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GRAZING INCIDENCE IMAGING TELESCOPE FOR X-RAY ASTRONOMY  
USING SOUNDING ROCKETS

FINAL REPORT

Grant NSG 5091

1 January 1976 thru 31 January 1979

September 1979



Prepared For  
National Aeronautics and Space Administration  
Goddard Space Flight Center  
Greenbelt, Maryland 20771

Smithsonian Institution  
Astrophysical Observatory  
Cambridge, Massachusetts 02138

The Smithsonian Astrophysical Observatory  
and the Harvard College Observatory  
are members of the  
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## 1.0 INTRODUCTION

On July 19, 1978, sounding rocket 25.037 was successfully launched from the White Sands Missile Range. This rocket carried an X-ray image experiment aloft in order to test the prototype detector being flown on the NASA High Energy Astrophysical Observatory to be launched in November, 1978. The primary goal of this sounding rocket flight was to successfully image a point X-ray source (Sco X-1) and to determine the detector background characteristics in a space environment. Both of the objectives were met in this flight, with particular emphasis on the background measurements.

## 2.0 DESCRIPTION OF EXPERIMENT

The purpose of this sounding rocket project was the verification of the HRI detector design by the use of a HEAO-B prototype in an actual flight environment. The maintenance of position sensing characteristics and of a low background event count rate is to be evaluated under real conditions. Environmental factors which can conceivably affect the operations of the HRI include the ambient neutral and charged particle densities, the electromagnetic radiation field (especially ultraviolet radiation), and the vibration and acceleration induced at launch.

The principal scientific subsystems of the rocket payload are the imaging grazing incidence reflection X-ray mirror, the HRI detector, a motorized vacuum housing gate valve, and an aspect camera. A schematic drawing of the payload is shown in Figure 1.

The X-ray telescope mirror consists of two beryllium pieces, each a surface of revolution about a common axis. The front surface is a paraboloid, the rear surface, an hyperboloid. The focal length of this mirror is 52" (this is measured from the joint between the two mirror sections).

The telescope is fastened to a set of 4 steel rails which are anchored to the cylinder nearby the mirror. These rails are attached to the cylinder at the detector end with the freedom to move longitudinally. This maintains the detector in the focal plane of the telescope during the heating of the cylinder at launch.

The HRI detector consists of a stack of two microchannel plates in chevron configuration above a crossed grid charge detector. Incoming X-ray photons enter the channels of the top microchannel plate at an angle of approximately  $3^\circ$ , and create a number of photoelectrons upon interacting in the channel wall. When these electrons, which are accelerated by the applied voltage, collide with the channel wall, more electrons are liberated. This process continues until a pulse of approximately  $10^8$  electrons

