NOAA Technical Memorandum ERL SEL-77

TIROS/NOAA SATELLITES SPACE ENVIRONMENT MONITOR ARCHIVE TAPE DOCUMENTATION - 1988 UPDATE

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Space Environment Laboratory
Boulder, Colorado
May 1988

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UNITED STATES
DEPARTMENT OF COMMERCE

C.William Verity
Secretary

NATIONAL OCEANIC AND
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Environmental Research
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TIROS Satellites and Satellite Meteorology

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TIROS/NOAA Satellites Space Environment Monitor Archive Tape Documentation – 1988 Update

V. J. HILL, D. S. EVANS, H. H. SAUER

ABSTRACT

TIROS/NOAA satellite archive tapes containing data obtained with the Medium Energy Proton and Electron Detector (MEPED), High Energy Proton and Alpha Particle Detector (HEPAD), and Total Energy Detector (TED) are described. Descriptions of the data include orbital and housekeeping details and the information needed to decode and understand the data. Specifications of the data channels are supplied, with the timing information needed to convert the data to usable information. Description of the archive tape format gives the information needed to read the tape and unpack the data. Appendices supply the retrieval routines used by the Space Environment Services Center in Boulder.

1.0 Introduction

The TIROS/NOAA (Television and Infrared Observation Satellite/National Oceanic and Atmospheric Administration) satellites carry a set of instruments to detect and monitor the influx of ions and electrons into the upper atmosphere as a result of solar and magnetospheric activity. The set of instruments is called the Space Environment Monitor (SEM). SEM data are received in near-real time at the Space Environment Services Center (SESC) of the Space Environment Laboratory in Boulder, Colorado. The data are used operationally by SESC and are also archived on magnetic tape. Tape copies can be obtained from:

National Oceanic & Atmospheric Administration
National Environmental Satellite, Data, and Information Service
National Geophysical Data Center E/GC2
325 Broadway
Boulder, Colorado 80303, U.S.A.

The TIROS/NOAA archive tapes contain orbital and housekeeping information, and data from the three SEM instruments:

1. The MEPED: Medium Energy Proton and Electron Detector.

2. The HEPAD: High Energy Proton and Alpha Particle Detector.

3. The TED: Total Energy Detector.

Five TIROS/NOAA satellites have been launched, and four more spacecraft are scheduled in the series. The lifetime of each satellite is about 2 years; at most, two satellites are operational at any time. Figure 1.1 shows the location of the SEM instruments on the spacecraft.

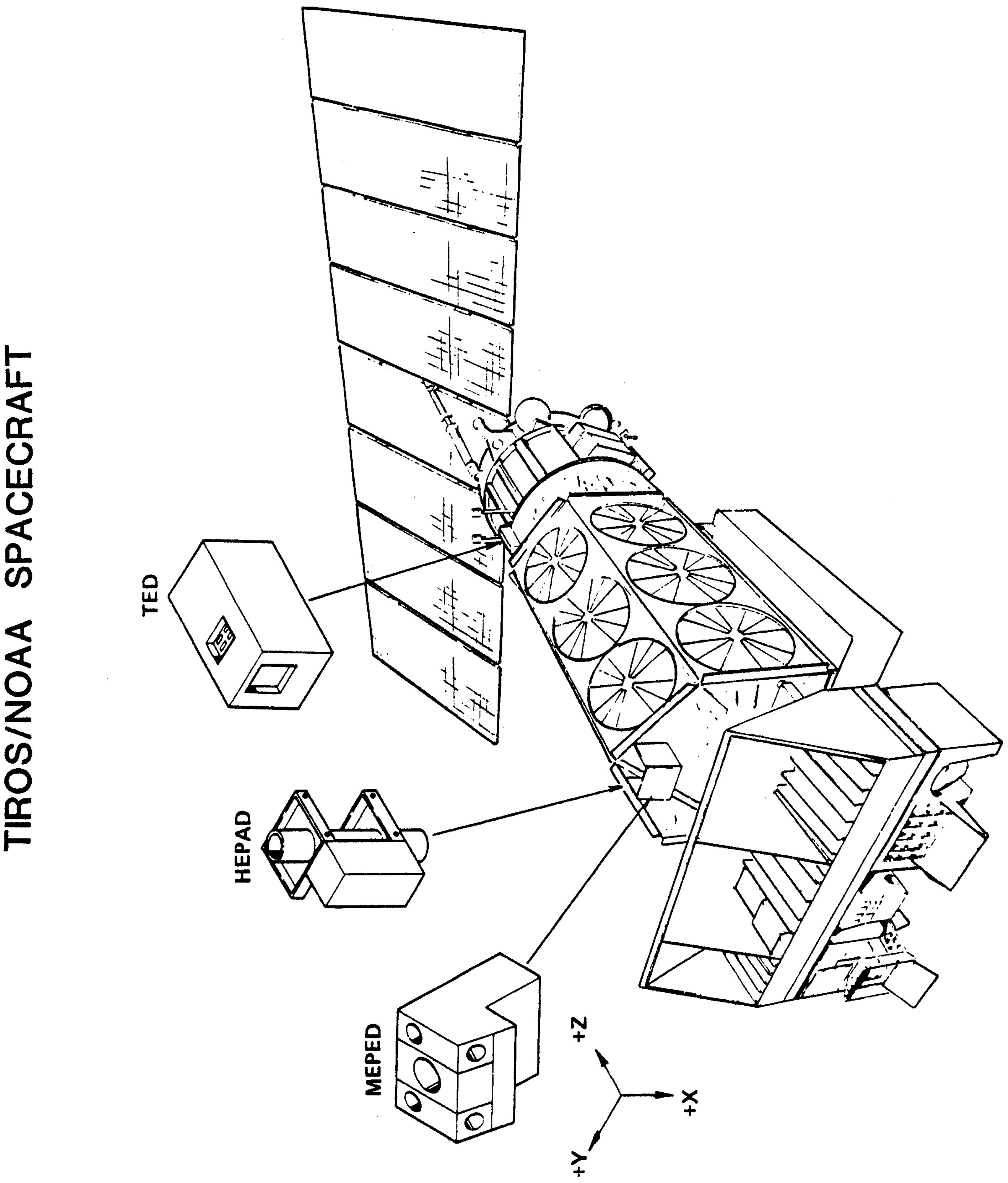


Figure 1.1 SEM instruments on TIROS/NOAA spacecraft

Table 1.1 shows the data available on the TIROS/NOAA Archive tapes. Archive tapes are created within two weeks of real-time.

Table 1.1 Data on TIROS/NOAA Archive Tapes

Satellite	Data on Archive Tapes		
TIROS-N	02 November 1978	-	27 February 1981
NOAA-6	28 June 1979	-	09 May 1983
	01 July 1984	-	30 June 1985
	15 October 1985	-	18 November 1986
NOAA-7	11 July 1981	-	10 February 1985
	MEPED and HEPAD turned off 01 April 1982		
NOAA-8	09 May 1983	-	14 June 1984
	01 July 1985	-	14 October 1985
	No HEPAD instrument on NOAA-8		
NOAA-10	11 October 1986	-	current
	No HEPAD instrument on NOAA-10		

This document is designed to assist the user in reading and decoding the NOAA Satellite Archive Tapes and in understanding the information contained in the SEM data. It includes descriptions of the instruments and detailed specifications of the data channels, with timing information. These specifications are necessary to convert the data to usable information. The SEM instrument descriptions were written by the primary investigators. For more information about the instruments, data, current uses, and published papers, contact Dr. D. S. Evans (about the TED) or Dr. H. H. Sauer (about the MEPED and HEPAD) at the National Oceanic & Atmospheric Administration, Space Environment Laboratory R/E/SE, 325 Broadway, Boulder CO 80303. The SEM instruments and the raw telemetry format (with housekeeping words) are described in detail in the NOAA Technical Memorandum "The TIROS-N/NOAA A-J Space Environment Monitor Subsystem" (Seale, R. A., and R. H. Bushnell, 1987. The TIROS-N/NOAA A-J Space Environment Monitor Subsystem. NOAA Tech. Memo. ERL SEL-75, NOAA Environmental Research Laboratories, Boulder, Colo.)

2.0 MEPED Instrument Description

The MEPED (Medium Energy Proton and Electron Detector) is that portion of the SEM designed to measure the flux of protons (ions) and electrons mirroring above, and precipitating into, the high-latitude ionosphere. Each MEPED consists of two sensor sub-assemblies: the directional particle detectors and the omnidirectional proton detectors.

The directional particle detectors are mounted in two pairs, one of each pair detecting electrons, the other detecting protons (and heavier ions having energies greater than 6 MeV). One pair of detectors is mounted to view outward along the Earth-satellite radial vector. At geomagnetic latitudes greater than 30 deg these detectors view charged particles that are in the atmospheric loss cone and will enter the atmosphere. The other detector pair is mounted to view at about 80 deg to the first and, for magnetic latitudes greater than 30 deg, will measure particles that have pitch angles near 90 deg, i.e., particles that are outside the loss cone and are trapped. The estimated local pitch angles of the particles observed by these two pairs of directional detectors at any point in the orbit are calculated using a model magnetic field developed at the National Space Science Data Center (Stassinopoulos and Mead, 1972). The pitch angles are included in the archive tape header record.

The electron detector within each directional pair is a thin (700 μm) 25 mm^2 solid-state detector covered by 0.51-μm-thick nickel foil (0.70 μm in the case of TIROS-N), which suppresses detector response to photons and reduces pulse pile-up caused by incident low-energy electrons or protons. Electronic pulse height discrimination is used to select pulses due to incident electrons of nominal energies greater than 30 keV, 100 keV, and 300 keV (taking into account a nominal 5 keV energy loss as the electron passes through the foil). The contaminant response to protons which deposit more than 1 MeV in the detector is eliminated electronically. The detectors are, however, sensitive to protons between about 135 keV and 1 MeV. Data from the directional proton detectors may be used to correct for this effect.

The proton detector within each directional detector pair is a two-element solid-state detector telescope. The front element has an effective area of 25 mm^2 and thickness of 200 μm the back element has an effective area of 50 mm^2 and a thickness of 200 μm also. A 2500-gauss magnet is mounted across the input aperture of this detector assembly to prevent any electrons of energies less than 1.5 MeV from reaching the detectors. The front face of the front detector of the telescope is coated with an aluminum layer 18 μg cm^{-2} thick, which serves both as one electrical contact and to suppress the detector's sensitivity to photons.

Electronic pulse height discrimination, together with coincidence logic on the pulses from the two detectors in the telescope, is used to select protons in four energy passbands (nominally 30–80 keV, 80–250 keV, 250–800 keV, and 800–2500 keV) and an integral channel for energies greater than 2.5 MeV. A second set of pulse logic isolates events due to ions ($Z>2$) of energies between 6 MeV and 55 MeV.

Table 2.1 lists the nominal energy ranges for the MEPED Detectors. The geometric factor for both the electron and proton directional detector system is 9.5×10^{-3} cm^2 ster.

Table 2.1 MEPED detector energy ranges

Data channel	Energy range 90–deg detector and 0–deg detector
Proton Telescope Passbands	
0I and 90I	6–55 MeV
0P1 and 90P1	30–80 keV
0P2 and 90P2	80–250 keV
0P3 and 90P3	250–800 keV
0P4 and 90P4	800–2,500 keV
0P5 and 90P5	> 2,500 keV
Electron Detector Passbands	
0E1 and 90E1	> 30 keV
0E2 and 90E2	> 100 keV
0E3 and 90E3	> 300 keV

The omnidirectional sensors comprise three nominally identical Kevex Si(Li) solid-state detectors of 50-square-mm area by 3-mm thickness, independently mounted under spherical shell moderators. Each detector has a full–opening viewing angle of 120 deg in the zenith direction. The omnidirectional flux is defined as the flux through a unit cross section sphere: Flux = counts/omnidirectional geometric factor.

Table 2.2 MEPED omnidirectional sensors

Data channel	Energy response	Approx. area cm^2 solid angle ster	Omnidirectional geometric factor	Moderator material thickness
P6	16– 80 MeV	0.5 (π)	.09375 cm^2	Aluminum .050 in
	80–215 MeV	0.43 (4π)	.215 cm^2	
P7	36– 80 MeV	0.5 (π)	.09375 cm^2	Copper .230 in
	80–215 MeV	0.43 (4π)	.215 cm^2	
P8	80–215 MeV	0.43 (4π)	.215 cm^2	Mallory .086 in

The equality of the secondary energy responses of channels P6 and P7 is a reflection of the design decision to equalize the out–of–aperture response of the three omnidirectional sensors. This allows correction through subtraction of the P8 channel output from the primary channel response from P6 and P7.

