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STUDY OF AN ASTRONOMICAL EXTREME ULTRAVIOLET ROCKET SPECTROMETER FOR USE ON SHUTTLE MISSIONS

Final Report

Contract NAS5-23697

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October 20, 1977

Mr. Dick Ott
Code 742
NASA Goddard Space Flight Center
Greenbelt, Maryland 20771

Subject: Contract NAS5-23697
C. S. Bowyer, Principal Investigator

Dear Mr. Ott:

~~Enclosed please find 1 copy of the final report for subject contract.~~

Sincerely,

Stuart Bowyer
Professor of Astronomy

cc: Publication Branch ✓
Patent Counsel
Contracting Officer

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1. SUMMARY

Many of the scientific returns of the early Shuttle sortie missions may be derived from the use of scientific instrumentation which has been previously developed and flown on rockets. This situation is a consequence of the funding constraints and schedule limitations of scientific participation during the first few years of Shuttle operations.

Accordingly, herein we study the adaptation of an extreme ultraviolet astronomy rocket payload for flight on the Shuttle. The purpose of this study is to provide NASA with a sample payload for determining integration and flight procedures for experiments which may typically be flown on Shuttle missions.

Our study will concern itself with the electrical, mechanical, thermal, and operational interface requirements between the payload and the Orbiter. Of particular concern is establishing a baseline payload accomodation which utilizes proven common hardware for electrical, data, command, and possibly real-time monitoring functions. This objective is intended to allow the greatest flexibility in configuring each mission with the available payload, without overly complicating the system interface requirements. Furthermore, we define the instrument integration and checkout procedures necessary to assure satisfactory in-orbit instrument performance, and we identify those procedures which can be implemented in such a way as to minimize their impact on Orbiter integration schedules. This approach is intended to minimize the preparation and checkout time for this instrument in order to keep the overall mission participation cost to a minimum.

2.0 SCIENTIFIC RATIONALE AND OBJECTIVES OF THE EXPERIMENT

The extreme ultraviolet (EUV) region of the electromagnetic spectrum has only very recently been seriously considered for observations of cosmic (non-solar) objects. The two chief factors responsible for the neglect of this area were first the consistently pessimistic appraisals of the photoelectric opacity of the local interstellar medium at these wavelengths; secondly there existed very incomplete observational or theoretical evidence for the existence of objects on the extreme left (i.e., high temperature end) of the Hertzsprung-Russell diagram which would be strong EUV emitters. In addition considerable technical difficulties have existed for the development of optics and detectors for EUV photons.

In spite of this early discouraging prognosis, the first sources of cosmic EUV sources were recently discovered by the Berkeley group using a grazing incidence telescope flown as part of the Apollo-Soyuz Test Project. Of thirty programmed targets thought to be likely candidates, four were found to be copious emitters in the EUV. Two of these are identified with the very hot white dwarfs HZ 43 and Feige 24 which have temperatures in the 50,000 to 100,000 °K range. A third was the cataclysmic variable SS Cygni which was undergoing a major outburst at the time. A fourth was the nearby main sequence star Proxima Centauri. The observation of EUV emission from HZ 43, some 70 pc from the Sun, is very encouraging for it indicates that EUV observations are possible over substantial path lengths. In addition it appears that HZ 43 and Feige 24 are not isolated objects, for an unbiased survey of the southern hemisphere by the Berkeley group revealed the existence of another EUV source as intense as HZ 43.

The discovery of these first non-solar EUV sources confirms the revolution in the understanding of conditions in the local interstellar medium. It is now apparent that the typical local interstellar medium is very thin with a number density as low as .01 particles cm^{-3}, rather than having typical densities of 1 atom cm^{-3} which are characteristic of the average density in the galaxy. As we have discussed in detail this will permit EUV observations of normal stars (such as the Sun or Proxima Centauri) over several tens of parsecs, and of very intense EUV emitters (such as HZ 43) over a hundred parsecs. This development will allow the detailed observations of the coronae of normal stars; this may well be the most profound influence of EUV astronomy, in particular for our understanding of solar type stars.

The only observations to date are broad band ($\Delta\lambda \sim 200$ Å) photometry of a few selected objects. Clearly the observations of prime importance for a detailed understanding of the emission processes are good resolution spectroscopy. The EUV emission of the Sun for instance, shortward of ~ 1800 Å, is characterized by numerous lines seen in emission each of which can be a sensitive probe of the physical conditions in the emitting region.

In the case of hot white dwarfs, two emission processes, emission from a corona and photospheric surface emission, have been proposed. In the case of photospheric emission the spectrum will be dominated by the effect of the heavy element absorption edges, most prominently those of helium at 228 Å and 504 Å. Indeed observation of these edges will provide the only sensitive probe available of abundances in such objects. If, however, the emission is due to coronal emission from a hydrogen rich corona, the observation of emission lines due to heavy elements, primarily helium is expected. Only good resolution spectra will convincingly resolve these questions.

The objectives of the program are to obtain good resolution spectra ($\Delta\lambda \sim 25$ Å) of the brightest EUV sources in the sky.

3.0 INSTRUMENT DESCRIPTION

The instrument consists of the components shown schematically in Figure 3-1. Each component is described briefly in the following paragraphs. A photograph of the instrument is shown in Figure 3-2.

3.1 Payload Shell. The payload structure consists of an internal support structure and payload shell. The payload shell serves to support the instrument in the rocket configuration, and to support an interior heat shield to minimize thermal variations of the internal structure. The shell is also dust tight to permit a dry nitrogen purge of the instrument prior to launch.

In the rocket configuration the payload shell is constructed in two sections. One of these sections houses a second STRAP IV star tracker to permit offset guiding for faint targets. This tracker shell would be removed for Shuttle use and replaced by a bulkhead. For Shuttle purposes a mechanical door would be mounted on the forward end of the payload shell to provide a dust-free enclosure.

The payload shell is 142 cm long, 43 cm in diameter, and weighs 32 kg. Access panels on the shell allow the instrument components to be tested and removed without disassembly of the instrument.

3.2 The Instrument Support Structure. The instrument is assembled within an instrument support structure. This structure maintains the alignment of the instrument. The structure is attached to the shell at a single flange located near the center of gravity of the instrument. The support structure can be used to support a thermal control system. The weight of the support structure is 15.9 kg (35 lb.)

3.3 The Optics. The optics are of Wolter-Schwarzschild type II configuration, and are indicated in Figure 1. They consist of a large conical primary mirror, of largest diameter 38 cm and total length 73 cm, and a small conical secondary of 10 cm length. The optical elements are made of type 6061 aluminum alloy and are fabricated from four separate forgings. All the individual sections are attached to a single support ring near the center of gravity of the optical assembly which attaches to the top of the instrument support structure. The optics also include a spider support for the prime STRAP IV star tracker as an intrinsic element. This permits rigid alignment to be maintained between the tracker and the optical axis.

The total weight of the optics and star tracker is 30.91 kg (68 lb).

3.4 The Spectrometer. The spectrometer is preceded by a collimator and a magnetic broom (B $\sim$ 300 gauss in the gap, 10 gauss at 1 inch). These minimize the instrument background due to stray light and charged particles. No photons or electrons can reach the detector without first suffering at least one reflection.

The spectrometer itself is housed in a sealed vacuum box with a remotely operated electrically actuated gate valve. Until observations begin

