Polar Orbiting Environmental Satellite
Space Environment Monitor - 2
Instrument Descriptions and Archive Data Documentation

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Abstract

Beginning with NOAA-15, an upgraded Space Environment Monitor (SEM-2) is included in the POES satellite instrument complement. This document contains the technical descriptions of the improved Total Energy Detector and upgraded Medium Energy Proton and Electron Detector. A thorough description of the content of the archive data tape and all the information required to convert the archived data to usable information is given. The description of the archive file format provides the information needed to read and unpack the data from the file. Appendices provide examples of 'C' and FORTRAN programs that read the archive file and technical information regarding the instruments and conversion of raw data to physical units.

1 Introduction

The National Oceanic and Atmospheric Administration Polar Orbiting Environmental Satellites (POES) (formerly known as TIROS for Television and InfraRed Observation Satellite) carry a suite of instruments that detect and monitor the influx of energetic ions and electrons into the atmosphere and the particle radiation environment at the altitude of the satellite. Both phenomena vary as a result of solar and geomagnetic activity. Beginning with the NOAA-15 satellite, an upgraded version of the Space Environment Monitor (SEM-2) is being flown. A number of SEM-2 instruments have been procured and it is anticipated that the SEM-2 instruments will be included on the NOAA/POES satellites until superceded by the NPOESS satellite program sometime after 2010.

Because the SEM-2 instruments differ significantly from the earlier SEM-1, there has been a complete revision to the data processing and archiving process. A number of improvements have also been included. Among these are incorporating up-to-date satellite orbit information and magnetic field models in the calculation of various magnetic coordinates, improved data quality control, and modern data storage media.

The archive data are written to CD-ROM, each disk containing 2-months of data. Copies may be obtained from:

National Oceanic and Atmospheric Administration
National Environmental Satellite, Data, and Information Service
National Geophysical Data Center E/GC2
325 Broadway
Boulder Colorado 80303, USA
Attn: Mr. Daniel Wilkinson

This technical memorandum is designed to assist the user in reading the SEM-2 data archive files and in interpreting the information contained in the SEM-2 data. The memorandum includes a description of the instruments and their operation, information needed to convert telemetered sensor responses to physical parameters, specifications of all data channels, and a description of added information, such as orbital parameters.

2 Total Energy Detector (TED) SEM-2 Instrument Description and Operation

2.1 Instrument Description

The Total Energy Detector is designed to measure the energy flux carried by auroral particles, both positively charged ions (assumed here to be protons) and electrons, into the polar atmosphere. The magnitude and spatial extent of this energy flux are good measures of both the level of auroral activity and the atmospheric response to that energy input.

The TED in SEM-2 contains eight individual cylindrical curved-plate, electrostatic-analyzer, Channeltron charged-particle detector systems. The eight detector systems are divided into two sets of four systems, each set viewing charged particles coming from different directions so that measurements of directional energy fluxes carried by auroral particles are made at two different angles to the geomagnetic field. One set of four is mounted on the three-axis stabilized spacecraft so that the center of each detector field of view is outward along the local zenith, parallel to the Earth-center-to-satellite radial vector, which is the –X direction in spacecraft coordinates (see Figure 2.1.1). This detector set is referred to as the 0º detectors. The second set of four detectors are mounted so that each detector field of view is centered at 30° to the Earth-center-to-satellite radial vector, toward the –Z direction in spacecraft coordinates. In this document, data from the detector set that views radially outwards (0º) have names with the suffix "0" while data from the set viewing at 30° to the local zenith have names with the suffix "30".

Of the four detector systems in each set, two are devoted to measuring protons. The electrostatic analyzer voltage in one detector system is swept to measure protons over the energy range 50 eV to 1000 eV while the analyzer voltage in the second is swept to measure protons over the energy range 1000 eV to 20,000 eV. The remaining two detector systems are devoted to measuring electrons, with one covering the energy range 50 eV to 1000 eV and the second 1000 eV to 20,000 eV.

The field of view of the electron and proton 1000-20,000 eV detector systems are 1.5° by 9°, half angles. The field of view of the 50 - 1000 eV electron detector system is 6.7° by 3.3°, half angles. The field of view of the 50 - 1000 eV proton detector system is 6.6° by 8.7°, half angles.

The analyzer energy sweep for all eight detectors is divided into eight contiguous energy bands. The edge and center energies of each band are listed in Table 2.1.1. Energy bands 1 through 8 are for the low energy detector systems that sweep from 50 eV to 1000 eV while 9 through 16 are for the high-energy detector systems that sweep from 1000 eV to 20,000 eV.

Table 2.1.1
TED Energy Bands

Energy Band	Low-Energy Edge (eV)	Center Energy (eV)	High-Energy Edge (eV)	Total Energy Band Width (eV)
1	50	61	73	23
2	73	89	106	33
3	106	130	154	48
4	154	189	224	70
5	224	274	325	101
6	325	399	473	148
7	473	580	688	215
8	688	844	1000	312
9	1000	1227	1454	454
10	1454	1784	2115	661
11	2115	2595	3075	961
12	3075	3774	4472	1397
13	4472	5488	6503	2031
14	6503	7980	9457	2954
15	9457	11605	13753	4296
16	13753	16877	20000	6247

Within each energy band the energy sweep is stepped upward in time through eight equally spaced energy levels, but because the width of each energy band increases in a logarithmic manner the step size increases with increasing energy band.

The full energy sweep cycle time for each detector system is 2.0 seconds. The analyzer sweep over a single energy band takes 0.2 seconds so the sampling over the eight bands making up the full energy range requires 1.6 seconds. The reset of the analyzer plate voltage requires 0.2 seconds. During the remaining 0.2 seconds of an instrument cycle the analyzer plate voltages are set to electrical ground, while counts from each Channeltron particle sensor are accumulated to provide a measure of the background response of each detector system. The energy sweep, reset, and background accumulation are done simultaneously for all eight detector systems.

The on-board Data Processing Unit (DPU) compresses all TED sensor "count" data to fit the 0 to 255 dynamic range of the digital word transmitted from the NOAA/POES satellite. The software that reads the archive data record decompresses the data word according to the table in Appendix B before passing the data to a user. A unique negative value for a data word indicates the data word had been lost in the processing and a data "pad" had been inserted.

2.2 Determination of Particle Directional Energy Flux Moments

The on-board DPU accumulates the Channeltron particle detector responses (counts) from each detector system during each 0.2-second energy sweep through an energy band. At the completion of a full energy sweep, an on-board microprocessor manipulates these data to obtain the integrated auroral particle directional energy flux moment from each of the eight detector systems. (The integrated directional energy flux moment is defined as the energy flux carried by particles having energies within a defined range, originating from a differential solid angle and passing through a differential area that is oriented normal to the particle velocity vector).

The on-board data processing takes into account both the increasing energy of the particles being measured during the course of a full energy sweep, and (to first order) the dependence of the Channeltron counting efficiency upon particle energy and species. This is done by applying multiplicative weighting factors to the counts accumulated within each energy band.

Table 2.2.1 lists the weighting factors used for the TED instrument on-board NOAA-15, that is, TED instrument Serial Number 011. Similar information for the other TED instruments is included in Appendix C. The "Particle Energy" weighting factors are determined from laboratory calibrations of each instrument and represent a combination of the weight given to the particle energy and to the varying Channeltron detection efficiency. The "Detection Efficiency" weighting factors are a second order correction for any remaining difference in detector counting efficiency between the four lowest energy bands and the four highest. The "Detection Efficiency" weight factor is only applied, if at all, to the counts accumulated in the four highest energy bands in each detector system.

The microprocessor in the DPU constructs the integrated particle energy flux moment for each detector system by multiplying the sensor counts accumulated within each energy band by both of the appropriate weighting factors and then summing the eight resulting values together. The data from the 0º detector systems are in archive array *ted0* and the data from the 30º detector systems are in archive array *ted30* (see Section 4.4.1).

Table 2.2.1
TED Weighting Factors
TED Serial Number 011

0º electron low-energy band number	Particle energy weight	Detector efficiency weight	30º electron low-energy band number	Particle energy weight	Detector efficiency weight
1	1.0	1.0	1	1.0	1.0
2	1.5	1.0	2	1.5	1.0
3	2.0	1.0	3	2.0	1.0
4	3.0	1.0	4	3.0	1.0
5	4.0	1.0	5	4.0	1.0
6	6.0	1.0	6	6.0	1.0
7	8.0	1.0	7	8.0	1.0
8	12.0	1.0	8	12.0	1.0
0º electron high-energy band number	**Particle energy weight**	**Detector efficiency weight**	**30º electron high-energy band number**	**Particle energy weight**	**Detector efficiency weight**
9	1.0	1.0	9	1.0	1.0
10	1.5	1.0	10	1.5	1.0
11	3.0	1.0	11	3.0	1.0
12	4.0	1.0	12	4.0	1.0
13	8.0	0.667	13	8.0	0.667
14	16.0	0.667	14	16.0	0.667
15	24.0	0.667	15	24.0	0.667
16	48.0	0.667	16	48.0	0.667
0º proton low-energy band number	**Particle energy weight**	**Detector efficiency weight**	**30º proton low-energy band number**	**Particle energy weight**	**Detector efficiency weight**
1	1.0	1.0	1	1.0	1.0
2	1.5	1.0	2	1.5	1.0
3	2.0	1.0	3	2.0	1.0
4	2.0	1.0	4	2.0	1.0
5	3.0	1.0	5	3.0	1.5
6	4.0	1.0	6	4.0	1.5
7	6.0	1.0	7	6.0	1.5
8	8.0	1.0	8	8.0	1.5
0º proton high-energy band number	**Particle energy weight**	**Detector efficiency weight**	**30º proton high-energy band number**	**Particle energy weight**	**Detector efficiency weight**
9	3.0	1.0	9	3.0	1.0
10	4.0	1.0	10	4.0	1.0
11	4.0	1.0	11	4.0	1.0
12	6.0	1.0	12	6.0	1.0
13	8.0	1.0	13	8.0	1.0
14	12.0	1.0	14	12.0	1.0
15	12.0	1.0	15	12.0	1.0

0º electron low-energy band number	Particle energy weight	Detector efficiency weight	30º electron low-energy band number	Particle energy weight	Detector efficiency weight
16	16.0	1.0	16	16.0	1.0

The factors that convert the telemetered integrated energy flux moment data (after decompression using the table in Appendix B) to physical units have been determined using a combination of laboratory calibration and computer simulation of the sensor responses to model particle energy spectra. The factors that convert from decompressed data values to integrated energy flux values in units of mW m^{-2} $ster^{-1}$ for the TED instrument on NOAA-15, as integrated over the appropriate energy range, are given in Table 2.2.2. This information is listed in Appendix C for other TED instruments.

