NASA-CR-177902

SPACELAB LYMAN ALPHA-WHITE LIGHT CORONAGRAPH PROGRAM

NASA Contract No.: NAS5-26079

Final Report

For the period 12 March 1980 through 1 October 1983

Principal Investigator

Dr. John L. Kohl

June 1986

Prepared for

National Aeronautics and Space Administration
Goddard Space Flight Center
Greenbelt, MD 20771

by

Smithsonian Institution
Astrophysical Observatory
Cambridge, MA 02138

The Smithsonian Astrophysical Observatory is a member of the Harvard-Smithsonian Center for Astrophysics

The NASA Technical Officer for this contract is Mr. Charles G. Stouffe
Code 430.0, Goddard Space Flight Center, Greenbelt, MD 20771.

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Final Report

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SPACELAB LYMAN ALPHA-WHITE LIGHT CORONAGRAPH PROGRAM

ABSTRACT

Under this contract, the Phase I Definition of the Spacelab Lyman Alpha-White Light Coronagraph Program was completed. This program, which is a joint program of the Smithsonian Astrophysical Observatory (SAO) and the High Altitude Observatory (HAO), was organized under a single Principal Investigator, Dr. John L. Kohl. The Spacelab Lyman Alpha Coronagraph (SLAC) of the SAO and the White Light Coronagraph (WLC) to be provided by the HAO are two separate coronagraphs which would be operated in a joint fashion during Spacelab missions to be flown by the Space Shuttle. The two instruments would be used to perform joint observations of solar coronal structures from 1.2 to 8.0 solar radii from sun-center in vacuum ultraviolet and visible radiations. The experimental objective of the joint SAO/HAO program is to measure temperatures, densities and flow velocities throughout the solar wind acceleration region of the inner solar corona.

The Phase I Definition activity resulted in 1) the successful definition and preliminiary design of the experiment/instrumentation subsystem and associated software, ground support equipment and interfaces to the extent required to accurately estimate the scope of the investigation and prepare an Investigation Development Plan; 2) the performance of the necessary functional, operations and safety analyses necessary to complete the Experiment Requirements Document; and 3) the presentation of the aforementioned at a NASA Requirements Review.

1. INTRODUCTION

The Spacelab Lyman Alpha-White Light Coronagraph Program is a joint program of the Smithsonian Astrophysical Observatory (SAO) and the High Altitude Observatory (HAO) and was organized under a single Principal Investigator, Dr. John L. Kohl. The Spacelab Lyman Alpha Coronagraph (SLAC) of the SAO and the White Light Coronagraph (WLC) to be provided by the HAO are two separate coronagraphs which would be operated in a joint fashion during STS/Spacelab missions. A technical and managerial interface agreement between the two institutions, which essentially states that the two instruments would be developed under separate funding arrangements between NASA/SAO and NASA/NSF/HAO, was established. This arrangement was driven by the requirement that HAO must be funded via fund transfer to NSF and could not be a SAO subcontractor.

The Spacelab Lyman Alpha-White Light Coronagraph Program would provide two instruments that comprise the Acceleration Region Coronagraphs (ARC) experiment as shown in Figures 1 and 2. The SLAC instrument would be provided by SAO working in conjunction with the Ball Aerospace Systems Division (BASD), and the WLC would be built by HAO.

SAO and HAO agreed that, to the greatest extent possible, they would simplify the interface between the two instruments. Consequently, the instruments are separate in interfacing to the Spacelab Command and Data Management Subsystem (CDMS) and Electrical Power Distribution Box (EPDB). Each instrument has its own thermal control system, and the thermal interaction between the two would be minimized. However, a mechanical interface exists in that the WLC is mounted to SLAC with a three-point kinematic mount, but each coronagraph is otherwise structurally self-sufficient.

SLAC would be mounted to a Coalignment System (CAS) which in turn would mount to the Instrument Pointing Subsystem (IPS) cruciform, the Solar Optical Telescope (SOT) structure, or to a pointing system on a Pallet of Opportunity.

It is planned that BASD, under SAO direction would design, fabricate, and test the SLAC flight hardware and would develop a major portion of the SLAC Dedicated Equipment Processor (DEP) software. BASD would integrate WLC and SLAC to form ARC, testing the combined instrument package. Following acceptance testing at BASD, WLC and SLAC would

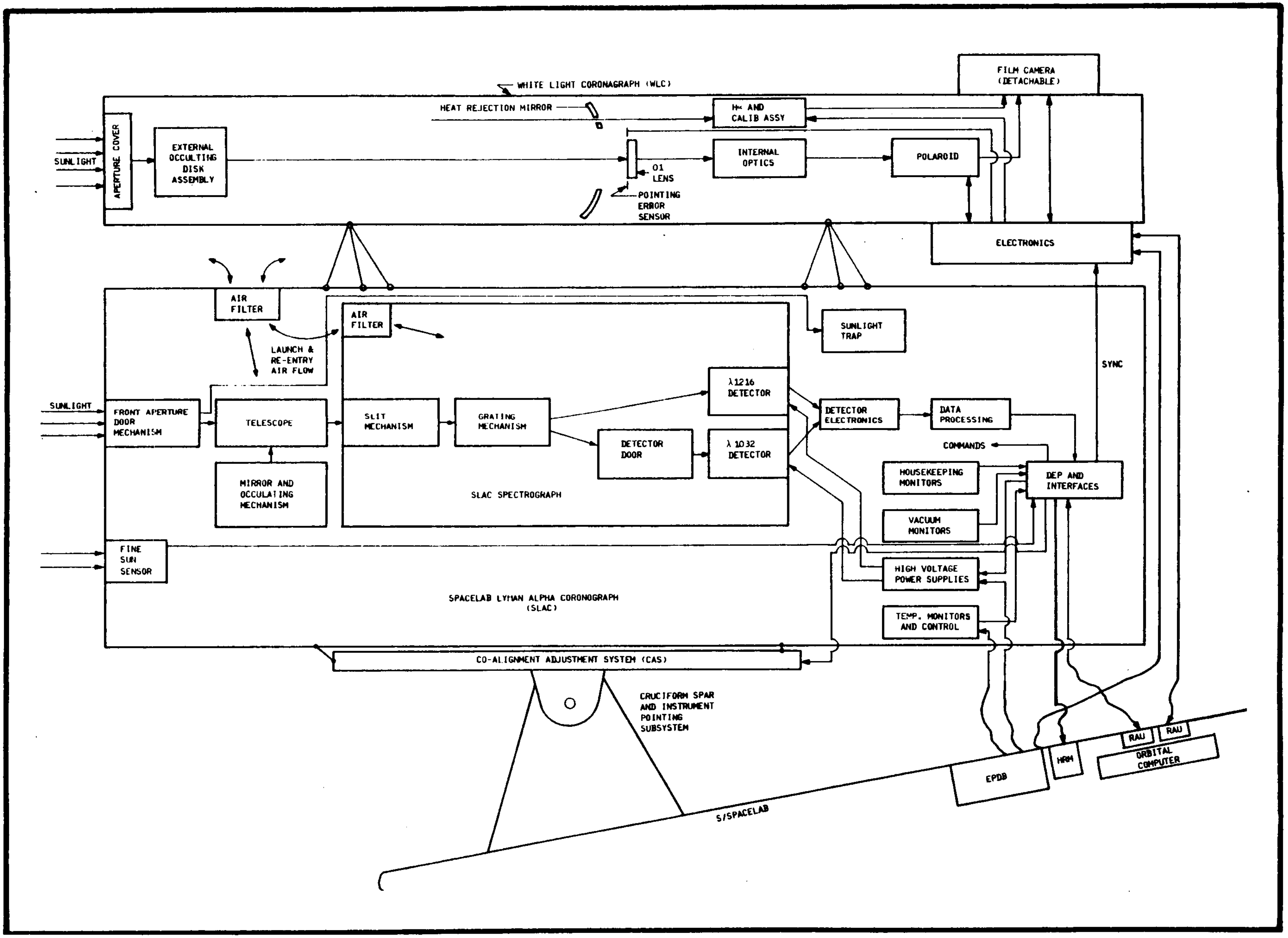

Fig. 1. Acceleration Region Coronagraphs (ARC) Experiment Functional Block Diagram.

