Space Environment Monitor Subsystem

The Space Environment Monitor (SEM) measures *in situ* the effect of the sun on the near-earth solar-terrestrial electromagnetic environment, providing real-time data to the Space Environment Services Center (SESC). The SESC, as the nation's "space weather" service, receives, monitors, and interprets a wide variety of solar-terrestrial data, and issues reports, alerts and forecasts for special events such as solar flares or geomagnetic storms. This information is important to the operation of military and civilian radio wave and satellite communication and navigation systems, as well as electric power networks, and to the mission of geophysical explorers, Shuttle and Space Station astronauts, high-altitude aviators, and scientific researchers.

The SEM subsystem consists of four instruments used for *in situ* measurements and monitoring of the near-earth (geostationary altitude) space environment and for observing the solar X-ray output. An energetic particles sensor (EPS) and high energy proton and alpha detector (HEPAD) monitor the incident flux density of protons, alpha particles, and electrons over an extensive range of energy levels. Solar output is monitored by an X-ray sensor (XRS) mounted on an X-ray positioning platform, fixed on the solar array yoke. Two redundant three-axis magnetometers, mounted on a deployed 3-meter boom, operate one at a time to monitor earth's geomagnetic field strength in the vicinity of the spacecraft. The SEM instruments are capable of ground command-selectable, in-flight calibration for monitoring on-orbit performance and ensuring proper operation.

Energetic Particles Sensor

The EPS performs three integral measurements (at geostationary orbit) of electrons from 0.6 to more than 4.0 megaelectronvolt (MeV), a seven-channel differential analysis of protons from 0.8 to 500 MeV, and a six-channel differential analysis of alpha particles from 4 to 500 MeV per nucleon. The EPS also provides all the support required by the HEPAD, which extends the EPS energy ranges to greater than 700 MeV for protons and to greater than 3400 MeV per nucleon for alphas. The EPS and HEPAD are housed within the spacecraft main body and view the space environment through apertures.

The EPS unit consists of a telescope subassembly, a dome subassembly and signal analyzer unit/data processing unit (SAU/DPU); the latter unit provides the final amplification of the telescope and dome output signals. These components are housed on a separate panel, mounted on the spacecraft's south equipment panel, providing a clear field of view towards the west.

The telescope uses two silicon surface barrier detectors that output charge pulses to charge sensitive preamplifiers within the telescope, converting them into voltage pulses; this preconditions the signals sent to the SAU/DPU. These detectors sense low energy protons in the range of 0.8 to 15 MeV and alpha particles in the range of 4 to 60 MeV. The two detectors, surrounded by tungsten shielding, are arranged in a telescope configuration: a 50-µm, 100-mm^2 front detector and a 500-µm, 200-mm^2 rear detector. Tungsten collimators define the field of view of 70° and eliminate detector edge effects. Sweeping magnets exclude electrons below about 100 kiloelectronvolts (keV), while a 0.145-mil aluminum foil excludes light. The outer surface of the front solid-state detector is covered with 130 µg/cm^2 of aluminum, rendering it light tight.

The dome employs three sets of two 1500-µm, 25-mm^2, silicon surface barrier detectors, each with different thickness moderators covering the respective pairs' independent fields of view, thus providing three different energy thresholds. As in the telescope, the solid state detector output charge pulses are passed through charge sensitive preamplifiers, converting them into voltage pulses before being routed to the SAU/DPU. After processing, the output of the detector pairs

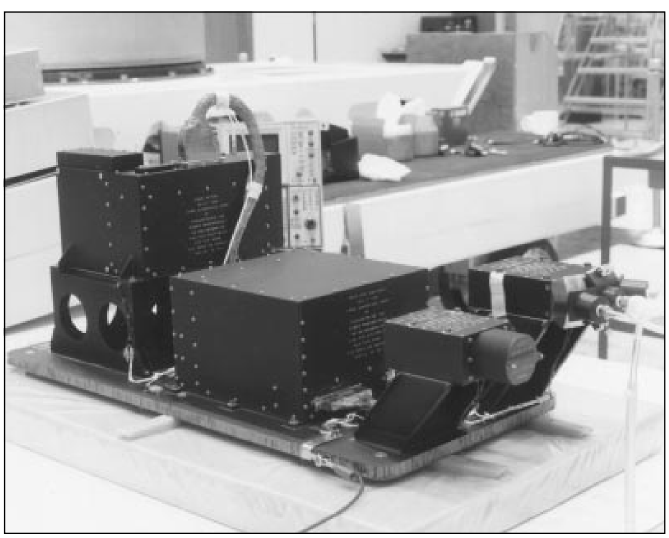
Energy Ranges for the Energetic Particles Sensor and High Energy Proton and Alpha Particle Detector

