SOLAR SATELLITE PROJECT

HARVARD COLLEGE OBSERVATORY

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OSO-G1

EXPERIMENT HANDBOOK

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OSO-G1 EXPERIMENT HANDBOOK

CORRECTIONS

Page 1, L.4	OSO-G spacecraft <u>not</u> OSO-G1 spacecraft.
Page 12, Fig. 4	15V converter <u>not</u> 15V invertor
Page 19, L.2	focal <u>not</u> vocal
Page 20, L.24	pointing <u>not</u> printing
Page 33, L.17	binary <u>not</u> vinary
Page 42, L.16	step <u>not</u> stop
Page 67, L.19	an illumination <u>not</u> a illumination
L.20	solar disc (diameter ~32 arc minutes) <u>not</u> arc seconds

Page 73, add Section 5.3.4 "Finally, external noise is generated (generally using a badly shielded motor or some equivalent device) and an attempt is made to cause the motor drive curcuit to be spuriously stimulated with this noise. If all is well the attempt fails."

Page 74, L.3 & 4 (~416 kilocycles, ~830 kilocycles, etc.) <u>not</u> (N416 kilocycles, and 380 kilocycles).

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INTRODUCTION

This report gives a comprehensive introduction to the Harvard College Observatory (HCO) Orbiting Solar Observatory (OSO-G1) instrument. This instrument is scheduled to orbit with the OSO-G1 spacecraft in the summer of 1969. The instrument is a spectrometer and spectroheliometer designed to examine the extreme ultraviolet (EUV) portion of the sun's electromagnetic radiation.

This report presents a summary of the scientific objectives of the instrument, a detailed description of the instrument's components, a list of instrument-spacecraft interface parameters, and a description of appropriate handling, storage, inspection, and testing procedures. The report attempts to give sufficient technical background material to make it useful to persons of varied technical knowledge. The report is also intended to be used as a major source of information for persons actually handling the instrument.

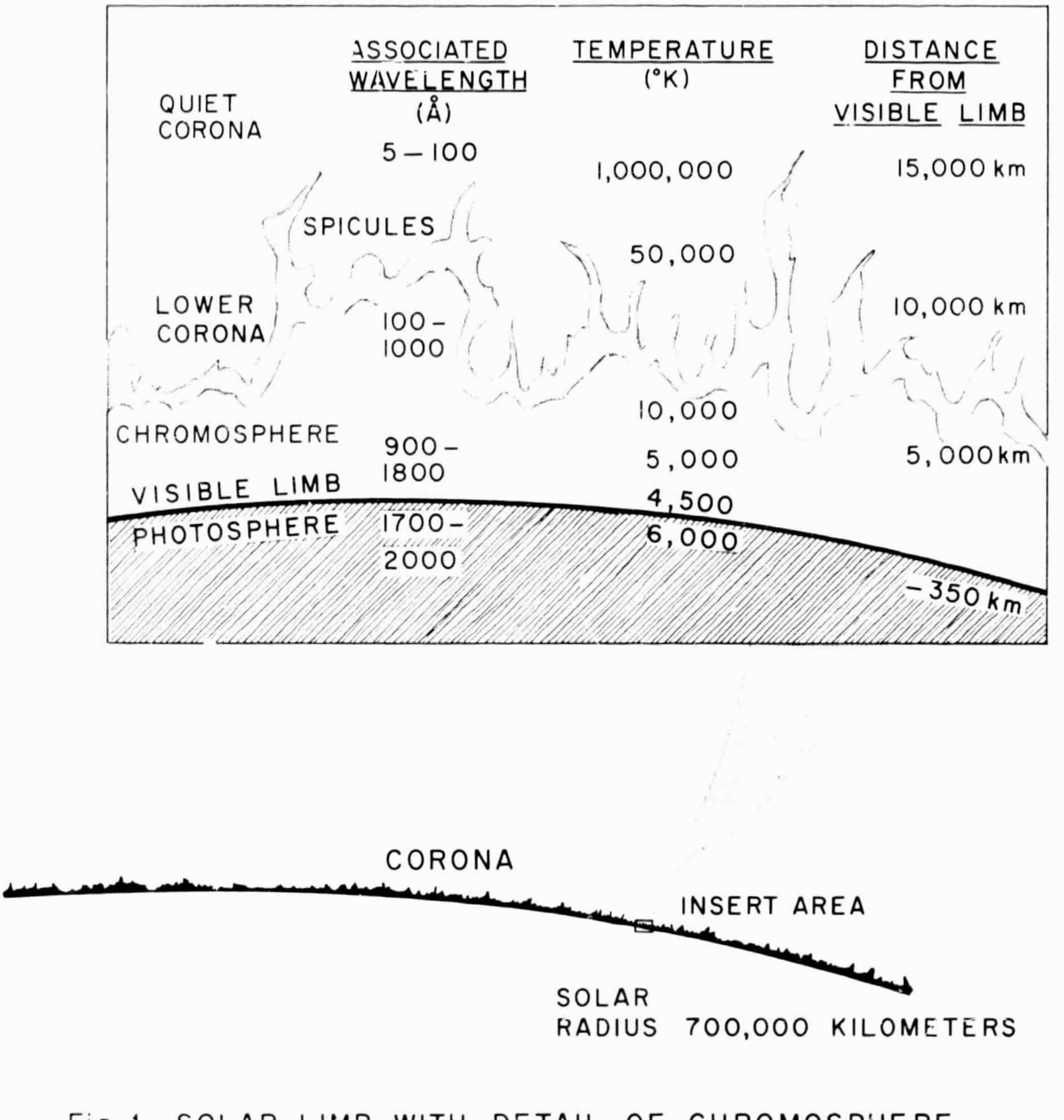


Fig. 1 -- SOLAR LIMB WITH DETAIL OF CHROMOSPHERE

1.0 SCIENTIFIC OBJECTIVE

The Harvard OSO-G1 instrument is an extreme ultraviolet (EUV) spectrometer and spectroheliometer. It was designed to measure the intensities of the solar radiation in the wavelength range 285 Angstroms (Å) to 1370 Angstroms. In orbit the instrument obtains spectra of the radiation emanating from a small area (35 arc seconds square) on or near the solar disc and forms raster pictures (large rasters) of an area 46 arc minutes square centered on the visible solar disc (which is 32 arc minutes in diameter). Small rasters about 7 arc minutes square can also be formed. Each raster picture is formed from a series of measurements of radiation intensity at a selected wavelength set by command from ground stations.

The solar atmosphere is customarily divided into three regions: 1) the photosphere, the outer surface layer of the visible solar disc; 2) the corona, a region of hot gas and plasma extending many solar radii outward from the photosphere; and 3) the chromosphere, a transitional region between the photosphere and the corona. These regions are depicted in Fig. 1.

The earth's atmosphere effectively absorbs much of the incident solar radiation as indicated in Fig. 2. Thus until the advent of high altitude sounding rockets and artificial satellites, astrophysical investigations of the sun were restricted to a few bands of wavelengths in the visible, infrared, near ultraviolet, and radio frequency regions; of course, high energy particles and cosmic rays also penetrate the atmosphere and are detected.

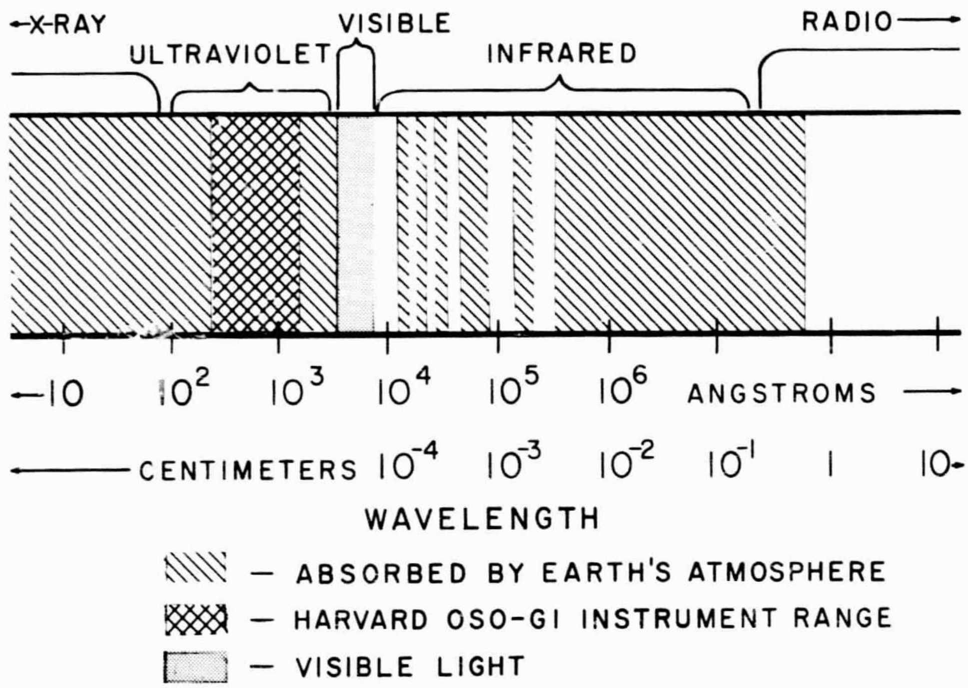


Fig. 2 — ABSORPTION SPECTRUM OF EARTH'S ATMOSPHERE

Since radiation from the solar photosphere occurs in the visible region of the electromagnetic spectrum, the photosphere can be studied from observatories on the earth's surface. Likewise a few strong spectral lines in the visible region emanate from the chromosphere and can be studied from the earth's surface. However, only chromospheric layers with temperatures less than about 10,000°K can be observed. The visible light from the hotter, more tenuous layers of the upper chromosphere and corona (cf. Fig. 1) cannot be distinguished in front of the sun's disc because it is swamped by light from the photosphere.

However, a great deal is known about the general structure of the corona from observations made during eclipses, when the moon covers the bright photosphere. Observations are also made with coronagraphs at high altitude sites where one can use occulting discs to artificially block the photospheric image. Under these conditions the corona's extension above the sun's limb is readily visible. However, the corona is then viewed edge on, so that little spatial resolution is obtained.

A detailed study of the outer layers of the solar atmosphere is of fundamental importance to geophysics, physics, and astronomy for several reasons:

The earth lies within the outer reaches of the solar corona and is affected by events occuring throughout the solar atmosphere. The large scale disturbances that occur in the chromosphere are associated with the so-called active regions, such as sunspots (cool areas), plage regions (hot areas), and flares. Particles ejected by flares are carried as part of the solar wind and can cause disturbances in the earth's atmosphere such as auroral displays (Northern Lights), electromagnetic storms, blackouts in radio reception, and possibly even alteration of terrestrial weather patterns. In order to understand and hence predict these phenomena, we must obtain a thorough knowledge of the solar medium in which they originate.

Important physical processes take place in the solar atmosphere that cannot easily be duplicated in the laboratory. For instance, in the low density chromosphere the scale length of the interaction between radiation and matter is greater than what could be realized by any conceivable laboratory equipment. The temperature of the photosphere is a relatively cool 4500°K to 60,000°K, while corona temperatures exceed 1,000,000°K (Fig. 1). Thus a very steep thermal gradient occurs in the chromosphere. Associated with this gradient are complex magnetohydrodynamic effects, jets of ionized gas, and other turbulent convective precesses. These phenomena are only partly understood. Plasma spicules are also present. They are best seen in silhouette immediately before and after a solar eclipse. Motions in the solar convection zone produce shock waves in the chromosphere and corona which transfer large amounts of energy to these outer layers, and the temperatures in the corona become very high (up to several million degrees Kelvin). Outflowing solar material can be observed as the solar wind at distances from the sun corresponding to the earth's orbit and beyond.

Chromospheres and coronas are found, on a much greater scale, on other stars. Indeed, they probably play an important role in the life history of many stars and quite possibly in the life history of the universe. Since the solar atmosphere is the only one for which our observations can be spatially resolved, study of the solar atmosphere is of basic importance to all astronomy.

One good way to obtain information about the corona is to make spectroheliograms in the far ultraviolet. Most emission lines from the coronal transition zone and the corona have wavelengths shorter than 1500Å. Thus the spectrum in the far ultraviolet is highly important for the study of the corona. Fortunately, the radiation of the photosphere (which radiates approximately as a black body of 6000°K temperature) is very weak in the far ultraviolet, so that it is easy to observe the coronal emission lines in front of the solar disc.

Finally, by observing the emission lines from atoms in various stages of ionization, we can obtain information on the temperature of the solar atmosphere at various heights above the surface of the photosphere. At temperatures of several tens of thousands of degrees atoms lose only their outer electrons and are, hence, in low stages of ionization. As the temperature increases atoms are stripped of more electrons and attain higher stages of ionization. Each atom at a particular stage of ionization has its own characteristics and unique spectrum different from the spectrum of any other stage of ionization of the same element and different from the spectrum of any stage of ionization of any other element. Each stage of ionization corresponds to a particular range of temperatures. Since the temperature of the solar atmosphere increases rapidly with height above the photospheric surface, a given stage of ionization of an atom is formed and radiates only within a small range of heights in the solar atmosphere.

The region 300Å to 1400Å is particularly useful because it contains spectral lines formed at temperatures ranging from ten thousand to several million degrees Kelvin. An instrument designed to measure EUV intensities in this wavelength interval with spatial resolution can provide extensive information on the three-dimensional structure of the chromosphere, the corona, and the transition region between them.

Examples of the type of data expected from the Harvard OSO-G1 instrument are presented in Fig. 3. These data were obtained by the OSO-IV instrument in the fall of 1967. Figure 3 shows the spectrum of the center of the solar disc as observed by the Harvard Spectrometer. Many of the strong emission lines are identified below the spectrum. Note that the majority of the lines are emitted by the abundant elements H, He, C, N, O, Ne, Mg, Si, S, and Fe in various stages of ionization, from neutral (Roman numeral I) to 15 times ionized (Roman numeral XVI).

Above the spectrum we see a quasi-photographic representation of four of the spectroheliograms, in spectral lines that are produced at temperatures varying from ten thousand degrees Kelvin to two and one

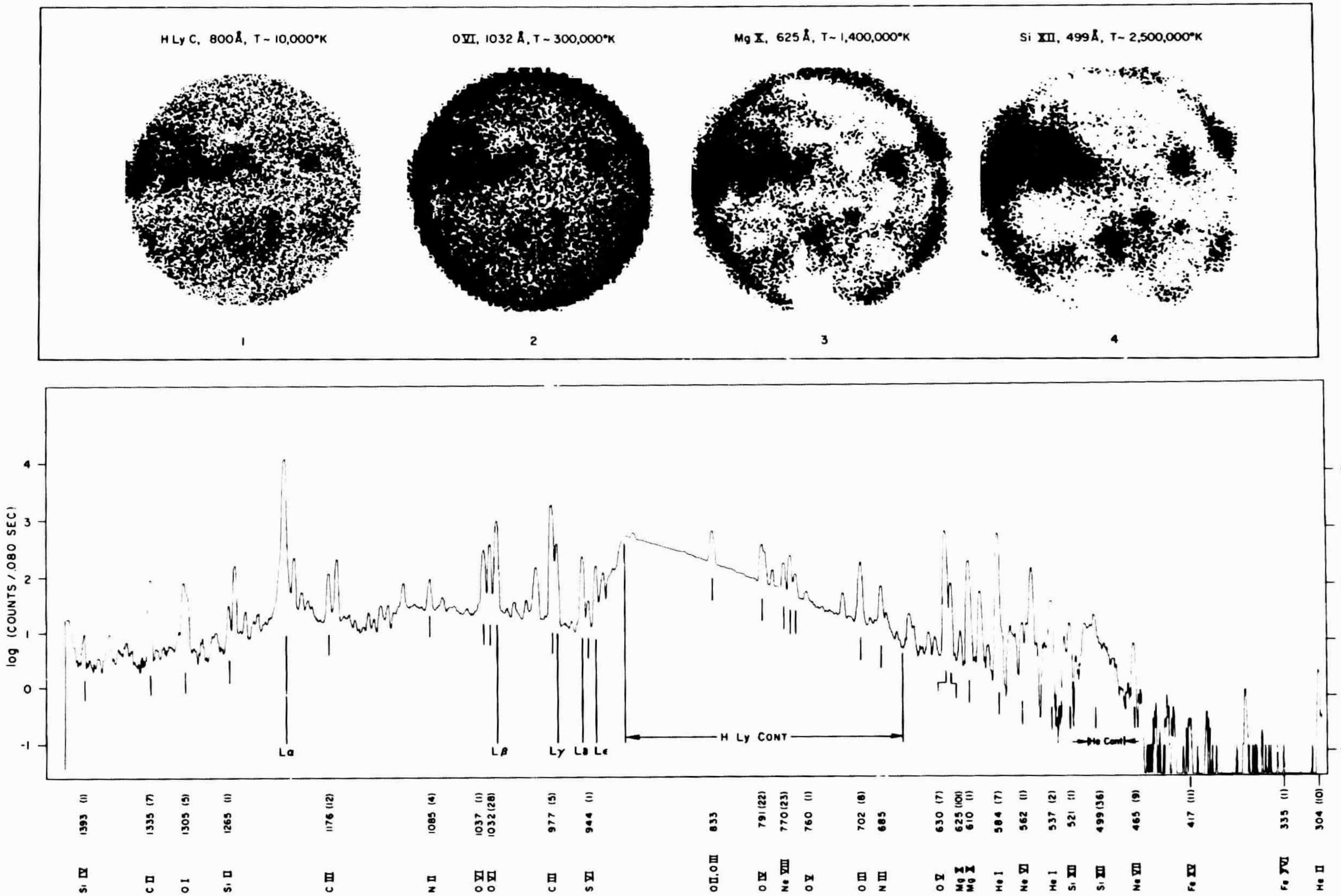


Fig. 3 — DATA FROM THE OSO-IV INSTRUMENT

half million degrees Kelvin. The heights at which these lines are produced vary from a few thousand kilometers to several tens of thousands of kilometers above the photospheric surface. The increased emission above the limb in Mg X and Si XII is quite evident; indeed it spills out beyond the edge of OSO-IV's 40 arc minute square field of view.

