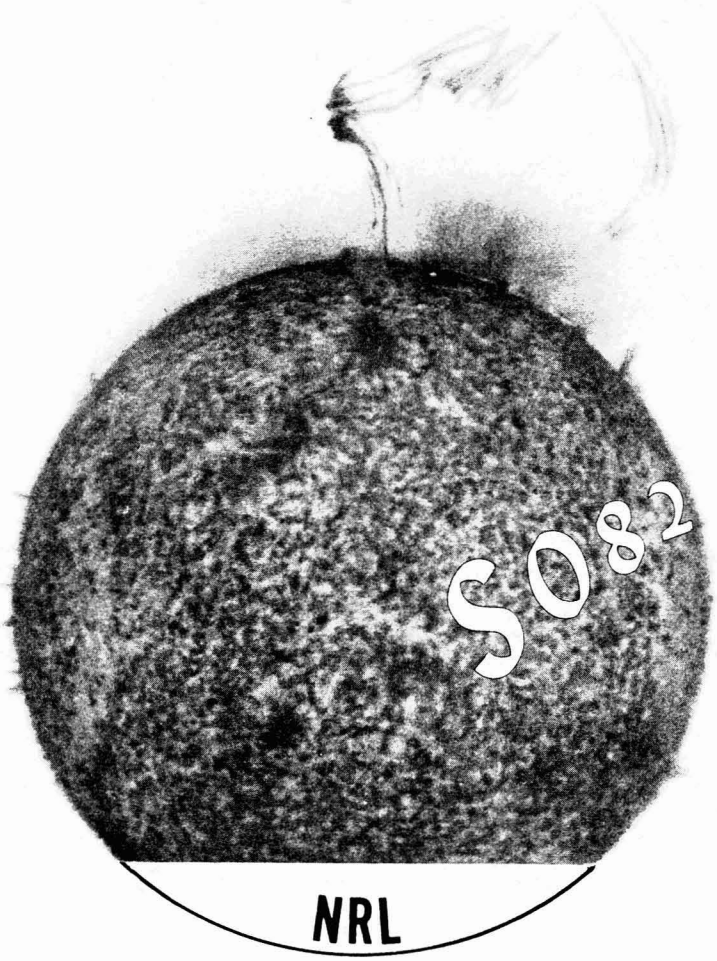
N. P. Patterson

NRL/ATM PROGRAM



FINAL REPORT

PREPARED FOR
US NAVAL RESEARCH LABORATORY
WASHINGTON, D.C.

BALL BROTHERS RESEARCH CORPORATION
SUBSIDIARY OF BALL CORPORATION
BOULDER, COLORADO

A HUGE ERUPTION FROM THE SURFACE OF THE SUN SEEN IN THE LIGHT OF HE II AT 304Å
9 AUGUST 1973

This photograph, obtained during the Skylab 3 Mission, reveals for the first time that helium erupting from the sun can stay together to altitudes up to 500,000 miles. After being ejected from the sun, the gas clouds seem to have come to a standstill, as though blocked by an unseen wall, and some material appears to have been directed back toward the sun as rain, distinguished by fine threads. At present it is a challenge to explain this mystery — what forces expelled these huge clouds, then blocked its further progress, yet allowed the cloud to maintain its threads. Both magnetic fields and gravity must play a part, but these curious forms seem to defy explanation based on magnetic and gravitational fields alone.

The instrument which produced this image was an extreme ultraviolet spectroheliograph, designed and constructed by the Naval Research Laboratory and the Ball Brothers Research Corporation under the direction of Dr. R. Tousey, the Principal Investigator for this NASA experiment. To the left may be seen the sun's image in emission from iron atoms which have lost 14 electrons by collision in the suns' million-degree coronal plasma gas.

BALL BROTHERS RESEARCH CORPORATION

BOULDER, COLORADO

FINAL REPORT

NRL/ATM PROGRAM

620-225 7 June 1974

Contract No. N00014-67-C-0470
(DPR-S-60404-G)
Exhibit C-1 Phase III CDRL
Sequence No. 15

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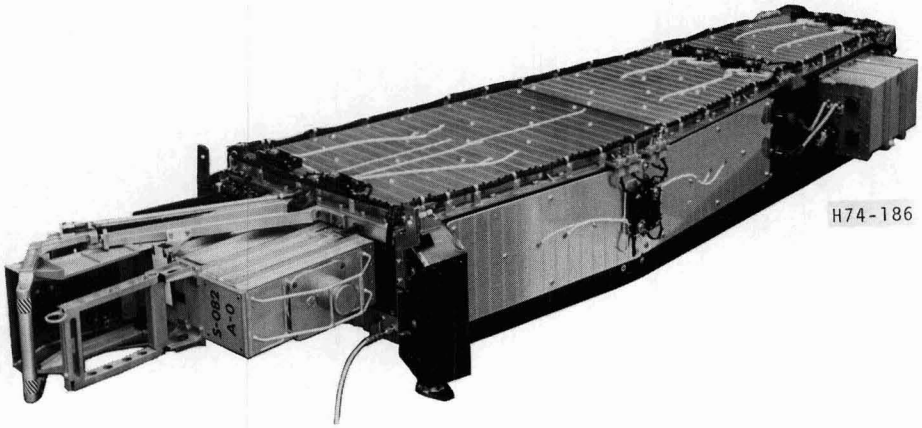
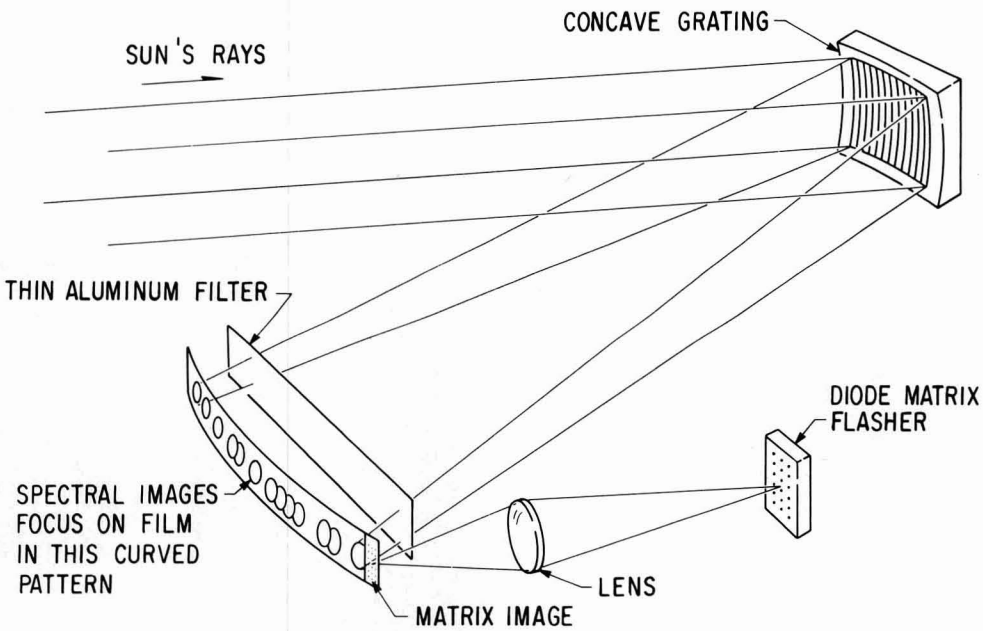
FORM BR-72

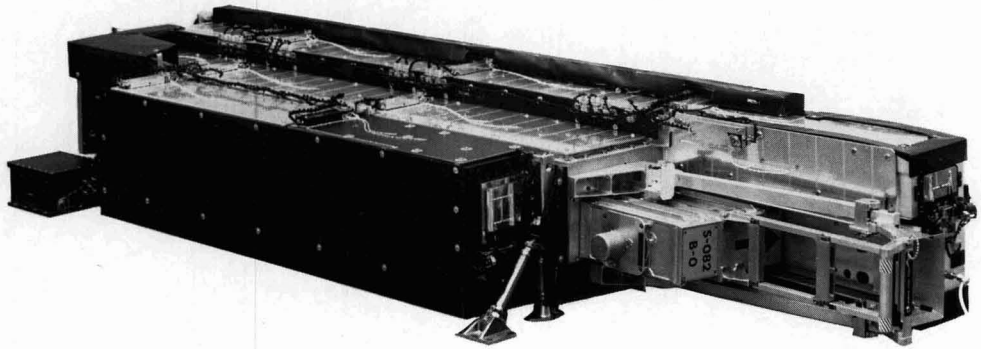


S-082A CORONAL XUV SPECTROHELIOGRAPH



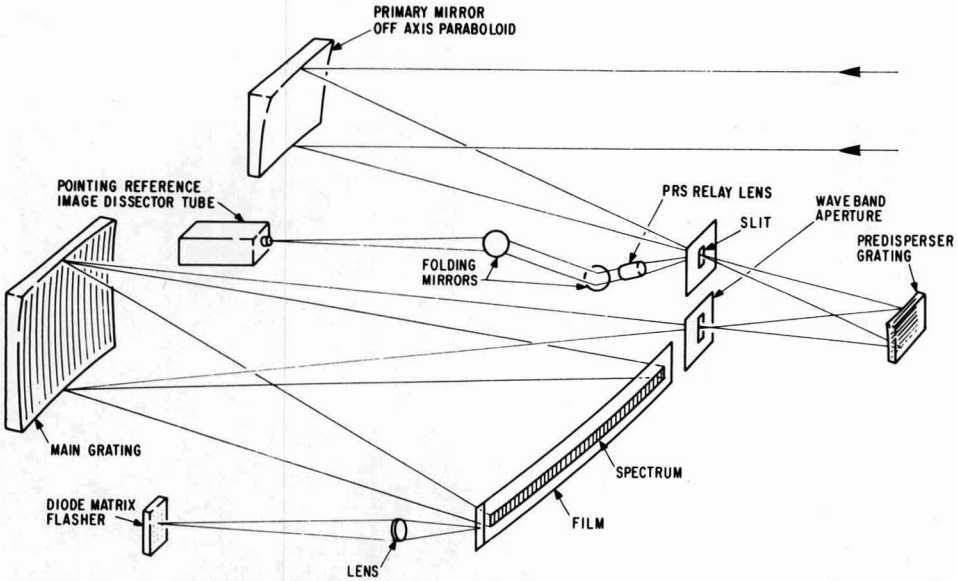
SCIENTIFIC PARAMETERS

SPECTRAL RANGE:	150Å - 335Å; 321Å - 625Å
SOLAR IMAGE DIAMETER:	18.6 mm
DISPERSION ALONG SOLAR DIAMETER:	24Å
RESOLUTION SPECTRAL:	0.13Å for feature 10 arc-seconds in size
SPATIAL:	~5 arc-seconds (depends on λ and thermal control)
GRATING LINE DENSITY:	3600 lines/mm
WIDTH OR FULED AREA:	120 mm
FOCAL LENGTH:	2.0 m
SPECTRAL ORDER:	1st
REQUIRED ATM POINTING STABILITY:	± 2.5 arc-second - pitch, yaw ± 7.5 arc-minute - roll



H74-185

S-082B CORONAL XUV SPECTROGRAPH



SCIENTIFIC PARAMETERS

SPECTRAL RANGE:	970Å through 1970Å - (2nd Order); 1940Å through 3940Å - (1st Order)
SPECTRAL RANGE:	970Å through 1970Å - (2nd Order); 1940Å through 3940Å - (1st Order)
RESOLUTION SPECTRAL:	0.08Å (2nd Order); 0.16Å (1st Order)
SPATIAL:	~3 Arc-Seconds
DISPERSION:	8.3 $\frac{Å}{MM}$ (1st Order); 4.2 $\frac{Å}{MM}$ (2nd Order)
SLIT SIZE:	10μ x 300μ (2 x 60 Arc-Seconds)
GRATINGS PREDISPERSER (2):	150 Lines/MM; 36 MM Wide; 50 CM Radius; 300 Lines/MM; 36 MM Wide; 50 CM Radius
MAIN:	600 Lines/MM; 152 MM Wide; 200 CM Radius

FOREWORD

This document contains the report on the NRL/ATM program from development through flight performance. Experiment conceptual design and all optical systems design were performed at the Naval Research Laboratory, Washington, D.C., under the direction of Dr. R. Tousey and Mr. J. D. Purcell. Ball Brothers Research Corporation, Boulder, Colorado (BBRC), performed the mechanical and electrical design, development, fabrication, and test of the S082A Coronal Spectroheliograph, S082B Spectrograph, Flight Design Verification Units, Calibration Systems, and Support Equipment. These efforts were performed under Contract No. N00014-67-C-0470 with the Naval Research Laboratory and under the technical direction of the NRL Principal Investigator, Dr. R. Tousey, and the NRL program manager, Mr. R. Schumacher. This document was prepared in accordance with the requirements of Sequence No. 15 of the Phase III Contract Data Requirements List, Exhibit C-1 to the Contract.

ACKNOWLEDGMENTS:

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1.0 PROGRAM CONTRACTUAL SUMMARY

1.1 CONTRACTUAL REQUIREMENTS

Ball Brothers Research Corporation (BBRC), Boulder, Colorado was awarded Contract No. N00014-67-C-0470 on 1 June, 1967, retroactive to 15 March 1967, by the Naval Research Laboratory (NRL), Washington, DC. This was a contract for the design, development, fabrication and test of an Extreme Ultraviolet (XUV) Coronal Spectroheliograph (Instrument A), XUV Spectrograph (Instrument B), XUV Video Detector System (XUV Monitor), and Rocket Flight Design Verification Units (RFDVU). The Instrument A, Instrument B and XUV Monitor were solar observation instruments for use in the Apollo Telescope Mount (ATM) of the Apollo Applications Program (subsequently designated as Skylab). The RFDVU's were the engineering flight verification units for the ATM instruments' designs. Preliminary design was accomplished in part on Contract No. N00014-66-C-0077 which was scheduled for the Advanced Orbiting Solar Observatory (AOSO) Spacecraft, a non-manned vehicle, containing an NRL UV Spectroheliograph instrument. This contract was canceled as the result of the cancellation of the AOSO Program.

Subsequent modifications to this contract added the following major efforts:

- An Additional XUV Spectroheliograph, Spectrograph and XUV Monitor Designated S053 (This requirement was deleted 4 Oct, 1969.)
- Calibration Rocket Instruments
- Astronaut Training Hardware
- Experiment Checkout Equipment
- Spare Flight Cameras and Canisters

- Spare Flight Parts (Reference BBRC Document No. 620-26)
- Refurbishment and Reflight of Flight Design Verification Units (FDVU's)
- Refurbishment and Reflight of Calibration Rocket Instruments
- Refurbishment of Qualification ATM Hardware to Flight Quality Flight Backup Units (FBU's)
- System Integration and Test Support of Refurbished Qualification Hardware on the ATM Flight Backup Unit
- Integration Timing and Control Unit
- FDVU Film Camera
- Phase III Post-Delivery Support (MSFC)
- JSC Mission Engineering Support
- Flight Controllers
- KSC Launch Support
- Engineering Data and Drawings Submittal
- Post-Mission Support
- Clean Room Purge System
- NRL/HCO/ATM Transporter Purge System
- Balloon Ozone/Nitric Oxide Experiment

The contract was a composite of the original contract plus 25 change orders and 64 modifications. The contract schedule contained 38 items of work, of which Item 13 contained 213 engineering change proposals (ECP's). For a detailed status of all ECP's, refer to BBRC Document No. 620-5, Configuration Status Report for NRL/ATM SO82 Instruments.

1.2 MILESTONES

Major end items were designed, fabricated and tested to BBRC prepared, and NRL approved, Design and Performance Specifications (D&PS) and End Item Test Specifications per contract requirements. Delivery of hardware was accomplished using DD Form 250 for transfer of title. Figure 1-1 is a chart depicting the major milestones during the program, Table 1-1 is a listing of major hardware items delivered under the contract, and Table 1-2 is a summary of the major problems and resolutions.

Documents were delivered to the customer by letter of transmittal and Section 8.0 contains a listing of the major documents prepared under the contract.

Field support was provided at Marshall Space Flight Center (MSFC), Huntsville, Alabama, Johnson Space Center (JSC), Houston, Texas, and John F. Kennedy Space Center (KSC), Kennedy Space Center, Florida, during the ATM system integration, system tests, prelaunch tests and flight activities. Field support was also provided at a number of facilities to support integration, test and launch of the RFDVU's, the Calibration Rocket (CALROC) instruments, and NRL/BBRC Balloon Payload.

The FDVU's successfully demonstrated the design concepts of the ATM SO82A and SO82B Instruments. The CALROC Instrument successfully provided calibration data for correlation with data obtained from

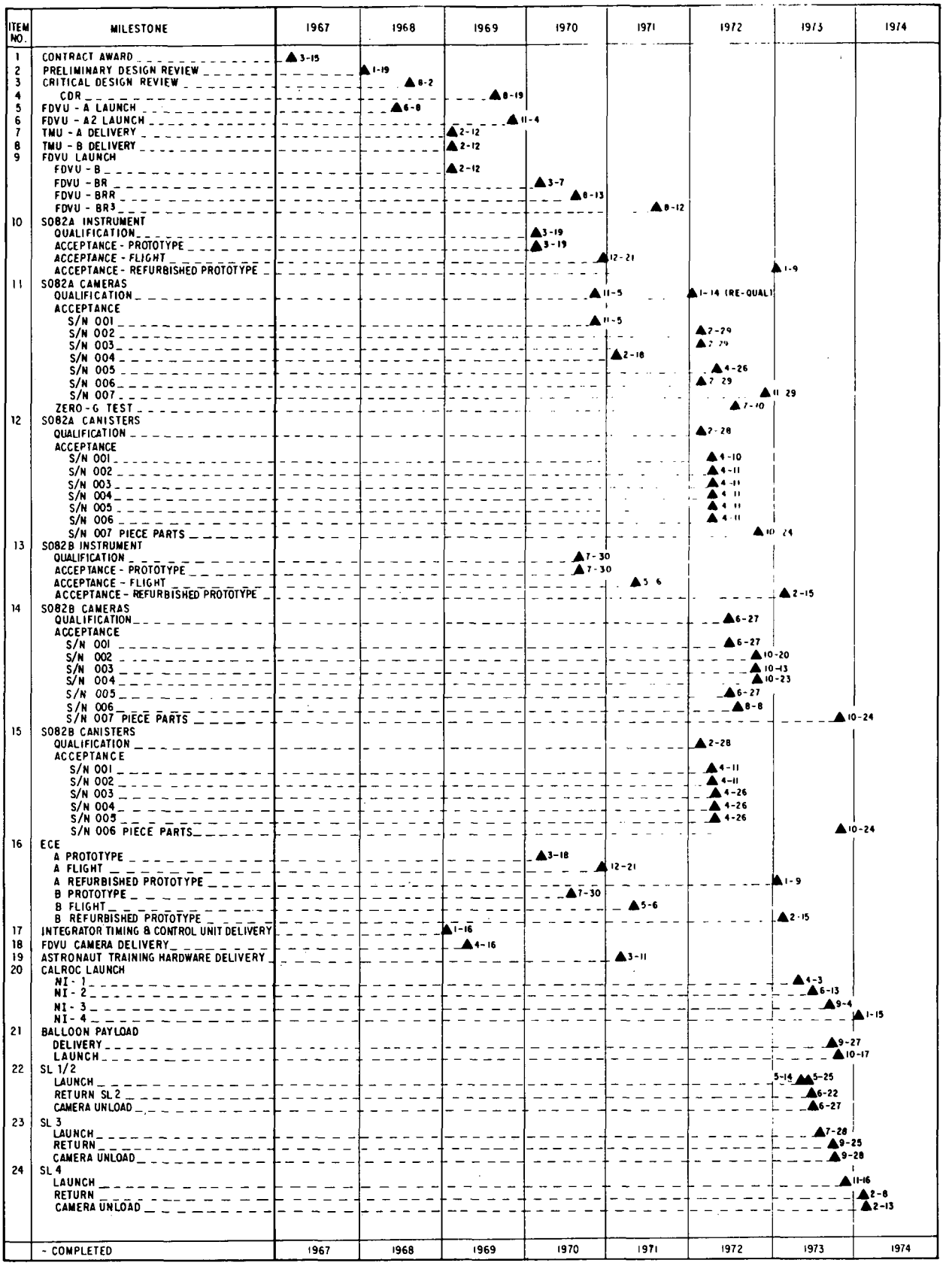


Figure 1-1. Major Milestones

Table 1-1

Major Hardware Items Delivered Under Contract

Sheet 1 of 4

Contract Item No.	Delivery Date	Description
3	2/12/73	26502-1 XUV Coronal Spectroheliograph, Engineering Model
3	2/12/73	26503-1 XUV Spectrograph, Engineering Model
4	5/6/68	Rocket Flight DVU, Instrument A
4	1/31/69	Rocket Flight DVU, Instrument B
5	2/14/69	Thermal Unit A
5	2/16/69	Thermal Unit B
14a	3/18/70	Prototype Spectroheliograph - Instrument A (Mission I)
14a	11/5/70	XUV Film Magazine (Film Camera) Prototype Serial No. A001 (Mission I)
14b	12/21/70	Flight Unit Spectroheliograph - Instrument A (Mission I)
14		Flight Unit Spectroheliograph - Instrument Cameras as follows:
14c	2/29/72	Serial No. A002
14c	2/29/72	Serial No. A003
14c	2/18/71	Serial No. A004
14c	4/26/72	Serial No. A005
29	2/29/72	Serial No. A006
29	11/29/72	Serial No. A007
14d	1/9/73	Refurbished Prototype Spectroheliograph and Film Camera
16		Experiment Checkout Equipment (ECE) (Instrument A) as follows:
16a	3/18/70	Prototype (Mission I)
16b	12/21/70	Flight (Mission I)
16e	1/9/73	Refurbished Prototype ECE

Table 1-1

Major Hardware Items Delivered Under Contract

Sheet 2 of 4

Contract Item No.	Delivery Date	Description
17a	7/30/70	Prototype Spectrograph - Instrument B (Mission I)
17b	5/6/71 7/3/71	Flight Unit Spectrograph - Instrument B (Mission I)
17c	6/27/72	Prototype Spectrograph - Film Camera S/N B001
17		Flight Unit Spectrograph - Film Cameras as follows:
17d	10/20/72	Serial No. B002
17d	10/13/72	Serial No. B003
17d	10/23/72	Serial No. B004
17d	6/27/72	Serial No. B005
29	8/8/72	Serial No. B006
29	10/24/73	Serial No. B007 (Piece Parts Only)
17e		Film Camera Canisters as follows:
	4/11/72	Serial No. A001
	4/11/72	Serial No. A002
	4/11/72	Serial No. A003
	4/11/72	Serial No. A004
	4/11/72	Serial No. A005
	4/11/72	Serial No. A006
	4/11/72	Serial No. B001
	4/11/72	Serial No. B002
	4/26/72	Serial No. B003
	4/26/72	Serial No. B004
	4/28/72	Serial No. B005
29	10/24/72	Serial Nos. A007 & B006 (Piece Parts Only)
17g	2/15/73	Refurbished Prototype Spectrograph - and Film Camera

Table 1-1

Major Hardware Items Delivered Under Contract

Sheet 3 of 4

Contract Item No.	Delivery Date	Description
19		Experiment Checkout Equipment - Instrument B, as follows:
19a	7/30/70	Prototype (Mission I)
19b	5/6/71 7/3/71	Flight (Mission I)
19e	2/15/73	Refurbished Prototype ECE
20	10/10/69	Rocket Flight Spectroheliograph Instrument FDVU-A2
21	1/17/69	Integration Timing and Control Unit
22	4/16/69	FDVU Camera
24	2/23/70	Rocket Flight Spectrograph Instrument RFDVU-BR
25	10/1/71 6/23/72 10/27/72 1/24/72	Electronic Type Spares Provisioning
29	10/24/73	Mechanical Spares
32	7/13/70	FDVU-BRR Restoration and Launch Support Including Offset Command System
33	11/13/70 4/20/71	Clean Room Purge System
34	2/26/74	Mounting Plates for Film Camera Canisters
35	12/24/70	NRL/HCO/ATM Transporter Purge System
36	3/11/71	Astronaut Training Hardware
37	8/10/72 11/15/72	FDVU-BR^3 Restoration and Reflight
38		NRL/ATM Calibration Systems as follows:
38a	10/2/7 2/8/73 3/19/73	3 Each Instrument Structures

Table 1-1

Major Hardware Items Delivered Under Contract

Sheet 4 of 4

Contract Item No.	Delivery Date	Description
38b	3/14/72 8/28/72 11/3/72	3 Each Spectroheliograph (A) Mechanical Subsystems
38c	10/2/73 2/8/73 3/19/73	3 Each Spectrograph (B) Mechanical Subsystems
38d	9/27/72 5/31/72 7/6/72	3 Each Spectrograph (C) Mechanical Subsystems
38e	10/18/72 8/3/72 4/25/72	3 Each Heliograph (H) Mechanical Subsystems
38f	10/2/72 2/8/73 3/19/73	3 Each H-Alpha (Hα) Mechanical Subsystems
38g	10/12/72 2/8/73 3/21/73	3 Each Instrument Electronics Subsystems
38h	10/12/73 2/8/73 3/21/73	3 Each IDT Fine Pointing System (FPS)
38i	10/12/72 2/8/73	2 Each Instrument (ICE) Checkout Consoles, Including a Telemetry Receiver and Discriminator
38j	11/7/72 9/5/72 9/5/72	3 Sets Telemetry Antenna Hardware
38k	9/27/73	Calibration System for S082B
38ℓ	2/26/74	Refurbishment of NI-2/3 Calibration Rocket

Table 1-2

SUMMARY OF PROGRAM MAJOR MILESTONES

Item	Problem	Resolution
1	Destruction of FDVU-A due to recovery system failure	Rebuild the FDVU-A payload
2	Lack of available NASA funds early in the program	BBRC provided company funds
3	Severe thermal environment imposed on ATM	BBRC designed and built an active thermal control system
4	Design problems occurred in the film cameras	A "Tiger Team" was established to provide sufficient resources to effect a redesign of certain mechanisms and maintain schedule
5	Miscellaneous test failures of both prototype and flight units	See BBRC Document numbers 620-158 and 620-163
6	CALROC instrument (NI-1) had a pointing failure and the recovery parachute failed to open	The schedule for the NI-2 instrument was accelerated to be used as an engineering model
7	S082A camera failed during SL-2 mission	An SL-3 S082A camera was utilized by the astronauts and a backup unit supplied for SL-3
8	Quality of engineering data received during the missions was not usable	Reprocessing of data by NASA and manual reduction of the data is being accomplished by BBRC

the ATM SO82A and SO82B Instruments. The SO82 Instruments provided all scientific data within performance parameters and the only significant failures were a jammed camera on the SL-2 Mission and a pointing reference subsystem (PRS) failure during the SL-4 Mission. The S/N A003 Film Camera jammed after exposure number 19 out of 200 exposures, but no data was lost due to replacement of the camera with a Mission SL-3 camera. A replacement camera for SL-3 was launched with the SL-3 crew. The failure of the PRS caused no significant effect on Mission SL-4 data.

1.3 EXPERIMENT OBJECTIVES

The experiment objectives were defined initially in the proposal for: Experiment A - ATM Coronal XUV Spectroheliograph, and Experiment B - ATM Chromospheric XUV Spectrograph which were submitted to NASA by NRL on NASA Form 1138 dated August, 1966. Revised proposals were submitted to NASA on Form 1346 dated 20 October 1967. The scientific objectives of the experiements were described in detail in these proposals, the basic design concepts for the two instruments were established and the operational requirements were defined. Objectives of the SO82A experiment were:

A. Record in great spatial detail the emission pattern of the entire chromosphere and corona.

B. Map different layers in the solar atmosphere, by selecting the appropriate XUV wavelengths to obtain solar temperature, density and composition ("weather") maps at many heights.

C. Study active regions, record their appearance at different heights and watch them develop from day to day.

D. Observe XUV emissions beyond the limb in the corona that originate from the rear side of the sun.

E. Record the development of solar flares, watch their temperatures change and see their effects propogate up through the atmosphere.

F. To photographically record coronal images of the sun in the various wavelengths between 150 and 650Å.

Objectives of the S082B Experiment were:

A. Obtain in great detail the spectra of selected small isolated regions of the sun.

B. Study, quantitatively, the change in the spectrum crossing from the photosphere, to the chromosphere, to the corona. Derive from this the detailed temperature and density model.

C. Record flare spectra with spectral resolution much greater than S082A.

D. Record spectra of special regions, and so determine their nature.

E. To photographically record line spectrograms of solar radiation between 970 and 1970Å and between 1940 and 3940Å.

From the experiment objectives and the NRL furnished basic design concepts, the design and performance requirements were developed into the D&PS specifications. The operational requirements were first developed and defined in the Astronaut Operations Requirements Documents (AORD), initially issued 5 May 1967 with several subsequent revisions. In March 1971, formulation of the Joint Observing Program (JOP) was initiated by the ATM Principal Investigators (PI's) as a group. The JOP, first published 1 September 1971, contained a consolidated statement of the research objectives of

all the ATM experiments as a group and the operational observing program required to meet these objectives. After several revisions by the ATM PI's, the JOP's were eventually incorporated into the formal NASA Mission Requirements Document (MRD) which became the official authority for operation of the ATM experiments during the Skylab missions.

Throughout the development of the ATM Program, from the initial definition of the objectives in 1966 to the last revision of the JOP in the MRD which occurred well into the Skylab mission, changes were required in the instrument operating procedures, often necessitating changes or additions to the instrument hardware.

1.4 PROGRAM MANAGEMENT

BBRC employed a combination of project and line organizations throughout the NRL/ATM Program. The project organization, directly responsible for achieving the goals of the NRL/ATM Program, was assigned to a particular individual, the Program Manager. To assist him in managing the many specific disciplines of the program, project engineers were assigned for the most significant, functional areas ordinarily emphasized by NASA programs. During different phases of the program, the project organization was adapted to the requirements of that particular phase activity. The nominal structure of this organization as it relates to the line organizations of the company is shown in Figure 1-2.

The line organizations were organized under, and managed by, the Director for Aerospace Technology and the Director for Aerospace Operations. Technology contained the personnel and facilities for detail design, packaging, design analysis, materials evaluation and reliability. Operations contained personnel and facilities for quality assurance, production shops, production process evaluation and test facilities. Personnel assigned to the NRL Program out of the Technology and Operations Organizations were located and

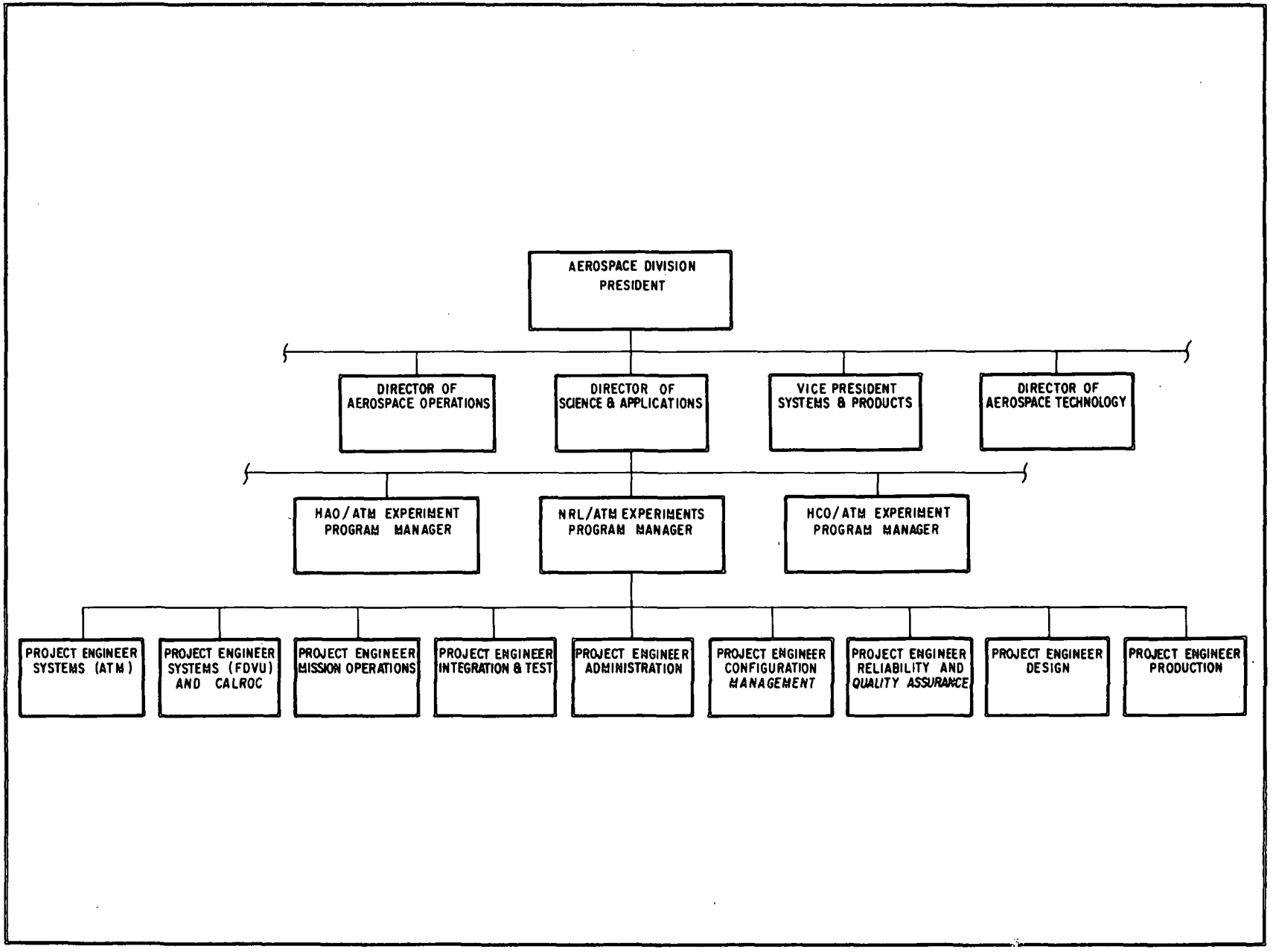


Figure 1-2. Management Organization Chart

organized into an integrated project team operating under the technical direction of the Program Manager and the appropriate Project Engineers. The responsibilities of each project engineer were as follows:

Systems (ATM) - The system project engineer was responsible for the technical interface with NRL and MSFC through the use of system and interface specifications. He had systems engineering responsibility for the ATM instruments and related equipment. Those reporting to him were responsible for the system design: mechanical, optical and electrical. He monitored the detail design and signed his approval of engineering drawings. He acted for the Program Manager in his absence. He was responsible for the systems engineering operations during the mission at MSFC.

Systems (FDVU & CALROC) - Managed the design, development, fabrication, test and launch support of the sounding rocket versions of the NRL/ATM instruments.

Mission Operations - Managed the personnel assigned to JSC for mission planning, astronaut training and mission support. He ensured that instrument operations during the mission would meet scientific and engineering objectives.

Integration and Test - Managed the engineers and technicians who performed the final systems integration and test. He also translated test specifications into plans and procedures, defined test facility needs, and provided personnel to support MSFC, JSC and KSC tests.

Administrator - The program administrator established work breakdown structure and task funding. He prepared manloading, expenditure, financial and progress reports, provided contract change proposals and technical support for contract negotiations. He also prepared all work orders for work direction by the Program Manager.

Configuration Management - Defined configuration tasks for control and accountability of the various hardware designs. He managed the preparation of all project documents and ECP's and maintained accountability of all technical material flowing to and from NRL and NASA.

Reliability and Quality Assurance - Managed and planned all QA & R activities to ensure that hardware reliability and quality would meet contractual and mission requirements.

Design - Managed the detail design activities, and defined design tasks and personnel requirements.

Production - The management of all production activities was performed by this project engineer. He defined the production facilities and personnel requirements to fabricate the various hardware designs.

2.0 DESIGN AND DEVELOPMENT

This section provides a summary description of the hardware design and development of the SO82A XUV Coronal Spectroheliograph, the SO82B XUV Spectrograph and the XUV Monitor Instrument Systems and Subsystems. The associated ground support equipment is also discussed. The design and development included reviews, analyses and tests to assure that the instruments, cameras, canisters and the ECE, as designed and fabricated, would meet the design and performance requirements. During 1967 and early 1968, a Preliminary Design Review (PDR) was conducted by MSFC to baseline the requirements documents.

The initial systems design, performance, fabrication and test requirements for the instruments were specified in BBRC Document Nos. CP25905 for SO82A and CP25100 for the SO82B and XUV Monitor. The requirements for the Experiment Checkout Equipment (ECE) were defined in BBRC Document Nos. CP24038 and CP24039 for SO82A and SO82B respectively. Additional NASA/BBRC interface requirements were specified in the MSFC controlled Experiment Interface Defining Document (EIDD) No. 50M02462 and Interface Control Document (ICD) No. 50M35586.

A Critical Design Review (CDR) was conducted by MSFC to baseline the hardware design. All critical instrument components were breadboarded, tested and evaluated as part of the design effort. The results of these development tests are contained in BBRC Document No. 620-40 entitled "Design Verification Test Reports for NRL/ATM Experiments SO82A and SO82B." The development items included Thermal Mechanical Units (TMU), Engineering Model Units (EMU) and Flight Design Verification Units (FDVU) of the SO82A and SO82B Instrument systems.

An in-depth description of further design and development details can be obtained from BBRC Document Nos. 620-158 and 620-163 entitled "Inputs to Skylab Design Certification Review Report for S082A and S082B" respectively.

Further definition of the systems descriptions and how they function is contained in BBRC Document Nos. 620-53 and 620-54 entitled "Description and Operating Instructions for S082A and S082B" respectively, BBRC Document Nos. 620-43 and 620-44 entitled "Description and Operating Instructions for ATM/LM Simulator and Checkout Console GS13 and GS14" respectively.

2.1 S082A XUV CORONAL SPECTROHELIOGRAPH

To meet the scientific objectives, the S082A XUV Coronal Spectroheliograph Instrument was designed as a slitless spectrograph. Figure 2-1 shows the instrument subsystems and major components of each subsystem. Figure 2-2 shows the arrangement of the major components within/on the instrument.

The instrument was comprised of a housing that enclosed a series of optical elements and to which was attached the control electronics, the thermal control system and a removable film strip camera.

The instrument provided both automatic film exposure sequences and manually controlled time exposures. The instrument was operated entirely by remote command from the ATM Control and Display (C&D) Panel during the mission or from the ECE during ground testing.

Spectroheliograms were photographically recorded by opening the instrument aperture door and then operating the film camera. After 200 exposures were completed, the film camera was removed from the instrument by an astronaut during EVA and returned to earth for processing.

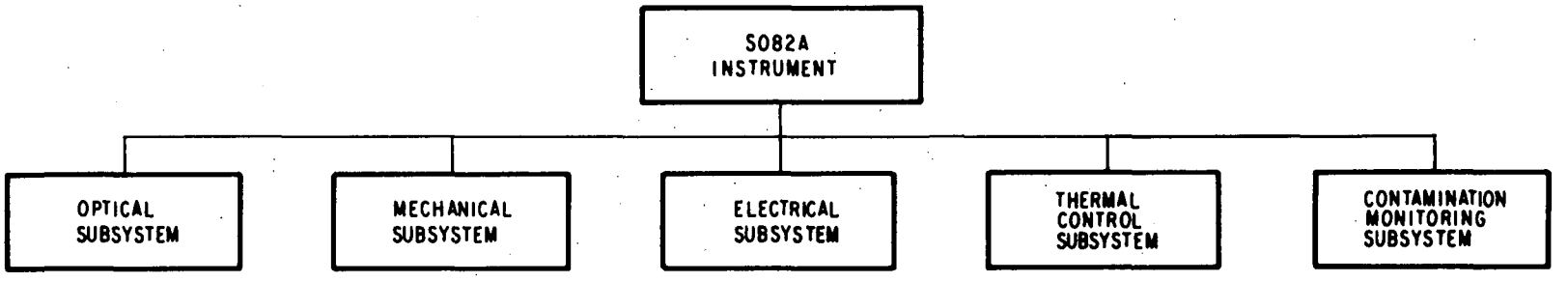


Figure 2-1. S082A Instrument Subsystems and Components

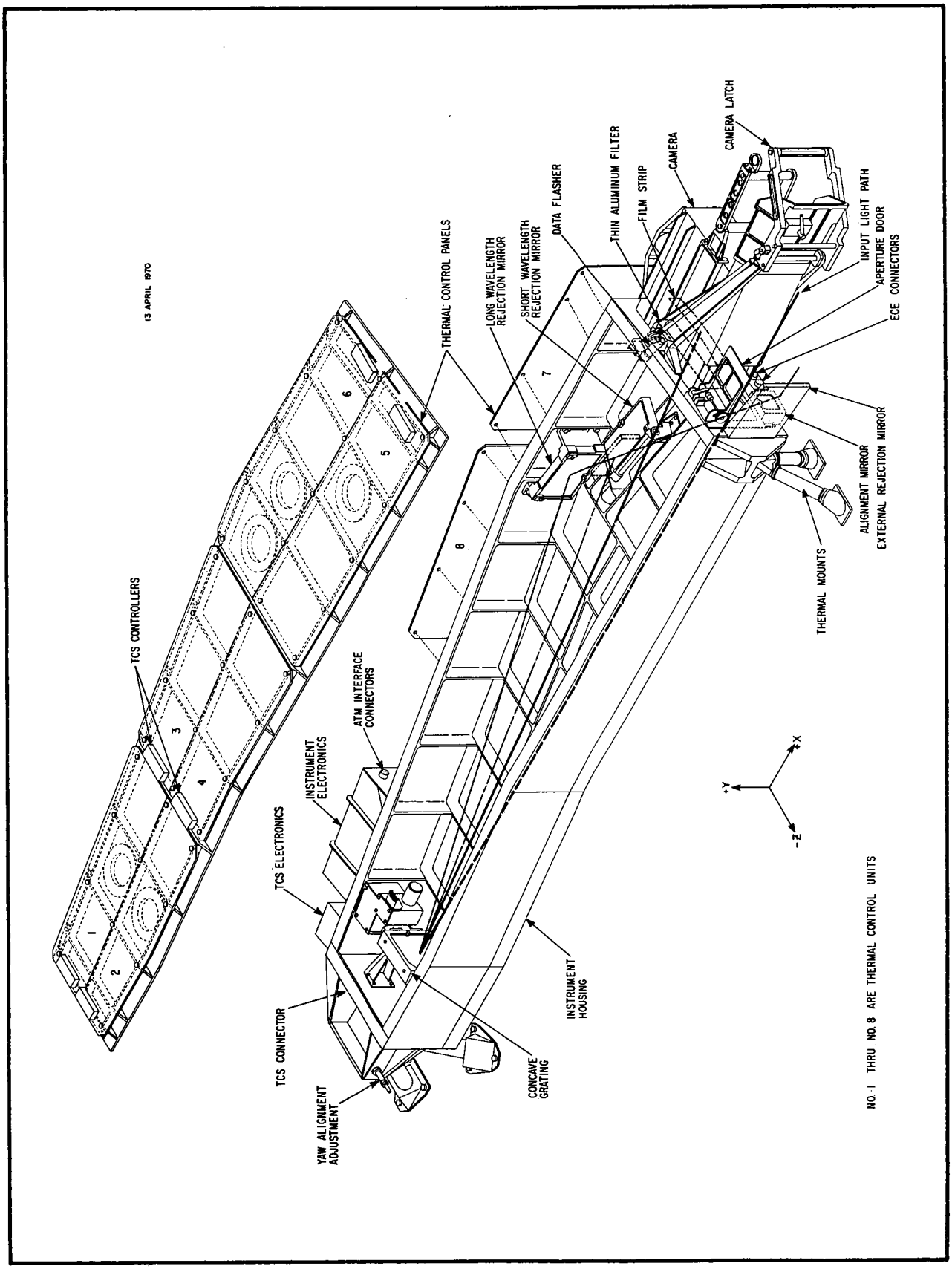


Figure 2-2. Arrangement of Major Components of S082A Instrument

Except when the camera was installed on the instrument, each camera was stored in a canister to protect the camera and film from atmospheric, thermal, launch vibration and recovery shock environments.

2.1.1 Mechanical Subsystem

The instrument mechanical subsystem consisted of a case and cover assembly that served as an optical bench, thermal mounts that coupled the instrument to the ATM spar, and several mechanisms.

2.1.1.1 Case and Cover Assembly

The matched case and cover assembly, made from 6061-T651 aluminum alloy, comprised the basic structure of the instrument housing and provided a single, rigid, light-tight housing after assembly. The case consisted of a series of welded panels with integral ribs and stiffeners. The case had openings for the camera mounting plate and the entrance aperture door and provided machined mounting points for attachment of the thermal mounting legs, thermal control subsystem, camera latch and guide rail assembly, power supplies and electronics assembly. The cover was machined from a single plate with stiffeners and ribs as an integral part. Access ports were provided in the cover to permit optics adjustments and to perform instrument alignment.

2.1.1.2 Thermal Mounts

The instrument had six high thermal impedance legs that allowed mounting on a single surface of the ATM spar. The six titanium legs were equipped with ball joints to prevent instrument case bending due to instrument to spar temperature variations.

The front (sun) end of the instrument had three legs: two in a bipod mount and the third a single vertical leg. The remaining three legs formed a tripod mount at the rear of the instrument that contained a pitch and yaw adjustment mechanism. The tripod legs

were welded to a common support housing at their apex. This support contained a ball joint in a piston which was part of the pitch and yaw adjustment mechanism. The pitch and yaw mechanism provided ±10 arc minutes of adjustment in each direction to permit instrument alignment on the ATM spar.

2.1.1.3 Aperture Door Assembly

The aperture door assembly was located at the sun end of the instrument, adjacent to the camera, and prevented the entry of light and contaminant particles to the optical system when the instrument was not in use. The aperture door, when closed, created a simplified labyrinth seal against light and particle entry (See Figure 2-3).

The mechanism for opening and closing the door consisted of a stepper motor with a splined shaft which meshed with a gear pinned to the shaft about which the door rotated. At the end of this shaft, opposite the motor and gear, was a 90-degree cam segment that drove the door by engaging a 180-degree semicircular projection from the door.

When the motor was energized, it drove the gear and shaft through 90 degrees before the cam segment engaged the projection on the door. During this 90 degrees of free travel, the spring-loaded latch lifted up clear of the notch it rested in when locked, and allowed the door to swing open. After opening to the 90-degree, fully-open position, the latch rode down into a similar notch in the door, locking it in the open position. The basic operating sequence was the same for closing. The motor rotated 90 degrees per step and at a rate of 10 steps per second. The motor shaft spline had 13 teeth which mesh with a 156-tooth gear, for a ratio of 1 to 12.

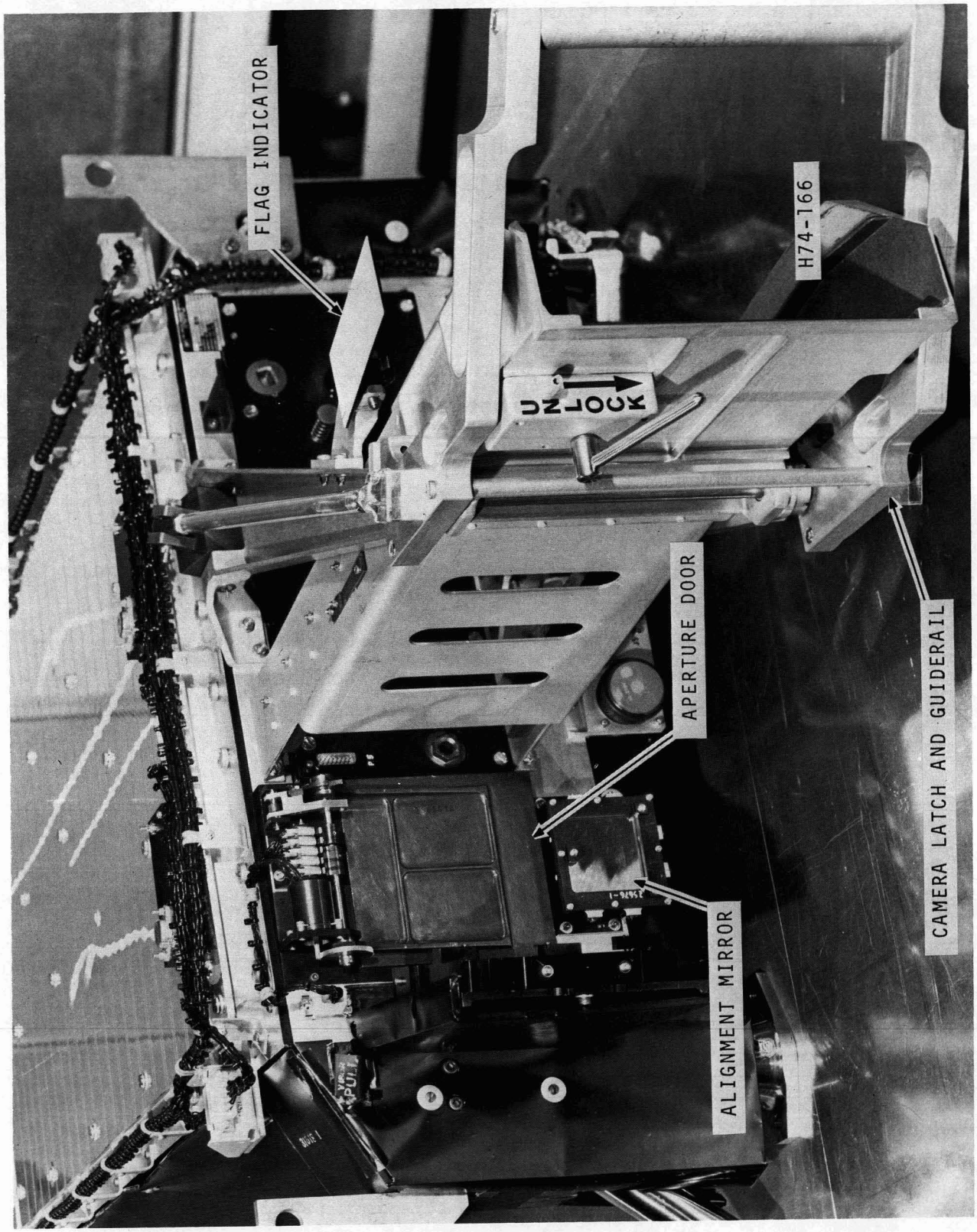


Figure 2-3. S082A Instrument Sun End

2.1.1.4 Camera Latch and Guide Rail Assembly

The camera latch and guide rail assembly consisted of a large welded guide rail, a lever-operated latching mechanism and a movable handle mounted on the sun end of the instrument. The latch and guide rail mechanism allowed installation and removal of the camera from the instrument by an astronaut during extra vehicular activity (EVA). Considerable effort went into interfacing with NASA Crew Systems on this assembly.

Located on the guide rail was a flag indicator assembly that indicated when the camera had mated properly with the instrument and was ready for use (see Figures 2-3 and 2-4).

2.1.1.5 Camera Mounting Plate Assembly

The camera mounting plate was attached to the case at the front (camera) end of the instrument. It provided a guide for positioning the camera in the correct attitude and alignment for operation; an aperture for light from the main grating to the camera; an aperture and enclosure for light from the data flasher; an electrical connector for the camera power; and a door to seal the instrument when the camera was not installed (see Figure 2-4).

2.1.1.6 Grating Assembly

The grating is a precision optical element mounted in a movable frame that allows selection of either of two wavelength bands to be directed to the film camera (see Figure 2-5).

The grating was held in focus and alignment by spring-loaded adjusting screws within a frame structure. The adjusting screws were backed up with positive stops to prevent grating displacement or damage during handling and launch. The frame was supported by flexible pivots on one edge which provide the hinge line about which the grating was moved from short to long wavelength positions. A cam follower was mounted to the frame side opposite to

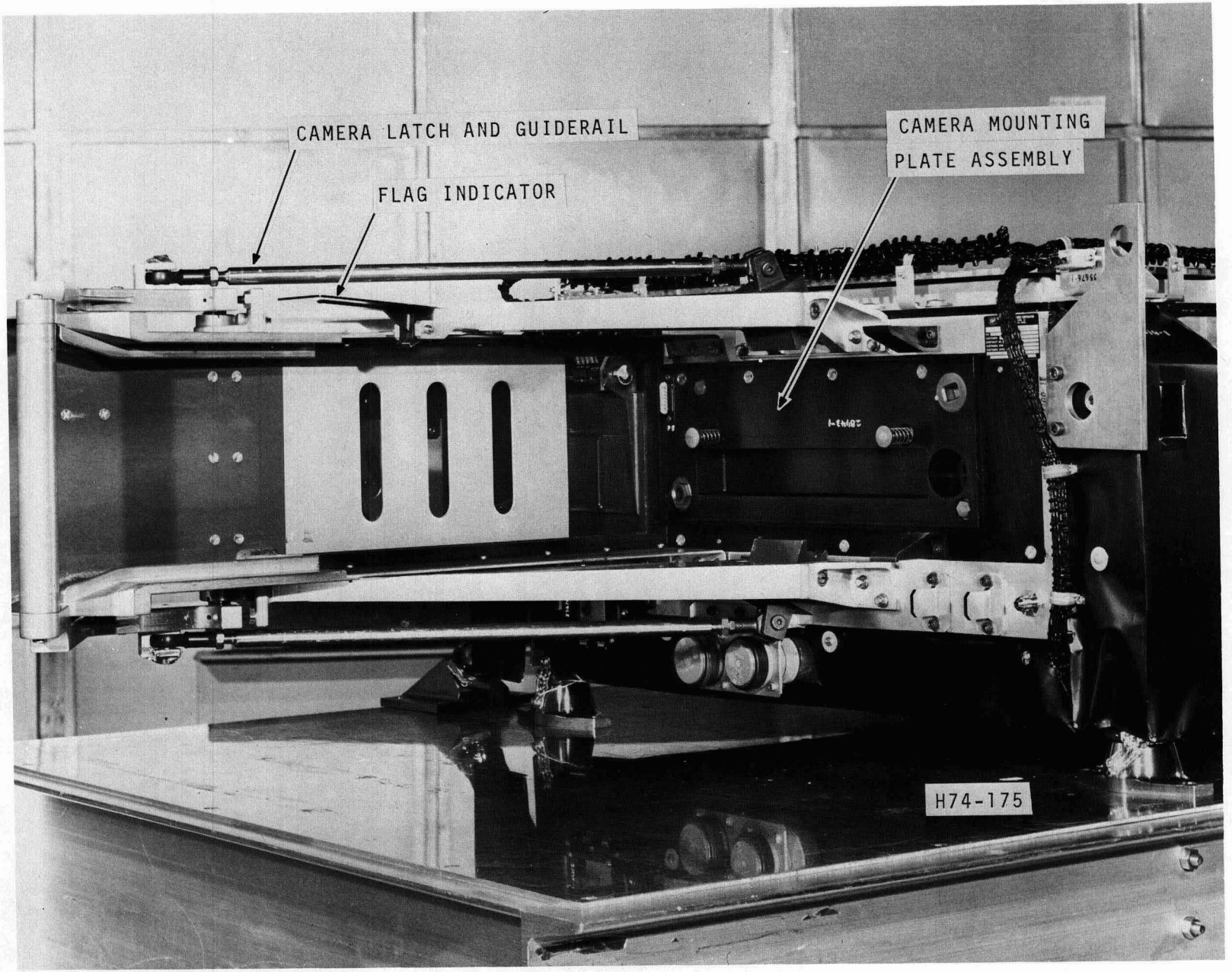


Figure 2-4. S082A Instrument Sun End

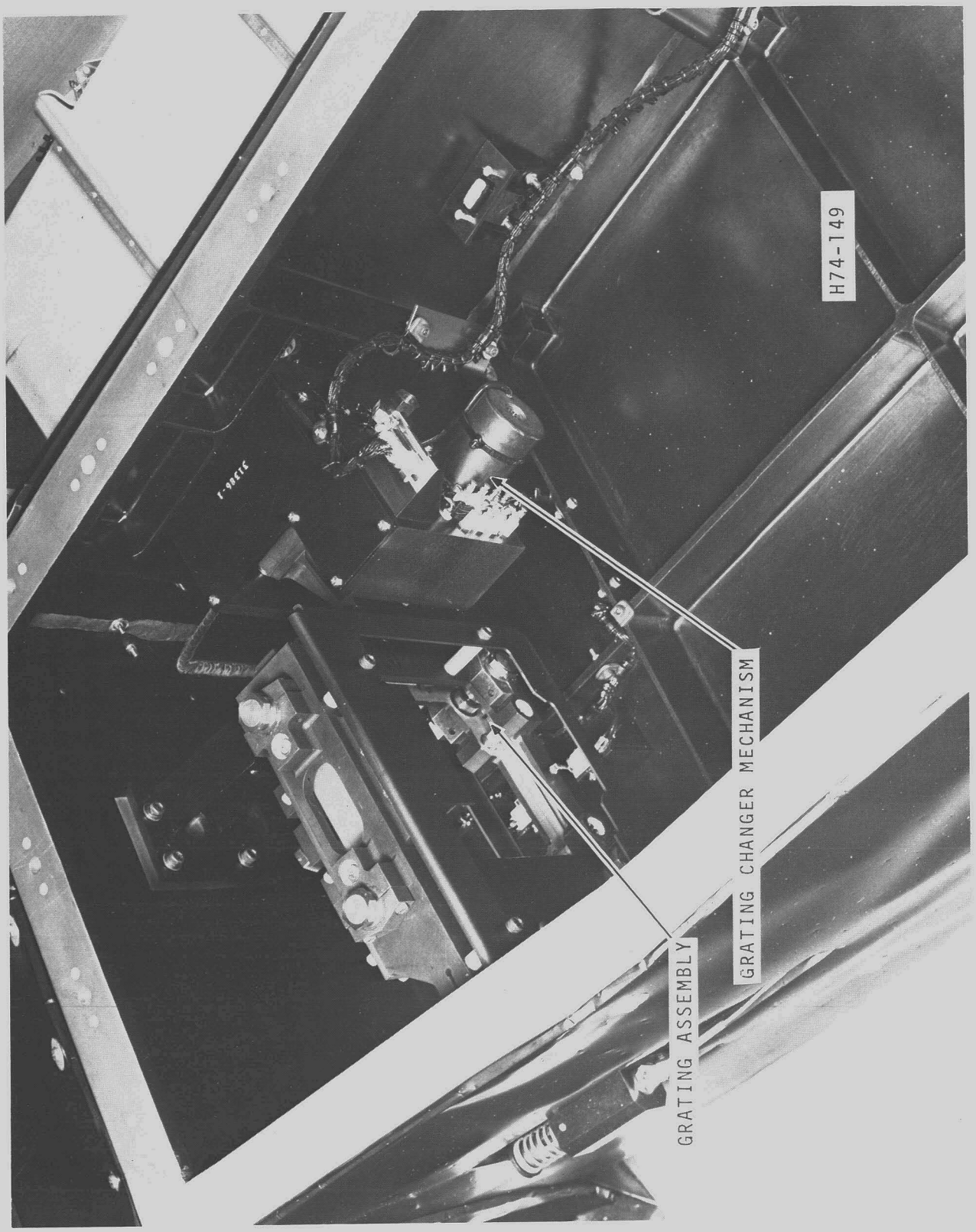


Figure 2-5. S082A Grating Assembly

the hinge line, and was engaged with a barrel cam which provided the mechanism of position change as well as position locking in either of the two grating positions. The actuating barrel cam was driven by a bi-directional, four-phase, 90-degree stepper motor driven at 10 pps through a gear reduction of 33 to 1. The actuating time from locked position to locked position was 1.5 seconds. Microswitches were actuated in each position to indicate grating position for telemetry and logic signals.

2.1.1.7 Heat Rejection Mirrors

Two of the heat rejection mirrors were mounted internally to the instrument housing and the third externally to the aperture door. The mirrors were highly polished aluminum plates. Each mirror was held within an aluminum frame on all six sides by Vespel-tipped spring plungers and nylon pads. The fixed, long wavelength mirror (see Figure 2-6) was internally fastened to the sidewall of the instrument housing.

The movable, short wavelength mirror was attached to the bottom of the housing. The short wavelength mirror mechanism consisted of a servo-stepper motor with a 10 tooth gear. The driven gear was pinned to the shaft about which the counterbalanced frame containing the mirror rotates.

The stepper motor stepped in 90-degree increments and at a rate of 10 steps per second. The spline with 10 teeth meshes with the 150 tooth gear, providing a ratio of driver to driven of 15 to 1. Therefore, since the motor requires 0.1 second to rotate 90 degrees, the mirror required 1.5 seconds for full travel. Microswitches provided mirror position signals to the telemetry and instrument logic.

2.1.1.8 Film Camera (see Section 2.4)

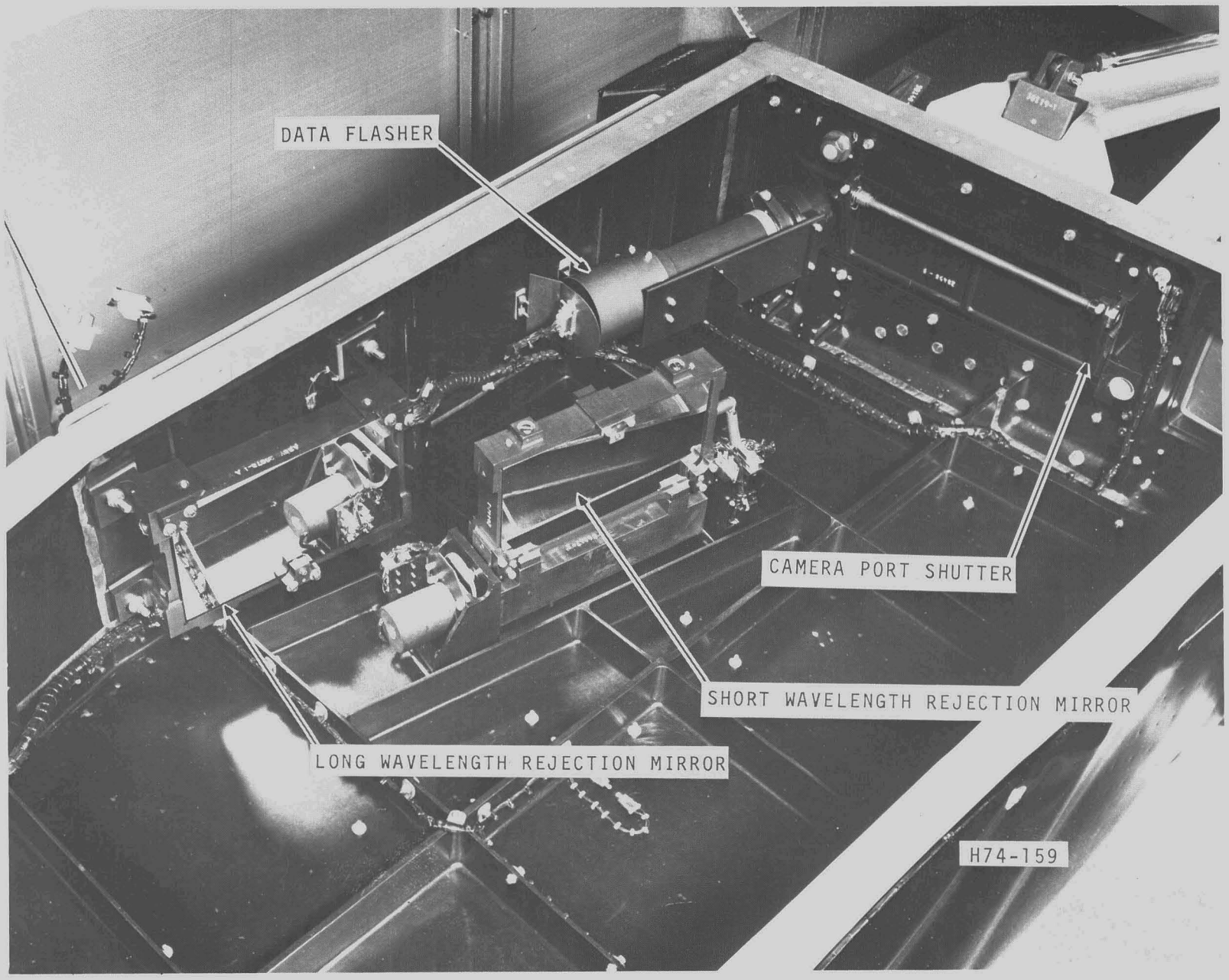


Figure 2-6. S082A Heat Rejection Mirror

2.1.2 Electrical and Electronics Subsystem

The XUV Spectroheliograph Electronics consisted primarily of the following subsystems:

- Power Supplies
- Internal Mode Timing Electronics
- Mechanism Drive Electronics
- Temperature Sensors
- Telemetry
- Command Sensors
- ATM Panel Indicators
- Diode Array

The electronics generally used a basic design philosophy of using simple, proven design and components where possible, providing necessary troubleshooting outputs, 100 percent margin on mechanism drivers, and maximum possible bench testing to assure reliability and compatibility of the design with all interfaces.

The nearly complete electronics assembly is shown in Figures 2-7 and 2-8. The micrologic cordwood construction provided a very high packaging density. The micrologic cordwood module is discussed in detail in BBRC Document No. 620-20.

During the design and sub-system test phase some noise problems were encountered and resolved with the S082A electronics. Performance during instrument systems tests, integration with ATM and mission operations was flawless.

2.1.2.1 Power Supplies

The power supply consisted of two primary subsystems: (1) A switching regulator to regulate raw 28 VDC to 20 VDC ± 0.1 VDC; and (2) A DC-DC converter to provide the various isolated DC required by the remainder of the electronics. The powers required are:

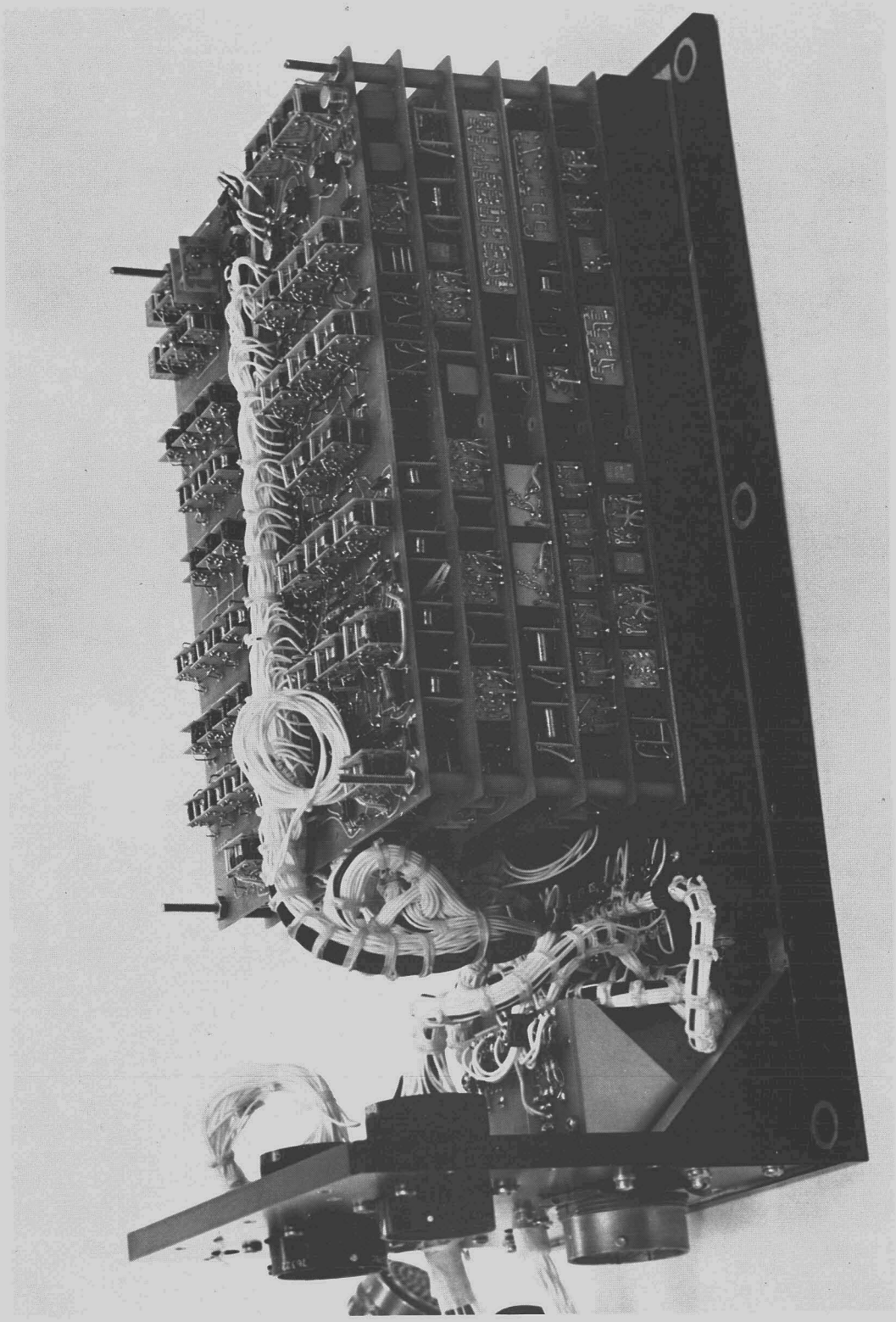


Figure 2-7. Electronics Assembly (Cover Removed)

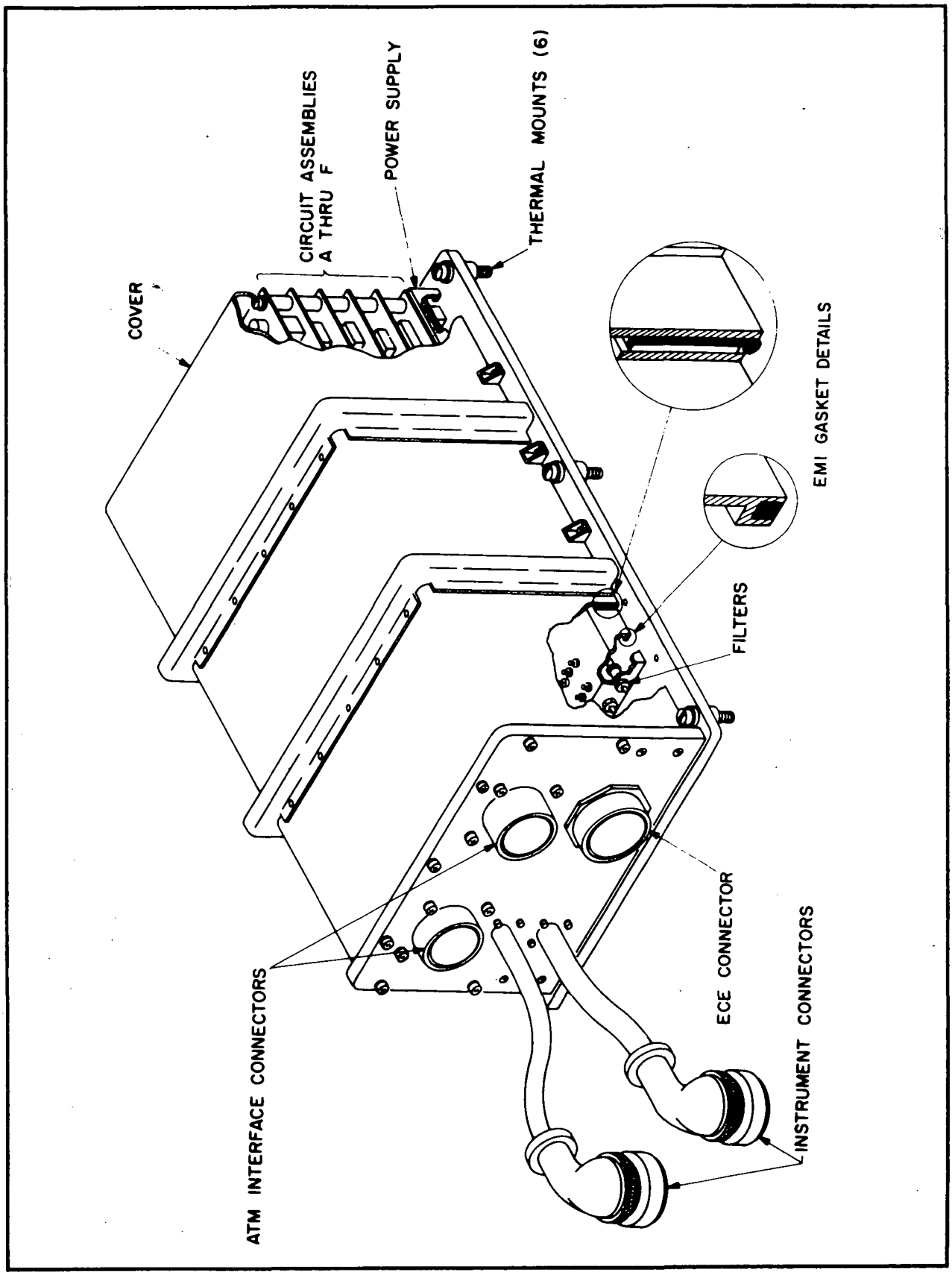


Figure 2-8. Electronics Assembly

Voltage	Current
+ 5 VDC Analog	200 ma
+ 5 VDC Sync	100 ma
+15 VDC Analog	150 ma
-15 VDC Analog	150 ma
+ 5 VDC Logic	500 ma
+ 5 VDC Digital	10 ma
+ 5 VDC Timer	60 ma

In the design, two DC-DC converters were used; one drives the four power levels required for sensing temperature and telemetry, the second for all other power used when the instrument was in an active operating mode. The switching regulator was used because of the inherent high efficiency of these units. Extra precautions were employed to eliminate noise normally associated with switching regulators and DC-DC converters.

2.1.2.2 Internal Mode Timing Electronics

The mode timing electronics provided the proper exposure times for the three automatic modes of operation: Auto 1 Mode, Auto 2 Mode and Flare Mode. These exposure times are shown in Tables 2-1, 2-2 and 2-3. The exposure times were derived from a basic 3.6 kHz clock frequency provided by the ATM. The 3.6 kHz was divided through simple micrologic bi-stable multivibrators. Diode Transistor Logic (DTL) micrologic was selected because of its availability and low power requirements.

In addition to deriving the required exposure times, the internal timing electronics developed the signals necessary to command wavelength changes when appropriate and camera cycling automatically after each exposure.

Table 2-1
AUTO 1 MODE EXPOSURE TIMES

Exposures	Grating Position	
	Short Wavelength	Long Wavelength
Normal	10.0 seconds	20 seconds
	40.0 seconds	80 seconds
	160.0 seconds	320 seconds
Short	2.5 seconds	5 seconds
	10.0 seconds	20 seconds
	40.0 seconds	80 seconds
Long	40.0 seconds	80 seconds
	160.0 seconds	320 seconds
	640.0 seconds	1280 seconds
	DATA SOURCE: CP25905	

2.1.2.3 Mechanism Drive Electronics

The mechanisms, including the camera film strip exchanger, the grating, the white light rejection mirror, and the aperture door all used stepper motors as the driving electromechanical devices. The pulses required were again derived from 3.6 kHz divided down to the 10 Hz driving frequency. All drive interface electronics were essentially switching circuits, and the necessary phase relationships were developed using DTL micrologic identical to those used elsewhere in the electronics.

The camera shutter was a solenoid mechanism, and monostable multivibrators were used to develop the required drive times. The interface to the solenoids were essentially identical to those used for the stepper motor drivers.

Table 2-2

Auto 2 Mode Exposure Times

Normal Exposures					
10	seconds	SW	or	20	seconds LW
20	seconds	LW		10	seconds SW
40	seconds	SW		80	seconds LW
80	seconds	LW		40	seconds SW
160	seconds	SW		320	seconds LW
320	seconds	LW		160	seconds SW
Short Exposures (X/4)					
2.5	seconds	SW	or	5.0	seconds LW
5.0	seconds	LW		2.5	seconds SW
10.0	seconds	SW		20.0	seconds LW
20.0	seconds	LW		10.0	seconds SW
40.0	seconds	SW		80.0	seconds LW
80.0	seconds	LW		40.0	seconds SW
Long Exposures (4X)					
40	seconds	SW	or	80	seconds LW
80	seconds	LW		40	seconds SW
160	seconds	SW		320	seconds LW
320	seconds	LW		160	seconds SW
640	seconds	SW		1280	seconds LW
1280	seconds	LW		640	seconds SW

DATA SOURCE: CP25905

Table 2-3
Flare Mode Exposure Times

Exposure Number	Wavelength	Exposure Length (seconds)
1	Short	2.5
2	Short	10.0
3	Short	40.0
4	Long	5.0
5	Long	20.0
6	Long	80.0
7	Short	2.5
8	Short	10.0
9	Short	40.0
10	Short	10.0
11	Short	40.0
12	Short	160.0
13	Long	10.0
14	Long	40.0
15	Long	160.0
16	Short	2.5
17	Short	10.0
18	Short	40.0
19	Short	10.0
20	Short	40.0
21	Short	160.0
22	Long	10.0
23	Long	40.0
24	Long	160.0

2.1.2.4 Temperature Sensors

The S082A temperature sensors consisted of absolute and differential temperature sensors. The coarse and fine absolute sensors were very similar in design, and differed only in the temperature range covered. The coarse temperature sensor had a range of 50°F to 100°F. The fine temperature sensors were used to detect the electronic package temperature, and in six places to detect the instrument case temperature. The range of the fine sensors was 50°F to 80°F.

The differential temperature sensors were used to detect different temperatures of the instrument case. Three pairs of carefully selected and matched thermistors were used to measure the differential temperature across the case, and three additional matched thermistor pairs measured the difference temperature from the instrument lid to the base.

The temperature sensors were required to calculate the potential case distortions because of temperature variation causing optical degradation. With the instrument optically aligned at approximately 70°F absolute and 0°F differential, any temperature change would cause some distortion, and knowledge of the magnitude of temperature changes allowed the optical distortion to be calculated.

2.1.2.5 Telemetry

The telemetry system had three subcommutated channels of 15 inputs each, and three digital channels. The digital channels monitored the two camera shutter positions and the short wavelength grating position. The subcommutated channels monitored the instrument temperature sensors, all voltages, all mechanism positions and the mode of instrument operation. The commutator used the 1/15 Hz rate provided by the ATM.

2.1.2.6 Command Sensors

The command sensors were primarily a buffered Schmidt trigger type of circuit. Since the commands provided by the ATM were 28 VDC in magnitude it was possible to use high level noise rejection circuits to prevent unwarranted commands. In the actual design the instrument would not respond to less than 15 VDC inputs or greater than 15 VDC for less than 3.2 milliseconds.

2.1.2.7 ATM Panel Indicators

The mechanism positions and mode of operation were output to the TM panel to indicate instrument operation to the ATM operator.

The list of commands and their function is shown in Table 2-4.

2.1.2.8 Diode Array

A diode array consisting of 40 light emitting diodes were used to annotate time information on each film strip. The day, hour, minute, second and millisecond were recorded on film when the shutter initially opened. Prior to closing the shutter, minutes, seconds and milliseconds were recorded. This provided an accurate time the film was exposed and the duration of the exposure (see Figure 2-6).

2.1.2.9 Electromagnetic Interference

Potential electromagnetic interference (EMI) problems were considered in the initial instrument design. Isolated power supplies to separate various instrument functions were used to preclude EMI problems; i.e., analog telemetry, the diode array, the internal timing circuits, the ATM clock, etc. All the returns, both signal and power, were routed through the ATM interface cables to a single point ground in the ATM. Cable layouts provided separation of the mechanism's high current lines from the signal and sensing lines for temperatures, position indicators, etc.