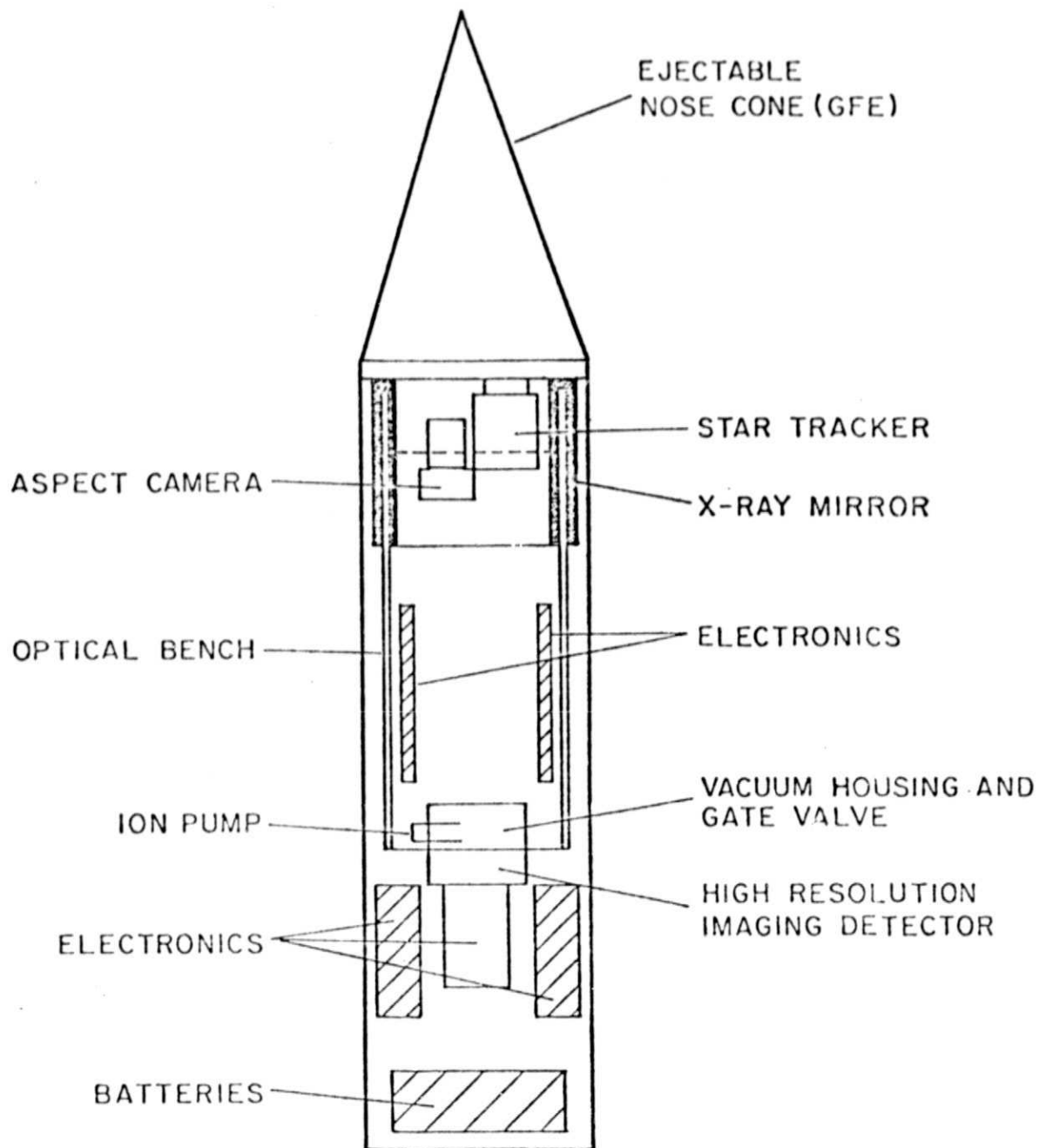


Figure 1: Schematic Diagram: High Resolution Rocket Payload

emerges from the bottom of the second microchannel plate. The position of this charge cloud is detected by a set of two orthogonal grids and the associated processing electronics.

The microchannel plates must be kept in vacuum prior to launch. For this reason they are enclosed in a vacuum housing upon which a motorized gate valve is mounted. This gate valve opens at an altitude of approximately 140 km.

An aspect camera with a 135 mm, f/1.8 lens is used to monitor the payload pointing during flight. This camera, and a star tracker furnished by NASA, are mounted in the center of the X-ray mirror.

### 3.0 FUNCTIONAL DESCRIPTION

A block diagram of the payload electrical system is shown in Figure 2. We include SAO drawing HRR-142 which shows timing and power control networks and SAO drawing HRR-160 which is a telemetry interface (parallel to serial data converter) schematic. A timing diagram for the parallel to serial data converter is included in Figure 3.

The electrical system of the payload is composed of:

- a) timing circuits
- b) power control circuits
- c) camera control and drive circuits
- d) detector electronics
- e) gate valve motor and control circuit
- f) telemetry interface
- g) detector grid voltage supply
- h) channel plate high voltage supply
- i) monitor circuits