The spectroheliograms shown in Fig. 3 were obtained within a period of six hours so that direct comparisons are meaningful. Active regions are visible in all four as black emitting areas concentrated in zones North and South of the equator. North is at the top, and east is to the left.

2.0 THE HARVARD OSO-G1 INSTRUMENT

2.1 GENERAL DESCRIPTION

The Harvard OSO-G1 instrument is a spectrometer and spectroheliometer designed to measure the intensities of solar radiation in the extreme ultraviolet wavelength range (300Å-1400Å). The positions of the main components in the instrument are illustrated in Fig. 4, a photograph of the instrument with its cover removed. The functional relationships of the main elements are presented schematically in the block diagram in Fig. 5. Incoming solar radiation is reflected by the mirror and imaged on the entrance slit, which defines the instrument's spatial resolution. Radiation which passes through the entrance slit impinges on the diffraction grating, and is reflected and dispersed into its spectral components. By rotating the grating about its pivots the various selected UV wavelengths can be positioned on the exit slit. The exit slit defines the instrument's spectral resolution. Once through the exit slit the UV photons impinge on the cathode of an open photomultiplier. The photomultiplier produces pulses of electrons whose number corresponds to the number of incident UV photons. These pulses are amplified and counted, then read out periodically to the spacecraft's data system.

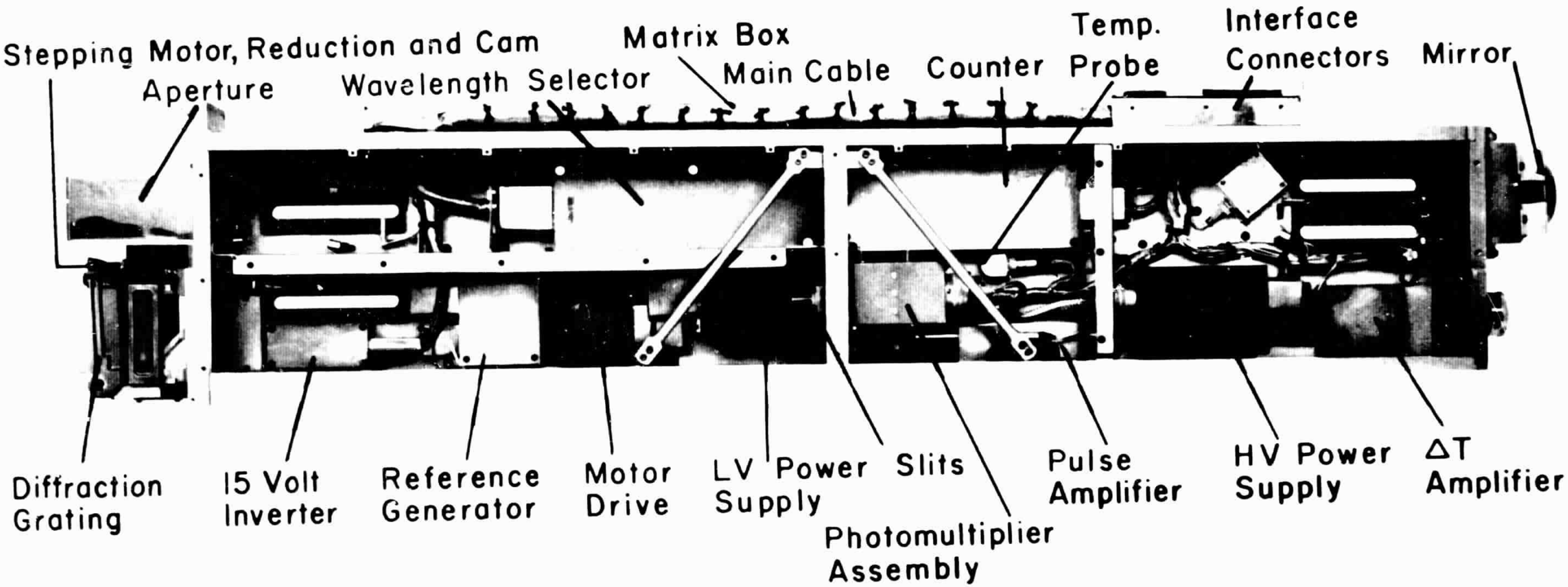


Fig. 4 — HARVARD OSO-G1 INSTRUMENT

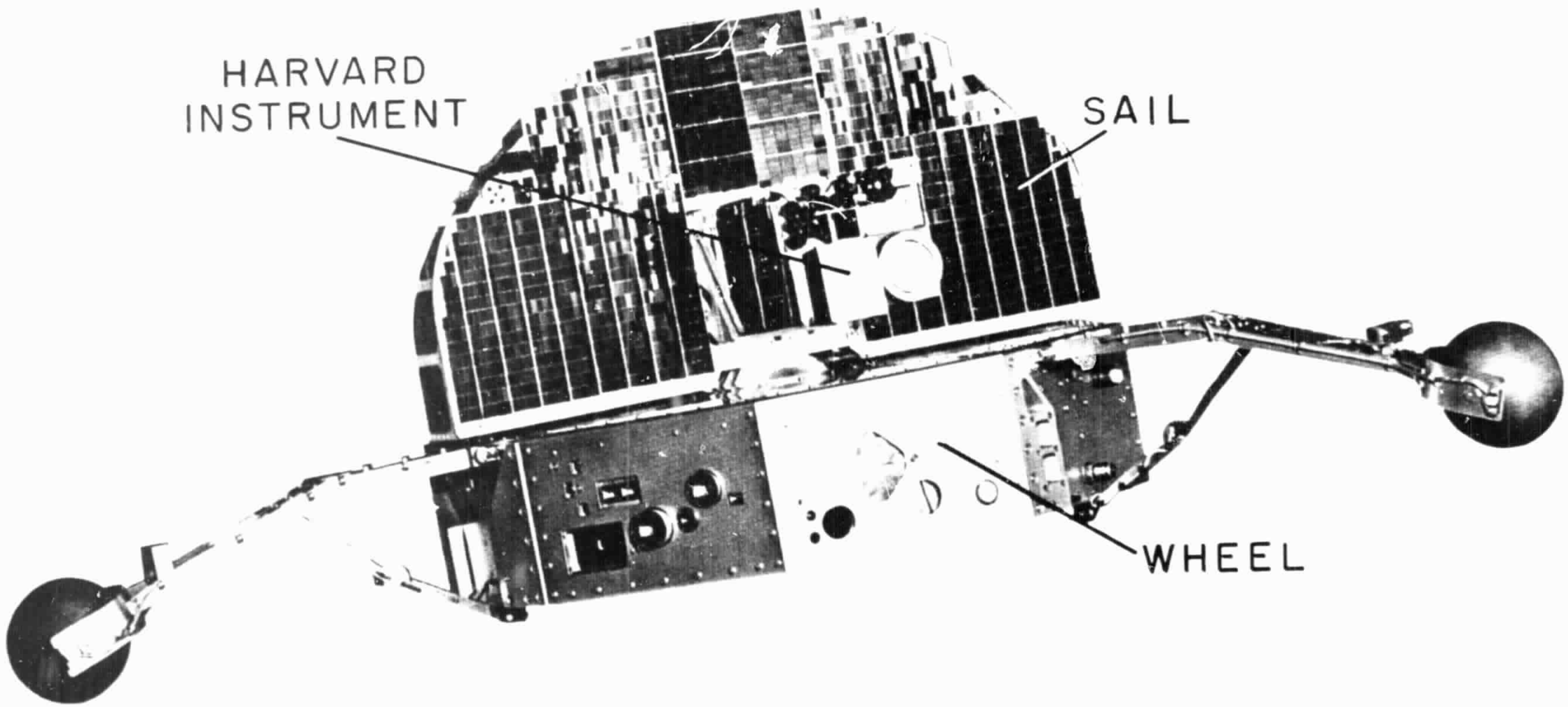


Fig. 4A-OSO-IV SPACECRAFT

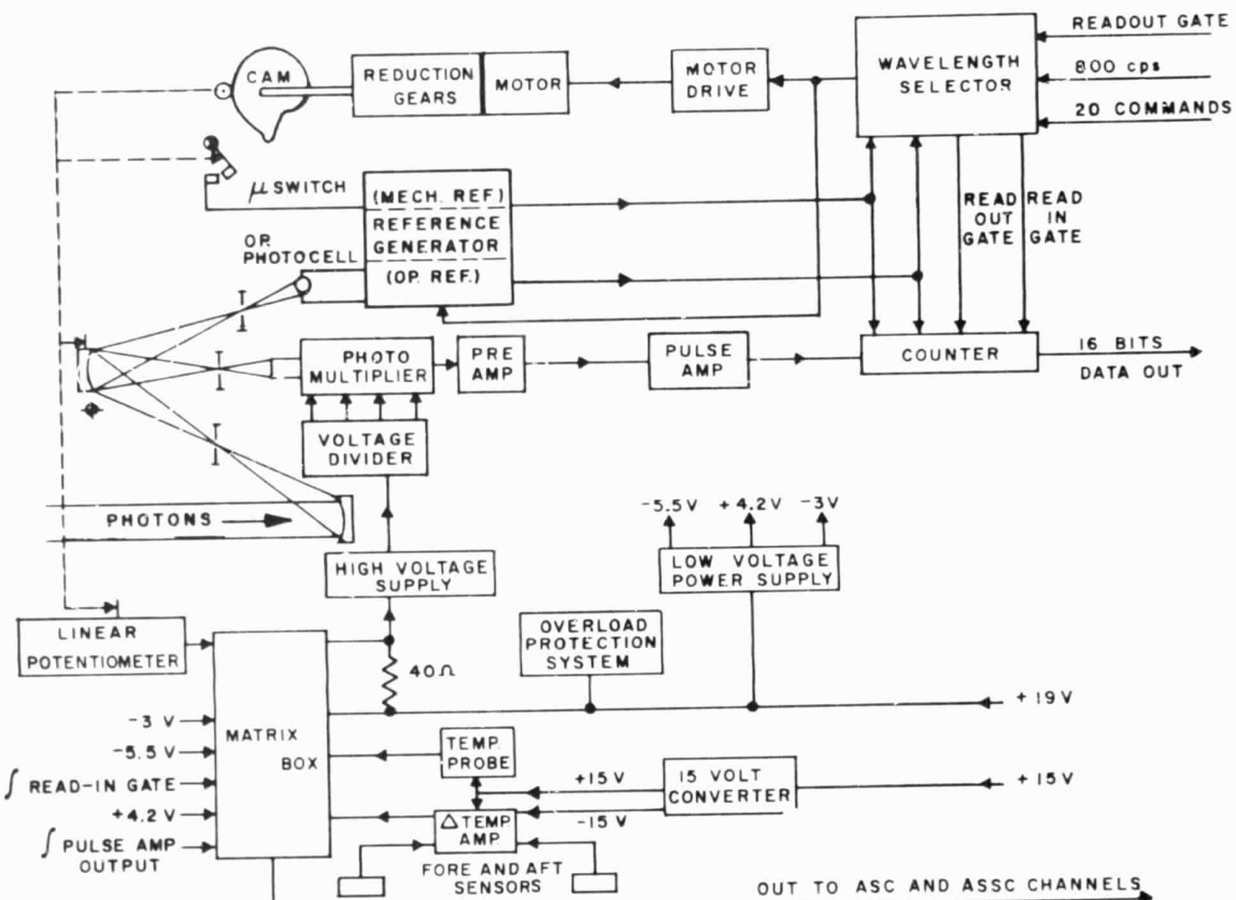


Fig. 5 - HARVARD OSO-G1 BLOCK DIAGRAM

DRAWING NO.	NEGATIVE NO.
I - 272	

2.2 OPERATIONAL MODES

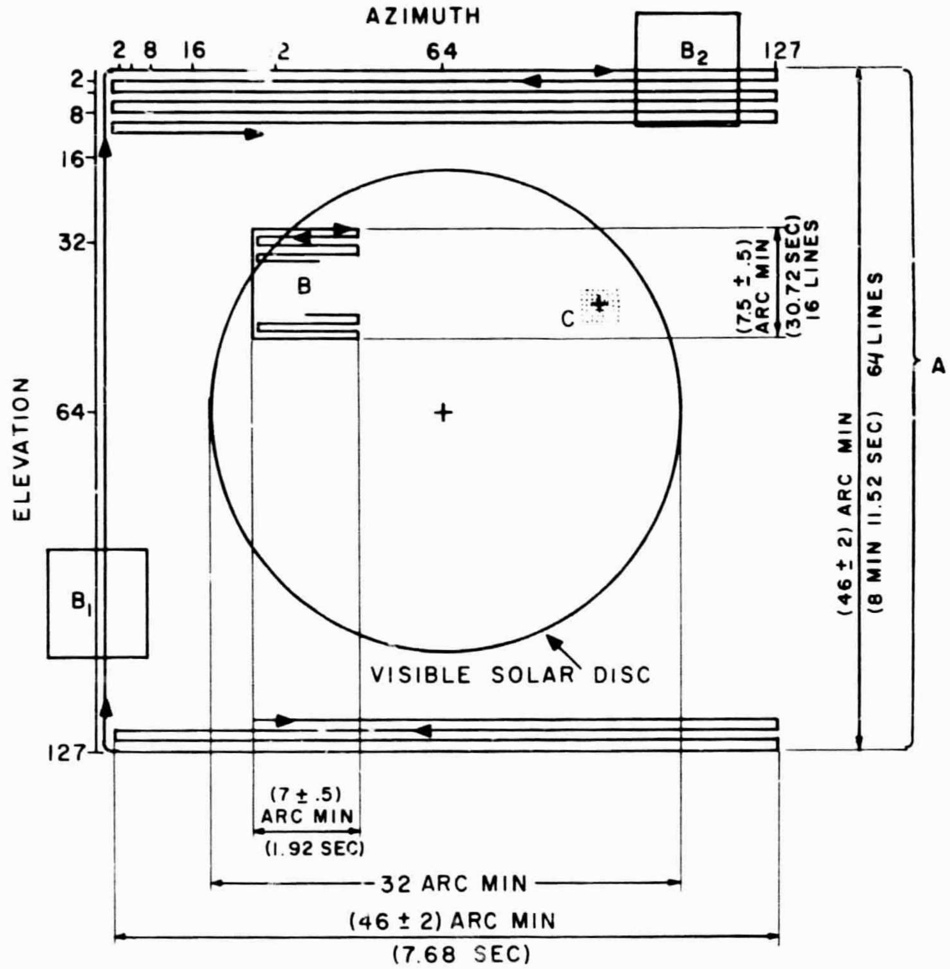
The Harvard OSO-G1 instrument (mounted in the spacecraft) is designed to operate in four basic modes:

a) Large raster, wavelength fixed.