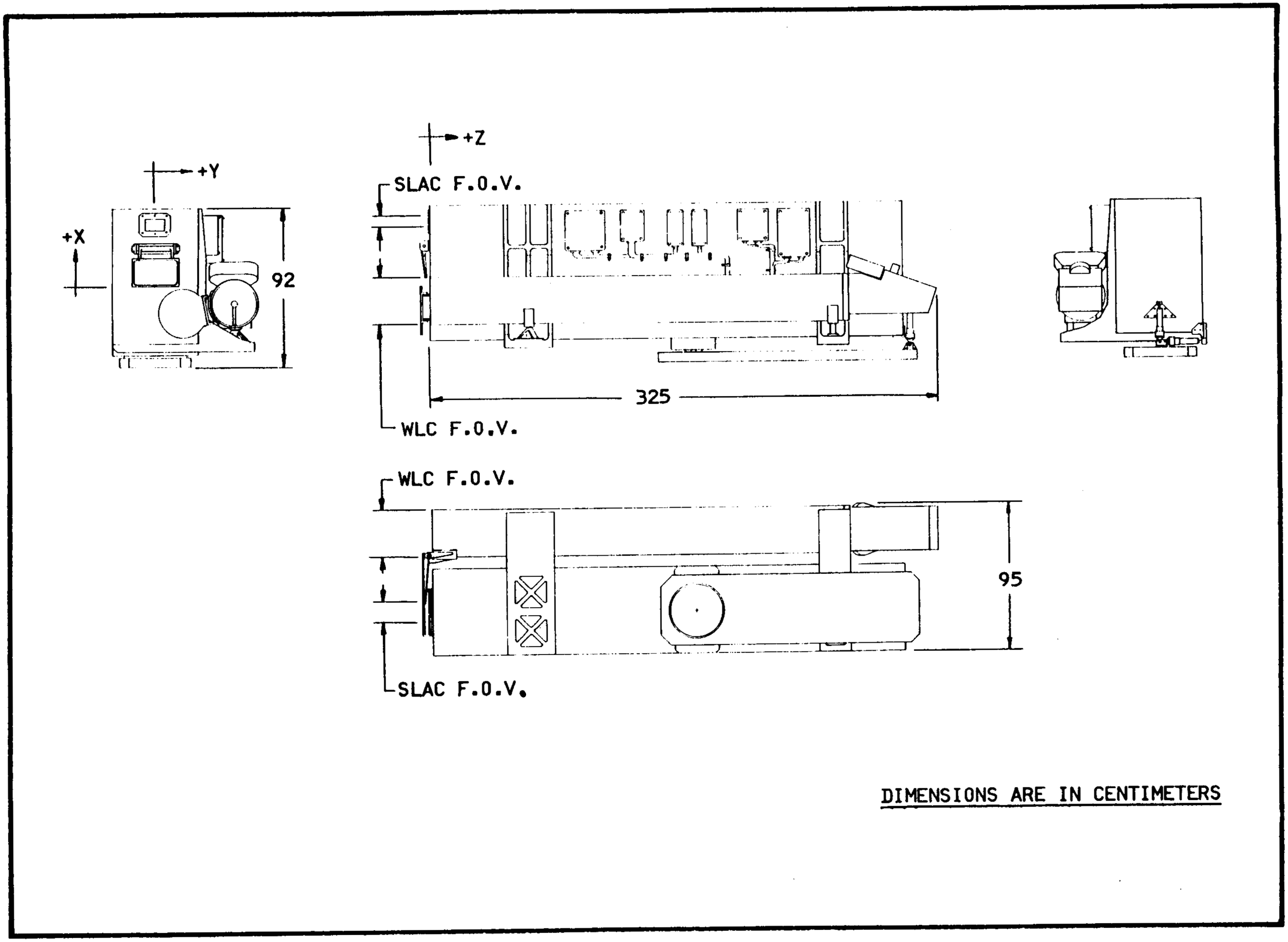

Fig. 2. ARC Mechanical Layout.

be separated and shipped to their respective institutions. SAO would develop the major portion of the Instrument Ground Support Equipment (IGSE) including calibration, testing, and instrument handling devices and would also develop all Electrical Ground Support Equipment (EGSE) resident software, additional DEP software and would specify the NASA supplied software. The final alignment, calibration and performance testing of SLAC would be performed at SAO followed by a system integration of the calibrated WLC and SLAC instruments at SAO prior to shipment of ARC to NASA/KSC for integration, mission operations and deintegration, which would be performed by SAO with the participation of HAO and BASD.

The major tasks that were undertaken during the course of this contract were 1) performing the necessary definition and preliminary design of the experiment/instrumentation subsystem and associated software, IGSE and interfaces to the extent required to accurately estimate the scope of the investigation; 2) performing the necessary functional, operations and safety analyses to determine the requirements for a Spacelab mission resulting in the completion of an Experiment Requirements Document; 3) preparing an Investigation Development Plan; 4) conducting a Requirements Review; and 5) initiating the development of a few of the long-lead items associated with the SLAC instrument. These tasks are described in more detail in Sections 2 through 6.

It should be noted that this is a final report on the work carried out by SAO under its contract NAS5-26079 with NASA and is not intended to serve as a final report for the HAO activity, which was carried out under a separate funding arrangement with NASA. All information relating to the WLC instrument is furnished in an attempt to supply an overview to the reader and should not be construed as a definitive statement of the work carried out by HAO on their instrument.

2. DESCRIPTION OF EXPERIMENT

2.1 Summary of Experimental Objectives

The SAO/SLAC and the HAO/WLC would be used as co-observing instruments to measure coronal temperatures, densities and flow velocities for solar structures throughout the solar wind acceleration region of the inner corona. Data from both instruments are required to achieve our principal scientific objectives which are:

(a) To determine the coronal atomic hydrogen and proton temperatures ($T_H \sim T_P$) from 1.2 to 8 solar radii from sun-center.

(b) To determine coronal atomic hydrogen and electron densities (n_H and N_e).

(c) To determine coronal mass flow velocities. The ratio of the intensity of Lyman alpha light to visible light would be employed to determine velocities >100 km sec^{-1}, e.g., for large velocities expected in magnetically open coronal regions, and the ratio of the intensity of O VI light to visible light will yield the flow velocity in the case of low and intermediate densities and low (<100 km sec^{-1}) velocity. Such measurements may result in the discovery of solar wind sources other than coronal holes.

(d) To specify at least an upper limit to non-thermal velocities in the corona and the temperature of O VI.

(e) To determine the coronal electron temperature (T_e).

(f) Through the use of the measured and derived parameters, to study coronal momentum and energy transfer in conjunction with models of the coronal expansion.

(g) To estimate the mass flux of the solar wind, particularly that arising from regions other than coronal holes.

2.2 SLAC Instrument Characteristics

SLAC is an ultraviolet coronagraph using a slowly-scanning telescope mirror to observe a 30 arc minute × 100 arc minute sector of the corona from 1.2 to 7.4 solar radii. The sector is selected by rolling the IPS around the sun-center. Offset pointing also permits occasional solar disk observations as well as coronal observations out to 8.0 solar radii. A spectrograph analyzes the telescope image light spectrally with 0.08 Å resolution and observes a 30 arc minute coronal strip with 0.2 arc minute resolution. Discrete-anode microchannel array detectors provide spatial and spectral information.

2.2.1 SLAC Flight Instrument Hardware

The SLAC instrument layout is illustrated in Figure 3. Functionally, SLAC is a reflective telescope with external and internal occultation, followed by a toroidal grating spectrograph. The detectors are two discrete-anode microchannel arrays. The instrument electronics interfaces with Spacelab command and telemetry and includes "smart" commands and data processing for a simple interface with the Mission/Payload Specialist.

Structurally, SLAC consists of the main case, telescope, spectrograph and two electronics boxes which are mounted to the back of the main case. This case supports the telescope-mirror assembly, spectrograph, front aperture door assembly and sunlight-trap. The HAO/WLC is mounted to the outside of the main case which is intended to be mounted to a NASA provided Coalignment Adjustment System which, in turn, is mounted to the IPS cruciform. SLAC would be designed to be compatible with a NASA provided thermal shroud and would contain heaters and thermal sensors.

