

Data Set Catalog #206

ATS-1

66-110A-02C 3 tapes
2.5 Minute Magnetic Field Averages

66-110A-02E 22 tapes
15 second magnetic Field Averages

66-110A-02G 1 tape
Tape logs

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1. INTRODUCTION:

The documentation for this data set was originally on paper, kept in NSSDC's Data Set Catalogs (DSCs). The paper documentation in the Data Set Catalogs have been made into digital images, and then collected into a single PDF file for each Data Set Catalog. The inventory information in these DSCs is current as of July 1, 2004. This inventory information is now no longer maintained in the DSCs, but is now managed in the inventory part of the NSSDC information system. The information existing in the DSCs is now not needed for locating the data files, but we did not remove that inventory information.

The offline tape datasets have now been migrated from the original magnetic tape to Archival Information Packages (AIP's).

A prior restoration may have been done on data sets, if a requestor of this data set has questions; they should send an inquiry to the request office to see if additional information exists.

2. ERRATA/CHANGE LOG:

NOTE: Changes are made in a text box, and will show up that way when displayed on screen with a PDF reader.

When printing, special settings may be required to make the text box appear on the printed output.

Version	Date	Person	Page	Description of Change
01				
02				

3 LINKS TO RELEVANT INFORMATION IN THE ONLINE NSSDC
INFORMATION SYSTEM:

<http://nssdc.gsfc.nasa.gov/nmc/>

[NOTE: This link will take you to the main page of the NSSDC Master Catalog. There you will be able to perform searches to find additional information]

4. CATALOG MATERIALS:

- a. Associated Documents To find associated documents you will need to know the document ID number and then click here.
<http://nssdcftp.gsfc.nasa.gov/miscellaneous/documents/>

- b. Core Catalog Materials

ATS 1

SPMS 00545

2.5 MIN AVG VECT MAG FLD TAPE

66-110A-02C

THIS DATA SET HAS BEEN RESTORED. ORIGINALLY IT CONTAINED THREE 7-TRACK, 800 BPI TAPES WRITTEN IN BCD. THERE IS ONE RESTORED TAPE WRITTEN IN ASCII. THE DR TAPE IS A 3480 CARTRIDGE AND THE DS TAPE IS 9-TRACK, 6250 BPI. THE ORIGINAL TAPES WERE CREATED ON AN IBM 360 COMPUTER AND THEY WERE RESTORED ON THE MODCOMP CLASSIC II COMPUTER. THE DR AND DS NUMBERS ALONG WITH THE CORRESPONDING D NUMBERS AND THE TIME SPANS ARE AS FOLLOWS:

DR#	DS#	D#	FILES	TIME SPAN
DR004080	DS004080	D008826	1	12/07/66 - 12/31/66
		D008825	2	01/01/67 - 11/16/67
		D008824	3	01/01/68 - 12/29/68

ATS 1

SPMS 00544

15 SEC. VECTOR MAG. FIELD CORR. - TAPE

66-110A-02E

THIS DATA SET HAS BEEN RESTORED. ORIGINALLY IT CONTAINED 22 7-TRACK, 800 BPI TAPES WRITTEN IN BCD. THERE ARE THREE RESTORED TAPES WRITTEN IN EBCDIC. DATA OFF OF TWO OF THE ORIGINAL TAPES WERE LOST, THE TAPE NUMBERS ARE D010604 AND D010605. THE TAPES WERE NOT STACKED IN TIME SEQUENTIAL ORDER. THE DR TAPES ARE 3480 CARTRIDGES AND THE DS TAPES ARE 9-TRACK, 6250 BPI. THE ORIGINAL TAPES WERE CREATED ON AN IBM 360 COMPUTER AND WERE RESTORED ON THE MODCOMP. THE DR AND DS NUMBERS ALONG WITH THE CORRESPONDING D NUMBERS AND TIME SPANS ARE AS FOLLOWS:

DR#	DS#	D#	FILES	TIME SPAN
DR003275	DS003275	D010587	1	01/01/67 - 02/09/67
		D010588	2	02/10/67 - 03/20/67
		D010589	3	12/27/66 - 12/31/66
		D010590	4	12/07/66 - 12/26/66
		D010591	5	05/01/67 - 06/09/67
		D010592	6	06/10/67 - 07/19/67
		D010593	7	01/01/68 - 02/09/68
DR003276	DS003276	D010594	1	12/27/67 - 12/27/67
		D010595	2	11/17/67 - 12/23/67 (a)
		D010596	3	10/08/67 - 11/16/67
		D010597	4	07/20/67 - 08/28/67
		D010598	5	08/29/67 - 10/07/67
		D010599	6	03/22/67 - 04/30/67
		D010600	7	03/21/68 - 04/29/68
DR003277	DS003277	D010601	1	02/10/68 - 03/18/68
		D010602	2	07/19/68 - 08/24/68
		D010603	3	06/09/68 - 07/18/68
		D010606	4	11/16/68 - 12/25/68
		D010607	5	10/07/68 - 11/15/68
		D010608	6	08/28/68 - 09/17/68

(a) D010595 - 1 error, record 331, File 1

ATS-1

OCTAL COMMANDS LOGS ON TAPE

66-110A-02G

SPMS-00543

THIS DATA SET HAS BEEN RESTORED. ORIGINALLY THERE WAS ONE 9-TRACK, 800 BPI TAPE, WRITTEN IN BINARY. THERE IS ONE RESTORED TAPE. THE DR TAPE IS A 3480 CARTRIDGE AND THE DS TAPE IS 9-TRACK, 6250 BPI. THE ORIGINAL TAPE WAS CREATED ON AN IBM 360 COMPUTER. THE DR AND DS NUMBER ALONG WITH THE CORRESPONDING D NUMBER AND TIME SPAN ARE AS FOLLOWS:

DR#	DS#	D#	FILES	TIME SPAN
DR002903	DS002903	D010673	1-3	01/01/66 - 12/31/68 (a)

(a) D010673 - 23 errors, records 153, 159, 165, 168, File 2; records 136, 178, 253, 342, 396, 456, 462, 466, 493, 497, 530, 582, 586, 587, 593, 599, 602, 615, 622, File 3

66-110A-02C

ATS-1

2.5 MINUTE MAGNETIC FIELD AVERAGES

This data set consists of 3, 800 BPI, BCD 7-track tapes. The 'D' tapes were produced on the IBM/360 and the 'C' tapes on the 7094. Each tape contains one data file.

<u>D#</u>	<u>C#</u>	<u>START</u>	<u>STOP</u>
D-08824	C-08206	1/01/68	12/29/68
D-08825	C-08207	1/01/67	11/16/67
D-08826	C-08208	12/07/66	12/31/66

ATS 1 DATA TAPES
WO 2 SERIES - 2.5 MINUTE AVERAGES
(TAPE DESCRIPTION)

These 3 tapes contain data from December 7, 1966 to December 31, 1968 (2.5 minute averages).

The data were written by an IBM 360 model 91 on 7-track unlabeled tapes at 556 bits per inch, even parity with translate feature turned on. There is one file per tape containing 40 days of data. Each record is in BCD format, 80 bytes long and blocked at 3200 bytes.

The time spans for the tapes are:

W26600 December 7, 1966 - December 31, 1966

W26700 January 1, 1967 - December 31, 1967

W26800 January 1, 1968 - December 31, 1968✓

The format for the data records is:

<u>Character</u>	<u>Description</u>	<u>Format</u>
01-02	Last Two Digits of Year	I2
03-05	Day of Year	I3
07-08	Hour	I2
09-10	Minute	I2
11-12	Second	I2
13-19	V Component of Dipole VDH	F7.1*
20-26	D Component of Dipole VDH	F7.1*
27-33	H Component of Dipole VDH	F7.1*
34-40	Spacecraft State Indicator	F7.1

*The data flag is 9999.9

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SANTA BARBARA • SANTA CRUZ

UCLA, INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS
LOS ANGELES, CALIFORNIA 90024

January 19, 1973

Mr. Donald J. Hei, Jr.
Data Acquisition and
Analysis Branch
National Aeronautics and
Space Administration
Goddard Space Flight Center
Greenbelt, Maryland 20771

Dear Don:

We are sending you two packages of Cal Comp plots of ATS-1 data. These plots are the 2 1/2 minute averages of the magnetic field in dipole V, D, H coordinates. The boxes contain 35 rolls of Cal Comp output for the dates indicated in the enclosed lists.

I just discovered a serious error in the paper on "Coordinate Transformations Used in Processing ATS-1 Magnetic Field Data". I am rewriting several pages and will send you a modified version.

We are still working on writeups, more plots of 15 second averages, the altitude-orbit printout and rapid fluctuation data.

Sincerely,

Robert L. Matheron
Assistant Professor

RLM:ko

encls.

ATS-1 2.5 Minute Plots - 1967

<u>Roll No.</u>	<u>Date</u>
1	Dec. 7, Dec. 31, 1966
2	Jan. 1, Jan. 20, 1967
3	Jan. 21, Feb. 9, 1967
4	Feb. 10, Mar. 1, 1967
5	Mar. 2, Mar. 20, 1967
6	Mar. 21, April 10, 1967
7	April 11, April 30, 1967
8	May 1, May 20, 1967
9	May 21, June 9, 1967
10	June 10, June 29, 1967
11	June 30, July 19, 1967
12	July 20, Aug. 8, 1967
13	Aug. 9, Aug. 28, 1967
14	Aug. 29, Sept. 17, 1967
15	Sept. 18, Oct. 7, 1967
16	Oct. 8, Oct. 26, 1967
17	Oct. 27, Nov. 16, 1967
18	Nov. 17, Dec. 6, 1967
19	Dec. 7, Dec. 27, 1967

ATS-1 2.5 Minute Plots - 1968

<u>Roll No.</u>	<u>Date</u>
1	Jan. 1, Jan 20, 1968
2	Jan. 21, Feb. 9, 1968
3	Feb. 10, Feb. 29, 1968
4	Mar. 1, Mar. 18, 1968
5	Mar. 19, April 9, 1968
6	April 10, April 29, 1968
7	April 30, May 18, 1968
8	May 20, June 8, 1968
9	June 9, June 28, 1968
10	June 29, July 18, 1968
11	July 19, Aug. 7, 1968
12	Aug. 8, Aug. 24, 1968
13	Oct. 7, Oct. 26, 1968
14	Oct. 27, Nov. 15, 1968
15	Nov. 16, Dec. 5, 1968
16	Dec. 6, Dec. 29, 1968

Coordinate Transformations
Used in Processing ATS-1
Magnetic Field Data

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Abstract

A complete description is given of all coordinate transformations used in processing the UCLA magnetometer data from ATS 1. Starting with the measurement coordinate system (MEAS) we progressively consider the following coordinate systems: geocentric equatorial inertial (GEI), geocentric solar earth equatorial (GSEE), geographic (GEO), rotational VDH (ROT VDH), dipole VDH (DIP VDH). We then discuss the ATS-1 ephemeris tapes and the manner in which necessary transformation matrices are derived from its contents. We then describe approximations made during routine data processing which greatly reduced the complexity and data handling. We then demonstrate that these approximations were justified in view of unknown errors in the components of the spacecraft field. Finally, we describe the printout made from the ephemeris tapes. This printout is so organized that all necessary information is available to either transform the original data without approximation or to correct files of processed data for the approximations used. The ATS-1 ephemeris is available either as a BCD print tape or microfilm images of printer listings from the National Space Science Data Center.

Introduction

As discussed in a recent paper by Russell [1971], geophysical coordinate transformations are extremely important for work in solar-terrestrial physics. This is particularly true for experimental work in magnetic field measurements where the observations taken in an instrument (or spacecraft) coordinate system must be transformed to a meaningful geophysical system for comparison with theory. Russell has carefully described most of the systems in common use, so we will not repeat this discussion. However, in the processing of ATS 1 magnetic field data we have used several specific systems not described by Russell. Consequently our purpose in this report is to provide a detailed description of these and the coordinate transform procedures used in the data processing.

The following report is divided into five sections. These include:

- 1) Coordinate systems with Z axis parallel to the earth's axis,
- 2) Transformation from measurement (MEAS) to inertial (EI) coordinates.
- 3) Transformation from rotational VDH to dipole VDH coordinates,
- 4) Actual transformations used,
- 5) Description of ATS 1 ephemeris tape print out.

Section 5 is particularly important since it describes the approximations used in our transformation equations and justifies their use.

The ATS 1 spacecraft was placed in a synchronous, equatorial orbit very near the intersection of the geographic and geomagnetic

equatorial planes. Its spin axis was maintained almost anti parallel to the earth's rotation axis. More exactly, on January 1, 1968, its geographic coordinates were $R = 6.6 R_e$, $\lambda_{SC} = -150.4^\circ$ East longitude, $\theta_{SC} = -.2^\circ$ latitude, and its spin axis made an angle of $.6^\circ$ with respect to the earth's rotation axis.

BODY coordinates were defined by the satellite spin vector (BODY Z) and the satellite sun sensor (BODY X). This coordinate system was fixed in the spacecraft and rotated with it. Magnetic field observations made in BODY coordinates were spin demodulated into a non-rotating measurement (MEAS) coordinate system with its Z axis opposite to the spacecraft spin axis, i.e., nearly parallel to the earth's rotation axis. The X axis was defined by a sun pulse, such that the sun vector always lies in the X-Z plane of the MEAS system as shown in Figure 1.

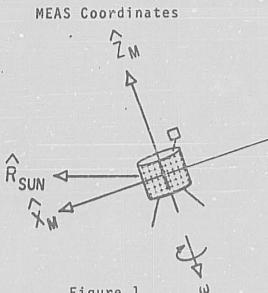


Figure 1

Coordinate Systems with the Z Axis Parallel to the Earth's Rotation Axis

Since the earth's rotation axis is fixed in inertial space, it is convenient to introduce an inertial coordinate system with

its Z axis parallel to the rotation axis. This system is the Geocentric Equatorial Inertial Coordinates (GEI) illustrated in Figure 2.

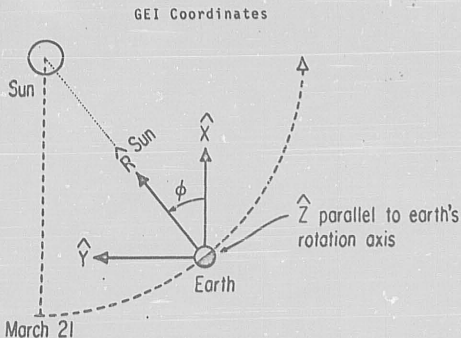


Figure 2

The X axis of this system points to the sun at the vernal equinox (March 21). We note the sun vector rotates once per year about the Z axis at a non-uniform rate dependent on the exact trajectory of the earth about the sun.

Another coordinate system which fixes the sun vector is obtained by rotating about the Z axis of GEI coordinates, so that the sun vector lies in the new X-Z plane. This coordinate system is the Geocentric Solar Earth Equatorial (GSEE) system illustrated in Figure 3. The GSEE system corresponds exactly to the GEI system at the vernal equinox.

GSEE Coordinates

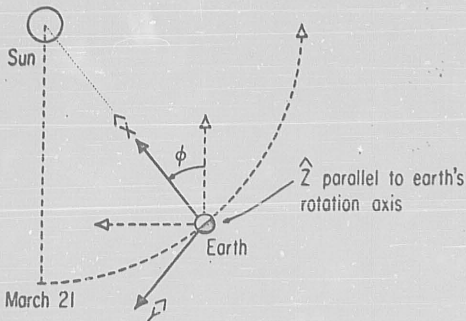


Figure 3

Any vector in GSEE coordinates can be found from its representation in GEI coordinates by a simple rotation, i.e.,

$$\underline{V}(\text{GSEE}) = (A) \cdot \underline{V}(\text{GEI}) \quad (1)$$

$$\text{where } A = \begin{pmatrix} \cos \phi & \sin \phi & 0 \\ -\sin \phi & \cos \phi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\text{with } \phi = \text{ATAN2}(\hat{R}_y^{\text{sun}}, \hat{R}_x^{\text{sun}})$$

and $\hat{R}^{\text{sun}}$ is expressed in GEI coordinates

Since the GSEE coordinate system is quasi-inertial on the time scale of a day any quantity fixed with respect to the rotating earth will appear to rotate with respect to the Z axis of GSEE coordinates. Examples are the earth's magnetic field at the

spacecraft and the spacecraft position. The earth's field is approximately fixed because of the relation between the sources of the field and the rotation axis. The spacecraft position is fixed because of the synchronous equatorial orbit.

The fundamental coordinate system fixed in the rotating earth is geographic coordinates (GEO) shown in Figure 4. The Z axis of this geocentric system is parallel to the earth's rotation axis and the X axis passes through the geographic prime meridian (Greenwich).

GEO Coordinates

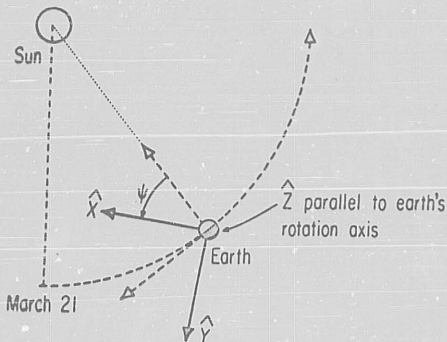


Figure 4

By definition noon universal time occurs when the geographic prime meridian contains the subsolar point, i.e., when the geographic

X-Z plane contains the sun vector. Thus, the GEO system is coincident with the GSEE system at 1200 universal time, and differs at later times only by a rotation through an angle ψ . By inspection ψ is given by:

$$\psi = \frac{UT-12}{24} * 2\pi$$

Thus a vector in GEO coordinates can be obtained from its representation in GSEE coordinates by a simple rotation, i.e.,

$$\begin{aligned} \underline{V}(\text{GEO}) &= (B) \cdot \underline{V}(\text{GSEE}) \\ \text{where } (B) &= \begin{pmatrix} \cos\psi & \sin\psi & 0 \\ -\sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{pmatrix} \end{aligned} \quad (2)$$

with ψ defined as above.

A more convenient geocentric rotating coordinate system is one which has its X axis at the longitude of the satellite and its Z axis parallel to the earth's rotation axis. This system is the rotational VDH system shown in Figure 5.

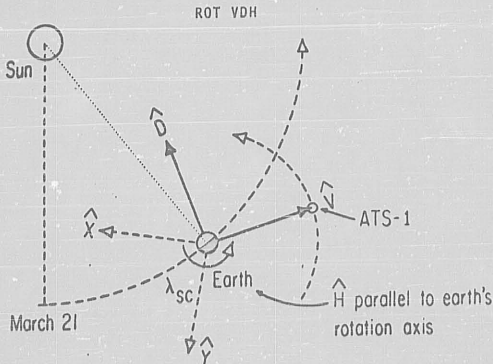


Figure 5

In Figure 5, λ_{sc} is the geographic longitude of the ATS 1 spacecraft. Clearly, rotational VDH is obtained from the GEO system by a rotation about the Z axis by an angle λ_{sc} , i.e.,

$$\underline{V}(\text{ROT VDH}) = (C) \cdot \underline{V}(\text{GEO}) \quad (3)$$

and λ_{sc} = geographic longitude of satellite.

All four of the preceding coordinate systems have their Z axes parallel to the earth's rotational axis. Each system is derivable from the preceding system by a simple rotation about the Z axis. Thus, given a vector in GEI, we have from Equations 1-3.

$$\begin{aligned} \underline{V}(\text{GSEE}) &= (A) \cdot \underline{V}(\text{GEI}) \dots \phi \\ \underline{V}(\text{GEO}) &= (B) \cdot \underline{V}(\text{GSEE}) \dots \psi \\ \underline{V}(\text{ROT VDH}) &= (C) \cdot \underline{V}(\text{GEO}) \dots \lambda_{sc} \end{aligned}$$

Here the angle associated with each rotation is shown at the end of the formula. Normally we are not interested in the GEO representation, so we take advantage of the fact that the rotation angles for successive rotations about the same axis are additive. Thus:

$$\underline{V}(\text{ROT VDH}) = (D) \cdot \underline{V}(\text{GSEE}) \quad (4)$$

$$\text{where } D = \begin{pmatrix} \cos \zeta & \sin \zeta & 0 \\ -\sin \zeta & \cos \zeta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\text{with: } \zeta = \phi + \lambda_{sc} = \frac{\text{UT}-12}{24} \cdot 2\pi + \frac{\lambda_{sc}}{360} \cdot 2\pi$$

$$\text{or: } \zeta = \frac{\text{UT}-12 + (\lambda_{sc}/15^\circ)}{24} \cdot 2\pi \quad (5)$$

Physically ζ is the angle of the ATS 1 spacecraft with respect to

the noon meridian at which time rotational VDH and GSEE coordinates are coincident. For the nominal location of ATS-1 at -150° east longitude we have:

$$\zeta = \frac{(\text{UT}-22) \cdot 2\pi}{24}$$

Transformation from ATS 1 MEAS Coordinates to GEI

Since the ATS 1 spacecraft is spin stabilized, its spin axis remains nearly fixed in inertial space apart from attitude control maneuvers. Thus, the GEI coordinates of the MEAS Z axis are almost always constant. The MEAS X axis is defined as being perpendicular to the Z axis such that the X-Z plane contains the sun vector. In GEI coordinates the sun vector rotates once per year about the Z axis. Consequently, in one day the GEI coordinates of the MEAS X axis rotate by less than 4.0° about the MEAS Z axis.

Information about the orientation of the MEAS Z axis in GEI coordinates can be obtained from the ATSl ephemeris tapes. A listing of the contents of this tape is given in Appendix 1. To interpret this listing we use the result of page 97, [Goldstein, 1965], showing the relation between direction cosines and the transformation matrix from an old (unprimed) to a new (primed) coordinate system. In particular:

$$\tilde{V}'(\text{NEW}) = \begin{pmatrix} \hat{X}' \cdot \hat{X} & \hat{X}' \cdot \hat{Y} & \hat{X}' \cdot \hat{Z} \\ \hat{Y}' \cdot \hat{X} & \hat{Y}' \cdot \hat{Y} & \hat{Y}' \cdot \hat{Z} \\ \hat{Z}' \cdot \hat{X} & \hat{Z}' \cdot \hat{Y} & \hat{Z}' \cdot \hat{Z} \end{pmatrix} \cdot \tilde{V}(\text{OLD})$$

Columns of this matrix are clearly the unit vectors of the old

system expressed in terms of the new system.

If we identify the old system as ATS-1 MEAS coordinates and the new system as GEI we see that the third column is the MEAS Z axis in GEI coordinates. Referring back to the discussion of Figure 1, we recall that the Z axis of the MEAS coordinate system is anti parallel to the Z axis of BODY coordinates. From Appendix 1 we find the GEI components in BODY coordinates of the $\hat{Z}^B$ axis are given by:

$$\hat{Z}^B = (W_{23}, W_{24}, W_{25})$$

where W_{23} references WORD (28) of the ephemeris tape record. Thus, the GEI components of the MEAS Z axis are given by a vector of opposite sign, i.e.,

$$\hat{Z}^{BM} = \begin{pmatrix} -W_{23} \\ -W_{24} \\ -W_{25} \end{pmatrix} = \begin{pmatrix} ZM(X) \\ ZM(Y) \\ ZM(Z) \end{pmatrix}$$

The exact orientation of the MEAS Z axis in GEI coordinates is most easily defined by two angles in spherical coordinates.

$$\theta_{ZM} = \text{ARCCOS} (-W_{25}) \quad (6)$$

$$\phi_{ZM} = \text{ATAN2} (-W_{24}, -W_{23})$$

To obtain the two remaining unit vectors of the MEAS coordinate system, we note that $\hat{Y}^M$ is perpendicular to the plane defined by $\hat{Z}^M$ and the sun vector $\underline{R}^{\text{sun}}$. Thus:

$$\hat{Y}^M = \frac{\hat{Z}^M \times \underline{R}^{\text{sun}}}{|\hat{Z}^M \times \underline{R}^{\text{sun}}|}$$

$$\text{Let } \underline{P} = \underline{Z\hat{M}} \times \underline{R^{\text{sun}}}$$

from Appendix 1 the sun vector in GEI is:

$$\underline{R^{\text{sun}}}(\text{GEI}) = (W_{14}, W_{15}, W_{16})$$

Thus:

$$\underline{P} = \begin{pmatrix} W_{15} \cdot W_{25} & - & W_{16} \cdot W_{24} \\ W_{16} \cdot W_{23} & - & W_{14} \cdot W_{25} \\ W_{14} \cdot W_{24} & - & W_{15} \cdot W_{23} \end{pmatrix} = \begin{pmatrix} P_X \\ P_Y \\ P_Z \end{pmatrix}$$

The magnitude of $\underline{P}$ is easily determined:

$$|\underline{P}| = \sqrt{P_X^2 + P_Y^2 + P_Z^2}$$

Thus:

$$\underline{Y\hat{M}} = \frac{\underline{P}}{|\underline{P}|} = \begin{pmatrix} YM(X) \\ YM(Y) \\ YM(Z) \end{pmatrix}$$

Having both $\underline{Z\hat{M}}$ and $\underline{Y\hat{M}}$, we can easily determine the $\underline{X\hat{M}}$ unit vector from:

$$\underline{X\hat{M}} = \underline{Y\hat{M}} \times \underline{Z\hat{M}} = \begin{pmatrix} W_{24} \cdot YM(Z) & -W_{25} \cdot YM(Y) \\ W_{25} \cdot YM(X) & -W_{23} \cdot YM(Z) \\ W_{23} \cdot YM(Y) & -W_{24} \cdot YM(X) \end{pmatrix} = \begin{pmatrix} XM(X) \\ XM(Y) \\ XM(Z) \end{pmatrix}$$

Combining our results we have:

$$\underline{V}(\text{GEI}) = \begin{pmatrix} XM(Z) & YM(X) & ZM(X) \\ XM(Y) & YM(Y) & ZM(Y) \\ XM(Z) & YM(Z) & ZM(Z) \end{pmatrix} \cdot \underline{V}(\text{MEAS})$$

or:

$$\underline{V}(\underline{GEI}) = (W) \cdot \underline{V}(\underline{MEAS}) \quad (7)$$

We may summarize our analysis to this point by writing down three transformation equations.

$$\begin{aligned} \underline{V}(\underline{GEI}) &= (W) \cdot \underline{V}(\underline{MEAS}) \\ \underline{V}(\underline{GSEE}) &= (A) \cdot \underline{V}(\underline{GEI}) \dots\dots \\ \underline{V}(\underline{ROT VDH}) &= (D) \cdot \underline{V}(\underline{GSEE}) \dots\dots \end{aligned}$$

Note that the transformation (W) is not a simple rotation, hence,

no single angle is specified. For the case of perfect alignment of the satellite spin axis MEAS coordinates are identical to GSEE.