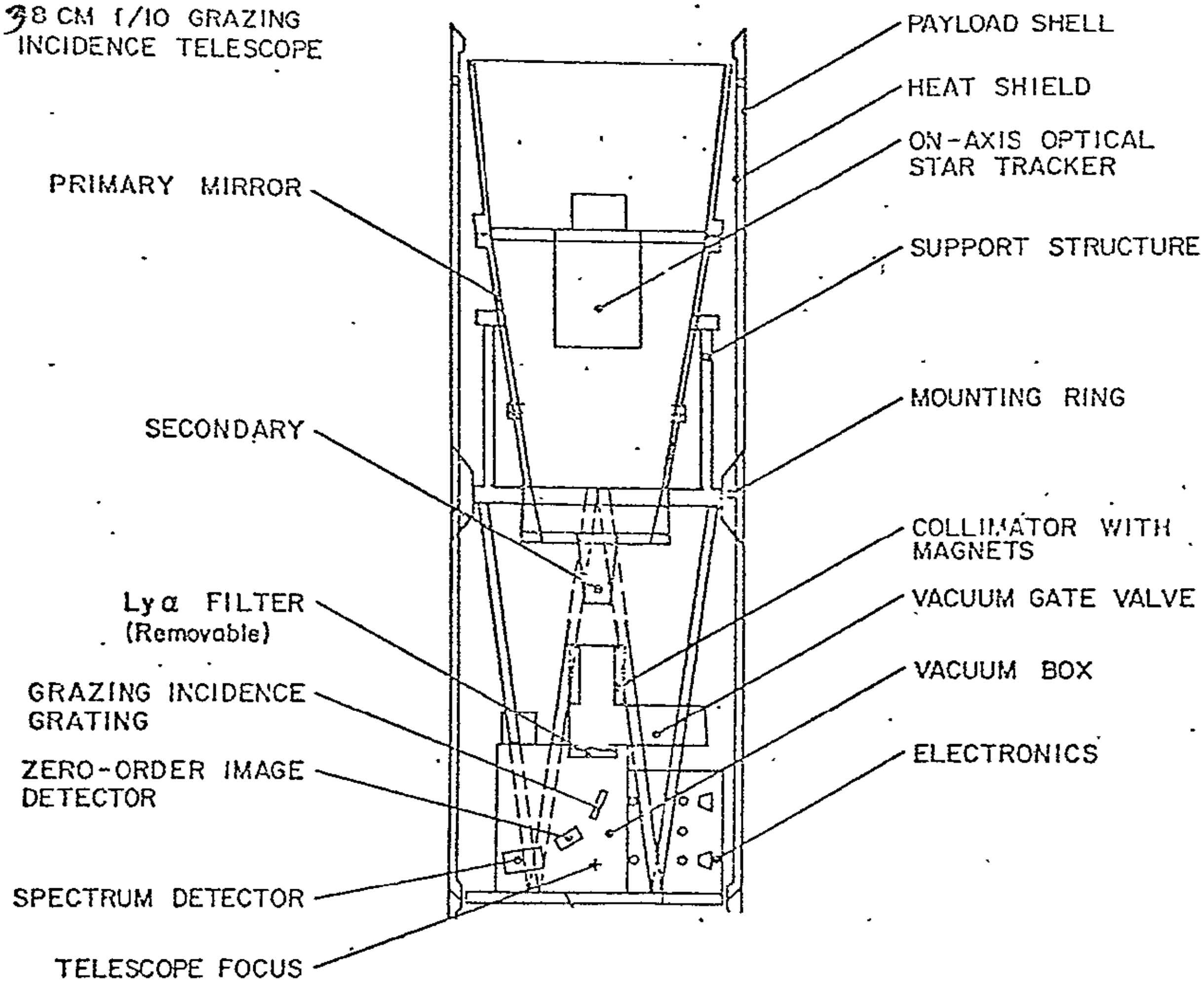

Figure 3-1. EUV Spectrometer Payload Diagram

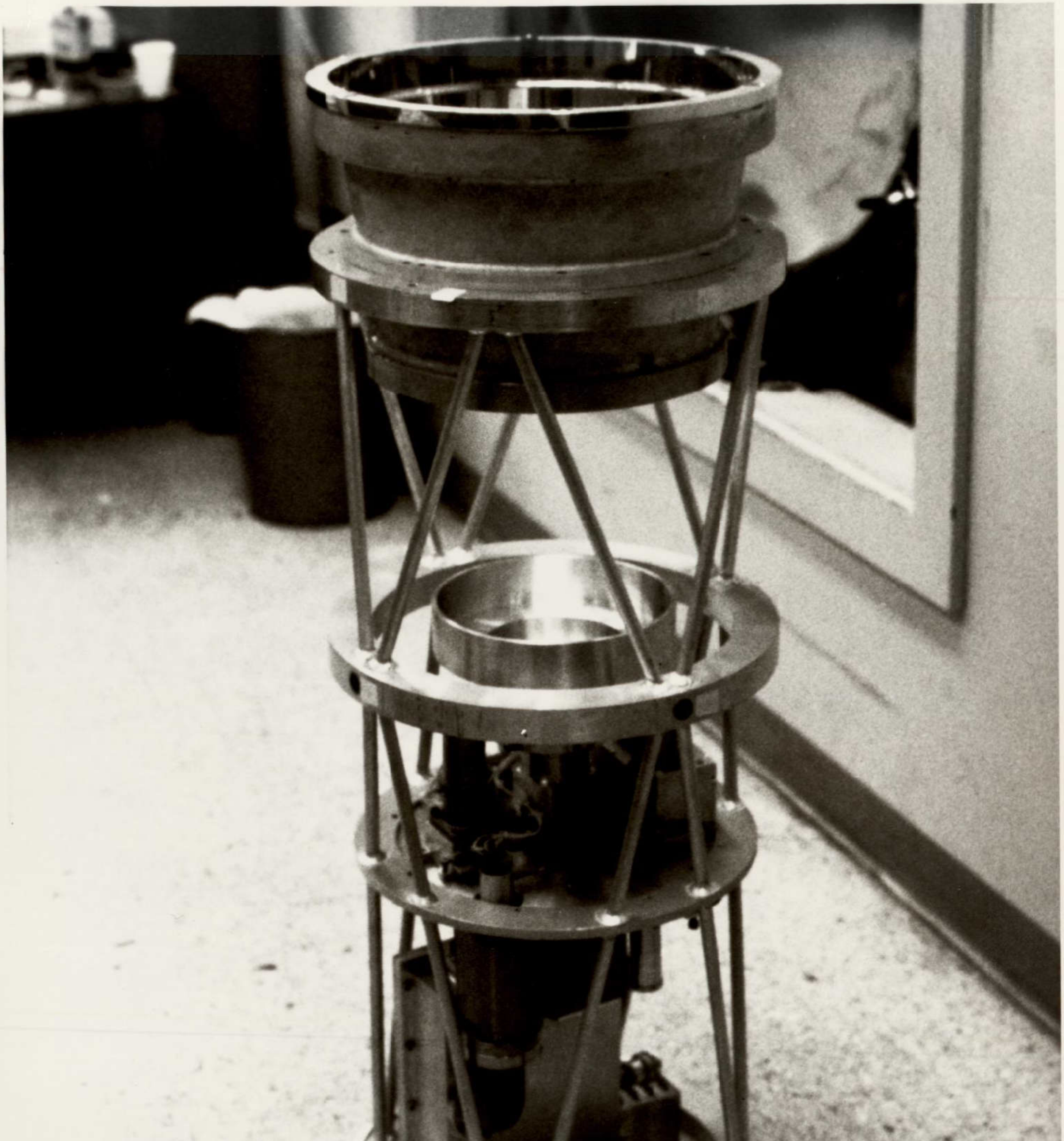

Figure 3-2. Photograph of the EUV spectrometer with shell removed.

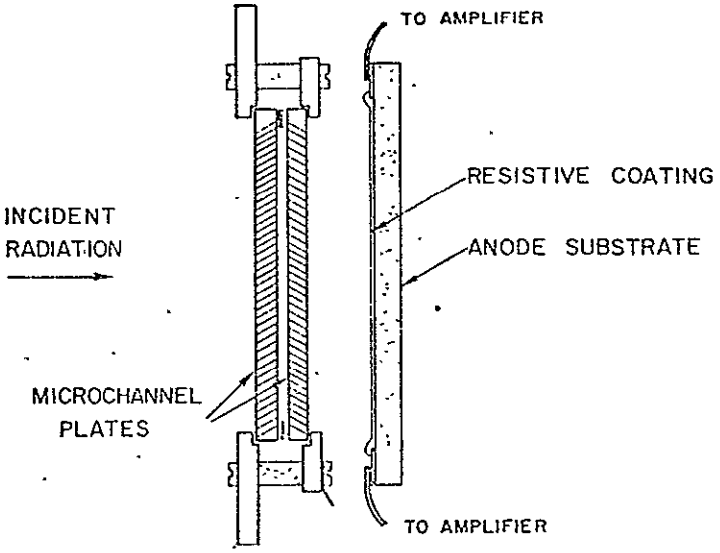

Figure 3-3. RANICON diagram.

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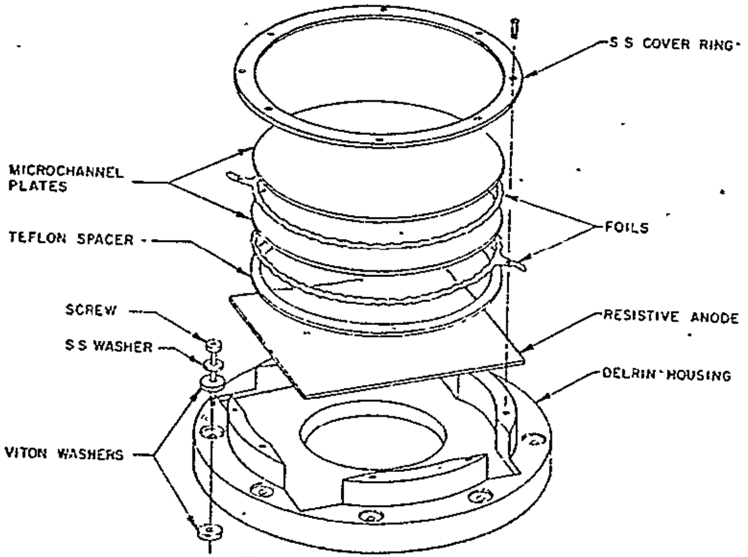

Figure 3-4. Detector assembly.

typical bore diameters of 25 microns and lengths of 1 mm. These channels function as independent photon or electron detectors in the same way as conventional single channel electron multipliers (CEMs). The cascaded chevron configuration provides a gain of greater than 10^7 before regenerative ion feedback becomes a problem. Because of the small channel spacing, the electron multiplication remains well localized and these devices provide spatial resolution of the order of 50 microns. The MCP offers many of the advantages of the CEM in photon counting, in particular its high sensitivity to vacuum UV radiation and its low background.

Each electron cloud produced by the MCPs is intercepted by the resistive anode, which encodes the position of the event by virtue of the fact that the ratio of the charge signals reaching opposite ends of the anode is a function of the event position. Thus, a ratio circuit (connected to the anode via charge sensitive amplifiers) serves to locate the coordinates of successive photon events. In the payload described here, the detector is made sensitive in two dimensions simultaneously by equipping the anode with four edge contacts, four charge amplifiers, and two synchronized ratio circuits.

The spatial resolution of a ranicon is limited by the channel spacing of the MCP, by the thermal noise fluctuations produced in the resistive anode, and by the 8 bit (256 channel) quantization accuracy of the analog-to-digital ratio analyzer circuitry. The system resolution which results is about 300 microns rms over a 70 mm field of view.

The count rate capability of the detector is set partly by the pulse recovery characteristics of the MCP employed, and partly by the 12 microsecond dead time (per event) of the pulse amplifier and ratio circuit electronics. Because the actual count rates range from a few hundred to a few thousand cps, the detector count rate limitations introduce a counting loss of at most a few per cent of the events.

The electical power requirement for the detector consists solely of the DC bias for the MCP: -2000 volts at 10 microamperes. This potential is generated by a dedicated DC-DC converter included in the instrument electronics. The detector operates at ambient temperature, i.e., it requires no refrigeration. It does require a clean, high vacuum for operation; this environment is furnished by the vacuum enclosure described above in connection with the spectrometer, since the detector is located adjacent to the diffraction grating, within the enclosure.

3.6 Detector Electronics. The electronics subsystem required for operation of the EUVS detectors is diagrammed in Figure 3-5. The anode of each detector is connected to four charge sensitive low noise amplifiers. These in turn connect to a pulse position analyzer (PPA) circuit, which comprises a pair of synchronized ratiometric analog to digital converters and a window discriminator. The resulting digital words are parallel transferred to an interface circuit, whose function is to allow the detector data to become synchronized with the Orbiter data system rather than timed with respect to the photon arrivals. Data transfers for which no photon was detected are filled with zeros.

The electronics assembly mounts on the rear of the detector housing, and includes both high and low voltage power converters for operation from unregulated 28 volts dc. A command relay board is incorporated to control

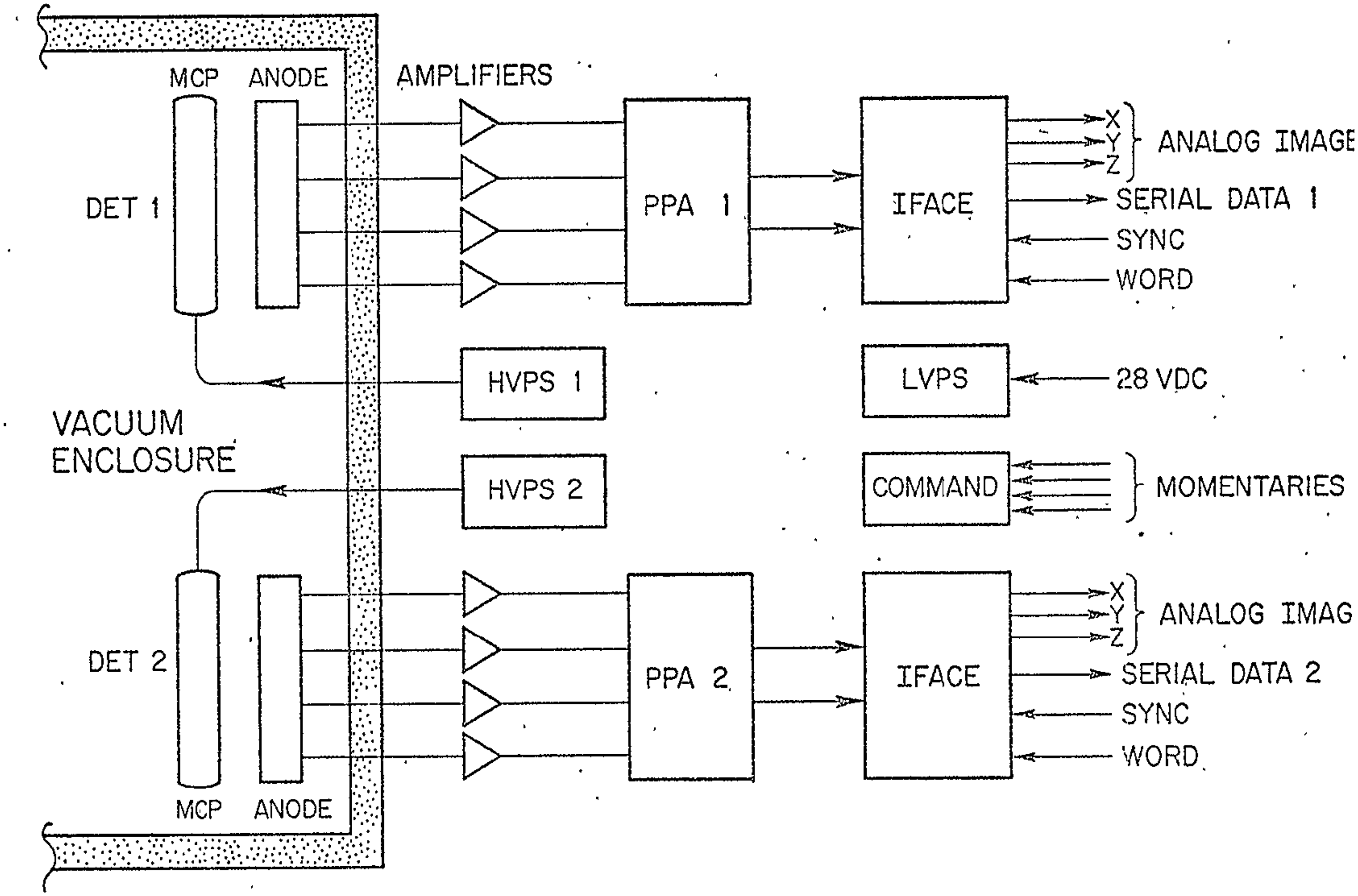

Figure 3-5. Block diagram of the instrument electronics.

discriminator levels and detector high voltage settings.

