(NASA-TM-83999) THE DE MAGNETCMETEF PREPFOCESSOF USERS GUIDE (NASA) 81 p HC A05/MF A01 CSCL 09B

N83-12882

Unclas
G3/61 01163

NASA

Technical Memorandum 83999

The DE Magnetometer Preprocessor Users Guide

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SEPTEMBER 1982

National Aeronautics and
Space Administration

Goddard Space Flight Center
Greenbelt, Maryland 20771

THE DYNAMICS EXPLORER MAGNETOMETER PREPROCESSOR USERS GUIDE

by

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September 1982

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1.0) INTRODUCTION

The Dynamics Explorer (DE) spacecraft were designed to make physical measurements of the strong interactive processes occuring in the Earths vicinity. DE-A is in an eccentric orbit (a = 12775 KM, e = 0.95, I = 90°, Period = 440 minutes) and DE-B is in a less eccentric orbit (a = 802 KM, e = 0.62, I = 90°, Period = 101 minutes). The spin rates are approximately 10 RPM for DE-A and 1 revolution per orbit for DE-B. The co-planar polar orbits facilitate the acquisition of data at two altitudes within common flux tubes and in polar regions [see references 6,7 and 8]. This document describes the processing of the magnetometer data from both DE spacecraft.

The DE instrument complements are as follows:

DE-A (High altitude Mission)

<u>Fields</u>

1. Magnetometer-A (data processing described in this document)
2. Plasma Wave Instrument

<u>Optical Emissions</u>

3. Spin-Scan Auroral Imager

<u>Charged Particles</u>

4. Retarding Ion Mass Spectrometer
5. High Altitude Plasma Instrument
6. Energetic Ion Composition Spectrometer

DE-B (Low Altitude Mission)

<u>Fields</u>

1. Magnetometer-B (data processing described in this document)
2. Vector Electric Field Instrument

Neutral Particles

3. Neutral Atmosphere Composition Spectrometer
4. Wind and Temperature Spectrometer

Optical Emissions

5. Fabry-Perot Interferometer

Charged Particles

6. Ion Drift Meter
7. Retarding Potential Analyzer
8. Low Altitude Plasma Instrument
9. Langmuir Probe Instrument

The DE magnetometers are triaxial fluxgates with orthogonal axes. These fluxgates are the ring core type. The dynamic range of these sensors is ±6000nT. The range is extended to the ±62000nT required for the DE mission by using a compensating field which has increments of approximately 8000nT from -56000nT to +56000nT. The residual analog outputs (ambient field minus compensation field) of each axis are band limited (DC to 25 Hz with a 6db per octave roll off) and multiplexed through a 12 bit analog to digital converter. The magnitude of the compensation field is represented by 4 bits. Both of the above values are retrieved from the telemetry data base as the least significant byte of two 4 byte words. The 8 low order bits of the residual coming from one word and the 4 high order bits of the residual and the value of the compensating field coming from the other word [see note 6]. The DE-A magnetometer also has the capability of auto-ranging to a ±1000nT mode or a ±80nT mode [see reference 4]. The data are sampled at a rate of 16 times per second.

The data processing facility consists of two computers, the Sigma 9, (Xerox) and the Mission Analysis Computer System (MACS), (IBM 4341). The Sigma 9 has four data bases, the telemetry (TM) data base, the orbit and attitude (OA) data base, the mission analysis files (MAFs) and the Solar-Terrestrial parameters (STP) data base. The MACS has three data bases, the orbit and attitude (OA) data base, the mission analysis files

(MAFs) and the Solar-Terrestrial parameters (STP) data base. Sigma 9 is the preprocessing computer, on which the TM data are processed and placed in MAFs. The MAFs can be transferred to the MACS over a highspeed data link. Analysis and further processing is accomplished on the MACS utilizing the MAFs. MAFs cannot be transfered back from the MACS to the Sigma 9 computer [see reference 12].

The Sigma 9 has the following capabilities and hardware:

<u>Memory</u>

1.5 megabytes of 32 bit words.
Maximum program size 72K words.

Hardware	Quantity
Tape drives, 9 track, 800/1600 BPI.	10
Disk drives, 86.5 megabytes each.	14
Line printers	2
Card readers	2
Card punch	1
TTY lines	2

The MACS (IBM 4341) has the following capabilities and hardware:

<u>Memory</u>

4 megabytes of 32 bit words.

Hardware	Quantity
Tape drives, 9 track, 1600/6250 BPI.	4
Disk drives, 635 megabytes each.	5
Line printer	2

Shared capabilities and hardware:

Remote terminals		Quantity
Digital Equipment Corporation VT-100	Alphameric terminal	1
Princeton Electronic Products 8500M	Grey scale terminal	1
Tektronix 4002	Vector graphics	2
Tektronix 4006	Vector graphics	1
Tektronix 4014	Vector graphics	2
Tektronix 4027	Color terminal	1
Textronix 4610	Hardcopy	1
Textronix 4631	Hardcopy	1
Textronix 4632	Hardcopy	1
Varian 4241	Hardcopy	1
Digital Equipment Corporation LSI 11/23	Minicomputer	1

Graphics

Information International Inc. FR80 — Microfilm and microfiche [see reference 5]

Graphics software

Tektronix, Plot-10, Interacitve Graphics Library [see reference 10]

Precision Visuals Inc., DI3000 [see reference 3]

1.1) PROGRAM FUNCTIONAL DESCRIPTION.

This program provides preliminary data processing for DE magnetometer data for both the A and B spacecraft. This processing includes the following:

1. Retrieval of telemetry data.
2. Conversion of telemetry data to engineering units in sensor cordinates [see notes 6, 13 and 14].
3. Removal of outlyers and replacement with interpolated data.
4. Orthogonalization of data in sensor coordinates and rotation of this data into spacecraft coordinates [see note 4].
5. Generation of the spacecraft coordinate system (SPC COOR) MAF using full rate data.

6. Read the SPC COOR MAF and convert data to the geographic inertial (GEI) coordinate system, this conversion includes despinning for DE-A [see reference 11].
7. Average GEI data at a rate of from 1 to N, (default = 8).
   a. Full rate data will be passed through the program untouched.
   b. Data with an averaging rate of from 2 to 5 will not have the standard deviation computed.
   c. Data with an averaging rate of from 8 to N will be averaged and will also have standard deviation computed for each averaging interval. If more than one fourth of the data are rejected, neither the average nor the standard deviation will be computed and fill data will be inserted and flagged with a 1 in the least significant bit, bit 1. If some, but less than one-fourth, of the data are rejected, the standard deviation will not be computed and the averaged measurement will be flagged with a 1 in bit 2.
   d. The theoretical magnetic field data, obtained from the OA data base [see reference 2], will be subtracted from the averaged GEI data to produce ΔGEI.
8. Convert ΔGEI data to the geographic spherical (GGS) cordinate system and to the geomagnetic spherical (GMS) coordinate system to provide ΔGGS and ΔGMS [see reference 11].
9. Generate the GEOA MAF which will contain flags, GEI, σGEI, ΔGGS, and ΔGMS data.
10. Add ΔGGS and the theoretical GGS magnetic field to obtain GGS and convert GGS and the theoretical GGS magnetic field data to the magnitude declination inclination (BDI) coordinate system [see reference 1].
11. Subtract the theoretical BDI magnetic field from the BDI data to obtain ΔBDI.
12. Generate the BDIA MAF containing flags, BDI, theoretical BDI magnetic field and ΔBDI data.

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While, in general, processing for DE-A and DE-B magnetometer data is the same, there are minor differences in the algorithms used to convert from telemetry data to the sensor coordinate system. The differences in processing between DE-A and DE-B data are as follows:

1. The DE-A and DE-B data are taken from different telemetry words.
2. When processing the DE-A data the program must compensate for three different ranges while for DE-B processing only one range need be considered.
3. The conversion algorithms (ie. from raw telemetry data to engineering units) are slightly different.

All of the other processing uses identical programs, accessing only different parameters for each spacecraft. The data flow for processing both DE-A and DE-B data is identical at the level of detail addressed in this document. The differences are covered by the notes in Appendix C.