The SLAC primary mirror is an off-axis parabola of 800 mm focal length and 100 mm x 80 mm clear aperture. It views the corona through the entrance aperture and images the corona at the spectrograph entrance slit. The telescope mirror is mounted on a mechanism which rotates it about the center of the mirror face, moving the coronal image radially and also moving the internal occulter which is mounted near the face of the primary. The spectrograph, which is an independent and removable assembly, includes its own case, the entrance slit assembly, the grating drive assembly, the detector assembly, the heaters and the thermal sensors. The entrance slit assembly provides four selectable entrance slits with widths of 19μ, 40μ, 675μ and 1165μ. The spectrograph is a Rowland-circle type, but with a toroidal grating (radius-dispersion = 1500 mm, radius-cross = 1460 mm, and ruled surface 233 mm (dispersion) × 25 mm) to provide stigmatic imagery over a 820 Å - 1640 Å range in first order. The grating is pivoted about the center of the Rowland circle using a lead-screw mechanism. Because optimal reflection of λ1216 and λ1032 radiation requires different coatings, part of the grating is coated with osmium and the remainder with Al MgF_2 such as to maximize the efficiency at λ1032 Å and λ1216 Å, respectively. The corresponding halves of the telescope mirror are similarly coated to optimize the total performance of the instrument for these two wavelengths.

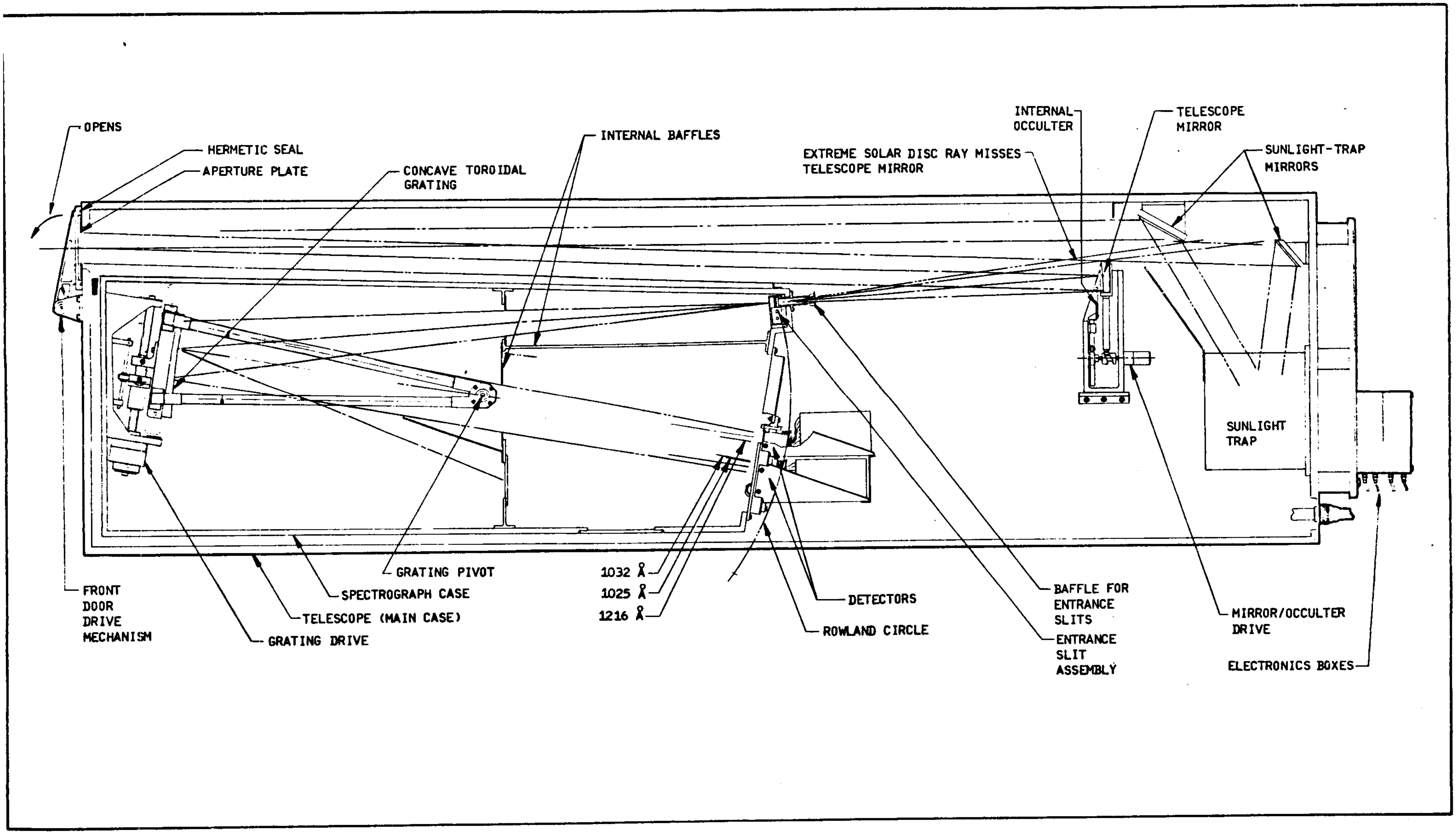

Fig. 3. SLAC Layout.

The detectors for the first flight are two 25 mm diameter (active area) discrete-anode microchannel arrays (see Figure 4). These permit two-dimensional imaging so that intensity measurements can be made simultaneously at various wavelengths and at various spatial elements along the entrance slit image. The detector for H I Lyman alpha (λ1216 detector) is windowed and evacuated at all times and includes a vac-ion pump for vacuum pumping and readout. The detector for O VI λ1032 (λ1032 detector) will not have a window but will have a motor-driven door and a vac-ion pump to permit evacuation until internal spectrograph conditions become acceptable. The anode layout is identical for the two detectors. Using the grating drive assembly, the λ1216 detector can cover a wavelength range of 1050 Å to 1674 Å and the λ1032 detector can cover a range of 746 Å - 1492 Å in first order while maintaining spectral focus.

Alignment mirrors are mounted on the sun ends of SLAC and WLC to facilitate coalignment of the SLAC and WLC and to a coalignment system which is used for coalignment with IPS and for off-set pointing.

The electronics system (see Figure 5) consists of detector signal processing elements, signal accumulation and formatting electronics, instrument controller electronics, motor drive electronics, heater drive and temperature readout electronics, high voltage power supplies and controllers, and the interfaces to the Spacelab Remote Acquisition Unit (RAU) and High Rate Multiplexer (HRM). These electronics are packaged into four modules, two containing the detector preamplifiers and discriminators, one containing the instrument controller and RAU/HRM interface and one containing all other elements.

The instrument is capable of executing several standardized observing sequences. Pre-programmed command sequences are initiated through the RAU and generated by a DEP. New command sequences may be input to the experiment processor via the RAU, by the Mission/Payload Specialist or from the POCC. Roll command sequences are an integral part of all observing programs.

A sequence is initiated by command. The DEP then positions all mechanisms and commands a starting wavelength, a step interval rate and wavelength range. The wavelength scan, for line profiles, is begun by stepping the grating-drive motor. Accumulated detector counts are read out periodically. In the INTENSITY mode the wavelength stepper motor is inhibited and the "step rate" controls only the detector integration time. The observing sequence may continue through several wavelength