Table 2-4

INSTRUMENT SYSTEM OPERATION
(Sheet 1 of 4)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
1. THERMAL ON or OFF	Not a functional command. It causes application or removal of 28 VDC ATM power to instrument thermal control subsystem.	Instrument thermal control subsystem begins functioning when the instrument temperature reaches proper values, the heater panels begin cycling on and off individually to maintain temperature.	ON: 1. Instrument temperature between 40 and 70°F 2. (Orbital Operation) ATM canister thermal control system operating. OFF: None
2. MAIN POWER ON or OFF (Interlocked with PWR/DOORS off)	Not a functional command. It causes application or removal of 28 VDC ATM power to instrument electronics.	Instrument converter is turned on to supply power for analog telemetry and ATM synchronization interface. After execution, the following indications are present: 1. Aperture door closed indication to control panel. 2. Analog telemetry (temperature monitors) available for sampling. 3. Instrument is capable of responding to PWR/DOORS ON command.	ON: 1. Instrument temperature between 50 and 80°F 2. (Orbital Operation) THERMAL ENABLE and temperature stabilized. OFF: 1. PWR/DOORS OFF (Interlocked with MAIN POWER). 2. Instrument aperture door closed indication.
3. PWR/DOORS ON	Applies continuous 28 VDC command to instrument to turn on all internal converter power and open instrument aperture door.	Instrument converter is turned on to supply power for internal logic, digital telemetry and mission time interface. Following this, instrument aperture door is opened. (See No. 14 below for modified operation with APERTURE DOOR OPEN INHIBIT command.) After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to control panel. 3. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 4. All telemetry measurements available for sampling. 5. Instrument is capable of responding to all other functional commands.	1. MAIN POWER ON. 2. (Orbital Operation) Instrument must be pointed toward sun and thermally stabilized.
4. PWR/DOORS OFF	Applies continuous 28 VDC command to instrument to turn off internal converter power and close instrument aperture door.	Instrument aperture door is closed; camera shutter is closed (if open) and film is cycled; all instrument converter power for internal logic, digital telemetry, and mission time interface is turned off. After command execution, the following indications are present: 1. Aperture door closed indication to control panel. 2. Analog telemetry (temperature monitors) available for sampling). 3. Instrument is capable of responding to PWR/DOORS ON command.	None
5. TIME MODE/START	Causes the film camera shutter to open, beginning a single exposure.	Camera shutter opens and film strip is exposed; ATM mission time is encoded on edge of film strip by data flasher. After command execution, the following indications are present: 1. Aperture door open indication to control panel.	1. PWR/DOORS ON. 2. No other exposure mode in process. ("Ready" condition on control panel.)

Table 2-4 (continued)
(Sheet 2 of 4)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		2. Shutter open indication to control panel. 3. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 4. Telemetry indicates these conditions.	
6. AUTO 1 MODE/ START	Initiates an AUTO 1 mode automatic film exposure sequence.	Camera shutter opens and film strip is exposed; ATM mission time is encoded on edge of film strip by data flasher. Sequence of three exposures is completed automatically, with mission time encoded at beginning and end of each. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to control panel. (Alternates with shutter closed indication as exposures are completed.) 3. AUTO 1 Mode on indication to control panel. (Remains until final exposure is completed.) 4. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 5. Film cycle pulse (after each exposure) to control panel. 6. Telemetry indicates these conditions.	1. PWR/DOORS ON. 2. No other exposure mode in process. ("Ready" indication on control panel.)
7. AUTO 2 MODE/ START	Initiates an AUTO 2 mode automatic film exposure sequence.	Film camera shutter opens and film strip is exposed; ATM mission time is encoded on edge of film strip by data flasher. Sequence of six exposures is completed automatically, with mission time encoded at beginning and end of each. Grating and heat rejection mirror positions are changed after each exposure except the last. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to control panel. (Alternates with shutter closed indication as exposures are completed.) 3. AUTO 2 mode on indication to control panel. (Remains until final exposure is completed.) 4. Grating short or long wavelength position and heat rejection mirror position indication to control panel change after each exposure except the last. 5. Film cycle pulse (after each exposure) to control panel. 6. Telemetry indicates these conditions.	1. PWR/DOORS ON. 2. No other exposure mode in process. ("Ready" indication on control panel.)
8. FLARE ENABLE	Enables the instrument to accept a FLARE MODE INITIATE command.	Enable condition is stored in instrument logic. Any mode in process is not affected. After command execution, the following indications are present: 1. Aperture door open indication to control panel.	1. PWR/DOORS ON.

Table 2-4 (continued)
(Sheet 3 of 4)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		2. Normal indications from mode in process. 3. Flare mode enable indication to control panel. 4. Telemetry indicates these conditions.	
9. FLARE INHIBIT	Removes FLARE ENABLE condition.	Enable condition stored in instrument logic is removed. Any mode in process is not affected. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Normal indications from mode in process. 3. Telemetry indicates these conditions.	1. PWR/DOORS ON.
10. MASTER FLARE MODE INITIATE	Initiates a flare mode automatic film exposure sequence.	Any mode in process, except a flare mode, is immediately terminated and camera shutter is closed. If FLARE ENABLE was previously commanded, the grating and heat rejection mirror move to the short wavelength position; the camera shutter opens and film strip is exposed; ATM mission time is encoded on edge of film strip by data flasher. Sequence of 24 exposures is completed automatically, with mission time encoded at beginning and end of each. Grating and heat rejection mirror positions are changed between exposures as programed. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to control panel. (Alternates with shutter closed indication as exposures are completed.) 3. Flare mode on indication to control panel. 4. Grating short or long wavelength position and heat rejection mirror position indication to control panel in accordance with program. 5. Film cycle pulse (after each exposure) to control panel. 6. Telemetry indicates these conditions. If FLARE ENABLE was not previously commanded, the instrument remains in ready condition awaiting further commands. After FLARE MODE INITIATE command, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to control panel. 3. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 4. Telemetry indicates these conditions. If FLARE ENABLE was not previously commanded and if another automatic mode is in process, the automatic mode will be terminated. If a flare mode was in process, the command is negated and the flare mode continues.	1. PWR/DOORS ON. 2. FLARE ENABLE ON.

Table 2-4 (concluded)
(Sheet 4 of 4)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
11. STOP	Terminates any mode in process.	If the camera shutter is open, ATM mission time (15 least significant bits) is encoded on edge of film strip by data flasher; shutter is closed; film is cycled, mode in process is terminated. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to control panel. 3. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 4. Film cycle pulse to control panel (if shutter was closed by STOP command). 5. Telemetry indicates these conditions.	1. PWR/DOORS ON.
12. WAVE-LGTH SHORT/ LONG	Changes the wavelength to be photographed.	Grating and movable heat rejection mirror move to position commanded. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Grating and heat rejection mirror position indication, as commanded, to control panel. 3. Telemetry indicates these conditions.	1. PWR/DOORS ON. 2. No automatic exposure mode in process. ("Ready" indication on control panel.)
13. EXPO-SURE SHORT/ LONG	Prescales AUTO 1 mode or AUTO 2 mode exposures to long or short duration.	Instrument exposure-time programer loads either long or short prescale factor, as commanded. Subsequent automatic exposures in AUTO 1 and AUTO 2 modes will be 1/4 or four times normal exposure time. (Command is cleared automatically after either mode and may be removed manually by STOP command.) After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Long or short exposure indication, as commanded, to control panel. 3. Grating short or long wavelength position and heat rejection mirror position indication to control panel. 4. Telemetry indicates these conditions.	1. PWR/DOORS ON. 2. No automatic exposure mode in process. ("Ready" indication on control panel.)
14. APERTURE DOOR OPEN INHIBIT (From ECE Only)	Allows instrument PWR/ DOORS ON command to be executed with the door remaining closed. Used for ground test only.	If commanded before PWR/DOORS ON, instrument performs all functions of PWR/DOORS ON command (see No. 3 above), except aperture door does not open. If commanded after PWR/DOORS ON, aperture door is opened.	1. MAIN POWER ON. 2. PWR/DOORS OFF.

2.1.3 Optical Subsystem

The basic optical design of the S082A Spectroheliograph was specified by NRL in their proposal to NASA on Form 1346 dated 20 October 1967. Implementation of the optical design into the instrument hardware design was developed through many consultations between NRL scientists and BBRC engineers. Figure 2-9 shows the optical layout. The principal optical components are the concave grating and the thin aluminum filter. Secondary components include the heat rejection mirrors and the data flasher projection system.

The concave grating was procured from Bausch and Lomb by the NRL and furnished to BBRC as Government Furnished Equipment (GFE). The thin aluminum filters, which are mounted in each film camera, were developed by Sigmatron for NRL and furnished to BBRC as GFE. Heat rejection mirrors and data flasher optics were designed and procured by BBRC.

The first flight grating was installed in the S082A Flight Instrument in June 1970. It soon became apparent that excessive focused scattered light was produced by the flight grating. The fault was traced to defective rulings on the master grating from which the flight replicas were made. In September 1970 a new master grating was ruled by Bausch and Lomb, new replicas were made, and a satisfactory flight grating was installed in October 1970.

The thin aluminum filters were designed to mount directly in front of the film strip in each camera. The thin aluminum filter, 1000 Angstroms thick, is supported on a fine wire mesh which is secured to a rigid metal frame for mounting in the camera. Production of satisfactory filters of this size with acceptably small pinholes required a very extensive development effort by Sigmatron.

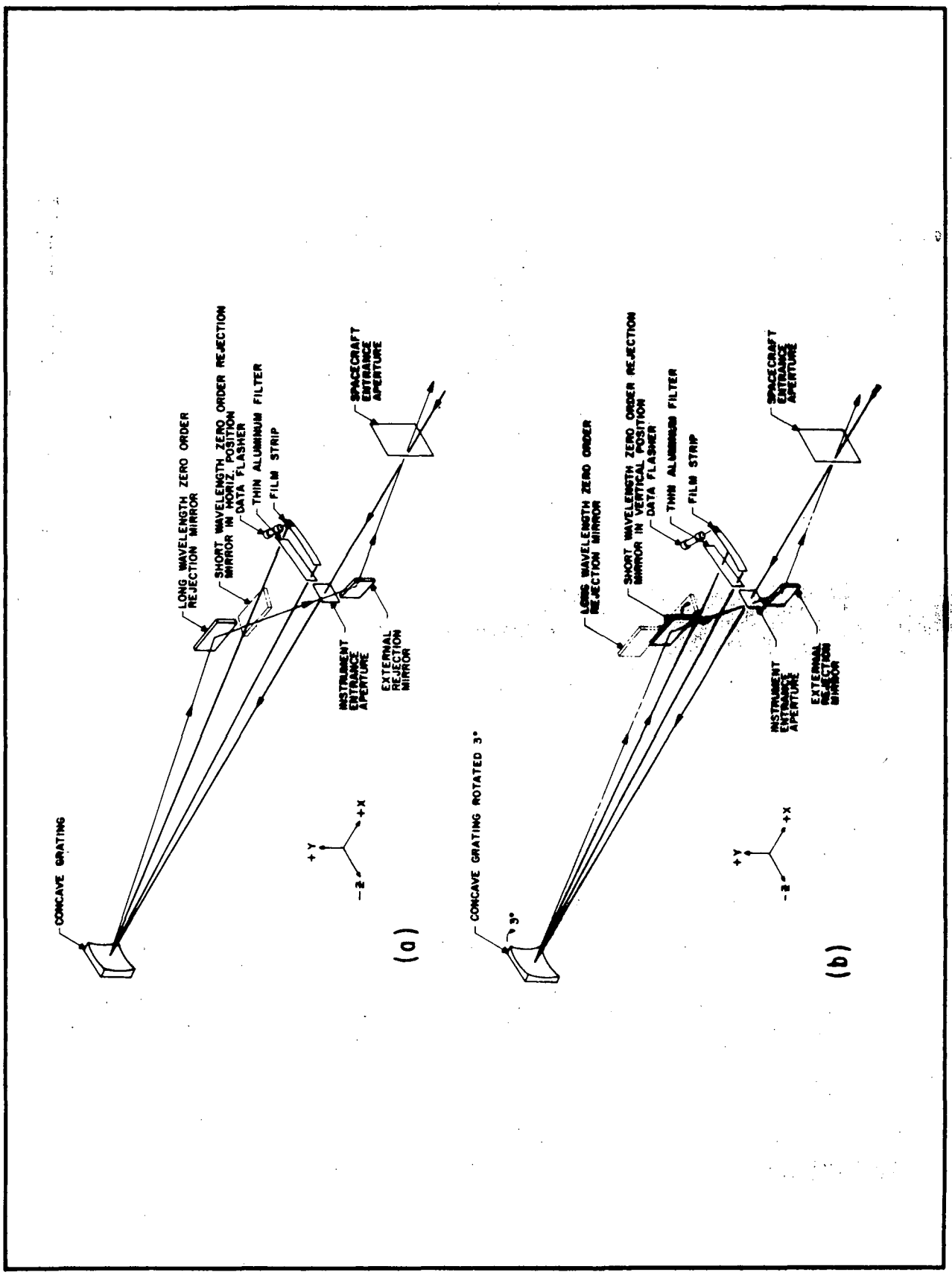


Figure 2-9. Optical System Schematic

2.1.4 Thermal Control Subsystem

The thermal control subsystem (TCS) was designed to maintain the absolute temperature (mean) of the instrument housing within ±8°F of the alignment temperature and maintain thermal gradients between the case sides and between the case top and bottom to less than 0.6°F. The TCS prevented the instrument temperatures from varying over a range which would have caused optical misalignment and focus shifts that would have degraded recorded data.

The TCS consisted of an active heating system and a passive radiation system (insulation) for controlling and stabilizing instrument temperature. The active heating system provided five independent honeycomb panels with strip heaters. All heater panels were equipped with independent temperature-sensing thermistors and controller circuitry. The five heater panels provided eight individually controlled thermal zones.

2.1.4.1 Active Heating System

Low thermal inertia heater panels were used to modulate radiation heat flow from the comparatively high thermal inertia instrument to the cold wall of the ATM canister. Controlling the heat flow in this manner isolated the instrument from environmental temperature variations without introducing thermal gradients into the instrument case.

The heater panels were thermostatically controlled using thermistors connected in a bridge circuit whose output was sensed by an amplifier. The bridge amplifier provided an analog voltage of 0 to 5 volts, corresponding to a temperature range of 70°F to 76°F. The amplifier output went to a level detector and comparator switch. The comparator output drove a current amplifier to switch the heater elements.

An overtemperature sensing and control circuit was also provided for each heater panel. It had its own thermistor and electronics, completely redundant to the primary temperature sensing and control circuitry. The overtemperature control ensured against a failure of the primary controller in the ON condition. The overtemperature circuitry used a separate thermistor in a bridge circuit whose output is fed directly into a differential amplifier and comparator. If an overtemperature condition had occurred, the output would have opened a relay and disabled the power supply to the heaters until the panel temperature dropped to an appropriate level.

2.1.4.2 Passive Insulation System

The passive insulation system consisted of insulation panels mounted at locations not covered by the heater panels. The insulation panels consisted of multiple-layers of aluminized Mylar enclosed in Lexan cover sheets.

All internal and external surfaces of the instrument housing and optical mounts had finishes selected for optimum radiation coupling in order to minimize thermal gradients in the case. The electronics were mounted on thermal insulating mounts and radiation isolated from the case with surface finishes selected for passive thermal control to the canister cold wall. The instrument to ATM spar mounts were designed to provide very high thermal impedance.

2.1.4.3 Additional Detail Information

Additional Thermal Control System details may be found in BBRC Document TR73-15 entitled "New Technology Report - Thermal Control System for NRL/ATM S082B Spectrograph". Although this report was directed to the S082B Instrument, the design concept applies to the S082A Instrument also.

2.2 S082B XUV SPECTROGRAPH

To meet the scientific objectives, an instrument designated as the S082B XUV Spectrograph was designed. Figure 2-10 shows the instrument subsystems and major components of each system. Figure 2-11 shows the arrangement of the major components within/on the instrument.

The instrument consisted of a housing that enclosed a series of optical elements and to which was attached the control electronics, the thermal control system and a removable film strip camera. The instrument was operated entirely by remote command from the ATM C&D Panel or from the ECE. The instrument provided both automatic film exposure sequences and manually-controlled time exposures.

A Pointing Reference System (PRS) provided absolute pointing reference to solar white light features by providing to the astronaut a video image of a portion of the sun as it was imaged on the spectrograph entrance slit by the telescope. The PRS also provided increased automatic pointing accuracy (±1 arc second absolute) and a position relative to the solar limb during spectral measurements of the limb transition region.

Spectrograms were photographically recorded by opening the instrument aperture door and then operating the film camera. After the exposures were completed (up to 1600/camera), the film camera was removed from the instrument by an astronaut during EVA and returned to earth for processing.

Except when the camera was installed on the instrument, each camera was stored in a canister to provide environmental protection.

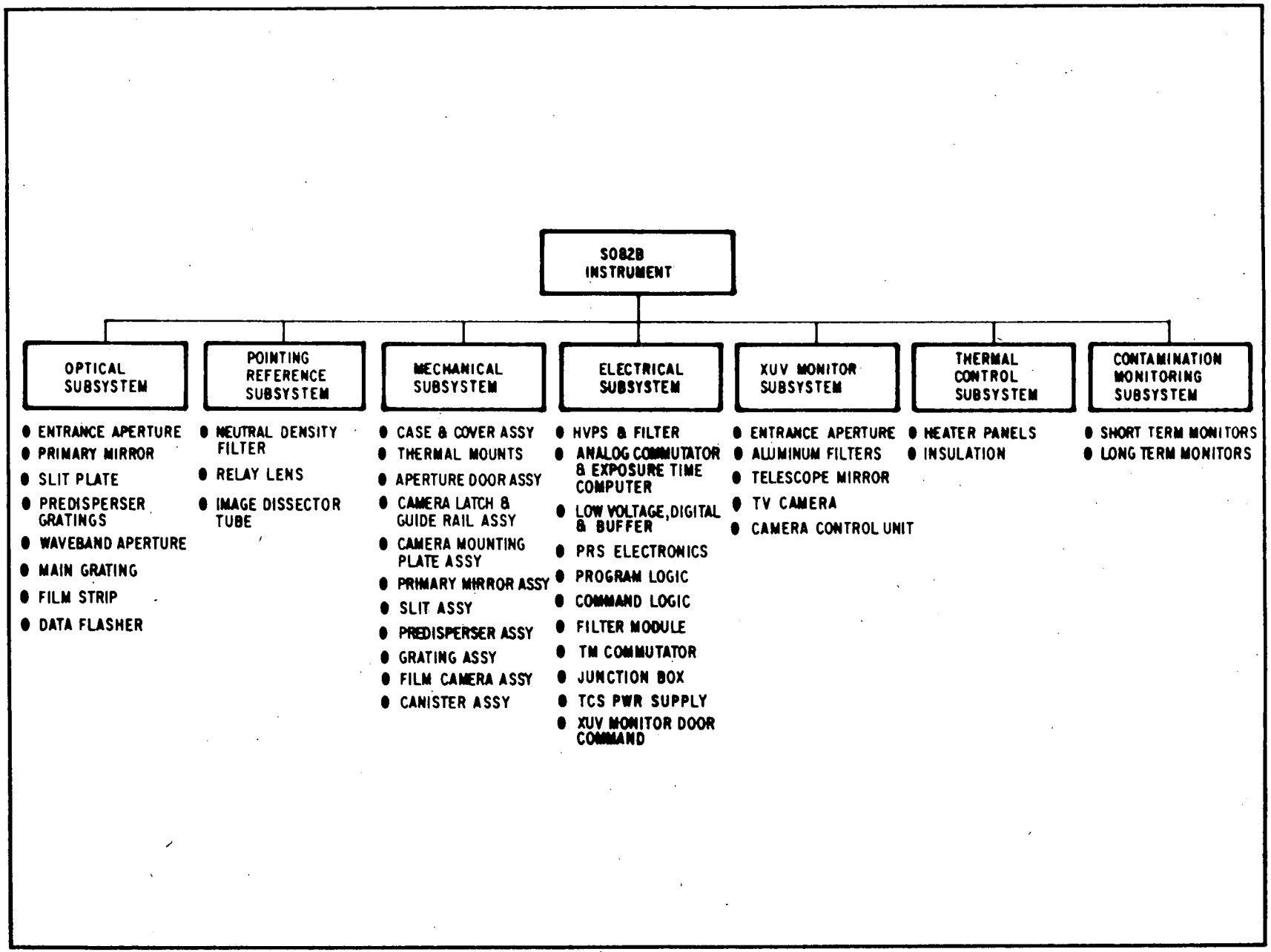


Figure 2-10. S082B Instrument Subsystems and Components

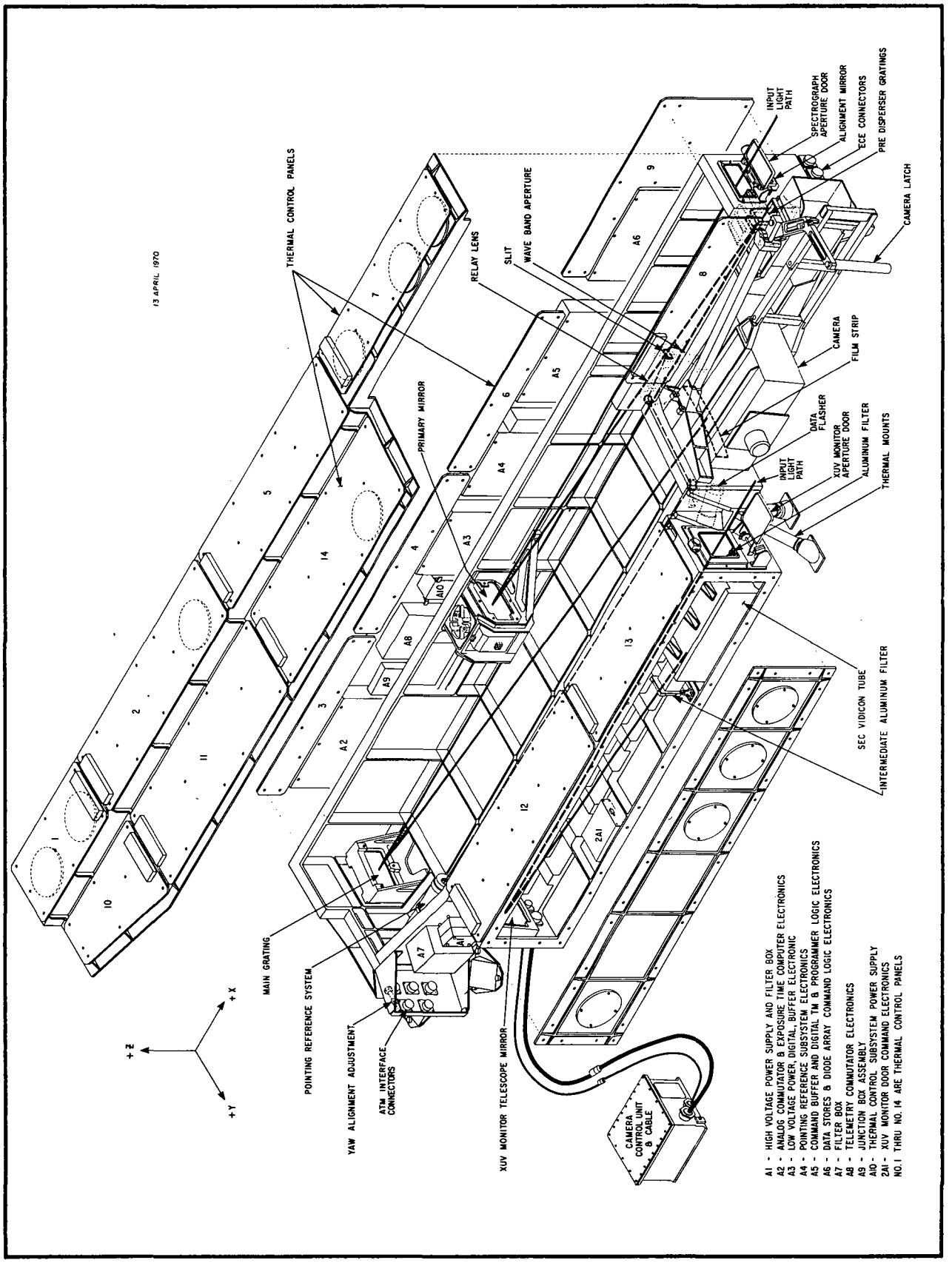


Figure 2-11. Arrangement of Major Components of S082B Instrument

2.2.1 Mechanical Subsystem

The instrument mechanical subsystem consisted of a case and cover assembly that served as an optical bench, the thermal mounts, the fixed optical subassemblies and several mechanisms.

2.2.1.1 Case and Cover Assembly

The matched case and cover assembly, made from 6061-T651 aluminum alloy, comprised the basic structure of the instrument housing and provided a single, rigid, light-tight housing after assembly. The case consisted of a series of welded panels with integral ribs and stiffeners. The case had openings for the camera mounting plate and the entrance aperture door and provided machined mounting points for attachment of the thermal mounting legs, thermal control subsystem, camera latch and guide rail assembly, power supplies, electronic subassemblies and the XUV Monitor case. The cover was machined from a single plate with stiffeners and ribs as an integral part and ports were provided for access.

2.2.1.2 Thermal Mounts

The instrument had six high thermal impedance legs that allowed mounting on a single surface of the ATM spar. The six titanium legs were equipped with ball joints to compensate for temperature variations and thus aid in preventing thermal and mechanical distortion of the case which would have caused optical misalignment. The thermal mounts are the same as for the S082A.

2.2.1.3 Aperture Door Assembly

The aperture door assembly was located at the sun end of the instrument and prevented entry of light and contamination particles to the optical elements when the instrument was not in use. The door, when closed, created a simplified labyrinth seal against light or particle entry. The mechanism for opening and closing the door is the same as that for the S082A.

2.2.1.4 Camera Latch and Guide Rail Assembly

The camera latch and guide rail assembly consisted of a large welded guide rail, a lever-operated latching mechanism, and a movable handle mounted on the sun end of the instrument similar to that for the S082A Instrument.

2.2.1.5 Camera Mounting Plate Assembly

A camera mounting plate assembly was attached to the case at the front (camera) end of the instrument, the same as for the S082A.

2.2.1.6 Primary Mirror Assembly

The primary mirror was a 3.38 x 6.00 inch off-axis section of a paraboloid with a 1 meter focal length. The mirror was made of Cervit material to minimize thermal distortion.

The primary mirror was rigidly held in focus and alignment by adjustment screws within an Invar alloy frame structure. The frame structure was installed between and attached to flexible pivots that allowed the mirror and frame assembly to pivot about an axis parallel to the long axis of the spectrograph entrance slit (see Fig. 2-12). A torque motor controlled by the PRS was attached to the lower flex pivot and provided the force to deflect the pivot flexures up to 35 arc seconds either side of center. The whole assembly was housed in a rigid structural support that was bolted and pinned to the main instrument case wall.

2.2.1.7 Slit Plate Assembly

The spectrograph entrance slit (see Fig. 2-13) was 10 microns wide by 300 microns long, which corresponds to a solar field of view of 2 arc seconds by 60 arc seconds.

The slit plate assembly (Fig. 2-14) consisted of a primary structural support attached to the main case wall that supported and positioned the slit plate, a heat rejection mirror, waveband aperture,

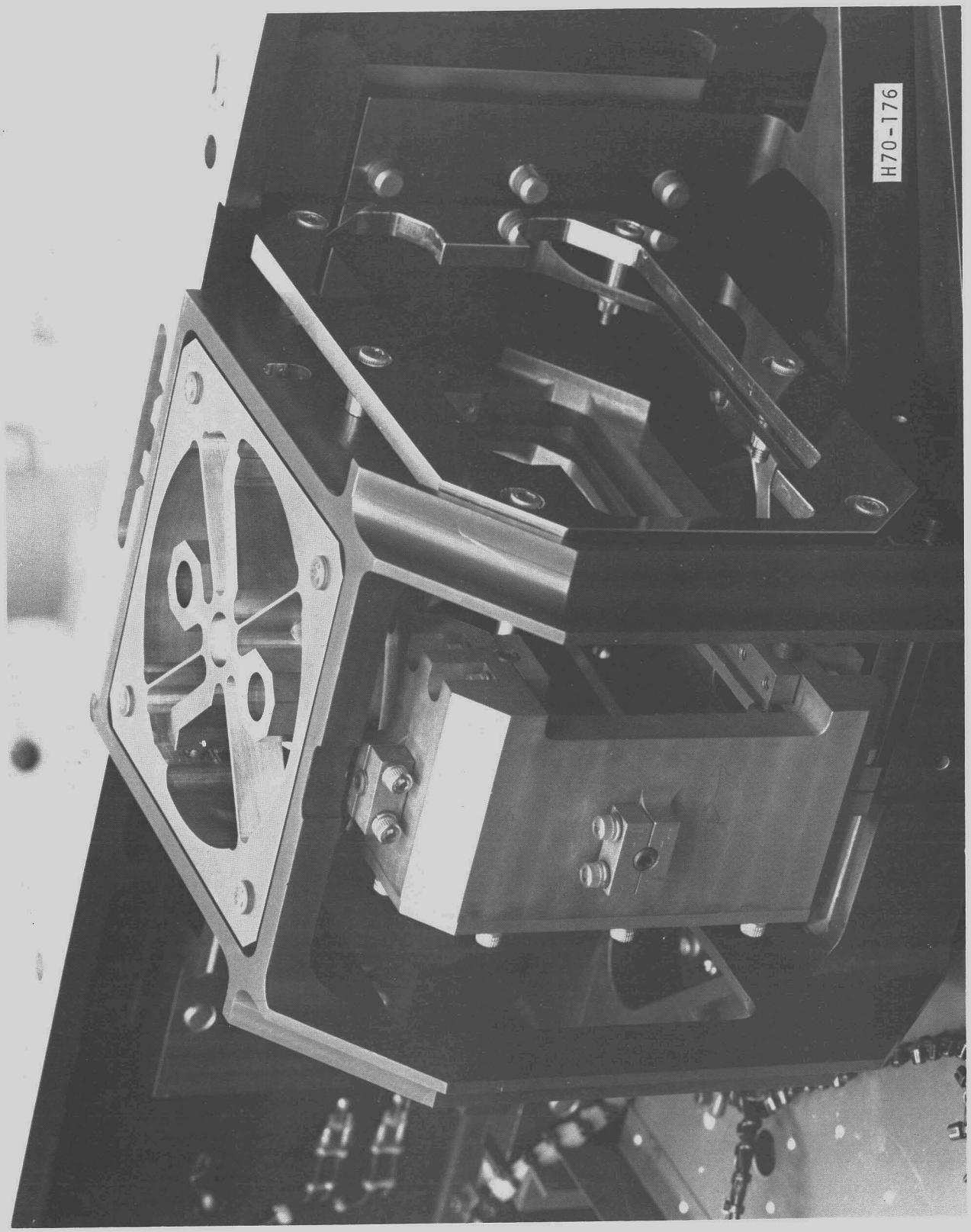
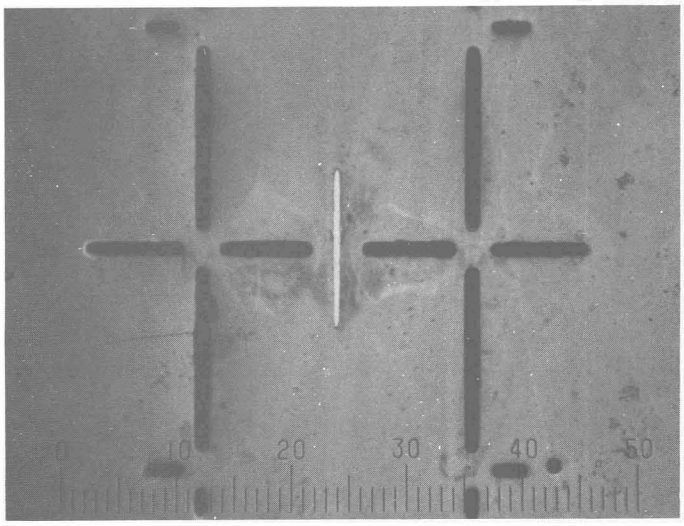


Figure 2-12. Primary Mirror Assembly



Microscope View of Slit and Fiducial Marks at 75X Magnification

Figure 2-13. Spectrograph Slit and Fiducial Marks

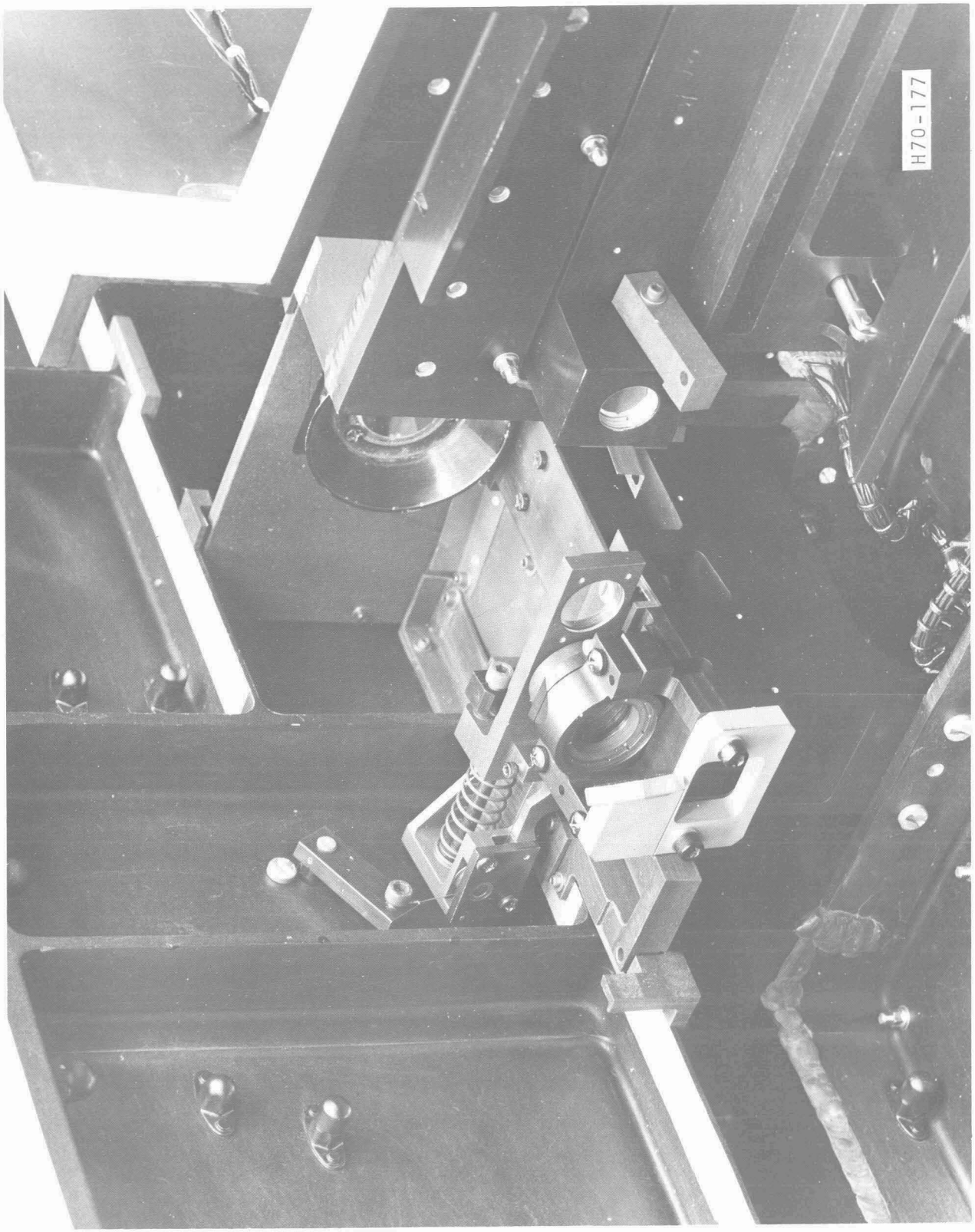


Figure 2-14. Slit Assembly

and the PRS neutral density filter, relay lens and first folding mirror.

The slit plate contained both the 10 x 300 micron slit and the PRS fiducial markings (see Fig. 2-13). Physically, the slit plate assembly consisted of the slit plate sandwiched between a front and a back plate. The slit plate itself was a very thin copper sheet containing the slit, with one surface nickel plated and etched to provide the PRS fiducial lines. The front plate incorporated a 0.100 inch diameter hole through which the slit and fiducial marks were viewed. The rear plate had a 0.06 inch diameter orifice to prevent restriction of the light passing through the slit.

The heat rejection mirror in the slit plate assembly consisted of a one inch diameter aluminized surface over electroless-nickel-plated aluminum alloy. This annular mirror reflected the white light solar image that exceeded the 3 arc minute field of view of the slit plate, back to the primary mirror and subsequently overboard through the entrance aperture.

2.2.1.8 Predisperser Assembly

The predisperser gratings were used to select the two spectral bands of the spectrograph. They were held in a drum type mechanism which rotated the long or the short wavelength band grating into position as required. The gratings were concave, with a 50 centimeter radius. The ruled area of each grating was 36 x 40 millimeters on a 50 x 50 millimeter glass blank (see Fig. 2-15).

2.2.1.9 Waveband Aperture

The waveband aperture was a slot 16.10 millimeters high by 1.27 millimeters wide located on the optical path between the predisperser and the main grating. The aperture passed wavelengths of 970 to 1970 Å when the short wavelength predisperser grating was in use, 1940 to 3940 Å when the long wavelength predisperser was in use.

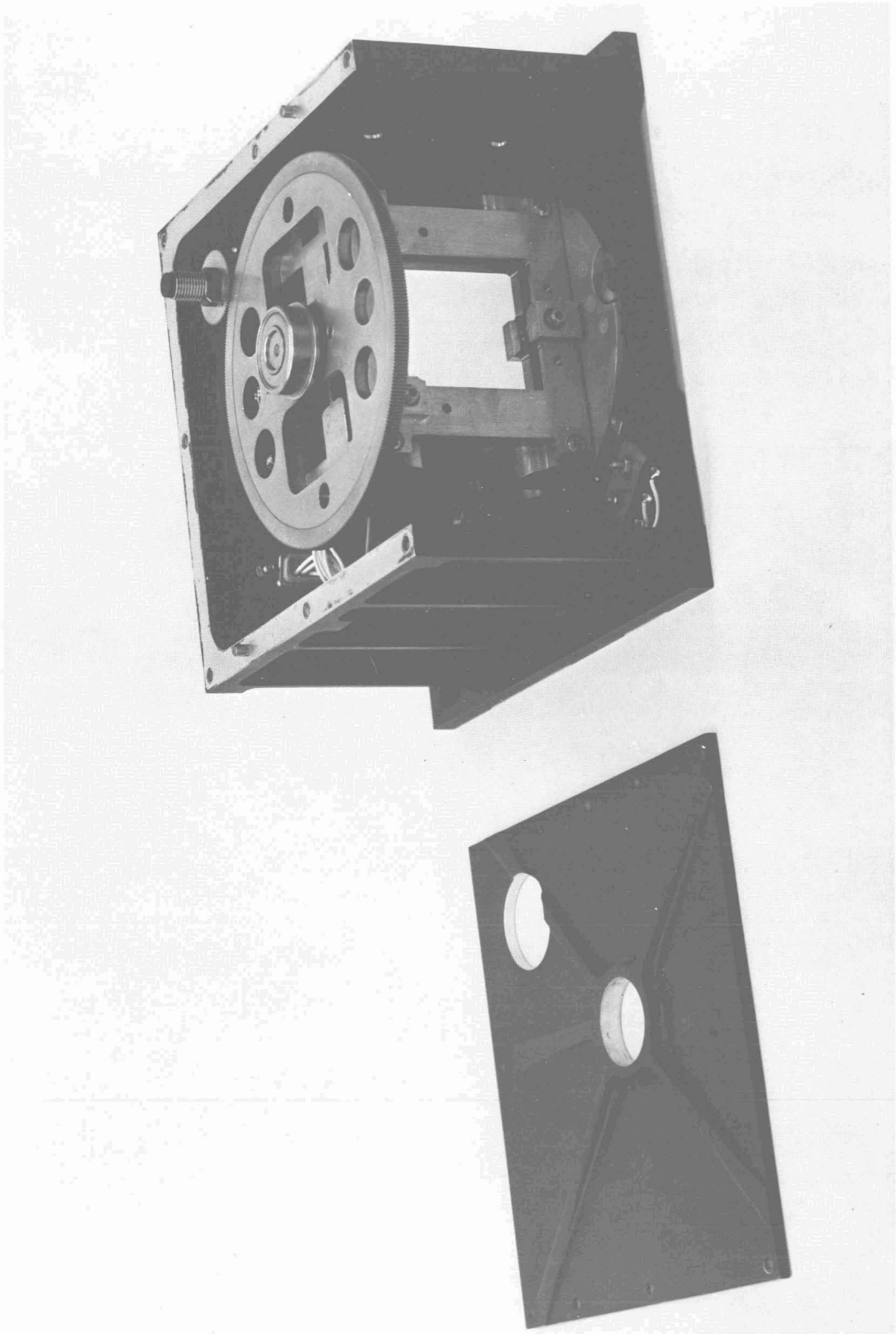


Figure 2-15. Predisperser Assembly

Light at other wavelengths was prevented from reaching the main grating by light baffles.

2.2.1.10 Main Grating Assembly

The main grating was a 2 meter radius concave grating with 600 grooves per millimeter ruled in a 76 x 152 millimeter area on an 85 x 160 millimeter glass blank. It was held in focus and alignment by adjusting screws within a frame structure. The adjusting screws were backed up with positive stops to prevent grating displacement or damage during handling and launch. The frame was rigidly attached to the main instrument case wall (see Fig. 2-16).

2.2.1.11 Film Camera Assembly

See Section 4.2.

2.2.2 Electrical and Electronics Subsystem

The S082B UV Spectrograph Electronics consisted primarily of the following subsystems:

- Power Supplies
- Internal Mode Timing Electronics
- Mechanism Drive Electronics
- Temperature Sensors
- Telemetry
- Command Sensors
- ATM Panel Indicators
- Diode Array

The electronics generally used a basic design philosophy of using simple proven design and components where possible, providing necessary troubleshooting outputs, 100 percent margin on mechanism drivers, and maximum possible bench testing to assure reliability and compatibility of the design with all interfaces.

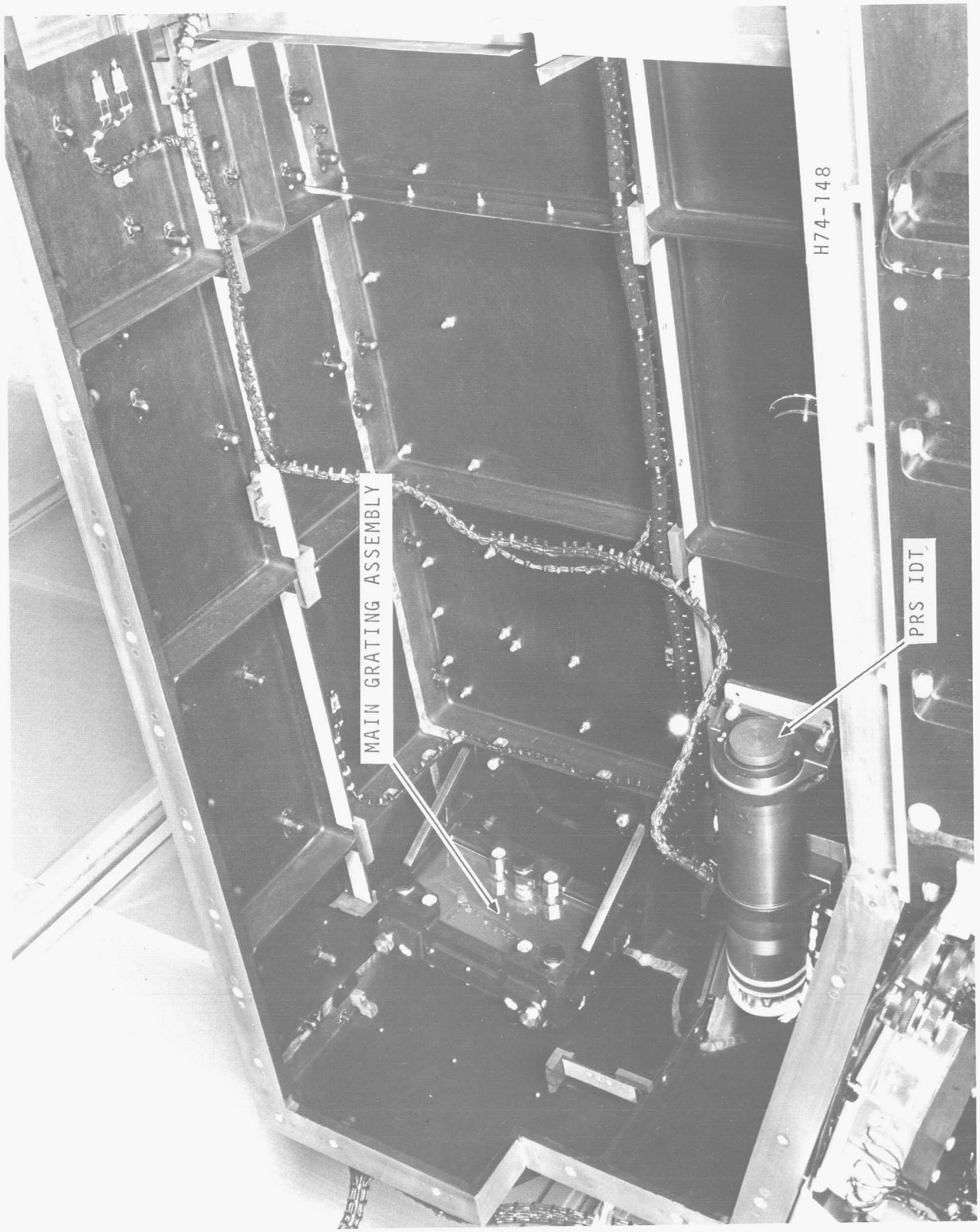


Figure 2-16. Main Grating Assembly (S082B)

The list of commands and their function is shown in Table 2-5.

The nearly complete electronics assembly is shown in Figure 2-17 and a conceptual diagram is shown in Figure 2-18. The micrologic cordwood construction provided a very high packaging density. A method to further increase the packaging density of the S082B electronics consisted of the welded matrix fence. This matrix fence removes some of the module to module interconnections from the printed wiring board and transfers these interconnections to the "fence". The welded matrix fence is a module with vertical and horizontal ribbons. Interconnections between the vertical ribbons (the module pins) and the horizontal ribbons formed a circuit path. The fence pins were then soldered to the printed wiring board to complete a circuit path. Both the micrologic cordwood module and the welded matrix fence are discussed in BBRC Document No. 620-20. In addition, a New Technology Report No. TR71-08 discusses the welded matrix fence.

During the design and subsystem test phase, significant noise problems were encountered with the S082B electronics and resolved. During the instrument systems test, integration with the ATM and Mission Operations, essentially no problems were encountered with the exception of the Pointing Reference System limb pointing mode failure during the final days of the SL-4 Mission. This failure is believed to be the result of loss of Image Dissector Tube sensitivity.

2.2.2.1 Power Supplies

The power supply consisted of four primary subsystems: One (1) switching regulator to regulate raw 28 VDC to 20 VDC ±0.1 VDC; and three (3) DC-DC converters to provide the various isolated DC required by remainder of the electronics. The powers required are:

Table 2-5

S082B INSTRUMENT COMMANDS (Sheet 1 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
1. THERMAL ON or OFF (latched)	Not a functional command. It causes application or removal of 28 VDC ATM power to instrument thermal control subsystem.	Instrument thermal control subsystem begins functioning. When the instrument temperature reaches proper values, the heater panels begin cycling on and off individually to maintain temperature. After execution the following indications are present: 1. Partial analog telemetry (TCS panel temperatures and reference temperatures) available for sampling.	ON: 1. Instrument temperature between 40 and 70°F. 2. (Orbital Operation) ATM canister thermal control system operating. OFF: None
2. MAIN POWER ON or OFF (latched)	Not a functional command. It causes application or removal of 28 VDC ATM power to instrument electronics.	Instrument converter is turned on to supply power for analog telemetry and ATM synchronization interface. After execution, the following indications are present: 1. Aperture door closed indication to control panel. 2. Analog telemetry (temperature monitors) available for sampling. 3. Instrument will respond to PWR/DOORS ON command or XUV MONITOR commands.	ON: 1. Instrument temperature between 50 and 80°F. 2. (Orbital Operation) THERMAL ENABLE. OFF: 1. PWR/DOORS OFF 2. Instrument aperture door closed indication.
3. PWR/DOORS ON (momentary)	Applies continuous 28 VDC command to instrument to turn on all internal converter power and open instrument aperture door.	If not in HOLD: Instrument converter is turned on to supply power for internal logic, digital telemetry, and mission time interface. Following this, instrument aperture door is opened. (See No. 18 below for modified operation with aperture door open inhibit command.) After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. All telemetry measurements available for sampling. 5. Instrument will respond to all other normally functional commands. If in HOLD: All internal power is already on. Immediately following command, instrument aperture door is opened. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Hold indication to control panel. 5. Mode indication (whichever mode was held) to control panel. 6. All analog telemetry and limb offset digital telemetry (only) available for sampling. 7. Instrument will respond to any normally functional command except WAVE LGTH SHORT or LONG, or any MODE START command.	1. MAIN POWER ON. 2. (Orbital Operation) Instrument must be pointed toward sun and thermally stabilized. 1. MAIN POWER ON. 2. HOLD commanded previously while PWR/DOORS ON. 3. (Orbital Operation) Instrument must be pointed toward sun and thermally stabilized.
4. PWR/DOORS OFF (momentary)	Applies continuous 28 VDC command to instrument to turn off internal converter power (if not in HOLD) and close instrument aperture door.	If not in HOLD: Instrument aperture door is closed; camera shutter is closed (if open) and film is cycled; all instrument converter power for PRS, internal logic, digital telemetry, and mission time interface is turned off. After command execution, the following indications are present: 1. Aperture door closed indication to control panel. 2. Analog telemetry (temperature monitors) available for sampling. 3. Instrument is capable of responding to PWR/DOORS ON command or XUV MONITOR commands.	None

Table 2-5 (continued)
(Sheet 2 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		If in HOLD: Instrument aperture door is closed. After command execution, the following indications are present: 1. Aperture door closed indication to control panel. 2. Shutter closed indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Hold indication to control panel. 5. Mode indication (whichever mode was held) to control panel. 6. All analog telemetry available for sampling. 7. Instrument will respond to any normally functional command except WAVE LGTH SHORT or LONG or any MODE START command. If HOLD is removed, instrument will shut down as above.	1. Instrument in HOLD.
5. WL DISPLAY (WL display command to PRS) (momentary)	Causes PRS to enter the white light display state.	From PRS OFF condition: A relay is closed which supplies +15 VDC to the PRS and turns on the high voltage supply for the image dissector tube. After command execution, the following indications are present: 1. White light video image of the slit plate is generated. 2. White light display on is present on digital telemetry. 3. Other instrument commands or indications are not affected by this command or state, except as noted above.	1. PWR/DOORS ON. 2. (Ground Operation): The neutral density filter must be removed and simulated solar illumination must be focused on the primary mirror. 3. (Orbital Operation): The instrument will normally be pointed on the disk.
		From LIMB SCANNING or LIMB POINTING states: PRS immediately shifts to WL display state. The primary mirror is released to null (zero mirror offset). After execution the same indications as above are present.	1. Limb scanning or Limb pointing on.
6. LIMB SCAN on (momentary)	Causes PRS to enter the limb scanning state.	From PRS OFF condition: A relay is closed which supplies ±15 VDC to the PRS and turns on the high voltage supply for the image dissector tube. After command execution, the following indications are present: 1. Limb scanning on indication to control panel and digital telemetry. 2. Limb offset digital (BCD) output to control panel and digital telemetry. 3. Other instrument commands or indications are not affected by this command or state except as noted above.	1. PWR/DOORS ON. 2. (Ground Operation): The ECE OFFSET ENABLE switch must be actuated, or the neutral density filter must be removed and simulated solar illumination must be focused on the primary mirror. 3. (Orbital Operation): The instrument must be pointed to within ±40 arcseconds of the solar limb and the slit must be approximately parallel to the limb.
		From WL display state: PRS immediately shifts to limb scanning state and video display is turned off. After command execution, the same indications as above are present.	1. WL Display on. 2. (Ground Operation): The ECE OFFSET ENABLE switch must be actuated, unless simulated solar source is used. 3. (Orbital Operation): The instrument must be pointed to within ±40 arcseconds of the solar limb and the slit must be approximately parallel to the limb.
		From limb pointing state: PRS immediately shifts to limb scanning state and the primary mirror is released to null (zero mirror offset). After command execution, the same indications as above are present.	1. Limb pointing on.

Table 2-5 (continued)
(Sheet 3 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
7. LIMB PTG on (momentary)	Causes PRS to enter the limb pointing state.	PRS immediately shifts to limb pointing state and servo control of the primary mirror is activated to maintain the limb offset point. After command execution, the following indications are present: 1. Limb pointing on indication to control panel and analog telemetry. 2. Limb offset digital (BCD) output to control panel and digital telemetry. 3. Mirror offset voltage to control panel meter and analog telemetry. 4. Auto offset mode start command is enabled. 5. Other instrument commands or indicators are not affected by this command or state except as noted above.	1. Limb scanning on. 2. Limb offset between +40 arc-seconds and -40 arc-seconds.
8. MAN STEP (momentary)	Causes limb offset point to shift +2 arc-seconds.	PRS immediately changes limb offset point by +2 arc-seconds and maintains the new offset. After command execution, the following indications are present: 1. Limb pointing on indication to control panel and analog telemetry. 2. Limb offset digital (BCD) output to control panel and digital telemetry. 3. Mirror offset voltage to control panel meter and analog telemetry. 4. Auto offset mode start command remains enabled. 5. Other instrument commands or indicators are not affected by this command or state except as noted above.	1. Limb pointing on. 2. No automatic mode in process or in HOLD. 3. Limb offset between +40 arc-seconds and -40 arc-seconds. 4. Mirror offset below positive limit by at least 2 arc-seconds of movement. (100 percent represents approximately 70 arc-seconds of movement.)
9. TIME MODE START (momentary)	Causes the film camera shutter to open, beginning a single exposure.	Film camera shutter opens and 1/8 of film strip is exposed (eight exposures per film strip); ATM mission time, ATM pitch, yaw, data good, FSS bias and limb offset are encoded on edge of film by data flasher. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Operate indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Telemetry indicates these conditions. 5. PRS and XUV MONITOR indications are independent of the above conditions.	1. PWR/DOORS ON. 2. No other exposure mode in process. ("Ready" condition on control panel.) 3. PRS as desired.
10. AUTO MODE start (momentary)	Initiates an Auto mode automatic film exposure sequence.	Film camera shutter opens and first exposure is begun. Sequence of eight exposures is completed automatically with predisperser grating shifting after each exposure, including the last. ATM mission time, ATM pitch, yaw, data good, FSS bias, mode identification and limb offset are encoded on edge of film at the beginning of each exposure by the data flasher; ATM roll and mission time are encoded at the end of each exposure. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to telemetry. (Alternates with shutter closed indication as exposures are completed.) 3. Operate indication to control panel. (Remains until final exposure is completed.) 4. Predisperser grating short or long wavelength position indication to control panel changes after each exposure. 5. Film cycle pulse (after each exposure) to control panel. 6. Telemetry indicates these conditions. 7. HOLD command may be used to stop and hold this mode.	1. PWR/DOORS ON. 2. No other exposure mode in process. ("Ready" indication on control panel.) 3. PRS as desired.

Table 2-5 (continued)
(Sheet 4 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		8. PRS and XUV monitor indications are independent of the above conditions. However, if PRS limb scanning or limb pointing is on, spectral mode exposure times will be automatically prescaled according to the limb offset zone.	
11. AUTO STEP MODE start (momentary)	Initiates an Auto Step mode film exposure sequence.	PRS shifts to -12 arc-seconds limb offset and film camera shutter opens to begin first exposure. One Auto mode is completed at this position and the PRS shifts to -4 arc-seconds limb offset, where another Auto mode is completed. The entire sequence progresses in this manner until the final Auto mode is completed at +20 arc-seconds limb offset (total of 80 exposures). Exposure times are automatically prescaled according to the limb offset zone. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to telemetry. (Alternates with shutter closed indication as exposures are completed.) 3. Operate indication to control panel. (Remains until final exposure is competed.) 4. Predisperser grating short or long wavelength position indication to control panel changes after each exposure. 5. Film cycle pulse (after each exposure) to control panel. 6. Limb pointing on indication to control panel. 7. Limb offset digital output to control panel. (Changes as point is changed.) 8. Mirror offset voltage to control panel meter. (Changes as point is changed.) 9. Telemetry indicates these conditions. 10. HOLD command may be used to stop and hold this mode, but PRS must then be repointed to the correct limb offset before removing HOLD to resume mode. 11. XUV monitor indications are independent of the above conditions.	1. PRS in limb pointing state. 2. No other exposure mode in process. ("Ready" indication on control panel.)
12. FLARE ENABLE (momentary)	Enables the instrument to accept a FLARE MODE INITIATE command.	Enable condition is stored in instrument logic. Any mode in process is not affected. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Normal indications from mode in process. 3. Normal indications from PRS and XUV monitor. 4. Flare mode enable indication to control panel. 5. Telemetry indicates these conditions.	1. PWR/DOORS ON.
13. FLARE INHIBIT (momentary)	Removes FLARE ENABLE condition.	Enable condition stored in instrument logic is removed. Any mode in process is not affected. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Normal indications from mode in process. 3. Normal indications from PRS and XUV monitor. 4. Telemetry indicates these conditions.	1. PWR/DOORS ON.
14. MASTER FLARE MODE INITIATE (momentary)	Initiates a flare mode automatic film exposure sequence.	Any mode in process except a flare mode, is immediately terminated; PRS is turned off and the camera shutter is closed. If FLARE ENABLE was previously commanded, the predisperser grating moves to the short wavelength position, the camera shutter opens and film is exposed. ATM mission time, pitch, yaw, roll, data good, FSS bias, mode identification, and limb offset are encoded by the	1. PWR/DOORS ON. 2. FLARE ENABLE ON.

Table 2-5 (continued)
(Sheet 5 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		data flasher on each exposure. Sequence of 48 exposures is completed automatically. Predisperser grating position is changed between exposures as programed. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter open indication to telemetry. (Alternates with shutter closed indication as exposures are completed.) 3. Flare mode on indication to control panel. 4. Predisperser grating short or long wavelength position indication to control panel in accordance with program. 5. Film cycle pulse (after each exposure) to control panel. 6. Telemetry indicates these conditions. 7. PRS may be turned on at any time if desired, but OFFSET STEP is disabled. 8. XUV monitor indications are independent of the above conditions. If FLARE ENABLE was not previously commanded, the instrument remains in ready condition awaiting further commands. After FLARE MODE INITIATE command, the following indications are present: 1. Aperture door open indication to control panel. 2. Shutter closed indication to telemetry. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Telemetry indicates these conditions. 5. XUV monitor indications are independent of the above conditions. If a flare mode was in process, the command is ignored.	
15. STOP (momentary)	Terminates any mode in process.	If the camera shutter is open, ATM mission time (13 least significant bits) and ATM roll are encoded on edge of film strip by data flasher; shutter is closed; film is cycled and mode in process is terminated. After command execution, the following indications are present. 1. Aperture door open indication to control panel. 2. Ready indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Film cycle pulse to control panel (if shutter was closed by STOP command). 5. Telemetry indicates these conditions. 6. PRS and XUV monitor indications are independent of the above conditions.	1. PWR/DOORS ON.
16. WAVE LTH SHORT/LONG (momentary)	Changes the wavelength to be photographed.	Predisperser grating moves to position commanded. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Predisperser grating position indication as commanded, to control panel. 3. Telemetry indicates these conditions. 4. PRS and XUV monitor indications are independent of the above conditions.	1. PWR/DOORS ON. 2. No automatic exposure mode in process. ("Ready" indication on control panel.)
17. HOLD (latched)	Stops and holds any automatic mode for later resumption.	Terminates exposure in process; ATM roll and mission time data are encoded on film exposure by data flasher; shutter is closed, and film is cycled; mode in process is stopped	1. PWR/DOORS ON.

Table 2-5 (concluded)
(Sheet 6 of 6)

COMMAND NAME	FUNCTION	INSTRUMENT RESPONSE	PREREQUISITES
		but held in the programer; PRS is turned off. After command execution, the following indications are present: 1. Aperture door open indication to control panel. 2. Operate indication to control panel. 3. Predisperser grating short or long wavelength position indication to control panel. 4. Mode indication to telemetry. 5. Hold indication to telemetry. 6. All analog telemetry and limb offset digital telemetry (only) available for sampling. 7. Instrument will respond to any normally functional command except WAVE LGTH SHORT or LONG, XUV SLIT MAN STEP, or any MODE START command.	
18. APERTURE DOOR OPEN INHIBIT (continuous)	Allows instrument PWR/DOORS ON command to be executed with the door remaining closed. For ground test only.	If commanded before PWR/DOORS ON, instrument performs all functions of PWR/DOORS ON command (see No. 3 above) except aperture door does not open and a light-emitting diode group is turned on to focus a test-light image on the faceplate of the PRS image dissector tube. If commanded after PWR/DOORS ON, there is no effect. This command has no effect upon the XUV monitor aperture door.	1. MAIN POWER ON. 2. PWR/DOORS OFF.
19. XUV MON DOORS OPEN/CLOSE (momentary)	Opens or closes the XUV monitor aperture door.	XUV monitor aperture door opens or closes. When door is closed, a microswitch causes power to be applied to light-emitting diodes which light the faceplate of the XUV monitor camera. This command and the aperture door circuits are independent of all other commands and indicators. After command execution, the following indications are present: OPEN: 1. XUV monitor door open indication to control panel. CLOSED: 1. XUV monitor door closed indication to control panel. 2. Four dots may be seen on the XUV monitor video display if the camera has been turned on.	1. MAIN POWER ON.
20. XUV MON PWR ON/OFF (latched)	Not a functional command. It causes application or removal of 28 VDC ATM power to the camera control unit.	After a one to two-minute delay, high voltage power is applied to the XUV monitor camera, allowing normal operation to begin. After command execution and the time delay, the following indications are present: 1. XUV monitor video output is generated. If instrument XUV monitor aperture is closed, four dots may be seen on the video monitor. If the aperture is open, an XUV solar image is presented.	1. (Ground Operation): Insure that excessive light is not impinging on the camera faceplate. 2. XUV MON selected on monitor 1 or 2.
21. XUV MON GRID DISCH (momentary)	Recovers XUV monitor camera from a latched condition resulting from excessive light on the faceplate.	Reduces suppressor grid to ground. Condition requiring this command appears at the video monitor as a black spot or area persisting on an excessively bright image. While grid is grounded, the image appears very defocused or blurry. After release of the command, a normal image will appear if the excessive light condition causing the problem has been eliminated.	1. XUV MON PWR ON.
22. XUV MON INTEG (momentary timed)	Integrates image on XUV monitor camera target while command is present.	Turns off the electron beam and allows a buildup of image energy on the target. When command is removed, the integrated image flashes on the video monitor for the duration of one frame (1/15-second).	1. XUV MON PWR ON.
23. XUV MON GAIN control (7 position rotary switch)	Adjusts XUV monitor camera gain downward in 7 steps.	From position 7 (maximum gain) the camera is reduced by a factor of approximately 1.7 with each step on the switch.	1. XUV MON PWR ON.

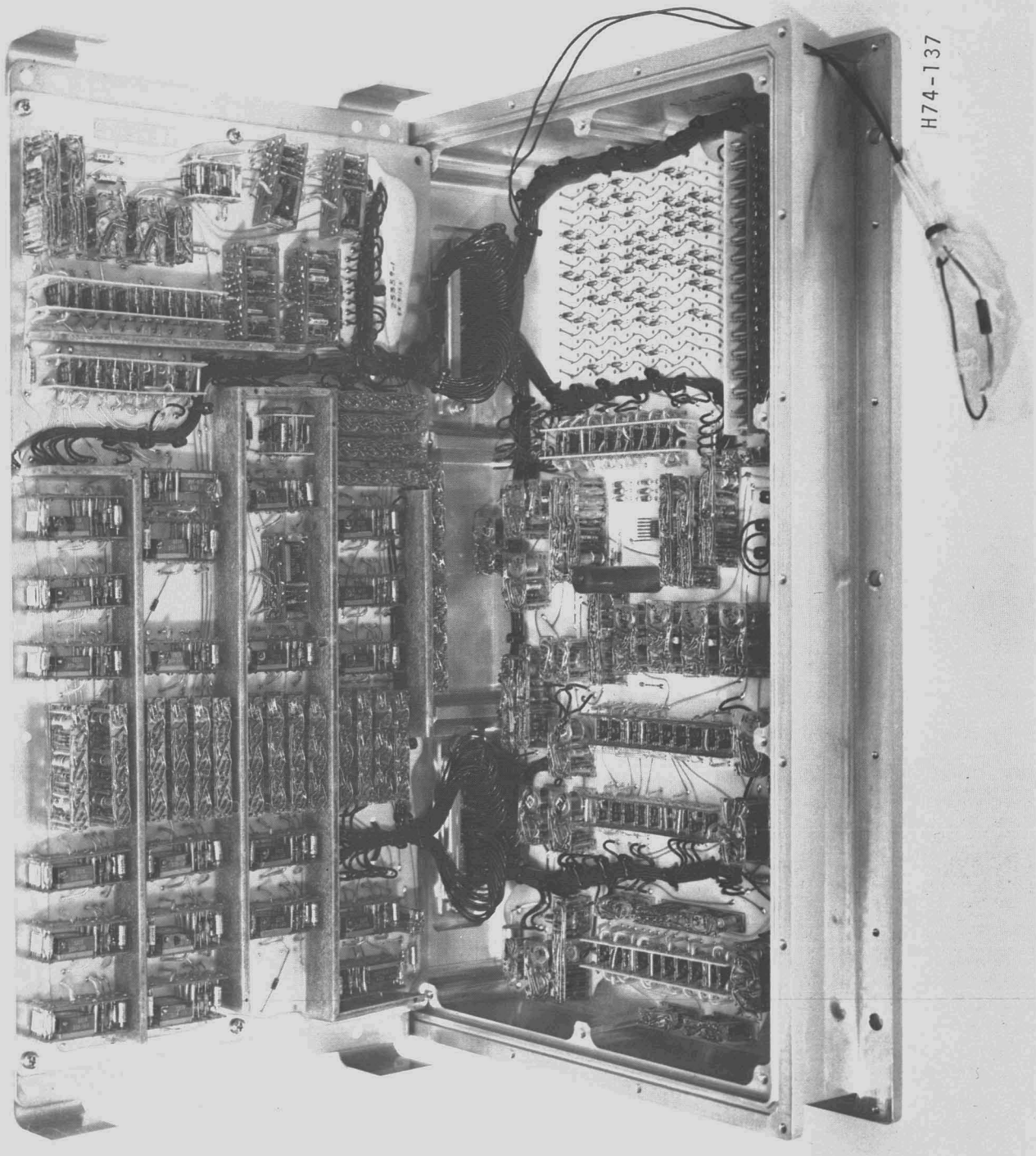


Figure 2-17. A2 Electronics Assembly (Analog Commutator and Exposure Time Computer Assembly)

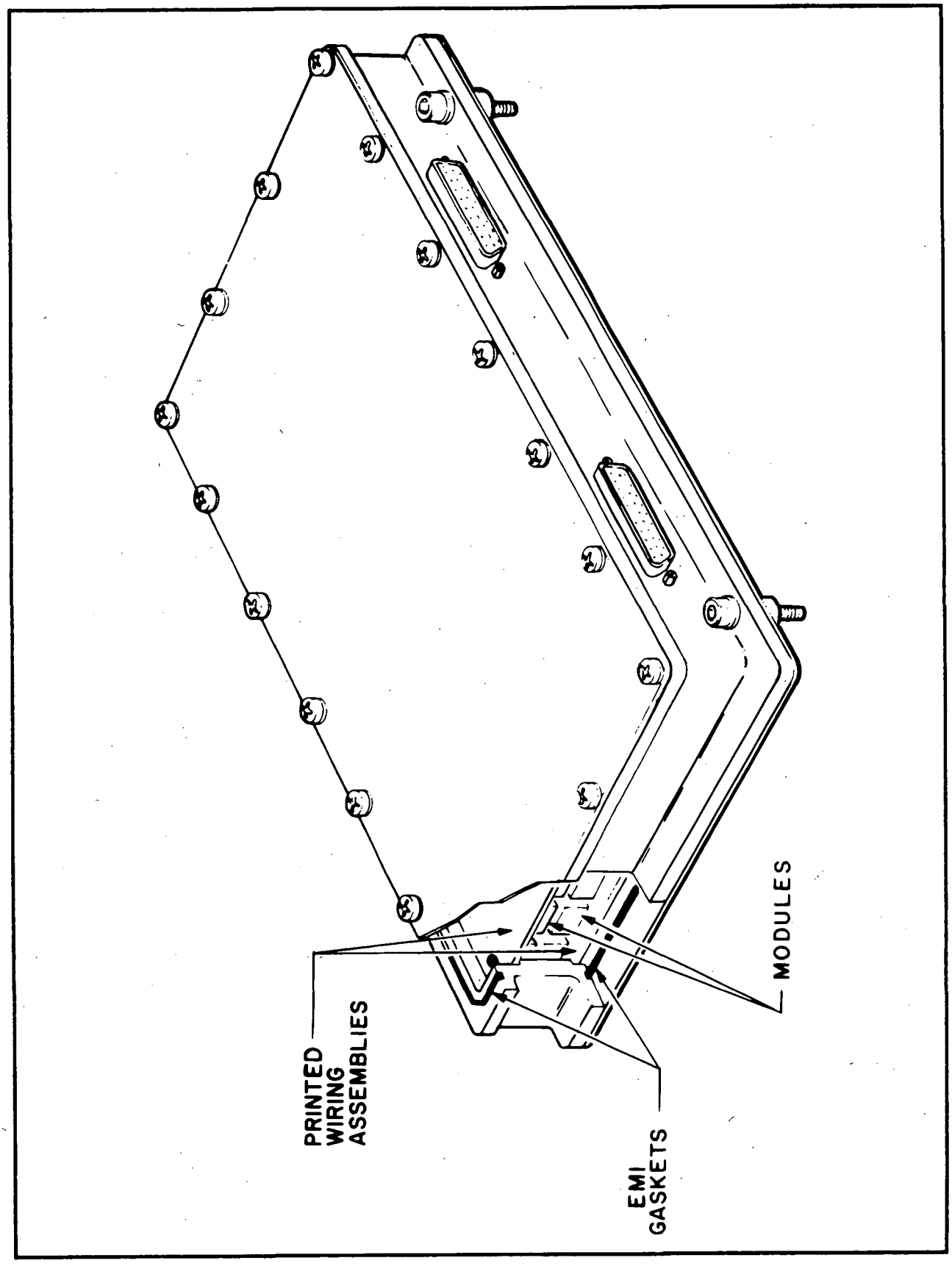


Figure 2-18. Typical Construction of S082B Electronic Assemblies

Voltage	Current
+ 5 VDC Analog	200 ma
+ 5 VDC Sync	100 ma
+15 VDC Analog (Servo & Commutator)	223 ma
-15 VDC Analog (Servo & Commutator)	175 ma
+15 VDC Analog Video	150 ma
-15 VDC Analog Video	150 ma
+ 5 VDC Logic	750 ma
+ 5 VDC Digital	100 ma
+ 5 VDC ASAP	150 ma

In the design three DC-DC converters were used: one provided two of the isolated powers required for sensing temperature and telemetry, the second for all other power used when instrument was in an active operating mode, and the third provides the isolated power for the PRS system and the commutator. The switching regulator was used because of the inherent high efficiency of these units. Extra design precaution was required to eliminate noise normally associated with switching regulators and DC-DC converters.

2.2.2.2 Internal Mode Timing Electronics

The mode timing electronics provided the proper exposure times for the three automatic modes of operation: Auto Mode, Auto Step Mode and Flare Mode. These exposure times are shown in Tables 2-6, 2-7 and 2-8. The exposure times were derived from a basic 3.6 kHz frequency provided by the ATM. The 3.6 kHz was divided through simple micrologic bi-stable multivibrators. DTL micrologic was selected because of its availability and low power requirements.

In addition to deriving the required exposure times, the internal timing electronics developed the signals necessary to command wavelength changes when appropriate and camera cycling automatically after each exposure.

Table 2-6

S082B AUTO MODE EXPOSURE TIMES

Auto Mode Exposure Times for Limb Scanning State in Zone 1, Limb Pointing State in Zone 1, and White Light Display State.

Short Wavelength Predisperser Grating	Long Wavelength Predisperser Grating
2.5 seconds	0.312 second
10.0 seconds	1.25 seconds
40.0 seconds	5.0 seconds
160.0 seconds	20.0 seconds

NOTE: Zone 1 includes positions on disc and off limb through +1 arc-second. This table applies to the white light display state for any pointing position.

Auto Mode Exposure Times for Limb Scanning State and Limb Pointing State in Zone 2.

Short Wavelength Predisperser Grating	Long Wavelength Predisperser Grating
10.0 seconds	2.5 seconds
40.0 seconds	10.0 seconds
160.0 seconds	40.0 seconds
640.0 seconds	160.0 seconds

NOTE: Zone 2 includes positions off limb from +2 through +9 arc-seconds.

Auto Mode Exposure Times for Limb Scanning State and Limb Pointing State in Zone 3

Short Wavelength Predisperser Grating	Long Wavelength Predisperser Grating
16.0 seconds	4.0 seconds
64.0 seconds	16.0 seconds
256.0 seconds	64.0 seconds
1024.0 seconds	256.0 seconds

NOTE: Zone 3 includes positions off limg +10 arc-seconds and greater.

DATA SOURCE: CP25100

Table 2-7

S082B AUTO STEP MODE EXPOSURE TIMES

Zone	1		2		3	
Predis-perser Grating Position	Short	Long	Short	Long	Short	Long
Exposure Duration	2.5 sec 10 sec 40 sec 160 sec	0.312 sec 1.25 sec 5.0 sec 20 sec	10 sec 40 sec 160 sec 640 sec	2.5 sec 10 sec 40 sec 160 sec	16 sec 64 sec 256 sec 1024 sec	4 sec 16 sec 64 sec 256 sec

Table 2-8

S082B FLARE MODE SEQUENCE EXPOSURE TIMES

Set	Wavelength	Exposure Duration (Seconds)			
1	Short	0.312	1.25	5.0	20
2	Short	0.312	1.25	5.0	20
3	Long	0.156	0.625	2.5	10
4	Short	0.312	1.25	5.0	20
5	Short	0.312	1.25	5.0	20
6	Long	0.156	0.625	2.5	10
7	Short	1.25	5.0	20.0	80
8	Long	0.156	0.625	2.5	10
---------- Wait 120 Seconds ----------					
9	Short	1.25	5.0	20.0	80
10	Long	0.156	0.625	2.5	10
---------- Wait 120 Seconds ----------					
11	Short	1.25	5.0	20.0	80
12	Long	0.156	0.625	2.5	10

2.2.2.3 Mechanism Drive Electronics

The mechanisms including the camera film strip exchanger, the grating and the aperture door, all used stepper motors as the driving electromechanical devices. The pulses required are again derived from 3.6 kHz divided down to the driving frequency required. All drive interface electronics were essentially switching circuits, and the necessary phase relationships were developed using DTL micrologic identical to those used elsewhere in the electronics.

The camera shutter was a solenoid mechanism, and monostable multivibrators were used to develop the required drive times. The interface to the solenoids were essentially identical to those used for stepper motor drivers.

2.2.2.4 Temperature Sensors

The S082B temperature sensors consisted of absolute and differential temperature sensors. The coarse and fine absolute sensors were very similar in design, and differed only in the temperature range covered. The coarse temperature sensor had a range of 50°F to 100°F and was used on the slit plate, the primary mirror mount and the electronics. The fine temperature sensors were used to detect the electronic package temperature and in 11 places to detect the instrument case temperature. The range of the fine sensors was 50°F to 80°F.

The differential temperature sensors were used to detect difference temperatures across the instrument case. Four pairs of carefully selected and matched thermistors were used to measure the differential temperature across the case, and four additional matched thermistor pairs measured the difference temperature from the instrument lid to the base.

The temperature sensors were required to calculate the potential case distortions because of temperature variation causing optical

degradation. With the instrument optically aligned at approximately 70°F absolute and 0°F differential, any temperature change would cause some distortions and knowledge of the magnitude of temperature changes allowed the optical degradation to be calculated.

2.2.2.5 Telemetry

The telemetry system had four subcommutated channels of 15 inputs each and 14 digital channels. The digital channels monitored the two camera shutter positions and the short and long wavelength grating positions, many of the operating modes, film transport position, the XUV Monitor and instrument door OPEN. The subcommutated channels monitored the instrument temperature sensors, all voltages, all remaining mechanism positions and the remaining modes of instrument operation. The commutator used the 1/15 Hz clock rate provided by the ATM.

2.2.2.6 Command Sensors

The command sensors were primarily of the buffered Schmidt trigger type of circuit. Since the commands provided by the ATM were of 28 VDC in magnitude and less than 5 VDC low level, it was possible to use high level noise rejection circuits to prevent unwarranted commands causing instrument operation. In the actual design the instrument would not respond to less than 15 VDC input or greater than 15 VDC for less than 3.2 milliseconds.

2.2.2.7 ATM Panel Indicators

The mechanism positions and mode of operation were output to the TM panel to indicate instrument operation to the ATM operator.

2.2.2.8 Diode Array

The diode array consisted of light emitting diodes and was used to annotate time, ATM pointing information and PRS pointing information for each exposure on the film strip. Time in day, hour, minute,

second and millisecond, and roll, pitch and yaw were recorded on film each time the film camera shutter was opened. In addition, time in minutes, seconds and milliseconds was recorded immediately prior to the shutter closing. Therefore, time, pointing position and exposure time were recorded for each exposure.

2.2.2.9 Electromagnetic Interference

Potential EMI problems were considered in the initial instrument design. Isolated power supplies, to separate various instrument functions, were used to preclude EMI problems; i.e., analog telemetry, the diode array, the internal timing circuits, the ATM clock, etc. All the returns, both signal and power, were routed through the ATM interface cables to a single point ground in the ATM. Optical couplers were used in some circuits to isolate the ATM input from the instrument. Cables provided separation of the mechanism high current lines from the signal and sensing lines for temperatures, position indicators, etc. In spite of these precautions, a number of noise problems were encountered during the subsystem tests of the flight packaged electronic boxes. These problems were resolved with significant effort and presented no further difficulties throughout the systems tests or flight operations.

2.2.3 Optical Subsystem

The basic optical design of the S082B Spectrograph was specified by NRL in their proposal to NASA on Form 1346 dated 20 October 1967. Implementation of the basic optical design into the instrument hardware design was developed through many consultations between NRL scientists and BBRC engineers. Figure 2-19 shows the optical layout. The principal optical components are the primary mirror, the spectrograph slit, predisperser gratings and the main grating. Secondary components include the data flasher projection system and the pointing reference system relay lens and folding mirrors shown in Figure 2-20.

