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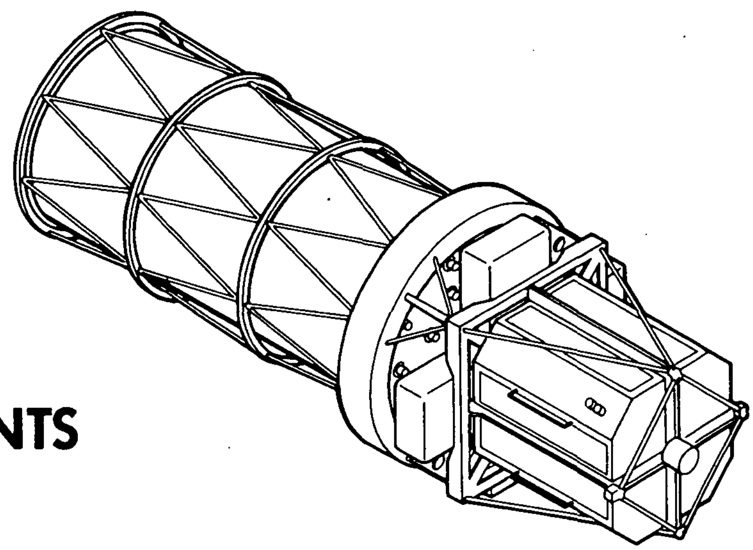
(NASA-CR-150143) SPACE TELESCOPE PHASE B DEFINITION STUDY. VOLUME 2A: SCIENCE INSTRUMENTS, f24 FIELD CAMERA Final Report (Perkin-Elmer Corp.) 150 p HC A07/MF A01 CSCL 20F G3/74

N77-15828

Unclas 59638

PERKIN-ELMER
OPTICAL TECHNOLOGY DIVISION

SPACE TELESCOPE PHASE B DEFINITION STUDY FINAL REPORT



VOLUME II-A SCIENCE INSTRUMENTS

f24 FIELD CAMERA

APRIL 1976

GEORGE C. MARSHALL SPACE FLIGHT CENTER
HUNTSVILLE, ALABAMA

CONTRACT NAS8-29948

ST 0027-76

PERKIN-ELMER

Engineering Report Number: ER-321

Date: April 1976

Prepared By: R. P. Grosso/D. J. McCarthy

Subject: Space Telescope, Phase B Definition Study, Vol. II-A f/24 Field Camera, Final Report - Contract NAS8-29948

Publication Review:

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Abstract: Final Report for the analysis and design of the f/24 Field Camera for Space Telescope. Camera designed for application to the radial bay of the Optical Telescope Assembly with an on axis field of view of 3 arc-minutes by 3 arc-minutes.

FOREWORD

This Final Report, Volume II-A, documents and summarizes (per the requirements of Marshall Space Flight Center (MSFC) Procurement Document 395-MA-06) the analysis and preliminary design of an f/24 Field Camera for the Space Telescope. The Final Report also includes Volume I, Executive Summary; Volume II-B, Preliminary Design of the Optical Telescope Assembly; Volume III, Safety Analysis. The results of the Phase C/D Program Planning are contained in Perkin-Elmer Reports ER-317, ER-318 and ER-319.

This Science Instrument is designed for a radial module position in the Optical Telescope Assembly. It is intended as a wide field imaging camera for investigations into the physics of galaxies and faint stars. It will also operate simultaneously with other instruments, in a sky search or sky mapping mode. The design was accomplished as part of the ST Phase B Definition Study, Optical Telescope Assembly/Science Instruments for NASA, Marshall Space Flight Center under Contract NAS8-29948. Technical direction for the Science Instrument design was provided by the Goddard Space Flight Center.

Volume II-A reports on the following Science Instruments for ST:

- f/24 Field Camera
- f48/96 Planetary Camera
- Faint Object Spectrograph
- IR Photometer
- Astrometer
- High Speed Point/Area Photometer
- High Resolution Spectrograph

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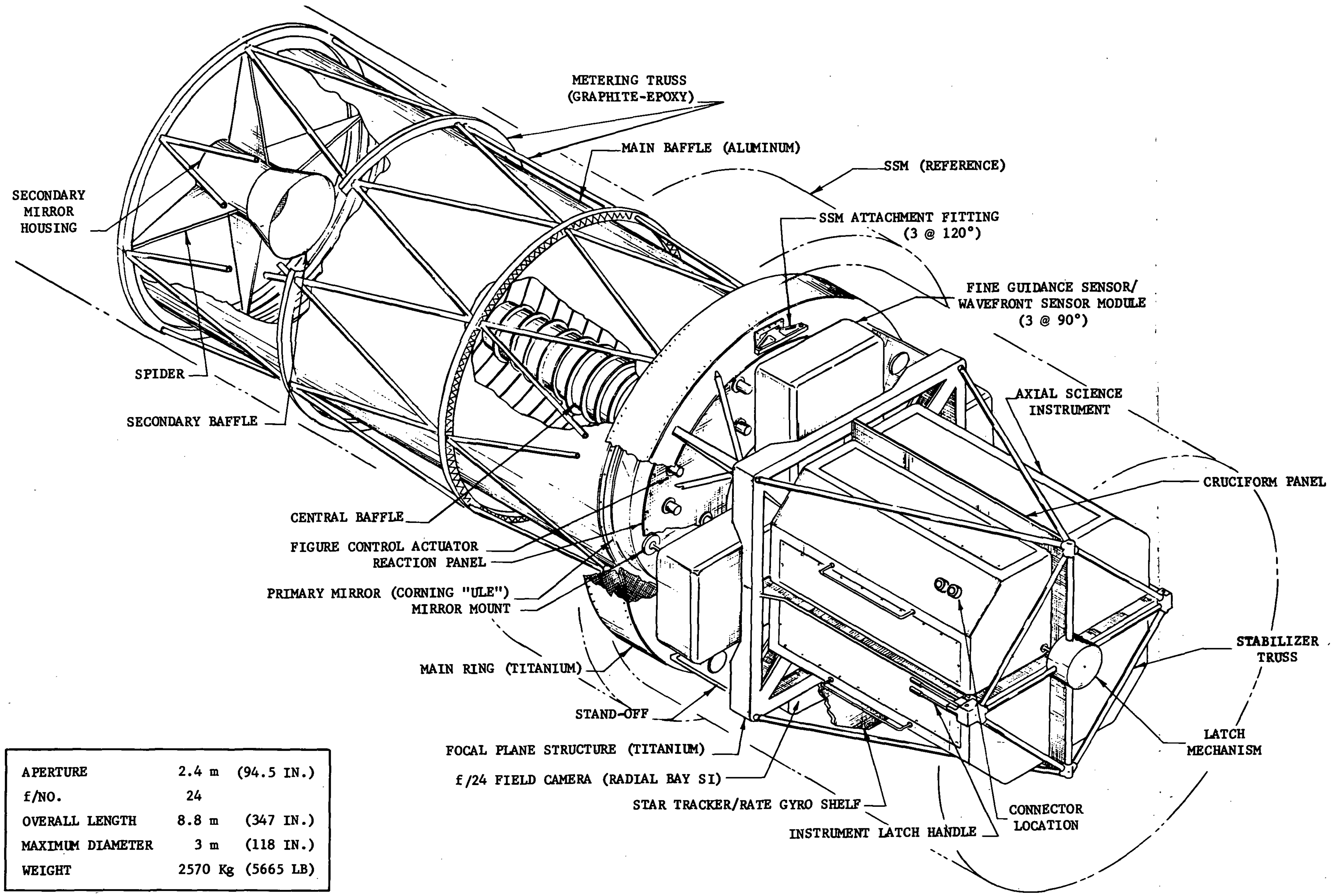

APERTURE	2.4 m	(94.5 IN.)
f/NO.	24	
OVERALL LENGTH	8.8 m	(347 IN.)
MAXIMUM DIAMETER	3 m	(118 IN.)
WEIGHT	2570 Kg	(5665 LB)

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FOLDOUT FRAME 1

Optical Telescope Assembly
With Science Instruments

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GLOSSARY

BFL	Back Focal Length
FGS	Fine Guidance Sensor
FID	Final Instrument Definition (document)
FOS	Faint Object Spectrograph
FOV	Field of View
FPS	Focal Plane Structure
GSFC	Goddard Space Flight Center
HRC	High Resolution Camera
HRS	High Resolution Spectrograph
HSAP	High Speed Point/Area Photometer
LED	Light Emitting Diode
LiF_2	Lithium Fluoride
M_gF2	Magnesium Fluoride
MSFC	Marshall Space Flight Center
MTF	Modulation Transfer Function
opd	Optical Path Difference
OTA	Optical Telescope Assembly
OTA/SI	OTA with Integrated Science Instruments
PDS	Power Distribution System
PCS	Pointing Control System
R&I	Receive and Inspection
SECO	Secondary Electron Conduction Orthicon
SI	Science Instrument
SSM	Support Systems Module
ST	Space Telescope
TCS	Temperature Control System
TCU	Thermal/Structural Unit

SECTION 1

REQUIREMENTS

1.1 Performance Requirements

The f/24 Field Camera is a wide field imaging camera, of medium resolution and high photometric dynamic range, capable of observing objects as dim as $m_v 23$.

The Field Camera will be used as a "primary" instrument in a number of scientific investigations, particularly those of galaxies; however, it is also a requirement that this instrument has the ability to operate in a serendipitous mode - simultaneously with another instrument. In this manner, regions of the terrestrial sphere may be photographed with a wide field camera simultaneously with other investigations in a nearby region of the sky, in an attempt to discover new dim objects, or to perform limited sky mapping.

Both spatial resolution and field of view are limited by the available SEC Orthicon detector - placed effectively at the center of the f/24 OTA focal plane. Spectral bandwidth is selectable by filter wheels within the overall spectral region 115nm to 800nm.

The significant performance requirements are tabulated in Table 1-1.

1.2 Interface Requirements

In order to take full advantage of the spatial resolution of the OTA, and to minimize photometric losses by multi-reflective paths, the f/24 Field Camera is required to fit into the radial instrument bay of the OTA. This bay is located as shown in Figs. 1-1 and 1-2, just forward of the OTA focal plane. The overall envelope dimensions are shown in Fig. 1-3.

The region of the OTA focal plane allocated to the f/24 radial bay is shown in Fig. 1-4, and the OTA focal plane image characteristics over this region are shown in Fig. 1-5. At the extreme corner of the 3 arc-min x 3 arc-min required field, the OTA astigmatism is approximately 100μ, and field curvature results in a center to corner focus difference of approximately 600μ.

Other pertinent design requirements affecting the preliminary design of the f/24 radial bay Field Camera are summarized in Table 1-2 .

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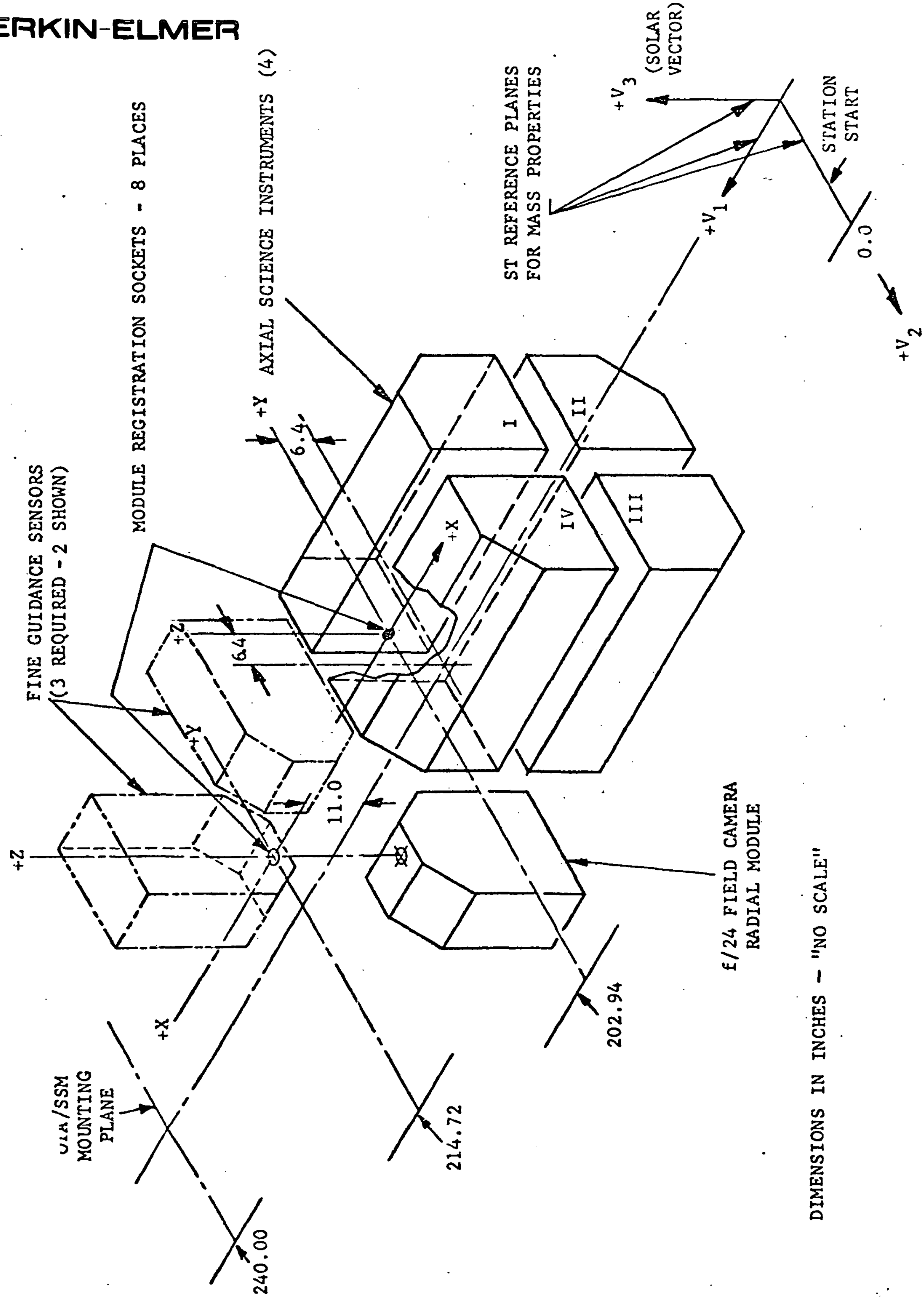

Figure 1-2. SI Radial and Axial Module Orientation

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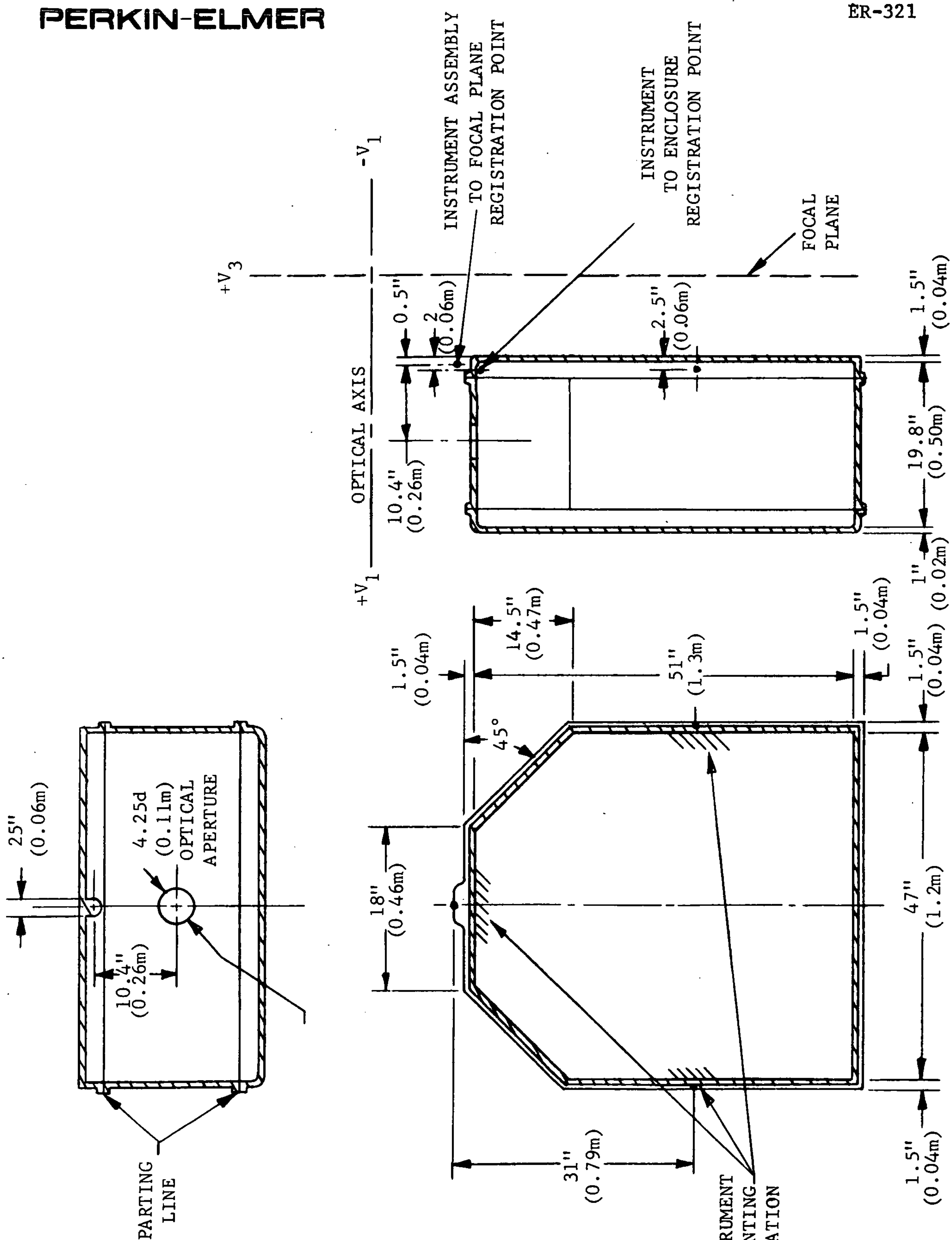


Figure 1-3. Radial SI Enclosure Interior Envelope

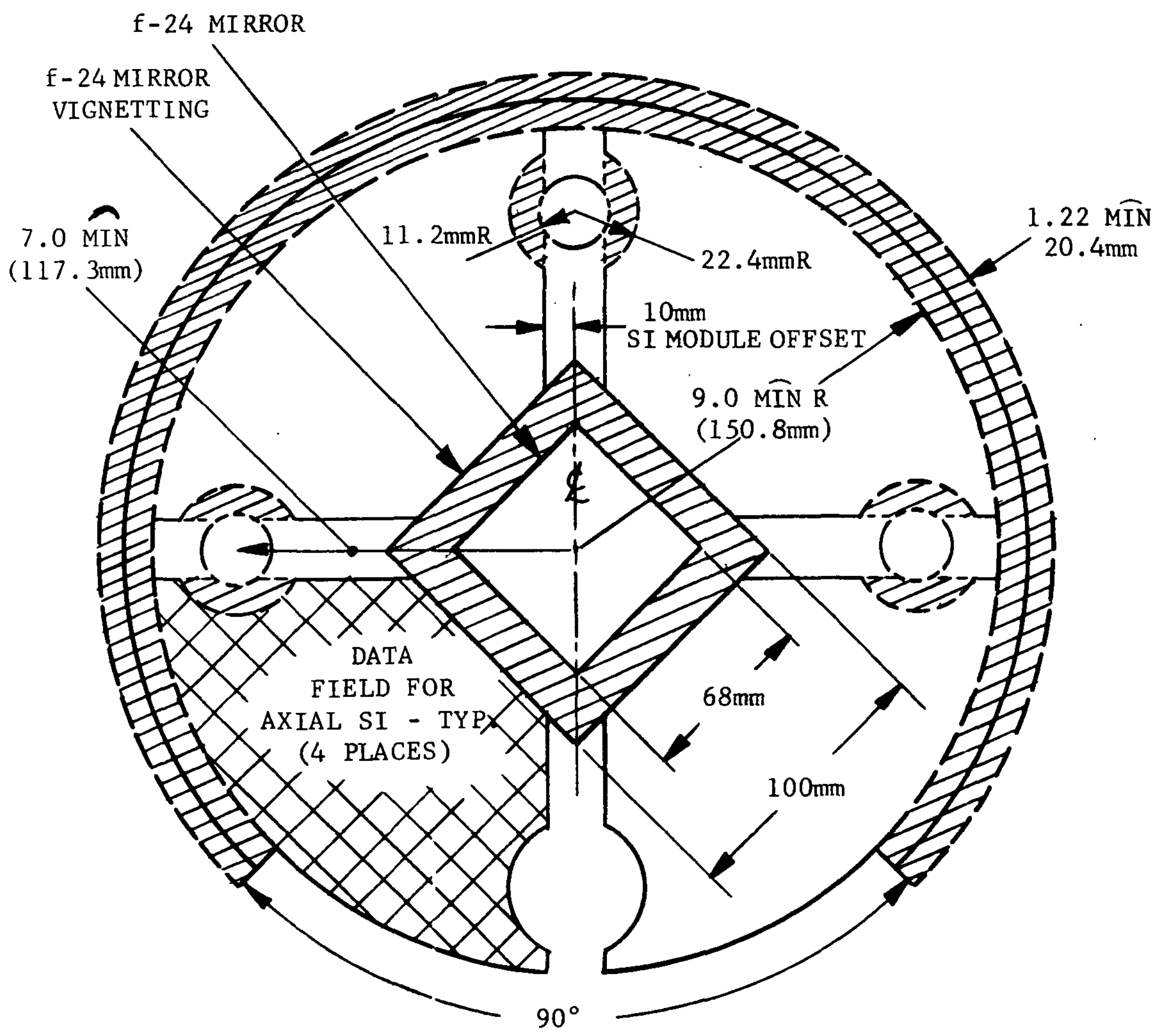
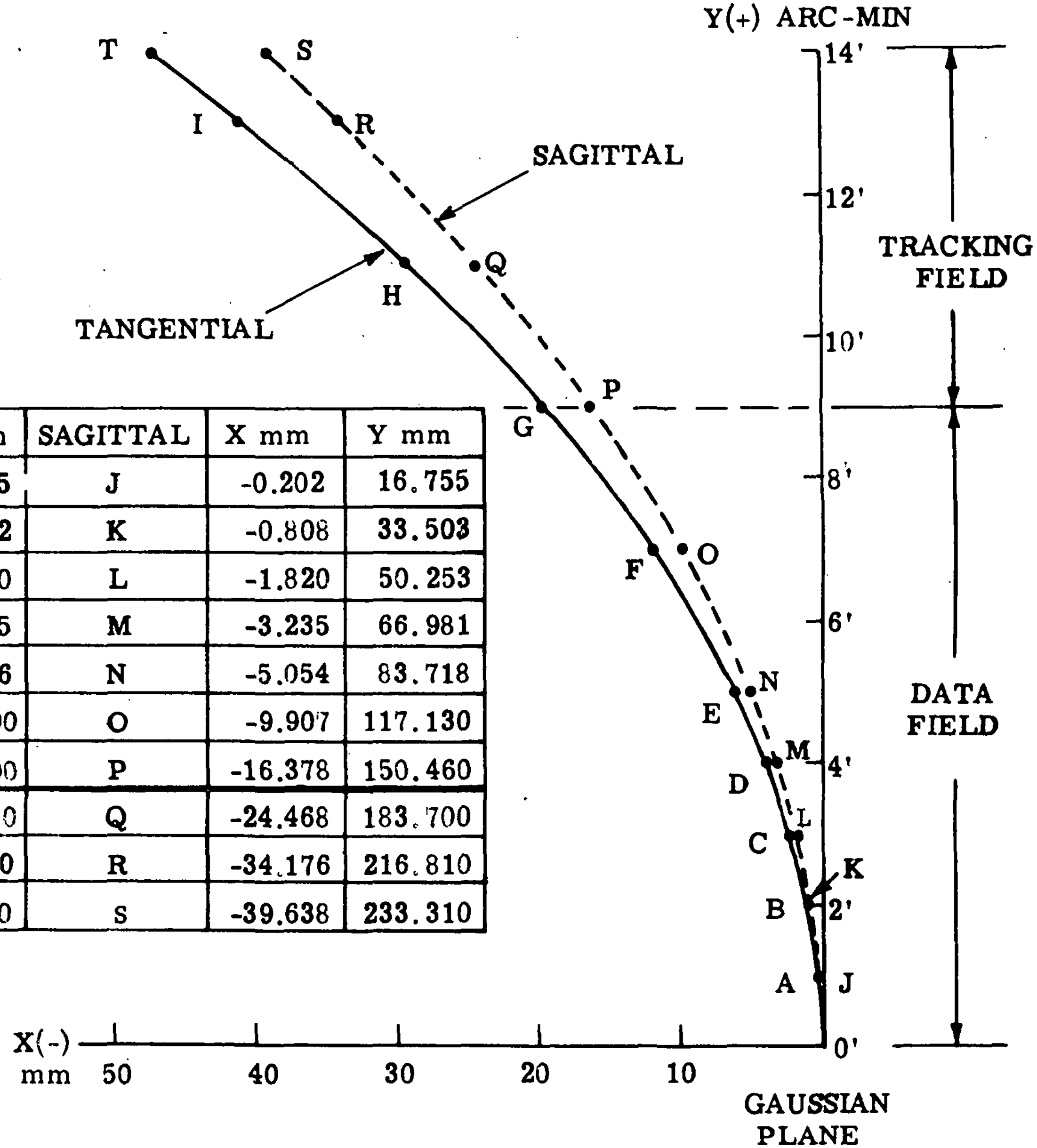


