Document:
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Magnetic Field Data Base Generator

for the

Fourier Program

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Magnetic Field Data Base Generator for the Fourier Program

User's Guide

I. Purpose

The magnetic field data for PIONEER is converted to a Fourier Program compatable tape, with timing adjusted to S/C time. A listing may also be generated, even if no tape is desired.

II. Input Required

1. Magnetic Field Tape
   (See the system documentation of this program for the format)
2. Output 9-track, 1600 BPI, NL tape
3. Trajectory tape
4. User Namelist:

Parameters	Type	Default	Description
QVOLS(6,10)	10*A6	*'s	Up to 10 EBCDIC input magnetic field tapes to process
QODB(6,2)	2*A6	*'s	Up to 2 EBCDIC output tape names
INTRVL	I*4	0	Averaging interval desired, in seconds
QTAPE	L*1	F	T=create output data base
NFILE	I*4	1	Output tape start file:
QTRAJ(6)	A6	blanks	Trajectory tape EBCDIC name
ITRFIL(2)	I*4	1,1	Start, end file number of the trajectory tape data to correlate with the magnetic field data
QPRINT	L*1	T	A listing of the data is desired
IMODE	I*4	none - required parameter	Mode of Spacecraft: 0 = Cruise Mode 1 = Jupiter Encounter 2 = Saturn Encounter

Parameters	Type	Default	Description
SOLAR(3)	R*4	1,1,1	Coordinates of the solar spin axis Cruise Mode: Solar = 0.03252 0.12194 0.99200 Jupiter Encounter: Solar = -0.01447871 -0.03481712 0.99928882
JTPTYP	I*4	none - required parameter	Unit type of input Magnetic Field Tape 7 = 7 Track 9 = 9 Track

III. Output Generated

1. Listing of the magnetic field data
2. A Fourier Program compatible magnetic field data base tape.

IV. Error Handling

Messages or Return Code	Error and Recovery
7	The timing is in error. Check the times and the average interval input for validity.
'END OF PROGRAM DUE TO END OF TRAJECTORY TAPE'	More data was to be processed than was contained on the trajectory tape. Check the tape for contents.
1	User-input flags are inconsistent, QTAPE or QPRINT must be set.true.
'READ ERROR ON TRAJECTORY TAPE. RECORD SKIPPED'	Self-explanatory

V. JCL

1. Unit 8 is the output Fourier magnetic field data base.

```
//FT08F001 DD
```

Source : SEVAK.MAGDBG.FORT (MAGDBG)
jcl : SBPIO.LIB.CNTL (SMAGDBGN)
load module : SBPIO.MAGDBG.LOAD

Magnetic Field Processing for the Fourier Program

I. Purpose

The magnetic field data for PIONEER is to be used in the Fourier program for listing and plotting. A new data base will consist of the data averaged over a user-specified time interval which would be consistent with the "FLUX" tape which is used as input to the Fourier program. Data specific to the Fourier program's use is included, as well as the original data in the input magnetic field tape for processing by other programs. All values will be averaged with a resolution of one minute, with no interpolation. All values are average over the interval in a simple manner: $\langle X \rangle = \Sigma X_i/N$, where N = # of intervals included in the sum of X_i.

II. Description

Each input magnetic field tape is one output file. Because the volume of data is small, there will be no tape catalog, and the data most likely will be confined to one tape.

The generated data base tape will be of one averaging interval, with resolution of one minute, the resolution of the input tape. No interpolation will be done for averages of non-integral multiples of one minute due to the expected stability of the field. The times on the output tape will be event times, adjusted from the input tape ground receipt times. The program will be modular, so future changes to incorporate slightly different computations of output will be more easily made.

Input coordinate transformations will be performed depending on the mode of the input tape. If Saturn encounter, the input coordinates will not be transformed. If the input is Cruise Mode in Pioneer inertial coordinates, the transformation will be to Solar-Heliographic coordinates. If the input is Cruise Mode in Solar-Heliographic coordinates, the transformation will be to Pioneer inertial coordinates. If Jupiter encounter, the input coordinates will be transformed to Pioneer inertial coordinates.

NOTE: All cruise mode magnetic field data prior to and including 1976 is in Solar-Heliographic Coordinates.

All cruise mode magnetic field data post 1976 is in Pioneer inertial coordinates.

III. Formulas

A. Distance from S/C to Earth:

$$R = (R_1{}^2 + R_2{}^2 - 2R_1R_2(\cos(A)\cos(B)\cos(C) + \sin(A)\sin(B)))^{1/2}$$

where: R_1 = Distance from S/C to sun
R_2 = Distance from Earth to sun
A = Theta for S/C
B = Theta for Earth
C = $\text{Phi}_{s/c} - \text{Phi}_{Earth}$

B. If u is the unit vector in the direction of B, and if $x = |\hat{u}|\cos\alpha$ and $y = |\hat{u}|\cos\beta$, and $z = |\hat{u}|\cos\gamma$, $|\hat{u}| = 1$, then Phi, Theta are:

$$\text{Phi} = \phi = \text{ATAN2 } (y/x) = \text{ATAN2} \left(\frac{\langle\cos\beta\rangle}{\langle\cos\alpha\rangle} \right)$$

$$\text{Theta} = \theta = 90 - \cos^{-1} z = 90 - \cos^{-1}(\langle\cos\gamma\rangle)$$

For PIONEER, -x=y' and y=x', x', y' are input.

C. Transformation Matrix

Used to transform Jupiter Encounter Coordinates and Solar-Heliographic coordinates to Pioneer Inertial Coordinates. The transpose of this matrix is used to transform Pioneer Inertial Coordinates to Solar-Heliographic Coordinates.