3.7 Aspect Determination and Attitude Control. In sounding rocket flights, the payload described herein utilizes a STRAP IV attitude control system to point the instrument to within 5 arc minutes of a desired target. This degree of accuracy is achieved in two steps. First, the gyroscopically stabilized inertial reference unit of the STRAP IV is sufficiently accurate that, in spite of launch-induced gyro errors, stellar targets can be initially acquired within the 2° radius field of view of the optical tracker. Upon initial acquisition, the gyro errors are nulled to an accuracy of about one arc minute at the position of the update star. The EUV spectrometer has a 5 arc minute field of view; that is, to obtain useful data, the system must be oriented to within 5 arc minutes of each EUV target in order to yield useful spectral data.

For EUV targets which are brighter than fourth magnitude visually, the optical tracker is employed in a direct acquisition mode in which the instrument is pointed by feedback from the tracker.

For EUV targets which are visually too faint for tracker guiding, but which have a guide star within two degrees, the tracker can be electrically biased to give a feedback null at the position of the EUV target. In this electrically offset guiding mode, the system errors are still small enough to satisfy our 5 arc minute error criterion.

For EUV targets which have no conveniently nearby guide star, the sounding rocket payload uses the rate integrating gyros of the STRAP IV to provide an inertially-defined angular offset from previously viewed update stars.

To adapt this instrument to the STS Orbiter, we shall retain the primary optical tracker as a fine error sensor, but mount the instrument on an IPS or SIPS rather than on the STRAP IV. In this way, the ability to update the attitude of the instrument in essentially real time will be retained. The interfaces between the instrument and the pointing system, and between the tracker and the operator, will be detailed below.

4.0 POINTING REQUIREMENTS

The instrument described above has a limited pointing tolerance within which acceptable data are acquired, and beyond which little or no useful data are obtained. As mentioned before, the edge of the spectrometer field of view lies five arc minutes away from the optical axis of the instrument. Consequently, pointing errors larger than this value result in an essentially complete loss of data. However, other considerations also bear on this question, because the image quality is not uniform over the five arc minute field; the best images (and hence the most sensitive spectra) are obtained when a target is placed within the central arc minute. This situation is discussed here.

4.1 Telescope Optics. The figuring and polishing of the optics limits the on axis image blur size to ten arc seconds. In addition for off-axis images the inherent geometrical aberrations of the optics contribute to the blur. This blur contribution increases as the square of the distance off axis and is equal to the polishing blur for a source five arc minutes off axis. Hence the poorer the pointing accuracy the greater the image blur. The effect of image blur is to reduce the resolution of the EUV spectra, and also to reduce the signal to noise ratio of a faint stellar object. Consequently, for many of our targets it is highly desirable to minimize the aberration-induced blur by keeping the target within about one arc minute of the axis.

4.2 The Grating Aberrations. The grating produces a stigmatic image for a chosen "blaze" wavelength for an on axis source. For off axis sources at any other wavelengths several grating aberrations degrade the achievable spectral resolution. Pointing errors thus impair the quality of the data.

4.3 Pointing Stability. The data analysis is carried out by integrating the signal over the detector region which is illuminated by the spectrum. Determination of the zero point of the spectrum is performed by monitoring the zero order image. The accuracy of this procedure depends upon the source strength and the pointing jitter. For one of the brightest sources known, HZ 43, the zero order image strength is expected to be 100 counts/sec. A pointing stability lower than 15 arc sec/sec/axis with a ± 5 arc minute deadband can be successfully corrected during post flight analysis. For fainter sources, however, the zero order image cannot be reliably tracked in the EUV. Consequently it becomes necessary to rely upon the stability of the instrument pointing system for most targets. The durations of individual target observations will vary from 1 to 40 minutes, during which times attitude variations should not exceed 19 arc seconds along the pitch and yaw axes. Stabilization in roll (around the viewing axis) is much less critical; even with a 5 arc minute pointing error, less than 10 arc seconds of image motion would occur for a roll angle of two degrees.

Table 4-1: Pointing Requirements

	Pitch	Yaw	Roll
Absolute Accuracy			
maximum quality	60 $\overset{\frown}{\mathrm{sec}}$	60 $\overset{\frown}{\mathrm{sec}}$	N/C
useful data	300 $\overset{\frown}{\mathrm{sec}}$	300 $\overset{\frown}{\mathrm{sec}}$	2°
Stability			
maximum quality	10 $\overset{\frown}{\mathrm{sec}}$	10 $\overset{\frown}{\mathrm{sec}}$	2°
useful data	60 $\overset{\frown}{\mathrm{sec}}$	60 $\overset{\frown}{\mathrm{sec}}$	2°

These considerations are summarized in Table 4-1. The stability figures listed apply for the duration of each astronomical observation, 1 to 40 minutes.

5.0 MECHANICAL INTERFACE

In this section we detail the requirements for the instrument mounting provisions.

5.1 Weight and Dimensions. The instrument weight breakdown is given in Table 5-1, exclusive of the mounting adapter chosen. The payload shell is 142 cm long by 43 cm diameter (56 inches by 17 inches). An additional 40 cm of length should be kept clear at the forward end of the payload to permit the end door to swing open.

Table 5-1 Instrument Weight Breakdown

Element	Weight	
Optics	58 lbs.	72 lbs = 33 kg
Tracker	10	
Spider	4	
Vacuum box	15 lbs.	58 lbs = 26 kg
Electronics	16	
Pump	12	
Motor assemblies	15	
Internal support structure	35 lbs	120 lbs = 55 kg
Misc.	15	
Shell	70	
		250 lbs = 114 kg

5.2 Mounting Provisions. The EUV spectrometer is equipped with two alternative mounting provisions: a base mounting ring (identical to that employed in Black Brant V applications) for "floor" mounting, or alternatively a slightly larger ring which surrounds the cylindrical housing at its center of gravity. In either case, the spectrometer components are held in alignment by the metering truss described previously, with the truss being supported at its center of gravity by the payload shell cylinder. The strength and stiffness of this shell is sufficient to carry the inertial loads caused by the EUV spectrometer when secured either at its base or around its center of gravity. The resonance frequencies of the structure are sufficiently high (above 5 Hz) to preclude significant feedback stability problems with the instrument pointing system.

5.3 Aperture Cover. A motor-driven door will be provided to ensure contamination protection during launch and landing. The door also serves as a light and front thermal shield.

The door will be a clam shell design, with two half-opening sections to reduce the hinged mass. Thus, the EUV telescope will not be unbalanced by opening of the doors. The design will be of a lightweight nature but with adequate stiffness, such as honeycomb. A ruggedized drive system will be used. One concept for the drive would be a ball and screw actuator driven by a motor and gear head. A similar drive design has been previously used on space flight instruments to actuate doors. The gearhead would be a reducer to minimize the inertia.

The use of a ball and screw up front serves several important functions. It has precision capability and excellent load capacity. It also is a torque multiplier with an efficiency of approximately 90% when converting rotary to linear motion. The doors should pose no design problems.

The door will seal the canister in a dust tight condition so that dry nitrogen purge can be carried out. The door will be activated automatically by a sensor whenever the Sun is within 90° of the instrument axis. The door commands can all be overtaken, however, from the instrument control panel.

5.4 <u>Pallet Interface</u>. The instrument can operate in either IPS or SIPS configurations. For the IPS mount a single pallet is needed to accomodate the instrument. The truss is equipped with the necessary launch lock interface. After launch it is translated back and the IPS clamps on to the rear of the telescope.

For a pallet mount the structural interface will be a truss picking up a minimum of six hard point attachments. Thus the truss structure is used to distribute loads to the pallet hard points.

Finite element models have been prepared for instruments comparable to the EUV spectrometer and hard mounted to a standard pallet. The analysis took into consideration two conditions, crash and landing. For the crash condition, load factors of -9.0 g(x-axis), ±1.5 g (y-axis), and -4.5 g (z-axis) were applied simultaneously. For the landing condition -2.4 g (x-axis), and -6.0 g (z-axis) were applied simultaneously. With a load limit of 4,136 kg on a pallet hard point and using an instrument weight of 1200 kg, an adequate margin existed. In this model ten pallet hard points were used.

This instrument in comparison weighs 114 kg, and picks up a minimum of six pallet hard points. In the detailed analysis, if a larger margin of safety should be deemed necessary, it would be relatively easy to pick up more pallet hard points. However, the present safety margins appear entirely adequate at the present time.

6.0 ELECTRICAL INTERFACES

Three principal kinds of electrical interfaces are required between the EUV spectrometer and the electrical scientific instrument support subsystems: power, commands, and output data. In this section, we document these interface requirements.

6.1 Power Requirements. All subsystems of the EUVS operate from unregulated +28 V (± 4 V) DC power, which shall be made available to the EUVS by way of the appropriate Shuttle experiment power distribution box (EPDB). All EUVS subsystems satisfy the power grounding and isolation requirements established for the Spacelab 2 mission. They provide at least 1 megohm isolation to the spacecraft structure and signal grounds, on both the +28 V and return wires.

The five electrical power loads within the EUVS are listed in Table 6-1 and described in greater detail here.

The EUVS detector is maintained under vacuum at all times to ensure its calibration stability and accuracy. Accordingly the detector is fitted with a motor-driven vacuum cover which is to be activated open early in the mission before observations are begun, and shut after the observations are completed but prior to the Orbiter descent. This item (Item 1 of Table 6-1) draws 75 W during actuation. Activation lasts 3 seconds.

Item 2 is the motor-driven aperture door described previously in Section 5 of this proposal. It is to be kept shut during orbital daytime

Table 6-1

EUV Spectrometer Power Systems

Item	Function	Voltage	Power	Usage
1.	Vacuum cover	28dc	75W	Twice/mission
2	Aperture cover	28dc	75W	20 sec/orbit
3	Optics Heaters	28dc	100W	20% - 100% duty
4	Electronics	28dc	25W	During data coll.
5	Vacuum pumps	28dc	20W	Almost continuous

or any time that volatile condensible materials (VCM) are being knowingly vented, to protect the optics and detector from solar damage or contamination. The anticipated usage of this door is approximately two ten-second intervals per observing orbit.

Item 3 constitutes a set of thermostatically controlled heaters mounted to the objective mirror of the EUVS, intended to minimize condensation of volatile condensible material (VCM) onto the active mirror surfaces. Depending upon the orbital thermal profile, the duty cycle of the heaters will be automatically established at between 20% and 100%. This system is to be turned on 20 minutes prior to the opening of the aperture cover, and left in its powered condition for as long as the cover is open.

Item 4 comprises the electronics package load contained within the EUVS. Power consumption is approximately 25 watts and must be on during all data collection.

Item 5 is power to the ion pumps associated with the spectrometer/detector vacuum housing. This power bus must be left on as continuously as practical during prelaunch and orbital operations, so that the high vacuum pumps can maintain a desirably gas-free detector environment. This power bus must be shut off when data are being collected. It is also desirable that this bus be energized as continuously as practical following the data collection phase of the mission and, if possible, during and after re-entry and landing.

We anticipate that a control panel for the EUVS will be fitted at a specialist station in the AFD. The EUVS will be operated by five toggle switches controlling these five subsystems.