Figure 1-4. f/24 Focal Plane, SI Data Fields



α	TANGENTIAL	X mm	Y mm	SAGITTAL	X mm	Y mm
1.0'	A	-0.244	16.755	J	-0.202	16.755
2.0'	B	-0.976	33.502	K	-0.808	33.503
3.0'	C	-2.197	50.250	L	-1.820	50.253
4.0'	D	-3.905	66.985	M	-3.235	66.981
5.0'	E	-6.102	83.706	N	-5.054	83.718
7.0'	F	-11.962	117.090	O	-9.907	117.130
9.0'	G	-19.776	150.390	P	-16.378	150.460
11.0'	H	-29.552	183.560	Q	-24.468	183.700
13.0'	I	-41.200	216.590	R	-34.176	216.810
14.0'	T	-47.881	233.040	S	-39.638	233.310

Figure 1-5. Focal Plane Topography

TABLE 1-2

DESIGN REQUIREMENTS

Weight, Enclosure	100 pounds (max)
Weight, f/24 Camera & Optical Bench	300 pounds (max)
Temperature (optics)	66 - 70°F
Conductance to Focal Plane	0.15 Btu/Hr-°F (max)
Radiation to Focal Plane	0.10 Btu/Hr-°F (max)
Voltage	28 VDC ± 5 VDC
Maximum Allowable Average Power	100 watts
Reliability	0.85 for 1 year orbital operation

Acceleration Factors (g)

Mission Phase	Equivalent Quasi-Static Limit Loads					
	x_{max}	x_{min}	y_{max}	y_{min}	z_{max}	z_{min}
Launch Release	0.4	-3.4	0.8	-0.8	3.0	-3.0
SRM Cutoff/Separation	2.0	-4.0	0.4	-0.4	0.8	-0.8
Reentry	1.4	0.6	0.7	-0.7	4.0	2.0
Payload Deployment	0.2	-0.2	0.2	-0.2	0.2	-0.2

SECTION 2

FIELD CAMERA CONFIGURATION

2.1 GENERAL CONFIGURATION

The overall layout of the Radial Bay f/24 Field Camera is given in Figure 2-1, sheets 1, 2 and 3 (reference Perkin-Elmer Drawing 679-10045). The key elements of the instrument design are:

- Pick-off Mirror Assembly
- SEC Orthicon/camera assembly
- Optical Bench
- Filter subsystem
- Shutter subsystem
- Port door subsystem
- Calibration subsystem
- Radial Bay Module
- Thermal Control subsystem
- Instrument Control Electronics

The SEC Orthicon detector, with cooled photocathode, views through a single 45° flat mirror, the central 3'x3' portion of the OTA field of view. Details on the optical quality of the OTA focal plane, on the various optical configurations considered for this design and the analyses of the selected optical configuration are given in Section 3 of this report.

All elements of the field camera, including the optical pick-off mirror assembly, are mounted to the optical bench. The bench has two functions: (1) to maintain the functional elements of the instrument in proper alignment and (2) to position the field camera relative to the optical axis and focal plane of the OTA. Additional details of this structure are given in Section 5. The field camera is self contained within a radial bay module (similar modules house the three Fine Guidance sensor subsystems). The module is replaceable on orbit as described in Section 5. The module also provides the stabilized thermal environment and heat dissipation system for the instrument.

The detector identified for use in the field camera is a magnetically focussed SEC Orthicon. It has a 70mm diameter photocathode, and is capable of a 2000 line scan with 2000 pixels per line over a 50mm x 50mm square area.

The SECO detector is the subject of current design/development and definition effort at Princeton University Department of Astrophysical Sciences. Detectors of this general type have been constructed and used

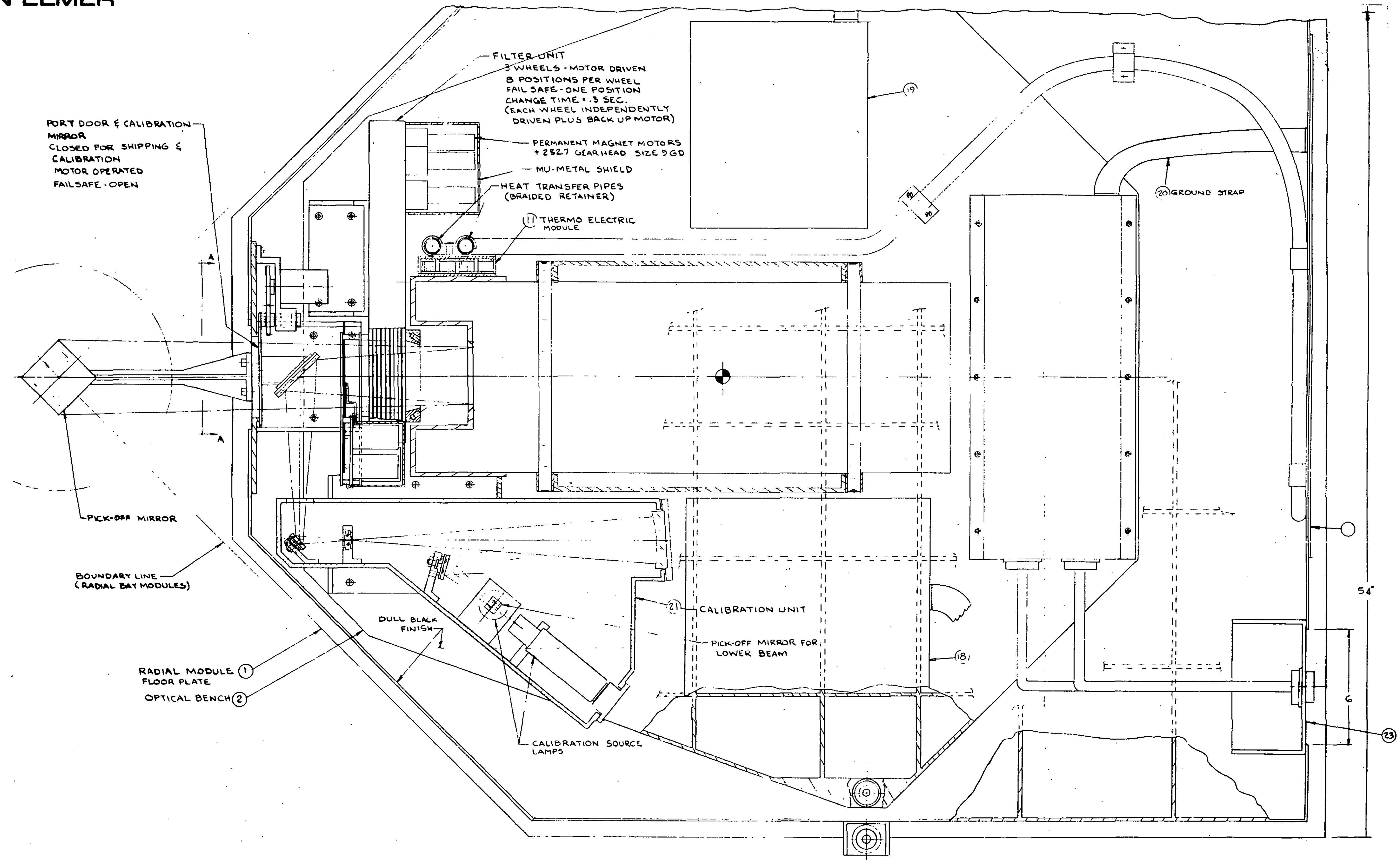


Figure 2-1. f/24 Camera Overall Layout - Sheet 1

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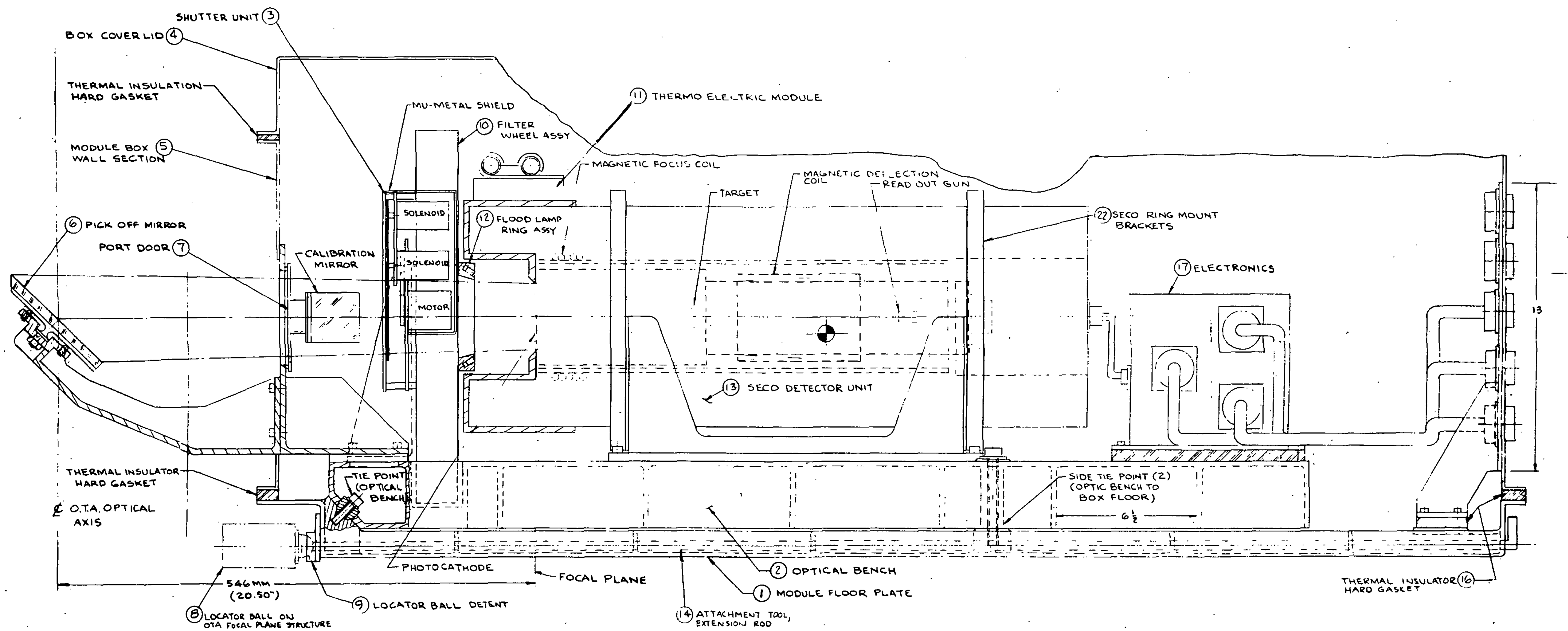

Figure 2-1. f/24 Camera Overall Layout - Sheet 2

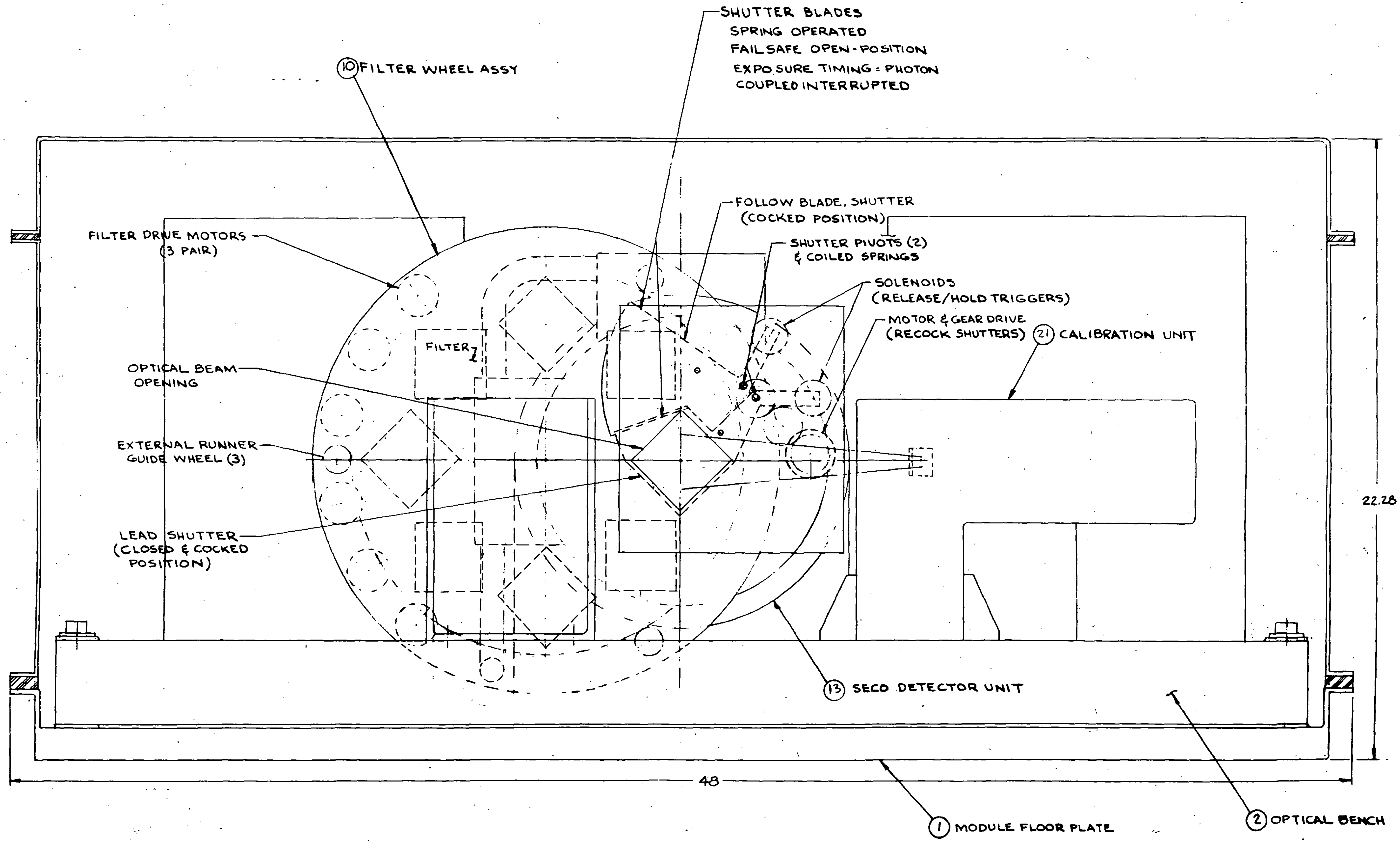

Figure 2-1. f/24 Camera Overall Layout - Sheet 3

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in ground based observing programs as well as laboratory studies of their performance characteristics.

To reduce the tube dark current and optimize signal to noise ratio, the photo cathode will be cooled to 270°K. (26.6F).

Heat is pumped from the photocathode area by a thermoelectric cooler through copper heat straps and heat pipes to the module outer surface for dissipation to the SSM wall. Current conservative estimates of the power necessary to effect cathode cooling to 270°K are approximately 20w. However, this power may be reduced significantly by careful thermal/mechanical/electronic design of the detector package. Specific recommendations are included in Section 5 on the thermal design.

A system of filter wheels, just ahead of the detector enables observations in pre-selected spectral bandwidths and polarizations, and a shutter assembly, close to the entrance port provides exposure time control.

Separate from the shutter, a port door subsystem closes the camera to outside contamination sources. With the door closed, a calibration unit is able to inject light from a tungsten or deuterium continuum source via a mirror on the door into the optical path of the camera for calibration of photocathode/filter response.

Power, commands, instrumentation and science data are transferred directly between the SSM (Support Systems Module) and the individual science instruments. Consideration of the use of a dedicated science instrument computer or of individual micro processors located within each science instrument is still under study by NASA. The instrument functional block diagram is shown in Figure 2-2.

2.2 SEQUENCE of OPERATION

The f/24 Field Camera is one of the "core" scientific instruments designated for the ST (the other is the Faint Object Spectrograph). As noted in Section 1, the f24 camera will be in use extensively both for observations directly planned and in a sky mapping serendipitous mode during use of any one of the other ST science instruments. The critical consequence of this mapping mode is a high duty cycle. To perform both modes of operation requires that the camera design be reliable and flexible to a wide range of observational requirements.

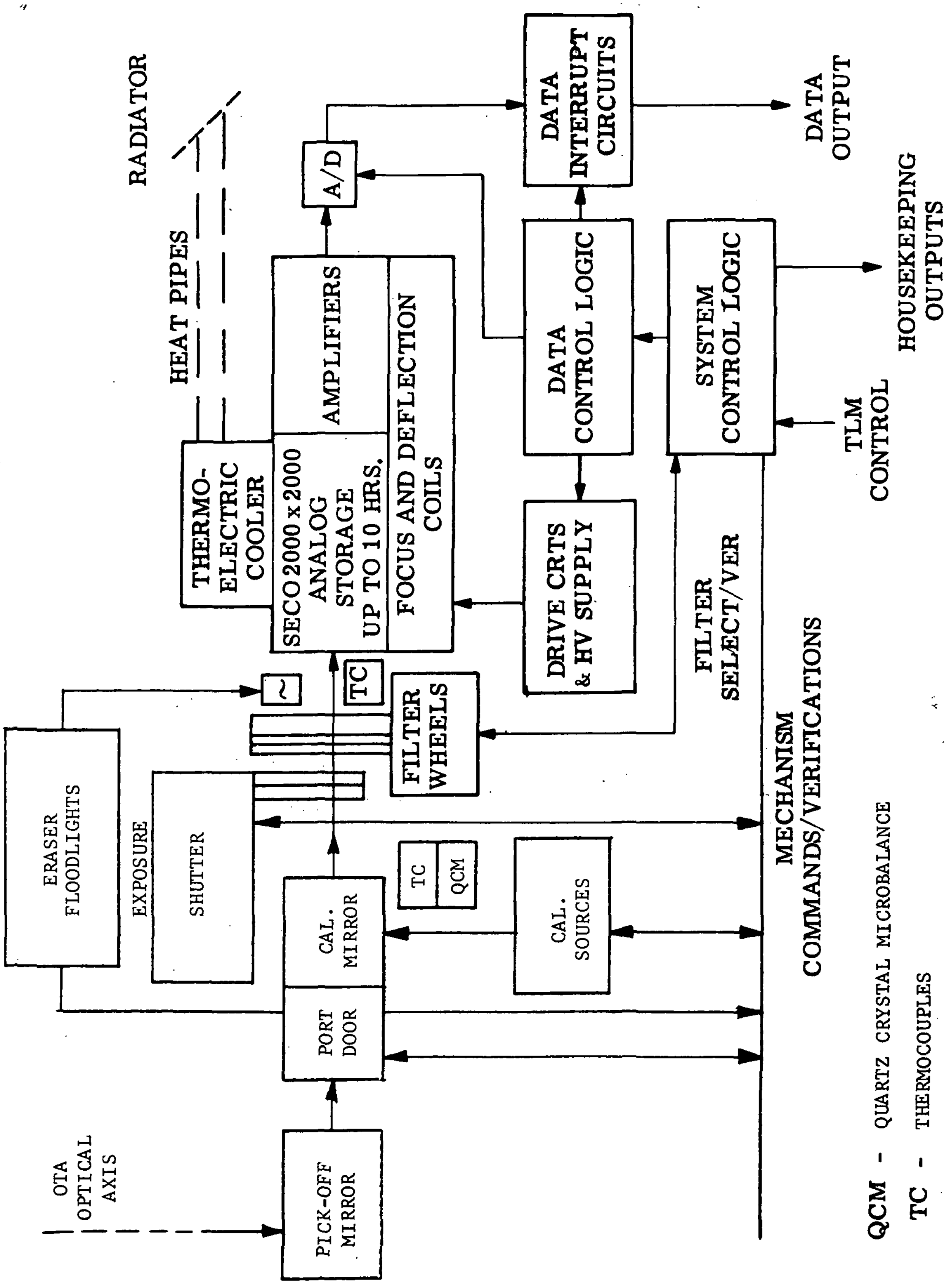

Figure 2-2. Functional Block Diagram

Acquisition

The Field Camera has a passive role during the acquisition operation. The object or sky area to be viewed is selected and commands given to the ST Pointing Control System (PCS) to point the line of sight of the OTA at the selected area. The accuracy to which this can be done is dependent on the accuracy to which the object is known but generally will be within 1 to 10 arc sec.rms. The ST is stabilized in this position by the PCS; the FGS (Fine Guidance Sensor) in the OTA interferometrically senses any drift away from the selected guide star and sends an error signal to the PCS of the SSM to maintain stabilization.