The current preprocessor program size is 62K words (248K bytes) and is not overlayed. The primary space limitation is that all MAF files and scratch disk space is charged against the users account during run time. The space required for a run using production defaults is 832 granules* of disk space, 62K words of memory and 15 minutes of CPU time per hour of telemetry data processed.

The plot program is a completely independent program. It accesses the GEOA and BDIA MAF's and selects the variables to be plotted based on input and/or default parameters. The JCL files [see Appendix A] MAGJCLGA and MAGJCLGB execute the preprocessor program and then execute the plot program. Only start and stop date and time are passed from the preprocessor to the plot program in a combined run. The JCL selects an input file which contains the correct default parameters.

*granule = 512 words
word = 4 bytes

2.0) Software description.

The DE magnetometer (MAG) preprocessor has the following functions:

1. Data Management.
2. Processing magnetometer telemetry data.
3. Generating MAFs.
4. Providing a run summary report.

The functional flow of the program is described, in detail, in sections 2.1 and 2.2.

2.1) PDL flow description.

Logical variables:

LOACHK - If true, a search is made by OACHEK for the time of the first valid orbit and altitude data on or after the start of the requested data span.

LRDGEO - If true, processing will begin with the geographic spherical averaged (GEOA) MAF.

LRDSPC - If true, the processing will begin with the spacecraft coordinate system (SPC COOR) MAF.

LSCPRT - If true, data in the orthogonalized spacecraft coordinate system is printed.

LTMFIL - If true, decimal values of unprocessed magnetic field telemetry data are written to a file for use in instrument calibration.

LTMPRT - If true, a hexadecimal dump is made of selected words of telemetry data as well as producing the above telemetry file

LSPCST - If true, processing will end with the SPC COOR MAF.

LGEOST - If true, processing will end with the GEOA MAF.

Other Variables:

N - The number of measurements in each average.

Start PDL:

```
Initialization (set up defaults).
Read control variables and test their validity.
IF LOACHK.
Then find the time of the first valid orbit and altitude data after
     the requested start time.
End IF.
IF .NOT. LRDGEO.
Then IF .NOT. LRDSPC.
     Then DO Until telemetry data is valid.
               Search for valid telemetry data.
          End DO.
          IF (.NOT. (LTMPRT .OR. LTMFIL .OR. LSCPRT)).
          Then Write open and initialize the SPC COOR MAF.
          End IF.
          Read calibration constants.
          Do until all requested data are processed.
               Read telemetry data [see note 6].
               IF LTMPRT.
               Then print selected telemetry words from one major
                    frame.
               End IF.
               IF LTMFIL.
               Then write decimal values of X, Y and Z, telemetry
                    words to a file.
               End IF.
```

Convert telemetry data to engineering units [see notes 6, 13 and 14].

Edit data for outlyers.

Interpolate and flag edited data.

IF LTMPRT.

Then print data in sensor coordinates.

End IF.

Convert the magnetometer data from sensor coordinates to orthogonal spacecraft coordinates [see note 4].

IF LSCPRT.

Then print the data in orthogonal spacecraft coordinates.

End IF

IF (.NOT. (LTMPRT .OR. LTMFIL .OR. LSCPRT)).

Then write one record to the SPC COOR MAF.

End IF.

End DO.

IF (LTMPRT .OR. LTMFIL .OR. LSCPRT).

Then STOP.

End IF.

Write close the SPC COOR MAF.

IF LSPCST.

Then STOP.

End IF.

Read open the SPC COOR MAF.

Write open and initialize the GEOA MAF.

Do until all requested data are processed.

Do N times.

Read one record from the SPC COOR MAF

Access the orbit and altitude file to obtain the translation and rotation matrix to go from the spacecraft (SPC) coordinate system to the geographic inertial (GEI) coordinate system [see reference 11] and the theoretical GGS magnetic field.

```
                Average GEI data to obtain N measurement averages
                     and standard deviations.
                Subtract the theoretical magnetic field values
                     from the averaged measurements to obtain
                     ΔGEI.
                Convert ΔGEI to ΔGGS and ΔGMS [see reference 11].
            End DO.
            Write a record to the GEOA MAF.
        End DO.
        Write close the GEOA MAF.
        IF LGEOST.
        Then STOP.
        End IF.
    End IF.
    Read open the GEOA MAF.
    Write open and initialize the BDIA MAF.
    Do until all requested data are processed.
        Read one record from the GEOA MAF.
        Access the orbit and altitude file to obtain the theoretical
            GGS magnetic field.
        Add the theoretical GGS magnetic field to ΔGGS to obtain
            GGS.
        Convert GGS and the theoretical GGS magnetic field to
            magnitude declination inclination (BDI) cordinates [see
            reference 1].
        Subtract the theoretical BDI magnetic field from BDI to
            obtain ΔBDI .
        Write one record to the BDIA MAF.
    End DO.
    Write close the BDIA MAF.
    STOP.

End PDL:
```

2.2) Detailed flow description.

The preprocessor first reads the input control parameters (see program options, section 3.1). It then accesses and decodes unprocessed magnetometer measurements taken from the telementry data base. Calibration constants are then used to convert the telemetry data to engineering units [see notes 6, 13 and 14]. The data is then edited and bad data is flagged. The flagged data is replaced by interpolated values. An orthogonalization matrix is used to convert data from sensor coordinates to an orthogonal spacecraft coordinate system [see note 4]. The full rate data records are then written into the SPC COOR MAF.

For further processing the SPC COOR MAF is read and processed in single record increments. This processing consist of converting each measurement to the GEI coordinate system, averaging, where $I = 2 \rightarrow N$, and computation of standard deviation, where $I = 8 \rightarrow N$. The theoretical GEI magnetic field is then subtracted from the averaged GEI data to provide ΔGEI. The ΔGEI data are then converted to ΔGGS and ΔGMS. The data records are then written to the GEOA MAF.

Additional processing is provided by reading the GEOA MAF to retrieve ΔGGS. Retrieve the GGS theoretical magnetic field from the OA data base. Add ΔGGS and the theoretical magnetic field to obtain GGS. Compute BDI and the BDI theoretical magnetic field. Subtract the BDI theoretical magnetic field from BDI to obtain ΔBDI. The above data are then written to the BDIA MAF.

See Appendix B for information about the structure and contents of each MAF.

3.) Users guide.

This section describes the input required by the DE-MAG preprocessor. The input required for batch processing of magnetometer data is a single line entry containing the command BATCH, the JCL name, the START date, the START time the STOP date, and the STOP time in the following format:

```
!BATCH MAGJCLA 'START'='date,time','STOP'='date,time' [see reference 13]
```

The above line of code processes a segment of data using production defaults.

START date = The last two digits of the year and the three digit Julian date for a total of five digits.
START time = The time in integer milliseconds of day, eight digits.
STOP date = The last two digits of the year and the three digit Julian date for a total of five digits.
STOP time = The time in integer milliseconds of day, eight digits.

An interactive run is initiated by executing the following line of code:

```
!XEQ MAGI [see reference 13]
```

The above line of code executes a command list which sets up DCBs and initiates program execution. The user then responds to questions and prompts from the program.

3.1) Program options.

1. Setup an input dataset for a batch run?
   This option allows the user to build a dataset on fortran unit 6 for later use in a batch run. In the generated dataset this response will be set to no, (N), because a yes, (Y), terminates the run when this file is complete.

2. Wait for telemetry promotion?
   If Y is chosen the program will wait for a telemetry data promotion, if N is chosen the program will terminate if no telemetry data is on line.

3. Production defaults?
   If Y is selected the program will only ask for the desired data span and run with production defaults listed earlier. The selection of N elicits further prompts.

For options 4, 5, and 6, no MAFs are produced and no OA data are required.

4. Print telemetry data?
   The Y response to this option provides a hexidecimal listing of selected words of telemetry data, a decimal listing of sensor coordinate data, a listing of option 5 and causes the run to terminate after this is accomplished.

5. Build telemetry file?
   Provides a telemetry file of decimal values of unprocessed magnetometer data for use in instrument calibration. If chosen, this option will cause run termination after producing the file and checking option 6.