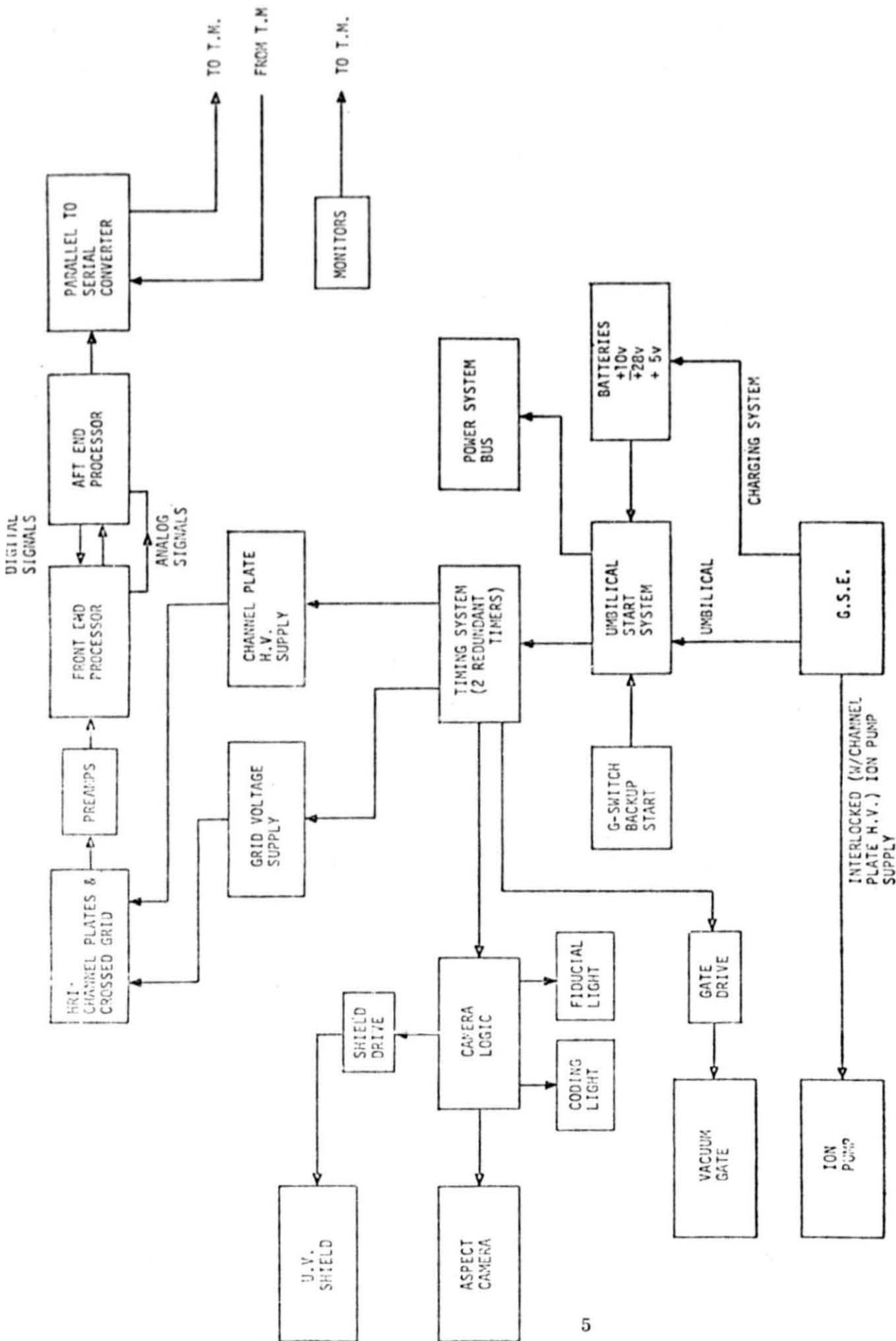


Figure 2: ELECTRICAL BLOCK DIAGRAM  
HIGH RESOLUTION ROCKET  
18 May '977

### 3.1. Payload Timing

The operation of the aspect camera drive, gate valve motor, channel plate high voltage supply, and grid bias supply is controlled by two redundant timers. The timers are initiated at  $T + 0$  seconds by a redundant system. The primary initiation system consists of two relays which are locked out prior to launch by a short circuit through the umbilical cable (drawing HRR-142). When the umbilical is disconnected at launch the relays latch and the timer motors are energized. Alternatively, power may be applied to the timer motors through a G-switch. A safety plug will be installed on the payload to keep the umbilical from operating in case of accidental disconnection of the cable before launch. This plug will be removed by SAO personnel just before the tower is finally cleared.

### 3.2 Power Control

Low voltage power is available to the payload electronics if either of two relays is latched. One of these relays is operated from the GSE console. The other is operated by the G-switch.

### 3.3 Camera Control

The aspect camera is driven by a clutch-brake motor combination. The electronics panel contains a module which provides timing, pulse shaping, and driving circuits for the motors. The camera frame rate is approximately 1 second per frame. In conjunction with the pulsing of the camera motor, the circuitry actuates small light bulbs which provide fiducial marks on the aspect film. A coding light for the camera is also actuated every eighth frame.

### 3.4 Detector Electronics

The detector electronics package includes analog and digital processing circuits. For every event that is detected coarse and fine digital position information (13 bits each

for X and Y coordinates) and digital pulse height (3 bits) is generated. If the event is valid, as determined in the electronics package, a data ready pulse is sent out and the digital information is presented as levels on 29 separate lines. Upon reception of a data clear pulse the electronics will process the next event that occurs.

### 3.5 Telemetry Interface

Tables 1 through 3 give, respectively, the telemetry channel assignments, the bit assignments for channels 2-5, and the assignments to the commutator for channel 6.