Table 2.2.2
Conversion to Integrated Directional Energy Flux Moment
TED Serial Number 011

Sensor	Energy range eV	To convert decompressed counts to mW m-2 ster-1 multiply by
0º low-energy electron	50 - 1000	1.746 x 10-6
30º low-energy electron	50 - 1000	2.322 x 10-6
0º high-energy electron	1000 - 20000	5.328 x 10-5
30º high-energy electron	1000 - 20000	5.782 x 10-5
0º low-energy proton	50 - 1000	1.030 x 10-6
30º low-energy proton	50 - 1000	8.628 x 10-7
0º high-energy proton	1000 - 20000	3.652 x 10-5
30º high-energy proton	1000 - 20000	2.602 x 10-5

It should be noted that the archive data record does not include the physical values for the directional energy flux moments, but only the compressed sensor response value as computed by the DPU and telemetered from the spacecraft. The decompressed data values are multiplied by the appropriate factors in Table 2.2.2 to obtain directional energy flux moments in physical units.

2.3 Determination of Particle Omni-directional Energy Fluxes

The principle objective of the TED instrument is to monitor the auroral particle energy deposition into the atmosphere. This physical parameter is computed from the directional energy flux observations using the procedure set down in Raben, et al. (1995) and is briefly described here.

Auroral particles measured by the TED detector systems can reach the atmosphere at 120 km altitude only if their pitch angle, α_{sat}, at the satellite location satisfies the relation

Equation 2.3.1 $$sin^2(\alpha_{sat}) \leq \sqrt{(B_{sat} / B_{120})} = sin^2(\alpha_{mir})$$

B_{sat} is the scalar magnetic field at the satellite and B_{120} is the scalar magnetic field strength at 120 km altitude along the magnetic field line of force joining the satellite to the location where the particles would enter the atmosphere. Particles with pitch angles not satisfying this relationship will magnetically mirror and return upward along the magnetic field line before reaching the atmosphere. The particle pitch angle is, by convention, the angle between the velocity vector of a particle and the local magnetic field direction. For the TED instrument viewing directions, the corresponding particle pitch angles at the satellite will generally be ≤ 90º in the Northern Hemisphere, and ≥ 90º in the Southern). The parameters B_{sat} and B_{120}, together with the pitch angles of the particles being measured at the satellite by the two sets of TED detectors, are calculated using a magnetic field model. The calculation is carried out every 8 seconds along the satellite orbit and the results are included in the archive data record array *head* (see Section 4.2.2). Also included in the *head* array are the particle pitch angles transformed from their values at the satellite to 120 km altitude using the relation:

Equation 2.3.2 $$sin^2(\alpha_{120}) = sin^2(\alpha_{sat})\sqrt{(B_{120} / B_{sat})}$$

If $sin(\alpha_{120}) > 1.0$, the particles measured at the satellite do not reach the atmosphere.

The calculation of omni-directional energy flux involves evaluating the following integral.

Equation 2.3.3 $$E_F = 2\pi \int E_D(\alpha) sin\alpha cos\alpha \, d\alpha$$

$E_D(\alpha)$ is the pitch angle dependent integrated directional energy flux moment defined above, and α is the particle's pitch angle. If α is the pitch angle transformed to 120 km altitude using equation 2.3.2, then the integration limits for α are 0º to 90º in the Northern Hemisphere or 180º to 90º in the Southern. E_F is the energy flux through a unit area normal to the magnetic field vector carried by downward moving particles within the energy range of E_D.

Using the integrated directional energy flux moments as determined from Table 2.2.2, the omni-directional energy flux moments for electrons of energies between 50 eV and 1000 eV and between 1000 eV and 20,000 eV, and for protons of energies between 50 eV and 1000 eV and between 1000 eV and 20,000 eV can be calculated. These four calculated values constitute the first four of the seven elements in the archive record array *tedfx*.

There are three cases that must be considered in the calculation of these four omni-directional energy flux moments.

Case 1. Both sets of TED detectors view particles that reach the atmosphere. This is the case for all observations made at geographic latitudes poleward of about 30º in both the Northern and Southern Hemispheres.

The particle pitch angle that is midway between those viewed by the two sets of TED detector systems is calculated ($\alpha_{mid} = (\alpha_1+\alpha_2)/2.0$), and then the set of TED detectors that view particles with pitch angles closest to 0º (180º in the Southern Hemisphere) is identified. (There are geographic locations in the Southern Hemisphere where the detector set that is viewing 30º from the zenith is actually sensing incident particles with pitch angles closer to 180º than the set viewing the zenith). Using the superscript "1" to denote the directional energy flux moment obtained from the detector viewing closest to 0º which is assumed to be representative of the directional energy flux moments at angles between 0º and the angle given by α_{mid}, and the superscript "2" to denote the directional energy flux moment obtained from the other detector set, which is representative for all angles between α_{mid} and 90º, Equation 2.3.3 reduces to

Equation 2.3.4 $$E_F = \pi\left({}^1E_D \sin^2(\alpha_{mid}) + {}^2E_D\,(1.-\sin^2(\alpha_{mid}))\right)$$

The calculation of E_F is executed four times, using values of ${}^1E_D$ and ${}^2E_D$ from the sensor pairs listed in Table 2.2.2, to yield integrated omni-directional energy flux moments for electrons between 50 and 1000 eV and between 1000 and 20,000 eV, and for protons between 50 and 1000 eV and between 1000 and 20,000 eV.

Case 2. Only one set of the TED detectors view particles that reach the atmosphere. This is the case for many observations made at latitudes equatorward of 30º but poleward of the equatorial regions.

Whenever one set of TED detectors is viewing particles that will magnetically mirror before reaching the atmosphere, the integrated directional energy flux moment measurements provided by the other detector are assumed to be representative of energy fluxes at all pitch angles. In this case Equation 2.3.3 reduces to

Equation 2.3.5 $$E_F = \pi E_D$$

where E_D is provided by the detectors viewing particles that reach the atmosphere. The meaning of all elements in *tedfx* is described above.

Case 3. Neither set of TED detector systems views particles that reach the atmosphere. This is often the case for observations made in the equatorial regions. In this case the energy flux moments are set to a "pad" value.

It should be noted that the integrated omni-directional energy flux moments computed in this fashion are energy fluxes through unit areas at the top of the atmosphere that are oriented normal to the magnetic field vector. If the magnetic field vector is not perpendicular to the top of the atmosphere, these energy flux moments should be corrected by multiplying by $cos\beta$, where β is the inclination of the magnetic field to the vertical. This correction has not been made in the calculation of integrated omni-directional energy fluxes. The angle β can be calculated from the three components of the magnetic field vector at 120 km altitude that are included in the array *head* (Section 4.2.2) and the correction made if required.

2.4 Identification of Particle "Characteristic" Energy

There is a requirement that the instrument identify for each particle species, detector system viewing direction, and energy sweep the particular energy band in the full energy range 50 to 20,000 eV that contained the maximum directional energy flux. The DPU performs this function at the completion of each energy sweep by comparing the sensor responses accumulated in each energy band and selecting the energy band with the maximum response. The comparison takes into account the particle energy and energy bandwidth associated with each band, the Channeltron detection efficiency, and additional weighting to account for differences between the 50-1000 eV and 1000-20,000 eV detector systems. The identification is made for both electrons and protons, at both the zenith and 30º viewing angles for each 2-second instrument cycle. The four identifications of the energy band containing the maximum directional energy flux and the actual sensor responses within those energy bands (see Section 2.5) are transmitted for every 2-second instrument cycle.

Simulations were of the detector system responses to Maxwellian particle energy distributions were conducted. These simulations verified that the energy band identified by the DPU as the one with the maximum energy flux was most often the energy band that actually contained the maximum in the differential energy flux, an energy twice the temperature of a Maxwellian distribution, and was never more than one energy band different from the correct one.

2.5 Particle Intensities Within Specific Energy Bands

In addition to the sensor responses within the "characteristic" energy bands that are available for every instrument cycle, actual sensor responses in four of the sixteen specific energy bands for each detector system are telemetered on a subcommutated, low duty cycle basis. These energy bands are numbers 4 and 8 from the 50 - 1000 eV lower energy detector systems and bands 11 and 14 from the 1000 - 20,000 eV higher energy systems.

Keeping in mind that the archive record contains 32 seconds of data (16 energy sweep cycles of the TED detector systems), the sequence of data readouts is listed in Table 2.5.1.