Thus, we may write:

$$\underline{V}(\text{GEI}) = (\underline{W}) \cdot \underline{V}(\text{GSEE})$$

$$\underline{V}(\text{GSEE}) = (\underline{A}) \cdot \underline{V}(\text{GEI})$$

or:

$$\underline{V}(\text{GSEE}) = (\underline{A}) \cdot (\underline{W}) \cdot \underline{V}(\text{GSEE})$$

Clearly then, $(\underline{A}) \cdot (\underline{W}) = (\underline{I})$, or:

$$(\underline{W}) = (\underline{A})^{-1} = (\underline{A})^T \text{ since } (\underline{A}) \text{ is an orthogonal matrix.}$$

In the typical case we have:

$$\underline{V}(\text{GSEE}) = (\underline{A}\underline{W}) \cdot \underline{V}(\text{MEAS}) \quad (8)$$

where the product matrix $(\underline{A}\underline{W})$ is approximately the identity matrix. Further as we have shown above both $(\underline{A})$ and $(\underline{W})$ change only slightly during one day apart from attitude control maneuvers.

Transformation from Rotational VDH to Dipole VDH

As discussed above, the earth's magnetic field is fixed in rotational VDH coordinates. However, this is not the most convenient system, since geographic meridians do not correspond to magnetic meridians. Another geocentric rotating coordinate system is the DIPOLE VDH system illustrated in Figure 6. The $\hat{H}_D$ axis is chosen parallel to the earth's dipole axis and $\hat{V}_D$ is taken perpendicular to $\hat{H}_D$ radially outward through the satellite.

To obtain this coordinate system, we must express unit vectors along the spacecraft position vector and along the dipole axis in rotational VDH coordinates. Then we use the results of Goldstein

DIP VDH

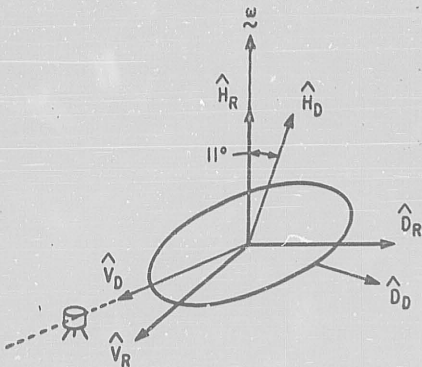


Figure 6

discussed earlier to express the transformation matrix in terms of these unit vectors. From the definition of rotational VDH coordinates the unit spacecraft position vector is simply:

$$\hat{V}_D = \hat{R}_{SC} (ROT VDH) = \begin{pmatrix} \cos \theta_{sc} \\ 0 \\ \sin \theta_{sc} \end{pmatrix} = \begin{pmatrix} V_D(V) \\ V_D(D) \\ V_D(H) \end{pmatrix}$$

where θ_{sc} is the geographic latitude in geographic coordinates of the spacecraft, and $\hat{V}_D$ is the first unit vector of DIP VDH.

The antipole unit vector $-\hat{\mu}$ in ROT VDH may be obtained from its representation in GEO coordinates by the GEO-ROT VDH transformation

matrix. Using the geographic coordinates of the north dipole axis we obtain [Russell, 1971]:

$$-\hat{\mu}(\text{GEO}) = (0.06859, -0.18602, 0.98015)$$

But according to equation (3):

$$\underline{V}(\text{ROT VDH}) = (C) \cdot \underline{V}(\text{GEO})$$

$$\text{where } C = \begin{pmatrix} \cos \lambda_{sc} & \sin \lambda_{sc} & 0 \\ -\sin \lambda_{sc} & \cos \lambda_{sc} & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

where λ_{sc} = geographic longitude of the spacecraft.

Thus:

$$\hat{H}_D = -\hat{\mu}(\text{VDH}) = \begin{pmatrix} 0.06859 \cos \lambda_{sc} & -0.18602 \sin \lambda_{sc} \\ -0.06859 \sin \lambda_{sc} & -0.18602 \cos \lambda_{sc} \\ 0.98015 & \end{pmatrix} = \begin{pmatrix} H_D(V) \\ H_D(D) \\ H_D(H) \end{pmatrix}$$

To determine the second unit vector we calculate the cross product

$$\hat{D}_D = \hat{H}_D \times \hat{V}_D$$

or:

$$\hat{D}_D = -\hat{\mu}(\text{ROT VDH}) \times \hat{R}_{sc}(\text{ROT VDH})$$

Working out the cross product we obtain:

$$\hat{D}_D = \begin{pmatrix} \sin \theta_{sc} * H_D(D) \\ \cos \theta_{sc} * H_D(H) - \sin \theta_{sc} * H_D(V) \\ -\cos \theta_{sc} * H_D(D) \end{pmatrix} = \begin{pmatrix} D_D(V) \\ D_D(D) \\ D_D(H) \end{pmatrix}$$

The full transformation matrix from rotational to dipole VDH

coordinates can now be written using the rule that rows of the transformation matrix are the unit vectors of the new system (DIP) expressed in the old (ROT), i.e.,

$$\underline{V}(\text{DIP VDH}) = (M) \cdot \underline{V}(\text{ROT VDH}) \quad (12)$$

where:

$$(M) = \begin{pmatrix} V_D(V) & V_D(V) & V_D(H) \\ D_D(V) & D_D(D) & D_D(H) \\ H_D(V) & H_D(D) & H_D(H) \end{pmatrix}$$

and the quantities such as $V_D(H)$ have been defined by Equations

For a given geographic location of the spacecraft the matrix (M) is completely constant. Using the geographic coordinates of ATS 1 on January 1, 1968, ($\theta_{sc} = .1$, $\lambda_{sc} = -150.4$)

$$(M) = \begin{pmatrix} 1.0000 & .0000 & -.0001 \\ .0000 & .9802 & -.1278 \\ .0323 & .1278 & .9801 \end{pmatrix}$$

We note that this transformation is nearly a rotation about the V axis of ROT VDH to line $\hat{H}_D$ up with the dipole axis. This fact is a consequence of the location of ATS 1 very near the intersection of the geographic and geomagnetic equators.

Coordinate Transformation During ATS 1 Data Processing

According to the preceding discussion the sequence of transformations performed on the magnetic field data is summarized by the following set of equations:

$$\underline{B}_{COR}(MEAS) = \underline{B}_{MEA}(MEAS) + \underline{C}(MEAS)$$

where $\underline{B}_{MEA}$ = measured magnetic field in MEAS coordinates

$\underline{C}$ = correction vector added to the measured field
to remove effects of spacecraft field

$\underline{B}_{COR}$ = corrected magnetic field

$$\underline{B}(GSEE) = (AW) \cdot \underline{B}_{COR}(MEAS) \quad (\text{cf. Eq. 8})$$

$$\underline{B}(\text{ROT VDH}) = (D) \cdot \underline{B}(GSEE) \quad (\text{cf. Eq. 4})$$

$$\underline{B}(\text{DIP VDH}) = (M) \cdot \underline{B}(\text{ROT VDH}) \quad (\text{cf. Eq. 12})$$

Thus:

$$\underline{B}(\text{DIP VDH}) = (MDAW) \cdot \underline{B}_{MEA}(MEAS) + \underline{C}(MEAS) \quad (13)$$

For a constant spin axis alignment, (AW) changes slowly on the time scale of a day and is nearly an identity matrix. For a fixed spacecraft location, (M) is constant and for ATS 1, close to an identity matrix. The last matrix (D) is a simple rotation about a Z axis and depends only on universal time UT and the geographic longitude λ_{SC} of the spacecraft. Thus the entire transformation (MDAW) is nearly a rotation about the MEAS V axis.

In actual fact, we have made several assumptions to simplify the data processing. The first assumption is that the satellite spin axis was exactly parallel to the earth's rotation axis. This assumption is equivalent to setting (AW) = (I). Second, we assumed that the spacecraft longitude was exactly -150° East. This fixes the rotation angle ζ (cf. Eq. 5) as:

$$\zeta = \frac{UT-22}{24} * 2\pi$$

Further, this angle defines the rotation matrix (D'). Finally, we assumed the spacecraft was located exactly in the equatorial plane, $\theta_{sc}=0.0$, fixing the transformation matrix (M) as:

$$(M) = \begin{pmatrix} .99943 & -.00657 & -.003296 \\ 0 & .98071 & -.19550 \\ .033609 & .19539 & .98015 \end{pmatrix}$$

Because of the foregoing assumptions the final corrected data in DIP VDH coordinates are slightly in error. To correct this error, we must make a time dependent transformation as derived below.

The exact transformation is:

$$\underline{B}^E(DIP\ VDH) = (MDAW) * \underline{B}(MEAS)$$

The actual transformation used was:

$$\underline{B}^A(DIP\ VDH) = (M'D') * \underline{B}(MEAS)$$

multiplying by (M'D')^T gives:

$$(M'D')^T * \underline{B}^A(DIP\ VDH) = \underline{B}(MEAS)$$

Then multiply by (MDAW)

$$(MDAW) * (M'D')^T * \underline{B}^A(DIP\ VDH) = (MDAW) * \underline{B}(MEAS)$$

but the right hand side is just $\underline{B}^E(DIP\ VDH)$

Thus:

$$\underline{B}^E(DIP\ VDH) = (MDAW)(M'D')^T * \underline{B}^A(DIP\ VDH) \quad (14)$$

The correction matrix is almost a similarity transformation of (AW), i.e.,

$$(C) = [(MD)(AW)(M'D')^T]$$

Rewrite this as:

$$(C) = [(MD)(AW)(MD)^T] * [(MD)(M'D')^T]$$

The second bracket becomes:

$$[(MD)(M'D')^T] = [M(DD'^T)M'^T]$$

We note that $(D')^T$ is a left hand rotation about a Z axis using the assumed -150° east longitude. In contrast (D) is a right hand rotation about the same axis of the actual spacecraft longitude λ_{sc} . Since the angles associated with two right hand rotations we have:

$$\Delta\zeta = \zeta_{\lambda_{sc}} + (-\lambda_{150^\circ})$$

Here the minus sign corresponds to a left hand rotation.

But:

$$\Delta\zeta = \frac{UT-2 + \lambda_{sc}/150}{24} * 2\pi - \frac{UT-12 + -150^\circ/15^\circ}{24} * 2\pi$$

$$\text{or: } \Delta\zeta = \frac{\lambda_{sc} + 150^\circ}{360^\circ} * 2\pi$$

Since $\lambda_{sc} \sim -150^\circ$ $\Delta\zeta$ is a very small number

Thus:

$$(DD'^T) = \begin{pmatrix} \cos\Delta\zeta & \sin\Delta\zeta & 0 \\ -\sin\Delta\zeta & \cos\Delta\zeta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

But $\Delta\zeta$ small implies:

$$\cos\Delta\zeta \approx 1$$

$$\sin\Delta\zeta \approx \Delta\zeta$$

$$(DD^T) = \begin{pmatrix} 1 & \Delta\zeta & 0 \\ -\Delta\zeta & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix} = (I) + (\Delta)$$

which is very nearly an identity matrix and is constant since $\Delta\zeta$ is independent of time.

The matrix (M') differs from M only as a consequence of 1-2° errors in the spacecraft latitude and longitude.

Consequently we write $(M') = (M + \epsilon)$

Similarly we showed (AW) is nearly the identity matrix, i.e.,

$$(AW) = (I + \delta)$$

Thus we write:

$$\begin{aligned} C &= [MD(I+\delta)(MD)^T] * [M(I+\Delta)(M^T + \epsilon^T)] \\ &= [MD(MD)^T + (MD)^T] * [M(M^T + M^T + I\epsilon^T + \epsilon^T)] \\ &= [(MD)(MD)^T + (MD)\delta(MD)^T] * [MM^T + M\Delta M^T + M\epsilon^T + MD\epsilon^T] \end{aligned}$$

hence:

$$(C) = [I + (MD)\delta(MD)^T] * [I + M\Delta M^T + M\epsilon^T + M\Delta\epsilon^T]$$

$$\begin{aligned} \text{or: } (C) &= I + (MD)\delta(MD)^T + M\Delta M^T + M\epsilon^T + M\Delta\epsilon^T \\ &\quad + [(MD)\delta(MD)^T] * [M\Delta M^T + M\epsilon^T + M\Delta\epsilon^T] \end{aligned}$$

We drop all matrices which are second or higher order in the small quantities, thus:

$$(C) \approx I + M(D\delta D^T)M^T + M\Delta M^T + M\epsilon^T \quad (15)$$

Then defining $(\Delta C) = (C) - (I)$,

$$(\Delta C) = M[D\delta D^T]M^T + [M\Delta M^T + M\epsilon^T]$$

The matrices $(M), \Delta, \epsilon$ depend only on position of the spacecraft so may be considered constant over many days. Similarly δ is a result of changes in the sun vector in an inertial coordinate system fixed to the earth, so it is constant on the time scale of hours. (D) is rapidly varying due to the earth's rotation. Thus, to calculate the correction matrix, we must determine the time varying matrix (D) , carry out four matrix multiplications and one matrix addition. Then we have from Equations 14 and 15:

$$\underline{B}^E(\text{DIP VDH}) = [(I) + (\Delta C)] \cdot \underline{B}^A(\text{DIP VDH})$$

or:

$$\underline{B}^E = \underline{B}^A + (\Delta C) \cdot \underline{B}^A$$

Returning to the fundamental Equation 13, we see that it is simpler to recalculate $\underline{B}^E$ than it is to correct $\underline{B}^A$ as just described.

Further, we note that the components of the correction vector in Equation 13, i.e., $\underline{C}(\text{MEAS})$ are not known to better than 10%. In addition, there is an unknown seasonal dependence imbedded into the correction vector. Thus we write:

$$\underline{C}(\text{MEAS}) = \underline{C}' + \underline{S} \pm \underline{N}$$

where $\underline{C}'$ is the proper correction vector, $\underline{S}$ is the unknown seasonal dependence and $\pm \underline{N}$ is a random error.

$$\underline{B}^A(\text{DIP VDH}) = (M'D') [\underline{B}_m + \underline{C}' + \underline{S} \pm \underline{N}]$$

where the vector on the right side is in MEAS coordinates.

$$\text{Let us define } (M'D') \cdot \underline{V}(\text{MEAS}) = \underline{V}^A(\text{DIP VDH})$$

Then:

$$\underline{B}^A = (\underline{B}_m^A + \underline{C}'^A) + \underline{S}^A \pm \underline{N}^A \text{ all in DIP VDH}$$

Thus, the true field (improperly transformed) is:

$$(\underline{B}_M^A + \underline{C}^A) = \underline{B}^A + (\underline{S}^A \pm \underline{N}^A)$$

To correct for the improper transformation we multiply by $(I+\Delta C)$ and obtain the true field $\underline{B}$ in the proper coordinate system.

Thus:

$$\underline{B} = (I+\Delta C) \cdot (\underline{B}_M^A + \underline{C}^A) \quad (16)$$

$$\underline{B} = (I+\Delta C) \cdot [\underline{B}^A + (\underline{S}^A \pm \underline{N}^A)]$$

$$\underline{B} = \underline{B}^A + [(\Delta C) \cdot \underline{B}^A - (\underline{S}^A \pm \underline{N}^A) - (\Delta C) \cdot (\underline{S}^A \pm \underline{N}^A)]$$

We note that $\underline{S}^A$ and $\underline{N}^A$ are small compared to $|\underline{B}^A|$. Also, we know the elements of $\Delta C \ll 1$. Thus, the last term is of second order and may be neglected. However, then:

$$\underline{B} \approx \underline{B}^A + [(\Delta C) \cdot \underline{B}^A - (\underline{S}^A \pm \underline{N}^A)]$$

The unknown seasonal dependence $\underline{S}^A$ is of order 10-20% of $\underline{B}^A$.

The random noise $\underline{N}^A$ is of order 10% of $\underline{B}^A$. As can be seen from Appendix 2 $(\Delta C) \cdot \underline{B}^A$ will be of the same order as these unknowns.

In view of the smallness of the known correction $(\Delta C) \cdot \underline{B}^A$ compared to the unknown $\underline{S}^A$ and $\underline{N}^A$, there appears to be no justification for correcting our actual dipole field data $\underline{B}^A$ (DIP VDH). Thus, we conclude that our original assumptions about the location and orientation of ATS 1 were adequate for what can be done with the data.

Printout of the ATS-1 Ephemeris Tape

In the preceding sections we have discussed the transformation of coordinates used in the processing of ATS-1 magnetic field data.

We concluded that our assumptions about the location and orientation of ATS 1 were justified in view of the unknown errors in the spacecraft field correction vector. In the hope that future work may reduce these correction vector errors to the point that errors in the transformation equations are significant we have produced a printout of the ephemeris tape. To limit the size of this printout and also to eliminate the need for future use of the original ephemeris tapes, we have appropriately formulated the transformation equations. An example printout of the ephemeris for one complete day is given in Appendix 2. This printout is self-explanatory so we do not discuss it here. We note that hourly values are for approximate work only, and should be recalculated according to the formulas given in the ephemeris heading. The various matrices have been calculated using the following formulas. The abbreviation W_{17} refers to word 17 of the ephemeris tape as described in Appendix 1.

$$A = \begin{pmatrix} \cos \phi & \sin \phi & 0 \\ -\sin \phi & \cos \phi & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

where $\phi = \text{ATAN2}(W_{15}, W_{14})$

$$W = \begin{pmatrix} XM(X) & YM(X) & ZM(X) \\ XM(Y) & YM(Y) & ZM(Y) \\ XM(Z) & YM(Z) & ZM(Z) \end{pmatrix}$$

where:

$$ZM(X) = 0W_{23}$$

$$ZM(Y) = -W_{24}$$

$$ZM(Z) = -W_{25}$$

$$YM(X) = A^* (W_{15} \cdot W_{25} - W_{16} \cdot W_{24})$$

$$YM(Y) = A^* (W_{16} \cdot W_{23} - W_{14} \cdot W_{25})$$

$$YM(Z) = A^* (W_{14} \cdot W_{24} - W_{15} \cdot W_{23})$$

$$\text{with } A = \frac{1}{\sqrt{P_X^2 + P_Y^2 + P_Z^2}}$$

Here P_X refers to the quantity in parenthesis in the expression for $YM(X)$, similarly for P_Y and P_Z .

$$XM(X) = (W_{24} \cdot YM(Z) - W_{25} \cdot YM(Y))$$

$$XM(Y) = (W_{25} \cdot YM(X) - W_{23} \cdot YM(Z))$$

$$XM(Z) = (W_{23} \cdot YM(Y) - W_{24} \cdot YM(X))$$

$$M = \begin{pmatrix} V_D(V) & V_D(D) & V_D(H) \\ D_D(V) & D_D(D) & D_D(H) \\ H_D(V) & H_D(D) & H_D(H) \end{pmatrix}$$

Where:

$$V_D(V) = \cos(SCLAT)$$

$$D_D(V) = \sin(SCLAT * H_D(D))$$

$$H_D(V) = 0.06859 * \cos(SCLONG) - 0.18602 * \sin(SCLONG)$$

$$V_D(D) = 0.0$$

$$D_D(D) = \cos(SCLAT) * H_D(H) - \sin(SCLAT) * H_D(V)$$

$$H_D(D) = 0.06852 * \sin(SCLONG) - 0.13602 * \cos(SCLONG)$$

$$V_D(H) = \sin(SCLAT)$$

$$D_D(H) = -\cos(SCLAT) * H_D(D)$$

$$H_D(H) = 0.98015$$

$$\text{with } SCLAT = W_{74}$$

$$SCLONG = W_{75}$$

$$D = \begin{pmatrix} \cos \zeta & \sin \zeta & 0 \\ -\sin \zeta & \cos \zeta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

$$\text{where } \zeta = \frac{UT - 12.0 + (SCLONG/15.0) * 2\pi}{24.0}$$

with UT = universal time in hours.

Note that hour, minute and second are given by words W_4 , W_5 , and W_6 .

$$(DEL C) = (C) - (I)$$

where:

$$(C) = (MDAW) * (M'D')^T$$

(M') is obtained by setting $SCLAT = 0.0$ and $SCLONG = -150.0^\circ$ in the preceding formula for (M). Thus:

$$(M') = \begin{pmatrix} .99943 & -.00657 & -.003296 \\ 0 & .98071 & -.1955 \\ .033609 & .19539 & .98015 \end{pmatrix}$$

(D') is obtained by calculating D as above with

$$\zeta = \frac{UT-22}{24} * 2\pi$$

Acknowledgments

I wish to acknowledge the many helpful discussion of coordinate transformations I have had with my co-worker Dr. C.T. Russell.

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References

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Appendix 1

DESCRIPTION OF THE ATS

EPHEMERIS TAPE
TAPE PRODUCED 04/30/1968 PFM 64

THIS TAPE CONTAINS AN EPHEMERIS FOR ATS/B. THESE DATA SPAN A PERIOD FOR 02/21/1968 - 02/27/1968. QUESTIONS SHOULD BE REFERRED TO R. G. CHAPLICK OR G. D. REPASS AT GSFC 301-982-4373.

MANEUVERS DURING THIS PERIOD

NONE

UNITS OF THE MAGNETIC SHELL PARAMETER(L) ARE
THOSE USED BY DR. C. E. MCILWAIN (1 UNIT = 6371.2 KM)

//// THE FIELD USED IS GSFC/65 AT EPOCH 1965.0, (HENDRICKS AND
CAIN, J.GEOPHYS. RES., 71, 346-7) //

THERE ARE MANY FILES ON THIS TAPE. FILE 1 WILL ALWAYS BE
WRITTEN IN BCD. THE OTHER FILES WILL BE WRITTEN IN BINARY.

EXECUTED ON AN IBM 7094 COMPUTER. AT SOME TIME IN THE
FUTURE THE PROGRAM WILL BE REWRITTEN IN 360/FORTRAN AND
COMPILED AND EXECUTED ON A 360 SYSTEM.

A JET PROPULSION LABORATORY PLANETARY SYSTEM EPHEMERIS TAPE
WILL BE THE SOURCE OF THE LUNAR/SOLAR POSITIONS.

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SAN DIEGO, UCSD-SP-65-5, AUGUST 16, 1965

GEOMAGNETISM BY CHAPMAN AND BARTELS, PAGE 646

COMPUTATION OF THE GEOMAGNETIC FIELD FROM SPHERICAL
HARMONIC EXPANSION BY CAIN, HENDRICKS, DANIELS, JENSEN
GSFC-X-611-64-316, OCTOBER 1964

USES DESCRIPTION OF JPL EPHEMERIS TAPES BY P.R. PEABODY, J.F. SCOTT,
AND E.G. DROZCO, JPL TECHNICAL REPORT NO. 32-580, MARCH 2, 1964

JGR 69, 1181, 1964

JGR 70, 3017, 1965

THE FIELD USED IS GSFC/65 AT EPOCH 1965.0, (HENDRICKS AND
CAIN, J.GEOPHYS. RES., 71, 346-347)

FILE 1. THIS BCD IDENTIFICATION FILE.

FILE 2. EPHEMERIS CONSTANTS (EXAMPLES IN PARENTHESES)
WORD 01 = FIRST 2 DIGITS OF THE SATELLITE ID NUMBER
(61)
WORD 02 = LAST 3 DIGITS OF THE SATELLITE ID NUMBER
(123)
WORD 3 = YEAR OF FIRST DAY ON TAPE (1966)

WORD 4 = DAY NUMBER OF FIRST DAY ON TAPE (348)
 WORD 5 = YEAR OF LAST DAY ON TAPE (1966)
 WORD 6 = DAY NUMBER OF LAST DAY ON TAPE (355)
 WORD 7 = NUMBER OF POSITIONS PER DAY (288)
 WORD 8 = LONGITUDE OF DIPOLE, 69. DEGREES WEST
 WORD 9 = LATITUDE OF DIPOLE, 78.5 DEGREES NORTH
 WORD 10 = CANONICAL UNIT OF LENGTH IN KILOMETERS
 (6378.388)
 WORD 11 = CANONICAL UNIT OF VELOCITY IN KILOMETERS
 PER SECOND (7.90547226)
 WORD 12 = ASTRONOMICAL UNIT OF LENGTH IN KILOMETERS
 = 149599000.
 WORD 13 = WORDS 13 AND 14 ARE USED TOGETHER TO
 DEFINE THE GEOMAGNETIC MODEL USED.
 THE FIELD USED IS GSFC/65 AT EPOCH 1965.0
 WORD 14 = (GSFC/65)
 WORD 15 = SATELLITE SPIN RATE-RPM

N.B., WORDS 1 AND 2 ARE THE SPACECRAFT IDENTIFICATION NUMBER

WORDS 1 TO 7 ARE FIXED POINT NUMBERS
 WORDS 8 TO 12 ARE FLOATING POINT NUMBERS
 WORDS 13 AND 14 ARE ALPHAMERIC NUMBERS
 WORD 15 IS A FLOATING POINT NUMBER

NOTE THAT WORDS 4 AND 6 DO NOT DEFINE THE START AND END TIMES
 ON THOSE DAYS RESPECTIVELY. THE HOUR, MINUTE, SECOND GROUP ON FIRST
 DAY WILL BE 00/00/00. DATA WILL CONTINUE THROUGH THE LAST DAY.