A drawing, SAO HRK-160, of the interface circuit which converts the parallel digital information from the detector to serial form suitable for transmission on telemetry channels 2, 3, 4, and 5, is included. A timing diagram for this interface is given in Figure 3.

The sequence of operations in this interface is as follows. The leading edge of the channel 2 enable gate triggers a 1  $\mu$ sec long pulse. This 1  $\mu$ sec pulse is gated with a level which indicates whether data is available which has not yet been loaded into the telemetry interface. If "new" event data is available the 1  $\mu$ sec pulse will be passed on to the load pins of the five parallel-load shift registers. This loads the new event data into the shift registers.

The leading edge of the channel 2 enable also sets a flip-flop which enables the clock input to the shift registers. The output of the registers is presented to the appropriate TM channel input. Upon every clock pulse the data is shifted right one bit, presenting a new bit to the telemetry interface. Thus the parallel event information is converted to serial form.

The 1  $\mu$ sec pulse is also used to generate a data clear pulse to be returned to the detector, and to clear the flip-flop which indicates that "new" data is available. When another event is processed by the detector a data ready pulse resets the flip-flop and

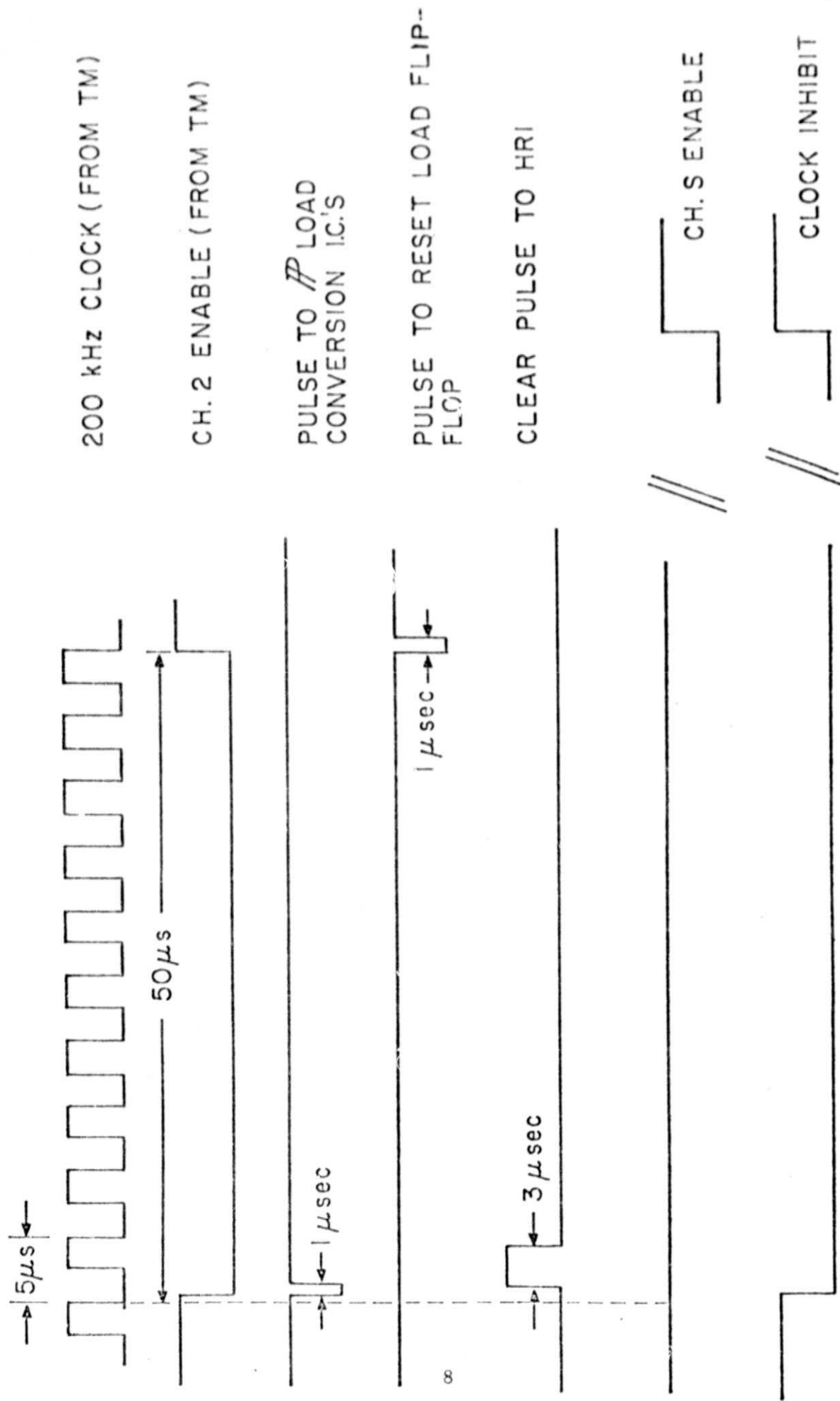


Figure 3: Timing Diagram: Parallel to Serial Converter

Table 1. Telemetry Mainframe Channel Assignments

| <u>Channel</u> | <u>Data</u>             |
|----------------|-------------------------|
| 0              | *                       |
| 1              | *                       |
| 2              | Digital experiment data |
| 3              | Digital experiment data |
| 4              | Digital experiment data |
| 5              | Digital experiment data |
| 6              | Channel plate H. V.     |
| 7              | UV shield monitor       |
| 8              | *                       |
| 9              | *                       |
| 10             | *                       |
| 11             | *                       |
| 12             | *                       |
| 13             | *                       |
| 14             | *                       |
| 15             | Monitor M1 through M30  |

\* not used by experiment

Table 2. Bit Assignments: Experiment Digital Data  
Telemetry channels 2-5

| <u>TM Channel</u> | <u>TM Bit</u> | <u>Experiment Bit</u> |
|-------------------|---------------|-----------------------|
| 2                 | Parity        | Ground                |
|                   | MSB           | y MSB Coarse bit 13   |
|                   | 2             | y 12                  |
|                   | 3             | y 11                  |
|                   | 4             | y 10                  |
|                   | 5             | y LSB Coarse 9        |
|                   | 6             | y MSB Fine 8          |
|                   | 7             | y 7                   |
|                   | 8             | y 6                   |
| 3                 | LSB           | y 5                   |
|                   | Parity        | Ground                |