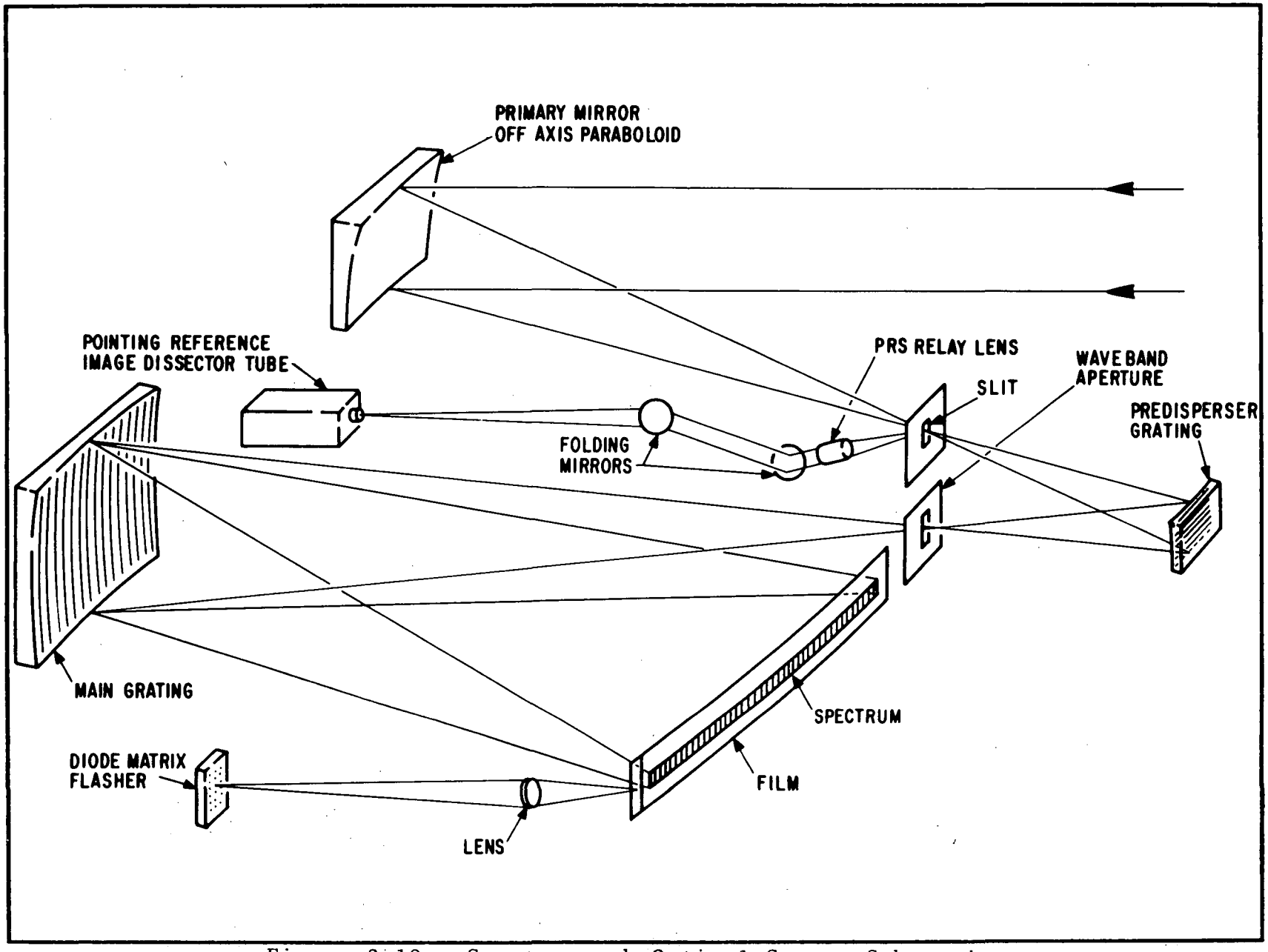


Figure 2-19. Spectrograph Optical System Schematic

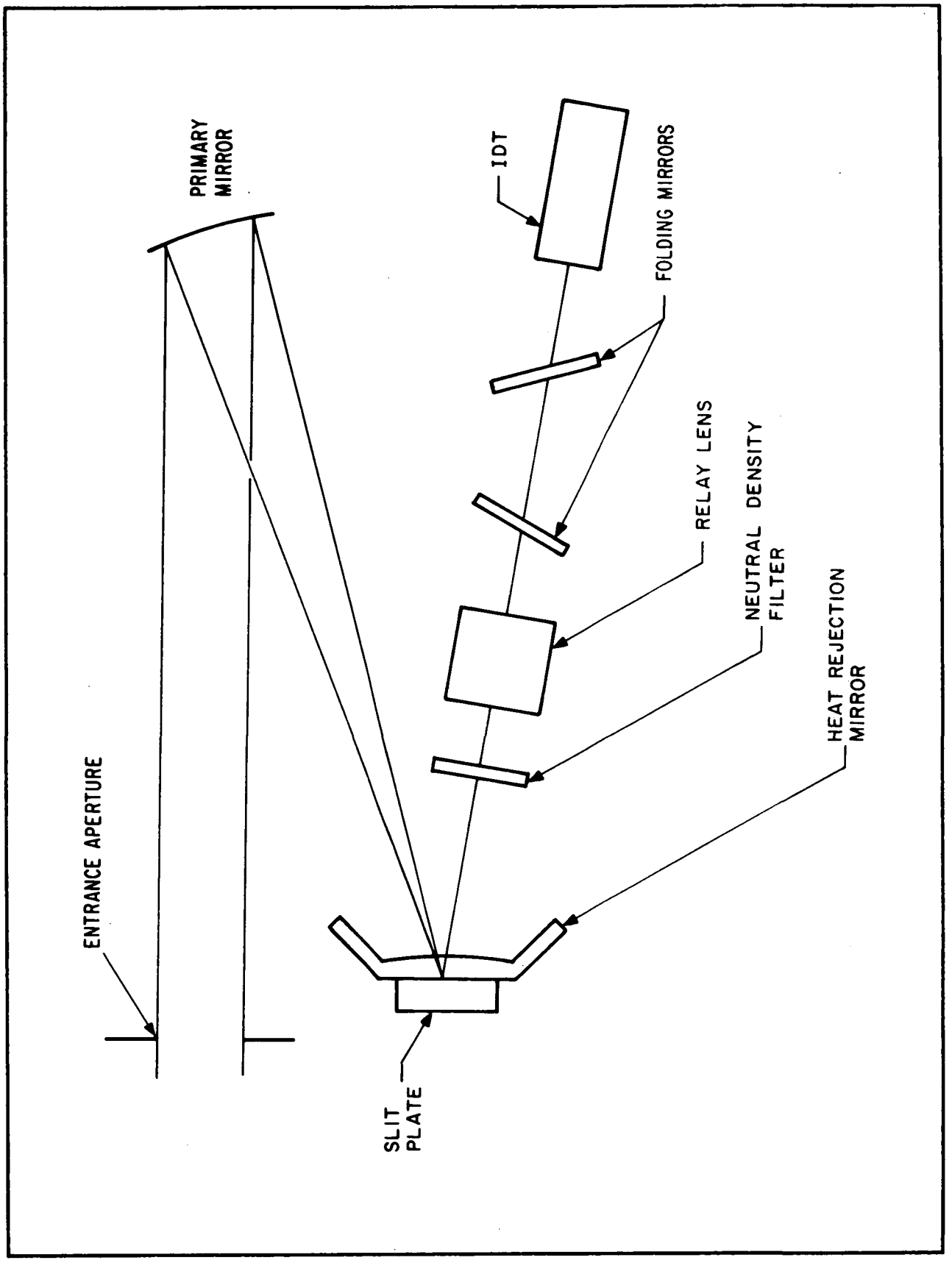


Figure 2-20. Pointing Reference Subsystem Optical Schematic

The primary mirror was procured from Perkin-Elmer by NRL and furnished to BBRC as Government Furnished Equipment. The main grating and two predisperser gratings were procured from Bausch and Lomb by NRL and furnished to BBRC as GFE. Data flasher optics and pointing reference system optics were designed and procured by BBRC.

After it had been installed in the S082B Flight Instrument for nearly a year, it was discovered that the flight main grating had suffered a marked decrease in optical efficiency. Intensive investigation at NRL revealed the cause to be an intermetallic reaction between the gold and aluminum layers used in the replica grating construction. The results of this investigation were described by Hunter, Mikes, Anstead and Osantowski in *Applied Optics*, September 1971, Vol. 10, No. 9, page 2199. As a result of this discovery, the main grating and both predisperser gratings were replaced with gratings constructed with aluminum on aluminum, eliminating the gold-aluminum interface.

A considerable amount of development effort was expended in order to produce satisfactory predisperser gratings. The major development events were as follows:

A. The predisperser grating rulings were divided into ten panels, each with a slightly different ruling constant, for the purpose of minimizing the astigmatism effect of the main grating. It was found necessary to modify the set of ruling constants of these gratings in order to obtain the desired degree of astigmatism correction.

B. Tests made with the first flight quality gratings in the instrument, indicated a high level of stray light generated by the predisperser gratings. It was necessary to replace these gratings twice with improved quality gratings in order to obtain satisfactory scattered light performance.

C. In order to obtain a suitable intensity distribution in the long wavelength range, it was decided to change the overcoating of the long wavelength predisperser grating from magnesium fluoride to a combination of germanium and zinc sulphide.

D. And finally, it was necessary to replace the predisperser gratings again, just before delivery of the instrument, in order to eliminate the gold-aluminum interface problem discussed above in connection with the main grating.

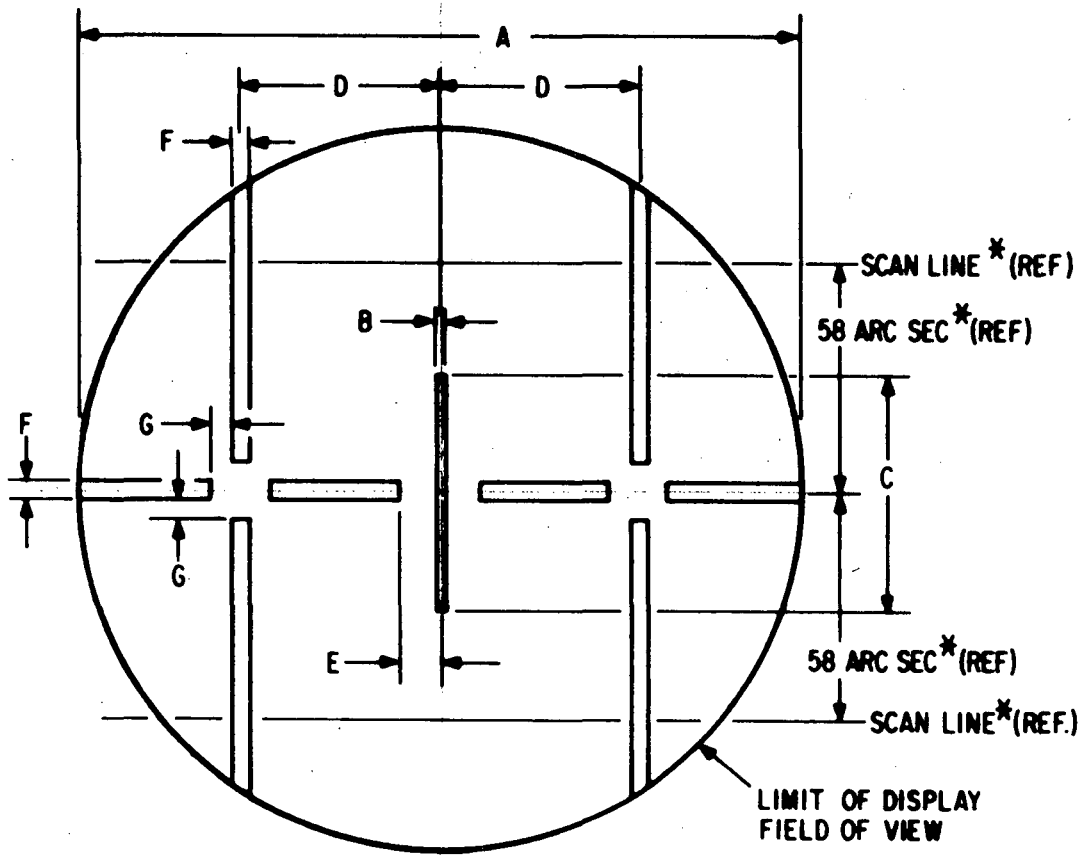
The spectrograph slit plate, described in Section 2.2.1.7 and Figure 2-21, was developed and fabricated by the Buckbee-Mears Company under contract with BBRC. The very small dimensions, the high mechanical precision and the severe optical performance requirements made the fabrication of the slit plate a real state-of-the-art development. A great amount of cooperative effort was expended by Buckbee-Mears and BBRC to obtain a slit plate of acceptable quality for the flight instrument.

2.2.4 Pointing Reference Subsystem

The purpose of the PRS was to provide a dual function video system that would do the following:

A. Provide the astronauts with a high resolution TV display for use in pointing the instrument slit at solar features or at the solar limb.

B. Provide a decimal readout, in arc seconds, of the pointing angle between the solar limb and the instrument slit. It would also hold a selected instrument pointing angle by servo control of the primary mirror. The decimal readout was visually displayed on the astronaut's C&D Panel, recorded on the film data and transmitted by telemetry.



	DIMENSIONS ARC SECONDS	MM* (REF.)	INCH* (REF.)
A	180* NOMINAL	0.873	0.0344
B	$2^{+0.3}_{-0.2}$	0.0097	0.00038
C	60 ± 3	0.291	0.0115
D	50 ± 0.5	0.242	0.0095
E	10 ± 1	0.048	0.0019
F	4 ± 0.6	0.019	0.00076
G	5 ± 1.5	0.024	0.00095

NOTE: HORIZONTAL LINE TO BE CENTERED RELATIVE TO SLIT LENGTH C WITHIN 0.5 ARC SECOND

* THESE DIMENSIONS ARE FOR INFORMATION ONLY.

DIMENSIONS IN ARC SECONDS VIEWING ANGLE RELATIVE TO SOLAR IMAGE, BASED ON ONE METER EFFECTIVE FOCAL LENGTH PRIMARY MIRROR.

Figure 2-21. Instrument Slit Plate

The optical layout of the PRS is shown in Figure 2-22. The slit plate configuration is shown in Figure 2-21.

The reflected image of that portion of the solar image focused on the slit plate by the primary mirror was refocused on the Image Detector Tube (IDT) face via the PRS optics. The optics consisted of a relay lens, two folding mirrors, a neutral density filter and a bandpass filter. The image focused on the IDT face was near the optimum wavelength for the IDT and had been attenuated to provide proper light levels under space sun illumination.

In the TV mode the IDT scanned the slip plate image at standard TV rates. Horizontal and vertical scanning was developed by linear integrators using ATM supplied drive signals for integration reset. The IDT video output was preamplified at the IDT prior to amplification and impedance matching by the video electronics for interfacing with the ATM video system.

In the pointing mode the image on the photocathode was scanned above and below the slit with a 1 kHz horizontal scan supplied by the PRS electronics. This gave the distance from the fiducial mark to the sun's limb in an electrical signal. This signal was shaped and processed in the video electronics and converted into pulses indicating the distance between the fiducial mark and the limb as a function of sweep scan time. These two pulses were then processed by logic electronics to generate a readout of the slit position with respect to the solar limb in arc seconds.

To control the distance between the slit and the limb a particular conditioned video pulse width was memorized by the logic electronics. Any change in conditioned video was compared with the stored video and the difference generated an error signal. This error signal was processed by the servo electronics to drive the primary mirror torque motor and, thus, closed the optical feedback path to the

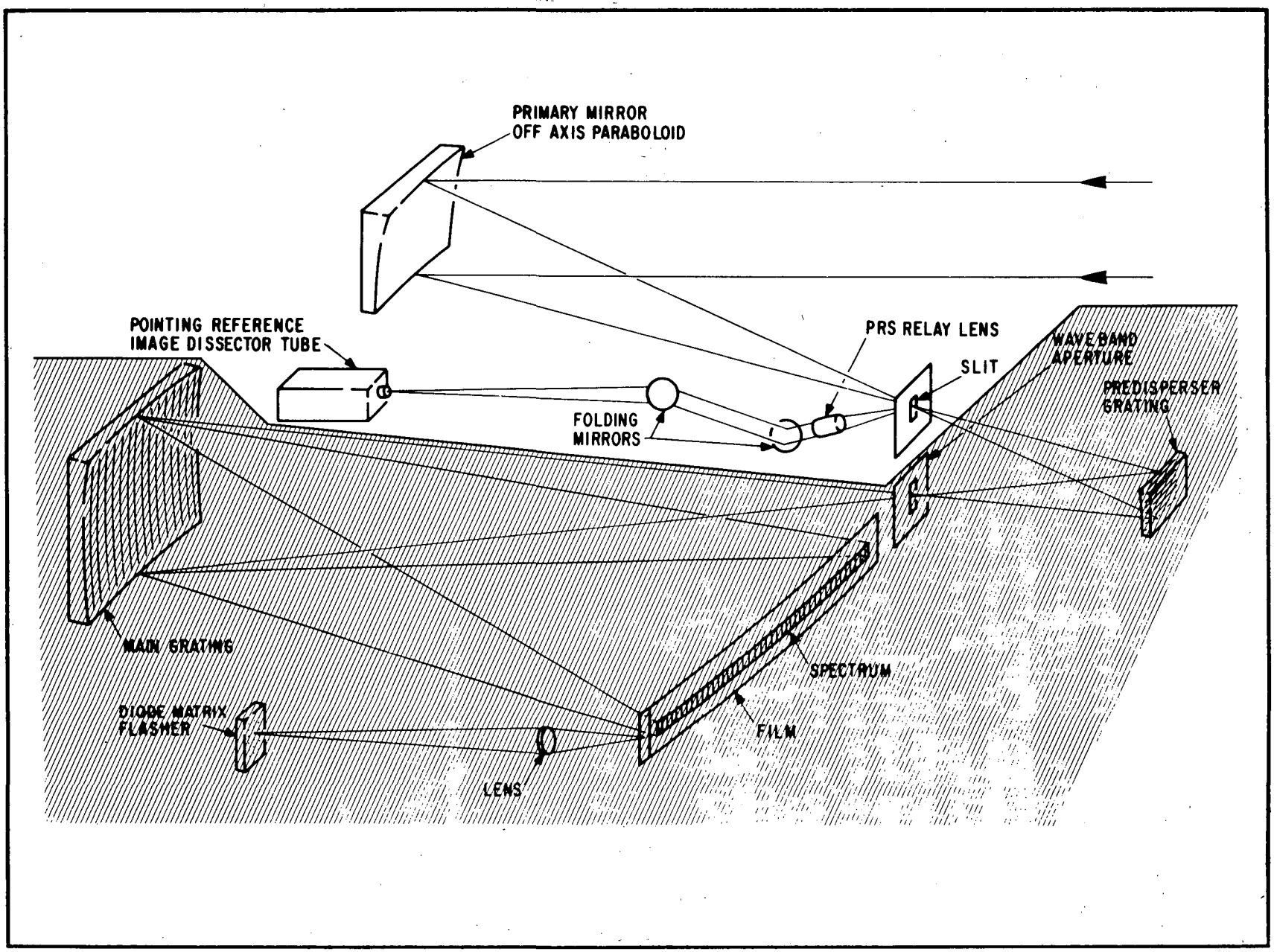


Figure 2-22. PRS Optical Schematic

IDT. The system was designed to sample for presence of video at the start of each sweep. If video was not present, the direction of sweep would reverse. This allowed pointing at either the right or left limb without rolling the ATM canister.

A test light was provided for ground test only. It consisted of four (4) light emitting diodes and a lens assembly. The light was projected directly on the IDT. A lockout device was provided to prohibit the lights from being illuminated when the aperture door was open.

2.2.5 Thermal Control Subsystem

The TCS maintained the absolute temperature (mean) of the instrument housing within ±1.25°F of the alignment temperature and maintained thermal gradients between the case sides and between the case top and bottom to less than 0.2°F. The TCS prevented the instrument temperatures from varying over a range which would have caused optical misalignment, focus shifts, and image smearing that would have degraded recorded data.

The TCS consisted of an active heating system and a passive radiation system (insulation) for controlling and stabilizing instrument temperature. The active heating system had 14 independent honeycomb panels with strip heaters. All heater panels were equipped with independent temperature-sensing thermistors and controller circuitry.

An analog telemetry monitoring subchannel for heater panel and instrument reference temperatures was provided for each heater panel. Nine of the heater panels were mounted on the top surface of the instrument. The remaining five were installed on the side walls.

2.2.5.1 Active Heating System

Low thermal inertia heater panels were used to modulate heat flow from the comparatively high thermal inertial instrument to the cold wall of the ATM canister. Controlling the heat flow in this manner isolated the instrument from environmental temperature variations without introducing thermal gradients into the instrument case.

The heater panels were thermostatically controlled using thermistors connected in bridge circuits. There were two temperature-control bridge-circuit amplifiers per controller, one for instrument-case sensing and one for panel sensing. The instrument amplifier provided an analog voltage of 0 to 5 volts, corresponding to a temperature range of 68 to 72°F. The panel amplifier provided an analog voltage of 0 to 5 volts, corresponding to a temperature range of 65 to 80°F. These amplifier outputs were summed and provided to a level detector and comparator switch. The summation provided an adjustable trigger level to the heater panels that was a function of the average instrument case temperature. In this manner, the active heating system was able to maintain the fine thermal tolerance necessary to maintain focus of the 5 meter optical path.

An overtemperature sensing and control circuit was also provided for each heater panel. It had its own thermistor and electronics, completely redundant to the primary temperature sensing and control circuitry. The overtemperature control ensured against a failure of the primary controller in the ON condition. The overtemperature circuitry used a separate thermistor in a bridge circuit whose output was fed directly into a differential amplifier and comparator. If an overtemperature condition had occurred, the output would have opened a relay and disabled the power supply to the heaters until the panel temperature dropped to an appropriate level.

2.2.5.2 Passive Insulation System

The passive insulation system consisted of insulation panels mounted at locations not covered by the heater panels. The insulation panels consisted of multiple-layers of aluminized Mylar enclosed in Lexan cover sheets. Surface area not covered by active heater panels or passive insulation was covered with reflective aluminum tape.

All internal and external surfaces of the instrument housing and optical mounts had finishes selected for optimum radiation coupling in order to minimize thermal gradients in the case. The electronics were mounted on thermal insulating mounts and radiation isolated from the case with surface finishes selected for passive thermal control to the canister cold wall. The instrument to ATM spar mounts were designed to provide very high thermal impedance.

2.2.5.3 Additional Detail Information

Additional thermal control system details may be found in BBRC Document No. TR73-15 entitled "New Technology Report - Thermal Control System for NRL/ATM S082B Spectrograph".

2.3 XUV MONITOR

An XUV Monitor was designed on the basis of a NRL concept, fabricated and tested, to provide a real time video solar image in the spectral range 170 to 650 Å to aid the astronaut in selecting operating times and regions of the sun to be photographed. Figures 2-10 and 2-11 show the XUV Monitor subsystem and arrangement of components. The system was independent of, but structurally attached to, the S082B Instrument. The system consisted of a case, a telescope mirror, three thin aluminum filters, a wavelength conversion phosphor, a low light level (LLL) television (TV) camera, and a camera control unit (CCU). The CCU was mounted on the ATM spar, remote from the

XUV Monitor. The S082B TCS provided a controlled thermal environment. The XUV Monitor was operated from the ATM C&D Panel.

The XUV Monitor showed the sun's XUV emission pattern studied by the S082A, S082B and other ATM experiments, and made it possible to point the S082B at XUV features of interest that were not visible in H-Alpha or white light.

The flight performance of the XUV Monitor was not satisfactory on the SL-2 Mission since the system gain was not sufficient to provide the astronauts with a clear picture of the XUV quiet sun. Video pictures downlinked to the ground could be processed for long integration images that were of high quality but, in general, the astronauts could detect only the bright active regions.

In the interval between the SL-2 and SL-3 Missions, BBRC modified a Night Vision Labs low light level, long image persistence scope and developed a mounting bracket to attach to the C&D Panel display tubes. In addition, a SX-70 Polaroid camera was adapted to take photos of the XUV and white light corona video displays in order to provide the astronauts with a record of solar evolution. These items were launched with the SL-3 astronauts and were used very successfully on the SL-3 and SL-4 Missions.

2.3.1 XUV Monitor Mechanical Subsystem

The XUV Monitor mechanical subsystem consisted of a case and cover assembly, the telescope mirror assembly, the aperture door assembly and the intermediate filter mechanism.

2.3.1.1 Case and Cover

The matched case and cover assembly, made from 6061-T651 aluminum alloy, was attached to the side of the S082B instrument case. The construction technique and features were identical to that of the S082B case and cover. The case had openings for the entrance aperture door and provided mounting points for the attachment of thermal

control subsystem, the filter mechanism, the LLL TV camera, the telescope mirror, and the aperture door assembly. A special mounting system was provided to electrically isolate the LLL TV camera (see Fig. 2-23).

2.3.1.2 Aperture Door Assembly

The XUV Monitor door is similar to the main instrument except that its base frame also incorporated mounting provisions, including vibration isolation mounts, for a thin aluminum filter. The total door assembly was attached to the front of the XUV Monitor case such that it could be removed from the instrument. This provision was made so that the thin aluminum filter could be inspected or replaced after instrument installation on the ATM spar. The aperture door open and close mechanism was like that of the S082A and S082B instrument aperture doors.

2.3.1.3 Telescope Mirror Assembly

The telescope mirror was a 4.50 x 4.50 inch off-axis paraboloid section with a 1 meter focal length. The mirror was made of low expansion Cervit material. The optical axis of the XUV Monitor telescope was aligned parallel to the optical axis of the spectrograph telescope to point the spectrograph slit to a solar feature that appeared only in the XUV wavelengths.

The mirror was rigidly bonded at three edges to three titanium spring fingers. The fingers were in turn bolted to a spherically surfaced plate. The spherical surface segment and its mating seat were used for fine alignment. The whole mirror and frame assembly was pinned and bolted to the rear wall of the XUV Monitor case after alignment. Additional mirror bonding information may be found in BBRC Document No. TR68-43 entitled "New Technology Report - Precision Mounting by Bonding for Instrument Optical Elements".

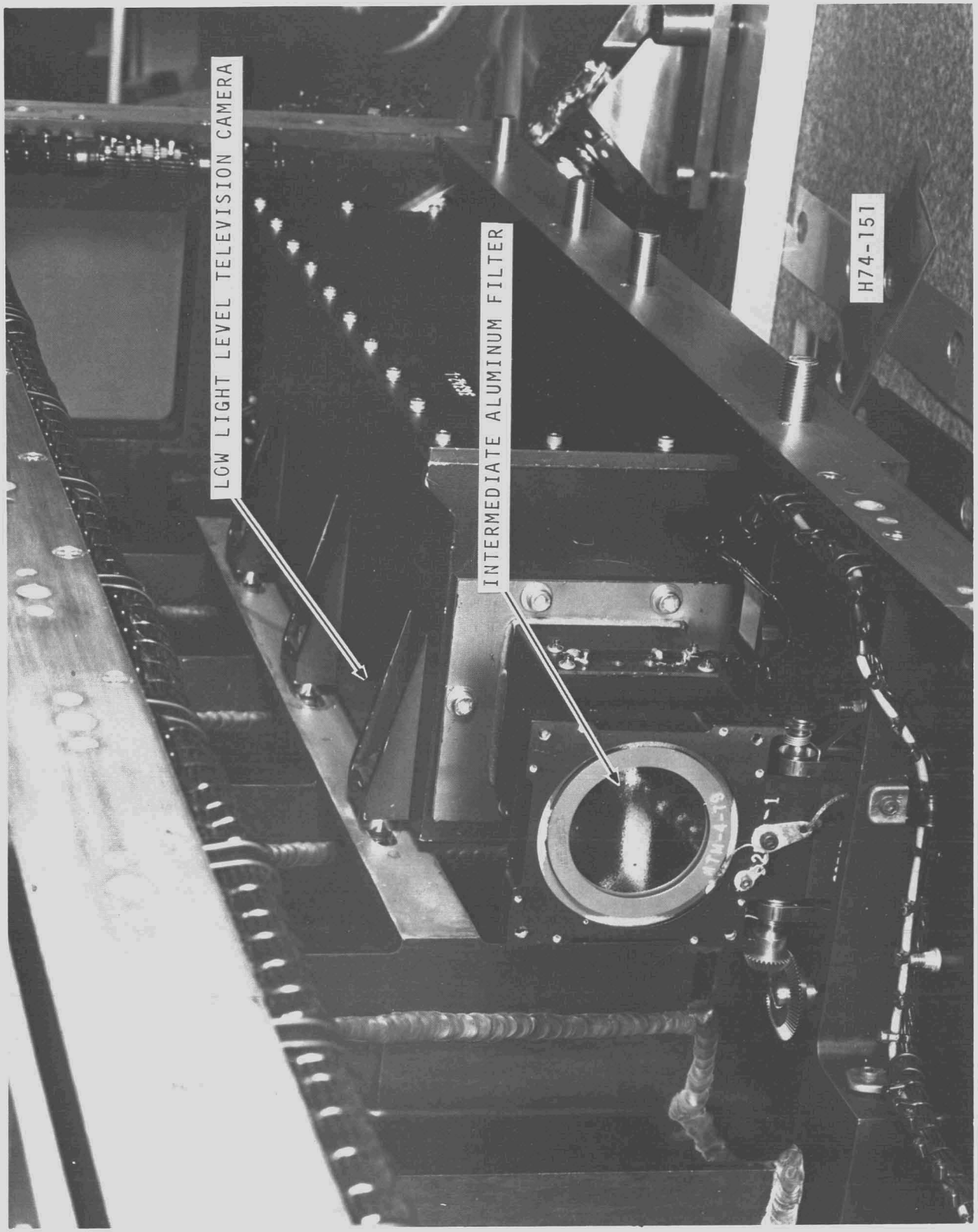


Figure 2-23. Low Light Level Television Camera

2.3.1.4 Aluminum Filters

The thin aluminum filters were aluminum films approximately 1000 Å thick. One filter was located inside the aperture door, one in front of the camera, and one deposited on the faceplate of the camera.

The first two were supported on fine mesh screens, which in turn were attached to more substantial mounting frames. The first of these filters, in its supporting frame, was mounted on vibration isolation pads in the aperture door frame and is removable for inspection and/or replacement. The second (or intermediate filter) was mounted in front of the low light level camera face on vibration isolation pads in a light baffle and frame mechanism. The mount allowed manual removal of the filter from the optical path during ground testing and spring return to its nominal position when a cable pull was released.

2.3.2 Electrical and Electronics

The XUV Monitor had a self-contained GFE video system that operated independent of the instrument video system (PRS). The camera contained a secondary electron conduction (SEC) vidicon with a fixed reticle deposited on the faceplate (see Fig. 2-24). The center cross and circle could be used by the astronaut for pointing. The corner patterns were used in ground test and flight for evaluating system performance. The corner patterns were not covered by the quaterphenyl phosphor and aluminum filter, and could be illuminated by four light-emitting diode test lights when the aperture door was closed. Though masked off by the round monitor bezel in the C&D Panel display, the corner patterns were visible on the downlinked TV and in ground testing, and were used to verify the TV camera had not degraded. Each square area provided a black reference signal, and each bar group provided amplitude response for the respective corner.

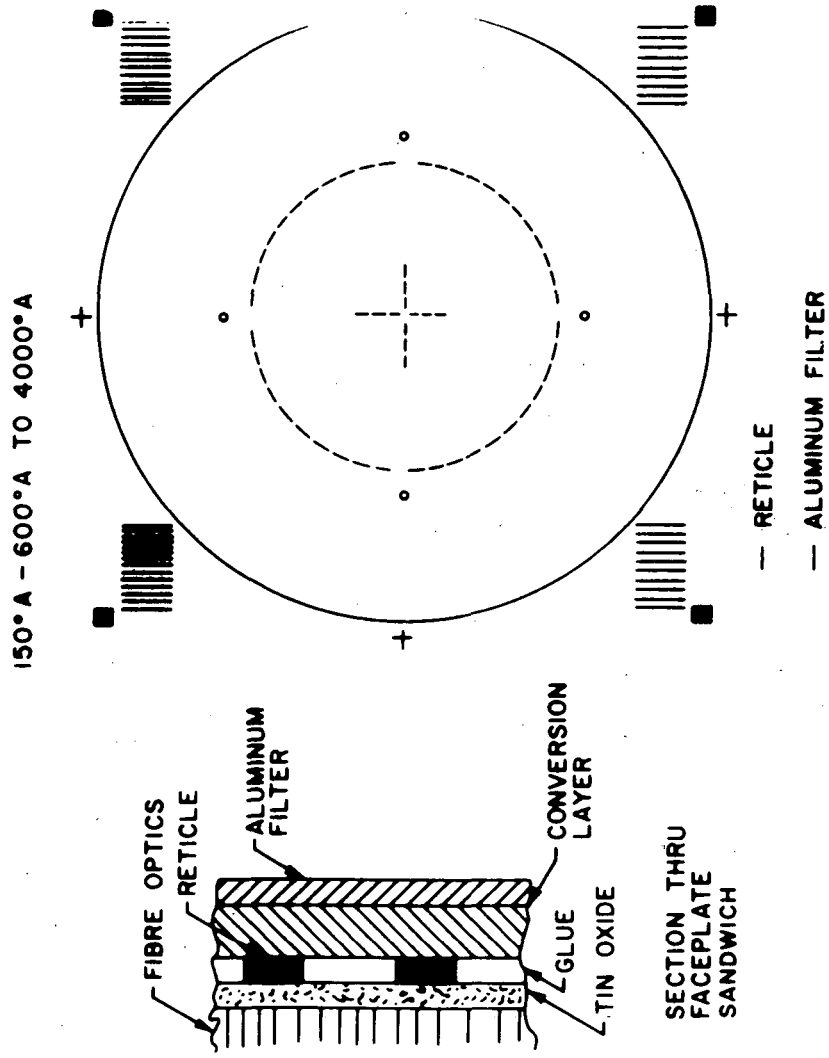


Figure 2-24. XUV Monitor Conversion Layer and Face Plate Reticle

The test lights also illuminated the four pinholes near the center circle of the reticle. This provided a verification to the astronauts that the XUV Monitor was operating properly with the instrument aperture door closed. Any other pinholes in the filter would also be illuminated and gave a check on degradation of the aluminum filter on the SEC faceplate.

2.3.3 XUV Monitor Optical Subsystem

The XUV Monitor optical system is shown in Figure 2-25. The optical components are the off-axis paraboloid mirror, thin aluminum filters, the quaterphenyl phosphor, and the faceplate of the low light level video camera.

The telescope mirror was procured from Perkin-Elmer by NRL and furnished to BBRC as Government Furnished Equipment.

The first two thin aluminum filters, described in paragraph 2.3.1.4, were developed by Sigmatron, Inc. for NRL and furnished to BBRC as Government Furnished Equipment. A very extensive development effort by Sigmatron was required to produce satisfactory filters acceptably free of pinholes over such a large area with the extremely thin (1,000 Angstrom) aluminum films.

The low light level SEC video camera was furnished by MSFC to NRL. NRL contracted with Westinghouse to apply the conversion layer, reticle and thin aluminum filter, described in Figure 2-24, to the faceplate of the video camera tube. The purpose of the quaterphenyl conversion layer was to transform the extremely short wavelength energy in the XUV image to longer wavelengths within the sensitivity range of the video tube.

Three thin aluminum filters were deemed necessary in order to provide adequate assurance that the XUV image would not be degraded or destroyed by longer wavelength energy reaching the low light level

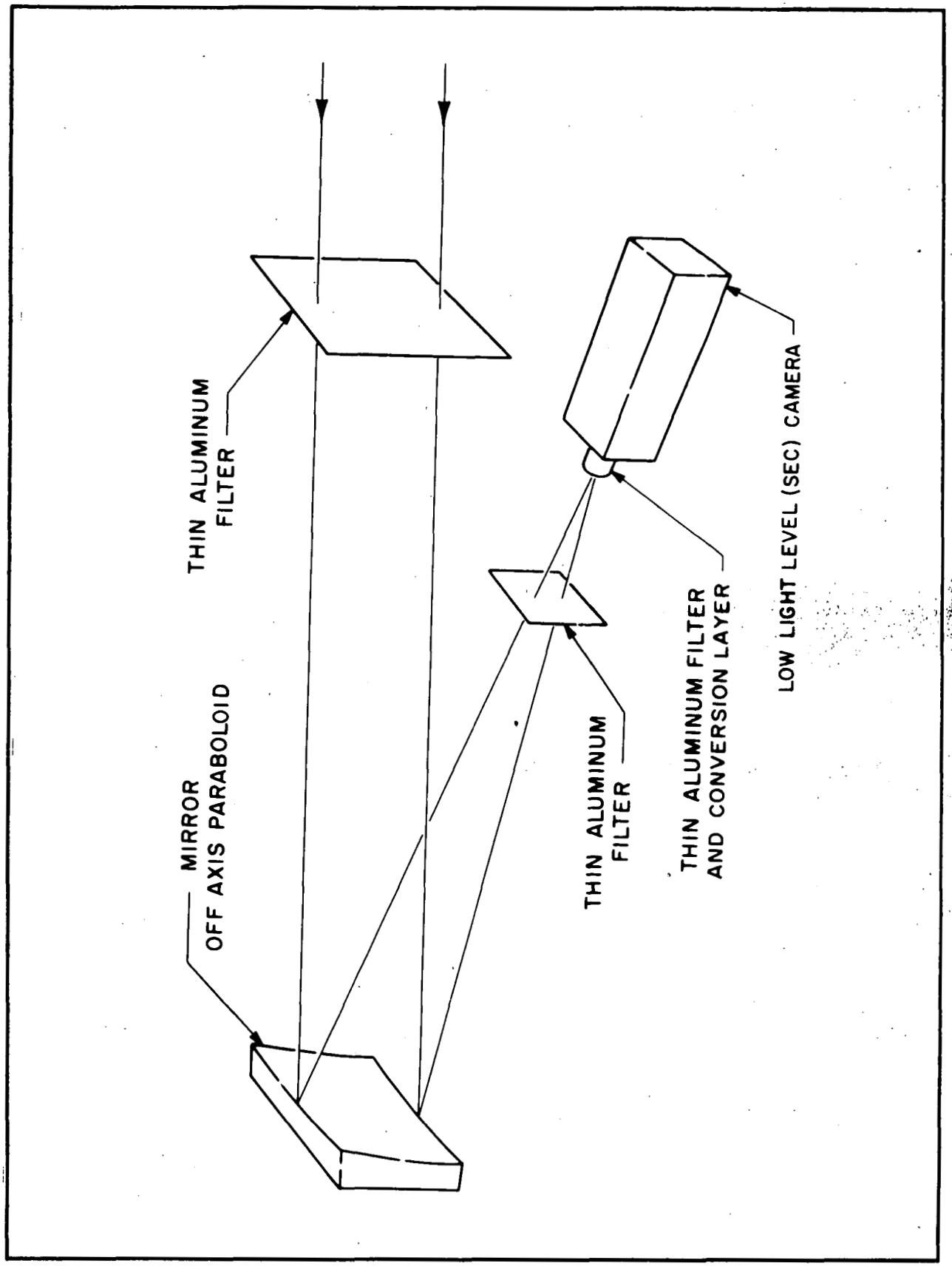


Figure 2-25. XUV Monitor Optical Schematic

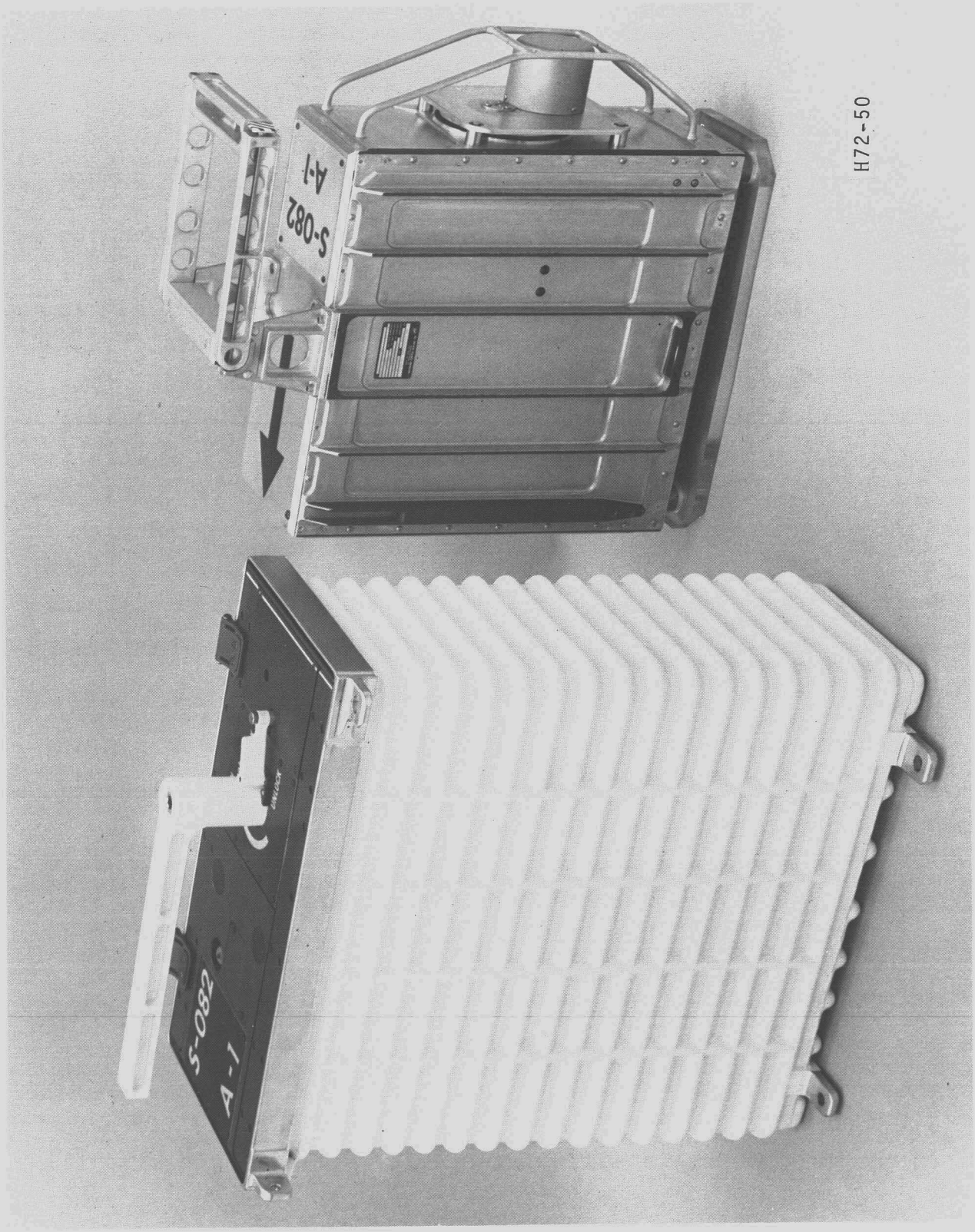
camera. Intensity of solar radiation in the visible wavelengths is more than a million times that in the wavelength range of the XUV Monitor. A certain number of small pinholes were considered inevitable in any one filter, and any one filter was considered to be fairly susceptible to damage or degradation. In any case, the risk factor for one filter to protect the low light level camera from excessive white light leakage was too great. With the three filters located as they were, one on the video camera faceplate, one midway between faceplate and mirror, and the other at the instrument entrance aperture, light passing through any one pinhole was distributed over a large area of the other two filters, thus minimizing the unwanted light transmission to a very low level. In addition, the filter deposited over the quaterphenyl protected the phosphor from degradation in the vacuum alignment.

2.4 FILM CAMERAS AND CANISTERS

The film cameras were removable components of the instruments. When removed they were stored in canisters which provided environmental protection for the XUV sensitive film. See Figure 2-26. The cameras were attached to the sun end of the instruments by means of the camera latch and guide rail assembly. Long, folding handles on the cameras opened and locked for ease of installation on the instruments. Insertion and locking of the cameras, automatically opened the camera aperture doors in the instrument housings and mated the electrical connectors.

The canisters were stored in the MDA or CM during the Skylab missions and were used for storage of the cameras prior to, during and after flight. The cameras/canisters were shipped and stored in MSFC-provided shipping containers during all ground operations.

A sizable effort went into developing the cameras and canisters to satisfy the human factor requirements. Considerable interfacing with the astronauts and the NASA Crew Systems culminated with the delivery of the Astronaut Training Hardware.



H72-50

Figure 2-26. Camera Canister (With S082A Camera)

The S082A and S082B cameras have some minor differences but for the purposes of this report they are treated as one. For more details of their design see BBRC Document No. 620-158 for S082A and 620-163 for S082B.

2.4.1 Camera Assembly

The camera housing was a light-tight, aluminum alloy box and contained 200 film strips and a blank holder in two stacks. The film strips were 35mm x 258mm XUV sensitive film held in anodized aluminum holders on S082B and stainless steel holders on S082A. The end clips on the film holders were a combination of Lexan and Teflon. The camera face contained the rectangular aperture for admitting XUV light from the main grating and the circular aperture for time data from the diode array. An electrical connector for camera power and signal circuits was mounted in one corner and mated with a corresponding connector on the camera mounting plate. The camera face was also equipped with two guide pins and two alignment pads that provided precise alignment of the camera position after insertion and locking (see Fig. 2-27).

The major elements of the camera were housing, shutter assembly and a film changing mechanism. Figure 2-28 shows a cutaway view of the camera to expose its major components.

The shutter assembly was mounted just behind and attached to the camera faceplate. The shutter blade was attached to a lever driven by an oscillating cam. The cam, in turn, was rotated through an arc in either direction by one of the levers on the shafts of the rotary solenoids.

The film-changing mechanism consisted of several timed, cam-actuated mechanisms for feeding, positioning and retracting successive film strips for exposure. It provided the means for removing an exposed film strip from the film carrier and placed it in the retraction stack, while simultaneously removing a new film strip from the

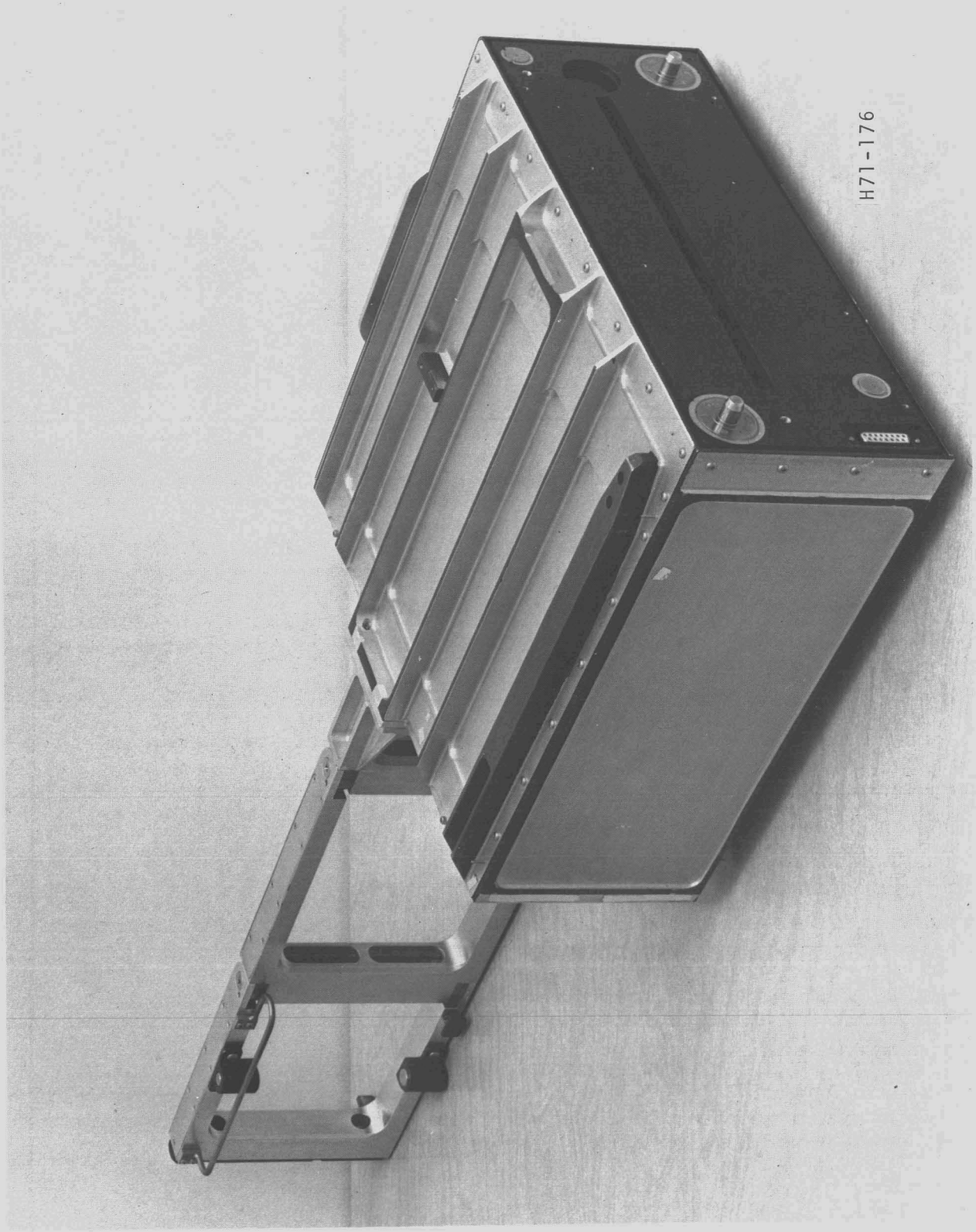


Figure 2-27. S082B XUV Film Magazine (Film Strip Camera)

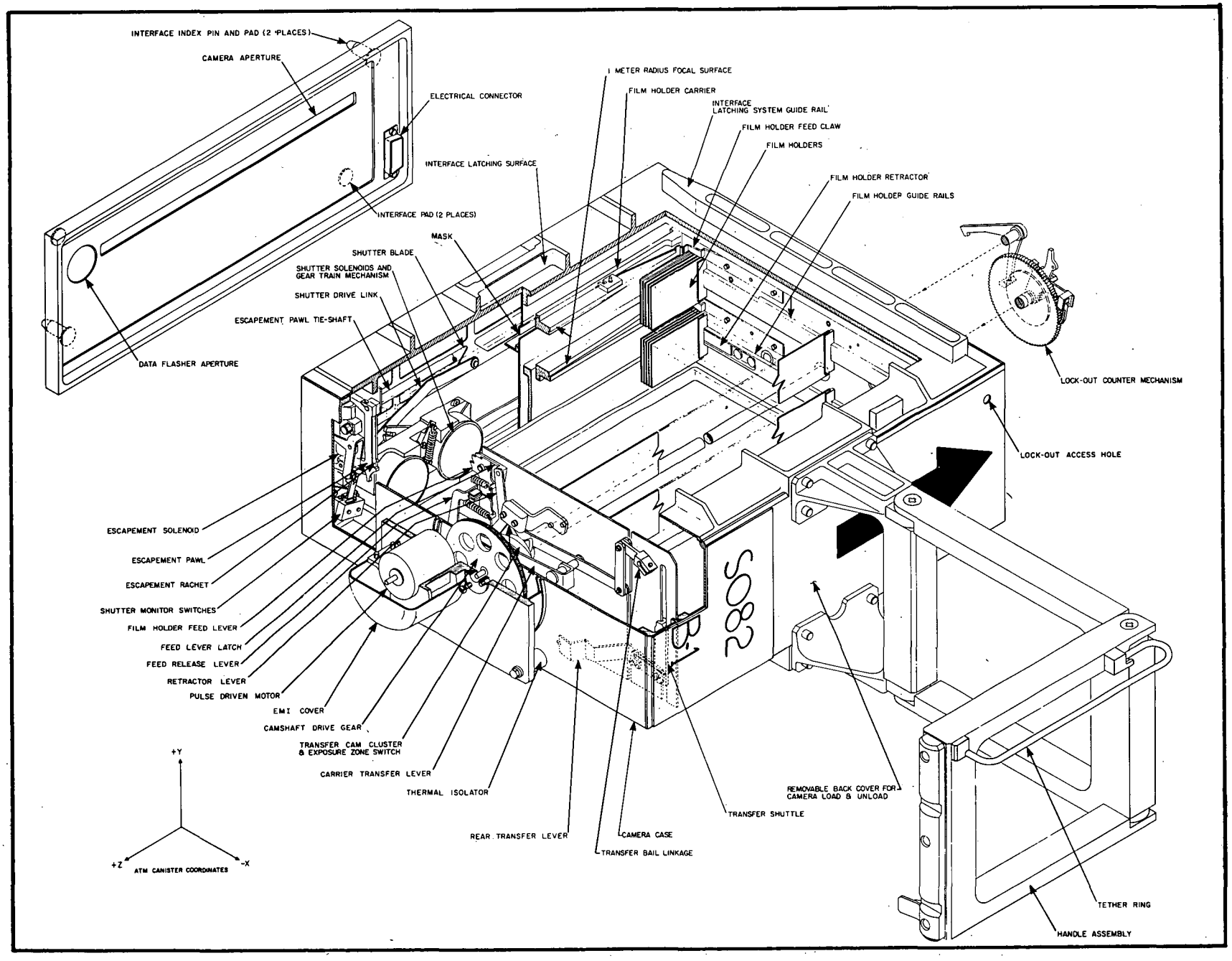


Figure 2-28. Cutaway View of S082B Film Camera

retraction stack and placing it in the feed stack. The S082B camera also provided a solenoid-driven escapement mechanism so that eight full-width spectrograms were obtained on each film strip.

The operation of the film changing mechanism is shown by the numbered events in the diagram in Figure 2-29.

The film changing mechanism was driven by a pulse driven stepper motor and reducing gear drive train. Symmetrical cam clusters were provided on each side to drive the various mechanisms. A lockout exposure counter was also provided which counts the number of film strips exposed and locks the film changing mechanism to prevent double exposures. (See Figs. 2-30 and 2-31)

The S082A camera had a thin aluminum filter which screened out all wavelengths except the desired wavelength band between 150 and 650Å. This filter was located in the camera immediately in front of the film and behind the shutter. It consisted of a thin film (1000Å) of pure aluminum deposited to a fine wire matrix which, in turn, was bonded to a rigid frame to prevent distortion.

Table 2-9 contains the engineering parameters associated with both cameras. For a complete description of the camera and its operation, see New Technology Report "Spectrographic Film Strip Camera TR71-02".

2.4.1.1 Significant Problems and Solutions

Stepper Motor - The three phase variable reluctance stepper motor did not perform well in the extremely variable torque load of the camera. The gear ratio to the function shaft was decreased by a factor of two and an improved motor with 25 percent more torque was obtained. Further design changes were made which smoothed the torque load, the most significant of which was the reduction of the large negative torque induced by the retractor system. For further

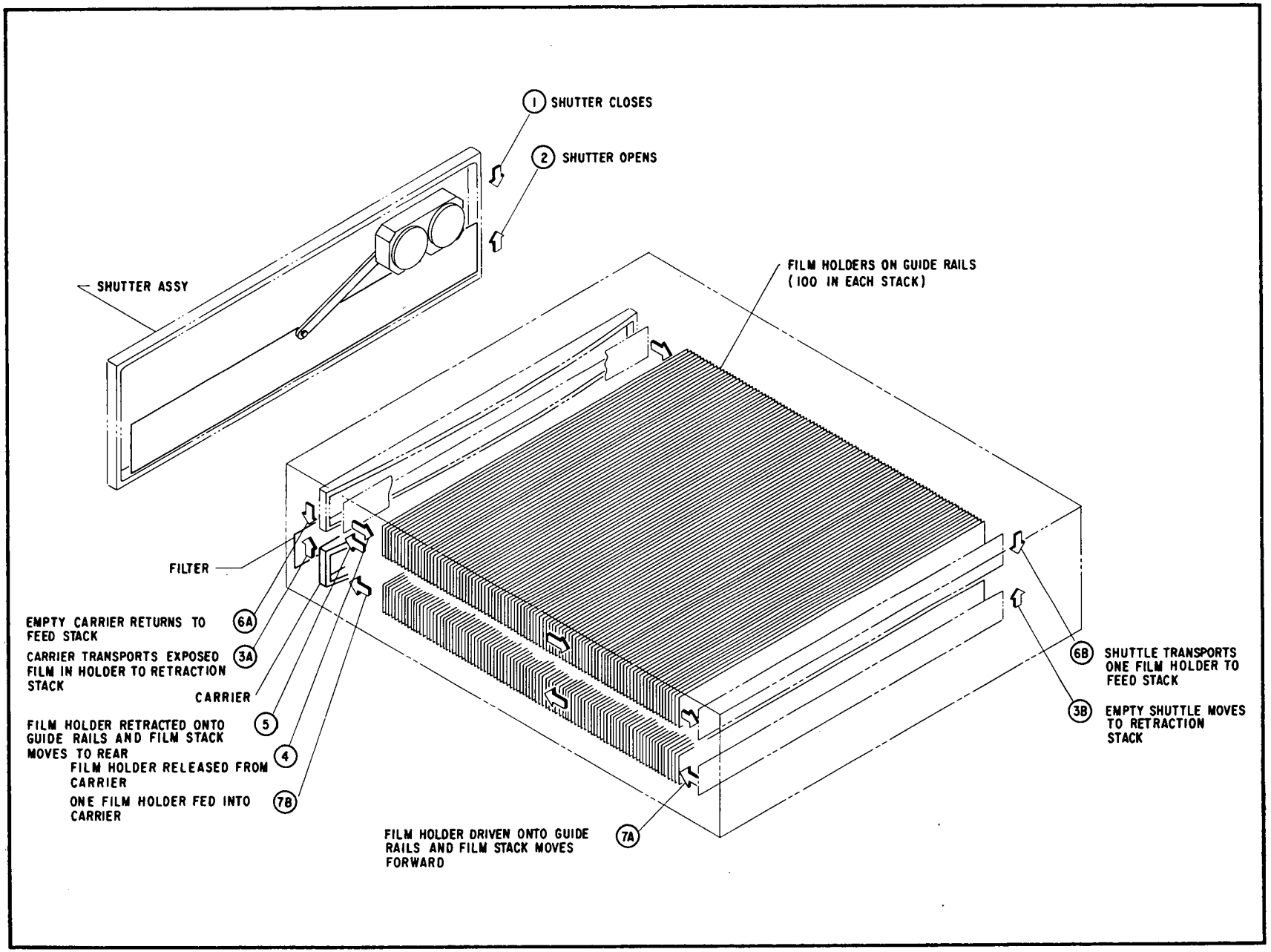


Figure 2-29. Diagram of Film Changing Sequence

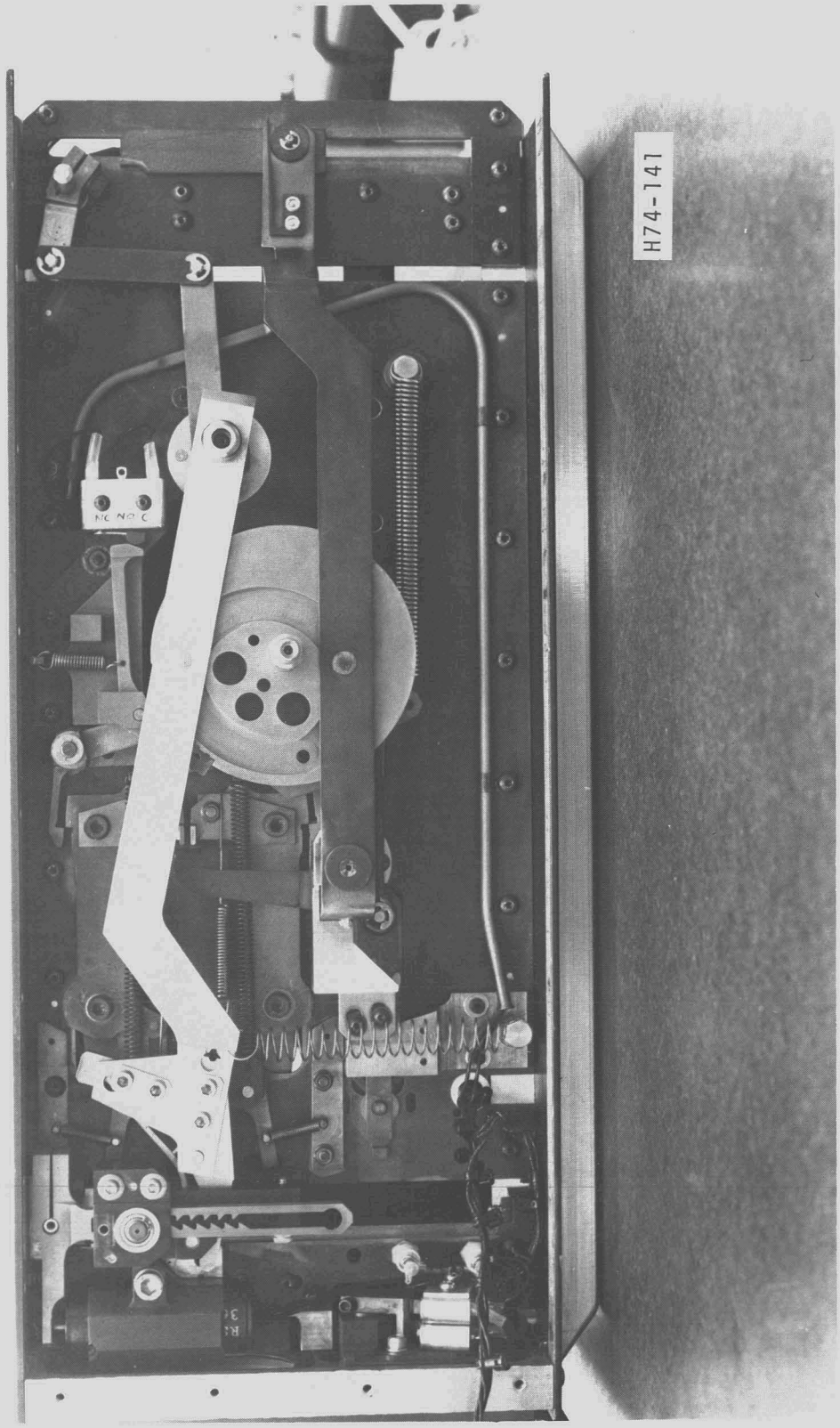


Figure 2-30. S082B Film Camera Motor Side with Cover Removed

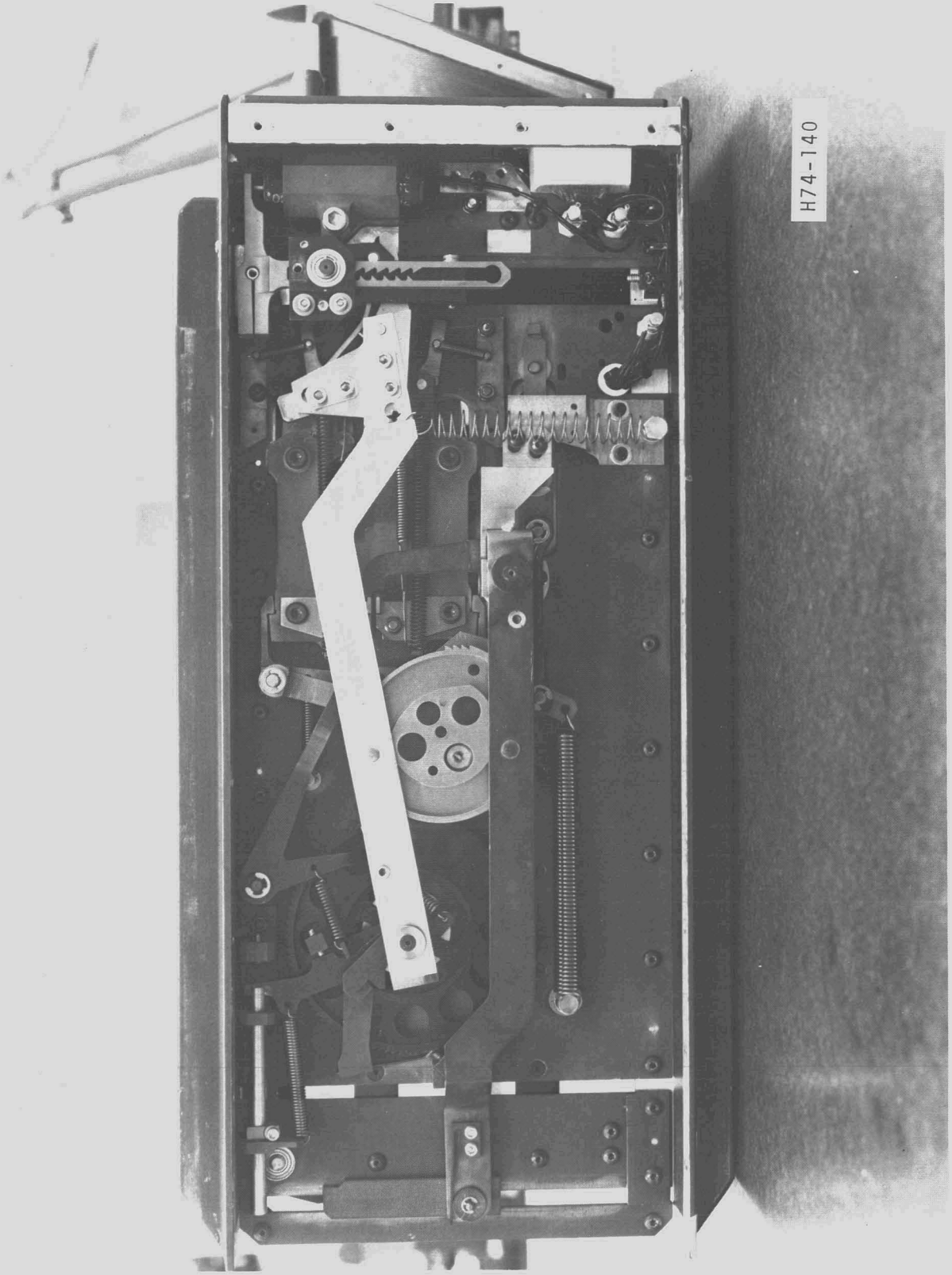


Figure 2-31. S082B Film Camera Counter Side with Cover Removed

Table 2-9

PERFORMANCE CHARACTERISTICS

Parameter	"A" Camera	"B" Camera
Physical Size:	429mm x 4140.2mm x 155mm	431mm x 415mm x 155mm
• Weight, Loaded	14.54 543 kg	15.422 kg
Number of Film Holders:	201-203	201-203
Power, Drive Motor:		
• Type	3-Phase VR Stepper	3-Phase VR Stepper
• Rate	600 pps	600 pps
• Voltage	22-32V	22-32V
• Current	1.3 A	1.3 A
Power, Drive Time:	1.898 sec nom	1.879 sec nom
Power, Escapement Solenoids:	2 push in parallel	2 push in parallel
• Voltage	22-32V	22-32V
• Current	2 x 0.55A to 0.8A	2 x 0.55A to 0.8A
• Time	100ms	27ms
Power, Shutter Solenoids:	2 rotary	2 rotary
• Voltage	22-32V	22-32V
• Current	1.29A to 1.88A	1.29A to 1.88A
• Time	100ms	60ms
Focal Plane:		
• Curvature	2m	1m
• Radius Tolerance	78.64 to 78.84mm	39.35 to 39.39mm
Film Position Tolerance:	$<3 \times 10^3$ from preacceptance to post vibration	40.4114mm to 40.5384mm
Film:		
• Type	SWR 101 or SWR 104	SWR 101 or SWR 104
• Base	0.007-inch Estar thick	0.007-inch Estar thick
• Size	248mm x 35mm	248mm x 35mm
Data Flasher Chip Film:		
• Type	Plus X Pan (4147)	Plus X Pan (4147
• Base	0.007-inch Estar thick	0.007-inch Estar thick
No. Exposures/Film Strip:	1	8
Useful Area/Exposure:	242.01mm x 31.06mm	240.28mm x 4.013mm
Shutter:	Single blade	Single blade
• Blade Transition Time	<35ms	<10ms
• Maximum Exposure	Unlimited	Unlimited
• Open/Close	Independent Solenoids	Independent Solenoids

details see BBRC Document No. TN 72-32 entitled "The 3 Phase - Variable Reluctance 15° Stepper Motor".

Friction and Lubrication - Camera test failures occurred because of high friction problems. There were two categories of these problems: very high friction parts surfaces and the premature wearout of the dry film lubricant. The first problem in general related to the Nituff-processed parts. The solution to the problem was the meticulous preparation of the surfaces prior to the Nituff, careful honing of the parts after Nituff, and the burnishing of the surfaces with Vac-Kote (see BBRC Document No. BPS 18.20). For greater details on the process see BBRC Document No. TR72-30 entitled "Application Note on the Use of Nituff as a Hard Vacuum Lubricant".

The premature wearout of the dry film lubricant was identified first on the retractor cams. Very erratic cycle time was obtained from one camera to another. The problem was partially solved by changing the cam profile to minimize the loads and by changing the lubricant. Techniques were developed for observing the change in torque due to lubrication degradation, frequent visual inspections and a maximum cycle limit established. The flight preparation BBRC Document No. 620-199 details these inspections. See BBRC Document No. TN 72-33 entitled "Techniques for Real Time X-Y Plotting of Force Vs Position Characteristics on Complex Spring/Friction Moving Mechanisms" for a new technique developed for observing the friction characteristics of sliding surfaces.

Camera Performance Evaluations - During the testing of the first cameras there were no methods for separating causes and effects of problem areas. Problem and failure would occur dynamically. Progressively techniques of failure analysis were developed. High speed movies were taken, and drive times were monitored as indicators of failures or future failures. A method of obtaining torque load information out of the motor current (L/W trace) was found.

These items resulted in the introduction of a 100 percent monitoring of currents, switch actuations and timing which provided an insight to the camera operation (see paragraph 2.4.1.2).

Focal Plane - It was identified from instrument optical tests that the focal plane tolerance had to be improved from ±0.12mm to ±0.05mm on the S082B Instrument. A major camera redesign was performed involving a new carrier, major timing changes, and a new film holder. The VanHoosier technique was developed to verify surface/position of the actual film using a wire grid, a laser, a photographic camera, a microdensitometer and a computer. The position of the carrier was carefully set and frequently measured against a reference gauge.

Film Holders - The original stainless steel film holders proved to be almost impossible to fabricate. By adding ribs to them the original specifications were met but for the more accurate focal plane tolerance an aluminum holder was developed that proved very successful. See Memorandum B4204 71.156, entitled "Film Holders - Historical Itemized Summary".

At the end of the SL-3 Mission, film blemishes were noted during development of the S082A Spectroheliograms. These blemishes consisted of streaking patterns on some of the film strips. These streaks were of variable density and location on the film strips, but all of them were located near the edge of the ridges on the back of the stainless steel film holders. A review of the SL-2 S082A film showed a few faint traces of the same type blemish, but no trace of the problem could be detected on any of the S082B film.

A crash analysis and test program was instigated in an effort to define the cause of the problem in order to correct it prior to the SL-4 Mission. Some similar effects were noted after a test that included vibration of the camera inside the canister in a reduced

pressure dry nitrogen environment, and then rapidly opening the canister inside a vacuum chamber. These results were not repeatable and no definitive cause of the problem could be established in the available time.

The significant fact that no problem could be found with the same type film mounted on ribless aluminum holders in the S082B cameras led to a decision to modify the S082A cameras with aluminum film holders. This modification and a brief camera retest program were performed rapidly enough to resupply the SL-4 Mission with modified S082A film cameras. The flight performance of the cameras and the quality of the returned film was excellent.

Some of the film from the SL-4 S082B camera also indicated another type blemish which appeared to be the result of a light leak. The characteristic patterns of the light leak, if that is the cause, are very unusual and do not seem to fit any rational relationship to the locations of the film in the camera. The camera has been re-tested and shows no trace of light leaks. A continuing effort is underway to try to identify the cause of the problem.

2.4.1.2 Instrumentation

The instrumentation was used to provide remote data acquisition during cycling of the NRL/ATM S082A and S082B cameras for engineering evaluation. The following data points were monitored:

Channel No.	Measurement Name
1	Audio
2	Motor Switch
3	Phase I Motor Drive Voltage
4	Escapement Voltage
5	Escapement Current 2
6	Escapement Current 1

Channel No.	Measurement Name
7	Motor Current (Total)
8	Phase II Motor Drive Voltage or "B" Switch Buffer
9	Phase III Motor Drive Voltage or "B" Panel Driver
10	Shutter Closed
11	Shutter Open
12	Accelerometer #1
13	Accelerometer #2
14	Function Shaft Potentiometer or Shutter Current

The camera and instrumentation were connected as indicated in Figure 2-32 and all electrical signals were recorded on magnetic tape. The instrumentation was used whenever power was applied to the camera. A calibration box was used to simulate a camera and verify the instrumentation prior to connecting a camera.

The instrumentation and a visicorder were also used to visually monitor all data points for any anomalies, particularly drive time between exposure positions. Before cycling the camera, the magnetic tape was annotated with the serial number of the camera being tested, voltage level, camera attitude and any other pertinent data.

The data acquisition system was used during all of the tests at BBRC, KSC, unloading at NRL, and during Zero-g tests.

2.4.1.3 Achievements

These film strip cameras are space proven successful with only one failure out of ten (10) flown on Skylab. The program advanced the state-of-the-art of dry lubricants for sliding surfaces. New concepts in quality control were derived in the flight preparation program of cameras. Mechanical tolerances were achieved in assemblies which are normally only accomplished in piece parts. Film handling technology and clean room/dark room QA monitoring techniques were developed that permitted four (4) operators to work in

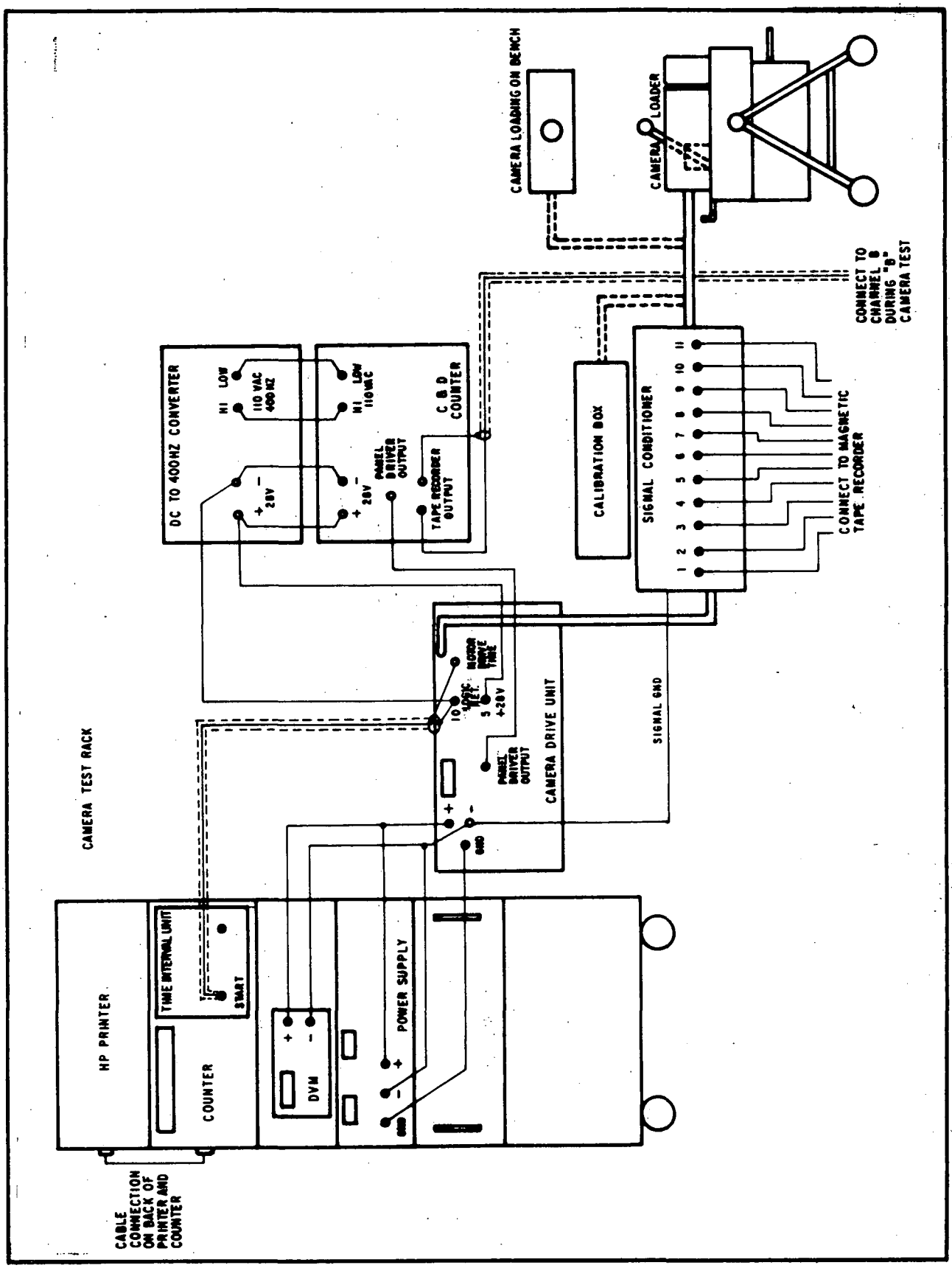


Figure 2-32. Instrumentation Setup

total darkness for up to seven (7) hours without touching the film emulsion, which would be degraded by any mechanical contact.

2.4.2 Canister Assembly

The canister assembly is a vacuum sealable container used for storage of the film camera when the camera was not mounted on the instrument. The prime purpose of the canister was to protect the XUV sensitive film in the cameras from the MDA and CM atmosphere. A canister was provided for each camera. The canister assemblies were identical for the S082A and S082B except for the external markings. The canisters were designed for use in a space environment and consisted of a housing, a handle operated lid and redundant relief valves.

The canister housing was explosively formed from stainless steel. The canister was attached to the MDA by four lugs on the housing for launch and orbital stowage. These same attach points were used in the CM for resupply and return of the camera/canisters. The inside surfaces of the housing and lid were lined with aluminized Mylar enclosed in sheets of Lexan plastic, to isolate the film in the camera from solar heat during EVA. A fitting, located on the lid, allowed evacuation and back-filling with nitrogen prior to launch.

The canister lid contained the lid handle, handle lock and relief valves. Rotation of the lid handle provided actuation of a valve to allow pressure equalization. An O-ring formed a seal between the lid and housing. Redundant relief valves provided a positive internal differential pressure during launch depressurization, when the canister contained a camera. During re-entry, the relief valves remained closed. Development problems, similar to those for the film cameras, were experienced relative to high friction and dry film lubricant wearout of sliding mechanisms.

2.5 GROUND SUPPORT EQUIPMENT

The prime electrical interface to the S082A and S082B during ground tests was provided by the ATM/LM Simulator and Checkout Console. The S082A ATM/LM Simulator and Checkout Console is shown in Figure 2-33 and the Console for S082B is shown in Figure 2-34.

These consoles simulated the complete ATM interface including Commands, Powers, Clocks, etc. All inputs and outputs to the console simulated the appropriate loads and impedances to be provided by the ATM.

A complete description of these consoles is provided in BBRC Document Nos. 620-43 and 620-44.

Other electrical equipment required is standard ground test equipment, including oscilloscopes, VOM, VTVM, power supplies, timers and pulse generators.

The major mechanical test fixtures used with these instruments were the Zero-g test fixture, the ATM spar simulator, the alignment vacuum chamber, thermal fixtures, thermal vacuum chamber and the vibration test fixtures.

The Zero-g test fixture was used to determine potential optical degradation when subjected to a simulated Zero-g environment. The ATM spar simulator was used during thermal vacuum test to provide proper thermal loads to the S082A and S082B Instruments.

An alignment collimator was developed specifically to optically align each instrument. Other special optical equipment included an alignment slit, apertures for the collimator, exposure timing unit, free-flow discharge lamps, instrument mounting pattern template, slit illuminator assembly and a test film plane.