FILE 3 TO END. EACH FILE WILL CONTAIN DATA FOR ONE CALENDAR
 DAY. EACH RECORD WILL CONSIST OF 82 WORDS. THE TIME IN MINUTES
 BETWEEN RECORDS CAN BE COMPUTED BY $1440/(\text{WORD } 7)$ OF FILE 2.
 THE LAST FILE WILL CONTAIN DATA FOR THE COMPLETE DAY DEFINED BY WORD 6
 OF FILE 2.

COORDINATE SYSTEMS

INERTIAL COORDINATE SYSTEM (X,Y,Z)

THE ORIGIN IS AT THE CENTER OF THE EARTH
 +X-AXIS POINTS TOWARD THE VERNAL EQUINOX
 +Z-AXIS IS CO-LINEAR WITH SPIN AXIS OF EARTH
 +Y= Z-CROSS-X

4

GEODETIC COORDINATE SYSTEM (N,F,D)

THE ORIGIN IS AT THE SUB-SATELLITE POINT
 THE ORIGIN LIES ON THE SURFACE OF THE EARTH. N AND E
 LIE IN THE LOCAL HORIZONTAL PLANE RELATIVE TO THE
 SURFACE OF THE EARTH.
 N AXIS LIES IN THE PLANE OF THE LOCAL MERIDIAN AND
 IS POSITIVE NORTH.
 E AXIS IS NORMAL TO THE PLANE OF THE LOCAL MERIDIAN
 AND IS POSITIVE EAST.
 D AXIS LIES ALONG THE LOCAL VERTICAL RELATIVE TO THE
 SURFACE OF THE EARTH AND IS POSITIVE AS MEASURED
 FROM THE ORIGIN INTO THE EARTH.

SPACECRAFT BODY SYSTEM (XB,YB,ZB)

FOR SPIN STABILIZED SATELLITES

ZR AXIS IS COLINEAR WITH SPACECRAFT SPIN AXIS
XB AXIS IS NORMAL TO THE ZR AXIS AND LIES IN THE
PLANE OF ZR AND THE FINE SUN SENSOR
YR AXIS IS ZR-CROSS-YB

FOR ATS-A GRAVITY GRADIENT STABILIZATION

- THE ORIGIN IS AT THE SPACECRAFT CENTER OF GRAVITY (HAC STA. 1A.5)
- +XB AXIS IS IN THE PLANE NORMAL TO THE AXIS OF THE CYLINDRICAL BODY AT HAC THETA = 180 DEGREES
- +YB AXIS IS AT HAC THETA = 90 DEGREES
- +ZB AXIS COMPLETES THE RIGHT HANDED COORDINATE SYSTEM AND IS ALONG THE AXIS OF THE CYLINDRICAL BODY (ZR = XB CROSS YB)

WORDS 61 TO 72 ARE COMPONENTS OF UNIT VECTORS IN THE SPACECRAFT BODY COORDINATE SYSTEM

THE DIPOLF SYSTEM IS THAT DEFINED BY CHAPMAN AND BARTELS.
DATA IN THE DIPOLF SYSTEM WILL BE GIVEN AS EAST LONGITUDE AND
COLATITUDE.

5

REGULAR B VECTOR IS THE MAGNETIC FIELD VECTOR ACCORDING TO
THE DIPOLF MODEL DEFINED BY WORDS 13 AND 14 OF FILE 2.

DISTORTED B VECTOR IS THE MAGNETIC FIELD VECTOR ACCORDING
TO THE DISTORTED DIPOLF MODEL.

PHASE ANGLE IS THE ANGLE BETWEEN THE ATS-B POSITIVE XB-AXIS
AND THE VECTOR FROM THE CENTER OF THE EARTH TO THE SPACECRAFT.
PHASE ANGLE WILL NOT BE COMPUTED FOR ATS A-IT WILL BE WRITTEN
AS ALL SEVENS.

POLARIZATION ANGLE AS DEFINED BY MR. R. J. DARCEY IN MEMO
TO ALL EXPERIMENT MANAGERS ON 28 JULY 1965.

QUOTE --
MEASUREMENT OF POLARIZATION ANGLE

THE POLARIZATION ANGLE MEASURED AT ATS GROUND STATIONS SHALL
BE DEFINED AS THE ANGLE BETWEEN THE INCIDENT ELECTRIC FIELD VECTOR
AND THE PLANE DETERMINED BY THE LOCAL VERTICAL AND THE LINE BETWEEN
THE GROUND STATION AND THE SATELLITE. IT SHALL HAVE POSITIVE SENSE
WHEN MEASURED COUNTER-CLOCKWISE AT THE GROUND STATION AND VIEWED
TOWARD THE SPACECRAFT.

R. J. DARCEY

-- END QUOTE

WORDS 1 TO 5 ARE FIXED POINT NUMBERS
WORDS 6 TO 82 ARE FLOATING POINT NUMBERS

ALL DISTANCES, VELOCITIES, ANGLES WILL BE EXPRESSED
IN CANONICAL UNITS OF LENGTH, CANONICAL UNITS OF
VELOCITY, AND RADIAN. UNITS OF MAGNETIC FIELD
VECTOR ARE GAMMA = 1.0×10^{-5} GAUSS.

UNITS OF THE MAGNETIC SHELL PARAMETER(L) ARE
THOSE USED BY DR. C. E. MCILWAIN (1 UNIT = 6371.2 KM)

WORD 01 = YEAR (1966)	)
WORD 02 = MONTH (12)	) EPOCH IN UNIVERSAL
WORD 03 = DAY (23)	) TIME OF POSITION AND
WORD 04 = HOUR (15)	) VELOCITY DATA OF THIS
WORD 05 = MINUTE (47)	) RECORD

WORD 06 = SECOND (48,123))
 WORD 07 = ANGLE IN THE EQUATORIAL PLANE FROM THE 6
 INERTIAL +X-AXIS TO THE GREENWICH MERIDIAN
 (POSITIVE EAST)
 WORD 08 = SPACECRAFT INERTIAL X COMPONENT (CUL)
 WORD 09 = SPACECRAFT INERTIAL Y COMPONENT (CUL)
 WORD 10 = SPACECRAFT INERTIAL Z COMPONENT (CUL)
 WORD 11 = SPACECRAFT INERTIAL X-DOT COMPONENT (CUL)
 WORD 12 = SPACECRAFT INERTIAL Y-DOT COMPONENT (CUL)
 WORD 13 = SPACECRAFT INERTIAL Z-DOT COMPONENT (CUL)
 WORD 14 = SUN INERTIAL X COMPONENT (CUL)
 WORD 15 = SUN INERTIAL Y COMPONENT (CUL)
 WORD 16 = SUN INERTIAL Z COMPONENT (CUL)
 WORD 17 = COS(XR,X)
 WORD 18 = COS(YR,Y)
 WORD 19 = COS(XR,Z)
 WORD 20 = COS(YR,X)
 WORD 21 = COS(YR,Y)
 WORD 22 = COS(YR,Z)
 WORD 23 = COS(ZR,X)
 WORD 24 = COS(ZR,Y)
 WORD 25 = COS(ZR,Z)
 WORD 26 = X-INERTIAL COMPONENT OF REGULAR B VECTOR
 WORD 27 = Y-INERTIAL COMPONENT OF REGULAR B VECTOR
 WORD 28 = Z-INERTIAL COMPONENT OF REGULAR B VECTOR
 WORD 29 = X-INERTIAL COMPONENT OF DISTORTED B VECTOR
 WORD 30 = Y-INERTIAL COMPONENT OF DISTORTED B VECTOR
 WORD 31 = Z-INERTIAL COMPONENT OF DISTORTED B VECTOR
 WORD 32 = MAGNITUDE OF REGULAR B VECTOR
 WORD 33 = MAGNITUDE OF DISTORTED B VECTOR
 WORD 34 = N-GEODETIC COMPONENT OF REGULAR B VECTOR
 WORD 35 = E-GEODETIC COMPONENT OF REGULAR B VECTOR
 WORD 36 = D-GEODETIC COMPONENT OF REGULAR B VECTOR
 WORD 37 = N-GEODETIC COMPONENT OF DISTORTED B VECTOR
 WORD 38 = E-GEODETIC COMPONENT OF DISTORTED B VECTOR
 WORD 39 = D-GEODETIC COMPONENT OF DISTORTED B VECTOR
 WORD 40 = B-SUB-THETA OF REGULAR B VECTOR
 WORD 41 = B-SUB-PHI OF REGULAR B VECTOR
 WORD 42 = B-SUB-R OF REGULAR B VECTOR
 WORD 43 = B-SUB-THETA OF DISTORTED B VECTOR
 WORD 44 = B-SUB-PHI OF DISTORTED B VECTOR
 WORD 45 = B-SUB-R OF DISTORTED B VECTOR
 WORD 46 = COLATITUDE SPACECRAFT IN DIPOLE SYSTEM
 WORD 47 = LONGITUDE SPACECRAFT IN DIPOLE SYSTEM
 WORD 48 = COLATITUDE SUN IN DIPOLE SYSTEM
 WORD 49 = LONGITUDE SUN IN DIPOLE SYSTEM
 WORD 50 = COLATITUDE XB IN DIPOLE SYSTEM
 WORD 51 = LONGITUDE XB IN DIPOLE SYSTEM
 WORD 52 = COLATITUDE YB IN DIPOLE SYSTEM
 WORD 53 = LONGITUDE YB IN DIPOLE SYSTEM
 WORD 54 = COLATITUDE ZB IN DIPOLE SYSTEM
 WORD 55 = LONGITUDE ZB IN DIPOLE SYSTEM
 WORD 56 = COLATITUDE REGULAR B IN DIPOLE SYSTEM
 WORD 57 = LONGITUDE REGULAR B IN DIPOLE SYSTEM
 WORD 58 = COLATITUDE DISTORTED B IN DIPOLE SYSTEM
 WORD 59 = LONGITUDE DISTORTED B IN DIPOLE SYSTEM
 WORD 60 = L = MAGNITUDE OF MAGNETIC SHELL PARAMETER

THE FOLLOWING ARE COMPONENTS OF UNIT VECTORS IN THE
 SPACECRAFT BODY SYSTEM. THESE VECTORS ARE DIRECTED
 TOWARD THE OBJECTS GIVEN BELOW.

WORD 61 = XB TO EARTH CENTER
 WORD 62 = YB TO EARTH CENTER
 WORD 63 = ZB TO EARTH CENTER
 WORD 64 = XB TO SUN
 WORD 65 = YB TO SUN
 WORD 66 = ZB TO SUN

WORD 67 = YR ALONG REGULAR B VECTOR DIRECTION
 WORD 68 = YR ALONG REGULAR B VECTOR DIRECTION
 WORD 69 = ZR ALONG REGULAR B VECTOR DIRECTION
 WORD 70 = YR ALONG DISTORTED B VECTOR DIRECTION
 WORD 71 = YR ALONG DISTORTED B VECTOR DIRECTION
 WORD 72 = ZR ALONG DISTORTED B VECTOR DIRECTION
 WORD 73 = GEODETIC LATITUDE OF SATELLITE
 WORD 74 = GEOCENTRIC LATITUDE OF SATELLITE
 WORD 75 = LONGITUDE (+EAST) OF SATELLITE
 WORD 76 = DISTANCE OF SATELLITE FROM CENTER OF EARTH
 WORD 77 = ALTITUDE OF SATELLITE
 WORD 78 = PHASE ANGLE
 WORD 79 = POLARIZATION ANGLE FOR ROSMAN
 WORD 80 = POLARIZATION ANGLE FOR MOJAVE
 WORD 81 = POLARIZATION ANGLE FOR TOCWCCMA
 WORD 82 = POLARIZATION ANGLE FOR JAPAN

***** WARNING *****

IF FOR SOME REASON THE ATTITUDE CANNOT BE DETERMINED, ANY VALUE
 PERTAINING TO ATTITUDE WILL BE WRITTEN AS ALL SEVENS. WORDS 17
 TO 25, 50 TO 55, 61 TO 72, 78 TO 82 COULD BE WRITTEN IN THIS
 MANNER.

WORD 15 OF FILE 2 COULD BE ALL SEVENS AT SOME TIME.

END

LISTING OF AT5-1 EPHEMERIS TAPE FOR USE IN MAGNETIC FIELD DATA PROCESSING

THE TRANSFORMATION FROM (MEAS) TO (SDIPVDH) COORDINATES (MCPERRON, 1972) IS GIVEN BY: $(SDIPVDH) = (MDAH) \cdot (MEAS)$.
 MATRICES (M), (A), (W) ALL CHANGE SLOWLY WITH THE LOCATION AND ORIENTATION OF THE SPACECRAFT AND ARE PRINTED BELOW FOR EVERY HOUR.
 THE MATRIX (D) CHANGES RAPIDLY SINCE IT IS A FUNCTION OF THE SATELLITE HOUR ANGLE. IT IS GIVEN BY A SIMPLE RIGHT HAND ROTATION
 ABOUT THE Z AXIS BY THE ANGLE: $A = 2\pi \cdot (1 - UT - 12.063 \text{ LONG} / 15.0) / 24$.
 MAGNETIC FIELD DATA PROCESSING WAS CARRIED OUT UNDER THE ASSUMPTIONS THAT ATS-1 WAS IN THE EQUATOR AT -150 DEGREES EAST LONGITUDE
 WITH ITS SPIN AXIS PARALLEL TO THE EARTH'S ROTATION AXIS. MATRIX (DELCL) IS A SMALL CORRECTION MATRIX FOR THE ASSUMPTIONS AND IS
 USUALLY NEGLECTIBLE.

TIME				GEOGRAPHIC		POLAR ANGLES(DEG)		JF SAT		MATRIX ELEMENTS											
				[SATELLITE LOC(DEC)]		SPIN AXIS IN GEI COORD		[PHI(ZM)]		135.1				135.1				135.1			
YEAR	MON	DAY	HOUR	SCLAT	SCLONG(EAST)	THETA(ZM)				135.1				135.1				135.1			
1968	1	3	0	-0.2	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	1	-0.3	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	2	-0.3	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	3	-0.3	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	4	-0.2	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	5	-0.2	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	6	-0.1	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			
1968	1	3	7	-0.1	-150.4	0.6				135.1				135.1				135.1			
				B(GSEE)	= (AM)*B(MEAS)					135.1				135.1				135.1			
				B(IPIVDH)	= (PI)*B(ROTVDH)					135.1				135.1				135.1			
				B(DIPVDH)	= (MDAM)*B(MEAS)					135.1				135.1				135.1			
				B(EIDIPVDH)	= (I+DELC)*B(DIPVDH)					135.1				135.1				135.1			

LISTING OF ATS-1 EPHEMERIS TAPE USE IN MAGNETIC FIELD DATA PROCESSING

*** NOTE ***

THE TRANSFORMATION FROM (MEAS) TO (DIPVDM) COORDINATES (MCPHERSON, 1972) IS GIVEN BY: $B(DIPVDM) = (MDVM) * B(MEAS)$.
 MATRICES (M), (A), (N) ALL CHANGE SLOWLY WITH THE LOCATION AND ORIENTATION OF THE SPACECRAFT AND ARE PRINTED BELOW FOR EVERY HOUR.
 THE MATRIX (D) CHANGES RAPIDLY SINCE IT IS A FUNCTION OF THE SATELLITE HOUR ANGLE. IT IS GIVEN BY A SIMPLE RIGHT HAND ROTATION
 ABOUT THE Z AXIS BY THE ANGLE: $A = 2\pi * (UT - 12) * 360 / 15.03724$.
 MAGNETIC FIELD DATA PROCESSING WAS CARRIED OUT UNDER THE ASSUMPTIONS THAT ATS-1 WAS IN THE EQUATOR AT -150 DEGREES EAST LONGITUDE
 WITH ITS SPIN AXIS PARALLEL TO THE EARTH'S ROTATION AXIS. MATRIX (DELCL) IS A SMALL CORRECTION MATRIX FOR THE ASSUMPTIONS AND IS
 USUALLY NEGLIGIBLE.

TIME				GEOGRAPHIC		POLAR ANGLES(DEG) OF SAT		MATRIX ELEMENTS	
YEAR MON DAY HOUR				SATELLITE LOC(DEC)	SPIN AXIS IN GEI COORD	[SCLAT SCLONG(EAST)] [THETA(ZM)]			
1968	1	3	8	-0.0	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0024 1.0000 0.0056) (-0.0089-0.0056 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000-0.0000 0.0323) (0.0 0.9800 0.1279) (-0.0001-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.8639-0.4548 -0.0836) (0.5037-0.8474-0.0887) (0.0048-0.1187 0.9814)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0019-0.0037 0.0176) (-0.0075-0.0122 0.0771) (-0.0703-0.0463-0.0148)	
1968	1	3	9	0.1	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0024 1.0000 0.0056) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0003 0.0323) (0.0 0.9801 0.1279) (0.0024-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.9648-0.2590-0.0561) (0.2630-0.9463-0.1094) (0.0083-0.1203 0.9813)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(0.0001-0.0002-0.0012) (-0.0042-0.0142 0.0791) (-0.0589-0.0605-0.0147)	
1968	1	3	10	0.1	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0024 1.0000 0.0056) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0003 0.0323) (0.0 0.9801 0.1279) (0.0024-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.9999-0.0057-0.0241) (0.0044-0.9808-0.1223) (0.0113-0.1224 0.9811)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(0.0002 0.0038-0.0193) (-0.0003-0.0142 0.0719) (-0.0442-0.0716-0.0145)	
1968	1	3	11	0.2	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0023 1.0000 0.0056) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0004 0.0323) (0.0 0.9800 0.1279) (0.0034-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.9670-0.2479 0.0100) (-0.2545-0.9486-0.1264) (0.0134-0.1248 0.9809)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0017 0.0072-0.0354) (0.0030-0.0123 0.0624) (-0.0269-0.0768-0.0143)	
1968	1	3	12	0.2	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0023 1.0000 0.0055) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0005 0.0323) (0.0 0.9800 0.1279) (0.0043-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.8682 0.4846 0.0441) (-0.4461-0.9519-0.1216) (0.0147-0.1275 0.9805)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0051 0.0091-0.0488) (0.0049-0.0048 0.0490) (-0.0080-0.0814-0.0141)	
1968	1	3	13	0.3	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0023 1.0000 0.0055) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0006 0.0323) (0.0 0.9800 0.1279) (0.0046-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.7102 0.6662 0.0759) (-0.7039-0.6972-0.1081) (0.0150-0.1301 0.9801)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0089 0.0090-0.0579) (0.0048-0.0049 0.0327) (0.0112-0.0790-0.0139)	
1968	1	3	14	0.3	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0023 1.0000 0.0055) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0006 0.0323) (0.0 0.9800 0.1279) (0.0050-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.5038 0.8450 0.0291) (-0.8637-0.4951-0.0669) (0.0142-0.1327 0.9798)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0120 0.0070-0.0627) (0.0028-0.0015 0.0145) (0.0295-0.0714-0.0138)	
1968	1	3	15	0.3	-150.4	0.6		135.1	
				B(GSEE) = (A)*B(MEAS)		(A) =		(1.0000-0.0024 0.0089) (0.0023 1.0000 0.0055) (-0.0089-0.0055 0.9999)	
				B(DIPVDM) = (M)*B(ROTVDH)		(M) =		(1.0000 0.0006 0.0323) (0.0 0.9800 0.1279) (0.0048-0.1279 0.9801)	
				B(DIPVDM) = (MDVM)*B(MEAS)		(MDVM) =		(-0.2631 0.9441 0.1236) (-0.7647-0.2592-0.0941) (0.0125-0.1349 0.9794)	
				BE(DIPVDM) = (I+DELCL)*B(DIPVDM)		(DELCL) =		(-0.0137 0.0036-0.0626) (-0.0006 0.0034-0.0643) (0.0453-0.0591-0.0137)	

*** NOTE ***

TIME				GEOGRAPHIC		POLAR ANGLES(DEG) OF SAT		MATRIX ELEMENTS	
YEAR	MON	DAY	HOUR	SCLAT	SCLONG(EAST)	SPIN AXIS IN GEI	COORD		
1968	1	3	16	0.2	-150.4	0.6		135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0069-0.0055 0.9999) (M) = (1.0000 0.0006 0.0323)(0.0 0.9800 0.1279)(0.0043-0.1279 0.9601) (MDAM) = (-0.0044 0.9788 0.1365)(-0.9999-0.0057-0.0274)(0.0099-0.1366 0.9791) (DELCL) = (-0.0134-0.0002-0.0576)(-0.0044 0.0003-0.0225)(0.0573-0.0428-0.0136)	
				B(GSEE) = (AM)*B(MEAS)				135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0005 0.0323)(0.0 0.9800 0.1279)(0.0035-0.1279 0.9601) (MDAM) = (0.2545 0.9467 0.1406)(-0.9670 0.2482 0.0067)(0.0066-0.1377 0.9789) (DELCL) = (-0.0112-0.0033-0.0481)(-0.0075-0.0017-0.0387)(0.0645-0.0236-0.0136)	
1968	1	3	17	0.2	-150.4	0.6		135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0005 0.0323)(0.0 0.9800 0.1279)(0.0035-0.1279 0.9601) (MDAM) = (0.2545 0.9467 0.1406)(-0.9670 0.2482 0.0067)(0.0066-0.1377 0.9789) (DELCL) = (-0.0112-0.0033-0.0481)(-0.0075-0.0017-0.0387)(0.0645-0.0236-0.0136)	
				B(GSEE) = (AM)*B(MEAS)				135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0005 0.0323)(0.0 0.9800 0.1279)(0.0035-0.1279 0.9601) (MDAM) = (0.4961 0.8499 0.1358)(-0.8682 0.4852 0.0408)(0.0029-0.1381 0.9785) (DELCL) = (-0.0078-0.0050-0.0347)(-0.0092-0.0049-0.0520)(0.0662-0.0031-0.0137)	
1968	1	3	18	0.1	-150.4	0.6		135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0005 0.0323)(0.0 0.9800 0.1279)(0.0035-0.1279 0.9601) (MDAM) = (0.4961 0.8499 0.1358)(-0.8682 0.4852 0.0408)(0.0029-0.1381 0.9785) (DELCL) = (-0.0078-0.0050-0.0347)(-0.0092-0.0049-0.0520)(0.0662-0.0031-0.0137)	
				B(GSEE) = (AM)*B(MEAS)				135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0002 0.0323)(0.0 0.9800 0.1279)(0.0013-0.1279 0.9601) (MDAM) = (0.7040 0.6950 0.1223)(-0.7102 0.6891 0.0725)(-0.0010-0.1375 0.9787) (DELCL) = (-0.0040-0.0048-0.0184)(-0.0090-0.0086-0.0613)(0.0622 0.0171-0.0138)	
1968	1	3	19	0.1	-150.4	0.6		135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0002 0.0323)(0.0 0.9800 0.1279)(0.0013-0.1279 0.9601) (MDAM) = (0.7040 0.6950 0.1223)(-0.7102 0.6891 0.0725)(-0.0010-0.1375 0.9787) (DELCL) = (-0.0040-0.0048-0.0184)(-0.0090-0.0086-0.0613)(0.0622 0.0171-0.0138)	
				B(GSEE) = (AM)*B(MEAS)				135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0000 0.0323)(0.0 0.9800 0.1279)(0.0001-0.1279 0.9601) (MDAM) = (0.8638 0.4926 0.1010)(-0.5038 0.6459 0.0966)(-0.0049-0.1364 0.9788) (DELCL) = (-0.0008-0.0027-0.0010)(-0.0070-0.0117-0.0061)(0.0528 0.0354-0.0139)	
1968	1	3	20	0.0	-150.4	0.6		135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000 0.0000 0.0323)(0.0 0.9800 0.1279)(0.0001-0.1279 0.9601) (MDAM) = (0.8638 0.4926 0.1010)(-0.5038 0.6459 0.0966)(-0.0049-0.1364 0.9788) (DELCL) = (-0.0008-0.0027-0.0010)(-0.0070-0.0117-0.0061)(0.0528 0.0354-0.0139)	
				B(GSEE) = (AM)*B(MEAS)				135.1 (-----COLUMN 1-----)(-----COLUMN 2-----)(-----COLUMN 3-----) (AM) = (1.0000-0.0024 0.0089)(-0.0023 1.0000 0.0055)(-0.0089-0.0055 0.9999) (M) = (1.0000-0.0003 0.0323)(0.0 0.9800 0.1279)(-0.0012-0.1279 0.9601) (MDAM) = (0.5647 0.2565	

Correction and Analysis of ATS-1
Magnetometer Data During 1971

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APPENDIX A

REPORT ON THE ATS-1 MAGNETOMETER PROJECT

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1. INTRODUCTION

Values of ATS 1 Data. The ATS 1 satellite was placed in synchronous orbit in December 1966. Since its launch, it has operated almost continuously, measuring the vector magnetic field. At the time of launch this instrument was the most sensitive flux-gate magnetometer in space and, in addition, had the highest sample rate of any satellite magnetometer. The fact that it is located in the equatorial plane and its orbital period is locked to the rotation period of the earth has made possible a number of unique studies. All of these depend on the fact that the satellite sweeps out one complete revolution of the magnetosphere every day at a fixed point in the earth's magnetic field. This makes possible statistical studies of the occurrence of various phenomena which take place at the synchronous orbit. Any eccentric satellite requires a full year to make such a circuit and requires many years to acquire comparable statistics.