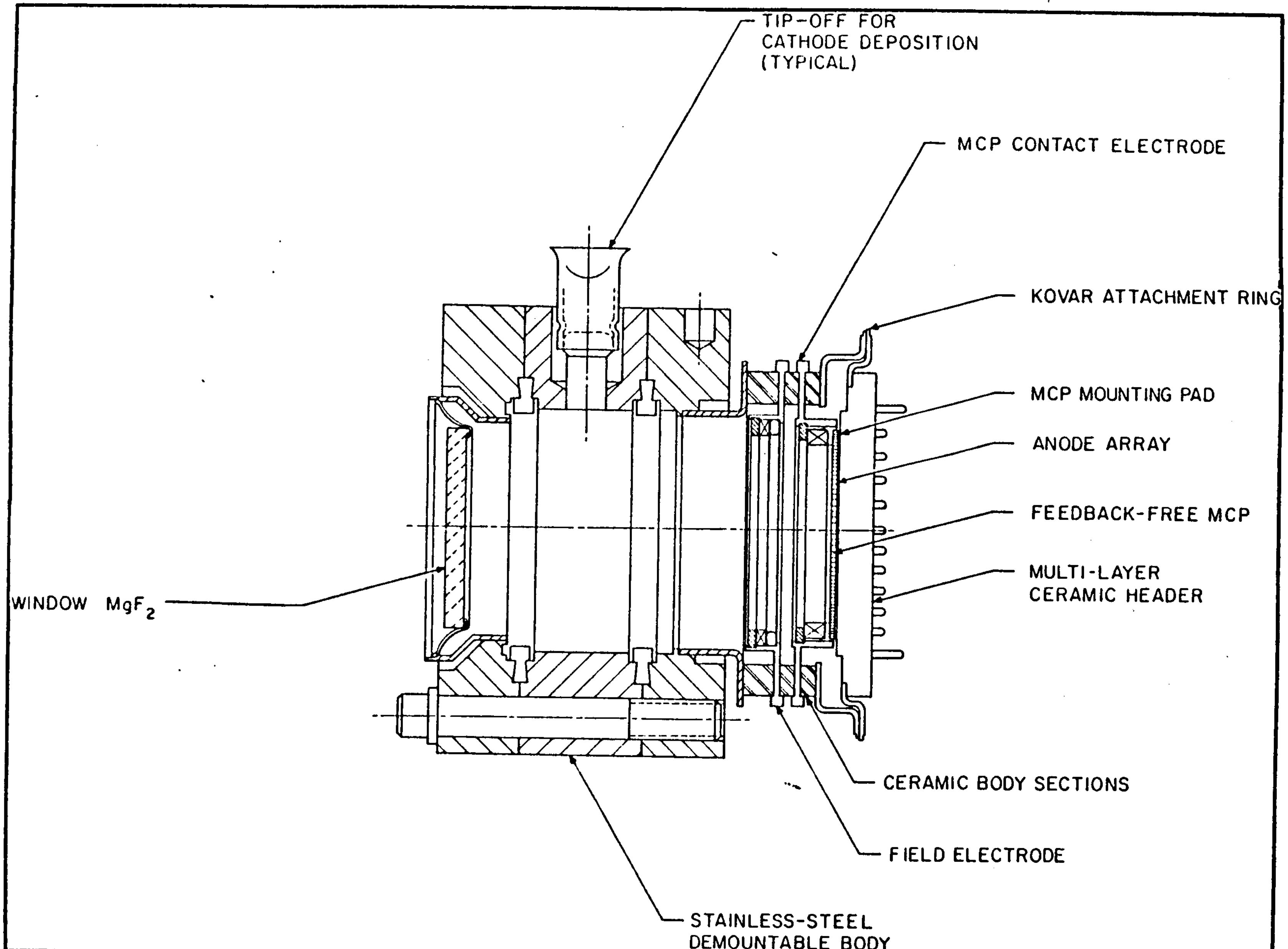

Fig. 4. Discrete-Anode Microchannel Array Detector.

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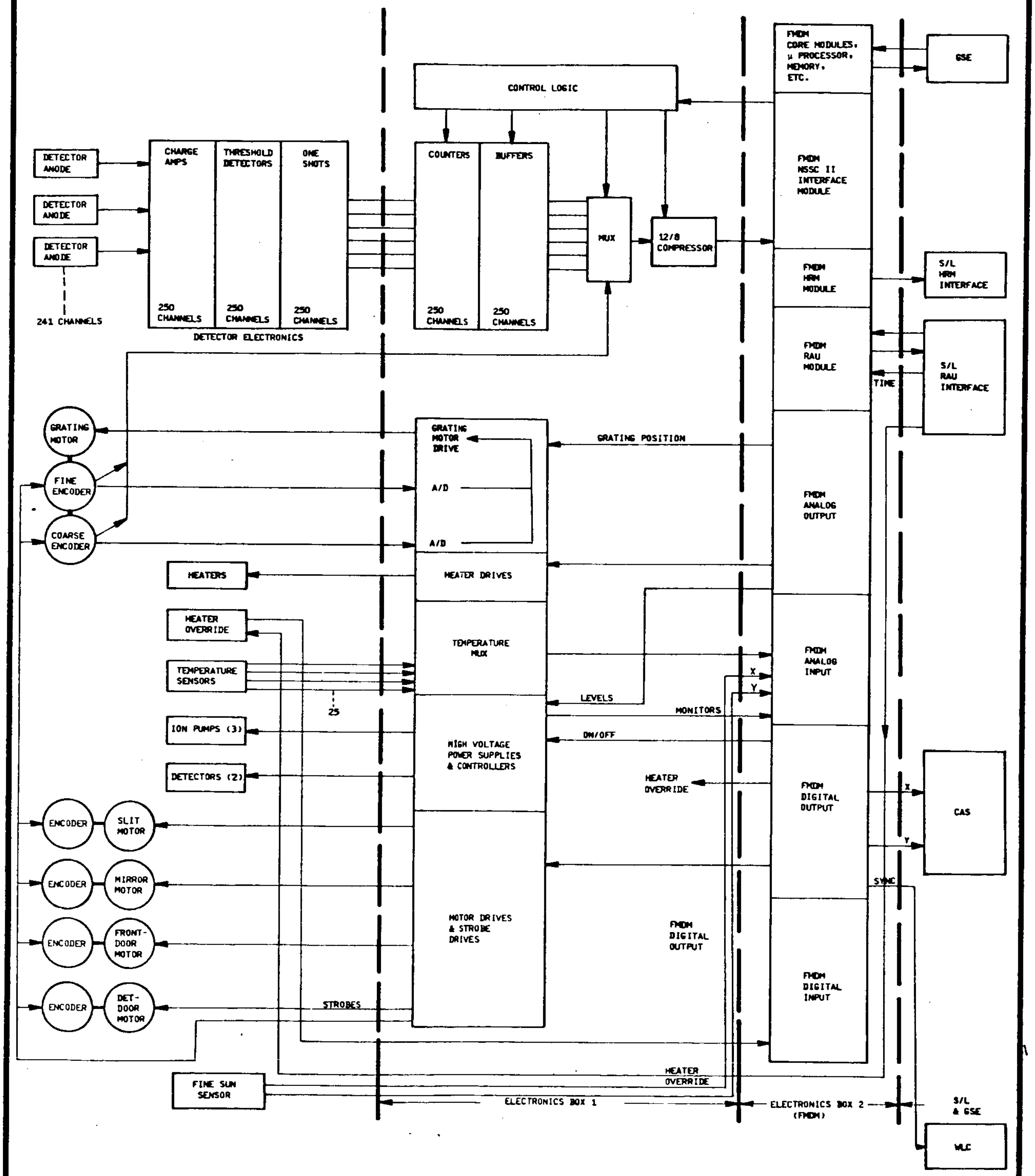

Fig. 5. SLAC Electronics Block Diagram.

scans while other variables, such as mirror position, are changed.

2.2.2 SLAC Electronic Ground Support Equipment

Figure 6 is a block diagram of the SLAC EGSE. It consists of a Tektronix Universal Development Station (UDS), an Intermetrics Spacelab Experiment Interface Device (SEID), the SLAC Interface Module (IM) and a DEC PDP 11/44 mini-computer with peripherals.

The USD would form the core of the Special Testing Equipment (STE) to be provided by BASD. The UDS is a commercially available system used to develop the DEP resident software and to provide the means to interact with the DEP. This unit would be interfaced with the instrument controller through a special breakout box that would be designed for that function.

A functional diagram of SEID is provided in Figure 7. SEID is a self-contained 19-inch rack mounted instrument containing all essential interfaces to the SLAC including the following functions:

1. Block of 16 on/off commands.
2. Block of 16 flexible inputs.
3. Block of 16 additional flexible inputs.
4. Block of IPCM commands and IPCM data channels.
5. Additional block of IPCM commands and IPCM data channels.
6. High speed serial interface.
7. user Time Clock (UTC) and reset lines.
8. HRM Interface (TTL).
9. Block of 2K bytes of Random Access Memory (RAM) (software use).

The SLAC/IM would be designed at SAO. It would provide power supplies, various interconnectors and switches required to operate SLAC in a manual mode and a simulation of SLAC mechanisms and readouts which are needed to test EGSE hardware and software. The mirror drive and grating drive would be simulated as would count rates from the microchannel array detectors. There would also be a simulation of discrete levels such as front door open/closed, etc. Analog outputs including high and low voltage readings, temperatures and vacuum changes would also be simulated.