|                   | MSB           | y 4                   |
|                   | 2             | y 3                   |
|                   | 3             | y 2                   |
|                   | 4             | y LSB Fine 1          |
|                   | 5             | x MSB Coarse 13       |
|                   | 6             | x 12                  |
|                   | 7             | x 11                  |
| 4                 | 8             | x 10                  |
|                   | LSB           | x LSB Coarse 9        |
|                   | Parity        | Ground                |
|                   | MSB           | x MSB Fine bit 8      |
|                   | 2             | x 7                   |
|                   | 3             | x 6                   |
|                   | 4             | x 5                   |
|                   | 5             | x 4                   |
|                   | 6             | x 3                   |
| 5                 | 7             | x 2                   |
|                   | 8             | x LSB Fine 1          |
|                   | LSB           | PHA MSB               |
|                   | Parity        | Ground                |
|                   | MSB           | PHA 2SB               |
|                   | 2             | PHA LSB               |
|                   | 3             | Ground                |
|                   | 4             | Ground                |
|                   | 5             | Ground                |
|                   | 6             | Ground                |
|                   | 7             | Ground                |
|                   | 8             | Ground                |
|                   | LSB           | Ground                |

Table 3. Telometry Assignments: Monitors Channel 15

| <u>Subchannel</u> | <u>Assignment</u>             |
|-------------------|-------------------------------|
| 1                 | + 28V unregulated             |
| 2                 | + 10V unregulated             |
| 3                 | - 10V unregulated             |
| 4                 | + 5V unregulated              |
| 5                 | + 28V unregulated (post fuse) |
| 6                 | + 10V unregulated (post fuse) |
| 7                 | - 10V unregulated (post fuse) |
| 8                 | + 5V unregulated (post fuse)  |
| 9                 | not used                      |
| 10                | Grid Bias voltage             |
| 11                | Camera Clock                  |
| 12                | Shutter pulse                 |
| 13                | Clutch off                    |
| 14                | Shutter on                    |
| 15                | Gate open                     |
| 16                | Gate closed                   |
| 17                | Timer Motor #1                |
| 18                | Timer Motor #2                |
| 19                | not used                      |
| 20                | + 28V clutch                  |
| 21                | + 5V coding light             |
| 22                | Shield monitor                |
| 23-31             | not used                      |