Normal Operation

Following acquisition of the selected target the following operational sequence is followed:

- Operation of the Filter subsystem to place the selected filter into the optical path. Details of this design and operation are given in Section 2-4.
- Operation of the Shutter subsystem to control the exposure period. Details of this design and operation are given in Section 2-3.
- Following closing of the follower shutter blade (and before resetting of shutters) the SECO detector is read out directly to the ground via the SSM or into data storage on the SSM.
- Operation of the erase lamps to clear the SECO in preparation for the next exposure.
- Resetting of the shutters to the start position.
- Repeat of above sequence - changes will include selection of other filters/transmission gratings, different time exposures and other targets.
- Operation of the TCS (Temperature Control System) to maintain the photo cathode at 270^{o}K and the camera optics as defined in the Requirements, Section 1.
- The Port Door is not used (closed) during normal operation of the Field Camera and is not closed during periods when the camera is not in use. It is closed only during periods of instrument calibration.

Calibration

Calibration is accomplished by executing the following operations:

- Closing of the Port Door. This moves a calibration fold mirror onto the optical center line of the SECO detector. The door is fail-safe open; impact of failure on calibration is discussed in Sections 2.5 and 4.0.
- Turn-on of the calibration source - two sources provide the spectral range defined in Section 4.
- Operation of the Filter subsystem to place the selected filters into the optical path.
- Operation of the Shutter subsystem to control calibration time.
- Read-out of SECO detector and transmission of data via SSM to ground station. Erase and repeat with different filters.
- Turn-off of calibration source and opening of the Port Door.

2.3 SHUTTER SUBSYSTEM

Exposure time control for the f/24 Field Camera is effected by a two shutter subsystem shown in Figure 2-3. The two shutter blade concept permits good control for the very short time exposures (of the order of 10 milliseconds) and at the same time easily adapts to the longer exposure periods as well. The operational sequence is as follows:

1. Release of the lead shutter blade by command. This opens the optical path to the SECO detector.
2. Release of the follower shutter blade by a second and separate command. This covers the optical path to the SECO. The time delay between the two shutter release commands establishes the exposure period.
3. Simultaneous resetting or cocking of both shutter blades to their start positions by a small electric motor drive. The optical path remains covered during this operation.

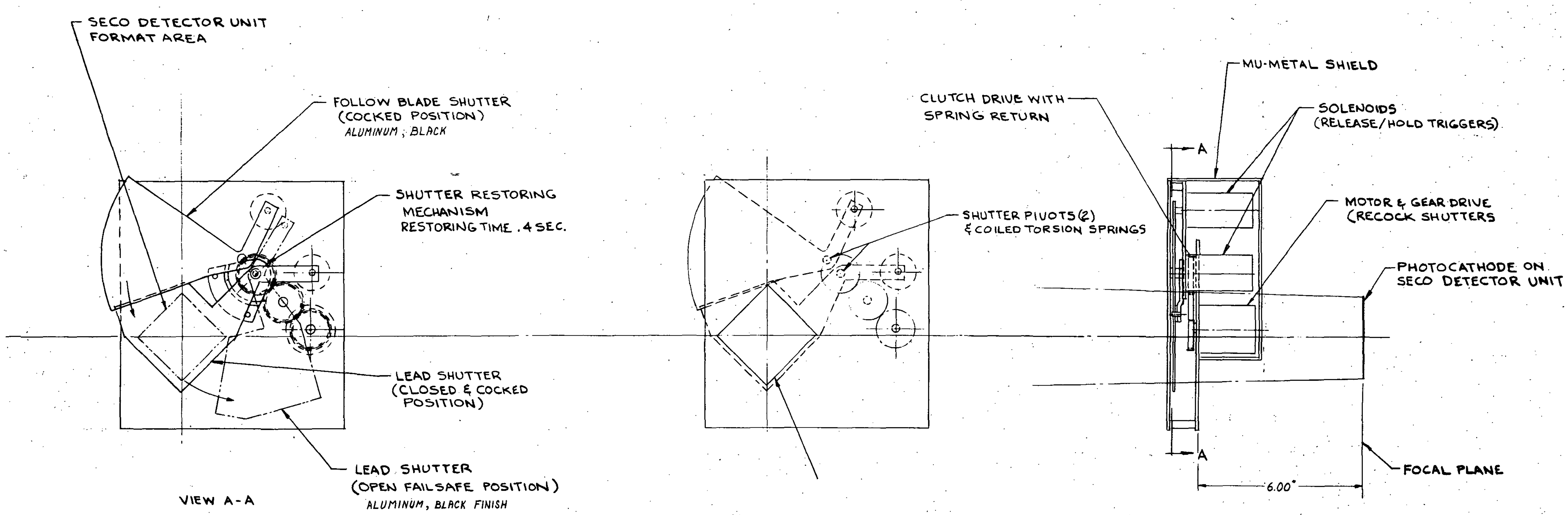

Figure 2-3. Shutter and Shutter Restoring Mechanism

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The lead shutter blade is initially cocked, against a torsion spring, in position to block the optical path as shown in view A-A, Figure 2-3. The first exposure control command removes power from the hold solenoid, allowing a spring driven trigger to disengage from the shutter blade arm. Thus released, the lead shutter moves through a nominal 60° arc about its pivot bearing and exposes the SECO to the optical clear aperture. The lead shutter is captured at the end of its travel by a U-clamp type stop which gently brings it to a stop, avoiding excessive vibration of the camera assembly. A highly reliable light emitting diode (LED) and photo sensor sense completion of the operation and provide instrumentation data. The sensor will monitor the actuation end of the shutter (end away from the optical aperture), thus permiting adequate space for shielding sensor light from the aperture. The sensor is 'on' during all operation of the camera.

A second command, triggered after the required exposure period has transpired, provides power to the follower shutter blade solenoid, actuating its release trigger. Also spring driven, this blade similarly rotates to a position covering the SECO aperture. A LED and photo diode senses and provides instrumentation data on completion of this event.

The power "on" release of both shutter blades provides the shutter subsystem with a fail-safe mode, fail-safe being defined here as a shutter failure with the optical path to the SECO unblocked. A power failure of the lead shutter command will result in the shutter moving to the open position. The camera can continue in operation following such a failure by either direct controlling of the SECO camera or by initiating exposure control by using the motor driven reset to open the optical path and release of the follower shutter blade to end the exposure. This latter back-up operation mode would preclude very short exposures, i.e. $\lesssim$0.5 seconds.

The mu-metal shield around the active solenoids will eliminate the possibility of their magnetic fields influencing the performance of the SECO camera.

The resetting of the two shutter blades is accomplished by the action of a small electric motor driven quick-return mechanism which simply pushes both blades into their latched position and then returns to its start position to be ready for the next reset cycle.

The design configuration of the shutter subsystem defined above was utilized successfully for many years on the principal camera of the Stratoscope II telescope. Requirements on that program also included exposure periods from 25 ms to hours. No operational failures of this camera shutter or reset mechanism were experienced during many hours of ground test or the several flights of this system. The shutter blades are light weight, constructed from aluminum, and thus very responsive to their spring drives. The solenoids should be double wound to provide redundancy. There are no critical manufacturing or assembly tolerances in the design; solenoids, motors, magnetic clutches, etc. may be selected from components previously space qualified.

2.4 FILTER WHEEL ASSEMBLY

The filter wheel assembly, shown in Figure 2-4, is located immediately ahead of the detector. It contains 3 independently driven wheels, each wheel containing eight filter positions. In each wheel, one position is open (no filter), and the remaining seven are available for optical elements such as filters, neutral density attentuators, and transmission gratings. A list of possible filter candidates, extracted from the HRC Final Instrument Definition Report, is given in Table 2-1.

Each filter wheel is driven by a redundant pair of electric motors and electromagnetic clutches. Filter wheel rotation is always in the same direction. Indexing time to change from one filter position to the next is approximately 0.3 seconds; therefore the maximum time required to obtain any filter combination is approximately 2.5 seconds.

The clear aperture of each filter wheel position is 60 mm x 60 mm square. Location of the filter assembly close to the detector image plane reduces the need for high optical figure quality in the filter elements, but does require that the filters be uniform in their spectral transmissivity characteristics. Since the filter elements are placed in a converging optical bundle, their presence affects the focal plane location. This effect is proportional to filter element thickness. If only one filter is used and plain glass is placed in the "blank" hole, then the instrument can be focused for this case. However, it is preferable to have nothing at all in the blank spaces and to use two filter elements in combination for certain operational modes. Thus to minimize the focus error effects, the filter elements should be kept as thin as practical (about 3 mm) and the instrument focused for the case of 2 filter elements in the optical train.

Table 2-1 Possible Filter Complement

f/24 Focal Plane							
1.	TG-1	8.	1200 Å	15.	ND-1	22.	5007
2.	TG-2	9.	1500 Å	16.	ND-2	23.	6563
3.	U	10.	1900 Å	17.	glass	24.	-
4.	B	11.	2200 Å	18.	SiO_2	25.	-
5.	V	12.	2500 Å	19.	3728 Å	26.	-
6.	R	13.	2800 Å	20.	4363 Å	27.	-
7.	I	14.	3200 Å	21.	4860 Å	28.	-

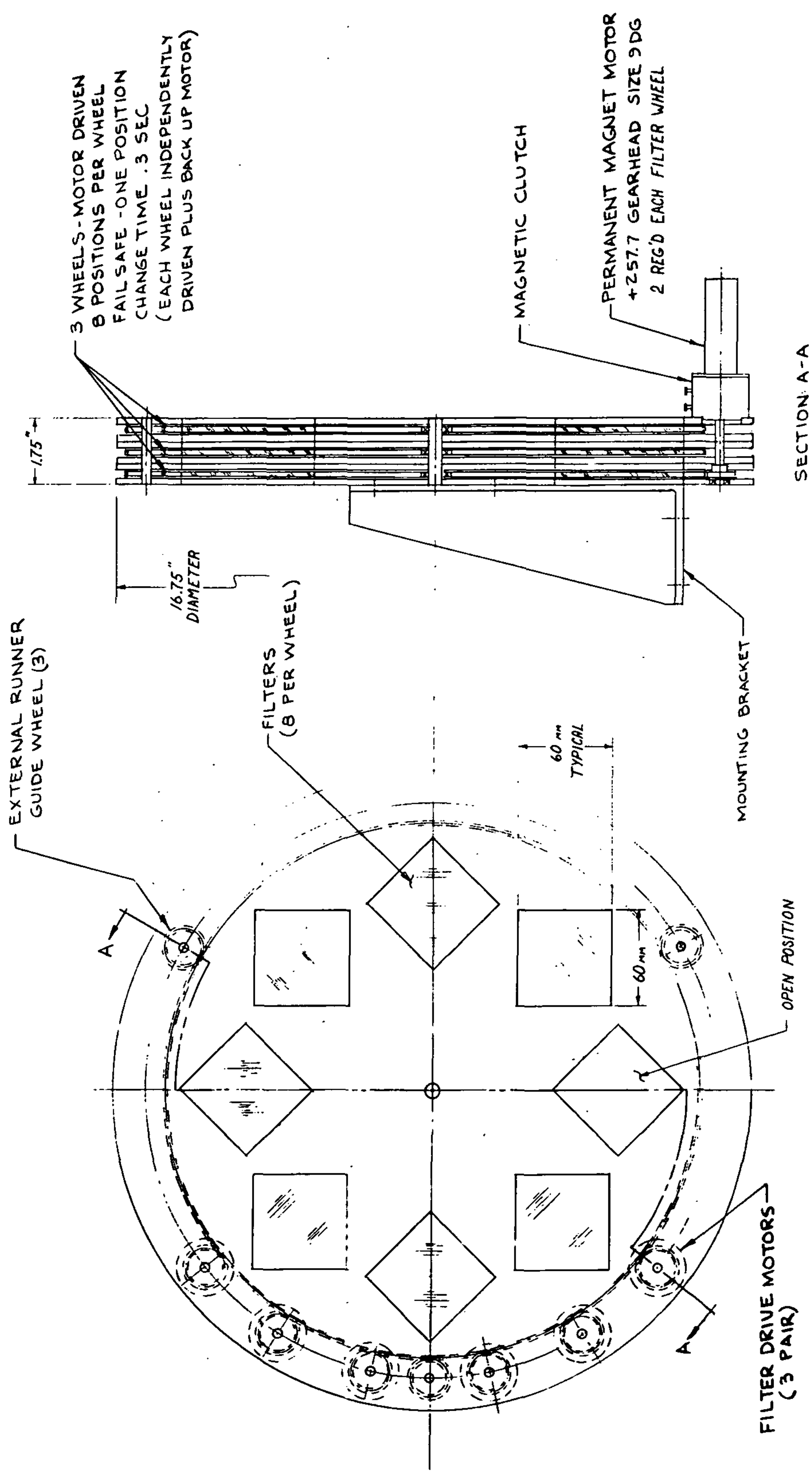

Figure 2-4. Filter Wheel Unit

Each of the three filter wheels has eight stop positions, each position being identified with the filter or optical element located at that point. Commands are sent simultaneously to one, two or all of the three wheels. Detents at each "filter" position insure a uniform "centering" of the element (the beam size is 55x55mm so a precise location is not critical) and eliminates the critical requirement for positioning from the motor/magnetic clutch. Eight light emitting diodes/photo sensors (not shown in Fig. 2-4) provide instrumentation data on exact rotational position (filter location). These sensors monitor the wheel at a position opposite the aperture - this will provide adequate space for shielding against stray light.

Reference to Figure 2-1 shows the very limited space between the front of the radial bay module and the SECO camera. All of the functional subsystems of the camera (filter wheel, shutter and calibration optics) require access to the light path in this area. As a result the filter wheels have been designed as a thin disc. Three (3) external guide wheels are provided to the periphery of each filter wheel to provide support to the thin filter wheel structure to insure that the wheel rotates in a uniform plane and to provide support/damping against vibration.

Two drive motors are provided to each filter wheel - one is used normally to move the wheel to a selected position, the second serving as a back-up drive system. In the event of the failure of one filter wheel drive, the fail-safe mode of operation is to use the back-up drive motor to rotate that wheel to the "open" filter position. An alternative to this mode of operation is to continue using the filter wheel via the back-up drive with the risk that a second failure (in this back-up drive) would leave the filter wheel inoperative with perhaps an unfortunate filter now permanently lodged in the optical path. The present design provides no provision for clearing this problem via on-orbit maintenance.

The rotating filter wheel concept was judged the most reliable for the f/24 camera design, considering the limited space and size and number of filters. Translating or insertion type designs have been used in the past and were considered but were not applicable here primarily because of the large number of filters. Perkin-Elmer has used the rotary filter configuration most often and it has proven to be simplest in design and very reliable. There are no special problems - manufacturing tolerances are nominal and the motors, clutches, bearings and engineering data sensors are readily qualified from previous space equipment designs.

2.5 PORT DOOR SUBSYSTEM

The port door subassembly is shown in Figure 2-1. The prime function of this door is to (1) move the calibration mirror into position along the optical path of the camera and (2) seal off background light during the calibration measurements. The small flat mirror, which folds the calibration source light onto the optical axis,is fixed to the port door. The pivot shaft, about which the door rotates as it closes, provides a small helical motion to insure a good light seal in the closed position.

The port door is open during the general operation/use of the Field Camera. It requires no power in this position, and is held there by a spring on the pivot shaft (reference Figure 2-5).

The door is closed only during periods of instrument calibration. Power is applied to the resetting (cocking) motor/magnetic clutch which drives the door closed over the entrance aperture of the instrument. (This closing brings the calibration mirror into position on the optical axis.) In this closed position the door is captured and held by a solenoid operated latch; power is required on this solenoid to hold the latch/door. With the door held closed by the latch, power is then removed from the motor/magnetic clutch. Power is held on the solenoid during the period that the camera is being calibrated. When calibration is complete, the power to the solenoid is removed, the latch releases and the door returns under its spring drive to the open position.

The requirement for power to the solenoid to hold the door in the closed position provides a fail-safe mode for the port door. In the event that the solenoid fails or power to this subsystem is lost the door will automatically return and stay at the full open position. The most significant consequence of this will be that the calibration mirror cannot be deployed and the internal calibration source then is rendered inoperative. In this event, calibration will have to be conducted by imaging a known stellar point source onto the photo cathode and raster scanning this source over the photocathode by exercising the OTA in a similar raster scan pattern.

Use of the port door as a means for contamination control was considered during the study. The real trade is between improved levels of cleanliness and the risk that a door closed will remain closed and end all use of the instrument. The study concluded that aperture doors are to be avoided wherever possible and that operations such as closing the port door for calibration should be conducted as infrequently as possible.

The port door subsystem presents no special problems in either design or manufacture. Tolerances are everywhere nominal. Components to include the motors, clutches, solenoids, etc. should be available and readily qualified for this application.

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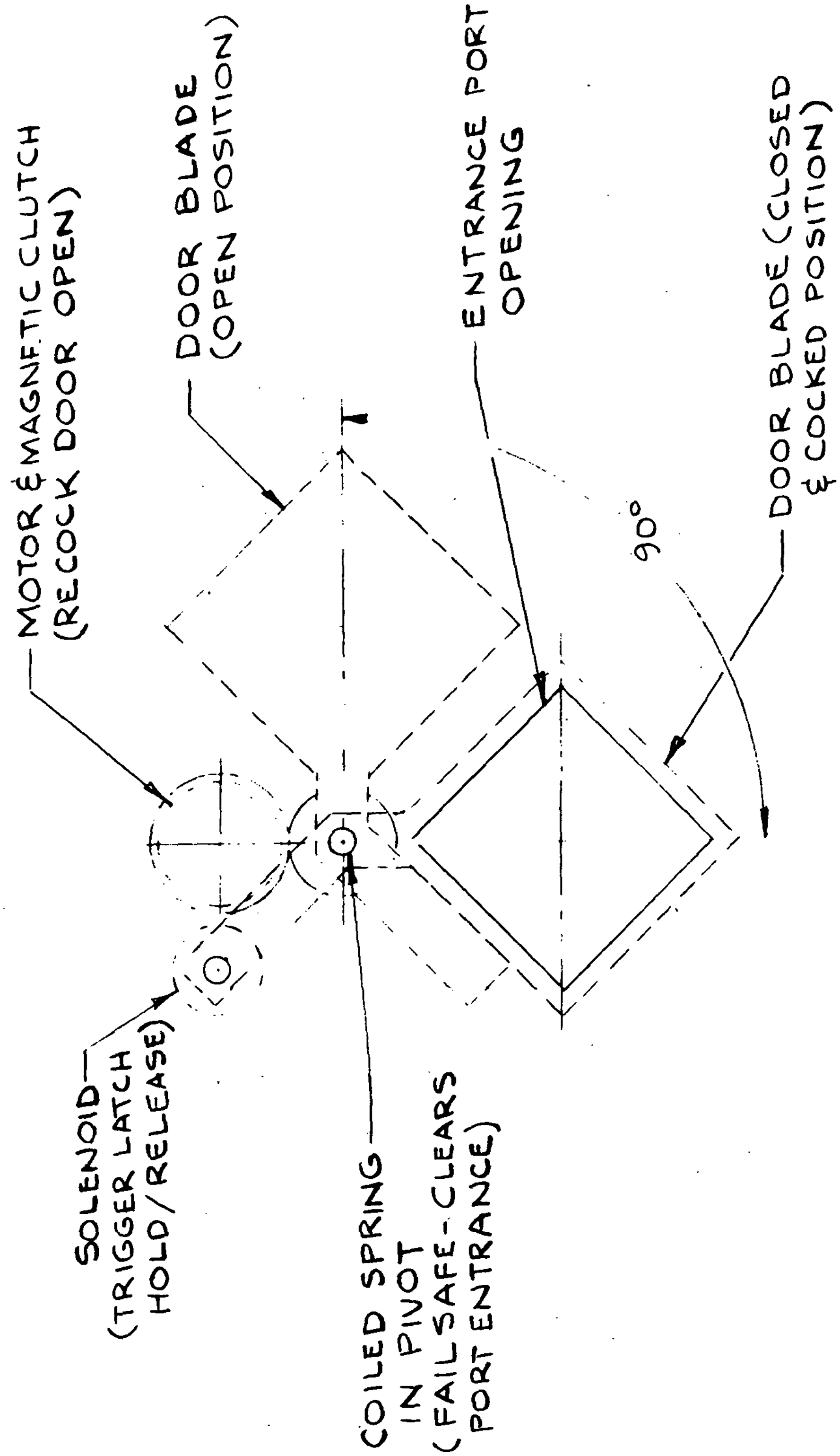


Figure 2-5. Port Door Operation

2.6 MAINTENANCE

The f/24 Field Camera is completely contained within the radial bay module defined in Figure 1-3. The instrument is maintainable on orbit by removal/changeout of the complete module.

The design is such that proper registration of the locator detent on the radial module (reference Figure 2-1) with the locator ball (a fixed part of the OTA) and attachment of the module at the two fixed points on the OTA focal plane structure will locate the pick-off mirror on the OTA optical axis at the position to image the field of view on the SECO photo cathode. Guides to assist a suited astronaut in the change-out operation are not shown but will be built into both the OTA focal plane structure and the radial module. The module is secured (bolted) directly to the ball detent through the attachment tool shown in Figure 2-1. The clamping mechanism to secure the module at the two side points is a part of the OTA.

The electrical connectors are located on the outer surface of the module for easy access by the astronaut. They are available space replaceable types which can be opened/closed by a fully suited astronaut.

2.7 WEIGHT AND POWER SUMMARY

Table 2-2 summarizes the weight and power consumption of the Field Camera, by major subassembly.

Weights have been computed from design drawings wherever appropriate. Manufacturers' weight data has been used in estimating purchased parts.

As mentioned earlier in this section, the power required to cool the detector could conceivably be reduced by careful design of the detector package (reference Thermal Design, Section V).

A typical field camera operational power profile is shown in Fig. 2-6.