Let	$\| \ \|$	denote	magnitude
	X	"	vector product
	δsc	"	celestial latitude of the spacecraft
	λsc	"	celestial longitude of the spacecraft
	δE	"	celestial latitude of the Earth
	λE	"	celestial longitude of the Earth
	Rsc	"	Sun - Spacecraft distance
	Re	"	Sun - Earth distance

T = transform matrix
= U • V where U,V, & T are all 3X3 matrices

to calculate the

U Matrix: SOLAR(3) = solar spin coordinates
X1(3) = COS δsc cos λsc,
COS δsc sin λsc,
sin δsc

Y1(3) = (SOLAR X X1) ÷ || SOLAR X X1 ||

Z1(3) = X1 X Y1

$$U(3,3) = \begin{bmatrix} X1(3) \\ Y1(3) \\ Z1(3) \end{bmatrix}$$

V Matrix:

$P(1) = -Rsc \cos \delta sc \cos \lambda sc + Re \cos \delta e \cos \lambda e$
$P(2) = -Rsc \cos \delta sc \sin \lambda sc + Re \cos \delta e \sin \lambda e$
$P(3) = -Rsc \sin \delta sc + Re \sin \delta e$

Z1(3) = P/||P||
X1(3) = [0 0 1] X Z1
Y1(3) = Z1 X X1

V(3,3) = [X1(3) Y1(3) Z1(3)]

T Matrix:

T = UV

$$\Longrightarrow t_{ij} = \sum_k U_{ik} V_{kj}$$

to transform the coordinates:

LET BX, BY, BZ denote the original coordinates

new x coord. = BX • T(1,1) + BY • T(2,1) + BZ • T(3,1)
new y coord. = BX • T(1,2) + BY • T(2,2) + BZ • T(3,2)
new z coord. = BX • T(1,3) + BY • T(2,3) + BZ • T(3,3)

$$MAG = \text{magnitude} = \left((\text{new } x)^2 + (\text{new } y)^2 + (\text{new } z)^2\right)^{1/2}$$

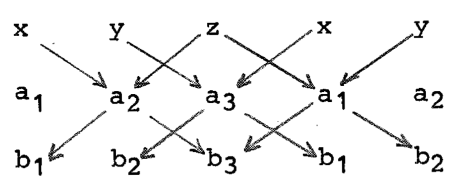
$\cos \alpha$ = new x/MAG
$\cos \beta$ = new y/MAG
$\cos \gamma$ = new z/MAG

D. <u>Vector Product</u>

LET A = vector 1
B = vector 2

$$A \times B = (a_2b_3 - a_3b_2)\ x + (a_3b_1 - a_1b_3)\ y + (a_1b_2 - a_2b_1)\ z$$

which is the expanded form of the determinant



resulting vector is

$$V = \begin{bmatrix} (a_2b_3 - a_3b_2) \\ (a_3b_1 - a_1b_3) \\ (a_1b_2 - a_2b_1) \end{bmatrix}$$

$$||V|| = \left(V(1)^2 + V(2)^2 + V(3)^2\right)^{1/2}$$

IV. Contents

The tape will be fixed, blocked, with byte length of 160/record. It will be multi-filed with a new file beginning with each input magnetic field data tape. The following values will comprise the record:

Byte Field	Type	Description
1-4	I4	Year of start of interval
5-8	I4	Day of start of interval
9-12	I4	Seconds of day of start of interval
13-16	I4	Interval in seconds of the average
17-20	R4	Milliseconds of data in the interval
21-24	I4	Input tape flag: 0=cruise, 1=Jupiter,2=Saturn
25-28	R4	*<cosα> in S/C spin coordinates
29-32	R4	*<cosβ> in S/C spin coordinates
33-36	R4	*<cosγ> in S/C spin coordinates

Byte Field	Type		Description
37-60	24*L1		The Phi sector counts, 15° sectors
61-72	12*L1		The Theta sector counts, 15° sectors
73-76	R4	*	$\langle B_x \rangle$ in desired coordinate system
77-80	R4	*	$\langle B_y \rangle$ in desired coordinate system
81-84	R4	*	$\langle B_z \rangle$ in desired coordinate system
85-88	R4	**	$\langle B_x \rangle$ in input tape coordinates
89-92	R4	**	$\langle B_y \rangle$ in input tape coordinates
93-96	R4	**	$\langle B_z \rangle$ in input tape coordinates
97-100	R4		$\langle B_x^2 \rangle$ in input tape coordinates
101-104	R4		$\langle B_x B_y \rangle$ in input tape coordinates
105-108	R4		$\langle B_x B_z \rangle$ in input tape coordinates
109-112	R4		$\langle B_y^2 \rangle$ in input tape coordinates
113-116	R4		$\langle B_y B_z \rangle$ in input tape coordinates
117-120	R4		$\langle B_z^2 \rangle$ in input tape coordinates
121-124	R4	**	$\langle \cos\alpha \rangle = B_x/B$ in input tape coordinates
125-128	R4	**	$\langle \cos\beta \rangle = B_y/B$ in input tape coordinates
129-132	R4	**	$\langle \cos\gamma \rangle = B_z/B$ in input tape coordinates
133-136	R4		$\langle \lvert B \rvert \rangle$
137-140	R4		$\langle \lvert B^2 \rvert \rangle$
141-160	--		Spare bytes

* Always in PE coordinates

** If input data is cruise mode, post 1976, these values are in SH coordinates even though the input is in PE coordinates

V. Coordinate System

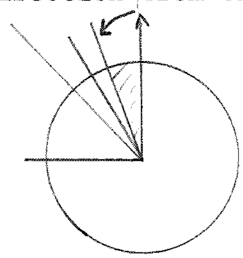
The coordinate system used for the Fourier input is a right-handed system using X axis as the reference direction. The X axis lies in the ecliptic plane, pointing toward the Sun. The Y axis lies in the ecliptic plane, ⊥ to X axis. The Z axis is zenith, perpendicular to the ecliptic plane.

The cosines are then defined as follows:

$$\langle \cos\alpha \rangle = \langle B_x/\lvert B \rvert \rangle$$
$$\langle \cos\beta \rangle = \langle B_y/\lvert B \rvert \rangle$$
$$\langle \cos\gamma \rangle = \langle B_z/\lvert B \rvert \rangle$$

where B_x, B_y, and B_z are the components of the magnetic field in S/C spin coordinates.

The Phi and Theta arrays are oriented to the reference direction such that 0° is the reference direction, and thus, Phi (1) for example, is the sector value averaged from 0° to 15° centered on 7.5° in the counter-clockwise direction from the reference direction:



VI. Common Blocks

The FTIO package will be used in creating the tape, with the following common used as output:

```
COMMON /MAGIN/MRY,MDAY,MSC,INTRVL,DMILLI,ISATRN,COSA,COSB,COSG,
     QPSECT(24),QTSECT(12),BX,BY,BZ,AVGS(14),SPARE(5)
```

where IMPLICIT REAL (A-H),INTEGER (I-N),LOGICAL*1 (Q)

Magnetic Field Tape Generator

I.

A. Overview

The magnetic field data for PIONEER is to be used in the Fourier Plot Program for listing and plotting. A new data base will consist of the data averaged over a user-specified time interval which would be consistent with the input data base to the Fourier program. Data specific to the Fourier program's use is included, as well as the original data in the input magnetic field tape for processing by other programs. All values will be averaged with a resolution of one minute, with no interpolation. All values are averaged over the interval in a simple manner: $\langle X \rangle = \Sigma X_i/N$, where N = # of intervals included in the sum of X_i.