The total electrical energy required by the EUVS during a nominal mission having ten orbits of nighttime data collection is 4600 watt-hours assuming a worst-case thermal budget.

6.2 Command System. The EUV spectrometer is intended to be an autonomous, self-sufficient instrumentation package capable of conducting stellar EUV spectroscopy with a minimum of operator assistance. The part-time attention of a payload specialist is required to verify the activation and deactivation of the instrument, to verify the attitudes of the IPS or SIPS, and to verify data flow while observations are being conducted. However, in the event of a component or subsystem failure it would be useful to utilize the command capability of the CDMS and RAU to permit in-flight calibration or reconfiguration of the EUVS. Such commands would be generated by the Payload Specialist upon noting and diagnosing an instrument malfunction, with the assistance of the ground support team.

For this purpose, a tentative command list is given in Table 6-2. The command status configuration of the EUVS is controlled by a number of magnetic latching relays (Teledyne 422-DD) located in the EUVS electronics package. Accordingly, the command system interface appropriate to the EUVS is the 28 volt momentary-pulse port of the RAU. One wire is assigned to this interface for each command function, i.e., each relay coil, plus a return wire.

Table 6.2

EUVS Command Functions

1. HV 1 enable
2. HV 1 disable
3. HV 1 A mode
4. HV 1 B mode
5. HV 2 enable
6. HV 2 disable
7. HV 2 A mode
8. HV 2 B mode
9. Discriminator 1 low
10. Discriminator 1 high
11. Discriminator 2 low
12. Discriminator 2 high
13. Test pulser enable
14. Test pulser disable

6.3 Data Interface. Three principal types of data are generated by the EUVS during flight operation: primary digital scientific data, secondary analog housekeeping data, and tertiary bilevel command-status monitor data. These are described in this section, and summarized in Table 6-3.

The digital data are generated by the two photon-counting detectors of the EUVS, which under normal circumstances are operated simultaneously. When a photon is detected, the detector signals trigger the analysis electronics and a sixteen bit word is generated. The first eight bits of each such word represent the X-coordinate of the detected photon, and the second eight bits are reserved for the Y-coordinate. The 16 bit word is held in a buffer register until a data transfer through the RAU to the CDMS is available.

One characteristic of photon-counting detectors is that photons arrive and are analyzed at random time intervals, while data transfer opportunities recur periodically. Thus depending on the average photon count rate, a certain fraction of the data transfers have no information; these are filled

TABLE 6-3

EUVS DATA INTERFACES TO RAU

Function	Implementation	Quantity	Voltage Levels	Sample rate each port
Primary digital	3 wire bit serial; clock, enable, data	2	TTL	4000 words/sec, 16 bit words
Analog monitor	1 wire per channel	18	0 to +5V	1 sps, 8 bit accuracy
Bilevel monitor	1 wire per channel	7	0 to +5V	1 sps, 1 bit accuracy

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Actual data transfer from each detector's register can be most simply implemented with a three-wire serial RAU port. With this connection, the RAU furnishes a continuous bit-frequency synchronization clock, and on a second wire the RAU periodically sends a 16 bit duration word enable pulse. The third wire carries the serial digital data from the EUVS to the RAU, which then transfers it to the CDMS for transmission or recording. Two such ports are requested for the EUVS, one for each detector. Voltage and current levels are defined by standard TTL levels. The bit clock rate is unimportant as long as it is not less than 64 kHz; the minimum word rate on each port is 4000 words/second during EUVS data collection.

Analog data are generated by the EUVS for housekeeping and fault-detection purposes. Approximately 18 voltages will be required. Each signal has a 0 to +5 volt range, and is to be sampled at a rate of approximately once per second. Sample accuracy of +1% is required, which can be easily met with a multiplexer and eight bit ADC within the RAU.

Digital bilevel data are generated to echo the status of the command relay register. Seven bilevel monitor wires service the command list given in table 6-3. Voltages and currents are compatible with standard TTL levels or with high-impedance 2 volt threshold sense inputs. A sample rate of once per second will suffice.

The reduction of the scientific data from the EUVS requires, in addition to its own output data, knowledge of two kinds of auxiliary data: aspect and time. For the purposes of the present study we have assumed that the aspect sensor signals and/or gyro position angles will be available data within the CDMS, and that timing information will be available by some means (e.g. frame numbering in telemetry format).

6.4 Live Monitor Capability (Optional). One useful characteristic of the existing EUVS electronics design is a live time (unbuffered) image monitoring capability. Although we do not require that EUVS images be monitored in real time as part of the scientific data collection, the use of this feature may prove valuable to the Payload Specialist in verifying the proper operation of the EUVS and its aspect control. The use of this capability can also serve to reduce or eliminate the workload of the CDMS dedicated experiment computer with respect to image accumulation and display. Accordingly, in this section we describe this direct analog live monitor capability.

As described above, the photon-counting sensors of the EUVS trigger dedicated pulse-position analyzer circuits whose digital outputs define the location of the detected event. These circuits are also provided with digital-to-analog converters, one for each X and each Y axis. If an ordinary XY oscilloscope is connected to these converters and to a Z-axis intensification terminal (also provided) one can view the images in real time.

To implement this capability would thus require a conventional XY oscilloscope located at the PSS; and two three-wire analog interfaces between the EUVS and this oscilloscope.

The expected count rate from a bright source such as HZ 43 is 100 c/s hence the source image will easily be distinguished from the diffuse background which is expected to be only a few counts per second over the image spot size. Since the high sensitivity region of this instrument is in the center of the field of view, it is desirable to correct the pointing if any major offsets are found. Thus if the option is available early in the flight, a calibration observation can be performed to establish any systematic offsets. These can then be keyed in to the CDMS dedicated instrument computer. If at any other time during an observing run, payload specialist time is available, the pointing can be verified by inspecting the location of the target in the instrument field of view. It is emphasized however that this procedure is not required, but would provide a convenient in flight check of the instrument and pointing system performance.

6.5 Use of Onboard Computer (Optional). If a portion of a CDMS experiment-dedicated onboard computer is available to the EUVS, it will become possible for the PS to interact with the live digital data in a particularly useful way via this computer. Specifically, it will be practical to accumulate the digital image in a portion of the computer's random access memory and periodically update a CRT display at the PSS with the accumulated image. Such a capability would allow the PS to verify proper targeting of the EUVS and ascertain correct instrument operation. The hardware requirements amount to approximately 16K of random access image memory and 20K of program. Again, this capability is not a requirement for scientific data collection.

7.0 Safety Provisions

For the purposes of instrument safety, Orbiter power system safety, and crew safety, the following instrument design features will be incorporated. First, current surges in the sensor electronics subsystem will be limited to predetermined safe levels through the use of input circuitry which includes a current limiting characteristic. This peak surge current shall not exceed three times the steady drain of the circuits. Redundant parallel fuses will also be employed. Overvoltage transient protection will be provided by MIL-qualified transient absorbers. Second, the electromechanical cover and door drive circuits will be protected by fuses and transient overvoltage absorbers. Finally, the heater circuit will be protected by fuses. For crew safety, connector current capacity and wire gauges will be chosen to accomodate the rated fuse current of each power circuit.

The EUVS contains no pyrotechnic devices, no pressurized fluids or gases, no poisonous, hazardous, explosive, flammable, or radioactive substances.

8.0 Instrument Operations

The EUVS has been configured in such a way as to be as autonomous as is practical within the cost and schedule restrictions of the shuttle program. Nontheless, a degree of Payload Specialist (PS) participation in the operation of the EUVS will be required. In this section we discuss these requirements and address the possibility of ground scientific-support team participation. Finally, we consider the steps needed to plan an EUVS mission, including examples of contingency observing schedule decision points.

8.1 Payload Specialist Role. Under the shuttle guidelines, the operator of scientific instruments is termed the Payload Specialist. During portions of the mission allocated to EUVS data collection, we shall rely upon the PS for carrying out three kinds of interactions with the instrument: power switching functions, target acquisition, and data flow verification. These activities follow the general outline given in Table 8-1 where individual target group lists will be prepared prior to the mission. Under such a plan, the various targets are assigned a variety of on-target observing times according to the expected signal-to-noise ratio for that target. Typical on-target dwell times vary from one minute to an entire orbital-nighttime pass. After each target is acquired, the PS will verify proper EUVS data flow at the PSS; this could involve a green/red go/no-go indicator, a form of analog or digital count rate meter, or some form of analog or digital image display. At the end of each observing run, the PS is responsible for powering down the EUVS and shutting its aperture door, to avoid possible VCM contamination of the optics or detector and to eliminate the possibility of detector damage from direct sunlight being focussed by the EUVS optics onto the detector.

The routine monitoring of a variety of instrument housekeeping functions could be accomplished by the PS on a time-available basis. In the interests of simplifying the PS workload, however, such tasks could perhaps more efficiently be executed by a specific small computer program loaded into the onboard computer, or could even be done through telemetry and ground-

Table 8-1

Nominal Observing Plan

ACTIVITY	RESPONSIBILITY	TIME
EUVS Heaters ON	PS	TSS - 20 minutes
Maneuver Orbiter attitude	Crew	TSS - 5 minutes
Maneuver IPS to target 1	PS	TSS
Open Aperture door	PS	TSS + 2 minutes
Stabilize on target 1	PS	TSS + 4 minutes
Vacuum pump pwr OFF	PS	TSS + 4 minutes
Instrument power ON	PS	TSS + 5 minutes
Verify data flow	PS	TSS + 5 minutes
(Optional) live image trim	PS	TSS + 6 minutes
Maneuver IPS to target 2	PS	TSS + 11 minutes
Stabilize on target 2	PS	TSS + 12 minutes
Instrument power OFF	PS	TSS + 40 minutes
Shut aperture door	PS	TSS + 40 minutes
End observing run		TSR

TSS = time of orbital sunset. TSR = orbital sunrise.

based data processing support.

8.2 Ground Support Team. We do not anticipate the need for the EUVS experimenters to participate in the day-to-day scheduling decisions during the mission. If required by NASA, however, a support team would be assembled with primary responsibility for observing plan amendments or substitutions. Such observing plan modifications might become necessary during the mission for any of the following reasons:

1) the discovery through other means of some short-lived transient phenomenon (e.g., a supernova or galactic radio nova);
2) a failure in some portion of the EUVS, its IPS, or associated data system;
3) a failure of some other onboard experiment making available additional EUVS observing time.

In this connection, it might be desirable that at least a portion of the primary scientific data from the EUVS be made available within a few hours of its acquisition. We have considered several subdivisions of responsibility for this data manipulation and display function, with the following conclusions:

1) The first possibility would be to provide no quick-look data to the ground support team, but instead rely upon occasional reports by the PS as to the image quality, instrument background noise level, attitude control stability, calibration repeatability, and degree of "visibility" of targets. This approach at first appears to offer the lowest hardware and software costs, but considerably increases the scope of the required PS training program and inflight PS and computer workload; moreover, it

would considerably reduce the flexibility of the EUVS program to accomodate unanticipated factors.

2) Another solution would be the centralized-computer data distribution system familiar to Apollo experimenters. Here, the spacecraft data are processed in essentially real time by a single very large computing facility at the mission control site. The reduced data are used to frequently update a number of console displays whose formats have been specified to the mission software specialists in advance. Although this approach would not be capable of handling the EUVS image display requirements, it would be possible to monitor a number of diagnostic variables computed from the image data and allow some degree of assessment of the astronomical data.

3) The most powerful and flexible quasi-real-time EUVS support facility would be an experiment-specific ground support equipment (GSE) based on a conventional user-dedicated minicomputer. This GSE could also be employed in prelaunch and postlaunch testing and calibration. Its software and peripheral devices would be optimized by the experimenter team for the tasks of rapidly assessing EUVS image data. The chief problem area with this approach would be the data interface between the GSE and the TDRSS port at the mission control facility. However, if some standard TDRSS interface were to be adopted which is compatible with commercially available minicomputers, this difficulty would be overcome.