Table 2.5.1
Sequence of the Readout of TED Sensor Responses in Specific Energy Bands

Energy Sweep Cycle	TED Sensors	Energy Bands Read Out
1, 5, 9, and 13	0º electron sensors	4, 8, 11, and 14
2, 6, 10, and 14	30º electron sensors	4, 8, 11, and 14
3, 7, and 11	0º proton sensors	4, 8, 11, and 14
4, 8, and 12	30º proton sensors	4, 8, 11, and 14

Proton sensor energy band response data from sweep cycles 15 and 16 are missing because accumulated background responses from the eight individual detector systems are telemetered instead.

These telemetered and decompressed sensor responses may be converted to physical units: either the particle directional energy flux contained in that energy band (in units of mW m^{-2} $ster^{-1}$) using the multiplicative factors in Table 2.5.2, or differential-directional particle number flux (in units of particles m^{-2} sec^{-1} $ster^{-1}$ eV^{-1}) using the multiplicative factors in Table 2.5.3.

Table 2.5.2
Multiplicative Factors to Convert Actual Counts Within an Energy Band to Directional Energy Flux Contained Within that Energy Band

TED S/N 011 Electron Detector System

Energy band	Band center energy (eV)	0º electron sensor to convert counts to mW m^{-2} $ster^{-1}$	30º electron sensor to convert counts to mW m^{-2} $ster^{-1}$
1	61	1.363×10^{-6}	1.821×10^{-6}
2	89	2.126×10^{-6}	2.824×10^{-6}
3	130	3.147×10^{-6}	4.151×10^{-6}
4	189	4.633×10^{-6}	6.179×10^{-6}
5	274	6.834×10^{-6}	9.105×10^{-6}
6	399	9.901×10^{-6}	1.313×10^{-5}
7	580	1.451×10^{-5}	1.931×10^{-5}
8	844	2.113×10^{-5}	2.809×10^{-5}
9	1227	4.948×10^{-5}	5.296×10^{-5}
10	1784	8.045×10^{-5}	8.668×10^{-5}
11	2595	1.310×10^{-4}	1.414×10^{-4}
12	3774	2.126×10^{-4}	2.298×10^{-4}
13	5488	3.438×10^{-4}	3.722×10^{-4}
14	7980	5.527×10^{-4}	5.998×10^{-4}
15	11605	8.793×10^{-4}	9.562×10^{-4}
16	16877	1.378×10^{-3}	1.502×10^{-3}

TED S/N 011 Proton Detector System

Energy band	Band center energy (eV)	0º proton sensor to convert counts to mW m^{-2} $ster^{-1}$	30º proton sensor to convert counts to mW m^{-2} $ster^{-1}$
1	61	7.511×10^{-7}	8.123×10^{-7}
2	89	1.160×10^{-6}	1.233×10^{-6}
3	130	1.614×10^{-6}	1.769×10^{-6}
4	189	2.265×10^{-6}	2.554×10^{-6}
5	274	3.141×10^{-6}	3.674×10^{-6}
6	399	4.325×10^{-6}	5.185×10^{-6}
7	580	6.004×10^{-6}	7.420×10^{-6}
8	844	8.304×10^{-6}	1.055×10^{-5}
9	1227	9.307×10^{-5}	7.056×10^{-5}
10	1784	1.231×10^{-4}	9.196×10^{-5}
11	2595	1.623×10^{-4}	1.199×10^{-4}
12	3774	2.131×10^{-4}	1.554×10^{-4}
13	5488	2.800×10^{-4}	2.012×10^{-4}
14	7980	3.664×10^{-4}	2.590×10^{-4}
15	11605	4.772×10^{-4}	3.298×10^{-4}
16	16877	6.149×10^{-4}	4.135×10^{-4}

Table 2.5.3
Multiplicative Factors to Convert From Actual Counts Within an Energy Band to Directional Number Flux at the Center Energy of that Band

TED S/N 011 Electron Detector System

Energy band	Band center energy (eV)	0º electron sensor convert counts to particles m^{-2} sec^{-1} eV^{-1} $ster^{-1}$	30º electron sensor convert counts to particles m^{-2} sec^{-1} eV^{-1} $ster^{-1}$
1	61	6.015×10^6	8.036×10^6
2	89	4.398×10^6	5.842×10^6
3	130	3.108×10^6	4.101×10^6
4	189	2.167×10^6	2.890×10^6
5	274	1.511×10^6	2.012×10^6
6	399	1.050×10^6	1.393×10^6
7	580	7.260×10^5	9.665×10^5
8	844	5.013×10^5	6.665×10^5
9	1227	5.543×10^5	5.932×10^5
10	1784	4.277×10^5	4.608×10^5
11	2595	3.305×10^5	3.565×10^5
12	3774	2.551×10^5	2.758×10^5
13	5488	1.971×10^5	2.134×10^5
14	7980	1.521×10^5	1.650×10^5
15	11605	1.171×10^5	1.272×10^5
16	16877	8.968×10^4	9.764×10^4

TED S/N 011 Proton Detector System

Energy band	Band center energy (eV)	0º proton sensor convert counts to particles m^{-2} sec^{-1} eV^{-1} $ster^{-1}$	30º proton sensor convert counts to particles m^{-2} sec^{-1} eV^{-1} $ster^{-1}$
1	61	3.314×10^6	3.583×10^6
2	89	2.400×10^6	2.552×10^6
3	130	1.595×10^6	1.748×10^6
4	189	1.060×10^6	1.195×10^6
5	274	6.948×10^5	8.124×10^5
6	399	4.590×10^5	5.502×10^5
7	580	3.006×10^5	3.714×10^5
8	844	1.971×10^5	2.504×10^5
9	1227	1.043×10^6	7.910×10^5
10	1784	6.532×10^5	4.879×10^5
11	2595	4.064×10^5	3.006×10^5
12	3774	2.524×10^5	1.844×10^5
13	5488	1.571×10^5	1.134×10^5
14	7980	9.763×10^4	6.976×10^4
15	11605	6.062×10^4	4.282×10^4
16	16877	3.748×10^4	2.619×10^4

2.6 TED Sensor Background Responses

The final 0.2 seconds of each TED instrument cycle is devoted to obtaining the Channeltron sensor background measurement. Counts from each Channeltron are accumulated during this 0.2 seconds for 16 consecutive instrument cycles for a total integration time of 3.2 seconds. The background data from each of the eight Channeltron particle detectors is telemetered once every 32 seconds, instead of the proton energy bands 4, 8, 11, and 14 responses, during energy sweeps 15 and 16 (see Section 2.5).

2.7 TED Correction for High Background

There are portions of the POES orbit where a significant contribution to the TED sensor responses is from very energetic particles that penetrate the instrument shielding and reach the Channeltron particle detectors. Such intervals are identified by unusually high count rates in the sensor background channels. When the background rates are elevated, the TED sensor responses are corrected for the penetrating radiation, and the energy flux moments calculated using the corrected responses. While the calculated energy flux moments in the archive data file are corrected values, the sensor responses stored in the archive data record are the uncorrected data as telemetered from the satellite. Whenever a correction for high background has been made to the energy flux moment, a flag is set in the array *qual*.

2.8 TED Data Quality Control

The TED sensor data are subjected to two tests for internal consistency. The first is a comparison of the sensor responses in energy bands 3, 7, 10, and 13, whenever available from a given detector system, with that system's sensor response in the energy band identified as containing the maximum in the particle directional energy flux. A sensor response in any of those four energy bands that convert to a directional energy flux greater than the identified maximum is an indication of questionable data. A flag is set in the array *qual* to indicate that fact (Section 4.5.1).

The second test is a comparison of the directional energy flux contained in the energy band identified as being the maximum, to the total directional energy flux integrated over the full energy range of that sensor. If the directional energy flux within that single energy band exceeds the directional energy flux integrated over the full range, there is likely an error in data transmission and a flag is set in the array *qual* (Section 4.5.1).

2.9 Timing of TED Data Acquisition Relative to Time Tag

The time tag provided in the archive record is the time tag assigned at the beginning of a 2-second interval, when data that are transferred from the SEM-2 DPU to the POES data handling system are introduced into the POES data format. That time is not the time the actual measurement was made by the SEM-2. The archive record provides data time tags every 8 seconds (every fourth 2-second cycle of the TED instrument) and that time refers to the first of the four cycles. It is implicit that the times associated with the second, third, and fourth cycles are incremented by 2-seconds each.

The timing of the actual data acquisition in the TED instrument relative to time T, the time tag given the individual data point in the archive record, are given in Table 2.9.1

Table 2.9.1
Timing of TED Functions Relative to Data Time Tag

TED function	Time interval relative to T
Full energy sweep	– 1.2 s to + 0.4 s
Accumulation in energy bands 1 and 9	– 1.2 s to + 1.0 s
Accumulation in energy bands 2 and 10	– 1.0 s to – 0.8 s
Accumulation in energy bands 3 and 11	– 0.8 s to – 0.6 s
Accumulation in energy bands 4 and 12	– 0.6 s to – 0.4 s
Accumulation in energy bands 5 and 13	– 0.4 s to – 0.2 s
Accumulation in energy bands 6 and 14	– 0.2 s to 0.0 s
Accumulation in energy bands 7 and 15	0.0 s to + 0.2 s
Accumulation in energy bands 8 and 16	+ 0.2 s to + 0.4 s
Plate voltage reset	+ 0.4 s to + 0.6 s
Accumulation of background data	+ 0.6 s to + 0.8 s

Background data are telemetered once every 32 seconds and represent responses accumulated during the background dwell period for 16 consecutive 2-second instrument cycles. Given a time T, referring to the time tag at the start of a 32 second archive record, the first of the 16 accumulation periods is between T – 5.4 and T – 5.2 seconds while the last accumulation period is between T + 26.6 and T + 26.8 seconds.