In this mode the spacecraft's pointing control system will scan the instrument's field of view across a square area 46 x 46 arc minutes centered on the solar disc. The spacecraft sweeps the instrument across each azimuth line at 360 arc seconds per second. A complete large raster will contain 64 lines with 96 intensity measurements (at a fixed wavelength) on each raster line. Each large raster takes 8 minutes 11.52 seconds to complete.

b) Small raster, wavelength fixed.

This mode will be used for detailed studies of active regions with good spatial and temporal resolution (35 arc seconds and 30 seconds, respectively). The small raster will cover an area 7 x 7.5 arc minutes centered at a selected offset pointing position. For small rasters the instrument is swept at 218 arc seconds per second across each azimuth line. One small raster will contain 16 lines with 24 intensity measurements (at a fixed wavelength) on each raster line. A complete small raster is produced in 30.72 seconds. In addition to its intrinsic value, the small raster mode will be used operationally to establish the proper offset position for the next two modes.



A. Large Raster

B. Small Raster (B_1 and B_2 indicate extreme azimuth and elevation positions of small raster.)

C. Offset Point (44 bits elevation and 94 bits azimuth) and adjacent offset grid points.

Fig. 6 — RASTER PATTERNS AND OFFSET POINTING GRID

DRAWING NO.	NEGATIVE NO.
I-228	

c) Pointing, wavelength scan.

In this mode the spacecraft will point the instrument at one of the 128 x 128 points in a square matrix covering the same area as the large raster pattern (46 x 46 arc minutes centered on the solar disc). While the instrument is pointed, its diffraction grating will be stepped and intensity measurements will be taken over the full wavelength range of the instrument (300-1400Å). This complete wavelength scan will take approximately 15 minutes.

d) Pointing, wavelength fixed.

In this mode the instrument will monitor the intensity of a single selected wavelength of UV radiation from a selected offset spot with high temporal resolution (80 milliseconds). The sun's rotation will, however, cause some spatial blurring in this mode.

Figure 6 indicates the relative sizes of the sun's disc, the large raster, and the small raster. The azimuth and elevation coordinates of points in the offset point matrix are also indicated. Table I presents a summary of the parameters associated with the operational modes. Because the instrument's azimuth scan is continuous there is a definite length of integration time in the large raster and small raster modes. Thus, the raster pattern is not a matrix of contiguous squares. Rather, the pattern consists of rectangles that overlap horizontally.

TABLE I

OPERATIONAL MODE PARAMETERS

Mode	Size	Resolution	Sweep Speed (Azimuth)	Frame Period
Large Raster	46 x 46 arc min.	96 overlapping elements Az, 64 lines El.	360 arc sec/sec. (24 MF/line) (7.68 sec/line)	8 min 11.52 sec. (491.52 sec)
Small Raster	7 x 7.5 arc min. (Az x El)	24 overlapping elements Az, 16 lines El.	218 arc sec/sec (6 MF line) (1.92 sec/line)	30.72 sec.
Offset Pointing	46 x 46 arc min.	128 x 128 points in grid	--------------	------------

El = Elevation; Az = Azimuth; MF = Main Frame

2.3 OPTICS

The OSO-G1 optical system is composed of a telescope mirror, entrance slit, diffraction grating, exit slit, and zero order slit. The layout of these elements is shown in Fig. 7.

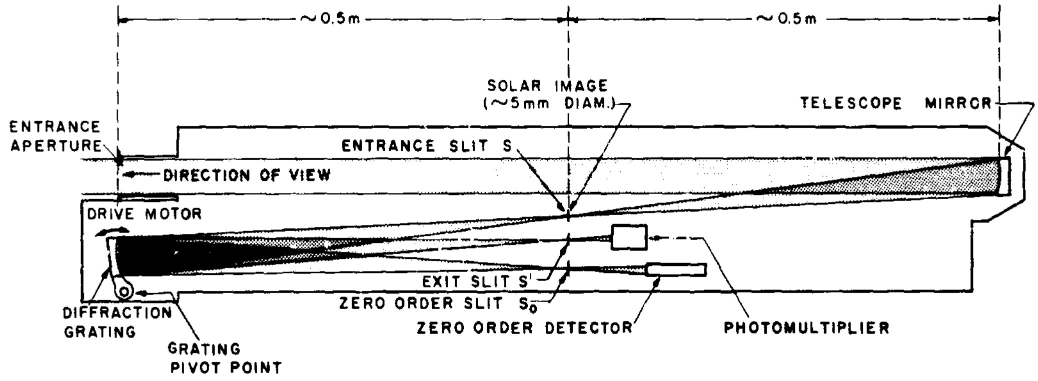


Fig. 7— HARVARD OSO-G1 OPTICAL LAYOUT

2.3.1 TELESCOPE MIRROR

The telescope mirror is an off-axis paraboloid with a rocal length of 494.6 millimeters (mm) and a surface area of 43 x 43 mm. The pole of the telescope surface is 5° off axis; its distance from the focal point is 494.6 mm.

The mirror surface is specified to be diffraction limited at 5,500Å or a shorter wavelength with a surface roughness of less than 50Å. The mirror is coated with iridium for best UV reflectivity.

A monitor mirror of the same surface quality as the telescope mirror was coated with iridium simultaneously with the telescope mirror and accompanies the instrument during all pre-launch activities. The monitor mirror will be removed just before launch so that its reflectivity (representing the reflectivity of the telescope mirror at the time of launch) can be measured.

2.3.2 ENTRANCE SLIT

The entrance slit is a field stop for the telescope which allows radiation from an area of the solar image 35 x 35 arc seconds square to pass to the grating. With a distance of approximately 495 mm from the telescope surface pole to the focus, an area 35 x 35 arc seconds square corresponds to a slit dimension of 84 micrometers (μm). The actual area of the entrance slit is measured to within 2%.

This slit size will provide adequate spatial coverage for the small raster where the line spacing is 30 arc seconds and for the large raster where the line spacing is 43 arc seconds. This spatial coverage is acceptable since the small raster will be the most important instrument mode, and the large rasters will be used for survey purposes only.

The offset printing grid provides 128 x 128 points within an area 46 x 46 arc minutes square. The offset points lie in a matrix with horizontal and vertical distances of 22 arc seconds between adjacent points.

Thus, there is a satisfactory match between entrance slit size and point spacing.

2.3.3 DIFFRACTION GRATING

The grating is concave with a 498.4 mm radius of curvature. The grating is a Bausch & Lomb original, rules with 1800 lines/mm in gold which has been evaporated on a fused silica substrate. The mono-partite ruling is blazed at 800Å.

The grating is mounted in a Johnson-Onaka mount, so that the perfect focus is designed to be at 800Å. The grating angle is changed by a cam which is driven by a stepping motor. To complete one full cam rotation requires 11,824 ±1 steps. The cam is divided into two principal portions. First, a positive slope provides an approximately linear relation between wavelength and cam rotation. The exact relation between wavelength and cam rotation for scientific calibration will be computed from laboratory data. Second, a steep negative slope provides the retrace within a small increment of a full cam rotation.

The mechanical and optical references of the grating drive system provide two independent means of reference for setting the spectrometer to a given wavelength. The mechanical reference is directly related to the position of the cam. A projection on the cam causes the diffraction grating mount to close a microswitch. The mechanical reference position is defined as the first step during which the microswitch is closed. The mechanical reference indication is produced by the reference generator and read out through the data system (cf. § 2.4.2) as long as the microswitch is held closed (for approximately 180 steps of the cam).

The optical reference is directly related to the angular position of the diffraction grating. Specular reflection from the grating surface when directed through the zero order slit illuminates a photocell. The optical reference position is defined as the fifth step during which visible light shines on the zero order photocell. The optical reference indication is produced by the reference generator beginning at the optical reference position and continuing as long as the zero order photocell is illuminated. This procedure is followed in order to distinguish between true optical reference position (photocell illuminated during approximately 20 steps of the cam) and the position of the retrace slope of the cam during which the photocell is illuminated for a few steps (less than five steps). Note that the photocell responds to visible light and that the instrument, therefore, must be pointed at the visible solar disc, if the optical reference is to be of use.

A functional sketch of the cam profile is shown in Fig. 8. One motor step corresponds to a change of 0.1Å in wavelength, i.e., there are ten steps per Angstrom. The reciprocal dispersion of the spectrometer is 11.1Å/mm.

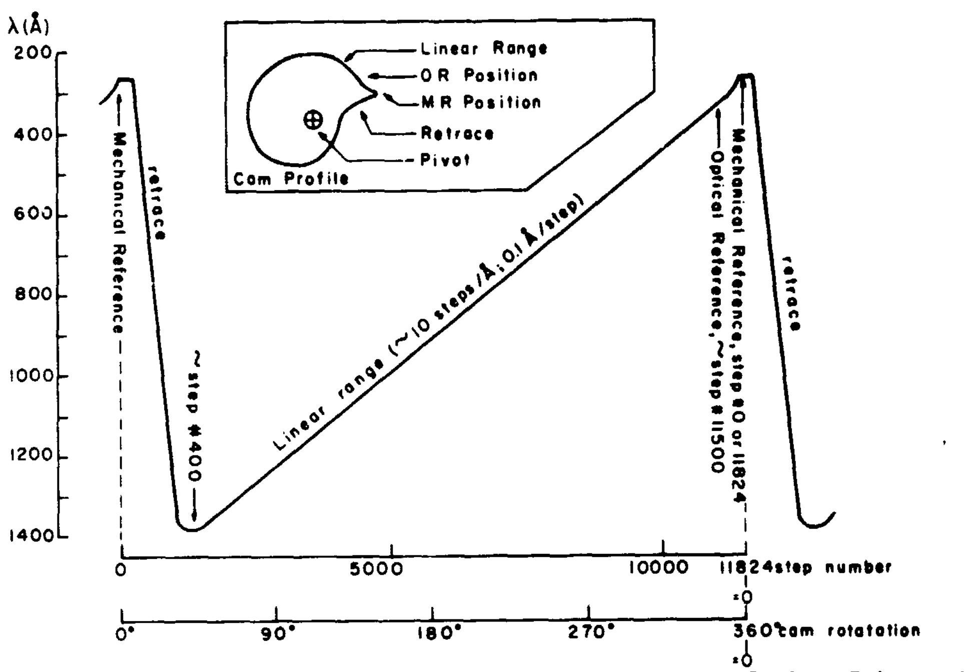


Fig. 8—FUNCTIONAL DIAGRAM of CAM and SKETCH of CAM PROFILE (Insert)

2.3.4 EXIT SLIT

The height of the exit slit is 1540 μm which is high enough to accommodate the full astigmatic image of the entrance slit. The width of the exit slit is 277 μm. These dimensions yield an instrument profile (the apparent broadening of a monochromatic input due to exit slit width and other instrument characteristics) with a flat top of about 12 steps (~1.2Å) wide near the best focus of the grating (~800Å) and about 20 steps (~2Å) wide near the extreme grating positions (corresponding to ~300Å or ~1400Å). Thus, the grating projects radiation of a given spectral line through the exit slit if the grating is set to within ±6 steps of the central position for that line (±10 steps at extreme grating positions). The instrument profile has a full width at half intensity of 3.0Å.

2.3.5 ZERO ORDER SLIT

Zero order (all wavelengths, including visible) light is focused on the zero order slit in a particular range of angular positions of the grating (cf. § 2.3.3). The zero order slit is mounted so that no lateral blur occurs. The zero order slit is 84 μm wide and 1500 μm high.

2.4 DETECTION AND DATA

2.4.1 DETECTION SYSTEM

The detection system depicted in Fig. 5 consists of a photomultiplier, temperature compensating voltage divider, preamplifier, pulse amplifier, and a fourteen stage counter-shift register.

The photomultiplier is a modified windowless Bendix Model-310 magnetic electron multiplier (MEM) with a tungsten photocathode. The photomultiplier is open because no envelope or window material is known which is transparent to UV radiation less than approximately 1050Å wavelength (the limit for lithium fluoride). The tungsten photocathode is used because tungsten has a relatively high work function. Thus, the photomultiplier is effectively blind to photons with longer wavelength (above 2000Å through visible and infrared) and consequently lower energy than the desired EUV photons.

EUV photons passing through the instrument's exit slit impinge on the photocathode and liberate electrons from the surface of the tungsten. These primary electrons are accelerated by crossed electric and magnetic fields into cycloidal arcs. When each electron strikes the dynode strip it liberates a few secondary electrons which continue down the strip. Additional secondary electrons are produced at each collision until the final pulse of electrons is collected at the anode. In this way a single EUV photon incident on the photocathode can produce a current pulse at the anode of the photomultiplier. The current pulses from the anode are transmitted to the preamplifier.

The photomultiplier requires about 1700 volts potential for proper operation. The temperature compensating voltage divider provides intermediate voltages for the various MEM terminals necessary to assure that the photomultiplier gain (number of electrons collected at the anode per primary photo-electron) is independent of temperature.

The preamplifier converts high impedance current pulses from the photomultiplier to low impedance voltage pulses which are amplified by the pulse amplifier and passed to the counter.

A block diagram of the counter is presented in Fig. 9. The signal from the pulse amplifier arrives at the count input in the upper left corner of the diagram. During the 40 millisecond (ms) readin gate signal, the inhibit generator is prevented from operating, and the input gate is opened to allow the flip-flop modules A, B, and C to count incoming pulses. These modules were designed to operate at the lowest power consumption consistent with adequate counting speed. Following the end of the readin gate signal the counter remains inactive for 20 ms. During this time a motor stepping pulse may index the grating 0.10Å when the instrument is in the wavelength scan mode. Following the 20 ms quiescent period the readout gate signal from the spacecraft activates the shift generator for 20 ms. During that time the "1's" and the "0's" stored in the A, B, and C flip-flops, the mechanical reference flip-flops, and the optical reference lines are shifted out serially to the spacecraft's telemetry system. Then the cycle begins again with a readin gate signal at the end of the readout gate. The counter's basic 80 ms data cycle (40 ms readin + 20 ms quiescent + 20 ms readout) is synchronized with the spacecraft's telemetry main frame by the readout gate provided by the spacecraft. The readin gate is generated in the wavelength selector. The relationships of the various waveforms are illustrated in Fig. 10.

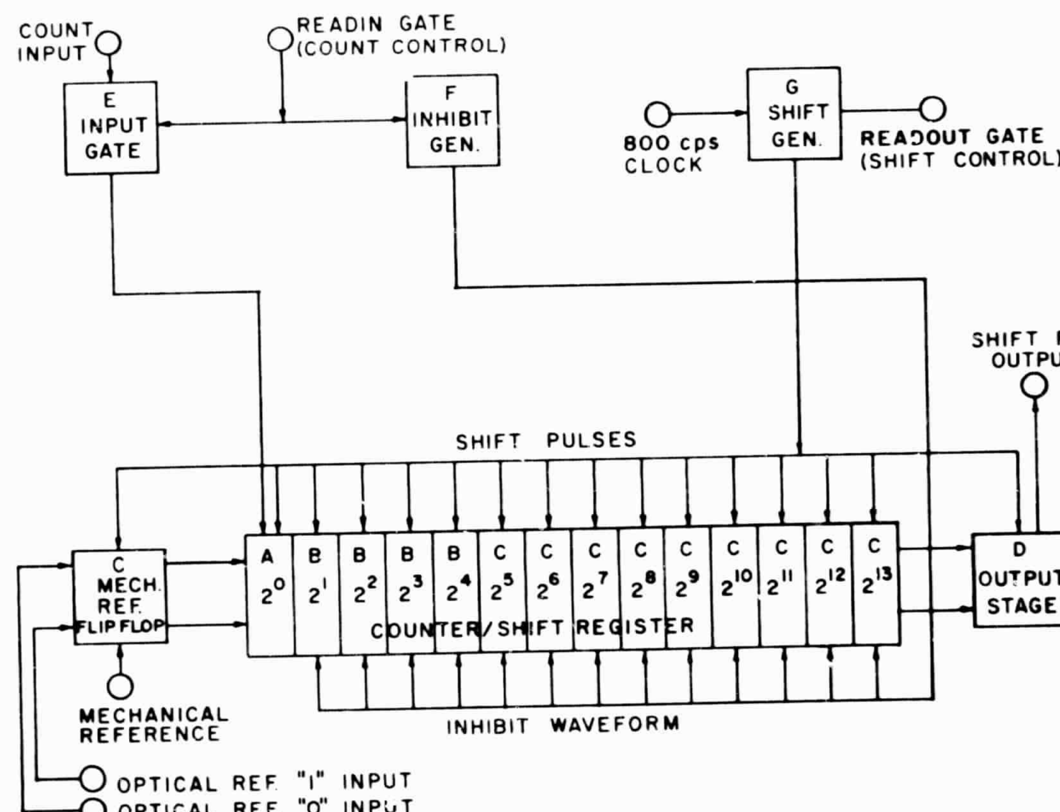


Fig. 9 —HARVARD OSO-G1 COUNTER BLOCK DIAGRAM

DRAWING NO. I-269	NEGATIVE NO.