3.0 HEPAD Instrument Description

The HEPAD (High Energy Proton and Alpha Detector) senses the intensity in the local zenith direction of ambient solar protons above 370 MeV in four energy bands and of ambient solar alpha particles above 640 MeV/nucleon in two energy bands. Three detectors are employed in a telescope configuration: two solid-state detectors (defining the telescope acceptance aperture) and a Cerenkov radiator/PMT (performing the energy analysis for events producing a triple coincidence in the three detectors).

In-flight calibrations permit the energy-band boundaries to be established to better than +20%:

(1) Large characteristic proton spectrum

$$J(>P) = 2 \times 10^{4} \quad e^{-P/200} \quad \text{per cm}^{2} \text{ sec ster}$$

where: $P = (E^{2} + 1876E)^{1/2}$

(2) Orbit average electron background

$$J(>E) = 8.8 \times 10^{5} \quad E^{-1} \quad \text{per cm}^{2} \text{ sec ster}$$

where: E represents particle energy in MeV.

The geometric factor of the telescope acceptance aperture is about 0.9 cm^{2} ster with a half-angle field of view of about 24 deg. Spectral intensity data are supplied at a rate of one sample every 4 seconds. The electronic circuit logic establishes the detector response as given in Table 3.1.

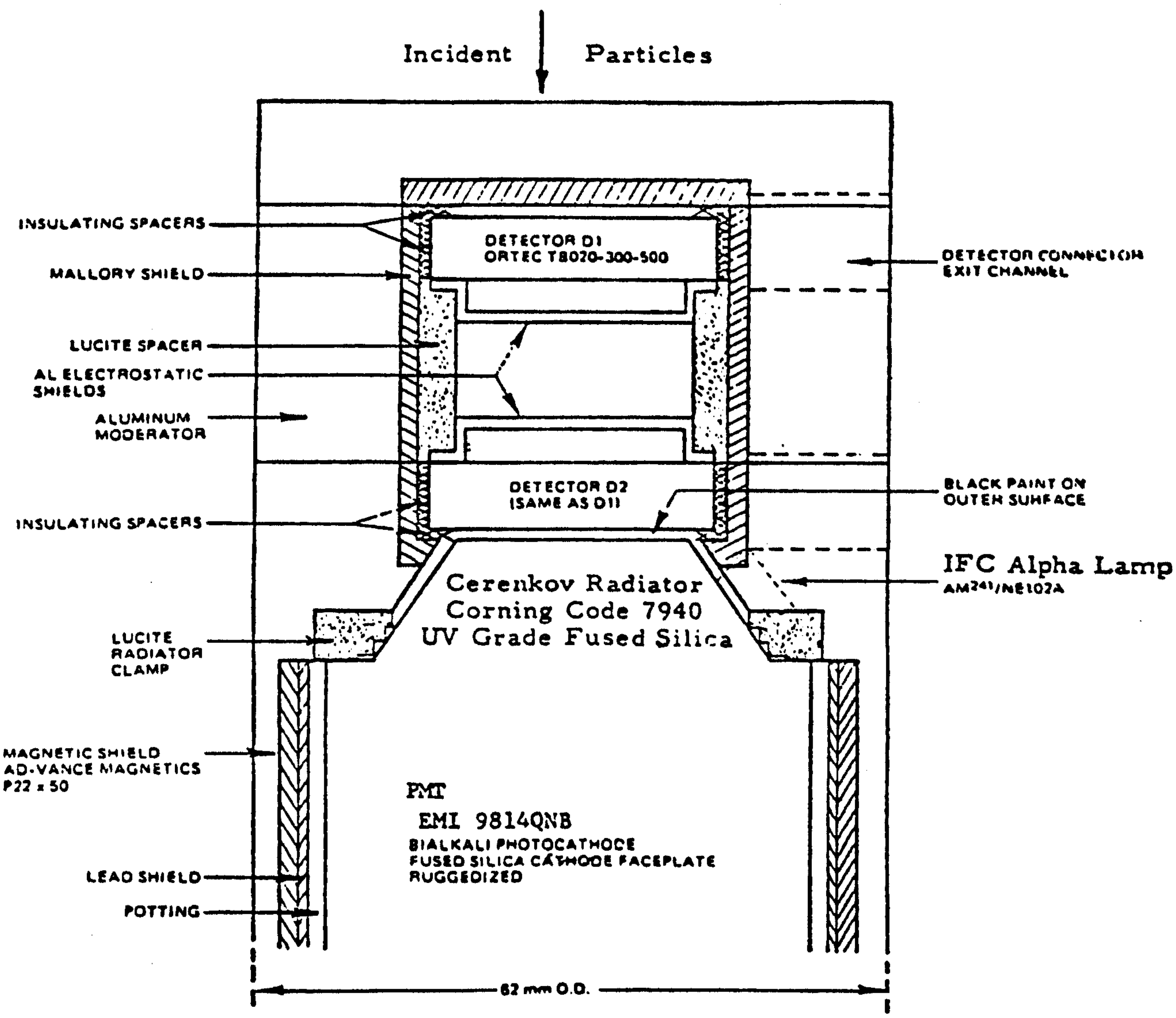
Table 3.1 HEPAD detector outputs

Datal channe	Nominal output			Count accumulation interval	Nominal max. random rates (pps)
P1	Protons	370–490	MeV	4 s	620
P2	Protons	490–620	MeV	4 s	420
P3	Protons	620–850	MeV	4 s	260
P4	Protons	>850	MeV	4 s	260
alpha 1	Alphas	600–875	MeV/nucleon	4 s	80
alpha 2	Alphas	>875	MeV/nucleon	4 s	85
S1	1SSD	#1 Singles LS #9		94 ms	1.8×10^{5}
S2	1SSD	#2 Singles LS #7		94 ms	1.6×10^{5}
S3	1PMT	Singles LS #1		94 ms	5.6×10^{4}
S4	1PMT	Gain monitor LS #4		2.5 s	2.0×10^{3}
S5	1SSD	#1, #2 Double coincidence		1.2 s	2.0×10^{4}

Data channels S1–S3 identify events exceeding the most sensitive pulse-height-discriminator (LS) thresholds associated with the two SSDs and the PMT; channel S5 identifies time-coincident events in the two SSDs that exceed these thresholds. Channel S4 identifies PMT events produced by the IFC radioactive source that exceed the fourth PMT LS threshold.

Figure 3.1 shows a plan view of the telescope assembly. Two surface-barrier silicon detectors D1 and D2 (area 3 cm^2, thickness 500 μm, totally depleted) define an acceptance aperture of about 24 deg half-angle or geometric factor about 0.9 cm^2 ster. All linear trajectories passing through these detectors also pass through the conical fused silica radiator (special PMT faceplate), which has an average thickness of about 17 mm. For an isotropic environment, the probability distribution of pathlengths in the conical radiator has a mean value 1.05 times the axial thickness of 14 mm, so the average Cerenkov radiation amplitude should correspond to traversal of about 18 mm of silica. Silica is employed as the radiator to provide the desired proton energy threshold (about 320 MeV) and to allow efficient transmission of the shorter wavelengths of the Cerenkov light (cutoff about 1900Å). Most of the area of the radiator's conical surface is bare to allow total internal reflection of incident Cerenkov light from all trajectories within the acceptance cone. Assuming an average quantum efficiency of 18% and full light collection efficiency within the 2000–4500Å interval, 225 photoelectrons should be produced by axial protons of $\beta = 1$.

Mallory metal (high–Z) is employed to shield the detectors against bremsstrahlung generated by ambient electrons (thickness is one absorption length for E<350 keV). Similarly, an aluminum moderator (low–Z) is employed to shield these detectors against ambient electrons and protons, and to suppress the bremsstrahlung radiated by the stopping electrons. Within the out–of–aperture solid angle, the moderator will stop protons of <80 MeV and electrons of <7 MeV. For in–aperture directions, the shielding is effective against protons of <65 MeV and electrons of <4 MeV and will absorb about 15 MeV from a 370–MeV proton. Shielding of the detectors from "upward-"entering protons of E<90 MeV is supplied by the silica radiator and the magnetic shield, lead shield, and aluminum shell surrounding the PMT.



DETECTOR AREA: 3 cm^2
DETECTOR SEPARATION. 2.9 cm
GEOMETRIC FACTOR: G = 0.9 cm^2-STER
ACCEPTANCE APERTURE: 68% OF G WITHIN < 24° HALF-ANGLE
100% OF G WITHIN < 34° HALF-ANGLE

Figure 3.1 HEPAD telescope assembly

4.0 TED Instrument Description

The TED (Total Energy Detector) measures the total energy flux carried into the atmosphere by charged particles of auroral energies.

Four separate electrostatic-analyzer charged-particle detector systems were included on TIROS/NOAA and were mounted in pairs. Within each pair, one analyzer system was devoted to measuring electrons and the other to measuring positive ions (protons). The two pairs view charged particles coming from different directions so that observations can be made of the directional energy flux at two different angles to the local geomagnetic field direction. One of these pairs views outward, parallel to the Earth center radial vector, so that it measures charged particles whose velocities are toward the Earth along this radial vector. The other pair views at an angle of 30 deg to the first. In this documentation, data from the first pair are tagged with the prefix 0 and data from the second pair with the prefix 30. It is stressed that these two angles are defined with respect to the Earth center-satellite vector and have nothing to do with the pitch angle α associated with the charged particles being measured.

The two detector systems within each pair are alternated between measuring electrons and measuring protons. The time taken for a full cycle is 2 s. The first half cycle (1 s) is devoted to measuring electrons. This 1-s period is divided into 13 equal segments. During the first 1/13 s a background measurement is taken; during the final 1/13 s the instrument undergoes a reset sequence during which no data are taken. During the center 11/13 s the analyzers are swept, effectively linearly with time, from an energy of 300 eV to an energy of 20,000 eV. The total number of counts accumulated by the detector during this sweep is telemetered to the ground as a measure of the integrated (from 300 eV to 20,000 eV) directional energy flux carried by the electrons observed by that particular detector. During the second half of the cycle the process is repeated for protons using the second detector system.

4.1 Terminology and Transmission Sequence

0E–FD and 30E–FD: The total number of counts accumulated during a sweep on the 0- and 30-deg electron detectors. These numbers are linearly related to the directional energy flux carried by electrons between 300 eV and 20,000 eV.

0P–FD and 30P–FD: The corresponding total accumulated counts for the 0- and 30-deg proton detectors during the second part of the 2 s instrument cycle.

The four data points (0E–FD, 30E–FD, 0P–FD, and 30P–FD) are regarded as the prime data from the TED instrument and are transmitted continuously every 2 s (about 15 km of spacecraft travel).

The TIROS/NOAA instrument also telemeters data points that are related to the directional energy fluxes associated with electrons or ions having energies within selected, narrow energy bands. Thus, an estimate can be made of what energy particles are carrying the bulk of the energy flow and at what altitude in the atmosphere this energy will ultimately be deposited.

The maximum count accumulated in a single 1/13-s subinterval during a given sweep of a given detector system and the corresponding energy band number are transmitted every 2 s from both detector pairs for both particle species. These data represent both the energy band containing the most energy flux and the value of that directional energy flux:

0DE–M, 30DE–M, 0DP–M, 30DP–M: The maximum count

0E–M, 30E–M, 0P–M, 30P–M: The corresponding interval number.

During the full energy sweep from 300 eV to 20,000 eV, which takes 11/13 s, the number of detector counts are accumulated during each successive 1/13 s interval, potentially giving 11 data points from each detector during an energy sweep. Since there are two detector pairs studying two particle species there are potentially four sets of measurements, each containing 11 energy channels generated every 2 s. However, data concerning only one of these energy channels is transmitted every detector sweep. This channel is the one that accumulated the greatest number of counts during the sweep. The channel number and the accumulated counts are transmitted from each detector once every 2-s experiment cycle. In addition, and at a lower duty cycle, the counts accumulated by each detector within energy channels 1, 3, 5, and 7 are transmitted to provide four-point energy spectrums. This lower-duty cycle is 8 s and involves transmitting in sequence the four-point measurements from the 0-degree electron, 30-degree electron, 0-degree proton, and 30-degree proton detector systems. The latter cycle is interrupted every fourth 8-s cycle in order to transmit background count-rate data from each detector.

Background data are also included as a quality check on the operation of the instrument. The counts registered by each detector during the first 1/13 s (background phase) of each sweep are accumulated for 16 sweeps—a total of 1.23 s. The accumulated counts 0E–BK, 0P–BK, 30E–BK, 30P–BK, are transmitted once each 32 s in place of the normal transmission of 0DE–1, 0DE–3, 0DE–5, 0DE–7. These numbers are generally less than 50 and, should they exceed 200, possible instrument malfunctions ought to be considered.

4.2 Conversion

There are two physical interpretations of the counts accumulated during a single subinterval of the energy sweep. The first relates this number to the directional energy flux within the limited energy range swept by the detector in the 1/13–s subinterval. The second is obtained by dividing the directional energy flux by the width of the energy band sampled, thus obtaining the directional differential energy flux at the center energy of the band.