The value of such studies is enhanced by the fact that magnetic field lines intersecting the auroral zone pass near or through the synchronous orbit. This fact has made the ATS 1 data extremely useful in studies of the magnetospheric substorm, magnetic storms and auroral zone micropulsations.

Problems of Spacecraft Field. Despite the fact that the magnetometer has worked properly enabling us to complete a number of important studies, we have encountered major problems in the analysis of the data. These problems arise from the facts that the spacecraft was not originally designed to carry a magnetometer and that no boom was provided to separate the instrument from the spacecraft.

As a consequence, the spacecraft field at the magnetometer is comparable to the ambient field. This problem would not be serious if the field were known or constant. Unfortunately, this field is dependent on the spacecraft state, which changes as often as 100 times per day. Unless this field is determined for each state, no absolute measurements of the field are possible.

In addition to the problem just discussed, the absence of a boom has made it difficult to study fluctuations of the field. Here the problem arises from field transients caused by the changing spacecraft state. These transients introduce noise spikes and gaps into the magnetometer data. Similarly, other environmental experiments produce periodic disturbances at the spacecraft.

During the past year we have developed methods for handling the preceding difficulties. Use of these methods has enabled us to begin a number of interesting projects otherwise not possible. In the following sections we describe these methods and summarize the results of our analysis.

II. ATS 1 CHRONOLOGY

The UCLA magnetometer on ATS 1 has operated continuously now for almost 5 years. During this time the percent data recovered from the satellite has typically been about 80%. A month-by-month plot of this data recovery is included as Figure 1. During this time there have been two major changes in the satellite which, in order to compensate for, our existing data processing programs must be modified. The first of these occurred on November 2, 1969, when the satellite sun sensor failed. The signal from such a sensor is required to resolve the output of the magnetometer transverse to the spin axis into two orthogonal components fixed in inertial space.

The second event occurred on June 30, 1970, when Goddard Space Flight Center ceased recording the output of the EME package on ATS 1. Special arrangements made with NOAA at Boulder, Colorado, supported by the Office of Naval Research, have made it possible to continue recording the telemetered data. However, the format of the data tapes is quite different from those originally supplied to UCLA. These events and several others of lesser importance are summarized in the chronology of Table 1.

III. CORRECTION OF ATS-1 MAGNETIC FIELD OBSERVATIONS

Absolute Correction for Eclipse State

Sources of DC Interference. As viewed by our data processing program, the ATS 1 magnetometer consists of two sensors, one parallel and one perpendicular to the satellite spin axis. The parallel sensor is effectively fixed in relation to all electrical currents flowing in the rotating spacecraft and measures

the magnetic field of these currents. This spacecraft field is superimposed on the natural field parallel to the spin axis and must be subtracted from the measurements to obtain the natural field.

The perpendicular sensor rotates at the satellite spin frequency and records the projection of the transverse component of the field on the instantaneous position of the sensor. This projection is a maximum when the sensor and transverse field are parallel, and a minimum when they are antiparallel. By noting the phase of this signal relative to a signal from the sun sensor, it is possible to resolve the sensor signal into two orthogonal components.

Interference with the perpendicular sensor is caused by any magnetic field which is periodic at the spin frequency. Such a signal arises from the solar panels in two different ways. First, the magnetometer is located on the rim of a cylindrical spacecraft and during one rotation moves first toward the subsolar point and then away. Since the currents flow only in the cells near the subsolar point, the magnetometer is moving first toward the currents and then away. The magnetic field at the magnetometer due to these currents will thus increase and decrease periodically at the spin frequency. We note at a fixed point in space, there would be no variation in the magnetic field due to this effect.

There is a second way, however, in which the field varies periodically at both the magnetometer and also at a fixed point in space. This results from the asymmetric distribution of solar cells due to openings in the side of the spacecraft. Since there

are no cells, there is no current. Thus, the magnitude of the currents at the subsolar point, and hence magnetic fields at the magnetometer, are modulated periodically at the spin rate.

The above periodic variations in the magnetic field at the spin frequency are superimposed on the variation due to rotation of the perpendicular sensor in the transverse natural field. The output of this sensor is the sum of these two signals. We note also that the solar cell currents remain constant in amplitude and phase for a given state of the spacecraft. Thus, when the sensor signal is resolved into two orthogonal components, the periodic interference signal appears as constant offsets in the two orthogonal components of the transverse field. As with the parallel sensor discussed previously, these two offsets must be subtracted from the measured field to obtain the actual field.

It should be mentioned that the parallel sensor also records a signal at the spin frequency due to the above sources. Since the desired information about the natural field is at frequencies less than the spin frequency, this interference can be eliminated by low-pass filtering the output of the parallel sensor. We note, however, that for a given state of a spacecraft the phase of this interference signal depends on the relative position of the sun and the magnetometer, i.e., this error signal acts as a sun sensor.

Determination of Perpendicular Offset in the Eclipse State. For the sake of argument, let us assume that the spacecraft state remains constant. Then the offsets in the two components of the transverse field are determined as follows. Near the equinoxes a satellite in equatorial orbit is eclipsed by the earth near

local midnight. When the satellite enters the earth's shadow, the currents in the solar cells vanish along with their magnetic effects. At this time, the measured field becomes equal to the natural field. The offsets which occur in the two orthogonal components of the transverse field at this time are just the corrections which must be applied for this spacecraft state.

The actual determination of these two offsets is complicated by two factors. First, as soon as the spacecraft enters the earth's shadow the signal from the sun sensor disappears. This means that resolution of the signal from the transverse magnetometer into two orthogonal components fixed in inertial space depends upon extrapolation of the phase angle of the spacecraft's spin. This extrapolation can be made by assuming the spin rate is constant with a value equal to that at the beginning of eclipse. This assumption is valid only for a short interval of time.

The second factor is that the spacecraft begins to cool in the shadow and shrinks. This, in turn, causes it to spin faster. As a consequence, the phase angle of the spinning spacecraft differs from the predicted, and inertial reference is lost. At this point, large sinusoids appear in the X and Y components until a sun sensor signal is again available. The offsets must be measured as soon after the spacecraft enters the complete shadow as possible.

An example of these effects is shown in Figure 2. Eclipse entry begins at 0934:30 UT. Transient effects of this entry are over by 0938. The X and Y offsets between these two times are approximately 12 and 18 gamma, respectively. Since no solar cell currents are flowing at this later time, we assume the measured

field is exactly equal to the natural field. Thus, the correction vector (C_X , C_Y , C_Z) to be added to the data for the particular state of the spacecraft on entry to this eclipse has X and Y components of 12 and 18 gamma.

The effects of losing the signal from the sun sensor and cooling of the spacecraft are also apparent in this figure. Large amplitude sinusoids in X and Y gradually increase in frequency as the assumed spin frequency departs from the actual frequency. At about 1045 the satellite emerges from eclipse and the measured field is again comparable to the field before eclipse.

Determination of Parallel Offsets in the Eclipse State.

In contrast to the situation for the transverse sensor, there is no equally satisfactory method of determining the offset in the parallel sensor. The method we use is based upon the assumption that the natural field will be the same at a fixed point in the magnetosphere provided the solar wind parameters remain fixed. The local time for which the effects of changes in these parameters will be the least in the synchronous orbit is at local noon. Thus, we take the average of the field measurements in the parallel sensor at local noon on quiet days for a given state of the spacecraft. On the basis of previous reports, Sugiura et al. (1970), Fairfield (1968) and Russell (1970), we take the field at this point to be about 120 gamma. The difference between this value and our observations is the correction to be applied to the parallel component for this spacecraft state.

Absolute Correction for Three Equinoxes. The results of

our determination of absolute corrections for three successive equinoxes after launch are shown in Table 2. This correction vector differs from the example above because of a difference in spacecraft state. The standard deviations shown for each component of the correction vector represent the variation in the offset for about 10 separate measurements. The large absolute variation in the Z component of the correction vector is due to the effects of differing solar wind parameters on supposedly similar quiet days. It should be noted that the percent error in all three corrections are comparable. Also, we note that the ambient field at ATS 1 typically has perpendicular and parallel components of 25 and 100 gamma. Consequently, the percent errors in the corrected field components are not significantly different.

It is also important to note that the three successive determinations of offsets are the same within the indicated experimental error. As a consequence, we have considerable confidence in the values obtained.

Spacecraft States and Associated Correction Vectors

Determination of Spacecraft State. As mentioned previously, the state of the spacecraft changes frequently as commands are sent turning the various subsystems on and off. The currents flowing either in the circuits of the spinning spacecraft or in the inertially fixed solar cells change due to different power requirements. Thus, for each new state of the spacecraft a new correction vector is required.

An example of the effects of these changes is shown in the right panel of Fig. 3. The rate at which these changes occur as well as the

magnitude of their effects creates a serious problem. In our initial attempts to find consistent correction vectors for various states, we discovered that almost all of the communications subsystems as well as the cloud camera affect the spacecraft field. In addition, we have found that in some cases the order, i.e., time history, of the commands is important.

As a result of these observations, we found it necessary to create a complete time history of the spacecraft state. Since a complete log of all commands sent to the spacecraft is kept by the ATS operations office of Goddard Space Flight Center, it was possible to create such a history. Our initial attempts to do this failed, however. We found that our final keypunched version of the command log had innumerable errors. These errors were consequences of human mistakes in every step of the process of producing the log. The first two steps were relatively simple. We checked for valid command numbers and time sequence. After this step we developed a spacecraft state simulation program.

The purpose of this program was to detect inconsistencies in the sequence of commands. For example, a command to change the mode of a subsystem which was supposedly off is inconsistent.

In order to remove inconsistencies such as the one in the preceding example, we found it necessary to scan both the later log and the uncorrected magnetometer data. When a number of other commands manipulating the same subsystem were found, it was assumed that a command was missing from the log. If the command was one which was known to affect the magnetometer, the uncorrected data were scanned to locate the time the command must have been sent.

In many cases, commands were added or deleted in order to produce a consistent command log. In a number of cases the decision of how to remove the inconsistency or where to place the pseudo-command was arbitrary.

The above procedure, while creating a consistent log, cannot guarantee a completely accurate one. Fortunately, most of these problems involve subsystems whose states were changed a number of times per day so that any errors in the state do not persist. In addition, such errors, if they affect the magnetometer, become evident in the final, corrected data and appropriate corrections can be made to the spacecraft state.

Several pages from our current listing of the spacecraft state log are shown in Table 3. Note these pages include the time interval of the eclipse of Figure 2. In the box at the top left of the page is a textual description of the

spacecraft state at the time of the first command listed. At the top right of the box is an interpretation of the listing. Successive times down the page are times the commands in the second column were sent. The third column interprets the command number. The next four columns give a textual description of the state of the major subsystems. The next column, containing three groups of eight characters, is a hexadecimal listing of the spacecraft state vector. When this vector is expanded into a binary number, the successive bits represent on-off states of the various subsystems as well as the order in which some of these were turned on. The next column is a flag presently not used. The final three columns are the three components of the correction vector which must be added to the measured field to obtain the actual field for the state. The flag 3333.3 indicates the correction is not presently known.

Additional information about this listing is contained in Tables 4 and 5. In Table 4 all possible commands sent to the spacecraft are listed in increasing order (note their octal base). In Table 5 we give a complete description of the spacecraft state vector and its interpretation.

As a measure of the magnitude of the task discussed above, it should be noted that during the first two years of operations there were 60,000 commands sent to the spacecraft.

Determination of Relative Offsets. Once the state vector was known it became possible to determine the changes in the field as transitions between states occurred. Conceptually,

the procedure is simple. Referring to Figure 3, all that is necessary is to measure the changes in each component of the field during the transition. In practice, the large number of states and errors in the measurements make this an almost impossible task without computer assistance.

The automated procedure which we developed is the following. Using a data set (in this case disk storage) containing the state vector, we read through the uncorrected magnetic field data tapes. At each point where a transition occurred the data were read into core memory. Since the accuracy of the command log is only ± 5 seconds and the magnetometer time resolution is 0.16 seconds, it was necessary to locate the exact time of the offset. If this time was located, averages of the measured field vector before and after the offset were made and subtracted. This change in the correction vector was recorded on an output data set along with the state vector before and after the offset. If no clear indication of the offset was found, the event was discarded. Similarly, if two transitions occurred less than 5 seconds apart, the event was also discarded.

The preceding data set was then sorted, first according to initial state and then according to final state, and finally by the magnitude of the offset in the Z component. This data set was then scanned using the UCLA interactive console system. Events for which the magnitude of the offset in any of the three components was radically different from the typical values for the group were deleted manually. The edited data set was then processed by computer, creating averages and standard deviations for each

group containing the same initial and final states. The standard deviation for each group was then used to reject any values more than 1 standard deviation away from the mean for the group. Finally, averages and standard deviations were determined for each group in the final version of the data set.

The justification for the above procedure is based on the observation that many of the calculated offsets were clearly in error. These errors were due to difficulties in locating the exact time of offset, transient fields during the change in state, and natural fluctuations in the field.

Determination of Most Frequent States. An examination of the data set of average offset vectors between vector states revealed that there were many state transitions that did not change the spacecraft field. On the basis of these, we were able to determine which subsystems were unimportant. This, in turn, allowed us to "mask" certain bits in the spacecraft state vector as unimportant (refer to Table 3 for explanation of vector).

The next step in the procedure was to read through the state vector tape, determining the total length of time the spacecraft existed in each state. In this process we used the "equivalenced" state vectors, i.e., state vectors in which the unimportant subsystems were masked in the sorting procedure. A listing of these states is given in Table 6. These states are listed according to decreasing total time the spacecraft was in the indicated state. The final column of this table indicates the percent of the total data that can be corrected if all the correction vectors to this point in the table are known.

It is evident from examination of Table 6 that 95% of the data can be corrected with only 45 of the state vectors known. Clearly, there is a point of diminishing return in which the labor involved in determining the correction is more lengthy than the amount of data gained. The heavy line across the table represents our arbitrary cutoff point.

Determination of Absolute Correction Vectors for Most Frequent States. Using Table 6, we have been systematically determining the correction vectors for states of decreasing total duration. Our method is a manual one and proceeds as follows. We begin with the correction vector for the eclipse mode determined as discussed previously. We then use the listing of state transitions and associated changes in the correction vector to determine the correction vector for nearly identical states. Proceeding in this way, we establish a tree of related states and their absolute correction vectors.

Clearly, as states become progressively more distant from the eclipse state, the errors in the absolute correction vector become larger. However, the fact that single commands turn off a number of subsystems simultaneously guarantees that no state is too distant.

Automatic Correction of Magnetometer Data

Correction Procedure. The data set containing the state vector and associated correction vectors is sufficient information to correct the data at 15 second time resolution. A data tape containing uncorrected magnetic field data at 0.16 time resolution is read into the computer memory. Fifteen second averages of each measured field component are created. A comparison of the time of this average to the state vector listing determines the appropriate correction vector to be added to the calculated averages. The particular average including the time of transition between states is flagged.

The corrected fields are obtained in spacecraft coordinates in which the Z axis is parallel to the satellite spin axis, the sun vector lies in the XZ plane, and the Y axis completes the right-handed system. Note the spacecraft is located in the earth's equatorial plane with its spin axis as close to parallel to the earth's rotation axis as possible. Consequently, the XYZ coordinate system of spacecraft coordinates is equivalent to geocentric solar earth equatorial coordinates (Russell, 1971). In the XYZ system the coordinate axes rotate once every 24 hours with respect to a magnetic meridian plane. Consequently, the data are transformed to the rotational VDH coordinate system. In this system H is still parallel to the satellite spin axis as was the Z axis of the XYZ system. The V axis is radially outward and D is azimuthally eastward in the equatorial plane. In this rotational VDH system the dipole field at ATS 1 has

constant components of $(-7, 22, 107)$. These constant offsets are somewhat inconvenient so another transformation is made to produce the dipole VDH system (Russell, 1971). In this system H is antiparallel to the earth's magnetic dipole axis and V radially outward in the magnetic equatorial plane. Since the location of ATS 1 at 150° W longitude is almost exactly at the intersection of the rotational and magnetic equatorial planes this transformation is nearly an 11° rotation about the V axis. In addition to the above, another transformation is made when the spacecraft spin axis is not parallel to the earth's rotation axis. This transformation is applied immediately after corrected field values are obtained in spacecraft coordinates and converts the field to GSEE coordinates. The format of the final corrected data tapes is shown in Table 7.

An example of data corrected by the above procedures is shown in Figure 3. The right-hand panel shows the uncorrected data and the left-hand panel the corrected field in dipole VDH coordinates. The V component is approximately -7 gamma, the D component nearly 0, and the H component about 115 gamma. The missing data after 0330 are due to unknown correction vectors associated with several transition states of short duration. The pulses apparent in all three components are due to the spin scan cloud camera. As discussed in the next section, we are presently unable to correct these pulses. We also note that the correction at 0344 is not quite right.

Another example of automatically corrected data is shown in Figure 4. Here 2-1/2 minute averages for the entire day have been plotted. Spikes in all three components are the effects of the spin scan cloud camera pulses shown in Figure 3 at higher time resolution. Infrequent small offsets in the three components are consequences of turning the camera on or off. Finally, the large offsets in the H component are due to incorrect correction vectors associated with the VHF transmitters. Despite the remaining difficulties the data plotted in Figure 4 represent a considerable achievement. To obtain similar but less accurate results by our previous hand corrections would involve more than a week of labor. The following section discusses the remaining problems to be solved.

Remaining Problems

Several problems in the automatic correction of data remained to be solved. The most serious of these is the effects due to the spin cloud camera. The camera takes approximately 22 minutes to complete a scan. Then during 2-1/2 minutes it resets for another scan. Fairly large offsets are associated with the reset mode. Somewhat smaller offsets are associated with turning the camera on and off. The magnetic effects of the reset mode have been found to be functions of universal time. This apparently results from the fact that the camera operation is synchronized in such a way as to obtain the picture of the earth at any local time. In other words, the magnetic effects are organized in the rotational VDH system rather than the XYZ system based on the sun vector. However, our correction procedures must be carried out on data in the XYZ system.

Another problem is that the actual time between scans is not constant interval but a constant number of spacecraft rotations. Consequently, the repetition period varies with the spin rate.

Still another problem is the fact that the camera starts or stops wherever it is in its cycle when an on or off command is received. This makes it particularly difficult to predict when the first reset mode will occur.

The VHF transmitters on the spacecraft also cause considerable difficulty. As power to these is turned on, large offsets occur which decay asymptotically in about 15 minutes

to a smaller offset. In addition, transitions between states appear to be considerably more variable when the VHF transmitters are on.

IV. CALCULATION OF POWER SPECTRA USING DATA WITH VARIOUS TYPES OF INTERFERENCE

Types of Interference. As discussed in the introduction, there are a number of forms of spacecraft interference which appear in the output of the magnetometer. These include the DC offsets discussed in the previous section, data gaps, noise spikes and periodic signals. Each of them introduces difficulties when an attempt is made to calculate power spectra. We have found, however, that a relatively simple procedure enables us to derive most of the spectral information without the necessity of initial corrections. The nature of these difficulties and our procedures are discussed below.

Figure 5 displays magnetometer data at the highest meaningful time resolution 0.32 seconds. In this figure the vertical scale is 5 gammas per division and the horizontal scale is 5.12 seconds per division. This choice of horizontal scale is determined by the satellite telemetry rate which completes one sequence per 5.12 seconds. In each sequence there are sixteen 0.32-second averages. At the bottom of the figure, textual material presents time and 1.28 second averages of each component of the measured field. The coordinate system is essentially geocentric solar earth equatorial coordinates as described in the previous section.

One type of interference occurs at 0335:00.8 where there is a DC offset in all three components of the field. This offset

should be compared to the same offset plotted at 15 second time resolution in Figure 3. Spectral analysis of raw data containing such offsets results in spectra which show little besides the Fourier resolution of a sequence of random step functions.

Another type of interference appears at 0335:31.5 where a gap in the data is flagged by a large number. Spectral analysis of the raw data would simply give the Fourier resolution of a large pulse. A similar, though less important problem occurs at 0333:51.6 where a small noise spike in the Y component appears.

Still another problem is a high frequency interference signal of several gamma amplitude present throughout the data. The signal is most obvious in the Y component as a ramp function of 5.12 seconds duration. The ramp is clearly correlated with the boundaries between telemetry sequences. Since a ramp function has a Fourier spectrum containing all harmonics of the repetition period, the power spectrum of these data contains a sequence of harmonic spectral lines with the fundamental at $(1/5.12 \text{ Hz})$.

A similar interference signal at lower frequency occurs only in the parallel (Z) component. At 0335:16.2 a two gamma jump in Z is the beginning of a 16 sequence (81.2 sec) ramp. Spectral analysis of decimated data, i.e., 10 second averages, also produces harmonically related spectral lines due to this ramp.

As discussed in the introduction, the source of these interference signals is the spacecraft. The problem is compounded by the lack of a boom for the magnetometer. The origin of the offsets parallel and transverse to the spin axis was discussed in the

previous section. The origin of noise spikes and data gaps is usually transient fields which the basic magnetometer responds to but which are mostly filtered out of the final signal by sampling filters. As discussed in a report by Barry and Snare (1966) the high sensitivity and wide dynamic range of the magnetometer is achieved through a coil system which adds constant increments of field to the sensor to keep it in center range. If a transient field forces the magnetometer to change levels, i.e., add field for more than the time between successive readouts of the level, then a gap is introduced in the data with the basic data processing program. This is necessary because levels are read out only one-fourth as often as the basic magnetometer. When two successive readouts of the level are different, it is not known where in the intervening four data points the level change occurred. If the transient causes the level to change twice between readouts returning to its original value, only the sampling filters recognize this change and a noise spike results.

The exact origin of the periodic interference signals has not been investigated. They are almost certainly the result of other environmental measurement experiments whose operations are synchronized by the satellite telemetry rate. For example, particle detectors scan energy with a repetition period which is a fixed number of telemetry sequences.

Techniques of Spectral Analysis

The problems discussed in the previous section make it impossible to perform spectral analysis on the raw data. As a consequence, we have developed several strategies which allow us to avoid these problems. The most straightforward of these is to hand correct the data. This process is laborious and as a consequence limited to decimated data, for example, 15 second averages, where there are fewer points needing correction. This process is carried out by making a printer plot similar to that shown in Figure 5 for the decimated data. Times of bad points are then identified, gaps interpolated, and offsets measured. This information is keypunched and fed to a control program which carries out the appropriate operations at the times determined by the scanning process. The time series resulting from this is free of errors so spectral analysis is carried out in the normal way.

The second procedure is more subtle and justified by mathematical theory developed by Parzen (1962). Intuitively, it seems that it should be possible to use the available data in time series containing gaps to determine a spectrum. The standard technique of spectral analysis discussed by Blackman and Tukey (1958) begins with the determination of the correlation functions. For example,

$$C_{XX}(k) = \frac{1}{N-k} \sum_{j=1}^{N-k} X_j \cdot X_{j+k}$$

Here X_j represents the j th sample of some variable in the time series X . For a given lag k the correlation function is a single number determined by a sum of cross products over the

entire time series. If a few points are missing in the time series, it will not change the correlation function by much if the normalization constant $1/(N-k)$ is adjusted to be the total number of available cross products.

If the correlation function is calculated in the preceding manner we can Fourier transform it without further problems and obtain the power spectrum. It can be shown that this procedure is entirely equivalent to that described in the paper by Parzen (1962) and is mathematically justified.

It should be recognized that although this process handles gaps, spikes and offsets remain serious problems. To deal with these we have introduced an additional step in the determination of spectra. We begin by calculating the first difference time series, subtracting the j th point from the $j+1$ th point and dividing by the time separation. This process approximates the derivative operation at low frequencies. The first difference time series has zero mean, offsets appear as spikes, and spikes appear as a pair of oppositely directed spikes. Gaps widen and the flags are set to 0 (the mean of the first difference time series). In the next step we pass through the series setting all spikes larger than a specified value to 0. This new series has no remaining problems except gaps and may then be analyzed by the technique described above. The resulting spectrum must be corrected, however, for the effects of the first difference operation. This is done by dividing each power spectral estimate by the reciprocal of the square of the transfer function of the first

difference operator. This process is called recoloring and produces the spectrum of the original undifferenced data.

It should be pointed out that in addition to eliminating the problems of spikes and offsets there are other advantages as well. For example, geophysical spectra typically have steep power law decreases in power with increasing frequency. The usual Blackman-Tukey technique of spectral analysis is particularly sensitive to distortion of higher frequency estimates by power at low frequencies. The first difference operation effectively decreases the slope of the spectrum. For example, a $1/f^2$ spectrum of the original data becomes a flat spectrum.