2.10 TED In-Flight Calibration

The TED instrument performance is periodically checked by means of an in-flight calibration (IFC) procedure; this procedure has two phases. The first involves feeding all eight Channeltron pulse amplifier and pulse height discriminator chains with pulses of varying amplitude from an on-board pulse generator. This is done while cycling the pulse height discriminator thresholds through four levels and verifying that those thresholds trip at the appropriate input pulse amplitudes. This phase of the IFC lasts 32-seconds and a flag is set in the SEM-2 status data to indicate that an IFC is in progress.

The second phase of the IFC involves continuous cycling of all pulse height discriminator thresholds through the four levels, while the TED continues normal operation without any artificial pulse stimulus. This phase continues for approximately one orbit of the satellite or about 100 minutes. The purpose of this phase of the IFC is to determine whether the cycling of the threshold levels has a significant effect on the overall sensor responses during times when auroral particle fluxes are significant. If there is a significant reduction in sensor responses as the pulse height discriminator thresholds increase, it indicates degradation in the Channeltron particle sensors. Increasing the Channeltron operating voltage by ground command compensates the gain degradation. The TED IFC flag continues to be set until the completion of the second phase of the IFC.

Archive data taken during the first phase of the IFC must be discarded, and the data during the second phase should be treated with caution.

3 MEPED Instrument Description

3.1 Overview

In addition to the TED, the SEM-2 includes a set of solid-state energetic particle detectors that monitor the intensities of protons and electrons over a range extending from 30 keV to more than 200 MeV. Particles having those energies include the radiation belt (Van Allen belt) populations, the particles in energetic solar particle events (solar proton events), and the low energy portion of the galactic cosmic ray population. Enhanced fluxes of these particles entering the atmosphere can produce significant and widespread degradation in short-wave radio propagation; in extreme cases even radio blackouts. The energetic particles also contribute to astronaut radiation exposure, especially on high inclination orbit missions during energetic solar particle events.

In order to monitor the particle fluxes over this wide range of energy and for both protons and electrons, the MEPED includes eight separate particle detector systems. Two are proton solid-state detector telescopes that monitor the intensity of protons in six energy bands over the range 30 keV to 6,900 keV. Two are electron solid-state detector telescopes that monitor the intensity of electrons in three energy bands in the range 30 keV to 2,500 keV. The remaining four detector systems are “dome” or “omni-directional” detector systems designed to be sensitive to very energetic protons incident on a solid-state detector over a wide range of angles. Metal absorbers set the specific proton energy thresholds for the “dome” detectors over the detector.

The following sections describe each detector system in more detail.

3.2 Proton Solid State Detector Telescope

Figure 3.2.1 is a cross-section schematic of the proton solid-state detector telescope. A magnetic field of approximately 0.2 Tesla is applied across the entrance aperture and collimator structure to prevent electrons entering the aperture with energies less than about 1,000 keV from reaching the solid-state detectors. With the exception of the entrance aperture, the detectors are surrounded by a combination of aluminum and tungsten shielding to prevent electrons of energies less than 6,000 keV or protons of energies less than 90 MeV from penetrating the structure walls and reaching the detectors.

Both solid-state detectors are totally depleted silicon surface barrier detectors, each 200 microns thick. The front detector, D1, has a sensitive area of 25 mm^2 while the back detector, D2, has a sensitive area of 50 mm^2. The front surface of each detector is covered with an aluminum film 20 μg cm^{-2} thick to reduce light sensitivity and provide an electrical contact.

Protons that enter through the collimator structure and are stopped by the first detector (no coincidence with a response in the back detector) are sorted according to their energy loss in the detector, determined by electronic pulse height analysis, into one of five proton energy ranges. A sixth proton energy band is established when a proton passes through the front detector and is stopped by the back detector, producing coincident responses in both detectors.

Two identical proton solid-state detector telescopes are included in the SEM-2. One (the 0º telescope) is oriented so that the central axis of the field of view is rotated in the XZ plane 9º from the –X direction toward the –Z direction (see Figure 1). The second (the 90º telescope) is oriented so that the center axis of the field of view is rotated 9º in the YZ plane from the +Y direction (anti-parallel to the satellite's velocity vector) also toward the –Z direction. These rotations ensure a clear field of view.

The proton energies, which take into account the energy lost in passing though the 20 μg cm^{-2} aluminum layer, together with the detector pulse height logic to select those energies, are given in Table 3.2.1. The pulse height levels, L1 through L5 refer to particle energy loss thresholds in the front detector, and L6 refers to the particle energy loss threshold in the back detector.

Table 3.2.1
MEPED Proton Energy Bands and Pulse Height Logic

Channel Identification	Electron Energy Range	Pulse Height Level Logic	
0/90 P1	30 keV to 80 keV	L1 on	but not L2 or L6
0/90 P2	80 keV to 240 keV	L1 and L2 on	but not L3 or L6
0/90 P3	240 keV to 800 keV	L1 and L3 on	but not L4 or L6
0/90 P4	800 keV to 2500 keV	L1 and L4 on	but not L5 or L6
0/90 P5	2500 keV to 6900 keV	L1 and L5 on	
0/90 P6	>6900 keV	L1 and L6 on	but not L5

Data from each proton telescope are accumulated for 1.0 second but the accumulation electronics are shared between the two detectors so that a full data set from both requires 2.0 seconds to acquire.

The nominal geometric factor for the proton solid-state detector telescopes is .01 cm^2 ster. To obtain the proton directional number flux within a given proton energy channel the count rate, in counts per second, should be multiplied by 100. The resulting flux is in units of protons cm^{-2} sec^{-1} $ster^{-1}$.

Experience has shown that the front silicon solid-state detector in the proton telescope suffers radiation damage that becomes significant after two to three years of operation. The effect of the radiation damage is to reduce the fraction of free charge produced in the detector by incident particles that is collected within the 85 nsec integration time set by the charge-sensitive amplifier. This reduction, in turn, can effectively raise the energy thresholds to values well above those listed above. For this reason, some care should be used in interpreting data obtained by the proton detector telescopes after three years of operation.

3.3 Electron Solid State Detector Telescope

Figure 3.3.1 is a cross-section schematic of the electron solid-state detector telescope. With the exception of the entrance aperture, the detectors are surrounded by a combination of aluminum and tungsten shielding to prevent electrons of energies less than 6,000 keV or protons of energies less than 90 MeV from penetrating the structure walls and reaching the detector. The final aperture in the collimator structure is covered by a 0.76 micron thick nickel foil (678 μg cm^{-2}) to reduce light sensitivity and stop low energy protons from reaching the solid-state detector.

The solid-state detector in the electron detector telescope is a totally depleted silicon surface barrier detector, 700 microns thick with a sensitive area of 25 mm^2. The front surface of the detector is covered with an aluminum film 20 μg cm^{-2} thick to further reduce light sensitivity and provide an electrical contact.

The energy deposited in the detector by particles incident on the detector is pulse height analyzed. One discriminator amplitude level (L4) is set to an equivalent particle energy loss of 2,500 keV, and is used in anti-coincidence with the other discriminator levels to exclude sensor responses to particles depositing more than 2,500 keV energy in the detector.

Two identical electron solid-state detector telescopes are included in SEM-2. One, the 0º telescope, is oriented so that the central axis of the field of view is rotated in the XZ plane 9º from the –X direction toward the –Z direction (see Figure 2.1.1). The second, the 90º telescope, is oriented so that the center axis of the field of view is rotated 9º in the YZ plane from the +Y direction (anti-parallel to the satellite velocity vector) also toward the –Z direction. These rotations ensure a clear field of view.

Table 3.3.1 gives the electron energies, taking into account the energy lost in passing though the nickel foil and aluminum layer, together with the detector pulse height logic used to select those energies.

Table 3.3.1
MEPED Electron Energy Bands and Pulse Height Logic

Channel Identification	Electron Energy Range	Pulse Height Level Logic	
0/90 E1	30 keV to 2500 keV	L1 on	but not L2 or L4
0/90 E2	100 keV to 2500 keV	L1 and L2 on	but not L3 or L4
0/90 E3	300 keV to 2500 keV	L1 and L3 on	but not L4

The electron detector telescopes are also sensitive to protons entering through the collimator with enough energy to pass through the nickel foil and into the detector. The proton energies, taking into account energy loss in passing through the foil that will produce responses in the three electron energy channels are given below.

Table 3.3.2
MEPED Electron Detector Sensitivity to Protons

Channel Identification	Sensitive to Protons Having Energies
0/90 E1	210 keV to 2700 keV
0/90 E2	280 keV to 2700 keV
0/90 E3	440 keV to 2700 keV

In principle, the contribution of protons to the total electron telescope sensor response can be determined from the proton detector telescope observations, but the effects of radiation damage to the silicon detectors in the proton detector system can make this correction uncertain. Care should be taken in interpreting observations from the electron detector telescope at times when the proton telescope sensor response indicates large fluxes of protons in the >200 keV energy range.

Data from each electron detector telescope are accumulated for 1.0 second but the accumulation electronics are shared between the two detectors so that a full data set from both requires 2.0 seconds to acquire.

The nominal geometric factor for the electron solid-state detector telescopes is .01 cm^2 ster. To obtain the electron directional number flux within a given electron energy channel, the count rate, in counts per second, should be multiplied by 100. The resulting flux is in units of electrons cm^{-2} sec^{-1} $ster^{-1}$.