6. Print data in spacecraft coordinates?
   The data are printed and the run is terminated.

7. Stop processing with the spacecraft file?
   Processing is terminated after the SPC COOR MAF is completed.

8. Test for valid OA data?
   This option provides for special cases where OA data may be neither required nor desired.

9. Number of points in average?
   This option allows for selection of the desired averaging rate, 1 to N.

10. Begin processing with the spacecraft file?
    Provides for starting the processing with a SPC COOR MAF.

11. Begin processing with the GEO file?
    Provides for starting the processing with a GEOA MAF.

12. Stop processing with the GEO file?
    Processing is terminated with completion of the GEOA MAF.

13. Input start date, start time, stop date, stop time, and satellite ID. The date and time are in the same format as for batch runs.

14. Is this correct?
    If N is entered input 13 must be re-entered.

15. Are all entries correct?
    If N is entered all selections must be re-entered.

3.2) Production defaults.

Do not setup an input dataset for a batch run.

Wait for telemetry promotion.

Do not print telemetry data.

Do not write (or print) telemetry calibration file.

Do not print magnetometer data in spacecraft coordinates.

Test for valid orbit and attitude data.

Provide 8 point averages.

Produce SPC COOR MAF.

Produce GEOA MAF.

Produce BDIA MAF.

3.3) Batch JCL description, for listings see appendix A.

The JCL files used in batch processing of DE-A magnetometer data are described below:

MAGJCLA - Exercises production defaults.

MAGJCLFA - Provides a telemetry file for use in instrument calibration.

MAGJCLGA - Exercises production defaults and provides selected graphs on microfiche.

MAGJCLHA - Processes high resolution data using all other production defaults.

MAGJCLIA - Processes data beginning in an intermediate mode, that is it starts with a SPC COOR MAF and builds the GEOA MAF and the BDIA MAFs.

MAGJCLPA - Provides a print out of selected telemetry words in hexidecimal, decimal values of the magnetometer telemetry data, (telemetry calibration file), magnetometer data in sensor coordinates, and magnetometer data in spacecraft coordinates.

MAGJCLSA - Exercises production defaults except that processing is terminated after completion of the SPC COOR MAF.

The JCL files used in batch processing of DE-B magnetometer data are described below:

MAGJCLB - Exercises production defaults.

MAGJCLFB - Provides a telemetry file for use in instrument calibration.

MAGJCLGB - Exercises production defaults and provides selected graphs on microfiche.

MAGJCLHB - Processes high resolution data using all other production defaults.

MAGJCLIB - Processes data beginning in an intermediate mode, that is it starts with a SPC COOR MAF and builds the GEOA MAF and the BDIA MAFs.

MAGJCLPB - Provides a print out of selected telemetry words in hexidecimal, decimal values of the magnetometer telemetry data, magnetometer data in sensor coordinates, and magnetometer data in spacecraft coordinates.

MAGJCLSB - Exercises production defaults except thet processing is terminated after completion of the SPC COOR MAF.

The JCL files used in batch processing of customized DE-A and DE-B runs are described below:

MAGJCLCA - Provides for customizing a DE-A batch run to individual needs other than those listed earlier in this section. In order to use this option a file must be provided containing the input parameters appropriate to the desired run. This file can be constructed either by using the editor or by entering XEQ MAGI and responding to the first prompt, "Set up an input dataset for a batch run?", with Y, responding to other prompts as appropriate, when the XEQ terminates, enter "COPY DSOUT6 OVER yourfile", and then enter "BATCH MAGJCLCA 'INFILE'='yourfile'. After the run is finished "yourfile" must be deleted. The use of apostrophes in the BATCH command are essential.

MAGJCLCB - Provides for customizing a DE-B run as described for MAGJCLCA.

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10. Plot 10 Terminal Control System User's Manual, Beaverton Oregon:Tektronix, April 1980.

11. Russell, C. T., "Geophysical Coordinate Transformations", Cosmic Electrodynamics, 2, 184-196, 1971.

12. Smith, P. H., Freeman, C. H., and Hoffman, R. A., "Dynamics Explorer Science Data Processing System", Space Sciences Instrumentation, 5, 561-573, 1981.

13. Time-Sharing Reference Manual, Xerox Control Program-five (CP-V), Xerox 560 and Sigma 6/7/9 Computers, Honeywell Information Systems Inc., 1978.

APPENDEX A

FILE: MAGI

```
!SET F:6/DSOUT6;OUT
!SET F:7/DSOUT7;OUT
!SET F:8/DSOUT8;OUT
!SET F:9/DSOUT9;OUT
!SET F:10/DSOUT10;OUT
!SET F:11/DSOUT11;OUT
!SET F:12/DSOUT12;OUT
!SET F:13/DSOUT13;OUT
!SET F:35/DSOUT35;OUT
!SET F:201/DSOUT201;OUTIN
!SET F:205/DSOUT205;OUTIN
!SET F:206/DSOUT206;OUTIN
!SET F:305/DSOUT305;INOUT
!S L4:MAG
!COPY DSOUT6,DSOUT7,DSOUT8,DSOUT9,DSOUT10 TO LP
!COPY DSOUT11,DSOUT12,DSOUT13,DSOUT35 TO LP
!R
```

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FILE: MAGJCLA

```
!JOB MAG,U6PGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLFA

```
!JOB MAG,UöBGL,7
!DEFAULT CORE=72,CPU=1,'ZMAG'='MAG,MAG','SATID'='A','FILE35'='DXOUT35'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:35,(FILE,FILE35),(OUT)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
Y
N
N
START.STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLGA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=60,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU),(9T,1),(LO,600),(UO,600)
!ASSIGN F:13,(FILE,PLOTIN),(OUT)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
!SET F:705/DB:KINPUT
!SET F:706/DB:GRBANK.VEFI;INOUT,SHARE
!SET F:707/LBLINP.VEFI;IN,SHARE
!SET F:708/DB:KOPTINA
!SET F:709/DB:KBANK;INOUT,SHARE
!SET F:710/KPLTST;INOUT
!SET F:711/MAGTPINV;INOUT;SAVE
!SET F:5 DC/KRETRN;IN,SHAPE
```

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```
!SET F:6 DC/ERROR80;OUT;SAVE
!SET F:3 /KPL1;INOUT;SAVE
!SET F:7 DC/FONTS;IN
!SET F:11 DC/METAFILE.ACCOUNT;IN;SAVE
!SET F:13/DI3000.LIBRARY;IN
!SET F:17;SIMP;LIBRARY;IN
!SET F:16 9T#3301;OUT
!SET F:105/PLOTIN;IN
!SET F:201 /A
!SET F:202 /B
!SET F:203 /C
!SET F:204 /D
!SET F:211 /E
!SET F:212 /F
!SET F:213 /G
!SET F:214 /H
!SET F:215 /I
!RUN (LMN,L7:KGRAF12,MAG)
!PMDE
!EOD
```

FILE: MAGJCLHA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=5,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
N
1
N
N
N
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLIA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:205,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
N
8
Y
N
N
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLPA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=1,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
Y
Y
N
8
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLSA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='A'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLFB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=1,'ZMAG'='MAG,MAG','SATID'='B','FILE35'='DXOUT35'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:35,(FILE,FILE35),(OUT)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
Y
N
N
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLGB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=60,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU),(9T,1),(LO,600),(UO,600)
!ASSIGN F:13,(FILE,PLOTIN),(OUT)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
!SET F:705/DB:KINPUT
!SET F:706/DB:GRBANK.VEFI;INOUT,SHARE
!SET F:707/LBLINP.VEFI;IN,SHARE
!SET F:708/DB:KOPTINB
!SET F:709/DB:KBANK;INOUT,SHARE
!SET F:710/KPLTST;INOUT
!SET F:711/MAGTPINV;INOUT;SAVE
!SET F:5 DC/KRETRN;IN,SHAPE
```

```
!SET F:6 DC/ERROR80;OUT;SAVE
!SET F:3 /KPL1;INOUT;SAVE
!SET F:7 DC/FONTS;IN
!SET F:11 DC/METAFILE.ACCOUNT;IN;SAVE
!SET F:13/DI3000.LIBRARY;IN
!SET F:17;SIMP;LIBRARY;IN
!SET F:16 9T#3301;OUT
!SET F:105/PLOTIN;IN
!SET F:201 /A
!SET F:202 /B
!SET F:203 /C
!SET F:204 /D
!SET F:211 /E
!SET F:212 /F
!SET F:213 /G
!SET F:214 /H
!SET F:215 /I
!RUN (LMN,L7:KGRAF12,MAG)
!PMDE
!EOD
```

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FILE: MAGJCLHB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=5,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
N
1
N
N
N
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLIB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
N
8
Y
N
N
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLPB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=1,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
Y
Y
N
8
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

FILE: MAGJCLSB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='B'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!DATA
N
Y
N
N
N
N
Y
Y
START,STOP,SATID
Y
Y
N
!EOD
!RUN (LMN,L4:STMREL,MAG)
!PMDE
!DATA
START,SATID
!EOD
```