Accordingly we recommend the last approach. In estimating its costs we have assumed that the instrument calibration and test GSE (which would in any event encompass image evaluation and display capabilities) could be interfaced to the TDRSS data port at negligible additional cost.

9.0 Environmental Constraints

In this section we discuss the impact of the thermal environment and cleanliness requirements on the use of the EUVS on board the Orbiter.

9.1 Thermal Considerations. Thermal control is important to the optimum performance of the experiment. The individual components of the instrument are insensitive to temperature and will not be damaged by exposure to extremes of temperature to be expected in the Orbiter bay. However, the alignment of the instrument package suffers with thermal change and the instrument sensitivity depends directly on the alignment. In the spectrometer telescope, the alignment may be considered in two parts -- maintaining focus and preventing distortion in the optics.

The focus requirements are set by the optics used. The large area telescope has a focal length of 380 cm. The diameter of the objective mirror is 38 cm. As the optics obey the Abbe sine condition this system may be considered to have a focal ratio (f number) equal to 380/38 = 10. In order not to dominate the errors, the focusing must be as good as possible. Rays reach the grating as much as 3° off axis. If the instrument is focussed correctly, and the focal plane detector is then moved a distance D centimeters along the optical axis, the diameter of the blur circle will grow by 0.1 D. Since the focal length is 380 cm this represents an increase of .015 D degrees. The sensitivity of the instrument depends on the resolution, and to satisfy the resolution budget, D must be maintained to 0.5 mm or less from the nominal focal point. Hence the structure which holds the detector positioned relative to telescope mirror must not be allowed to expand or contract more than 0.5 mm. The detector support structure is one meter in length, so it must not expand or contract more than 1 part in 2000. As aluminum expands 25 parts in 10^{-6} per degree, this allows us a comfortable range of $\pm 20^{\circ}$ C before thermal effects defocus the instrument. The specifications on a uniform expansion of the mirror itself are similar as it is to be made of the same material.

A much stricter thermal limit is set by the internal distortions in the mirror. For example, let us imagine that the secondary surface of the mirror developed a thermal gradient of ΔT degrees between the front and the rear. This would cause a change of radius of $\alpha R \Delta T$ over the axial length Z of the secondary, or would introduce an additional slope of α $\alpha R \Delta T/Z$, where R is the radius of the optic and α is the coefficient of expansion. Photons reflected by the secondary would leave at an angle wrong by $2\ \alpha R \Delta T/Z$, and after travelling a distance of p to the focal plane the linear spot size would be $4\alpha\ R\Delta T/Z$. For parameters appropriate for this telescope, the thermal gradient across the mirror should not exceed about 3°C if the image is to be satisfactory.

Clearly these specifications cannot be met if the instrument is exposed directly to the interior of the Orbiter. Thus it will be necessary to enclose the assembly in a thermally insulated housing. This will protect the alignments and mirror from radiative inputs from the bay and the sun. The experiment housing will have a lid which closes whenever the Orbiter enters daylight. This will protect the mirror from obtaining uneven heat distributions due to radiative coupling from the Earth, the Sun, and the Orbiter bay itself.

To achieve the required level of thermal control, we propose to combine the passive thermal canister concept with an active, thermostatically controlled heater approach. The objective of this two-fold thermal design is to meet the rather stringent requirements for gradients across the mirror while keeping the overall optics temperature somewhat warmer than ambient (to minimize VCM contamination) yet within the overall absolute thermal tolerances derived above.

The worst-case heat loss rate of the EUVS occurs when viewing deep space for extended periods of time. The 1400 cm^2 instrument aperture constitutes a net cooling load of 58 watts. Under steady state conditions, this load must be supplied by conduction and radiation from surrounding warmer components, and by dissipation within the instrument itself. Since we prefer to operate the optical surfaces somewhat above ambient, we plan on equipping the optics with approximately 100 watts of contact heaters, which are controlled by thermostats to shut off if the mirror temperature should reach the upper end of the desired temperature range. If the EUVS is regarded as a thermally isolated entity coupled to the pointing system canister and the Orbiter bay solely by radiation, its thermal resistance will lie in the range 2-10 watts per degree C, depending upon finish. Thus the thermostatic heaters should be able to maintain a positive temperature differential of 10-20 °C at 100% duty cycle.

The payload shell furnishes a desirable degree of isolation from thermal gradients caused by the net flux of heat past (and through) the EUVS. This shell incorporates a thin, polished aluminum thermal barrier suspended 10 mm inside its 4 mm thick aluminum alloy skin. In addition, multilayer insulation fills the space between the mirror optics and the barrier. Consequently, exterior transverse and longitudinal temperature gradients will not be appreciably coupled to the EUVS optics.

Several present designs for Orbiter instrument pointing systems include an exterior canister. An example is the BBRC SIPS concept. If such a pointing system is adopted, the EUVS would benefit to some degree from the benign thermal environment interior to the canister. This benefit would be manifested principally as a reduction in heater duty cycle and power consumption caused by the increased thermal resistance provided by the canister. We emphasize, however, that the EUVS is thermally self-sufficient by virtue of the active and passive control systems described here. Thus, we do not require that the instrument pointing system provide thermal control.

9.2 Cleanliness Requirements. The EUVS has two kinds of requirements on handling and operating procedures necessary to ensure optimum scientific return. The first requirement is that the optical system must not become contaminated with organic material or condensible vapor; such contamination seriously degrades the performance of the system. The second requirement is that the ambient gas pressure within the detector housing must not be allowed to rise above the 10^{-5} torr level while the detector is operating. Most observations will be conducted with the Ly α filter deactivated and the detector housing vented to the Orbiter bay.

The reason for this second requirement is that the MCP detectors are very sensitive to gas pressures above 10^{-5} torr. Pressures in excess of 10^{-5} torr cause an increase in background counting rate, which in turn can degrade the sensitivity of the instrument. When the filter is electrically commanded into position, the sensitivity is reduced somewhat but external pressures as high as 10^{-3} torr can be tolerated. We do not expect the bay to be an ultra-high vacuum environment, but we do not forsee any problem with excess pressure while the bay doors are open. In sounding rocket payloads that were of the "visibly clean" standard which will be used on Shuttle, experience has shown that the pressure will drop to below 10^{-6} torr within five minutes of achieving altitude. When the Shuttle bay doors are closed it is possible that the internal pressure in the bay may rise. The solution to this problem is simply to shut off power to the experiment just prior to closing the bay doors, and not reactivate the experiment until five minutes after reopening the door.

Gaseous organic matter has been known to decrease the transmission of ultrathin filters used on satellites. Although this effect may exist in Spacelab, the severe transmission losses have been seen to occur only on a timescale of about six months -- much longer than the mission length planned here. The EUV filters used on the Apollo-Soyuz mission for nine days showed no decline in transmission despite the spacecraft's mode of operation which was dirtier than the Shuttle. Finally, a periodic five minute recalibration (e.g. once every two days) of the instrument is possible simply by observing one of the better studied EUV sources in the sky.

Cleanliness on the ground prior to launch is also very important to correct operation of the instrument. Humidity and dust attack the very smooth surface of the telescope mirrors. After prolonged exposure to moisture the surface can develop microscopic uneveness that can significantly decrease the reflectivity of the surface, changing the calibration of the instrument. Similarly, dust can reduce reflectivity. The instrument is housed in a dust tight canister sealed by the aperture door. It is important to keep the interior of the canister free from dust, moisture and volatile contaminants. Prolonged exposure (more than 1000 hours) will result in degraded reflectivity efficiency of the optics. The required cleanliness can be maintained by a continuous purge with dry gaseous nitrogen that has been filtered to class 100. The canister can be slightly overpressurized so that the positive pressure keeps dust inflow to a minimum. A flow rate of 10 liter/hour will be sufficient. The purge gas temperature is not critical.

It is desirable that the gaseous nitrogen purge be maintained as much as possible during integration to the pallet and to the Orbiter payload bay. Starting and stopping of a dry nitrogen purge does not require the presence of the experimenter. Dry nitrogen is inserted through a standard gas line flange on the instrument canister; no damage can result from overpressurization or underpressurization.

During times when a dry nitrogen purge is not available, such as during shipping, the instrument should be enclosed in an airtight plastic bag to avoid contamination. Upon recovery of the payload a dry nitrogen purge should be re-initiated to prevent any degradation of the optics before recalibration.

A 20 liter/second ion pump is used to keep the detector box pumped down. The pump will operate effectively only below 10^{-5} torr hence requires the sorption pump to bring the pressure down to the ion pump operating range.

Outgassing of the detector elements limits the length of time that the detector can be left without pump power. It should be possible to turn the pump power off for up to 72 hours. If the box pressure has risen so that ion pump operation is not possible, roughing with the sorption pump will be required. Prolonged (more than 100 hours) exposure of the filters and detector to near atmospheric pressure may result in degradation of the filters and changes in the performance of the detector. However, the detector will regain its previous performance after return to vacuum and 48 hours of outgassing.

Since it is highly desirable to maintain the detector box vacuum, power must be supplied at all possible times. If power supply must be interrupted (during shipping, etc.), it is expected that the ion pump can be reactivated when power is again available. However, if the box pressure has risen, the rough pump will have to be used. Power to the ion pump can be terminated up to 72 hours before Shuttle launch.

10.0 Viewing and Orbit Constraints.

The long periods of time we will be observing our targets while on Shuttle will lead to sensitivities greatly exceeding those presently available. However, when integrating for long periods of time, the instrument background becomes the limiting factor for the system. A second important factor in target selection and scheduling is the effect of atmospheric attention of EUV radiation at Shuttle altitudes. In this

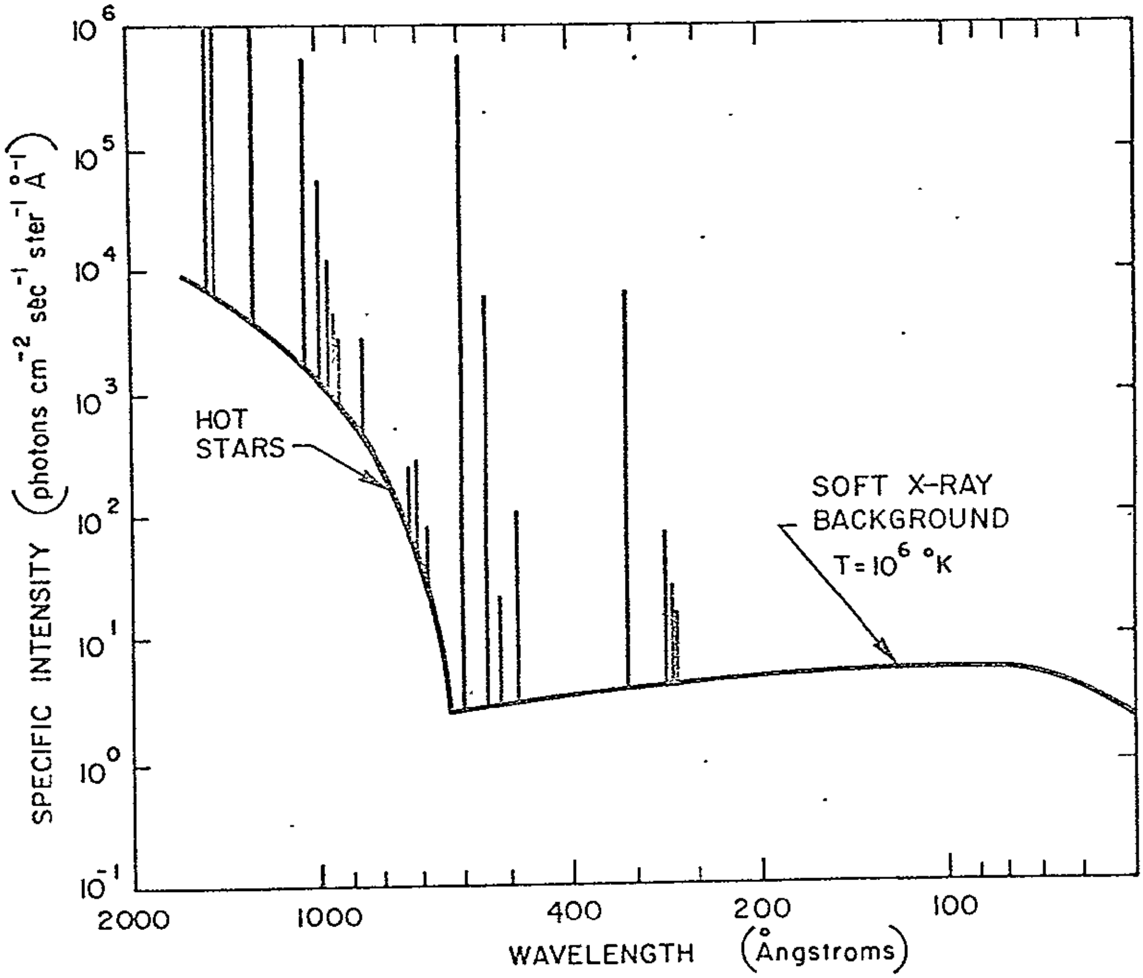


Figure 10-1. Expected intensity of the night EUV sky excluding astronomical point sources for the viewing conditions appropriate to the EUVS.

section we review these constraints.