The electron telescope sensor responses are checked to make certain that the responses in the >30 keV channel are always greater than or equal to the responses in the >100 keV channels. The responses in the >100 keV channel should always be greater than or equal to the responses in the >300 keV channel. If this is not the case, it indicates that a bit error is present and the appropriate flag is set in array *qual* (see Section 4.5.1).

3.4 Omni-directional (Dome) Solid State Detectors

Four separate omni-directional solid-state detectors are included in the SEM-2 in order to monitor the high energy proton fluxes associated with energetic solar particle events. The basic design of all four sensors is identical (see Figures 3.4.1 and 3.4.2).

Each omni-directional sensor contains a silicon surface-barrier, solid-state detector, 3 mm thick, with a 50 mm^2 sensitive area – a circle 8 mm in diameter. The detector is located under a nearly hemispheric metal shell or moderator. The thickness of the shell and the shell material determine the minimum proton energy required to both penetrate the shell and deposit 2.5 MeV of energy in the detector, the threshold for generating a detector count.

The omni-directional detectors are mounted to view radially outwards from the earth with the central axis of each detector oriented 9º from the –X direction toward the –Z direction (see Figure 2.1.1) parallel to the viewing axis of the 0º MEPED proton and electron detector telescope units.

With the exception of the field of view subtended by the hemispheric shell, the detector assembly is surrounded by tungsten shielding to reduce the detector response to energetic particles incident from directions other than through the dome.

The absorber shell for detectors P6 and P7 encompass about a 120º field as viewed from the solid-state detector (see Figure 3.4.1) while the absorber shell for detectors P8 and P9 encompass about a 180º field, that is a full hemisphere, as viewed from the solid-state detector (Figure 3.4.2). It should be also noted that the tungsten shielding surrounding the solid-state detectors in P8 and P9 is the same thickness as the tungsten dome so that, unlike P6 and P7, the proton energy required to reach the detector is independent of the direction of arrival, neglecting the presence of the spacecraft structure and additional absorbing material.

Table 3.4.1 lists the detector designation, shell thickness, shell material, and minimum proton energy required to penetrate the shell or the tungsten shielding and produce a detector response.

Table 3.4.1
Minimum Detectable Proton Energies

Detector	Shell Material	Thickness (mm)	Minimum Energy to Penetrate the Shell and be Detected	Minimum Energy to Penetrate the Shielding and be Detected
P6	Aluminum	1.37	16 MeV	70 MeV
P7	Copper	2.13	35 MeV	70 MeV
P8	Tungsten	4.57	70 MeV	70 MeV
P9	Tungsten	14.96	140 MeV	140 MeV

(*Note* that there is an ambiguity between the *omni-directional* detector P6 and the highest energy channel, P6, in the proton detector *telescope* system. The ambiguity is removed, since the proton detector telescope channels always have a prefix “0” or “90”).

The maximum proton energy sensed by the omni-directional detectors is determined by the requirement that the protons, after passing through all the absorbing material, lose 2.5 MeV of energy in the solid-state detector in order to be counted. The energy of the proton entering the solid-state detector, even after passing through the various absorbing materials, is usually sufficient for it to pass entirely through the detector, and the energy actually deposited in the detector decreases with increasing proton energy. As the particle energy increases, the energy lost in the silicon detector eventually becomes less than 2.5 MeV, and that proton is not longer counted. The proton path length through the detector is variable, however, and can range from as long as 10 mm for a proton that enters the detector obliquely, to as short as 3 mm for a proton that enters normal to the detector face. This variation in path lengths and corresponding energy loss in the detector leads to a wide variation in the maximum proton energy that will be detected. Table 3.4.2 lists the maximum proton energies detectable by each of the four omni-directional detectors under four conditions; for a proton incident through the shell directly along the central axis of the detector, for a proton entering through the shell but at 60º to the central axis and passing obliquely through the solid-state detector, for a proton penetrating the tungsten shielding from below the detector on a path along the central axis, and for a proton penetrating the tungsten shielding at an angle of 120º to the central axis. Note that for detectors P8 and P9 the first two cases are identical to the last two.

While there is a wide variation in the maximum detectable proton energy as a function of the particle angle of incidence, a reasonable assumption for the maximum energy, valid for all four omni-directional detectors and all angles of incidence, is about 500 MeV.

Table 3.4.2
Maximum Detectable Proton Energies

Detector	0º Incidence Through Shell	60º Incidence Through Shell	180º Incidence Through Shielding	120º Incidence Through Shielding
P6	215 MeV	1100 MeV	235 MeV	1110 MeV
P7	220 MeV	1100 MeV	235 MeV	1110 MeV
P8	235 MeV	1110 MeV	235 MeV	1110 MeV
P9	275 MeV	1130 MeV	275 MeV	1130 MeV

The geometric factors (transfer functions) needed to convert the omni-directional solid-state detector responses to proton flux values are not uniquely defined, being very dependent upon proton energy and the angular distribution of the proton population. Appendix F outlines procedures for recovering proton number fluxes from the omni-directional sensor responses for two angular distributions of particles that are typically encountered.

3.5 Timing of MEPED Data Accumulation Relative to Time Tag

Table 3.5.1 lists the accumulation periods for each of the 22 MEPED sensor channels and the accumulation start and end times relative to the data point time tag in the archive data record.

Table 3.5.1

Detector Channel Identification	Accumulation Period (sec)	Accumulation Interval Relative to Archive Record Time Tag
0 E1	1.0	– 1.80 s to – 0.80 s
0 E2	1.0	– 1.80 s to – 0.80 s
0 E3	1.0	– 1.80 s to – 0.80 s
0 P1	1.0	– 1.80 s to – 0.80 s
0 P2	1.0	– 1.80 s to – 0.80 s
0 P3	1.0	– 1.80 s to – 0.80 s
0 P4	1.0	– 1.80 s to – 0.80 s
0 P5	1.0	– 1.80 s to – 0.80 s
0 P6	1.0	– 1.80 s to – 0.80 s
90 E1	1.0	– 0.80 s to + 0.20 s
90 E2	1.0	– 0.80 s to + 0.20 s
90 E3	1.0	– 0.80 s to + 0.20 s
90 P1	1.0	– 0.80 s to + 0.20 s
90 P2	1.0	– 0.80 s to + 0.20 s
90 P3	1.0	– 0.80 s to + 0.20 s
90 P4	1.0	– 0.80 s to + 0.20 s
90 P5	1.0	– 0.80 s to + 0.20 s
90 P6	1.0	– 0.80 s to + 0.20 s
Omni-directional P6	2.0	– 1.80 s to + 0.20 s
Omni-directional P7	2.0	– 1.80 s to + 0.20 s
Omni-directional P8	4.0	– 3.80 s to + 0.20 s
Omni-directional P9	4.0	– 3.80 s to + 0.20 s

3.6 MEPED In-Flight Calibration

The MEPED instrument undergoes a weekly in-flight calibration procedure. This procedure involves stimulating each of the MEPED sensor charge-sensitive-amplifier, threshold-discriminator chain with pulses whose amplitudes increase linearly with time. By noting the time when the output of each sensor energy channel begins to respond to this stimulus, the threshold discriminator level and corresponding energy in keV is checked. By observing the change in the stimulus pulse amplitude required to completely “turn on” the lowest energy level of each sensor, the noise level of that solid-state detector is also determined.

An in-flight calibration lasts for 384 seconds and while it is in progress an appropriate status flag is set. During that time MEPED data should be ignored.

Procedures and software to analyze the in-flight calibration data from the MEPED suite of sensors have been developed at SEC and the reduced calibration data are included in the history of the instrument performance.

4 Polar Orbiting Environmental Satellite (POES) Archive Data File

This section describes the data contained in the archive record. An archive record comprises 32 seconds of data, including a full set of orbital parameters provided every 8 seconds (sub-satellite latitude and longitude every 2 seconds), 16 full data collection cycles from the TED, the MEPED electron and proton telescope instruments, the P6 and P7 omni-directional detector sensors, and 4 full cycles of the P8 and P9 omni-directional detector sensors. A full set of background data from the 8 TED detector systems is included once in the 32 second archive record. Finally, a selected portion of the SEM-2 instrument status, temperature, and system health data as well as data quality and ancillary information are included.

Appendix D provides a C language program and Appendix E a FORTRAN language program that can be used to access the archive data. In this document, two dimensional arrays will be referred to as (i,j) for FORTRAN and as [j] [i] for C. The i and j values differ in position because of the difference in the way C and FORTRAN deal with column/row majority in two dimensional arrays. With the exception of the array *tedback*, described in Section 2.4.4, the 'j' dimension in a two dimensional array is either 4 or 16; 4 for arrays that contain values for every 8 seconds, and 16 for arrays that have values for every 2 seconds of data. In both cases the arrays contain data spanning 32 seconds. In this section of the document, Tables number the dimension 'i' beginning with 1. In 'C' the index would start from 0.

In general, the data in the archive record can be divided into five types: instrument status and health information, time and orbit parameter information, MEPED sensor data, TED data, and data quality and ancillary information.

The data in each of these five categories that are returned by the program that reads the archive record are described in detail.

4.1 Instrument Status and Health

Instrument status and health information is returned from the read program in two arrays. The first array is named *status*, which contains 10 elements, and the second is named *analog* and contains 17 elements.

4.1.1 *status* Array

The contents of the *status* array are summarized in Table 4.1.1. This array occurs once per archive record and is applicable to the entire 32 seconds of data.