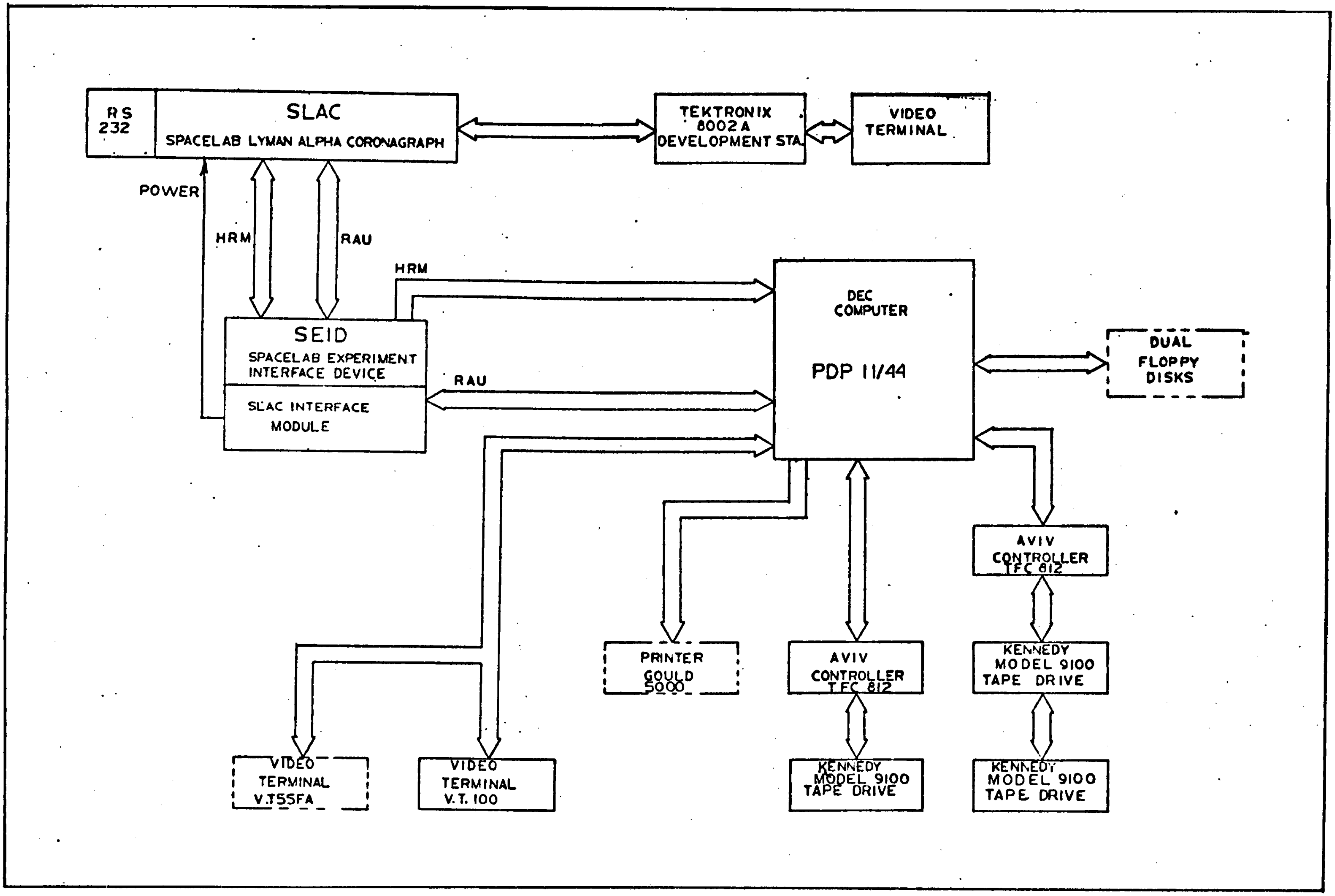

Fig. 6. Block Diagram of SLAC EGSE.

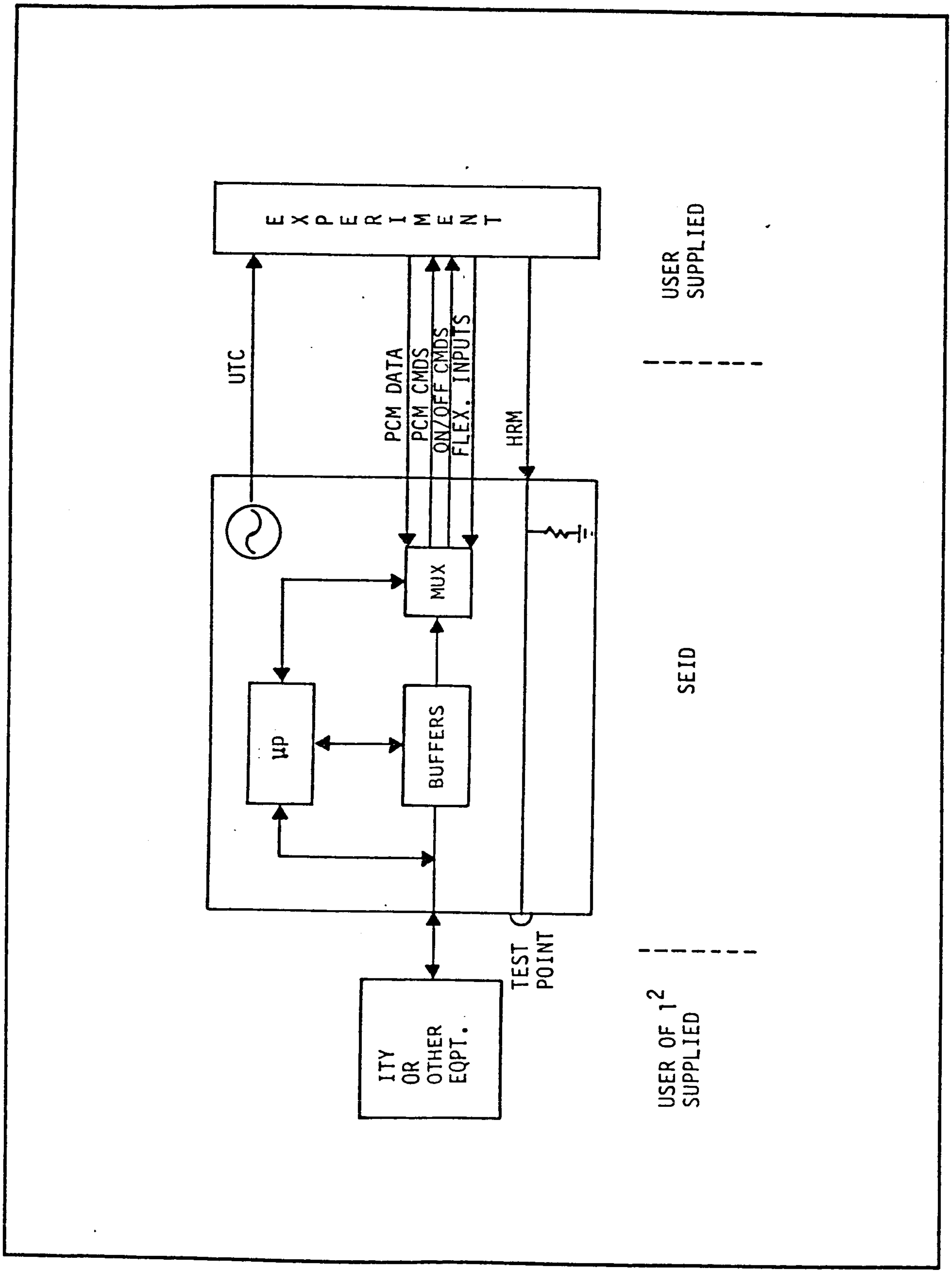

Fig. 7. SEID Functional Diagram.

The SLAC/EGSE would be built around a PDP 11/44 mini-computer. It would have two terminals, a printer, and three tape drives integrated with two tape formatters. Two tape drives would be used for real time data capture during test, calibration, integration and during the mission, and the other tape drive would be used for quick-look analysis and software development. A dual floppy disk for additional storage and software development would also be required.

2.2.3 SLAC Mechanical Ground Support Equipment

The SLAC instrument would be aligned, tested and calibrated at SAO using a modified version of the existing 16 meter long evacuable solar simulator test chamber. This test chamber (see Figure 8) can be used to simulate coronal observations at ultraviolet wavelengths and would be used for radiometric and wavelength calibrations as well as stray-light testing of the SLAC instrument.

2.2.4 SLAC Software

Software to be developed for the SLAC program consists of software designed to reside in the SLAC instrument controller hereafter called the DEP, software designed to reside within the hardware/software development station provided with the DEP, software designed to reside within the EGSE, software designed to reside in the Spacelab Experiment Computer (EC) as Experiment Computer Application Software (ECAS) and Operations Software (ECOS), and software residing in the NASA computer at the Payload Operations Control Center (POCC). BASD would be responsible for acquiring and generating rudimentary software resident in the DEP and DEP software development station. SAO would be responsible for acquiring and developing the software to reside in the EGSE and for expanding upon the DEP software for the test and calibration program and flight operations. We assume that NASA will be responsible for providing the software residing within the EC and the NASA computer at the POCC.