The generated data base tape is made of one averaging interval, with resolution of one minute which is the resolution of the input tape. No interpolation will be done for averages of non-integral multiples of one minute due to the expected stability of the field. The times on the output tape will be event times, adjusted from the input tape ground receipt times.

B. Input Required

1. Input magnetic field tape, post 1976

The tape is multi-filed with each file containing one day's data. The data exists in three average periods: minute, hour, and day averages.

2. Structure

Header record: 1440 minute average records

24 hour average records
1 day average record
5 spare records

The data is read with FORTRAN formatted reads as follows:

Header record: (3X,I2,2X,F3,4X,A1,15X,6E15.7,30A4)

Variable	Format	Description
	3X	
IYR	I2	Last two digits of year
	2X	
IDAY	I3	Day of year
	4X	
ISC	A1	Spacecraft (F or G)
	15X	

Variable	Format	Description
HRANGP	E15.7	Distance of spacecraft from sun (km)
CELLTP	E15.7	Heliocentric celestial latitude of spacecraft (degrees)
CELLNP	E15.7	Heliocentric celestial longitude of spacecraft (degrees)
REARSU	E15.7	Distance of Earth from sun (km)
CELLTE	E15.7	Heliocentric celestial latitude of Earth (degrees)
CELLNE	E15.7	Heliocentric celestial longitude of Earth (degrees)
TEXT	30A4	Text describing the file

The above trajectory data is often filled with zeros, thus a trajectory tape is used to convert ground receipt times to event times.

Data records: (8E15.6,15X,7E15.6)

Variable	Format	Description
DT	E15.7	Number of milliseconds for which data exists in the period over which the average was taken
EV(1)	E15.7	$\langle B_x \rangle$
EV(2)	E15.7	$\langle B_y \rangle$
EV(3)	E15.7	$\langle B_z \rangle$
EV(4)	E15.7	$\langle B^2 \rangle$
EV(5)	E15.7	$\langle B_x B_y \rangle$
EV(6)	E15.7	$\langle B_x B_z \rangle$
EV(7)	E15.7	$\langle B_Y{}^2 \rangle$
	15X	
EV(8)	E15.7	$\langle B_y B_z \rangle$
EV(9)	E15.7	$\langle B_z{}^2 \rangle$
EV(10)	E15.7	$\langle \cos \alpha \rangle = \langle B_x / \lvert B \rvert \rangle$
EV(11)	E15.7	$\langle \cos \beta \rangle = \langle B_y / \lvert B \rvert \rangle$
EV(12)	E15.7	$\langle \cos \nu \rangle = \langle B_z / \lvert B \rvert \rangle$
EV(13)	E15.7	$\langle \lvert B \rvert \rangle$
EV(14)	E15.7	$\langle \lvert B \rvert^2 \rangle$

3. Input Magnetic Field Tape, 1976 and before

The text portion of the header record is not present.

The data is read with Fortran formatted reads as follows:

Header record: (3X,I2,2X,F3,4X,A1,15X,6E,15.7)

4. Trajectory Tape

Tape Characteristics

Blksze = 12640
Lrecl = 1264
Recfm = FB
Den = 4
Label = Sl
Track = 9-track

5. File Formats

Each file corresponds to a particular time period, not necessarily in chronological order. The records are read into a common block as follows:

Header record - skipped
Data records:

Variable	Type	Definition
DTSP50	R*8	Time (sec.) past 0^h Jan. 1, 1950
DJULDT	R*8	Julian date (days)
ITIME(6)	I*4	Year, month, day, hour, min. second
DEC2(153)	R*4	Element #8 = distance of S/C from earth (km) Element #11 = sun-earth distance (km) Element #17 = sun-spacecraft distance (km) Element #20 = celestial latitude of S/C (deg) Element #21 = celestial longitude of S/C (deg) Element #22 = celestial latitude of earth (deg) Element #23 = celestial longitude of earth (deg)

C. Output Generated

1. Fourier Magnetic Field Data Base

This tape is an option in case only a listing is desired.

Tape Characteristics

Blksize = 7200
Lrecl = 160
Recfm = FB
Den = 3
Label = NL
Track = 9-track

2. File Format

Each file is one imput magnetic field tape of about one week of data. It is read into a common block called /MAGN/ (see Common Block Definitions).

There are no file headers.

Byte Field	Type		Description
1-4	I4		Year of start of interval
5-8	I4		Day of start of interval
9-12	I4		Seconds of day of start of interval
13-16	I4		Interval in seconds of the average
17-20	R4		Milliseconds of data in the interval
21-24	I4		Input tape flag: 0=cruise, 1=Jupiter, 2=Saturn
25-28	R4	*	$\langle \cos\alpha \rangle$ in S/C spin coordinates
29-32	R4	*	$\langle \cos\beta \rangle$ in S/C spin coordinates
33-36	R4	*	$\langle \cos\gamma \rangle$ in S/C spin coordinates
37-60	24*L1		The Phi sector counts, 15° sectors
61-72	12*L1		The Theta sector counts, 15° sectors
73-76	R4	*	$\langle B_x \rangle$ in desired coordinate system

Byte Field	Type	Description
77-80	R4	* $\langle B_y \rangle$ in desired coordinate system
81-84	R4	* $\langle B_z \rangle$ in desired coordinate system
85-88	R4	** $\langle B_x \rangle$ in input tape coordinates
89-92	R4	** $\langle B_y \rangle$ in input tape coordinates
93-96	R4	** $\langle B_z \rangle$ in input tape coordinates
97-100	R4	$\langle B_x^2 \rangle$ in input tape coordinates
101-104	R4	$\langle B_x B_y \rangle$ in input tape coordinates
105-108	R4	$\langle B_x B_z \rangle$ in input tape coordinates
109-112	R4	$\langle B_y^2 \rangle$ in input tape coordinates
113-116	R4	$\langle B_y B_z \rangle$ in input tape coordinates
117-120	R4	$\langle B_z^2 \rangle$ in input tape coordinates
121-124	R4	** $\langle \cos\alpha \rangle = B_x/B$ in input tape coordinates
125-128	R4	** $\langle \cos\beta \rangle = B_y/B$ in input tape coordinates
129-132	R4	** $\langle \cos\gamma \rangle = B_y/B$ in input tape coordinates
133-136	R4	$\langle \lvert B \rvert \rangle$
137-140	R4	$\langle \lvert B^2 \rvert \rangle$
141-160	--	Spare bytes

* Always in PE coordinates

** If input data is Cruse Mode, post 1976, these values will be in Solar-Heliographics coordinates even though the input is in Pioneer inertial coordinates.