Following is the conversion between the telemetered values and the corresponding directional energy flux in physical units. The difference between electron and proton conversion reflects a difference between detection efficiencies of the two particle species:

Directional energy flux (ergs cm^{-2} s^{-1} $ster^{-1}$) =

For electrons:	$1.905 \times 10^{-3} \times$ (0E–FD or 30E–FD)
For protons:	$1.50 \times 10^{-3} \times$ (0P–FD or 30P–FD)

A data point can be multiplied by the following conversion factors to convert from counts to differential directional energy flux: Differential directional energy flux (ergs cm^{-2} s^{-1} $ster^{-1}$ eV^{-1}) at the center energy =

For Electrons	3.78×10^{-7}	(for all energy bands)
For Protons	2.97×10^{-7}	(for all energy bands)

Table 4.2 lists the details of each of the energy bands with the multiplying constants required to convert the raw data point to a physical quantity, it also shows the altitudes in the atmosphere where electrons within each band will deposit their energy.

Table 4.2 TED energy bands and altitudes of energy deposition

Energy band number	Edges of band (eV)	Center energy (eV)	Conversion from counts to directional energy flux (ergs cm^{-2} s^{-1} $ster^{-1}$)		Altitude at which energy will be deposited (km)
			Electrons	Protons	
1	300 - 458	379	5.97×10^{-5}	4.69×10^{-5}	>300
2	458 - 773	616	1.19×10^{-4}	9.38×10^{-5}	215
3	773 - 1088	931	1.19×10^{-4}	9.38×10^{-5}	190
4	1088 - 1718	1403	2.38×10^{-4}	1.88×10^{-4}	165
5	1718 - 2349	2033	2.38×10^{-4}	1.88×10^{-4}	145
6	2349 - 3610	2979	4.76×10^{-4}	3.75×10^{-4}	130
7	3610 - 4870	4250	4.76×10^{-4}	3.75×10^{-4}	120
8	4870 - 7392	6131	9.52×10^{-4}	7.50×10^{-4}	115
9	7392 - 9914	8653	9.52×10^{-4}	7.50×10^{-4}	108
10	9914 - 14957	12436	1.90×10^{-3}	1.50×10^{-3}	105
11	14957 - 20000	17479	1.90×10^{-3}	1.50×10^{-3}	104

The physical parameters listed in Table 4.2 are measured at the satellite at 850 km altitude. These measured values must be manipulated, together with a geomagnetic field model, to obtain the truly relevant parameter: the magnitude of the energy flow into the atmosphere and the location at which this energy input is occurring.

Figure 4.1 illustrates this situation. The charged particles measured at the satellite are guided along the magnetic field lines. Because these magnetic lines of force are not radially outward, the point at which the field line that passes through the satellite actually intersects the atmosphere may be displaced considerably from the subsatellite point. In the TIROS/NOAA data-processing system, a magnetic field model is used to trace the field line passing through the satellite to the point where the field line intersects the atmosphere at 120 km (Foot Of the Field Line, FOFL). The coordinates of this point, both geographic and geomagnetic, together with the solar time and magnetic time, are calculated and given in the archive tape header records. By convention, if TIROS/NOAA is north of the geomagnetic equator, the FOFL is taken to be in the Northern Hemisphere. Otherwise the foot of the field line is in the Southern Hemisphere.

The angles between the geomagnetic field direction and the look direction of the two detector pairs are also computed using the same geomagnetic field model. These two angles are the local pitch angles of the charged particles being studied by the two detector pairs. However, because of the "magnetic mirror effect" on the motion of charged particles, the pitch angles these particles have at the location of the satellite are not the same pitch angles the particles would have at the top of the atmosphere (120 km). The relation between the two pitch angles is

$$\sin \alpha_{120} = \sqrt{\frac{B_{120}}{B_{850}}} \sin \alpha_{850}$$

where α_{120} = particle's pitch angle at the FOFL

α_{850} = particle's pitch angle at the TIROS/NOAA spacecraft

B_{120} = geomagnetic field strength at the FOFL

B_{850} = geomagnetic field strength at the TIROS/NOAA spacecraft

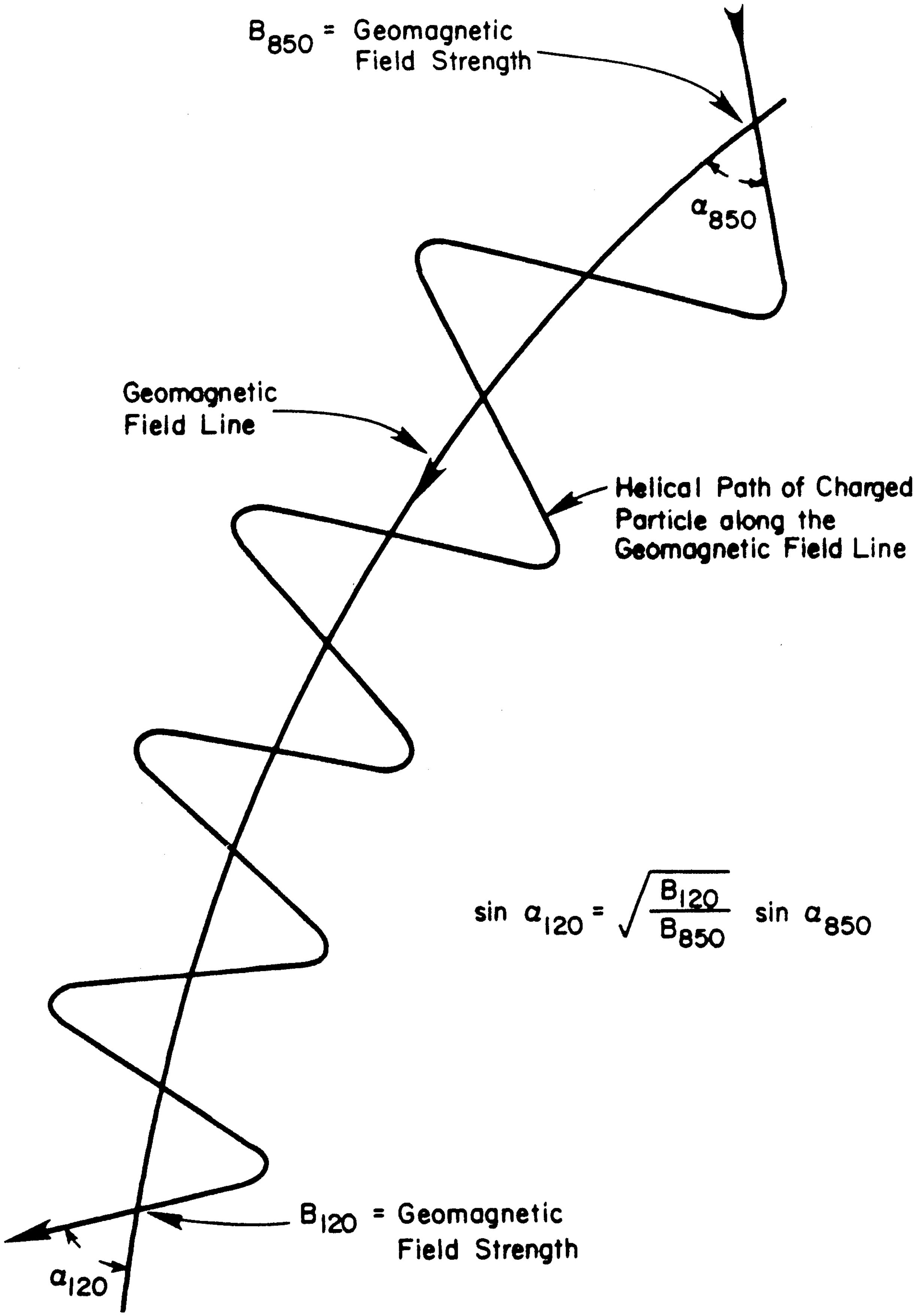


Figure 4.1 Path of charged particles along the geomagnetic field line

Figure 4.2 illustrates how the pitch angle of a charged particle varies as it moves along the geomagnetic field line between TIROS/NOAA and the atmosphere. Note that convention defines a particle's velocity vector and the direction of the magnetic field. This means that, in the Northern Hemisphere, charged particles moving downward toward the atmosphere have pitch angles between 0 and 90 deg. In the Southern Hemisphere, charged particles moving toward the atmosphere have pitch angles between 90 and 180 deg.

Note also that it is possible for the sin α_{120} to exceed 1.0. Physically, this occurs when the charged particles measured going downward toward the atmosphere at TIROS/NOAA in fact magnetically mirror before reaching the atmosphere and return back up the magnetic field line. Such particles cannot be counted as contributing to the energy influx into the Earth's atmosphere. In the course of data processing, all parameters concerning the geomagnetic field are computed once each 8 s and given in the header format. These parameters are included:

(1) The three vector components of the geomagnetic field at TIROS/NOAA together with the scalar magnitude of the field.

(2) The geographic location where the geomagnetic flux tube that threads TIROS/NOAA intersects the top of the atmosphere at 120 km.

(3) The geomagnetic coordinates of the FOFL and the local solar and geomagnetic times of the FOFL.

(4) The three-vector components of the geomagnetic field at the FOFL together with the scalar magnitude of the field.

(5) The pitch angles of those charged particles being observed by the two TED detector systems as transformed to the FOFL.

By using the measurements of 0E-FD, 30E-FD, 0P-FD, and 30P-FD, together with the pitch angles at which the measurements were made (as transformed to 120 km), the quantity

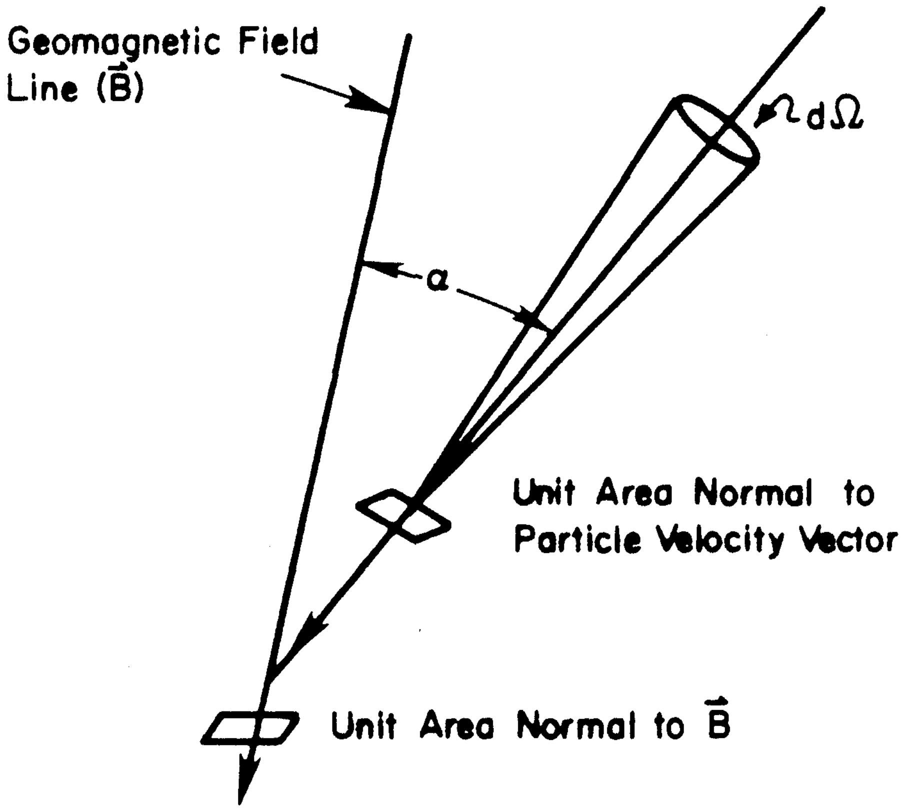
$$E_T = 2\pi \int_0^{\pi/2} E_D(\alpha) \sin\alpha \cos\alpha \, d\alpha$$

may be evaluated independently for both electrons and ions. The sum of these two is converted to physical units (milli-ergs cm $^{-2}$ s $^{-1}$) and becomes the "Total Energy Flux" value given in the TED format.

If neither of the two detector pairs is viewing charged particles that reach the Earth's atmosphere, then the value of the Total Energy is set to 0. However, the actual values of 0E-FD, 30E-FD, 0P-FD, and 30P-FD remain available in the output record. The situation in which neither detector pair views charged particles that can reach the atmosphere is confined to measurements made at rather low geographic latitudes where any energy flow into the atmosphere is expected to be small in any case.

The TED detector system was originally designed to be operated in any one of three different modes in order to compensate for possible detector failures. However, the instrument has thus far proved reliable, so there is a policy that the TED instrument is operated only in its normal mode.