There is one remaining limitation on the above procedure. The Blackman-Tukey technique is exceedingly slow and expensive to use on a computer. An alternative procedure uses the fast Fourier transform (FFT) algorithm developed recently by Codey and Tukey (1965). In this procedure the first difference time series is Fourier transformed by the FFT algorithm and spectra determined directly from the Fourier coefficients. The disadvantage of this process is that data gaps appear as modulation of the original time series. This modulation may be thought of as multiplication of the original time series by a function whose value is either 1 or 0 depending upon whether data are available or not. By a fundamental theorem in Fourier analysis, multiplication in the time domain becomes convolution in the frequency domain. In other words, the power spectra obtained using the FFT are distorted by the convolution of the spectrum of the modulation with the spectrum of the undistorted time series.

Empirically we find that for most of our work to date this distortion is not significant. This fact can be shown by comparing the spectra obtained using the FFT and the modified Blackman-Tukey technique described above. It can be understood theoretically by recognizing that the Fourier spectrum of a modulation function consisting of a sequence of 1's interspersed with a short sequence of 0's randomly spaced is sharply peaked at zero frequency. Convolution of this spectrum with any arbitrary spectrum does not produce significant changes.

Example Spectra. An example of cross spectral analysis of first difference time series with the FFT technique just described is shown in Figure 6. The original data are taken from a quiet day and are essentially the same as that shown in Figure 5. In calculating these spectra we have used data at highest meaningful time resolution, 0.32 seconds, to emphasize the high frequency portion of the spectrum. Also, the spectra in this figure have not been recolored.

Examining the top left panel, we note a peak in the spectrum at 0.4 Hz. This peak is a consequence of two factors. The steep fall off above this frequency results from numerical filters applied in the basic demodulation program to reject the approximately 1.6 Hz spin frequency of the satellite. The slower fall off at low frequencies is the result of the first difference operator discussed above.

In the top right panel the same spectra are plotted with a linear frequency scale. At approximately 0.2 Hz a very sharp spectral line appears at the frequency corresponding to the

satellite telemetry sequence. Also apparent are a number of harmonics of this line at higher frequency.

The bottom right panel shows the coherency between the indicated pairs of components. The harmonic lines are particularly apparent in this display.

Another example of spectra is shown in Figure 7. The original data include large amplitude, irregular pulsations at ATS 1. These spectra differ from the previous example in that they have been recolored for the first difference operator. Also, eigenanalysis has been carried out on the spectral matrix obtaining principal axis coordinates at each frequency. In the top left panel the dashed line labeled "quiet" is the trace of the spectral matrix on a quiet day. Note the steep decrease above 0.4 Hz is still apparent.

At the top right it is quite apparent that the spectra lines are distinct from the remainder of the spectrum. Their narrow width and high polarization (bottom right panel) distinguishes them from typical geophysical phenomena. A final example of spectra is shown in Figure 8. In this case the original first difference time series was decimated creating six second averages in order to study lower frequency waves. The sharp spectra line at 0.01 Hz is a natural signal of unusually narrow bandwidth. On the flank of this peak at 0.0122 Hz is the fundamental of a 16 telemetry sequence ramp in the Z component of the original data.

V. SCIENTIFIC RESULTS

1. Storm Time Meridional Oscillations

Quasi-sinusoidal magnetic field oscillations (micropulsations) are regularly observed at ATS-1 during geomagnetic storms. The wave events typically occur during the main phase and tend to be confined to the afternoon sector. Detailed analysis of 3 such storm time events was discussed by Barfield et al. (1971). Preliminary results of a statistical survey of all the storm time events observed during 1967 have corroborated the earlier conclusions of Barfield et al., and are presented here.

The statistical survey included some 21 events which were well enough defined to be recognizable from a visual scan of the magnetometer data. An "event" was defined as any period of time in which at least 5 cycles of a wave were present. During some events, the oscillations actually subsided for a time equivalent to several cycles, but in each case they began again with no significant change in the oscillation characteristics.

The occurrence statistics of the observed events show that the oscillations occur most often during the main phase, usually near the main phase minimum. In addition the local time distribution of the events is such that the oscillations have a maximum probability of occurring just prior to local dusk with a sharp cutoff at dusk.

The observed events typically began abruptly, lasted approximately one hour and ended suddenly. A close correlation with sub-storm expansions was observed for the bulk of the observations and in addition, the majority of the event onsets were briefly preceded

by a rapid decline of the field strength at the satellite. Those events which did not exhibit substorm correlation typically followed an enhancement of the main phase decrease at the satellite.

Spectral analysis of the observed events indicate that the frequency of the waves may range from .003-.007 Hz, and the most probable frequency is $\sim .005$ Hz. The waves tend to be linearly polarized with the axis of polarization lying in a plane roughly defined by the magnetic meridian plane.

The preliminary results of the study suggest that the observed stormtime oscillations may be generated by an instability of the enhanced stormtime ring current, and the associated hot ($\beta \gg 1$) plasma. It has been observed that the ring current is strongest during the main phase of the geomagnetic storm reaching a maximum intensity at the main phase minimum (Frank, 1967). Further, it is thought that the partial ring current attains its maximum strength during the main phase, with a longitudinal extent from midnight westward to the afternoon sector. The fact that the observed waves occur only during storms, primarily during the main phase, and in the afternoon sector lends strong support to the possibility that they are associated with a ring current instability.

Recent work by Crooker and Siscoe (1971) using magnetometer data from a chain of low latitude ground stations, has shown evidence that during disturbed times the maximum depression due to the partial ring current is near 1800 LT. They conclude that the position of this maximum depression, presumably indicative of the azimuthal location of the maximum of the partial ring current, may vary as much as 45° from 1800 LT. The local time probability distribution

derived from the work of Crooker and Siscoe agrees well with the local time occurrence distribution of our observations, that is the percentage of events observed at a given local time (in the afternoon sector) corresponds roughly to the probability that the maximum ring current effect is at that local time. This is true for the afternoon sector only; the results of Crooker and Siscoe shown the distribution of the maximum ring current nearly symmetric about 1800 LT, while the observed ATS-1 events have a sharp cut-off at dusk.

The source of the assymetry of our observations about dusk is open to question. However, with the assumption that some other physical mechanism (e.g., change in effective L shell) prevents occurrence of the waves after dusk, the work of Crooker and Siscoe lends strong support to the suggestion that the stormtime oscillations are due to a characteristic instability of the partial ring current.

If the observed wave events are associated with the peak in the partial ring current, as suggested, then the characteristic dip in field strength prior to the events may be viewed as evidence of newly injected plasma brought in by the substorm process. Thus, the responsible instability could be generated by one or both of the concomitant effects of the injection process. First, a fluid instability such as the drift mirror instability (Hasegawa, 1969; Barfield et al., 1971), or alternatively the steep gradients induced by the rapid injection could trigger a gradient associated instability such as the compressional Alfvén wave instability (e.g., Cladis, 1971).

The long duration of the wave events coupled with their restricted frequency range and well defined orientation suggests a resonance of the magnetospheric cavity. Whether the duration of an event is temporally or spatially limited is still unclear.

Several suggestions have been made regarding the origin of oscillations similar to those described here, (Sonnerup et al., 1969; Hasegawa, 1969; Lanzerotti et al., 1969; Cladis, 1971). Cladis (1971) suggested that meridional oscillations of the magnetic field could be generated by injection of high energy plasma into the ring current. Such injections would be likely during geomagnetic substorms, as mentioned before (Davis and Parthasarathy, 1967). Sonnerup et al. (1969) suggested that such oscillations could be due to "the particle population sloshing back and forth along the field lines." Hasegawa (1969) suggested the drift mirror instability of the ring current. As pointed out by Barfield et al. (1971), it is not possible to support or deny the plausibility of any of these theoretical proposals solely on the basis of the satellite magnetic field observations.

In summary, the stormtime micropulsations observed at ATS-1 suggest the following model. The spatial gradients of the storm-time ring current are enhanced by newly injected plasma during a magnetospheric substorm. Broad band oscillations produced by an instability of this current are then filtered by the resonant properties of the magnetosphere to produce the observed oscillations. Such a proposed model is attractive and we believe, premature. Several critical question remain to be answered.

Concerning the cause of the instability, all the models proposed predict a well defined correlation between the magnetic field oscillations and the high energy particle population. We have not yet investigated such relationships in detail, although Barfield and Coleman (1970) did note that the energetic protons and electrons fluctuated coherently with the magnetic field for one event of the type discussed here. It is suggested that further investigations are required before a definitive statement can be made concerning the particle behavior during the observed events.

It has also been noted that during many of the oscillation events mentioned, Pc 1 oscillations were observed at ATS-1 (e.g., Barfield and Coleman, 1970). Such high frequency oscillations could be a damping mechanism for the Pc 4-5 oscillations and possible correlations between the two wave classes should be investigated.

The question of the significance of the characteristic dip in field strength prior to the oscillations has yet to be resolved. As previously discussed by Barfield et al. (1971), such a dip would be predicted by the two models considered most likely. If the field decrease does imply a severe field distortion at ATS-1, then the background field geometry prior to and after the dip requires careful study in order to comment on the plausibility of the proposed mechanisms.

Although the observed characteristics of the stormtime oscillations point strongly to the ring current as an energy source for the waves, the point is far from resolved. Two other sources exist at the ATS-1 orbit which would produce a similar field-

25.99 -31.76 0.0 68001 031500 -13.59 23.75 -33.92 0.0 24.39 -33.38 0.0
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68001 032000 -6.11 29.52 -32.62 0.0 68001 032500 -6.12 28.71 -32.46 0.0 REC 3, LENGTH 3204
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68001 033000 -9.46 28.27 -32.22 0.0 68001 033500 -5.00
68001 033230 -8.34 30.12 -33.99 0.0 68001 033730 -2.44 32.88 -35.51 0.0
31.49 -34.56 0.0 68001 034000 6.67 34.91 -32.40 0.0
68001 034230 15.26 32.56 -29.76 0.0 68001 034730 22.93
68001 034500 18.47 32.98 -26.64 0.0 68001 035000 15.96 19.80 -23.67 0.0
21.65 -26.66 0.0 68001 035230 13.46 23.03 -17.83 0.0
68001 035500 11.21 20.41 -15.43 0.0 68001 040000 -11.09
68001 035730 -3.57 15.96 -16.76 0.0 68001 040230 -14.23 19.29 -23.22 0.0
18.50 -26.32 0.0 68001 040500 -17.06 20.93 -13.10 0.0
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22.91 -15.91 0.0 68001 041500 -14.85 23.50 -18.05 0.0
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68001 043230 -4.10 26.42 -27.25 0.0 68001 043730 -5.65
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27.64 -27.98 0.0 68001 045500 -4.67 26.18 -27.95 0.0
68001 045730 -4.93 27.74 -26.85 0.0

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28.17 -27.54 0.0 68001 050500 -6.75 27.71 -27.20 0.0
68001 051000 -10.90 28.04 -28.07 0.0 68001 051500 -11.26
68001 051230 -11.55 28.80 -27.64 0.0 68001 051730 -10.45 30.17 -26.35 0.0
29.50 -27.19 0.0 68001 052000 -7.79 31.07 -25.85 0.0
68001 052230 -4.54 32.24 -23.94 0.0 68001 052730 -3.26
68001 052500 -4.23 32.70 -23.23 0.0 68001 053000 -1.30 35.00 -22.18 0.0
33.77 -22.52 0.0 68001 053230 0.02 36.16 -22.20 0.0
68001 053730 2.52 36.82 -23.67 0.0 68001 054000 1.16
36.55 -22.50 0.0 68001 054230 -2.41 35.49 -24.66 0.0
68001 054500 -4.23 34.56 -21.66 0.0 68001 055000 -4.30
68001 054730 -3.23 34.95 -21.32 0.0 68001 055230 -3.56 36.14 -26.30 0.0
35.38 -25.38 0.0 68001 055730 -3.01 37.00 -27.40 0.0
68001 060000 -2.72 38.06 -29.46 0.0 68001 060500 -7.37
68001 060230 -3.72 38.60 -29.34 0.0 68001 060730 -8.73 37.82 -29.82 0.0
37.86 -30.27 0.0 68001 061000 -8.09 38.44 -29.52 0.0
68001 061230 -7.28 38.86 -27.42 0.0

68364 170230 -20.66 -7.42 122.80 0.0	68364 170000 -21.16 -6.94 123.34 0.0	68364 171000 -20.65 -7.91 124.33 0.0	68364 170730 -20.87 -7.74 123.35 0.0	68364 170500 -20.82 -7.63 122.63 0.0
68364 171500 -20.72 -8.42 126.01 0.0	68364 171230 -20.44 -8.03 124.81 0.0	68364 172230 -20.46 -9.74 128.60 0.0	68364 172000 -20.68 -9.68 128.16 0.0	68364 171730 -20.92 -9.05 127.10 0.0
68364 172730 -19.77 -9.25 130.76 0.0	68364 172500 -20.00 -9.63 129.55 0.0	68364 173500 -19.91 -6.81 131.58 0.0	68364 173230 -19.24 -7.80 131.40 0.0	68364 173000 -19.72 -8.72 131.35 0.0
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68364 175230 -19.25 -4.48 130.72 0.0	68364 175000 -19.13 -4.88 130.87 0.0	68364 175730 -17.79 -4.63 132.57 0.0	68364 175500 -18.22 -4.32 132.04 0.0	
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68364 181730 -14.94 -5.14 132.61 0.0	68364 181500 -14.76 -4.92 131.53 0.0	68364 182500 -14.91 -5.02 133.07 0.0	68364 182230 -14.86 -4.86 130.78 0.0	68364 182000 -14.96 -5.01 132.19 0.0
68364 183000 -15.23 -5.04 134.70 0.0	68364 182730 -15.18 -5.24 133.82 0.0	68364 183730 -14.99 -4.81 135.59 0.0	68364 183500 -15.16 -4.94 132.77 0.0	68364 183230 -15.48 -4.93 133.51 0.0
68364 184230 -14.47 -4.64 134.80 0.0	68364 184000 -14.65 -4.41 134.11 0.0	68364 185000 -15.75 -4.42 135.54 0.0	68364 184730 -15.51 -4.75 135.55 0.0	68364 184500 -14.88 -4.66 134.60 0.0
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68364 193230 -15.34 -1.69 136.72 0.0	68364 193000 -14.66 -2.04 136.63 0.0	68364 193730 -15.03 -1.88 137.18 0.0	68364 193500 -15.26 -1.62 136.87 0.0	
68364 194500 -14.95 -1.65 137.72 0.0	68364 194230 -15.39 -1.46 138.21 0.0	68364 195230 -14.74 -1.63 137.99 0.0	68364 194730 -14.88 -1.59 138.19 0.0	
68364 195730 -12.12 -0.32 131.35 10.00	68364 195500 -15.12 1.37 128.34 10.00	68364 200230 -11.13	68364 200000 -11.42 -1.01 132.95 10.00	

68364 201000 -10.17 -1.86 135.66 14.00	68364 200730 -10.39 -1.67 135.82 10.00	68364 200500 -10.89 -1.20 133.62 10.00	68364 201230 -10.42 -2.49 137.45 14.00
68364 202230 -14.84 -2.22 140.36 6.00	68364 202000 -15.29 -2.31 140.35 6.00	68364 201730 -15.30 -2.54 140.14 6.00	68364 201500 -13.12 -2.46 140.73 6.00
68364 203500 -13.60 -2.44 139.15 6.00	68364 203230 -13.57 -1.57 137.08 6.00	68364 203000 -14.84 -0.68 135.43 6.00	68364 202500 -14.36 -2.50 140.93 6.00
68364 204730 -13.25 -2.42 139.56 6.00	68364 204500 -13.25 -2.36 140.11 6.00	68364 204230 -13.38 -2.42 141.33 6.00	68364 204000 -13.63 -2.55 140.88 6.00
	68364 205730 -10.84 -0.11 135.25 6.00	68364 205500 -12.73 -2.36 140.08 6.00	68364 205230 -12.90 -2.82 140.15 6.00

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68364 210000 -12.37 -3.02 140.75 6.00	68364 210730 -12.04 -3.31 140.63 6.00	68364 210500 -12.03 -3.07 140.74 6.00	68364 210230 -11.94 -3.07 140.74 6.00
68364 211230 -11.32 -3.13 139.87 6.00	68364 211000 -11.75 -3.07 139.24 6.00	68364 210730 -12.04 -3.31 140.63 6.00	68364 211500 -11.30 -2.78 140.52 6.00
68364 212500 -11.46 -2.62 139.99 6.00	68364 212230 -10.51 -2.70 139.34 6.00	68364 212000 -9.92 -0.13 135.89 6.00	68364 211730 -11.64 -0.13 135.89 6.00
68364 213730 -10.80 -1.91 138.78 6.00	68364 213500 -10.68 -2.01 138.25 6.00	68364 213230 -11.00 -2.34 139.17 6.00	68364 213000 -11.37 -2.29 139.79 6.00
68364 215000 -9.91 -1.62 139.90 6.00	68364 214730 -10.62 -1.66 139.88 6.00	68364 214500 -8.52 -1.92 139.46 6.00	68364 214230 -9.86 1.29 134.79 6.00
68364 220230 -9.47 -0.75 139.00 6.00	68364 220000 -9.65 -0.72 137.91 6.00	68364 215730 -9.33 -1.14 138.38 6.00	68364 215500 -9.62 -1.75 138.88 6.00
68364 221500 -7.48 -0.30 134.24 6.00	68364 221230 -8.61 -0.30 127.86 6.00	68364 221000 -8.79 -0.40 133.01 6.00	68364 220730 -7.71 0.40 135.82 6.00
68364 222730 -7.29 0.82 134.43 6.00	68364 222500 -7.55 -0.03 135.50 6.00	68364 222230 -8.09 -0.35 134.53 6.00	68364 222000 -8.09 -0.38 135.35 6.00
	68364 223730 -7.06 0.48 134.44 6.00	68364 223500 -7.32 0.34 135.04 6.00	68364 223230 -6.07 2.90 130.17 6.00

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68364 224000 -7.05 0.69 132.53 6.00	68364 224730 -6.78 0.21 132.94 6.00	68364 224500 -6.82 0.29 132.10 6.00	68364 224230 -6.67 0.62 132.80 6.00
68364 225230 -7.71 3.10 128.70 6.00	68364 225000 -7.05 0.37 133.16 6.00	68364 224730 -6.78 0.21 132.94 6.00	68364 225500 -5.89 1.08 133.32 6.00
68364 230500 -5.13 -0.21 131.10 6.00	68364 230230 -5.80 -0.40 130.18 6.00	68364 230000 -6.80 -0.19 134.14 6.00	68364 230730 -4.92

REC

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REC

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-0.19 132.67	6.00		68364 231230	-4.89	68364 231000	-5.09	-0.19 133.66	6.00
		68364 231500	-4.66	0.38 133.78	6.00	-0.05 134.46	6.00	
68364 231730	-3.89	1.57 132.81	6.00					
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		68364 232730	-2.25	3.26 132.87	0.0			
68364 233000	-2.04	3.18 133.16	0.0			68364 233230	-2.10	
3.09 132.90	0.0			68364 233500	-2.24	2.81 132.10	0.0	
		68364 234000	-1.82	3.11 133.04	0.0			
68364 234230	-1.62	3.42 132.46	0.0			68364 234500	-1.81	
3.43 133.24	0.0			68364 235000	-1.47	3.56 132.73	0.0	
		68364 235230	-1.54	3.52 132.50	0.0			
68364 235500	-1.29	3.82 131.72	0.0			68364 235730	-0.61	
3.92 131.99	0.0							
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66365 226730 -9.64	-1.22 143.33	6.00	66365 221230 -8.56	1.66 146.60	2.00	66365 221000 -9.99	
1.05 146.26	2.00		66365 221500 -10.14	1.26 146.33	2.00		
	66365 221730 -8.67	2.20 145.11	2.00				
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66365 222000 -9.68	1.58 146.27	2.00	66365 222500 -9.82	1.30 147.82	2.00	66365 222230 -8.32	
1.80 147.85	2.00		66365 222730 -8.02	1.94 147.50	2.00		
	66365 223000 -9.20	1.68 147.50	2.00			66365 223500 -8.33	
66365 223230 -8.80	2.01 147.42	2.00				1.68 147.92	2.00
1.83 147.66	2.00		66365 223730 -9.56	1.32 147.31	2.00		
	66365 224000 -10.48	1.19 144.58	2.00			66365 224730 -8.28	
66365 224500 -9.43	1.74 142.66	2.00	66365 225000 -8.19	1.42 147.25	2.00	1.66 145.59	2.00
1.99 143.02	2.00		66365 225230 -9.17	1.12 147.00	2.00		
	66365 225500 -12.18	1.79 144.53	2.00			66365 230000 -11.32	
66365 225730 -12.80			66365 230230 -9.79	3.17 144.42	2.00	2.52 144.16	2.00
2.36 143.77	2.00		66365 230500 -3.71	3.69 145.31	2.00		
	66365 230730 -8.61	4.29 146.11	2.00	66365 231500 -8.39	4.86 145.74	2.00	
66365 231000 -7.92			66365 231730 -8.97	5.09 145.16	2.00	66365 231230 -8.39	
4.07 146.73	2.00					4.86 145.74	2.00
	66365 232000 -9.98	4.44 146.89	2.00	66365 232730 -7.46	-0.22 142.72	6.00	
66365 232230 -9.22	4.10 147.77	2.00	66365 233000 -10.18	-0.80 142.18	6.00	66365 232500 -7.51	
1.37 148.04	6.00					-0.22 142.72	6.00
	66365 233230 -10.36	-2.09 142.65	6.00	66365 234000 -7.94	-0.90 140.64	6.00	
66365 233500 -9.55	-1.44 142.07	6.00	66365 234230 -5.46	-0.66 142.93	6.00	66365 233730 -8.94	
-1.48 140.53	6.00					-0.90 140.64	6.00
	66365 234500 -8.20	-1.01 145.07	6.00	66365 235230 -7.53	1.13 141.42	6.00	
66365 234730 -10.84	-0.52 145.59	6.00	66365 235500 -9.08	-0.35 143.58	6.00		
1.87 140.16	6.00						
	66365 235730 -8.19	-0.05 142.92	6.00				
0000							

REC 16. LENGTH 3204

OUTPUT UNIT FILE AND RECORD HISTORY

UNIT 15 FILE 1 CONTAINS 5760 RECORDS

D-10587

OUTPUT UNIT 15 CONTAINS 2282.65 FEET OF DATA

TAPE ON INPUT UNIT 5 SUCCESSFULLY DUPED

ATS-1

15 SECOND MAGNETIC FIELD AVERAGES

This data set consists of 22, 800 BPI, BCD, 7-track tapes. The 'D' tapes were produced on the IBM/360 and the 'C' tapes on the 7094. Each tape contains one data file.

<u>D#</u>	<u>C#</u>	<u>START</u>	<u>STOP</u>
D-10587	C-08236	1/01/67	2/09/67
D-10588	C-08237	2/10/67	3/20/67
D-10589	C-08238	12/27/66	12/31/66
D-10590	C-08239	11/17/66	12/26/66
D-10591	C-08240	5/01/67	6/09/67
D-10592	C-08241	6/10/67	7/19/67
D-10593	C-08242	1/01/68	2/09/68
D-10594	C-08243	12/27/67	12/27/67
D-10595	C-08244	11/17/67	12/23/67
D-10596	C-08245	10/08/67	11/16/67
D-10597	C-08246	7/20/67	8/28/67
D-10598	C-08247	8/29/67	10/07/67
D-10599	C-08248	3/22/67	4/30/67
D-10600	C-08249	3/21/68	4/29/68
D-10601	C-08250	2/10/68	3/19/68 -
D-10602	C-08251	7/19/68	8/24/68
D-10603	C-08252	6/09/68	7/18/68
D-10604	C-08253	4/30/68	6/08/68
D-10605	C-08254	12/26/68	12/29/68
D-10606	C-08255	11/16/68	12/25/68
D-10607	C-08256	10/07/68	11/15/68
D-10608	C-08257	8/28/68	9/17/68

ATS 1 DATA TAPES
W1 SERIES - 15 SECOND AVERAGES
(TAPE DESCRIPTION)

These 22 tapes contain data from December 7, 1966 to December 31, 1968. (15 second averages).

The data were written by an IBM 360 model 91 on 7-track unlabeled tapes at ⁸⁰⁰~~556~~ bits per inch, even parity with translate feature turned on. There is one file per tape containing 40 days of data. Each record is in BCD format, 80 bytes long and blocked at 3200 bytes.