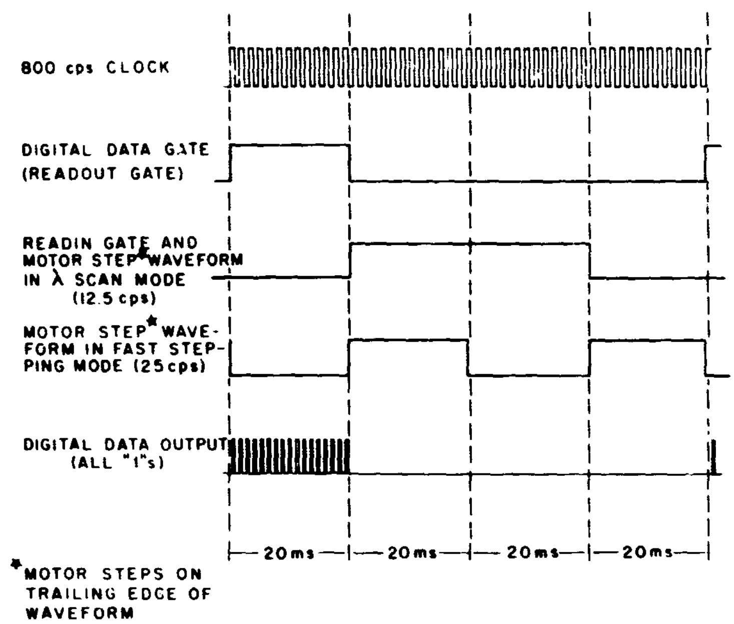


Fig. 10 – HARVARD OSO-G1 TIMING WAVEFORMS

2.4.2 DATA FORMAT

Data from the Harvard instrument is multiplexed into the spacecraft's data main frame as shown in Fig. 11. The spacecraft has an internal clock which generates a square wave at 800 cycles per second (cps). The timing of this clock sets the rate at which data from the various experiments is read out and recorded on the spacecraft's tape-recorder. The data acquisition rate of the spacecraft is 800 binary bits per second. The spacecraft's data main frame

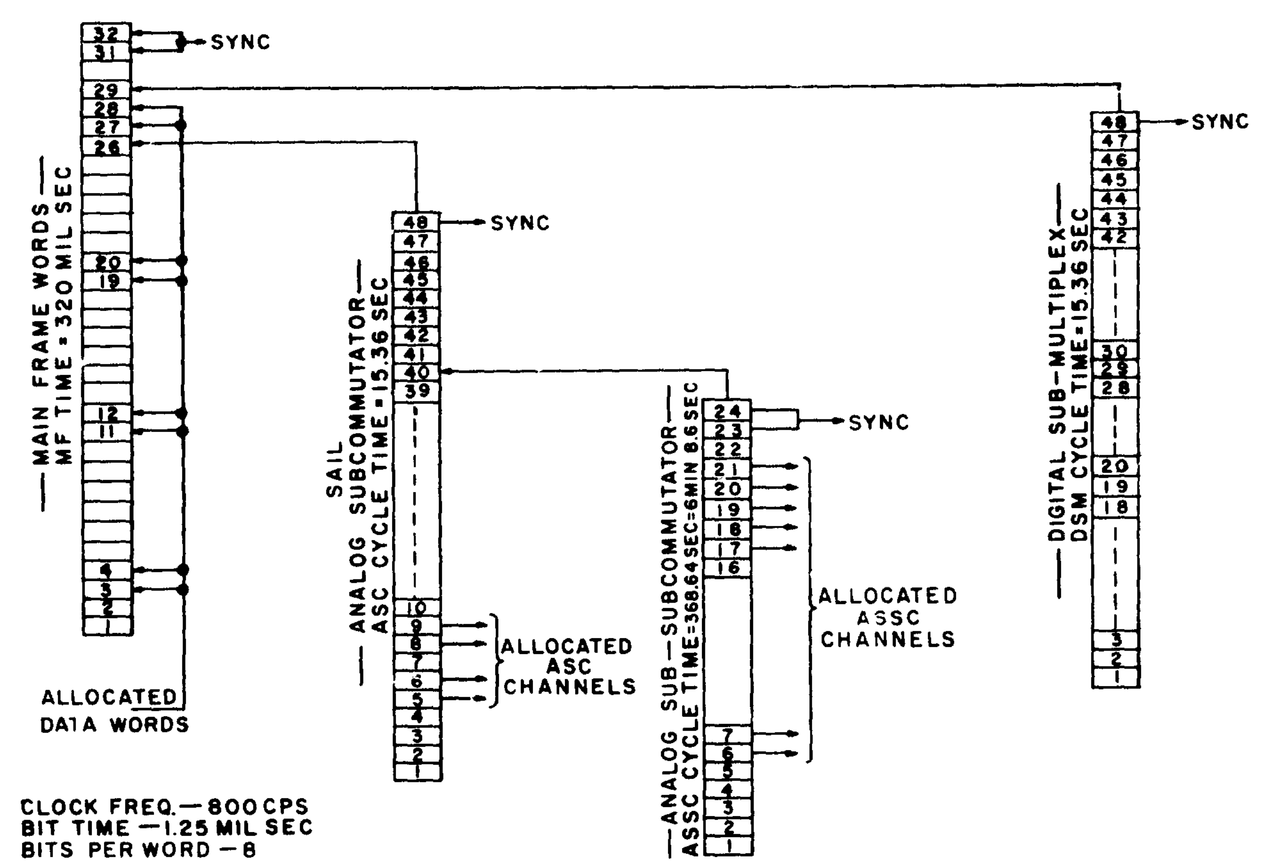


Fig. 11 — SPACECRAFT'S DATA MAIN FRAME

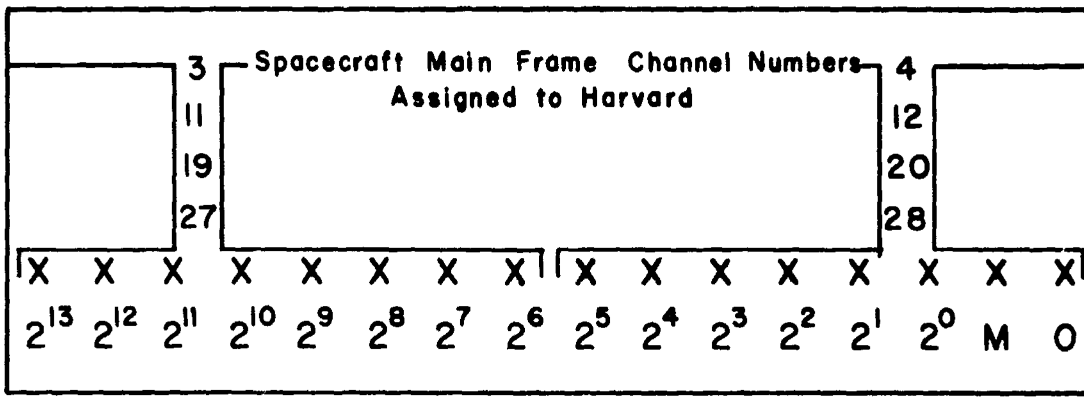
DRAWING NO.	NEGATIVE NO.
I—312	

consists of 32 eight bit data words. Each data word has a duration of 10 ms (8 data bits/800 bits per second) and the main frame has a duration of 320 ms. In addition to the data words from the various experiments, each main frame contains a word from one of the 48 channels of the digital submultiplex (DSM), a word from the wheel analog subcommutator (WASC), a word from one of the 48 channels of the sail analog subcommutator (referred to here as ASC), and two synchronizing words at the end of each main frame. Channel 40 of the ASC contains the word from one of the 24 additional channels of the analog sub-subcommutator (ASSC). All this is illustrated in Fig. 11.

Since only one of the 48 DSM channels will be read out during each main frame, a particular DSM channel will be read out once every 15.36 seconds (48 channels x 320 ms). This is the DSM cycle time. Similarly, the ASC with 48 channels has a cycle time of 15.36 seconds. The ASSC has a cycle time of 6 minutes 8.64 seconds (24 channels x 48 channels x 320 ms).

Four equally spaced pairs of adjacent eight bit words have been allocated to Harvard. As indicated in Figs. 11 and 12, these words occur in main frame channels 3-4, 11-12, 19-20, and 27-28. By treating each pair of eight-bit words as one word we can define the basic Harvard data unit as a sixteen-bit word. A Harvard data word is read out once every 80 ms during normal main frame operation.

BASIC HARVARD DATA WORD



$2^{13} - 2^{0}$ = PHOTON COUNT

M = MECHANICAL REFERENCE INDICATION

O = OPTICAL REFERENCE INDICATION

X = DATA BIT (8 BITS/MAIN FRAME WORD)

REFERENCE BIT STATES

Instrument Condition	Data Bits	Duration
	MR OR	
Grating in MR position or End of raster or Night or Instrument OFF	00	8 seconds (min.) 640 ms continuous continuous
Grating in OR position	11	640 ms (min.)
Normal operating state (neither MR nor OR)	10	continuous
Forbidden state under normal conditions	01	

Fig. 12-HARVARD OSO-G1 DATA FORMAT

In the sixteen-bit Harvard word the first fourteen bits refer to the state of the counter at the conclusion of the previous readin period. The last two bits are reference or flag bits that indicate the states of the mechanical reference (MR) and optical reference (OR). Figure 12 indicates the interpretation of the basic Harvard data word.

The Harvard data word is read out beginning with the most significant digit (2^{13}) of the photon count from the previous 40 ms readin period and continuing to the least significant (2^0) photon count bit. Then the mechanical reference indication and, finally, the optical reference indication are read out.

A "0" in the MR indication shows:

(1) The diffractions grating is in the MR position (i.e., the cam has closed the MR microswitch), or

(2) The instrument has completed a raster (this will occur in 8 successive Harvard words after each raster), or

(3) The spacecraft is in the night portion of its orbit, or

(4) The instrument is OFF (low voltage and high voltage power supplies turned off).

A "1" in the MR indication shows the absence of the above conditions. A "1" in the OR indication shows that the grating is in the OR position (so that visible light shines on the OR photocell). A "0" in the OR indication shows that the grating is not in that position.

In addition to the UV data words in the main frame, Harvard has four ASC channels and seven ASSC channels. As listed in Table II, these channels are used to monitor internal instrument parameters.

Analog readings are provided by transducers and special circuit arrangements. These yield analog voltages from 0 to 5 volts under normal conditions. The analog voltage of the appropriate ASC channel is sampled and encoded during the first millisecond at the beginning of word 26 in the data main frame. Similarly, the appropriate ASSC channel is sampled and encoded at the beginning of word 40 in the ASC sequence. The digital multiplexer and encoder converts an analog voltage to an eight-bit vinary word by a method of successive approximations: the most significant bit (2^7 bit) is encoded first during 10 microseconds, then the next most significant bit (2^6 bit) during the following 10 microseconds and so on to the least significant bit during the final 10 microseconds of the 80 microseconds encoding time. The encoding is designed to be linear with a range of 0 to 255 counts representing the analog voltages from 0 to 5 volts. One ASC channel is read out during word 26 of each main frame. The readout begins just after the sampling and encoding time.

TABLE II

HARVARD ANALOG CHANNELS

CHANNEL NUMBER	FUNCTION
ASC-5	High Voltage Input Current. Indicates current through primary side of the HV power supply. Nominally ~9 milliamperes (18 digitized).
ASC-6	Grating Position. Linear potentiometer indicates position of diffraction grating from retrace (190 digitized) to 0 steps (Mech. Ref.) (50 digitized). Linear potentiometer voltage summed with -3V supply voltage. -3V failure biases output 1 volt positive.
ASC 8 and 9	Ratemeter/+4.2V. Sums +4.2 supply voltage with integrated pulse amp output. With no counts analog signal is +4.2V (213 digitized). Analog signal decreases with increase in pulse amp output frequency.
ASSC 6 and 18	Absolute Temperature. Indicates internal temperature at center of instrument. Nominally ~15°C (131 digitized).
ASSC 7 and 19	ΔT. Indicates difference in temperature between fore and aft ends of instrument. Nominal variation once per orbit ~ 1-3°C (110-240 digitized).
ASSC 17	-5.5V/Readin Gate. Sums -5.5V supply voltage with integrated readin gate waveform. Nominally +1.1V (55 digitized).
ASSC 20	Overload Protection Status. Indicates HV OP system tripped or not tripped. Nominally +1.9V (97 digitized) or 0V (0 digitized) respectively. The OP system will normally remain in the "not tripped" state.
ASSC 21	Overload Protection Bypass. Indicates HV OP system enabled or disabled. Nominally +1.9V (97 digitized) or 0V (0 digitized) respectively. The OP system will normally remain enabled.

2.5 COMMAND AND CONTROL

The commands used to operate the Harvard OSO-G1 instrument are listed in Table III. The electrical power commands control the instrument's electrical power systems. The wavelength selector commands can initiate the wavelength scan mode of instrument operation or can set the diffraction grating at a specified position for large or small raster modes of operation (refer to § 2.2).

These commands are sent to the spacecraft from ground stations. The electrical power commands (except Overload Protection Enable and Disable) are acted on in the spacecraft's junction box (J-box). The overload protection commands are acted on in the K-box of the Harvard instrument. The spacecraft directs the wavelength selector commands to the Harvard instrument's wavelength selector module for implementation.

2.5.1 ELECTRICAL POWER COMMANDS

Electric power for the Harvard OSO-G1 instrument is provided by the spacecraft through the +19 volt (V) launch power line, the +19V day power line, and the +15V regulated power line. The +15V power line enters the instrument's 15 volt converter (cf. Fig. 5). The +15V and -15V provided by the converter power the instrument's temperature probe and differential temperature amplifier.

TABLE III

HARVARD OSO-G1 COMMANDS

SPACECRAFT COMMAND NUMBER	HARVARD COMMAND NAME
ELECTRICAL POWER COMMANDS	
535	Harvard Instrument ON
[redacted] 530	Harvard Instrument OFF
[redacted] 567	High Voltage ON
416	High Voltage OFF
417	High Voltage Day
418	High Voltage Launch
337 or 341	Overload Protection Enable
336 or 340	Overload Protection Bypass
WAVELENGTH SELECTOR COMMANDS	
331 or 408	Wavelength Scan
338 or 342	Wavelength Reset
339 or 343	Reset Override
344 or 346	Optical Reference Select
345 or 347	Mechanical Reference Select
348 or 352	Motor Start
349 or 353	Wavelength Select 1
354	Wavelength Select 2
351 or 355	Wavelength Select 3
360	Wavelength Select 4
356 or 362	Wavelength Select 5
366	Wavelength Select 6
357 or 363	Wavelength Select 7
361	Wavelength Select 8
358 or 364	Wavelength Select 9
326	Wavelength Select 10
359	Wavelength Select 11
325	Wavelength Select 12
365	Wavelength Select 13
327	Wavelength Select 14

The switching system for the instrument's +19V power is illustrated in Fig. 13. The +19V launch power is available at all times (i.e., day and night). The +19V launch power line supplies power to the instrument's wavelength selector. The +19V day power is available only during satellite day (approximately two-thirds of each orbit) unless the spacecraft Day-Night Override command is sent. That command activates the spacecraft's day-night relay which allows +19V day power to continue through satellite night.