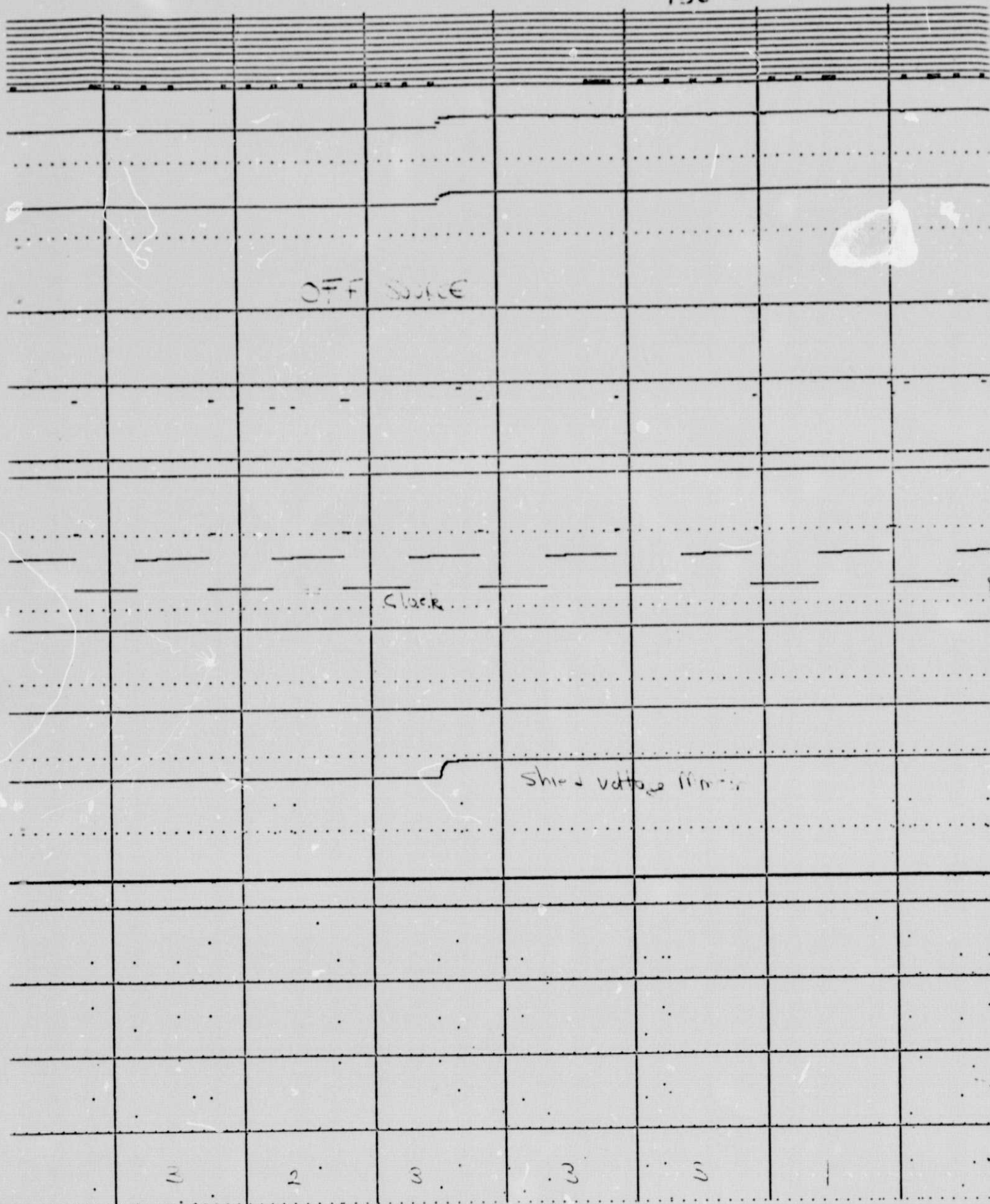
the system is ready to load digital information upon reception of the next channel 2 enable gate.

#### 4.0 FLIGHT DATA

The telemetry record for this flight has been analyzed to determine the detector background rate and to obtain an actual point source image for a celestial X-ray source (Figures 4 and 5). The background rate in flight was measured by counting the events which occurred on the detector away from the expected position of Sco X-1, and also by counting events during that portion of the flight when the experiment was not pointed towards Sco X-1. We found a rate equal to that measured on the ground during testing and calibration of about 3 counts/second over the entire detector.

The detector background was also determined as a function of the voltage applied to the ion shield which is in front of the microchannel plates as shown in Figure 6. A programmer on the payload electronics varies the DC voltage on the shield from -10V to +10V in 5V increments during the flight with a stepping time of about 5 seconds. We measured no correlation of the detector background count rate with shield voltage confirming our belief that most of the background is internal to the MCPs. Moreover, there is essentially no induced background in the detector due to charged particles encountered in flight. These results were used to help plan initial operations for the HEAO-B mission which was launched in November, 1978.