The time spans for the tapes are:

W16632	December 7, 1966 - December 25, 1966
W16636	December 26, 1966 - December 31, 1966
W16700	January 1, 1967 - February 9, 1967
W16704	February 10, 1967 - March 21, 1967
W16708	March 22, 1967 - April 30, 1967
W16712	May 1, 1967 - June 9, 1967
W16716	June 10, 1967 - July 19, 1967
W16720	July 20, 1967 - August 28, 1967
W16724	August 29, 1967 - October 7, 1967
W16728	October 8, 1967 - November 16, 1967
W16732	November 17, 1967 - December 26, 1967
W16736	December 27, 1967 - December 31, 1967
W16800	January 1, 1968 - February 9, 1968
W16804	February 10, 1968 - March 20, 1968
W16808	March 21, 1968 - April 29, 1968
W16812	April 30, 1968 - June 8, 1968

W16816	June 9, 1968 - July 18, 1968
W16820	July 19, 1968 - August 7, 1968
W16824	August 28, 1968 - October 6, 1968
W16828	October 7, 1968 - November 15, 1968
W16832	November 16, 1968 - December 25, 1968
W16836	December 26, 1968 - December 31, 1968

The format for the data records is:

<u>Character</u>	<u>Description</u>	<u>Format</u>
01-02	Last Two Digits of Year	I2
03-05	Day of Year	I3
07-08	Hour	I2
09-10	Minute	I2
11-12	Second	I2
13-19	V Component of Dipole VDH	F7.1*
20-26	D Component of Dipole VDH	F7.1*
27-33	H Component of Dipole VDH	F7.1*
34-40	X Component of Uncorrected XYZ	F7.1*
41-47	Y Component of Uncorrected XYZ	F7.1*
48-54	Z Component of Uncorrected XYZ	F7.1*
55-61	Spacecraft State Indicator	F7.1*

*The data flag is 9999.9

66-110A-02G

ATS-1 TAPE LOGS

This data set consists of 1, 800 BPI, Bln data tape. There are 3 data files each containing one year of data with a header and trailer file. The 'D' tape is 9-track and the 'C' tape 7-track, both were produced on the 360.

<u>D#</u>	<u>C#</u>	<u>START</u>	<u>STOP</u>
*D-10673	C-08216	1/01/66	12/31/68

* Good data starts on 12/07/66

ATS 1 State Vector Tapes
(Description of Tape Logs)

The tape LOGS contains 3 files, holding the octal commands sent to the ATS 1 satellite from December 7, 1966 to December 31, 1968.

The data is standard IBM sysout output routed to a 9-track labeled tape at 800 bits per inch, odd parity with translate feature turned on. There are 3 files, each containing one year of data. Each record is in ebcdic format, 133 bytes long, and blocked at 7182 bytes.

The time span and data set name for each file is:

<u>File #</u>	<u>DS Name</u>	<u>Time</u>
1	LOGS66	December 7, 1966 - December 31, 1966
2	LOGS67	January 1, 1967 - December 31, 1967
3	LOGS66	January 1, 1968 - December 31, 1968

particle configuration to that described here. Vasyliunas (1968) has shown that the inner edge of the plasma sheet moves well within the ATS-1 during substorms. Cummings et al. (1969) concluded from a study of quiet time oscillations at ATS-1 that the plasmopause often crosses the ATS-1 orbit. Either of these spatial boundaries could produce the field distortion and steep gradients thought to exist during the stormtime wave events. The importance of each of those possibilities remains to be resolved.

Those events for which no rapid substorm associated field decrease is displayed may be important in that for those cases the enhancement of the main phase decrease might imply entry by the satellite into a region where the distortion exists, rather than a temporal change in the field. The two types of onsets require additional investigation as to the possible implications of temporal versus spatial extent of the resonance, although adequate statistics are not available from the present study.

Another yet unsolved puzzle concerns whether or not the oscillations observed at the satellite are propagated to the ground. For the events studied thus far, auroral zone ground magnetograms were inspected for correlated activity. The results were inconclusive, as in each case there was irregular activity at the ground over a wide frequency range. There were no obvious changes in the ground data correlated with the wave activity at the satellite. Lack of digital data at the ground precluded a comparison of wave spectra.

Intermittent digital ground magnetometer data are now available from the conjugate point of ATS-1, at Tungsten, N.W.T., Canada,

beginning in June, 1969. Spectral comparison of the satellite and conjugate point magnetometer data would be valuable in answering the question of propagation to the ground.

If the observed wave events are in fact standing waves, then a seasonal variation in the orientation of the oscillations would be expected (Barfield and Coleman, 1970). However, for the events studied so far, the bulk of the events were near the equinoxes, preventing any conclusion as to seasonal variations.

In summary, it appears that the stormtime meridional oscillations observed at ATS-1 are a regular feature of the geomagnetic storm, and may provide an effective monitor on the substorm injection process. However, much work remains to be done; a partial list of the necessary tasks is presented in the following section.

2. Ground-Satellite Correlations

For several years the National Science Foundation has supported a magnetic observatory at the conjugate point of ATS-1. This support includes the operation, data processing and analysis of the ground data. Similar support for the satellite data is derived from our NASA grant. During the last year we have carried out preliminary analysis for several distinct wave phenomena observed simultaneously at the ground and the satellite during magnetospheric substorms. The first results were presented by McPherron and Coleman (1971) at the spring meeting of the American Geophysical Union in Washington, D.C. More complete results were presented by McPherron (1971b) at the Fifteenth General Assembly of I.U.G.G. in Moscow. A brief summary of these results is given below.

2A. Transfer Function of the Field Line for Pc 1. A Pc 1 wave event was recorded at the ground station during the expansion phase of a magnetospheric substorm. The local time of this station was near 1800 (dusk). These facts suggest the event was of the IPDP type although a digital dynamic spectrum of the ground signal did not reveal the characteristic upward sweep. Dynamic spectra for simultaneous data recorded at the satellite were also prepared and compared to the ground data. This comparison showed the ground signal was considerably more complex than the satellite signal. This difference was attributed to horizontal propagation of the Pc 1 waves from a number of field lines to the ground station.

Two time intervals when the dynamic spectra showed similar excitation at the ground and satellite were chosen for more careful

study. In one case, the ratio of power at the satellite to the ground was 2.6; in another case, the ratio was 8.6. A possible interpretation of this follows from the fact that Pc 1 waves are presumed to be collimated to a flux tube. If this is true, the signal amplitude must change significantly as a function of position relative to the center of this tube. Thus, a very slight change in the relative conjugacy of ATS-1 and Tungsten could cause a large change at the satellite and almost none at the ground. The implication of this interpretation is that a correct determination of the absolute transfer function will be quite elusive. At best, it seems likely that it can only be determined statistically under the assumption that the largest observed attenuation between satellite and ground occurs when the satellite is centered in the collimated wave.

There exists the possibility of determining the relative transfer function if it can be assumed that the amplitude distribution of various frequency components within the flux tube is the same. Again, this seems unlikely because of the cyclotron instability thought to be responsible for the generation of Pc 1 depends on the equatorial gyrofrequency of the given line, i.e., the lower frequencies are generated at larger L values. Finally, with a single station it is difficult to separate the components of the signal at the ground which are incident above the station and those propagating horizontally.

B. Polarization of Pc 1 in Space. For a number of years the body of theoretical speculation about the origin of Pc 1 has been

based on the assumption that Pc 1 are generated by a cyclotron instability of 1-100 keV protons at about $6 R_E$ in the equatorial plane. This speculation was justified on a basis of dynamic spectra of the signal obtained at the ground showing the repetition period for pearl-type Pc 1 activity is longer at higher frequencies. This is what is expected for the dispersion relation satisfied by the left-hand elliptically polarized Alfvén wave propagating along the field. Ground observations have not been able to establish the validity of this assumption because the ionosphere can reverse the polarization of the Pc 1 signal as it passes through. The observations show both polarizations at the surface. For IPDP events of the same frequency as pearls, it has been generally assumed that a similar source mechanism exists as for pearl pulsations.

We have examined four IPDP events to date and find that all are left-handed elliptically polarized in the equatorial plane at synchronous orbit. Three of these events are positively identified from ground dynamic spectra as IPDP events. While it is recognized that four events are insufficient to decide the question completely, we feel these observations are sufficient to justify the basic assumption of the cyclotron instability of protons gyrating in a left-hand sense, as has been commonly assumed.

C. Pi 2 Noise Bursts on the Ground and in Space. Pi 2 noise bursts are known to be associated with the onset of substorm expansion and have been studied in some detail, but their role in substorm process is not known. From the one event we have examined it appears these bursts may be related to field aligned currents

feeding the westward electrojet.

In an event comprising two bursts recorded shortly before local midnight, we find that sudden decreases in the north-south component of the surface field were closely associated with sudden increases in the east-west component at the satellite. At the ground, a decrease in the north-south field is normally attributed to the westward electrojet while at the satellite the D component variations are usually associated with field aligned currents.

A comparison of power spectra for the ground and satellite data of this event shows comparable spectral density at 0.01 Hz. The surface spectrum falls off rapidly toward higher frequency, roughly as $1/f^3$. In contrast, the satellite spectrum decreases more slowly as $1/f^2$.

A frequently reported feature of Pi 2 bursts is an enhancement of fluctuations at about 0.3 Hz. This enhancement was observed during the two Pi 2 bursts in our event. In both bursts the signals in the horizontal plane were approximately 70% polarized. The polarization was right-hand elliptical with respect to the ambient magnetic field (in the sense of electron gyration). The two bursts differed only slightly in their frequency (0.28 and 0.32 Hz) but had quite different ellipticities (0.2 and 0.5) and orientation (east-west and north-south).

From this very preliminary study we have tentatively concluded that Pi 2 bursts are caused by sudden, perhaps quasi-sinusoidal changes in the field aligned currents driving the westward electrojet. Furthermore, it appears from the distinct polarization characteristics of the 3-second enhancement that this portion of

the burst is of magnetospheric origin rather than an ionospheric cavity resonance as has previously been suggested.

D. Band-Limited Pi 1 Micropulsations. Band limited Pi 1 micropulsations, sometimes called Pi(c), are a regular feature of the recovery phase of substorms in the morning sector. To date, we have examined four events of this type. Two of these were selected from ground data and two from satellite data. For the two events selected from the ground data there was no wave activity at the satellite. In contrast, the two events selected from satellite data did show evidence of corresponding activity at the ground. Unfortunately, for neither of these was digital ground data available. A summary of the results for each of these events is given below.

The first event occurred at ATS-1 on August 17, 1967. The particle data for this event have been examined in some detail by Parks and Winckler (1969). They showed that the fluxes of trapped electrons at ATS-1, as well as precipitated electrons at College, Alaska (650 km west of ATS-1 conjugate point) were periodically modulated at several frequencies. Spectral peaks were seen at frequencies corresponding to periods of 25, 18.3, 9.53, and 6.11 seconds. Dynamic spectral analysis showed that the maximum modulation was 11.3 second period. These observations were made near the dawn meridian during the recovery phase of the magnetospheric substorm.

Using these results as a guide, we have performed spectral analysis over the time interval of the maximum modulation of particle fluxes. We find a pronounced spectral peak at 26

seconds with the rms signal power over the band approximately 0.4 gamma. Doing eigen and coherency analysis on the spectral matrix, we find that the signal was linearly polarized with the major axis orientated 60° from the dipole V axis toward the D axis. The major axis also made an angle of 60° with respect to the H axis. (The dipole VDH coordinate system has H antiparallel to the earth's dipole axis and V radially outward in the magnetic equatorial plane.)

The second event, June 8, 1966, was observed by the OGO-5 satellite as it was inbound across the dawn meridian near the magnetic equatorial plane. The original motivation for studying this event was the fact that OGO-5 passed extremely close to the ATS-1 satellite and magnetic field data were available from it as well. Results of this analysis have been published by McPherron and Coleman (1971) and are only briefly summarized here.

The pulsations were quasi-sinusoidal with period 22 seconds and rms amplitude 0.3 gamma. Their average polarization was transverse to the main magnetic field with the major axis azimuthal in the equatorial plane. The average ellipticity was 0.3 and the predominant sense of rotation right-handed with respect to the main magnetic field (in the sense of electron gyration). Instantaneously, these parameters were quite variable with the pulsations occurring in bursts propagating at various angles with respect to the field. The waves were observed in a region of essentially dipolar field; however, the waves were first observed just inside a sharp transition from a region of continuous field to rapidly increasing field.

No modulation of trapped electrons ($E > 50$ kev) by the pulsations greater than 4% was observed on the same satellite; however, whistler chorus did appear to consist of quasi-periodic burst. Simultaneous magnetic field observations at the ATS-1 conjugate point and also at College, Alaska, showed the pulsations were present on the ground with the same frequency and comparable amplitude. Field observations at ATS-1 did not indicate any wave activity despite the fact that it was clearly present near its conjugate point. It was noted however, that the first OGO-5 observations of these waves were made just inside the ATS-1 orbit. Consequently, it seems quite likely that these waves are radially localized in the equatorial plane and spread somewhat in the ionosphere at the foot of their favored field line. This event also occurred during the recovery phase of a magnetospheric sub-storm near the dawn meridian.

Two additional events were chosen from digital ground data at the ATS-1 conjugate point, Tungsten, N.W.T., Canada. These events were selected from microfilm plots of micropulsation and bay activity at the ground station. Both events were chosen near the dawn meridian during the recovery phase of substorms. Both events had rms amplitudes of about 1-2 gamma. Also, both events were polarized transverse to the main magnetic field and oriented with the major axis east-west. In contrast to these properties, the two events were quite distinct in their frequency and sense of rotation. One event had a 40 second period and was right elliptically polarized, the other 20 second period and left elliptically polarized. Spectral analysis of the satellite data for both events

showed a completely quiet field.

From the preceding discussion, it is clear that any definite conclusions are premature. However, it seems likely that the waves are spatially limited and that close conjugacy between the ground and the satellite are required before simultaneous observations are possible.

3. Support of Other Projects

A. Field Aligned Currents. During the past year we have continued our study of field aligned currents using the ATS-1 data in conjunction with ground data. Major support for personnel on this aspect of our work is derived from an ONR contract, however, corrected data used in this project are a result of work performed on the NASA grant described herein.

Initial results were presented at the April, 1971 meeting of the American Geophysical Union in Washington, D.C., by Horning et al. (1971). Further work is described in a manuscript under preparation. Briefly, this work studies the simultaneous changes in the H component at ATS-1 and its subsatellite point, Honolulu, during substorm expansions. We find that Honolulu and ATS both observed the same variations in H, an increase near midnight and a decrease during dusk. The simultaneous variations can only be understood in terms of two distinct field aligned current systems flowing on field lines outside ATS-1. The first system, centered in the predawn sector, may be viewed as a collapse of the near-tail current system by diverting this current through the auroral ionosphere as the westward auroral electrojet. The second system is

centered near dusk and appears to be a similar closure of the partial ring current via field aligned currents through the ionosphere as an eastward auroral electrojet.

B. Multi-Satellite Correlations. Corrected ATS-1 magnetometer data have been used in a multi-faceted study of the substorm sequence. This study shows that the sequence of events thought to occur on a basis of disparate observations of different events by different investigators actually holds for a single substorm event. These results are in agreement with current speculation about the cause of magnetospheric substorms. This speculation suggests that southward interplanetary magnetic fields cause merging of field lines on the dayside of the magnetopause and consequent erosion of flux from the dayside. This flux is transported by the solar wind and added to the geomagnetic tail. The reduced cross section of the dayside increases the angle of attack of the solar wind on the magnetopause boundary. The resulting increase in normal stress reduces the cross section of the near tail despite the fact that it contains greater magnetic flux. As a consequence, there is a large increase in the magnitude of the near tail field. Simultaneously, the plasma sheet near the earth thins and its inner edge approaches the earth.

This sequence of events constitutes what we have called the growth phase of magnetospheric substorms. A detailed presentation of these results is given in a sequence of nine papers submitted for publication in the Journal of Geophysical Research (see nine references under McPherron et al., 1972, general title: Satellite Studies of Magnetospheric Substorms on August 15, 1968). These

experimental observations in conjunction with numerous other reports in the recent literature form the basis of a quantitative theory of the substorm growth phase worked out recently by Coroniti and Kennel (1971).

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Figure Captions

1. Percent data recovered from UCLA magnetometer on ATS-1 since launch in December, 1966. (Refer to Table 1.)

2. Example showing measured magnetic field during eclipse of ATS-1. The Z axis is parallel to the satellite spin axis, the sun vector lies in the X-Z plane and Y completes the orthogonal system.

3. Right panel shows uncorrected magnetic field measurements in X, Y, Z coordinate system, defined for Figure 2. Left panel shows the same data after automatic correction and transformation to the dipole VDH coordinate system. In the VDH system H is anti-parallel to the earth's magnetic dipole axis. V is radially outward in the magnetic equatorial plane and D azimuthal eastwards.

4. Plot of 2-1/2 minute averages of ATS-1 magnetic field produced by automatic correction procedure.

5. High time resolution plot of ATS-1 magnetic field measurements. The amplitude scale is 5 γ /division and the time scale 5.12 seconds/division. Successive plotted points are 0.32 second averages. Textual material at the left includes time in the form HHMMSS.S and 1.28 second averages of the measured field components in gamma.

6. Results of cross spectral analysis of 0.32 time resolution magnetic field data. The original time series has been differenced and all gaps and spikes set to zero. Spectral lines are due to a ramp function interference signal containing all harmonics of the 5.12 second telemetry rate.

7. Results of eigen and coherency analysis of spectral

matrix. Spectra have been recolored for the effects of the first difference operator. Note narrow band width and high polarization of spectral lines due to interference signal.

8. Eigen and coherency analysis of unusually narrow band width signal at low frequencies. A sequence of harmonic spectral lines is due to a 16 telemetry sequence ramp function (.0122 Hz).

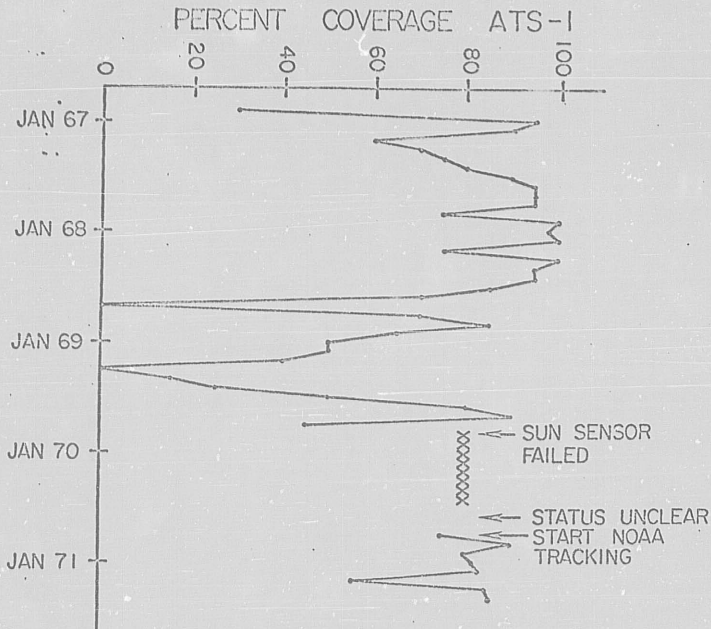


Figure 1

DAY078

DATE 03 19 10 67

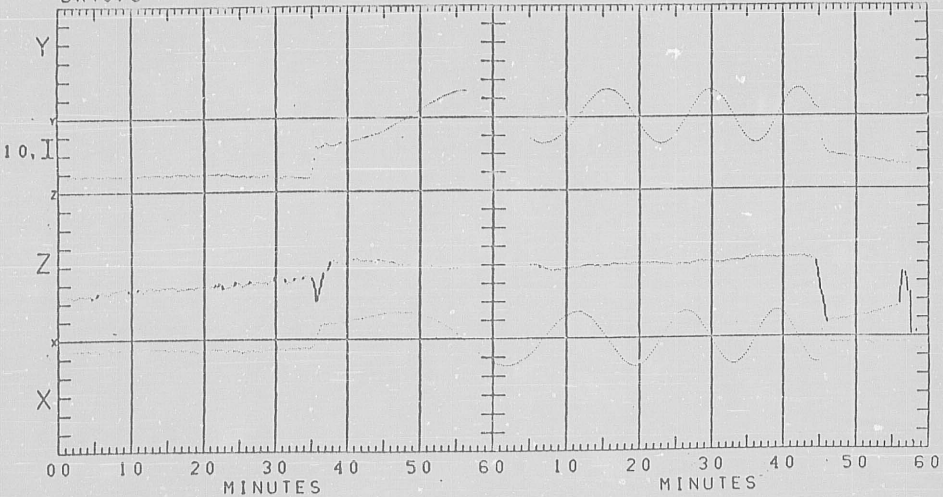


Figure 2

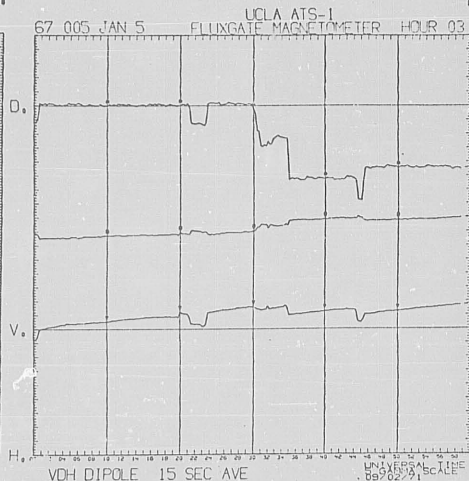
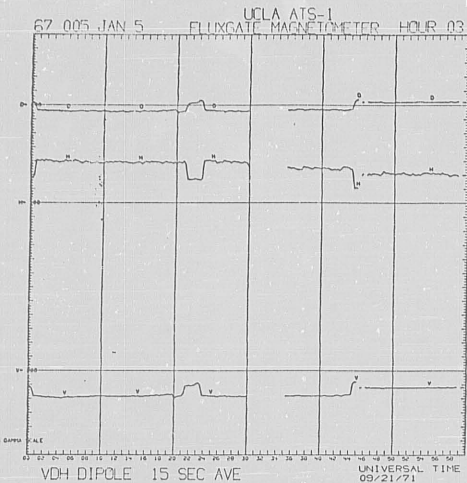
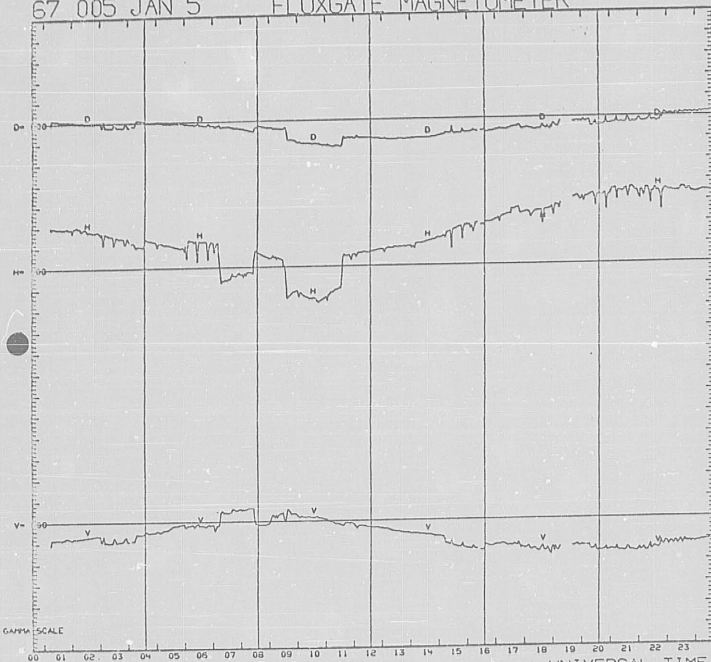


Figure 3

67 005 JAN 5

UCLA ATS-1
FLUXGATE MAGNETOMETER



VDH DIPOLE 2.5 MIN AVE

UNIVERSAL TIME
09/21/71

Figure 4

JAN 05, 1967

X OFFSET +20 GAMMAS, Y OFFSET -10 GAMMAS.