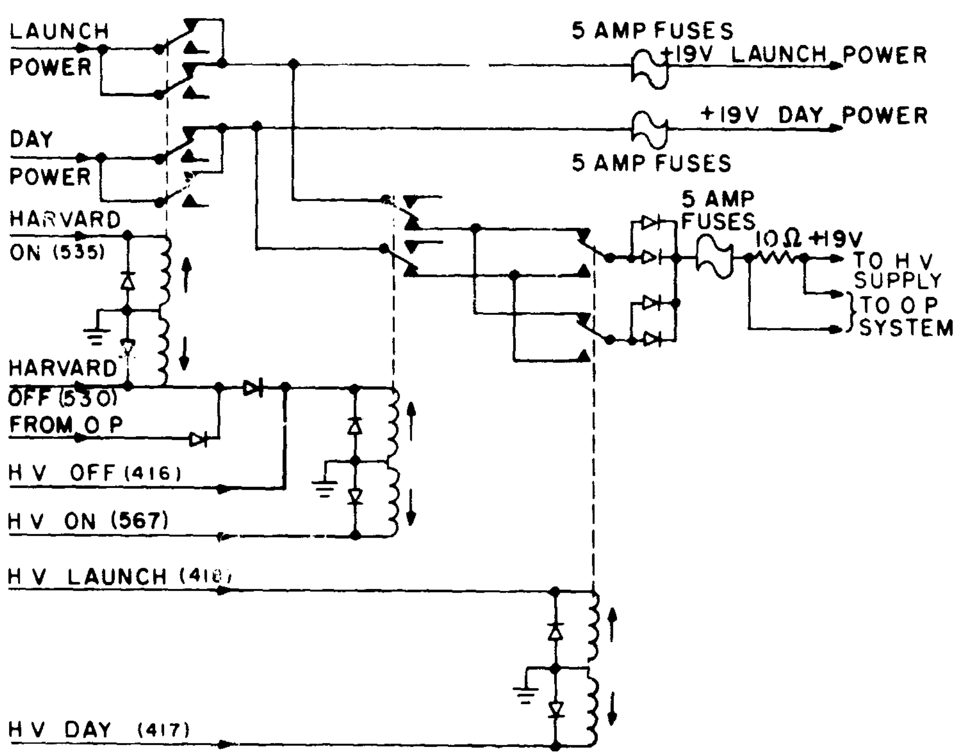


Fig. 13 - HARVARD POWER SWITCHING DIAGRAM

The command number of each Harvard power command is included in parenthesis after the command name in Fig. 13.

The +19V source for the high voltage power supply may be either launch power or day power as indicated in Fig. 13. All other systems in the Harvard instrument (except the wavelength selector, see above) are powered by +19V day power by way of the low voltage power supply (cf. Fig. 5).

The Harvard instrument ON command turns on all instrument electronics except the high voltage power supply. The high voltage supply is controlled separately by the High Voltage ON and High Voltage OFF commands. The Harvard Instrument OFF command turns all power off (including the high voltage power). The High Voltage Day or High Voltage Launch command will be sent once to select the source of +19V high voltage input power: either the day bus-power or the launch bus-power. The Overload Protection Enable command activates the overload protection system on the high voltage power supply. The Overload Protection Bypass command can deactivate that system in case it stops functioning properly.

The Overload Protection (OP) system referred to above and in Fig. 13 was designed to protect the instrument's high voltage supply from excessive currents. If the input current to the high voltage supply exceeds 18 ±1 milliamps (180 millivolts across the 10 ohm resistor) for more than 100 milliseconds, the OP system sends out a pulse to the Harvard OFF line which turns the instrument OFF (cf. Fig. 13). Low voltage power can be turned on again only after the Harvard Instrument ON command is sent. High voltage power can then be returned only after the High Voltage ON command is sent.

2.5.2 WAVELENGTH SELECTOR COMMANDS

The simplified block diagram of the wavelength selector in Fig. 14 should aid in explaining the operation of the wavelength selector commands. The wavelength selector has three basic modes of operation: wavelength (λ) scan, reference select, and wavelength select. The operating modes are described below. In all of these modes the wavelength selector receives the square wave clock signal (800 cycles per second) and the readout gate for synchronization from the spacecraft. The 800 cps signal is divided by 32, then divided by 2, to provide the Harvard readin gate for the counter circuits. The 40 ms readin gate begins at the fall of the Harvard readout gate (cf. Fig. 10).

Wavelength Selector Modes:

1) Wavelength Scan. This mode is initiated by sending the Wavelength Scan command. When the command is received a pulse is sent through the upper coil (labeled "C" in Fig. 14) in the mode select relay (K2) which pulls the switch into the position shown in Fig. 14. In that configuration 12.5 cps pulses are directed to the motor drive circuits. These motor stepping pulses are synchronized so that the cam is moved one step forward after each readin gate. At that rate 15 minutes 45.68 seconds are required for one full rotation of the cam

(11,824 steps, i.e., one complete wavelength scan).

2) Reference Select. This mode is used to bring the diffraction grating to either optical reference position or mechanical reference position. The optical reference position is more precise, but the mechanical reference microswitch has operational advantages. To send the grating to a reference position from the wavelength scan mode either the Optical Reference (OR) Select or the Mechanical Reference (MR) Select command must be sent.

The OR Select command sends a pulse through the left coil (A) of the reference select relay (K1) and pulls the switch into contact with the OR pulse line that comes from the instrument's reference generator. The command also sends a pulse through the lower coil (D) of the K2 relay which pulls that switch down to the 25 cps line from the "Or" gate shown in Fig. 14. Similarly, the MR Select command pulls the K1 relay switch to the MR pulse line and pulls the K2 switch to the 25 cps line (thus stopping the wavelength scan mode).

The Reset Override command resets all fourteen stages of the wavelength select counter to logical "0" and resets the OR/MR flip-flop and the wavelength select flip-flop so that the outputs of both flip-flops to their respective "And" gate logic circuits are logical "0's). Thus, no pulses pass through the "And" gates and motor stepping halts. The Wavelength Reset

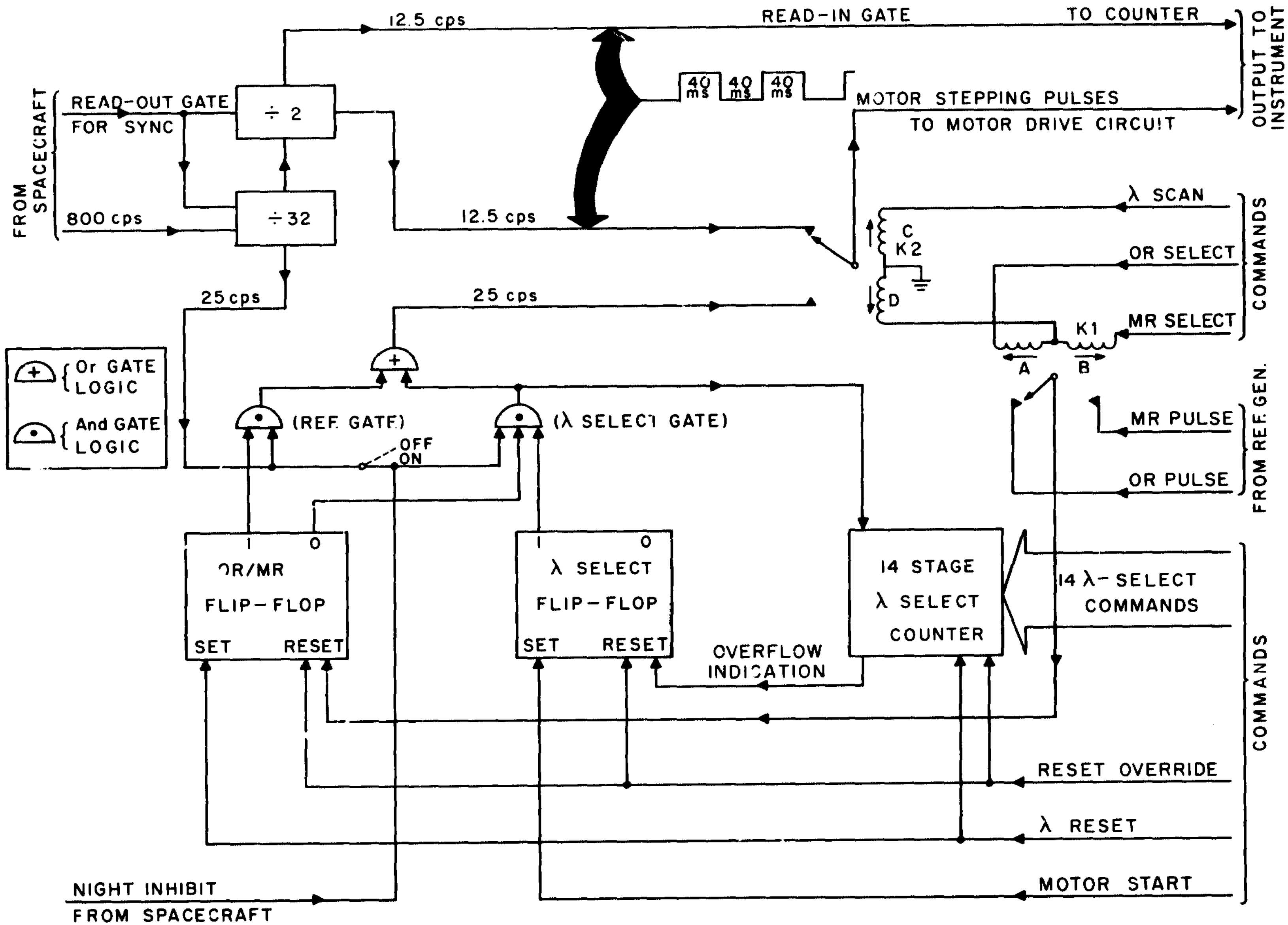


Fig. 14— WAVELENGTH SELECTOR BLOCK DIAGRAM

DRAWING NO.	NEGATIVE NO.
I-310	

command sets the OR/MR flip-flop (i.e., puts a logical "1" into the reference gate and a logical "0" into the wavelength select gate). This allows 25 cps pulses to pass through the reference gate to the motor drive circuit. When the grating has been stepped to the appropriate reference position a pulse from the reference generator through the K1 switch resets the OR/MR flip-flop (i.e., puts a logical "0" into the reference gate and a logical "1" into the wavelength select gate). Since the wavelength select flip-flop was in the reset state, no pulses pass through the "And" gates and motor stepping halts. The grating will remain at the desired reference position until further commands are sent.

3) Wavelength Select. This mode is used to stop the diffraction grating to a selected position from a known position (a reference position or a known wavelength position). If the instrument is not in the wavelength scan mode, the Reset Override command is sent to clear the counter and reset the OR/MR and wavelength select flip-flops. Then the appropriate ones of the fourteen Wavelength Select commands are sent (see example below) to set flip-flops in the wavelength select counter. The Motor Start command then sets the wavelength select flip-flops and allows 25 cps pulses to pass through the wavelength select "And" gate to the motor drive circuit. 25 cps pulses also pass into the fourteen stage counter. When the

counter overflows (goes from an all "1" condition to an all "0" condition) the wavelength select flip-flop is reset and motor stepping halts.

Since the motor steps until the fourteen stage counter overflows, if all fourteen flip-flops are set in logical "1" states by wavelength select commands, the motor will step once. If all fourteen flip-flops are left in the logical "0" state (no wavelength select commands sent) the motor will step 16,384 (2^{14}) steps before overflow. Thus the motor will take a number of steps equal to the complement of the number commanded to the fourteen stage counter (i.e., 16,383 minus the number commanded) plus one step. An example of the use of the fourteen Wavelength Select commands is given below.

Suppose an experimenter wants to examine the 1041Å wavelength radiation from the sun. Assume the diffraction grating projects this wavelength on the photomultiplier when the cam is 8818 steps from its optical reference position. If the grating is at optical reference the experimenter must command the motor to take 8818 steps. Thus, following the Reset Override command he would send Wavelength Select 2, 3, 4, 8, 9, 11, 12, 13 and Motor Start. Figure 15 illustrates the procedure for determining appropriate Wavelength Select commands.

4) <u>Wavelength Select Via Reference</u>. The wavelength selector is capable of combining the advantages of the

Number Value	Selective Subtotal Add	Check when value is used. ↓	Check when value is *not* used. ↓		
		0	1	Command	Command Numbers
$2^{13} = 8192$	8192	x		Wavelength Select 14	327
$2^{12} = 4096$			x	Wavelength Select 13	365
$2^{11} = 2048$			x	Wavelength Select 12	325
$2^{10} = 1024$			x	Wavelength Select 11	359
$2^9 = 512$	8704	x		Wavelength Select 10	326
$2^8 = 256$			x	Wavelength Select 9	358 or 364
$2^7 = 128$			x	Wavelength Select 8	361
$2^6 = 64$	8768	x		Wavelength Select 7	359 or 363
$2^5 = 32$	8800	x		Wavelength Select 6	366
$2^4 = 16$	8816	x		Wavelength Select 5	356 or 362
$2^3 = 8$			x	Wavelength Select 4	360
$2^2 = 4$			x	Wavelength Select 3	351 or 355
$2^1 = 2$			x	Wavelength Select 2	354
$2^0 = 1$	8817	x		Wavelength Select 1	349 or 353
Add +1			↑ Send Commands Checked Above.		

Total Steps = 8818

FIGURE 15 - WAVELENGTH SELECT COMMANDS FOR 8818 STEPS.

reference select and wavelength select modes in one continuous operation. This capacity is used when an experimenter commands the instrument to get out of wavelength scan and go to a selected wavelength position by way of a reference position. To do this the experimenter sends either the OR Select or the MR Select command. This stops the wavelength scan. The Reset Override command clears the fourteen stage counter and resets the OR/MR flip-flop and the wavelength select flip-flop so that no pulses pass to the stepping motor. The Wavelength Reset command sets the OR/MR flip-flop and allows stepping pulses to go to the motor drive circuits until the grating reaches the selected reference position. When that occurs a pulse from the Reference Generator resets the OR/MR flip-flop. If the appropriate Wavelength Select commands and the Motor Start command have been sent, the resetting of the OR/MR flip-flop opens the wavelength select "And" gate at the same time that it closes the reference "And" gate.

Note: The two outputs of the OR/MR flip-flops are mutually exclusive. When the flip-flop is set the output to the reference gate is "1", and the output to the wavelength select gate is "0". When the flip-flop is reset the outputs are reversed.

With the wavelength select gate open, 25 cps pulses pass to the motor drive circuit until the counter overflows and resets the wavelength select flip-flop.

TABLE IV

COMMAND SEQUENCES

OPERATING MODE	COMMAND SEQUENCE	INSTRUMENT RESPONSE
Wavelength Scan	Wavelength Scan	Motor steps at rate of 12.5 steps per second (i.e., one step after each readin gate).
Reference Select (From Wavelength Scan)	1. Optical or Mechanical Reference Select 2. Reset Override 3. Wavelength Reset	1. Stops wavelength scan. Sets K1 relay. 2. Clears 14 stage counter; resets OR/MR and wavelength select flip-flops. Stops motor stepping. 3. Steps grating to selected reference position at 25 steps per second.
Wavelength Select (From a known wavelength or reference position.)	1. Reset Override 2. Wavelength Select (1 through 14) 3. Motor Start	1. Clears 14 stage counter; resets OR/MR and wavelength select flip-flops. Stops motor stepping. 2. Sets appropriate flip-flops in 14 stage counter. 3. Steps motor at 25 steps per second until grating has reached desired position (i.e., until 14 stage counter overflows).
Wavelength Select Via Reference (From Wavelength Scan)	1. Optical or Mechanical Reference Select 2. Reset Override 3. Wavelength Reset 4. Wavelength Select (1 through 14) 5. Motor Start	1. Stops wavelength scan. Sets K1 relay. 2. Clears 14 stage counter; resets OR/MR and wavelength select flip-flops. Stops motor stepping. 3. Steps grating to selected reference position at 25 steps per second. 4. Sets appropriate flip-flops in 14 stage counter. 5. Steps grating to selected wavelength at 25 steps per second immediately after grating arrives at reference selected above.

Then the grating should be in the desired position. Table IV summarizes the basic sequences of operating commands. The wavelength selector sends readin and readout gates to the counter during all modes of instrument operation.

One other function of the wavelength selector module should be mentioned. The motor drive circuit operates on +19 volt day power from the spacecraft. Since this power is not available during satellite night, the motor does not step at night. However, stepping pulses from the wavelength selector may continue. In the wavelength select mode this would mean that the fourteen stage counter would count pulses until it overflowed, even though the motor was not stepping the grating. Then the grating position would be unknown. To prevent this a night inhibit flip-flop (pictured as an ON-OFF switch in Fig. 14) was inserted between the reference gate and the wavelength select gate along the 25 cps line from the divide-by-32 stage. This flip-flop prevents pulses from passing through the wavelength select gate during satellite night. Hence the wavelength select counter is not activated during night and the grating will resume stepping to its selected position when power returns the next satellite morning.