Table 4.1.1
Contents of the *status* Array

Array Element	Descriptor	Range of Data Value	Interpretation
1	MEPED On-Off	0 or 1	0 for MEPED off, 1 for MEPED on
2	TED On-Off	0 or 1	0 for TED off, 1 for TED on
3	MEPED IFC	0 or 1	1 if MEPED in-flight calibration in progress, 0 if in-flight calibration not in progress
4	TED IFC	0 or 1	1 if TED in-flight calibration in progress, 0 if in-flight calibration not in progress
5	TED electron discriminator level	0 to 3	see below
6	TED proton discriminator level	0 to 3	see below
7	TED electron HV supply	0 to 7	see below
8	TED proton HV supply	0 to 7	see below
9	μ processor in use	0 or 1	0 if micro-processor A is on 1 if micro-processor B is on
10	μ processor error flag	0 or 1	0 if no processor error detected 1 if a processor error detected

The pulse-height discriminator levels for the TED electron and TED proton detector systems can be independently changed to one of four values by ground command. This was done in case electronic noise produced spurious counts that a higher pulse height discrimination level would suppress. Normally the pulse height discriminator levels for both the electron and proton detector systems are set to the lowest level (zero).

The high voltage applied to the Channeltron particle detectors in the TED electron and proton detector systems can be independently changed to one of eight levels by ground command. This is done to compensate for gain degradation in the Channeltron particle detectors. This degradation can, over time, be severe enough that the pulse outputs from these detectors would fall below the threshold set by the pulse height discriminators. Increasing the high voltage on the Channeltron detectors increases their gain to overcome any degradation. The Channeltron high voltages for both the electron and proton detector systems are initially set to the lowest voltage state.

4.1.2 *analog* Array

The contents of the *analog* array are summarized in Table 4.1.2. This array occurs once per archive record and is applicable to the entire 32 seconds of data.

Table 4.1.2
Contents of the *analog* Array

Array Element	Descriptor	Nominal Value	Interpretation
1	TED +5 V monitor	+ 5.0 V	TED electronics +5 V monitor
2	TED electron Channeltron high voltage monitor	+ 2600 V	Voltage monitor dependent upon commandable high voltage setting
3	TED proton Channeltron high voltage monitor	+ 1700 V	Voltage monitor dependent upon commandable high voltage setting
4	TED sweep voltage monitor	variable 0 to + 500 V	Electrostatic analyzer plate voltage monitor
5	TED temperature	variable –20 to + 20 ºC	TED instrument temperature
6	MEPED +5 V monitor	+ 5.0 V	MEPED electronics +5 V monitor
7	MEPED circuit temperature	variable –20 to + 20 ºC	MEPED circuit board temperature
8	MEPED omni-directional detector bias voltage	+ 650 V	Omni-directional solid-state detector bias voltage
9	MEPED proton telescope detector bias voltage	+ 60 V	Proton telescope solid-state detector bias voltage
10	MEPED electron telescope detector bias voltage	+ 150 V	Electron telescope solid-state detector bias voltage
11	MEPED proton telescope detector temperature	variable –20 to + 20 ºC nominal 0 ºC	Proton telescope, solid-state detector temperature
12	MEPED electron telescope detector temperature	variable –20 to + 20 ºC nominal 0 ºC	Electron telescope solid-state detector temperature
13	MEPED omni-directional detector temperature	variable –20 to + 20 ºC nominal 0 ºC	Omni-directional solid-state detector temperature
14	DPU + 5 V	+ 5.0 V	Data Processing Unit

Array Element	Descriptor	Nominal Value	Interpretation
	monitor		+5 V monitor
15	processor A +5 V monitor	+ 5.0 V	processor A monitor + 5 V if processor A is on
16	processor B +5 V monitor	0.0 V	processor B monitor 0 V if processor B is off
17	DPU temperature	variable –20 to + 20 ºC	Data processing unit temperature

4.2 Timing and Orbital Information

Timing and orbital information are returned from the read program in three arrays. The first is called ihd, which contains 6 elements, and the second is named head, and contains 27 elements. Both ihd and head are returned four times for each 32-second archive record or every 8 seconds. The third array is called ssLoc, and has 2 elements; it is returned sixteen times for each 32 second record or every 2 seconds.

4.2.1 ihd Array, dimensioned (6,4) in FORTRAN, [4][6] in ‘C’

The contents of the ihd array are summarized in Table 4.2.1. The entries are for the first 2 seconds of each 8-second iteration of ‘j’.

Table 4.2.1
Contents of the jth iteration of the ihd Array

i	Descriptor	Nominal Value	Interpretation
1	satellite ID	Satellite Dependent	NOAA-15 has ID of 4 NOAA-16 has ID of 2
2	year	>1998	The 4 digit year
3	day of year	1 to 366	The 3 digit day of the year
4	millisecond of day	0 to 86399000	Milliseconds of the UT day at the start of the 8 second data block
5	satellite altitude	850	satellite altitude in km
6	orbit number	up to 65335	orbit number incremented at northbound equator crossing

4.2.2 head Array, dimensioned (27,4) in FORTRAN, [4][27] in ‘C’

The contents of the head array are summarized in Table 4.2.2. The entries are for the first 2 seconds of each 8-second iteration of 'j'.

The majority of the entries in head are calculated from a magnetic field model using knowledge of both the orbit and the three-axis stabilized orientation of the satellite. For the NOAA/POES satellite data processing these calculations are done using a current International Geomagnetic Reference Field (IGRF) model for the epoch midway through the year the data were acquired. For example, all magnetic orbital data during the year 2000 were calculated using the IGRF 2000.5 model. The geocentric radius of the satellite orbit is also updated once a year using the ephemeris from January 1 of that year. For NOAA-15 in 2000, the geocentric distance to the satellite varied between 7188 and 7204 km. For purposes of the magnetic calculations the orbit was assumed circular around the earth center with a radius of 7195 km. It is planned that the magnetic calculations will be updated once a year using the new IGRF model and satellite orbit information.

The determination of the "foot-of-the-field-line" (*fofl*) location – the geographic point where the magnetic field line threading the satellite intersects 120 km in altitude above the earth, where precipitating auroral particles detected at the satellite actually enter the atmosphere – is done by tracing in 1 km steps (using a program kindly provided by Joseph Cain, private communication, 1983) along the magnetic field direction calculated from the IGRF model until the 120 km altitude is reached. The hemisphere, northern or southern, for the *fofl* location is based upon whether the satellite is north or south of the geomagnetic equator.

The IGRF model is also used to calculate the three components (positive eastward, positive southward, and positive radially outward) of the magnetic field vector at the satellite. The magnetic field direction, together with knowledge of the viewing directions of the SEM-2 sensors relative to the orientation of the three-axis stabilized spacecraft, permits calculation of the angle between the central axis of each sensor field of view and the magnetic field. This angle is converted to the magnetic pitch angle of the charged particles sensed by the various detectors, the convention being that the pitch angle is the angle between the particle velocity vector and the magnetic field direction.

The magnetic field vector at the *fofl* location is also calculated using the IGRF model. The pitch angles (p/a) of the particles detected at the satellite are transformed to their values at the *fofl* location using the ratio of magnetic field strength at the satellite to that at the *fofl*. If the particles detected at the satellite magnetically mirror above the atmosphere, the *fofl* pitch angle is set to a "pad" value (see Table 4.2.2).

The McIlwain *L*-value at the satellite location is calculated from the INVAR FORTRAN program that is available from the National Space Science Data Center at the Goddard Space Flight Center in Greenbelt, MD. INVAR uses the IGRF model and the *L*-value calculations are updated once a year with the updated IGRF model. If the calculated *L*-value is greater than 20.0, the *L*-value is set to a "pad" value (see Table 4.2.2).

The dipole magnetic latitude and magnetic longitude at the *fofl* location are calculated using the position of the north magnetic pole that is returned by the INVAR routine. This position is updated once a year for the archive data processing.

The corrected magnetic latitude at the *fofl* location is computed using the routine written by Papitashvili and Papitashvili following the procedure given by *Gustafsson, et al.* (1992). This routine also uses the IGRF magnetic field model, and the corrected magnetic latitude calculations are updated once a year.

The eccentric magnetic local time at the *fofl* location is calculated following the procedures set down by *Cole*, (1963) and *Fraser-Smith*, (1987). The calculation is updated once a year using the current IGRF model field. The eccentric magnetic local time is returned as an angle from 0º to 360º, with 0º being magnetic midnight, and the angle incremented by 15º per hour magnetic local time.

The local time is calculated at the sub-satellite location by assuming the local time is the Universal Time incremented by one hour for every 15º east of the Greenwich meridian. The equation of time is not used in the calculation, so this variable is only approximately the true local solar time at the sub-satellite point. The local time is also returned as an angle from 0º to 360º with 0º being midnight.

The calculations that involve the magnetic field are not performed in full for each data point in the archive processing; instead a table is created once a year with all the magnetically controlled orbital parameters calculated for a grid of geographic latitudes and longitudes. A cubic interpolation is then used to compute orbital parameters for each data point, given the sub-satellite location along the orbit. The errors introduced by this procedure are negligible.

