS. It produces CHRONSCI tapes and prepares amplitude and quality catalog tapes (see Section 4).
DCB	Data control block.
DECOM tape	Combines the MAGSAT telemetry data provided by IPD (see Section 3.1 and Appendix A).
DODS	Definitive Orbit Determination System.
DSC0, 1	Digital subcom 0, 1.
DUL	DODS units of length = 10,000 kilometers.
DUT	DODS units of time = 864 seconds.
EBCDIC	Extended Binary Coded Decimal Interchange Code.
EPHEM tape	Contains the MAGSAT ephemeris (orbit) data provided by APL (see Section 3.2.1 and Appendix C).
Gamma	10^{-5} gauss.
Gauss	Unit of magnetic field.
IPD	Information Processing Division at GSFC.
JCL	Job control language.

L	McIlwain magnetic shell parameter.
MAGSAT	Magnetic Field Satellite.
Major frame	Equals 256 minor frames (2.1 minutes of data).
MDPS	MAGSAT Data Processing System.
MJD	Modified Julian day.[1]
MLT	Geomagnetic local time.
MSC&AD	Mission Support Computing and Analysis Division at GSFC.
NEV	Topocentric coordinates (North-East-Vertical).
Postprocessing	Software which prepares summary reports, plots, investigator tapes from the tapes output by the CRONICLE program.
Preprocessing	Software which produces DECOM status report, clock coefficient report, condensed orbit/attitude tapes, and condensed orbit tapes.
Quality catalog	Contains summaries of digital and analog engineering data for every 512 minor frames (4.2 minutes) of telemetry data and associated data quality and edit statistics (see Section 5.5).
QUEST	Refers to the attitude determination least-squares program.
RFT	Reference frame time.

[1]The Modified Julian Day used in the MAGSAT processing may not agree with other definitions for MJD. For MAGSAT data, the first data day, November 2, 1979, corresponds to MJD 44179.

S/C	Spacecraft.
SMAG	Scalar magnetometer sequence, equal to 32 DECOM minor frames.
USGS	United States Geological Survey.
UT	Universal time.
UTC	Universal time coordinated.
VMAG	Vector magnetometer sequence.

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