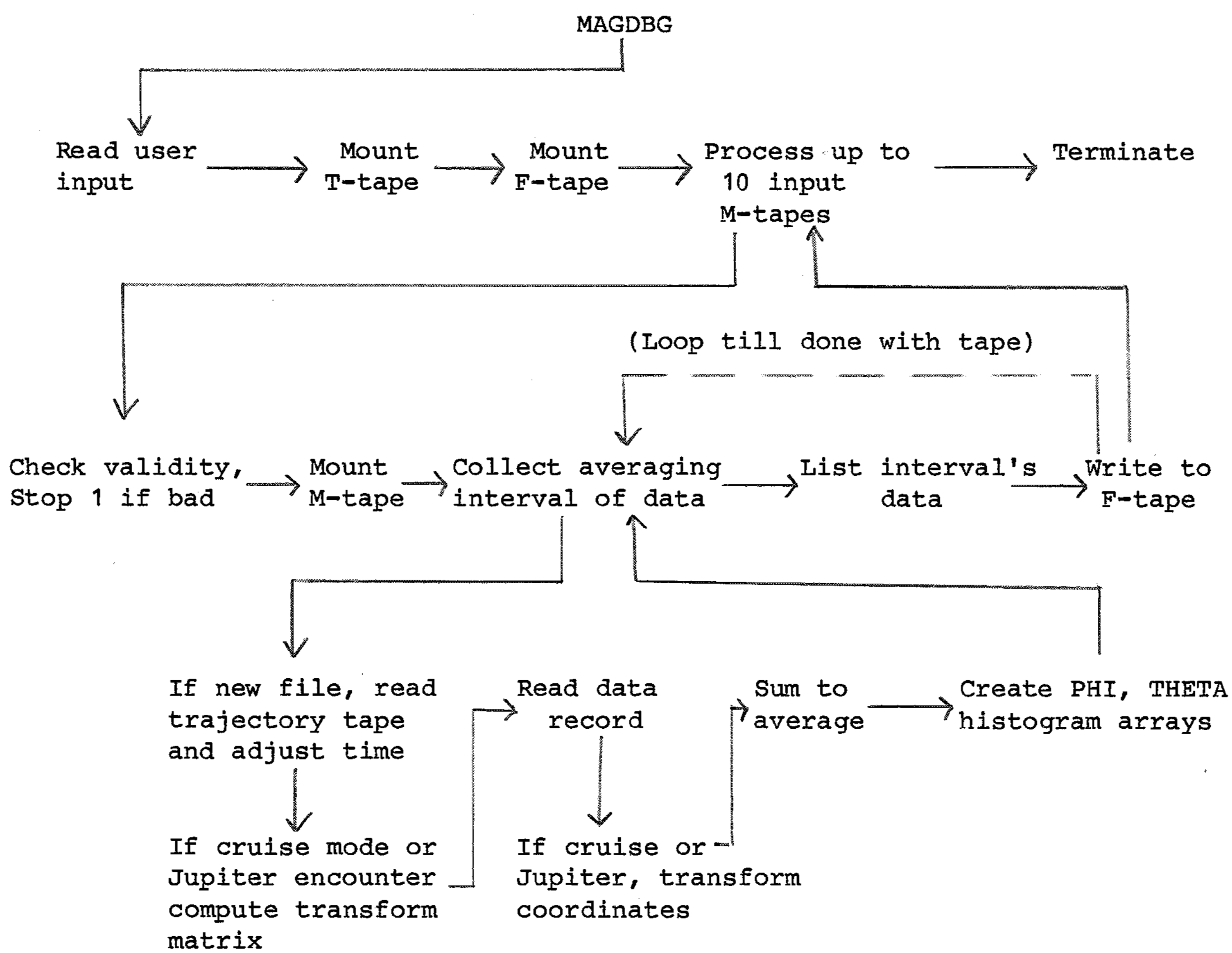
3. Listing

A listing of the times and above data is generated at user's options.

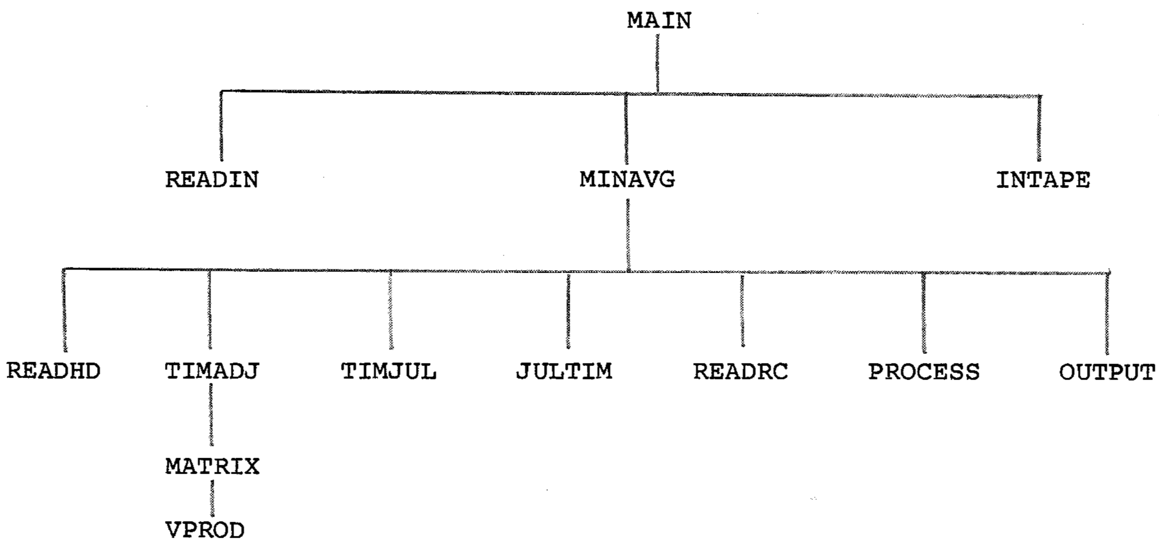
II. Program Documentation

A. Design Flow

M-Tape = input magnetic field tape
F-Tape = output Fourier data base tape
T-Tape = Trajectory tape



B. Block Diagram



C. Module Definition

Module	Purpose
MAIN	Controls program flow
INTAPE	Mounts and positions proper input magnetic field tape
JULTIM	Converts modified Julian time (epoch 1972) to year, month, day, hour, minute, second
TIMJUL	Reverses order of JULTIM, converting to modified Julian time (epoch 1972)
TIMADJ	Reads the trajector tape and returns the difference in seconds of ground receipt time and S/C event time
MATRIX	Calculates the transform maxtrix used to transform Cruise Mode (SH) and Jupiter encounter coordinates into Pioneer inertial coordinates, and Cruise Mode (PE) coordinates into Solar-Heliographic coordinates
VPROD	Calculates the vector product of two vectors
MINAVG	Collects the averaging intervals and processes them from the minute averages of the magnetic field tape
PROCES	Collects the histrograms for PHI and THETA and sends the current data into the average
OUTPUT	Prepares the data for output and lists it if desired
READIN	Reads in and prints out user parameters
READHD	Reads the header record of either a 7-track or 9-track tape
READRC	Reads in a 7200 byte block of data and returns 240 bytes of data to the program

D. Common Blocks

1. Common/TAPE/NVOL,NFILE,ITRFIL(2),QVOLS(6,10),QODB(6,2),QNDB (6,2),QTRAJ(6)

Holds all tape information.