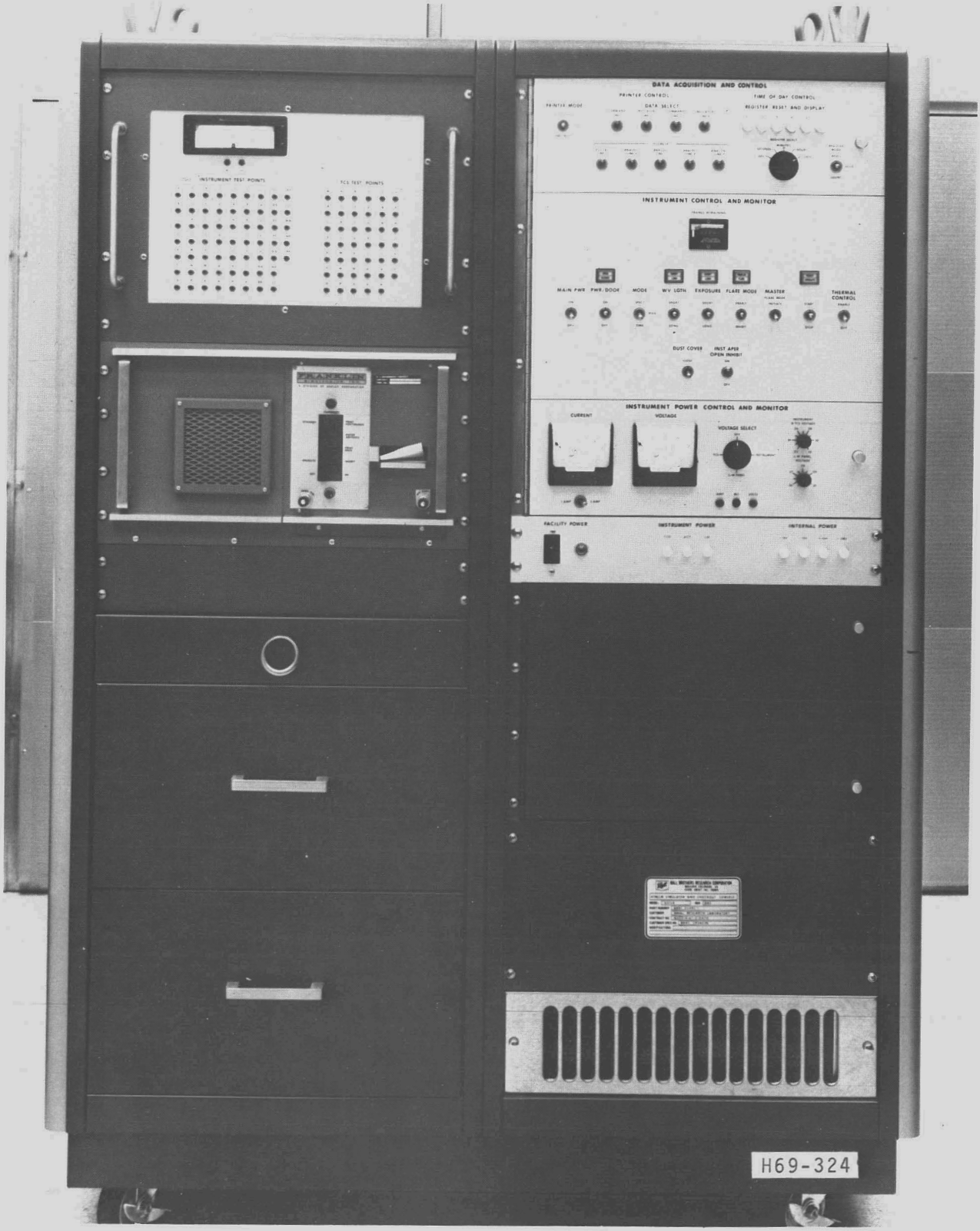


Figure 2-33. ATM/LM Simulator and Checkout Console (S082A)

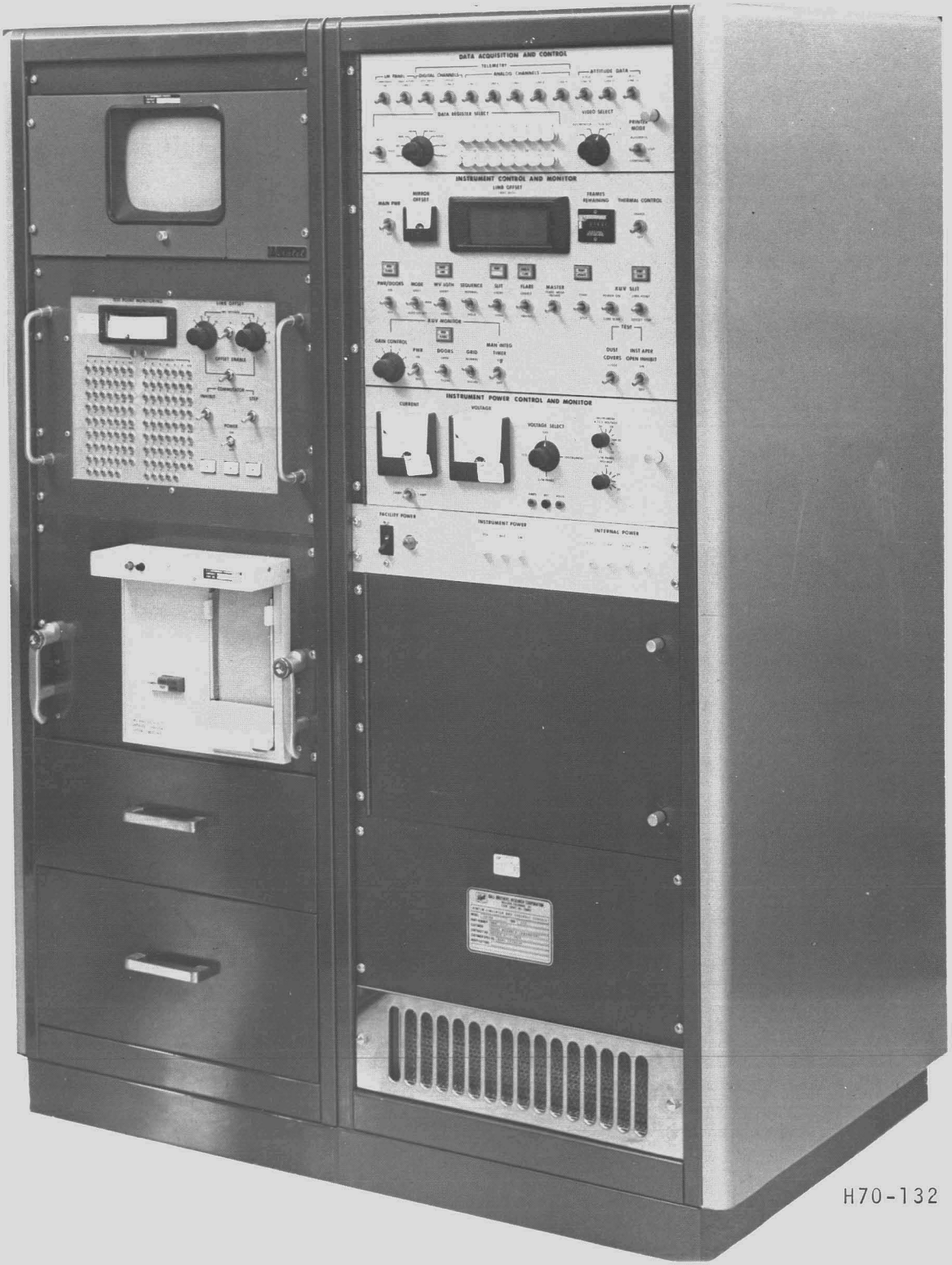


Figure 2-34. ATM/LM Simulator and Checkout Console

The alignment slit was used to align the primary mirror. A small pinhole was used in place of a slit to obtain a near diffraction limited image off the primary mirror. Collimator apertures were used to provide a simulated (in size and resolution) sun. A very fine screen mesh (up to 2000 lines/inch) and standard Air Force targets were used to determine resolution.

The Exposure Timing Unit was used with the LM Simulator consoles to provide calibrated exposure time other than exposure times normally provided by the instruments.

The free flow gas discharge lamps (NRL furnished) were used to provide an ultraviolet spectrum for S082A and S082B in the vacuum alignment chamber. The instrument mounting pattern templates were provided by MSFC and used for verification of mounting compatibility with the ATM spar.

The Slit Illuminator Assembly was used to illuminate the slit plate on the S082B Instrument to check the spectra location in the waveband aperture and the spectra position in the camera aperture. Test film planes were used during initial instrument alignment phases and as camera test tooling.

Special instrument shipping containers were designed and fabricated to provide environmental protection during shipping. These containers included a provision for a continuous purge with dry nitrogen gas to maintain a clean atmosphere surrounding the instruments. For further details see BBRC Document No. 620-60.

In addition to the special test equipment many standard mechanical and optical tools were used throughout the program for test, alignment, adjustment, etc. These tools are described in further detail in BBRC Document No. 620-89.

2.6 RELIABILITY

2.6.1 General

The reliability program conducted during the design and development of the S082A and S082B Instruments is defined in Part I of the Reliability Assurance Program Plan (RAPP), BBRC Document No. TR 67-57. This plan was originally issued to meet only the minimum requirements of NASA NPC 250-1, Reliability Program Provisions for Space System Contractors. However, subsequent review of requirements with NRL and MSFC resulted in implementation of essentially all NPC 250-1 provisions (reference TR 67-57, Revision A).

The quality assurance requirements were based on the provisions of NPC 200-2, Quality Program Provisions for Space System Contractors and are contained in Part II of the RAPP. A similar upgrading of QA requirements was included in Revision A to the RAPP.

Although specific NASA specifications for disciplines such as module welding and hand soldering were not imposed by contract, BBRC made every effort to meet or exceed the requirements of these documents. In those cases where BBRC considered their existing methods to be adequate or superior to those required by NASA, deviations were submitted on MSFC Form 847. Approximately 75 deviations were subsequently approved by NRL and MSFC. Refer to Tables 2-10 and 2-11 for a detailed listing of these deviations.

A full time engineer was assigned for the majority of the program to review all drawings and specifications for reliability considerations, conduct design reviews, manage the parts program and stress analysis activities, monitor test activities and prepare various reliability reports.

Table 2-10

WAIVER AND DEVIATION LIST,
S082A FLIGHT INSTRUMENT
(Sheet 1 of 2)

Item No.	Waiver/DAR No.	Description	Applicable Specification	Associated Risk
		DEVIATION APPROVAL REQUESTS (DAR'S)		
1	67-01, 67-03R1, 67-09R1, 47-10R1, 67-11, 67-12R1, 67-13R1, 67-19R1, 67-20R1, 67-39R1, 67-40, 67-42, 68-22, 68-23, 68-24, 69-03R1, 69-07 thru 69-15, and 69-27.	Deviations were made to the quality requirements for hand soldering of electrical connections.	NPC 200-4	None. All deviations are considered minor and most have been successfully used on other space hardware applications.
2	67-05R1, 67-07R1, 67-14R1, 67-15, 67-16, and 67-18.	Deviations were made to the design and fabrication requirements for printed wiring boards.	MSFC-STD-154	None. All deviations are considered minor and most have been successfully used on other space hardware applications.
3	67-21R1	Deviations were made to the procedure for conformal coating of printed circuit assemblies.	MSFC-PROC-293	None. BBRC uses epoxy conformal coating per MSFC-PROC-257A which is acceptable for space applications.
4	67-23, 67-24R1, 67-26, 67-27, 67-28R2, 67-29R1, 67-30, 67-31, 68-28, 68-29.	Deviations were made to the procedure for conformal coating of printed circuit assemblies.	MSFC-PROC-257	None. All deviations are minor.
5	67-32R1, 67-33	A deviation was made to the humidity requirements specified in the standard for design and operational criteria of controlled environmental areas.	MSFC-STD-246	None. BBRC uses a later issue of MSFC-STD-246 and allows humidity to be zero to 50 percent rather than 45 ± 5 percent.
6	68-6 thru 68-21, 69-01	Deviations were made to the standard for fabrication of electronic welded modules.	MSFC-STD-271	None. All deviations are minor.
7	69-06	A deviation was made to a requirement for soldering electrical connectors.	NHB 53004	None. All deviations are minor.
8	67-34, 68-27R2, 69-04, 69-05, 69-16 thru 69-26, 70-01, 70-02.	Minor deviations were made to test tolerances and parameters specified in the environmental design and qualification test criteria document for ATM components.	50M02408	None. All deviations are minor.
9	68-1 thru 68-5	Minor deviations were made to the standard for ATM weldable lead material for component parts.	50M02436	None. All deviations are minor.
10	70-08	The diode array PWA was reworked to salvage the A002 board.	25448	None. Repaired circuit trace is considered flight worthy.

Table 2-10 (concluded)
(Sheet 2 of 2)

Item No.	Waiver/DAR No.	Description	Applicable Specification	Associated Risk
		DEVIATION APPROVAL REQUESTS (DAR'S) (continued)		
11	70-09	Material was removed from wrong area to statically balance the short wavelength rejection mirror assembly. Two small weights were added to replace material removed.	26440	None. Assembly has been tested numerous operations without problem.
		WAIVERS		
12	W057	Counterbalance weight on CAM assembly not to Rev A which adds more weight to effect balance.	31381	None. Satisfactory balancing was achieved with the smaller weight.
13	W062	Swaged monel terminals have cracks.	25732	None. Cracks are common when swaging monel.
14	W063	No. 24 awg wire used instead of No. 22 awg on short wavelength rejection mirror assembly due to temporary unavailability.	26440	None. No. 24 awg wire will allow a 0.5 derating.
15	W065	Mount holes in camera guide frame slotted 0.12-inch to improve alignment and reduce camera insertion force.	30142	None. Slotting of holes resulted in conformance to force requirements.
16	W066	Grating failed to change position once during entire acceptance test.	29300	None. Anomaly cannot be repeated.
17	W067	Replacement of A1 flatpack micrologic on A8 module was accomplished by lap welding of Kovar leads to Kovar ribbon resulting in a deviation to a production process.	25305	None. Fabrication technique was acceptable to reliability and quality.

Table 2-11

WAIVER AND DEVIATION LIST,
S082B FLIGHT INSTRUMENT
(Sheet 1 of 2)

Item No.	Waiver/DAR No.	Description	Applicable Specification	Associated Risk
		DEVIATION APPROVAL REQUESTS (DAR'S)		
1	67-01, 67-03R1, 67-09R1, 67-10R1, 67-11, 67-12R1, 67-13R1, 67-19R1, 67-20R1, 67-39R1, 67-40, 67-42, 68-22, 68-23, 68-24, 69-03R1, 69-07 thru 69-15, 69-27.	Deviations were made to the quality requirements for hand soldering of electrical connections.	NPC 200-4	None. All deviations are considered minor and most have been successfully used on other space hardware applications.
2	67-05R1, 67-07R1, 67-14R1, 67-15, 67-16, 67-18.	Deviations were made to the design and fabrication requirements for printed wiring boards.	MSFC-STD 154	None. All deviations are considered minor and most have been successfully used on other space hardware applications.
3	67-21R1	Deviations were made to the procedure for conformal coating of printed circuit assemblies.	MSFC-PROC-293	None. BBRC uses epoxy conformal coating per MSFC-PROC-257A which is acceptable for space applications.
4	67-23, 67-24R1, 67-26, 67-27, 67-28R2, 67-29R1, 67-30, 67-31, 68-28, 68-29.	Deviations were made to the procedure for conformal coating of printed circuit assemblies.	MSFC-PROC-257	None. All deviations are minor.
5	67-32R1, 67-33	A deviation was made to the humidity requirements specified in the standard for design and operational criteria of controlled environmental areas.	MSFC-STD-246	None. BBRC uses a later issue of MSFC-STD-246 and allows humidity to be zero to 50 percent rather than 45 + 5 percent.
6	68-6 thru 68-21, 69-01.	Deviations were made to the standard for fabrication of electronic welded modules.	MSFC-STD-271	None. All deviations are minor.
7	69-06	A deviation was made to a requirement for soldering electrical connectors.	NHB 53004	None. All deviations are minor.
8	67-34, 68-27R2, 69-04, 69-05, 69-16 thru 69-26. 70-01, 70-02.	Minor deviations were made to test tolerances and parameters specified in the environmental design and qualification test criteria document for ATM components.	50M02408	None. All deviations are minor.
9	68-1 thru 68-5	Minor deviations were made to the standard for ATM weldable lead material for component parts.	50M02436	None. All deviations are minor.
10	70-06R1	A substitute material (303 cres) was used to fabricate the mirror adjustment screws. Drawing specifies 302 cres.	28659	None. Substitute material is equivalent for intended function.

Table 2-11 (concluded)
(Sheet 2 of 2)

Item No.	Waiver/DAR No.	Description	Applicable Specification	Associated Risk
		DEVIATION APPROVAL REQUESTS (DAR'S) (continued)		
11	70-12R1	A circuit trace was repaired to salvage a parent board 26640M.	26560	None. Repaired circuit trace is considered flight worthy.
12	71-02R1	An engineering model predisperser drum was used to preclude major schedule impact.	24708	None. Drum is identical to flight requirements except for application of finish and the shaft size. Differences are not considered critical to functional operation.
13	71-03R1	Several design changes were incorporated into the 1A5 box to preclude major schedule impact. Rework caused deviations to soldering requirements.	25352 NPC 200-4	None. Rework is considered acceptable for flight use.
14	71-07	The predisperser exhibits a failure rate of 0.24 percent in that it occasionally fails to move to the commanded position.	29301	At the present failure rate, approximately 0.25 percent film data loss will result.
15	D009	Capacitor ST31094M561 substituted for ST22323M561D in frequency coupling isolator module assembly.	25404	None. Substituted part is considered acceptable for intended function.
		WAIVERS		
16	W071	ECP's 120 and 123 allowed changes to the external cable assembly to separate high and low current wires to eliminate an EMI problem. Modified cable not requalified.	31015	None. New cable eliminated EMI problem. Construction is same and was qualified by similarity. Cable also passed instrument acceptance tests.
17	W072	Re-documents condition of predisperser operation as defined in Item 14.	29301	At the present failure rate, approximately 0.25 percent film data loss will result.
18	W073	The 1.25-second exposure is out of specification. Can be as short as 0.99-second.	CP25100	None. Since diode array provides actual exposure time, no loss of scientific data will result.
19	W074	Two resistors in PRS electronics not conformal coated per drawing requirement.	26661 26640	None. Absence of conformal coating considered not critical to performance.

2.6.2 Parts Program

This program was planned and funded to be a high reliability effort with maximum emphasis on using established reliability (ER) parts. Where ER parts were not available special effort was devoted to preparation of part specifications, vendor surveys and part evaluations in advance of part procurement. Within the BBRC reliability department the Parts group had assigned engineers for the various part categories. These engineers worked closely with the subsystem design engineers and had ready access to piece part manufacturing representatives. The intent of this effort was to minimize the number of new parts being selected for the S052, S055 and S082 instruments while selecting the best part for the application. Due to the number of new parts being specified, the GSFC and MSFC Preferred Parts Lists were of little value in reducing the amount of specification and evaluation effort. The MSFC Parts Technology group, however, provided a considerable amount of information about vendor problems and assisted in piece part failure analysis.

The result of the S082 parts program is summarized in the NRL/ATM Approved Parts List, BBRC Document No. 620-7C. This list contains 157 standard (ST) part specifications, 66 selected part (SP) specifications, 54 procurement specifications and 44 reports on special evaluations conducted at BBRC. The ST's contain detailed part parameters and approved sources; the SP's identify special screening required at receiving such as power age and X-ray; and the procurement specification, which is referenced in the ST, identifies vendor/BBRC receiving tests and packaging/certification requirements. Approximately one-half the cost in preparing specifications and conducting part evaluations was shared with the S052 and S055 Programs.

2.6.3 Design Reviews

A formal CDR was held at BBRC. The NASA response to the designs presented concluded that insufficient testing had been accomplished

with respect to mission objectives. It was also felt that additional analysis was required to reduce single failure points and provide redundancy in certain areas. For these reasons a delta CDR was held to present additional test data and reliability analyses. Subsequent design reviews at BBRC were confined primarily to NRL and MSFC representation and were generally a part of program reviews.

Prior to the formal release of drawings for a particular subassembly, an internal design review was held by Reliability to resolve drawing comments and accomplish drawing sign-off by the various design, production and project participants. Approximately 3500 drawings were released. Subsequent drawing changes were controlled by the project Configuration Change Board (CCB) of which the reliability engineer was a member.

2.6.4 Reliability Analysis

MSFC Drawing 10M30111A was used as a guide in preparing Parts I, II and III of the Failure Mode, Effect and Criticality Analyses (FMECA). Parts I and II were completed for S082A in April 1968 and are contained in BBRC Document TN 68-38. The comparable report for S082B is BBRC Document TN 68-67 and was completed in July 1968. Reviews by MSFC resulted in several recommendations which were incorporated in the Revision A release of these documents. Also contained in Revision A is the more comprehensive Part III effort. A preliminary release of both documents was submitted to NRL in June 1969; however, no further action was directed due to an apparent lack of funding and the fact that the designs were essentially complete. All design changes after about mid-1969 were of a make-work category.

The calculated probability of mission success, given a mission duration of 56 days, was 99 percent for S082A and 97.5 percent for S082B. These predictions were based on meeting the primary mission objective of acquiring solar photographic data which allowed for failure of all or part of the telemetry circuits.

In retrospect, a considerable amount of effort was devoted to performing analyses of piece part stress and failure mode and finally ranking various circuits and subsystems by criticality. Future NASA scientific experiment developments should consider the following points:

A. Failure mode and criticality analyses are of limited value since these experiments rarely have a means for redundant subsystems.

B. Reliability predictions are meaningless for a one-of-a-kind design.

C. Piece part stress analysis should only be accomplished with the initial conception of design to permit changes readily. Actual stress values should be recorded on a copy of the drawing with no further tabulation or documentation.

Any savings of effort from the above approach could be invested in additional parts selection and screening.

2.6.5 Reporting

A summary of accomplishments and future activities was provided as a portion of the program monthly progress report. Failure reports were prepared by the assigned reliability engineer with assistance from the Parts group. The following NASA reports were

reviewed on a routine basis to determine any impact on planned piece part usage. In some cases significant program impacts came to light which required further piece part screening and in some cases a complete replacement of a particular part type.

- GSFC parts and components evaluation reports
- MSFC parts evaluation reports
- GSFC failure analysis reports
- GSFC quality assurance briefs
- MSFC parts newsletter
- MSFC construction analysis reports
- NASA alerts

2.6.6 Reliability Evaluations

The majority of reliability tests and evaluations was on particular electronic piece parts as noted in Section 2.6.2. A few evaluations were conducted at the electronic module level of assembly with one test at the parent board level. The parent board evaluation was accomplished using a typical S082B electronic parent board. The purpose of this evaluation was to determine if an assembly consisting of various module configurations and a large printed wiring board (0.062 x 8 x 12-inches) would successfully pass worst-case ATM thermal and vibration environments. BBRC Document No. 620-14 provides the test plan with the test results contained in Document No. 620-20. The results demonstrated that the techniques being pursued for packaging both S082A and S082B electronics would have a high probability of success.

2.7 MATERIALS

A significant effort was devoted to materials selection and contamination control during the design and development of the

instruments. MSFC Document 50M02442 entitled, "ATM Material Control for Contamination Due to Outgassing", was used as a guide for material consideration. However, many materials on this list were unacceptable for use on or in the S082 instruments, film cameras, and camera canisters. Therefore all candidate materials were evaluated, tested, and selected for control of any contaminants that could have affected the optical surfaces or thermal control surfaces in the instruments. Materials that analysis indicated were potential sources of particulates, condensable contaminants, cold welding, or whiskering in the atmosphere or in vacuum were tested. Testing included long term thermal vacuum exposure and/or operation, residual gas analysis (RGA), infrared spectral analysis, vacuum weight loss, vacuum exposure nephelometer (VEN), and measurement of reflectance or transmission changes to sample optics in the near and extreme ultraviolet. In addition, all materials were evaluated and/or tested for compatibility with the SWR film and the film holder materials were tested for compatibility with the film developer solutions and processes. Materials that were batch critical (some epoxy and plastics, anodize, chromocoat, paints, wire insulation, electronic components, etc.), were tested on a 100 percent sample basis. All contamination critical processes were documented and frequently checked. Materials that were required but not compatible with the contamination control requirements (most electronic components) were encapsulated with a suitable epoxy. Others that could be cleaned up with solvents, detergents and vacuum baking were tested after the cleaning process.

Special cleaning processes were developed to clean all components after fabrication and assembly. These cleaning procedures were developed to remove all machine oils, skin oils, silicones, plasticizers, and other contaminants encountered. In addition to standard clean room practices, all facilities, fixtures, tools, and test equipment and personnel were evaluated for condensable

contaminant potential and appropriate control procedures were developed. Special personnel training classes were established and periodic training implemented. Handling and transporting of clean components and subassemblies at BBRC was done with specially fabricated clean boxes or in nylon 6 bags, purged with dry nitrogen. All vacuum chambers were equipped with highly effective cold traps and/or sorption pumping systems and were checked for contaminants prior to each use. Each vacuum test was monitored with RGA and sample optics for UV reflectance measurements. A real time contamination monitor was developed by NRL for instrument qualification and acceptance vacuum tests and for the ATM tests in the MSC vacuum chamber. Ultra-clean, dry nitrogen supplies were established and a purge system developed for internal purge of the instruments at all times prior to launch. Sample optics were mounted inside the instruments and short term UV reflectance measurements were periodically made. Long term sample optics were removed immediately prior to launch for evaluation of the accumulated degradation of the optical elements since calibration. All moving parts were lubricated with materials and/or processes compatible with extended vacuum operation and with the contamination control requirements. There were four major lubrication systems used in the instruments and cameras.

- Nituff (Anodized Aluminum/Teflon)
- Polyimide Bonded Dry Film (M_oS_2/Sb_2O_3)
- Mechanically Bonded Dry Film (Peened M_oS_2)
- Mechanically Bonded Dry Film (Burnished M_oS_2)

An accountability of all material used on the S082 instruments, cameras and canisters can be obtained in the following Materials Identification Lists:

BBRC Document No.	Subsystem
620-6	S082A and S082B Instruments
620-131	S082 Film Cameras
620-138	S082 Camera Canisters
620-195	S082 Film Cameras and Canisters - Non-Metallic List

3.0 HARDWARE FABRICATION

The fabrication of instruments and ground support equipment was primarily accomplished within BBRC facilities. Figure 3-1 shows representative fabrication areas used to produce S082 hardware. All fabrication operations were the responsibility of the Project Engineer for Production with a selected group of engineers and technicians assigned to him for accomplishing the various production tasks external to the fabrication shops. These tasks included planning, scheduling, expediting, resolution of fabrication problems, subsystem test procedure preparation and testing of completed modules, assemblies and subsystems. All contract hardware delivered to the customer was initially procured by Production as piece parts, assemblies or completed items and then processed and inspected as necessary to provide the final configuration of items required. A listing of hardware fabricated for formal delivery to the customer is contained in Table 1-1, Major Hardware Items Delivered Under Contract.

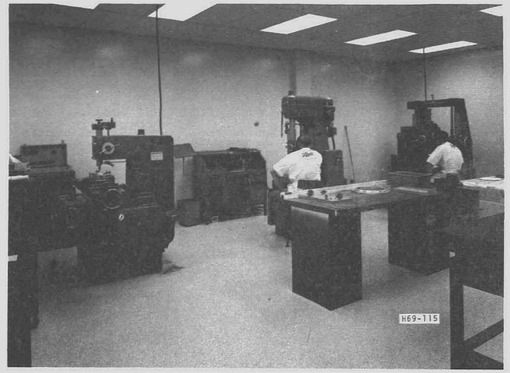
3.1 PROCESSES AND PROCEDURES

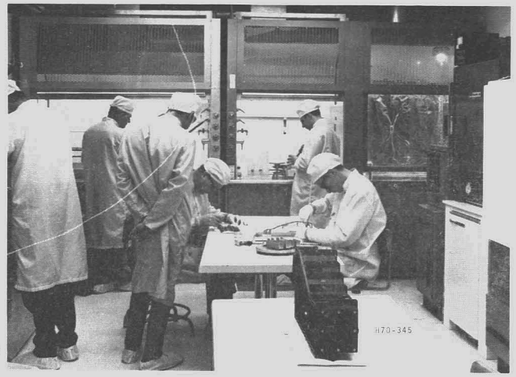
Procedures for controlling production processes within BBRC facilities were identified as Ball Process Standards (BPS's) and referenced on the engineering drawings. The special materials used in these processes were procured to Ball Material Specification (BMS's) and referenced in the BPS's. Generally, these process procedures pertained to soldering of electronics, welding of electronics, potting/coating/bonding, assembly methods and preparation of metal surfaces. A more detailed listing of processes used is contained in BBRC Document Nos. 620-6, 620-131, 620-138 and 620-195, Materials Identification List.

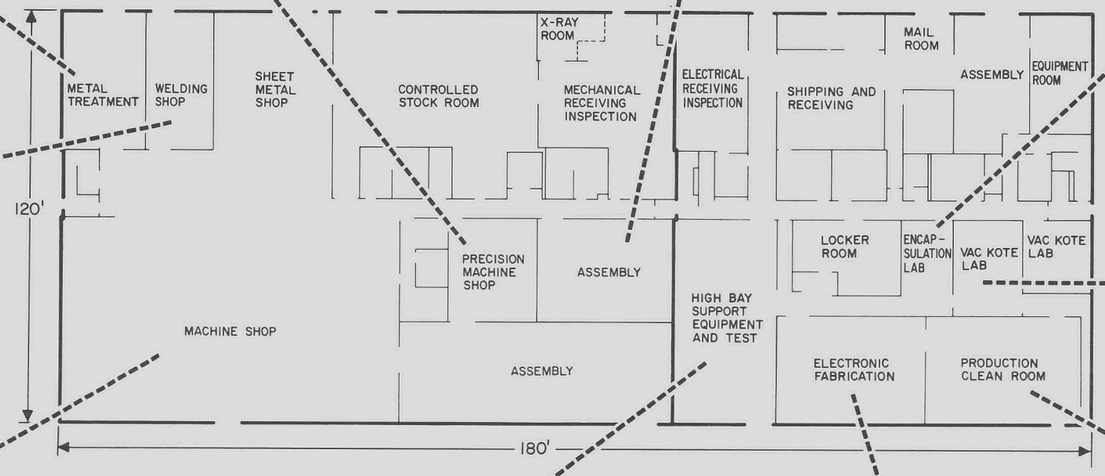
Specifications and procedures for testing mechanical parts/assemblies, and electronic modules/ assemblies were prepared by the appropriate production subsystem engineers, and reviewed and approved

PRODUCTION & SUPPORT BUILDING

GROUND FLOOR - 36,000 SQ. FT.







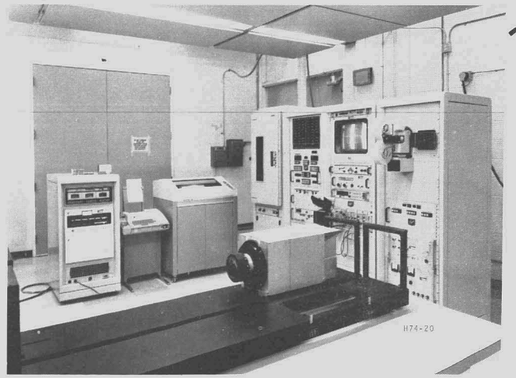


Figure 3.1. Production and Support

by Design and Reliability. These documents were controlled by Production and identified as P110,XXX. Approximately 250 of these documents were prepared.

To facilitate the assembly, processing and test efforts approximately 450 special tools and fixtures were required. Each of these items was informally documented as production drawings and identified by a T-XXXXX number.

3.2 CONTAMINATION CONTROL

Due to the stringent requirement for minimizing contamination of optics by particulate matter and vacuum outgassing, all fabrication procedures were upgraded where necessary. Several special production procedures were prepared to control cleaning of certain parts and assemblies. Generally all items were washed with alcohol, xylene, and freon. Ultrasonic cleaning was used where feasible. All completed assemblies including assembled instruments less optics were vacuum baked for up to 48 hours. These procedures were very effective in removing machining oils, skin oils, silicones, plasticizers, and particulates.

To maintain hardware in a clean condition, essentially all assembly and test operations were conducted in Class 10,000 clean rooms per MSFC Standard 246A. In addition to standard clean room practices, all facilities, fixtures, tools and test equipment and personnel were evaluated for condensable contaminant potential and appropriate control procedures implemented. Special personnel training classes were established to emphasize the effect of contamination on hardware performance and teach methods for reducing the contamination potential. Cases in which hardware was accidentally contaminated or failed to meet established requirements were documented on NMR's and dispositioned for recleaning as directed by the MRB.

3.3 PRODUCTION CONTROL

All requirements for procurement and in-house routing of parts and material were identified on production requisitions. Inspected parts were routed to a limited access storeroom for storage by project. Fabrication of parts and assemblies was authorized and controlled by production orders or certification logs. Assemblies with more than six piece parts usually required certification logs to properly document the configuration, piece part traceability, and production/inspection steps.

3.4 SUBCONTRACTS

Subcontract purchases were made on several items that required facilities and/or processes not readily available at BBRC. To ensure thorough bid review and implementation of program requirements, procurement review meetings were held with participation by appropriate project and company line organization personnel.

3.5 MECHANICAL FABRICATION

The panels of the instrument cases were machined by numerically controlled mills and then welded using special fixtures. Completed cases were inspected for correct dimensions and then black anodized except for faying surfaces which were chromocoated. The total instrument case effort was a subcontract item. Because of variations in anodize and weld quality, the best cases were selected for the flight instruments. The titanium piece parts for the instrument thermal mounts (legs) were machined in-house and welded as a subcontract effort. Figure 3-2 depicts the manner in which the tubes were welded to their respective mountings.

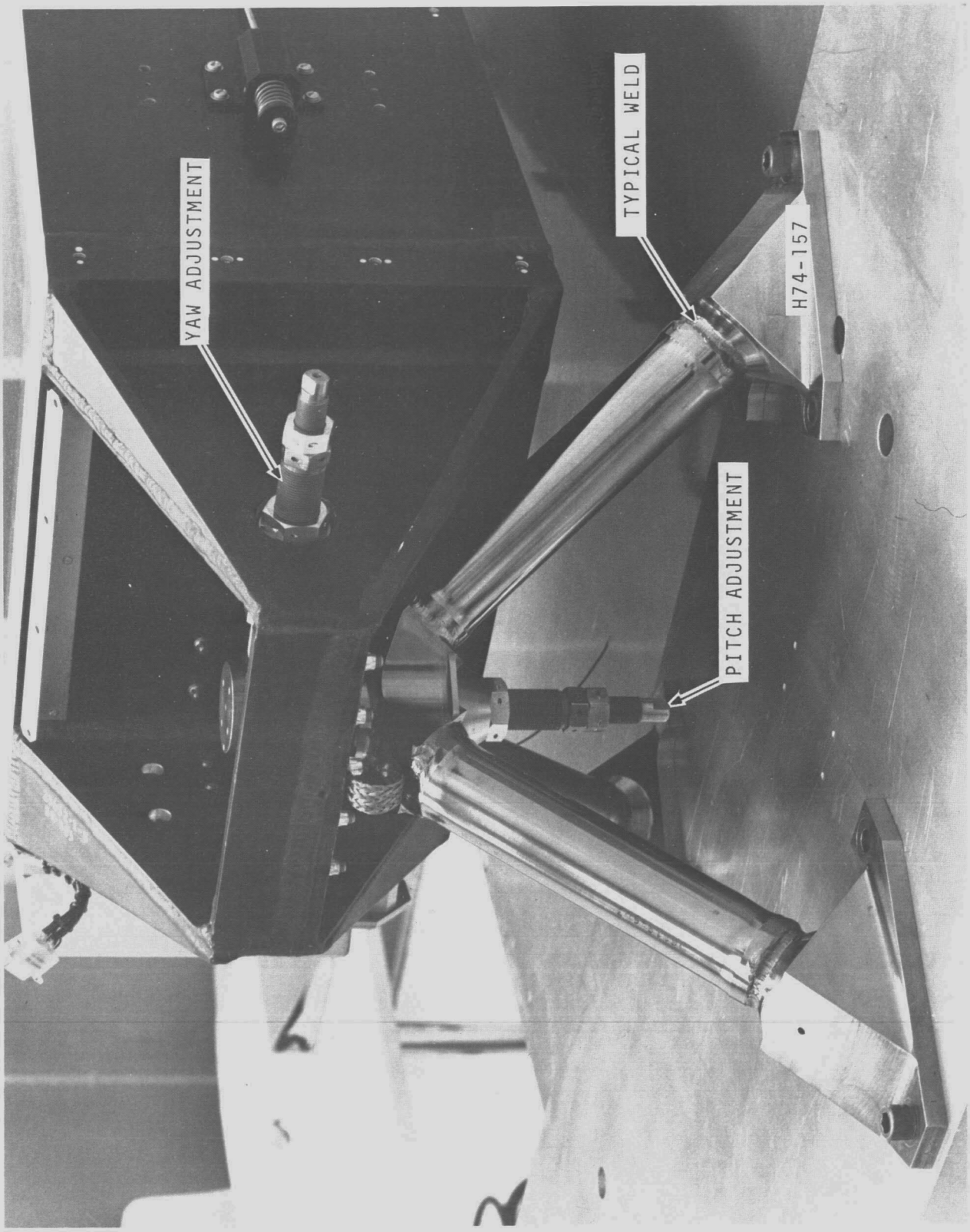


Figure 3-2. S082A Tripod Assembly

Mechanisms consisting of aperture doors, optical mounts, camera latch and guide rail assemblies, light baffles and electronic housings were fabricated and assembled in-house. No significant problems were encountered. Several metal finishes consisting of chromocoat, anodize, and paint were provided as BBRC processes. Metal heat treating and Nituff lubrication were supplied by vendors. Bearings in mechanisms and similar surfaces were lubricated at BBRC with vacuum compatible lubricants consisting of either molybdenum disulfide or polyimide.

The housings and mechanisms for the FDVU and CALROC instruments were fabricated and assembled in-house with the exception of CALROC cases which were provided by Bristol Mfg., Canada.

3.6 OPTICS

All XUV gratings, S082B primary mirror, XUV monitor mirror and aluminum filters were GFE from NRL. The XUV monitor mirror was bonded to its mounts with epoxy at BBRC. Reference BBRC New Technology Report TR68-43 for further details of this mounting technique. Frames were fabricated at BBRC for the filters and then sent to the NRL subcontractor for filter installation. The optics were installed in their mounts by the Integration and Test group. BBRC procured the remaining optic elements consisting of relay lens, neutral density filter, folding mirrors, image dissector tube, and slit plate. Fabrication of the slit plates by Buckbee-Mears required many process changes and refinements before flight quality hardware was achieved. The optics for the rocket systems were similar in nature to the ATM and similar mounting techniques were used.

3.7 ELECTRICAL

All electronic assemblies were fabricated in-house with the exception of S082B items consisting of the PRS ±15V power supply procured from Matrix, the Image Dissector Tube (IDT) from ITT Industrial Lab, and the diode array from Fairchild. Module assembly was typically performed in a controlled production area with parent board and box assembly performed in a Class 10,000 clean room. To ensure traceability and control all electronic fabrication and inspection were documented by means of the BBRC certification log system.

Soldered modules were assembled by technicians certified in accordance with NASA publications NPC 200-4 and NHB 5300.4 (3A). BBRC training facilities and process controls were periodically reviewed by MSFC production process control personnel to ensure NASA approval of the methods and techniques being used. The most unique soldering process developed was the tooling and methods for soldering flat pack micrologic in cordwood modules. A typical model is shown in Figure 3-3. Special tools were developed to position the printed wiring boards (PWB's) and bend the micrologic leads into a shape containing stress relief while providing the desired contact area with the PWB. Initially the micrologic leads were hand soldered with most flight and spare modules reflow soldered to provide more uniform soldering control and reliability.

The most serious problem encountered with all types of soldered modules was the inability to procure consistent high quality PWB's with plated-through holes. Extensive vendor search efforts resulted in only three acceptable sources. Further, in-house inspection typically reduced purchased quantities by up to 50 percent. The new result was high module cost due to PWB

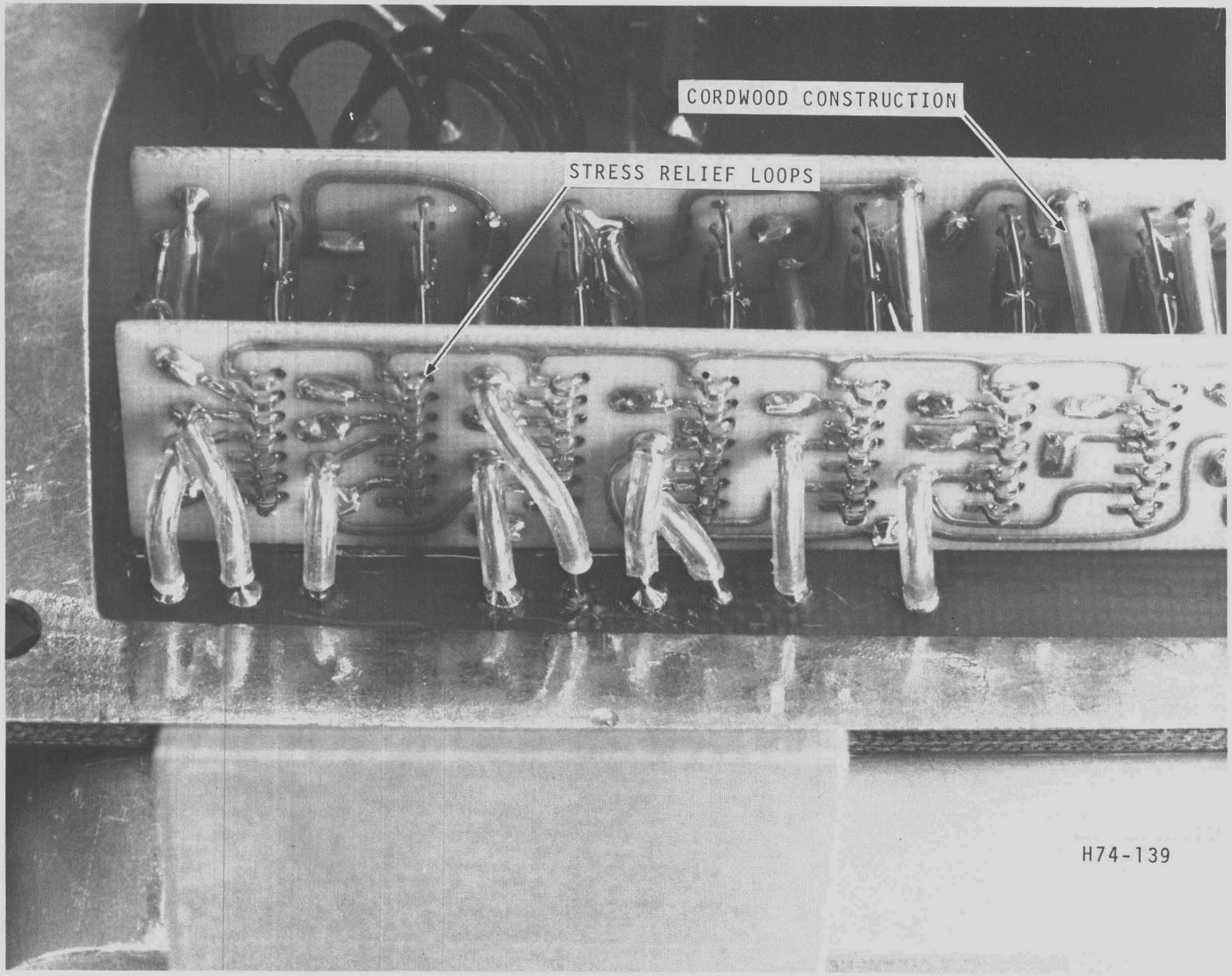


Figure 3-3. Typical Soldered Module

scrappage, PWB handling and re-inspections, and schedule work-arounds for module non-availability.

The majority of modules on S082B was of a welded configuration as shown in Figure 3-4 and proved to be the least difficult to produce interms of quality, reliability, cost and schedule. Module welding was performed per MSFC-STD-271 as implemented by BBRC BPS 23.03. Weld schedules were developed for a number of different lead materials including solder plated copper. A special weld schedule qualification was performed with copper to assure MSFC of its ability to produce consistent high quality weld connections.

After module assembly all modules were conformal coated with a thin coat of clear hard epoxy (Epon 828). This technique left the module free of damage during test handling and still repairable if MRB desired to salvage a defective module. It also provided module strength sufficient for aerospace application as opposed to solid potting.

Figure 3-5 shows a typical relationship of soldered and welded modules in conjunction with the matrix fence. Refer to BBRC Report No. TR71-08 for further description of the matrix fence as a means for increasing circuit interconnections on two-sided PWB's.

Bench tests were performed on assembled parent boards before conformal coating with polyurethane and again at the black box assembly level. Testing of S082B electronic boxes proved inconclusive in some respects in that a total circuit function might be contained in as many as three different boxes. All completed boxes and assemblies received a thermal or thermal vacuum bakeout before installation on the instrument case.

Instrument internal and external wiring harnesses were first laid out on simulated instrument cases and then the connectors were potted with polyurethane or DC 93-500. The most difficult cable

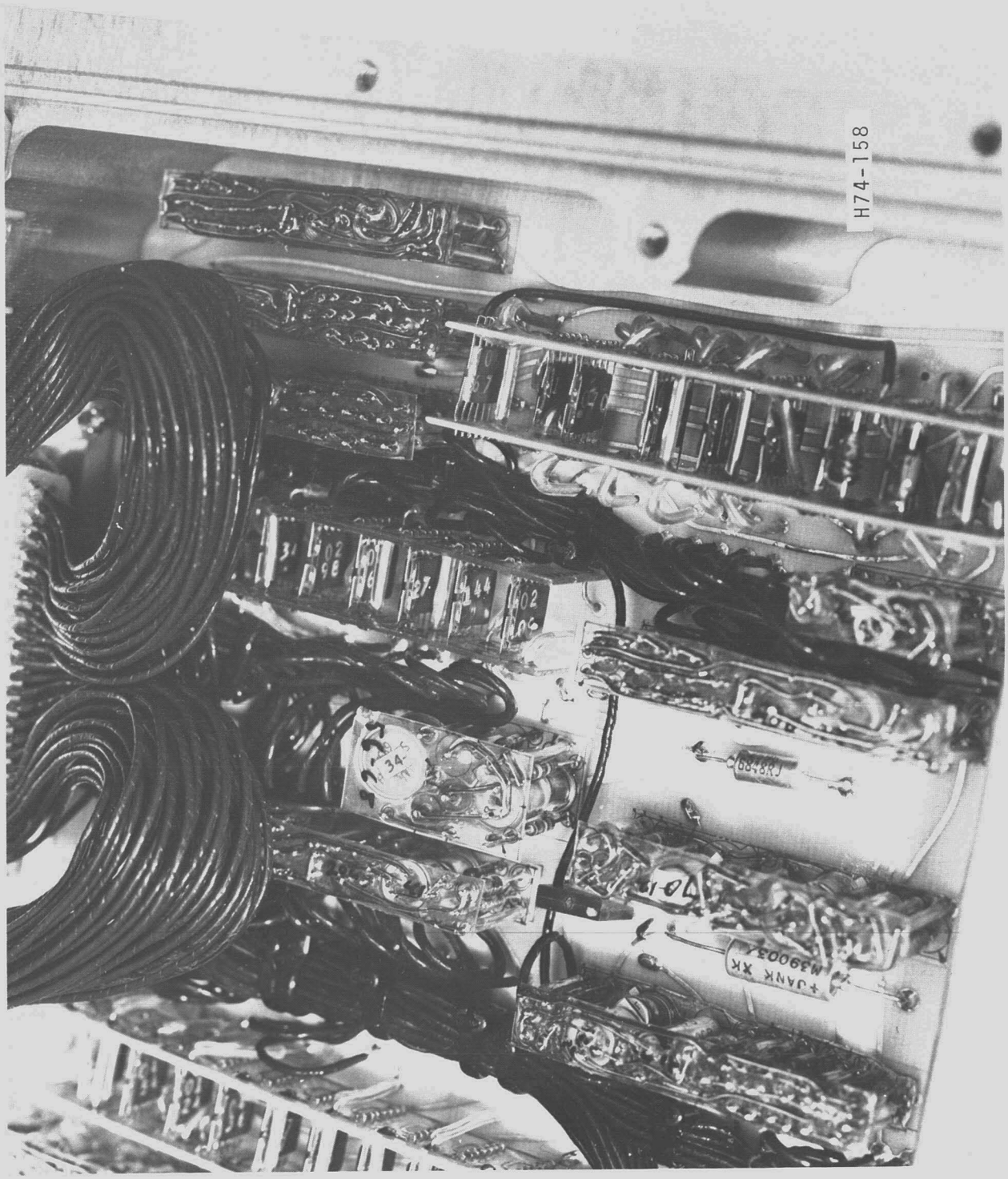


Figure 3-4. Welded Module Construction

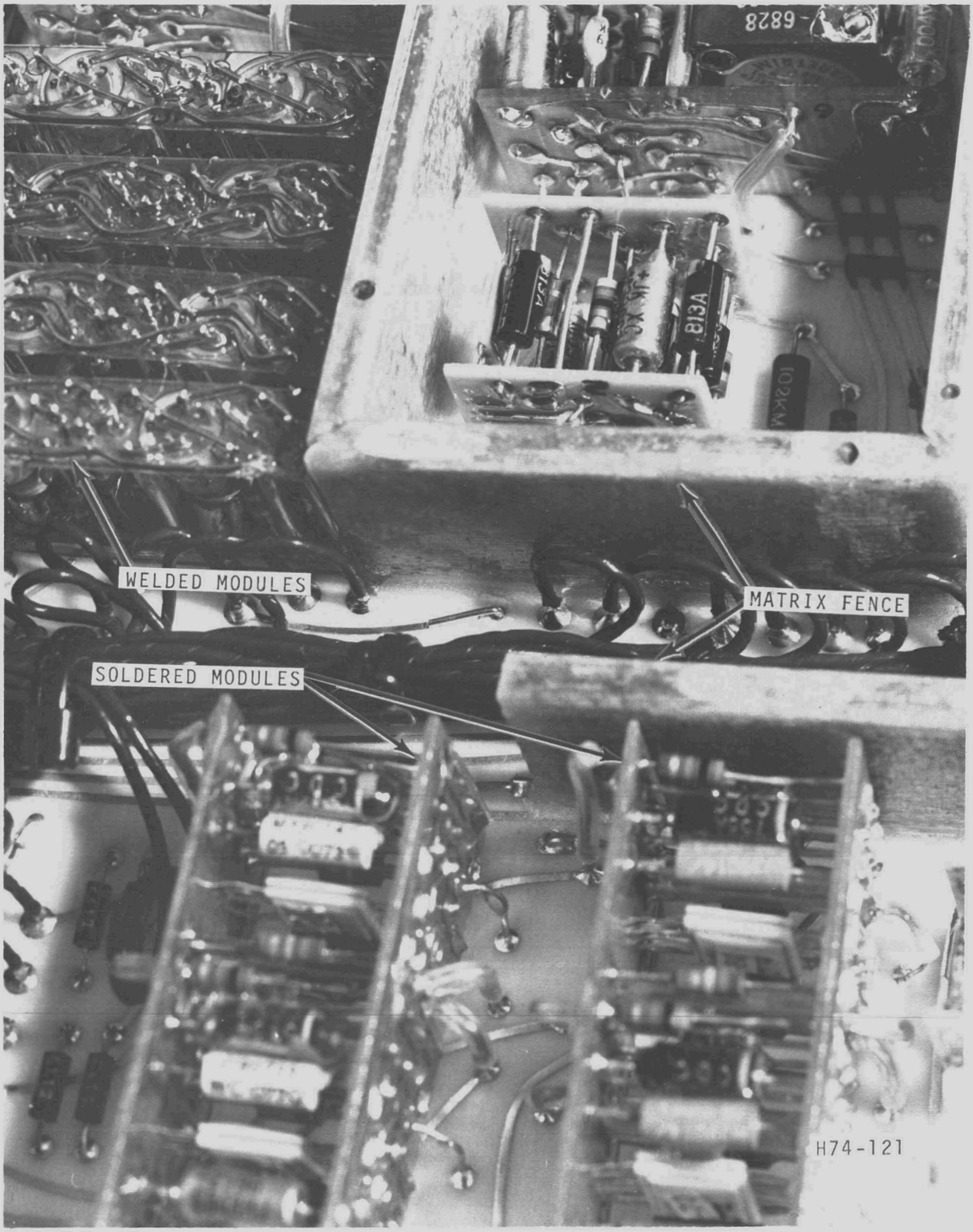


Figure 3-5. Typical Electronic Assembly

problem was concerned with stress relieving of wire bundles adjacent to the 100 pin double density connectors on S082B.

Several wires were broken during cable handling and when electronic boxes were installed or removed. Broken wires were replaced where feasible; however, a few solder splices were authorized by MRB.

All FDVU and CALROC electronics were assembled in generally the same facilities and using the same techniques as ATM hardware except with less stringent inspections and less record keeping. Most piece parts were of commercial or military grade.

The final electronic assembly task of the S082 program was concerned with the fabrication of three S082B Auxiliary Timer units to support the SL-4 Mission. Based on data evaluation of the SL-2 and SL-3 exposures, a revised exposure sequence for S082B was found to be desirable. The auxiliary timer was designed, fabricated and launched with the SL-4 astronauts. This unit was inserted between the control and display panel and the cables leading to the instrument during SL-4. To minimize fabrication time the following techniques were used.

A. An aluminum box was formed and welded in-house.

B. Micrologic modules containing 54L logic were welded in cordwood style.

C. Switches and connector were provided as GFE.

Figure 3-6 shows the assembly without the mounting base and Figure 3-7 shows a closeup of the welded micrologic modules.

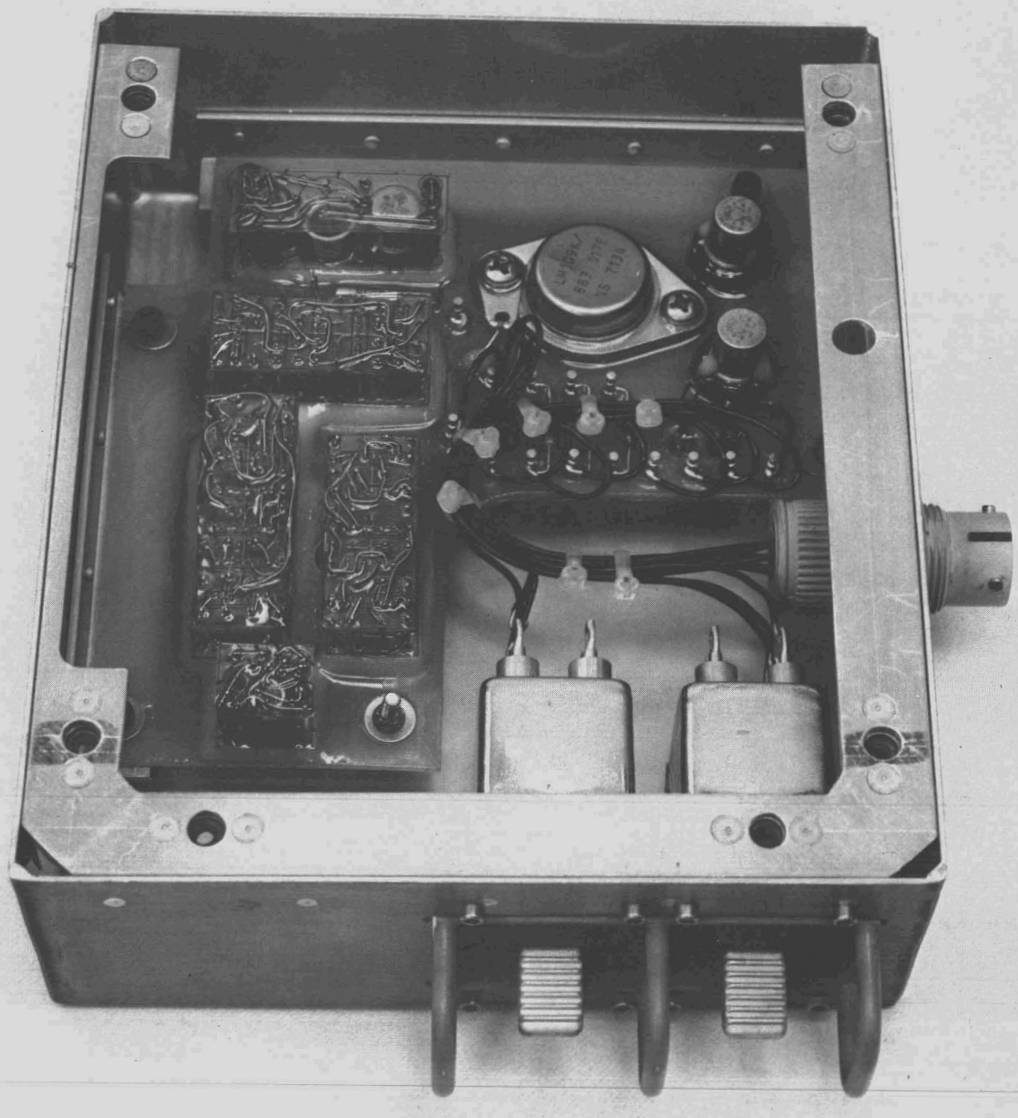


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Figure 3-6. S082B Auxiliary Timer

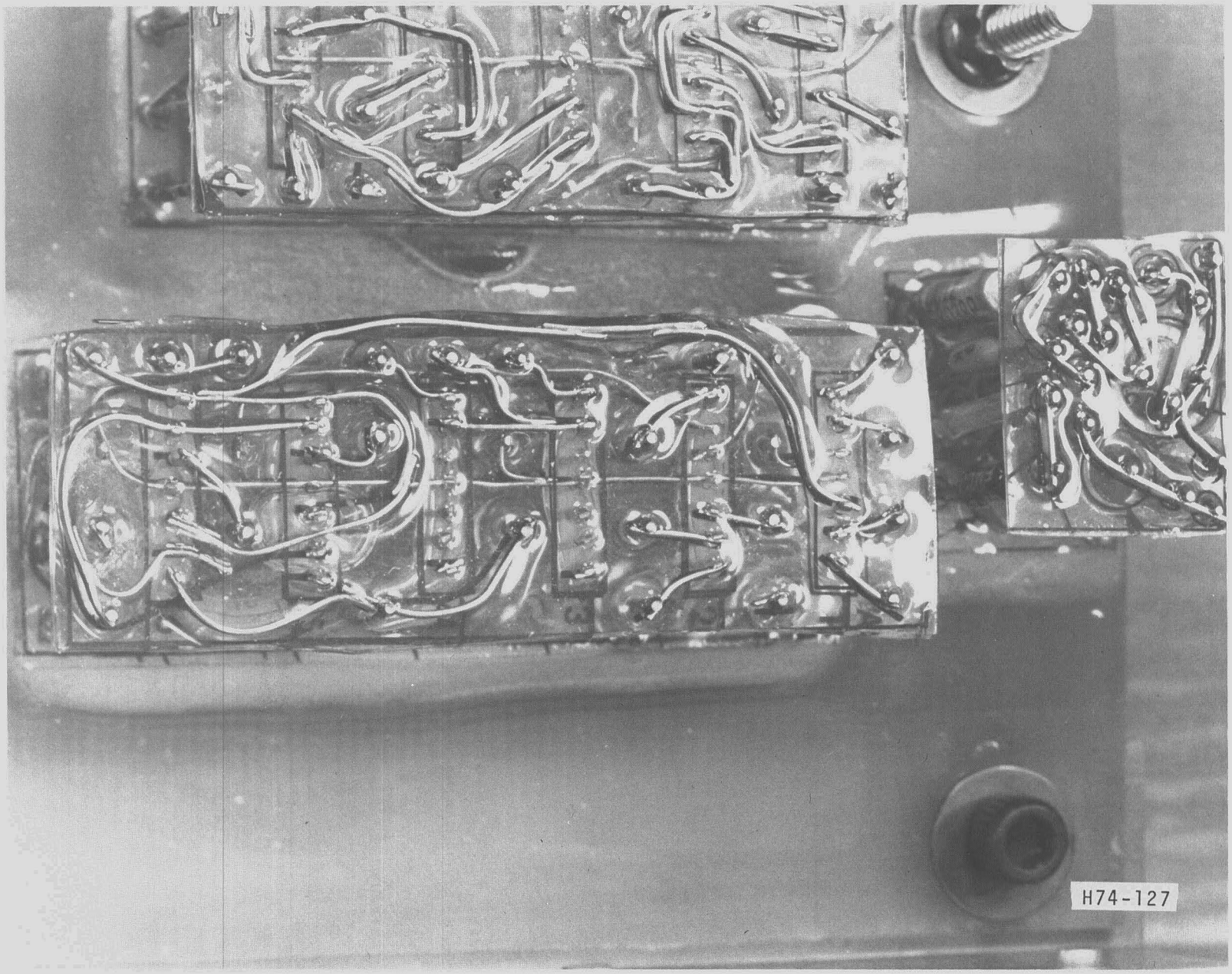


Figure 3-7. S082B Auxiliary Timer Micrologic Module

3.8 THERMAL CONTROL

The aluminum honeycomb panels and thermal blanket elements of the active thermal control system (TCS) were procured from Parsons and Thermal Systems, respectively. To minimize procurement effort the subcontracts included TCS hardware for the S052 and S055 instruments. Blanket installation on the panels and attachment of thermistors, wires and controllers were accomplished in-house. Thermistor attachment was a unique potting problem to solve because of the fragile thermistor construction. The process selected first placed epoxy on the thermistor with only lead wires exposed before placing the thermistor in a hole on the panel and potting with polyurethane. The ±15V TCS power supplies were assembled and solid potted in-house.

3.9 CAMERA AND CANISTER FABRICATION

The ATM camera fabrication was probably the most stringent of any of the mechanical fabrication efforts associated with the program. The cameras each had approximately 500 different part number parts with a total part count of approximately 1,900 per camera. Considerable specialized tooling was fabricated to facilitate piece part fabrication and camera assembly. The fabrication techniques involved standard machine shop techniques plus cylindrical grinding, spring fabrication, wire cut electrical discharge machining, electron beam welding, injection molding, form die operations, cam grinding, state-of-the-art lubrication techniques, unique film carrier fabrication, and high speed dynamic analysis. In addition, high lustre surface polishing was performed at assembly to reduce operating frictions and provide extremely close fit tolerances. During the production phase, high speed movies were made of the camera mechanism motions to help in dynamic analysis and camera redesigns.

The wire-cut electrical discharge machining (EDM) was used to machine the S082B camera ratchet pawls. This method of obtaining the eight-step positioning of the film plane was developed after many other techniques were evaluated. The pawls were procured at a cost far less than could have been done with conventional machining techniques. Wire-cut EDM allows precision cutting of prehardened parts and greatly reduces warpage from heat. Detailed information can be obtained from:

AGIE Industrial Electronics, Ltd.
6616 Losone
Locarnd, Switzerland

Film carrier fabrication required the generation of precision one-meter and two-meter radius surfaces on aluminum. This was accomplished by designing and fabricating special tooling that consisted of:

- One-meter and two-meter curvature generation tooling
- Two-meter and one-meter assembly tooling

The curvature was generated by use of a rotary table (serves as axis of rotation). This was connected by means of a brass bushing to the mounting plate (2 feet by 7 feet by 2 inches thick). At the opposite end of the rotary table, the mounting plate was supported on a large brass bushing cross-slide mechanism and power driven with a ball screw device.

The mounting plate was milled perpendicular to the axis of rotation and dowel pins installed parallel to the axis of rotation. A mounting block for the piece part had bored holes matching the dowel pins.

The entire operation was conducted on the DeVlieg and, before any cutting took place, the tooling was turned in all three axes.

The assembly tooling consists of two ground dowel pins mounted in a block, exactly five inches apart. A stop was positioned at one end of the mount which accurately located the center (high point) of curvature of the carrier. The sliding pad-located surfaces where then machined, relative to the center of curvature.

After considerable evaluation of vendor processes, acceptable film retainers were procured from Plastic Tooling Aids and were fabricated by an injection molding process. After the retainers were procured they were hand polished to give the type of mating surfaces required for proper camera operation.

The stainless steel film holders for the S082A camera were fabricated by Premium Allied Tool and were flown on the first and second ATM missions, but the BBRC-built S082B aluminum film holders were flown on the last mission for both "A" and "B" cameras.

The stainless film holders fabricated by Premium Allied Tooling would not hold conformity close enough for the S082B cameras and the final configuration was an anodized aluminum film holder fabricated at BBRC.

The film holders were fabricated by shearing to size, machining the retainer slots and then machining the edges to provide a thin section for final form die operations. Each film holder was hand worked to assure proper film clearance before being anodized.

After initial piece part fabrication to the released engineering drawings, all piece parts were thoroughly cleaned to remove all volatile and particulate contaminants. Assembly and test operations were accomplished under clean room conditions.

The case assembly required that six side plates all be drilled, reamed and pinned simultaneously to maintain precision perpendicularity and parallelism between all parts.

Camera assembly was accomplished, almost exclusively, on granite surface plates with precise measurements and adjustments being made at each step of the buildup. As an example, the feed claw adjustment required accuracies in the order of one ten thousandths. As the assembly was being built up, all moving mating surfaces were polished to minimize sliding and/or rotational frictions. The lubricants used were all of a non-conventional dry film type.

At specified steps throughout the camera buildup, specially fabricated torque measuring devices were utilized to measure camera operating torques to verify that all adjustments and fitting operations were still within specification.

After completing the camera assembly, each camera was tested to verify proper operating sequence, torques, times and film holder changing. Also, each camera was checked for cleanliness levels and light-tightness. After adequate production testing to verify that each camera was an operational unit, it was delivered to Integration and Test for acceptance testing. Figure 3-8 shows the production clean room area used for camera and canister assembly and post manufacturing checkout.

Several of the high load areas of the camera required relubrication at specified operational intervals. This relubrication was accomplished by partial disassembly and reprocessing the piece parts through the lubrication process.

The canister fabrication was unique to the program in that the shell and base were explosive formed parts. The reason explosive formed parts were used was to obtain a rib structure that would give the required strength and still meet the weight requirements. Equivalent

Figure 3-8. Production in Clean Room

strength versus weight requirements could not have been achieved by conventional machining techniques.

The fabrication of the canisters was accomplished by a series of weldment and machining operations.

The main shell structure was composed of the explosively formed shell, the explosively formed base, a partially machined upper flange, various base and shell stiffeners, and machined brackets. These parts are all sequentially welded together with spot welding and heliarc welding techniques to form a shell assembly. After the shell assembly was welded, final machining was performed to provide accurate fit for the camera. Final machining had to be performed at the assembly level because even with tooling, minor warping still occurred during welding. The final machining included the machining of the holes in the bottom of the canister to mate with the cameras as well as the top flange to give proper depth and centrality when the camera was installed. The canister lid assembly piece parts were machined and/or procured, then cleaned, lubricated, and assembled. The lid assembly required that each lid be assembled and mated to its respective shell assembly since the lid securing action was accomplished by the engagement of six pins sliding up cam surfaces machined in the upper flange of the shell assembly. Lid adjustments were made to assure that the pins moved far enough up the ramp to adequately compress the O-ring seal, but did not move far enough to make handle closing forces too high. Also, the lid to camera interface had to be adjusted to provide a preload against the cameras so that a positive pressure would be maintained against the cameras under all expected conditions. All the valves for the canister were procured, cleaned, lubricated, and calibrated prior to installation.

After the complete canister assembly, each unit was thoroughly tested to verify minimum leak rate and proper valve operation and handle forces.

3.10 GROUND SUPPORT EQUIPMENT

The main ATM ground support equipment was composed of two fixed GSE stations and two portable test sets. There were also many smaller electrical and mechanical pieces of ground support equipment.

The ground support equipment was fabricated of commercial quality parts and hardware to commercial type specifications. Two sets of fixed ground support equipment were fabricated, one used with the prototype instrument and one used with the flight instrument.

The other types of ground support equipment included a range of items from the large trunion fixtures that were fabricated to permit rotation of the complete instruments while fastened to the shipping container base to the single piece lifting lugs that were used to fasten a crane to the instrument. Between these extremes were mechanical and electrical support items fabricated to tooling drawings and used at all stages to either simplify the fabrication techniques or used as safety devices to help prevent damage to the hardware.

There were various pieces of ground support equipment fabricated for usage on the other hardware systems fabricated under the contract, but they were all less extensive than the GSE used on the ATM hardware.

3.11 SPARE PARTS PROGRAM

The spares program was initiated in late 1969 to ensure the availability of spare parts and assemblies to correct failures during field tests of prototype and flight instruments. Originally the program was scoped to include spare mechanisms (optical mounts and cameras), electronic assemblies, and one set of electronic parent board assemblies. However, to minimize the cost while still maintaining a viable spares program, the list was reduced to long lead items for mechanisms, one set of electronic assemblies, one set of heater panel assemblies, one assembled camera, one set of camera parts, and one set of canister parts per instrument. A few spare parts were included for the electrical checkout consoles. The final list of spares is contained in the Spare Parts Exhibit, BBRC Document No. 620-26, Revision E. Spare Parts Control Plan, BBRC Document No. 620-77 was prepared to define the general conduct of the program acceptance tests, delivery, storage, and issue of spare parts. In summary, the spares were assembled using flight configuration engineering drawings and the same fabrication, quality assurance, and test controls used on flight hardware. All spares were stored in a specially controlled area of BBRC Production Stores. Only a few of the spares were actually required to correct field problems. The spare S082A film camera, Serial No. A006, was flown on the SL-3 and SL-4 missions. The unassembled S082A spare camera parts were used to fabricate the A007 camera which was flown on SL-2. Most of the remaining spares were consumed in the refurbishment of prototype instruments.

3.12 RELIABILITY AND QUALITY CONTROL

3.12.1 Reliability

3.12.1.1 Parts Support

The various parts engineers of the Reliability Parts Group provided support to BBRC procurement to interpret specification requirements, provide technical liaison with part manufacturers or their area representatives, and identify alternate approved sources. Support to Quality Assurance primarily consisted of evaluating and dispositioning part defects identified during receiving inspection and assistance on test techniques and equipment.

During the production phase the most significant parts problems were related to Fairchild 9040 series micrologic, CKR-12 ceramic capacitors and Siliconix 2N3384 FET transistors. The micrologic problem related to metallization defects as reported in MSFC Document S&E-ASTR-RMD-69-1. Subsequent corrective action resulted in process changes by Fairchild and reprocurement by all high reliability users. Over 2,000 replacements were procured for S082 experiments. The impact on program schedule was minimized by the loan of some new parts from MSFC and the Sandia Corp. The 2N3384 FET transistors initially procured revealed a lead bonding defect known as "purple plague" (Reference MSFC Report S&E-QUAL-FP-CA53, dated 13 August 1970). Corrective action consisted of the manufacturer changing from gold to aluminum lead wires and replacement of the A2 electronic assembly on the S082B flight instrument. The CKR-12 ceramic capacitors exhibited a high failure rate due to separation of bonding between lead wire and metallization as well as poor separation between metallized plates. Due to the extensive usage of these parts the corrective action entailed the following items:

- X-Ray of assembled electronics
- Improved heat sinking methods
- Replacement of certain flight items containing new capacitors of an improved design (glass encased)

In summary, the parts program effort throughout the production phase required continual emphasis to identify parts with questionable reliability with implementation of screening tests for the noted defect where possible or reprocurement of improved parts.

3.12.1.2 Engineering Support

Throughout the production phase the assigned reliability engineer reviewed module and assembly test procedures to ensure sufficient testing to establish that piece parts were not damaged during assembly and that test methods preserved assembly quality. He also dispositioned approximately 200 reliability data reports (RDR's) originated by production on various test anomalies. This reporting system permitted the rapid disposition and initiation of corrective action on problems relating to errors in fabrication or test without preparation of formal failure reports. Problems caused by part defects were analyzed in detail by the parts group and then documented in failure reports. Parts requiring more sophisticated analysis techniques, such as by a Scanning Electron Microscope, were sent to Parts Technology at MSFC. Table 3-1 summarizes the failure reports prepared during the fabrication phase.

Table 3-1

SUMMARY OF FABRICATION
FAILURE REPORTS

Page 1 of 3

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2178	S082A	One Shot Module	Capacitor (ST22323)
2183	S082A	Sequence Programmer	9040 Micrologic (ST23519)
2184	S082B	Digital Electronics, PWA	9040 Micrologic (ST23519)
2185	S082A	Actuator, PWA	9042 Micrologic (ST23525)
2187	S082A	Mode Selector, PWA	Transformer (SP24944)
2188	S082B	PRS 10v Regulator Module	709 Amplifier (ST23486)
2191	S082B	PRS Compensation Amplifier Module	Checkout Design Deficiency
2201	S082A	Power Supply, PWA	Checkout Design Deficiency
2225	S082B	Electronic Assembly	9042 Micrologic (ST23525)
2229	S082B	Electronic Assembly	9040 Micrologic (ST23519)
2235	S082A	Mode Selector, PWA	9040 Micrologic (ST23519)
2238	S082B	TCS Commutator Assembly	2N5116 Transistor (SP28537)

Table 3-1

SUMMARY OF FABRICATION
FAILURE REPORTS

Page 2 of 3

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2267	S082A	Commutator PWA	2N3384 Transistor (SP23542)
2272	S082B	Electronic Assembly	9042 Micrologic (ST36187)
2274	S082A	Power Supply	9042 Micrologic (ST23525)
2275	S082B	Electronic Assembly	9042 Micrologic (ST36187
2288	S082B	Photon Coupled Isolator Module	2N2222A Transistor (SP23418)
2296	S082B	Film Camera	Bearing (S5632)/Design Deficiency
2298	S082B	Film Camera	Bearing (S5632)/Design Deficiency
2364	S082B Spares	Zone Hold Module	9040 Micrologic (ST36187)
2387	S082B	Row Commander Module	2N222A Transistor (SP23418)
2388	s082B	TM Commutator Assembly	2N5116 Transistor (SP28537)
2389	S082B Spares	Polarity Detector Module	2N3972 Transistor (SP23449)
2391	S082A Spares	Analog Switch Module	2N3384 Transistor (ST32132)

Table 3-1

SUMMARY OF FABRICATION
FAILURE REPORTS

Page 3 of 3

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2395	S082B	TCS Power Supply	Design Deficiency
2366	S082B	Electronic Assembly	9042 Micrologic (ST23525)
2367	S082B	Electronic Assembly	9041 and 9042 Micrologic (ST23522 and ST23525)

3.12.2 Quality Assurance

3.12.2.1 Inspection

All parts were routed to either the mechanical or electrical sections, as applicable, for inspection to design drawing or part specification requirements. Inspection planning and results were documented on an inspection record (BR-49) and filed by engineering part number for future reference. Before parts were routed to production stores each lot was identified with a numbered Material Identity Tag (MIT) and referenced on the BR-49 for traceability purposes.

Any discrepancy between actual part parameters and specification requirements were documented on a Nonconforming Material Report (NMR) and submitted to quality engineering for Material Review Board (MRB) action.

These sections were also responsible for inspection of small assemblies. Certain electrical inspectors were trained and certified for inspection of solder and weld joints associated with all levels of electrical assembly. Verifications of proper assembly and assembly to the latest mandatory drawing revision letter were documented in production certification logs. These serialized logs contained all information of a particular assembly and related part numbers, revision letters, MIT traceability numbers, inspection steps, and inspection status. The as-built configuration was obtained from these logs and recorded in the official Configuration Identification List (CIL). Completed certification logs were audited and filed by the quality control section.

3.12.2.2 Quality Control

Inspectors from the quality control section were responsible for witnessing major assembly operations, performing source inspections and auditing the conformance of company operations to the procedures in the company and program quality assurance manuals. Assembly operations consisted of witnessing the assembly and bench tests of film cameras, canisters, and instrument mechanisms. They also witnessed electronic module and black box bench tests. All test results were documented on test procedure data sheets and filed with the applicable certification logs.

Quality control conducted source surveys of those vendors bidding on subcontracted items. The results of these surveys were a major factor in the final selection of the following subcontractors for the noted items.

Subcontractor	Item
ITT Industrial Labs (BSC-177)	Photosensor Detector Assembly (IDT) Part No. 23888-501
Matrix Research and Development (BSC-160)	±15 Volt Power Converter Assembly Part No. 24575-1
General Precision (BSC-155)	Relay Lens Assembly, Part No. 22366-1
American Air Filter (BSC-181)	Shipping Container, Part No. 27621-1
Buckbee-Mears	Slit Plate Assembly, Part No. 33893-1
Parsons	Thermal Control Panels (Honeycomb)
Thermal Systems	Heater Elements

Source inspections per BBRC Quality Procedure No. 404 were conducted to ensure that all contractual requirements had been met. Out-of-specification conditions were documented on Vendor

Information Requests (VIR's) and submitted to BBRC for determination of item acceptance. Correction of vendor quality control systems were requested on a QA Corrective Action Request (CAR).

3.12.2.3 Quality Engineering

The assigned quality assurance (QA) engineer was responsible for ensuring that all inspections and reporting required by the RAPP were performed. He was also responsible for convening MRB meetings to disposition defects submitted on NMR's.

During the production phase, approximately 2,500 NMR's were written and dispositioned by the MRB. The four-member MRB consisted of the BBRC Quality Engineer, the BBRC Design Engineer(s), the resident NRL representative and the resident MSFC Quality Laboratory representative. The large quantity of NMR's is owed to the fact that all defects, whether affecting function or cosmetics, were documented on the NMR form. A pre-MRB to disposition minor defects directly on the applicable inspection paperwork was not permitted.

Subsequent to the approval of the QA plan in Part II of the RAPP a formal MSFC quality survey was conducted on 5-8 August 1968. A number of minor discrepancies were identified by the survey and corrected by BBRC. Final resolution of questions raised by the survey were resolved in a meeting at the MSFC Qualification Laboratory on 9 March 1969. The most significant corrective action taken was a review of all completed NMR's to ensure that (1) all drawing changes requested by the MRB had been accomplished, (2) all defects affecting reliability were further documented on Deviation Approval Requests (DAR's) or waivers, and (3) the four-member MRB had signed all NMR's.

The QA engineer prepared and submitted to the production supervisor corrective action requests (CAR's) on processes and operations resulting in recurring hardware defects.

4.0 INTEGRATION AND TEST

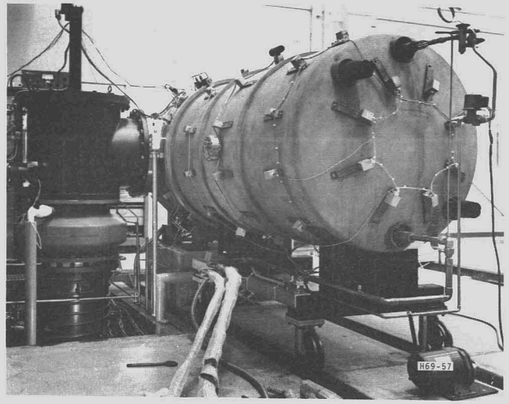
Integration and Test (I&T) of the S082 instruments at BBRC was performed in class 10,000 work and test areas. Figure 4-1 shows representative integration and test areas. Instrument subassemblies were received from production for integration. Integration and assembly was a cooperative effort with I&T personnel performing alignment, focus and checkout while production personnel completed the mechanical assembly. Alignment, focus and test were performed using procedures based on the appropriate Design and Performance Specifications (D&PS), test plans and test specifications (see BBRC Documents CP25100 and CP25905). Assembly was completed to the appropriate instrument configuration drawings. Qualification tests were conducted on prototype instruments, cameras and canisters to qualify the design for use in Skylab. The prototypes were later refurbished and became a part of the ATM flight backup unit (FBU). Acceptance tests were conducted on all flight units to ensure these units fulfilled the requirements of the D&PS's and End Item Test Specifications. Quality Control witnessed all tests and maintained parts traceability and instrument configuration records. A summary of failure reports and deviation/waivers is provided in Section 4.6.

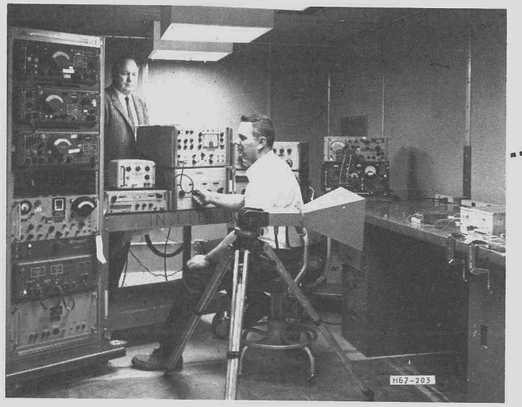
Upon installation of the instruments on the ATM spar at MSFC, a series of ATM systems tests was performed. An ATM system thermal vacuum test was performed in the large vacuum chamber at JSC on both prototype and flight units. An all systems pre-flight test was conducted in the Vertical Assembly Building on the flight instrument at KSC.