Table 4.2.2
Contents of the *j*th iteration of the *head* Array

i	Descriptor	Nominal Value Or Range	Comment
1	satellite inclination	98.6º	
2	sub-satellite latitude	–90.º to +90.º	
3	sub-satellite longitude	0.º to 360.º	
4	radial component of ***B*** at the satellite	–50000. to +50000.	nanoTesla
5	east component of ***B*** at the satellite	–50000. to +50000.	nanoTesla
6	south component of ***B*** at the satellite	–50000. to +50000.	nanoTesla
7	scalar value of *B* at the satellite	+50000.	nanoTesla
8	0º TED p/a at the satellite	0º to +180º	
9	30º TED p/a at the satellite	0º to +180º	
10	0º MEPED p/a at the satellite	0º to +180º	
11	90º MEPED p/a at the satellite	0º to +180º	
12	radial component of ***B*** at the *fofl*	–50000. to +50000.	nanoTesla
13	east component of ***B*** at the *fofl*	–50000. to +50000.	nanoTesla
14	south component of ***B*** at the *fofl*	–50000. to +50000.	nanoTesla
15	scalar value of *B* at the *fofl*	+60000.	nanoTesla
16	0º TED p/a at the *fofl*	0º to +180º	–999.0 if particles mirror above atmosphere
17	30º TED p/a at the *fofl*	0º to +180º	set to –999.0 if particles mirror above atmosphere
18	0º MEPED p/a at the *fofl*	0º to +180º	set to –999.0 if particles mirror above atmosphere
19	90º MEPED p/a at the *fofl*	0º to +180º	set to –999.0 if particles mirror above atmosphere
20	*fofl* geographic latitude	–90.º to +90.º	
21	*fofl* geographic longitude	0.º to 360.º	
22	*fofl* geomagnetic latitude	–90.º to +90.º	
23	*fofl* geomagnetic longitude	0.º to 360.º	
24	McIlwain *L*-value	0.9 to 20.0	set to –999.0 if *L* > 20.0
25	corrected magnetic latitude	–90.º to +90.º	
26	sub-satellite local time	0.º to 360.º	

i	Descriptor	Nominal Value Or Range	Comment
27	fofl magnetic local time	0.º to 360.º	

4.2.3 *ssLoc* Array, dimensioned (2,16) in FORTAN, [16][2] in 'C'

The contents of the array called *ssLoc* are summarized in Table 4.2.3. The higher temporal resolution, 2-second orbital data are included to assist in interpolating the lower resolution orbital data in the *head* array should it be required.

Table 4.2.3
Contents of the j^{th} iteration of the Array *ssLoc*

i	Descriptor	Nominal Value or Range
1	sub-satellite latitude	–90.º to +90.º
2	sub-satellite longitude	0.º to 360.º

4.3 MEPED Sensor Data

The MEPED sensor data are contained in 3 arrays returned from the archive record, providing data with a 2-second time resolution. The first array is called *mep0* and contains data from both the 0º proton and 0º electron telescopes. The next array is called *mep90* and contains data from both the 90º proton and 90º electron telescopes, and the third array is named *mepOmni* and contains data from the four omni-directional solid-state detectors.

4.3.1 *mep0* and *mep90* Arrays, dimensioned (9,16) in FORTRAN, [16][9] in 'C'

The contents of the *mep0* and *mep90* arrays are summarized in Tables 4.3.1a and 4.3.1b.

Table 4.3.1a
Contents of the j^{th} iteration of the Array *mep0*

i	Descriptor	Valid Range	Comment
1	0P1	0. to 1998848.0	set to –999.0 for missing data
2	0P2	0. to 1998848.0	set to –999.0 for missing data
3	0P3	0. to 1998848.0	set to –999.0 for missing data
4	0P4	0. to 1998848.0	set to –999.0 for missing data
5	0P5	0. to 1998848.0	set to –999.0 for missing data
6	0P6	0. to 1998848.0	set to –999.0 for missing data
7	0E1	0. to 1998848.0	set to –999.0 for missing data
8	0E2	0. to 1998848.0	set to –999.0 for missing data

i	Descriptor	Valid Range	Comment
9	0E3	0. to 1998848.0	set to –999.0 for missing data

Table 4.3.1b
Contents of the j^{th} iteration of the Array *mep90*

i	Descriptor	Valid Range	Comment
1	90P1	0. to 1998848.0	set to –999.0 for missing data
2	90P2	0. to 1998848.0	set to –999.0 for missing data
3	90P3	0. to 1998848.0	set to –999.0 for missing data
4	90P4	0. to 1998848.0	set to –999.0 for missing data
5	90P5	0. to 1998848.0	set to –999.0 for missing data
6	90P6	0. to 1998848.0	set to –999.0 for missing data
7	90E1	0. to 1998848.0	set to –999.0 for missing data
8	90E2	0. to 1998848.0	set to –999.0 for missing data
9	90E3	0. to 1998848.0	set to –999.0 for missing data

4.3.2 *mepOmni* Array, dimensioned (4,16) in FORTRAN, [16][4] in 'C'

The contents of the *mepOmni* array are summarized in Table 4.3.2. Note that the P8 and P9 sensor data are subcommutated and valid data for each are contained only in alternate 2-second repetitions of *mepOmni.*

Table 4.3.2
Contents of the j^{th} iteration of the Array *mepOmni*

i	Descriptor	Valid Range	Comment
1	P6	0. to 1998848.0	set to –999.0 for missing data
2	P7	0. to 1998848.0	set to –999.0 for missing data
3	P8	0. to 1998848.0	set to –999.0 for missing data data valid only for 1st, 3rd, 5th, 7th, 9th, 11th, 13th, and 15th 2-second intervals
4	P9	0. to 1998848.0	set to –999.0 for missing data data valid only for 2nd, 4th, 6th, 8th, 10th, 12th, 14th, and 16th 2-second intervals

4.4 TED Sensor Data

The TED sensor data are contained in six arrays returned from the 32-second archive record. Two arrays, called *ted0* and *ted30*, contain full data sets from both the 0º TED and 30º TED sensors that are gathered during every 2-second instrument cycle. The arrays called *ted0s* and *ted30s* contain the sensor observations that are obtained in selected energy bands on a lower duty cycle (see Section 2.5). The fifth array, named *tedfx*, contains the various energy flux moments calculated from the data every 2-seconds, and the sixth array, called *tedback*, contains the TED sensor background data.

4.4.1 *ted0* and *ted30* Arrays, dimensioned (8,16) in FORTRAN, [16][8] in 'C'

The contents of the *ted0* and *ted30* arrays are summarized in Tables 4.4.1a and 4.4.1b. An explanation of the elements in these two arrays is in Sections 2.2 and 2.4.

Table 4.4.1a
Contents of the *j*th iteration of the Array *ted0*

i	Descriptor	Valid Range	Comment
1	0º, 50 – 1000 eV electron integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
2	0º, 50 – 1000 eV proton integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
3	0º, 1000 – 20000 eV electron integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
4	0º, 1000 – 20000 eV proton integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
5	energy band containing maximum in 0º electron flux	1 to 16	set to –999.0 for missing data
6	energy band containing maximum in 0º proton flux	1 to 16	set to –999.0 for missing data
7	0º electron sensor response in the "maximum" energy band	0. to 1998848.0	set to –999.0 for missing data
8	0º proton sensor response in the "maximum" energy band	0. to 1998848.0	set to –999.0 for missing data

Table 4.4.1b
Contents of the j^{th} iteration of the Array *ted30*

i	Descriptor	Valid Range	Comment
1	30º, 50 – 1000 eV electron integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
2	30º, 50 – 1000 eV proton integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
3	30º, 1000 – 20000 eV electron integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
4	30º, 1000 – 20000 eV proton integrated energy flux	0. to 1998848.0	set to –999.0 for missing data
5	energy band containing maximum in 30º electron flux	1 to 16	set to –999.0 for missing data
6	energy band containing maximum in 30º proton flux	1 to 16	set to –999.0 for missing data
7	30º electron sensor response in the "maximum" energy band	0. to 1998848.0	set to –999.0 for missing data
8	30º proton sensor response in the "maximum" energy band	0. to 1998848.0	set to –999.0 for missing data

4.4.2 *ted0s* and *ted30s* Arrays, dimensioned (8,4) in FORTRAN, [4][8] in 'C'

The contents of the arrays *ted0s* and *ted30s* are summarized in Tables 4.4.2a and 4.4.2b. These arrays contain the sensor responses in the four preselected energy bands that are returned from the TED instrument on a lower duty cycle than the 2-second instrument cycle time. An explanation of the elements in these two arrays is in Section 2.5. If an element has missing data, the value returned from the archive record is set to a "pad" value. Note that 0º and 30º proton data are not taken during the fifteenth or sixteenth 2-second interval in the 32-second record, as sensor background data are telemetered instead.