TABLE 2-2

WEIGHT AND POWER SUMMARY

	Weight (Lbs)	Power (Watts)
Pick off Mirror	5	-
Detector	130	20
Filter	15	(15)
Shutter	5	(15)
Calibration	10	(15-20)
Port Door	5	(15)
Electronics	30	30
Thermal	5	15
Optical Bench	50	-
Module	90	-
Field Camera Module	345	65 Average* 95 Peak

*Allowable power 100 watts

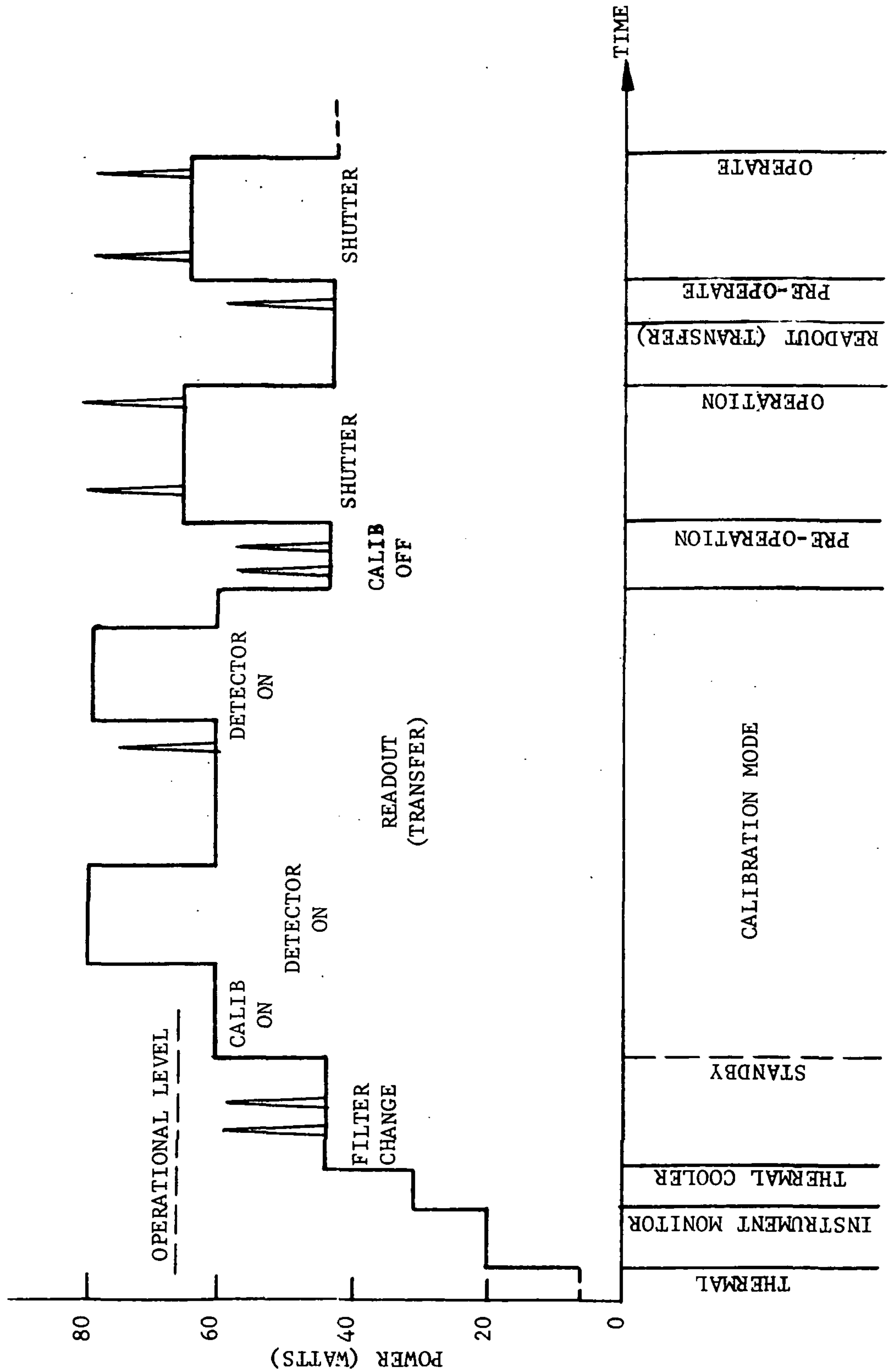


Figure 2-6. Typical Camera Power Profile

SECTION 3

OPTICAL SYSTEM DESIGN

3.1 GENERAL

The performance of the f/24 Field Camera depends on the design of the optics of the instrument and the design of the ST Ritchey-Chretien telescope. Consequently, the contributions of both must be considered in the design. The analysis of instrument performance is from the celestial sphere through the telescope to the Field Camera optical system (its filters and mechanisms) to the detector.

This section of the Final Report is divided into three parts. The optical parameters of the Ritchey-Chretien telescope and its interface with the camera are discussed in Paragraph 3.2. Possible design configurations of the f/24 Field Camera are discussed in Paragraph 3.3. The design of the camera optics, their performance with the telescope, and the characteristic features of the system are discussed in Paragraph 3.4.

3.2 OTA/SI OPTICAL INTERFACE

The optical interface between the OTA (Optical Telescope Assembly) and the SI's (Science Instrument) is considered in five parts:

- OTA/SI performance requirements
- OTA design
- Focal plane access
- OTA image quality/field correction
- Performance-influencing factors
  - Optical tolerances
  - Pointing jitter
  - Stray light

A summary of OTA minimum performance requirements is given in Figure 3-1. The difference between the design wavefront error of .05λ(λ/20) rms opd at 632.8 nm and the implied .074λ(λ/13.5) rms

CALCULATED PERFORMANCE (ON-AXIS)	
ENTRANCE PUPIL DIAMETER	2.4 M
SYSTEM FOCAL RATIO	f/24
DESIGN SYSTEM WAVEFRONT ERROR	.05λ rms
DESIGN, TEST AND VERIFICATION WAVELENGTH	632.8 nm
CENTRAL OBSCURATION	34% (Maximum)
ENCIRCLED ENERGY	
0.075 ARC-SEC RADIUS	60%
WAVELENGTHS	121.6 nm to 632.8 nm
RESOLUTION	
RAYLEIGH CRITERION	0.1 ARC-SEC

Figure 3-1. Optical Performance Requirements

error to meet the 60 percent encircled energy requirement in a 0.075 arc-sec radius circle for the OTA provides for hardware contingency.

The portion of the ST performance budget allocated to the OTA is shown in Figure 3-2. The first major division of performance responsibility is between image motion and image quality. The first of these is attributed primarily to the telescope pointing system, while the second is attributed to the quality of the OTA optics.

The optical design prescription for the OTA 2.4 meter Ritchey-Chretien and its first order parameters are summarized in Figure 3-3. The system is composed of two pure conic sections (hyperboloids) and nominally provides a geometrically perfect image on-axis. Off-axis, the sytem, as with all Ritchey-Chretiens, is afflicted by field curvature and astigmatism. Details of system performance follow, but note that the actual design central obscuration is 31 percent. This is 3 percent less (72mm of diameter) than the maximum 34 percent allowed. The implied design margin is available for further baffle design, and if not used, provides additional performance margin.

The 28 arc-minute unvignetted field of view provided by the Ritchey-Chretien is allocated among the science instruments, pointing system and wavefront sensors as shown in Figure 3-4. Four 90° unvignetted segments of image are provided for the axial science instruments. Each extends a maximum of 9 arc-minutes (150 mm) from the OTA optical axis. The fifth science field, taken from the center of the OTA field of view, is allocated to the f24 Field Camera. The remainder of the field, from 9 to 14 arc-minutes, is reserved for the offset tracking sensor. The areas of the focal plane made inaccessible by the wavefront sensor pickoff mirrors and the structural components between instrument modules are also shown.

Within the telescope unvignetted field of view astigmatism and field curvature are the only significant aberrations present. These aberrations are detailed in Figure 3-5. The astigmatism, field curvature and small amount of distortion of the 2.4 meter ST Ritchey-Chretien are shown in the telescope's f24 image plane map. Out to a radius of about 4-1/2 arc-minutes compromise foci are available where diffraction-limited image quality can be provided, at 632.8 nm wavelength, for small regions of the focal plane. Beyond this point, optical correction must be provided to achieve diffraction limited quality.

In addition to the aberrations detailed in Figure 3-5, the diffraction effects inherent in the baseline OTA design modify nominal performance. Figure 3-6 summarizes these characteristics and shows their effects on performance. The vertical marks indicate the nominal design points of the parameters for the preliminary design OTA.

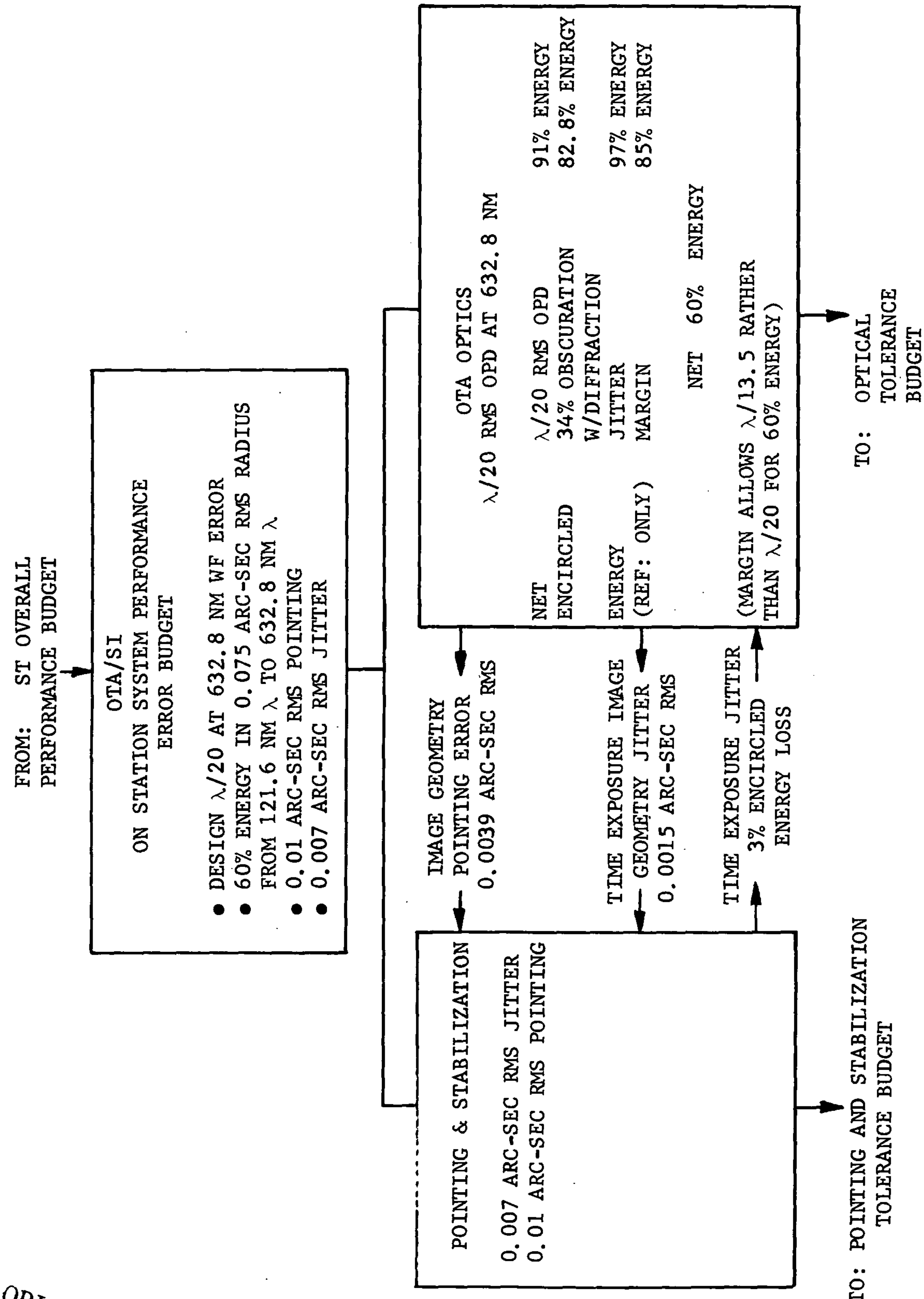
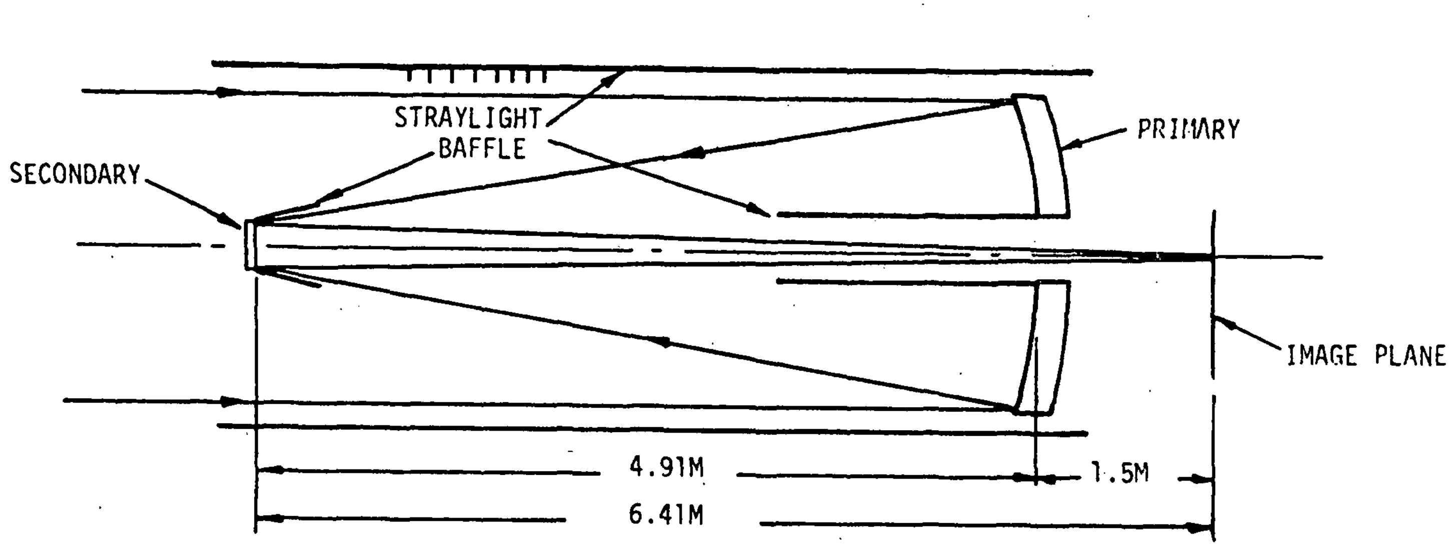


Figure 3-2. OTA/SI Tolerance Budget



Elements

- Primary - ULE Hyperbola, 11.04m Radius, 5.52m EFL, 2.4m Aperture, f/2.3
- Secondary - ULE Hyperbola, 1.358m Base Radius, 10.43 Magnification, 0.31m Aperture, f/2.23

System

• Aperture	2.4 m
• Focal Ratio	f/24
• Linear Obscuration Ratio	0.31
• EFL	57.6 m
• Back Focal Length	1.5 m
• Plate Scale	57.6 mm/mrad (16.76 mm/arc-min)
• Field of View Diameter	467 mmϕ, 8.1 mrad, 28 arc-min
• Data Field Diameter	300 mmϕ, 5.2 mrad, 18 arc-min
• Tracking Field Size	1.5×10^{-5} sr (180 arc-min)^2
• Coating	500Å to 800Å al w/250Å MgF
• Wavelength Range	100 nm to 1 mm
• Spatial Resolution (at 633 nm)	0.48μ rad (0.1 arc-sec) Rayleigh

Figure 3-3. OTA Optical Design

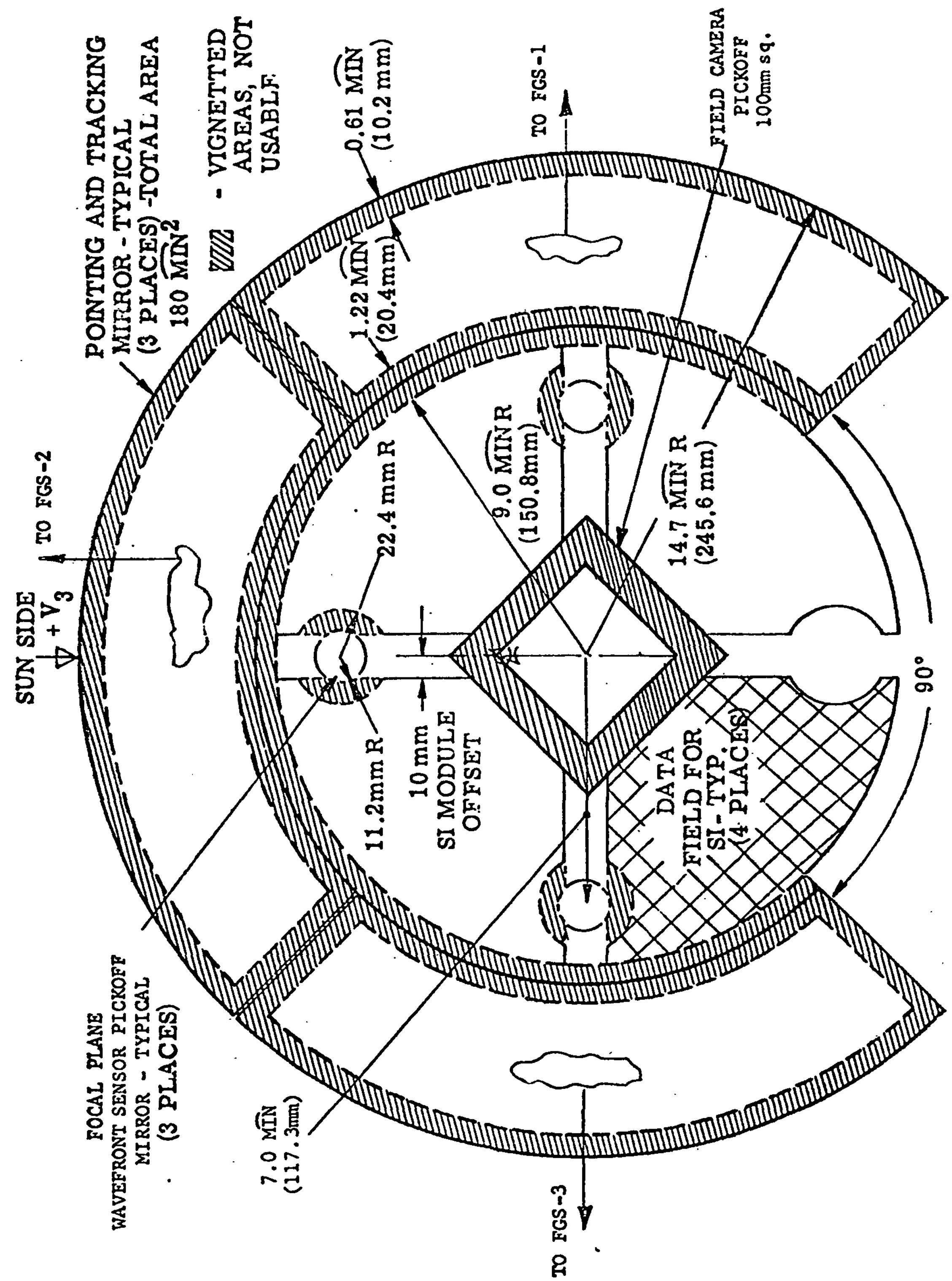
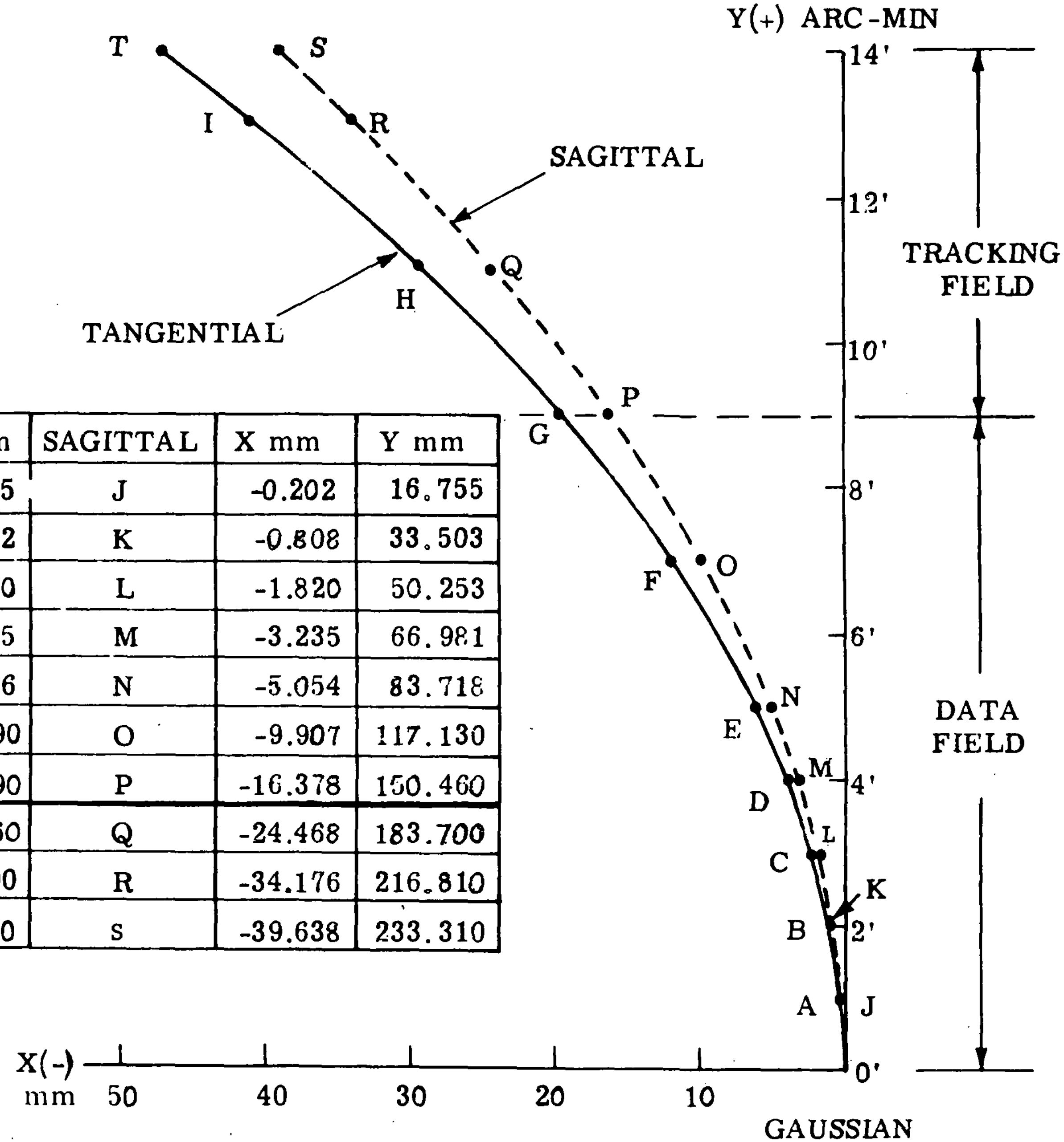