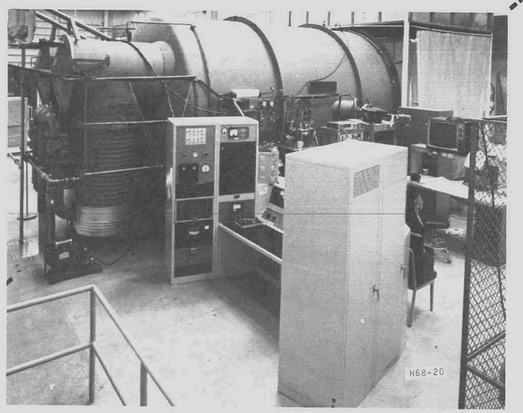
4.1 S082A INSTRUMENTS

4.1.1 Prototype

The prototype instrument was the qualification unit. It was exposed to more severe environmental levels than the flight unit. The instrument was tested and delivered with setup (visible light) type optics and it conformed to all the requirements of the D&PS.

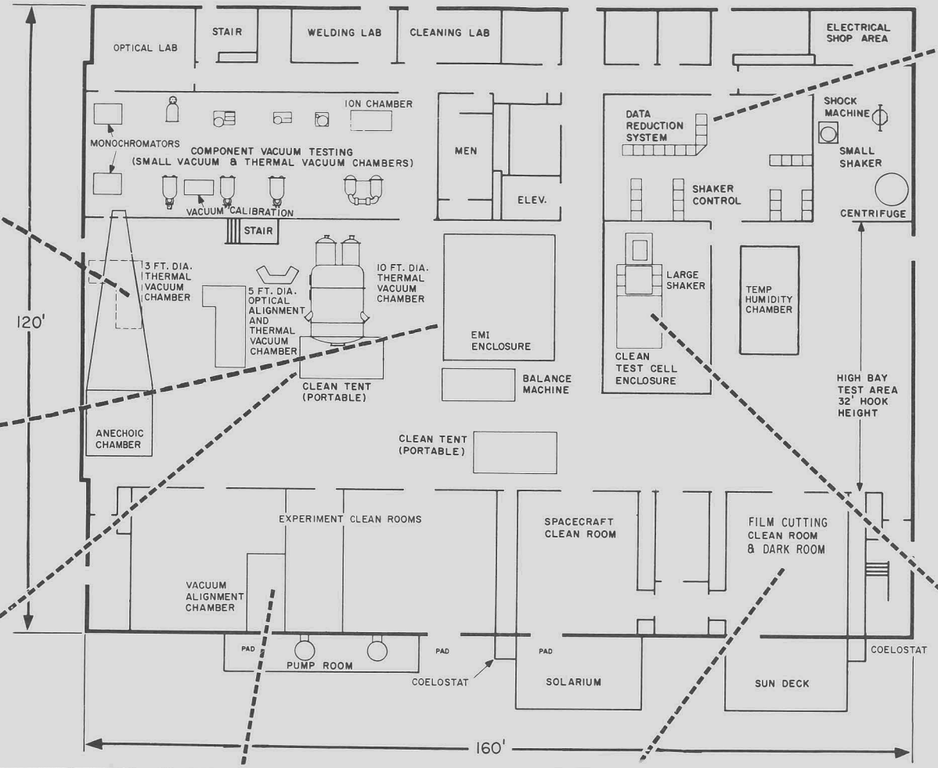




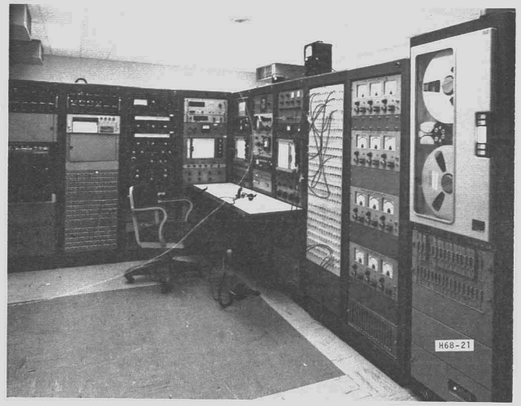


INTEGRATION, TEST AND ENVIRONMENTAL BUILDING

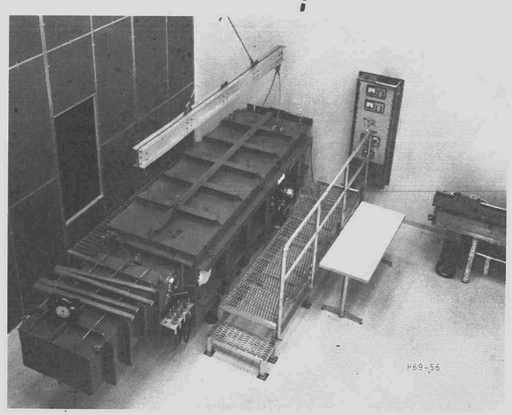
MAIN FLOOR - 19,200 SQ. FT.



ENVIRONMENTAL DATA CENTER



DATA PROCESSING CENTER



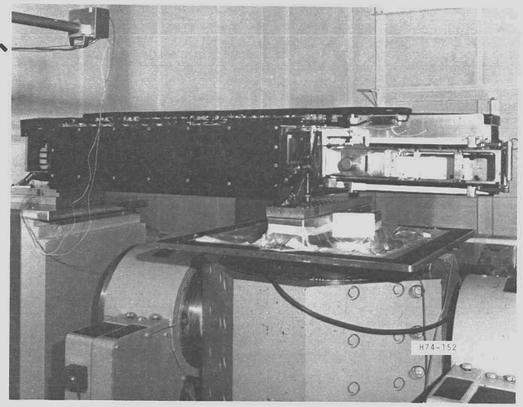


Figure 4.1. Integration and Test

4.1.1.1 Integration and Optical Alignment

The instrument subsystems were integrated into the system as optical alignment was performed per BBRC Procedure No. 24951. The first alignment activity was the reference mirror or external alignment. This mirror defined the optical axes of the instrument and provided the necessary interface for MSFC to mount and align the instrument on the spar.

Setup type optical elements (i.e., grating rules for visible light output at the film plate instead of the ultraviolet wavelengths) were installed in the mounts. The use of these gratings permitted alignment of the instrument in air rather than in a vacuum chamber. Optical alignment of the instrument was completed with only minor problems occurring with the mechanical subsystems.

Functional testing of the instrument revealed some minor problems with the electronics and TCS controllers. Modifications to the TCS controllers and complementary one-shots placed in the electronics package eliminated the problems. Functional testing of the system was performed prior to qualification to assure all systems were performing properly.

4.1.1.2 Qualification Testing

Qualification testing of the prototype instrument (see Figure 4-2) was performed in accordance with End Item Test Plan, BBRC Document No. 620-4, and met the requirements of the D&PS and End Item Test Specification, BBRC Document No. 28340. Qualification test procedures are shown in Table 4-1.

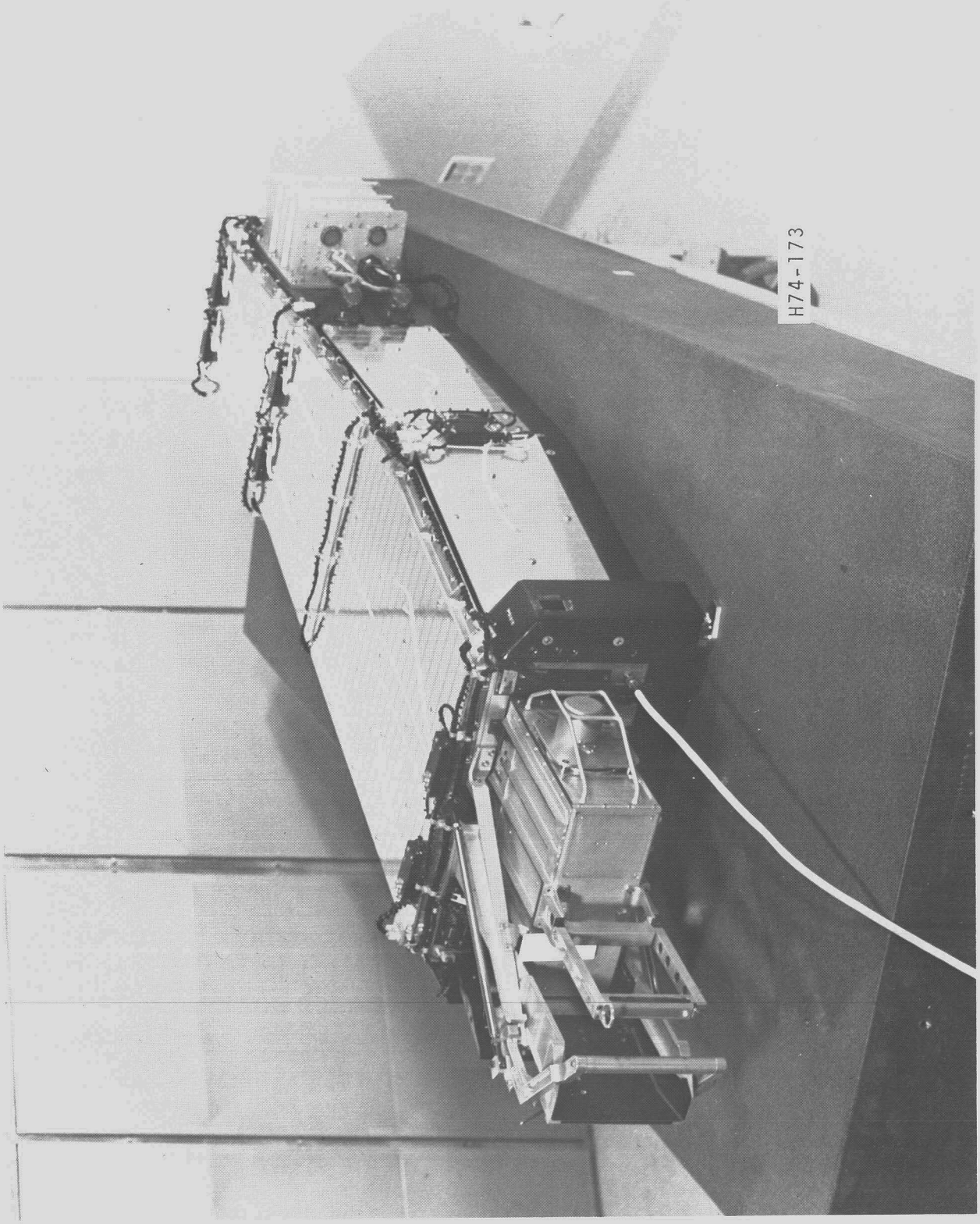


Figure 4-2. NRL/ATM S082A Coronal Spectroheliograph Instrument

Table 4-1
S082A PROTOTYPE TEST PROCEDURES

Test Procedure	Number
Physical Measurements	30547
Pre-qualification	30548
EMI	30549
Vibration	30550
Post-Environmental	30551
Acoustic	30552
Thermal Vacuum	30554
Post-Thermal Vacuum	30555
Vertical Position	30556

Physical measurements testing verified that the instrument met the envelope, weight, and center of gravity requirements (see Figure 4-3). Minor deviations were waived as they did not interfere with any interface requirements. The Pre-Qualification Functional Test verified that the system was functioning in accordance with the requirements of the End Item Test Specification. This test also furnished a baseline of the instrument operation and performance both electrically and optically with which to compare the instrument during post-environmental testing. An electromagnetic interference test (EMI) was performed to verify electromagnetic compatibility of S082A with the ATM systems. The levels and frequencies of conducted and radiated interference voltages emanating from the instrument were determined. Conducted, radiated, and magnetic susceptibility tests were performed to evaluate the possible degrading effects of externally generated electrical stimuli upon the instrument. Sine and random vibration tests of the instrument were performed to qualification levels in three major

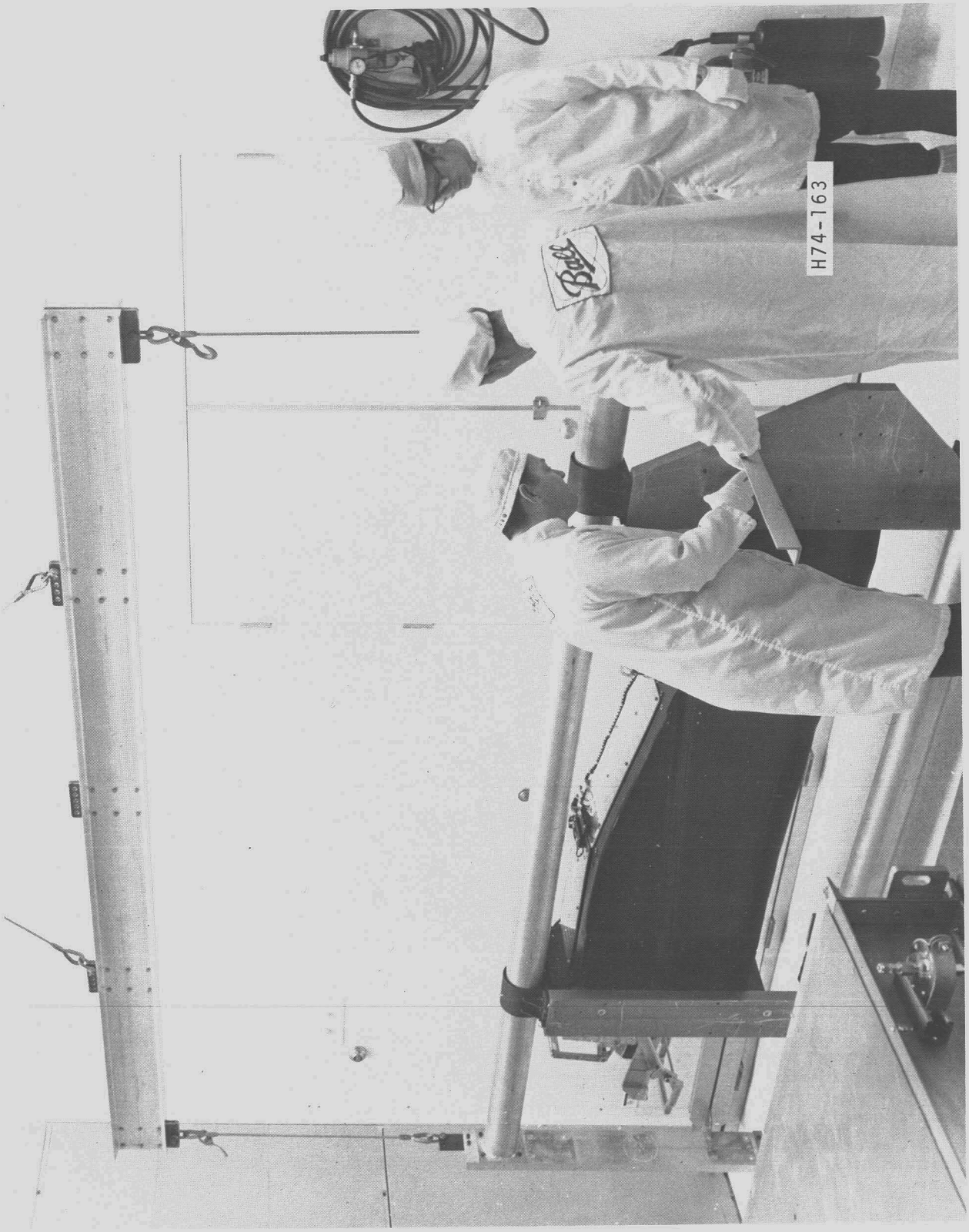


Figure 4-3. NRL/ATM Prototype Instrument S082A Weight and CG Tests

axes (see Figures 4-4, 4-5, and 4-6 for example of vibration test setups). Post-environmental tests were performed to verify that the instrument would operate according to specification after being subjected to qualification environmental testing. Acoustic tests were performed on the instrument electronic package to verify that it could withstand the acoustic launch environment. Thermal vacuum was performed to demonstrate that the instrument would operate according to specifications while in-flight simulating vacuum environment (see Figure 4-7). The test also demonstrated that the instrument would function after being subjected to nonoperating temperature extremes. Vertical position test was performed to demonstrate that the instrument would function properly in a vertical attitude gravity reference.

A complete test report of all the qualification tests may be found in BBRC Document No. 620-69, "Prototype Test Report".

4.1.2 Flight

The flight instrument was identical to the prototype instrument except it contained flight type optics for the acceptance test and delivery. Alignment was more difficult because of the need to perform the optics alignment checks in vacuum. The flight unit testing was performed by the same personnel as the prototype unit. The results of acceptance testing of the flight instrument was verification of the instrument performance and reliability.

4.1.2.1 Integration and Optical Alignment

Optical alignment began with the instrument reference mirror. This mirror, located externally to the case, was aligned perpendicular to the mechanical longitudinal axes and parallel to the transverse mechanical axis. From this reference the instrument optics (grating and heat rejection mirrors) were aligned. The

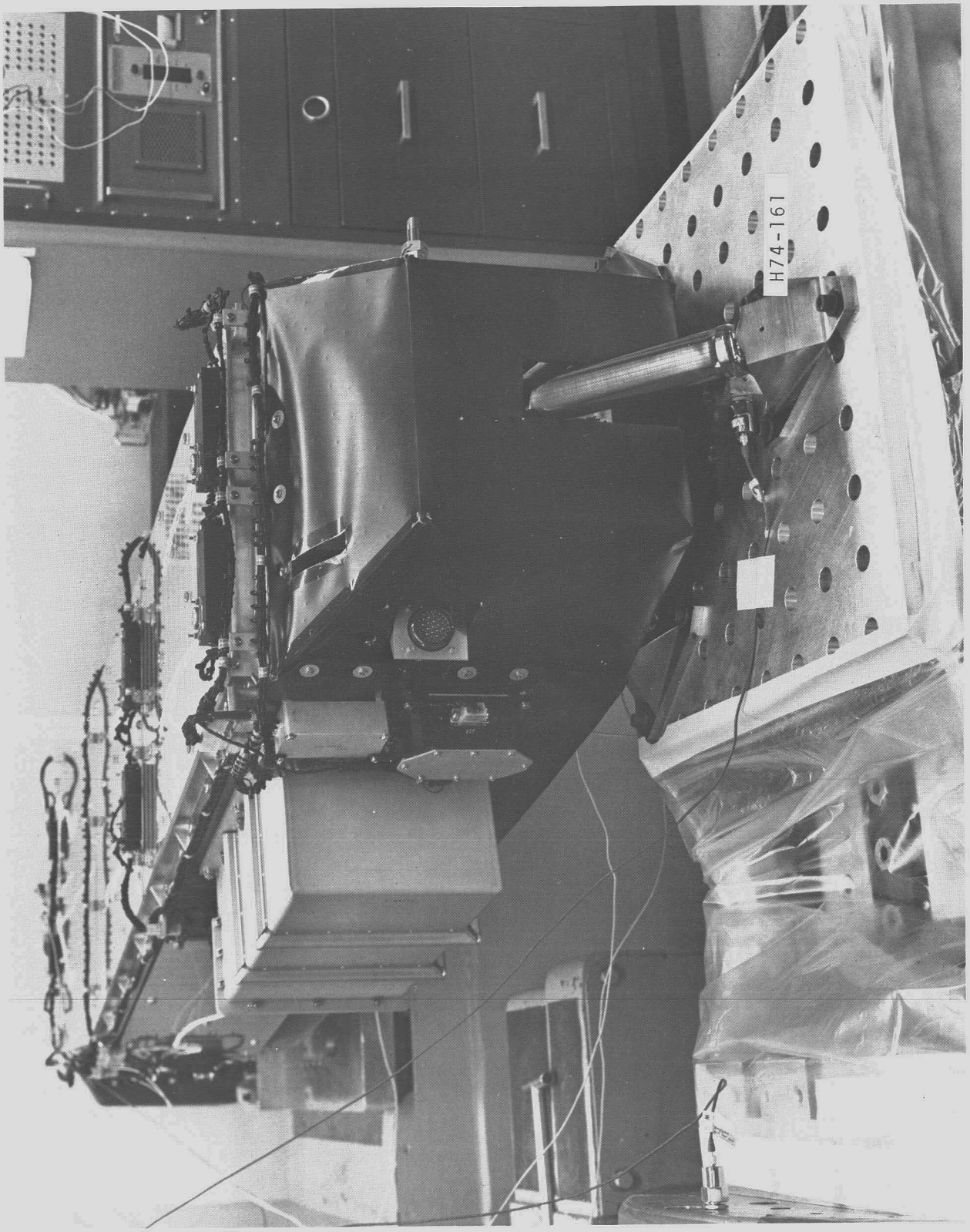


Figure 4-4. NRL/ATM Prototype Instrument S082A Vibration Qualification

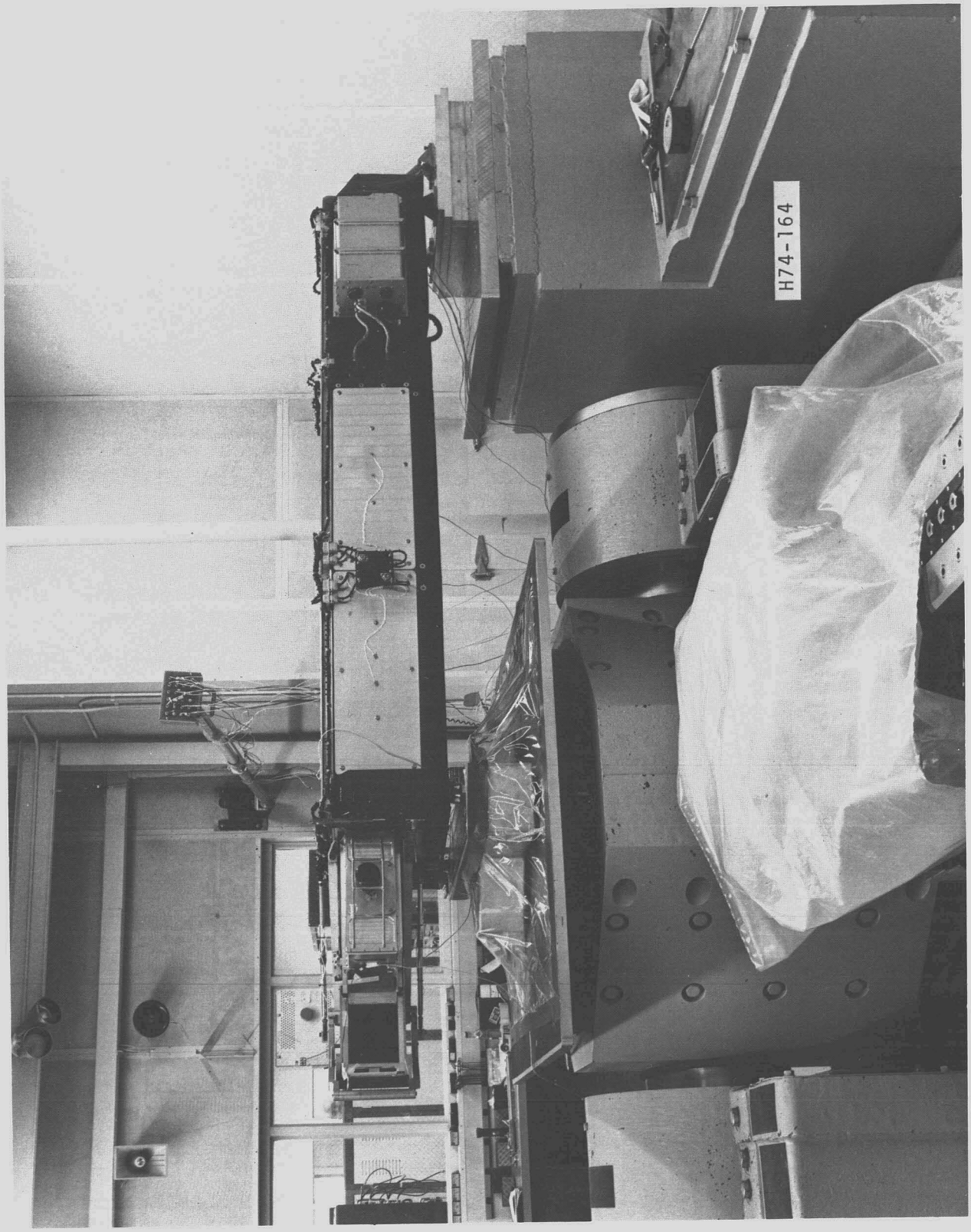


Figure 4-5. NRL/ATM Prototype Instrument S082A Vibration Qualification

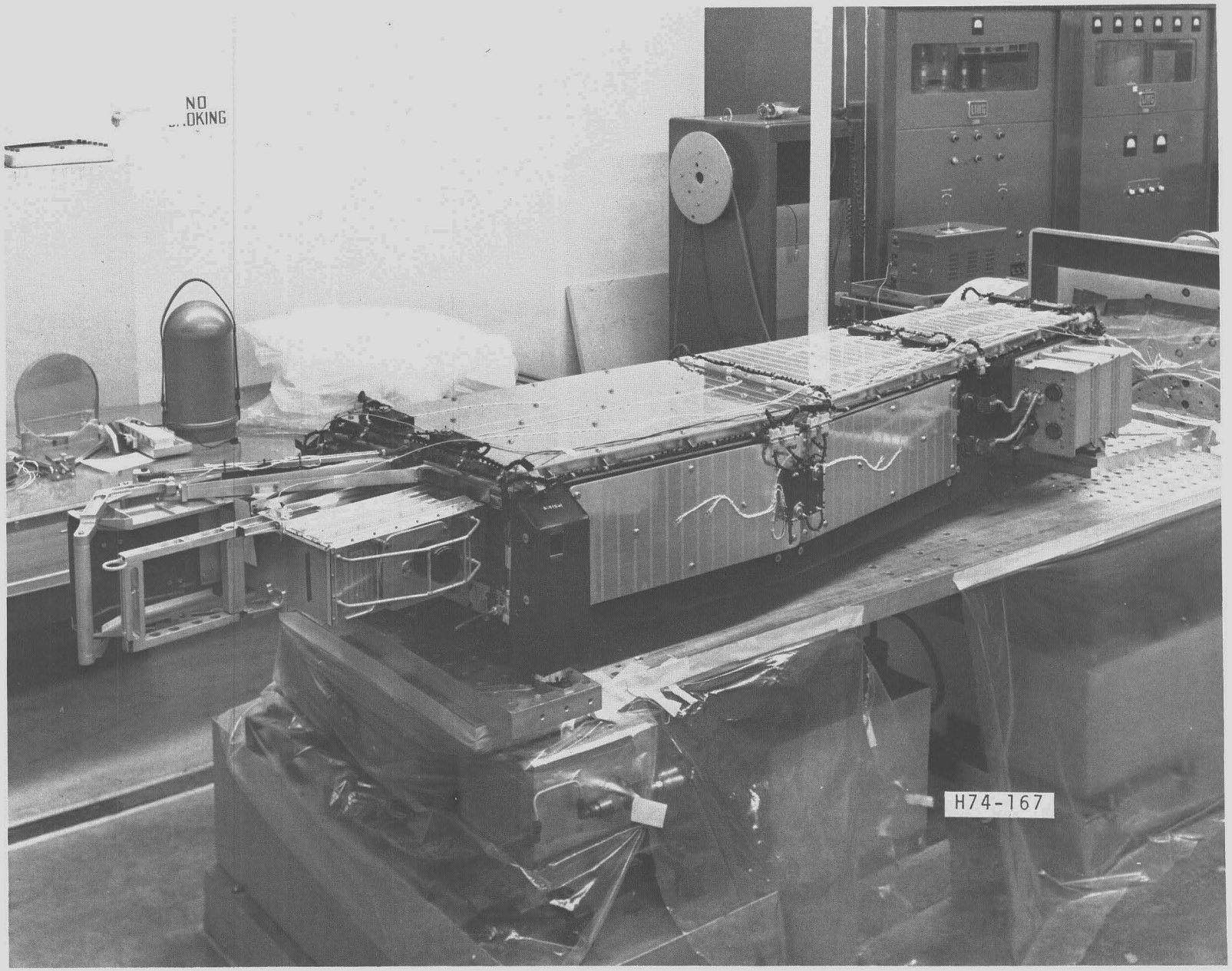


Figure 4-6. NRL/ATM Prototype Instrument S082A Vibration Qualification

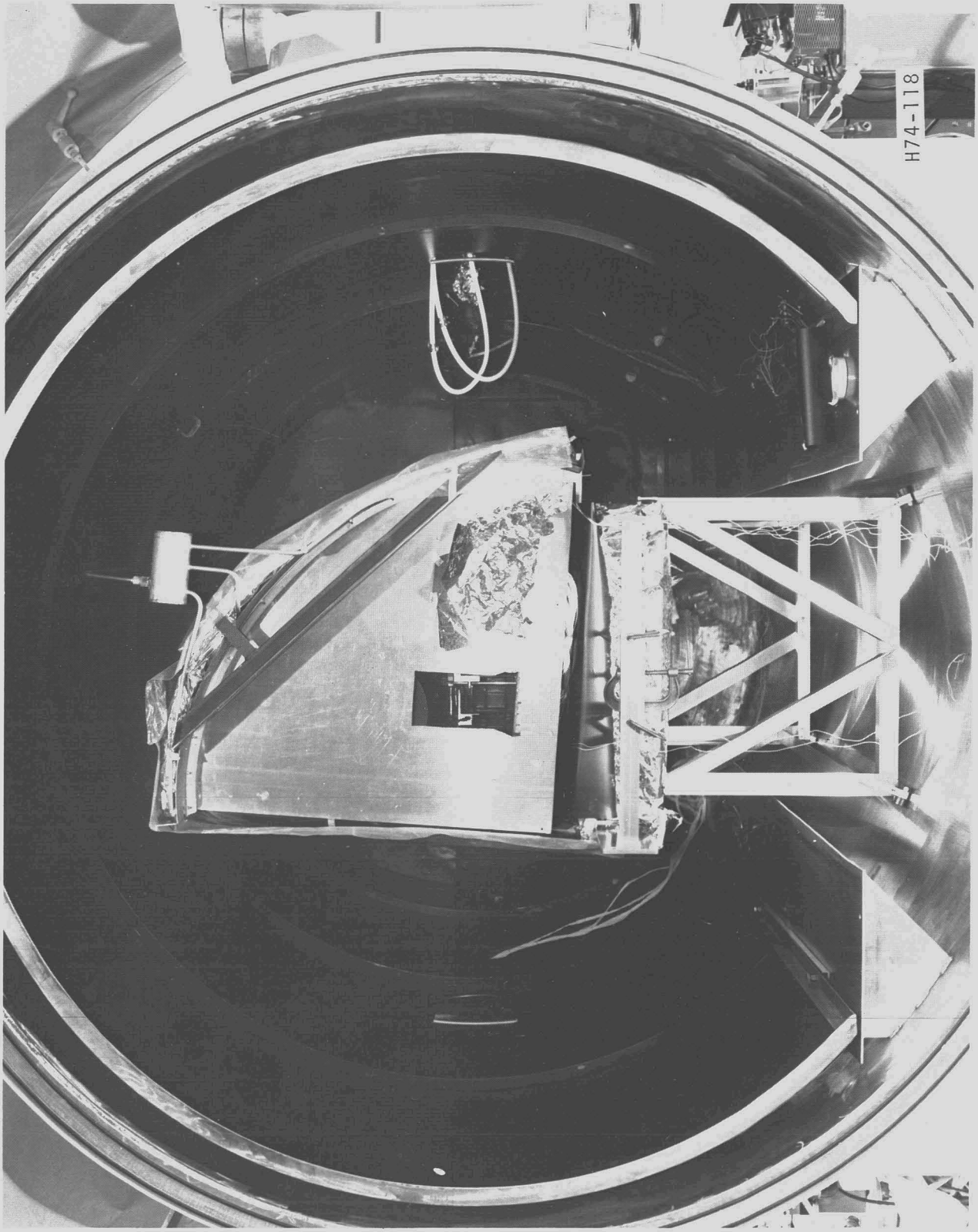


Figure 4-7. Thermal Vacuum of S082A Instrument On Simulated Spar Inside Vacuum Chamber

setup optics were installed on the instrument and alignment performed in air. The grating and internal heat rejection mirrors were then aligned.

The flight optics were prepared to be installed when setup optics were removed from the cells. The transfer of the gratings was done maintaining all the coarse alignment. With the installation of flight optics, contamination monitor mirrors were placed in the instrument to record the environment to which the flight optics were exposed. These monitors were checked periodically for any contaminants.

The first alignment photographs under vacuum showed severe stray light coming from the flight grating. The grating proved to be at fault and NRL ordered a new grating to be ruled. During this time, the remaining mechanical work, functional testing, and some of the acceptance testing was performed.

Upon receipt of the new grating, optical alignments were begun. Optimum focus and alignment were achieved and the remaining acceptance tests and optical calibration were performed.

4.1.2.2 Acceptance Testing

Acceptance testing of the flight instrument was performed to the same test plan, specifications, and procedures as for the prototype instrument. EMI and acoustic tests were not performed on the flight instrument as they were a qualification level test.

A pre-acceptance test was performed to establish, before the flight instrument was subjected to environmental testing, that the instrument operated in accordance with the requirements. This test also provided a baseline of the instrument operating parameters to which all other post-environmental tests were compared.

The Thermal Vacuum Test was performed to simulate as closely as possible the actual flight conditions of the mission. The ECE console was utilized to simulate the ATM at the instrument interface. In total the instrument was subjected to 120 hours of vacuum at a pressure of 1×10^{-5} torr, and during this time some 40 simulated orbits were run operating all instrument functions. The Post-Thermal Vacuum Test was performed to verify that all instrument functions/components which could not be checked during thermal vacuum test were operating normally. All systems functioned properly during this test with no data changing significantly from that taken prior to thermal vacuum test. Vibration testing subjected the instrument to acceptance level random vibration in three axes. A post-vibration test was performed to verify the instrument operation subsequent to vibration testing. All systems functioned properly during this test, with no data changing significantly from the test data taken during pre-acceptance testing. A physical measurements test was performed to verify instrument weight, center of gravity, physical dimensions.

An analysis of the test results verified the instrument's conformance to the D&PS and the End Item Test Specification, and its flight worthiness.

More details of the acceptance testing may be found in the Acceptance Test Report, BBRC Document No. 620-80.

4.1.3 Acceptance and Shipment

After the successful completion of all qualification or acceptance tests an Acceptance Meeting was conducted by Configuration Management. The purpose of this meeting was to review all qualification or acceptance data (qualification for the prototype instruments and acceptance for the flight) and to transfer the title for the hardware. A DD Form 250 transferred the title from BBRC to NRL and a MSFC Form 71 transferred the title from NRL to

MSFC. Complete data packages, which contained copies of the DD Form 250, MSFC Form 71, NMR's written during tests, waivers, DAR, all systems test data, and two copies of drawings of all subassemblies, were delivered to the customer with the hardware. Copies of the Certificate of Component Qualification and Verification of Qualification Unit Configuration were included where applicable. During the meeting all test data, the configuration of the hardware and the completeness of the data package were reviewed. When the customers were satisfied, the transfers of title were signed and the Government took possession of the equipment.

After the acceptance meeting the instruments were placed in their shipping containers (see Figure 4-8) in preparation for shipment. The shipping containers were previously cleaned and prepared for receiving the instruments. The shipping containers had provisions for purging the instrument and container with dry nitrogen and carried its own supply (see Figure 4-9). It also had a means of monitoring pressures, temperature, humidity, and shock. The instrument was mounted on vibration isolation mount to prevent excessive vibration (see Figures 4-10 and 4-11). After the instrument was mounted on the shipping container base the cover was put on and sealed to the base (see Figure 4-12).

The equipment and associated data packages were loaded on an air ride van and shipped to MSFC by Government carrier.

4.2 S082B INSTRUMENTS

4.2.1 Prototype Instrument

The prototype instrument was qualified to more severe testing in environmental levels than the flight unit. The prototype instrument conformed to flight configuration except for the following:

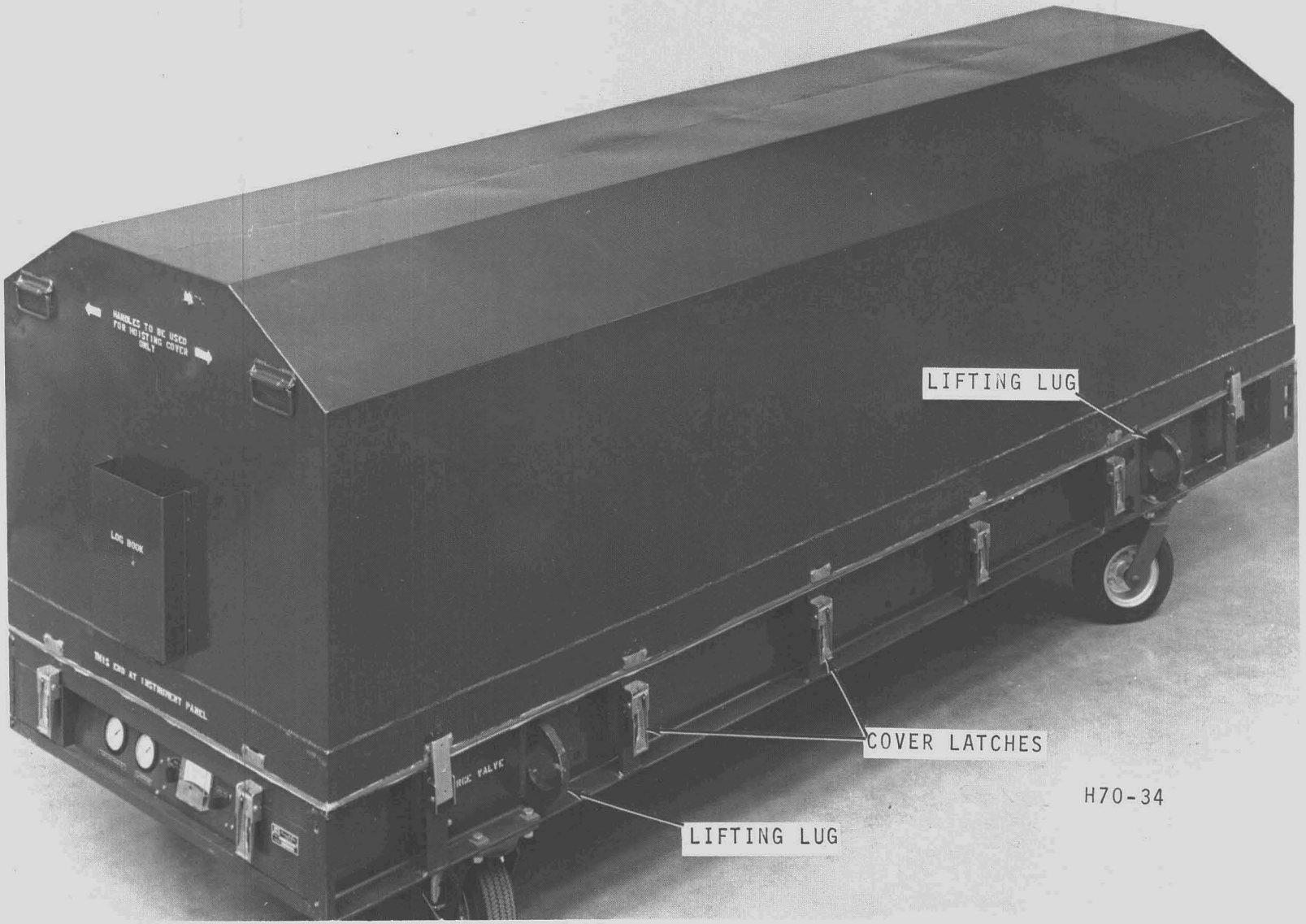


Figure 4-8. Shipping Container

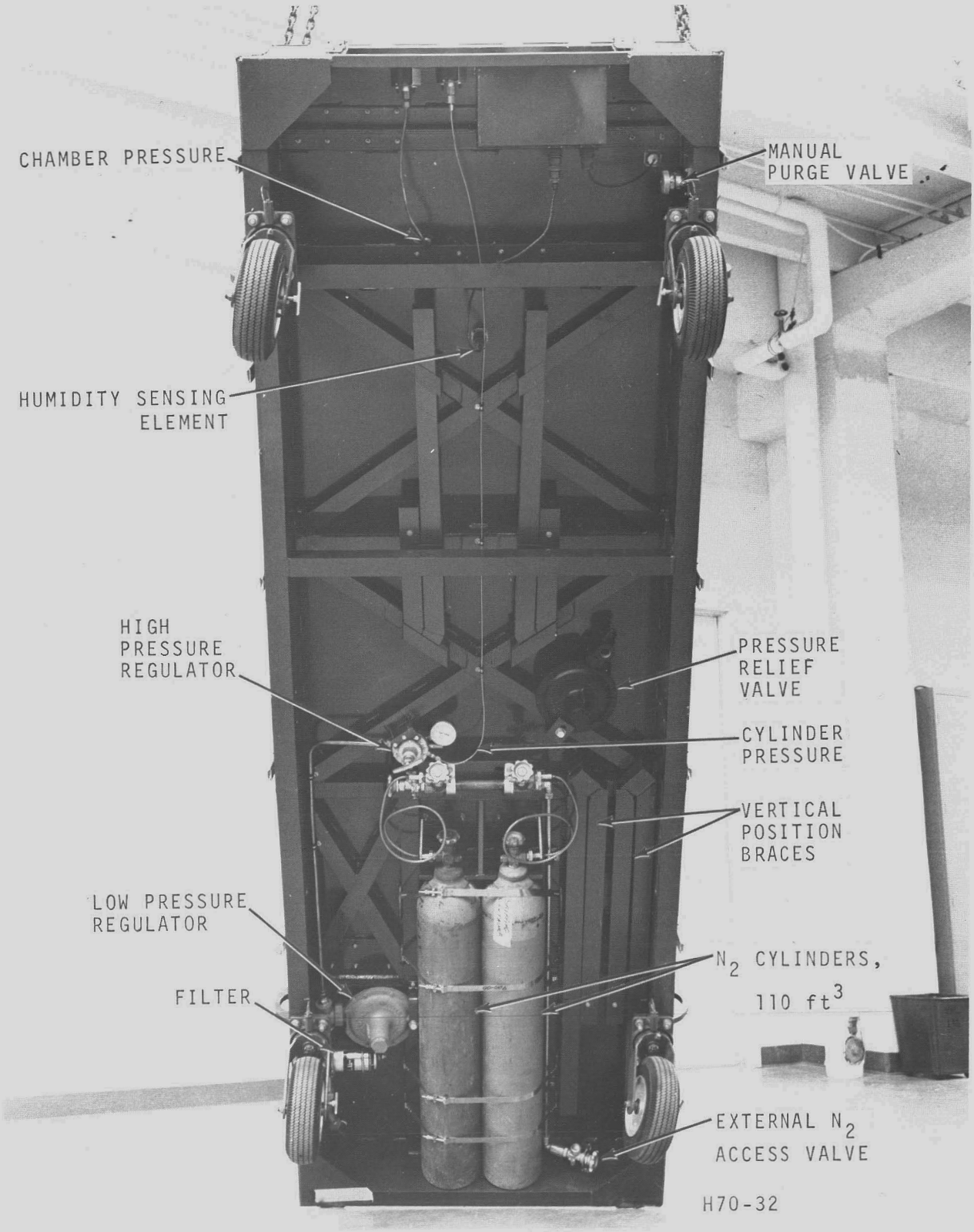


Figure 4-9. Bottom of Shipping Container

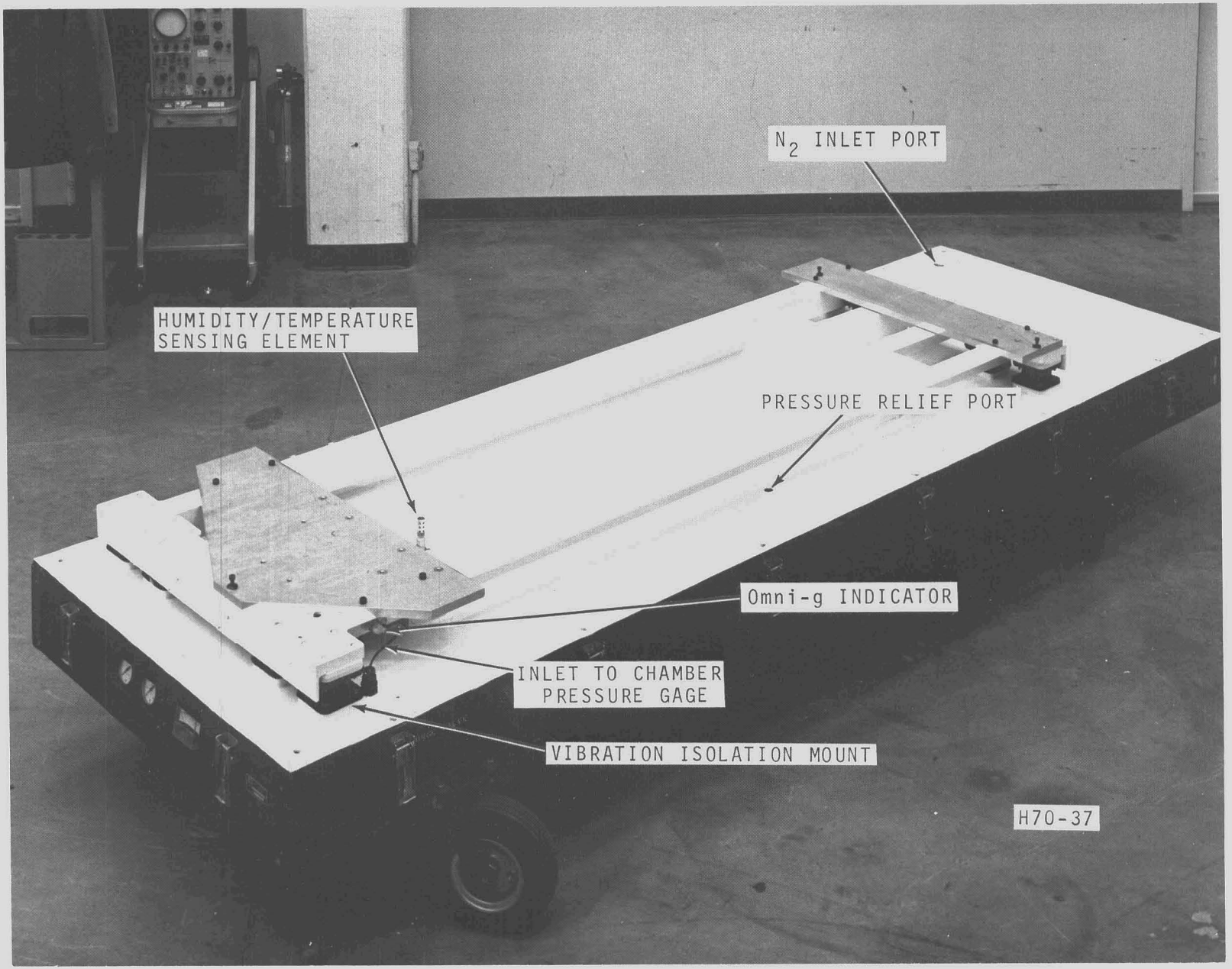


Figure 4-10. Shipping Container Base

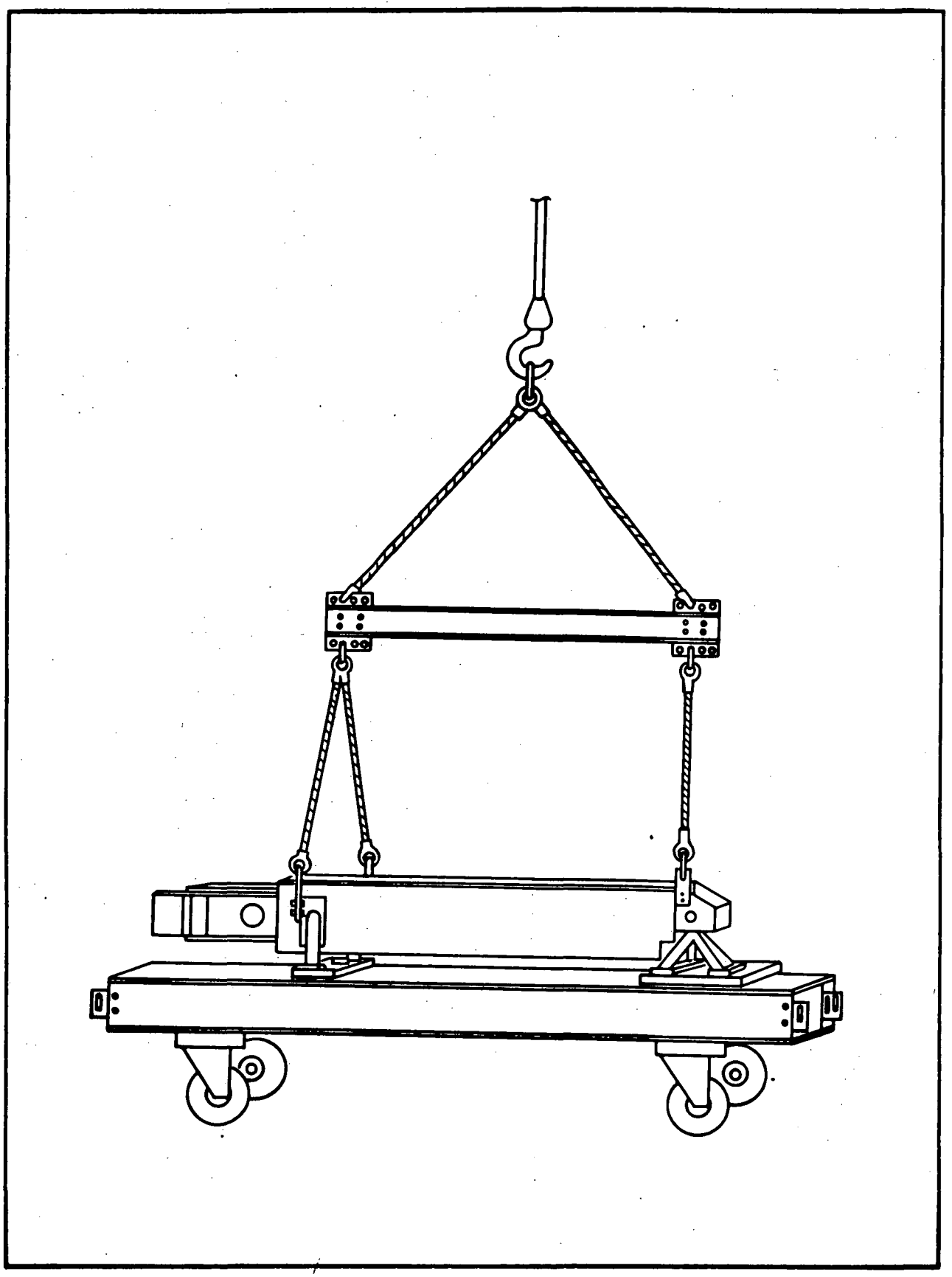


Figure 4-11. Loading Instrument in Shipping Container

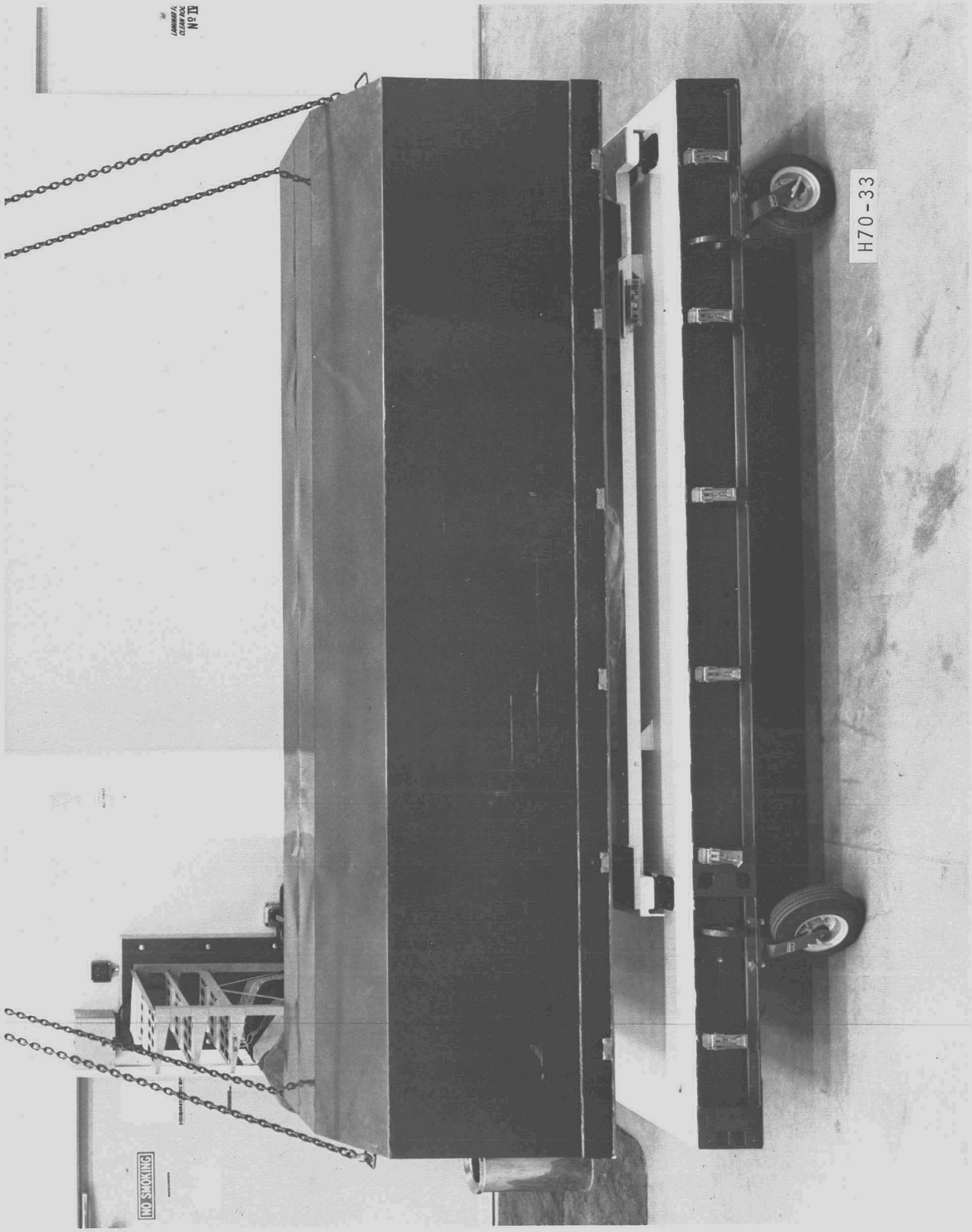


Figure 4-12. Installing Shipping Container Cover

A. Setup optics were installed in the spectrograph instead of flight optics.

B. XUV Monitor was a white light system instead of XUV.

C. Predisperser drive mechanism was redesigned for the flight instrument.

D. XUV Monitor intermediate filter was not grounded.

E. External cable assembly was redesigned for the flight instrument.

4.2.1.1 Integration and Optical Alignment

Optical alignment was performed per BBRC Procedure No. 24952 and consisted of alignment of the mechanical and optical axis, focusing the primary mirror, co-focusing and co-aligning the predisperser gratings, alignment and focusing the main grating, final alignment of the spectrograph, co-alignment of the spectrograph and the XUV Monitor, focusing the XUV Monitor, focusing and aligning the pointing reference (PRS) optical system.

Problems encountered during mechanical assembly and alignment were primarily mechanical fit problems and were corrected with minor modifications. Most electronic problems were in pulse timing and required a significant number of module modifications. Some problems required printed circuit board modifications, which were made on the prototype boards with new modified boards being procured for the flight electronics.

4.2.1.2 Qualification Testing

Qualification testing of the prototype instrument was performed in accordance with End Item Test Plan, BBRC Document No. 620-17, and met the requirements of the D&PS and End Item Test Specification,

BBRC Document No. 28341. The list of qualification test procedures is shown in Table 4-2.

Table 4-2
S082B PROTOTYPE TEST PROCEDURES

Test Procedure	Number
Pre-Qualification	30563
EMI	30564
Acoustic	620-62
Vibration	30565
Post-Vibration	30566
Thermal Vacuum	30569
Post-Thermal Vacuum	30570
Vertical Alignment	30571
Physical Measurements	30562

Pre-qualification tests (see Figure 4-13) verified that the instrument mechanical, optical, and electronic subsystems met the required specifications. The data obtained during this test was the reference for evaluating system performance in subsequent BBRC and post-delivery testing. Parameters verified during pre-qualification testing were:

- Optical alignment and focus
- Instrument/ATM mechanical and electrical interfaces
- Performance at high, low, and nominal bus voltages
- Telemetry
- Instrument/astronaut interfaces
- Video system resolution and sensitivity
- Power requirements

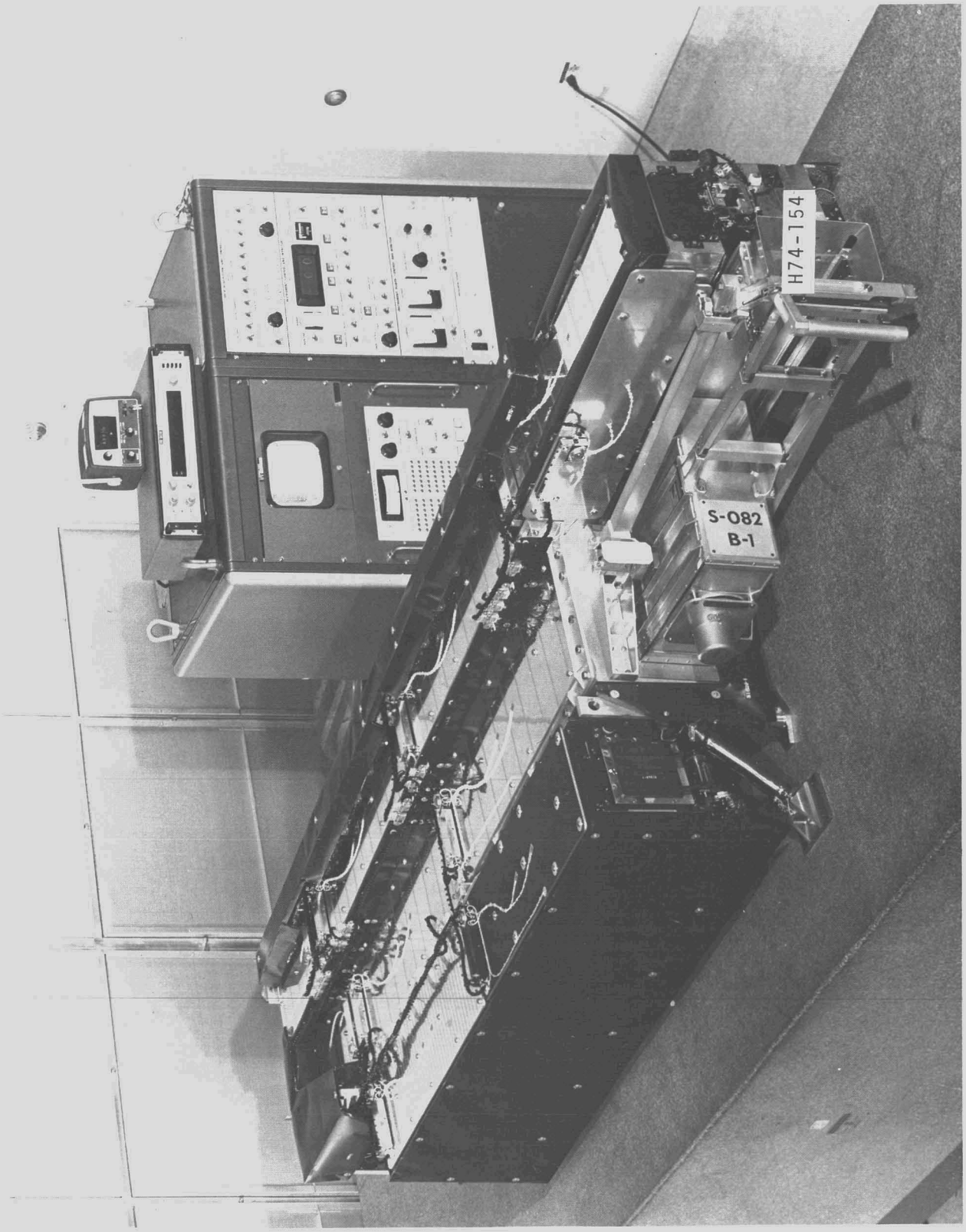


Figure 4-13. S082B Instrument Prequalification Tests

EMI test resulted in installation of EMI filters at the instrument/ATM power line interface to reduce conducted interference to the ATM power buses.

The PRS IDT and electronics package were subjected to acoustic testing at Point Magu, California. The completed instrument assembly was subjected to qualification level sine and random vibration in three axes. (See Figs. 4-14 and 4-15 for examples of vibration test setups.)

The instrument was subjected to thermal vacuum test that verified the instrument electromechanical, electronic, thermal control and video subsystem performance under simulated flight environment conditions. The test results showed the thermal control system to be marginal in its capability to maintain the required instrument temperature (70 ± 1.25 °F) at low spar and shroud temperatures. The cause was excessive heat loss at the junction of the spar simulator and instrument passive thermal control blankets . Additional passive blankets (mini-skirts) were added to the instrument, and exposed surfaces were covered with thermally reflective tape. These modifications were verified in reruns of the thermal vacuum test (see Figs. 4-16 and 4-17).

The predisperser had intermittent failures in the electromechanical drive mechanism and it was decided to leave the prototype predisperser as-is and redesign the mechanism for the flight instrument. The redesigned predisperser was qualified per BBRC Procedure No. 37353 and is covered by BBRC Report No. 620-73.

During the second thermal vacuum rerun, the PRS Limb Offset readout fluctuated approximately 2 arc seconds from the proper value. The problem was an unstable reference oscillator in one of the electronics assemblies.

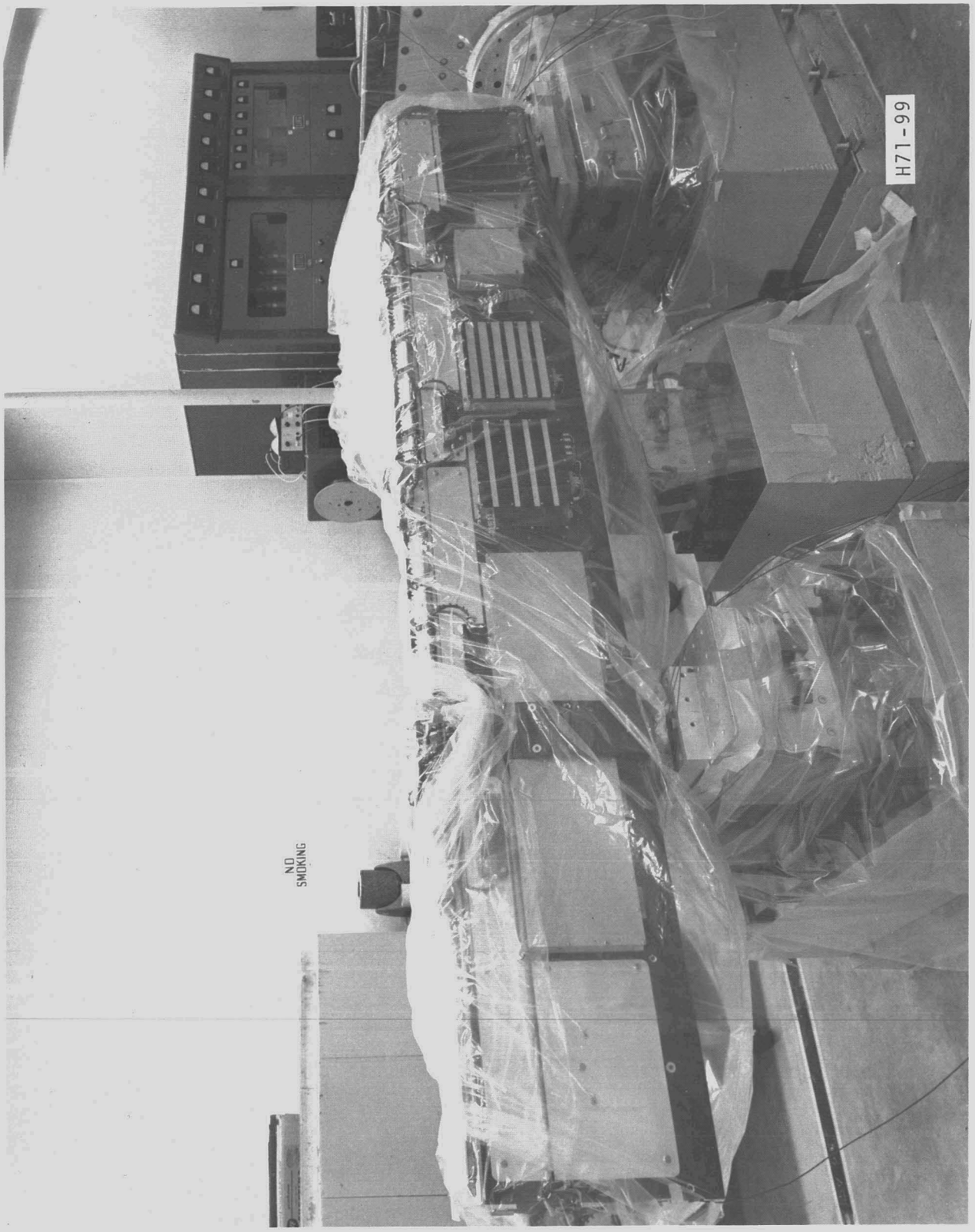


Figure 4-14. S082B Spectrograph on Vibration Table

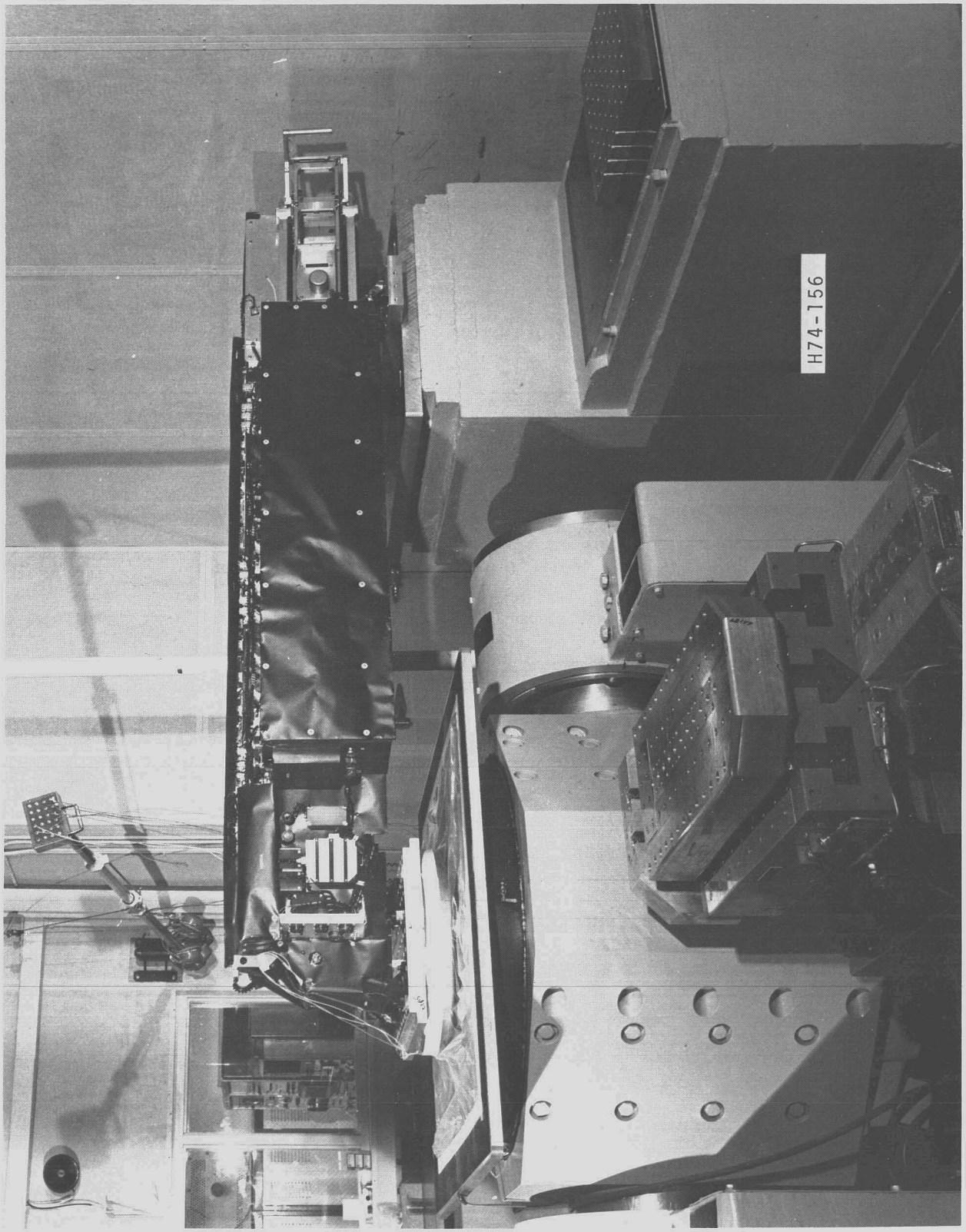


Figure 4-15. S082B Instrument Vibration Test

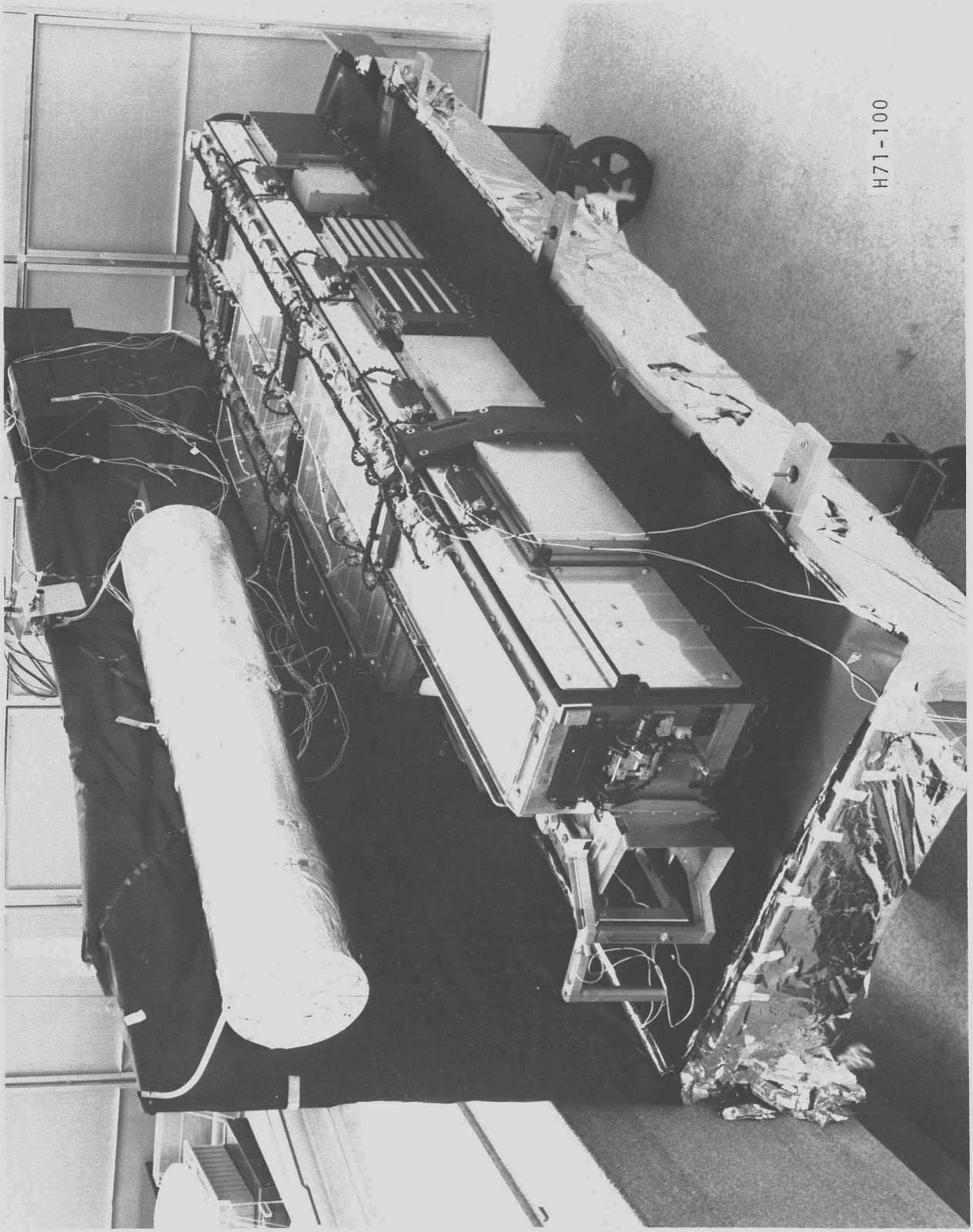


Figure 4-16. S082B Spectrograph on Simulated Spar

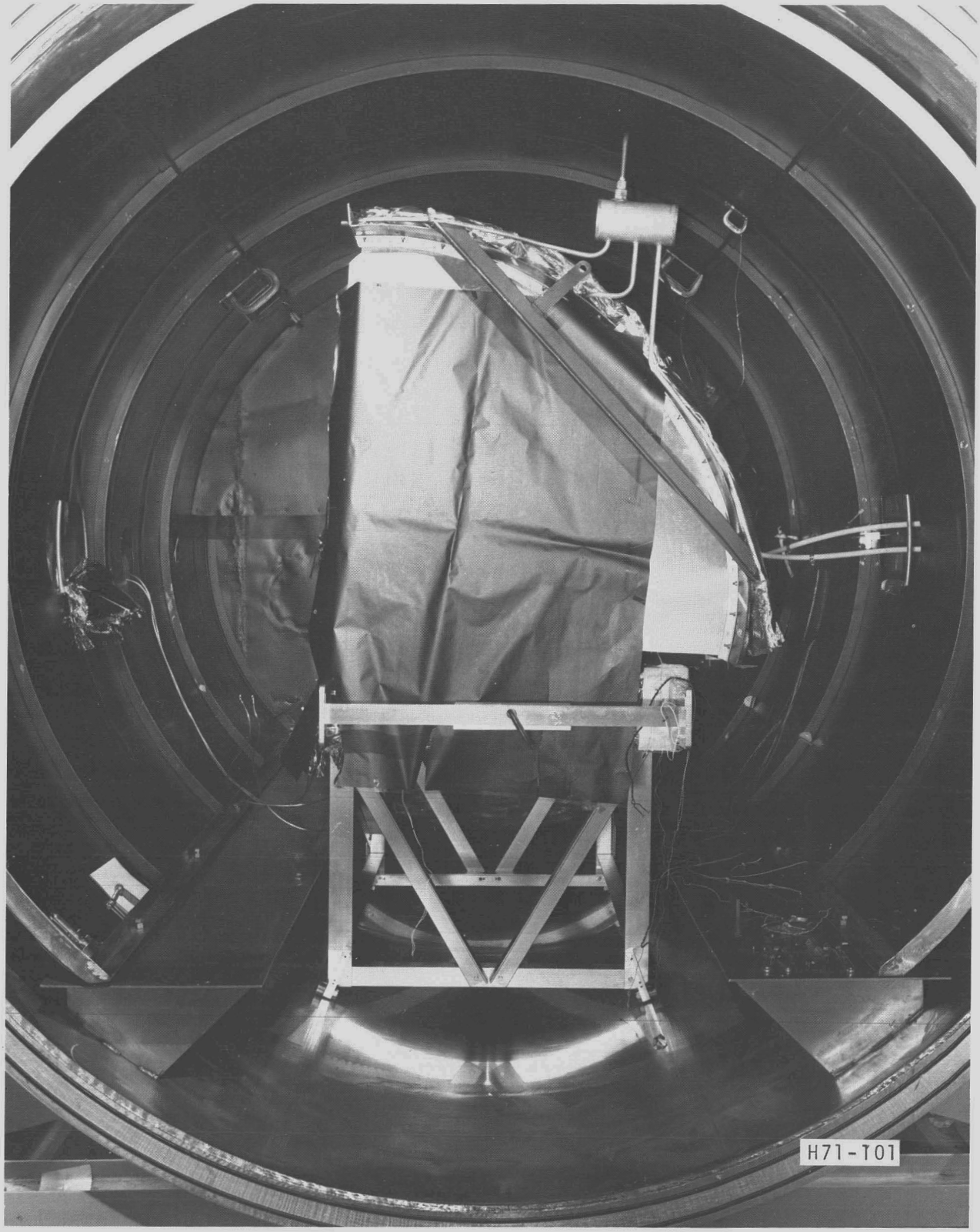


Figure 4-17. S082B Spectrograph in BBRC/NASA-4 Vacuum Chamber

Vertical alignment test was performed with the instrument mounted on a test fixture in sun end up and sun end down positions (see Fig. 4-18). It was performed to determine instrument operation and alignment characteristics under these gravity conditions because post-delivery test would be performed in these attitudes. Test results showed some movement in the predisperser alignment that resulted in the short wavelength spectrum being occulted by the waveband aperture. A test tool was designed to facilitate determination of the exact position of the spectrum in the waveband aperture. The instrument predisperser was then realigned, centering the spectrum in the waveband aperture. Vertical alignment testing was then repeated with no problems. This test tool was used throughout flight alignment and testing to check for proper predisperser alignment.

Physical measurements tests were performed to verify the instrument met the envelope, weight and center of gravity requirements.

Additional test details may be found in BBRC Test Report No. 620-87.

4.2.2 Flight Instrument

The flight instrument was identical to the delivered prototype instrument except for the predisperser, external cable, flight optics and XUV Monitor. Alignment and test were more difficult because of the vacuum requirement for XUV Spectrograph and XUV Monitor optical operations. Knowledge obtained from the prototype integration and test was used to refine and improve the flight instrument operations.

4.2.2.1 Integration and Optical Alignment

Setup type (i.e. visible light gratings) were installed and aligned. These optics provided a fit check of the mounts and the positions of the mounts as well as coarse alignment of the system. Setup optics were removed and flight optics, consisting of the main grating and predispersers, were installed. A coarse alignment of the spectrograph was performed in order to check stray light of the system.