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FILE: MAGJCLCA

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='A','INFILE'='YOURFILE'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:105,(FILE,INFILE),(IN)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!RUN (LMN,L4:STMREL,MAG)
!PMDE
```

FILE: MAGJCLCB

```
!JOB MAG,U6BGL,7
!DEFAULT CORE=72,CPU=15,'ZMAG'='MAG,MAG','SATID'='B','INFILE'='YOURFILE'
!DEFAULT 'START'='00000,12345678','STOP'='00000,12345678'
!LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
!ASSIGN F:105,(FILE,INFILE),(IN)
!ASSIGN F:201,(FILE,SPCMAF)
!ASSIGN F:205,(FILE,BDIMAF)
!ASSIGN F:206,(FILE,GEOMAF)
!ASSIGN F:305,(FILE,CALFIL)
!RUN (LMN,L4:ZMAG)
!RUN (LMN,L4:STMREL,MAG)
!PMDE
```

Sample run using production defaults.

```
JOB MAG,U6BGL,7
LIMIT (COR,CORE),(ACCOUNT),(TIME,CPU)
ASSIGN F:201,(FILE,SPCMAF)
ASSIGN F:205,(FILE,BDIMAF)
ASSIGN F:206,(FILE,GEOMAF)
ASSIGN F:305,(FILE,CALFIL)
ASSIGN F:108,(DEVICE,LP)
RUN (LMN,L4:ZMAG)
PMDE

                    VERSION    2
                    MARCH 20,1982

 CALL INITL
 CALL INPUT
  SET UP AN INPUT DATA SET FOR A BATCH RUN ?  Y OR N
  WAIT FOR TM DATA PROMOTION ? Y OR N
  DO YOU WANT PRODUCTION DEFAULTS ?  Y OR N
  INPUT START DATE, START TIME, END DATE,
  AND SATELLITE ID IN THE FOLLOWING FORMAT.
 STDATE, STIME, EDATE,ENDTIME, SATELLITE ID
 YYDDD,MILLISEC,YYDDD,MILLISEC,S
 START DATE = 82175 START TIME = 54100000
 END   DATE = 82175 END   TIME = 55900000
 SATELLITE I.D. = B

 IS THIS CORRECT ?  Y OR N
```

```
**************************************************

      THE FOLLOWING OPTIONS WERE REQUESTED

 DON'T SET UP AN INPUT DATASET FOR A BATCH RUN.

 WAIT FOR TELEMETRY PROMOTION.

 USE PRODUCTION DEFAULTS.

 NUMBER OF POINTS IN AVERAGE. NAVERG =   8

 START DATE = 82175 START TIME = 54100000
 END   DATE = 82175 END   TIME = 55900000

 SATELLITE I.D. = B

**************************************************

  ARE ALL ENTRIES CORRECT? Y OR N

 CALL OACHEK

 STDATE = 82175 STIME = 51400000 ENDATE = 82175 ENDTIM = 55900000

 CALL TMREAD IN MAIN. STDATE = 82175 STIME = 54100000
 PROMOTION OF TM DATA IS REQUIRED
 STANDBY FOR STATUS OF PROMOTION ACTIVITY
 WAITING FOR PROMOTION JOB 1F1 TO RUN
 WAITING FOR PROMOTION JOB 1F1 TO RUN
 PROMOTION JOB 1F1 RUNNING
 PROMOTION JOB 1F1 RUNNING
 PROMOTION JOB 1F1 RUNNING
 PROMOTION COMPLETED
 PROMOTION SUCCEEDED
```

```
82175 54092021 83175 55900000
 CALL INTMAF
 CALL MAGF
  CALIBRATION DATA VALIDITY DATE = 85365

        .9999899864        -.0000832000        .0071870014
        .0028730000        -.9999499917        -.0046319999
```

120 word calibration table is listed here.