Finally, when these data are being analyzed, care should be taken in treating total energy flux values that exceed 100 ergs cm $^{-2}$ s $^{-1}$. Experience has shown that a high percentage (about 50%) of such data points are in fact associated with telemetry noise and do not represent valid observations.



$j(E,\alpha)$ = Particle Differential Directional Number Flux

$E(E,\alpha) = j(E,\alpha)E$ = Particle Differential Direction Energy Flux

$$E_D(\alpha) = \int_0^{\infty} j(E,\alpha)\, E\, dE$$ = Particle Directional Energy Flux

$$E_T = 2\pi \int_0^{\pi/2} E_D(\alpha) \sin\alpha \cos\alpha \, d\alpha$$ = Particle Total Energy Flux (Evaluated at top of atmosphere)

Figure 4.2 Evaluation of particle total energy flux

5.0 Data Descriptions

This section specifies the data contained on the archive tapes and gives the timing information necessary to convert the data to usable units. In general the data can be divided into five types of information: orbital information, housekeeping information, MEPED data, HEPAD data, and TED data.

Orbital information contains the time of the data record and defines the location and orientation of the spacecraft at that time.

Housekeeping information specifies the status of each individual instrument (On or Off) and whether an in-flight calibration is in progress. Weekly calibrations of the SEM instruments appear on the archive tapes, and it is the user's responsibility to recognize and discard calibration data.

The MEPED, HEPAD, and TED data descriptions identify the data channels, detectors, particle types, and energy ranges on each instrument. The descriptions also include the channel name abbreviations used throughout this document and the record timing tables.

The archive tapes consist of short records, each containing 8 s of data. The begin time, called T0, is included on every record. T0 is the time of the orbital and housekeeping information on that record. However, T0 is not the time the MEPED, HEPAD, and TED data channels were sampled. The record timing tables (in sections 5.3, 5.4, and 5.6) show the time each data channel began accumulation, relative to T0. The length of the accumulation period is also included for converting counts per accumulation period into counts per second. An example of the record timing table for the MEPED data is shown below. In this example the MEPED data channels 0E1 to 0E3 are accumulated for 1 s each. The first readings of each of these data channels (MEPED words 8, 9 and 10) began accumulation at time T0-1 second. The second readings of each data channel (MEPED words 27, 28 and 29) began accumulation at T0+1 second. The user can determine the exact time a data channel was sampled and convert the value to "counts per second" by referring to the record timing tables.

Table 5.1 Sample record timing table

Word	Data channel	Accumulation period(s)	Accumulation begin time relative to T0(s)
.	.	.	.
.	.	.	.
8-10	0E1 to 0E3	1	−1
.	.	.	.
.	.	.	.
27-29	0E1 to 0E3	1	+1

5.1 Orbital Information

The Orbital Information in each data record gives the time of the record, the location and orientation of the spacecraft, and other values useful in evaluating the instrument data. All Orbital Information is valid for T0, the begin time of the record. All latitudes, longitudes, pitch angles, local times, and magnetic times are given in degrees. The units of the magnetic field parameters are gammas. Orbital Information includes values from the original raw data and calculated values.

The calculated values, helpful in evaluating the instrument data, are derived by the following method. Magnetic field and FOFL values, necessary to interpret the charged particle data, are calculated from the satellite location using a magnetic field model. The model uses a table look-up and interpolation scheme. The Geomagnetic Field parameters look-up table (Aarnes and Lundblad, University of Bergen, Norway; personal communication, 1979.) is a 4-deg-latitude by 4-deg-longitude grid of subsatellite locations. The computation of magnetic values for this table was done using the model magnetic field and field line tracing routines developed at the National Space Science Data Center (Stassinopoulos, E. G., and G .D. Mead, 1972. ALLMAG, GDALNG, LINTRA: Computer programs for geomagnetic field and field-line calculations. NASA/NSSDC Report 72-12.). The table was constructed for a single satellite altitude of 870 km and, strictly speaking, the table and interpolations are appropriate only for a satellite at that altitude. The TIROS/NOAA satellite are at altitudes ranging from 815 to 850 km so that errors are introduced by the procedure. However, at high latitudes, where the charged particle observations are most useful, these errors are not large.

Following are brief descriptions of the Orbital Information. Section 6 table 6.3.1 contains the data format, range of values, units and conversion factors.

Spacecraft ID

0 = zero fill record
1 = TIROS-N
2 = NOAA-6
4 = NOAA-7
6 = NOAA-8
8 = NOAA-10

Records containing all zeros are used to fill out the physical record at the end of the tape, these records can be uniquely identified because the spacecraft ID is zero.

T0, begin time of the record

The begin time of the record is defined by the year, day of the year, and milliseconds of the day in Universal Time. Records contain 8 s of data. They are ordered by time. There are no duplicate records and the time difference between records is always a multiple of 8 s. All orbital and housekeeping information is valid at T0.

Receiving station

This is the tracking station that recorded the original raw data as telemetered from the spacecraft. It does not affect or change the archive data in any way.

Station Codes:
0 = unknown
1 = Wallops Island, Virginia
2 = Gillmore Creek, Alaska
3 = Western European Satellites, Spain

Altitude of the satellite

TIROS/NOAA satellites are in near-circular orbits of about 850 km. In calculations for the archive tape involving altitude, 870 km is used for all spacecraft. An accurate altitude for each spacecraft at any time is not recorded, but the nominal altitude for each spacecraft is included on the archive tapes for the user's information.

TIROS-N = 853.5 km
NOAA-6 = 815.5 km
NOAA-7 = 849.2 km
NOAA-8 = 815.5 km
NOAA-10 = 833.0 km

Inclination of the satellite

Like the altitude, the satellite inclination is assumed to be constant. The nominal inclinations are written on the archive tapes for each spacecraft:

TIROS-N = 98.9 deg
NOAA-6 = 98.7 deg
NOAA-7 = 98.9 deg
NOAA-8 = 98.9 deg
NOAA-10 = 98.7 deg

Orbit number

The orbit number is a count of the number of times the satellite has orbited the Earth. The orbit number, or revolution number, is incremented when the satellite crosses the Equator from the Southern to the Northern Hemisphere. The orbital period of all spacecraft is approximately 102 minutes. Orbit numbers are based on time and estimated orbital period. They are assigned in Record Type 1.

Record type

On the original raw data tapes each logical record contains 32 s of data. To simplify the Archive data records these 32-s records are divided into four 8-s records. The four archive records all contain the same information except for slight differences in MEPED and TED data. These differences are described in Sections 6.3.4 and 6.3.6. In order to check for these differences each archive record contains a "Record Type," a number from 1 to 4 that denotes the record's location in the original raw data record.

Data at the Satellite

Geocentric latitude at the satellite
Geographic east longitude at the satellite

This is the subsatellite geocentric latitude and geographic east longitude for time T0. The subsatellite location is used to calculate all the following information at the satellite and at the FOFL.

BR: the radial component of the magnetic field strength in nT at the satellite, where positive is up.

BT: the north–south component at the satellite, where positive is south.

BP: the east–west component at the satellite, where positive is east.

BB: the total field at the satellite.

Data at the Foot of the Field Line

The Foot Of the Field Line (FOFL) is the point where the magnetic field line through the satellite crosses 120 km altitude. The model used to calculate the magnetic field vector at a given location is also used to trace the magnetic field line through the satellite to an altitude of 120 km in the local hemisphere.

Geographic latitude at the FOFL
Geographic east longitude at the FOFL

BR120: the radial component of the magnetic field strength in nT at the FOFL, where positive is up.

BT120: the north–south component at the FOFL, where positive is south.

BP120: the east–west component at the FOFL, where positive east.

BB120: the total field at the FOFL.

Geomagnetic latitude at the FOFL
Geomagnetic east longitude at the FOFL

The geographic latitude and longitude of the FOFL point is used as the input to a simple transformation to obtain the *un-corrected* dipole geomagnetic coordinates.

L–value at the FOFL

The L value is also computed, in the model, at the FOFL. If the L value is computed to be $\geq$15.00 it is considered to be undefined and the value set to 0.00. This causes no ambiguity because even at the magnetic equator the L value sampled by the satellite is never less than 1.10.

Pitch Angles

The pitch angles, with respect to the geomagnetic field, of the particles being sensed by the TED and MEPED detectors are calculated to help the users interpret the data. The pitch angle of the charged particles being sampled by a detector is the angle between the particle's velocity vector and the magnetic field. It is defined with the convention that 0 deg is a particle moving parallel to the magnetic field and 180 deg is a particle moving antiparallel to the magnetic field. The look direction of the detectors and three components of the magnetic field, together with the location of the satellite, are used to compute the pitch angles of the particles being measured at the satellite.

The calculations for the TED and MEPED detector systems are performed as follows:

TED0: The pitch angle of the particle being sensed by the TED 0 deg detector as transformed to the FOFL

TED30: The pitch angle of the particle being sensed by the TED 30 deg detector as transformed to the FOFL

These pitch angles have been transformed to the FOFL. If the particle mirrors above 120 km altitude, the pitch angle is given as 90 deg. The pitch angles assigned to the TED detectors (which view along the Earth-center radial vector and at 30 deg to that direction) are the pitch angles possessed by the particles and have been transformed from the satellite location to the FOFL to ease the integration over angle required to complete the energy flux *into* the atmosphere. The magnetic field intensity of the satellite and the magnetic field intensity at 120 km are used to transform the TED particle pitch angles from what they were at the satellite to what they would be at 120 km altitude at the FOFL. This transformation in pitch angles is necessary in order to perform a proper angular integral of the directional energy fluxes measured at the satellite to obtain the energy flux into the atmosphere.

MEPED81: MEPED 90 deg proton detector pitch angle at the satellite.

MEPED83: MEPED 90 deg electron detector pitch angle at the satellite.

MEPED0: MEPED 0 deg proton and electron detector pitch angle at the satellite.

NOTE: MEPED81 and MEPED83 are incorrect when the satellite is *northbound* on TIROS-N, NOAA-6, NOAA-7 and NOAA-8 tapes. On NOAA-10 they are correct.

For the MEPED detectors, pitch angles are calculated at the satellite position and are the angle between the detector look direction and the local magnetic field direction, not the angle between the particle velocity direction and the magnetic field. For example, in the Northern Hemisphere the MEPED0 pitch angle is between 90 and 180 deg while the *particle's* pitch angle is the supplement of this angle. The MEPED 90-deg electron and proton detectors are actually viewing at 83 and 81 deg to the Earth-center radial. The detectors will continue to be designated as the 90-deg detectors. The pitch angle calculations for the 90-deg electron and proton detectors have been performed incorrectly when the satellite is moving *northbound* geographically. The calculations when the satellite is southbound are correct. Although this error is minimum at high geographic latitudes, the error approaches 30 deg at some middle and low latitude locations. Care must be exercised in interpreting these pitch angles when the satellite is *northbound*.

Miscellaneous Information

Local time and *Magnetic local time*

The approximate local solar time at the subsatellite location is computed from the universal time T0 and the geographic longitude. Similarly, the eccentric dipole magnetic local time *at the subsatellite location* is computed from the subsatellite location, day, and universal time.

The local and magnetic local times are in degrees eastward from midnight and can be converted to hours by dividing by 15. The local time at the FOFL can be calculated as follows:

MIN = milliseconds of the day / 3,600,000

TIME = MIN + (FOFL geographic longitude in degrees / 15)

If TIME > 24 then TIME = TIME - 24

where TIME is the local time in hours, and TIME multiplied by 15 is the local time in degrees.

Program version

The Program Version number will be incremented whenever a change is made in the archive tape data or format. It is currently 1.

Zero fill

Three bytes of zero are left for later additions to the orbital information.

5.2 Housekeeping Information

The Housekeeping Information of the archive tapes includes instrument on/off flags, In-Flight Calibration (IFC) flags, TED flags, and Housekeeping values. All the flags and values are valid at T0, the begin time of the record.

Instrument flags

The instrument on/off flags are normally in the "on" state but should always be checked. On occasion, an instrument has been mysteriously commanded "off" and remained so for up to two weeks.

IFC flags

In-Flight Calibrations (IFC) are conducted approximately once per week and they appear on the tapes in the same format as the other data. If the IFC flag is equal to 1 (yes), an IFC is in progress. The IFC flags should be checked on every record and the data discarded when an IFC is in progress. The calibration sequence begins for all instruments at the same time, but the MEPED IFC lasts for 576 s and the TED/HEPAD lasts for 768 s. Sometimes, however, only partial calibrations are on the tape. This happens when the flags are set accidentally by telemetry noise and/or when data are missing from the archive tape because of telemetry problems.

TED flags

The TED MODE and TELEMETRY FORMAT flags together show what data are being sampled in the TED experiment. The following configurations are possible, but only the first setting (MODE 0 or 2, FORMAT 1) has been, or is expected to be used.