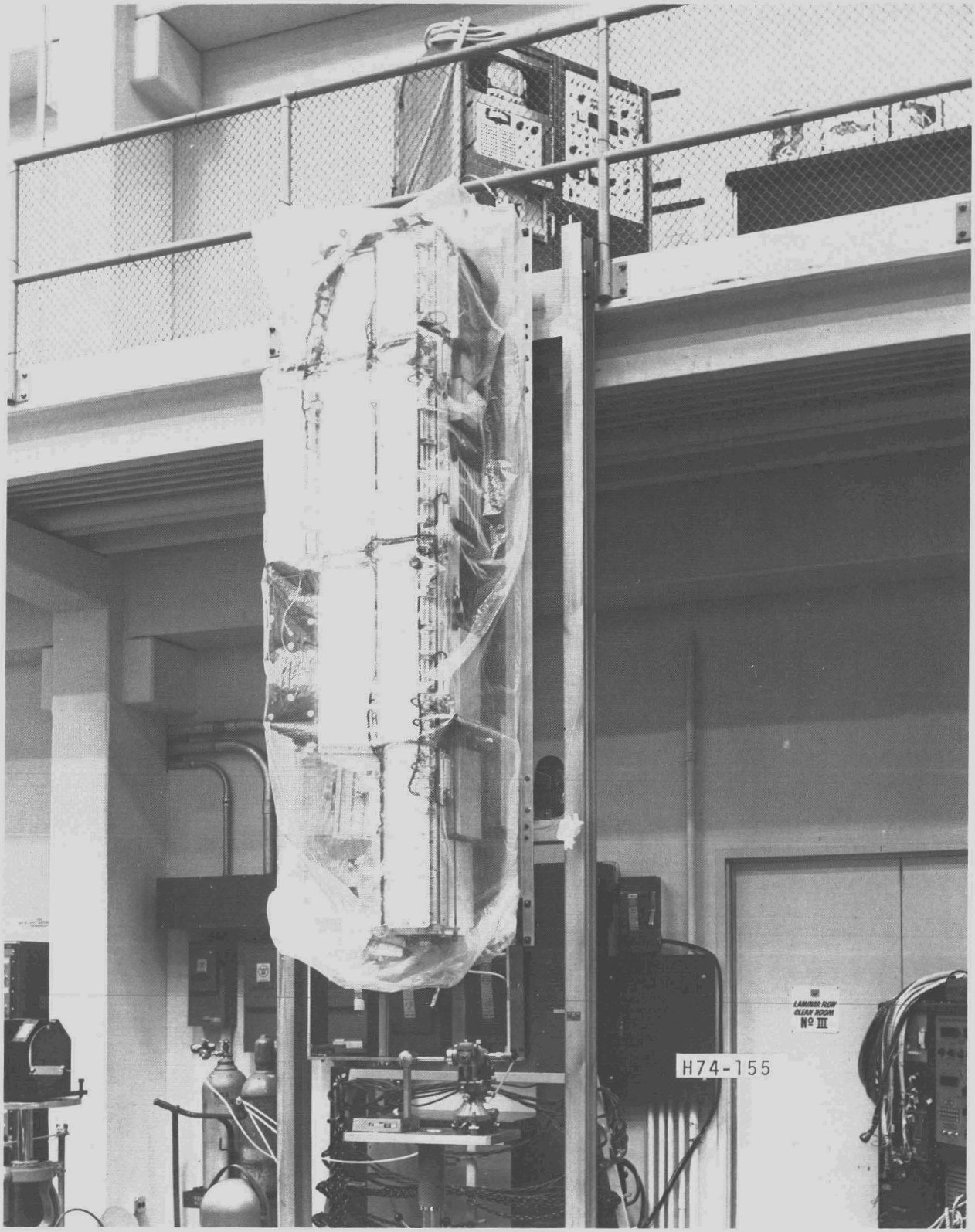


Figure 4-18. S082B Spectrograph Vertical Test (Sun End Down)

Light leaks in the baffles were identified and proper changes made. Optical alignment of the spectrograph system was performed per BBRC Procedure No. 24952.

A decision was made to replace the predispersers, in the case of the long wavelength to reduce the spectral intensity in the longer wavelength region, and the case of the short wavelength predisperser to reduce the second order stray light. Optical alignment of the spectrograph was continued in vacuum and results of spectrograms showed an inconsistency from film to film. The film was not being located in the same position in the camera each time an exposure was made. Specification changes were made to reduce the allowable film position tolerance in the camera. A significant number of camera design modifications and a change of film holder material from stainless steel to aluminum were required to meet these new specifications.

The flight XUV Monitor mirror was installed, focused, and co-aligned to the primary mirror.

Vibration testing was repeated and post-vibration test results showed no change from pre-acceptance testing.

Physical measurements testing verified the instrument met the envelope, weight and center of gravity requirements.

Additional testing details may be found in BBRC Test Report No.620-133.

4.2.2.2 Acceptance Testing

Acceptance testing of the flight instrument was performed in accordance with the same test plan, specification and procedure as the prototype instrument. EMI and acoustic tests were not performed on the S082B flight instrument as they were qualification requirements only.

A simulated zero-g test was performed to determine the effects of zero-g on the instrument optical alignment (see Figure 4-19). Spectrograph pictures were taken with the instrument "upside up" and "upside down" while mounted on a special test fixture. These spectrograph pictures had the waveband aperture image superimposed on the slit image to show spectrum position in the waveband aperture. Test results showed negligible change in alignment and in spectrum position in the waveband aperture.

The sun end down position of vertical alignment test was performed and spectrograph pictures were taken as in the zero-g test. This was to verify the flight instrument did not have a similar movement of the spectrum in the waveband aperture on the prototype instrument. Test results showed no detectable movement.

Preacceptance test verified that the instrument mechanical, optical, and electronic subsystems met required specifications. The data obtained during this test was the reference for evaluating system performance in subsequent BBRC and post-delivery testing. The test data was used extensively in preparation of mission operation procedures. Parameters verified during this test were the same as in prototype qualification preacceptance test.

Vibration test subjected the instrument to acceptance level random vibration in three axes. Post-vibration test results showed no change in test parameters from the preacceptance test.

Thermal vacuum test on the flight instrument was essentially the same as was performed on the prototype instrument except for the following:

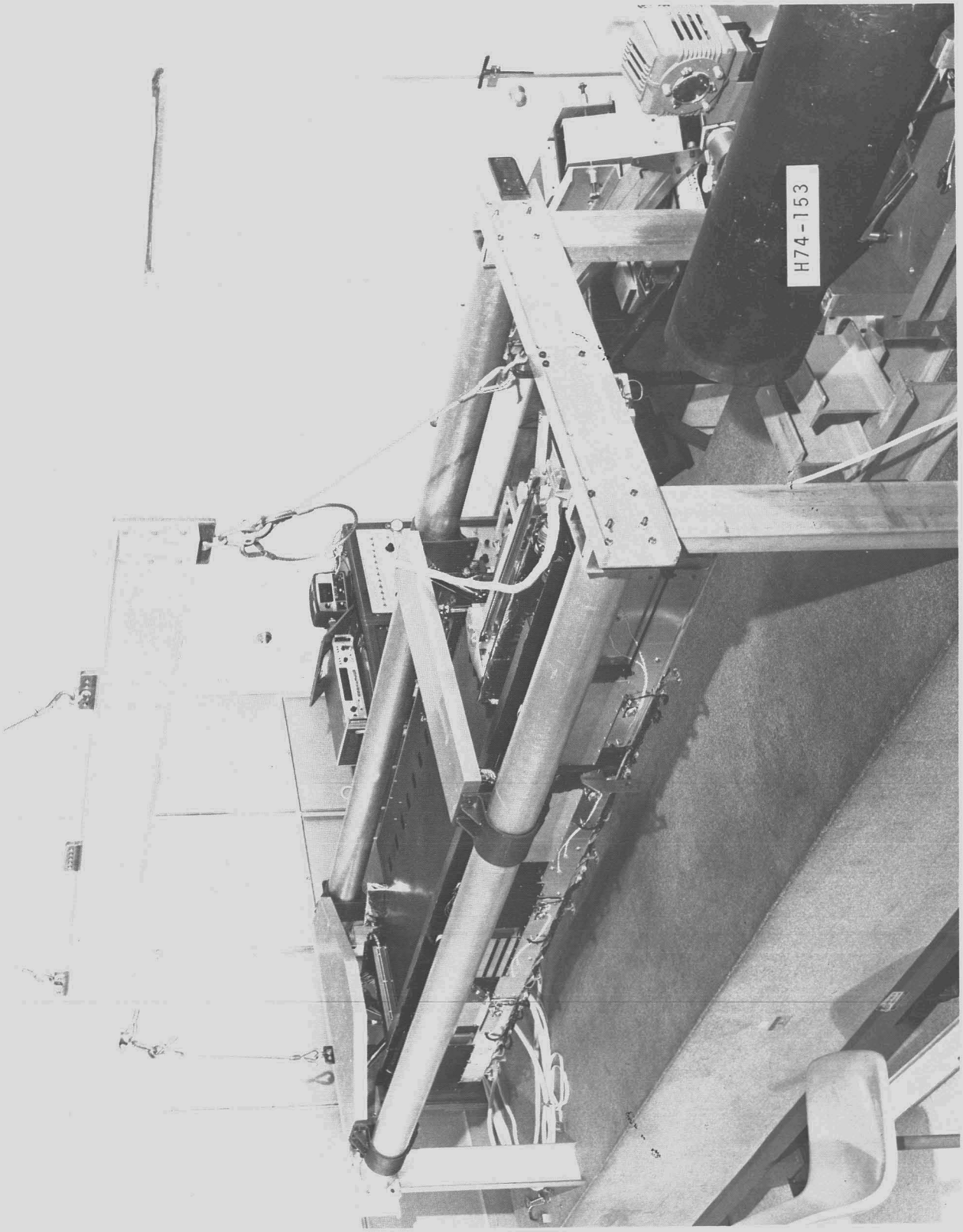


Figure 4-19. S082B Spectrograph Simulated Zero G

A. Nonoperating temperature extremes were acceptance levels instead of qualification levels.

B. Spectrograph pictures were taken at cold, hot, and nominal shroud temperatures.

C. PRS white light display evaluation was performed at cold, hot, and nominal shroud temperatures.

D. Diode array data was exposed on film at each exposure.

Test results of thermal vacuum and post-thermal vacuum tests showed no change in test parameters from preacceptance test results.

PRS sun checks were performed using a heliostat to verify internal video levels expected under space conditions were of the proper levels.

Calibration was performed following post-thermal vacuum testing. NRL requested additional calibration tests after analyzing the first data and determined from these tests that the optical efficiency of the system was degraded. Tests to determine the cause of the degradation required the instrument lid to be removed for efficiency measurements of the predisperser gratings and the main grating. The main grating and the predisperser gratings were replaced with new units.

Optical alignment of the system proceeded rapidly because of optical measurements performed on the main grating and predisperser gratings prior to removal from the mechanical assembly. These measurements required special test fixtures that provided precision mounting of the mechanical assembly so the newly installed gratings could be aligned to the old grating measurements. Alignment was completed and satisfactory calibration tests were performed.

The final acceptance test sequence discovered a marginal condition in the pointing reference system during sun checks. Slight refocusing of the system was performed and the electronic detection level was adjusted to correct this condition.

Pre-acceptance test was repeated with all test parameters remaining unchanged from the original pre-acceptance test except for the improved optical efficiency.

4.2.3 Acceptance and Shipment

See Section 4.1.3

4.3 FIELD INTEGRATION AND TEST AT NASA FACILITIES

The instruments were delivered to MSFC where receiving acceptance tests were performed. See Table 4-3 for milestone schedule of all field integration and tests. MSFC installed the instruments on the ATM spar and performed optical coalignment (see Figs. 4-20, 4-21 and 4-22). When the ATM assembly was completed, a series of post-manufacturing tests were performed and qualification testing of the ATM prototype began. Qualification tests consisted of systems test, non-operating vibration test, a thermal vacuum test and optical calibration which were performed in the vacuum chamber at JSC. The ATM was placed sun-end-down in the vacuum chamber, the chamber was evacuated, and the XUV light sources were operated. Since the S082A and S082B prototype instruments contained white light setup optics, the optical calibration test was simply a functional test of the calibrated XUV light sources. Had the prototype instruments contained XUV optics, spectrograms and spectroheliograms would have been obtained.

During the thermal vacuum test the ATM was installed sun-end-up, the vacuum chamber walls were cryopumped with liquid nitrogen, and a multilamp sun simulator was installed above a transparent window in the top of the vacuum chamber (see Figs. 4-23 and 4-24).

Table 4-3

Field Integration and Test Schedule

Title	Completion Dates	
	Prototype	Flight
Instrument (S082A/B) Receiving Tests (MSFC)	15 Aug 1970	6 Aug 1971
Post-Manufacturing ATM Instrument Tests (MSFC)	10 Jul 1971	27 Apr 1972
ATM System Test (MSFC)	30 Sep 1971	22 May 1972
ATM Vibration (Non-Operating) (MSFC)	19 Apr 1972	2 Jun 1972
ATM Thermal Vacuum (JSC)		
a) Orbital Mission Simulation	18 Nov 1971	3 Aug 1972
b) Optical Calibration	12 Oct 1971	30 Aug 1972
ATM Delivery to KSC	N/A	21 Sep 1972
Instrument Verification (O&C Bldg)	N/A	3 Nov 1972
ATM System Test (O&C Bldg)	N/A	6 Jan 1973
Crew Interface Checks (O&C Bldg)	N/A	4 Dec 1972
ATM Assembly to Skylab (VAB)	N/A	30 Jan 1973
ATM/MDA/OWS System Test	N/A	28 Feb 1973
ATM/MDA/OWS Flight Readiness Test (VAB)	N/A	24 Mar 1973
Flight Film Stowage		
(VAB) SL-1	N/A	2 Apr 1973
(PAD) SL-1	N/A	11 May 1973
SL-3	N/A	25 Jul 1973
SL-4	N/A	13 Nov 1973

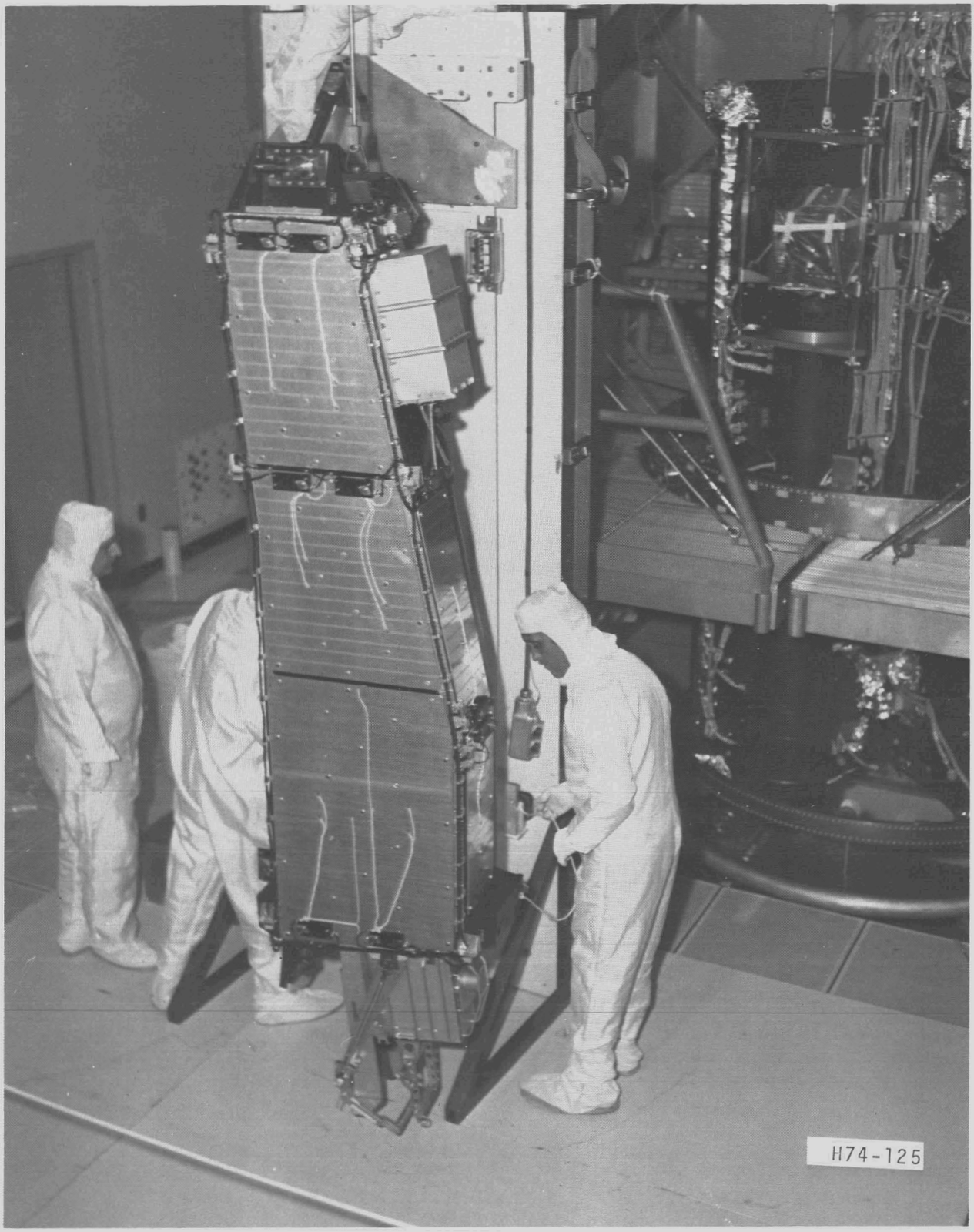


Figure 4-20. S082A Preparation for Mounting to ATM Spar

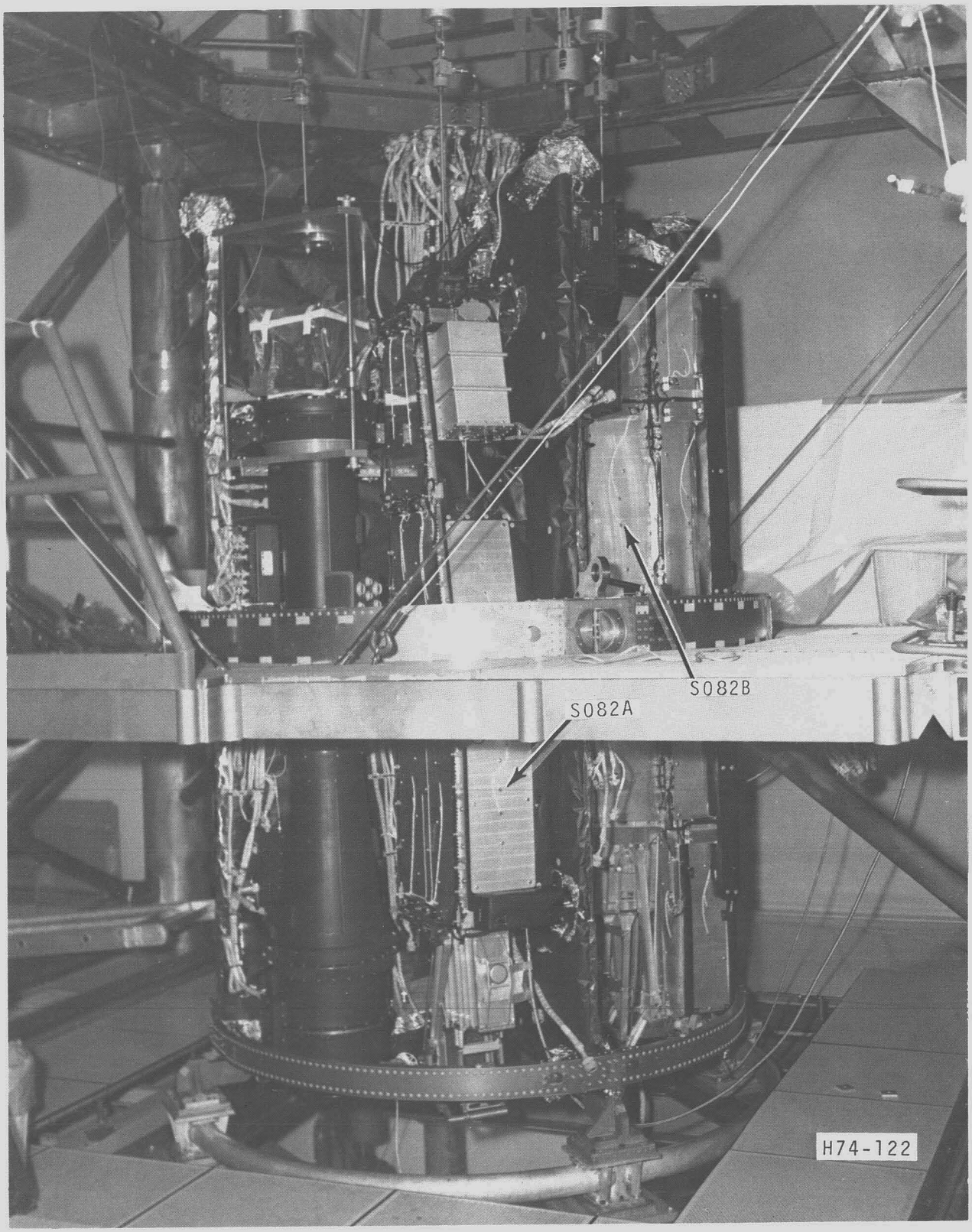


Figure 4-21. ATM Spar Assembly, S082A and B Installed and Ready for Coalignment to Fine Sun Sensors

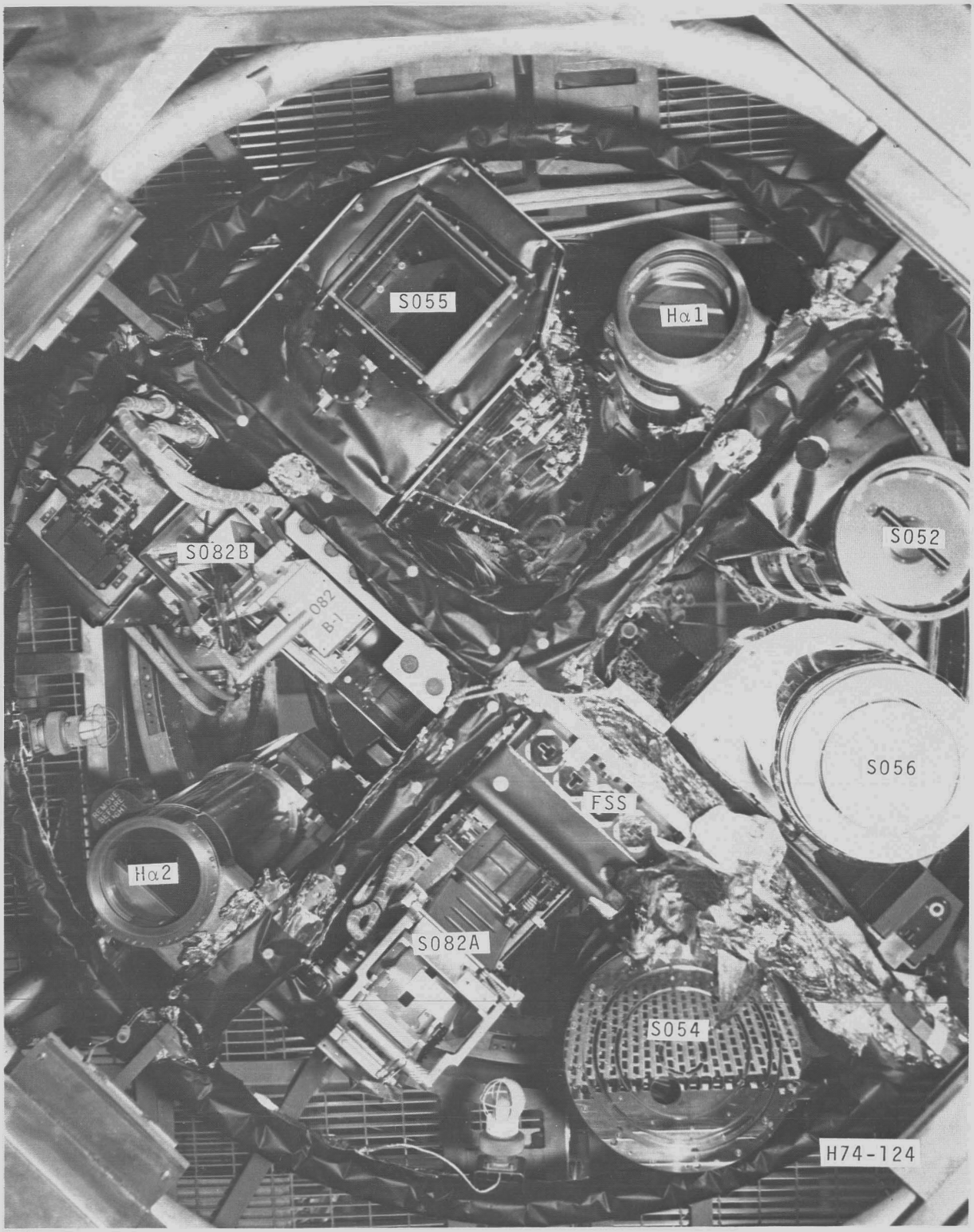


Figure 4-22. Sun End - ATM Spar Assembly

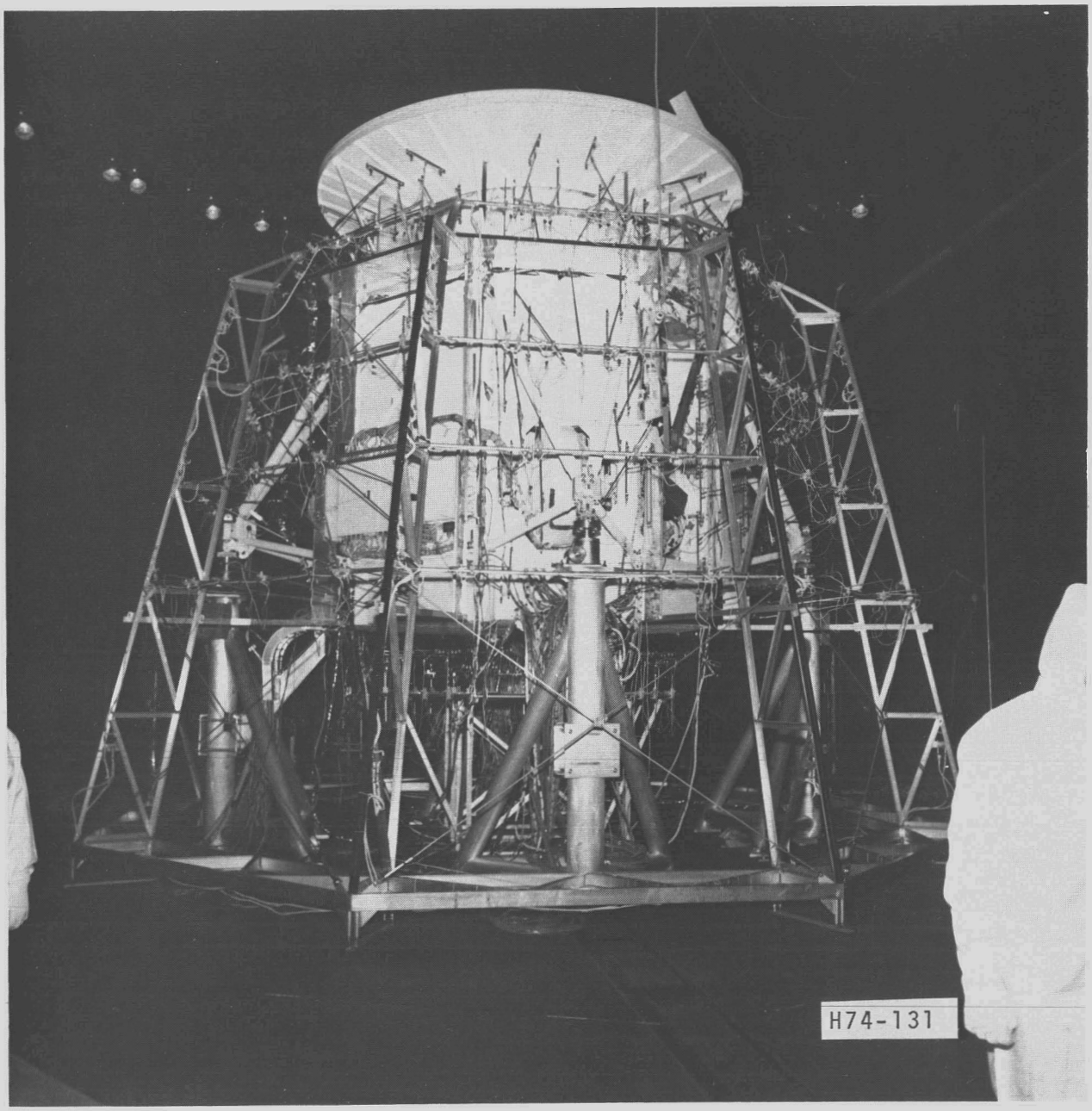


Figure 4-23. ATM Sun End Up in JSC Thermal Vacuum Chamber

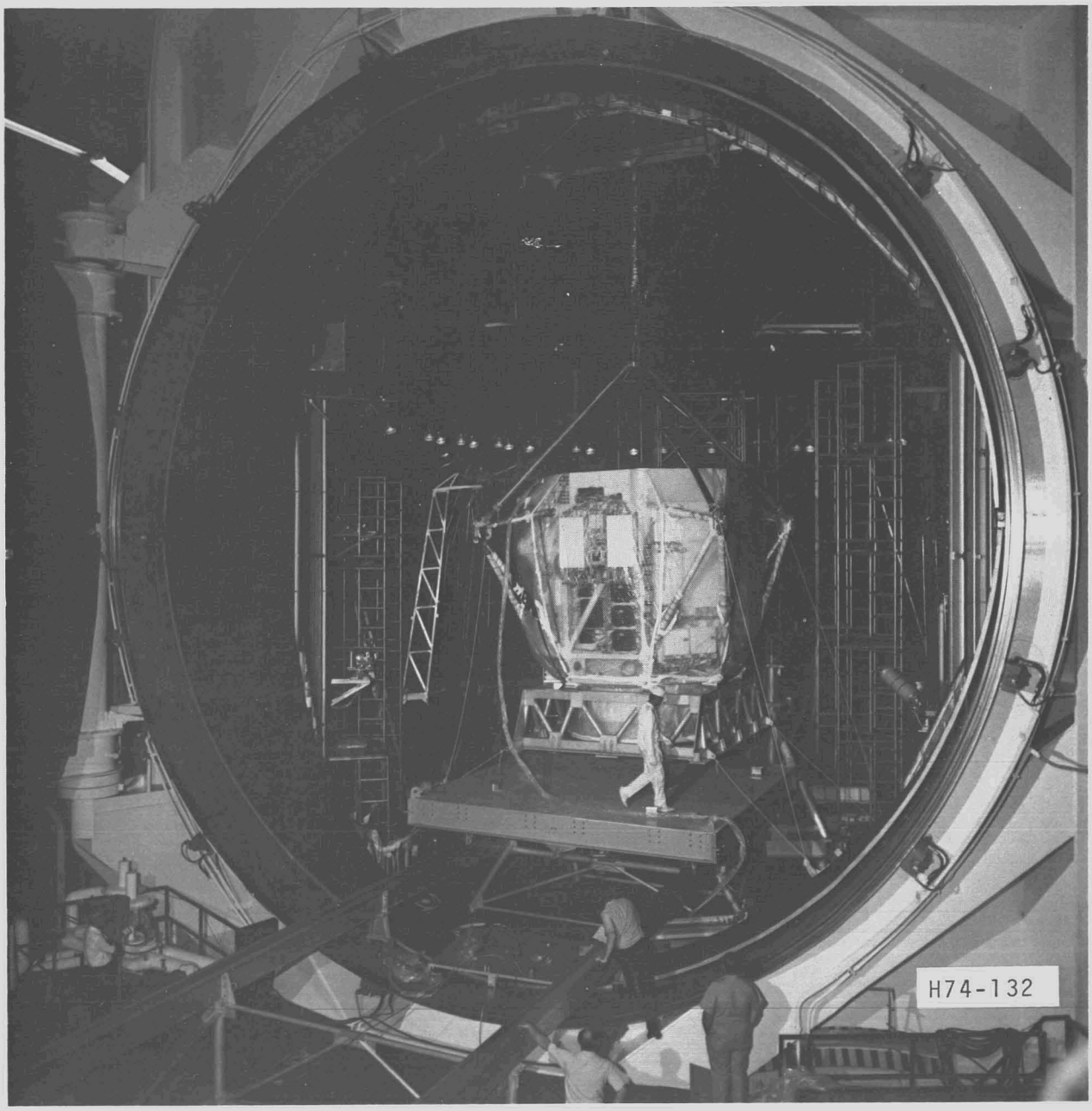


Figure 4-24. ATM Sun End Down in JSC Thermal Vacuum Chamber

The sun simulators were turned on and off to simulate orbital day and night conditions. Although thermal vacuum tests at BBRC had simulated the S082A and S082B relationship to the ATM spar and to other adjacent instruments, the thermal vacuum test at JSC was the only simulation of the space environment for the ATM subsystem. The test simulated seven calendar days of ATM operation and exercised the extremes of cold or hot orbital environment by varying the ratio of orbital sunlight to darkness.

When qualification testing of the prototype ATM was completed, no system integration of the ATM with the prototype MDA and OWS was performed. A prototype Skylab was not built. The prototype ATM was disassembled at MSFC and the S082A and S082B instruments were returned to BBRC where they were refurbished as flight backup units.

When acceptance testing of the S082A and S082B flight instruments was completed at BBRC, they were delivered to MSFC. At MSFC, the flight instruments underwent receiving acceptance tests, ATM assembly, and ATM flight acceptance testing. ATM flight acceptance tests were the same as ATM prototype qualification tests with the exception of vibration and optical calibration. Vibration of the flight ATM was in one axis only and at one-fourth the level of prototype ATM vibration. (Reference 50M02417, ATM System Specification for Performance and Design Requirements, paragraph 10.3.) Flight ATM optical calibration used the same test setup as the prototype but in the flight ATM test, spectrograms and spectroheliograms were obtained. Recordings of a resolution pattern on the XUV monitor were also made These images provided a check of S082A and S082B instruments and XUV monitor sensitivity and a baseline for space flight data comparison.

When flight ATM acceptance tests were complete, the ATM was transported to the Operation and Checkout (O&C) building at KSC.

The ATM was transported to KSC in the NASA-supplied Super Guppy airplane. The S082A and S082B instruments were continually purged with nitrogen from the NRL/HCO/ATM Transporter Purge System designed and fabricated by BBRC. Figure 4-25 shows the ATM as it was being loaded into the ATM transporter. Figure 4-26 shows the ATM transporter being unloaded from the airplane.

The post-manufacturing tests and system functional tests performed at MSFC were repeated at KSC and served as acceptance tests for MSFC delivery of the flight ATM to KSC. Upon completion, the ATM was moved from the O&C Building to the Vehicle Assembly Building (VAB) for integration into the Skylab. Skylab systems tests were the first tests involving interaction of the ATM, MDA, and OWS. The systems tests included countdown of the Skylab 1 launch vehicle and simulated orbital operations. The tests concluded with installation of flight loaded film cameras on the S082A and S082B instruments and final preparation of the instruments for launch. During the launch preparation period, two S082A and two S082B film cameras, each in canisters, were stored in film vaults in the MDA. Further support was provided later for film camera stowage in Skylab 3 and Skylab 4 Command and Service modules.

4.3.1 S082A ATM Prototype Qualifications

Throughout NASA acceptance testing and ATM qualification testing the S082A prototype instrument performed without significant problems. The initial concern, when S082A was operated in conjunction with ATM systems, was the possibility of electromagnetic incompatibility. However, S082A logic circuits were not susceptible to disturbance from any ATM operations. The S082A temperature control system performed acceptably during ATM thermal vacuum testing. During prototype testing, non-flight film cameras were used but very few problems occurred. A few

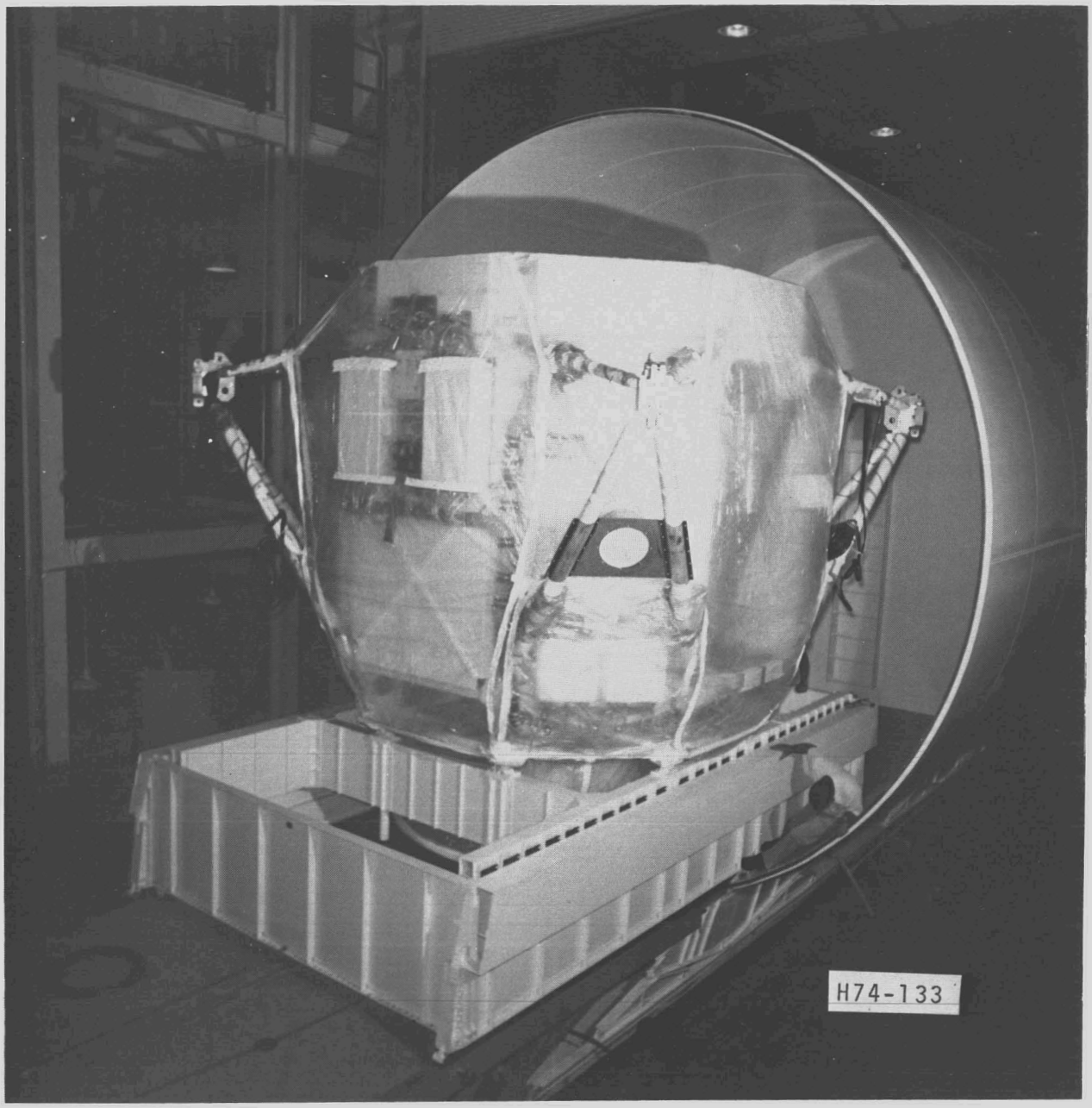


Figure 4-25. ATM Installation in Transporter

Figure 4-26. Unloading ATM Transporter from Guppy

interface problems and hardware problems occurred which were easily corrected.

The launch lock on the Instrument "A" camera latch was damaged and had to be replaced.

When S082A was first operated in conjunction with the ATM all S082A telemetry fluctuated erratically. BBRC had interpreted the interface specification with the understanding that ATM would sample each measurement four times per second, the four samples being averaged, and S082A would commutate to a new measurement once each second. ATM was sampling each measurement only once and was commutating to a new measurement at four per second. The interface control document was open to misinterpretation. The compromise solution was a hardware change by ATM resulting in commutation of one measurement per second with ATM sampling each measurement only once. The desired averaging was lost.

MSFC continually worked on the S082A ATM thermal shield aperture door and achieved gradual improvement. Failures occurred throughout the ATM prototype test program.

4.3.2 S082B ATM Prototype Qualification

The S082B prototype instrument experienced some minor system interface problems and two component failures during NASA acceptance testing and ATM qualification. The temperature control system performed as expected during ATM thermal vacuum. Non-flight film cameras were used but very few problems occurred. S082B was susceptible to disturbance from some ATM operations.

The first component failure occurred during test following ATM assembly, a module failed in the diode array electronics causing several diodes not to indicate on film. The prototype was returned to BBRC following ATM qualification and the problem with the diode

array electronics was to be analyzed. But during failure analysis the circuit began working again and could not be made to fail. A micrologic flip-flop was identified as the probable malfunctioning component.

The second component failure occurred during ATM thermal vacuum testing at JSC. The auto mode would not continue after opening the film camera shutter for the first time. This failure was also analyzed after return of the prototype S082B Instrument to BBRC. Analysis isolated the failure to a faulty micrologic which was further analyzed at MSFC. The failure analysis indicated a random component failure and was verified by a special test in which another A2 electronic box was placed in a thermal vacuum environment and 2406 Auto modes were completed under thermal extremes. The exposure time computer operated normally during the special test and no further corrective action was considered necessary.

As with S082A, both the S082B and XUV Monitor ATM thermal shield aperture doors were troublesome throughout testing.

Also, as with S082A, S082B commutated telemetry was being sampled faster than it was being commutated. The same compromise fix was incorporated as explained for S082A.

During PRS video testing and operation of the PRS in Limb Point or Limb Scan modes, the voltages associated with the PRS fluctuated. The problem was caused by multiple grounding of the PRS electronics which occurred due to the video coax outer conductors being connected to ATM skin. Per the interface control document, the coax cable outer conductors were to be isolated. MSFC designed and installed isolation amplifiers in each of the video lines and no further voltage fluctuations occurred.

When the PRS video was first used after completion of ATM assembly, a black line was visible diagonally across the left fiducial line.

A small piece of contamination had lodged on the slit plate. Later, just prior to thermal vacuum testing, a larger piece of contamination was visible on the right side of the slit plate. Neither piece of contamination affected PRS operation or obscured the slit opening. Because of this contamination problem, cleanliness control measures on the flight instrument were increased. No contamination was ever apparent on the flight slit.

Throughout prototype ATM testing, the S082B frames remaining counter on the ATM C&D Panel counted more frames than were actually taken. This was erroneously attributed to the non-flight film camera being used. Later, flight testing correctly attributed the problem to an incompatibility between S082B frames remaining output and the frames remaining counter input. The problem was corrected on the flight ATM by addition of a filter to the ATM electronics. A more direct fix would have been to modify S082B electronics, but the electronics were inaccessible.

4.3.3 S082A ATM Flight Acceptance and Skylab Integration

No significant S082A test problems occurred during S082A flight model NASA acceptance testing, flight ATM acceptance testing or Skylab integration testing at KSC. Also, no new system interface difficulties occurred. Some minor modifications were made to improve operation of the instrument and some related failures did occur as discussed below.

During receiving tests of the instrument at MSFC, NASA objected to one telemetry measurement which had a nominal voltage slightly higher than the 5.0 VDC limit of the MSFC test equipment. The instrument electronics box was returned to BBRC for recalibration of that particular telemetry measurement. This is mentioned as a significant item since it was a characteristic of both S082A and S082B telemetry that several voltages were too near the upper limit of the ATM system range.

Both prototype and flight instrument electronics had an operational logic deficiency that could possibly have led to a crew error. If a wavelength command was given for the same wavelength the grating was already in and then an Auto 2 mode was commanded, the Auto 2 mode would not sequence properly. This was corrected by addition of a relay to the short wavelength indication line which opened a contact in the short wavelength command line, thus preventing recommand of short wavelength. Long wavelength recommand was similarly prevented. The relays were added to ATM logic because of the inaccessibility of instrument electronics when installed in the ATM.

ATM thermal shield door failures occurred less often on the flight model than on the prototype but were never completely prevented. Failures of the thermal shield door limit switches had occurred on the prototype but were eliminated on the flight model by addition of travel limit stops. Door maintenance, requiring removal of the ATM sun shield, was performed at JSC both before and after thermal vacuum testing. Because of the problems with thermal shield doors the flight ATM had two modifications the prototype did not have. One was adding relay logic circuitry which allowed disabling door motor drive power. The second was adding the capability of pinning the doors in the opened position. These two modifications were used during the Skylab mission on both S082 thermal shield doors. Latching the thermal shield doors in the open position was performed during EVA, thus allowing additional data to be recorded.

S082A film cameras failures occurred five times during flight ATM testing. These failures are covered in more detail in paragraphs 4.5.2 and 4.5.4. The first four failures resulted in corrective actions which were successful in preventing the particular failure modes from ever recurring. The fifth, and last, test failure cleared itself immediately and was finally termed a one

time anomaly. The failure mode could not be reproduced and no corrective action was considered appropriate.

4.3.4 S082B ATM Flight Acceptance and Skylab Integration

There were a few significant test problems and interface problems affecting the S082B flight instrument during NASA test activities. These problems all received corrective action and total performance of the S082B flight unit was relatively troublefree.

During MSFC receiving acceptance tests for the S082B flight instrument, two component failures occurred. An error had been made at the ECE test connection panel causing a short which damaged the output module for the C&D console hold indication. In the same test, a shift in calibration of one of the analog telemetry commutators was identified. The two electronic boxes containing the failed components were returned to BBRC for failure analysis and repair. Accidental damage to the hold indication was verified and the module was replaced. The telemetry shift was attributed to a faulty capacitor which was also replaced. The capacitor failure was the only random type component failure experienced during S082B or S082A flight instrument testing. When the electronic box repairs were completed, receiving acceptance tests were repeated at MSFC.

During post-manufacturing checkout of the flight ATM assembly, the S082B instrument would begin a flare mode when the PRS was turned on. This occurred most frequently when operating on only one of the two redundant 28 volt primary power buses. The additional current required by the instrument when the PRS was turned on caused a momentary drop in 28V primary voltage. The drop in voltage caused sufficient transients in the instrument electronics to trigger a flare mode start. The problem was corrected by bypassing the ATM primary power filter. The filter had not been described in the interface control document and was not compatible with instrument requirements.

As discussed previously all ATM thermal shield aperture doors were troublesome during ATM testing. During thermal vacuum testing at JSC, the newly installed replacement door motor for the XUV Monitor failed and would operate only if both motors were used. Adjustments made following thermal vacuum testing were successful in making the thermal shield doors more dependable for the testing at KSC. As the result of these continuing problems, the S082A and S082B instrument aperture doors were modified to prevent loss of thermal control in the event of ATM thermal door failure. These modifications, which included the addition of teflon mirrors to the outside of the instrument aperture doors, were implemented at KSC during the final test program.

During ATM post-manufacturing tests, the video sensitivity from the PRS was found to be low. The change from previous tests was approximately 21 percent. Calibration of the reference used for input light level determination was suspected since that detector had been recalibrated just prior to the test. The detector was returned to BBRC for a calibration check and found to be in error by approximately 25 percent. However, reference to the original tests had been lost by the recalibrations. A special test was performed at BBRC to reference an identical PRS image dissector tube to the sun using calculations to eliminate the atmospheric filtering effect. The reference PRS image dissector tube was later compared to the flight PRS image dissector tube in tests at KSC where ATM post-manufacturing tests were repeated. Results compared within 4 percent and PRS video sensitivity was accepted on that basis.

S082B film camera failures during flight ATM testing were very rare. Two occurred: one due to interference with a test tool, and one due to misadjustment of a film latch mechanism. The latter failure resulted in out-of-focus data in an internal alignment test. Readjustment corrected the problem.

When the PRS video was first viewed at JSC, a 3/8-inch black bar was visible on the left side of the C&D console television monitor screen. The XUV monitor also displayed a 1/4 moon crescent of white in the lower left corner of the round television display. Both of these appearance defects were emphasized by readjustment that had been performed on the C&D panel television monitors and on the XUV monitor camera control unit. Readjustments were again made, correcting the XUV monitor problem, and improving the PRS problem. After television monitor readjustment, the PRS display still had a small black bar on the left due to the PRS horizontal blanking pulse interval being in excess of specification. The condition had been present in both prototype and flight and could not be corrected without extensive dismantling of ATM. Final resolution was to accept the minor effect on appearance of the PRS display.

Thermal analysis of the data produced during ATM thermal vacuum testing at JSC revealed that heater control panel No. 6 was malfunctioning. The panel was not cycling in the 0.4°F band as designed but was cycling in the 6°F overtemperature band. The panel had been misadjusted at BBRC so that the overtemperature control point and the normal temperature control point were both 74°F. The malfunction was therefore, an adjustment problem, not a component failure The panel could not be adjusted with the instrument installed in the ATM. Since the heater control panel would not cause significant thermal distortion of the instrument, the condition was accepted without correction.

During the Crew Compartment Fit and Functional Check (C^2F^2) at KSC, all film cameras were installed on the instrument by astronauts from a Skylab backup crew. The crew objected to the amount of deflection of the camera handle, when the camera handle launch locks were in position. A modification was made to the crew's satisfaction.

An open loop video telemetry test was performed at KSC. In this test, ATM supplied video to the MDA which, in turn, supplied the video to a simulated CSM S-band video transmitter. The video transmission was received at MILA tracking station at KSC. PRS video had a 560 KHz noise bar pattern which was superimposed on the normal test pattern. The source was a voltage controlled oscillator used only during test so no corrective action was taken. Also, video was disrupted by audio noise when voice was transmitted with the video. Corrective adjustments were made to the modulator in the MDA and retest showed the problem was no longer present.

4.4 PROTOTYPE REFURBISHMENT

The S082A and S082B prototype instruments were returned to BBRC after completion of ATM qualification testing. The instruments were refurbished to flight quality for use on the ATM FBU. The refurbishment consisted of receiving inspection, modification, installation, and alignment of flight-type optics and acceptance testing. Refurbishment was approved by ECP 129 and was accomplished per Time Compliance Technical Order (TCTO) 2234.018A for S082A and TCTO 2234-019A for S082B.

4.4.1 S082A

4.4.1.1 Modification and Optical Alignment

A receiving inspection was performed and the instrument was disassembled. All moving mechanisms were carefully inspected for wear and lubrication breakdown. Any parts that exhibited either wear or lubrication breakdown were replaced and the electronics were replaced with spare electronic assemblies. A complete history of the prototype refurbishment activities may be found in BBRC Document No. 620-220, NRL/ATM S082A Refurbished Prototype Spectroheliograph Acceptance Test Report.

Reassembly of the instrument occurred in much the same manner as the flight and prototype were performed. Subassemblies were integrated into the instrument as required by optical alignment.

4.4.1.2 Acceptance Testing

Acceptance testing of the refurbished instrument was performed in accordance with the End Item Test Plan, BBRC Document No. 620-4.

The preacceptance test was performed to establish baseline instrument performance prior to environmental testing.

Vibration testing was performed to acceptance levels. A small shift was noticed in optical alignment after vibration. The alignment was corrected and a second vibration test was performed with good results.

Thermal vacuum and post-thermal vacuum test results showed no change in parameters from preacceptance test results. All systems performed normally throughout the test.

The vertical position test duplicated a failure that occurred on the flight instrument. The XUV monitor white light grating mask when pulled out, was interfering with the grating rotation from the short to the long wavelength position. Adjustments were made to correct this problem.

4.4.1.3 S082A Refurbished Prototype at MSFC

The refurbished prototype was assembled into the flight backup ATM which underwent tests only up to the experiment and ATM subsystem levels. At that stage testing was discontinued. The Skylab was performing satisfactorily and it was apparent that no

further requirement existed for a flight backup ATM. MSFC maintained the flight backup ATM in test readiness and provided support to the HOSC when problem simulation was desired. The S082A "Ready" indication problem was simulated on the flight backup unit. Also, the ATM Joint Operation Plans (JOP's) for SL-3 and SL-4 were performed on the flight backup unit to verify their correctness. The flight backup ATM, and its associated GSE, is now in storage at MSFC for possible reuse in the future.

4.4.2 S082B

4.4.2.1 Modification and Alignment

Refurbishment began with a receiving inspection of instrument damage, cleanliness, operation, calibration, and contamination. Mechanical disassembly of the instrument was completed and optical alignment was started. During alignments, the setup optics were replaced with flight optics, the predisperser was replaced with a flight qualified unit and the slit plate was replaced due to contamination. At final focus, a 400Å bandwidth, of the instrument's 3000Å coverage, was of inferior focus compared to the flight instrument. It was determined, by the customer, that the final focus condition was adequate to achieve the instrument's scientific objectives. A complete history of the refurbishment activities may be found in BBRC Document No. 620-219, NRL/ATM S082B Refurbished Prototype Spectrograph Acceptance Test Report.

Prior to refurbishment the spare electronics assemblies were checked out using the EMU case and original flight cable that was modified to simulate the final flight cable. This was done to expedite the refurbishment schedule. The new external instrument cable was found to have broken wires at the connectors. It was decided to rework the prototype cable to flight configuration.

The XUV monitor door drive electronics was modified so it would not drive open at main power ON. The prototype IDT did not have as uniform a response as the flight unit but it met acceptance specifications. The prototype active thermal control system panels were not replaced as they met all specification requirements. All gears and moving parts were disassembled, inspected, and relubricated prior to final assembly.

The XUV monitor was modified to use a channel electron multiplier array (CEMA) for converting XUV to white light. Engineering Orders (EO's) that were accomplished on the flight instrument, and not on the prototype, were incorporated. The refurbished instrument conformed to the flight instrument electrically, optically, and mechanically, though there were small hardware differences.

4.4.2.2 Acceptance Testing

Acceptance testing of the refurbished instrument was performed per the End Item Test Plan, BBRC Document No. 620-17. The electronic and PRS portions of the test were performed prior to completion of alignment due to schedule requirements. A thermal vacuum test, vibration test, and post-thermal vacuum test were performed. During thermal vacuum testing, the CEMA on the XUV monitor failed. A replacement was installed and verified during post-thermal vacuum testing. The instrument was prepared for delivery.

4.4.2.3 S082B Refurbished Prototype at MSFC

The refurbished S082B prototype was assembled into the FBU ATM which underwent tests only up to the experiment and ATM subsystem levels following its production phase at MSFC. At that stage,

testing was discontinued. The Skylab was performing satisfactorily and it was apparent that no further requirement existed for a FBU ATM. MSFC maintained the FBU ATM in test readiness and provided support to the HOSC when problem simulation was required.

The auxiliary timer built for flight ATM and launched with the SL-4 crew was tested with the FBU ATM at MSFC. It was also fit checked to the C&D console in the MDA at McDonnel Douglas Aircraft Corporation in St. Louis. This was an important step in obtaining acceptance for the auxiliary timer approach since able connections affecting several other ATM systems had to be disconnected. Crew procedures for installation of the auxiliary timer were proved during tests on the FBU ATM and the MDA.

The failure of the PRS in Limb Scan and Limb Point during SL-4 was also simulated at MSFC on the FBU during troubleshooting of that problem.

4.5 FILM CAMERAS AND CANISTERS

The film cameras were the prime means of collecting scientific data from the instruments. The complexity of the cameras and close mechanical tolerances of the drive mechanisms and the film plane position required precise monitoring of electrical and mechanical operation of the cameras. Many of the mechanical parameters monitored were not readily accessible and required development of special test fixtures. The instrumentation system identified in Section 2.4.1.2 was developed and used to monitor every operation of a film camera during qualification and acceptance testing.

4.5.1 Testing Performed at BBRC

Since the S082A and S082B cameras had a common application, they were exposed to the same types of tests. The mechanics of accomplishing the tests were different due to some differences between the S082A and S082B cameras. Notably, the focal plane measurements on S082B were more difficult and extreme due to the close tolerances required to maintain optical focus. Special measuring fixtures were developed to ensure precise S082B focal plane position when the camera was modified in this area, to improve its performance. The requirement for this modification was noted during S082B flight instrument optical alignment and was completed subsequent to instrument delivery. This approach was dictated by ATM scheduling and it prevented vacuum verification of the modified camera on the instrument.

The camera canisters for S082A and S082B were identical; therefore there was a need for only one qualification unit.

4.5.1.1 Qualification Testing

The prototype cameras were the qualification units. The only differences in qualification and acceptance tests were the vibration levels, and duration required. The cameras were subjected to two additional compliance runs during qualification tests. The camera qualification testing was performed in accordance with the appropriate instrument End Item Test Plan and met the requirements of the appropriate instrument D&PS and End Item Test Specification. Table 4-4 identifies the BBRC procedures used in the camera and canister qualification program.

Physical measurements tests verified the cameras met the appropriate envelope, weight and marking requirements.

Table 4-4
TEST PROCEDURES

Title	Number S082A	Number S082B
Physical Measurements	30557	30572
Pre-Qualification/Acceptance	30558	30573
Vibration	30559	30574
Thermal Vacuum	30560	30575
Post-Thermal Vacuum	30561	30576
Camera/Instrument Compatibility	36636	27316
Camera/Canister Launch Vibration	40751	40752
Canister Qualification	39797	39797
Canister Acceptance	39798	29798

Pre-qualification tests verified the camera met the appropriate mechanical, electrical and optical requirements prior to environmental testing. The data obtained during this procedure was the reference for evaluating camera performance in subsequent tests.

The cameras were operated using an instrument simulator that provided voltages, commands and monitors duplicating the appropriate instrument conditions.

The tests verified the camera electrical and mechanical operations with a full camera load. Verification of the film plane curvature and position as referenced to the instrument mounting interface plane was performed (see Figs. 4-27, 4-28 and 4-29). Stray light tests verified there were no light leaks that would degrade the film during crew installation and removal of the camera during flight EVA operations (see Fig. 4-30).

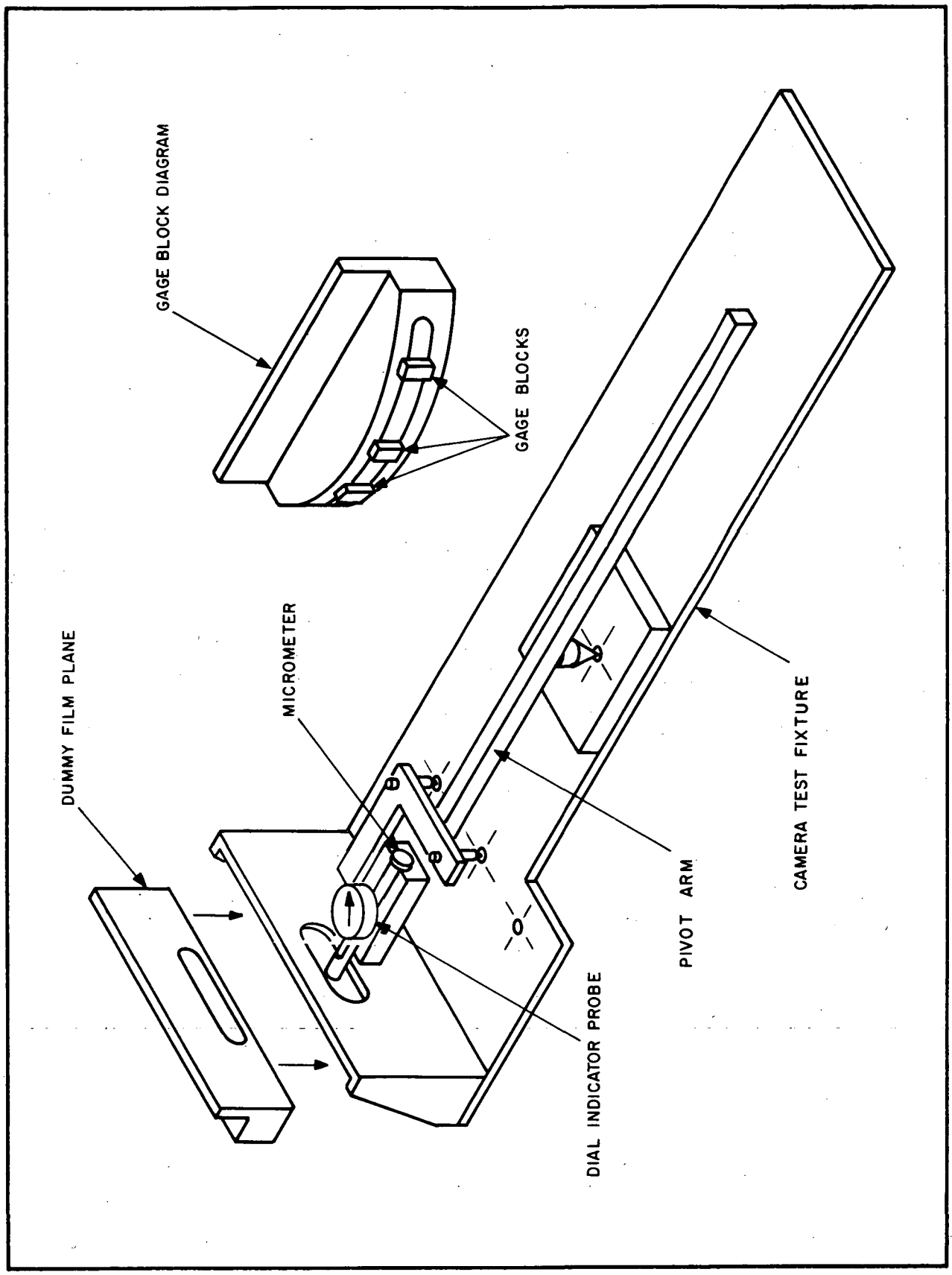


Figure 4-27. Optical Setup - Carrier Position Measurement

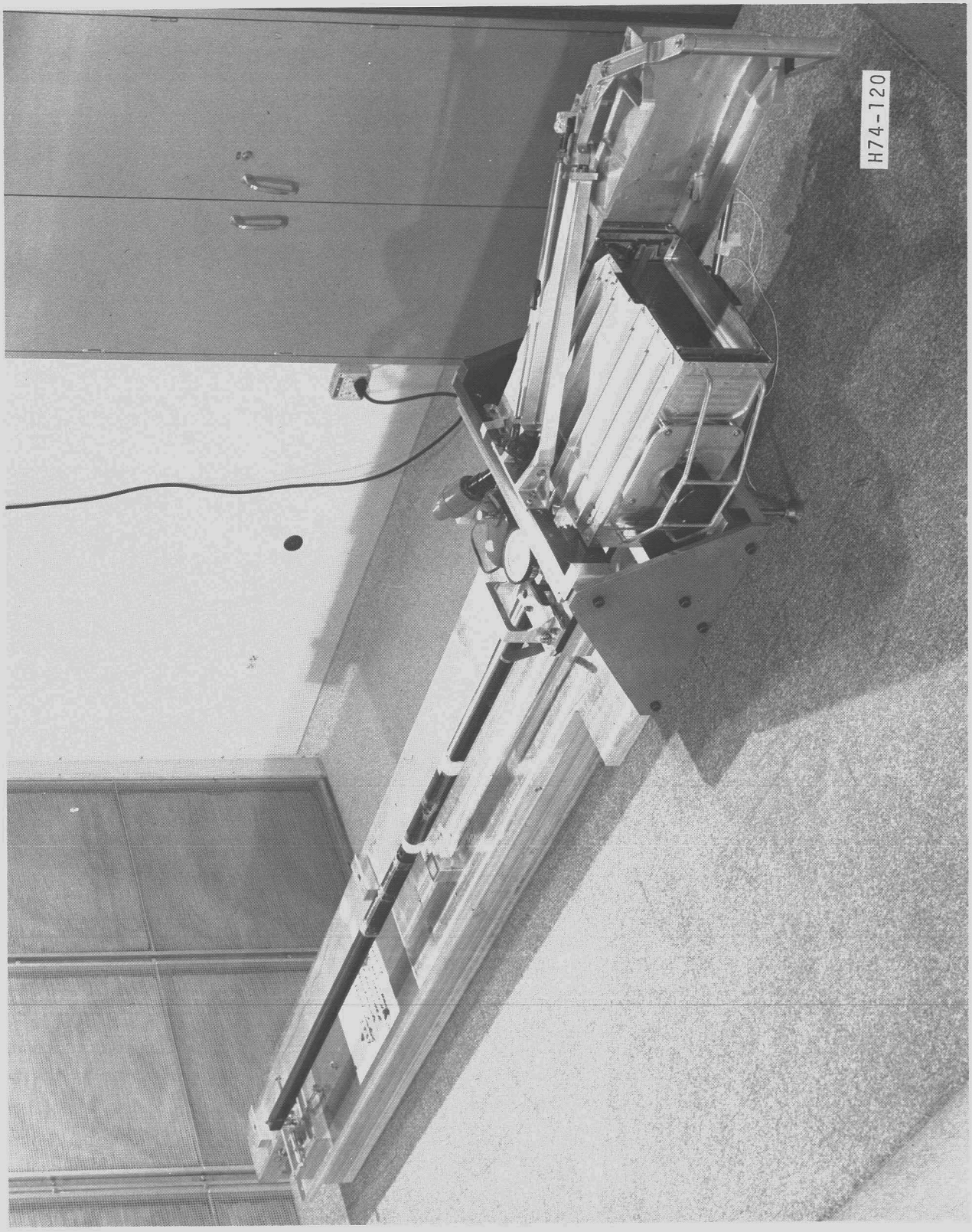


Figure 4-28. Camera Focal Plane Test Fixture

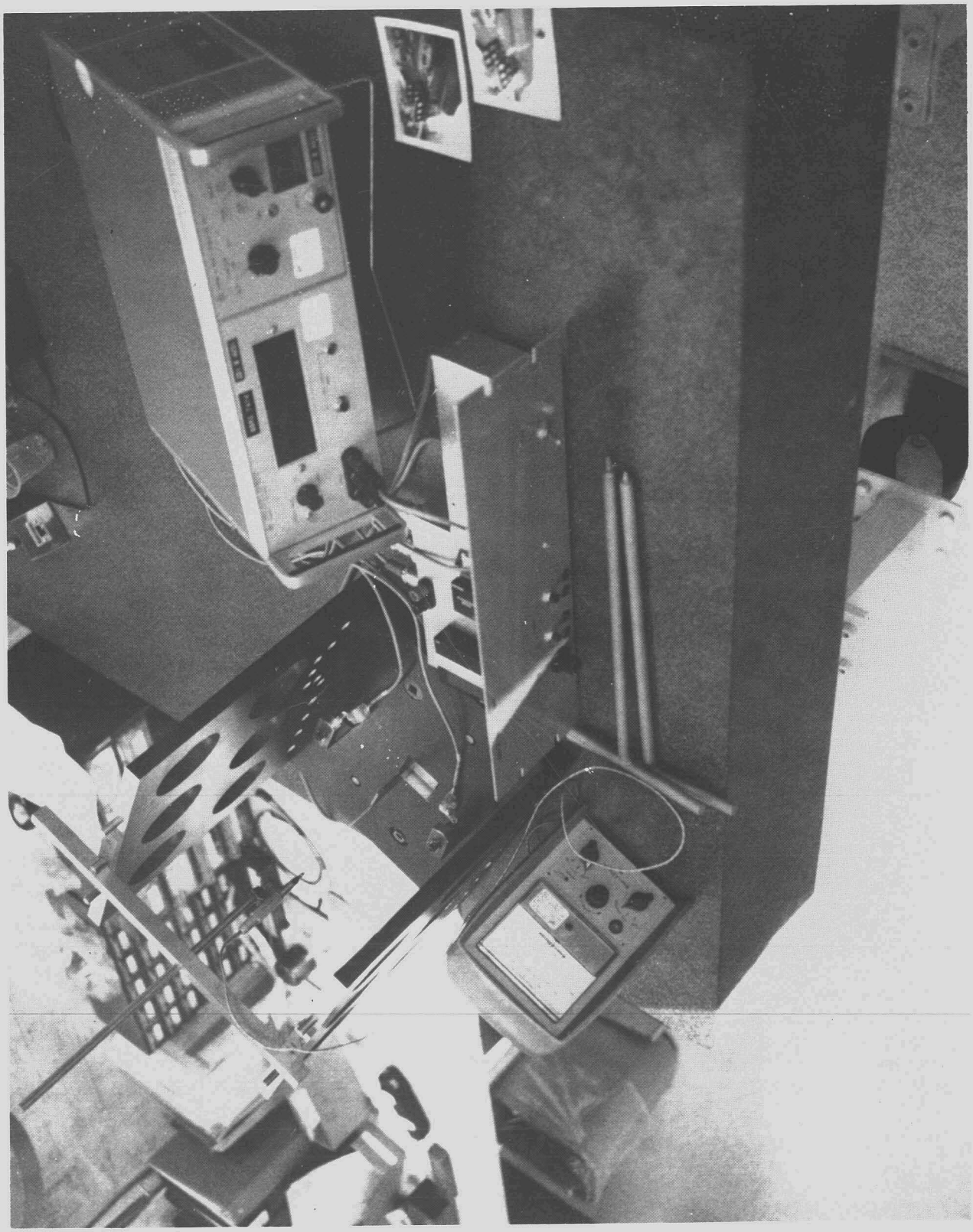


Figure 4-29. Apex Measurement Test Setup

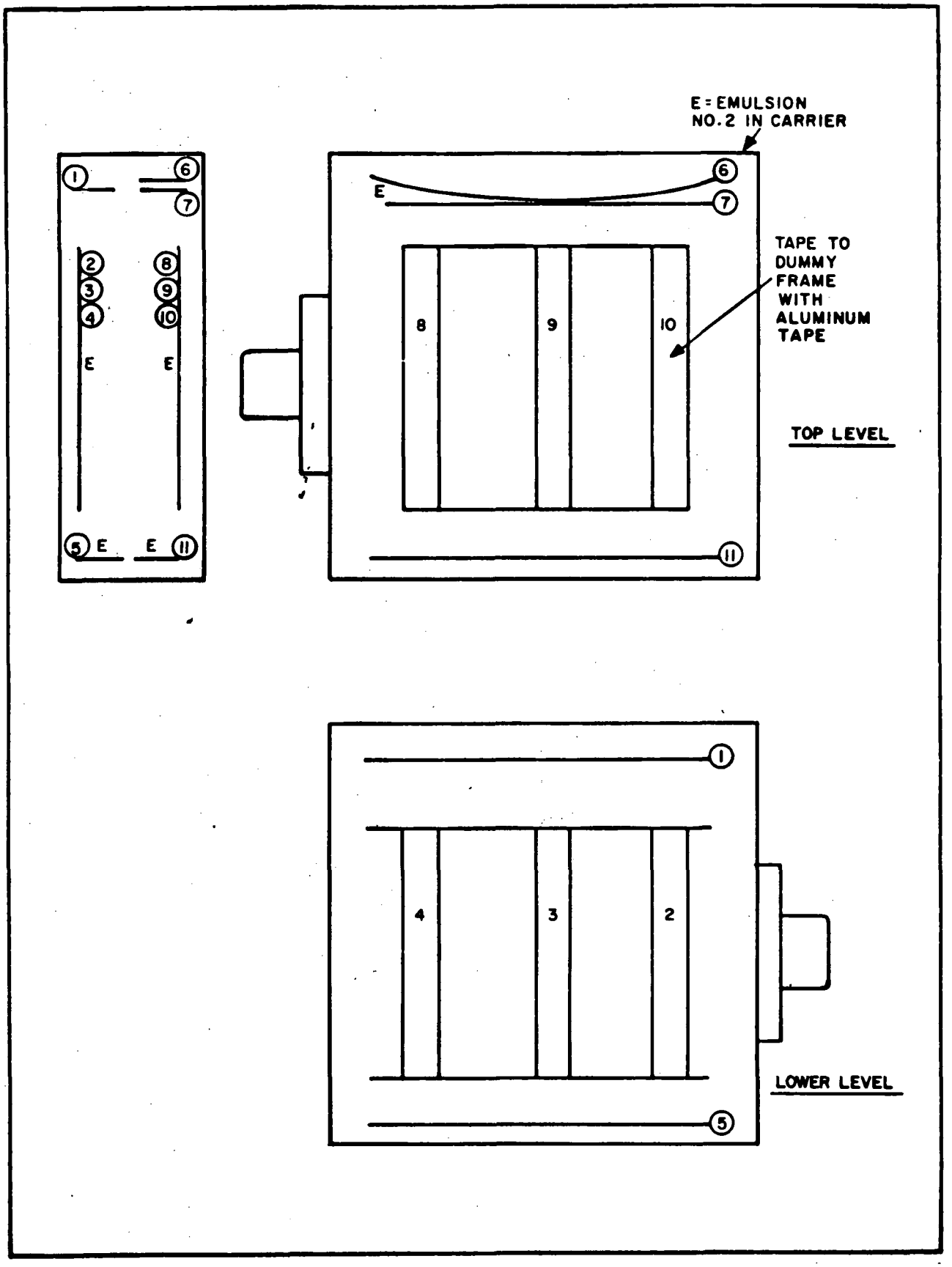


Figure 4-30. Film Loading Sequence, Camera Stray Light Test

The cameras were subjected to qualification level sine and random vibration (see Figs. 4-31, 4-32 and 4-33) with the cameras containing a full complement of film holders. Three film holders contained unexposed SWR Estar base film that was developed after vibration to verify no film degradation due to vibration. Proper camera operation was verified before and after vibration testing.

Thermal vacuum testing verified the fully loaded cameras performed within specification under flight simulated environmental conditions and at high, low and nominal voltage. Proper camera operation was verified before and after thermal vacuum.

The post-thermal vacuum testing was essentially a repeat of pre-qualification testing. This test verified no significant change in camera test parameters during environmental testing.

The camera/instrument compatibility test was a system verification that the instrument and its camera would meet the requirements of the design and performance specification and the test specification. The test verified the mechanical, electrical and astronaut interfaces and the system optical performance.

The camera/canister launch vibration test verified that the fully loaded camera, contained in its canister, would survive the launch vibration environment of the MDA and the CM (see Figs. 4-34, 4-35 and 4-36). Proper camera operation was verified before and after vibration.

The canister qualification test verified the canister met the envelope, weight, dimensional and marking requirements. Operating forces required in removing and installing the cameras were verified to be within specification. Purge, pressurization, leak and venting tests were performed to verify canister sealing capability to assure that the unit would provide adequate film protection.

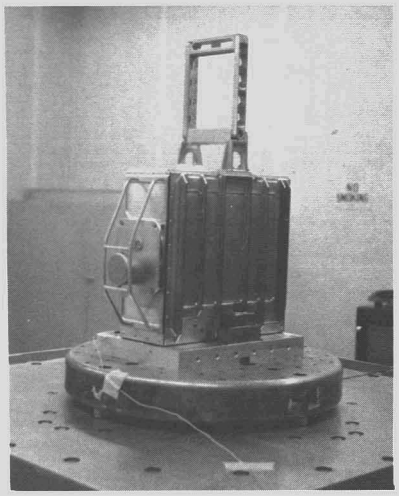


Figure 4-31. Film Camera 'X' Axis Vibration

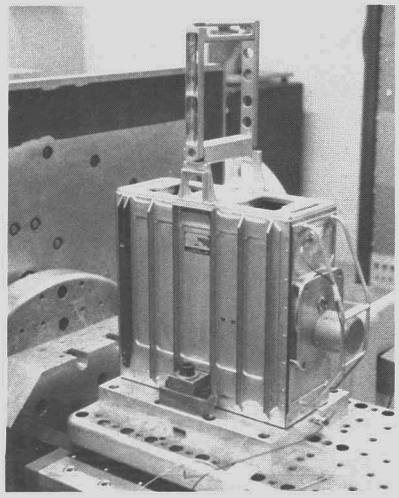


Figure 4-32. Film Camera 'Z' Axis Vibration

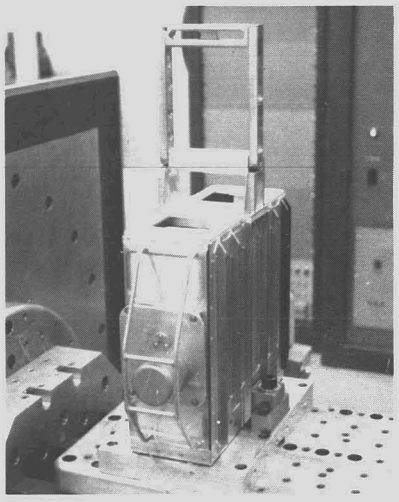


Figure 4-33. Film Camera 'Y' Axis Vibration

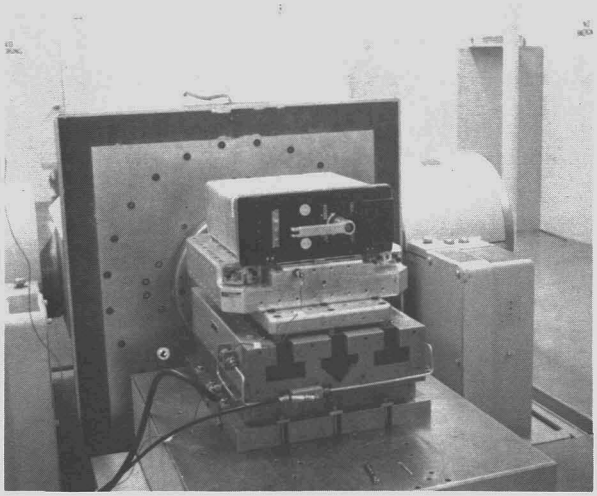


Figure 4-34. Camera/Canister 'X' Axis Vibration

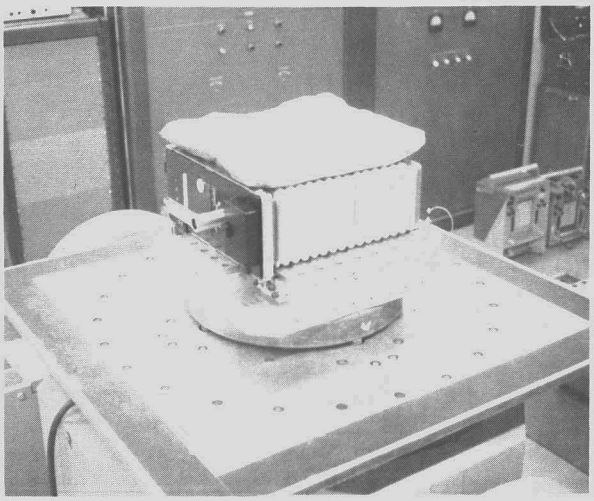


Figure 4-35. Camera Canister 'Y' Axis Vibration

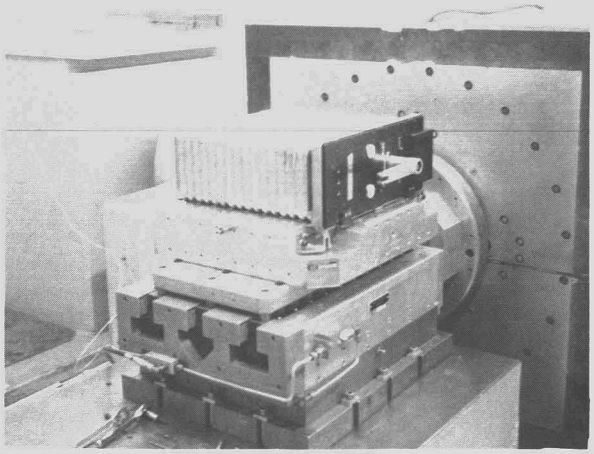


Figure 4-36. Camera Canister 'Z' Axis Vibration

The detailed results of the camera and canister testing, both qualification and acceptance, may be obtained from the reports noted in Table 4-5.

4.5.1.2 Acceptance Tests

The acceptance test sequence for each camera and canister was essentially the same as the qualification sequence. The vibration levels were lower and only one compliance run was performed during thermal vacuum as opposed to three during qualification tests. Some of the camera/instrument compatibility tests were performed in the field after delivery of the instruments.

4.5.2 Field Test at MSFC

Field ATM systems tests required numerous camera operations. Figure 4-37 shows installation of an S082A film camera on the instrument with the sun end of ATM down and solar shield installed. During this time the film cameras were still in the developmental stage; consequently several camera failures occurred in the field. As the development problems were solved the camera field operations improved.