```
 D   821755409202182175557960020B   MAGBSPC COOR
NUMBER OF RECORDS =     215
CALL MAGMAF
 D   821755409202182175557960020B   MAGBGEOA   8
CALL BDIMAF
 D   821755409202182175557960020B   MAGBBDIA   8
*STOP*
EOD
RUN (LMN,L4:STMREL,MAG)
PMDE
*STOP*
EOD
```

APPENDEX B

MAF File Structures

B.0) GENERAL BACKGROUND

The mission analysis file (MAF) system was established for use on DE satellite data. It supplies a flexible format to support the various experiments on board the spacecraft under some common guidelines. A detailed description of this system is contained in reference 2 chapter 3. The Sigma-9 MAF's are designed to be compatible with the Mission Analysis Computer System (MACS). MAF's created on the Sigma-9 may be Transferred to the MACS when needed. The MAF data base is divided into two parts, data files and directory files. The directory files describe attributes of the data files

These files are promoted and demoted from the tape files as needed. The formats of these files are as follows:

B.1) MAGNETOMETER MAF DATA FILES

1) SPCbCOOR - High resolution data file

Record size	512 four byte words, 4 vectors (each vector 128 words).
Vector types	flag, X, Y, Z.
Flag	Data quality indicator.
X, Y, Z	Measured magnetic field data in the cartesian spacecraft coordinate system.

2) GEOA#### - Averaged data file.

Record size	1664 four byte words, 13 vectors (each vector 128 words).
Vector types	flag, B_x, B_y, Bz, σB_x, σB_y, σB_z, ΔB_r, ΔB_θ, ΔB_ϕ, ΔB_{rm}, $\Delta B_{\theta m}$, $\Delta B_{\phi m}$.
Flag	Data quality indicator.

B_x, B_y, B_z	Magnetic field data in GEI coordinates.
σB_x, σB_y, σB_z	Standard deviation of average data in GEI coordinates.
ΔB_r, ΔB_θ, ΔB_ϕ	Measurement minus theoretical field in GGS coordinates.
ΔB_{rm}, $\Delta B_{\theta m}$, $\Delta B_{\theta m}$	Measurement minus theoretical field in GMS coordinates.

3) BDIA#### - Averaged data file.

Record size	1280 four byte words, 10 vectors (each vector 128 words).
Vector types	flag, B_m, D_m, I_m, B_t, D_t, I_t, Δ_B, Δ_D, Δ_I.
Flag —	Data quality indicator.
B_m	Measured magnitude.
D_m	Measured declination.
I_m	Measured inclination.
B_t	Theoretical magnitude.
D_t	Theoretical declination.
I_t	Theoretical inclination.
ΔB	Measured minus theoretical magnitude.
ΔD	Measured minus theoretical declination.
ΔI	Measured minus theoretical inclination.

B.2) MAGNETOMETER FILE DIRECTORY ENTRY

The directory entry consists of six information packets (62 words).

Packet	Words	Directory Information
1	1 - 9	Key packet
2	10 - 16	Data utilization packet
	17	Spare

3	18 - 24	Data application packet
	25 - 26	Spares
4	27 - 46	Optional word packet
5	47 - 51	System packet
	52 - 53	Spares
6	54 - 62	Explanitory key

Packets 5 and 6 can not be modified by the user, information on these packets can be found in reference 2.

Key packet — Provides the MAF data base with a unique identifier for each file.

Word	Item	Input	Type
1	File type	Dbbb	Character
2	Start date	YYDDD	Integer
3	Start time (msec)	########	Integer
4	Stop date	YYDDD	Integer
5	Stop time (msec)	########	Integer
6	Satellite I. D.	Abbb or Bbbb	Character
7	Instrument	MAGA or MAGB	Character
8	User defined	*	Character
9	User defined	*	Character

* The appropriate acronym that defines the MAF:

Word 8	Word 9
SPCb	COOR
GEOA	####
BDIA	####

Data utilization packet — Provides information about the file's design and size.

Word	Item	Input	Description
10	Data vector length	*	Record length in words
11	MAF data type	3	Variable increment
12	Abcessa type	4	Time
13	Abcessa increment	*	Time between records in msec
14	Start abcissa	YYDDD	Integer
15	Start abcissa	########	Integer
16	Vector type	1	Fixed format

* File type	Data vector length	Abcissa increment
SPCbCOOR	512 words	8000 msec
GEOA####	1664 words	8000 msec times the number of points in the averaging interval
BDIA####	1280 words	8000 msec times the number of points in the averaging interval

Data application packet — Provides information about the file's quality.

word	Item	Input
18	Data priority	1 → 10
19	Data quality	2 (some data manipulation)
20	Process state	2 (full resolution in MAF)
21	Program version	0 → 255
22	Display program	To be supplied
23	" "	" " "
24	" "	" " "

Optional word packet User defined words.

Word	Description
27	Orbit number
28	Beginning geodetic lattitude
29	Ending geodetic lattitude
30	Beginning invariant lattitude
31	Ending invariant lattitude
32	Beginning magnetic local time
33	Ending magnetic local time
34	Flags
35	YYDDD processing date
36	Month of processing date
37	Day of processing date
38	Year of processing date
39	Calibration date
40	YYDDD Date of mode change
41	Time of mode change (msec)
42	Spare
43	"
44	"
45	"
46	Time resolution

Words 40 and 41 apply to DE-A only and contain fill data for DE-B.

Flags:

Bits	Description
0	Spare
1	"
2	"
3	Lattitude direction, 0 - increasing, 1 - increasing.
4	Spare
5	"
6	"
7	"

8	Spare
9	"
10	"
11	"
12	"
13	"
14	"
15	"
16	Type of OA data, 0 - definitive, 1 - predicted.
17	Spare
18	"
19	"
20 - 21	Mode at start of pass.
22 - 23	Mode at end of pass.
24 - 31	Points per vector.

B.3) CALIBRATION MAF DATA FILES

1) CONSTANT - Calibration constants data file

Record size 160 four byte words.

<u>Word</u>	<u>Vector types for DE-A</u>	
1 - 9	ORTHA	Orthogonalization matrix [see notes 4, 13]
10 - 18	EA0	E^{α}_{0i} [see notes 6, 13]
19 - 27	EA1	E^{α}_{1i} "
28 - 36	EA2	E^{α}_{2i} "
37 - 45	EA3	E^{α}_{3i} "
46 - 54	FA0	F^{α}_{0i} "
55 - 63	FA1	F^{α}_{1i} "
64 - 72	FA2	F^{α}_{2i} "
73 - 81	FA3	F^{α}_{3i} "
82 - 90	CALFA	C^{α}_{Ai} "
91 - 99	FDELTA	δ^{α}_{Ai} "
100 - 103	PA	P_{Ai} "
104 - 160	SPARE	

Word	Vector types for DE-B	
1 - 9	ORTHB	Orthogonalization matrix [see notes 4, 14]
10 - 12	GI0	G_{0i} [see notes 6, 14]
13 - 15	GI1	G_{1i} "
16 - 18	GI2	G_{2i} "
19 - 21	GI3	G_{3i} "
22 - 24	HI0	H_{0i} "
25 - 27	HI1	H_{1i} "
28 - 30	HI2	H_{2i} "
31 - 33	HI3	H_{3i} "
34 - 36	CB	C_{Bi} "
37 - 40	PB	P_{Bi} [see notes 6, 14]
41 - 160	SPARE	

B.4) CALIBRATION FILE DIRECTORY ENTRY

The directory entry consists of six information packets (62 words).

Packet	Words	Directory Information
1	1 - 9	Key packet
2	10 - 16	Data utilization packet
	17	Spare
3	18 - 24	Data application packet
	25 - 26	Spares
4	27 - 46	Optional word packet
5	47 - 51	System packet
	52 - 53	Spares
6	54 - 62	Explanitory key

Packets 5 and 6 can not be modified by the user, information on these packets can be found in reference 2.

Key packet

Provides the MAF data base with a unique identifier for each file.

Word	Item	Input	Type
1	File type	DƀƀƀDƀƀƀ	Character
2	Start date	81001	Integer
3	Start time (msec)	00000000	Integer
4	Stop date	86001	Integer
5	Stop time (msec)	00000000	Integer
6	Satellite I. D.	Aƀƀƀ or Bƀƀƀ	Character
7	Instrument	MAGA or MAGB	Character
8	User defined	CONS	Character
9	User defined	TANT	Character

Data utilization packet

Provides information about the file's design and size.

Word	Item	Input	Description
10	Data vector length	160	Record length in words
11	MAF data type	3	Variable increment
12	Abcessa type	4	Time
13	Abcessa increment	0	Time between records in msec
14	Start abcissa	0	Integer
15	Start abcissa	0	Integer
16	Vector type	1	Fixed format

Data application packet — Provides information about the file's quality.

Word	Item	Input
18	Data priority	10
19	Data quality	4