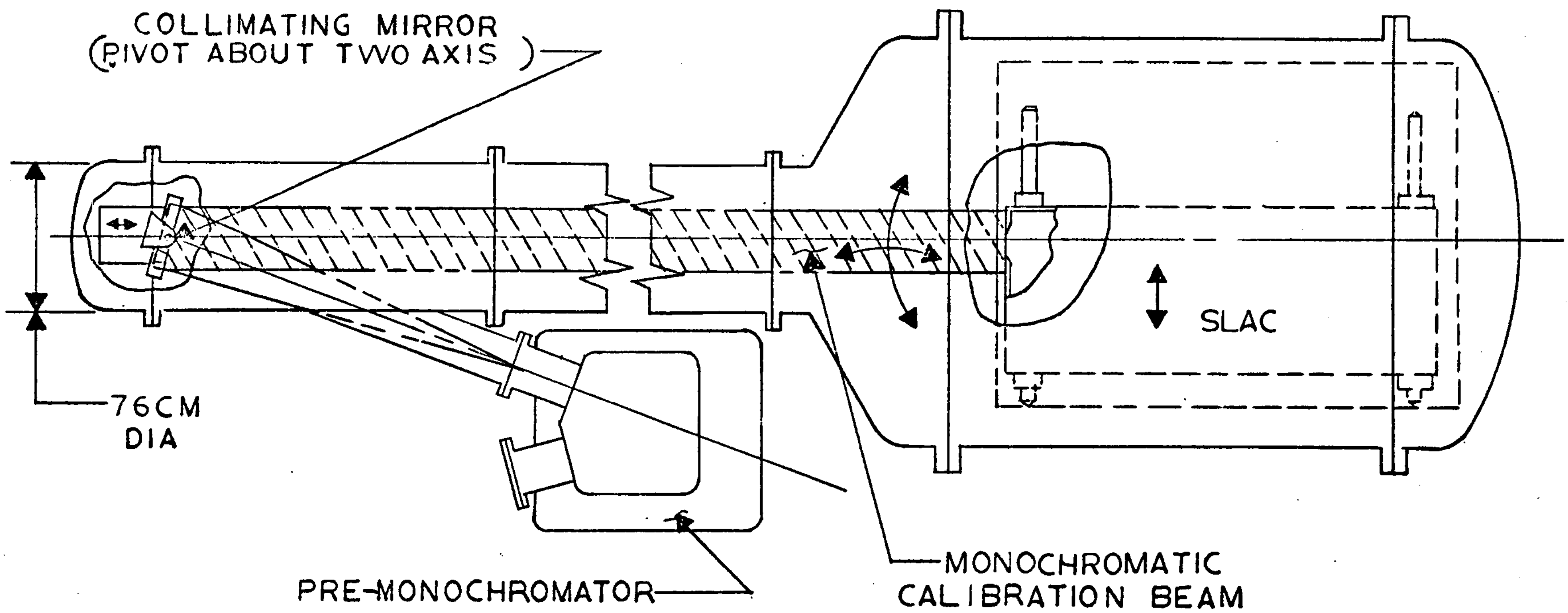

Fig. 8. Radiometric Calibration Arrangement.

DEP Software

The DEP controls the SLAC instrument, gathers data from the instrument, sends telemetry blocks to the HRM interface for transmittal to the ground and communicates with the EC through the RAU interface. During ground testing the DEP can be controlled through its RS-232 interface or through the RAU interface.

The software resident in the DEP would consist of five modules: (1) Instrument operation software, (2) sequential control driver software, (3) ECOS/ECAS interface software, (4) standardized routines furnished by the manufacturer of the DEP (i.e., Sperry) for interface control and self test operations and (5) telemetry formatting software.

BASD would procure the Sperry standard routine for interface control and self test operation along with the DEP hardware (designated as FMDM by Sperry). BASD would write the remaining software modules in a form sufficient for instrument check-out. SAO would provide the requirements for these software packages early in the program.

The BASD prepared sequential control software and ECOS/ECAS interface software would be sufficiently complete to check out interfaces with the instrument operation software and to perform instrument acceptance testing. These latter software modules would be upgraded by SAO for the testing and calibration program and for flight operations. In order to facilitate this SAO effort, BASD would structure the software for easy changes in the sequential control and ECOS/ECAS interface drivers and would furnish documentation, familiarization and design reviews as required to provide SAO with sufficient understanding of the resident software to permit them to alter, expand upon and interface to it.

SAO would develop software modules for sequential control and ECOS/ECAS interface and telemetry formatting that would be used in the instrument testing and calibration program and flight operations. These software modules would be installed after instrument delivery to SAO. These modules would be developed at SAO using a standard Z-80 microprocessor which is functionally equivalent to the flight quality Z-80 microprocessor in the DEP. The software would probably be written in the STOIC (Stack Oriented Interactive Compiler) language. STOIC is a general purpose interactive program which incorporates the capabilities of a compiler, assembler, debugger, loader, and operating system within a single consistent architecture. It is memory efficient while retaining high running speeds. In addition, the language is extremely flexible, permitting the user to develop a working vocabulary of routines tailored to his specific applications. the language is ideally suited to the task of designing software for a DEP in a spectroscopic instrument that is controlled in an interactive fashion by an external operator. This flexibility will be of particular value in the test and calibration program. The ECOS/ECAS interface would be designed so that the operator can control the experiment with simple alpha-numeric words such as HV ON, DOOR OPEN, RUN SURVEY, RUN MODES 8, 9, 12, etc. Control information uplinked from the POCC, however, would be in an extremely bit-efficient format.

EGSE Software

The GSE consists of two types of equipment, a DEP hardware/software development station and the EGSE. The hardware/software development station is utilized in the development of software for the DEP and control of the DEP for operations on the ground during the hardware development program. The software for this development station consists of standard material provided by the supplier of the development station.

The hardware and software for the EGSE to be used in the test, calibration, integration and mission operation phases of the program would be developed by SAO. Standard software development for the two processors in this system (SEID and PDP 11/44) would be purchased from the manufacturers. The remaining software would be developed by SAO and would make maximum use of software routines developed for other programs, particularly the rocket coronagraph program. Since all of our existing software routines are used in PDP equipment, they could be easily transferred to the EGSE.

The major elements of the EGSE software consists of packages for (a) real time data capture and recording, (b) display of real time and/or recorded data in digital and graphical formats on a CRT display or printer/plotter, (c) performing analyses of data (either test or flight data), (d) controlling the flight and test equipment during ground testing, (e) generating command sequences, and (f) simulating the relevant functions of the EC. Many of the software packages (especially in a, b, and c) would be used for both the testing and calibration programs and for flight operations in the POCC. We expect to develop and check out all of the EGSE software critical to the test and calibration program prior to delivery of the SLAC to SAO. Modification of the software packages necessary for flight operations at the POCC would be undertaken after instrument delivery.

Final Data Reduction Software

The reduction of final data would be performed using the Solar and Stellar Division PDP 11/60 computer which is currently being used in analysis of data acquired by the rocket coronagraph program. The EGSE system may also be utilized for processing final data from SLAC. Most of the software developed for quick-look analyses of the test and flight data would also be used in the final data reduction program. We anticipate that some of these software packages would be modified as a result of experience gained during the test and flight program in order to optimize reduction of the flight data. The software required for theoretical interpretation of the data would be build upon software already developed or currently under development for the rocket coronagraph.

NASA Software (ECOS/ECAS/POCC)

The detailed specifications for the ECAS software, ECAS display page formats, formats for the ECOS generated display pages and formats for the POCC CRT displays would be provided early in the Implementation Phase when the instrument design becomes finalized. A software package which simulates certain ECOS/ECAS functions would be written by SAO for the EGSE for testing the ECOS/ECAS interface software in the DEP.

2.3 WLC Instrument Characteristics*

The High Altitude Observatory (HAO) Spacelab White Light Coronagraph (WLC) telescope hereafter referred to as WLC or telescope consists of a precision electro-mechanical-optical telescope with external and

*The information contained in this report concerning the WLC is intended to serve as an overview from the SAO perspective and should not be construed as a statement of the High Altitude Observatory under any contracts they may have held with NASA.

internal occultation designed to study the solar corona from 1.2 solar radii up to 8 solar radii from the disk center.

the WLC instrument is composed of the following major subsystems: mechanical (aperture door, light tube/optical bench combination, optics housing and structural mounts), optical (external occulting disks, heat dump mirror, focussing lenses, folding mirrors, internal occulting disk and polaroid filters), thermal control (heater panels, multi-layer insulation and surface coatings), data recording (35 mm film camera) and electrical (8080A processor, motor drives, Thermal Control System (TCS) controllers and power supplies).

