# Engineering Notes

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## Design and Performance of the Solar Maximum Mission Hard X-Ray Burst Spectrometer

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### Design

THE hard x-ray burst spectrometer (HXRBS) is an instrument designed to investigate the role of high-energy electrons during solar flares. It is designed to obtain information on the spectral and temporal history of these energetic electrons. The energy level spectrum covers a range of 25-385 keV in 15 channels with a time resolution of 0.128 s. Counting rates are accumulated with a time resolution as short as 1 ms.

The detector (Fig. 1) on the HXRBS is very similar to the detector flown previously on OSO-5,[1] differing only in the central detector and charged-particle detector designs and the addition of calibration light pulses to the shield collimator (see Table 1). The detector consists of two primary crystal components: a disk-shaped CsI(Na) central detector and a CsI(Na) active collimator element which surrounds the central detector. Each of these two crystals is viewed by four photomultiplier tubes which convert the scintillation light pulses to electrical signals. The central crystal is the solar viewing detector, while the shield crystal serves as an x-ray collimator by providing for efficient x-ray attenuation from nonsolar directions as well as rejection of charged-particle background events.

A charged-particle detector made up of a Pilot B plastic scintillator viewed by a photomultiplier tube is mounted outside the beryllium housing. It is used to monitor the flux of charged particles in the satellite orbit and to trigger the shutdown of high-voltage power supplies to the detector photomultiplier tubes during passages through the South Atlantic Anomaly (SAA).

In-flight energy calibration of the central detector is achieved by the detection of 59.6 keV x-rays emitted by an $A_m^{241}$ radioactive source. The source is imbedded in a plastic scintillator button located in the detector field of view. The $A_m^{241}$ isotope decays by the simultaneous emission of a 59.6 keV x-ray and a 5 MeV alpha particle. The alpha particle loses energy in the button, producing a light pulse which is detected by the attached photomultiplier tube. This produces a calibrate event tag. The 59.6 keV x-ray particle emitted in coincidence with the alpha particle is detected, analyzed, and multiplexed into the telemetry data stream as a calibrator event. When the event is analyzed in a pulse height spectrum, a continuous monitor of detector energy calibration is provided.

Output signals from the photomultiplier tubes are summed and operated in anticoincidence with signals from the shield collimator, thus eliminating undesired events. Valid events are analyzed for pulse height in 15 channels between 25 and 385 keV. A spectrum is generated every 128 ms. This provides for statistically significant variations in spectrum data with very little or no spectrum distortion at high count rates. Instrument live time (time which the instrument is available to analyze events) is measured by accumulating the number of 500 kHz pulses during live time. These data are used to correct the spectrum data for instrument dead time.

In addition to the spectrum data the instrument provides a high-time-resolution count vs time readout. It uses a 32,768 byte solid-state memory operating as a continuously circulating buffer. Once a count has exceeded the trigger level set from the command stream, the memory continues to accumulate 19,456 more values. It then waits for a dump command from the telemetry and data processing unit (TLMDPU) subsystem. The time per sample can be commanded for 1-256 ms. The memory can operate in either a constant count (CC) mode (time required to count a specified number of events), or constant time (CT) mode (number of events during a specified period of time) and can count either central detector events or shield events. HXRBS is the first solar experiment to use a memory in this type of configuration (Table 1). The addition of this memory provides a time history of count rates before, during, and after a flare.

The valid events that are detected are passed to the source encoder (Fig. 2) which extracts the energy spectrum data and rate data. The source encoder passes it to the burst memory and to the TLMDPU subsystem. The TLMDPU then does the following: 1) accepts commands from either the spacecraft computer or from the ground, 2) routes these commands to the appropriate electronic subsystem, 3) accumulates health and safety data concerning the instrument and multiplexes it into the telemetry stream, and 4) accumulates the science data and places it into the telemetry data stream. The interface and

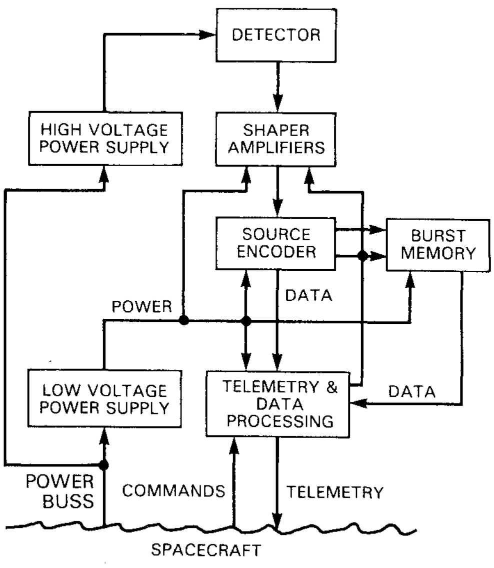


**Fig. 1 Instrument block diagram.**

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data rates are compatible with the Multimission Spacecraft (MMS) specifications.