20	Process state	5
21	Program version	0
22	Display program	b̸
23	" "	b̸
24	" "	b̸

Optional word packet — User defined words.

Word	Description
27	Julian day of latest calibration record
28	Day " " " "
29	Month " " " "
30	Year " " " "
31	Spare
32	"
33	"
34	"
35	"
36	"
37	"
38	"
39	"
40	"
41	"
42	"

43	Julian day of file creation			
44	Day	"	"	"
45	Month	"	"	"
46	Year	"	"	"

ƀ = Blank

= a decimal digit 0 - 9

APPENDEX C

DE-A & B MAGNETOMETER DATA PROCESSING

Note No. 1 July 25, 1979

1. Sensor cross-talks

Let the components of the true magnetic field intensity in the sensor coordinates be $B_i^{(s)}$ and the sensor readings, B_i, where i = 1,2,3 correspond to the sensor axes x, y and z. We assume that the cross-talk terms are linear. Then we have

$$\sum_{j=1}^{3} c_{ij} B_j^{(s)} = B_i \qquad i=1,2,3 \tag{1}$$

where the matrix $\underline{c}$ has elements:

$$\underline{c} = \begin{pmatrix} 1 & c_{12} & c_{13} \\ c_{21} & 1 & c_{23} \\ c_{31} & c_{32} & 1 \end{pmatrix} \tag{2}$$

namely, c_{ij} is the coefficient of the term representing the contribution of the field from the j-axis sensor to the i-axis sensor readings.

Writing (1) as

$$\underline{c}\ \underline{B}^{(s)} = \underline{B} \tag{1'}$$

we can solve (1') for $\underline{B}^{(s)}$:

$$\underline{B}^{(s)} = \underline{c}^{-1}\underline{B}' \tag{3}$$

where $\underline{c}^{-1}$ is the inverse matrix of $\underline{c}$, that is

$$\underline{c}^{-1}\,\underline{c} = \underline{1} \tag{4}$$

where $\underline{1}$ is the unit matrix.

2. Transformation from the sensor coordinates to the "sensor box" coordinates. Let the components of the magnetic field intensity in the "sensor box" coordinates be $B_i^{(b)}$. We write the transformation from the sensor coordinates.

$B_i^{(s)}$ = sensor coordinates

$B_i^{(b)}$ = sensor box coordinates

$B_i^{(c)}$ = s. s. coordinates

to the "sensor box" coordinates as

$$B_i^{(b)} = \sum_{j=1}^{3} a_{ij}^{(b)}\, B_j^{(s)} \tag{5}$$

or

$$\underline{B}^{(b)} = \underline{a}^{(b)}\, \underline{B}^{(s)} \tag{5'}$$

3. Transformation from the "sensor box" coordinates to the spacecraft coordinates. Let the components of the magnetic field intensity in the spacecraft coordinates be $B_i^{(c)}$. We write the transformation from the sensor box coordinates to the spacecraft coordinates as

$$B_i^{(c)} = \sum_{j=1}^{3} a_{ij}^{(c)} \; B_j^{(b)} \tag{6}$$

or

$$\underline{B}^{(b)} = \underline{a}^{(b)} \; \underline{B}^{(s)} \tag{6'}$$

4. Transformation from the sensor readings to the components in the spacecraft coordinates. Combining (3), (5') and (6'), we can obtain the field components in spacecraft coordinates, $B_i^{(c)}$, from the sensor readings, B_i, by the relation

$$\underline{B}^{(c)} = \underline{a}^{(c)} \; \underline{B}' \tag{7}$$

where the matrix $\underline{a}^{(c)}$ is the product:

$$\underline{a}^{(c)} = \underline{a}^{(c)} \; \underline{a}^{(b)} \; \underline{c}^{-1} \tag{8}$$

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DE-A & B MAGNETOMETER DATA PROCESSING

Note No. 2 July 26, 1979

Association of data readings with time

Instrument reading is triggered at the end of the transmission of the z-axis data, and the conversion of digital data is made in approximately 10 milliseconds. The data are then transmitted in the following minor frame.

Let the length of a minor frame be t_m and the length of time from the beginning of the minor frame to the end of the z location be t_1. Then the magnetometer data transmitted in a minor frame that starts at time t_0 are associated with time t given by

$$t = t_0 - (t_m - t_1)$$

The spacecraft clock gives 16,384 bits per second. With 128 x 8 bits per frame we have 16,384 ÷ (128 x 8) = 16 frames per second exactly. Thus

$$t_m = 1/16 \text{ seconds} = 0.0625 \text{ seconds}$$

The last MAG location in the minor frame is location 101 for DE-A and location 112 for DE-B. Therefore t is given by:

$$t = t_0 - 0.0625(1 - 101/128) = t_0 - 0.0131835937 \text{ seconds for DE-A}$$
$$t = t_0 - 0.0625(1 - 112/128) = t_0 - 0.0078125 \quad \text{seconds for DE-B}$$

It will be of interest to see if these time corrections are significant relative to various errors in the determination of time.

DE-A & B MAGNETOMETER DATA PROCESSING

NOTE NO. 4 JULY 17, 1980

Calibrations are made with respect to the "effective" sensor axes, X_i ($i = 1$, 2 and 3). The "effective" sensor axis X_i is defined such that when the other two components of the test coil field are varied, no changes are produced in the X_i sensor readings. This is done for the three axes, X_i ($i = 1$, 2 and 3). The "effective" sensor axes so defined are, in general, not orthogonal. The calibrations on the three sensors are made in the "effective" sensor axis coordinate system.

Let the optical axes be ξ_i ($i = 1$, 2 and 3), which are orthogonal. We express the transformation of a vector from the X_i coordinate system to the ξ coordinate system by

$$\xi_i = \sum_j \alpha_{ij} X_j \tag{1}$$

where α_{ij} is a 3x3 matrix.

Let the sensor platform axes be ξ_i (1= 1, 2 and 3) and the transformation of a vector from the ξ system to the ξ' system be expressed by

$$\xi_i' = \sum_j \rho_{ij} \xi_j \tag{2}$$

We now go from the sensor platform at the tip of the boom to the boom canister on the spacecraft. Let the canister axes be ξ_i'' (i=1, 2 and 3) and let the transformation from the platform ξ' system to the canister ξ'' system be

$$\xi_i'' = \sum_j \beta_{ij}' \xi_j' \tag{3}$$

Let the spacecraft axes be η_i (i = 1, 2, and 3), and let the transformation of a vector from the canister ξ'' system to the spacecraft η system be

$$\eta_i = \sum_j \beta''_{ij} \xi''_j \tag{4}$$

Thus the transformation of a vector from the "effective" sensor axis coordinate system to the spacecraft coordinate system is given by

$$\eta_i = \sum_j \gamma_{ij} X_j \tag{5}$$

where γ_{ij} is the product of the four matrices, γ, β, β' and β'', i.e.

$$\underline{\gamma} = \underline{\beta''}\ \underline{\beta'}\ \underline{\beta}\ \underline{\alpha}$$

or in terms of matrix elements,

$$\gamma_{ij} = \sum_k \beta_{ik} \{\sum_l \beta'_{k\rho} (\sum_m \beta_{\rho m} \alpha_{mj})\} \tag{6}$$

DE-A & B MAGNETOMETER DATA PROCESSING

NOTE NO. 6 JULY 30, 1980

Note No. 5 dated July 18, 1980 is superseded by this Note. Calibrations are made in the "effective" sensor axis coordinate system. The equation for the derivation of the magnetic field component along the i-th "effective" sensor axis is given by

$$B_i = (M_{1i} - 7)\, E_i^{\alpha} + (2048 + \delta_{Ai}^{\alpha} - M_{2i})\, F_i^{\alpha} + C_{Ai}^{\alpha} \qquad \text{for DE-A (6.1)}$$

$$B_i = (N_{1i} - 7)\, G_i + (2048 + \delta_{Bi} - N_{2i})\, H_1 + C_{Bi} \qquad \text{for DE-B (6.2)}$$

where i = 1, 2 and 3 represent the x, y and z axes respectively and where α in (6.1) denotes the mode in which the instrument is being operated.

The M's and N's are sampled 16 times per second by the telemetry system. The M_1's and N_1's are the numbers represented by the four most significant bits of the following telemetry words:

	i	1	2	3
DE-A	M_{1i}	70	97	100
DE-B	N_{1i}	56	79	101

The M_2's and N_2's are twelve bit numbers, consisting of the four least significant bits of the corresponding words for M_1's and N_1's and of the eight bits of the following words:

	i	1	2	3
DE-A	M_{2i}	71	98	101
DE-B	N_{2i}	69	80	112

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The constants E's, F's, G's, and H's are instrument gain parameters, which are weakly dependent on the sensor temperature. The sensor temperature is determined in the following way. Temperature is read out in word 68-25 on DE-A and in word 68-12 on DE-B; each of these 8 bit words is in an 8 second subcom channel. If the 8 bit word is denoted by V, the temperature, T, is given by

$$T_A = P_{AO} + P_{A1}V + P_{A2}V^2 + P_{A3}V^3 \qquad \text{for DE-A (6.3)}$$

or

$$T_B = P_{BO} + P_{B1}V + P_{B2}V^2 + P_{B3}V^3 \qquad \text{for DE-B (6.4)}$$

The parameters P_A's and P_B's are determined before launch. Temperatures T_A and T_B are in degrees Centrigrade and will be known to an accuracy of $1^\circ C$.

The coefficients E's, F's, G's, and H's in (6.1) and (6.2) are determined as functions of

$$T_A = T_A - 27^\circ C \qquad \text{for DE-A (6.5)}$$

or

$$T_B = T_B - 27^\circ C \qquad \text{for DE-B (6.6)}$$

by the following polinomials

$$E_i^\alpha(T'_A) = E_{0i}^\alpha + E_{1i}^\alpha T'_A + E_{2i}^\alpha T'^2_A + E_{3i}^\alpha T'^3_A$$

$$\text{for DE-A (6.7)}$$

$$F_i^\alpha(T'_A) = F_0{}^\alpha{}_i + F_1{}^\alpha{}_i T'_A + F_2{}^\alpha{}_i T'^2_A + F_3{}^\alpha{}_i T'^3_A$$

$$G_i(T'_B) = G_{0i} + G_{1i}T'_B + G_{2i}T'^2_B + G_{3i}T'^3_B$$

$$\text{for DE-B (6.8)}$$

$$H_i(T'_B) = H_{0i} + H_{1i}T'_B + H_{2i}T'^2_B + H_{3i}T'^3_B$$

The numerical coefficients in (6.7) and (6.8) are to be supplied and are unique for each axis (i) and range (α). For DE-A, the value of α, representing the mode of operation which is characterized by the range, is obtained from bits 65-33/2 and 65-33/1, i.e. the second and first significant bits, respectively, of the 8 bit 4 second subcom channel word, 65-33. The parameter α is coded in the following manner:

65-33/2	65-33/1	α
0	0	1
0	1	3
1	0	2
1	1	Not allowed

For DE-A, nominal values of the zero-th order term in E^{α}_{0i} and F^{α}_{0i} in (6.7) are as follows.

	E^{α}_{0i}			F^{α}_{0i}		
α \ i	1	2	3	1	2	3
1	8000.0	8000.0	8000.0	3.0000	3.0000	3.0000
2	-	-	-	0.5000	0.5000	0.5000
3	110.000	110.000	110.000	0.04000	0.04000	0.04000

Likewise, values of E^{α}_{1i}, E^{α}_{2i}, E^{α}_{3i}, F^{α}_{1i}, F^{α}_{2i}, and F^{α}_{3i} will be provided. For DE-B, nominal values of the zero-th order term in G_i and H_i in (6.8) are as follows:

i	1	2	3
G_{0i}	8000.0	8000.0	8000.0
H_{0i}	3.0000	3.0000	3.0000

Since word 65-33 is a 4 second subcom channel, the same parameter α is to be applied to all of the 64 samples within the subcom cycle. Bits 65-33/2 and 65-33/1 are repeated in the discrete output data bits 67-13/2 and 67-13/1, respectively. The range is permitted to change only at the start time of a four second subcom cycle. (The time of a range switch relative to the exact data-sample times will be discussed at the end of this Note.)

The small corrections δ^{α}_{Ai} and σ_{Bi}, to "2048" in (6.1) and (6.2) are to be provided. Approximate values of δ^{α}_{Ai} and δ_{Bi} are as follows:

	$\alpha \backslash i$	1	2	3
δ^{α}_{Ai}	1	-0.5	-0.2	0.5
	2	0.2	-0.8	1.4
	3	207.3	40.2	115.3
δ_{Bi}	-	1.1	1.1	2.5

The constants C^{α}_{Ai} and C_{Bi} are to be determined initially from ground tests and to be updated with flight data. It is import ınt to recognize that there is a time lapse of one minor frame before a range switch takes its effect. The data transmitted in the minor frame within which a range switch took place were taken with the range that had been operative prior to the range switch. The new range takes its effect starting from the data transmitt·d in the following minor frame.

As was explained in Note No. 2, July 26, 1979, the time t, of measurement has the following relation to the time, t_o, of the beginning of the minor frame in which the data are transmitted:

$$t = t_o - 0.0625\ (1 - 101/128) = t_o - 0.131835937 \text{ seconds for DE-A}$$

and

$$t = t_o - 0.0625\ (1 - 112/128) = t_o - 0.0078125 \text{ seconds for DE-B.}$$

DE-A AND B MAGNETOMETER DATA PROCESSING

NOTE NO. 10 (Revised) November 24, 1980

On DE-A Nadir Crossing Time

The Note No. 10, November 6, 1980, is to be replaced by this revised note. Dave Skillman has provided a correct understanding of the nadir pulse and the data on the nadir crossing time.

When the spacecraft Y,Z plane contains the nadir, i.e. the direction opposite to the zenith, a signal is given in word #14 in one of the minor frames #3, 7, 11 ....., 127 that comes first in the 1/2 second interval immediately following the 1/2 second interval in which this event took place (see Figure 1). This signal is "1" in the third most significant bit of word #14 in the minor frame.

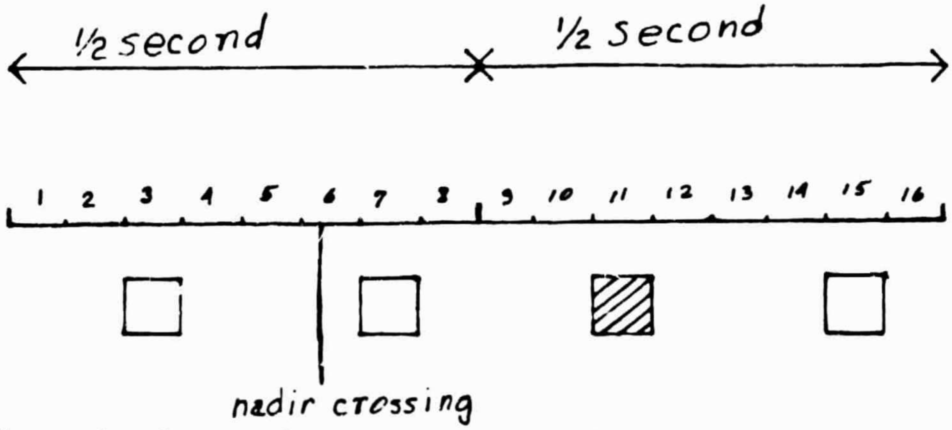

Figure 1. An example showing the relation between the time, T_N, at which the spacecraft Y,Z plane crosses the nadir and the minor frame (indicated by the shaded rectangle) in which the nadir signal is given.

It is noted that in the above account, the 128 minor frames in each major frame are numbered #1 through #128 and that the minor frame count, 0 through 127, is given in word #37 (called s/c subcom counter). It is also noted that the nadir crossing signal always comes in the third minor frame in a 1/2 second interval.

7, 8 9.1

The nadir crossing time, T_N, is obtained in the following manner, using the clock count which is registered in the ten-bit word composed of word #13 and the two most significant bits of word #14 in the minor frame in wich nadir signal is "on". The clock count, which runs 0 through 1023, indicates the "count" from the beginning of each 1/2 second interval, each count representing 1/2048 seconds. In the Sigma 9 computer, data are typically accessed by major frames (each major frame representing 8 seconds or 128 minor frames); also, with the data in a major frame, the time of the start of this major frame, T_{MAJ}, in milliseconds of day is returned. If a nadir crossing signal is "on", i.e., "1", in a minor frame with subcom counter count, s, then the nadir crossing time, T_N, is given by

$$T_N = T_{MAJ} + 0.5 \times (\mathrm{INT}\ (s/8) - 1) + \mathrm{COUNT}/2048$$

where the second term, i.e. $0.5 \times (\mathrm{INT}\ (s/8) - 1)$, represents the time, T_O of the beginning of the minor frame in which the nadir crossing occurred, measured from the beginning of the major frame, and where the third term represents the time from T_O to the nadir crossing.

The same clock count, COUNT, is repeated in the second minor frame (frame #15 in the example shown in Figure 1) designated for nadir crossing, in the 1/2 second interval in which the nadir signal was "on".

DE-A AND B MAGNETOMETER DATA PROCESSING

NOTE NO. 13 July 16, 1981

SUBJECT: Calibration - DE-A Magnetometer

1. Sensor Temperature

T_s	V_c
-15°C	5.07
-10°C	4.85
-5°C	4.57
0°C	4.27
+5°C	3.96
+10°C	3.55
+15°C	3.18
+20°C	2.83
+25°C	2.55
+31.1°C	2.27
+40°C	1.71

$$T_s = 96.9 - 46.806\ V + 9.64595\ V^2 - 0.9381\ V^3$$

2. Electronics Temperature

35°C	1.79
4.0°C	3.41
-6.0°C	4.07
35.5°C	1.93
24°C	2.37
-20°C	4.53
+50°C	1.23
-20°C	4.54
+50°C	1.35
-20°C	4.50
+50°C	1.44
-4°C	3.89

$$T_e = 105.7 - 56.69\ V + 12.86\ V^2 - 1.43\ V^3$$

3. DE-A Calibrations - Sensitivity