Table 4.4.2a
Contents of the *j^{th}* iteration of the Array *ted0s*

i	Descriptor	Valid Range	Comment
1	0º electron sensor response energy band 4	0. to 1998848.0	data taken in 1st, 5th, 9th, and 13th 2-second interval
2	0º electron sensor response energy band 8	0. to 1998848.0	data taken in 1st, 5th, 9th, and 13th 2-second interval
3	0º electron sensor response energy band 11	0. to 1998848.0	data taken in 1st, 5th, 9th, and 13th 2-second interval
4	0º electron sensor response energy band 14	0. to 1998848.0	data taken in 1st, 5th, 9th, and 13th 2-second interval
5	0º proton sensor response energy band 4	0. to 1998848.0	data taken in 3rd, 7th, and 11th 2-second interval
6	0º proton sensor response energy band 8	0. to 1998848.0	data taken in 3rd, 7th, and 11th 2-second interval
7	0º proton sensor response energy band 11	0. to 1998848.0	data taken in 3rd, 7th, and 11th 2-second interval
8	0º proton sensor response energy band 14	0. to 1998848.0	data taken in 3rd, 7th, and 11th 2-second interval

Table 4.4.2b
Contents of the *j^{th}* iteration of the Array *ted30s*

i	Descriptor	Valid Range	Comment
1	30º electron sensor response energy band 4	0. to 1998848.0	data taken in 2nd, 6th, 10th, and 14th 2-second interval
2	30º electron sensor response energy band 8	0. to 1998848.0	data taken in 2nd, 6th, 10th, and 14th 2-second interval
3	30º electron sensor response energy band 11	0. to 1998848.0	data taken in 2nd, 6th, 10th, and 14th 2-second interval
4	30º electron sensor response energy band 14	0. to 1998848.0	data taken in 2nd, 6th, 10th, and 14th 2-second interval
5	30º proton sensor response energy band 4	0. to 1998848.0	data taken in 4th, 8th, and 12th 2-second interval
6	30º proton sensor response energy band 8	0. to 1998848.0	data taken in 4th, 8th, and 12th 2-second interval
7	30º proton sensor response energy band 11	0. to 1998848.0	data taken in 4th, 8th, and 12th 2-second interval
8	30º proton sensor response energy band 14	0. to 1998848.0	data taken in 4th, 8th, and 12th 2-second interval

4.4.3 *tedfx* Array, dimensioned (7,16) in FORTRAN, [16][7] in 'C'

The contents of the array named *tedfx* is summarized in Table 4.4.3. The numerical values in *tedfx* are calculated from the telemetered electron and proton energy flux information found in the arrays *ted0* and *ted30*, using the laboratory calibrations of the instrument sensitivities and the procedures outlined in Section 2.3. Valid omni-directional energy fluxes may range from 0.0 to as high 600.0 ergs cm^{-2} sec^{-1} (equivalent to units of mW m^{-2}), with default values as noted in the table.

Table 4.4.3
Contents of the j^{th} iteration of the Array *tedfx*

i	Meaning of element units of mW m^{-2}	Assigned value in the case of missing data	Assigned value in the case of no TED sensor viewing particles entering the atmosphere
1	50-1000 eV electron omni-directional flux	-990.	-996.
2	1000-20000 eV electron omni-directional flux	-991.	-996.
3	50-1000 eV proton omni-directional flux	-992.	-996.
4	1000-20000 eV proton omni-directional flux	-993.	-996.
5	50-20000 eV electron omni-directional flux	-994.	-996.
6	50-20000 eV proton omni-directional flux	-995.	-996.
7	50-20000 eV proton plus electron omni-directional flux	-997.	-996.

4.4.4 *tedback* Array, dimensioned (2,4) in FORTRAN, [4][2] in 'C'

The contents of the array named *tedback* is summarized in Table 4.4.4. The index, i, that runs from 1 to 2 signifies whether the sensor background information is for the 0º TED detectors (index equal to 1) or for the 30º TED detectors (index equal to 2). The index, j, that runs from 1 to 4 references one of the four TED sensors at that orientation. The *tedback* array is returned once for each 32-second archive record.

Table 4.4.4
Contents of the Array *tedback*

i, j	Descriptor	Valid Range	Assigned value in the case of missing data
1,1	0º, high energy electron sensor background	0. to 1998848.0	-999.0
1,2	0º, low energy electron sensor background	0. to 1998848.0	-999.0
1,3	0º, high energy proton sensor background	0. to 1998848.0	-999.0
1,4	0º, low energy proton sensor background	0. to 1998848.0	-999.0
2,1	30º, high energy electron sensor background	0. to 1998848.0	-999.0
2,2	30º, low energy electron sensor background	0. to 1998848.0	-999.0
2,3	30º, high energy proton sensor background	0. to 1998848.0	-999.0
2,4	30º, low energy proton sensor background	0. to 1998848.0	-999.0

4.5 Data Quality and Ancillary Information

Data quality and ancillary information for each 32-second archive record are contained in the arrays called *qual*, *minor*, and *mdf*, and in three scalar numbers named; *cSum*, *cSumFlag*, and *major*.

The variable *cSum* refers to a checksum that is calculated by the DPU in the SEM-2 and inserted into the telemetry stream once each 32-seconds. The checksum telemetered from the satellite once each 32-seconds is the sum, modulo 256, of the values of the 640 SEM-2 data words that the DPU processed and passed into the Tiros Information Processor (TIP) data stream during the immediately previous 32-second major frame of data. This allows a cross check between the sum, modulo 256, of the 640 data words actually received and the sum calculated by the DPU. A disagreement between the sum calculated on the ground and that calculated by the DPU indicates that there is one or more telemetry bit errors in the 32-second TIP major frame received on the ground. The value of *cSum* is the checksum as received on the ground. Beginning with archive data processed in November, 2002 if the checksum as calculated by the on-board DPU is not available either because of a data gap or missing data, the value of cSum is set to 255 and the value of cSumFlag set accordingly.

The variable *cSumFlag* indicates whether the checksum as calculated in the archive processing from the data words received on the ground agrees with the checksum value in the telemetry stream. If there is a data gap, the telemetered checksum calculated for the last 32-second major frame of data received will be missing and the comparison cannot be made. The value of *cSumFlag* may be 0, 1, or 2 with the following meaning.

cSumFlag = 0, telemetered and calculated checksums agree, no bit errors present,

cSumFlag = 1, telemetered and calculated checksums disagree, bit errors likely,

cSumFlag = 2, a comparison could not be made because of data gaps.

The value of *major* is a major frame number that can range from 0 to 7. The major frame number is introduced into the TIP data stream by the satellite data handling system. The major frame number is necessary for decoding certain housekeeping data that are highly subcommutated. The major frame number is not required for the interpretation and the use of any SEM-2 sensor data.

4.5.1 *qual* Array

The array *qual* contains sixteen 2-byte integer elements for each 32-second archive record, and each entry provides data quality information about the data in the corresponding 2-second dataset. Individual bits in each entry of *qual* are set to either 0 or 1 to indicate the result of various data quality tests imposed on the data contained in each 2-second set. Only the 8 least significant bits of each integer word are used. Table 4.5.1 lists the meaning of each of the least significant bits.

Table 4.5.1
Contents of Array *qual*

Bit Location	Binary Value	Meaning
0 (lsb)	1	Not used
1	2	Not used
2	4	Not used
3	8	TED energy fluxes corrected for background (Sect. 2.7)
4	16	MEPED electron data not sensible (Sect. 3.3)
5	32	Inconsistency in TED 4-spectrum data (Sect. 2.8)
6	64	Inconsistency in TED energy flux moment (Sect. 2.8)
7 (msb)	128	Some data missing within the 2-second record

4.5.2 *minor* Array

The array called *minor* contains 16 values of the minor frame count that is introduced into the telemetered data stream from the satellite by the TIP. A TIP minor frame is 0.1 seconds long. There are 20 TIP minor frames making up a SEM-2 2-second dataset and 320 minor frames in a 32-second archive record that corresponds to a TIP major frame. The *minor* array contains the minor frame value at the start of each of the sixteen 2-second datasets making up an archive record. The sequence of values in *minor* should **always** be 000, 020, 040, 060, 080, 100, 120, 140, 160, 180, 200, 220, 240, 260, 280, and 300.

The data in minor are not absolutely required for the interpretation and use of any SEM-2 sensor data. These data are useful, however, to confirm the proper ordering of the MEPED omni-directional P8 and P9 data that are subcommutated. Data from the P8 sensor are read out during minor frame numbers 000, 040, 080, 120, 160, 200, 240, and 280, while data from the P9 sensor occur at minor frame numbers 020, 060, 100, 140, 180, 220, 260, and 300.

4.5.3 *mdf* Array, dimensioned (40,16) in FORTRAN, [16][40] in ‘C’

The processing of data downlinked from the POES satellite can occasionally suffer the loss of bit synchronization when the signal is poor. When this occurs the data processing software inserts pad values into the SEM-2 data stream. The numerical value of the inserted pad value is ambiguous because that value may also normally appear in the data stream. To remove this ambiguity, the processing software sets a flag indicating whether or not a pad value was inserted in each data word in the SEM-2 data stream that is passed to the Space Environment Center. The SEM-2 instrument was allocated two digital words in the POES TIP minor frame format. The minor frame cadence is one minor frame every 0.1-second, or 40 digital data words every 2-seconds. The array *mdf* has 40 elements, corresponding to each of those 40 data words, and is repeated sixteen times for a 32-second archive record. Each element has been cross-referenced to the appropriate SEM-2 data channel. Both the C language and FORTRAN language programs that read the archive record check the contents of the *mdf* array and, if an element in that array is set to 1 (indicating that a pad value had been inserted) the software will set the appropriate data element to the default missing data value which is –999.0.

Acknowledgements

The contribution to the SEM-2 project by Dr. Robert Bushnell, The SEM-2 Program Manager from 1989 until 1997 and Mr. Alexander (Bob) Muckle, the Program Manager since 1997 is gratefully acknowledged. The support of Mr. Richard Grubb, who has contributed in countless ways to the Space Environment Monitors that are included in both the GOES and POES satellites over the past three decades, is also acknowledged with pleasure. The contributions of Mr. William Barrett, Mr. Kelvin Fedrick, and Mr. Paul Packard to the assimilation of the SEM-2 data stream provided from the central processing facility at NESDIS were very important as were Mr. Barrett's oversight of the SEM-2 DPU design. Ms. Susan Sahm contributed significantly to the SEM-2 data processing program that created the archive file. Mr. Lawrence Puga did a masterful job of editing this document. Finally, the Space Environment Center would like to thank the technical and management staff at Panametrics, Inc., for the high quality design, construction, and testing of the SEM-2 instruments that was so critical to the success of the program.

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