Figure 3-4. f/24 Focal Plane Layout



α	TANGENTIAL	X mm	Y mm	SAGITTAL	X mm	Y mm
1.0'	A	-0.244	16.755	J	-0.202	16.755
2.0'	B	-0.976	33.502	K	-0.808	33.503
3.0'	C	-2.197	50.250	L	-1.820	50.253
4.0'	D	-3.905	66.985	M	-3.235	66.981
5.0'	E	-6.102	83.706	N	-5.054	83.718
7.0'	F	-11.962	117.090	O	-9.907	117.130
9.0'	G	-19.776	150.390	P	-16.378	150.460
11.0'	H	-29.552	183.560	Q	-24.468	183.700
13.0'	I	-41.200	216.590	R	-34.176	216.810
14.0'	T	-47.881	233.040	S	-39.638	233.310

Figure 3-5. Focal Plane Topography

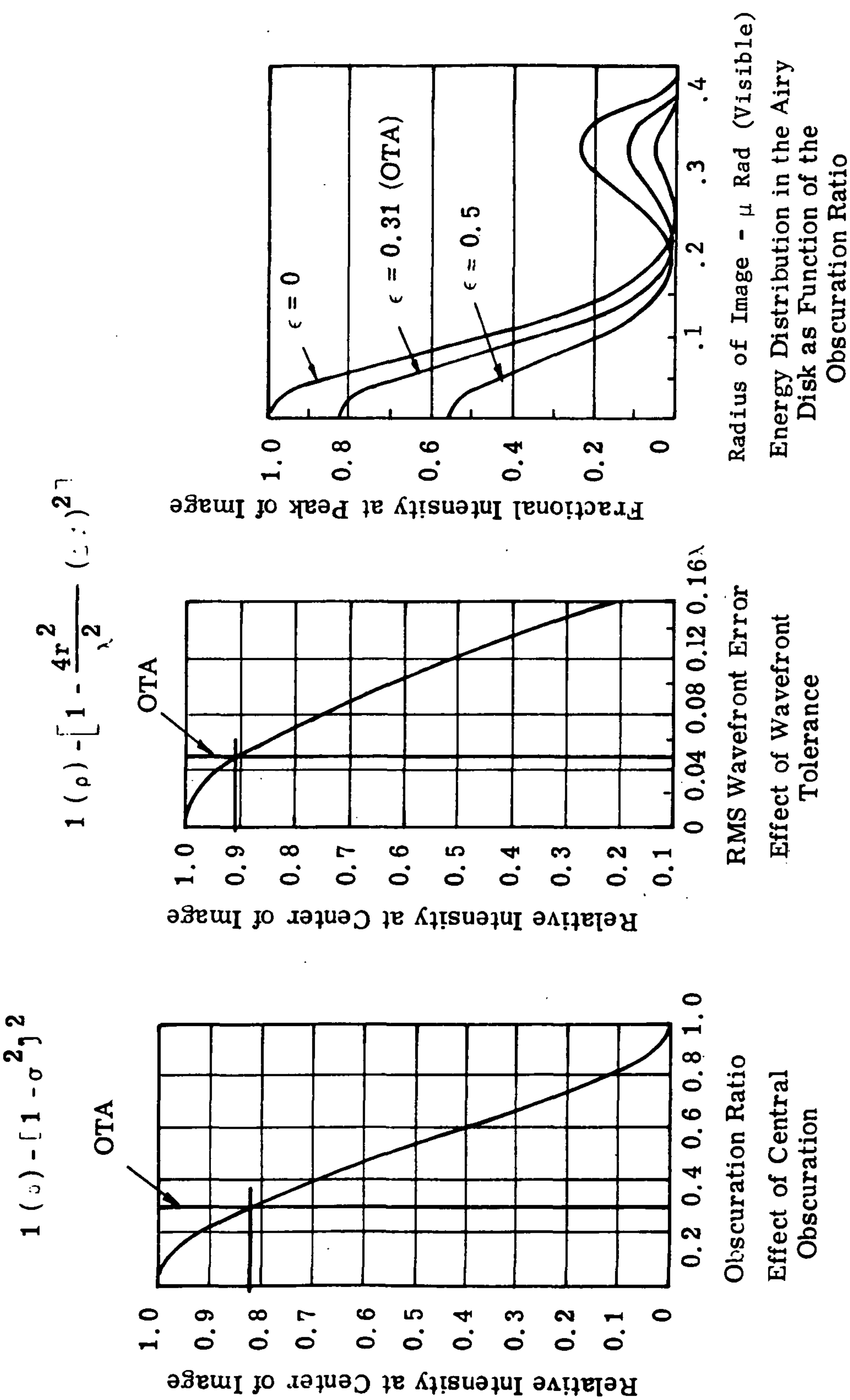


Figure 3-6. OTA Nominal Performance

Beyond the nominal telescope design performance, the assigned optical tolerances determine the ultimate performance. The tolerance allocation is made so as to achieve .05λrms at 632.8nm wavefront error on station. This near diffraction limited performance as provided by the OTA is not universally required by all instruments.

The instruments are designed and their tolerances are allocated to provide their required performance with the OTA budget taken into account. The tolerances for the Field Camera are detailed in Paragraph 3.4.

The OTA to SI interface tolerances are absorbed into the OTA tolerance budget and do not burden the instrument designs.

The preliminary design optical tolerance budget, as it evolved from the Phase B study is shown in Figure 3-7. It provides for initial ground setup, residuals after orbital corrections and system drifts between calibration periods.

Figure 3-8 is the computed expected performance of the OTA determined by evaluation of the completed preliminary design and is now that system's tolerance budget. Note that the required performance of .05λrms is slightly exceeded. This may be interpreted as additional design margin.

The final set of tolerances defining the OTA/SI interface are the instrument module mounting location accuracies and stabilities. These tolerances are summarized, for both the accuracies required for initial instrument placement and for drift over a calibration period, in Figure 3-9. The optical rms optical path differences induced by these tolerances are absorbed into the OTA structures tolerance budget in the overall .05λrms at 632.8nm wavelength budget. The numbers represent the accuracy and stability to which the SI modules will be held by the OTA Focal Plane Structure with respect to the OTA. Tolerances within the instrument module, between instrument components and the module mounting points, are included within the instrument budgets.

As an example of how this instrument placement tolerancing philosophy was carried out, focus maintenance is typical. Referring to Figure 3-10, the depth of focus band of the telescope is shifted and distorted by the OTA allowed tolerances to a controlled maximum. The SI placement band tolerance is established so that no matter where the instrument is within that band, it always lies within the focal depth of the telescope. As a result, the instrument is always in focus when installed in the system. The SI focus band is divided between all the OTA elements affecting the focus placement.

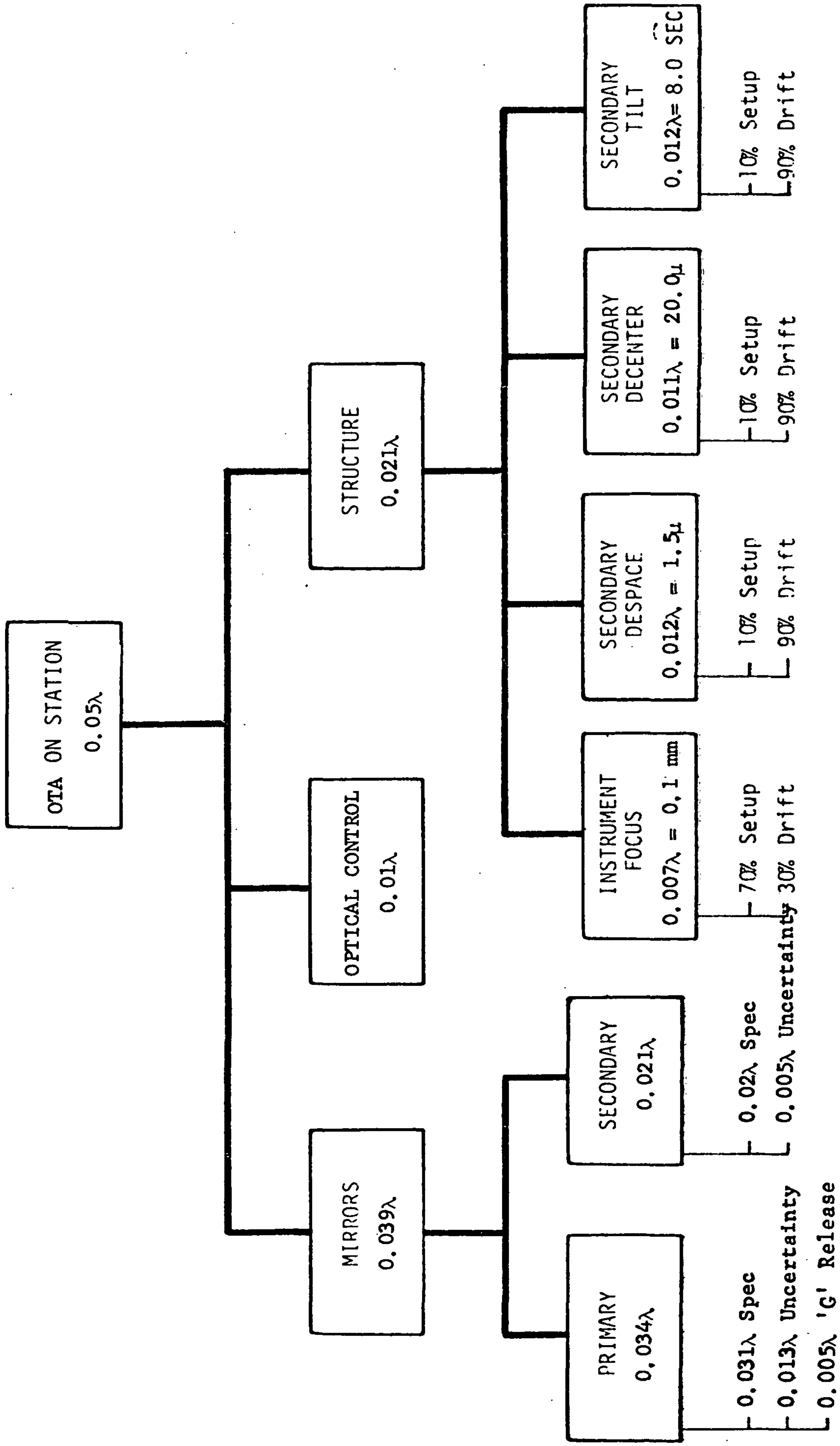


Figure 3-7. OTA Tolerance Budget Preliminary Design

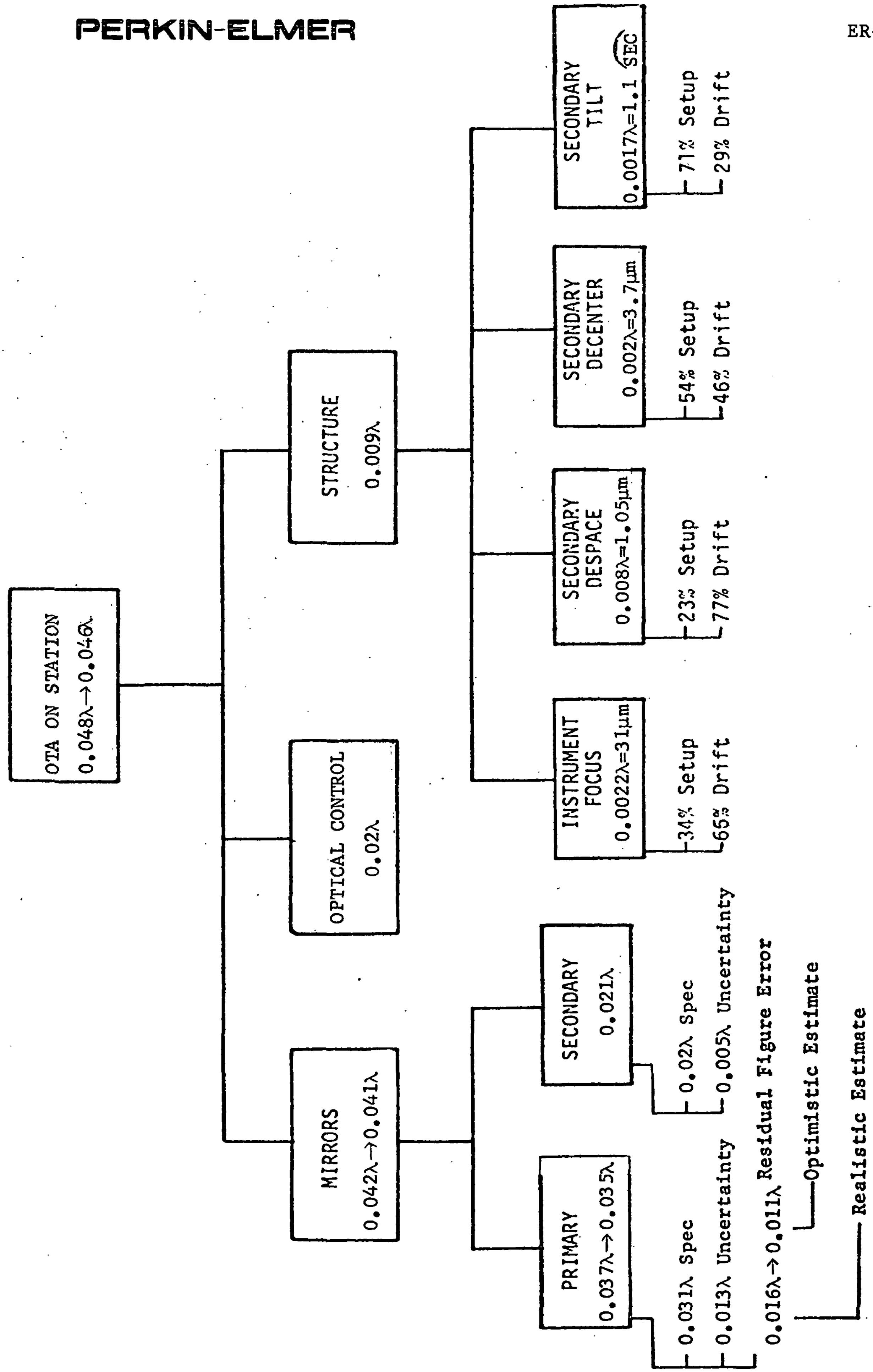


Figure 3-8. OTA Computed Performance Preliminary Design

- SI TO OTA TOLERANCES FOR ON-ORBIT INSTRUMENT REPLACEMENT

X = ± 0.1 mm	α = ± 0.5 mrad
Y = ± 0.1 mm	β = ± 0.5 mrad
Z = ± 0.026 mm	γ = ± 0.5 mrad

- LONG TERM INSTRUMENT STABILITIES (BETWEEN OTA/SI CALIBRATIONS AND DURING EXPOSURES)

X = ± 0.005 mm	α = ± 0.5 mrad
Y = ± 0.005 mm	β = ± 0.5 mrad
Z = ± 0.051 mm	γ = ± 200 μrad

- THE INDICATED TOLERANCES PERMIT UTILIZING FULL OTA CAPABILITY

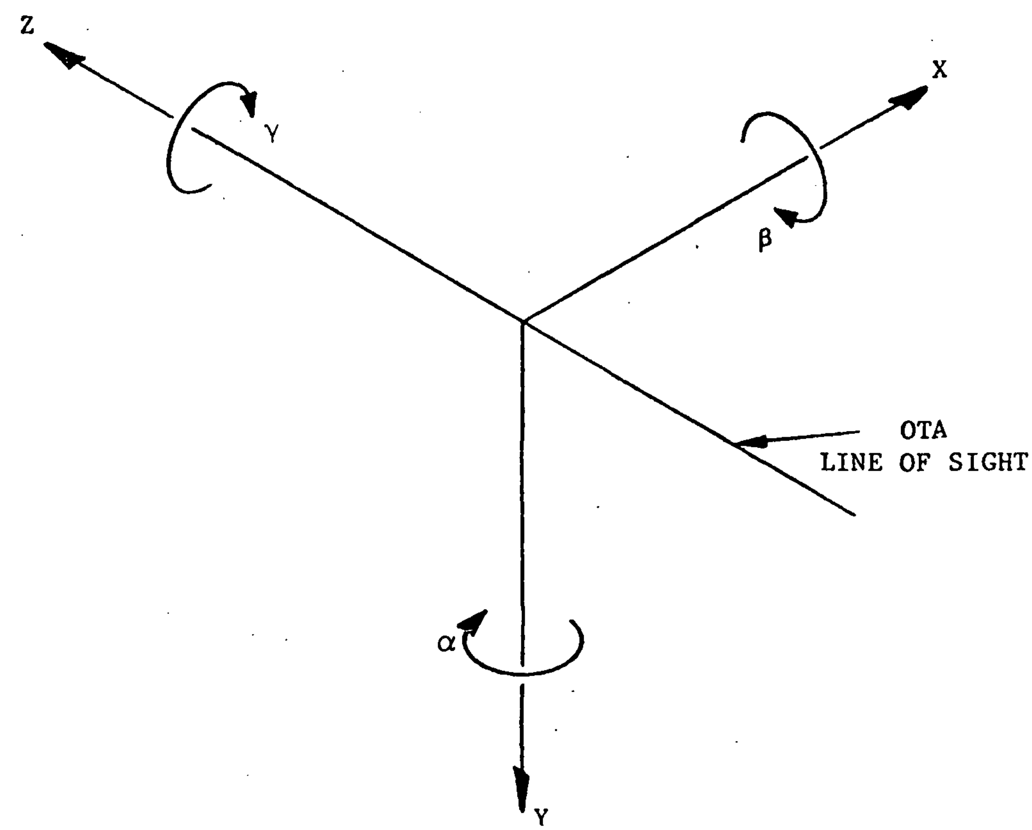


Figure 3-9. SI/OTA Interface Tolerances Allocation

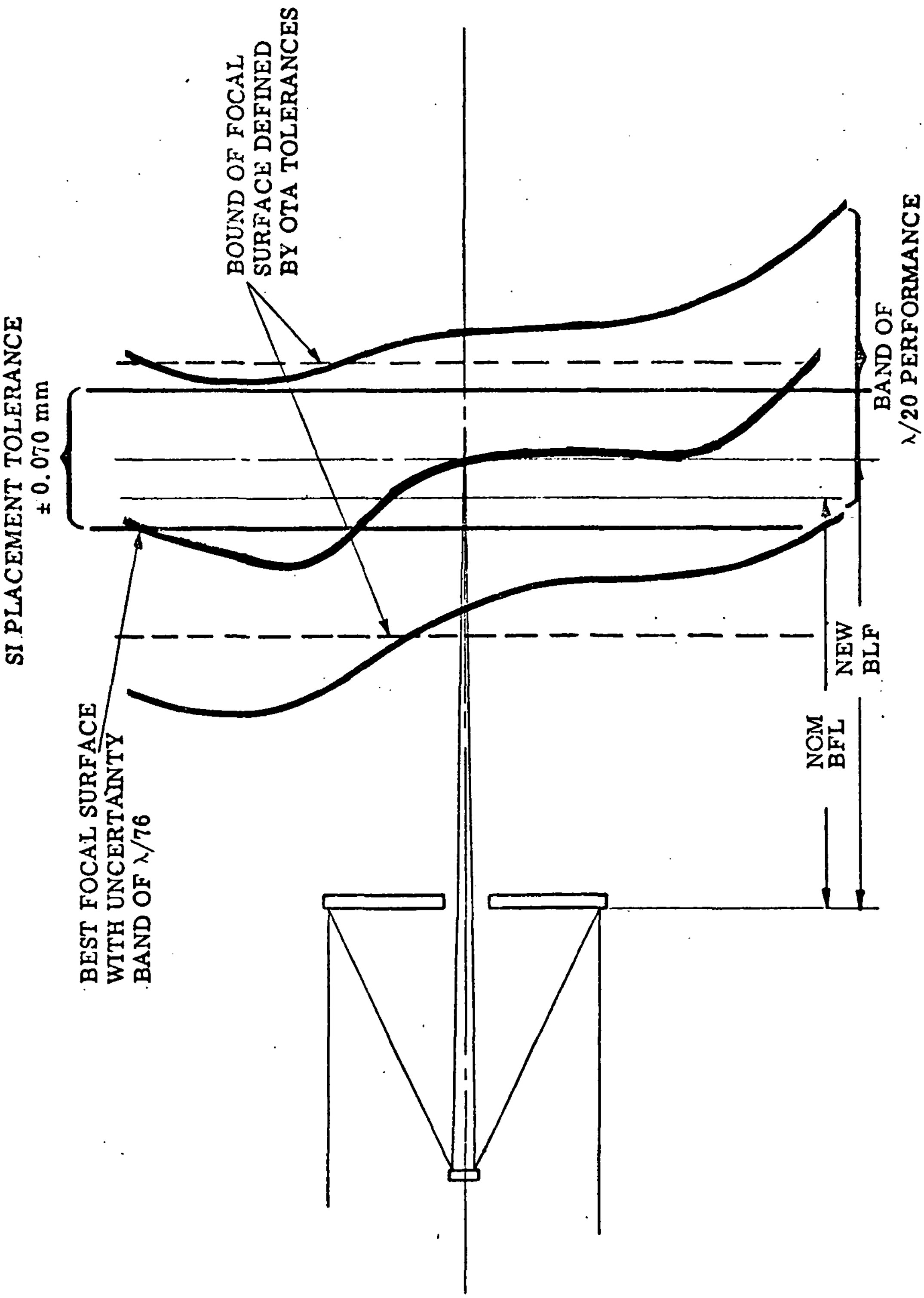


Figure 3-10. Focus Maintenance

3.3 CAMERA OPTICAL CONCEPT

The optical concept for the f/24 Field Camera was selected from several. These are:

1. A radial pickoff with field flattener. Fig. 3-11(a)
2. A radial pickoff without corrector and with SECO photocathode placed at the best axial focus position. Fig. 3-11(b)
3. A radial pickoff without corrector and with SECO photocathode placed at the best average focus for the field. Fig. 3-11(c)

The first requires a single M_gF_2 corrector lens either at the SECO faceplate or within 10mm of it. The element is plano/concave with a 200mm radius and provides a near perfect diffraction limited format. NASA indicated that grinding this surface into the front surface of the faceplate of the SECO is undesirable. Consequently it must be a separate element which is difficult to mount within the cone of the SECO tube. Its thruput loss as a separate element more than outweighs the 3 percent improvement in average encircled energy it provides. Consequently this approach was abandoned.