2.5.3 SPACECRAFT POINTING COMMANDS

Table V lists the commands for the spacecraft's Pointing Control System. These commands are used to

TABLE V

SPACECRAFT POINTING CONTROL COMMANDS
PERTINENT TO HARVARD INSTRUMENT

COMMAND NUMBER	COMMAND NAME
569	Offset Mode Off
570	Offset Mode On/Large Raster On
466	Azimuth Vernier Offset Bit
407	Azimuth Offset Bit 1
419	Azimuth Offset Bit 2
441	Azimuth Offset Bit 3
427	Azimuth Offset Bit 4
460	Azimuth Offset Bit 5
404	Azimuth Offset Bit 6
465	Elevation Vernier Offset Bit
401	Elevation Offset Bit 1
421	Elevation Offset Bit 2
448	Elevation Offset Bit 3
456	Elevation Offset Bit 4
425	Elevation Offset Bit 5
455	Elevation Offset Bit 6
413	Offset Point On
414	Offset Generator Reset
415	Small Raster On

TABLE VI

SPACECRAFT'S RESPONSE TO POINTING COMMANDS

OPERATIONS	COMMAND	RESPONSE OF SPACECRAFT
A. To turn on the offset mode electronics and/or to perform large rasters.	Offset Mode On/ Large Raster On	If offset mode electronics were off, turns them on. Resets azimuth and elevation offset registers. Initiates large raster.
B. To set coordinates for either the center of a small raster or for offset pointing.	Select proper combination of Azimuth Offset Bits 2^0 through 2^6 and: Elevation Offset Bits 2^0 through 2^6.	Loads a "one" into the 2^0 through 2^6 position of the azimuth and/or elevation offset registers. (Note: commands 466 and 465 for 2^0 bits are called Azimuth and Elevation Vernier offset bit, respectively.)
C. To change the offset pointing coordinates.	Offset Generator Reset.	Resets offset coordinates in azimuth and elevation register. Instrument points to upper left-hand corner of offset grid.
Alternate	Offset Mode On/Large Raster On.	Resets the offset coordinates. (A new selection of offset coordinates can be loaded into the azimuth and elevation registers.)
D. To select the small raster or the offset pointing mode after the proper coordinates are selected.	Small Raster On or: Offset Point On	Initiates small raster, centered at offset pointing position, which was preset in register. Points to preset azimuth and elevation position.
E. To return the normal pointing mode (with offset mode electronics turned off).	Offset Mode Off	Turns offset mode electronics off and points instruments toward center of solar disc.

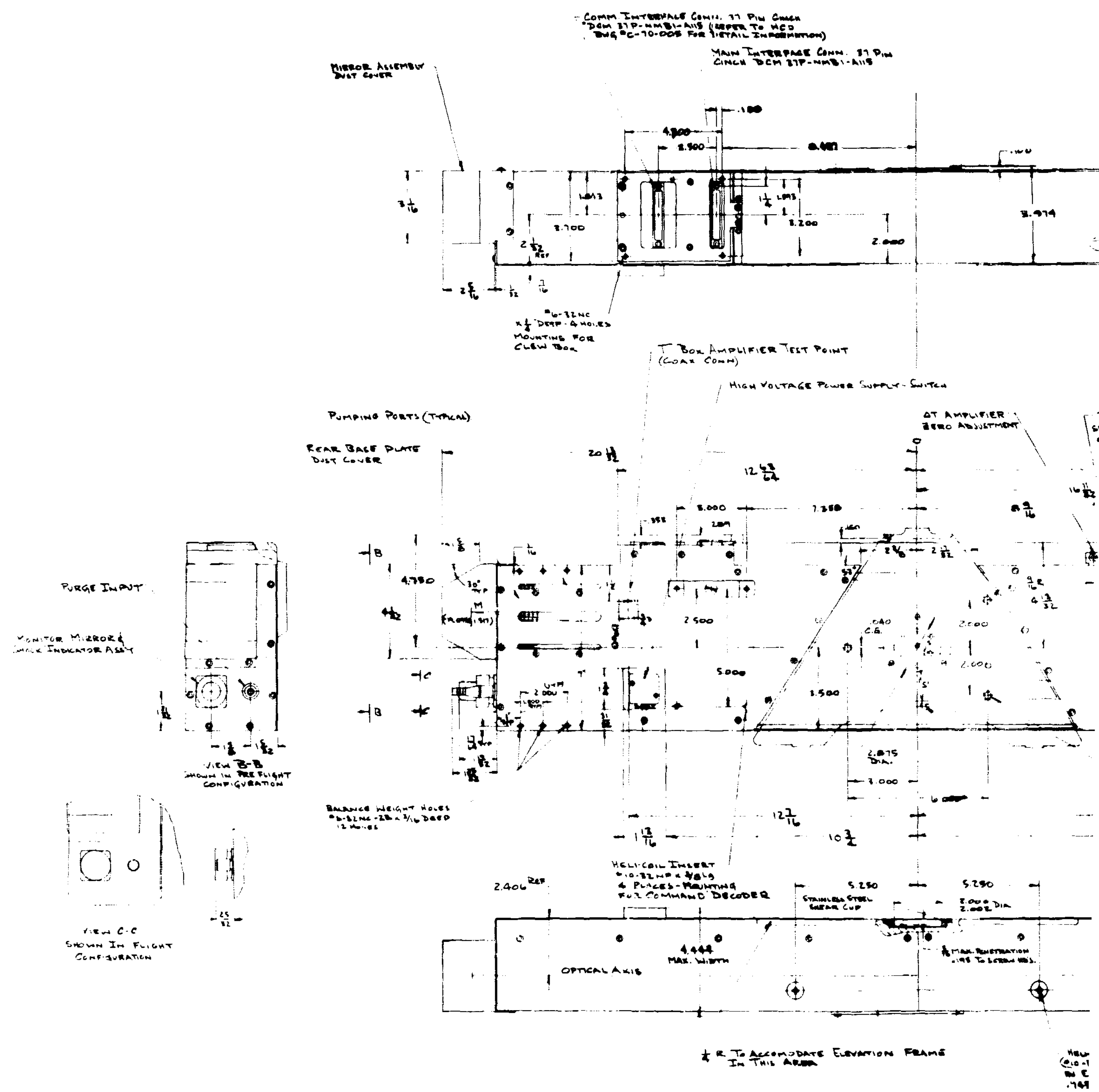
initiate the large and small raster modes of operation and to point the Harvard instrument at any of the 128 x 128 offset grid points.

The status of the pointing control system is monitored by spacecraft housekeeping channels in the ASC. The pointing control system delivers the start of raster signal to the Harvard instrument where it is encoded and read out as part of the sixteen-bit Harvard main frame data word (refer to §2.4.2).

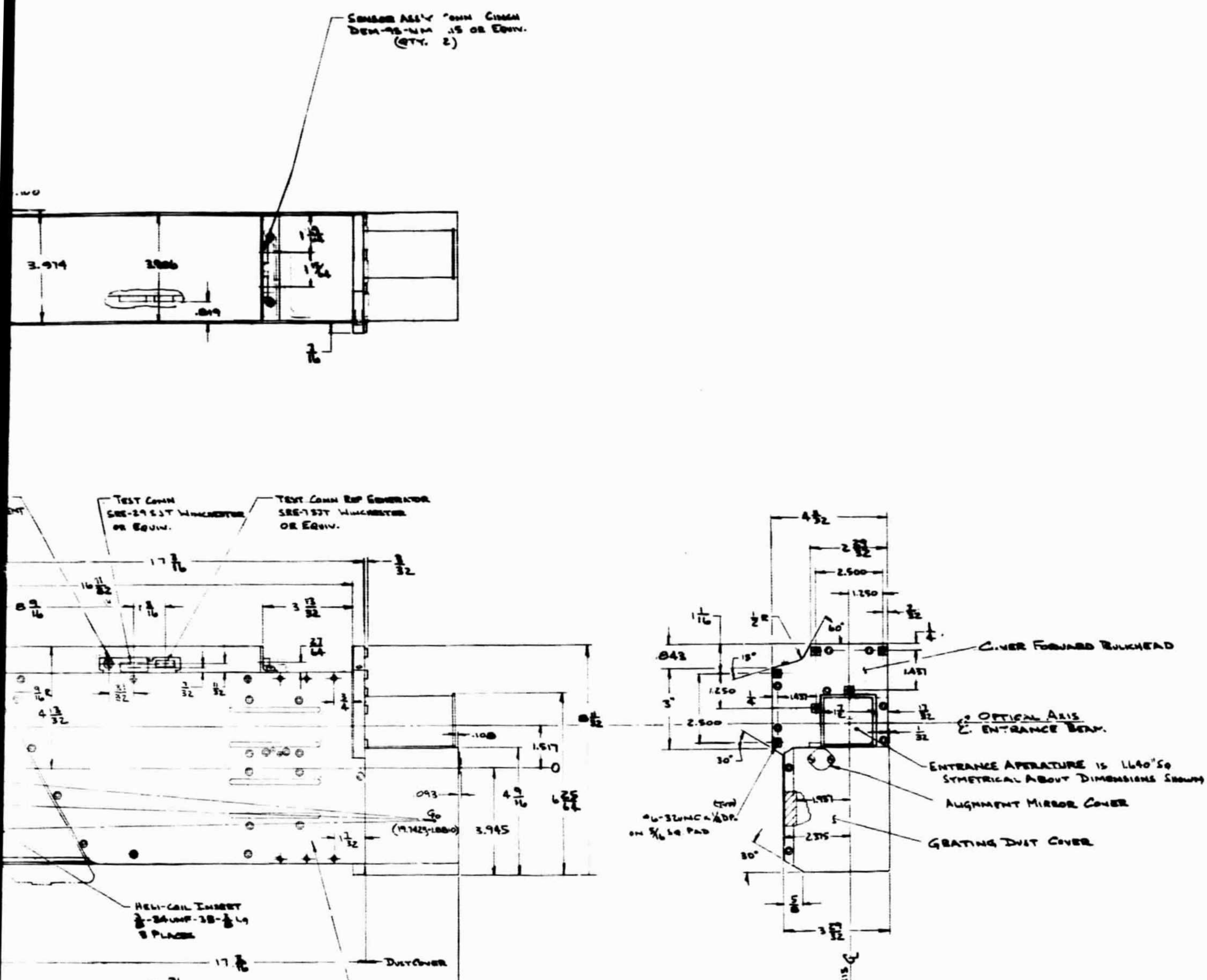
A summary of the spacecraft's response to pointing commands appears in Table VI. Note that when the offset electronics is turned on, the large raster is started immediately. The large raster cannot be ceneterd at an offset position. The small raster is always centered at an offset position. It is, therefore, not necessary to command the spacecraft to "Offset Pointing On" (413) before the Small Raster On command (415) is sent. If the Small Raster On command (415) is sent after the offset, azimuth, and elevation registers have been reset and before they are reloaded, the small raster is centered at the upper left-hand corner of the offset grid.

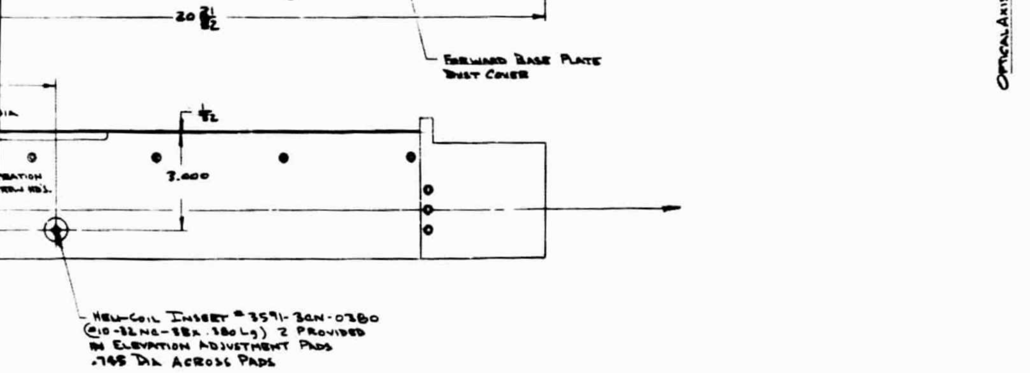
2.6 OTHER FEATURES

The Harvard OSO-G1 instrument is approximately one meter long. Other pertinent dimensions are contained in the diagram in Fig. 16. The photographs in Figs. 17, 18, and 19 present views of the instrument's



MIRROR ASSEMBLY DUST COVER
MAIN INTERFACE CONN. 37 PIN CINCH DCM 37P-NMB1-A115
#6-32NC x 1/4 DEEP - 4 HOLES MOUNTING FOR CLEW BOX
T BOX AMPLIFIER TEST POINT (COAX CONN)
HIGH VOLTAGE POWER SUPPLY - SWITCH
PUMPING PORTS (TYPICAL)
REAR BASE PLATE DUST COVER
ΔT AMPLIFIER ZERO ADJUSTMENT
PURGE INPUT
MONITOR MIRROR & LOCK INDICATOR ASS'Y
VIEW B-B SHOWN IN PRE FLIGHT CONFIGURATION
VIEW C-C SHOWN IN FLIGHT CONFIGURATION
BALANCE WEIGHT HOLES
HELI-COIL INSERT 4 PLACES - MOUNTING FOR COMMAND DECODER
STAINLESS STEEL SHEAR CUP
4.444 MAX. WIDTH
OPTICAL AXIS
R TO ACCOMODATE ELEVATION FRAME IN THIS AREA





NOTES:

1. ALL-HELI-COILS ARE SELF-LOCKING
2. WEIGHT 37.3 LBS.
3. SLIT LOCATIONS
   S=(0.3029,-0.1802)
   S'=(0.1656,-1.1974)
   S_0=(0.2251,-2.2546)
4. THIS DRAWING IS INTENDED TO DESCRIBE THE HARVARD (HCO) OSO-G1 INSTRUMENT CONFIGURATION. IT HAS BEEN DIMENSIONED TO DESCRIBE THE CRITICAL INTERFACES. ALL OTHER FEATURES MAY BE SCALED FOR ROUGH APPROXIMATION, HOWEVER IF DETERMINED TO BE CRITICAL CONSULT H.C.O. FOR EXACT DESCRIPTION.