The door mechanism, flip mirror and calibration path devices are designed with a manual override system. In the event of a primary drive system failure, the component can be manually removed from the optical path.

The camera is identical to the one used successfully on the Skylab Apollo Telescope Mount (ATM) mission and is thus space-qualified.

In addition to the main structure, an electronics assembly (separate from the telescope) would operate the WLC. The electronics rack would be detached from the telescope primarily to eliminate the thermal heat source from the precisely aligned telescope and would not be coupled to SLAC.

The near 0° C environmental conditions provided by the Spacelab thermal shroud dictate that the WLC telescope structure must be equipped with heater panels. Therefore an active Thermal Control System (TCS), in conjunction with Multi-Layer Insulation (MLI) blankets and surface finishes, would be provided to heat the structure to hold the temperature to within a 21±3° C range for proper operation.

The telescope would be kinematically hard-mounted onto the SLAC,and the joint instrument would become a coaligned, co-observing instrument package. During a normal observing mode, the WLC instrument would take white light photographs of the corona and a hydrogen alpha (Hα) picture of the solar disk while SLAC makes simultaneous, cospatial UV coronal measurements. Since it is anticipated that the WLC filter movements may introduce EMI problems while SLAC is simultaneously obtaining data, a SLAC supplied synchronization signal would be provided to inhibit such motions within WLC until appropriate times.

The WLC functional block diagram is shown in Figures 1 and 9.

The electrical interfaces between WLC and Spacelab are shown in Figures 1 and 10. The only mechanical interface that exists is between WLC and SLAC as shown in Figures 1 and 2.

2.4 Mission Characteristics

Any earth orbit above 200 km is satisfactory; however, it is desirable to have an orbit above 400 km. A minimum of 7 days for experiment operation is highly desirable; therefore, a 14-day mission is preferred to insure an acceptable environment during operations. ARC must be pointed accurately, and roll positioning would be periodically required. SLAC observations would be seriously impeded by contamination clouds, since many contaminants are opaque in the EUV region, and stray-light levels from scattered solar disk radiation could prohibit measurements. Hence, Orbiter attitudes and orbits requiring frequent thruster firings are undesirable.

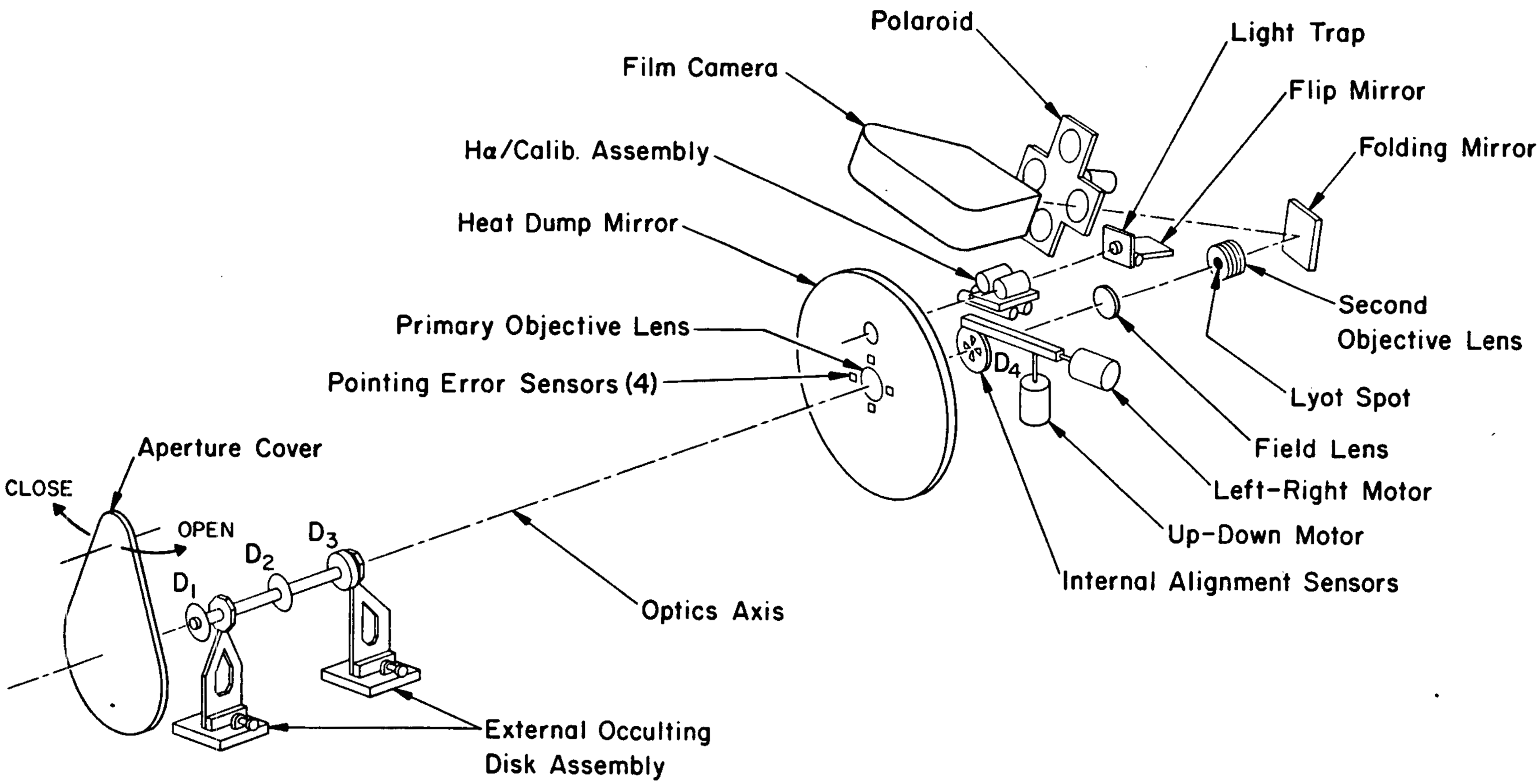

Fig. 9. HAO White Light Coronagraph Optical System Layout.