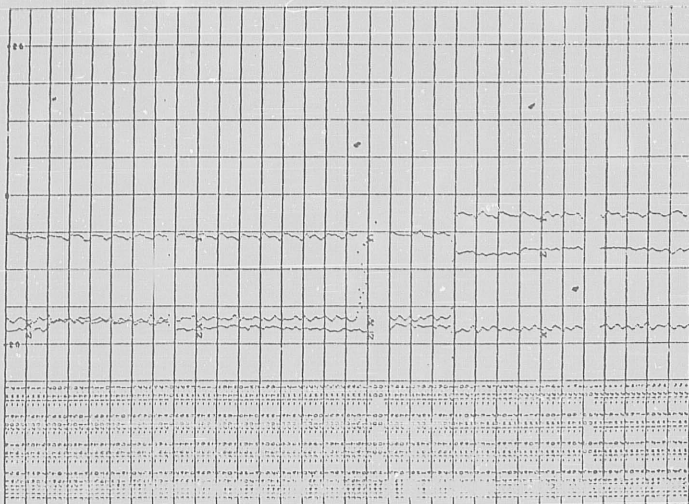


Figure 5

QUIET DATA
 0200-0211 UT OCT 9, 1969
 UCLA ATS-1 MAGNETOMETER

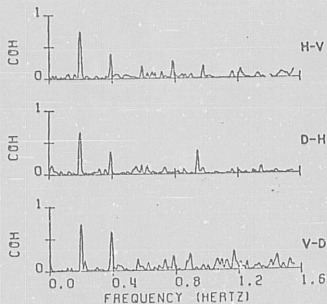
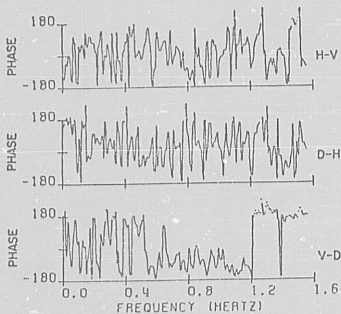
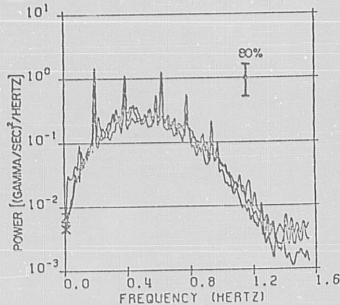
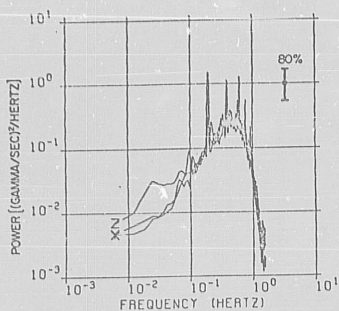
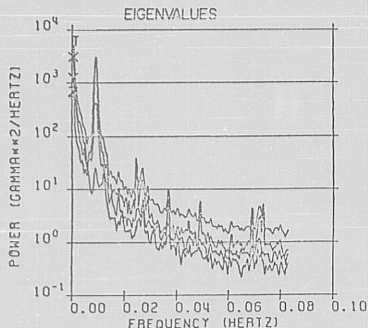
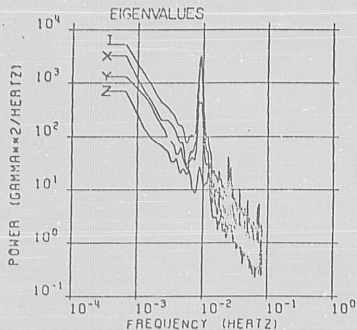


Figure 6

QUIET TIME TRANSVERSE WAVES
1550-2350 UT DEC 18, 1966
UCLA ATS-I MAGNETOMETER
EIGEN AND COHERENCY ANALYSIS



SPECTRAL ANALYSIS PARAMETERS

NPTS = 4096
DIGINT = 6.0 SECONDS
NDEG = 26
BNWIDTH = .0005289
BNSEP = .0003255

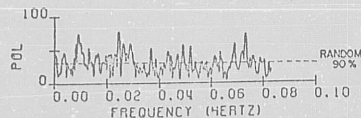
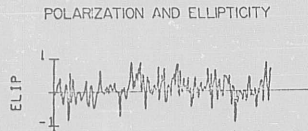
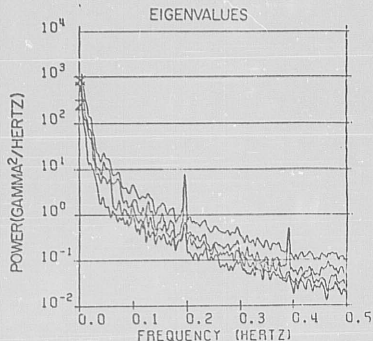
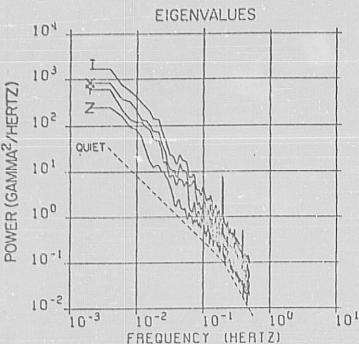


Figure 7

NOISE BURSTS
0808-0916 UT, OCT 10, 1969
UCLA ATS-1 MAGNETOMETER



SPECTRAL ANALYSIS PARAMETERS

NPTS = 4096
DIGINT = 1.0 SECONDS
NDEG = 26
BNWIDTH = .00317 HZ
BNSEP = .00195 HZ

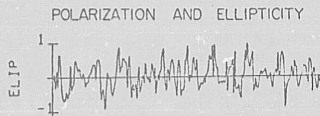


Figure 8

List of Tables

1. Table listing data recovered from UCLA magnetometer on ATS-1 since time of launch. Major events in the history of the spacecraft are indicated under remarks.
2. Correction vector for spacecraft field in eclipse zero modes at three successive equinoxes. An eclipse mode is defined as the state of the spacecraft at the time of eclipse. A zero mode is defined as a state in which a minimum number of sub-systems is operating.
3. Segment of the listing of the ATS-1 spacecraft state vector including the interval of time displayed in Figure 2. The three right most columns are the components of the correction vector for the indicated state. The symbols 3333.3 indicate an unknown correction.
4. List of octal commands sent to ATS-1 during 1967 and 1968. A brief interpretation of this command is given in second columns.
5. Interpretation of ATS-1 state vector. The state vector is broken into three words of eight characters each. Each character is in hexadecimal.
6. Listing of ATS-1 states during 1967 and then 1968. During each year the states are ordered by decreasing total duration.
7. Format of corrected data tapes.

Table 1

ATS-1 Received Data Coverage, Monthly
(Estimates)

<u>Yr</u>	<u>Mo</u>	<u>%</u>	<u>Remarks</u>
			Data starts Dec. 9, sporadic until 24th.
1966	Dec.	30	
	Jan.	95	
1967	Feb.	90	
	Mar.	60	
	Apr.	70	
	May	75	
	Jun.	80	
	Jul.	90	
	Aug.	95	
	Sept.	95	
	Oct.	95	
	Nov.	75	
	Dec.	100	
1968	Jan.	98	
	Feb.	100	
	Mar.	75	
	Apr.	100	
	May	95	
	Jun.	95	
	Jul.	85	
	Aug.	70	UCLA OFF starting August 23
	Sept.	0	UCLA OFF all month
	Oct.	70	UCLA OFF until Oct. 8
	Nov.	85	
	Dec.	65	No data Dec. 19 thru 27, and 30, 31
1969	Jan.	50	Usually OFF 1400-2200, RSST OFF starting 24
	Feb.	50	Usually OFF 1400-2200, RSST OFF all month
	Mar.	40	RSST OFF to 9th, ON 10th to 21st; UCLA OFF 21
	Apr.	0	UCLA OFF all month
	May	15	UCLA OFF to 10th; ON 11 to 25, OFF from 26
	Jun.	25	No data 1400 - 2400 every day; RSST & UCLA ON
	Jul.	50	No data from 15th to 28th
	Aug.	80	
	Sept.	90	
	Oct.	45	No data from 14th to 28th
	Nov.	80	RSST OFF Nov. 2; processing halted
	Dec.		
1970	Jan.		
	Feb.		
	Mar.	80	Unprocessed; can only estimate coverage
	Apr.		by looking at DECOM listings; Goddard
	May		still sending tapes for this period.
	Jun.		
	Jul.		Goddard may have data; status unclear.
	Aug.		
	Sept.		
	Oct.	75	NOAA Boulder Coverage
	Nov.	90	
	Dec.	80	

<u>Yr.</u>	<u>Mo</u>	<u>%</u>	<u>Remarks</u>
1971	Jan.	82	
	Feb.	83	
	Mar.	56	
	Apr.	85	
	May	85	
	Jun.	91	

Table 2

Correction Vector for Spacecraft Field
Comparison of Eclipse Zero Modes

	Spring 1967	Fall 1967	Spring 1968
CX	11.1±1	9.6±1	9.4±1
CY	22.8±1	22.3±1	22.7±1
CZ	82±7	89±8	90±6

```

[MICRO] SYSTEM#1 |OFF
[MICRO] WAVE SYSTEM#1 |F3CMHV
[MICRO] WAVE POWER |PSDS PEE4 PDE2
[VHF] REGULATORS |OFF
[SPIN] SCAN CLOUD CLOUD CAMERA |NORM
[TELEMETRY] |TM#1 TM#2 TM#3 TM#4 EN#1 EN#2 EN#3-SE#2-1
[ENE] POWER SUPPLY |PREG RL11 RE12 DSUP
[ENE] EXPERIMENTS |UCLA RICE AERO SOLA MINN MMAG BTLB

```

```

YEAR CAT PTH DY 4H:MM:SS
67 077 MAR 19 21:29:20
COM <--COMMAND INTERPRETATION-->
254 SSSCC SOUTH FRANK CVERSEILE
#MICRO#1#MICRO2#1#VST#2#2#2
100000001952400C5150294C7F
<-FLAG-> XXXX.X YYY.Y ZZZZ.Z
000000001 11.6 15.8 118.9

```

```

HH:MM:SS COM <--COMMAND INTERPRETATION--> #MICRO1# #MICRO2# #VHF#SSCC
01:10:20 133 SSSCC RFULATOR OFF OFF F3JONHV OFF OFF
01:10:50 270 #2 MICRC FT MODE CN OFF F3JONHV OFF OFF
01:58:35 174 #2 MICRC OFF OFF OFF OFF OFF OFF
01:59:30 376 VHF REGULATOR 1 CN OFF OFF 1 OFF
01:59:30 251 VHF REGULATOR 2 CN OFF OFF 12 OFF
01:59:55 275 VHF V/F GENERATOR 2 CN/OFF OFF OFF 12 OFF
02:25:45 302 VHF REGULATOR 1 OFF OFF OFF 2 OFF
02:27:05 027 VHF REGULATOR 2 OFF OFF OFF OFF OFF
02:27:30 275 VHF V/F GENERATOR 2 CN/OFF OFF OFF OFF OFF
02:27:55 164 #2 MICRC TWT 3 FIL ON OFF F3 OFF OFF
02:28:20 232 #2 MICRC TWT 4 FIL ON OFF F3F4 OFF OFF
02:28:50 316 #2 MICRC MA MODE ON OFF F3F4ON OFF OFF
02:32:20 126 #2 MICRC TWT HV ON OFF F3F4ONHV OFF OFF
01:04:25 270 #2 MICRC FT MODE CN OFF F3F4ONHV OFF OFF
01:18:30 374 #2 MICRC OFF OFF OFF OFF OFF
01:18:55 164 #2 MICRC TWT 3 FIL ON OFF F3 OFF OFF
01:19:20 270 #2 MICRC FT MODE CN OFF F3ON OFF OFF
01:22:55 126 #2 MICRC TWT HV ON OFF F3ONHV OFF OFF
01:23:20 232 #2 MICRC TWT 4 FIL ON OFF F3ONHV4 OFF OFF
01:27:10 374 #2 MICRC OFF OFF OFF OFF OFF
01:27:30 232 #2 MICRC TWT 4 FIL ON OFF F4 OFF OFF
01:28:00 270 #2 MICRC FT MODE CN OFF F4ON OFF OFF
01:31:30 126 #2 MICRC TWT HV CN OFF F4ONHV OFF OFF
01:31:55 164 #2 MICRC TWT 3 FIL CS OFF F4ONHV3 OFF OFF
01:35:35 374 #2 MICRC OFF OFF OFF OFF OFF
01:35:50 164 #2 MICRC TWT 3 FIL ON OFF F3 OFF OFF
01:36:30 232 #2 MICRC TWT 4 FIL CN OFF F3F4 OFF OFF
01:36:55 270 #2 MICRC FT MODE CN OFF F3F4ON OFF OFF
01:40:00 126 #2 MICRC TWT HV CN OFF F3F4ONHV OFF OFF
01:44:05 066 REPE SOLAR CELL HALT/RESKT CPP F3F4ONHV OFF OFF
01:51:20 336 #2 MICRC MA MODE CN OFF F3F4ONHV OFF OFF
01:53:30 374 #2 MICRC OFF OFF OFF OFF OFF
01:54:15 336 #2 MICRC MA MODE CN OFF ON OFF OFF
01:54:45 164 #2 MICRC TWT 3 FIL ON OFF ONF3 OFF OFF
01:58:45 126 #2 MICRC TWT HV ON OFF ONF3HV OFF OFF
01:59:15 232 #2 MICRC TWT 4 FIL CN OFF ONF3HV4 OFF OFF
01:03:35 374 #2 MICRC OFF OFF OFF OFF OFF
01:04:00 336 #2 MICRC MA MODE CN OFF ON OFF OFF
01:04:25 232 #2 MICRC TWT 4 FIL ON OFF ONF4 OFF OFF
01:08:25 126 #2 MICRC TWT HV ON OFF ONF4HV OFF OFF
01:09:15 164 #2 MICRC TWT 3 FIL ON OFF ONF4HV3 OFF OFF
01:13:40 374 #2 MICRC OFF OFF OFF OFF OFF
01:14:05 270 #2 MICRC FT MODE CN OFF ON OFF OFF
01:14:30 164 #2 MICRC TWT 3 FIL ON OFF ONF3 OFF OFF
01:18:30 126 #2 MICRC TWT HV ON OFF ONF3HV OFF OFF
01:08:10 060 #2 MICRC WDD MODE ON OFF CNF3HV OFF OFF
01:08:55 006 SSSCC REGULATOR ON OFF CNF3HV OFF NORM
01:09:20 066 REPE SOLAR CELL HALT/RESKT OFF CNF3HV OFF NORM

```

```

#MICRO1# #MICRO2# #VST#2#2#2
100000001952400C5150294C7F 000000001 11.5 18.1 114.6
100000001952400C5150294C7F 000000001 11.5 18.1 114.6
10000000140000000150094C7F 000000001 9.4 22.7 90.0
10000000140000000150294C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 14.3 10.8 118.3
10000000140000000150394C7F 000000001 14.3 10.8 118.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 12.6 15.7 125.4
10000000140000000150394C7F 000000001 12.6 15.7 125.4
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 11.5 18.1 114.6
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 12.6 15.7 125.4
10000000140000000150394C7F 000000001 12.6 15.7 125.4
10000000140000000150394C7F 000000001 12.6 15.7 125.4
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 10.0 21.5 102.4
10000000140000000150394C7F 000000001 11.7 18.1 116.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 9.4 22.7 90.0
10000000140000000150394C7F FFFFFF 333.3 333.3 333.3
10000000140000000150394C7F 000000001 10.0 21.5 102.4
10000000140000000150394C7F 000000001 11.7 18.1 116.3
10000000140000000150394C7F 000000001 11.7 18.1 116.3
10000000140000000150394C7F 000000001 13.3 16.7 120.9
10000000140000000150394C7F 000000001 13.3 16.7 120.9

```

```

MICROVAVE SYSTEM#1 1OFF
MICROVAVE SYSTEM#1 1CNF3HV
MICROVAVE POWER 1PSDS PER4 PDE2
VHF REGULATORS 1OFF
[SPIN SCAN CLOUD CLODE CAMERA] 1NORM
TELEMETRY 1TR#1 TR#3 TR#2 TR#4 &NC4 ENC2 E04-SC02-
PREG RLY1 RLY2 PSUP
PNE POWER SUPPLY 1UCLA RICE AERO SOLA MINN MMAG BILD
PNE EXPERIMENTS 1

```

```

YEAR DAY MTH DY HH:MM:SS
67 078 MAR 19 06:03:20
COM <--COMMAND INTERPRETATION-->
066 3EPE SOLAR CELL HALT/RESET
#MICRO#1#MICRO2#1#VST#1#1#
10000000195C400C5150294D7F
<-FLAG> XXXX.X YYY.Y ZZZZ.Z
00000001 11.7 16.7 120.9

```

HH:MM:SS	COM	<--COMMAND INTERPRETATION-->	#MICRO#1	#MICRO2#1	VHF#SSCC	#MICRO#1#MICRO2#1#VST#1#1#	<-FLAG>	XXXX.X	YYY.Y	ZZZZ.Z
08:10:30	070	-MISC ACCUMULATOR SELECT A	OFF	1CNF3HV	1OFF1NORM	10000000195C400C5150294D7F	00000001	11.3	16.7	120.9
08:23:00	254	\$SSCC SOUTH FRAME GEARHIDE	OFF	1CNF3HV	1OFF1NORM	10000000195C400C5150294D7F	00000001	11.3	16.7	120.9
08:34:50	133	\$SSCC REGULATOR OFF	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
08:35:20	271	#TR#1 SC0 1 ON 1/2 ON	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
08:41:55	131	#2 MICR WBD MODE SELECT	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
09:20:00	103	3EPE ECLIPSE PCDE ON	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
10:48:30	224	2ENE ECLIPSE MODE OFF	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
10:52:00	316	#TR#1 SC0 1 OFF 2 OFF	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
10:56:10	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
10:56:55	376	VXHF REGULATOR 1 ON	OFF	1OFF	11 OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
10:57:10	351	VXHF REGULATOR 2 ON	OFF	1OFF	112 OFF	10000000195C400C5150294D7F	00000001	14.3	10.8	136.3
10:57:55	275	VXHF W/F GENERATOR 2 CN/OFF	OFF	1OFF	112 OFF	10000000195C400C5150294D7F	00000001	14.3	10.8	136.3
11:59:45	270	#2 MICRO FT MODE ON	OFF	1ON	112 OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
12:00:15	164	#2 MICR TWT 3 FIL ON	OFF	1CNF3	112 OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
12:00:45	302	VXHF REGULATOR 1 OFF	OFF	1CNF3	121 OFF	10000000195C400C5150294D7F	00000001	10.0	21.5	102.4
12:01:10	027	VXHF REGULATOR 2 OFF	OFF	1CNF3	1OFF1OFF	10000000195C400C5150294D7F	00000001	10.0	21.5	102.4
12:01:40	275	VXHF W/F GENERATOR 2 CN/OFF	OFF	1CNF3	1OFF1OFF	10000000195C400C5150294D7F	00000001	10.0	21.5	102.4
12:02:05	066	2ENE SOLAR CELL HALT/RESET	OFF	1CNF3	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.7	16.1	116.3
12:04:15	126	#2 MICR TWT HV CN	OFF	1CNF3HV	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
12:10:50	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
12:11:15	376	VXHF REGULATOR 1 CN	OFF	1OFF	11 OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
12:11:40	251	VXHF REGULATOR 2 ON	OFF	1OFF	112 OFF	10000000195C400C5150294D7F	00000001	14.3	10.8	136.3
12:12:05	275	VXHF W/F GENERATOR 2 CN/OFF	OFF	1OFF	112 OFF	10000000195C400C5150294D7F	00000001	14.3	10.8	136.3
11:39:10	275	VXHF W/F GENERATOR 2 CN/OFF	OFF	1OFF	112 OFF	10000000195C400C5150294D7F	00000001	14.3	10.8	136.3
11:47:40	302	VXHF REGULATOR 1 OFF	OFF	1OFF	121 OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
11:48:40	027	VXHF REGULATOR 2 OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
11:49:25	164	#2 MICRO TWT 3 FIL ON	OFF	1F3	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
11:49:50	232	#2 MICR TWT 4 FIL ON	OFF	1F3F4	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
11:50:15	270	#2 MICR FT MODE ON	OFF	1F3F4ON	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
11:54:15	126	#2 MICR TWT HV CN	OFF	1F3F4ONHV	1OFF1OFF	10000000195C400C5150294D7F	00000001	12.6	15.7	125.4
14:28:25	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
14:29:00	164	#2 MICR TWT 3 FIL ON	OFF	1F3	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:29:10	270	#2 MICR FT MODE ON	OFF	1F3ON	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:33:00	126	#2 MICR TWT HV CN	OFF	1F3ONHV	1OFF1OFF	10000000195C400C5150294D7F	00000001	11.5	16.1	114.6
14:33:30	232	#2 MICR TWT 4 FIL CN	OFF	1F3ONHV F4	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:37:00	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
14:37:30	232	#2 MICR TWT 4 FIL ON	OFF	1F4	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:38:00	270	#2 MICR FT MODE CN	OFF	1F4ON	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:41:30	126	#2 MICR TWT HV CN	OFF	1F4ONHV	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:42:00	164	#2 MICR TWT 3 FIL ON	OFF	1F4ONHV F3	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:46:15	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
14:49:00	164	#2 MICR TWT 3 FIL CN	OFF	1F3	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:49:30	060	#2 MICR WBD MODE ON	OFF	1F3ON	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:53:00	126	#2 MICR TWT HV CN	OFF	1F3ONHV	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:54:30	270	#2 MICR FT MODE CN	OFF	1F3ONHV F4	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:55:00	232	#2 MICR TWT 4 FIL ON	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	00000001	9.4	22.7	90.0
14:58:15	374	#2 MICR OFF	OFF	1OFF	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3
14:59:05	232	#2 MICR TWT 4 FIL CN	OFF	1F4	1OFF1OFF	10000000195C400C5150294D7F	FFFFF	333.3	333.3	333.3

PAGE = 3

MICROWAVE SYSTEM#1		OFF	YEAR DAY MTH DY		HH:MM:SS
MICROWAVE SYSTEM#1		IF4	67 078 MAR 19		14:59:05
MICROWAVE POWER		PSDS PEB4 PDE2	COM <--CCPMAND INTERPRETATION-->		
VHF REGULATORS		OFF	232 42 MICRC TWT # FIL ON		
SPIN SCAN CLOUD CLOUD CAMERA		OFF	#MICRO1# #MICRO2# #VSTIEEE		
TELEMETRY		TH#1 TH#3 TH#2 TH#4 ENG4 ENC2 EGT4-SEGT2	10000000 142004200 50094D7F		
EME POWER SUPPLY		REG RLY1 REV2 PSUP	<-FLAG-> XXXX.X YYYI.Y ZZZZ.Z		
EME EXPERIMENTS		UCLA RICE AERO SOLA MINN MMAG BTLB	FFFFFFFF 3333.3 3333.3 3333.3		
HH:MM:SS COM <--COMMAND INTERPRETATION--> #MICRO1# #MICRO2# VHF#SSCC					
14:59:30	270	#2 MICRO FT MODE ON	OFF	#FNON	IF4 OFF
15:03:05	126	#2 MICRO TWT HV ON	OFF	#FNONHV	IF4 OFF
15:03:30	164	#2 MICRO TWT 3 FIL ON	OFF	#FNONHV3F	IF4 OFF
15:07:15	374	#2 MICRC OFF	OFF	IF3	IF4 OFF
15:07:45	164	#2 MICRO TWT 3 FIL ON	OFF	IF3	IF4 OFF
15:08:15	060	#2 MICRC WBD MODE ON	OFF	IF3ON	IF4 OFF
15:11:45	126	#2 MICRO TWT HV ON	OFF	IF3ONHV	IF4 OFF
15:12:15	006	SSCC REGULATOR ON	OFF	IF3ONHV	IF4 NORM
16:04:25	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
16:14:00	254	SSCC SOUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
16:18:20	254	SSCC SOUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
16:35:50	254	SSCC SOUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
17:16:50	020	-RISC ACCUMULATOR SELECT A	OFF	IF3ONHV	IF4 NORM
17:37:00	254	SSCC SOUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
17:43:00	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
19:07:10	066	EME SOLAR CELL HALT/RESET	OFF	IF3ONHV	IF4 NORM
19:19:50	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
19:50:00	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
20:07:50	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
21:15:10	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
21:16:05	254	SSCC SOUTH FRAKE OVERRIDE	OFF	IF3ONHV	IF4 NORM
21:52:20	133	SSCC REGULATOR OFF	OFF	IF3ONHV	IF4 OFF
21:59:30	374	#2 MICRC OFF	OFF	IF3	IF4 OFF
21:59:50	376	VHF REGULATOR 1 ON	OFF	IF3	IF4 OFF
22:00:10	251	VHF REGULATOR 2 CN	OFF	IF3	IF4 OFF
22:00:45	275	VHF W/F GENERATOR 2 CN/OFF	OFF	IF3	IF4 OFF
22:27:20	302	VHF REGULATOR 1 OFF	OFF	IF3	IF4 OFF
22:27:50	027	VHF W/F GENERATOR 1 OFF	OFF	IF3	IF4 OFF
22:28:20	275	VHF W/F GENERATOR 2 CN/OFF	OFF	IF3	IF4 OFF
22:29:00	060	#2 MICRO WBD MODE ON	OFF	IF3	IF4 OFF
22:29:25	164	#2 MICRC TWT 3 FIL ON	OFF	IF3	IF4 OFF
22:30:45	270	#2 MICRO FT MODE CN	OFF	IF3	IF4 OFF
22:33:40	126	#2 MICRO TWT HV ON	OFF	IF3	IF4 OFF
22:43:35	060	#2 MICRC WBD MODE ON	OFF	IF3	IF4 OFF
22:44:05	006	SSCC REGULATOR CN	OFF	IF3	IF4 NORM
22:46:00	340	SSCC NORMAL SCAN	OFF	IF3	IF4 NORM
22:57:55	254	SSCC SCUTH FRAKE OVERRIDE	OFF	IF3	IF4 NORM