TED MODE and TELEMETRY FORMAT descriptions:

MODE 0 or 2, FORMAT 1 - normal electrons and protons

MODE 1, FORMAT 1 - electron dwell, no protons

MODE 3, FORMAT 1 - proton dwell, no electrons

For 104 minutes after an IFC the TED channeltron gain is verified and the gain signal is changed. This does not affect the data but the user can check for this condition in the TED PHD flags. The normal value of the PHD flags is all zeros; any other value means the TED channeltron gain is being verified.

Housekeeping Values

No explanation of the housekeeping values is included here because they are for SEL's use in evaluating the performance of the instruments. Table 5.2 is a list of the housekeeping word abbreviations and their meaning.

Table 5.2 Housekeeping word descriptions

Detector word			Description
1	MPTT	MEPED	proton telescope temperature
2	METT	MEPED	electron telescope temperature
3	MELT	MEPED	electronics temperature
4	OMNI	MEPED	OMNI temperature
5	AMSS	MEPED	detector bias voltage
6	HELT	HEPAD	electronics temperature
7	PMTT	HEPAD	photo multiplier tube temperature
8	PMHV	HEPAD	high-voltage power supply monitor
9	HSSD	HEPAD	solid-state detector bias monitor
10	LVL	HEPAD	level calculated from PMHV and HELT
11	TEPS	TED	electron channeltron power supply monitor
12	TPPS	TED	proton channeltron power supply monitor
13	LVR	TED	low-voltage ramp monitor
14	CEA	TED	cylindrical electrostatic analyzer power supply monitor
15	TEDT	TED	temperature monitor

5.3 MEPED Data Description

MEPED data channels are directional measurements, at 0 and 90 deg (with respect to the local zenith) of protons, electrons and nominally omnidirectional measurements of protons. Channels I(positive Z $\geq$ 2 ions), E1 to E3, and P1 to P5 are read at 0 and 90 deg; P6, P7, and P8 are omnidirectional.

Table 5.3 MEPED data channels

MEPED data word	channel	Nominal energy Detector	Particle type	range keV
1	0I	0 deg Ions	Pos. (Z $\geq$2) Ions	6,000 - 55,000
2	90I	90 deg Ions	Pos. (Z $\geq$2) Ions	6,000 - 55,000
3	0P1	0 deg Proton	Protons	30 - 80
4	0P2	0 deg Proton	Protons	80 - 250
5	0P3	0 deg Proton	Protons	250 - 800
6	0P4	0 deg Proton	Protons	800 - 2,500
7	0P5	0 deg Proton	Protons	>2,500
8	0E1	0 deg Electron	Electrons	>30
9	0E2	0 deg Electron	Electrons	>100
10	0E3	0 deg Electron	Electrons	>300
11	90P1	90 deg Proton	Protons	30 - 80
12	90P2	90 deg Proton	Protons	80 - 250
13	90P3	90 deg Proton	Protons	250 - 800
14	90P4	90 deg Proton	Protons	800 - 2,500
15	90P5	90 deg Proton	Protons	>2,500
16	90E1	90 deg Electron	Electrons	>30
17	90E2	90 deg Electron	Electrons	>100
18	90E3	90 deg Electron	Electrons	>300
19	P6	Omnidirectional Proton	Protons	16 - 80 MeV 80 - 215 MeV
20	P7	Omnidirectional Proton	Protons	36 - 80 MeV 80 - 215 MeV
21	P8	Omnidirectional Proton	Protons	80 - 215 MeV

The MEPED consists of four sensor systems, two of which view at 0 deg and two of which view at 90 deg, with respect to the local zenith. Each pair of sensors consists of a proton telescope and a thin solid state electron detector. Each proton telescope measures ions in channels P1 through P5 over the range 30 keV to >2,500 keV. Channel I is sensitive to Z $\geq$ 2 ions in the range 6 MeV through 55 MeV. The proton telescope also measures nominally omnidirectional protons. The geometric factor for both the proton telescope and electron detector is 9.5×10^{-3} cm^2 ster.

On the MEPED each data channel is sampled four times every 8 s, except for the 0 I and 90 I channels which are sampled only once every 16 s. The record timing information for the MEPED is shown in Table 5.4.

Table 5.4 MEPED data - record timing

MEPED word	Data channel	Accumulation period (s)	Accumulation begin time relative to T0 (s)
1	0 I	16	−16
2	90 I	16	−16
3– 7	0P1 to 0P5	1	−1
8–10	0E1 to 0E3	1	−1
11–15	90P1 to 90P5	1	+0
16–18	90E1 to 90E3	1	+0
19–21	P6 to P8	2	−2
22–26	0P1 to 0P5	1	+1
27–29	0E1 to 0E3	1	+1
30–34	90P1 to 90P5	1	+2
35–37	90E1 to 90E3	1	+2
38–40	P6 to P8	2	+0
41–45	0P1 to 0P5	1	+3
46–48	0E1 to 0E3	1	+3
49–53	90P1 to 90P5	1	+4
54–56	90E1 to 90E3	1	+4
57–59	P6 to P8	2	+2
60–64	0P1 to 0P5	1	+5
65–67	0E1 to 0E3	1	+5
68–72	90P1 to 90P5	1	+6
73–75	90E1 to 90E3	1	+6
76–78	P6 to P8	2	+4

5.4 HEPAD Data Description

The HEPAD data channels are shown in table 5.5. Section 3 describes the instrument.

Table 5.5 HEPAD data channels

HEPAD word	Data channel	Detector	Particle type	Energy range	
1	P1	Proton	Protons	370 - 480	MeV
2	P2	Proton	Protons	480 - 640	MeV
3	P3	Proton	Protons	640 - 850	MeV
4	P4	Proton	Protons	>850	MeV
5	alpha 1		Alphas	640 - 850	MeV/Nucleon
6	alpha 2		Alphas	>850	MeV/Nucleon
7	S5			SSD D1-D2 Double Coincidences	
8	S4			PMT Gain Monitor	
9	S1			SSD D1 Singles	
10	S2			SSD D2 Singles	
11	S3			LSI (PMT Anode) Singles	

The HEPAD data channels are read out every 4 s; therefore, there are two values for each channel in every 8-s data record. The record timing information for the HEPED is shown in Table 5.6.

Table 5.6 HEPAD data - record timing

HEPAD word	Data channel	Accumulation period (s)	Accumulation begin time relative to T0 (s)	HEPAD word	Data channel	Accumulation period (s)	Accumulation begin time relative to T0 (s)
1	P1	4.0	-4.0	12	P1	4.0	+0.0
2	P2	4.0	-4.0	13	P2	4.0	+0.0
3	P3	4.0	-4.0	14	P3	4.0	+0.0
4	P4	4.0	-4.0	15	P4	4.0	+0.0
5	alpha 1	4.0	-4.0	16	alpha 1	4.0	+0.0
6	alpha 2	4.0	-4.0	17	alpha 2	4.0	+0.0
7	S5	1.2	-1.2	18	S5	1.2	+3.2
8	S4	2.5	+0.0	19	S4	2.5	+4.0
9	S1	0.1	+2.5	20	S1	0.1	+6.5
10	S2	0.1	+2.6	21	S2	0.1	+6.6
11	S3	0.1	+2.7	22	S3	0.1	+6.7

5.5 TED Data Description

The TED instrument and its data channels are described in Section 4. The TED data in each 8–s data record contains values from four different detectors, each sampled once every 2 s. Table 5.7 describes the data channels for each detector. Table 5.8 shows the sequencing of the data values, as they appear on the archive tape, and the record timing information.

Table 5.7 TED data channels

Data channel	Detector	Parameters	Energy interval during which counts accumulated
0DE–1	0 deg electron	differential directional energy flux	1st interval
0DE–3	0 deg electron	"	3rd interval
0DE–5	0 deg electron	"	5th interval
0DE–7	0 deg electron	"	7th interval
0DE–M	0 deg electron	"	maximum interval
0E–M		interval	interval max counts accumulated
0EF–D	0 deg electron	directional energy flux	all intervals
30DE–1	30 deg electron	differential directional energy flux	1st interval
30DE–3	30 deg electron	"	3rd interval
30DE–5	30 deg electron	"	5th interval
30DE–7	30 deg electron	"	7th interval
30DE–M	30 deg electron	"	maximum interval
30E–M		interval	interval max counts accumulated
30EF–D	30 deg electron	directional energy flux	all intervals
0DP–1	0 deg proton	differential directional energy flux	1st interval
0DP–3	0 deg proton	"	3rd interval
0DP–5	0 deg proton	"	5th interval
0DP–7	0 deg proton	"	7th interval
0DP–M	0 deg proton	"	maximum interval
0P– M		interval	interval max counts accumulated
0PF–D	0 deg proton	directional energy flux	all intervals
30DP–1	30 deg proton	differential directional energy flux	1st interval
30DP–3	30 deg proton	"	3rd interval
30DP–5	30 deg proton	"	5th interval
30DP–7	30 deg proton	"	7th interval
30DP–M	30 deg proton	"	maximum interval
30P M		interval	interval max counts accumulated
30PF–D	30 deg proton	directional energy flux	all intervals
Total Energy	all detectors	total energy flux	all intervals

Table 5.8 shows the TED record timing information for the TED in Normal Mode, Telemetry Format 1. This is the only configuration in which the TED has been operated. The accumulation period, written as 11/13, means eleven-thirteenths of a second. Note that the TED record contains four groups of data. The first 6 words of each group are from a different detector, but the remaining 14 words are the same detectors read every 2 s.

Table 5.8 TED data - record timing, for record types 1, 2, & 3

TED word	Data channel	Accumulation period (s)	Accumulation begin time relative to T0 (s)
1-4	0DE-1, 0DE-3, 0DE-5, 0DE-7	11/13	-2
5	0DE-M	11/13	-2
6	0E-M	-	-
7-8	0EF-D, 0DE-M	11/13	-2
9	0E-M	-	-
10-11	30EF-D,30DE-M	11/13	-2
12	30E-M	-	-
13-14	0PF-D, 0DP-M	11/13	-1
15	0P-M	-	-
16-17	30PF-D,30DP-M	11/13	-1
18	30P-M	-	-
19	Total Energy	-	-
20-23	30DE-1, 30DE-3, 30DE-5, 30DE-7	11/13	+0
24	30DE-M	11/13	+0
25	30E-M	-	-
26-27	0EF-D, 0DE-M	11/13	+0
28	0E-M	-	-
29-30	30EF-D,30DE-M	11/13	+0
31	30E-M	-	-
32-33	0PF-D, 0DP-M	11/13	+1
34	0P-M	-	-
35-36	30PF-D,30DP-M	11/13	+1
37	30P-M	-	-
38	Total Energy	-	-
39-42	0DP-1, 0DP-3, 0DP-5, 0DP-7	11/13	+3
43	0DP-M	11/13	+3
44	0P-M	-	-
45-46	0EF-D, 0DE-M	11/13	+2
47	0E-M	-	-

Table 5.8 TED data - record timing, for record types 1, 2, & 3 - continued

TED word	Data channel	Accumulation period (s)	Accumulation begin time relative to T0 (s)
48-49	30EF-D,30DE-M	11/13	+2
50	30E-M	-	-
51-52	0PF-D, 0DP-M	11/13	+3
53	0P-M	-	-
54-55	30PF-D,30DP-M	11/13	+3
56	30P-M	-	-
57	Total Energy	-	-
58-61	30DP-1, 30DP-3, 30DP-5, 30DP-7	11/13	+5
62	30DP-M	11/13	+5
63	30P-M	-	-
64-65	0EF-D, 0DE-M	11/13	+4
66	0E-M	-	-
67-68	30EF-D,30DE-M	11/13	+4
69	30E-M	-	-
70-71	0PF-D, 0DP-M	11/13	+4
72	0P-M	-	-
73-74	30PF-D,30DP-M	11/13	+4
75	30P-M	-	-
76	Total Energy	-	-

TED Background values, 0E–BK, 30E–BK, 0P–BK, and 30E–BK, are listed in place of the energy flux values for the sweep intervals 1, 3, 5, and 7 in RECORD TYPE 4. Table 5.9 shows where the background data appear in the record. (Note that background data are given only in RECORD TYPE 4.)

Table 5.9 TED background data channels – record type 4

TED word	Detector
1– 4	OE–BK, 30E–BK, 0P–BK, 30P–BK
5–19	same as RECORD TYPES 1, 2, & 3
20–23	zeros
24–38	same as RECORD TYPES 1, 2, & 3
39–42	zeros
43–57	same as RECORD TYPES 1, 2, & 3
58–61	zeros
62–76	same as RECORD TYPES 1, 2, & 3

TED Background data are the total number of counts accumulated during the first 1/13 s (background interval) of each of the 16 energy sweeps for each of the detectors, summed and read out once every 32 s.