The detected count rate from Sco X-1 was about 2 counts/second and the source appears as a point in the detector. The counting rate is somewhat lower than expected by about a factor of 2 to 4. This may be due to several factors such as mirror alignment, dirt on the mirrors, or that Sco X-1 is known to be variable and could have been in a low intensity state. Since the main objective of this flight was not a measure of either the



CLOCK

Shield voltage (V) = 0

210

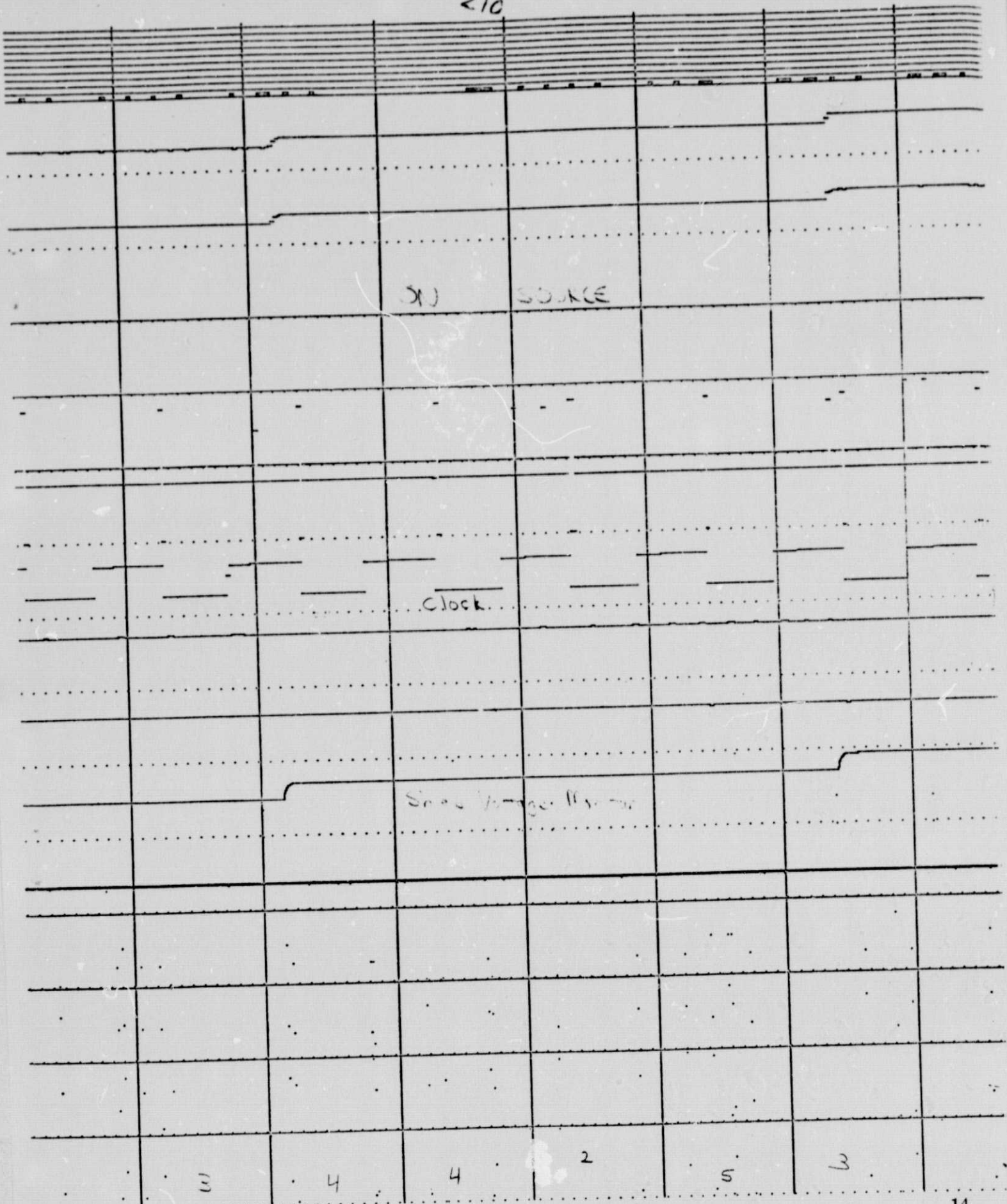


Figure 5

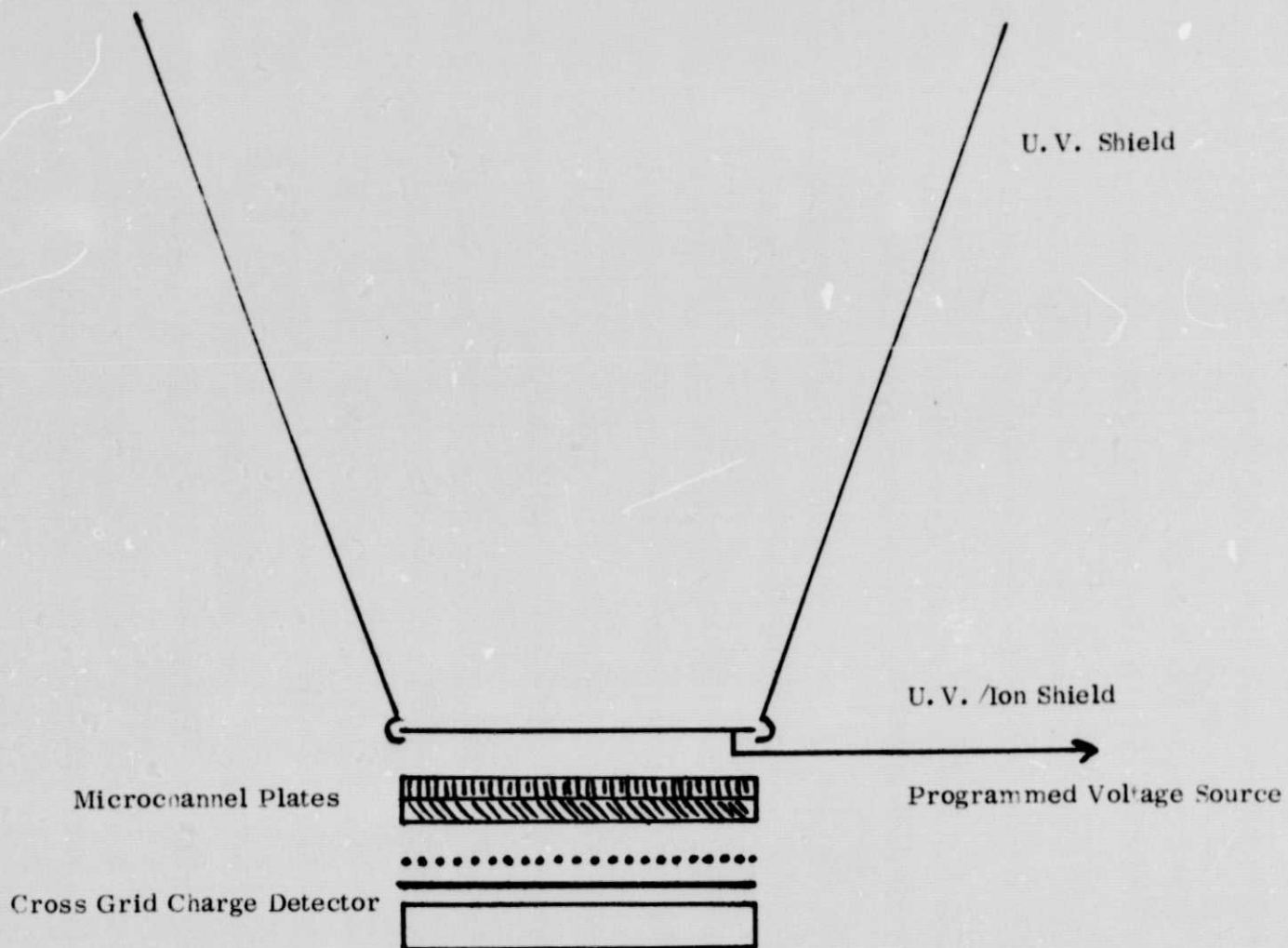


Figure 6

position or intensity of the source, no further efforts have been made to determine the cause of this low rate.

## 5.0 CONCLUSIONS

The sounding rocket program which culminated in the successful flight 25.037UH has been instrumental in the development and success of a high resolution imaging detector for X-ray astronomy. The experience gained in preparing for and carrying out this flight was put into immediate use in the HEAO program, and has contributed to the success of the HRI detector currently in use on the Einstein (HEAO-2) Observatory. We were able to test the detector in a space environment following launch shock and vibration and to demonstrate that the experiment was properly designed to survive and operate. We measured the inflight internal detector background and found it to be consistent with ground measured values. The entire experiment system worked properly and allowed us to record a 2-dimensional image of a non-solar celestial X-ray source for the first time.