LISTING OF INTERPRETATION OF ATS OCTAL COMMANDS

COM COMMAND INTERPRETATION	COM COMMAND INTERPRETATION
001 #1 MICRO TWT HV ON	176 +ORIENT THRUST 1 ON
002 *TM PCM ENCODER 1 ON	203 +ORIENT RESISTO JET REG ON
003 *TM TRANSMITTER 4 ON,2 CFF	207 # MICRO PSD OFF
004 #1 MICRO WBD MODE SELECT	210 +ORIENT FIRE RADIAL JET 1
006 \$SSCC REGULATOR ON	211 #1 MICRO MA MODE ON
007 @EME UCLA OFF	212 *TM TRANSMITTER 2 ON,4 OFF
013 +ORIENT THRUST 2 OFF	217 *TM SCO 2 ON
016 *TM PCM ENCODER SELECT WRD63	224 @EME ECLIPSE MODE OFF
017 -MISC ANGLE CENTER MODE SLCT	230 +ORIENT NUTATION REG OFF
020 -MISC ACCUMULATOR SELECT A	232 #2 MICRO TWT 4 FIL ON
022 #1 MICRO TWT 1 FIL ON	233 *TM TRANSMITTER 2 ENCDR SELECT
023 *TM TRANSMITTER 2 OFF,4 OFF	234 @EME SCLAR CELL ON
024 @EME EXP POWER SUPPLY ON X	235 @EME EXP BUS POWER ON ALT2
025 @EME BTL BIAS OFF	245 # MICRC PACE 2 ON,1 OFF
027 %VHF REGULATOR 2 OFF	250 *TM PCM ENCODER 1 OFF
034 %VHF W/F SWITCH 1 ON/OFF	251 %VHF REGULATOR 2 ON
040 *TM SCO 1 ON	253 #1 MICRO OFF
046 @EME RICE CN	254 \$SSCC SOUTH FRAME OVERRIDE
051 +ORIENT THRUST 1 OFF	255 @EME UNIV OF MINN MAG ON
060 #2 MICRO WBD MODE ON	256 @EME AFROSPACE ON
061 *TM PCM ENCODER 2 SELECT	270 #2 MICRO FT MODE ON
065 \$SSCC BACK-TO-BACK SCAN	271 *TM SCO 1 ON (W/F ON)
066 @EME SOLAR CELL HALT/RESET	273 +ORIENT FIRE AXIAL JET 1
076 # MICRC PACE 1 CN,2 OFF	275 %VHF W/F GENERATOR 2 ON/OFF
077 *TM PCM ENCODER 2 OFF	276 @EME EXP POWER SUPPLY OFF
101 +ORIENT FIRE APOGEE MOTOR	277 @EME BTL BIAS ON X
103 @EME ECLIPSE MODE ON	300 @EME BTL BIAS-OFF ENABLE
106 *TM PCM ENCODER SELECT WRD_	302 %VHF REGULATOR 1 OFF
107 -MISC SOLAR ARRAY UNPARALLEL	303 @EME EXP POWER SUPPLY ON
110 @EME RICE CFF	313 # MICRO PACE 1 OFF,2 OFF
113 @EME UNIV CF MINN ON	315 #1 MICRO TWT 2 FIL ON
120 # MICRO ANTENNA POSITIVE	316 *TM SCO 1 OFF,2 OFF
124 +ORIENT NUTATION REG ON	324 +ORIENT RESISTO JET REG OFF
125 @EME REGULATOR OFF	330 %VHF W/F SWITCH 2 ON/OFF
126 #2 MICRO TWT HV ON	334 -MISC SCLAR ARRAY PARALLEL
127 *TM PCM ENCODER 2 ON	335 +ORIENT FIRE AXIAL JET 2
130 @EME EXP BUS POWER ON ALT1	336 #2 MICRO MA MODE ON
131 #2 MICRO WBD MODE SELECT	337 *TM PCM ENCODER 1 SELECT
133 \$SSCC REGULATOR OFF	340 \$SSCC NORMAL SCAN
141 # MICRC PSD ON	341 @EME UCLA ON
144 *TM TRANSMITTER 3 ON,1 CFF	345 +ORIENT THRUST 2 ON
147 #1 MICRO FT MODE ON	354 *TM TRANSMITTER 1 OFF,3 OFF
150 %VHF W/F GENERATOR 1 ON/OFF	355 @EME REGULATOR ON
151 @EME EXP POWER SUPPLY OFF X	356 +ORIENT FIRE RADIAL JET 2
152 @EME BTL BIAS ON	357 #1 MICRO WBD MODE ON
164 #2 MICRO TWT 3 FIL ON	361 \$SSCC NORTH FRAME OVERRIDE
165 *TM TRANSMITTER 1 ENCDR SELECT	362 @EME SOLAR CELL OFF
172 @EME UNIV OF MINN MAG OFF	374 #2 MICRO OFF
173 @EME AFROSPACE OFF	375 *TM TRANSMITTER 1 ON,3 OFF
376 %VHF REGULATOR 1 CN	

Table 5
State Descriptor Words

Word 1	Word 2	Word 3
1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8	1 2 3 4 5 6 7 8

Word 1 = Micro 1 Subsystem

- 1) 1 WB MODE, MICRO 1 OFF
2 MA MODE, MICRO 1 OFF
- 4) 4 FT MODE, MICRO 1 OFF
9 WB MODE, MICRO 1 ON
A MA MODE, MICRO 1 ON
- C) C FT MODE, MICRO 1 ON
- 2) 0 ALL OFF
1 HIGH VOLTAGE ON
2 FILAMENT 2 ON
3 F2 & HV ON
4 FILAMENT 1 ON
5 F1 & HV ON
6 F1 & F2 ON
7 F1, F2, & HV ON
- 3) MICRO 1 MODE AFTER F1 TURNED ON
- 4) MICRO 1 SUBSYSTEMS AFTER F1 TURNED ON
- 5) MICRO 1 MODE AFTER F2 TURNED ON
- 6) MICRO 1 SUBSYSTEMS AFTER F2 TURNED ON
- 7) MICRO 1 MODE AFTER HV TURNED ON
- 8) MICRO 1 SUBSYSTEMS AFTER HV TURNED ON

WORD 2 = MICRO 2 SUBSYSTEM

- 1) 0 ALL OFF
1 PACE 2 ON
2 PACE 1 ON
3 PACE 1, PACE 2 ON
4 PSDS ON
5 PSDS & PACE 2 ON
6 PSDS & PACE 1 ON
7 PSDS, PACE 1 & PACE 2 ON
- 2) 0 ALL OFF
1 VHF 2 ON
2 VHF 1 ON
3 VHF 1 & VHF 2 ON

MICRO SUPPLY

VHF REGULATORS

Table 5, Continued

3)	0 OFF, NORMAL SCAN 1 OFF, BACK-TO-BACK SCAN 2 ON, NORMAL SCAN 3 ON, BACK-TO-BACK SCAN	SSCC
4)	0 ALL OFF 1 TM 4 ON 2 TM 2 ON 4 TM 3 ON 5 TM 3 & TM 4 ON 6 TM 2 & TM 3 ON 8 TM 1 ON 9 TM 1 & TM 4 ON A TM 1 & TM 2 ON	TELEMETRY
5)	0 ALL OFF 1 SCO 2 ON 2 SCO 1 ON 4 ENC 2 ON 5 ENC 2 & SCO 2 ON 6 ENC 2 & SCO 1 ON 8 ENC 1 ON 9 SCO 2 & ENC1 ON A SCO 1 & ENC1 ON B $8+2+1$ $D=8+4+1$ C = $8+4$	.ENCODERS & .SCO
6)	0 ALL OFF 1 PSUP 2 RLY2 3 RLY2, PSUP 4 RLY1 5 RLY1, PSUP 6 RLY1, RLY2 7 RLY1, RLY2, PSUP 8 PREG 9 PREG, PSUP A PREG, RLY2 B PREG, RLY2, PSUP C PREG, RLY1 D PREG, RLY1 PSUP E PREG, RLY1, RLY2 F PREG, RLY1, RLY2, PSUP	EME POWER
7)	0 OFF 1 AERO 2 RICE 3 = $2+1$ 4 UCLA 5 = $4+1$ 6 = $4+2$ 7 = $4+2+1$	EME EXPERIMENTS UCLA RICE AEROJET

Table 5, Continued

8)

Ø OFF
1 BTLB
2 MMAG
3 = 2+1
4 MINN
5 = 4+1
6 = 4+2
7 = 4+2+1
9 SOLA

9 = 8+1
A = 8+2
B = 8+2+1
C = 8+4
D = 8+4+1
E = 8+4+2
F = 8+4+2+1

SOLAR EXPERIMENT
MINNESOTA
MINNESOTA MAGN
BTLB

Table 6

00000000	00000000	50060000	46.91%
00000000	00000000	53060000	9.49%
87848687	00000000	50060000	9.33%
00000000	85840085	51060000	6.64%
00000000	87848687	50060000	5.70%
85840085	00000000	50060000	2.52%
00000000	85840085	50060000	2.41%
00000000	00000000	50060000	1.67%
00000000	00000000	50060000	1.08%
87848687	85840085	50060000	0.87%
85840085	85840085	50060000	0.74%
00000000	83008283	50060000	0.57%
00000000	00000000	53020000	0.56%
87848687	00000000	53020000	0.47%
00000000	00000000	51060000	0.46%
87848687	87848687	51060000	0.37%
00000000	85840085	50060000	0.37%
00000000	85840085	51060000	0.36%
00000000	00000000	53060000	0.36%
00000000	00000000	50060000	0.36%
87848687	85840085	51060000	0.34%
00000000	85840085	53060000	0.34%
00000000	87848687	53060000	0.33%
87848687	00000000	53020000	0.33%
00000000	85840085	53060000	0.33%
87848687	00000000	50060000	0.32%
00000000	85840085	50060000	0.30%
85840085	85840085	50060000	0.30%
84800000	00000000	50060000	0.29%
00000000	80000000	50060000	0.28%
85840085	00000000	53060000	0.27%
00000000	85840085	53060000	0.27%
83008283	00000000	50060000	0.26%
00000000	87848687	50060000	0.25%
07010808	00000000	35200000	0.24%
85840085	00000000	50020000	0.22%
87848687	00000000	50060000	0.22%
00000000	85840085	31060000	0.21%
00000000	00000000	52060000	0.20%
80000000	00000000	50060000	0.19%
00000000	84840000	51060000	0.15%
87848687	00000000	50060000	0.15%
87848687	85840085	50060000	0.14%
87848687	00000000	50060000	0.14%
85840085	00000000	50060000	0.13%
00000000	86848600	50060000	0.13%
80000000	00000000	50020000	0.13%
85840085	87848687	50060000	0.12%
00000000	83008283	50060000	0.12%
00000000	87848687	50060000	0.11%
80000000	00000000	50060000	0.11%
87848687	85840085	50020000	0.10%
00000000	85840085	52060000	0.09%
00000000	85840085	50060000	0.09%
00008283	00000000	50020000	0.08%

Table 6 (con't)

82008200	00000000	50060000	0.07%
00000000	182008200	50060000	0.07%
80000000	00000000	53060000	0.07%
87040687	00000000	50020000	0.07%
00000000	00000000	50260000	0.06%
87840685	00000000	50260000	0.06%
85840085	00000000	50260000	0.05%
00000000	187848785	50060000	0.05%
84840000	00000000	53060000	0.05%
00000000	187848785	50060000	0.05%
87848687	00000000	50260000	0.05%
87848687	00000000	53020000	0.05%
00000000	187848687	51060000	0.05%
87848687	00000000	52060000	0.05%
00000000	187848687	50060000	0.05%
87848687	00000000	52020000	0.05%
87848687	00000000	52060000	0.05%
87848685	00000000	50060000	0.05%
00000000	180000000	53060000	0.05%
87878283	00000000	50060000	0.04%
00000000	184840000	53060000	0.04%
00000000	155840085	51260000	0.04%
87848687	00000000	51060000	0.04%
87048687	185840085	50260000	0.04%
87040687	181000081	50260000	0.04%
85040085	00000000	50160000	0.04%
87040687	00000000	53060000	0.04%
87848687	00000000	53060000	0.04%
00000000	00000000	50260000	0.04%
85840085	185840085	50060000	0.04%
85840000	185840085	50260000	0.04%
87848687	183008283	50260000	0.04%
00000000	00000000	53000000	0.03%
00000000	185240085	53060000	0.03%
85840085	00000000	50060000	0.03%
85840085	185840085	53060000	0.03%
00000000	181000081	50260000	0.03%
00000000	183008283	53260000	0.03%
00000000	185840085	51060000	0.03%
84840000	00000000	51020000	0.03%
86848600	185840085	50260000	0.03%
00000000	185840085	53260000	0.03%
85840085	00000000	53020000	0.03%
00000000	187848687	52060000	0.03%
00000000	187868287	50060000	0.03%
87848687	188400000	50060000	0.02%
85840085	185840085	50220000	0.02%
00000000	00000000	52020000	0.02%
87868700	80000000	50260000	0.02%
00000000	187848687	50060000	0.02%
00000000	00000000	53020000	0.02%
00000000	188486200	53060000	0.02%
00000000	185840085	50260000	0.02%
87848687	00000000	50260000	0.02%
86808684	00000000	50060000	0.02%
00000000	185840085	50020000	0.02%
87040687	185840085	50260000	0.02%

Table 7
Format of ATS Levelled Data

This data will be printed on 7-track, BCD, 556 BPI tracks with record length of 132 characters, 20 records to the block.

Columns		Example	Explanation
02-03	Year-	67	Time of Mid point of average
04-06	Day	014	
08-09	Hour	11	
10-11	Minute	38	
12-15	Second	07.5	
17-22	V	-6.8 ¹	VDH Rotational System
23-28	D	10.2	
29-34	H	79.1	
35-40	V	-7.1 ¹	VDH Dipole System
41-46	D	-5.4	
47-52	H	79.3	
53-58	X	-1.1 ¹	Uncorrected XYZ System
59-64	Y	-24.6	
65-70	Z	-35.5	
71-76	XCV	11.5 ¹	Levels in XYZ System
77-82	YCV	18.1	
83-88	ZCV	114.6	
90-97	FLAG	00000001 ²	Level Flag
99-106	WORD 1	40000000 ³	State Vector
108-115	WORD 2	A51400A5	
117-124	WORD 3	50064D7F	

¹Values greater than 2000.0 are flags.

²Unknown levels have a flag of 'FFFFFFF' or 'EEEEEEEE'.

³Unknown states are set to zero.

[illegible]

0 67040 232600 -9.19 -0.28 122.07 -29.11 1.15 4.13 2.00
 67040 2326159999.999999.999999.999999.999999.99 2.00 67040 2326309999.999
 999.999999.999999.999999.999999.99 2.00 67040 232645 -11.73 -4.81 118.25 -25.66
 -4.66 1.34 2.00 67040 232700 -10.79 -5.54 118.67 -28.55 -4.93 1.87 2.0
 0 67040 232715 -10.87 -2.93 121.42 -29.77 -2.08 4.06 2.00
 67040 232730 -9.56 -1.26 122.46 -29.24 0.09 5.71 2.00 67040 232745 -9.98
 0.45 121.84 -30.23 1.36 5.78 2.00 67040 232800 -11.16 1.03 121.83 -31.56
 1.43 5.70 2.00 67040 232815 -10.85 -1.71 117.51 -30.00 -1.76 1.98 2.0
 0 67040 232830 -11.02 -4.12 117.23 -29.22 -4.08 2.23 2.00
 67040 232845 -10.80 -5.60 117.65 -28.58 -5.30 2.88 2.00 67040 232900 -10.74
 -2.71 122.32 -29.92 -1.80 6.89 2.00 67040 232915 -10.16 -1.21 121.85 -29.91
 -0.33 8.12 2.00 67040 232930 -10.11 0.53 121.81 -30.52 1.24 5.74 2.0
 0 67040 232945 -11.32 0.34 121.58 -31.58 0.55 5.59 2.00

0000

67040 233000 -12.53 0.26 121.16 -32.65 -0.08 5.23 2.00 67040 233015 -11.74
 -3.95 117.39 -30.12 -4.31 2.34 2.00 67040 233030 -10.88 -5.06 116.90 -28.89
 -5.10 2.04 2.00 67040 233045 -9.89 -3.61 117.10 -28.04 -4.22 5.92 0.0
 0 67040 233100 -9.90 -0.46 122.25 -27.12 -4.61 30.36 0.0
 67040 233115 -10.06 1.42 122.18 -27.94 -3.10 29.94 0.0 67040 233130 -11.49
 0.95 122.89 -29.20 -3.86 30.76 0.0 67040 233145 -12.85 0.18 122.76 -30.17
 -5.13 30.93 0.0 67040 233200 -13.43 -1.37 122.37 -30.12 -6.85 30.77 0.0
 0 67040 233215 -12.07 -2.46 122.12 -28.45 -6.88 27.69 2.00
 67040 233230 -10.77 -2.11 122.24 -27.40 -5.56 24.70 2.00 67040 233245 -9.82
 -0.26 122.23 -27.25 -3.54 24.29 2.00 67040 233300 -10.24 1.88 122.01 -28.46
 -1.83 28.17 2.00 67040 233315 -11.58 2.64 121.84 -29.99 -1.72 24.40 2.0
 0 67040 233330 -13.39 1.54 121.96 -31.27 -3.42 24.80 2.00
 67040 233345 -13.66 0.07 121.65 -31.23 -5.04 24.79 2.00 67040 233400 -13.79
 -1.71 122.07 -29.51 -6.14 25.52 2.00 67040 233415 -11.36 -2.25 122.21 -28.02
 -6.06 25.71 2.00 67040 233430 -9.74 -0.70 122.75 -27.13 -3.95 25.89 2.0
 0 67040 233445 -9.76 0.88 122.66 -27.83 -2.57 25.49 2.00
 67040 233500 -11.13 3.01 122.26 -29.90 -1.29 24.73 2.00 67040 233515 -12.68
 2.51 122.20 -31.15 -2.39 24.82 2.00 67040 233530 -12.92 0.50 122.07 -30.60
 -4.33 25.09 2.00 67040 233545 -12.98 -1.25 122.43 -30.02 -5.90 25.79 2.0
 0 67040 233600 -11.68 -1.82 121.85 -28.57 -6.01 25.29 2.00
 67040 233615 -10.19 -0.70 122.66 -27.72 -4.28 25.82 2.00 67040 233630 -9.70
 0.78 122.56 -27.87 -2.79 25.41 2.00 67040 233645 -10.86 2.14 122.16 -29.47
 -2.14 24.80 2.00 67040 233700 -11.24 2.24 123.55 -29.98 -1.97 26.14 2.0
 0 67040 233715 -12.04 0.09 123.05 -29.83 -4.33 26.12 2.00
 67040 233730 -13.32 -0.97 122.65 -30.58 -5.90 25.95 2.00 67040 233745 -12.11
 -4.32 124.47 -31.28 -4.10 12.37 2.00 67040 233800 -11.05 -3.33 124.05 -30.70
 -2.68 11.72 2.00 67040 233815 -9.54 -2.03 125.12 -29.94 -0.92 12.47 2.0
 0 67040 233830 -8.59 -1.18 125.09 -29.52 0.16 12.25 2.00
 67040 233845 -10.71 -0.26 124.57 -31.74 0.11 12.01 2.00 67040 233900 -11.05
 -1.18 124.82 -31.70 -0.90 12.05 2.00 67040 233915 -11.79 -2.82 124.80 -31.71
 -2.70 12.38 2.00 67040 233930 -12.35 -3.41 124.60 -31.93 -3.51 12.32 2.0
 0 67040 233945 -11.66 -3.42 124.92 -31.40 -3.19 12.51 2.00

0000

67040 234000 -10.46 -2.18 124.55 -30.80 -1.93 10.97 2.00 67040 234015 -8.67
 0.50 124.38 -30.28 0.41 7.22 2.00 67040 234030 -7.75 -0.33 122.14 -28.94
 -0.37 5.15 2.00 67040 234045 -7.82 -1.15 120.70 -28.55 -1.44 3.91 2.0
 0 67040 234100 -9.56 -2.21 120.99 -29.75 -3.05 4.45 2.00
 67040 234115 -10.16 -3.31 120.70 -29.84 -4.35 4.40 2.00 67040 234130 -10.15
 -3.70 120.02 -29.63 -4.83 3.82 2.00 67040 234145 -9.09 -2.64 120.09 -29.12
 -3.45 3.63 2.00 67040 234200 -7.81 -1.60 120.63 -28.46 -1.90 3.92 2.0
 0 67040 234215 -8.36 -1.52 120.47 -29.00 -2.11 3.76 2.00
 67040 234230 -9.00 -1.39 121.02 -29.70 -2.18 4.31 2.00 67040 234245 -8.80
 -2.34 120.57 -29.13 -2.97 4.43 2.00 67040 234300 -9.01 -2.59 120.91 -29.23
 -3.32 4.43 2.00 67040 234315 -10.15 -1.09 124.72 -31.22 -1.81 7.91 2.0
 0 67040 234330 -9.82 -0.61 124.63 -31.13 -1.28 7.71 2.00
 67040 234345 -8.02 -1.92 121.26 -28.70 -2.28 4.61 2.00 67040 234400 -7.89
 -1.77 120.67 -28.61 -2.22 3.99 2.00 67040 234415 -8.46 -1.66 120.23 -26.65

7. LENGTH 3204

8. LENGTH 3204

-5.80 24.40 0.0	67040 234445 -10.31	-0.54 123.83 -28.63	-5.63 31.94 0.0	67040 234515 -9.62
67040 234500 -10.82	-0.73 123.45 -28.99	-0.16 31.63 0.0	67040 234530 -9.32	-0.35 123.75 -27.87
-0.92 124.23 -28.13	-5.81 32.39 0.0	67040 234545 -8.76	0.77 124.07 -27.90	-3.88 31.87 0.0
-5.16 31.78 0.0	67040 234600 -8.47	1.14 124.30 -27.83	-3.40 32.01 0.0	67040 234630 -9.62
67040 234615 -9.17	1.01 123.54 -28.36	-3.99 31.31 0.0	67040 234645 -10.42	-1.04 123.62 -28.64
-0.57 124.02 -28.42	-5.65 32.12 0.0	67040 234700 -10.58	-0.34 123.58 -29.20	-5.90 31.66 0.0
-6.37 31.84 0.0	67040 234715 -9.66	0.26 123.40 -28.55	-4.97 31.34 0.0	67040 234745 -9.24
67040 234730 -8.99	0.29 123.27 -27.97	-4.70 31.18 0.0	67040 234800 -9.72	-1.15 124.36 -28.12
-0.21 123.68 -28.03	-5.19 31.69 0.0	67040 234815 -9.51	-1.13 123.90 -27.90	-6.16 32.11 0.0
-6.13 32.56 0.0	67040 234830 -9.32	-0.45 124.09 -29.09	-5.42 32.14 0.0	67040 234900 -9.85
67040 234845 -9.85	0.50 123.72 -29.15	-4.57 31.53 0.0	67040 234915 -9.57	-0.01 123.92 -28.55
1.69 123.51 -29.53	-3.95 31.17 0.0	67040 234930 -9.48	-1.30 124.02 -27.59	-6.77 32.34 0.0
-5.25 31.89 0.0	67040 234945 -9.55	-1.72 123.86 -27.79	-6.78 32.17 0.0	

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67040 235000 -10.25	-0.25 123.58 -29.04	-5.85 32.04 0.0	67040 235015 -9.95	REC	9, LENGTH 3204
0.80 123.74 -29.31	-4.82 31.58 0.0	67040 235030 -10.05	1.11 123.32 -29.51		
-4.70 31.10 0.0	67040 235045 -9.66	0.37 123.94 -28.91	-5.08 31.64 0.0		
67040 235115 -9.33	-1.24 123.63 -27.92	-6.39 32.04 0.0	67040 235130 -9.77		
-1.62 124.08 -27.29	-6.43 32.34 0.0	67040 235145 -8.58	-1.18 123.48 -27.28		
-6.09 31.66 0.0	67040 235200 -9.76	0.19 123.59 -28.93	-5.45 31.54 0.0		
67040 235215 -9.88	0.77 123.57 -29.37	-5.03 31.41 0.0	67040 235245 -9.38		
67040 235230 -6.52	0.71 123.56 -29.04	-4.93 31.40 0.0	67040 235300 -9.30	-0.35 123.25 -28.37	
0.09 123.63 -28.66	-5.41 31.59 0.0	67040 235315 -9.15	-1.26 123.63 -27.89	-6.51 31.90 0.0	
-5.85 31.30 0.0	67040 235330 -8.96	-1.04 124.37 -27.80	-6.09 32.52 0.0	67040 235400 -9.41	
67040 235345 -9.04	-0.26 124.32 -28.33	-5.52 32.32 0.0	67040 235415 -9.83	0.45 123.87 -29.36	
0.47 124.25 -29.01	-5.10 32.13 0.0	67040 235430 -10.20	0.02 123.39 -29.46	-6.06 31.39 0.0	
-5.40 31.75 0.0	67040 235445 -9.92	-0.68 123.85 -28.95	-6.47 31.97 0.0	67040 235515 -8.86	
67040 235500 -9.31	-0.57 123.81 -28.43	-5.20 31.91 0.0	67040 235530 -8.90	-0.22 123.76 -28.32	
-0.80 123.89 -28.00	-6.10 32.00 0.0	67040 235545 -9.22	0.61 123.43 -28.97	-5.18 31.28 0.0	
-5.66 31.76 0.0	67040 235600 -9.57	0.59 123.50 -29.29	-5.37 31.36 0.0	67040 235630 -10.02	
67040 235615 -10.08	0.43 123.71 -29.70	-5.74 31.62 0.0	67040 235645 -9.48	-0.28 123.26 -28.84	
-0.15 123.49 -29.37	-6.27 31.52 0.0	67040 235700 -8.91	0.01 123.69 -28.54	-5.60 31.65 0.0	
-6.18 31.30 0.0	67040 235715 -9.26	0.42 123.46 -29.03	-5.49 31.35 0.0	67040 235745 -10.12	
67040 235730 -9.63	0.14 123.61 -29.28	-5.84 31.36 0.0	67040 235800 -10.40	-0.14 123.11 -29.78	
-0.08 123.50 -29.58	-6.37 31.52 0.0	67040 235815 -10.14	0.05 123.10 -29.67	-6.37 31.10 0.0	
-6.54 31.15 0.0	67040 235830 -9.75	0.35 123.00 -29.47	-5.97 30.93 0.0	67040 235900 -9.44	
67040 235845 -9.70	0.20 123.50 -29.43	-6.00 31.45 0.0	67040 235915 -9.91	-0.41 123.65 -29.37	
0.13 123.81 -29.21	-5.91 31.75 0.0	67040 235930 -10.38	-0.41 123.15 -29.75	-6.99 31.26 0.0	
-6.66 31.72 0.0	67040 235945 -10.56	-0.30 122.62 -29.93	-7.10 30.71 0.0		

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10. LENGTH 3204

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20. LENGTH 1463

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