The changes and improvements which were incorporated into HXRBS over previous solar x-ray experiments are listed in Table 1. Another new approach taken during development was the use of the spacecraft interface simulator (SIS). The SIS simulated the electronic signals that would be passed to the instrument by the spacecraft during flight. It also arranged the data from the instrument into a data stream identical to the data stream that was presented to the experimenter's ground support equipment (GSE) during flight. By simulating the data stream during the early stages of instrument integration, programmers were able to develop and test the GSE software using real data. Also, the integration team was able to utilize the GSE system hardware and software early in the program. Compatibility problems were thus detected and corrected very early.

**Table 1 HXRBS improvements**

1) An increased count rate range (up to $5 \times 10^5$ counts/s).
2) A decrease in the effect of pulse pileup.
3) An increased sensitivity.
4) Four multiplexer tubes are summed together.
5) The ability to set a threshold level and require two of the four detectors to exceed it for a valid event (eliminates noise at low-activity levels).
6) The use of memory to accumulate time profiles of count rate activity during a solar flare.
7) It is operationally controlled by a spacecraft computer with occasional updates from ground control.
8) The use of a SIS between the instrument and the GSE permitted parallel development and utilization of both systems.

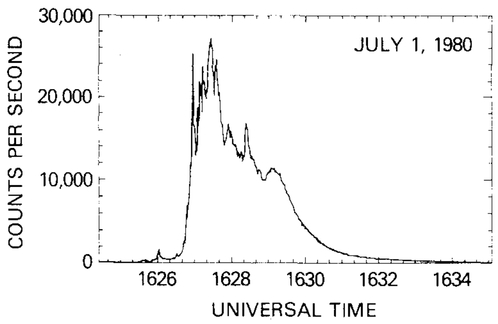


Fig. 2 Events vs time.

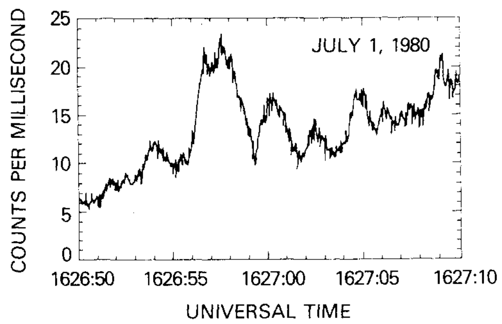


Fig. 3 Events vs time (memory).

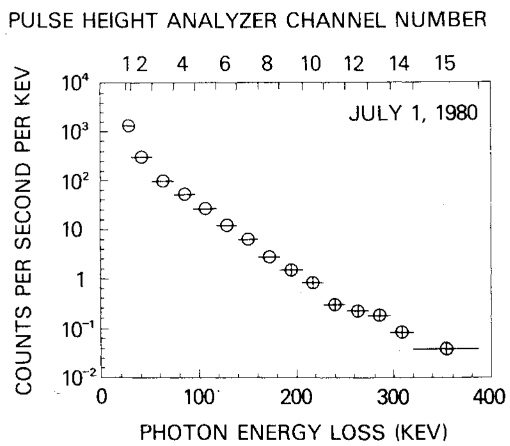


Fig. 4 Energy spectrum.

## Performance

At the time of this writing the HXRBS has performed flawlessly for approximately nine months. It has observed, archived, and analyzed over 1500 flares of varying magnitude and duration. Figures 2-4 illustrate typical data plots generated for each flare. This particular flare occurred July 1, 1980, and was one of the more active flares. Figure 2 is a plot of the number of valid events detected vs time. The general pattern of fast rise, followed by a second peak, and then followed by a slow decay in the count rate is typically but not exclusively the pattern of the flares seen. Figure 3 is a plot of the readout of the memory data expanded around a small section of the first peak in Fig. 2. A typical spectrum summed over an 8.192 s interval of this event is shown in Fig. 4. It indicates that most of the energy is in the lower energy channels. These spectra may be accumulated over varying periods of time as desired by the investigators.

HXRBS has not seen any evidence of count rates that exceed the maximum rate of the accumulators. It has seen very little evidence of spectral distortion or pulse pileup and has not had any hardware failures. There has been some evidence of gain changes in detector outputs, but not enough to require a change in the amplifier gains. These changes, which had been anticipated during the design of the instrument, have been due to a slight degradation of the photomultiplier tubes. This is a normal occurrence.

## Reference

[1] Frost, K., Dennis, B., and Lencho, R., "New Techniques in Astronomy," *IAU Symposium*, Vol. 41, 1971, p. 185.

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# Thermodynamics of Similar Particle-Laden Gas Flows in Convergent-Divergent Nozzles

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## Nomenclature

$A$ = cross-sectional area
$C_1$-$C_3$ = constants
$c''$ = specific heat of solid particles
$c^*$ = specific heat ratio = $c''/c_p$

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