10.1 Background. The detector's internal background counting rate is dominated by the flux of diffuse EUV radiation from the sky. This background ultimately sets the sensitivity of the spectrometer.

The intensity of the terrestrial and interplanetary emissions in the EUV is highly variable in space and in time. In general they are at their brightest near the horizons and when the spacecraft approaches the daylit portion of each orbit. It is also dependent on such diverse parameters as time of year, solar activity, solar flux and geomagnetic latitude. Consequently, a detailed analysis is necessary to predict accurately the terrestrial background for all the possible conditions affecting the proposed mission. We can, however, make a positive statement as to the maximum expected intensities as a function of wavelength for typical observing configurations. In Figure 10-1 we show the brightness of the overhead EUV sky in the absence of any astronomical point sources as seen from an observer at 250 km above the Earth's surface on the equator at midnight. The continua shown in Figure 10-1 represent the superposition of a thermal bremsstrahlung spectrum with temperature T = 10^6 °K and the expected flux of radiation from hot stars.

It is useful to compare the theoretically expected intensities of EUV emissions summarized in Figure 10-1 with the actual photometric observations of the emissions carried out by the Berkeley Apollo-Soyuz EUV telescope. The observations were conducted from a circular 220 km, 55° inclination orbit about the Earth. The EUV telescope during the course of the mission viewed the celestial sphere in a wide variety of directions

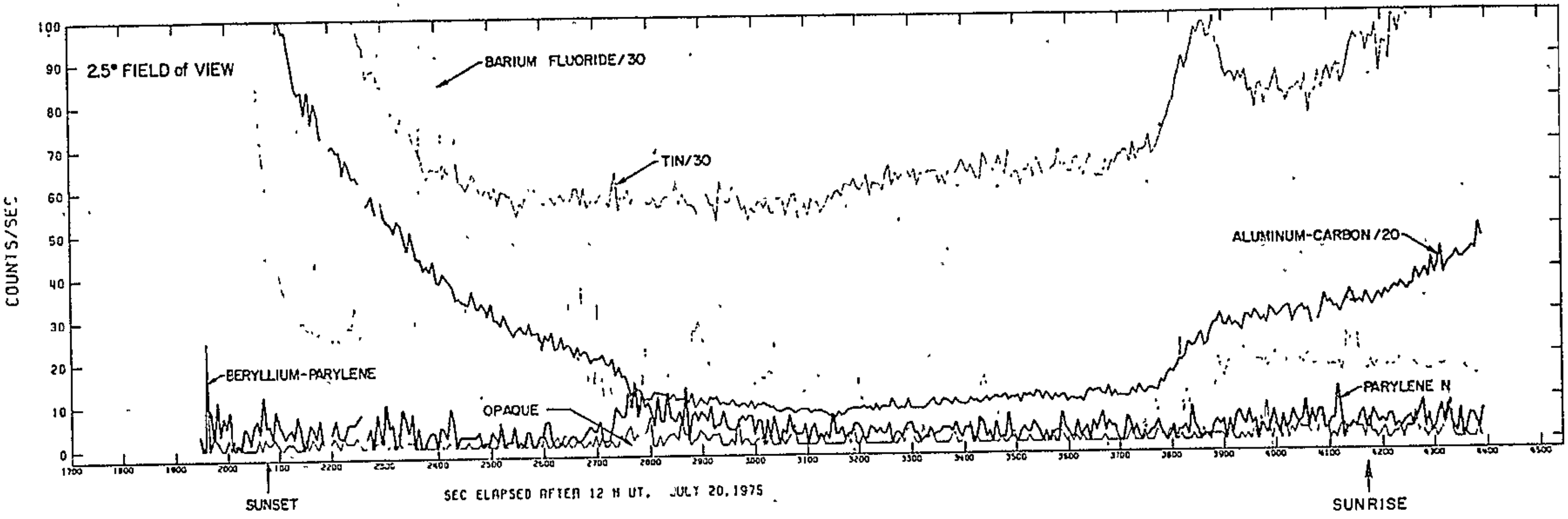


Figure 10-2. Count rates versus time of the six Apollo-Soyuz Test Project EUV telescope channels for a nighttime pass in attitude #1.

and spacecraft positions. In order to simplify a comparison between the results of this mission and the expected results of the extreme ultraviolet spectrometer we have selected a representative attitude configuration corresponding to a direction of observation which is roughly fixed in an inertial frame of reference during a complete nighttime pass and is quite close to the antisolar direction. The actual data for the five available bandpasses are shown in Figure 10-2. These bandpasses are 50 - 150 Å for Parylene N, 114 - 150 Å for Parylene N plus Beryllium, 170 - 500 Å for Aluminum plus Carbon, 500 - 800 Å for Sn, and 1350 - 1500 Å for the BaF_2 filter. The observed variations in the detector count rates are due to variations in a number of parameters such as local time, spacecraft position and atmospheric extinction. The general trend is easily discernable in the data displayed in this figure. It consists of a complete pass while the spacecraft was in the shadow of the Earth from spacecraft sunset at 12 hrs 34 min 40 sec UT to sunrise at 13 hrs 11 min 30 sec UT on July 20, 1975. All channels show an increase in count rates as the terminators are approached. This effect is particularly evident for the BaF_2, Sn and Al+C channels. A wide and shallow minimum is evident around the midnight sector, the duration in time of which varies from a minimum of approximately 20 minutes for these bandpasses to almost 35 minutes or approximately 90% of the total nighttime duration of the orbit for the other channels.

The observations we have discussed confirm the theoretical concepts governing the distribution of the diffuse EUV radiation from Shuttle altitudes. They also give a valid indication of the amount of time that can usefully be devoted to astronomical observations in the course of a spacecraft orbit for the various bandpasses in the proposed altitude configurations. Accordingly, we plan to conduct EUV observations only during those portions of each available orbit in which the spacecraft is in darkness. This constraint restricts the number and spatial distribution of EUV targets chosen for any given mission inclination and flight date. Specifically, it becomes practical to achieve long duration exposures (greater than 20 minutes) only for those targets which lie within 60° of the antisolar direction. Shorter exposures are necessary on the remaining stars.

10.2 Photoabsorption of EUV Radiation by the Atmosphere. The Earth's atmosphere is an efficient absorber of EUV radiation. EUV photons interact with terrestrial O_2, N_2 and O and deposit their energy almost exclusively in the thermosphere at altitudes between 100 and 200 km. In Figure 10-3 we show the vertical e^{-1} depth of EUV photons in the model atmosphere we expect during the Shuttle flights. This depth corresponds to the level in the atmosphere at which photons traveling vertically downwards are reduced to e^{-1} of their original number outside the absorbing medium. For these calculations we have used the model atmosphere computed by Jacchia (1971) for an exospheric temperature of 1.5×10^3 °K and the total absorption cross sections of N_2 and O_2 of Samson (1975, private communication) between 100 and 1000 Å and of Huffman et al. (1963) between 900 and 1000 Å. The smooth portion of the curve between 100 and 650 Å is due to photoionization of O_2, N_2 and O while the highly variable part between 650 and 1000 Å is mainly the result of band absorption by N_2. At the peaks of the N_2 transmission windows EUV photons may reach as far down as 115 km around 900 Å and about

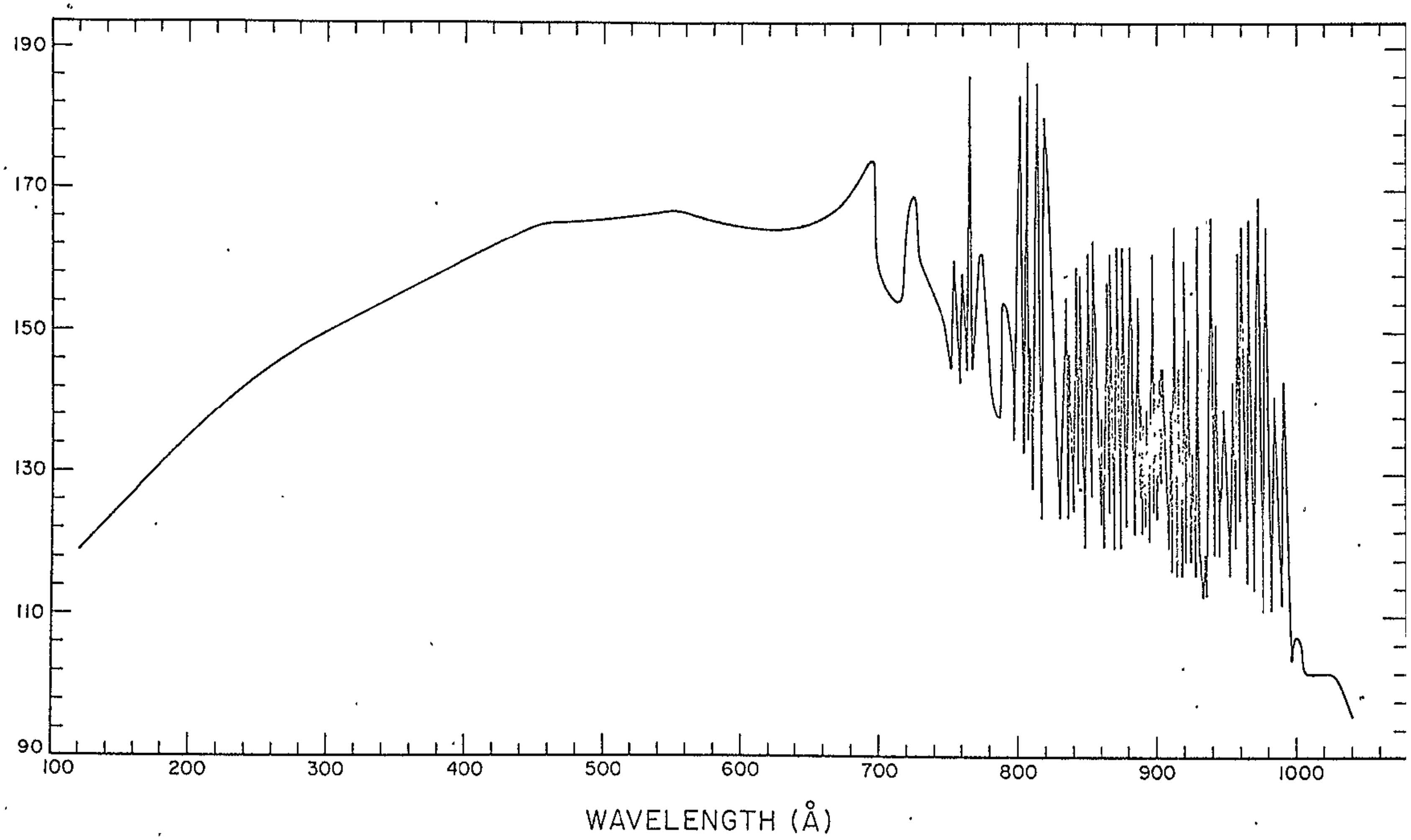


Figure 10-3. Altitude for 1/e vertical attenuation versus wavelength.