Particle Type	Channel Designation	Nominal Energy Range (MeV)	Detector Assembly
Proton	P1	≤ 0.8 to 4	Telescope
Proton	P2	4 to 9	Telescope
Proton	P3	9 to 15	Telescope
Proton	P4	15 to 40	Dome
Proton	P5	40 to 80	Dome
Proton	P6	80 to 165	Dome
Proton	P7	165 to 500	Dome
Proton	P8	350 to 420	HEPAD
Proton	P9	420 to 510	HEPAD
Proton	P10	510 to 700	HEPAD
Proton	P11	> 700	HEPAD
Alpha	A1	4 to 10	Telescope
Alpha	A2	10 to 21	Telescope
Alpha	A3	21 to 60	Telescope
Alpha	A4	60 to 150	Dome
Alpha	A5	150 to 250	Dome
Alpha	A6	300 to 500	Dome
Alpha	A7	2560 to 3400	HEPAD
Alpha	A8	>3400	HEPAD
Electron	E1	≥ 0.6	Dome
Electron	E2	≥ 2.0	Dome
Electron	E3	≥ 4.0	Dome
"Singles"	S1 to S5	—	HEPAD

Energetic Particles Sensor Performance Summary

EPS Parameter	Performance
Proton bands (P1 to P7)	7 bands 0.8 to 500 MeV, logarithmically spaced
Alpha particle bands	6 bands 3.2 to 500 MeV, logarithmically spaced
Electron bands (E1 to E3)	Integral bands with thresholds of E1: 0.55 MeV E2: 2.0 MeV E3: 4.0 MeV
Dynamic range	Cosmic ray background to largest solar particle event
Accumulation efficiency P1, E1, E2, and E3 bands P2 to P7 bands	 25% 50%
Sampling rate	Once every 10.2 or 20.5 s
Band edge stability	≤ ± 3%
Resolution	No worse than pseudolog compression of 19 to 8 bits, using 4 bits of mantissa and 4 bits of exponents
Geometric factor Telescope Dome	 > 0.06 cm^2 steradian > 0.25 cm^2 steradian
Field of view Telescope Dome	 1.1 steradian 2.0 steradian

EPS/HEPAD



provides data for four proton, three alpha, and three electron energy bands, ranging from 15 to 500 MeV for protons, 60 to 500 MeV for alphas, and less than 0.6 to more than 4.0 MeV for electrons.

High Energy Proton and Alpha Detector

The HEPAD senses incident flux of high energy protons (350 to greater than 700 MeV) and alphas (640 to greater than 850 MeV / nucleon). The unit consists of a telescope subassembly with two silicon surface barrier detectors, a Cerenkov radiator, and a photomultiplier tube (PMT), all arranged in a telescope configuration, and a signal analyzer subassembly. The Cerenkov radiator and PMT provide directional (front / rear incidence) discrimination and energy selection. The solid-state detectors differentiate between minimum ionizing protons and alpha particles and are shielded from protons below 70 MeV and electrons below 15 MeV by aluminum and tungsten barriers.

High Energy Proton and Alpha Detector Performance Summary

HEPAD Parameter	Performance
Spectral bands	
Proton	3 bands from 350 to >700 MeV
Alpha particle	2 bands from 2560 to 3400 MeV
Field of view	Conical, ~34° half angle
Geometric factor	0.9 cm^2-sr
Dynamic range	0 to 10^4 counts / s
Accumulation efficiency	100%
Stability and accuracy	≤ ± 15%
Data rate	
Primary data channel	Once every 10.2 s
Single channels	Once every 41 s
Count resolution	No worse than pseudolog compression of 19 to 8 bits, using 4 bits of mantissa and 4 bits of exponent
Contaminants	
Proton contamination in alpha channels	≤ 0.1%
Characterize response to penetrating electron in 2-13 MeV range	As specified
Lifetime	Ground commands to compensate for performance degradation during 5-year lifetime

The signal analyzer subassembly contains all the amplification and processing electronics required to sort the accepted telescope events into particular particle types and energy levels and to transmit data to the EPS SAU / DPU on 11 data lines (4 proton, 2 alpha, and 5 single channels). The five single channels are required to correct proton and alpha channel data. PMT operating voltage is changeable upon ground command to compensate for aging effects; turn-on detection circuitry ensures that the PMT voltage always initializes at the lowest value. In-flight calibration capability is also included.