The second axial focus option provides a 0.1λ rms image in the format corners, a detectable degradation. The average focus option never drops below $.048\lambda(\lambda/21)$ rms correction. This third option was selected.

3.4 CAMERA OPTICAL DESIGN

The optical system of the selected f/24 Field Camera concept consists of only a flat, 45° diagonal pickoff mirror at the center of the OTA field of view. There is also the necessary optical filter set.

The pickoff mirror is located 546mm ahead of the OTA f/24 focal plane. At this position it is sized with an aperture of 68mm by 96mm to fill the format of the SECO detector without vignetting. The plane projection of this mirror in the OTA focal plane was shown previously in Fig. 3-4. At the 546mm prefocus position an additional vignetting shadow is cast in the science field. All the other instruments designed for ST can operate with fields outside this shadow. There is, therefore, no impact on the other instrument designs caused by the axial pickoff of the field camera's image and the radial location of the instrument itself. This is shown in Fig. 3-12 The pickoff mirror feeds the image directly through the shutter and filter set to the SECO cathode.

The image provided to the camera detector is identical to the OTA image with all the characteristics discussed in Paragraph 3-2 applying directly. These must be evaluated with the 25 micrometer pixel of the SECO detector.

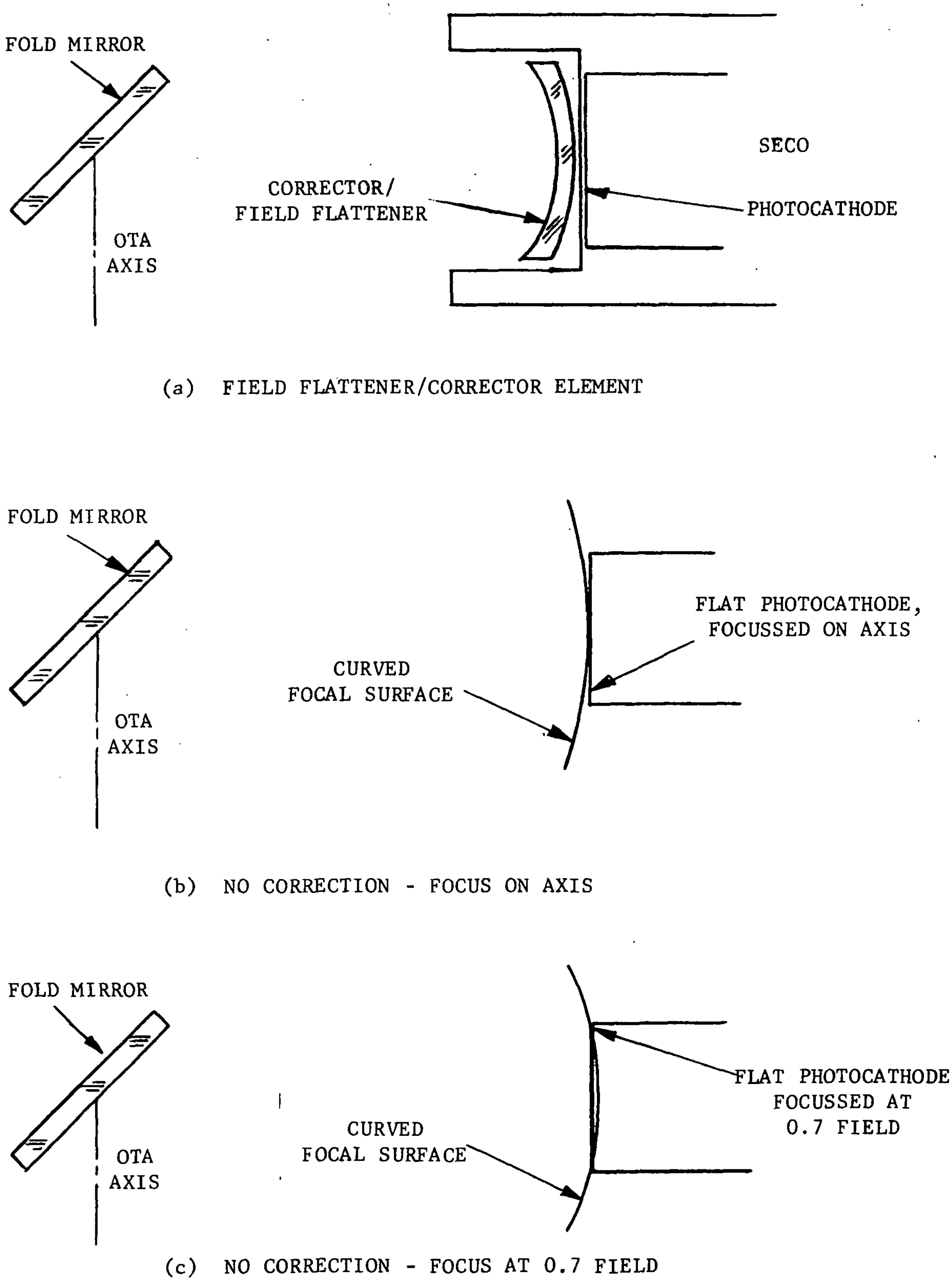


Figure 3-11. Candidate Optical Forms for Field Camera

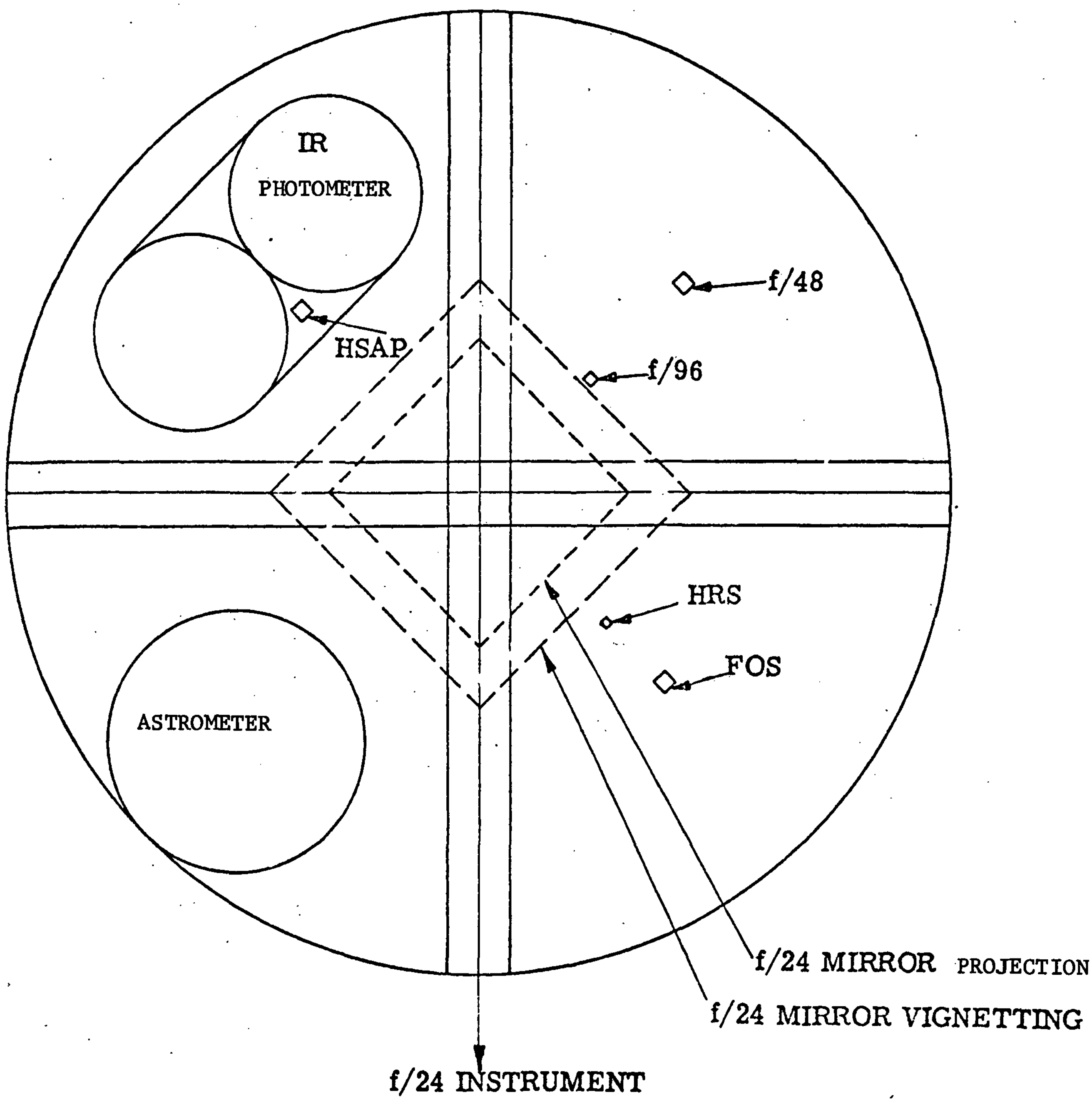


Figure 3-12. SI Entrance Apertures at OTA Focal Plane

The nominal design performance of the camera is evaluated first. This is done by computing the rms opds, the diffraction MTF, point spread function, and encircled energy for the camera in the nominal configuration. The output of these calculations is given in Appendix A. For the calculations the system is focused for the 0.7 field point of the image. At this focus the maximum opd anywhere in the image is minimized and the largest area of the format, surrounding the 0.7 zone is in best focus. At this, the recommended focus, the opds are as tabulated in Figure 3-13. This shows that, after combining the camera with the design wavefront error of 0.05λ rms of the OTA, the worst opd at the corner of the camera format is still .069λ(λ/14) rms (well within the accepted .083λ (λ/12) to .071λ(λ/14) rms definition of classical diffraction limit). If OTA performance is only the minimum .074λ(λ/13.5) rms, the opd at the corner of the camera format would be .088λ(λ/11.4) rms.

The possible MTF of the system is tabulated in Figure 3-14. The significant frequency is 20 line-pairs per millimeter, corresponding to the 25μ pixel size of the SECO. The unobscured and obscured theoretical performance of the system is shown to compare with the specified 50 percent response of the SECO at 20 line-pairs per millimeter.

The graphical presentation of the MTF given in Figure 3-15 shows that performance is nearly theoretical. Note that the effect of central obscuration is nearly maximized at the SECO pixel frequency. Maximum degradation of MTF at this frequency due to uncorrected field curvature and astigmatism is 6 percent.

The point spread functions at various points in the field were computed in generating the encircled energy. These are given in Appendix A. The encircled energy, the relative energy intercepted by a square 25mm detector at the focal plane from a point object, is plotted in Figure 3-16 vs. field angle. It varies from 62 percent to 67 percent over the field with an average of 64 percent. A perfect system would produce 67 percent across the field but would require additional optical components with thruput reductions in excess of the advantage gained.

On station, the operation of the Field Camera will be modified by OTA imperfections resulting from tolerances. If the encircled energy of that system were to drop to the minimum of 60% in .075 arc-seconds, the probable reduction in Field Camera performance would be a reduction in average encircled energy from 64 percent to 54 percent. MTF is reduced by a corresponding ratio.

Optical tolerances assigned to the Field Camera include only surface figure on the diagonal, focus, and image tube tilt. Holding these to .02λ rms, ±0.1mm and 10 arc-minutes respectively (standard shop practice) results in no significant image degradation.

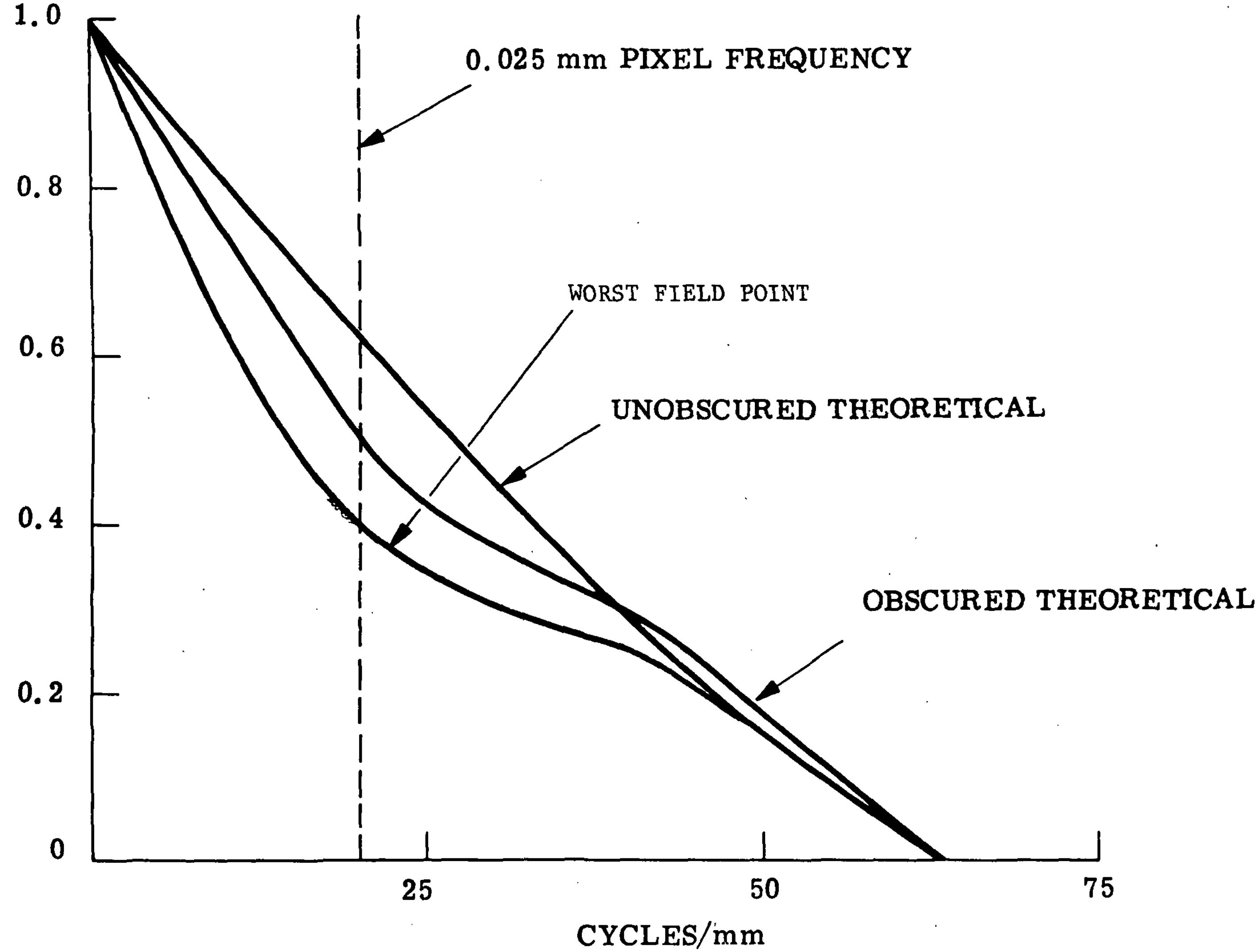
% FIELD	FIELD	RMS OPD of f/24 CAMERA	COMBINED (RSS) RMS OPD OF f/24 CAMERA AND λ/20 RMS OTA
0.0%	0.0 DEGREES	λ/23.45 = 0.043λ	λ/15.2 = .066λ
50.0%	0.01243	λ/31.58 = 0.0317λ	λ/16.9 = .059λ
70.0%	0.02487	λ/142.9 = 0.007λ	λ/19.8 = .050λ
100%	0.03517	λ/21.0 = 0.0476λ	λ/14.5 = .069λ

Figure 3-13. Field Camera Nominal OPD Performance
(Average Focus, 632.8 nm)

FREQUENCY (LINE-PAIRS/mm)	THEORETICAL UNOBSCURED MTF	THEORETICAL 31% OBSCURED MTF	ACTUAL 0 FIELD MTF	ACTUAL .5 FIELD MTF	ACTUAL .7 FIELD MTF	ACTUAL FULL FIELD MTF
10.0	0.805	0.722	0.693	0.705	0.721	0.676
20.0	0.611	0.468	0.426	0.443	0.468	0.402
30.0	0.439	0.344	0.321	0.331	0.344	0.308
40.0	0.279	0.288	0.261	0.272	0.287	0.247
50.0	0.130	0.143	0.133	0.137	0.143	0.127
60.0	0.034	0.037	0.036	0.037	0.037	0.036

- WAVELENGTH = 632.8 nm
- 20 LP/mm ⟶ 0.025mm PIXEL

Figure 3-14. Field Camera Nominal MTF Data (Average Focus)



• WAVELENGTH = 632.8 nm

Figure 3-15 Field Camera MFT Curves

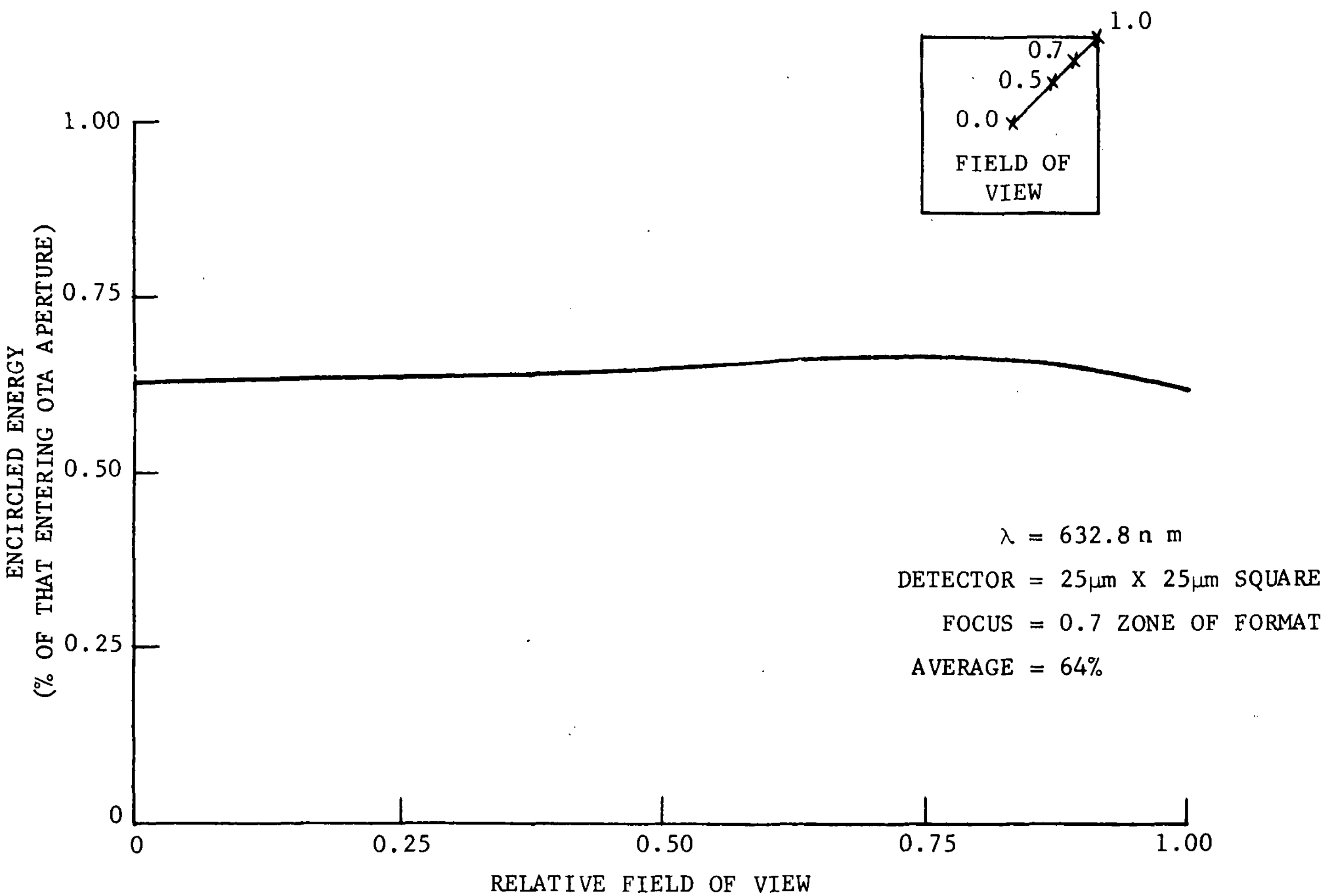


Figure 3-16. Field Camera Diffraction Encircled Energy
(25um square pixel) (Nominal System)

The nominal thruput of the f/24 Field Camera and the camera plus the Ritchey-Chretien are plotted in Figure 3-17. The thruput is reduced by the diagonal mirror an average of 5 percent over the transmission of the Ritchey-Chretien alone.