The DE magnetometer sensitivities are temperature dependent. The temperature calibrations are in general linear functions of temperature. Since the temperature controller is set to maintain the sensor at 27°C, the functions are expressed as:

$$f(t) = a_o + a_1(T-27)$$

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11.1 and 12.1

where T is the sensor temperature. There is no variation of calibration with electronics temperature.

The following table gives the calibrations for the three applicable modes for DE-A:

α		$50^\circ C$	$20^\circ C$	$0^\circ C$	a_o	a_1		δ
	E_1^1	8013.6	8016.6	8018.3	8015.8	-0.09447		
1	E_2^1	8092.4	8095.2	8098.7	8095.0	-0.12342		
	E_3^1	7943.2	7946.6	7948.3	7945.7	-0.10289		
	F_1^1	2.9299	2.9306	2.9319	2.9307	-3.87E-5	δ_1^1	-2.2
	F_2^1	2.9704	2.9716	2.9729	2.9715	-4.92E-5	δ_2^1	-1.7
	F_3^1	2.9715	2.9724	2.9736	2.9723	-4.11E-5	δ_3^1	0.8
	F_1^2	0.5199	0.52015	0.52040	[illegible]5201	-9.868E-6	δ_1^2	-4.0
2	F_2^2	0.52751	0.52776	0.52783	0.5277	-6.553E-6	δ_2^2	-3.2
	F_3^2	0.52773	0.52809	0.52814	0.52796	-8.500E-6	δ_3^2	0.0
	E_1^3	110.60	110.64	110.64	110.62	-8.421E-4		
3	E_2^3	111.70	111.76	111.79	111.74	-1.816E-3		
	E_3^3	109.69	109.71	109.74	109.71	-9.737E-4		
	F_1^3	0.03774	0.03775	0.03804	0.03782	-5.553E-6	δ_1^3	157.0
	F_2^3	0.03831	0.03834	0.03838	0.03834	-1.368E-6	δ_2^3	70.0
	F_3^3	0.03833	0.03839	0.03839	0.03836	-1.263E-6	δ_3^3	125.0

4. Transformation Matrices

The transformation from effective sensor coordinates to spacecraft coordinates is obtained from ground measurements of the transformation from effective sensor axes to the orthogonal optical cube followed by the transformation from cube axes to s/c coordinates obtained from alignment measurements on the spacecraft and unit level boom deployment tests.

The transformation from measurement coordinates to cube coordinates is:

$$(B) = \begin{pmatrix} 0.9999756 & 0.019007 & -0.002248 \\ -0.001837 & 0.9999373 & 0.0085239 \\ -0.004364 & -0.003343 & 0.999982 \end{pmatrix}$$

The transformation from cube to s/c coordinates is:

$$(A) = \begin{pmatrix} -0.90865 & 0.41743 & 0.00070 \\ 0.41753 & 0.90868 & -0.00803 \\ -0.00400 & -0.00754 & -0.99996 \end{pmatrix}$$

Thus, the transformation from sensor to spacecraft is given by:

$$(C) = (A) \times (B) = \begin{pmatrix} -0.909398 & 0.400131 & 0.006301 \\ 0.415886 & 0.916586 & -0.001223 \\ 3.7777E\text{-}4 & -0.004273 & -0.999997 \end{pmatrix}$$

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DE-A AND B MAGNETOMETER DATA PROCESSING

NOTE NO. 14 July, 24, 1981

SUBJECT: Calibration - DE-B Magnetometer

1. As with the DE-A magnetometer the temperature dependence of the calibrations constants is linear. Thus, the calibration constants are expressed in the form:

$$f(T) = a_o + a_1 \cdot (T-27)$$

where T is the sensor temperature. There is no variation of calibration with electronics temperature.

Because there is only one mode in the DE-B magnetometer operation the following table sufficies for the calibration constants.

	50°C	20°C	0°C	a_o	a_1		δ
E_1	7998.7	8005.5	8006.8	8003.1	-1.66E-1	δ_1	0
E_2	7837.0	7842.6	7845.5	7841.1	-1.71E-1	δ_2	0
E_3	7889.4	7895.6	7900.1	7894.3	-2.14E-1	δ_3	1.8
F_1	2.9890	2.9905	2.9918	2.9902	-5.57E-5		
F_2	2.9218	2.9235	2.9244	2.9231	-5.24E-5		
F_3	2.9628	2.9647	2.9664	2.9644	-7.16E-5		

2. Electronics Temperature formulas are:

$$T_s = 102.3 - 47.3\ V_s + 9855\ V_s^2 - 0.9594\ V_s^3$$

$$T_e = 206.8 - 156.8\ V_e + 45.0\ V_e^2 - 4.78\ V_e^3$$

where V_s is the equivalent voltage of telemetry word 68-12 and V_e is the equivalent voltage of telemetry word 68-13.

3. Transformation Matrices

The transformation from measurement coordinates to cube coordinates is:

$$(B) = \begin{pmatrix} .99999 & 5.361E-3 & -5.092E-4 \\ -2.436E-3 & .99992 & 8.171E-3 \\ -5.899E-3 & -8.261E-3 & .99994 \end{pmatrix}$$

The transformation from cube to spacecraft is

$$(A) = \begin{pmatrix} .9999996 & -2.478E-3 & 1.288E-3 \\ -2.443E-3 & -.999914 & 1.29E-2 \\ 1.257E-3 & -1.29E-2 & -.999919 \end{pmatrix}$$

Thus the transformation from measurement to spacecraft coordinates is:

$$(C) = (A) \times (B) = \begin{pmatrix} .99999 & 2.873E-3 & 7.585E-4 \\ -8.32E-5 & -.99995 & 4.730E-3 \\ 7.187E-3 & -4.632E-3 & -.99997 \end{pmatrix}$$

APPENDIX D

9/3/82

MEMORANDUM June 18, 1981

TO: DE Project Scientist

FROM: Masahisa Sugiura

SUBJECT: Mnemonics for Coordinates

B. G. Ledley, N. C. Maynard and I recommend the following 3-character mnemonics for the commonly used coordinates to be used in the utility programs:

Coordinate System	Mnemonic
(i) Cartesian coordinates	
Geocentric inertial	GEI
Solar ecliptic	SEC
Topographic	TOP
Solar geomagnetic	SGM
Solar magnetospsheric	SMS
Spacecraft	SPC
Local magnetic	LMG
(ii) Spherical coordinates	
Geographic spherical	GGS
Geomagnetic (dipole) spherical	GMS

APPENDEX E

9/3/82

MEMORANDUM June 18, 1981

TO: DE Project Scientist

FROM: Masahisa Sugiura

SUBJECT: Local Magnetic Coordinates

For general use by the DE Team I have prepared an algorithm to transform the components of a vector in the topographic coordinate system into components in the local magnetic coordinate system. The local magnetic coordinate (LMC) system (x', y', z') is defined as one in which (i) the z' axis is in the direction of the magnetic field vector $\vec{B}$, (ii) the y' axis is horizontal and is, more or less, eastward, and (iii) the x' axis completes a right-handed system.

In the topographic coordinate system, the x axis is northward, the y axis is eastward and the z axis, vertically downward.

Then the x', y', and z' components of a vector A in the local magnetic coordinate system is obtained from the topographic components by the following transformation.

$$\begin{pmatrix} A_{x'} \\ A_{y'} \\ A_{z'} \end{pmatrix} = \begin{pmatrix} \cos\alpha \sin\beta & \sin\alpha \sin\beta & -\cos\beta \\ -\sin\alpha & \cos\alpha & 0 \\ \cos\alpha \cos\beta & \sin\alpha \cos\beta & \sin\beta \end{pmatrix} \begin{pmatrix} Ax \\ A_y \\ A_z \end{pmatrix} \qquad (1)$$

where

α = east declination of $\vec{B}$

β = inclination of $\vec{B}$, measured positively downward
(= I in the ordinary notation)

A geomagentic reference field is normally given by B_r, B_θ, B_ϕ in spherical coordinates. Then, α and β are given by

$$\begin{aligned} \alpha &= \text{are tan}\,[B_\phi\,/(-B_\theta\,)] \\ \beta &= \text{arc tan}\,[B_r/B_\theta^2 + B_\phi^2)^{\ 1/2}] \end{aligned} \tag{2}$$

However, the standard program gives α (declination) and β (=I, inclination) as well as B_r, B_θ, and B_ϕ.

If we write (1) as

$$\mathbf{A}' = \underline{\mathbf{c}} \cdot \mathbf{A}$$

or

$$A_i' = \sum_J c_{ij}\, A_j \tag{3}$$

then the elements, c_{ij}, can be written in terms of field components:

$$\begin{aligned}
c_{11} &= \ B_r B_\theta/(HF) \\
c_{12} &= -B_r B_\phi/(HF) \\
c_{13} &= -H/F \\
c_{21} &= -B_\phi/H \\
c_{22} &= -B_\theta/H \\
c_{23} &= \ 0 \\
c_{31} &= -B_\theta/F \\
c_{32} &= \ B_\phi/F \\
c_{33} &= -B_r/F
\end{aligned}$$

$$H = (B_\theta^2 + B_\phi^2)^{1/2} \qquad \text{(horizontal field)}$$

$$F = (B_r^2 + B_\theta^2 + B_\phi^2)^{1/2} \qquad \text{(total field)}$$

It may be noted that the topographic components (A_x, A_y, A_z) of a vector, A, is related to those in geographic sphereical coordinates (A_r, A_θ, A_ϕ) by

$$A_x = - A_\theta$$
$$A_y = A_\phi$$
$$A_z = - A_r$$