Three significant S082A camera failures occurred; however, no significant failures occurred with the S082B cameras. One camera failed to transport film during diode array verification. Interference between the shuttles and the camera backplate caused this failure. The adjustment specification was revised to specify proper clearance between the back plate and shuttle transfer plate, and all cameras were adjusted to meet this specification. The second failure was due to bent feed claws caused by a field test tool. This test tool was a large brass plate used to simulate weight of film and holders which applied pressure on the

Table 4-5
CAMERA AND CANISTER REPORTS

BBRC No.	Title
S082A Camera Reports:	
620-75	Qualification Test Reports
620-136	Aluminum Filter Test Report
620-166	Acceptance Test Report, S/N A003
620-187	Acceptance Test Report, S/N A004
620-188	Acceptance Test Report, S/N A005
620-189	Acceptance Test Report, S/N A006
620-218	Acceptance Test Report, S/N A007
620-221	Flight Activity Dry Run Test Report, S/N A002
620-190	Zero-G Test Report
S082A Camera/Canister Reports:	
620-74	Qualification Test Report, S/N 001
620-146	Acceptance Test Report, S/N 002
620-148	Acceptance Test Report, S/N 003
620-149	Acceptance Test Report, S/N 004
620-150	Acceptance Test Report, S/N 005
620-151	Acceptance Test Report, S/N 006
S082B Camera Reports:	
620-165	Qualification Test Report
620-186	Acceptance Test Report, S/N B002
620-200	Acceptance Test Report, S/N B003
620-201	Acceptance Test Report, S/N B004
620-168	Acceptance Test Report, S/N B005
620-169	Acceptance Test Report, S/N B006
620-190	Zero-G Test Report
S082B Camera/Canister Reports:	
620-152	Acceptance Test Report, S/N 001
620-153	Acceptance Test Report, S/N 002
620-155	Acceptance Test Report, S/N 003
620-156	Acceptance Test Report, S/N 004
620-157	Acceptance Test Report, S/N 005

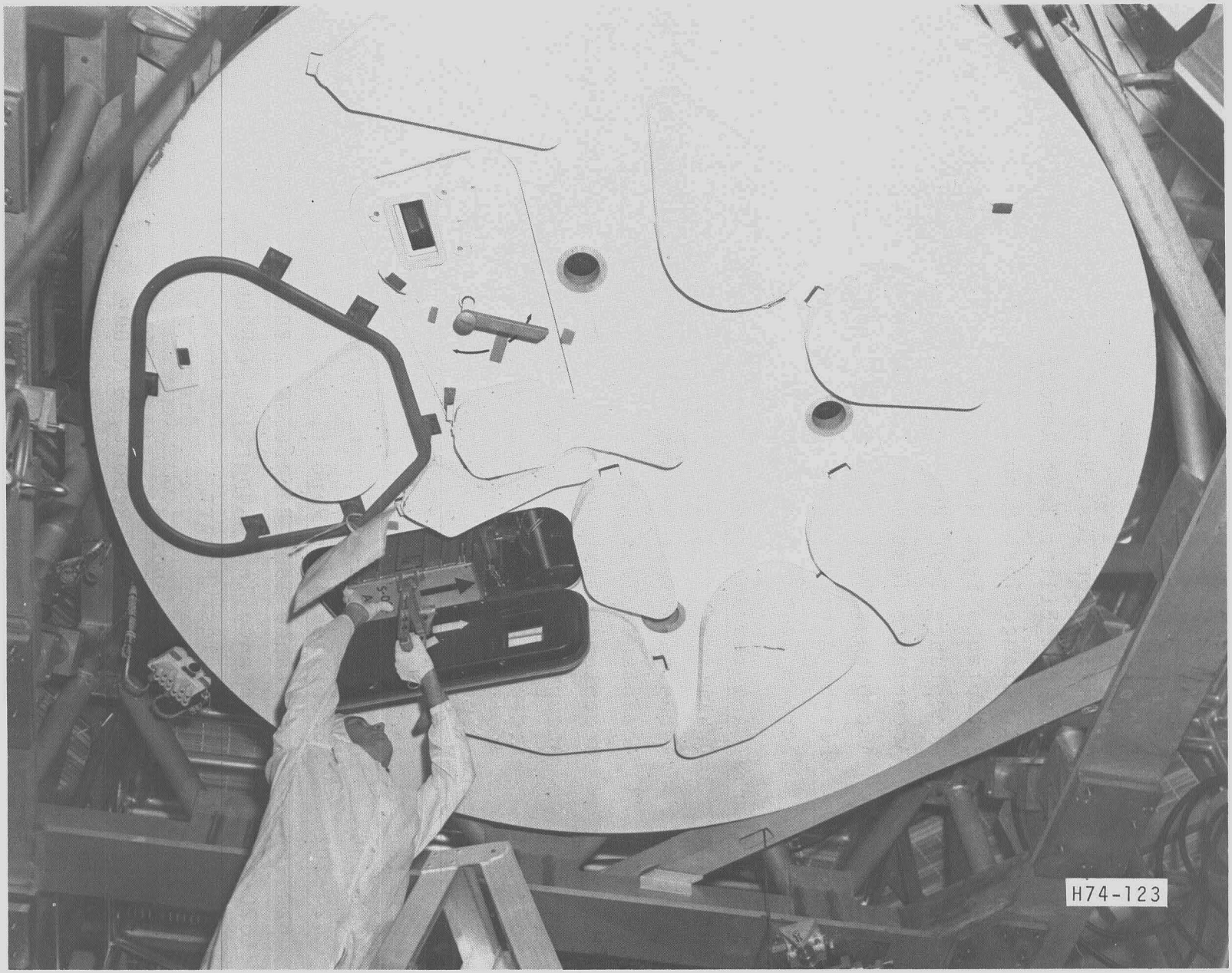


Figure 4-37. S082A Film Camera Installation

feed claws during installation. The use of this tool was discontinued, and actual film holders were used. The third was a failure to cycle during previbration verification. Failure was attributed to a metal chip on the film holder guide rails which resulted in a new cleaning procedure at BBRC. Corrective action to these three failures was effective because they never recurred.

4.5.3 Flight Preparations and Film Loading

Camera flight preparation began with filter installation on S082A cameras and a repeat of the stray light check performed. The camera was then fully loaded with flight film holders and nonflight film, and cycled through the camera to verify film holder/camera compatibility. The camera was then unloaded, the film removed and processed, and the film holders cleaned and gaged.

The film loading was performed in a darkroom dimly illuminated with infrared (nonvisible) light that would not expose the flight film. Quality control of the loading operation was assured by monitoring with three low light level cameras (one, remotely controlled), which were installed in holder cassettes (see Figures 4-38 and 4-39). The film was transferred from the cassettes to the camera and the camera back installed (see Figures 4-40 and 4-41). One-half of the film load was cycled through the camera with the shutter inhibited to prevent it from opening. The camera drive unit shown in Figure 4-42 was used to power the camera. This verified proper operation through one-half a camera load. The loaded camera was then placed in a vacuum chamber to dry the film. After completion of the film drying process, the loaded camera was installed in the canister, the canister evacuated and back-filled with dry nitrogen. The camera/canister assembly was

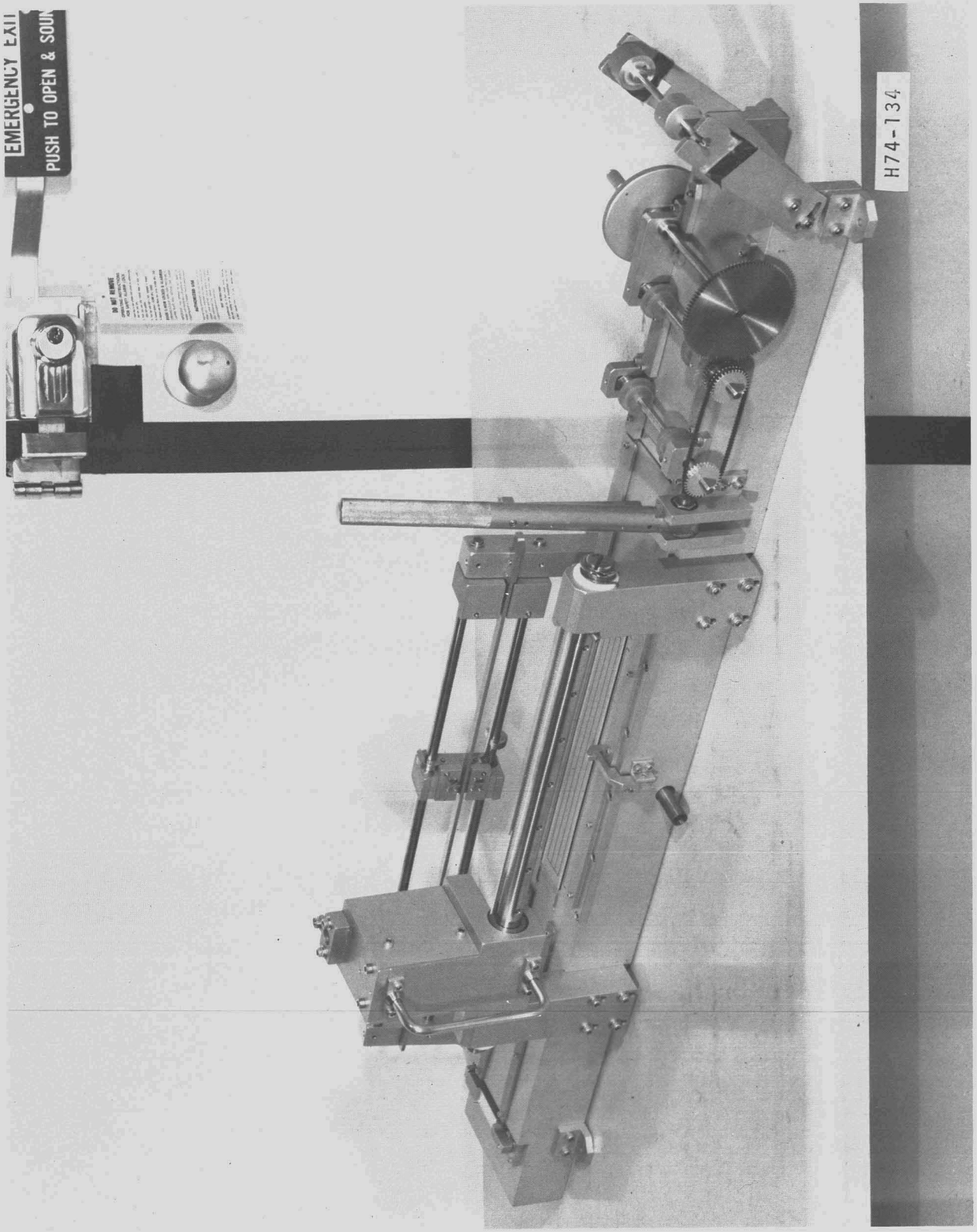


Figure 4-38. NRL Film Cutter

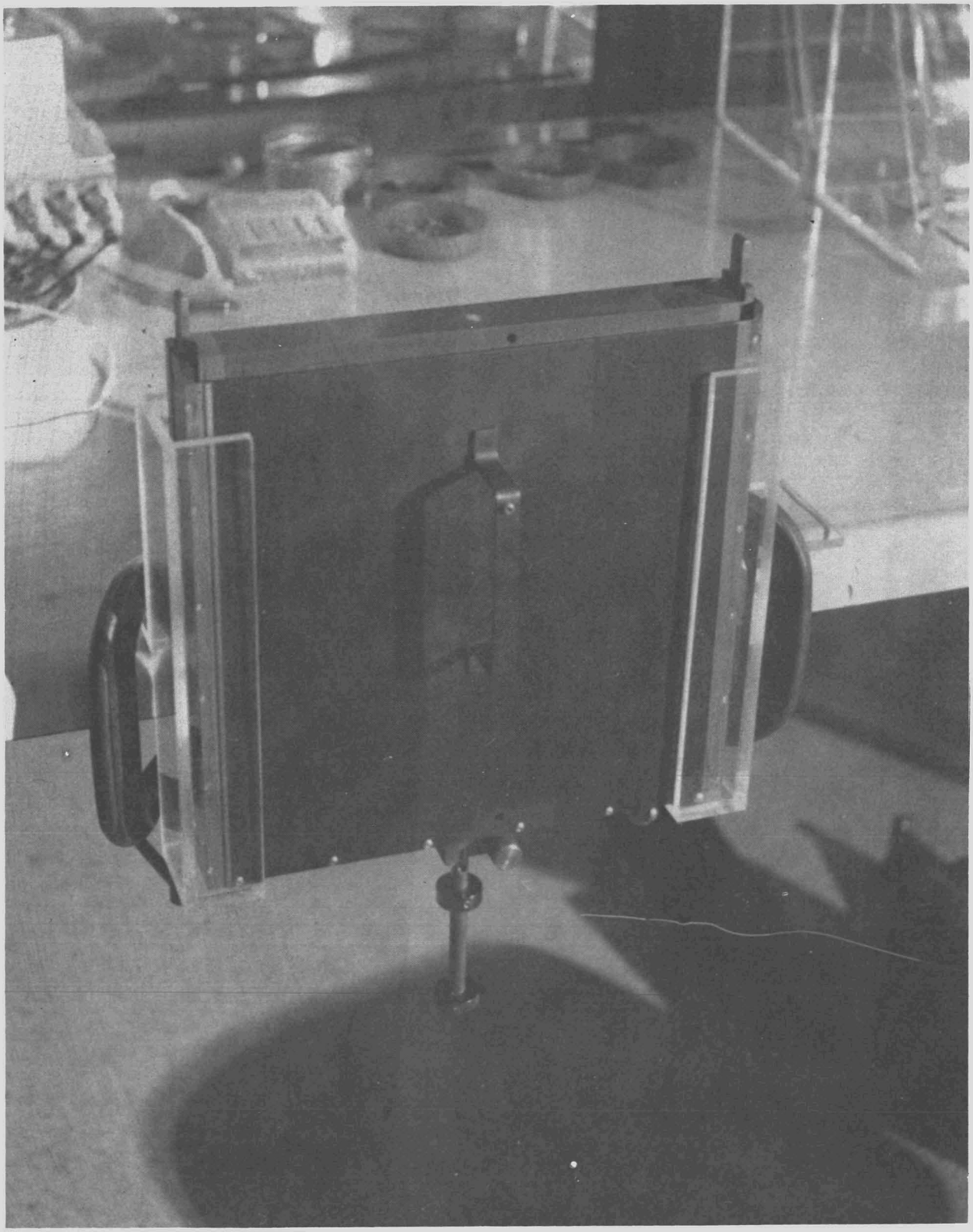


Figure 4-39. Film Holder Cassette

Figure 4-40. Camera Loading Fixture and Cassette

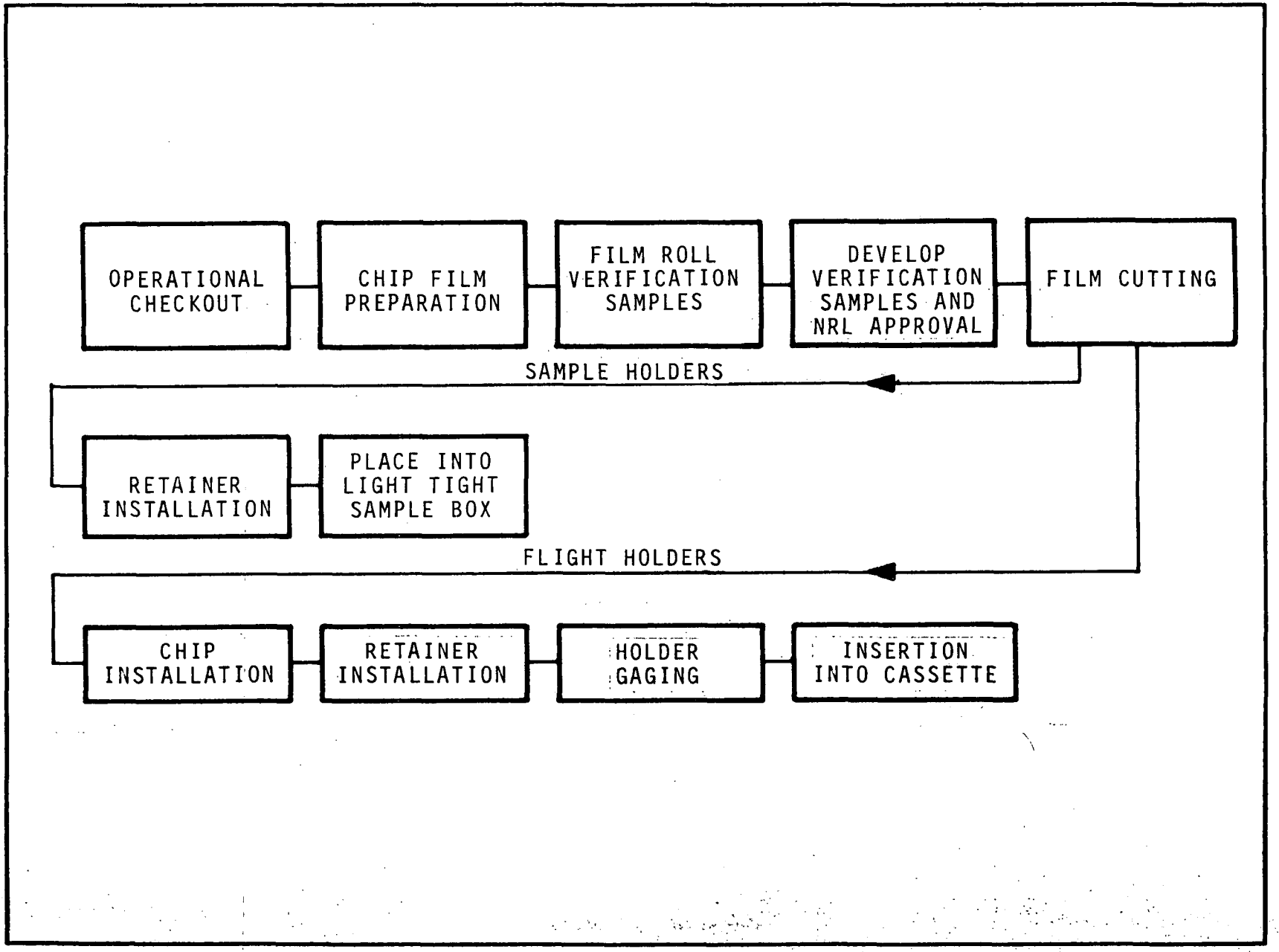


Figure 4-41. Flight Loading Flow Chart

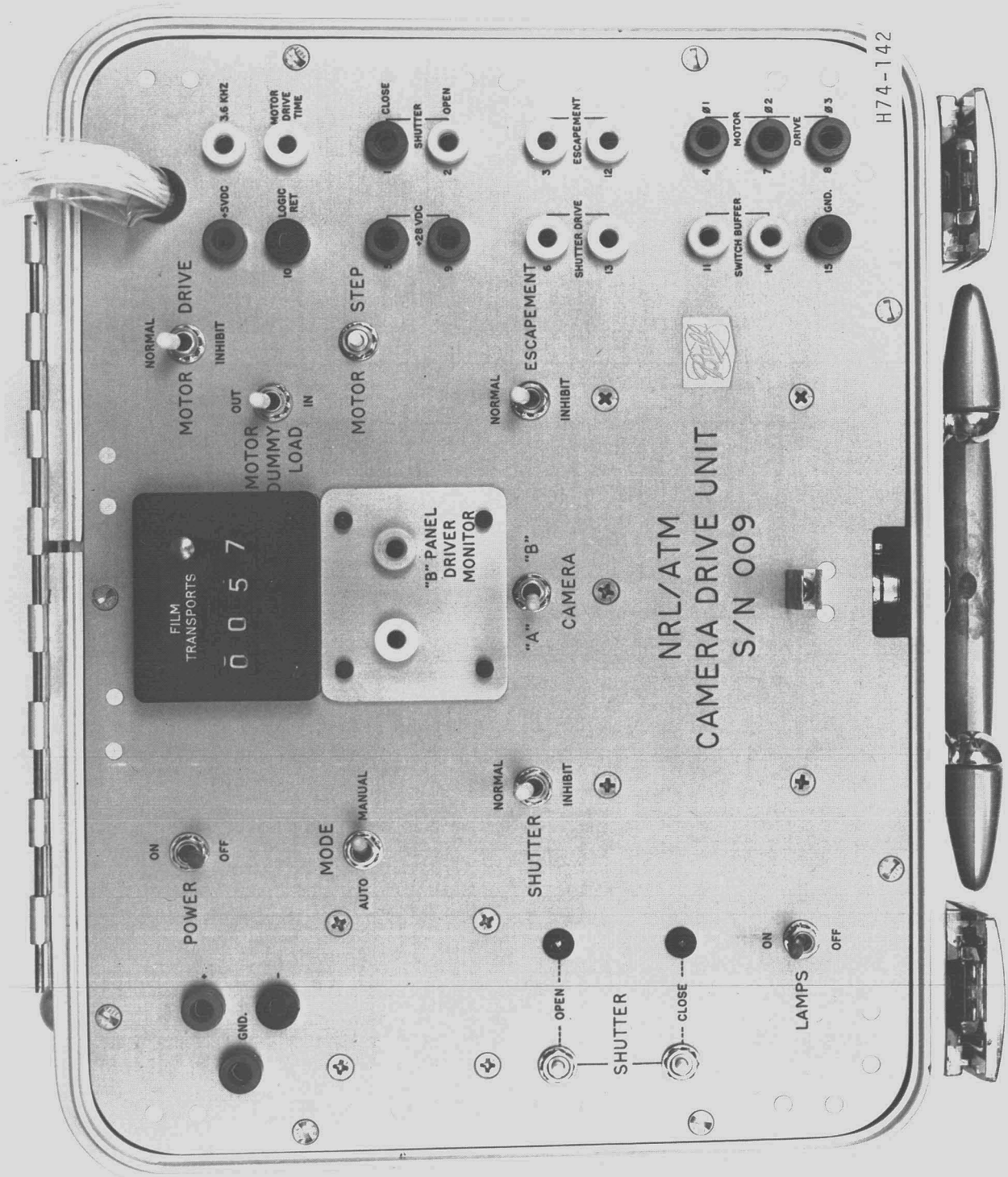


Figure 4-42. Camera Drive Unit

double-bagged, nitrogen purged, evacuated and sealed (see Figure 4-43). The camera/canisters were installed in an MSFC-provided shipping container and maintained between 40°F and 70°F throughout shipment to KSC (Figure 4-44).

4.5.4 KSC Camera/Canister Field Operations

4.5.4.1 Field Tests at KSC

The camera development problems caused serious schedule incompatibilities with the instrument. Due to this and the urgent need to gain more confidence in the system compatibility, additional camera/instrument testing was done at KSC, prior to the flight film loading. Two S082A camera failures resulted. The S082B cameras experienced no significant failures at KSC. The first failure of the S082A camera was a film jam during film loading. A procedural error which caused damage to a bearing in the film transport mechanism was identified and corrected. All cameras received a special check of these bearings. In the second failure the camera failed to complete film transport on the first command but did so on the second command. This failure could not be repeated and failure analyses failed to identify the cause. It was dispositioned as a one-time anomaly.

4.5.4.2 Flight Preparation

BBRC personnel accompanied each shipment of flight cameras to KSC. Upon arrival, the camera and canisters were removed from the shipping container, the canister internal pressure adjusted for the sea level ambient pressure, and warmed to prevent possible film damage during preflight verification. The camera was then removed from the canister and the remaining half of the film load cycled to complete the camera operational verification started at BBRC.

Figure 4-43. Camera/Canister Double Bag for Shipping (Nitrogen Purged)

H74-129

Figure 4-44. MSFC Shipping Container for Camera/Canister

Lockout was then reset, one film strip cycled and the camera installed in its canister. The canister was evacuated and back-filled with dry nitrogen. The camera and canister were installed in the shipping container and placed in cold storage until launch.

4.5.5 Post-Mission Camera Unloading

The cameras and canisters, installed in their shipping containers, were received by NRL personnel at JSC. They were hand-carried to NRL at Washington, D.C., maintaining the cold storage temperature initiated on the recovery ship. At NRL, the camera and canister were removed from the shipping container, warmed and the camera removed for unloading operations per BBRC Document No. 620-224. The recovered film was processed by NRL. The empty cameras were placed into canisters, nitrogen purged and placed in shipping containers at NRL.

Quality control of the film handling during camera unloading was maintained by utilizing the same personnel and equipment as for the loading and by remote monitoring with the LLLTV system. Extreme handling care was exercised in the preservation of this valuable data.

The S082A, S/N A003, camera jammed during the first Skylab mission. The camera was subsequently unloaded, several stringent tests were performed on the camera in an attempt to duplicate or determine the cause of failure. No indications of why the camera failed were observed and, through extensive testing, the failure could not be repeated.

Some of the S082B film strips from the last Skylab mission, exposed in the S/N B003 camera, exhibited several types of film fogging. Although scientific data loss was minimal, the possible causes of this phenomena are being investigated.

4.5.6 Zero-G Film Camera Tests

Two NRL/ATM film cameras (P/N 36360-501, S/N A002, and P/N 36361-501, S/N B001), were subjected to operational tests in a simulated orbital environment. The test was run to establish operational characteristics of the cameras in a zero-g field.

The zero-g test environment was attained in an aircraft flying parabolic maneuvers. Each zero-g cycle lasted approximately 25 to 30 seconds.

The camera test program was performed in accordance with BBRC Test Procedure No. 40118. Testing on the S/N A002 camera was on 10 and 11 July 1972. The S/N B001 camera was tested on 2 August 1972.

Each camera was placed into the airtight zero-g canister and purged with dry nitrogen gas. The cameras were mounted with similar mechanical interfaces as they would experience in actual flight (see Figures 4-45 and 4-46).

All equipment was placed into the aircraft and all preflight checkouts were completed. The S/N A002 camera had 18 preflight cycles placed on it and the S/N B001 camera had four preflight cycles placed on it.

During the zero-g flight test of S/N A002 film camera, it was operated for 201 cycles until lockout was reached. The camera was cycled eight or nine times during each zero-g period. The camera was also operated with high and low voltages (30.5 VDC and 25.0 VDC).

The S/N A002 camera was cycled five times for a post-zero-g instrumentation calibration.

Figure 4-45. Zero G Test Console and Camera Mounting Fixture (Front)

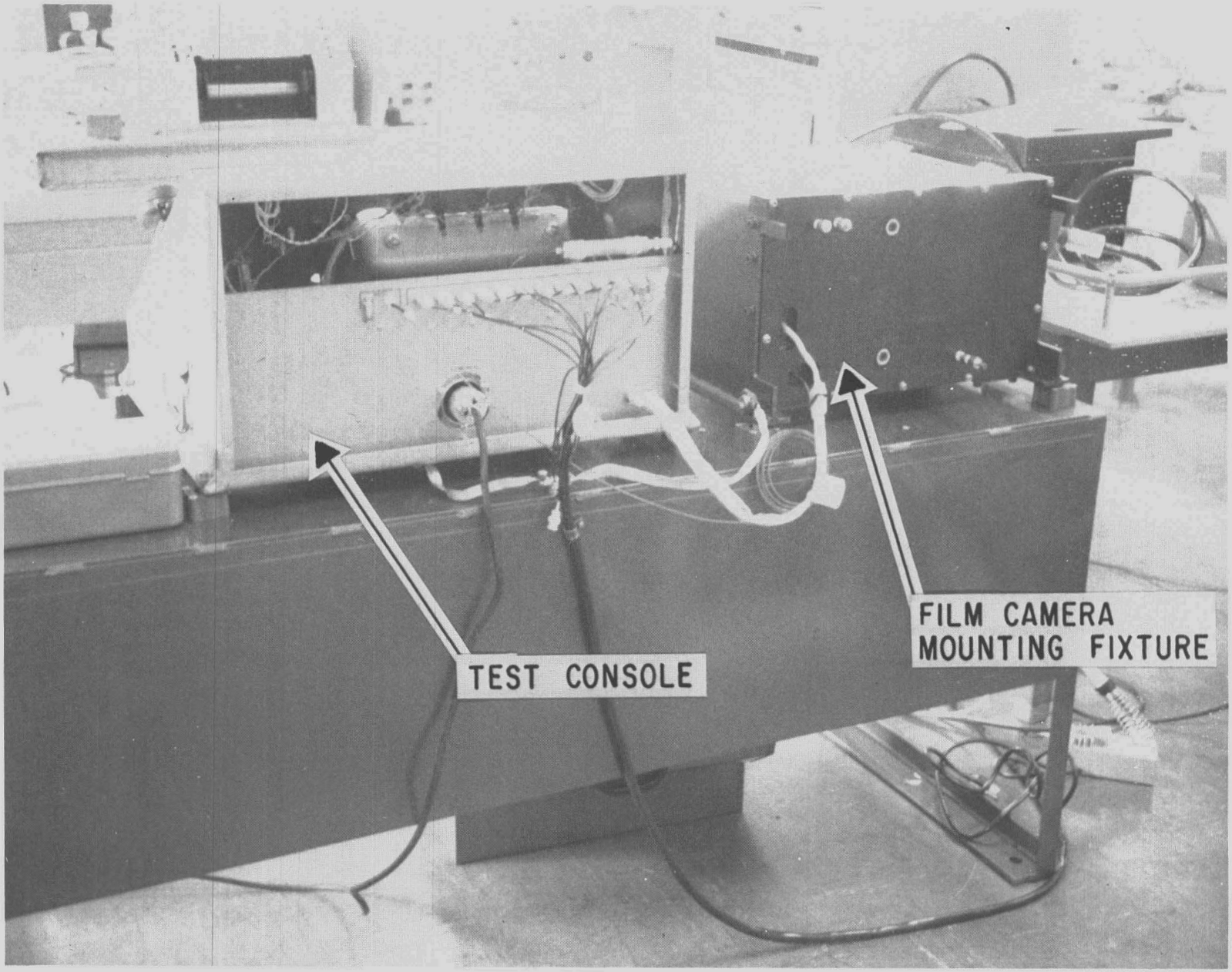


Figure 4-46. Zero G Test Console and Camera Mounting Fixture (Back)

The S/N B001 film camera was operated in a zero-g environment for 198 cycles until lockout was reached. It was also operated with the same voltage levels as the S/N A002 camera.

Following the normal zero-g test, the S/N B001 camera was subjected to a voltage drop test in a zero-g field to determine the lowest operational voltage (approximately 23 VDC).

The S/N B001 camera was then operated for ten cycles during the post-zero-g instrumentation calibration run.

The result of both camera tests indicated that the cameras operated per requirement while cycling in a zero-g field. The exception was on the S/N B001 camera which experienced skipped steps during the 6th and 13th cycles. This anomaly is not detrimental to camera operation and would only constitute a data loss of 0.18 percent.

Refer to BBRC Document No. 620-190, Zero-G Camera Test Report, for further data.

4.6 RELIABILITY AND QUALITY ASSURANCE

4.6.1 I&T Reliability

Throughout the integration and test phase the assigned reliability engineer was primarily involved with review and approval of all test procedures, approval of drawing changes and failure analysis/ reporting.

Test procedure changes occurring during test were red-lined into the QA copy and initialed by the test conductor, reliability engineer, and customer representatives. Failure reports prepared during integration, test, and post-delivery phases are summarized

in Tables 4-6 (Qualification), 4-7 (Acceptance), and 4-8 (Post-Delivery). With the elimination of failures due to certain design deficiencies, test errors, and defective lots of parts, the tables show a significant reduction in acceptance test failure reports as compared to qualification reports.

4.6.2 Quality Assurance

4.6.2.1 Inspection

All operations associated with instrument integration and test were under the cognizance of assigned quality control inspectors. Their responsibilities were as follows:

A. Maintained control of certification logs at all levels of assembly. This task included verification that all items of hardware and operation notes specified by applicable drawings were listed in the certification logs, serial, and/or MIT tag numbers recorded, and QA stamps placed to denote accept or reject of each hardware item or operation.

B. Verified that hardware configuration at all levels of assembly were as required by the authorized configuration identification list (CIL).

C. Witnessed all test operations to ensure that test methods, test results, and hardware handling were in accordance with applicable procedures.

D. Notified customer representatives of impending tests.

E. Prepared nonconforming material reports (NMR's) for all out-of-specification conditions.

Table 4-6

SUMMARY OF QUALIFICATION TEST FAILURE REPORTS

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2211	S082A	Filter Box Module	EMI Test Error
2212	S082A	Electronics Package	2N2222A Transistor (SP23418)
2227	S082A	Tripod Assembly	Piston (25577)
2228	S082A	Heater Panel Assembly	Thermistor (ST23303)
2237	S082B	Electronic Assembly	2N3384 Transistor (SP23542)
2254	S082B	TCS Power Supply	Test Error
2280	S082B	Electronic Assembly	Design Deficiency
2281	S082B	TCS	Design Deficiency
2290	S082B	PRS Electronic Assembly	Design Deficiency
2302	S082B	Electronic Assembly	2N3506 Transistor (SP23451)/Design Deficiency
2342	S082B	Predisperser Assembly	Design Deficiency
2348	S082B	Film Camera	Loading Error/ Design Deficiency
2354	S082B	Film Camera	Lubrication Failure/Design Deficiency

(Page 1 of 2)

Table 4-6 (continued)

SUMMARY OF QUALIFICATION TEST FAILURE REPORTS

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2363	S082B	Film Camera	Design Deficiency
2368	S082B	Electronic Subsystem	Coaxial Connectors

(Page 2 of 2)

Table 4-7

SUMMARY OF ACCEPTANCE TEST FAILURE REPORTS

(Page 1 of 1)

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2932	S082B	Electronic Assembly	CSR13 Capacitor (ST22282)
2394	S082B	Electronic Assembly	Assembly/Inspection Error
2397	S082B	Main Grating	Degradation of Grating Efficiency due to intermetallic reaction
2402	S082B	Electronic Assembly	Test Operator Error

Table 4-8

SUMMARY OF POST-DELIVERY FAILURE REPORTS

(Page 1 of 1)

Failure Report No.	Instrument	Assembly	Part Responsible for Failure
2403	S082B Flight	Electronic Assembly	CKR12 Capacitor (SP35028)
2428	S082B Prototype	Electronic Assembly	9040 Micrologic (ST23519)
2593	S082A Flight	Film Camera S/N A005	Test Operator Error/Design Deficiency
2594	S082A Flight	Film Camera S/N A004	Probably caused by partial load used for vertical tests
2595	S082B Flight	Film Camera S/N B006	Handle pivot shaft galled; design deficiency
2596	S082A Flight	Camera Canister S/N 002	Damage due to mishandling
2604	S082 Flight	Camera Canister	Analysis of organic odor
2610	S082B Flight	Camera Canister S/N 004	Damage due to mishandling
2418	S082A Flight	Film Camera S/N A006	Shuttle interference due to design deficiency

4.6.2.2 Quality Engineering

The assigned QA engineer ensured that all necessary inspections were accomplished and recorded by the quality control inspectors, nonconformances were dispositioned by the Material Review Board, and proper documentation accompanied each hardware shipment.

5.0 FIELD SUPPORT ACTIVITIES

Prior to, during, and after the Skylab missions, BBRC was required to supply systems engineering support to both MSFC and JSC at the NASA sites. These teams were a composite of key management, engineering, and test personnel, selected to support the Huntsville Operations Support Center (HOSC), the PI Science Team, and as Flight Controllers at the JSC Flight Control Center. They supplied mission planning and documentation, astronaut training and mission operational support. BBRC was also required to supply secretarial support for these teams.

5.1 MSFC MISSION SUPPORT

Several BBRC people were on site at Marshall Space Flight Center (MSFC) for approximately one year prior to the Skylab Mission, to aid in mission planning and preparation. This activity included general coordination and planning with the Huntsville Operations and Support Center (HOSC) and a continued definition of mission data requirements. Data requirements consisted of Auto Scan, Engineering Data Books (EDB), Compressed User Tapes (CUT) and systems data books. In addition, hardware support was provided relative to test schedule interface and equipment logistics.

Mission simulation tests were performed prior to the mission to check out the ground data system through the HOSC loop and to solve real time problems that required rapid solutions. These simulations were supported by the S082 systems engineering team from BBRC.

The MSFC Mission Support Team was on site (TDY) at MSFC during the entire Skylab Mission. This team was made up of key systems engineers who participated in the design, development, and test of the instruments. The team provided around-the-clock coverage and was backed up by systems specialists at BBRC as problems demanded.

The team personnel at MSFC monitored and evaluated the instruments' performance on a daily basis by console monitoring and evaluating real time and recorded data provided by the HOSC. Also daily communications with the principal investigator (PI) representatives at JSC aided in timely solutions to problems. The team provided work-arounds for all operational problems that resulted from instrument anomalies or Skylab/instrument interactions. They conducted systems and failure analysis, using available data, in conjunction with other instrument and ATM systems engineers.

Failure analysis support was enhanced by the use of the instrument engineering model units which were functional, and the Skylab/ATM flight backup units (FBU). The FBU was a fully operational ATM made up of the refurbished prototype units. It served as a valuable tool for fault simulation and operational work-arounds. BBRC also provided technical support to MSFC to establish the FBU as a flight-ready unit.

Included in the instruments performance evaluation was a computerized thermal distortion program. The program, developed by BBRC, provided the PI a near real time assessment of any photographic performance. The program input consisted of probe and sensor temperatures predominantly from the S082 instruments. The input information was processed through a series of matrices which produced the optical distortion parameters at the film plane. The parameters of image focus, and horizontal and vertical displacement with respect to time, were presented on machine-generated plots. Thus, degradation displacement rate and magnitude were available for correlation with selected exposure times. The program is capable of playing with the HOSC controlled tapes and Univac 1108 computer facilities at MSFC and at Slidell, Mississippi.

The mission support team was instrumental in the design, development, fabrication, test, and integration of the slit auxiliary timer for the S082B instrument on the SL-4 mission.

Post-mission activity continues in the areas of data processing and consolidation to improve the engineering data quality to an adequate level to be useful to the PI in scientific data evaluation. MSFC will continue to process SL-4 data and will reprocess SL-2 and SL-3 data with a planned completion during calendar year 1974. The data to be provided is in the form of CUT which will be transferred to NRL and EDB which will be provided to BBRC as they become available. Key personnel from the mission support team will upgrade the quality of the EDB by correlation with other data sources and submit the EDB corrections to MSFC. MSFC will then produce final versions of the EDB magnetic tape and tabulation and provide them to NRL.

BBRC will prepare a camera photographic log for each film camera flown on the Skylab mission. This log will summarize pertinent camera information to aid the PI's scientific data evaluation task.

5.2 JSC SUPPORT

Initially, in June 1970, two engineers were transferred to MSC (now JSC), Houston, to provide technical assistance pertaining to operation of the S082A and S082B instruments. One engineer was assigned to the Flight Control Division to aid in mission planning and in the definition of flight control requirements. The other was assigned to the Crew Procedures Division to assist in preparation of instrument operating procedures for the Skylab crew and to provide assistance in classroom instruction in the design, objectives, and operation of the instruments.

Within a year the JSC support requirements were expanded in both areas. Three additional engineers were requested by the Flight Control Division, making a total of four who were asked to undergo extensive training to become Flight Controllers for the S082 instruments during the Skylab mission. Duties in the Crew Procedures Division were expanded to include intensive direct training activities with the Skylab astronauts. A month before the mission began, a fifth flight controller was added to support the five flight control teams required for around-the-clock operation during the longer Skylab missions.

During the three manned Skylab missions, field support at JSC included the following:

A. Five flight controllers operated in the JSC flight control organization, manning the "SPEC" console, monitoring performance of the S082A and S082B instruments and providing flight control real time engineering decisions concerning instrument operations.

B. Continued support was provided for crew training of the second and third astronaut teams, and support was provided throughout the three missions for crew procedure revisions and updates.

C. Engineering support was provided to the NRL principal investigator and his team of scientists, assisting them in the planning and implementation of their scientific observing program throughout the Skylab missions.

6.0 MISSION PERFORMANCE

The S082A and S082B instruments were launched as a part of the Apollo Telescope Mount (ATM) portion of the Skylab 1 mission. The instruments were operated successfully during the subsequent Skylab (SL) 2, 3, and 4 manned missions and succeeded in obtaining high quality scientific data that equaled or exceeded the initial experiment and scientific objectives.

The Skylab mission schedule was as follows:

Mission	Launch Date	Termination Date	Duration [Days (D), Hours (H), Minutes (M)]		
SL-1	14 May 1973	N/A		N/A	
SL-2	25 May 1973	22 Jun 1973	28D	0H	49M
SL-3	28 Jul 1973	25 Sep 1973	59D	11H	9M
SL-4	16 Nov 1973	8 Feb 1974	84D	1H	15M

The total viewing time above 400 kilometers altitude for the Skylab mission was 724 hours 42 minutes.

6.1 S082A FLIGHT PERFORMANCE

The general operation and performance of the S082A Spectroheliograph instrument was excellent throughout the entire Skylab mission. One instrument and two related system problems occurred; however, acceptable work-arounds were implemented in each case.

A total of 1,024 exposures was accumulated on Kodak SWR 104 film and a small amount of SWR 101 film with six S082A film cameras, two on each mission. The SL-4 cameras were previously flown on SL-3. During SL-2, a film camera jam occurred; however, recovery was achieved by substituting the onboard SL-3 camera on the

subsequent extra vehicular activity (EVA) and by a resupply on the SL-3 launch.

Excellent instrument thermal and mechanism/subsystems performance as well as ATM pointing stability resulted in spatial resolution better than 2 arc-seconds. Although the spatial resolution of the data exceeded the specification requirements, faint streaks were observed on some of the SL-2 and SL-3 exposures. The streaks corresponded with the stainless steel film holder stiffener ribs. This problem resulted in a modification to the S082A cameras and use of the S082B flat aluminum film holders on SL-4, with excellent data results.

The instrument electronics and telemetry subsystem performed satisfactorily; however, an ATM/instrument interface problem occurred. The instrument operate light on the ATM C&D panel remained on after completion of an automatic sequence or a manual mode. The problem was isolated to a sneak circuit internal to the C&D subsystem. The inconvenience was overcome by a crew procedural change.

All telemetry data was normally updated at rates ranging from 12 update per second to one update every 15 seconds. Data noise or synchronization problems in the ATM telemetry caused some position monitors to exhibit false indications for one or more update periods. The most common result of this condition is that invalid film exposures were indicated or valid film exposures were missing. Therefore, a continuing data reduction effort will be maintained to sort out the engineering data necessary to reduce the scientific data.

The thermal control system performed well within its allowable tolerances. There were no failures in the TCS system, the

associated temperature sensors or the instrument temperature probes. The instrument average case temperature was maintained to $70^{\circ}F\ ^{+0.7}_{-2.0}$ under all operating conditions. The instrument was initially at $70^{\circ}F$ with an allowable deviation of up to $\pm 8^{\circ}F$.

Thirteen thermal distortion computer runs for SL-3 and ten runs for SL-4 verified that the image smear on the film plane, as a result of temperature gradients, was a small fraction of the allowable.

A related S082A problem occurred during SL-4 when the ATM thermal shield aperture door mechanism failed with the door in the Open position. The ATM door was subsequently pinned open by the astronaut on EVA. As the result of the aperture door thermal modifications implemented during KSC preflight tests, there was no loss of scientific data and the instrument thermal distortions were maintained within the allowable tolerances.

6.2 S082B FLIGHT PERFORMANCE

The general operation and performance of the S082B Spectrograph Instrument was acceptable throughout the Skylab Mission. The instrument operated normally in all modes. A review of the SL-2 data found the long wavelengths overexposed. This dictated an operational change that resulted in taking more manual exposures during SL-3. In order to reduce astronaut operating time, an auxiliary timer (see Fig. 6-1) was developed for the SL-4 Mission. BBRC designed, fabricated and tested the Slit Auxiliary Timer after the SL-3 Mission and in time for the SL-4 launch. This timing device was coupled to the C&D Panel by the crewman and it enabled him to take three automatic exposures of 10, 40 and 160 seconds in either the short or long wavelength. The exposures could also be scaled by 1/4 and 4 to provide ranges of 2.5 to 640 seconds. The timer provided efficient film management and simplified the astronaut operations on SL-4.

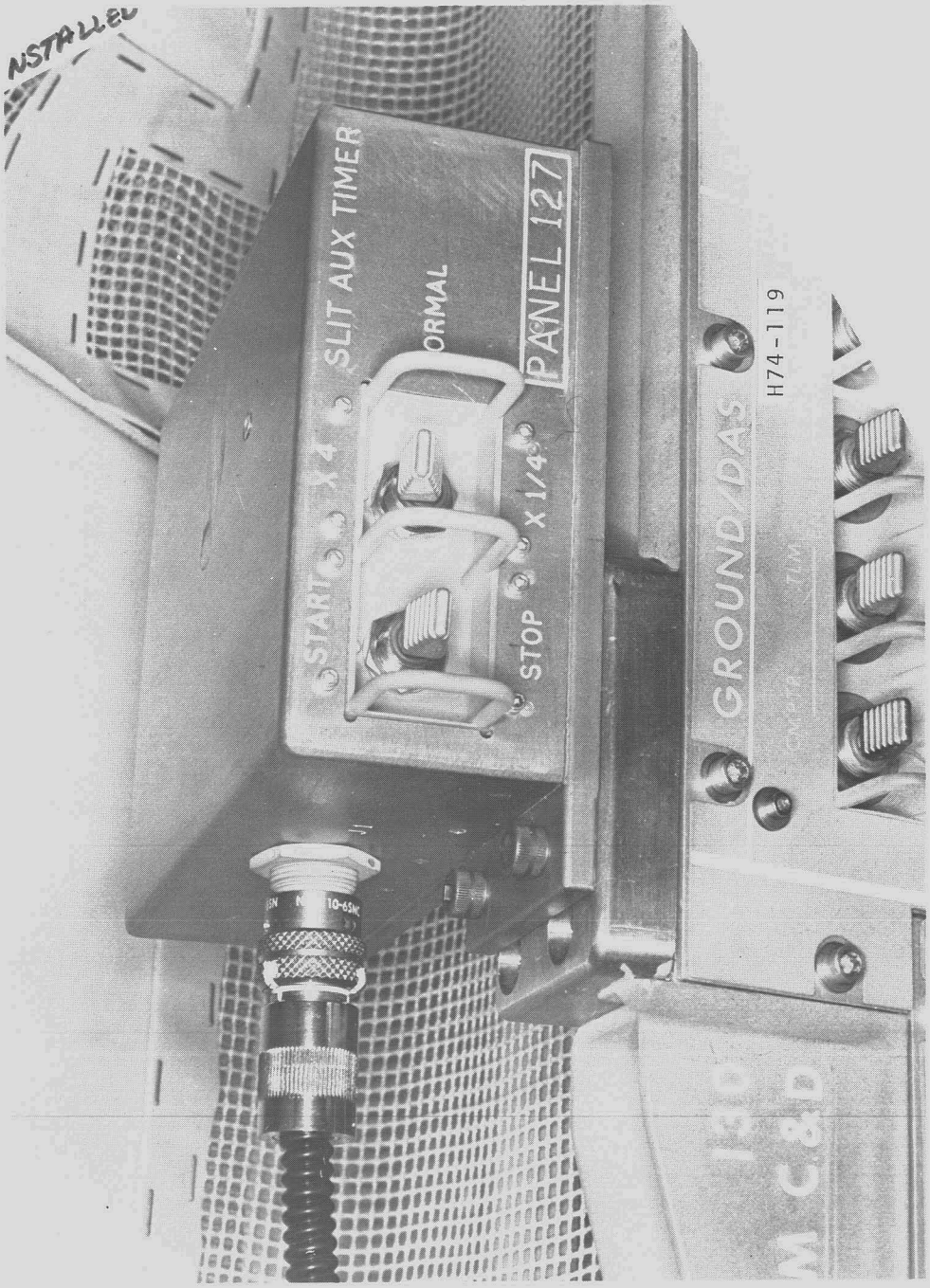


Figure 6-1. Slit Auxiliary Timer Installed on Flight Spare C&D Panel

A total of 6,411 exposures was accumulated with four SO82B film cameras. Two cameras were used on the SL-3 mission and one each on the SL-2 and SL-4 missions. The SL-4 camera was previously flown on SL-2. The SL-4 camera contained some special type SWR 101 film for the Comet Kohoutek observations, in addition to the normally used Kodak SWR 104 film. Excellent line spectra were obtained from the Skylab mission with many line widths as sharp as 12 to 15 microns.

The instrument electronics and telemetry system performed acceptably except for problems with the XUV monitor early in the mission and the PRS late in the mission.

The XUV video monitor in the C&D panel exhibited insufficient video levels to adequately determine solar activity without integration. With integration, the display time was too short to study the solar details. To enhance the usefulness of the system, a Polaroid SX-70 camera and Persistence Image Scope were launched on SL-3. The scope permitted the display to be observed for a longer duration, and the camera provided the crewman with a permanent record for historical reference and coordination with the principal investigator.

The PRS operated within specification during SL-2 and SL-3, maintaining ± 1 arc-second pointing accuracy. The operation of the PRS became marginal near the end of the SL-4 mission. Two of the three operation modes, Limb Scan and Limb Point, would not operate properly throughout the whole range of the system. The PRS would search for and not always lock onto the edge of the sun. Since the planned solar observations were within the PRS failure region, use of the PRS in the Limb Scan and Limb Point modes was discontinued for the remainder of SL-4. A suitable work-around was accomplished by using the ATM pointing system to position the sun's limb.

The S082B telemetry was not affected by noise, as much as the S082A, since all mechanical position monitoring telemetry was updated at 1/12 or 1/4 second intervals. ATM data noise and synchronization problems, however, also caused some film exposure record problems necessitating a continuing data reduction effort.

The TCS performed well within the allowable tolerances during normal solar observations. There were no failures in the TCS system, the associated temperature sensors or the instrument temperature probes. Thirteen thermal distortion computer runs were made for SL-3 and 49 runs were made for SL-4. The 49 runs included 27 runs for Comet Kohoutek observations and seven during full sunlit (high β angles) orbits. Excessive image smear and focus occurred during some of these long duration off pointing conditions. The extent of image degradation is a function of the degree of off pointing and duration.

The S082B ATM thermal shield door failed to close when commanded during SL-4. Because of this failure the drive mechanisms were disabled for both the main aperture and the XUV Monitor thermal shield doors, allowing them to remain open for the remainder of the SL-4 Mission. The instrument aperture door modifications, performed at KSC as the result of ATM thermal door test problems, allowed the TCS to maintain adequate control under these conditions.

The film camera canisters provided satisfactory environmental protection, for the cameras and film, when the cameras were not installed on the instruments.

Additional information relative to mission performance may be obtained from the following BBRC documents:

Document No.	Title
620-226	Skylab Missions SL-1/SL-2, NRL/ATM Instruments S082A and S082B
620-230	Skylab Mission SL-3, NRL/ATM Instruments S082A and S082B
620-237	Skylab Mission SL-4, NRL/ATM Instruments S082A and S082B

7.0 CALIBRATION SYSTEMS

The calibration systems encompass three (3) separate systems: the FDVU's, the CALROC's and the Stratospheric Ozone (Balloon Flights). The FDVU's were designed and developed to be launched from WSMR prior to the completion of the ATM instruments built to verify the engineering design concepts and define optimum exposure ranges for the ATM instruments. The CALROC Program was designed to fill the gap of two (2) years in which the ATM instruments could not be calibrated. The Stratospheric Ozone experiments measured the amount of ozone in the stratosphere for correlation with the ATM atmospheric absorption measurements.

7.1 FLIGHT DESIGN VERIFICATION UNITS (FDVU's)

The NRL/ATM FDVU-A Spectroheliograph and FDVU-B Spectrograph are Flight Design Verification Units (FDVU's) developed for engineering concept verification and exposure verification using discrete spectral and high spatial resolution solar intensity measurements. A total of six FDVU's was launched from White Sands Missile Range (WSMR) in support of the ATM Program during the period between June 1968 and August 1971. Two of the FDVU's launched were one-half scale model versions of the S082A Experiment (see Fig. 7-1) and four were of the S082B design (see Fig. 7-2). The two FDVU-A Instruments were different units, required by a recovery system failure on the first launch. The FDVU-B launches were all of the same basic unit, refurbished and reflown three times after the first launch in February 1969. Detailed information on all of the FDVU's can be found in the following BBRC Documents:

- Final Report - NRL/ATM Spectroheliograph Flight Design Verification Unit, FDVU-A2, BBRC Document No. 620-61 dated 27 March 1970.

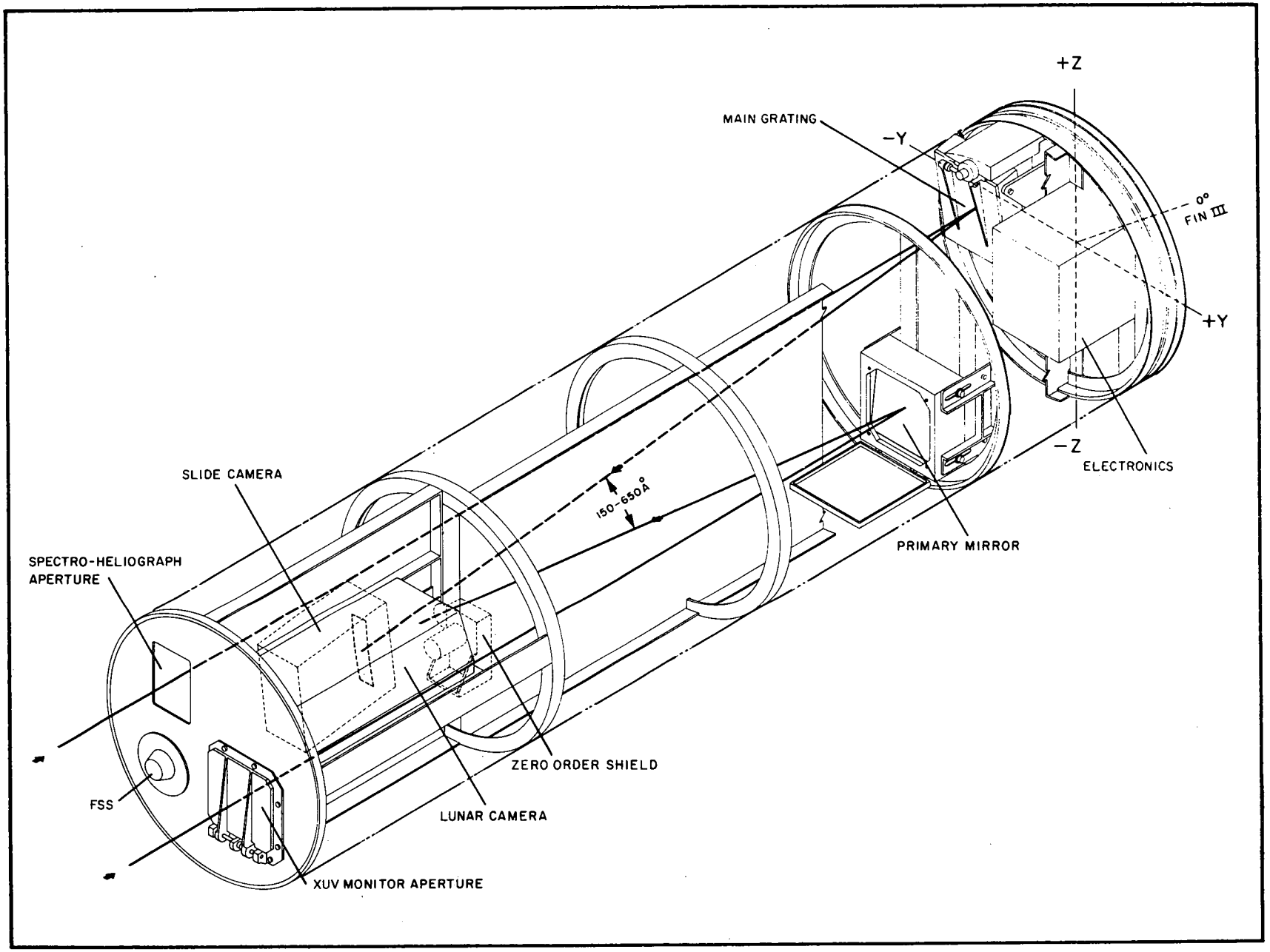


Figure 7-1. Line Drawing of NRL FDVU Instrument A

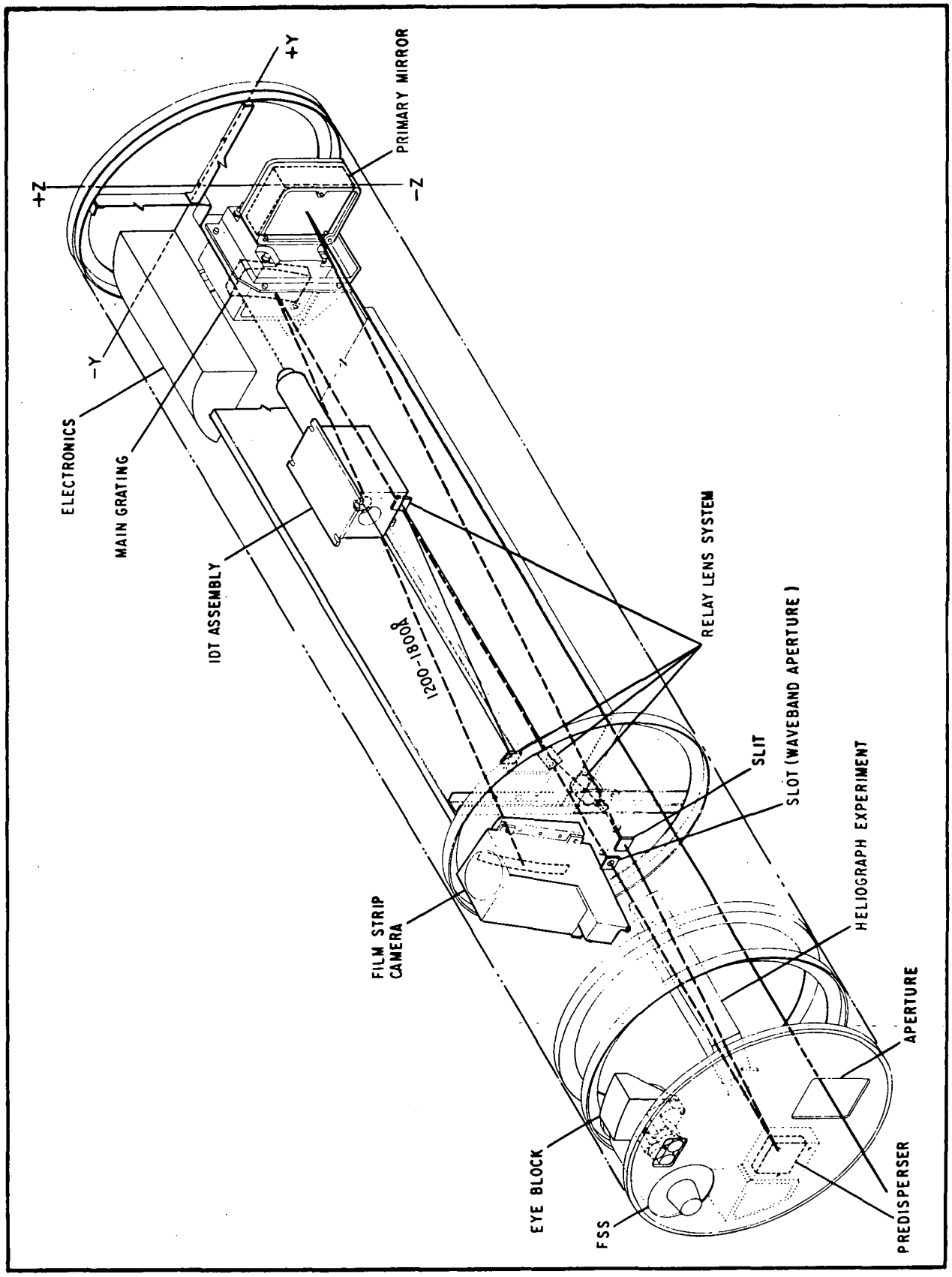


Figure 7-2. Line Drawing of NRL FDVU Instrument B

- Final Report - NRL/ATM Flight Design Verification Unit, FDVU-B Instrument BR^3, BBRC Document No. 620-128 dated 15 November 1971.

Briefly summarizing these reports, all the objectives of the FDVU-A instruments were satisfied with the flight of FDVU-A2 launched using an Aerobee 150 sounding rocket, on 4 November 1969 during a Class I bright solar flare. The launch occurred following a 14-day standby period waiting for a solar flare of suitable magnitude to occur coincident with periodic availability of launch support from the White Sands Missile Range.

All systems performed as designed during flight. Good spectroheliograms were obtained in the spectral region between 150 and 650Å. A video tape of the solar image in the 150 to 650Å region was obtained from XUV monitor. The payload was successfully recovered in good condition following the flight.

The FDVU-B instrument obtained data on the last two of its four flights. Most of the objectives were satisfied when FDVU-BR^3 was launched on an Aerobee 170 from the White Sands Missile Range at 3:00 p.m. Thursday, 12 August 1971. Flight objectives were the acquisition of additional solar XUV spectrograms on and near the solar limb, verification of solar intensity levels for the S082B Pointing Reference System (PRS) and verification of S082B Spectrograph design characteristics.

In spite of excessive pointing oscillations by the SPARCS pointing control (40 to 60 arc-second peak-to-peak at approximately 0.7 Hz) the instrument pointing reference system managed to hold the spectrograph entrance slit to within 10 arc-seconds of the desired position relative to the solar limb (goal was 1 arc-second). Good spectrograms were thus obtained although the instrument was badly damaged due to failure of the recovery parachute.

The FDVU's provided the desired engineering verification and solar intensity measurements necessary for the larger S082A and S082B experiments. Based on FDVU data analysis, changes were made to exposure times for both the S082A and S082B experiments.

In addition to these contributions to the ATM instruments, the FDVU's also provided a realistic background for personnel who were later involved with training the Skylab astronauts to operate the S082A and S082B instruments and the flight controllers on the ground to monitor the instruments' telemetry signals.

Some of the FDVU personnel participated in the nine-month Skylab mission. Other personnel with FDVU experience were instrumental in the calibration rocket (CALROC) program which provided real time calibration of the S082A and S082B experiments.

7.2 NRL CALIBRATION ROCKETS

When Skylab was launched on 14 May 1973, it has been more than two years since the last complete calibration of the instruments. During this time, the various tests performed on the Skylab Apollo Telescope Mount (ATM) cluster subjected the solar experiment instruments to environmental conditions which may have contaminated or otherwise changed their potential performance. Changes in the optical efficiency and the photographic emulsions were expected to occur when the instruments were exposed to the space environment throughout the Skylab mission.

Various techniques of in-orbit recalibration were considered but generally were ruled out since they also would be subjected to unpredictable changes.

Coordinated data taking by calibration instruments launched on sounding rockets and the Skylab orbiting instruments appeared to be the most practical approach. Thus, the birth of the NRL calibration rocket (CALROC) instruments.

Since the cycle time of the CALROC instrument through film load, preflight calibration, launch, and post-flight calibration was about eight days, and the conditions were closely controlled, unknown changes in the data were minimized.

7.2.1 Calibration Rocket Mission and Instrument Descriptions

The instruments were launched from the White Sands Missile Range (WSMR) in New Mexico on the Black Brant VC vehicles. The payload was separated from the rocket motor and pointed at the sun using the Solar Pointing Aerobee Rocket Control System (SPARCS) developed by Ames Research Center. A typical flight profile is shown in Figure 7-3. Overall arrangement of the rocket and the payload are shown in Figure 7-4.

Data was acquired during each flight by four experiments. Two subsystems aid in acquiring the data. The four experiments were all photographic.

A. "A" Spectroheliograph:

Photographed the full sun and provided 22 spectroheliograms from 170 to 760Å to aid in calibrating the Skylab ATM S082A Spectroheliograph.

B. "B" Spectroheliograph:

Acquired 24 spectrograms covering 1200 to 2135Å to calibrate the Skylab ATM S082B Spectrograph.

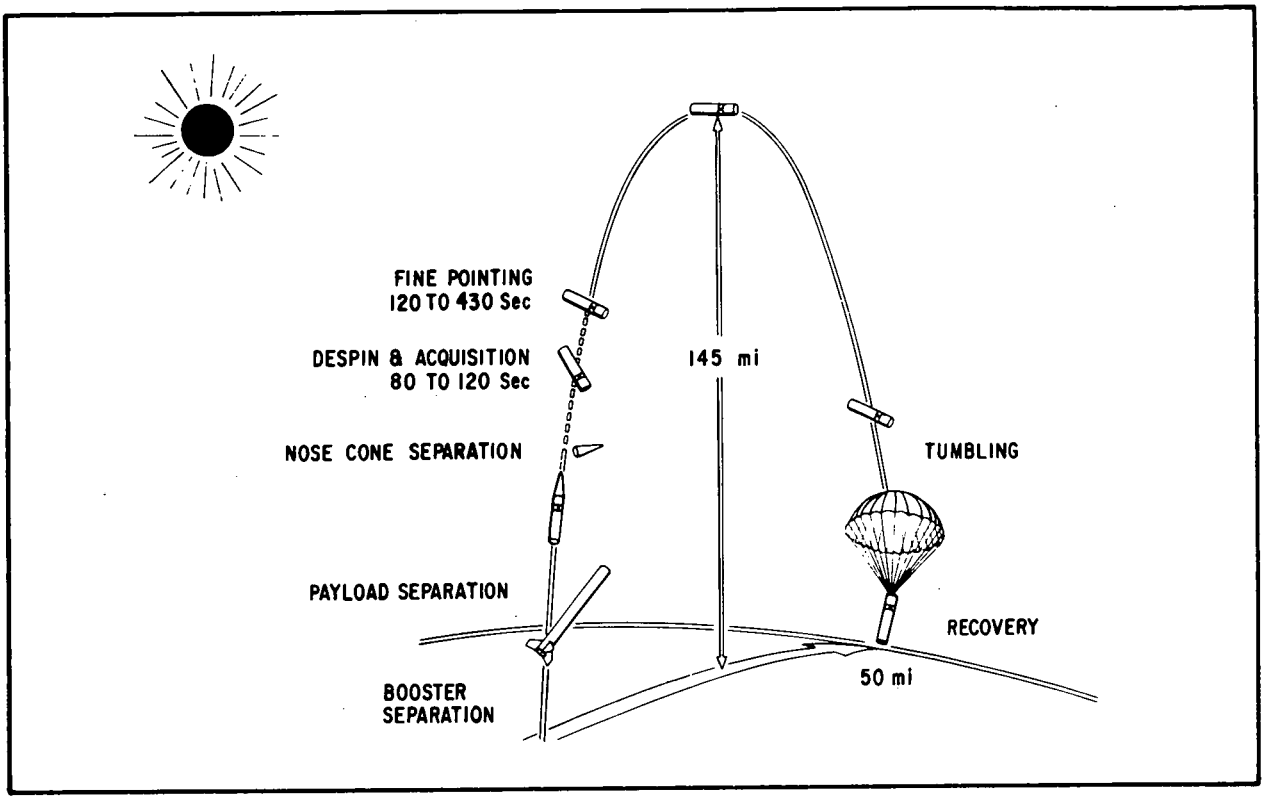


Figure 7-3. Typical Flight Profile

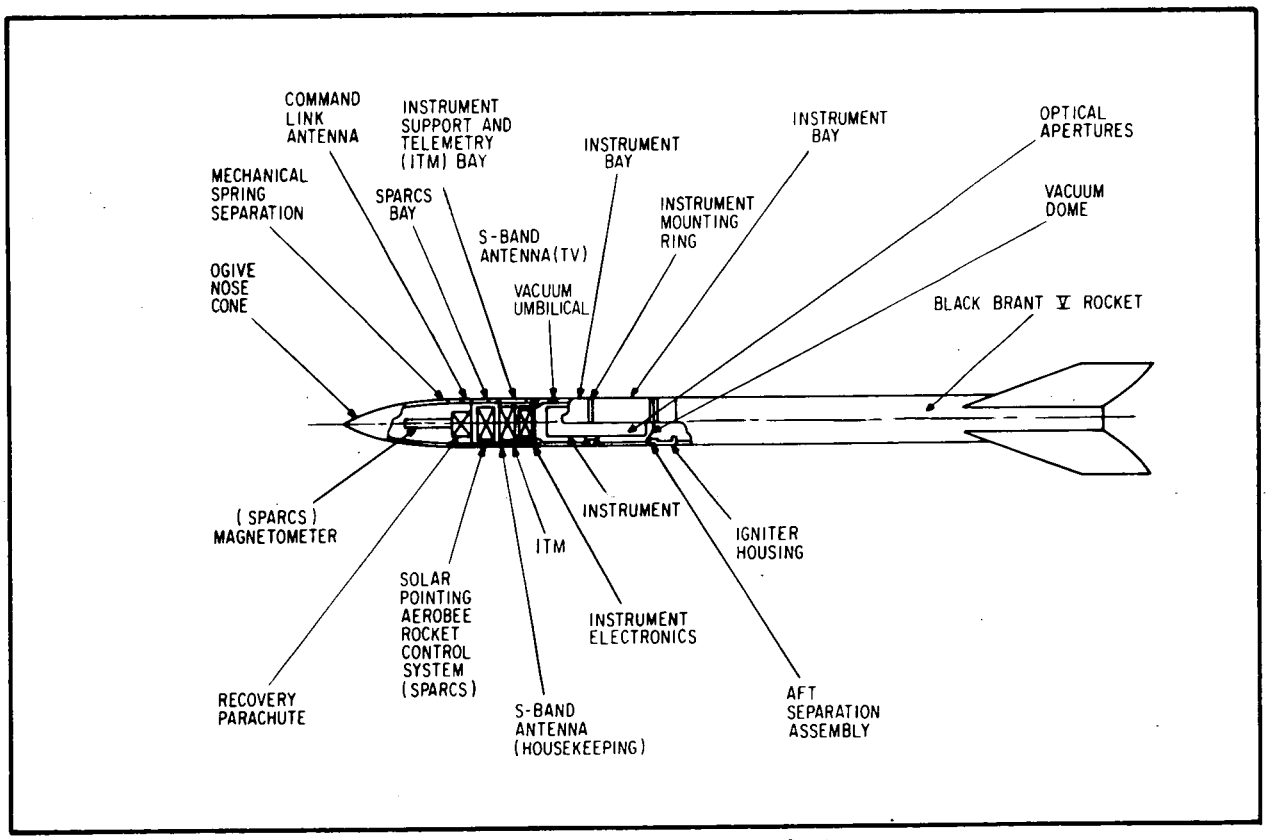


Figure 7-4. Rocket and Payload Arrangement

C. "C" Spectrograph:

This experiment acquired 24 spectrograms covering 1200 to 2000Å and provided H&D curves for the flight film being used in the CALROC experiments.

D. "H" Heliograph:

Provided 12 photographs of the full sun in the integrated wavelengths between 150 to 650Å for corollary information and ATM XUV video monitor reference.

The "A" Spectroheliograph and the "B" Spectrograph were one-half scale duplicate optical systems of the oribiting Skylab systems.

The supporting subsystems are:

- H-Alpha Television and Photographic Subsystem
- Fine Pointing Subsystem (FPS)

The absolute pointing position of the CALROC "B" Spectrograph Experiment was controlled with ±0.5 arc-second in azimuth by the FPS during flight. Absolute elevation position within a few arc-seconds and roll position within ±0.5° was controlled by the PI through a command link to the payload pointing system (SPARCS).

The solar coordinates of the photographed positions were determined in real time during the CALROC flight and were relayed to the Skylab astronauts who photographed the same point on the sun with the Skylab ATM S082B Spectrograph.

The absolute pointing position was determined from the H-alpha television image transmitted from the instrument during flight.

7.2.2 Summary

Three CALROC instruments were fabricated. Figures 7-5 and 7-6 show the CALROC's at WSMR.

The first instrument was launched before Skylab was launched to serve as an engineering model to uncover problems prior to the calibration launches during the Skylab orbital missions. The launch of the engineering round also served to set up and check out the complex ground equipment used by the CALROC PI to control and evaluate instrument pointing during the flight of the payload.

The engineering round (NI-1 - 21.011) was launched on 3 April 1973. Two problems resulted in a complete loss of data. The SPARCS did not acquire the sun and the parachute did not open. The resulting impact destroyed the instrument. All telemetry indicated the calibration instrument was performing as designed and would have acquired data if the instrument had pointed at the sun.

The second instrument (NI-2 - 21.012) was launched during the first Skylab orbital mission on 13 June 1973 and had to serve a dual purpose: engineering information and calibration. The instrument pointed and provided calibration information, but there was some loss of data due to problems which would have been observed had the engineering round been successful. Briefly, the problems were related to fogging of the SWR 101 UV film (the SWR 104 UV film did not fog) and several unexplained jumps in the SPARCS pointing position (approximately one arc minute) resulting in smearing of some of the photographs.

The third instrument (NI-3 - 21.013) was launched on 4 September 1973 from the WSMR. This instrument performed well and acquired calibration and scientific data from all experiments.

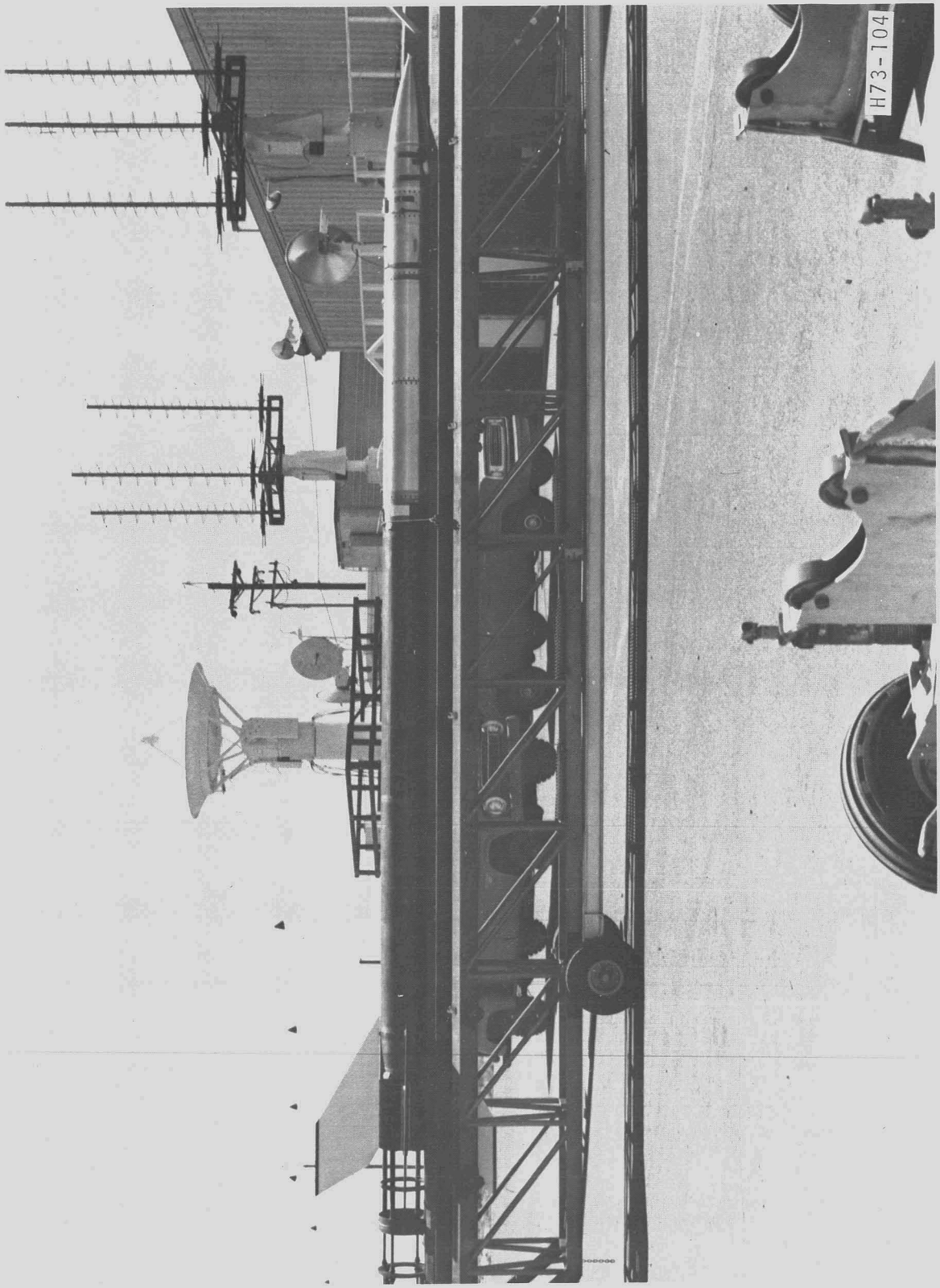


Figure 7-5. CALROC Ready for Tower

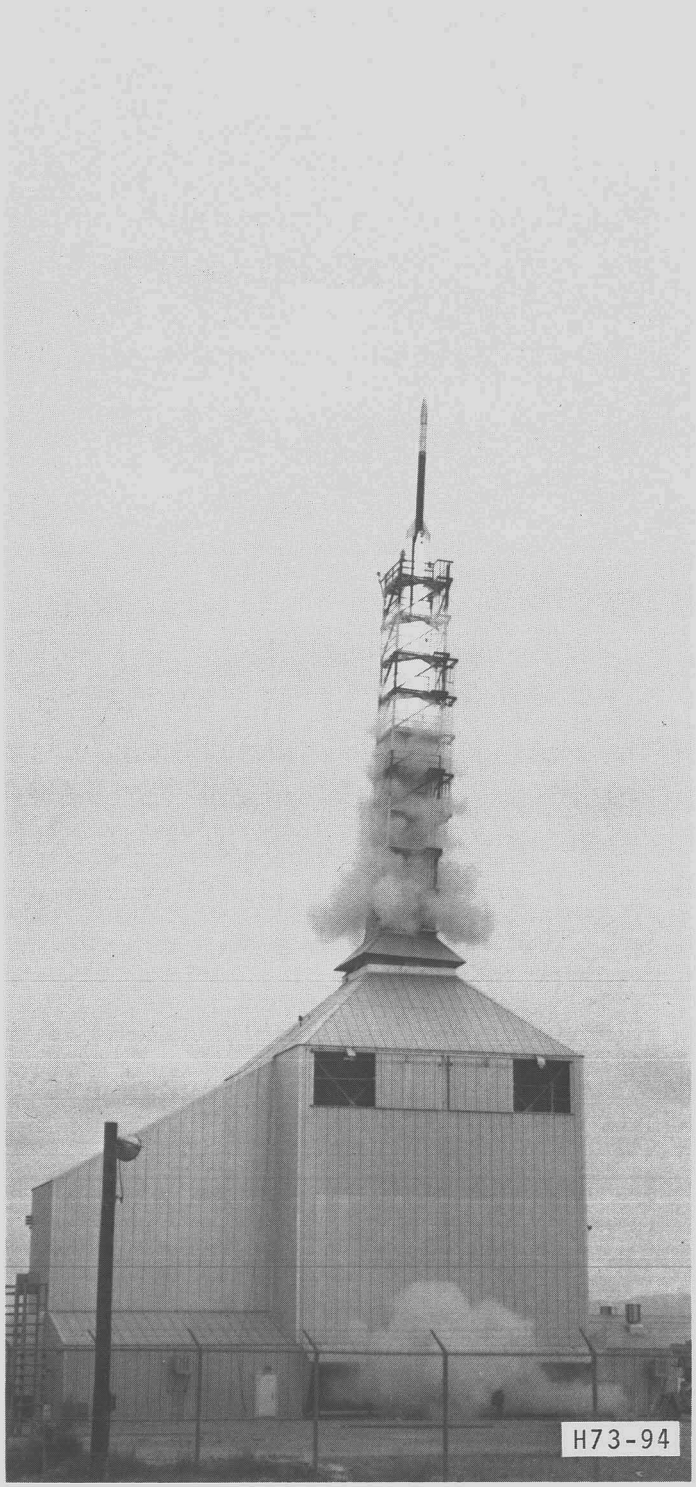


Figure 7-6. CALROC Launch from White Sands Missile Range

NI-3 instrument was refurbished and flown 15 January 1974 (21.014). This was a near perfect flight by all subsystems and excellent calibration data were obtained.

The CALROC instrument may well represent the most complex group of experiments ever assembled within a sounding rocket payload. In addition, the use of a television link and the command link provides the capability to point to specific H-alpha features or to any desired position on the sun. The FPS provides the additional capability to point to a position on or off the solar limb over a range of ±75 arc-seconds to within ±0.5 arc-second absolute pointing relative to the limb. The limit cycle (jitter) of the main pointing system (SPARCS) is removed in one axis by the FPS which provides pointing stability of ±0.25 arc-second.

The CALROC payloads have come as close as possible to putting the PI in the enviable position of the Skylab astronauts, as far as observing the sun in real time and selecting interesting features to which he can point and obtain scientific data. Previously, one had to depend on preprograming the pointing system and hoping for the best.

The Naval Research Laboratory has been well aware of the growing concern over increasing costs of sounding rocket payloads. These rising costs are due in part to the growing complexity of the payloads themselves as the experimenters continue to push the state-of-the-art to achieve more science.