6.0 Archive Tape Format

The physical format details of the archive tapes and the logical data records must be known, to read the tape and unpack the data. Figure 6.1 is a printout of one logical data record. The archive tape format and contents are the same for all spacecraft.

An archive tape contains data from one satellite for 10 or 11 days; thus, one calendar month requires three tapes. The first day of the month always starts a new tape. Raw input records with missing, bad, or ambiguous data have been discarded so that only good data records are on the archive tapes. All *records* are complete; however, there can be gaps between records where data were bad or missing. The percentage of good data from the TIROS/NOAA satellites is greater than 90% for most days. Zeros are sometimes used to fill out the last physical record on a tape. These zero records can be recognized by a SATELLITE ID of zero.

For users with access to the ERL computer system, there is a library of routines that read and unpack an archive tape record, and then pass the data to the user via a COMMON BLOCK. See Appendix A for a description of these routines.

6.1 Physical Tape Format

6.1.1 Tape Format

Packed binary
9 Track
1600 BPI density
456 60-bit words/physical record
or 3420 bytes/physical record
12 logical records/physical record
285 bytes/logical record
8 bits/byte

3 tapes/month
10 or 11 days/tape
9900 maximum physical records/tape
1 file/tape followed by an End Of Information (EOI)

The tapes are written on a Control Data Corporation (CDC) CYBER 170/750 machine with the NOS operating system. They are in CDC internal format with standard ANSI labels. If they are read on a non-CDC machine, the physical records will contain 3426 bytes; the last 6 bytes are internal CDC counters that can be ignored. The tape labels have a file identification in the form FI=TIROSN (or NOAA6, NOAA7, NOAA8), the satellite name.

6.1.2 Tape Summary

Two 80-byte tape label records (ANSI standard)
End Of File (EOF)
One "Tables Record" (3420 bytes)
Up to 9900 3420-byte physical "data records" (3426 bytes on non-CDC machines)
EOI—indicated by EOF, 80-byte trailer record, EOF, EOF.

TIROS/NOAA ARCHIVE RECORD FOR YEAR 83 DAY 254 HR 0 MIN 1 MSEC 30983

S/C ID 6 YEAR 83 DAY 254 MS 90983 REC STA 1 ALT 8155 INCL 989 ORBIT 2364 REC TYPE 2

SAT PAR GEOG LAT -40.41 LONG 300.62 BR 12968. BT -15146. BP 330. BB 19942.
FOFL PAR GEOG LAT -47.20 LONG 300.09 BR 19901. BT -20328. BP 1956. BB 28515.
GEOM LAT -36.04 LONG 8.81 L VALUE 1.49 TED0 114.71 TED30 114.46
MEP81 74.32 MEP83 75.60 MEP0 49.44 L TIME 301.00 ML TIME 300.54 VERS 1.

ON/OFF MEPED 1 HEPAD 0 TED 1 IFC MEPED 0 TED/HEPAD 0 TED MODE 0 FORMAT 1 TED PHD 0

	MPTT	METT	MELT	OMNI	AMSS	HELT	PMT	PMHV	HSSD	LVL	TEPS	TPSS	LVR	CEA	TEDT
HOUSEKEEPING	-11.8	-11.2	-10.7	-28.8	82.8	-67.0	-67.0	0.0	0.0	0.0	3.0	2.0	3.0	653.6	-11.5

HEPAD DATA IN COUNTS

BLOCK	P1	P2	P3	P4	A1	A2	S5	S4	S1	S2	S3
1	0	0	0	0	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0

MEPED DATA IONS 0I -1 90I -1

SUB	0P1	0P2	0P3	0P4	0P5	0E1	0E2	0E3	90P1	90P2	90P3	90P4	90P5	90E1	90E2	90E3	P6	P7	P8
5	197	561	165	20	46	689	441	149	87	133	52	16	71	29185	18945	3009	1889	1121	913
6	197	561	165	22	56	689	441	123	79	123	48	13	79	29185	18945	3009	1889	1121	913
7	189	593	173	14	60	753	473	133	83	165	58	15	75	30209	19969	3265	1953	1185	977
8	213	593	165	20	52	721	441	141	75	127	54	15	75	30209	19969	3137	2017	1249	977

TED DATA

0DE1	0DE3	0DE5	0DE7	0DE	0EM	FLUX	30DE1	30DE3	30DE5	30DE7	30DE	30EM	FLUX
5.	4.	4.	2.	9.	11.	.192	3.	2.	2.	4.	6.	2.	.177
0DP1	0DP3	0DP5	0DP7	0DP	0PM	FLUX	30DP1	30DP3	30DP5	30DP7	30DP	30PM	FLUX
0.	2.	2.	1.	4.	10.	.186	1.	3.	3.	5.	5.	7.	.218

0EFD	0DEM	0EM	30EFD	30DEM	30EM	0PFD	0DPM	0PM	30PFD	30DPM	30PM
20.0	9.	11.	21.0	7.	11.	7.8	5.	2.	12.5	4.	9.
17.0	5.	2.	21.0	6.	2.	13.5	6.	1.	8.5	3.	5.
22.0	7.	5.	21.0	7.	4.	13.5	4.	10.	9.5	4.	3.
18.0	6.	6.	27.0	8.	10.	7.3	4.	1.	11.5	5.	7.

Figure 6.1 A sample 8-s data record

6.1.3 Data

The data are packed binary, two's complement, signed integers. When a value can be negative an S is added following the number of bytes in the word, e.g. 2S means this is a signed 2-byte word. If all words are unpacked as unsigned integers, the signed values can be found as follows

1S: If the word is greater than	127,	subtract	256	(2^8)
2S: If the word is greater than	32,767,	subtract	65,536	(2^{16})
3S: If the word is greater than	8,388,607,	subtract	16,777,216	(2^{24})

6.2 Tables Record Format

Each archive tape starts with a "tables record" which is followed by up to 9900 "data records". The tables record is the same for all spacecraft and on all archive tapes. It contains the conversion tables to convert telemetry words to the detector response in counts per accumulation period. Data records are physical records of 3420 bytes, which contain 12 logical records of 285 bytes. On the archive tape, data values have not been converted to counts. There are two ways to convert the data: by using the conversion tables in the tables record (described in Section 6.2.1), or by using the conversion algorithms described in Section 6.2.2.

6.2.1 Conversion Tables

The conversion tables, in the tables record, are in two arrays called CC1 and CC2. The arrays are used as look-up tables to convert telemetry data words into counts per accumulation period. The CC1 and CC2 arrays each contain 256 24-bit words (see Table 6.1). Telemetry data words are always one byte (8 bits) in the range 0 - 255. To convert a telemetry word to counts, use the value of the telemetry word plus 1 (telemetry word + 1 range 1 - 256) as an index to the CC1 or CC2 array. The number indexed from the array will give counts per accumulation period. To convert counts per accumulation period to counts per second, see the record timing description and tables in Section 5.

The CC1 array is used for all telemetry data words except the TED total flux channels (0EF-D, 30EF-D, 0PF-D and 30PF-D) which use the CC2 array. Of course, conversion is only needed for values that measure counts, remember that the TED Interval and Total Energy Flux values are **not** counts.

The CC2 array is the same as CC1, except for CC2(105) through CC2(160), so it is not necessary to hold both arrays. In addition, CC2(145) through CC2(152) are not referenced by valid telemetry data, and so are set to −1 in the array.

Table 6.1 Tables record

Conversion array	Range	Units	factor	Number of words	Byte count	Bytes per word
CC1	0–499713	Counts	1	256	1 - 768	3
CC2	0.1–192512	Counts	0.1	256	769 - 1536	3

6.2.2 Conversion Algorithms

Instead of the CC1 and CC2 conversion tables, telemetry words can be converted to counts per accumulation period by using conversion algorithms. The algorithm variables are:

CTS = counts per accumulation period
Y = the four most significant bits of the telemetry word
X = the four least significant bits of the telemetry word
Note: Use only the integer portion of CTS.

CC1 normal conversion:

If Y = 0 thru 8	and X = 0 thru 15,	CTS = $[(X + 16.5) * 2^{(Y+6)}] + 1$
except if Y = 8	and X = 15,	CTS = 0.0
If Y = 9	and X = 0 thru 15,	CTS = X + 1.5
If Y = 10	and X = 0 thru 15,	CTS = X + 17.5
If Y = 11 thru 15	and X = 0 thru 15,	CTS = $[(X + 16.5) * 2^{(Y-10)}] + 1$

CC1 alternate conversion:

Add 113 (01110001 binary) to the word

If Y = 0,	CTS = X
If Y = 1 through 15,	CTS = $[(X + 15.5) * 2^{(Y-1)}] + 1$

Note: If Y > 2 and X = 0, add $2^{(Y-3)}$
If Y = 2 and X = 0, add 1

CC2 conversion for TED total flux channels 0EF-D, 0PF-D, 30EF-D, 30PF-D:

Use the CC1 conversion, with these exceptions:

If Y = 9 and X = 0 through 7, ERROR; this configuration cannot occur

If Y = 9	and X = 8 through 15,	CTS = X + .5
If Y = 8	and X = 0 through 15,	CTS = .125X + .0625
If Y = 7	and X = 0 through 7,	use CC1 except subtract 1
If Y = 7	and X = 8 through 15,	CTS = .25X + .125
If Y = 6	and X = 0 through 7,	use CC1 except subtract 1
If Y = 6	and X = 8 through 15,	CTS = .5X + .25

TED 0DE-M, 0DP-M, 30DE-M and 30DP-M:

Use CC1 conversion, except:

If Y = 0 and X = 0, check corresponding F-D channel

if counts are present in the F-D channel,	CTS = 1057.
if counts are not present in the F-D channel,	CTS = 0.0.

6.3 Logical Record Formats

Logical data records contain 8 seconds of instrument data plus the related orbital and housekeeping information.

The records are ordered by time; the time, T0, associated with every record is in milliseconds of the day. Orbital and housekeeping information is valid at T0, but other data are not (see the discussion on record timing, Section 5). Table 6.2 shows the general format of every logical record.

Table 6.2 Logical Record Format

Description	Number of bytes	Byte count
Orbital Information	72	1 - 72
Housekeeping Information	29	73 - 101
MEPED	78	102 - 179
HEPAD	22	180 - 201
TED	84	203 - 285
Total Bytes	285	

The format of all records is the same, but the values contained in certain fields of the MEPED and TED instrument data are not the same in all records. The original raw data tapes contain data "frames" of 32 seconds each. These frames are divided into four 8–s records on the archive tape. To identify which part of the original frame a record comes from, a number from 1 to 4 is included on each archive record to indicate "record type". Sections 6.3.3 and 6.3.5 describe the differences between the record types for the MEPED and TED data. Because the four record types were originally a single frame on the raw data tape they will always be in consecutive order; time gaps are possible only between record types 4 and 1.

In Tables 6.3 - 6.9 the headings mean the following:

Word: The position of the data within the COMMON BLOCK arrays described in Appendix A table A.2.

Description (or Data channel): The term used to identify the data.

Range: The maximum and minimum values of the data, after conversion.

Units: The units of the data, after conversion.

Conversion Factor: The number by which a data value must be multiplied to convert it to usable units. Note that for data being converted to counts this is the conversion table name; CC1 or CC2 (see Section 6.2).

Number of bytes: The number of bytes required for these data. An "S" means signed value.

Byte count: The position of the data within the whole 285–byte record.

6.3.1 Orbital Information Format

Table 6.3 shows the orbital information in every 8–s data record.

Table 6.3 Orbital Information

Word	Description	Range	Units	Conversion factor	Number of bytes	Byte count
1	Spacecraft ID	0 to 9			1	1
T0 Begin time of the record						
2	Year	78 to 99			1	2
3	Day of the year	1 to 366			2	3– 4
4	Milliseconds of the day	0 to 86400000			4	5– 8
5	Receiving station	0 to 6			2	9–10
6	Altitude	about 850.0	km	0.1	2	11–12
7	Inclination	about 99.0	deg	0.1	2	13–14
8	Orbit number (>12 years)	1 to 65535			2	15–16
9	Record type	1 to 4			2	17–18
Data at the satellite						
1	Geographic latitude	–90.00 to 90.00	deg	0.01	2S	19–20
2	Geographic east longitude	0.00 to 360.00	deg	0.01	2	21–22
3	BR	–41000 to 43000	nT		3S	23–25
4	BT	–27000 to 10000	nT		3S	26–28
5	BP	–10000 to 10000	nT		3S	29–31
6	BB	20000 to 45000	nT		2	32–33
Data at the Foot Of the Field Line (FOFL)						
7	Geographic latitude	–90.00 to 90.00	deg	0.01	2S	34–35
8	Geographic east longitude	0.00 to 360.00	deg	0.01	2	36–37
9	BR120	–58000 to 65000	nT		3S	38–40
10	BT120	–36000 to 15000	nT		3S	41–43
11	BP120	–15000 to 15000	nT		3S	44–46
12	BB120	20000 to 45000	nT		2	47–48
13	Geomagnetic latitude	–90.00 to 90.00	deg	0.01	2S	49–50
14	Geomagnetic east longitude	0.00 to 360.00	deg	0.01	2	51–52
15	L–value (set to 0.0 if greater than 14.99)	0.93 to 14.99		0.01	2	53–54

Table 6.3 Orbital Information - continued

Word	Description	Range	Units	Conversion factor	Number of bytes	Byte count
Pitch Angles						
16	TED 0 deg detector*	0.00 to 180.00	deg	0.01	2	55-56
17	TED 30 deg detector*	0.00 to 180.00	deg	0.01	2	57-58
18	MEPED 81 deg Electron detector**	0.00 to 180.00	deg	0.01	2	59-60
19	MEPED 83 deg Electron detector**	0.00 to 180.00	deg	0.01	2	61-62
20	MEPED 0 deg Electron detector**	0.00 to 180.00	deg	0.01	2	63-64
Miscellaneous information						
21	Local time**	0.00 to 360.00	deg	0.01	2	65-66
22	Magnetic local time**	0.00 to 360.00	deg	0.01	2	67-68
23	Program version	1 to 99			1	69
	Zero fill	0			3	70-72
				Total Bytes	**72**	

* at the Foot Of the Field Line (FOFL), 120 km
** at the satellite
Pitch angle detector sensor angle descriptions are with respect to the zenith (local Earth vertical).