The SAU / DPU multiplexes all of the EPS / HEPAD particle data (27 channels) and accumulates the results in compression counters. Outputs of these compression counters are transferred serially to spacecraft telemetry in an 80-channel submultiplexed data stream. The SAU / DPU also processes timing signals from the spacecraft telemetry unit, housekeeping telemetry, in-flight calibration, and control commands to the EPS / HEPAD subsystem. Upon ground command, the SAU / DPU in-flight calibration circuitry generates a sequence of amplitude modulated test pulses that are applied to the charge-sensitive preamplifier inputs to determine the stability of amplification chains and threshold discriminators.

X-Ray Sensor

The XRS is an X-ray telescope that measures in real-time solar X-ray flux in the spectral range of 0.5 to 3 angstroms (short sun channel) and 1 to 8 angstroms (long sun channel). The XRS assembly consists of a telescope collimator and sweeper magnet subassembly, dual ion chamber and preamplifier subassemblies, a DPU subassembly, and a bucking magnet subassembly.

X-rays are detected by two ion chambers, one for each spectral range. The detector output signals are processed by separate electronic channels that provide automatic range selection. Nominal flux levels expected are on the order of 2×10^{-8} to 2×10^{-3} W/m^2 for the long channel and 5×10^{-9} to 5×10^{-4} W/m^2 for the short channel. The capability is provided to calibrate each channel via ground command. Data transmitted through the spacecraft telemetry permit real-time ground determination of the solar X-ray emission in the two spectral bands.

The aperture of the XRS is provided with a pair of sweeper magnets to deflect incoming electrons away from the ion chambers so that only X-rays are admitted. An external bucking magnet is mounted to the XRS to minimize the magnetic signature induced at the spacecraft magnetometers.

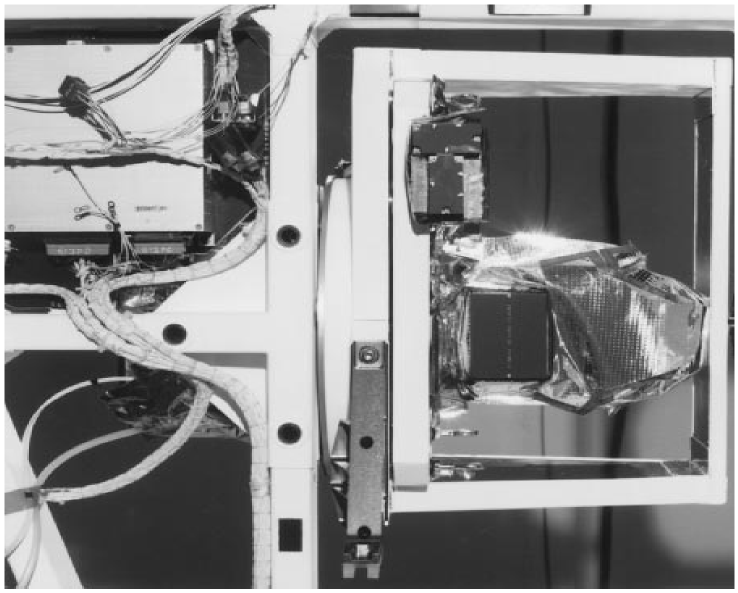
The XRS as a single unit is housed on the XRS drive assembly; this combination is mounted on the solar array yoke on the south side of the spacecraft body in a position that provides the XRS and drive assembly sun sensors a clear field of view to the sun at all times. The drive assembly moves the XRS along the north / south axis to track the sun's declination of ±23.5˚. The east / west motion of the

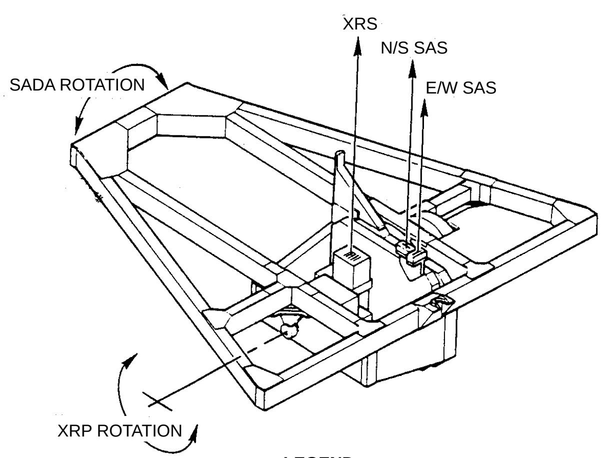
XRS is provided by the solar array drive assembly. During north / south stationkeeping maneuvers, the XRS is stowed; in this position the telescope is in-plane with and pointing to the edge of the solar array.