Early in the CALROC project, NRL concluded that the way to increase the amount of scientific data obtained per dollar spent

was to form an integrated team of Government and private contractor personnel to develop the instrument. This team concept provided maximum capability in all areas and resulted in the completion of these instruments at minimal cost and within the tight schedule.

For details of the NI-1, NI-2, NI-3 and NI-4 Calibration launches, see BBRC Document Nos. 620-223, 620-235, 620-232 and 620-233.

7.3 STRATOSPHERIC OZONE

During the third manned mission to Skylab, the S082B Instrument was operated and took pictures of the sun through the earth's atmosphere. Ozone in the stratosphere absorbs short wavelength ultraviolet radiation and this radiation, therefore, would be attenuated on the S082B film exposed during this time. The majority of ozone in the earth's atmosphere is located in the stratosphere but varies in concentration depending on the time of year, latitude above or below the equator, barometric pressure and on local weather that causes thunderstorms to rise and penetrate the low stratosphere.

As an aid to interpret and calibrate the S082B Instrument's experiment for atmospheric attenuation, an instrument was designed, fabricated and flown as a balloon payload into the stratosphere to establish a reference point. The data from this experiment was also applicable to the climatic impact assessment program being conducted by the Department of Transportation. This agency was gathering data to determine if nitric oxide that may be released in the stratosphere by a fleet of supersonic transports would combine with the ozone and deplete it to the extent that life on earth would be affected. NRL and DOT worked together to have BBRC conduct a balloon flight that had goals of measuring the ozone concentration and profile through the stratosphere, measuring nitric oxide concentration, determining ozone depletion with released nitric oxide and determining pollutant dispersion rates in the

stratosphere. The specific performance, design, and product configuration requirements for the balloon payload instruments were established in configuration item specifications. These specifications are CI43767 for ozone measurement instrument, CI43768 for nitric oxide measurement instrument, CI43769 for smoke generator, and CI43770 for balloon payload support structure. The following paragraphs describe the instruments.

7.3.1 Ozone Measurement Instrument

This instrument uses the "White Cell" principle of multiple reflections to obtain a 100 meter path length between mirros two meters apart. Two wavelengths of ultraviolet radiation are alternately passed through the white cell. The shorter wavelength (2537Å) is absorbed by ozone in proportion to the amount of ozone present while the longer wavelength (3131Å)is not absorbed and is used as a reference. The mirror support structure is invar tubing and plates. This material has low thermal expansion and therefore minimizes this effect on mirror alignment. The tubular support structure is designed with as much open area as possible to allow free circulation of ozone and nitric oxide. An electronic control box containing the source lamp and photomultiplier detector tube is mounted on top of the mirror support structure. The source lamp produces broadband ultraviolet radiation that passes through the white cell. A filter wheel driven by a rotary solenoid moves two bandpass filters back and forth through the exit beam before the beam enters the detector tube. A low noise amplifier is also in the control box to condition the photomultiplier tube output before the signal is telemetered to the ground. A functional block diagram of the ozone instrument is shown in Figure 7-7.

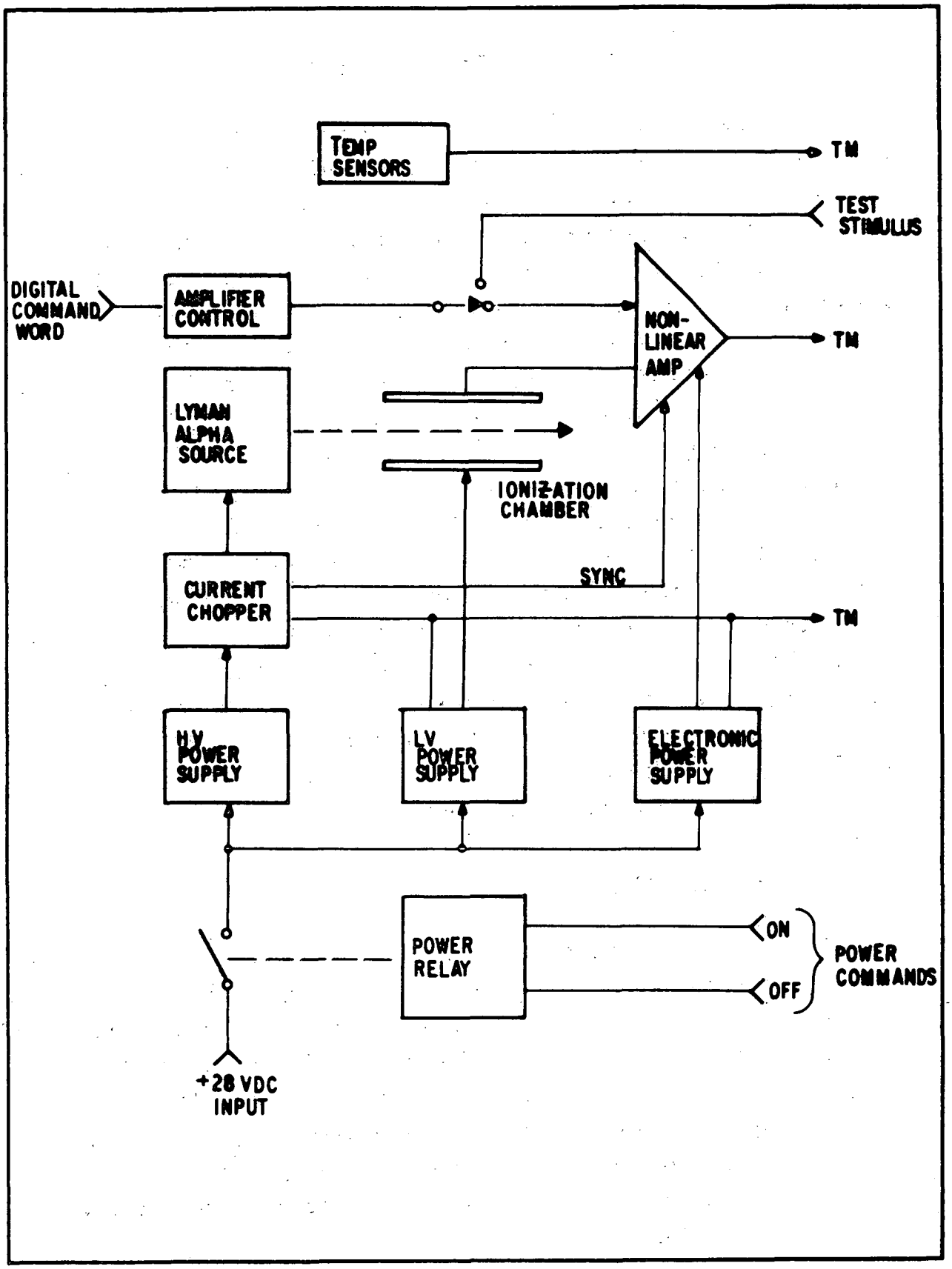


Figure 7-7. Functional Block Diagram Ozone Measurement Instrument

7.3.2 Nitric Oxide Measurement Instrument

This instrument uses an ionization chamber principle to detect nitric oxide. Lyman-α radiation ionizes nitric oxide which then causes a current to flow between two charged plates. The amount of current flow is proportional to the amount of nitric oxide present. Two lamps, one hydrogen and one xenon filled radiate alternately in between the charged plates. The hydrogen lamp produces strong Lyman-α radiation (1215.7Å) while the xenon lamp does not. Each lamp produces photoelectrons when the radiation falls upon an item such as the edges of exit apertures and produces a background current flow which is undesirable. A high impedance preamplifier is located near the detector plates but inside a protective metal box. The instrument electronics synchronously detects and filteres the ion current to provide the nitric oxide indication. Current due to xenon lamp-produced photoelectrons is used to cancel background photoelectron current produced by the hydrogen lamp, thereby resulting in a signal which is the sole result of nitric oxide ions. An electronics junction box is also used with this instrument for control and to condition the signals for telemetry. Figure 7-8 shows a functional block diagram of the nitric oxide instrument.

7.3.3 Smoke Generator

The smoke generator consisted of 20 cartridges and launchers and an electronics junction box. The launchers ejected the cartridges away from the payload so that when they exploded into a smoke puff would not contaminate the payload optics and thermal control systems. The smoke puffs were to be observed from the ground by photographing from two locations with Questar telescopes equipped with Nikon 35mm cameras. Time sequence photographs were then going to be used to determine dispersion rates in the stratosphere at the payload height.

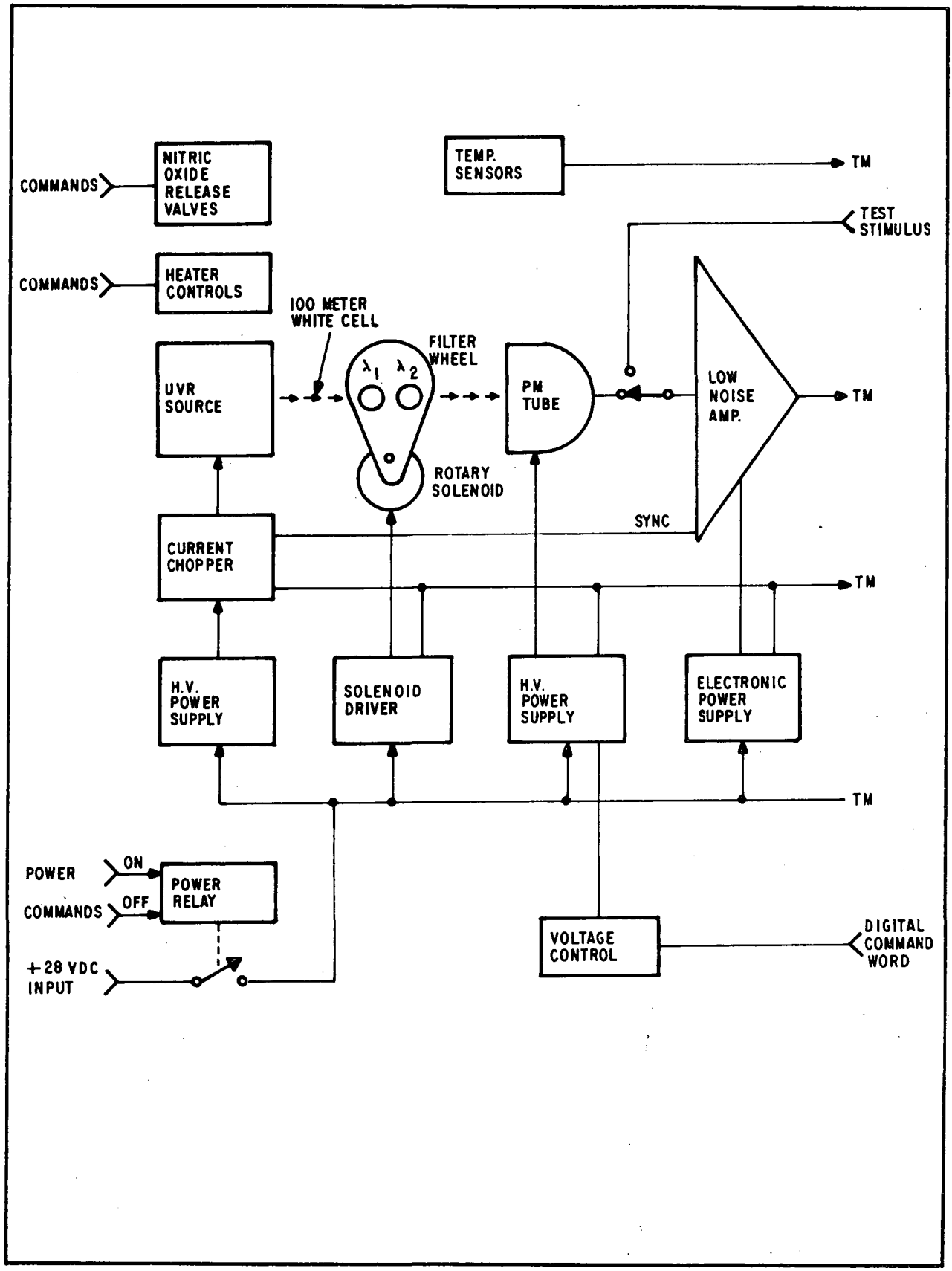


Figure 7-8. Functional Block Diagram Nitric Oxide Measurement Instrument

7.3.4 Nitric Oxide Release Subsystem

This part of the balloon payload was designed to release nitric oxide from a storage bottle at five pre-selected flow rates into the area of the White Cell. Reaction rates of nitric oxide with ozone were then to be determined by the increase in the 2537 Å signal.

7.3.5 Payload Support Structure

A triangular based pyramid tubular structure was designed to hold the scientific instruments. This configuration resulted from the requirements for an open structure for ozone and nitric oxide circulation, minimum blockage of the sun and the 2 meter long White Cell that had to be vertical. The Payload Support Structure also had provisions for the balloon command and telemetry package, ballast tanks and crushable pads for recovery. Figure 7-9 shows a photograph of the complete payload during final preparations before launch.

7.3.6 Pre-Flight Tests

Testing included thermal vacuum operation at BBRC and ambient operations at the National Scientific Balloon Facility (NSBF) at Palestine, Texas. The Nitric Oxide Instrument was also tested extensively in a vacuum bell jar. These tests established several design parameters for this instrument and a calibration curve of nitric oxide concentration versus output signal from the ion chamber. During the thermal vacuum tests, ozone was released into the chamber and the ozone instrument immediately detected its presence. The concentration decreased to zero in a few minutes as ozone is very reactive with most materials. The instrument registered the gradual decrease and was judged to have adequate sensitivity to measure ozone concentration in the stratosphere. After a cold soak period, the smoke cartridge launchers were activated and ejected a dummy cartridge and nitric oxide was released. The presence of nitric oxide was noted for a short time before the Nitric Oxide Instrument output became saturated. Later it was found that after activating

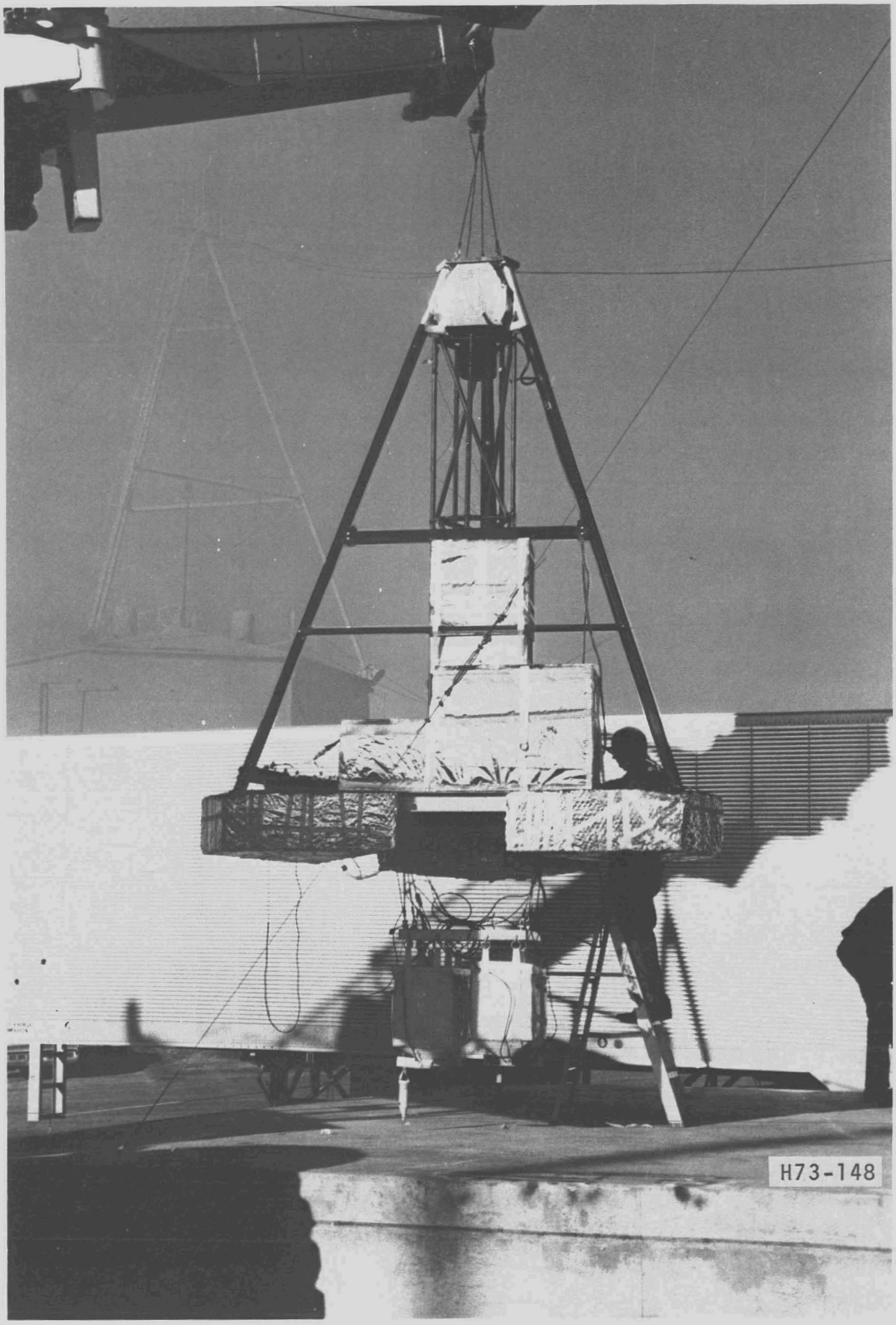


Figure 7-9. NRL Ozone/Nitric Oxide Balloon Payload

the nitric oxide release system it could not be completely shut off and subsequently exhausted all the storage bottle into the thermal vacuum chamber. The release system was reworked before the flight but the same thing apparently happened during the flight as the storage bottle was empty when the payload was recovered.

Ambient testing in full sunlight revealed a sensitivity of the Ozone Instrument to scattered radiation that saturated the 3131 Å output from the source lamp. This was reduced to an acceptable level by painting everything on the payload flat black, increasing the gain of the photomultiplier tube and adding a light emitting diode in front of the photomultiplier tube which supplied a simulated sun background during night and automatically dimmed during the daytime to produce a constant 3131 Å signal.

7.3.7 Flight Summary

The launch weight of the payload was 2,255 lbs which included 1,400 lbs of lead shot for altitude control. This much ballast was necessary to achieve the desired flight profile. Launch was in the late evening with enough helium in the balloon to go up to the first float altitude of 30 km. It was intended to have a 22-24 hour flight but the winds aloft were fast enough that the payload was out of range before dawn the next day. After the first float altitude, a second altitude was established at 26 km. During the descent to the third altitude, commands to the balloon control were erratic, resulting in a lower altitude than intended. The third float altitude was allowed to increase so commands would not have to be sent. At dawn the payload was already 190 miles down range and out of effective photographing and command range from the launch site. Two photographing crews followed the payload during the night, but lost ground after dawn when the wind aloft speed increased. The crews set up and attempted to take photographs of the smoke puffs which were released on commands from a chase airplane, but due to the distance no smoke was seen. During the early night

float altitudes, ozone was detected and the subsequent calculations indicated the instrument was measuring the expected concentrations. Due to the high wind aloft difficulty, only about one-fourth of the scientific objects were obtained. The payload was cut loose from the balloon at approximately 9:30 a.m. and was recovered in good condition near Scooba, Mississippi.

Detailed descriptions of the instruments, support electronics, balloon command and telemetry system, testing and flight parameters can be found in the Flight Report, NRL Ozone/Nitric Oxide Balloon Flight, BBRC NRL Project Report No. 620-231.

8.0 CONFIGURATION AND DOCUMENTATION MANAGEMENT

8.1 DOCUMENTATION

The major documents prepared on this program are listed in Tables 8-1 and 8-2. Table 8-1 is a numerical listing while Table 8-2 is a list by category. These documents were prepared and submitted in accordance with contract data requirements list (Exhibit C and C1) and program needs. The requirements for the engineering design, performance, and interfaces were established and specified. These requirements are defined in Design and Performance Specifications (D&PS) BBRC Document Numbers CP25100, CP25905, CP24038, and CP24039, and in the Experiment Interface Defining Document (EIDD) MSFC No. 50M02462. Preliminary D&PS's were prepared and submitted for approval during 1967. A preliminary Experiment Interface Requirements Document BBRC No. TR67-53 was submitted 15 May 1967 for approval. This document was later incorporated into the EIDD and published by MSFC. The preliminary Astronaut Operations Requirement Documents, BBRC Numbers TR67-54 and TR67-55 were submitted to NRL and subsequently were released as NRL documents. The End Item Test Specifications, BBRC Document Numbers 28340 and 28341, were prepared later as a subdocument to the D&PS's and detailed all qualification and acceptance tests. The Experiment Alignment Procedures, BBRC Document Numbers 24951 and 24952, were additional requirements documents prepared and submitted to the customer for approval.

All drawings are listed in the Authorized Build and Configuration List or Indentured Parts List for the particular end item in question. All drawings were prepared and maintained as required by the Configuration Management Plan for NRL/ATM experiments, BBRC Document No. 620-3. Approximately 3,500 drawings were produced with an average of five engineering change orders per drawing.

All contractual requirements specifications, drawings, and documents are listed in BBRC Document No. 620-5, Configuration Status Report for NRL/ATM S082 instruments. This document also contains lists of the engineering change proposals, specification changes, interface changes, deviation approval requests, deviations/waivers, 620 documents, time compliance technical orders, data request forms and technical directives.

8.2 DESIGN REVIEWS

Two formal design reviews were conducted by configuration management at BBRC at Boulder, Colorado. Both reviews were chaired by MSFC. The preliminary design review (PDR) was conducted in three parts, 18-20 July 1967, 26-27 September 1967, and 18-19 January 1968. The critical design review (CDR) was conducted in two parts, 29 July through 2 August 1968, and delta critical design review (ΔCDR) 18-19 August 1969.

The PDR consisted of three separate reviews as follows:

- Design/interface review (18-20 July 1967)
- Experiment interface review (26-27 September 1967)
- Man-machine interface review (18-19 January 1968)

The primary purpose of these meetings was to baseline the contractual requirements documents. The minutes and action items are recorded in the following documents:

- TR67-66, "Design/Interface Review Meeting (18-20 July 1967)"

- MSFC Memorandum of 29 September 1967 from E. H. Cagle: Subject, "NRL/BBRC/MSFC S053 Experiment Interface Review"

- MSFC Memorandum of 8 February 1968 from A. White and W. Keathley: Subject, "ATM-NRL Experiment S082A, S082B and S053B Man-Machine Interface Review Meeting"

The complete design and testing of both ATM instruments, including XUV monitor, were reviewed during the critical design review. The material presented during the review was recorded in the CDR handout. The primary objective of the CDR was to baseline the design of the instruments, cameras, and canisters. As a result of this review, it was determined that a delta CDR would be required to review areas which had not progressed to a point where they could be baselined. The minutes and action items are recorded in the following documents:

- MSFC Memorandum of 30 August 1968 from W. Keathley and A. White: Subject, "Minutes: Critical Design Review for the ATM Experiment S082"

- MSFC Memorandum of 14 January 1969 from W. Keathley and A. White: Subject, "Results of Naval Research Laboratory (NRL) S082 ATM Experiment Critical Design Review (CDR)"

The material presented in the delta CDR is recorded in the handout at the meeting.

The results of the PDR and CDR meetings are contained in the following documents:

- 620-158, Inputs to Skylab Design Certification Review Report NRL/ATM Experiment S082A

- 620-163, Inputs to Skylab Design Certification Review Report NRL/ATM Experiment S082B

8.3 CONFIGURATION AUTHORIZATION BOARD AND CHANGE CONTROL BOARD

At the outset of the contract the requirement for two configuration management boards was established.

The configuration authorization board (CAB) was organized immediately after the first part of the PDR with program manager as chairman and the project engineer, configuration management as secretary, acting for the chairman in his absence. The CAB was a nonvoting board in which the chairman had the final decision. After any document had been baselined by the customer any changes thereto became subject to CAB decision. If the board ruling was a Class I change, an engineering change proposal (ECP) was prepared and if approved by the CAB, was submitted to the customer for approval.

The change control board (CCB) reviewed and approved all Class II changes to the engineering drawings after the design had been baselined. The CCB also reviewed Class I engineering changes to ensure conformance with an approved ECP. This board was chaired by the project engineer, configuration management, and attended by system project engineer, design project engineer, drafting checker, and a representative of other areas as required, i.e., reliability, quality assurance, production, materials and processes, stress, weights, and thermal. The CCB was a nonvoting board in which the board chairman had the final decision.

Table 8-1

DOCUMENTATION NUMERICAL LISTING

Page 1 of 31

Doc No.	Title	Rev	Date
CI43767	SPECIFICATION, Configuration Item; Performance, design, and Product Configuration Requirements; Ozone Measurement Instrument; NRL/BBRC Balloon Payload	A	9/6/73
CI43768	SPECIFICATION, Configuration Item; Performance, Design, and Product Configuration Requirements; Nitric Oxide Measurement Instrument; NRL/BBRC Balloon Payload	A	9/6/73
CI43769	SPECIFICATION, Configuration Item; Performance, Design, and Product Configuration Requirements; Smoke Generator; NRL/BBRC Balloon Payload	A	9/6/73
CI43770	SPECIFICATION, Configuration Item; Performance, Design and Product Configuration Requirements; Balloon Payload Support Structure; NRL/BBRC Balloon Payload	A	9/6/73
CP22879	SPECIFICATION, Design and Performance; XUV Coronal Spectroheliograph Instrument ATM Experiment S053A; SCN's 1,2, 4,4R1,5,6,8,10,11,13,14,15,16,17,19, 20,21,23 and 24	Basic	8/30/67
CP22880	SPECIFICATION, Design and Performance; XUV Spectrograph Instrument ATM Experiment S053B; SCN's 1,2,3,5,5R1,6,8,10, 11,13,14,16,17,18,19,20,21,23,24,26, and 27	Basic	8/30/67
CP24038	SPECIFICATION, Design and Performance; Experiment Checkout Equipment, XUV Coronal Spectroheliograph Instrument A; SCN's 10 and 14	A	3/15/69
CP24039	SPECIFICATION, Design and Performance; Experiment Checkout Equipment, XUV Spectrograph Instrument B; SCN's 4,12, 16,17, and 18	A	3/15/69

Table 8-1

DOCUMENTATION NUMERICAL LISTING

Page 2 of 31

Doc No.	Title	Rev	Date
CP25100	SPECIFICATION, Design and Performance; XUV Spectrograph Instrument 1B ATM-A Experiment S082B; SCN's 43,44R1,45,47, 48,50,51,52,53,54,55,57,58,59,60R1,61, 62R1, and 63	C	8/10/70
CP25905	SPECIFICATION, Design and Performance; XUV Coronal Spectroheliograph Instrument ATM Experiment S082A; SCN's 39, 40,42,43,44,46,47,48R1,49,50R1, and 51	B	8/10/70
CP35690	SPECIFICATION, Configuration Item; NRL/HCO/ATM Transporter Purge Package	B	-------
CP36294	SPECIFICATION, Configuration Item; NRL/ATM Purge Control and Filter Unit	Basic	-------
F67-09	FEASIBILITY Analysis and Design for a Pointing Reference System	Basic	5/10/67
F67-10	HIGH Voltage Corona Detector System Study	Basic	6/9/67
F68-04	FINAL Report NRL/ATM Flight Design Verification Unit (FDVU) Instrument A	Basic	7/19/68
M69-29	REPORT on Retractor Cam and Lever Problems on the NRL Film Magazine (EMU-A and Prototype)	Basic	11/16/69
M69-30	REPORT on Shutter Functional Testing on the NRL Film Magazine (EMU-A)	Basic	11/17/69
TN67-44	EVALUATION of Fairchild Transistor 2N3504	Basic	7/19/67
TN67-47	EVALUATION of TRW and Dearborn Polycarbon Capacitors	Basic	8/4/67
TN67-56	EVALUATION of Fairchild Transistor 2N3964	Basic	10/1/67
TN67-58	EVALUATION of Field Effect Transistor 2N3972	Basic	8/18/67

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TN67-76	EVALUATION of Motorola Transistor 2N3506	Basic	10/2/67
TN67-82	EVALUATION of Fairchild LPDTul 9040, 9041 and 9042 Micrologic	Basic	10/2/67
TN67-83	EVALUATION of Motorola Transistor 2N3763	Basic	10/2/67
TN67-85	EVALUATION of Motorola Transistor 2N4222A Field Effect Transistor	Basic	10/9/67
TN67-94	EVALUATION of Vitramon VY15, VY20, and VY30 Porcelain Capacitors	Basic	10/20/67
TN67-96	EVALUATION of Amelco 2N3921 and Union Carbide 2N3954 Dual N Channel Field Effect Transistors	Basic	10/20/67
TN67-99	EVALUATION of Fairchild Transistor 2N4023	Basic	10/20/67
TN67-162	EVALUATION of Amelco and Fairchild 2N2920 Dual NPN Transistors	Basic	11/1/67
TN67-198	EVALUATION of Motorola Transistor 2N3447	Basic	11/28/67
TN67-204	EVALUATION of Metal Film Resistors, Extended Range, IRC Type CCB, Pyrofilm, Type PME 60 and PME 65	Basic	12/20/67
TN68-01	EVALUATION of General Electric 2N2364 NPN Transistor	Basic	1/12/68
TN68-30	VIBRATION Summary NRL/ATM Rocket Flight Design Verification Units	Basic	2/9/68
TN68-37	EVALUATION OF Pyrofilm Metal Film Resistors Type PME 60 and PME 50	Basic	3/1/68
TN68-38	RELIABILITY Analysis of XUV Spectroheliograph Instrument ATM-A Experiment SO82A	Basic	4/12/68

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TN68-42	EVALUATION of Amelco 807BE Integrated Operational Amplifier	Basic	3/18/68
TN68-49	EVALUATION of SC-1018-2 2KV Ceramic Capacitor	Basic	5/1/68
TN68-60	EVALUATION of Metallized Plastic Film Capacitors	Basic	5/17/68
TN68-65	SPECTROGRAPH Entrance Slit Shortener	Basic	6/4/68
TN68-66	POINTING Reference System (PRS)	Basic	6/4/68
TN68-67	ANALYSIS, Reliability of XUV Spectrograph Instrument S082B, ATM-A Experiment	Basic	7/18/68
TN68-94	EVALUATION of Fairchild and Solid State Products, Inc. 2N2891 Transistor	Basic	9/6/68
TN68-95	EVALUTION of Union Carbide 2N5114, 2N5115, 2N5116, and Amelco 2N5018, 2N5019, P-Channel Field Effect Transistor	Basic	8/28/68
TN68-98	EVALUATION of 3N74 Dual Emitter Transistor	Basic	10/1/68
TN68-110	EVALUATION of Motorola 2N3026 PNP Power Transistor	A	3/5/69
TN68-177	EVALUATION of Hewlett Packard 4310 and 4320 Photon Coupled Isolators	Basic	1/3/69
TN69-05	EVALUATION of the Microswitch IHMI	Basic	2/3/69
TN69-10	EVALUATION of Unijunction Transistor 2N4948	Basic	4/14/69
TN69-11	EVALUATION OF Motorola 2N3251 Transistor	Basic	2/14/69
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TN72-32	THE 3-Phase Variable Reluctance 15° Stepper Motor (Incorporated in the ATM/NRL Camera Design)	Basic	11/17/72
TN72-33	TECHNIQUES for Real Time X-Y Plotting of Force versus Position Characteristics on Complex Spring/Friction Moving Mechanisms (Developed for ATM/NRL Camera Programs)	Basic	11/20/72
TN69-46	EVALUATION of Fairchild μA709 Series Integrated Operational Amplifier	Basic	3/20/69
TN69-52	EVALUATION of Motorola 1N5285, 1N5288, 1N5291 Current Regulator Diodes	Basic	4/9/69
TN69-54	EVALUATION of Monsanto MV10A Visible Light Emitting Diodes	Basic	4/9/69
TN69-61	EVALUATION of Unitrode UTX4105 and UTX 4110 Diodes	Basic	5/1/69
TN69-77	FAILURE Mode, Effect and Criticality Analysis (Part III)	Basic	6/17/69
TN69-90	FAILURE Mode, Effect, and Criticality Analysis (Part III) of XUV Coronal Spectroheliograph Instrument S082A ATM-A Experiment	Basic	6/30/69
TR65-130	RELIABILITY Assurance Plan for NRL Spectroheliograph Experiment	Basic	12/22/65
TR66-110	EVALUATION of 1N4152 GE Diodes and FDH 600 Fairchild Diodes	Basic	12/15/66
TR67-53	PRELIMINARY Experiment Interface Requirements Document for NRL/ATM XUV Spectrograph and Spectroheliograph	A	5/15/67
TR67-54	PRELIMINARY Astronaut Operations Requirements Document XUV Coronal Spectroheliograph for the Apollo Telescope Mount	Basic	5/12/67

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TR67-55	PRELIMINARY Astronaut Operations Requirements Document XUV Spectrograph for the Apollo Telescope Mount	Basic	5/15/67
TR67-57	PLAN, Reliability Assurance Program, NRL/ATM Spectroheliograph and Spectrograph Experiments; SCN 2	A	4/5/68
TR67-59	PLAN, Electromagnetic Compatibility Control, Apollo Telescope Mount XUV Coronal Spectroheliograph and XUV Spectrograph Instruments; SCN 1	Basic	11/21/67
TR67-60	PLAN, Electromagnetic Compatibility Test, Apollo Telescope Mount XUV Coronal Spectroheliograph and XUV Spectrograph Instruments; SCN 2	Basic	10/31/67
TR67-66	DESIGN/Interface Review Meeting		7/18/67 7/20/67
TR68-43	NEW Technology Report Precision Mounting by Precision Mounting by Bonding for Instrument Optical Elements	Basic	7/26/68
TR69-11	NRL Spectrograph Thermal Model (NRL/ATM TMU-B) Production Notes	Basic	2/7/69
TR69-12	NRL Spectroheliograph Thermal Model (NRL/ATM TMU-A) Production Notes	A	2/7/69
TR69-13	MATERIALS Evaluation Report NRL/ATM XUV Coronal Spectroheliograph and XUV Spectrograph Instruments	Basic	3/15/69
TR69-16	ELECTRONIC Instrumentation NRL Photoelectric XUV Spectrograph/Spectroheliograph Instrument	Basic	3/1/69
TR71-02	NEW Technology Report Spectrographic Film Strip Camera	Basic	1/15/71
TR71-08	NEW Technology Report Matrix Fence for Printed Wiring Boards	Basic	2/15/71

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TR73-15	NEW Technology Report Thermal Control System for NRL/ATM S082B Spectrograph	Basic	10/73
22553	INTERFACE, Mounting Hole, NRL/ATM Instrument A	A	5/6/68
22555	OUTLINE, Configuration, NRL/ATM Experiment B	G	7/3/68
22643	LAYOUT, Optical, NRL/ATM Experiment B XUV Spectrograph	A	6/21/68
22664	OUTLINE, Configuration, NRL/ATM Experiment A, XUV Coronal Spectroheliograph	G	6/21/68
22801	SYSTEM, Optical, XUV Coronal Spectroheliograph, NRL/ATM Instrument A	C	3/27/73
24239	ENVELOPE, Camera Space, NRL/ATM	C	2/9/71
24240	ENVELOPE, Camera Canister Space, NRL/ATM	D	10/4/71
24490	INTERFACE, Mounting Hole, NRL/ATM Instrument B	Basic	-------
24669	ENVELOPE, Camera Space, NRL/ATM	D	6/27/72
24670	ENVELOPE, Camera Canister Space, NRL/ATM	D	10/4/71
24862	DRAWING, Portable Test Set, Instrument A	A	12/4/68
24951	PROCEDURE, Experiment Alignment, XUV Coronal Spectroheliograph NRL/ATM Experiment S082A	B	7/22/70
24952	PROCEDURE, Experiment Alignment, XUV Spectrograph NRL/ATM Experiment S082B	C	8/3/72
24967	DRAWING, Portable Test Set Outline, Instrument B	A	12/4/68

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25111	SYSTEM, Optical, XUV Spectrograph NRL/ATM Instrument B (S082B)	D	12/15/70
26482	OUTLINE, Configuration, NRL/ATM Instrument 1-A, XUV Coronal Spectroheliograph	F	3/27/73
26483	OUTLINE, Configuration, NRL/ATM Instrument 1-B, XUV Spectrograph	F	5/4/71
28340	SPECIFICATION, End Item Test, XUV Coronal Spectroheliograph Instrument ATM Experiment S082A; SCN's 20,22, 23R1,24R1,25 and 26	A	8/11/70
28341	SPECIFICATION, End Item Test, XUV Spectrograph Instrument ATM Experiment S082B; SCN's 15,16,17,19R2,20,22,24, 25R1,26R1,27 and 28	A	8/5/70
29300	ASSEMBLY, XUV Spectroheliograph NRL "A"	N	4/5/72
29301	ASSEMBLY, XUV Spectrograph NRL "B", Thermal Control Installation	M	4/5/72
30547	PROCEDURE, Physical Measurements Test, NRL/ATM S082A Spectroheliograph Instrument	B	12/11/69
30548	PROCEDURE, Pre-Qualification/Acceptance Test, NRL/ATM S082A Spectroheliograph Instrument	C	10/5/72
30549	PROCEDURE, EMI Test, NRL/ATM S082A Spectroheliograph Instrument	B	2/20/70
30550	PROCEDURE, Vibration Test, NRL/ATM S082A Spectroheliograph Instrument	C	10/15/70
30551	PROCEDURE, Post-Environmental Test, NRL/ATM S082A Spectroheliograph Instrument	D	8/31/72
30552	PROCEDURE, Acoustic Test, S082A Spectroheliograph Instrument Electronics	B	3/2/70

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30554	PROCEDURE, Thermal Vacuum Test, NRL/ ATM S082A Spectroheliograph Instrument	C	8/17/72
30555	PROCEDURE, Post Thermal Vacuum Test, S082A Spectroheliograph Instrument	A	6/22/70
30556	PROCEDURE, Vertical Position Test, S082A Spectroheliograph Instrument	Basic	3/6/70
30557	PROCEDURE, Physical Measurements Test, Film Cameras, NRL/ATM S082A Spectro-heliograph Instrument	A	8/28/70
30558	PROCEDURE, Pre-Acceptance Test, Film Cameras, NRL/ATM S082A Spectrohelio-graph Instrument	E	3/8/72
30559	PROCEDURE, Vibration Test, Replacement Camera, NRL/ATM S082A Spectrohelio-graph Instrument	C	12/31/71
30560	PROCEDURE, Thermal Vacuum Test, Replace-ment Camera, NRL/ATM S082A Spectro-heliograph Instrument	E	6/12/72
30561	PROCEDURE, Post Thermal Vacuum Test, Replacement Camera, NRL/ATM S082A Spec-troheliograph Instrument	C	3/9/72
30562	PROCEDURE, Physical Measurements Test, NRL/ATM S082B Spectrograph Instrument	B	1/8/71
30563	PROCEDURE, Pre-Qualification/Acceptance Test, NRL/ATM S082B Spectrograph Instru-ment	B	10/30/72
30564	PROCEDURE, EMI Test, NRL/ATM S082B Spectrograph Instrument	Basic	5/4/70
30565	PROCEDURE, Vibration Test, NRL/ATM S082B Spectrograph Instrument	B	10/5/72
30566	PROCEDURE, Post-Vibration Test, NRL/ ATM S082B Spectrograph Instrument	B	11/2/72

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30569	PROCEDURE, Thermal Vacuum Test, NRL/ ATM S082B Spectrograph Instrument	B	1/8/73
30570	PROCEDURE, Post Thermal Vacuum Test, NRL/ATM S082B Spectrograph Instrument	B	11/2/72
30571	PROCEDURE, Vertical Position Test, NRL/ ATM S082B Spectrograph Instrument	Basic	5/4/70
30572	PROCEDURE, Physical Measurements Test, Film Cameras, NRL/ATM S082B Spectrograph Instrument	B	5/3/72
30573	PROCEDURE, Pre-Acceptance Test, Film Cameras, NRL/ATM S082B Spectrograph Instrument	F	7/26/72
30574	PROCEDURE, Vibration Test, Replacement Camera, NRL/ATM S082B Spectrograph Instrument	E	8/2/72
30575	PROCEDURE, Thermal Vacuum Test, Replacement Camera, NRL/ATM S082B Spectrograph Instrument	E	8/2/72
30576	PROCEDURE, Post Thermal Vacuum Test, Replacement Camera, NRL/ATM S082B Spectrograph Instrument	C	8/8/72
31472	MEASUREMENT, Degradation, NRL/XUV LLLTV Camera	B	4/30/70
31555	PROCEDURE, Handling and Shipping, NRL/ ATM S082A Spectroheliograph and S082B Spectrograph Instruments	B	8/31/70
31876	PROCEDURE, Acceptance Measurements, Low Light Level Television Camera System, NRL/ATM	A	9/18/70
33849	PROCEDURE, Vacuum Contamination Test, LLLTV Camera Contamination Test	C	12/19/69

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34033	SPECIFICATION, Configuration Item, Performance/Design and Product Configuration Requirements, XUV Calibration Source Set NRL/ATM Program	*	11/12/69
35643	SPECIFICATION/Procedure, Post Delivery Receiving Test, NRL/ATM S082A Spectroheliograph Instrument	B	11/2/70
36360	ASSEMBLY, Magazine Configuration, XUV Film	K	1/24/72
36361	ASSEMBLY, Magazine Configuration, XUV Film	H	7/18/72
36564	SPECIFICATION/Procedure, Post Delivery Receiving Test, NRL/ATM S082B Spectrograph Instrument	C	2/9/73
36636	PROCEDURE, Film Camera/Instrument Compatibility Test, NRL/ATM S082A Spectroheliograph Instrument	B	11/7/70
37276	PROCEDURE, Predisperser Pre-Installation Test, S082B Spectrograph Instrument	Basic	8/25/70
37353	PROCEDURE, Predisperser Qualification Test, S082B Spectrograph Instrument	Basic	9/15/70
37391	PROCEDURE, Film Camera/Instrument Compatibility Test, NRL/ATM S082B Spectrograph Instrument	Basic	10/22/70
37488	SPECIFICATION/Procedure, Test, NRL/HCO/ATM Transporter Purge Package	Basic	12/19/70
38005	PROCEDURE, Filter Ground Wire Qualification Test, NRL/ATM S082B Monitor Instrument	Basic	12/10/70

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39384	PROCEDURE, Film Camera Loading, NRL/ ATM S082A Spectroheliograph and S082B Spectrograph	E	11/28/72
39797	PROCEDURE, Qualification Test, NRL/ ATM Canisters (BBRC Model AF10A)	A	4/4/72
39798	PROCEDURE, Acceptance Test, NRL/ATM Canisters (BBRC Models AF10A and AF10B)	A	3/10/72
40037	PROCEDURE, Calibration, NRL Camera Test Drive Control Unit	B	1/15/73
40118	PROCEDURE, Zero-G Test, NRL/ATM Film Cameras, CM10A and CM11A	Basic	6/2/72
40751	PROCEDURE, Supplemental Qualification Test, Film Camera CM10A, NRL/ATM S082A Spectroheliograph Instrument	Basic	2/1/72
40752	PROCEDURE, Supplemental Qualification Test, Film Camera CM11A, NRL/ATM S082B Spectrograph Instrument	A	5/12/72
40888	PROCEDURE, Acceptance Test, NRL/ATM S082A Spare Components	Basic	5/15/72
41856	PROCEDURE, Cleaning, NRL/ATM Film Camera	A	2/7/73
620-1	PLAN, Development and Operations, NRL Rocket Experiments	D	12/16/68
620-2	Not Used	---	--------
620-3	PLAN, Configuration Management, NRL/ ATM Experiments	Basic	12/8/67
620-4	PLAN, End Item Test, NRL/ATM S082A Spectroheliograph Instrument	B	4/1/69
620-5	REPORT, Configuration Status, S082 Instruments	P	4/18/73

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620-6	LIST, Material Identification, NRL/ ATM Instruments S082	A	8/25/69
620-7	LIST, Approved Parts, NRL/ATM Spectro-heliograph and Spectrograph	C	6/27/69
620-8	LIST, Authorized Build and Configura-tion, NRL/ATM Instrument S082A	AA	5/1/73
620-8-1	LIST, Authorized Build and Configura-tion, NRL/ATM Film Magazine Assembly (S082A Instrument) S/N 001 Prototype	F	11/3/70
620-8-2	LIST, Authorized Build and Configura-tion, NRL/ATM Film Magazine Assembly (S082A Instrument) S/N 002 Flight and Subsequent	T	5/1/73
620-9	LIST, Authorized Build and Configura-tion, NRL/ATM Instrument S082B	AE	5/1/73
620-9-1	LIST, Authorized Build and Configura-tion, NRL/ATM Film Magazine Assembly (S082B Instrument) S/N 001 Prototype	R	6/12/72
620-9-2	LIST, Authorized Build and Configura-tion, NRL/ATM Film Magazine Assembly (S082B Instrument) S/N 002 Flight and Subsequent	W	5/2/73
620-10	PROCEDURE, Vibration Test, ATM/TMU	Basic	7/17/68
620-11	PROCEDURE, Acoustic Noise, NRL/ATM	Basic	8/25/68
620-12	PROCEDURE, Preliminary Thermal Vacuum Tests, ATM/TMU	A	8/16/68
620-13	PROCEDURE, Thermal Vacuum Test, NRL/ ATM TMU-A and TMU-B	B	1/13/69
620-14	PLAN, Design Evaluation of Electronics Packaging, NRL/ATM	Basic	11/20/68
620-15	PROCEDURE, Spectrograph Calibration, FDVU "B"	Basic	9/20/68

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620-16	PROCEDURE, Spectrograph Experiment Functional Test and Flight Readiness Checklist NRL/ATM FDVU-B	B	6/15/70
620-17	PLAN, End Item Test, NRL/ATM S082B Spectrograph Instrument	A	4/1/69
620-18	PLAN, Test Responsibility, NRL/ATM FDVU-A2	Basic	4/16/69
620-19	PLAN, Development and Operations, NRL/ATM FDVU Spectroheliograph XUV Monitor Instrument A2	A	6/2/69
620-20	REPORT, Design Evaluation - Electronics Packaging, NRL/ATM	Basic	3/15/69
620-21	PLAN, Acceptance, NRL/ATM	Basic	5/15/69
620-22	INSTRUCTIONS, Description and Operating EX13B NRL TMU	A	3/1/69
620-23	INSTRUCTIONS, Description and Operating, EX14B NRL TMU	A	3/1/69
620-24	PROCEDURE, Predelivery Measurements and Checkout, NRL/ATM TMU-A and TMU-B	Basic	2/1/69
620-25	INSTRUCTIONS, Description and Operating, NRL/ATM Integration Timer	Basic	1/15/69
620-26	LIST, Recommended Spare Parts, NRL-A and B and ECE Instruments	E	3/18/73
620-27	REPORT, Calibration Test, FDVU-B Rocket	Basic	1/20/69
620-28	REPORT, Thermal Mechanical Unit, NRL/ATM A	Basic	5/15/69
620-29	REPORT, Thermal Mechanical Unit, NRL/ATM B	Basic	5/15/69
620-30	REPORT, Telescope Mirror Test, NRL/FDVU-B	A	6/26/69

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620-31	PLAN, Development and Operations, NRL Rocket Experiment FDVU-BR	Basic	6/2/69
620-32	PROCEDURE, Optical Alignment, NRL/ FDVU-B	*	------
620-33	REPORT, Flight Design Verification Unit (FDVU), Final, NRL/ATM Instrument B	Basic	6/9/69
620-34	MEASUREMENTS, Electrical Interface, S082A Spectroheliograph Instrument	Basic	5/15/69
620-35	PROCEDURE, Alignment, NRL/FDVU-A2 Spectroheliograph and XUV Monitor	Basic	7/1/69
620-36	PROCEDURE, Functional Test and Flight Readiness Check List, NRL/ATM FDVU-A2 Spectroheliograph - XUV Monitor	Basic	7/21/69
620-37	LIST, Authorized Build and Configuration, ATM/LM Simulator and Checkout Console "A"	A	12/17/70
620-38	LIST, Authorized Build and Configuration, ATM/LM Simulator and Checkout Console "B"	A	4/23/71
620-39	REPORT, Primary Mirror Mount Vibration Test, NRL/ATM FDVU-B	Basic	6/25/69
620-40	REPORT, Design Verification Test, NRL/ATM Experiments S082A and S082B	Basic	7/1/69
620-41	PROCEDURE, Optical Alignment, NRL/ ATM FDVU-BR	Basic	7/18/69
620-42	PROCEDURE, Thermal Control Subsystem (TCS) Adjustments, NRL/ATM S082A Spectroheliograph Instrument	Basic	8/29/69

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620-43	INSTRUCTIONS, Description and Operating, ATM/LM Simulator and Checkout Console, BBRC Models GS13A and GS13C	C	2/8/71
620-44	INSTRUCTIONS, Description and Operating ATM/LM Simulator and Checkout Console, BBRC Models GS14A and GS14C	C	2/8/71
620-45	PROCEDURE, Horizontal Vertical Three-Hour Launch Countdown, NA 4, 137DS, NRL/ATM FDVU-BR WSMR	Basic	9/10/69
620-46	CALIBRATION, Telemetry, NRL/ATM S082 Spectroheliograph Instrument	Basic	9/18/69
620-47	CALIBRATION, Telemetry, NRL/ATM S082B Spectrograph Instrument	B	3/20/73
620-48	CALIBRATION, Temperature versus Voltage, NRL/ATM S082A Spectroheliograph Instrument, Thermal Control Subsystem	Basic	9/18/69
620-49	CALIBRATION, Temperature versus Voltage, NRL/ATM S082B Spectrograph Instrument, Thermal Control Subsystem	Basic	4/20/70
620-50	PROCEDURE, Horizontal Vertical One-Hour Launch Countdown, NA4, 136DS, NRL/ATM FDVU-A2 WSMR	Basic	9/22/69
620-51	PROCEDURE, Optical Calibration, S082A Spectroheliograph Instrument	*	-------
620-52	PROCEDURE, Optical Calibration, S082B Spectrograph Instrument	*	-------
620-53	MANUAL, Description and Operation, NRL/ATM S082A Instrument	Basic	3/15/70
620-54	MANUAL, Description and Operation, NRL/ATM S082B Instrument	Basic	6/10/70

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620-55	PROCEDURE, TCS Adjustment, NRL/ATM S082B	Basic	11/3/69
620-56	INSTRUCTIONS, Description and Operating NRL/ATM Camera Test Drive Unit	*	-------
620-57	PROCEDURE, ECE Verification Test, Spectroheliograph Instrument "A"	A	1/30/73
620-58	PROCEDURE, ECE Verification Test, Spectrograph Instrument "B"	A	2/6/73
620-59	REPORT, Primary Mirror Test, NRL/FDVU-BR	Basic	1/13/70
620-60	INSTRUCTIONS, Description and Operating, NRL/ATM Shipping Containers	C	5/1/71
620-61	REPORT, Final, NRL/ATM Spectroheliograph FDVU-A2	Basic	3/27/70
620-62	PROCEDURE, Acoustic Test, Electronic Components	Basic	3/7/70
620-63	PROCEDURE, Film Camera Loading, NRL/ATM S082A Spectroheliograph and S082B Spectrograph	B	5/3/71
620-64	PROCEDURE, Functional Test for Special Acoustic Test Board, NRL/ATM S082B	*	-------
620-65	CALIBRATION, Telemetry, NRL/ATM S082A Spectroheliograph Instrument, Flight	C	1/24/72
620-66	CALIBRATION, Telemetry, NRL/ATM S082B Spectrograph Instrument, Flight	B	1/25/72
620-67	CALIBRATION, Temperature versus Voltage, NRL/ATM S082A Spectroheliograph Instrument, Thermal Control Subsystem, Flight	Basic	9/18/70

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620-68	CALIBRATION, Temperature versus Voltage, NRL/ATM S082B Spectrograph Instrument, Thermal Control Subsystem, Flight	B	11/20/72
620-69	REPORT, Qualification Test, NRL/ATM S082A Prototype Spectroheliograph	Basic	6/8/70
620-70	PROCEDURE, Predisperser Qualification Test, S082B Spectrograph Instrument	A	8/26/70
620-71	PROCEDURE, Ultraviolet Reflectance Measurement, NRL/ATM S082A and S082B Contamination Monitor Mirrors	Basic	8/15/70
620-72	REPORT, Final, NRL/ATM Flight Design Verification Unit FDVU Instruments BR and BRR	A	7/1/71
620-73	REPORT, Predisperser Qualification Test, S082B Spectrograph Instrument	Basic	9/18/70
620-74	REPORT, Qualification Test, NRL/ATM Canister Assembly, XUV Film Magazine, S082A XUV Spectroheliograph and S082B XUV Spectrograph Instruments	Basic	4/1/72
620-75	REPORT, Qualification Test, NRL/ATM XUV Film Magazine Assembly, S082A Film Camera	Basic	3/15/72
620-76	PROCEDURE, Checkout, NRL/HCO ATM Transporter Range Package	A	6/25/71
620-77	PLAN, Spare Parts Control, NRL/ATM	Basic	1/15/71
620-78	PLAN, Zero-G Test, NRL/ATM Film Cameras	A	3/20/72
620-79	REPORT, Filter Ground Wire Qualification Test, NRL/ATM S082B XUV Monitor Instrument	Basic	1/29/71
620-80	REPORT, Acceptance Test, NRL/ATM S082A Flight Spectroheliograph	Basic	3/1/70

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620-81	REQUIREMENTS, Experiments, TEES Instrument	Basic	-------
620-82	REQUIREMENTS, Astronaut Operation, TEES Instrument	Basic	-------
620-83	INTERFACE Control Drawing, Between TEES and T027 Instruments	Basic	-------
620-84	INTERFACE Control Drawing, Between TEES Mounting Pallet and OWS Storage Locker or Floor	Basic	-------
620-85	INTERFACE Control Drawing, Mechanical and Electrical, TEES IFTU	Basic	-------
620-86	MEASUREMENTS, Vibration During Q-18 Checks at MSFC, NRL/ATM Instrument	Basic	1/27/71
620-87	REPORT, Qualification Test, NRL/ATM S082B Prototype Spectrograph	Basic	2/15/71
620-88	DATA, Test, Astronaut Training Hardware	Basic	-------
620-89	REQUIREMENTS, GSE, NRL/ATM S082A and S082B Instruments	B	2/29/72
620-90	REPORT, Acceptance Test, NRL/ATM Clean Room Purge Control Unit	Basic	3/26/71
620-91	REPORT, Design Study, Photodiode Pointing Reference System	Basic	-------
620-92	PROCEDURE, Spectrograph Alignment and Focus, FDVU-BR[3]	Basic	5/15/71
620-93	TRAJECTORY, 13.62 ds FDVU-BR[3]	Basic	5/1/71
620-94	PROCEDURE, Primary Mirror Focus and Alignment, FDVU-BR[3]	Basic	5/11/71
620-95	PROCEDURE, Special NRL Line Profile Data, NRL/ATM S082B Flight Instrument	Basic	5/7/71

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620-98	PROCEDURE, PRS Preliminary Calibration and Test, FDVU-BR^3 Instrument	Basic	5/14/71
620-99	PROCEDURE, Special Calibration and Reflectance Check, NRL/ATM S082B Flight Instrument	Basic	5/17/71
620-100	PROCEDURE, Final PRS Test, FDVU-BR^3	Basic	-------
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620-102	PROCEDURE, Final Spectrograph Focus Verification, FDVU-BR^3	Basic	-------
620-103	PROCEDURE, PRS and Electronics Vacuum Test, FDVU-BR^3	Basic	-------
620-104	REQUIREMENTS, Spin Balance/M.I., FDVU-BR^3	Basic	-------
620-105	PROCEDURE, Integration and Test, FDVU-BR^3	Basic	-------
620-106	PLAN, WSMR Personnel Activities and Task Responsibility, FDVU-BR^3	Basic	-------
620-107	TESTS, Post Shipment Receiving, FDVU-BR^3	Basic	-------
620-108	CHECKS, Pre-Horizontal, FDVU-BR^3	Basic	-------
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620-115	PROCEDURE, PRS Focus and Alignment Vacuum Test, FDVU-BR[3]	Basic	-------
620-116	ASSIGNMENT, Team Identification and Task, NRL/ATM FDVU-BR[3]	Basic	5/20/71
620-117	SCHEDULES, Integration and Test, NRL/ATM FDVU-BR[3]	Basic	6/23/71
620-118	CHECKOUT, Experiment and ES/TM Electrical NRL/ATM FDVU-BR[3]	Basic	-------
620-119	LIST, White Sands Equipment Packing, NRL/ATM FDVU-BR[3]	Basic	-------
620-120	PROCEDURE, Vibration Test Electronics, NRL/ATM FDVU-BR[3]	Basic	-------
620-121	PROCEDURE, Command Link Operation and Test, NRL/ATM FDVU-BR[3]	Basic	6/28/71
620-122	TREES, Documentation, NRL/ATM S082A and S082B Instruments	Basic	7/15/71
620-123	HISTORY, Modification, NRL/ATM S082 Instruments and Related Equipment	Basic	10/5/72
620-124	PROCEDURE, ATM Dynamic Disturbance Measurement	A	5/10/72
620-125	LIST, Indentured Parts, NRL/ATM Canister Assembly BBRC Model AF10A	F	5/2/73
620-126	LIST, Indentured Parts, NRL/ATM Canister Assembly BBRC Model AF10B	F	5/2/73
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620-129	PROCEDURE, Removal and Test of Filters and Contamination Monitors, NRL/ATM S082A and S082B Flight Instruments	C	11/15/72
620-130	REPORT, Test, Prototype Experiment Spar Disturbance	Basic	10/13/71
620-131	LIST, Materials Identification, NRL/ ATM S082 Instrument Film Cameras	Basic	10/15/71
620-132	HISTORY, Life, NRL/ATM S082A and S082B Film Cameras	C	2/9/73
620-133	REPORT, Acceptance Test, NRL/ATM S082B Flight Spectrograph Instrument	Basic	1/15/72
620-134	PROCEDURE, Supplemental Qualification, NRL/ATM Film Cameras (BBRC Models CM10A and CM11A)	Basic	11/15/71
620-135	REQUIREMENTS, Logistics, NRL/ATM S082 Cameras and Canisters	A	4/10/73
620-136	REPORT, Test, NRL/ATM Aluminum Filter (S082A Camera P/N D81995-6373)	Basic	3/6/72
620-137	REPORT, Qualification Test, NRL/ATM Power Line Filter Assembly, S082B XUV Spectrograph Instrument	Basic	2/16/72
620-138	LIST, Materials Identification, NRL/ ATM S082 Instrument Camera Canisters	Basic	3/15/72
620-139	PLAN, Combined Vibration/Acceleration Test, S082A and S082B Film Cameras/ Canisters	Basic	3/15/72
620-140	SPECIFICATION, Design and Performance, NRL Calibration Rocket Instrument	Basic	4/15/72
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620-145	PLAN, Special Test, NRL/ATM S082B A-2 Electronics Box S/N 002 (Non-Flight)	Basic	4/1/72
620-146	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082A S/N 002	Basic	5/15/72
620-147	COMPONENTS, Operating Mechanical, S082A Instrument	Basic	4/24/72
620-148	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082A S/N 003	Basic	5/15/72
620-149	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082A S/N 004	Basic	5/15/72
620-150	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082A S/N 005	Basic	5/15/72
620-151	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082A S/N 006	Basic	5/15/72
620-152	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082B S/N 001	Basic	5/15/72
620-153	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082B S/N 002	Basic	5/15/72
620-154	REPORT, Special Tests, NRL/ATM S082B A-2 Electronic Box, S/N 002 (Non Flight)	Basic	4/28/72
620-155	REPORT, Acceptance Test, NRL/ATM XUV Camera Canister S082B S/N 003	Basic	5/19/72

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620-158	REPORT, Inputs to Skylab Design Certification Review, NRL/ATM S082A Experiment	Basic	6/1/72
620-159	PROCEDURE, Zero-G Test, S082A and S082B Film Cameras	C	3/13/73
620-160	PROCEDURE, Winding, NRL/ATM CALROC H-Alpha Oven	Basic	6/9/72
620-161	COMPONENTS, Operating Mechanical, NRL/ATM S082B Instrument	Basic	6/15/72
620-162	PLAN, Shock Test, S082A and S082B Film Cameras/Canisters	Basic	-------
620-163	REPORT, Inputs to Skylab Design Certification Review, NRL/ATM S082B Experiment	Basic	7/1/72
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620-165	REPORT, Qualification Test, NRL/ATM XUV Film Magazine Assembly (S082B Film Camera.	Basic	7/25/72
620-166	REPORT, Acceptance Test, NRL/ATM XUV Film Magazine Assembly (S082A Film Camera S/N A 003)	Basic	7/15/72
620-167	CALIBRATION, Telemetry, NRL/ATM S082A Spectroheliograph Instrument Refurbished Prototype	Basic	8/15/72
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620-171	LIST, Check, Flight Instrument ATM Post-Vibration Test Activities, NRL/ATM S082A and S082B Instruments	Basic	9/1/72
620-172	LIST, Check, Preparation of Flight Instruments for ATM Thermal Vacuum Test, NRL/ATM S082A and S082B Instruments.	Basic	9/1/72
620-173	LIST, Check, Flight Instrument ATM Post-Thermal Vacuum Test Activities, NRL/ATM S082A and S082B Instruments	Basic	9/1/72
620-174	PROCEDURE, Camera Removal and Installation, NRL/ATM S082A Instrument	Basic	9/1/72
620-175	PROCEDURE, Camera Removal and Installation, NRL/ATM S082B Instrument	Basic	9/1/72
620-176	PROCEDURE, Preparation of ECE for Use, NRL/ATM S082A and S082B Instruments	Basic	9/1/72
620-177	PROCEDURE, Installation and Removal of Clear Aperture Covers, NRL/ATM S082A and S082B Instruments	Basic	9/1/72
620-178	PROCEDURE, Removal and Installation of Aperture Door Assembly (In-Air Alignment Verification), NRL/ATM S082A Instrument	Basic	9/1/72
620-179	PROCEDURE, Light Collimator Set-Up and Operation, NRL/ATM S082A and S082B Instruments	Basic	9/1/72
620-180	PROCEDURE, Operation of XUV Monitor Intermediate Filter Pull Ring, NRL/ATM S082B Instrument	Basic	9/1/72

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620-183	PROCEDURE, Measuring of Coalignment Between XUV Slit and XUV Monitor, NRL/ATM S082B Instrument	Basic	9/1/72
620-184	PROCEDURE, Installation and Removal of Slit and Slot Illuminators, NRL/ ATM S082B Instrument	Basic	9/1/72
620-185	PROCEDURE, PRS Collimator Set-Up and Operation, NRL/ATM S082B Instrument	Basic	9/1/72
620-186	REPORT, Acceptance Test, S082B Camera S/N B002	Basic	11/27/72
620-187	REPORT, Acceptance Test, S082A Camera S/N A004	Basic	11/22/72
620-188	REPORT, Acceptance Test, S082A Camera S/N A005	Basic	11/27/72
620-189	REPORT, Acceptance Test, S082A Camera S/N A006	Basic	12/72
620-190	REPORT, Zero-G Test, NRL/ATM Camera	Basic	9/15/72
620-191	REPORT, Technical, S082 Camera Parts Susceptible to Stress Corrosion Cracking	Basic	10/5/72
620-192	INSTRUCTIONS, Operating, Camera Test Drive Control (BBRC P/N 40931-1)	Basic	10/4/72
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620-196	REPORT, Technical, CALROC Video Link Tests, NRL/ATM Program	Basic	10/27/72
620-197	INSTRUCTIONS, Description and Operating, Calibrated IDT Assembly, P/N 43005-1, NRL/ATM S082B Instrument	Basic	11/1/72
620-198	REPORT, Technical, Forces Required to Fail-Crew Actuated Handles, NRL/ATM S082 Instruments	Basic	11/1/72
620-199	PROCEDURE, Pre-Flight Functional Inspection, NRL/ATM S082A and S082B Instruments	B	3/9/73
620-200	REPORT, Acceptance Test, XUV Film Magazine Assembly S082B Film Camera S/N B003	Basic	11/27/72
620-201	REPORT, Acceptance Test, XUV Film Magazine Assembly S082B Film Camera S/N B004	Basic	11/27/72
620-202	REPORT, Pre-Integration and Test, NRL/ATM CALROC NI-1	Basic	-------
620-203	PROCEDURE, Installation of Cameras In Canisters, NRL/ATM S082	A	3/12/73
620-204	PROCEDURE, Preparation of Canisters for Flight, NRL/ATM S082	C	2/5/73
620-205	PROCEDURE, Preparation of Film Holders and Retainers for Flight, NRL/ATM S082 Cameras	E	3/29/73

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620-208	PROCEDURE, Stray Light Test, NRL/ATM S082A and S082B Cameras	A	12/26/72
620-209	PROCEDURE, Full Compliance Run, NRL/ ATM S082A Camera	A	3/7/73
620-210	PROCEDURE, Full Compliance Run, NRL/ ATM S082B Camera	Basic	-------
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620-215	PROCEDURE, Removal and Installation of Aluminum Filter, NRL/ATM S082A Camera	C	3/9/73
620-216	PROCEDURE, KSC Camera and Canister Flight Preps, NRL/ATM S082	C	4/14/73
620-217	PROCEDURE, Removal and Installation of Cameras in Canisters at KSC, NRL/ ATM S082A and S082B	Basic	3/12/73
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620-221	REPORT, Test, NRL/ATM Film Camera S/N A002 Flight Activity Dry Run	Basic	2/7/73
620-222	PROCEDURE, Post-Flight Handling, Storage and Shipping, NRL/ATM S082 Camera/Canister	B	4/17/73
620-223	FINAL Report for the NI-1 Calibration Rocket	Basic	11/20/73
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620-225	FINAL Report, NRL/ATM Program	Basic	-------
620-226	REPORT, Skylab Missions SL-1/SL-2, NRL/ATM Instruments S082A and S082B	Basic	8/9/73
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620-228	PROCEDURE, XUV Slit Auxiliary Timer	Basic	9/21/73
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620-236	NRL/ATM XUV Monitor Final Report	Basic	2/74
620-237	REPORT, Skylab Mission SL-4, NRL/ATM Instruments, S082A and S082B	Basic	3/25/74
620-238	NRL/ATM Thermal Distortion Performance for S082A and S082B Instruments	Basic	6/7/74
620-239	NRL/ATM Mission Engineering Data for S082A Spectroheliograph Exposures 1A001 through 1A019	Basic	5/22/74
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ANALYSIS, Feasibility and Design for a Pointing Reference System	F67-09
ANALYSIS, Reliability of XUV Spectroheliograph Instrument ATM-A Experiment S082A	TN68-38
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REQUIREMENTS, Spin Balance/M.I., FDVU-BR^3	620-104
SCHEDULES, Integration and Test, NRL/ATM FDVU-BR^3	620-117

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Documentation List By Category

TITLE	DOC NO.
SPECIFICATION, Configuration Item; NRL/ATM Purge Control and Filter Unit	CP36294
SPECIFICATION, Configuration Item; NRL/HCO/ATM Transporter Purge Package	CP35690
SPECIFICATION, Configuration Item; Performance, Design and Product Configuration Requirements; Balloon Payload Support Structure; NRL/BBRC Balloon Payload	CI43770
SPECIFICATION, Configuration Item; Performance, Design and Product Configuration Requirements; Nitric Oxide Measurement Instrument; NRL/BBRC Balloon Payload	CI43768
SPECIFICATION, Configuration Item; Performance, Design and Product Configuration Requirements; Smoke Generator NRL/BBRC Balloon Payload	CI43769
SPECIFICATION, Configuration Item; Performance, Design and Product Configuration Requirements; Ozone Measurement Instrument; NRL/BBRC Balloon Payload	CI43767
SPECIFICATION, Configuration Item; Performance/Design & Product Configuration Requirements, XUV Calibration Source Set, NRL/ATM Program	34033
SPECIFICATION, Design and Performance; Experiment Checkout Equipment, XUV Coronal Spectroheliograph Instrument A	CP24038
SPECIFICATION, Design and Performance, Experiment Checkout Equipment, XUV Spectrograph Instrument B	CP24039
SPECIFICATION, Design and Performance, NRL Calibration Rocket Instrument	620-140
SPECIFICATION, Design and Performance, XUV Coronal Spectroheliograph Instrument ATM Experiment S053A	CP22879
SPECIFICATION, Design and Performance, XUV Coronal Spectroheliograph Instrument ATM Experiment S082A	CP25905

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TITLE	DOC NO.
SPECIFICATION, Design and Performance, XUV Spectrograph Instrument ATM Experiment S053B	CP22880
SPECIFICATION, Design and Performance, XUV Spectrograph Instrument 1-B ATM-A Experiment S082B	CP25100
SPECIFICATION, End Item Test, NRL Calibration Rocket Instrument	620-141
SPECIFICATION, End Item Test, XUV Coronal Spectroheliograph Instrument ATM Experiment S082A	28340
SPECIFICATION, End Item Test, XUV Spectrograph Instrument ATM Experiment S082B	28341
SPECIFICATION, Experiment Interface Requirements Document (EIRD)	TR67-53
SPECIFICATION, Preliminary Astronaut Operations Requirements Document XUV Coronal Spectroheliograph for the Apollo Telescope Mount	TR67-54
SPECIFICATION, Preliminary Astronaut Operations Requirements Document XUV Spectrograph for the Apollo Telescope Mount	TR67-55
SPECIFICATION/PROCEDURE, Post Delivery Receiving Test, NRL/ATM S082A Spectroheliograph Instrument	35643
SPECIFICATION/PROCEDURE, Post Delivery Receiving Test, NRL/ATM S082B Spectrograph Instrument	36564
SPECIFICATION/PROCEDURE, Test, NRL/HCO/ATM Transporter Purge Package	37488
SPECIFICATION, Slit Auxiliary Timer	620-229
SYSTEM, Optical, XUV Coronal Spectroheliograph, NRL/ATM Instrument A	22801
SYSTEM, Optical, XUV Spectrograph, NRL/ATM Instrument B	25111

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TITLE	DOC NO.
TEST, Horizontal, FDVU-BR^3	620-109
TEST, Preliminary Integration, NRL/ATM CALROC	620-164
TEST, Vertical, FDVU-BR^3	620-110
TESTS, Post Shipment Receiving FDVU-BR^3	620-107
TRAJECTORY, 13.62 ds FDVU-BR^3	620-93
TREES, Documentation, NRL/ATM S082A & S082B Instruments	620-122

9.0 PROGRAM IMPROVEMENTS

This section is devoted to a look in retrospect at total program from concept through mission performance.

9.1 INITIAL DESIGN CRITERIA

Initial design criteria, primarily in the spacecraft technical interface area, was not adequately defined when the program began. This caused the design work to be seriously handicapped initially. Design criteria changes also occurred throughout the program. This can be attributed to evolutionary changes such as a revised launch configuration change, i.e., wet workshop to dry workshop configuration, etc.

9.2 SCHEDULES

Initial schedules for the design and development task were unrealistic. The first PERT schedule was a no-failure, 100 percent success schedule. The resultant delivery dates from that schedule were later than the dates requested by the NASA. The schedule conflict promoted cost increases and forced technical decisions that were not always the most attractive.

9.3 PROGRAM FUNDING

Delays in program funding periodically presented temporary conditions that required BBRC release of internal funds to permit program continuation.

9.4 QUALITY CONTROL IMPROVEMENTS

Throughout the program it was necessary to submit all nonconforming material reports (NMR's), regardless of type of defect, to the Material Review Board (MRB) for disposition. The effect was to place NMR approvals by NRL and NASA QA representatives in series with fabrication and test operations. While this mode of operation is acceptable for defects that adversely affect safety, reliability, and performance, it results in significant increases in cost and sometimes schedule to disposition of minor and cosmetic defects by a formal MRB. Future programs should allow the contractor additional responsibility in dispositioning minor defects with customer representatives serving only as a reviewing function. Also, these Class II defects should be dispositioned on production/QA inspection paperwork instead of preparing NMR's. Finally, the assigned contractor QA engineer should be the determining agent as to when an NMR will be initiated by inspection.

QA data reporting to the customer in terms of statistical tabulations relating quantities and types of defects should be eliminated in preference to on-site periodic audits. Any modifications of the QA program are best made by periodic review of methods with all corrections the responsibility of the assigned QA engineer.

9.5 RELIABILITY IMPROVEMENTS

Failure mode, effect and criticality analyses (FMECA's) on one-of-a kind aerospace experiments are of little value. The only aspect that should be considered is piece part stress analysis. This analysis, to be effective, should be conducted as circuits are conceived with stress numbers identified on circuit schematics for future reference. Probability-of-success numbers are of no value when every effort is being made to achieve 100 percent success

with the limits of time, money, and state-of-the-art being the principal obstacles. Identification of single failure points is also meaningless since nearly all components are necessary for proper operation of experiments that cannot afford the luxury of redundant systems.

9.6 DATA ACQUISITION

Skylab data system problems, such as noisy data and data dropouts, existed before launch of SL-1 and continued throughout the entire Skylab mission. Mission simulations indicated that the data system was not adequately developed; however, there was not enough time available prior to launch for correction. The lack of quality-continuous data made real time problem solving difficult.

Also the quality of engineering data records, such as the engineering data books (EDB) providing exposure related data, is not adequate to evaluate the scientific data. As a result, additional data reprocessing is necessary. Obviously the complexity of the complete Skylab data system and the magnitude of the data quantity were not recognized early enough to be resolved by SL-1 launch. Future programs, such as Space Shuttle, need to be cognizant of the Skylab data problems and the mission operations deficiencies to prevent their recurrence.

9.7 TECHNICAL IMPROVEMENTS

The following technical improvements to the S082A and S082B instruments are suggested after giving consideration to problems experienced during the testing program and the mission.

9.7.1 Electronics

A. Alter the design to provide easier programing of exposure times and exposure sequences.

1. If only ground changes are desired, this could be done with a program connector and/or programmable storage register.

2. If in-orbit changes are desired, it could be accomplished with multiple use commands and storage registers where data is loaded serially. Another choice would be permanent stored sequences and times that are selected from ground.

B. Alter the design for minimum use of one-shot circuits, and where they are used, improve one-shot design with buffers on the output and input.

C. Repackage to provide for box checkout capability and minimum interconnections between boxes. Buffer all box input and output circuits.

D. Improve design of power distribution system (external cable, filters, etc.).

E. Locate high current electronics (motor, drivers, solenoid drivers, and diode array drivers) closer to driver element.

9.7.2 Optical/Mechanical

A. Provide mounting methods to facilitate alignment changes under vacuum. Mounting system during alignment should be

repeatable (capability to remove optical element and retain alignment when reinstalled).

B. Improvement of alignment tools used during flight optics change to provide removal and replacement of optical glass in housings without losing alignment referenced to housing mounting axis.

C. Provide better access to optical elements and video cameras without removing lid.

D. Improve alignment and focusing methods for XUV monitor.

E. Provide rolling mechanisms interfaces as opposed to sliding, as their performance is more consistent.

9.8 IMPROVEMENT SUMMARY

Although many problems arose throughout the design, development, and the mission, acceptable solutions or work-arounds were always developed. Excluding the S082A camera problems and the S082B PRS problem identified in this report, the general performance of the S082 instruments must be rated as excellent. Over 7,400 exposures of quality scientific data were obtained on the combined Skylab missions. The Skylab mission can certainly be considered a very successful mission.

10.0 ABBREVIATIONS AND ACRONYMS

A	Ampere
Å	Angstrom
AORD	Astronaut Operation Requirement Document
AOSO	Advanced Orbiting Solar Observatory
ASAP	Auxiliary Storage and Playback
ATM	Apollo Telescope Mount
AWG	American Wire Gage
BBRC	Ball Brothers Research Corporation
BCD	Bianary Code Decimal
BMS's	Ball Material Specifications
BPS's	Ball Process Standards
CAB	Configuration Authorization Board
CALROC	Calibration Rockets
CAR	Corrective Action Request
CCB	Configuration Change Board
CCU	Camera Control Unit
C^2F^2	Crew Compartment Fit and Functional Check
C & D	Control and Display
CDR	Critical Design Review
CDRL	Contractual Data Requirements List
CEMA	Channel Electron Multiplier Array
CG	Center of Gravity
CIL	Authorized Configuration Identification List
CM	Command Module
CSM	Command Service Module
CUT	Compressed User Tapes
DAR	Deviation Authorization Request
DC	Direct Current
DC-DC	Direct Current to Direct Current
DD	Department of Defense
DOT	Department of Transportation
D & PS	Design and Performance Specifications
DTL	Diode Transistor Logic

ECE	Experiment Checkout Equipment; Electrical Checkout Equipment; or ATM/LM Simulator and Checkout Console
ECP	Engineering Change Proposals
EDB	Engineering Data Books
EDM	Electrical Discharge Machining
EIDD	Experiment Interface Defining Document
EMI	Electromagnetic Interference
EMU	Engineering Model Unit
EO	Engineering Order
ER	Established Reliability
EVA	Extra Vehicular Activity
FBU	Flight Backup Unit
FDVU	Flight Design Verification Unit
FMECA	Failure Mode, Effect and Criticality Analysis
FPS	Fine Pointing Sensor
FSS	Fine Sun Sensor
g	Gravity
GFE	Government Furnished Equipment
GND	Ground
GSE	Ground Support Equipment
GSFC	Goddard Space Flight Center
Hα or H-Alpha	Hydrogen Alpha
HCO	Harvard College Observatory
H & D Curves	Herter and Drifield
HOSC	Huntsville Operations Support Center
HP	Hewlett Packard
HV	High Voltage
Hz	Hertz
ICD	Interface Control Document
ICE	Instrument Checkout Console
IDT	Image Detector Tube
I & T	Integration and Test
JOP	Joint Observing Program
JSC	Johnson Space Center

k	kilo
kg	kilogram
kHz	kilo Hertz (kilo cycles per second)
KSC	Kennedy Space Center
LLL	Low Light Level
LM	Lunar Module
LV	Low Voltage
LW	Long Wavelength
L/W	Instrumentation Recordings
ma	mili ampere
MDA	Multiple Docking Adaptor
MILA	Merritt Island Tracking System
MIT	Material Inventor Tag
mm	milimeter
MON	Monitor
MRB	Material Review Board
MRD	Mission Requirements Document
ms	milisecond
MSFC	Marshall Space Flight Center
NASA	National Aeronautical and Space Administration
NHB	NASA Hand Book
NI	Naval Instrument
NMR	Nonconforming Materials Report
NRL	Naval Research Laboratory
NSBF	National Scientific Balloon Facility
O & C	Operations and Checkout Building
OWS	Orbital Work Shop
PAD	Launch Stand
PDR	Preliminary Design Review
PERT	Program Evaluation and Review Technique
PI	Principal Investigation
PM	Photo Multiplier
PRS	Pointing Reference (Sub)system
PWA	Printed Wiring Assembly
PWB	Printed Wiring Board

PWR	Power
QA	Quality Assurance
R	Reliability
R	Revision
RAPP	Reliability Assurance Program Plan
RDR	Reliability Data Request
RFDVU	Rocket Flight Design Verification Units
RGA	Residual Gas Analysis
SEC	Secondary Electron Conduction
SL	Skylab
S/N	Serial Number
SP	Selected Parts
SPARCS	Solar Pointing Aerobee Rocket Control System
"SPEC"	Spectrograph
ST	Standard Parts
STD	Standard
SW	Short Wavelength
SWR	Short Wavelength Radiation
Sync	Synchronization
TCS	Thermal Control Subsystem
TCTO	Time Compliance Technical Order
TDY	Temporary Duty
TM	Telemetry
TMU	Thermal Mechanical Unit
TN	Technical Notes
TR	Technical Report
TV	Television
UV	Ultraviolet
V	Volts
VAB	Vehicle Assembly Building
VDC	Voltage Direct Current
VEN	Vacuum Exposure Nephelometer
VIR	Vendor Information Request
VOM	Volt Ohm Meter

VR	Voltage Regulator
VTVM	Vacuum Tube Volt Meter
WL	Wave Length
WSMR	White Sands Missile Range
XUV	Extreme Ultraviolet
α	Alpha
ΔCDR	Delta Critical Design Review
<	less than
>	greater than