Variable	Type	Description
NVOL	I*4	Number of input tapes used so for this run
NFILE	I*4	The Fourier data base file #
ITRFIL(2)	I*4	Trajectory tape start, end files
QVOLS(6,10)	L*1	100 6-character names of input magnetic field tapes
QODB(6,2)	L*1	2 6-character names of the old data base
QNDB(6,2)	L*1	2 6-character names of the new data base
QTRAJ(6)	L*1	Trajectory tape name

2. Common /FLAGS/QNEW,QTAPE,QPRINT

Holds flags for processing.

Variable	Type	Description
QNEW	L*1	T = first time through program
QTAPE	L*1	T = add the data to the Fourier magnetic field data base
QPRINT	L*1	T = list the data on the line printer

3. COMMON

/MAGN/HYR,MDAY,MSC,INTRVL,DMILLI,ISATRN,COSA,COSB,COSG,QPSECT(24) QTSECT(12),BX,BY,BZ,AVGS(14),SPARE(5)

The output common for the Fourier data base.

The values corresponds to the Fourier data base system records, with the variable types as follows: IMPLICIT REAL (A-H),INTEGER(I-N),LOGICAL*1(Q)

4. COMMON /CRZMOD/AVGS2(6),SOLAR(3)

Holds arrays needed for coordinate transformation.

Variable	Type	Description
AVGS2(6)	R*4	Sums the transformed coordinate values and cosine values for averaging
SOLAR(3)	R*4	Coordinates of the solar spin axis

E. Formulas

1. Distance from S/C to Earth:

$$R = (R_1^2 + R_2^2 - 2R_1R_2(\cos(A)\cos(B),\cos(C) + \sin(A)\sin(B)))^{1/2}$$

where: R_1 = Distance from S/C to sun
R_2 = Distance from Earth to sun
A = Theta for S/C
B = Theta for Earth
C = $\mathrm{Phi}_{S/C} - \mathrm{Phi}_{Earth}$

2. If u is the unit vector in the direction of B, and if $x = |u|\cos\alpha$ and $y = |u|\cos\beta$, and $z = |u|\cos\gamma$, $|u| = 1$, then Phi, Theta are:

$$\mathrm{Phi} = \phi = \mathrm{ATAN2}\ (y/x) = \mathrm{ATAN2}\ \left(\frac{<\cos\beta>}{<\cos\alpha>}\right)$$

$$\mathrm{Theta} = \theta = 90 - \cos^{-1} z = 90 - \cos^{-1}\ (<\cos\gamma>)$$

For PIONEER, $x =- y'$ and $y = x'$, x',y' are from the input tape.

3. Transformation Matrix:

Used to transform Jupiter Encounter coordinates to Pioneer Inertial coordinates. The transpose of this matrix is used to transform Pioneer Inertial coordinates to Solar-Heliograpic coordinates.

LET: || || denote magnitude
X denote vector product
δsc " celestial latitude of the spacecraft
λsc " " longitude of the spacecraft
δE " " latitude of the Earth
λE " " longitude of the Earth
Rsc " Sun-spacecraft distance
RE " Sun-Earth distance

T = transform Matrix
= U • V   where U,V, & T are all 3X3 matrices

to calculate the:

U Matrix: SOLAR(3) = SOLAR SPIN COORDINATES

$X1(3) = \cos\delta sc \cos\lambda sc, \cos\delta sc \sin\lambda sc, \sin\delta sc$

$Y1(3) = (SOLAR \times X1) \div || SOLAR \times X1 ||$

$Z1(3) = X1 \times Y1$

$$U(3,3) = \begin{bmatrix} X1(3) \\ Y1(3) \\ Z1(3) \end{bmatrix}$$

V Matrix:

$P(1) = -R_{sc} \cos\delta_{sc} \cos\lambda_{sc} + R_E \cos\delta_E \cos\lambda_E$

$P(2) = -R_{sc} \cos\delta_{sc} \sin\lambda_{sc} + R_E \cos\delta_E \sin\lambda_E$

$P(3) = -R_{sc} \sin\delta_{sc} + R_E \sin\lambda_E$

$Z1(3) = P/||P||$

$X1(3) = [0\ 0\ 1] \times Z1$

$Y1(3) = Z1 \times X1$

$V(3,3) = [X1(3)\quad Y1(3)\quad Z1(3)]$

T Matrix: T = UV

$\Longrightarrow t_{ij} = \sum_k U_{ik} V_{kj}$ where $i = 1,2,3$, $j = 1,2,3$, $k = 1,2,3$

to transform the coordinates:

LET BX, BY, BZ denote the original coordinates.

new x coord. = BX • T(1,1) + BY • T(2,1) + BZ • T(3,1)
new y coord. = BX • T(1,2) + BY • T(2,2) + BZ • T(3,2)
new z coord. = BX • T(1,3) + BY • T(2,3) + BZ • T(3,3)

$MAG = \text{magnitude} = \left((\text{new } x)^2 + (\text{new } y)^2 + (\text{new } z)^2\right)^{1/2}$

$\cos\alpha = \text{new } x/MAG$

$\cos\beta = \text{new } y/MAG$

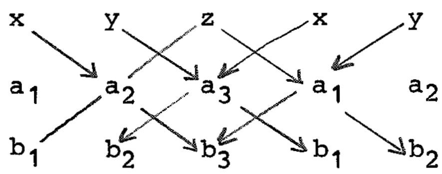
$\cos\gamma = \text{new } z/MAG$

4. Vector Product:

LET A = vector 1
B = vector 2

$$A \times B = (a_2b_3 - a_3b_2)x + (a_3b_1 - a_1b_3)y + (a_1b_2 - a_2b_1)z$$

which is the expanded form of the determinant



resulting vector is

$$V = \begin{bmatrix} (a_2b_3 - a_3b_2) \\ (a_3b_1 - a_1b_3) \\ (a_1b_2 - a_2b_1) \end{bmatrix}$$

$$|| V || = \left(V(1)^2 + V(2)^2 + V(3)^2\right)^{1/2}$$

F. Coordinate System

The coordinate system used for the Fourier input is a right handed system, using X axis as the reference direction. The X axis lies in the ecliptic plane, pointing toward the Sun. The Y axis lies in the ecliptic plane, peipendicular to X axis. The Z axis is zenith, perpendicular to the ecliptic plane.