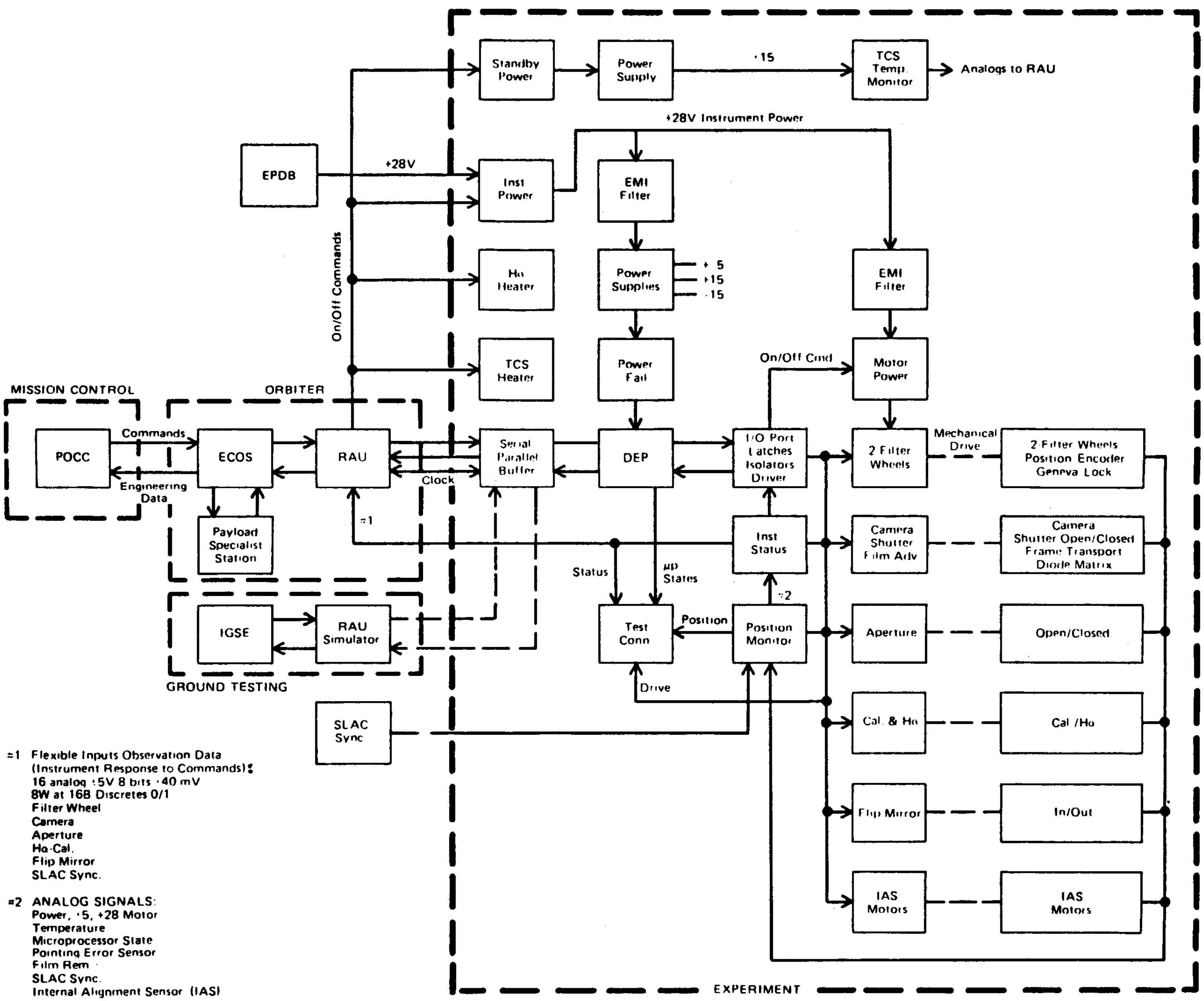

Fig. 10. WLC Electronics Block Diagram.

3. EXPERIMENT REQUIREMENTS DOCUMENT

A preliminary version of the Experiment Requirements Document (ERD) was prepared in accordance with the requirements of Section 4.3 of the Statement of Work contained in NASA Contract NAS5-26079 to the Smithsonian Astrophysical Observatory. The input provided was organized in direct response to Data Requirement No. 2 of NASA/GSFC Document DR-I-79 as further amplified by the NASA/GSFC Document entitled "Instructions for Data Requirement No. 2 of DR-I-79 (Experiment Requirements Document)" dated February 1980.

In accordance with these instructions, the initial ERD submittal emphasized Sections 1 (General Information), 2 (Physical and Functional Requirements) and 6 (Flight Requirements) and treated Sections 3 (Experiment Operational Procedures), 4 (Facilities and Support Requirements), 5 (Preflight Operations Requirements) and 7 (Postflight Experiment Requirements) as areas to be expanded upon later when the ERD was finalized. This document provided a preliminary idea of our STS/Spacelab requirements and in no sense described our final requirements, which were to be provided during the Implementation Phase.

The SAO/SLAC and HAO/WLC are co-observing instruments which, together, comprise the Acceleration Region Coronagraphs (ARC) experiment. ARC is considered to be a single instrument in the mechanical/optical sense but SLAC and WLC function as separate instruments in the electrical/thermal sense. Hence, the mechanical/optical requirements for SLAC and WLC were merged in the ERD and are described together under ARC headings whereas the electrical/thermal interface requirements are described separately under SLAC and WLC headings. Some categories discussed individually in this initial ERD submittal (e.g., Experimental Observations) were to merged in the future as the joint characteristics of the program became more fully developed.

Twenty (20) copies of this 110 page document were transmitted to NASA/GSFC on 15 September 1980.

4. INVESTIGATION DEVELOPMENT PLAN

The Investigation Development Plan (IDP), which described our plans for implementing the major program elements of the investigation, was prepared in accordance with the requirements of Section 4.2 of the Statement of Work of NASA Contract NAS5-26079 to the Smithsonian Astrophysical Observatory. The input provided was organized in direct response to the outline provided in NASA/GSFC Document DR-I-79, Data Requirement No. 1. It included a discussion of the following topics:

1. INTRODUCTION—Brief discussion of scientific objectives, investigative approach, overall development concept, project organization, etc.

2. APPLICABLE DOCUMENTS—Listing of major documents that apply to the experiment equipment and software.

3. SYSTEM DESCRIPTION—Description of equipment and software, including IGSE, that will be furnished by the developer. Indication of new development items.

4. SCHEDULES—Presentation of schedules of major program activities such as hardware/software design, manufacturing, verification, documentation preparation, instrument reviews, deliveries, data analysis, and field support.

5. WORK BREAKDOWN STRUCTURE—Description of a work breakdown structure for the planned activities.

6. PLANNED ACTIVITIES DESCRIPTION—A brief description of each of the planned activities and the approach for implementation.

7. ORGANIZATION PLAN—Definition of the organization that will perform this investigation.

8. CONTRACT PLANS—Description of plans for contracting major elements of support and interrelationships of the investigator team with contractors and the NASA organization.

9. MISSION OPERATIONS—Definition of approach and support required for mission operations.

10. FIELD SUPPORT—Description of plan for supporting integration and flight and postflight operations involving developer's experiment and associated equipment.

11. MISSION/PAYLOAD SPECIALIST DEFINITION—Definition of support and training required for supporting the investigation.

12. SHIPPING METHOD—Description of shipping plans.

13. SCIENTIFIC DATA ANALYSIS AND POSTFLIGHT REPORTING—Description of plans for completing scientific data analysis and postflight reporting.

14. OTHER PLANS—Description of plans as specified in applicable documents for:
    a. Reliability and Quality Assurance (including parts, materials and processes control plans)
    b. Software Development
    c. Verification
    d. System Safety
    e. Configuration Management
    f. Contamination Control

15. RESOURCES PLAN—An estimation of resources required (manpower, money, government-furnished property, and facilities) by major work breakdown element and timephase. This is a separately bound section of the IDP.

16. COST CONTROL AND REPORTING—Description of plans for controlling and reporting program costs in the resources plan.

In preparing the IDP, we considered two approaches for the SLAC instrument—a Full-Program, which fully utilized the microchannel array detectors, and a Base-Program, which provided a cost savings but used an array detector for limited observations of only H I Lyman alpha and used conventional Channel Electron Multipliers (CEM's) for shorter wavelengths. The major portion of the IDP described the Full-Program and the Base-Program was dealt with in Appendix B, which contained a separate budget and a description of the reductions in the SLAC instrument.

The IDP was divided into two parts with Part I describing the SAO portion of the program and Part II the HAO portion.

An attachment to the SLAC part of the IDP (Attachment I--SLAC Definition Phase Design Study Report) was also prepared. The purpose of this supplemental report was to describe the design of the SLAC instrument that resulted from the Definition and to document the basis for its makeup. Where significant, the report identifies the alternate solutions considered and the basis for their dismissal when applicable. It covers the general instrument concept; describes the detail designs associated with the telescope, spectrograph, electronics, detection and thermal systems; discusses the vacuum considerations within the system; and reviews the mechanical and thermal interfaces, the operation of the instrument and the test and calibration activities. Appended to this Design Study Report are four appendices that document: A) the design and performance requirements placed on the SLAC instrument and its major components and subsystems; B) the thermal analyses, model and results on the SLAC instrument in the Spacelab IPS environment; C) the structural and mass properties description of the ARC; and D) the modifications to the SLAC instrument required to reach the configuration upon which the Base-Program is structured.

Twenty (20) copies of the 333 page IDP were transmitted to NASA/GSFC on 15 September 1980, and twenty (20) copies of the 218 page Design Study Report were submitted to NASA/GSFC on 29 October 1980.

5. PROGRAM REVIEWS

5.1 Requirements Review

A Requirements Review was held at NASA/GSFC on 29-30 October 1980 in order to evaluate the readiness for entering into design. During this review, the preliminary Experiment Requirements Document and the Investigation Development Plan were reviewed in detail with emphasis on the design concepts, interface requirements, operational requirements and safety.

5.2 Informal Reviews

Two (2) technical reviews were held with NASA/GSFC during the course of this contract. The first was held on 16-17 April 1980 at NASA/GSFC and the second was held on 24 July 1980 at HAO's facility in Boulder, CO.

6. DEVELOPMENT OF LONG-LEAD ITEMS

In January 1981, supplemental funding was received from NASA that allowed SAO to undertake the following long-lead time development tasks:

- Layout of the required anode array and preparation of engineering documentation suitable for use in the procurement of the anode assemblies required in the detectors.

- Procurement of the anode array detector headers (2), microchannel plate (1), breadboard amplifier/discriminator (1) and vac-ion pump power supply (1).

- Initiation of a preliminary engineering study of the SLAC grating drive.

- Continuation of the solar simulator and test chamber modifications at the light-source end of the chamber.

- Initiation of construction of SLAC mock-up for stray-light tests.