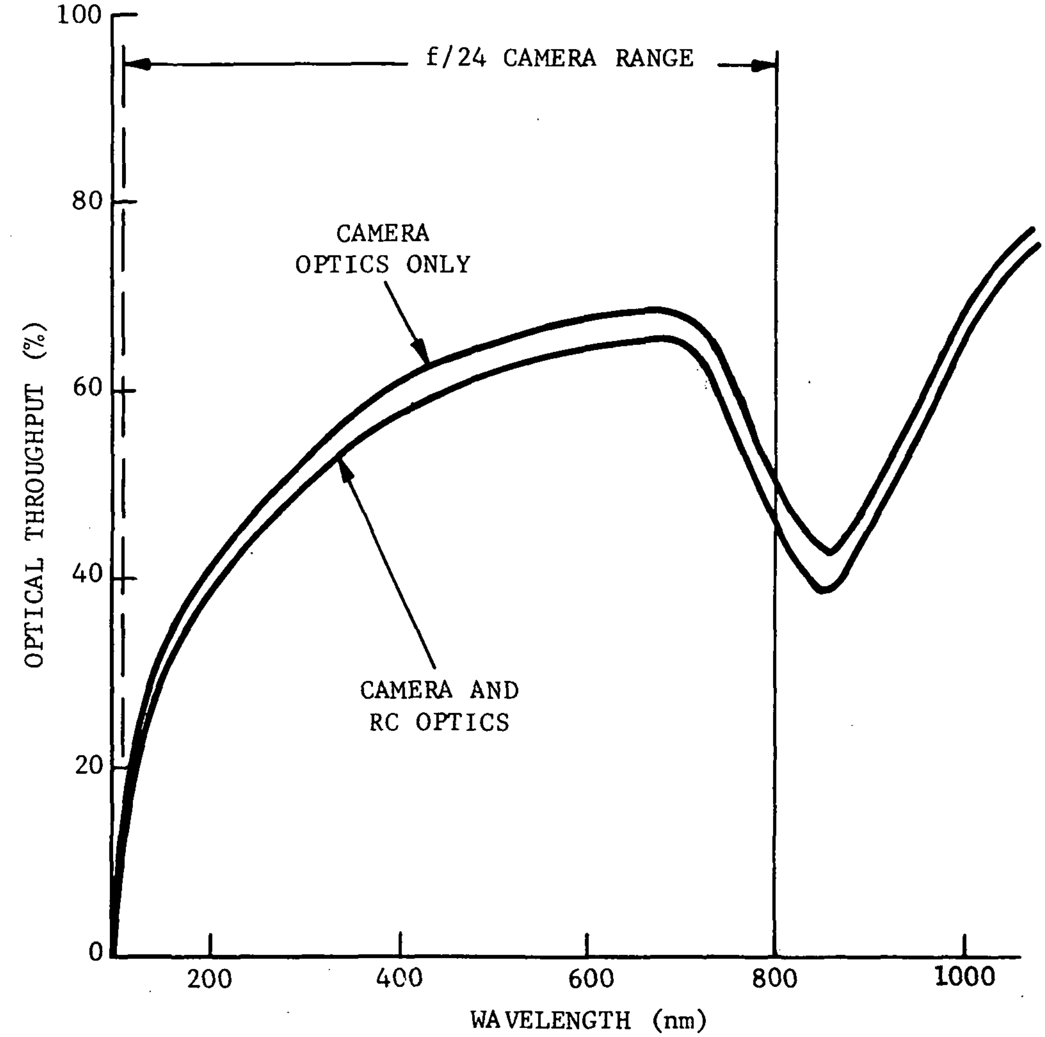


Figure 3-17. f/24 Field Camera Optical Throughput (500Å to 800Å A_ℓ + 250Å MgF_2)

SECTION 4

CALIBRATION

4.1 REQUIREMENTS

The prime requirement of the calibration unit is to provide information to the scientist on the spatial uniformity of Field Camera sensitivity. A secondary requirement is to provide a measure of camera throughput in absolute terms. This absolute testing of detector and optical system is performed using celestial sources.

Much of the scientific value of the f/24 Field Camera lies in its photometric measurement capability over a wide field of view. In order to preserve this capability, the calibration unit will be used at periodic intervals throughout the operational life of the instrument. Long term reliability is therefore a requirement in the calibration unit design. Fail-safe operation is also a requirement so that in the event of calibration unit failure, the camera remains operative. The calibration subsystem is shown in Figure 2-1.

4.2 CALIBRATION UNIT DESIGN

The calibration source is used to illuminate an elliptical condensor mirror, which reimages the source at a field lens. The field lens is chosen so as to relay the pupil (the elliptical condensor) of the system onto the detector photocathode. In this way, a uniform illumination intensity is achieved over the photocathode area. To eliminate the possibility of edge diffraction effects, and to provide easy alignment tolerances, the calibration unit pupil has been chosen to overfill the detector. The field lens may be made of L_iF_2 so as to provide the capability to perform calibration at U.V. wavelengths.

The same optical relay system is used in conjunction with two separate calibration sources, by placing each source slightly off axis. Both sources (ref. 4.3) can then provide equally uniform illumination of the photocathode, but with slightly different incident chief ray angles; - a difference which is of no practical consequence. The (unfolded) optical layout of the calibration unit is shown in Fig. 4-1.

As described in section 2.5, and shown in Fig. 2-1, the light beam from the calibration source unit is projected into the optical path of the

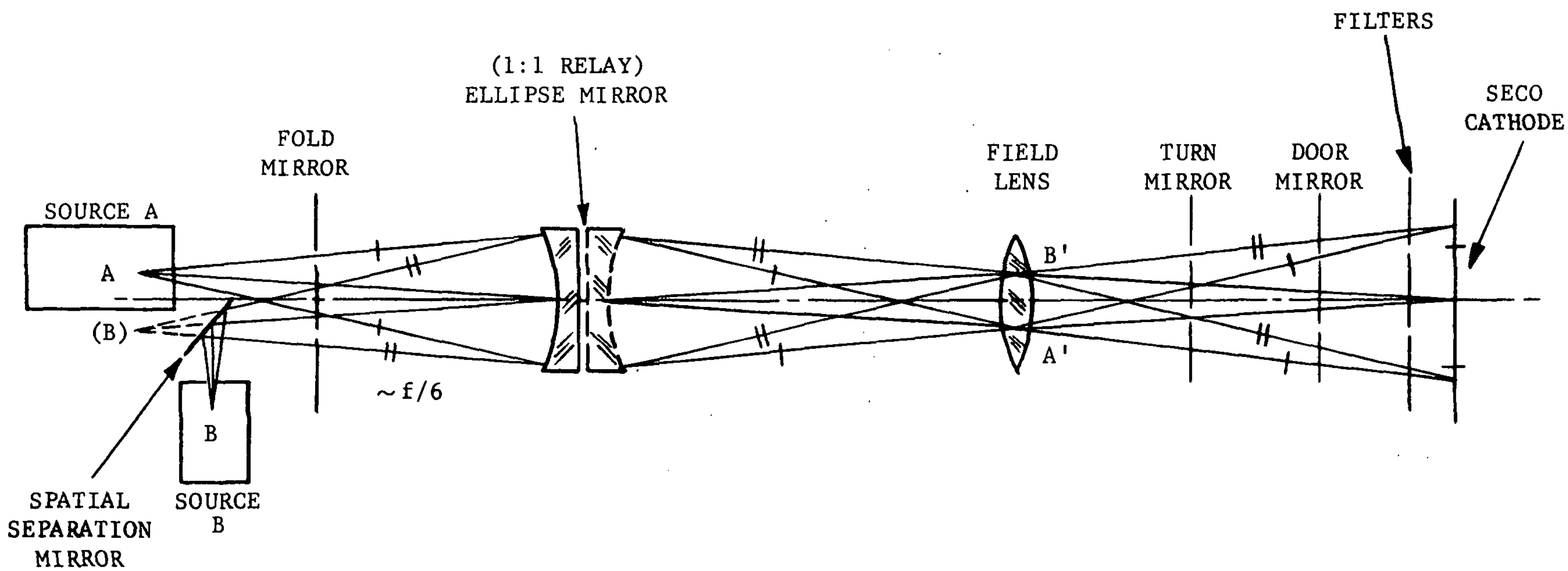


Figure 4-1. Unfolded Optical Schematic of Calibration Subsystem

camera unit by a fold mirror mounted to the inside of the port door. Thus, the calibration unit illuminates the detector through the camera shutter and filter wheeel assemblies. The calibration procedure thus takes into account shutter and filter wheel effects. An initial calibration exposure will be required for each filter or filter combination planned for scientific observations. Thereafter, periodic measurements to discern any temporal drift in characteristics will be required.

The steps in a typical nominal calibration sequence are as follows:

1. Close Port Door - this brings the calibration fold mirror into proper position on the camera optical axis and closes out all external light.

2. Select proper filter position.

3. Turn on calibration source - two are provided and are operated sequentially.

4. Conduct calibration measurement. Camera shutters control exposure periods.

5. Extinguish calibration sources.

6. Repeat steps 2, 3, 4 as many times as required.

7. Select filter position for next observational target.

8. Open Port Door - end calibration sequence.

As noted in Section 2-5, the operation of the Port Door is fail-safe in the "Open" position. In the event of a failure in the door assembly, the door would move to the "open" position and remain there. This would effectively remove the calibration fold mirror from use in the system. In this event, calibration of the detector would have to be conducted on planetary or stellar sources.

Such celestial calibration sources are, of course, small in angular subtense and therefore illuminate only a small portion of the photocathode. In order to calibrate detector uniformity, therefore, the celestial source must be "raster-scanned" over the photocathode area using the raster-scan capability of the OTA fine guidance subsystem. Under normal circumstances a complete raster scan will not be required. Taking advantage of previous uniformity measurement data, it is necessary only to re-check a small number ($\approx$ 10 or 20) of discrete locations in the field of view to determine any changes since the last calibration. Spatial variations in sensitivity are less likely to change with time, than is the spatial average sensitivity.

4.3 CALIBRATION SOURCES

In view of the importance of calibrating the uniformity of photocathode sensitivity, continuous (or broad band) sources are preferred over emission line (or narrow band) sources. The greater coherence of narrow band sources give rise to spurious diffraction effects which can cause a non-uniform illumination of the cathode area.

The calibration sources recommended for this preliminary design are a Tungsten-Halogen filament lamp and a Deuterium discharge tube. These two sources allow calibration throughout the spectral bandwidth of the camera unit. Typical output characteristics of these types of lamps are shown in Fig. 4-2.

Both of the recommended sources are readily available lamps, which have been widely used for many years as photometric and spectral calibration sources. Their performance characteristics are well understood and well documented. Such lamps are the standard illuminaants of most U.V./Visible laboratory spectrophotometers. When correctly operated they exhibit long lifetimes and require minimal warm-up times.

In order to extend the calibration range into the vacuum ultra-violet, however, alternate sources will be required. Candidates for consideration as future v-u-v calibration sources include the calibration source being developed for the International Ultra-violet Explorer (IUE) payload, and space qualified adaptation of the NBS high temperature Hydrogen arc discharge tube.

If these sources are used, then the field lens in the calibration unit must be made of a u-v transmitting material such as LiF_2.

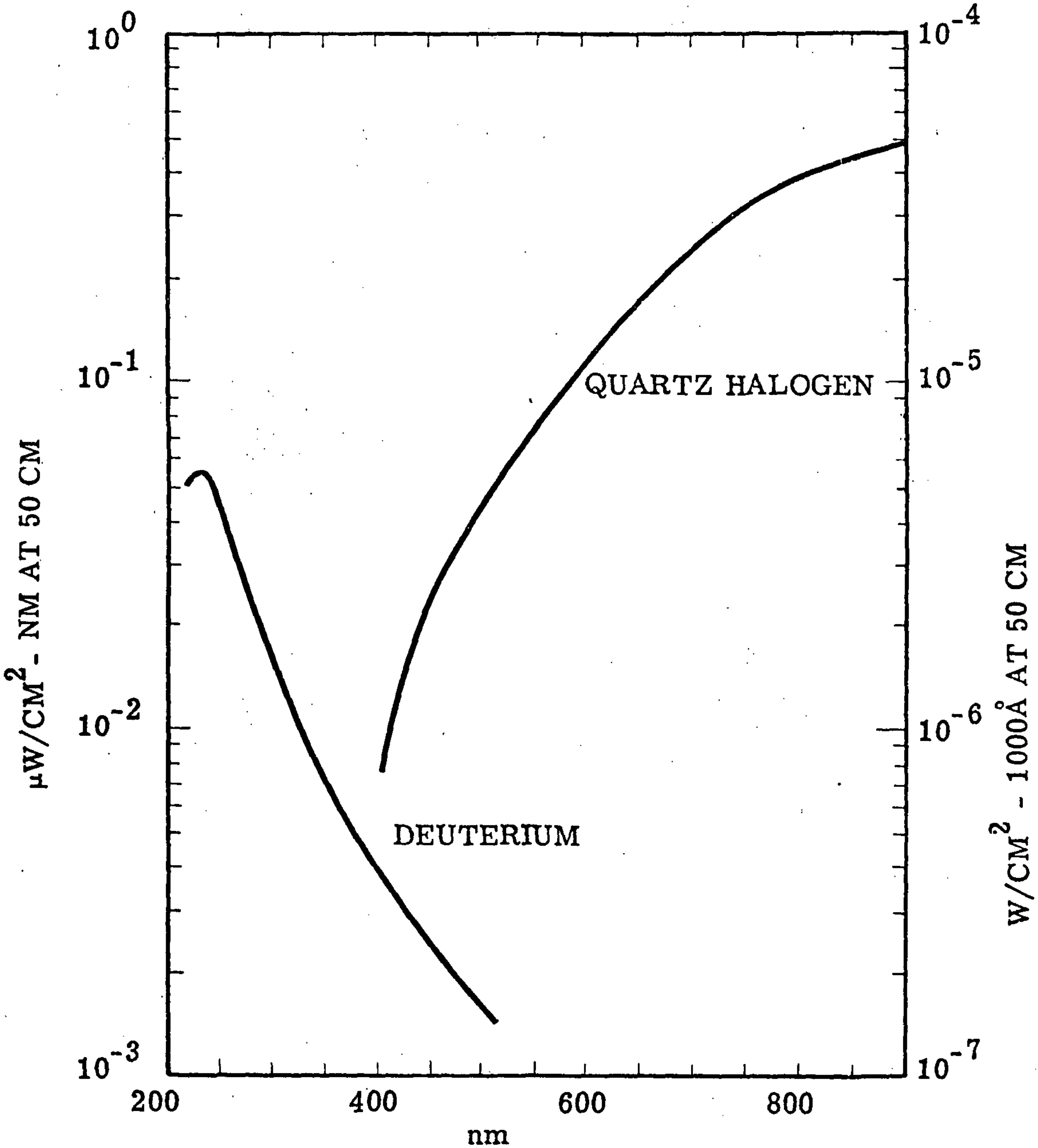


Figure 4-2. Calibration Source Levels

SECTION 5

STRUCTURAL/THERMAL DESIGN

5.1 STRUCTURAL REQUIREMENTS/INTERFACE WITH OTA

Figure 3-4 defines the configuration of the focal plane of the OTA. It shows that the central 18 arc-min diameter (12.06 inches) at the focal plane is allocated as the science data field for the five science instruments with allowance for a central 0.8 inch cruciform shaped area given to spacing between instruments and for structure. The f/24 Field Camera is allocated the 100mm x 100mm (4 inch square) central portion of the field with the remaining portion of the data field equally allocated in approximate 90° sections to each of the four axial science instruments. The focal plane structure with instrumentation is shown in Figure 1-1.

The OTA focal plane, beyond the 18 arc-min data field, extends out to a 29.4 arc-min diameter (19.65 inches). As shown, three 90° sections of this portion of the field are given as tracking field to the three Fine Guidance Sensors.

The prime requirements for the FPS are as follows:

- Maintain its locating surface (to which all instrumentation is attached) with respect to the optical axis to within a tolerance of 0.1mm and with respect to the curved focal plane with a tolerance of 0.07mm (ref. Sec. 3-2).
- Provide a means for registering all focal plane instrumentation to this mounting surface. In the case of the science instruments, the registration design must allow for repeatability of registration after orbital removal and replacement.
- Provide a stable surface, i.e. prevent relative motion between the science instruments and the Fine Guidance Sensors.

Because of the nature of ST, as a long lived National Observatory facility, and the varying requirements of the present, and as yet undefined future, science instruments, the tolerances established for the FPS are driven by essentially the requirements of the most sensitive anticipated SI.

The structural design of each science instrument must therefore be developed from a review and consideration of the performance of the OTA and the tolerances associated with the reference ball detent, to provide a science instrument mounting surface which will support and stabilize the instrument optical system to the extent required to achieve the performance specification.

The general OTA configuration is directed toward an instrument module which will achieve the following:

- Provide a mounting reference to the ball detent - and flexible connection to two other points on the OTA structure.
- Enclose and protect the science instrument.
- Provide a thermal environment both to stabilize the instrument and provide a means of dissipating heat to the SSM.

Within each module an optical bench is provided onto which the key elements of the instrument are mounted and aligned. Mounting faces and deflections from the module mounting must not be transmitted into the optical bench.

5.2 RADIAL MODULE

The OTA radial module is designed in three parts; a base section, midsection ring and a cover (reference Figures 1-3 and 2-1). The base section mounts directly to the OTA Focal Plane Structure at three points - the ball detent position at its front end and via two flex link latches on either side. These flex links are orthogonal to each other, providing a zero moment mount to the base section. This permits registration of the instrument via an optical bench with the two flexible tie downs preventing the introduction of external loads into the optical bench. The midsection ring is attached to, but thermally isolated from both the base and cover. This permits use of the outer surface facing the -V3 axis (reference Figure 1-2) as a radiation area for dissipating instrument heat without conducting heat into the base section (where it then can go into the focal plane structure and cause dimensional changes between the SI's and the Fine Guidance Sensor. The OTA FPS is temperature controlled at 70°F ±2°F and the stability of the science instruments to the fine guidance sensors is dependent on avoiding both temperature changes or gradients in this structure. The separate top cover allows easy access to the instrument for repair and/or adjustment without disturbing the heat pipe connection to the rear surface.

The base section is fabricated from a milled aluminum plate, this construction providing a light weight (~35 pounds) yet stiff ribbed structure. Internal rib spacing is 8 x 8 inches, rib depth is one inch and thickness is 1/8 inch. As noted above the module is attached to the FPS at three points - one at the ball detent and two via flex link latches on either side. The base section has three internal mounting points for the optical bench, each of these located near to the external tie points as shown in Figure 2-1.

The cover is also fabricated from a milled plate with an 8 x 8 inch rib pattern. Weight is estimated at 20 pounds, rib depth is 1/2 inch, rib thickness 1/16 inch and skin thickness is 1/16 inch.

The midsection ring is constructed of 1/16 inch aluminum stiffened in a standard monocoque configuration. Estimated weight is 25 pounds. This total module weight including brackets and hardware is ~ 90 pounds.

5.3 OPTICAL BENCH

The optical bench for the field camera provides a rigid base integral with the instrument elements and permits easy access/installation of the camera to the radial bay module. This optical bench will be kinematically mounted to the module base to ensure that distortions to the module due to mounting to FPS do not introduce change in the instrument alignment. As described in Section 5.2, the three tie points for the optical bench consist of a spherical seat joint and two side tie down points. These three tie points are located adjacent to the three tie points of the radial module box; the spherical seat being near the ball socket joint, and the two side points being near the two external flex tie points. This effectively prevents external moments from the focal plane structure from reaching the optical bench.

The bench, shown in Figure 2-1, is a lightened aluminum section with a solid overall top plate skin of 1/8 inch thickness with a skirt and ribs of 3 inch overall height. The 1/4 inch thick ribs are generally located in a square pattern on a 6.5 inch spacing. A closer spacing of four inches is used for a pair of ribs located down the center line of the bench and also for a pair running across between the two side mount location areas. This provides additional stiffness along a Tee pattern between the three load mount points. Local land areas are provided around the three mount points as well as many mounting bosses to receive the various camera substructural components. The optical bench structure weight is 50 pounds, including hardware.

The distance from the locating ball to the detector focal plane is maintained by the optical bench. The temperature control system will keep the aluminum optical bench at 70°F ±2°F. The critical dimension from the ball to the SECO mount locating pin and back to the SECO focal plane is approximately equivalent to 8 inches of aluminum. If the maximum temperature excursion is ±2°F the displacement $\Delta \ell$ of the focal plane relative to the locating ball will be

$$\Delta \ell = \alpha \ell \Delta T$$

where

$$\alpha_{al} \cong 13 \times 10^{-6} \; {}^{\circ}F^{-1}$$

$$\ell \cong 8 \text{ inches}$$

$$\Delta T = \pm 2^{\circ}F$$

therefore

$$\Delta \ell = \pm 208 \times 10^{-6} \text{ inches}$$

or

$$\Delta \ell \simeq \pm 5.28 \; \mu m$$

which is well within the tolerance error budget of the system.

5.4 ALIGNMENT WITH OTA FOCAL PLANE STRUCTURE

The design of the Focal Plane Structure was driven by configuration requirements. Structural performance was achieved by material selection and member sizing, having first defined the mechanical or configuration constraints. The structure is designed to accommodate the four large axial science instrument modules and four radial bay modules. Three of the radial bay modules are for fine guidance sensor instrumentation, and the fourth contains the f/24 Field Camera (reference Figure 1-1). All of the science instrument modules (both axial and radial) are replaceable on orbit by a suited astronaut.

The principal design requirements for the Focal Plane Structure are derived from the OTA system focus budgets and fine pointing accuracies. Focus shift allowed during an observation is 30μ total for this structure. This is achieved by using titanium and stabilizing the temperature of the structure to ±2°F. Half of the fine pointing error (0.005 arc-second) is budgetted for thermal effects during an observation. At the f/24 focus, 0.005 arc-second is equivalent to 1.4μ which then becomes the limit for any lateral change between a science instrument and its controlling star tracker (fine guidance sensor). This requirement is satisfied with a low expansion (Invar) mounting plate on the Focal Plane Structure which is the mechanical reference for both the FGS and the SI modules.

The deflection of the center of the Focal Plane Structure, relative to the primary mirror vertex, is 0.002 inch with the system vertical and with four 500 pound SI's installed. If this were permitted to exist as a gravity-release error, only 1/2μ of secondary mirror motion would be required to correct it on-orbit. The 0.01 inch axial position tolerance is correctable with a 2μ secondary shift.

Figure 5-1 shows the relative locations of the ball detents on the FPS Invar ring, these detents serving to accurately locate the science instruments to the Fine Guidance Sensors and both to the optical axis/ focal plane of the OTA. The four axial science instrument detents are identified as D_A and the four radical detents (one for the f/24 Camera, the other three for the 3 Fine Guidance Sensors)identified as D_R. The structural path between the axial and radial detent is not directly loaded by the preload force. This preserves alignment after a removal/ replacement cycle. This is accomplished by mounting the radial detent on a short intercostal outboard of the P, -P, P, ... forces. Thus, the radial detents, D_R, will follow and be located by the axial detents, D_A. These forces are also shown in Figure 5-1.

5.5 THERMAL DESIGN REQUIREMENTS

The thermal design requirements for the f/24 Field Camera in the OTA radial bay are as follows:

- Cooling of the SECO photocathode to 270°K (26.6°F)
- Thermal stabilization of the field camera optical system at 70°F ±2°F to maintain alignment and focus.
- Rejection of heat from the Field Camera (~ 80 watts) to the SSM Science Instrument bay shroud.