X-Ray Sensor Performance Summary

XRS Parameter	Performance
Spectral bands	
Channel A (short)	0.5 to 3.0 Å
Channel B (long)	1.0 to 8.0 Å
Threshold sensitivity	
Channel A	5×10^{-9} W / m^2
Channel B	2×10^{-8} W / m^2
Dynamic range	
Channel A	5×10^{-9} to 5×10^{-4}
Channel B	2×10^{-8} to 5×10^{-3}
Resolution	
Fluxes >20 times threshold	≤ 2% of reading
Sampling rate	Once every 0.512 s
Response time	
Time for output to reach 90% of final value after step change	2 s
Position determination	
Resolution	0.25°
Accuracy	0.50°

XRS Mounting on Yoke Assembly





LEGEND

E/W	East/West
N/S	North/South
SADA	Solar Array Drive Assembly
SAS	Sun Analog Sensor
XRP	X-Ray Positioner
XRS	X-Ray Sensor

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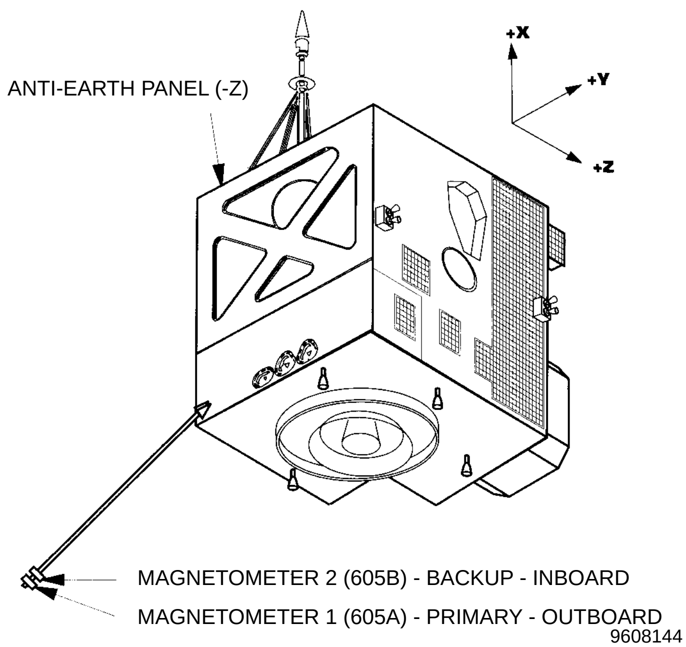
Magnetometers

The redundant magnetometers use two sensor heads, each containing three orthogonal flux-gate magnetometer elements, to measure three orthogonal vector components of the dc magnetic field applied to three flux-gate sensor elements. The applied field consists of the naturally occurring earth's field and the interfering field from the spacecraft components (the latter could be greater than the former). The determination of the ambient magnetic field in the vicinity of the spacecraft is continuous and simultaneous. The flux gates are located in a sensor assembly, attached to the end of a boom that places the sensor 3 meters away from the spacecraft body. Each flux gate magnetometer is aligned to within 0.5° of the spacecraft X, Y, and Z axes and has a linear range of ±1000 nanoTesla (nT).

The excitation and feedback signals from the sensors are routed to a dual magnetometer electronics unit located within the spacecraft main body where the signals are processed and formatted for spacecraft telemetry. An analog signal processor demodulates the flux-gate signals to produce an analog voltage proportional to the field magnitude with a polarity related to the direction of the field vector component being measured. Three analog signals representing the X, Y, and Z components of the surrounding magnetic field are digitized by a 16-bit analog-to-digital converter, producing as output a serial bit stream in which three groups of 16 bits are allocated to the polarity and magnitude of each of the three axes (a total of 48 bits).

The two three-axis magnetometers provide redundancy for measuring the geomagnetic field. One magnetometer is mounted on the boom 3 meters (9.8 feet) away (outboard) from the spacecraft, and the second, 30 centimeters (12 inches) inboard from the first on the same boom. Both magnetometers share the same telemetry channel, though only one magnetometer, with its associated three flux-gate sensors, can be powered at any time.

Magnetometers' Location



Magnetometer Performance Summary

Magnetometer Parameter	Performance
Null setting error	±2 nT
Dynamic range	±1000 nT, ambient field in any orientation
Sensitivity	10 mV / nT
Linearity	0.02% of full scale
Resolution	0.03 nT
Accuracy	< ±4 nT without temperature correction < ±1 nT with temperature correction
Noise	≤0.3 nT or 0.5% of reading whichever is greater
Data rate	1.95 Hz
Bandwidth	Dc to 0.5 ±0.032 Hz, presampling filter at –3 dB
Sensor axes orthogonality	Within ±0.5°
Sensor orientation	≤ ±1.0°, in spacecraft coordinates
Spacecraft field contamination Maximum permanent field Residual contamination after ground correction	 <200 nT < ±0.5 nT