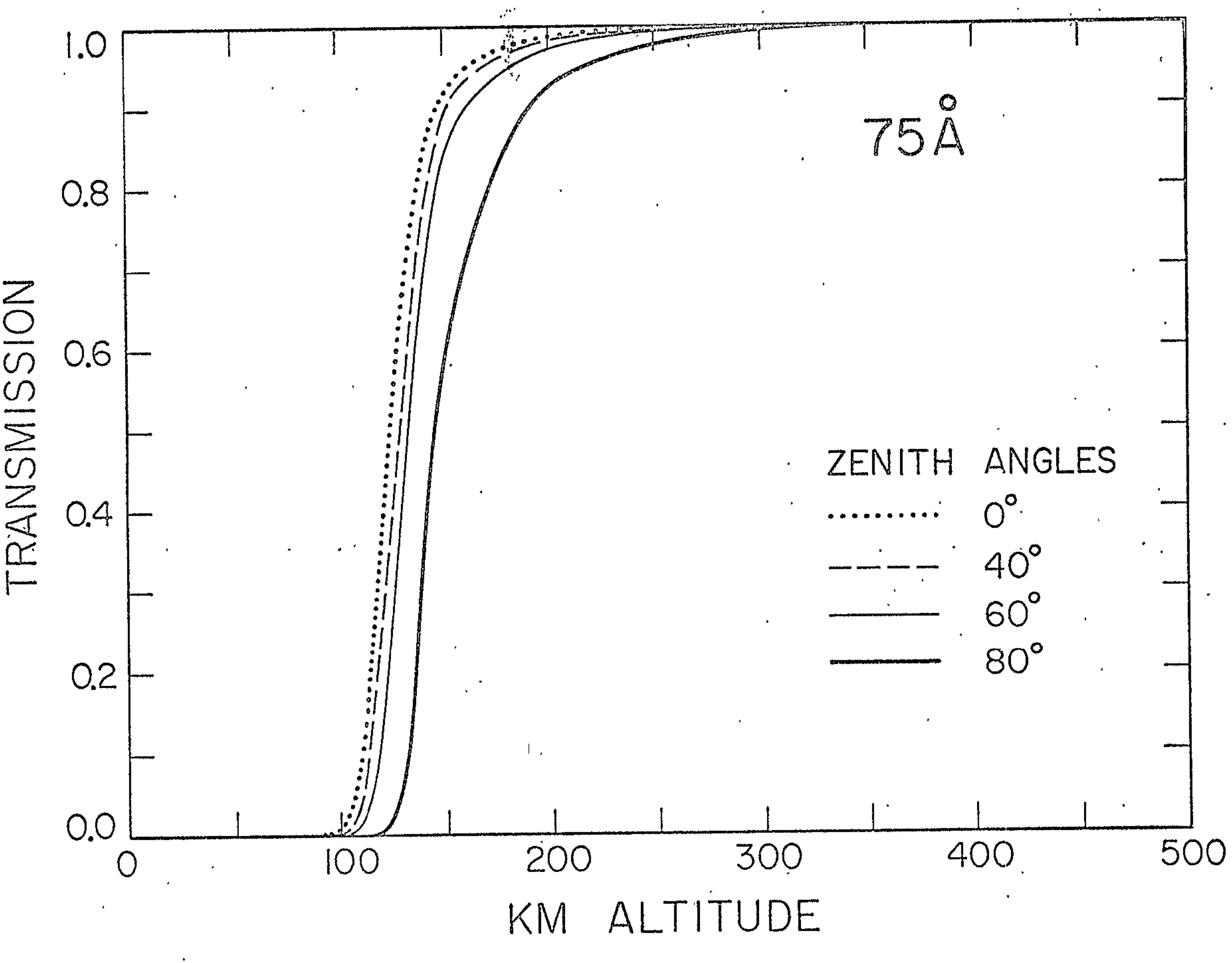


FIGURE 10-4a. ATMOSPHERIC TRANSMISSION VERSUS ALTITUDE.

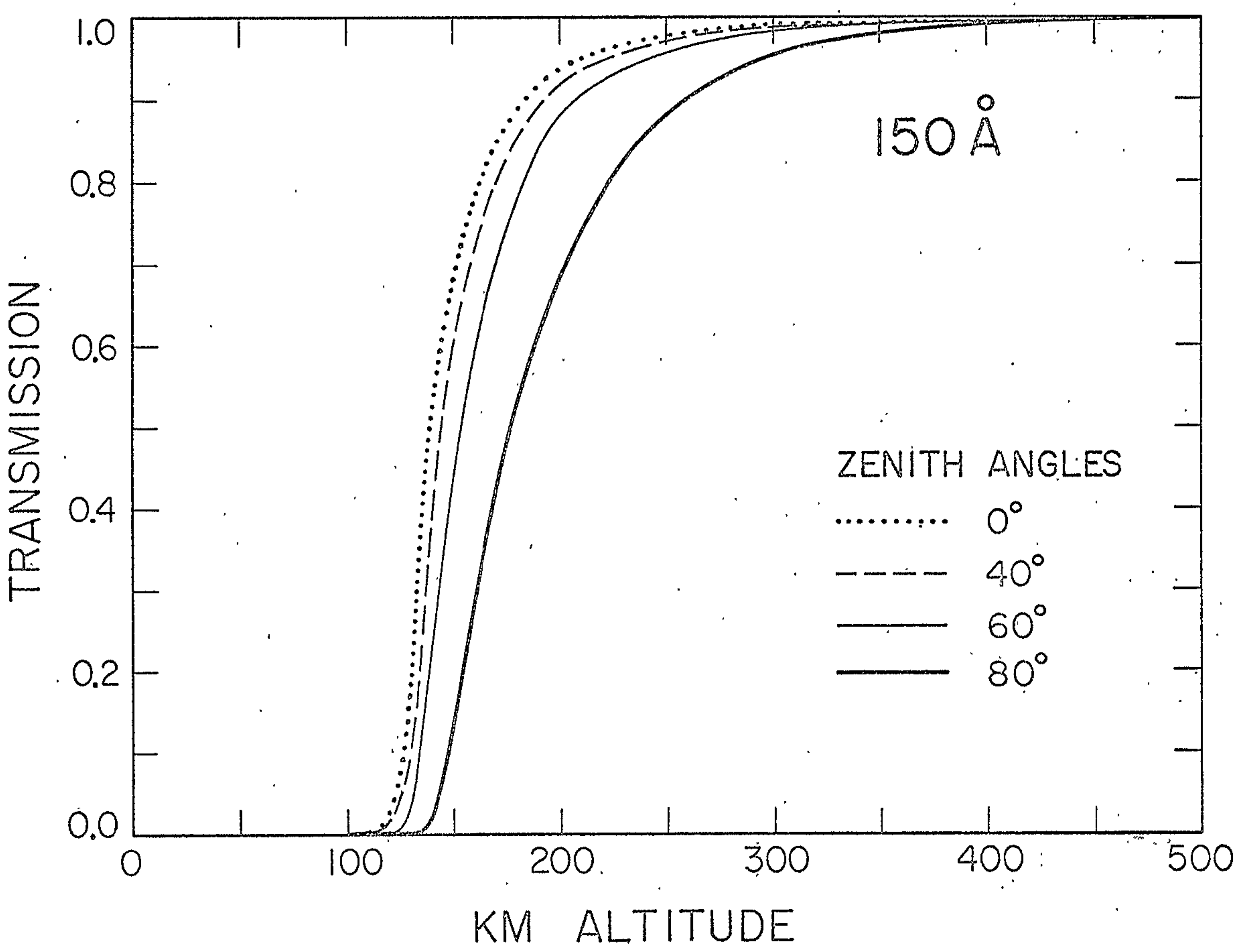

1.0
0.8
0.6
0.4
0.2
0.0
TRANSMISSION
0
100
200
300
400
500
KM ALTITUDE
150 Å
ZENITH ANGLES
0°
40°
60°
80°

Figure 10-4b.