FOLDOUT FRAME 2

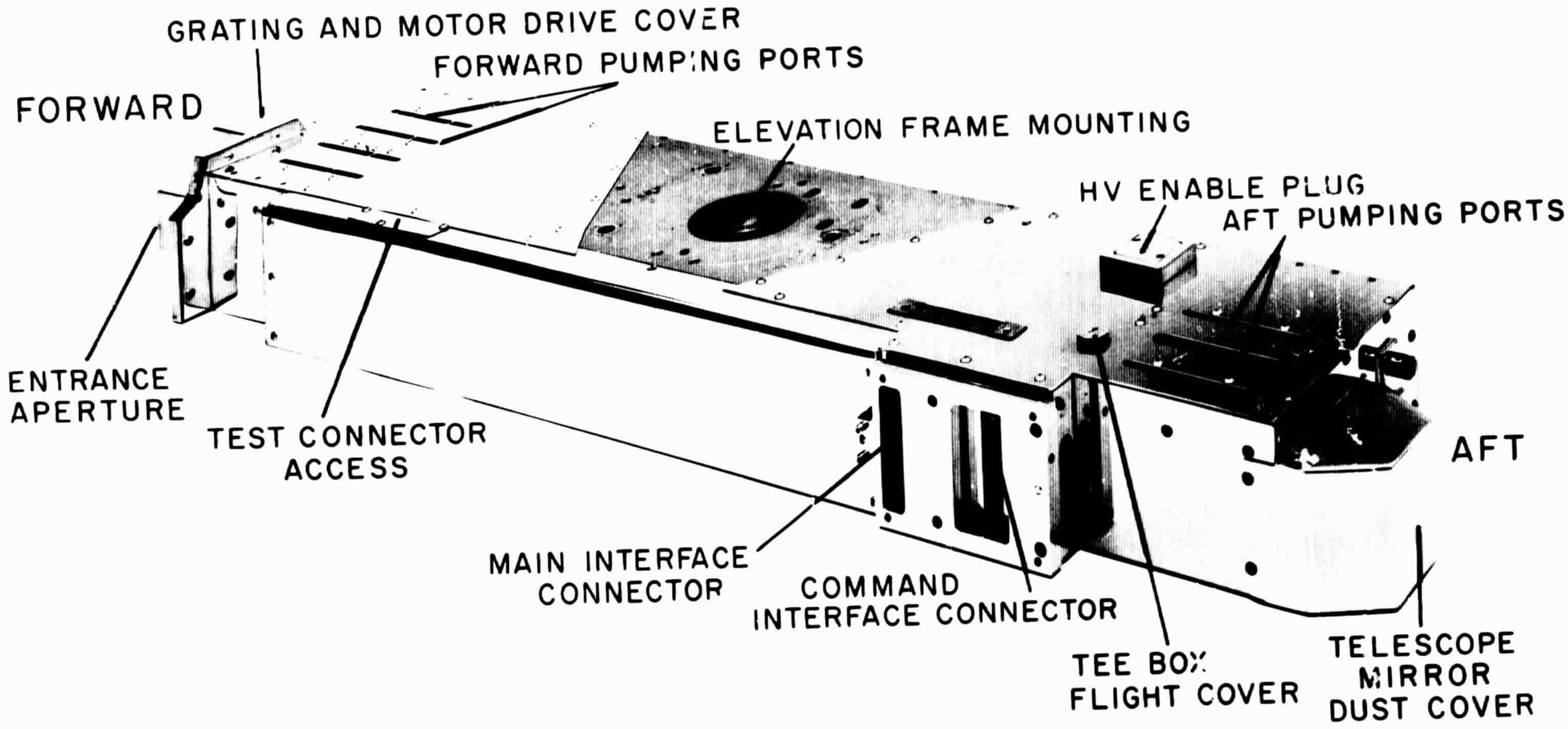


Fig. 17 – EXTERIOR OF HARVARD OSO-GI INSTRUMENT

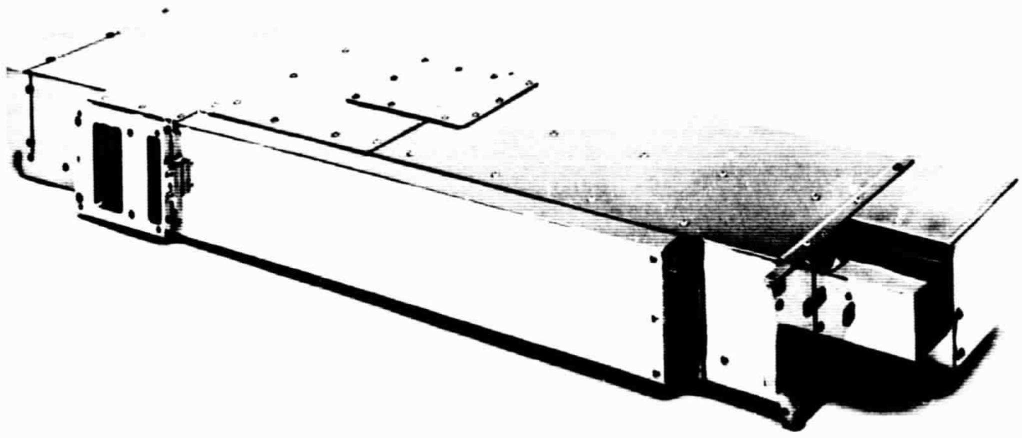


Fig. 18 - EXTERIOR VIEW 2

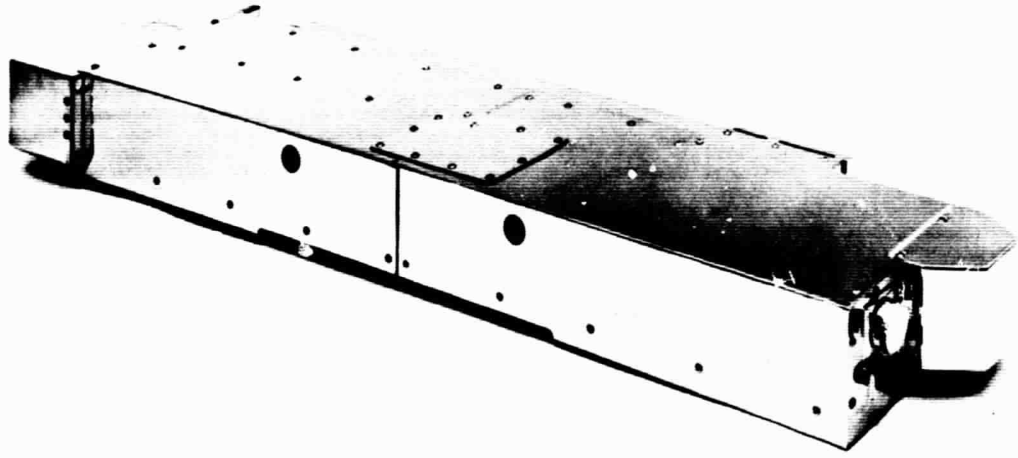


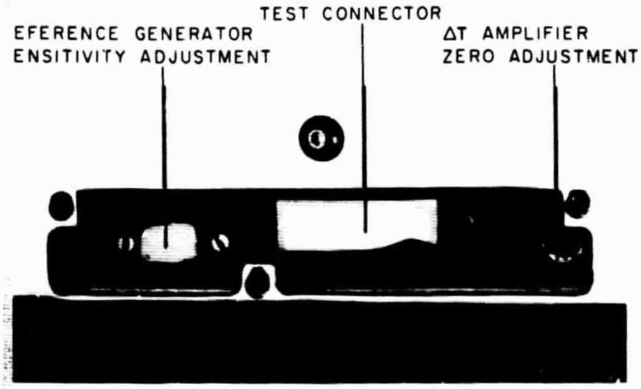
Fig. 19 - EXTERIOR VIEW 3

exterior. The instrument is mounted on the elevation frame in the sail section of the spacecraft. Commands to the instrument are received from the command decoder through the command interface connector. Other electrical signals between instrument and spacecraft pass through the main interface connector.

The upper photographs in Fig. 20 show two configurations of the test connector access. The left photo (A) shows the flight plug inserted in the sensitivity adjustment for the reference generator (left), the flight plug inserted in the test connector (center), and the zero adjust potentiometer for the ΔT amplifier (right). During instrument testing the flight plug on the test connector is removed and replaced by a test plug. Through the test plug the various analog voltages, the motor drive waveform, and other electrical signals within the instrument are monitored. For flight, the flight plugs are inserted and the test connector access is covered by the gold plate shown in the upper right photo (B) of Fig. 20. When the instrument is shipped for assembly into the spacecraft, the test connector access should be in its flight configuration.

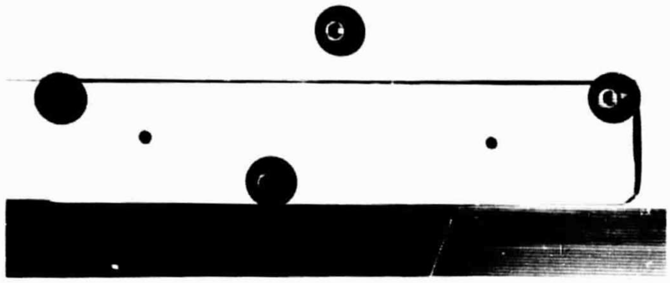
The lower photographs in Fig. 20 show the tee box test point in its test (C) and flight and shipping (D) configurations. This test point allows monitoring of the input signal to the instrument's counter from the pulse amplifier. The flight cover is gold plated.

A



'EST CONNECTOR ACCESS

B

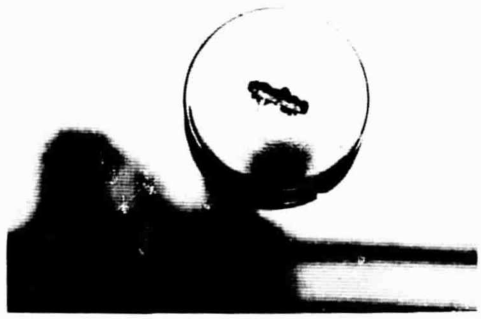


TEST CONNECTOR ACCESS
WITH FLIGHT COVER

C

'EE BOX TEST POINT

D



TEE BOX FLIGHT COVER

Fig. 20 — TEST ACCESS POINTS

The photographs in Fig. 21 show the three assemblies that may be inserted in the high voltage test point: the black dummy plug (E), the red test plug (F), and the gold enable plug (G). The dummy plug separates the high voltage power supply from its input lines. It is used during shipping. The test plug diverts the high voltage input signal to the test apparatus. The enable plug connects the +19 volt input to the high voltage power supply. This plug is inserted just before flight of the instrument.

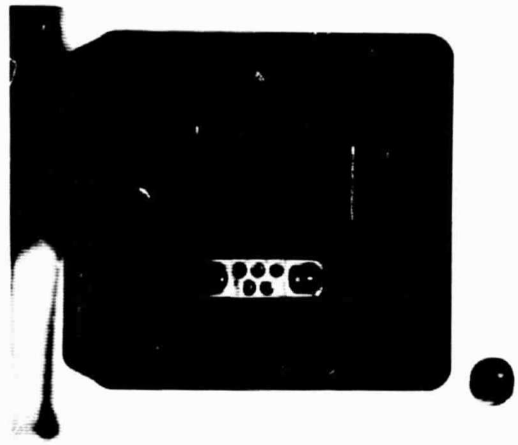
The photographs in Fig. 22 show the purge input and the monitor mirror and shock indicator assembly in three configurations. In the upper left photo (H) the purge input is covered with its gold cap, and the red shock indicator is in place. (The monitor mirror is attached to the shock indicator assembly.) This is the condition in which the instrument will be shipped. In the upper right photo (I) the red hose fitting has replaced the gold cap over the purge input. The dry nitrogen purge to be used on the instrument is described in §4.1. The hose fitting should be in place only during nitrogen purges. The lower photo (J) shows the instrument as it will appear just before flight with the gold cap on the purge input and the gold cover replacing the shock indicator.

Procedures for handling, storing, inspecting, and testing the instrument are described in the following sections.

E

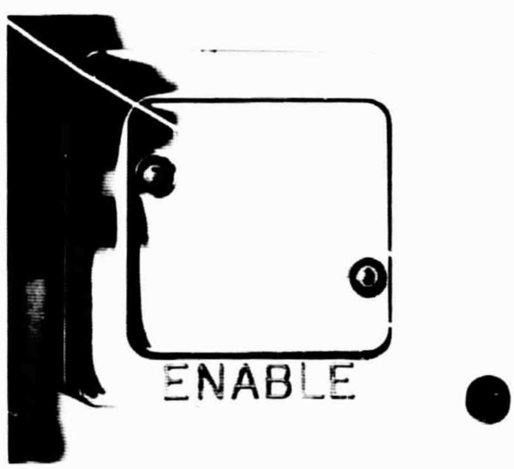
HV SHIPPING PLUG (BLACK)

F



HV TEST PLUG (RED)

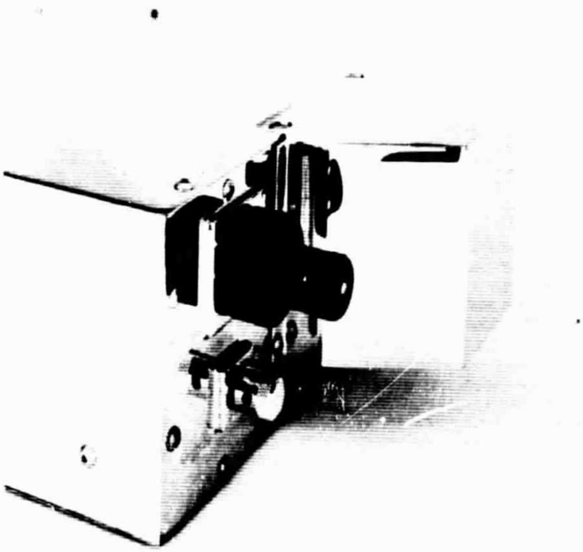
G



HV ENABLE PLUG (GOLD)

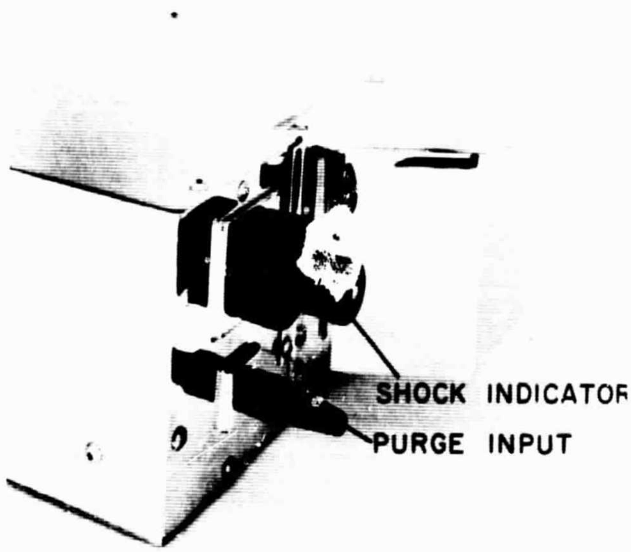
Fig. 21— HIGH VOLTAGE CONNECTOR PLUGS

H



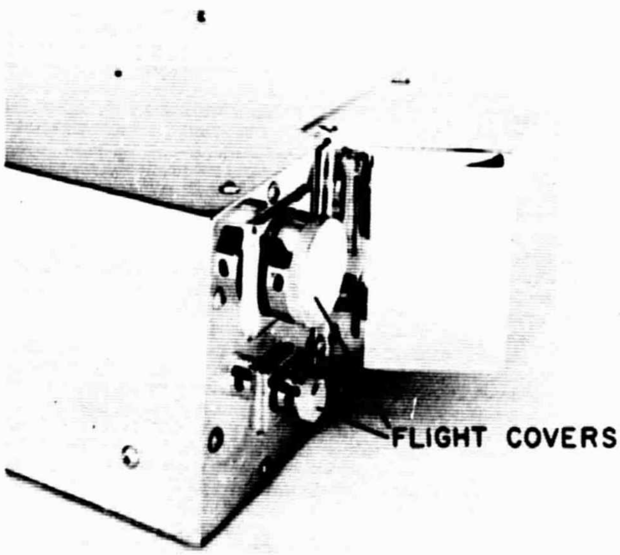
SHIPPING CONFIGURATION

I



TEST CONFIGURATION

J



FLIGHT CONFIGURATION

Fig. 22 – PURGE INPUT AND SHOCK INDICATOR

3.0 INSTRUMENT-SPACECRAFT INTERFACE

The Harvard OSO-G1 instrument is designed to comply mechanically, electrically, and magnetically to the instrument-spacecraft interface specifications of Ball Brothers Research Corporation, the spacecraft manufacturer. The Harvard instrument weighs 36 pounds 2.25 ounces. This weight does not include the weight of solar sensors, decoder, cables, connectors, or ballast to be added to the instrument by Ball Brothers. The center of mass of the instrument (without solar sensors, decoder, etc.) is 0.13 inches forward from the plane defined by the elevation axis and spin axis of the spacecraft, 2.916 inches outward from the spacecraft's spin axis, and 0.152 inches below the plane defined by the instrument's geometric center line and the elevation axis. The Harvard instrument's moment of inertia is 1.35 slug-ft^2. Any mechanical resonances in the instrument are greater than 200 cycles per second. The static balance and dynamic balance parameters will be adjusted by Ball Brothers. Figure 16 shows the external mechanical features of the instrument. As stated in § 4.3, lengths of attachment screws must conform to the Screw Penetration List accompanying each instrument. (cf. Table VII)

The magnetic field of the Harvard instrument is approximately 0.2 Gauss. The instrument's magnetic dipole moment is approximately 165 Gauss-cm^3.

TABLE VII

INTERFACE SCREW LIST
OSO-G1 FLIGHT INSTRUMENT I

Item	No. of Holes	Size & Pitch	Material	Maximum Allowable Penetration
Main mounting holes	3	3/8-24	Helicoil S.S.	.437 in.
Decoder mounting holes A. Base Plate B. Bar	 2 2	 10-32 10-32	 Helicoil S.S. Helicoil S.S.	 .375 in. .240 in.
Elevation pad holes	2	10-32	Helicoil S.S.	.375 in.
K-filter/junction module holes	4	6-32	Helicoil S.S.	.281 in.
Eyeblock connector mounting screws	4	4-40	Steel	.100 in.
Balance weight mounting screws	12	6-32	Helicoil S.S.	.312 in.
Cable clamps A. Forward bulkhead B. K-filter adapter plate	 1 1	 6-32 6-32	 Helicoil S.S. Helicoil S.S.	 .375 in. .375 in.
Eyeblock mounting screws	6	6-32	Helicoil S.S.	.375 in.