The cosines are then defined as follows:

$$\langle \cos\alpha \rangle = \langle B_x/|B| \rangle$$
$$\langle \cos\beta \rangle = \langle B_y/|B| \rangle$$
$$\langle \cos\gamma \rangle = \langle B_z/|B| \rangle$$

where B_x, B_y, and B_z are the components of the magnetic field in S/C spin coordinates.

The Phi and Theta arrays are oriented to the reference direction such that 0° is the reference direction, and thus Phi(1) for example is the sector value averaged from 0^o to 15^o centered on 7.5° in the counter-clockwise direction from the reference direction:

G. Module Documentation

All modules were designed, coded, and tested by Jenny Jacques, Code 664, November 1979. MATRIX, VPROD,READHD, and READRC were defined, coded, and tested by Ronnie Kell, Code 664, July 1981.

1. Module: MAIN

   a. Purpose: Controls program flow

   b. Calls: READIN,INTAPE,MINAVG

c. Commons:

Common	Variable	I/O
TRAJ	none used	
TAPE	ITRFIL	I
		QODBI
		NFILEI
		QTRAJI
FLAGS	QTAPE	I

d. Local Variables:

Name	Type	Description
QDONE	L*1	T = end of processing
MODE	I*4	Mode of spacecraft: 0=cruise 1=Jupiter 2=Saturn
ITPTYP	I*4	Type of input tape: 7=7-track 9=9-track

e. Algorithm:

The necessary tapes are mounted, then the data is collected with MINAVG which returns when finished with the entire tape. If no more input tapes are required, the program ends.

2. Module: INTAPE

a. Purpose: Mounts a new magnetic field input tape

b. Arguments:

Name	Type	I/O	Description
QDONE	L*1	O	T = no more tapes to mount
ITPTYP	I*4	I	Type of track: 7=7-track 9=9-track

c. Called by: MAIN

d. Commons:

Common	Variable	I/O
FLAGS	QNEW	I
	QTAPE	I
TAPE	NVOL	I,O
	NFILE	I,O
	QVOLS	I

e. Local Variables:

Name	Type	Description
QASTR	L*1	'*', which means no more entries in the name array.
LUN	I*4	Logical unit number - used to determine which unit to read, depending on ITPTYP

f. Algorithm:

The name array is checked to see if there are any more input tapes to mount. If not, QDONE is set to .true. and INTAPE returns. If there is another tape, it is mounted, and an EOF is placed on the Fourier data base.

3. Module: JULTIM

a. Purpose: Convert modified Julian time to year, day, seconds of day.

b. Arguments:

Name	Type	I/O	Description
IYR	I*4	O	Last two digits of year
IDAY	I*4	O	Day of year
ISECC	I*4	O	Seconds of day
LTIME	I*4	I	Modified Julian day

c. Called by: MINAVG

d. Commons:

Name	Variable	I/O
MAGN	INTRVL	I

e. Local Variables:

Name	Type	Description
RDYCN	R*4	Number of intervals per day
JDAY	I*4	Days since epoch day 1972
JAVGS	I*4	Number of intervals of day
LEAP	I*4	1=not leap year, 2=leap year
IDAYS(16)	I*4	Days since epoch for each year

f. Algorithm:

The number of days since epoch day Jan. 0, 1972 is found, and the number of intervals in the day is calculated. Then the year, day, and seconds are found by simple calculation using a pre-defined array.

4. Module: MINAVG

a. Purpose: To collect minute averages from the magnetic field tape and process them onto the output data base.

b. Arguments:

Name	Type	I/O	Description
MODE	I*4	I	Mode of spacecraft
ITPTYP	I*4	I	Tape type

c. Called by: MAIN

d. Calls: TIMADJ,OUTPUT,JULTIM,TIMJUL,PROCES,READHD,READRC,MATRIX

e. Commons:

Name	Variable	I/O
FLAGS	all	I
MAGN	MYR,MDAY,MSC, DMILLI,COSA to end	O

f. Local Variables:

Name	Type	Description
DATA(14)	R*4	Input data from magnetic field tape, summed into AVGS(14)
T(3,3)	R*4	Transformation MATRIX
IBLOCK	I*4	Counter for the blocks of input data processed. There are 48 blocks of data per day
TRAJ(6)	R*4	Input trajectory data from tape
JYR JDAY JSC JTIME	I*4	Year, day, seconds of day, and coverted time of the current data
ITOT	I*4	Number of input averages read in for the interval
QDONE	L*1	T=done with the input tape processing

Name	Type	Description
ITIMER	I*4	The averaging interval times, in epoch time
MINUTS	I*4	Counter for the minutes processed in the input tape data block
NUMAVG	I*4	Subset of ITOT; number of input averages accepted into the interval's sums
RMILLI	I*4	Milliseconds of data in the current record

g. Algorithm:

The flags and pointers are initialized, and the header to the day data is read. The time from the header is adjusted so that the time is S/C time instead of ground receipt time. Then the minute averages from the tape are processed as follows:

1. Average read in
2. Check for end of interval. If end, write it to the data base tape
3. Process the day through several steps in PROCES, summing it into the interval

After all the minutes for the day have been processed, the hour and day averages on the tape are skipped and the next day is processed as described above.