6.3.2 Status and Housekeeping Information Format

Tables 6.4 and 6.5 are the status and housekeeping information in every 8-s data record.

Table 6.4 Status Information

Status word	Description	Status	Position	Bits	Number of bytes	Byte count
1	MEPED on/off	1 = on, 0 = off	MSB**	1		
2	HEPAD on/off	1 = on, 0 = off		1		
3	TED on/off	1 = on, 0 = off		1		
4	MEPED IFC*	1 = yes, 2 = no		1	1	73
5	TED/HEPAD IFC*	1 = yes, 2 = no		1		
6	TED mode	0 to 3 2				
7	Telemetry format	1 = 1, 0 = 2	LSB**	1		
8	TED PHD flags	0 to 15		4-4	1	74
			Total Bytes		**2**	

* IFC = In-Flight Calibration
** MSB = the most significant bit of the word; LSB = the least significant bit.

Table 6.5 Housekeeping Information

Housekeeping word	Description	Range	Units	Conversion factor	Number of bytes	Byte count
1	MPTT	-67.0 to 40.6	deg C	0.1	2S	75- 76
2	METT	-67.0 to 40.6	deg C	0.1	2S	77- 78
3	MELT	-67.0 to 40.6	deg C	0.1	2S	79- 80
4	OMNI	-81.0 to 4.9	deg C	0.1	2S	81- 82
5	AMSS	-0.00 to 4640.30	volts	0.01	2	83- 84
6	HELT	-67.0 to 40.6	deg C	0.1	2S	85- 86
7	PMT	-67.0 to 40.6	deg C	0.1	2S	87- 88
8	PMHV	0.00 to 5.10	volts	0.01	2	89- 90
9	HSSD	0.0 to 5478.4	volts	0.1	2	91- 92
10	LVL	0 to 128*	level	1	1	93
11	TEPS	0 to 8*	level	1	1	94
12	TPPS	0 to 8*	level	1	1	95
13	LVR	0.00 to 5.10	volts	0.01	2	96- 97
14	CEA	0.0 to 791.5	volts	0.1	2	98- 99
15	TEDT	-67.0 to 40.6	deg C	0.1	2S	100-101
			Total Bytes		**27**	

* The valid range begins at 1, bad data is denoted by a zero (0).

6.3.3 MEPED Data Format

Table 6.6 shows the MEPED data in one 8-s data record. The 0 and 90 deg $Z \geq 2$ ions (MEPED words 1 and 2) are read out only once every 16 seconds and are therefore present only in record types 1 and 3. Words 1 and 2 of record types 2 and 4 contain -1. The record type is in the Orbital Information in every data record. All other channels are read every 2 seconds and are in four groups within the 8-s record. Remember, "counts" in the data record are counts per accumulation period.

Table 6.6 MEPED Data Format

MEPED word	Data channel	Units	Conversion factor	Number of bytes	Byte count
	Ions				
1	0I (Record Type 1 & 3 only)	Counts	CC1	1	102
2	90I (Record Type 1 & 3 only)	"	"	1	103
	Protons and Electrons				
3 to 7	0P1 to 0P5	"	"	5 X 1	104-108
8 to 10	0E1 to 0E3	"	"	3 X 1	109-111
11 to 15	90P1 to 90P5	"	"	5 X 1	112-116
16 to 18	90E1 to 90E3	"	"	3 X 1	117-119
19 to 21	P6 to P8	"	"	3 X 1	120-122
repeat words 3 to 21 (0P1 to P8)		"	"	19 X 1	123-141
repeat words 3 to 21 (0P1 to P8)		"	"	19 X 1	142-160
repeat words 3 to 21 (0P1 to P8)		"	"	19 X 1	161-179
		Total Bytes		**78**	

6.3.4 HEPAD Data Format

Table 6.7 shows the HEPAD data in one 8–s data record. Each data channel is read every 2 seconds, and the data are in four groups within the 8–s record. Remember, "counts" in the data record are counts per accumulation period.

Table 6.7 HEPAD Data Format

HEPAD word	Data channel	Units	Conversion factor	Number of bytes	Byte count
1	P1	Counts	CC1	1	180
2	P2	"	"	1	181
3	P3	"	"	1	182
4	P4	"	"	1	183
5	alpha 1	"	"	1	184
6	alpha 2	"	"	1	185
7	S5	"	"	1	186
8	S4	"	"	1	187
9	S1	"	"	1	188
10	S2	"	"	1	189
11	S3	"	"	1	190
	repeat P1 to S3	"	"	11 X 1	191–201
			Total Bytes	**22**	

6.3.5 TED Data Format

The TED data set is much larger and more complex than the other instrument data sets. It contains data from four different detectors, and each detector is sampled four times in every 8–s data record. However, although some values are read out four times per record, others are included only once. Table 6.8 shows the TED Record Format in record types 1, 2, and 3. Table 6.9 shows record type 4, which contains background information as well as the repeated detector data. Note that these and the other TED Tables are for PHD settings—Mode 0 Format 1; this is the only configuration in which the TED has operated.

Each data record contains TED data from four detectors: the 0–deg electron detector, the 30–deg electron detector, the 0–deg proton detector, and the 30–deg Proton detector. In record types 1, 2, and 3, the TED data contain four groups of 19 data words. The first six words of each group are different energy interval readings from one detector; each of the four detectors is used in one of the four groups. Words 7-18 are the same in each of the four groups, but contain only the maximum energy interval reading from each detector. Word 19 is the Total Energy Flux, calculated from the 0EF–D, 0PF–D, 30EF–D, and 30PF–D maximum energy interval data in that group. In record type 1 the first 19 words contain all zeros: at the beginning of the tape, after a time gap, or if the preceding record is missing.

In record type 4, words 1–4 of the first group contain background data. The first four words of the following groups contain zeros. Words 5–19 of all groups are the same as in record types 1, 2, and 3 (see table 6.9).

TED data are converted to counts using the CC1 or CC2 tables (except of course the Total Energy Flux values and 0E–M, 30E–M, 0P–M, and 30P–M, which need no conversion).

When the received signal is noisy and the data processing equipment loses synchronization, the value 1057 is put into the data word. Unfortunately, the value 1057 can represent a valid data point, and often does. The only way this ambiguity can be resolved is to examine all data channels for that time and to look for other anomalous data values (particularly housekeeping) which indicate noisy data. Such a subjective examination was not done on the archive tapes.

The total energy flux calculation always treats the value 1057 in the 0EF–D, 30EF–D, 0PF–D, or 30PF–D channels as noise. In such instances the Total Energy Flux is set to 0.00. If the value 1057 was, in fact, a valid data point and not telemetry noise, the Total Energy Flux would be about 8 ergs $cm^{-2}\ s^{-1}$.

Table 6.8 TED Data Format – record types 1, 2, 3

TED word	Data channel	Range	Units	Conversion factor	Number of bytes	Byte count
1	0DE–1		Counts	CC1	1	202
2	0DE–3		"	"	1	203
3	0DE–5		"	"	1	204
4	0DE–7		"	"	1	205
5	0DE–M		"	"	1	206
6	0E–M	1–11			1	207
7	0EF–D		"	CC2	1	208
8	0DE–M		"	CC1	1	209
9	0E–M	1–11			1	210
10	30EF–D		"	CC2	1	211
11	30DE–M		"	CC1	1	212
12	30E–M	1–11			1	213
13	0PF–D		"	CC2	1	214
14	0DP–M		"	CC1	1	215
15	0P–M	1–11			1	216
16	30PF–D		"	CC2	1	217
17	30DP–M		"	CC1	1	218
18	30P–M	1–11			1	219
19 Total Energy Flux 0.001 to 1000 ergs cm–2 s–1				0.001	3	220–222
			total bytes in group		**21**	
	30DE–1, 3, 5, 7		Counts	CC1	4	223–226
	30DE–M		"	CC1	1	227
	30E–M	1–11			1	228
repeat 0EF–D to Total Energy Flux (words 7–19)					15	229–243
			total bytes in group		**21**	
	0DP–1, 3, 5, 7		Counts	CC1	4	244–247
	0DP–M		"	CC1	1	248
	0P–M	1–11			1	249
repeat 0EF–D to Total Energy Flux (words 7–19)					15	250–264
			total bytes in group		**21**	
	30DP–1, 3, 5, 7		Counts	CC1	4	265–268
	30DP–M		"	CC1	1	269
	30P–M	1–11			1	270
repeat 0EF–D to Total Energy Flux (words 7–19)					15	271–285
			total bytes in group		**21**	
			Total Bytes		**84**	

Table 6.9 TED Background Data Format - record type 4

TED word	Data channel	Range	Units	Conversion factor	Number of bytes	Byte count
1	0E–BK		Counts	CC1	1	202
2	30E–BK		"	"	1	203
3	0P–BK		"	"	1	204
4	30P–BK		"	"	1	205
5–19	same as record types 1, 2 & 3					206–222
			total bytes in group		**21**	
	zeros					223–226
	same as record types 1, 2 & 3					227–243
			total bytes in group		**21**	
	zeros					244–247
	same as record types 1, 2 & 3					248–264
			total bytes in group		**21**	
	zeros					265–268
	same as record types 1, 2 & 3					269–285
			total bytes in group		**21**	
			Total Bytes		**84**	

APPENDIX A: Retrieval routines on the ERL computer

The archive tapes can be read and unpacked with routines from two libraries on the ERL CYBER 840 computer in Boulder. The routines run under CDC Fortran 5. Users who do not have access to the ERL computer can get listings of the libraries from Judy Stephenson at NOAA/SEL, RE/E/SE, 325 Broadway, Boulder, Colorado 80303.

To use the libraries the following control cards are needed. An archive tape is assigned to TAPE1 as shown. The volume serial numbers (VSN) for archive tapes are available from Judy Stephenson.

```
ATTACH(TLIB5/UN=TIROS)
ATTACH(ULIB5/UN=SELLIB)
LIBRARY(TLIB5/ULIB5)
LABEL(TAPE1,NT,D=1600,PO=R,F=I,LB=KL,FA=E,VSN=TXXXXX=NXXXXX)
```

Table A.1 is a sample program which reads an archive tape and print out 10 records. Is uses the library routines READIN (to set-up the range of data to retrieve) and CONTROL (to read the next logical data record into COMMON /REC/). Subroutine PRINTER, also in the library, prints out the data in COMMON /REC/ in the format shown in Section 6.1 (Figure 6.1).

Table A.1 Sample program

```
      PROGRAM PRINT
C      READ AND PRINT 10 RECORDS FROM A TIROS/NOAA ARCHIVE TIME
C
      COMMON/REC/ IHD(9), HEAD(23), ISTAT(8), HOUS(15), MEPI(2),
     1          MEP(19,4), IHEP(11,2), TED(18,4), TEDFX(4)
C
C               READ INPUT, SET LIMITS AND READ TABLES RECORD,
C               (ONLY CALLED ONCE)
      CALL READIN
C
C               READ AND PRINT DATA RECORDS UNTIL LIMITS REACHED
10    CALL CONTROL (IQT)
      IF (IQT .EQ. 1) GO TO 90
      CALL PRINTER
      GO TO 10
C
C               END FOUND
90    PRINT 9000
9000  FORMAT (*0END OF TAPE*)
      STOP
      END
```

INPUT

```
READ 10 RECORDS STARTING 1983, FEB 12, 1230UT. This is the comment card.
'START',83,33,12,30,0/
'RECORDS',1,10/
```

Subroutine READIN

Every program must begin with one call to subroutine READIN (form CALL READIN), which reads INPUT for the range of data to retrieve. The INPUT cards are described in Table A.2. At least one card, the *comment card*, must be in INPUT or the program will stop; it may be followed by as many *option cards* as needed. The comment card is one line describing the job. Option cards have the general format:

'keyword',P1,P2,P3,P4,P5/

where the keyword is enclosed in single quotes and followed by up to 5 integer parameters separated by commas and terminated with a slash. The current keywords are: START, END, ORBIT (or ORBITS), and RECORD (or RECORDS).