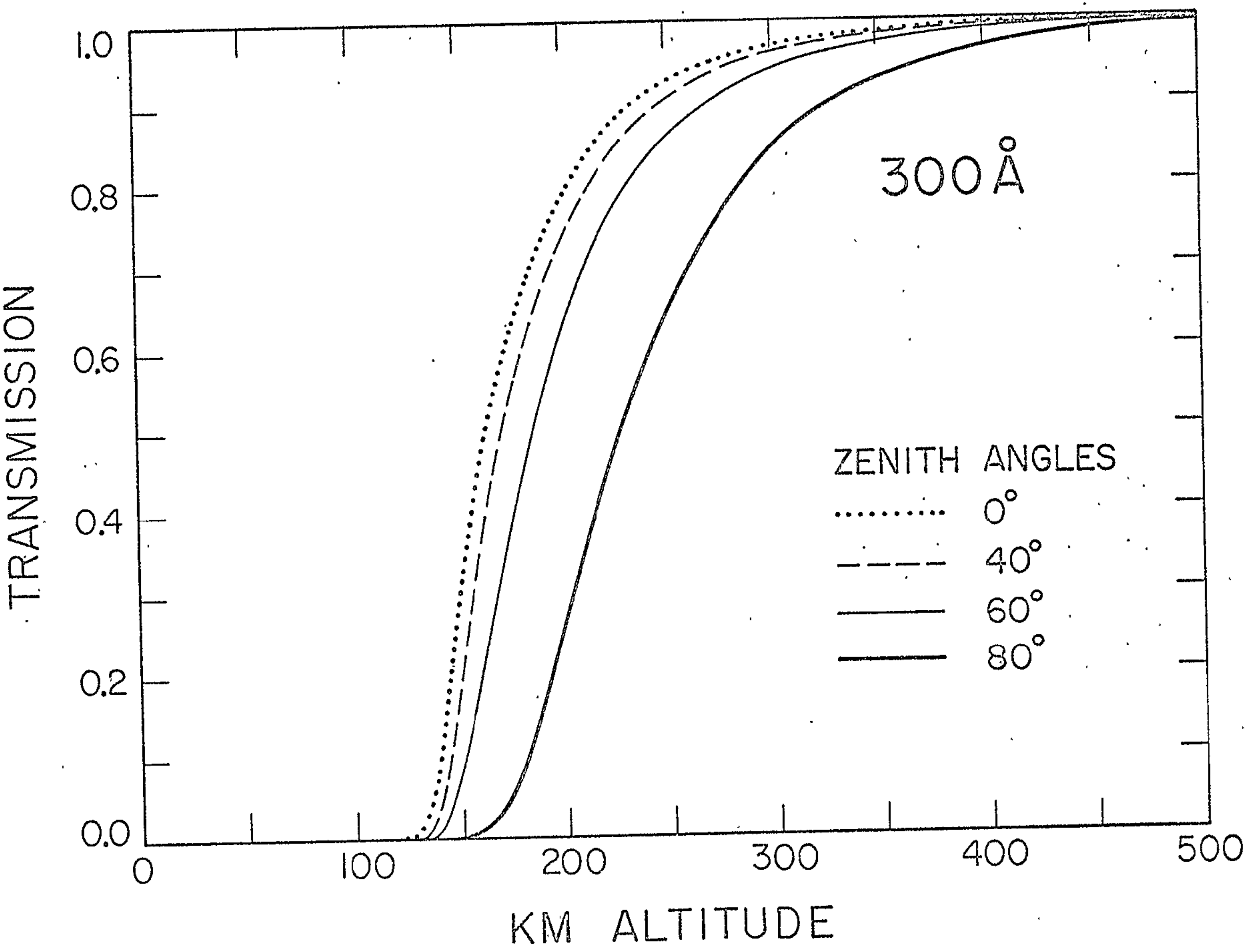
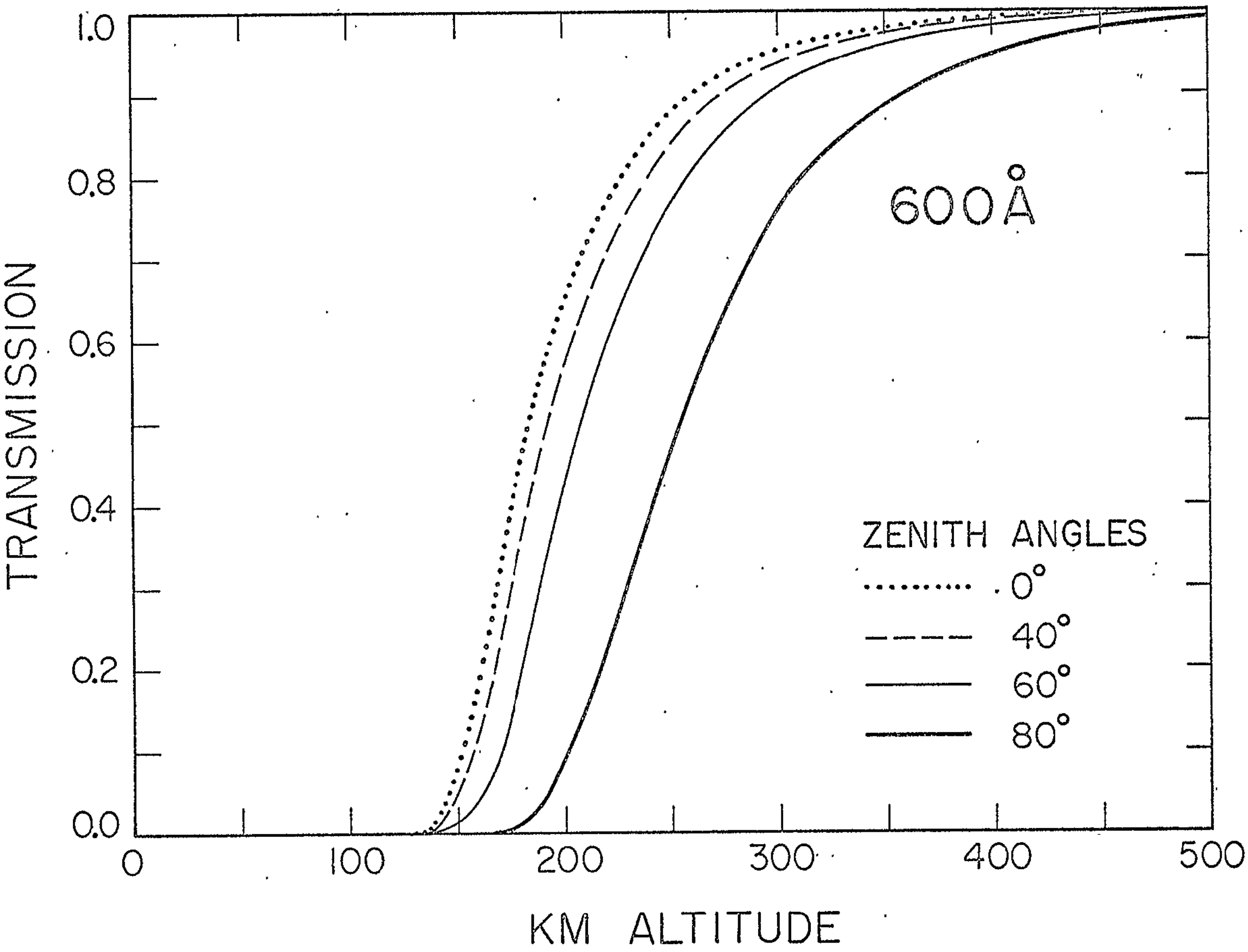

1.0
0.8
0.6
0.4
0.2
0.0
TRANSMISSION
0
100
200
300
400
500
KM ALTITUDE
300 Å
ZENITH ANGLES
0°
40°
60°
80°

Figure 10-4c



1.0
0.8
0.6
0.4
0.2
0.0
TRANSMISSION
0
100
200
300
400
500
KM ALTITUDE
600Å
ZENITH ANGLES
0°
40°
60°
80°

Figure 10-4d.

100 km at 1030 Å. If we wish to observe in the EUV out to 600 - 700 Å, however, the spacecraft must be at an altitude above 175 km for vertically incident cosmic EUV of any wavelength not to be attenuated more than a factor of e. We have to recognize, however, that we shall not always be observing directly overhead but at varying zenith angles as the spacecraft moves around the Earth in its orbit. To obtain the atmospheric extinction at EUV wavelengths for zenith angles greater than zero we must multiply the vertical opacity corresponding to the case shown in Figure 10-3 by a factor equal to the secant of the zenith angle out to approximately 70° and by the Chapman grazing incidence function beyond that.

We have carried through these calculations and the results are shown in Figure 10-4 a-d. Each graph represents the transmission versus altitude for a given wavelength at zenith angles of 0, 20, 40, 60 and 80°. They show that for typical Shuttle altitudes an atmospheric correction will have to be made during the data analysis. This is not a severe problem as the correction factors will not often exceed 30%. However, these considerations will have an important bearing on the preparation of detailed observing schedules.

11.0 Refurbishment of the EUVS

In this section we discuss the procedures necessary to refurbish the optical system and detector assembly for reflight.

11.1 Optics. Post-flight evaluation of the optical element will be performed to assess the level of refurbishment required. The optics will be tested in the Foucault beam facility at visible wavelengths to determine any figure distortions due to thermal or mechanical stresses during reentry. The EUV reflectivity will be measured to measure the level of surface contamination. If any surface scratching or pitting has occurred, its impact on the instrument sensitivity will be determined. Based upon the results of these investigations, the appropriate level of rework will be conducted as described here.

If the condition of the optics is such that only surface contamination is found, the mirror assembly will be removed as a unit from the EUVS and cleaned by vapor degreasing and ultrasonic methods. Following recalibration in the EUV, it would be determined whether or not a new gold coating would enhance the reflectivity. If the recoating is required, the optics would be disassembled and recoated. The programmatic impact of a recoating job is approximately $6000 and 6 weeks. Conducting the initial diagnostic cleaning and measuring costs approximately $2000 and 2 weeks.

If surface finish deterioration is found, such as pitting, scratching, or evidence of chemical exposure, it will become necessary to remove the mirror assembly, disassemble and clean it, and deposit and polish a thin layer of nickel. This is followed by a redeposition of the gold surface layer. The programmatic impact is a cost of approximately $20,000 and 12 weeks.

A third possiblity is a figure distortion of the mirror assembly. This could occur as a result of an adverse thermal or mechanical stress event. To recover from this situation, the elements must be recoated with a heavy layer of copper, and machined on a single point diamond turning lathe. As in the original construction the nickel is then deposited, polished and overcoated with gold. It is not anticipated that this degree of refurbishment would ever be required except in the case of a catastrophic Shuttle landing. However, the optical surface can be replaced in this way without rebuilding the telescope. The approximate cost is $60,000 and 24 weeks.

11.2 Detector Assembly. The detector assembly includes several components which require replacements. The ion pump, which has a limited useful lifetime, must be replaced before requalification of the instrument for flight. The aluminum filter, which is known to be susceptible to pinholing after a prolonged use, would also be replaced. The detector gain and sensitivity are redetermined. No degradation is expected. If the objectives of the reflight require it, a grating with different dispersion or efficiency curve can be substituted. The cost for detector refurbishment is estimated to be $12,000 and eight weeks.

11.3 Instrument Recalibration. The EUVE would be reassembled and recalibrated following the original calibration plan. This procedure requires eight weeks and approximately $5000.

12.0 Data Reduction and Analysis.

The analysis of EUVS data following a successful flight will follow the outline presented here. We describe the computing facility and a data processing plan which will permit the timely dissemination of results with feedback in the form of reflight observing lists.

12.1 Computing Facilities. Processing of data will be accomplished at the Space Science Laboratory (SSL) by utilizing the SSL's small computer center. At present the facilities of this center have an Interdata 70 as the central processing unit (CPU) with 64 K bytes of core storage. Peripherals include a Gould 5000 ultra high speed electrostatic printer (as well as a conventional Centronix medium speed line printer), card reader, a Tektronix 611 visual display unit (VDU), one Bright high speed 9 track 800/1600 bpi vacuum tape drive and three Cipher medium speed 9 track 1600 bpi tape drives. Additional memory capacity is provided by a Wangco dual disk drive which accomodates a 2.5 M byte portable disk pack. Communication with the CPU is accomplished by a teletype console.

These facilities are currently being greatly enhanced by the addition of an Interdata 732 CPU with 160 K bytes of core storage and an 80 M byte non-removable disk pack. This computer will share the printer/tape drive facilities described above as well as having its own console but will not have access to the VDU or portable disk packs (these are specifically tied to the Interdata 70). Consequently, all the data processing requirements of this mission can be accomplished with the acquisition of two additional pieces of hardware which will be dedicated to this work. Firstly, an additional 80 M byte disk drive plus pack (total cost approx. $9.5 K) to store the processed data for subsequent analysis. Secondly, a Tektronix 4010 VDU (approx. $5 K) to display the raw and processed data in order to aid the interactive analysis of data. The SSL provides its own in-house hardware and systems software maintenance and support, and so the data processing costs are fixed by the hardware procurement. The constant access and experience developed by SSL scientists in using the small on-site computers makes them ideally suited to processing data where a considerable amount of user interaction with the data is required.

12.2 Data Processing Plan. The post-flight data analysis involves several steps. The chief goal is to determine, for each EUV target, the energy distribution with respect to wavelength. This analysis is complicated to some extent by the fact that the stellar image and spectrum may actually be moving rather than stationary, due to the possibly varying aspect of the instrument. Thus the field of view must be searched by an interactive routine to find and follow each star in the zero-order detector while accumulating its spectrum in the first order detector.

The first step in the post flight data reduction is to edit the flight data into separate files of data associated with each target, and to locate and delete all defective data (dropouts or intervals of high background such as SAA passages). The second step in data reduction is location of the source image in the zero order detector. In practice the zero order image will lie anywhere in a circle 5 - 10 arcminutes in diameter, and so we cannot assume anything about the expected position of the spectrum of a source, even when the target coordinates are exactly known.

The field of view for each detector consists of 256 x 256 picture elements, or "pixels", for each detector and the data stream will simply consist of the (x,y) coordinates of the event that ocurred in each 160 μ time interval. (This corresponds to a data rate of approximately 100 kilobits per second, or approximately one magnetic tape per hour of astronomical observation). To locate the source image in the zero order detector, a special purpose interactive subroutine FOLLOW is guided to the brightest spot in the image field, and arithmetically follows this spot during subsequent image accumulations. A data file is produced which lists the detector coordinates of the star during the target observation period.

To accumulate the spectrum, another subroutine SPECTR is used. Here, photon events in the first order detector are accumulated in an array, whose index is determined both by the detector coordinates of the photon and by the star's position found by FOLLOW. In this way the instrument motion is, within limits, subtracted from the data and need not interfere with obtaining high resolution EUV spectra. In addition, SPECTR produces an image of the background EUV flux, which is subsequently subtracted from the target spectrum to give the observed excess count distribution. Finally, the detector, grating, optics, and atmospheric efficiency curves are employed to convert the observed counts into a true energy flux spectrum of the target.

A flow chart illustrating the data analysis procedure is shown in Figure 12-1.

ROCESSING FLOW CHART