5. Module: OUTPUT

a. Purpose: To prepare data for output to data base tape, listing it if desired.

b. Arguments:

Name	Type	I/O	Description
NUMAVG	I*4	I	# averages summed into the data
QPRINT	L*1	I	T=print the data
ITOT	I*4	I	# averages read from the tape for this interval
MODE	I*4	I	Mode for the spacecraft
ITPTYP	I*4	I	Tape type

c. Called by: MINAVG

d. Commons:

Name	Variable	I/O
MAGN	all but TIMES	I,O
TRNSFM	AVGS2(6)	I

e. Local Variables:

Name	Type	Description
IP	I*4	Pointer to Phi sector with the maximum counts
OUT(6)	R*4	Used to store data which is to be printed out
PHI	R*4	Sector degrees, for calculating the deviation in Phi
THETA	R*4	Sector, degrees for calculating the deviation in Theta
HOLD(6)	R*4	Array used to hold values when interchanging input and output coordinates

f. Algorithm:

Divide the summed values by the number of intervals. If print is desired, calculate the angles Phi and Theta, and their deviations. The Phi deviation is derived using the maximum counts sector as the middle sector of the formula.

g. Formulas:

The angles are created as:

$$PHI = \left(\tan^{-1} \left(\frac{\cos\beta}{\cos A}\right) \right)^{1/2} \quad (\text{modulus } 360^{\circ})$$

$$THETA = 90 - \cos^{-1} (COSG)$$

The deviations of Phi and Theta are:

$$\left| \frac{\sum_{i=1}^{n} C_i \theta_i^{2}}{\sum_{i=1}^{n} C_i} - \frac{\left(\sum_{i=1}^{n} C_i \theta_i\right)^2}{\left(\sum_{i=1}^{n} C_i\right)^2} \right|$$

where n=24 sectors for Phi, and
n=12 sectors for Theta

6. Module: PROCES

a. Purpose: To analyze each input average interval and to transform the coordinates into Pioneer inertial coordinates if the data is in cruise mode or from the Jupiter encounter.

b. Arguments:

Name	Type	I/O	Description
T(3,3)	R*4	I	Transformatin Matrix
RMILLI	R*4	I	Milliseconds of data of the average interval
ITPTYP	I*4	I	Tape type
DATA(14)	R*4	I	Data from input current interval
MODE	I*4	O	Mode of spacecraft

c. Called by: MINAVG

d. Commons:

Name	Variables	I/O
MAGN	AVGS,DMILLI, QTSECT,QPSECT	I,O
TRNSFM	AVGS2(6)	O

e. Local Variables:

Name	Type	Description
ANGL	R*4	Steps through the angles of Phi and Theta to collect the QTSECT and QPSECT arrays
PHI	R*4	The Phi angle for this average
THETA	R*4	The Theta angle for this average
TRANS(6)	R*4	The transformed coordinates and their cosine values
BMAG	R*4	Magnitude of the vector of transformed coordinates

f. Algorithm:

The input record data is summed to the collecting variables. Then the Phi and Theta histogram arrays are added to by the current interval's Phi and Theta.

g. Formulas:

$$\text{Phi} = \tan^{-1}\left(\frac{y}{x}\right), \text{ modulus } 360^{\circ}$$

where y=input x*(-1)
x=input y

Coordinate transformation:

x coordinate: TRANS(1)=BX * T(1,1) + BY * T(2,1) + BZ * T(3,1)
y coordinate: TRANS(2)=BX * T(1,2) + BY * T(2,2) + BZ * T(3,2)
z coordinate: TRANS(3)=BX * T(1,3) + BY * T(2,3) + BZ * T(3,3)

where BX,BY, & BZ are the original coordinates.

$$BMAG = \left((TRANS(1))^2 + (TRANS(2))^2 + (TRANS(3))^2\right)^{1/2}$$

$\cos\alpha$ = TRANS(1)/BMAG
$\cos\beta$ = TRANS(2)/BMAG
$\cos\gamma$ = TRANS(3)/BMAG

7. Module: READIN

a. Purpose: To read in user input options

b. Arguments:

Name	Type	I/0	Description
MODE	I*4	O	Mode of spacecraft 0=Cruise Mode 1=Jupiter 2=Saturn
ITPTYP	I*4	O	Tape type 7=7-track 9=9-track

c. Called by: MAIN

d. Commons:

Common	Variables	I/O
FLAGS	all	O
MAGN	INTRVL	O
TAPE	all	O
TRNSFM	SOLAR(3)	0

e. Local Variables: None

f. Algorithm:

Initialize the arrays with asterisks to signal end. Then read in the data via namelist and perform simple validity checks.

8. Module: TIMADJ

a. Purpose: To read the trajectory tape and find the time elapsed between the S/C and ground receipt times, adjusting the time from the data to be S/C time.

b. Arguments:

Name	Type	I/O	Description
IYR			Year, day, and seconds of
IDY	I*4	I,O	day of the current magnetic
ISC			field data
QDONE	L*1	O	T=end of trajectory tape usage
QNEW	L*1	I	T=first time in routine, skip file header

c. Called by: MINAVG

d. Commons:

Name	Variable	I/O
TRAJ	all	O
TAPE	ITRFIL	I,O

e. Local Variables:

Name	Type	Description
IDAY	I*4	Day of year
LEAP	I*4	1=not leap year, 2=leap year
QEOV	L*1	T=end of trajectory file reached
IDIFF	I*4	Seconds differences between ground receipt time (GRT) and S/C time
IMAGT	I*4	Time created from input time to compare with trajectory tape
ITRAJT	I*4	Time created from trajectory record to compare with input time

f. Algorithm:

A trajectory tape record is read and its time compared to the input time to be adjusted. If less, then the next record is read. When a record is found which has a time greater or equal, calculate the distance, hence time, between the earth and the S/C. Add this into the time to be adjusted. If an end of file is encountered, check to see if another file is allowed. If so, then continue. If not, return with flag set to end program.

g. Formulas:

$$\text{Difference in time} = \frac{R_{es}}{299792.5}$$

where R_{es} = distance from earth to S/C, km.

9. Module: TIMJUL

a. Purpose: Converts year, day, and seconds of day into one number for future time comparisons.

b. Arguments:

Name	Type	I/O	Description
IYR IDAY ISEC	I*4	I	Input time to convert
INTRVL	I*4	I	Averaging interval in seconds
JTIME	I*4	O	Converted time, # intervals since launch

c. Called by: MINAVG

d. Commons: none

e. Local Variables: none

f. Algorithm:

The time is converted using an array which contains the days elapsed since launch Jan. 0, 1972.

g. Formulas:

$$\text{Time} = \frac{\text{days since launch}}{\frac{\text{days}}{\text{interval}}} + \frac{\text{Seconds of day}}{\frac{\text{seconds}}{\text{interval}}}$$

10. Module: MATRIX

a. Purpose: To build a transform MATRIX, T, used to transfrom Cruise Mode (SH coordinates) and Jupiter encunter coordinates into Pioneer inertial coordinates. If the input is Cruise Mode (PE coordinates), then the transpose of the Matrix, T, is used to transform the data into Solar-Heliographic coordinates.

b. Arguments:

Name	Type	I/O	Description
MODE	I*4	I	Mode of spacecraft 0=Cruise Mode 1=Jupiter 2=Saturn
T(3,3)	R*4	O	Transformation MATRIX
ITPTYP	I*4	I	Tape type 7=7-track 9=9-track

c. Called by: MINAVG

d. Calls: VPROD

e. Commons:

Name	Variable	I/O	Description
TRAJ	DEC2(11)	I	Sun-Earth Distance
	DEC2(17)	I	Sun-Spacecraft Distance
	DEC2(20)	I	Celestial latitude of S/C
	DEC2(21)	I	Celestial longitude of S/C
	DEC2(22)	I	Celestial latitude of Earth
	DEC2(23)	I	Celestial longitude of Earth
TRNSFRM	SOLAR(3)	I	Coordinates of the Solar-spin axis

f. Local Variables:

Name	Type	Description
X1(3)	R*4	x transform-vector
Y1(3)	R*4	y transform-vector
Z1(3)	R*4	x transform-vector
P(3)	R*4	z transform-vector of the V matrix before normalization
U(3,3)	R*4	U matrix
V(3,3)	R*4	V matrix
T(3,3)	R*4	Transformation matrix
VECTOR(3)	R*4	Vector of vector products passed from subroutine VPROD
A(3)	R*4	Vector with elements [0 0 1]
DTRAJ(6)	R*4	Array containing the trajectory values expressed in radians
SIGN	R*4	1.0 if Cruise mode -1.0 if Jupiter encounter

g. Algorithm:

The trajectory values are converted from degrees to radians. If the input data is Jupiter encounter data, sign is changed to -1.0. The U matrix is calculated. The V matrix is calculated. The product of U and V is the transformation matrix, T.

If the transformation is from Pioneer Inertial to Solar Heliographic coordinates, the transformation matrix is the transpose of the matrix T.

h. Formulas:

U Matrix: SOLAR(3) = SOLAR SPIN COORDINATES

X1(3) = cos δsc cos λsc, cos δsc sin λsc, sin δsc

Y1(3) = (SOLAR X X1) ÷ || SOLAR X X1 ||

Z1(3) = X1 X Y1

$$U(3,3) = \begin{bmatrix} X1(3) \\ Y1(3) \\ Z1(3) \end{bmatrix}$$

NOTE: || || denotes magnitude

X denotes vector product

δsc " celestial latitude of S/C

λsc " " longitude of S/C

δE " " latitude of Earth

λE " " longitude of Earth

Rsc " Sun-S/C distance

RE " Sun-Earth

V Matrix:

$$P(1) = -R_{sc} \cos \delta_{sc} \cos \lambda_{sc} + R_E \cos \delta_E \cos \lambda_E$$
$$P(2) = -R_{sc} \cos \delta_{sc} \sin \lambda_{sc} + R_E \cos \delta_E \sin \lambda_E$$
$$P(3) = -R_{sc} \sin \delta_{sc} + R_E \sin \lambda_E$$

Z1(3) = P/||P||

X1(3) = [0 0 1] X Z1

Y1(3) = Z1 x X1

V(3,3) = [X1(3) Y1(3) Z1(3)]

T Matrix:

t = UV

$$\Longrightarrow t_{ij} = \sum_k U_{ik} V_{kj} \quad \text{where } i = 1,2,3;\ j = 1,2,3;\ k = 1,2,3$$

T^t:

$$t_{ij} = t_{ji} \quad j=1,2,3;\ i=1,2,3$$

11. Module: VPROD

a. Purpose: To perform vector product calculations and return the three coefficients as a three-element vector, together with the magnitude of this vector.

b. Arguments:

Name	Type	I/O	Description
VECTR1(3)	R*4	I	First vector of vector product
VECTR2(3)	R*4	I	Second vector of vector product
VECTR(3)	R*4	O	Vector of coefficients of vector product
VMAG	R*4	0	Magnitude of vector

c. Called by: MATRIX

d. Calls: none

e. Commons: none

f. Local Variables: none

g. Algorithm:

Calculate one coefficient of the vector product at a time and store in a three-element vector. Calculate the magnitude of this resulting vector.

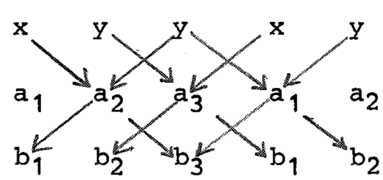
h. Formulas:

Vector product

let A = vector 1
B = vector 2

$$A \times B = (a_2b_3 - a_3b_2)x + (a_3b_1 - a_1b_3)y + (a_1b_2 - a_2b_1)z$$

which is the expanded form of the determinant



$$\text{VECTR} = \begin{bmatrix} (a_2b_3 - a_3b_2) \\ (a_3b_1 - a_1b_3) \\ (a_1b_2 - a_2b_1) \end{bmatrix}$$

magnitude:

$$\| \text{VECTR} \| = \left(\text{VECTR}(1)^2 + \text{VECTR}(2)^2 + \text{VECTR}(3)^2\right)^{1/2}$$

12. Module: READHD

a. Purpose: To read the daily header record of either a 7-track or 9-track tape.

b. Arguments:

Name	Type	I/O	Description
JYR	I*4	O	Year
JDAY	I*4	O	Day
QFLG	L*1	O	Spacecraft identifier F=Pioneer 10 G=Pioneer 11
TRAJ(6)	R*4	O	Input trajectory values (could be equal to zeroes)
ITPTYP	I*4	I	Tape type 7=7-track 9=9-track
QDONE	L*1	O	Flag indicating the end of data on the input tape

c. Called by: MINAVG

d. Calls: none

e. Commons: none

f. Local Variables:

Name	Type	Description
TEXT(30)	R*4	Input text portion of the header record of a 9-track tape

g. Algorithm:

Set the done flag to false unless end-of-file. If the input tape is 7-track, read from unit 9. If the input tape is 9-track, read from unit 10.

h. Formulas: none

13. Module: READRC

a. Purpose: To read a block of data from either a 7-track or 9-track tape and to return one record. (Each 7200 byte block contains 30 240 byte records)

b. Arguments:

Name	Type	I/O	Description
RMILLI	R*4	O	Milliseconds of data in the current record
DATA(14)	R*4	O	Input data from magnetic field tape
ITYTYP	I*4	I	Tape type 7=7-track 9=9-track
MINUTS	I*4	I	Counter for the minuts processed in the input tape data block. Used to calculate the current word of the block being processed
QDONE	L*1	O	Flag indicating the end of data on the input tape

c. Called by: MINAVG

d. Calls: none

e. Commons: none

f. Local Variables:

Name	Type	Description
RECORD(450)	R*4	Table of the input values read in one block of data. (30 records each containing 15 values=450)
IX	I*4	Index into the table Record
IZ	I*4	Last Record entry per day
J	I*4	Counts positions of the table Data

g. Algorithm:

If not end-of-file, done flag is set to false. If MINUTS=1, read a block of data. Return the number of milliseconds of data and the 14 data values.

h. Formulas: none