TABLE VIII

OSO-G1 POWER BUDGET

POWER LINE	CONDITION	CURRENT	ADJUSTED DRAIN
+19V Launch Power	Day Night	7 ma 7 ma	7 ma-hrs/orbit 5.25 ma-hrs/orbit
+19V Day Power	Quiescent *Wavelength Scan *Wavelength Select	64 ma 94 ma 123 ma	64 ma-hrs/orbit 13.91 ma-hrs/orbit
+19V High Voltage Power	Day ** (Day and Night)	10 ma 10 ma	10 ma-hrs/orbit 17.5 ma-hrs/orbit
		** Total	100.16 ma-hrs/orbit

* This is a worst case average for motor stepping assuming 28 full rotations of the cam per day (i.e., 1.75 cam rotations/orbit).

** It is assumed that the high voltage will be on during satellite day only (approximately 1 hour of each orbit).

The Harvard instrument requires approximately 100.16 milliampere-hours per orbit (ma-hrs/orbit) of the spacecraft's electrical power (cf. Table VIII). The electrical interface compliance test consists of measurements of passive impedances presented to the spacecraft by the Harvard instrument with instrument power off. This test prevents shorted or incorrectly terminated circuits within the instrument from damaging the spacecraft. A list giving the impedance value at each pin accompanies the instrument for delivery to Ball Brothers.

4.0 HANDLING STORAGE AND INSPECTION

4.1 HANDLING REQUIREMENTS

The HCO OSO-G1 instrument contains delicate optical elements that are precisely aligned and vulnerable to contamination. Mechanical shocks which might disturb alignment and degrade performance must be avoided. A shock indicator consisting of a spring loaded ball designed to release at 15 g's is fitted at the rear of the instrument (cf. Fig. 22). Harvard should be notified immediately if the shock indicator is triggered.

The HCO instrument has a highly polished, gold-plated exterior (cf. Figs. 17, 18, and 19) to obtain the proper thermal radiation properties. To prevent scratching or contamination of its external surface, it must always be handled with gloves and rested on clean, soft pads during bench tests, if no suitable fixture is available. Fingerprints on the instrument must be removed either with a minimum amount of isopropyl alcohol and a lint-free paper pad or by a careful dry wipe.

The instrument must be protected from humid or oil contaminated atmospheres, which can severely degrade the efficiencies of the reflective optics. All tests, checks, etc., should be performed under clean room conditions.

The instrument should be purged routinely with dry nitrogen gas at a low flow rate before it is returned to storage between tests. In case of contamination, a more extensive (higher pressure, larger gas volume) purge is necessary. The volume of gas and flow rate determine the quality of the purge.

Two rates of purging will be used. The first is a low pressure purge in which gas flows through the instrument at 10 cubic feet per hour. This flow rate can be attained with pressure less than 1 pound per square inch across the special fitting provided. The second purging rate requires higher pressure. Gas at 8 pounds per square inch will flow into the instrument at 40 cubic feet per hour. When flushing use the red hose fitting supplied since this contains the filter and flow limiter. When the nitrogen supply is shut off, the flushing port should be closed using its gold cap, the aperture cap replaced, and the instrument sealed in plastic bags to preserve the purge.

4.2 STORAGE

Between tests the instrument should be purged with dry nitrogen, sealed in clean plastic bags, and placed in its shipping container.

4.3 PRECAUTIONS

Particular care should be exercised when handling the instrument so that the wire screens in the pumping ports on the instrument's side are not damaged. The screen guards should be removed only when the instrument is put in a vacuum.

The high voltage system for the photomultiplier must NEVER be enabled except in vacuum (below 1 x 10^{-5} torr) or at the discretion of the HCO investigator. This system is controlled through the use of a special connector assembly which is accessible from the outside of the instrument and which, when installed, connects the 19V input to the primary side of the high voltage power supply. The gold "enable" assembly (cf. Fig. 21) which accomplishes this is also provided with an external test capability to assure that the connection is properly made. The alternate red "test" and black "dummy" assemblies are provided for special laboratory tests and for weight simulation respectively. The gold "enable" plug should NEVER be installed except during vacuum tests or immediately prior to launch.

The monitor mirror and shock indicator assembly (cf. Fig. 22) are installed in the instrument in order to provide data on optically degrading influences and mechanical shocks encountered prior to launch. This assembly should not be removed except on HCO direction, it should then be replaced by another such assembly or the flight cover.

Particular care must be exercised when installing external attachment screws. Screw length is critical, and if maximum depth of penetration is exceeded catastrophic damage to internal electronics or mechanisms might result.

4.4 RECEIVING INSPECTION

The instrument is shipped in a shock-absorbent, pressure-equalized, humidity-controlled, fiberglass case. Before shipment, the instrument is purged with dry nitrogen and sealed in plastic bags. A responsible person from Harvard will accompany it to supervise its handling in transit and deliver it to the destination.

Receiving inspection should include a visual check to assure that the instrument has suffered no obvious external damage during shipment. This is best done by careful inspection of the instrument's gold dust covers to determine if dents, scratches, or deformation have occurred. Particular attention should be paid to such vulnerable elements as:

a. Main and Command Connector bodies and pins.

b. The Eyeblock Connectors.

c. The two Test connectors on the top outer side behind the eyeblock connectors.

d. Pumping port screen and guards.

e. The purge input at the rear.

f. The monitor mirror housing and the shock indicator mounted on the aft end of the instrument.

Photographs should be sent to Harvard of all damaged areas and other irregular conditions which are found.

4.5 ALIGNMENT

The optical axis of the instrument must be parallel within 1 arc minute to the pointing vector defined by the spacecraft fine eyeblocks. In the OSO-G1 instrument this parallelism is achieved by using autocollimating techniques to align the internal optics and the mounting pads for both eyeblock assemblies to an alignment mirror (cf. front view, Fig. 16) on the front bulkhead. The mirror provides a precise permanent alignment datum so that individual optical elements can be replaced and realigned independently.

The alignment mirror is permanently installed early in the fabrication process so that it is orthogonal within 1 arc minute to a plane through the elevation pads and to the plane defined by the bearing surfaces at the shear support mounting screws. The instrument's optical vector is later adjusted to be parallel (within 10 arc seconds) to the alignment mirror normal by varying the positions of the collector mirror and the entrance slit. The eyeblock mounting pads, on the front of the instrument, are also adjusted so that their normals are within 15 arc seconds of the instrument optical axis, and within the same normal to the alignment reference mirror.

The internal optics are aligned by beaming light into the instrument aperture with a half-silvered mirror and observing with an autocollimating telescope the degree to which the illuminated image of the entrance slit registers on the telescope crosshairs. The telescope axis has previously been coaligned with the alignment mirror normal. When the instrument optics are properly aligned, the square slit image (which appears as a dark square on a illuminated field since it is front lit) will appear centered in the crosshairs of the telescope.

When the instrument is installed in the spacecraft and pointed at the sun, a basic check on overall alignment is possible by utilizing the output of the optical reference Sensor, available at the test connector. This signal is +4V when the grating is at the Optical Reference position and zero order light is imaged onto the zero order photocell, i.e., when the instrument is pointed at the sun's disc. When the instrument's 35 arc seconds square field of view scans beyond the limb of the solar disc (diameter ~32 arc seconds), the +4V reference sensor output voltage falls to zero.

The output error voltages of the azimuth and elevation servos in the spacecraft are zero when the instrument is pointed at the center of the solar disc, increasing linearly with the pointing error angle and changing sign at the null. Consequently, when the eyeblocks are correctly aligned, the +4V reference voltage will go to zero (signifying the solar limb) at the same servo voltage value in both the positive and negative directions. That is, the servo error-signal null will be an equal angular distance from the two solar limbs identified by the 0V to +4V and +4V to 0V transitions of the optical reference sensor output.

5.0 FUNCTIONAL TEST PROCEDURE

5.1 GENERAL

In essence, there are three levels of testing through which the instrument goes: Mechanical/ Environmental, performed to determine whether the instrument can and will survive the stresses to which it might be put; Calibration, to determine, within acceptable limits, the quantitative performance of the instrument; Functional, to ensure that the qualitative and quantitative performance of the instrument are within specified limits.

5.2 TEST ORGANIZATION

Functional tests are designed to check all of the circuits and systems within the instrument. At extremes of environment the functional, environmental, and calibration levels of testing tend to merge. That is, a single action by the tester might provide a data point for calibration, for environmental test, and for a functional test. In addition, functional tests on some systems, the photomultiplier for example, are performed only implicitly under environmental conditions and while performing or preparing for a calibration. The instrument may be thought of as a number of separate systems, the major ones of which intertwine in operation to cause a yield of scientific data, and the others of which monitor environment and functional status.

Functional tests are performed by exercising the fourteen position select commands, the six operational commands and the eight power commands. Their results are evaluated by monitoring the digital data output, the nine analog channels, six of which are telemetered by the spacecraft when the instrument is in orbit, and the various test points, at which the correctness of important waveforms may be confirmed. All functional tests are performed at the nominal bus-voltage, +19V DC, and at the two extremes, +16V and +22V DC.

Before functional testing begins, the spacecraft simulator is checked. The correct amplitude and phasing of the digital data gate and the 800 cps clock are confirmed. Then the response of the simulator to power commands is ascertained to be correct. The ground impedances of the instrument are measured, and the isolation among ground lines is confirmed. At this point in time, the instrument may be connected to the spacecraft simulator.

5.3 WAVELENGTH SELECTOR

The wavelength selector undergoes the first functional test when 19V launch power is turned on, the current drawn by the wavelength selector is monitored, and the readin gate is determined to be present and of proper amplitude and phase relationship to the digital data gate. The analog channels are monitored and their values noted. Day power is then turned on, the input current measured, and the analog channels again recorded.

If all is well up to this time, the formal functional tests are almost ready to begin. A brief check of the data output confirms that no spurious information is being processed by the instrument, and a check of the tee box test point (cf. Fig. 20) which monitors the pulse amplifier-counter interface confirms that the noise environment will not make the system signal-to-noise ratio unacceptable under any operational sequence. More will be said later of this test point.

The bulk of the functional testing involves exercising the wavelength selector. Most of the inputs to the instrument are commands to the wavelength selector. Further, the wavelength selector controls virtually all of the major timing functions of the instrument. Along with tests of the wavelength selector, the motor drive circuitry, motor, and reference generator will be checked. Thus the bulk of the functional testing evaluates the status of the entire command and control system.

5.3.1 WAVELENGTH SCAN

The first subsystem tested is the "wavelength scan". The command of that name is sent, and the indications of proper function are observed. The total input current is monitored and its level is compared with previously established criteria. The waveforms emanating from the motor drive circuitry are displayed on an oscilloscope and their shape and timing compared to the ideal. This comparison and the current drain yield all necessary relevant information on motor health, motor drive health, and on the wavelength selector's performance in the wavelength scan mode. Further, the ripple induced on ground lines by the motor stepping is confirmed to be within acceptable limits and to be unchanging with time.

5.3.2 MECHANICAL AND OPTICAL REFERENCE

The capability of the instrument to reach both references is then tested. This is done by commanding Mechanical Reference, observing the cessation of motor stepping, and commanding Wavelength Reset, which sends the grating toward mechanical reference at the appropriate stepping rate (25 cps) and with appropriate time registration. When the grating assembly reaches Mechanical Reference (MR) and stops, the analog channels are recorded (with emphasis placed on the linear potentiometer whose output is related to grating position).

A suitable sun substitute is set up and the grating commanded to Optical Reference. Correct attainment of Mechanical Reference (MR) and Optical Reference (OR), and an appropriate data channel readout attest to the satisfactory performance of the reference generator system.

5.3.3 WAVELENGTH SELECTOR

The next tests performed on the wavelength selector are those in which a specific number of steps are programmed into the selector and its output of the correct number of pulses at the correct time is verified. This activity is performed several times; several different numbers of steps are used to exercise each of the wavelength selector stages in all significant configurations.

5.4 DETECTION SYSTEM

The next block of testing involves the detection system, excluding its high voltage portions. This system involves the pulse preamplifier, pulse amplifier, and binary counter. A known pulse is put into a special test input which enters the preamplifier at a point before its first transistor. The output of the pulse amplifier, which drives the counter, is connected, via the hardwire test point mentioned previously, to an oscilloscope. In addition, the connection of amplifier output to counter is maintained.

The procedure for testing is to vary the repetition rate of the input pulses and confirm that the counter output is representing the number of input pulses per integration period. The spillover of the counter at the appropriate frequencies (N416 kilocycles, N380 kilocycles, etc.) is confirmed.

The output waveform of the amplifier is also observed. It must be relatively noise-free, as mentioned earlier, and it must conform to certain formally specified standards.

A final portion of this phase of the functional test involves the monitoring of the ratemeter analog channel. A preliminary or final calibration curve exists for the ratemeter, and the adherence to the calibration curve of the ratemeter is confirmed over a range of frequencies.

5.5 AUXILIARY SYSTEMS

The third phase of functional testing involves the auxiliary systems. These are the service systems and the monitoring systems. The power supplies, harness, temperature, other analog channels, monitors, and matrix box are included.

Much of the functional testing of the auxiliary system has already been done in the work on the command and control system and the low voltage part of the detection system. For example, those elements of the harness which are connected to the two systems previously mentioned have been checked simply by checking the systems. The fact that the analog channels are performing properly and that the overall current drain is correct strongly implies that the low voltage power supplies are fulfilling their tasks. The final non-environmental tests that are performed involve simulation of an end of raster input, causing the appropriate data conditioning system to react, and measuring the ion grid voltages.

5.6 ENVIRONMENTAL TEST PHASE

5.6.1 ABSOLUTE AND DIFFERENTIAL TEMPERATURE MONITORS

The next stage of functional test involves the environmental test phase of the instrument. When mounted in a thermal test environment, the rest of the auxiliary systems, namely the absolute and differential temperature monitors, may be checked. This is done, as in the case of the ratemeter check, by impressing a known input and comparing the output with the calibration curve. Both temperature monitoring systems use thermal inputs, as would be expected, and a rough idea of the levels of thermal input suffices for the check of the temperature systems. Thus, to check the absolute temperature probe, whose output varies by approximately 80 mv/°C, the temperature of the environment is measured and the probe output observed to be near its predicted point on the calibration curve. The ambient temperature is then raised about 10°C, and the output is observed to rise about 800 mv. Similarly, the differential temperature system is functionally tested by imposing two sets of differential temperatures on the instrument at two different ambient temperatures. The ΔT system test also checks the 15V converter.

5.6.2 HIGH VOLTAGE SYSTEM

Finally, the high voltage system is tested. For this test, the instrument must be at a pressure less than 1×10^{-5} torr, and must have been below that pressure for more than one hour.

While the output level of the high voltage monitor analog channel, the input current to the high voltage power supply, the tee box test point, and the output of the counter are being observed, and with the rest of the system on, the high voltage power supply is turned on in a prescribed way. For different power supplies, the technique of turn-on differs. No continuous counts are permissible, although a transient count upon turn on may be acceptable.

The test point output must show no ripple beyond 10% of the counter threshold. Further, if the ripple at the test point has changed over any time span, the system is unacceptable until the change is satisfactorily explained. The current into the high voltage system must fall within prescribed limits, and must not vary with time beyond a certain set of norms. Should the current decrease despite an increase in temperature, for example, it is likely that one of the norms has been violated.

After the high voltage system has operated quietly for some time (the required operating time should vary inversely to the time elapsed since the test was last done), monochromatic ultraviolet light of known intensity is introduced to the photomultiplier. This is done by moving the grating to the appropriate position while emplacing a monochromatic grating at the location of the telescope mirror. The amplifier output test point now displays pulses whose shape and size must conform to specification. In addition, the ratio of data counts to input light intensity must be stable with time and of satisfactory magnitude.

Upon completing all tests, the grating is commanded to "stow" position, its location of maximum mechanical stability, at the center of the microswitch closed position on the cam.