The comment card, the current date/time, and the option cards are printed on the top of the first page of output.

Table A.2 INPUT cards for subroutine READIN

INPUT card format	Description
NECESSARY CARD	
COMMENT CARD	up to 80 characters of general information which are printed on the output
OPTION CARDS	
'START',YR,DOY,HR,MIN,MSEC/	date/time to begin
'END',YR,DOY,HR,MIN,MSEC/	date/time to end
'ORBIT',n/	orbit number to begin processing
'ORBITS',n,m/	range of orbit numbers to process
'RECORD',n/	begin with nth data record on the tape after START and ORBIT are satisfied.
'RECORDS',n,m/	begin with the nth record on the tape after START and ORBIT are satisfied. Process through the mth record.
OPTION CARD PARAMETERS	
YR	year, 2 digits only - example 82
DOY	day of the year - 1 to 366
HR	hour of the day - any integer
MIN	minute of the hour - any integer
MSEC	millisecond of the minute - any integer
n,m	any integers

The option card parameters must be in the correct order, but it is not necessary to use all of them. For example, 1983 FEB 12 00:00:00 can be entered as

'START',83,33,0,0,0/ or 'START',83,33/

'RECORDS',5,10/ will return the 5th, 6th, 7th, 8th, 9th, and 10th record after the ORBIT number and START time are satisfied; if they are present.

Option cards can be used in any combination. When an ORBIT number is included the tape is read until the beginning ORBIT number is found; then the tape is read until the START time is reached. Finally the RECORD count begins, and the nth record from this point is the first record returned. Processing stops on the record after any limit is satisfied, e.g., after the END time is reached, the last ORBIT number is found, or the mth record is read. No checks are made on the date/times or other numbers to be sure they are valid or reasonable.

Subroutine CONTROL

Subroutine CONTROL (form CALL CONTROL (IQT) with COMMON /REC/) unpacks the next logical data record into the common block /REC/ (described in Table A.3). After every call to CONTROL the next 8-s data record is read, unpacked, converted to the units defined in Section 6, and then stored in COMMON /REC/. The format of COMMON /REC/ is:

```
COMMON /REC/  IHD(9), HEAD(23), ISTAT(8), HOUS(15), MEPI(2),
         MEP(19,4),IHEP(11,2), TED(18,4), TEDFX(4)
```

The variable IQT, in CONTROL's calling sequence, is a flag to signal good read or end.

If IQT = 0 the read was good and a new record is in /REC/.
If IQT = 1 a new record was not read. Processing has stopped because the end of the tape was reached or the end of the range was reached.

Reserved Names

The libraries use the following names for subroutines and common blocks, so the user's programs should not contain routines or variables with these names:

/CON/	READCW	UNPACK
CONTROL	READER	UNPACKH
INITCW	READIN	UNPACKM
/INPUT/	/REC/	UNPACKT
/IPR/	SKIPCW	UNPACK24
I2TT	UCTAB	UNPACK8
PRINTER		

Table A.3 Contents of COMMON /REC/

Variable type		Description
ORBITAL INFORMATION		
IHD(1)	Integer	Spacecraft ID
IHD(2)	"	Year
IHD(3)	"	Day of the year
IHD(4)	"	Millisecond of the day
IHD(5)	"	Receiving station
IHD(6)	"	Altitude
IHD(7)	"	Inclination
IHD(8)	"	Orbit number
IHD(9)	"	Record type
HEAD(1)	Floating point	Geographic latitude at the satellite
HEAD(2)	"	Geographic east longitude at the satellite
HEAD(3)	"	BR at the satellite
HEAD(4)	"	BT at the satellite
HEAD(5)	"	BP at the satellite
HEAD(6)	"	BB at the satellite
HEAD(7)	"	Geographic latitude at the FOFL
HEAD(8)	"	Geographic east longitude at the FOFL
HEAD(9)	"	BR120 at the FOFL
HEAD(10)	"	BT120 at the FOFL
HEAD(11)	"	BP120 at the FOFL
HEAD(12)	"	BB120 at the FOFL
HEAD(13)	"	Geomagnetic latitude at the FOFL
HEAD(14)	"	Geomagnetic east longitude at the FOFL
HEAD(15)	"	L-value
HEAD(16)	"	TED0 Pitch Angle
HEAD(17)	"	TED30 Pitch Angle
HEAD(18)	"	MEPED81 Pitch Angle
HEAD(19)	"	MEPED83 Pitch Angle
HEAD(20)	"	MEPED0 Pitch Angle
HEAD(21)	"	Local time at the satellite
HEAD(22)	"	Magnetic Local time at the satellite
HEAD(23)	"	Program version
HOUSEKEEPING INFORMATION		
ISTAT(1)	Integer	MEPED on/off
ISTAT(2)	"	HEPAD on/off
ISTAT(3)	"	TED on/off
ISTAT(4)	"	MEPED IFC
ISTAT(5)	"	TED/HEPAD IFC
ISTAT(6)	"	TED MODE
ISTAT(7)	"	TELEMETRY FORMAT
ISTAT(8)	"	TED PHD flags
HOUS(1) - HOUS(15)	Floating point	Instrument housekeeping words

MEPED DATA

MEPI(1), MEPI(2)	Integer	0I, 90I
MEP(1,n) - MEP(5,n)	"	0P1 to 0P5
MEP(6,n) - MEP(8,n)	"	0E1 to 0E3
MEP(9,n) - MEP(13,n)	"	90P1 to 90P5
MEP(14,n) - MEP(16,n)	"	90E1 to 90E3
MEP(17,n) - MEP(19,n)	"	P6 to P8
where n = 1 to 4		

HEPAD DATA

IHEP(1,n) - IHEP(4,n)	Integer	P1 to P4
IHEP(5,n)	"	alpha 1
IHEP(6,n)	"	alpha 2
IHEP(7,n)	"	S5
IHEP(8,n)	"	S4
IHEP(9,n)	"	S1
IHEP(10,n)	"	S2
IHEP(11,n)	"	S3
where n = 1 to 2		

TED DATA

TED(1,n)	Integer	0DE-1 *
TED(2,n)	"	0DE-3 *
TED(3,n)	"	0DE-5 *
TED(4,n)	"	0DE-7 *
TED(5,n)	"	0DE-M *
TED(6,n)	"	0E-M *
TED(7,n) - TED(9,n)	"	0EF-D, 0DE-M, 0E-M
TED(10,n) - TED(12,n)	"	30EF-D, 30DE-M, 30E-M
TED(13,n) - TED(15,n)	"	0PF-D, 0DP-M, 0P-M
TED(16,n) - TED(18,n)	"	30PF-D, 30DP-M, 30P-M
where n = 1 to 4		
TEDFX(m)	Floating point	Total Energy Flux
where m* = 1 to 4		

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* m = 1 for the 0-deg electron detector,
m = 2 for the 30-deg electron detector,
m = 3 for the 0-deg proton detector,
m = 4 for the 30-deg proton detector.

In record type 1, TED (1,1) through TED (18,1) contain zeros if the previous record was missing (i.e., if this is the first record on the tape or the first record after a time gap).

In record type 4, TED(1,1) through TED(4,1) contain background counts and TED(1,n) through TED(4,n), for n = 2, 3, 4 contain zeros.

APPENDIX B: Problems and errors in the archive data

Some problems have been found in the SEM data and the archive tapes since processing began in late 1978. The TED instrument data are analyzed carefully when the archive tapes are produced and all known problems with the data are noted below. The MEPED and HEPAD data have not been looked at consistently, and little is known about minor instrument problems. All known problems are described briefly in this section.

When the received signal is noisy and the data-processing equipment loses synchronization, the bad data words that result are set to 1057 on the raw data tapes. As noted, the value 1057 can represent a valid data point, and often does. The only way this ambiguity can be resolved is to examine all data channels looking for other anomalous data values (particularly housekeeping) that indicate noisy data. Such a subjective examination was not done on the archive tapes.

The Total Energy Flux data in the TED instrument (the only calculated data value on the archive tape) always treats the value 1057 in the 0EF-D, 30EF-D, 0PF-D, or 30PF-D channels as noise. In such instances the Total Energy Flux is set to 0.00. If the value 1057 was, in fact, a valid data point and not telemetry noise Total Energy Flux would be in the order of 8 ergs $cm^{-2}\ s^{-1}$.

The orbit number in the header information should increment as the satellite crosses from the Southern Hemisphere to the Northern Hemisphere in each orbit. Because of a problem in the algorithm used, some orbit numbers in the 1979 and 1980 data on both TIROS-N and NOAA-6 do not increment when the satellite is near the equator but change as far north as 20 deg. The orbit numbers in data from January 1, 1981, onward increment when the satellite is between 0 and 4 deg north of the equator.

The NOAA-7 TED 30-deg detector "sees" sunlight, which introduces a background response. This response occurs when the satellite is on the day side of the Earth, and is most apparent in the Northern Hemisphere during the Northern Hemisphere summer and in the Southern Hemisphere during the Southern Hemisphere summer. The magnitude of the undesirable detector response maximizes at the sub-solar location but is still observed to be present well into the auroral regions. The 0-deg detector is unaffected. When the contaminated 30-deg detector response is combined with the normal 0-deg response to obtain the Total Energy Flux at locations below the auroral zones (where the contamination is largest), an anomalous energy flux of about 0.1 erg $cm^{-2}\ s^{-1}$ is obtained. Those instances when the 30-deg detector contamination gives rise to totally incorrect total energy fluxes may be reliably identified with the following criterion. If the satellite is on the day side of the Earth and the 30-deg detector response exceeds the 0-deg detector response by more than a factor of 3, the 30-deg detector response should be ignored.

In 1982, NOAA-7 sustained a loss of TED data from day 068, 1145UT, through day 082, 1403UT. During this time the TED instrument was turned off in the course of testing for the source of interference with the NOAA-7 command receiver and then turned on again in an incorrect mode.

In 1982 there was another loss of TED data on NOAA-7 from day 328, 0100UT, through day 394, 1625UT. The TED was again turned off in order to check the source of contamination being sensed by a "contamination" detector on the spacecraft. After the instrument was turned back on again, there was evidence of an electrical interference source or corona, which affected the 30-deg proton detector in a spasmodic fashion for many days. This problem eventually went away, but while it was present it caused large count rates to appear in the 30-deg proton channel, which in turn resulted in large and incorrect Total Energy Fluxes.

When NOAA-8 came on-line the "sunlight" problem was more severe than on NOAA-7. A modification was made to the archive program that removes this contamination.

The MEPED and HEPAD instruments on NOAA-7 where permanently turned off April 1, 1982.

There is no HEPAD instrument on NOAA-8 or NOAA-10, and no HEPAD will be flown on later satellites.

NOAA-9 did not carry a SEM instrument, and NOAA-11 (scheduled for launch in the summer of 1988) will not carry a SEM.

Beginning on NOAA-10 a data quality flag was calculated during the archive processing and inserted into the HEPAD words (which are normally zero because there is no HEPAD instrument on NOAA-10).

IHEP(1,1) = 1 if some of the data in the last 4 seconds of the **previous** record is questionable.

IHEP(2,1) = 1 if some of the data in the first 4 seconds of this record is questionable.

IHEP (1,2) = 1 if some of the data in the first 4 seconds of this record is questionable.

IHEP(2,2) = 1 if some of the data in the last 4 seconds of this record is questionable.

NOTE: IHEP is the HEPAD array created by the retrieval routines described in Appendix A. On the archive tape these words are actually 143 and 144, so that they are converted to 0 and 1 by the look-up table; where 0 means all data is good, 1 means some data is questionable.

Table B.1 shows the dates and times of minor data problems.

Table B.1 Problems in the SEM data

Spacecraft	Year	Begin DOY/time	End DOY/time	Problem
TIROS-N	1979	188/0000UT	218/2359UT	Bad orbital data
TIROS-N	1979	188/2025UT	218/1324UT	TED data bad
TIROS-N	1980	067/0130UT	068/0130UT	All SEM data bad
TIROS-N	1980	268/1900UT	269/0730UT	Bad orbital data
NOAA-6	1980	062/0430UT	064/0000UT	Bad orbital data
NOAA-6	1980	329/0615UT	329/2300UT	Bad orbital data
NOAA-6	1981	250/1545UT	265/1443UT	No TED data

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