5.6 OTA/SI THERMAL INTERFACE

The thermal interfaces of the f/24 Field Camera with the OTA and the OTA and the SSM are shown in Figure 5-2 and are defined as follows:

- Field Camera interface with Focal Plane Structure is adiabatic
- Aft shroud rear wall is essentially adiabatic
- Aft shroud wall temperatures are:
    - Maximum average temperature +7°F
    - Minimum average temperature -40°F
    - Maximum temperature variation per orbit ±5°F

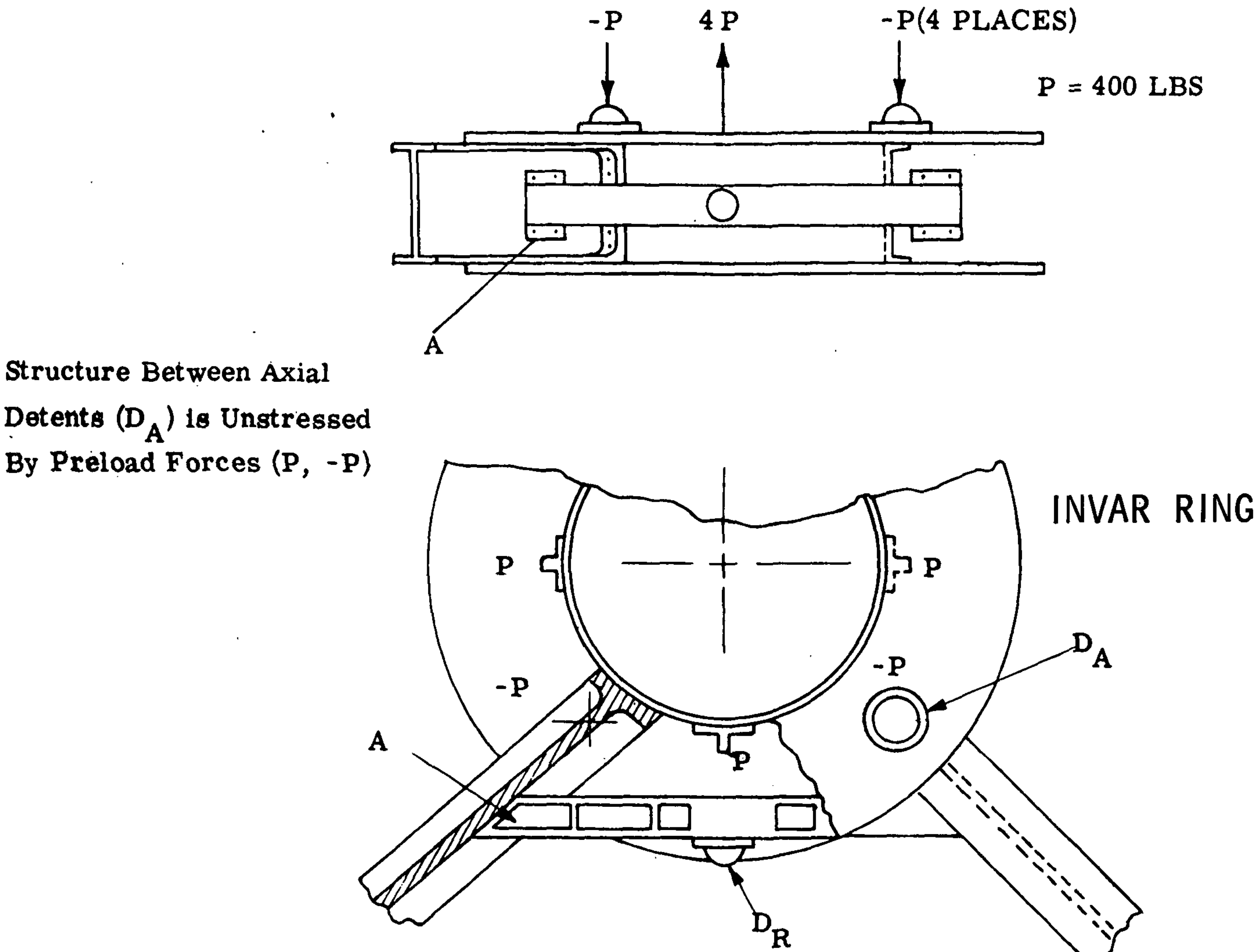
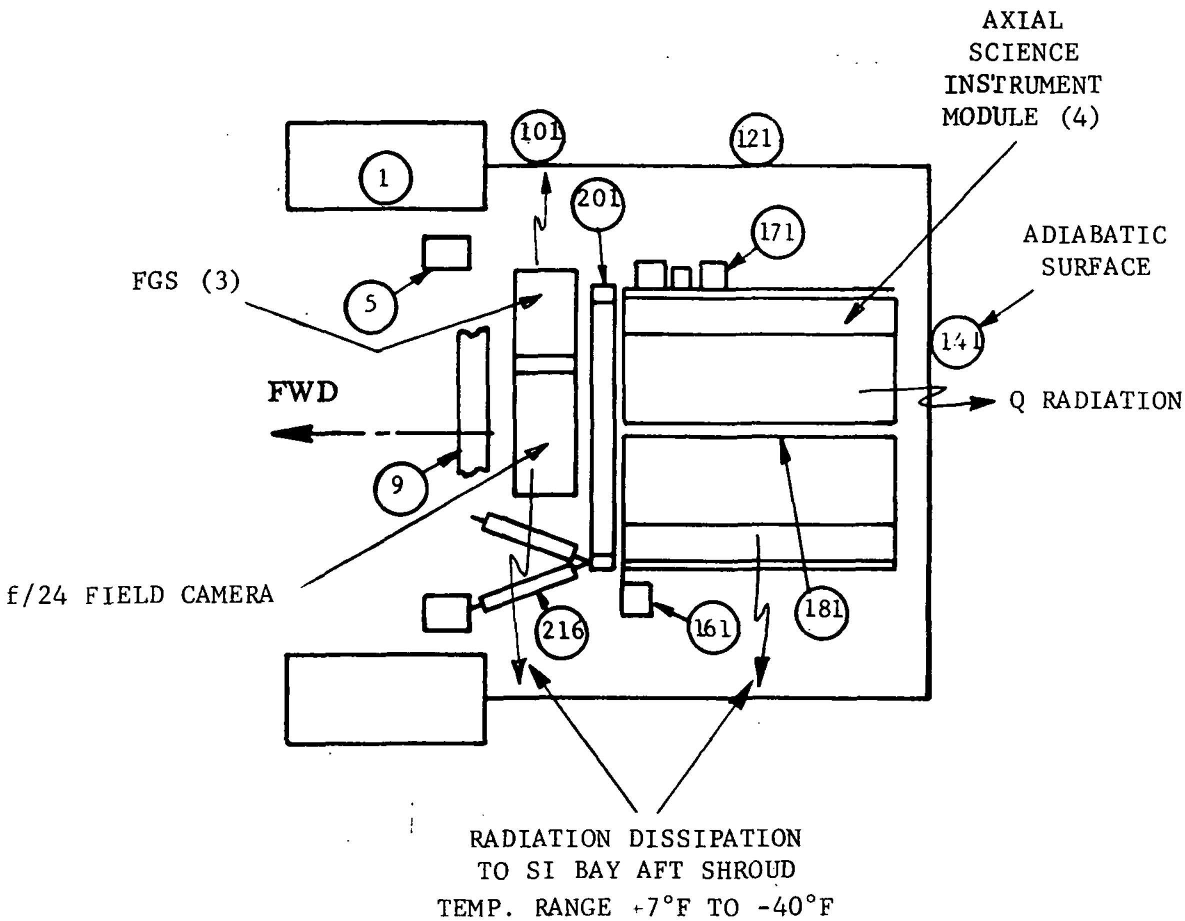


Figure 5-1. Detent/Preload Load Path



1	SSM
5	MOUNTING RING
9	ACTUATOR STRUCTURE
101	AFT SHROUD INNER WALL - FORWARD
121	AFT SHROUD INNER WALL - REAR
141	AFT SHROUD REAR WALL
161	SSM REF. GYRO
171	OTA ELECTRONICS
181	SPAR
201	FOCAL PLANE STRUCTURE
216	FPS SUPPORT BRACKETS AND STRUTS

Figure 5-2. f /24 Camera Thermal Interfaces

Figure 5-3 illustrates the design configuration for rejection of heat from the Field Camera module. The +V3 side of the telescope is nominally maintained toward the sun. All heat from the field camera is rejected to the -V3 side of the aft shroud.

Figure 5-4 defines the nominal power which must be rejected from the science instruments area. It includes power dissipation not only from the five science instruments but also from the OTA/SI electronics, SSM gyros and star trackers and the OTA Fine Guidance Sensor (reference Figure 1-1).

The radial bay of the OTA contains the f/24 Camera and the three fine guidance/performance control modules. Parasitic heat losses from the OTA/SI structure are estimated to be 40 to 100 watts. The f/24 Camera is the largest single heat source in this volume, rejecting about 80 watts compared with about 20 watts for each of the fine guidance modules.

All OTA structural members which interface with the science instruments whose dimensional stability is critical to good SI performance are maintained at 70°F +2°F. This includes the OTA Main Ring and the Focal Plane Structure to which all the SI's are mounted.

SI and other component module exterior walls facing the SSM aft shroud generally should have high emissivity exterior surfaces to maximize the radiative heat transfer from the module to the aft shroud.

5.7 f/24 CAMERA THERMAL DESIGN

The key features of the f/24 Field Camera thermal design are:

- The camera optics operate at 70°F ±2°F at all times. This provides isothermal relationships between manufacturing, alignment, test and operation and also minimizes contamination deposition on the optics. Individual heaters and thermostats will be located on the optical bench as required to insure temperature control.

- The SECO detector photocathode operates at 270°K (26.6°F) Thermoelectric modules are used to provide this cooling.

- The calibration subsystem imposes a short term heat load, but this does not adversely affect performance or stability.

- Thermocouples are used at sensitive points for monitoring and control. Platinum thermocouples will be used for both control and diagnostic purposes since they meet the required temperature tolerance and have long life characteristics.

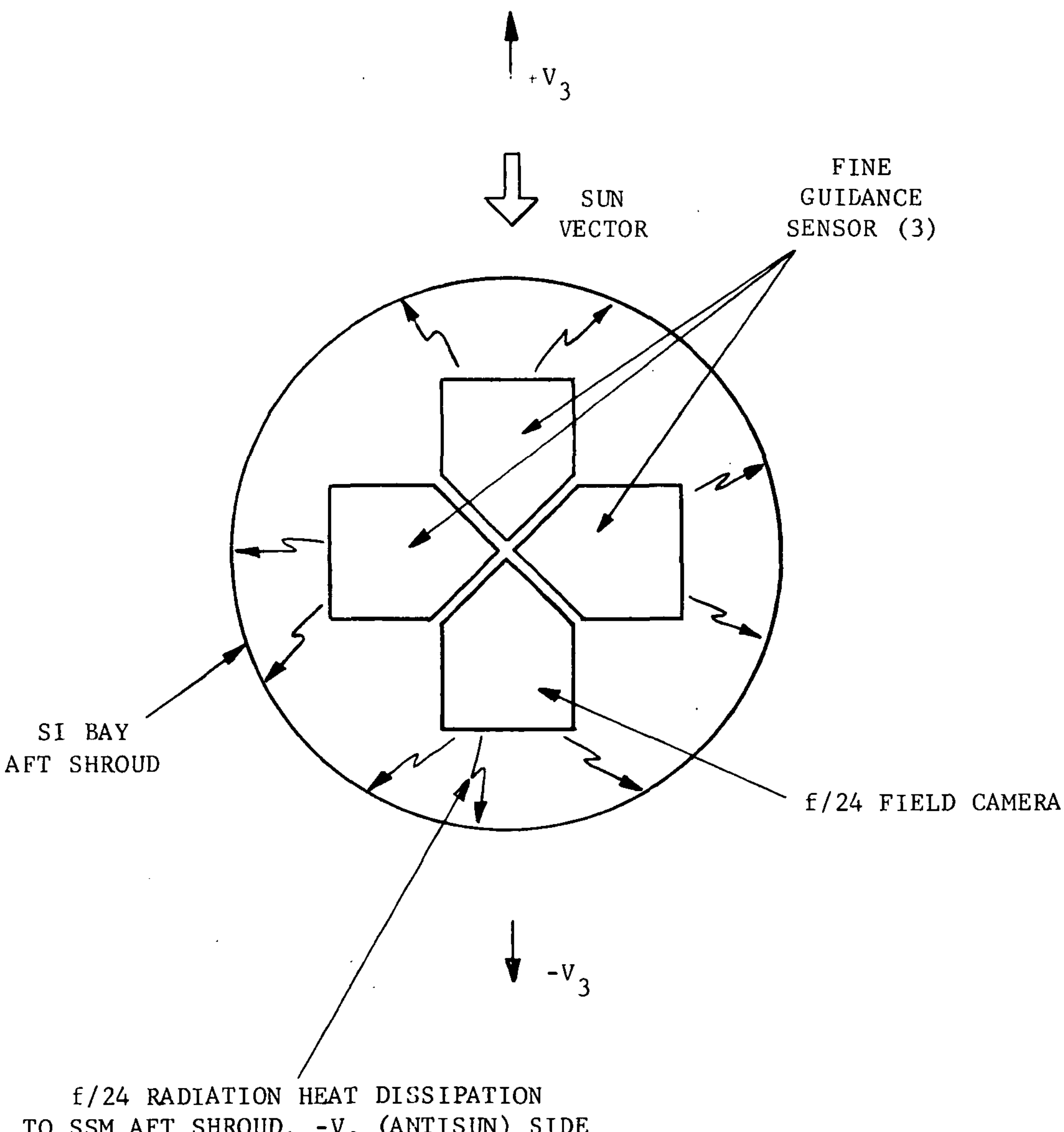


Figure 5-3. SI Radial Bay Heat Rejection

ITEM	HEAT REJECTION (WATTS)	
	MAXIMUM	TYPICAL
SCIENCE INSTRUMENTS (4)	400	300/400
FINE GUIDANCE SENSOR MODULES (3)	195	130
OTA ELECTRONIC CONTROLS	50	40
HEATED FOCAL PLANE STRUCTURE	100	40
REFERENCE GYROS AND STAR TRACKERS (SSM EQUIPMENT)	45	45
TOTAL	790	555/655

Figure 5-4. SI Bay Shroud Heat Rejection Summary

- Electronic units are located away from the instrument proper and are enclosed for thermal control/contamination assurance.

Power, dissipated from the detector and instrument electronics, is rejected to the wall of the SI module by radiation, thermoelectric cooling and conduction. The heat from the SI module exterior wall is rejected radiatively to the SI bay aft shroud wall. The -V3 wall of the module must radiate the 50 watts from the detector package plus an additional 30 watts from other heat sources inside the field camera. These other heat sources include:

- Temperature Control System Electronics
- Camera Control Electronics
- Motor, Solenoid, Magnetic Clutch power
- Local thermal control heaters
- Calibrator source power (periodic)

A 56°F SI wall will radiate 80 watts to a 7°F aft shroud inner wall if the IR emissivity (ϵ) of each surface is 0.9.

The heat rejection from the field camera container wall can be estimated from

$$Q = \sigma \bar{\epsilon} \, AF \left(T_{f/24}^{4} - T_{AS}^{4} \right)$$

where

$$\bar{\epsilon} \cong 0.8 \text{ (each surface} \equiv 0.9)$$

and

$AF \cong 8.55 \text{ ft}^2$ (radial f/24 camera container exterior surface seen by the aft shroud)

Therefore:

$$\begin{aligned} Q &= (0.1713 \times 10^{-8})\,(0.8)(8.55)(\overline{516}^4 - \overline{467}^4) \\ &= (1.172 \times 10^{-8})(709 - 476) \times 10^{8} \\ &= 273 \text{ BTU/hour} \\ &= 80 \text{ watts} \end{aligned}$$

If the exterior surface is 56°F (516°R) then a net of 80 watts may be rejected to the aft shroud at 7°F (467°R)

Heat straps are used to provide good thermal contact between the cooler hot junction and the heat pipe and at the heat pipe/SI wall junction. The heat strap permits relative motion at the junctions without degrading the thermal contact (reference Figure 2-1).

5.8 PICK-OFF MIRROR ALIGNMENT CONSIDERATIONS

The Field Camera has an integral pick-off mirror (reference Figure 2-1) which intercepts a portion of the signal and relays the information into the instrument. This assembly is subject to three thermal unbalances:

- The environment around the assembly is not uniform in temperature during normal operation.
- The temperature of the assembly may vary ±2°F, the range allowed for its control.
- The blackbody surroundings may vary ±2°F. A fore-and-aft temperature gradient within the assembly will be present if the surroundings about the assembly are at their maximum allowable extremes, e.g., the primary mirror inner light baffle at 68°F while the focal plane structure is 72°F.

The following analyses estimates the potential thermal effects of these unbalancing forces on the stability of the pick-off mirror assembly.

a. Non-uniform Environment

The governing equation is

$$\sum_{n} \sigma\epsilon\, AF\, (T^4 - T^4) = 0$$

Assume the blackbody temperature of the immediate surfaces are at 70°F and the OTA sink temperature is at -100°F. The mirror also views the front face of the axial modules and the rear of the primary mirror assembly. Assuming a worst case 65°F condition for these elements, the thermal environment of the pick-off is:

Item	ϵ	F	$\frac{A}{\Sigma A}$	Temp
OTA sink	0.02	0.01	0.2	-100°F
Axial SI's, etc.	0.05	0.05	0.4	65°F
Other	1.0	0.94	0.4	≅ 70°F
Pick-off Mirror Assembly	-	1.0	1.0	?

If the assembly structure is reflecting ($\varepsilon = 0.05$) and the pick-off mirror is silvered ($\varepsilon = 0.02$) then

$$\left[\varepsilon F \frac{A}{\Sigma A} \sigma (T^4 - T^4)\right]_{OTA} + \left[\varepsilon F \frac{A}{\Sigma A} \sigma (T^4 - T^4)\right]_{MLI} + \left[\varepsilon F \frac{A}{\Sigma A} \sigma (T^4 - T^4)\right]_{BB} = 0$$

or

$$\left[(0.02)^2\ 0.01\ (0.2)\{T+100\}\right]_{OTA} + \left[(0.05)^2\ 0.05\ (0.4)\{T-65\}\right]_{MLI}$$

$$+ \left[(0.05)\ (0.94)\ (0.4)\ \{T-70\}\right]_{BB} = 0$$

where

$$\sigma (T_A^4 - T_B^4) \approx (T_A - T_B) \text{ at } 70°F$$

Solving for (T-70)

$$[1360 \times 10^{-7}] + [2500 \times 10^{-7}] + 0.02\{T-70\} = 0$$

$$T_{Assembly} - 70 = 0.02°F$$

The conclusion is that the varying surrounding temperatures will have little effect on the pick-off mirror temperature and will not induce dimensional changes.

b. Thermostatic Tolerances

The thermostatic tolerance for the mirror assembly arm is ±2°F. If the arm is aluminum ($\alpha = 13 \times 10^{-6}\ °F^{-1}$) and 8 inches long, then

$$\begin{aligned} \Delta\ell &= \alpha\ell\Delta T \\ &= 13 \times 10^{-6} \times 8 \times 2 \\ &= 208 \times 10^{-6} \text{ inches} \end{aligned}$$

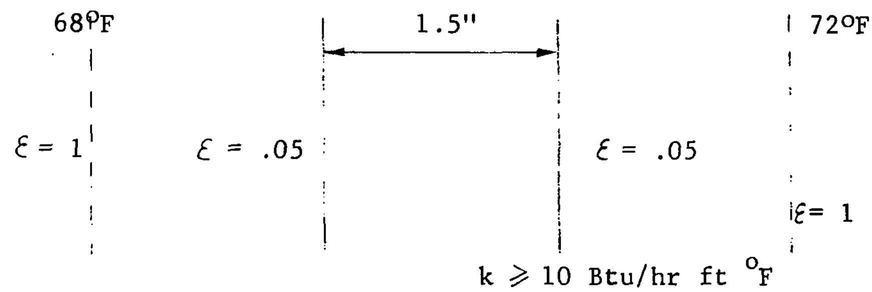
or about 5 μm. If the arm is graphite epoxy ($\alpha \cong \pm 0.03 \times 10^{-6}\ °F^{-1}$)

$$\begin{aligned} |\Delta\ell| &= 0.03 \times 10^{-6} \times 8 \times 2 \\ &= 0.48 \times 10^{-6} \text{ inches} \end{aligned}$$

or about 0.01 μm.

c. Ambient Variations

A typical pick-off mirror assembly arm thickness is 1.5 inches. If the assembly arm is reflecting (ε = 0.05) then we may estimate ΔT_{FA}, the fore-to-aft gradient, as follows



The material conductivity should be at least 10 BTU/hour ft °F. Therefore (per unit area)

$$\Delta T_{FA} \cong \frac{\sigma \varepsilon (T^4 - T^4)}{\frac{k}{\Delta X}} \approx \frac{\varepsilon\ (2°F)}{\frac{k}{(1.5/12)}}$$

$$\Delta T_{FA} \cong \frac{1.5}{12} \times \frac{0.05}{10} \times 2$$

$$\Delta T_{FA} = 0.00125°F$$

or about $\frac{1}{1000}$ of a °F which should produce a negligible mirror tilt.

5.9 SECO THERMAL DESIGN

The thermal control interface with the SECO detector is shown in Figure 5-5. The copper sleeve abuts the cold SECO cathode and carries the heat from the plane of the cathode to the cold junction of the thermoelectric cooler. Beryllium oxide spacers are used wherever electrical isolation is required. The heat dissipation within the SECO has been assumed as follows:

Item	Power
Magnetic Focus Coil	15 watts
Magnetic Deflection Coil	5 watts
Readout	2 watts
Photocathode	2 watts

It has been assumed that up to 6 watts may leak into the SECO from the environment. In the very worst case of having to remove all this 30W from the photocathode area, a thermoelectric cooler power of 20W would be required. A schematic of the temperature profile and heat flows for this case is shown in Figure 5-6.

The 30 watt heat load from the SECO detector is conducted from the SECO to the cold junction of a thermoelectric cooler by a copper sleeve with a temperature gradient of about 2°F. If the detector operating temperature is 26°F (270°K) then the thermoelectric cooler cold junction temperature will be about 24°F.

A standard thermoelectric cooler such as a Cambion Model 801-2001-01 can step up a 30 watt heat load from 24°F to 60°F with an added power input of 20 watts. The cooler COP (coefficient-of-performance) is

$$\frac{Q}{P} = \frac{30W}{20W} = 1.5$$

A simple ammonia heat pipe will transport the 50 watts from the cooler hot junction to the module exterior wall with a temperature difference of 4°F or less.

More likely as details of the SECO camera design are developed, the heat load to be removed from the photocathode, can be reduced to about 15W or less and the required thermoelectric cooling power to about 10W.

The following design features, applied to the detector package, will achieve this much reduced cooling power:

- Isolate the magnetic field coil from the photocathode by using a low conductance mounting design. A direct heat conduction path from the field coil (at 70°F) to the SECO housing (at 60°F) can carry 12 watts while the heat leak from the field coil to the photocathode is limited to 3 watts by a reflective low conductive spacer.

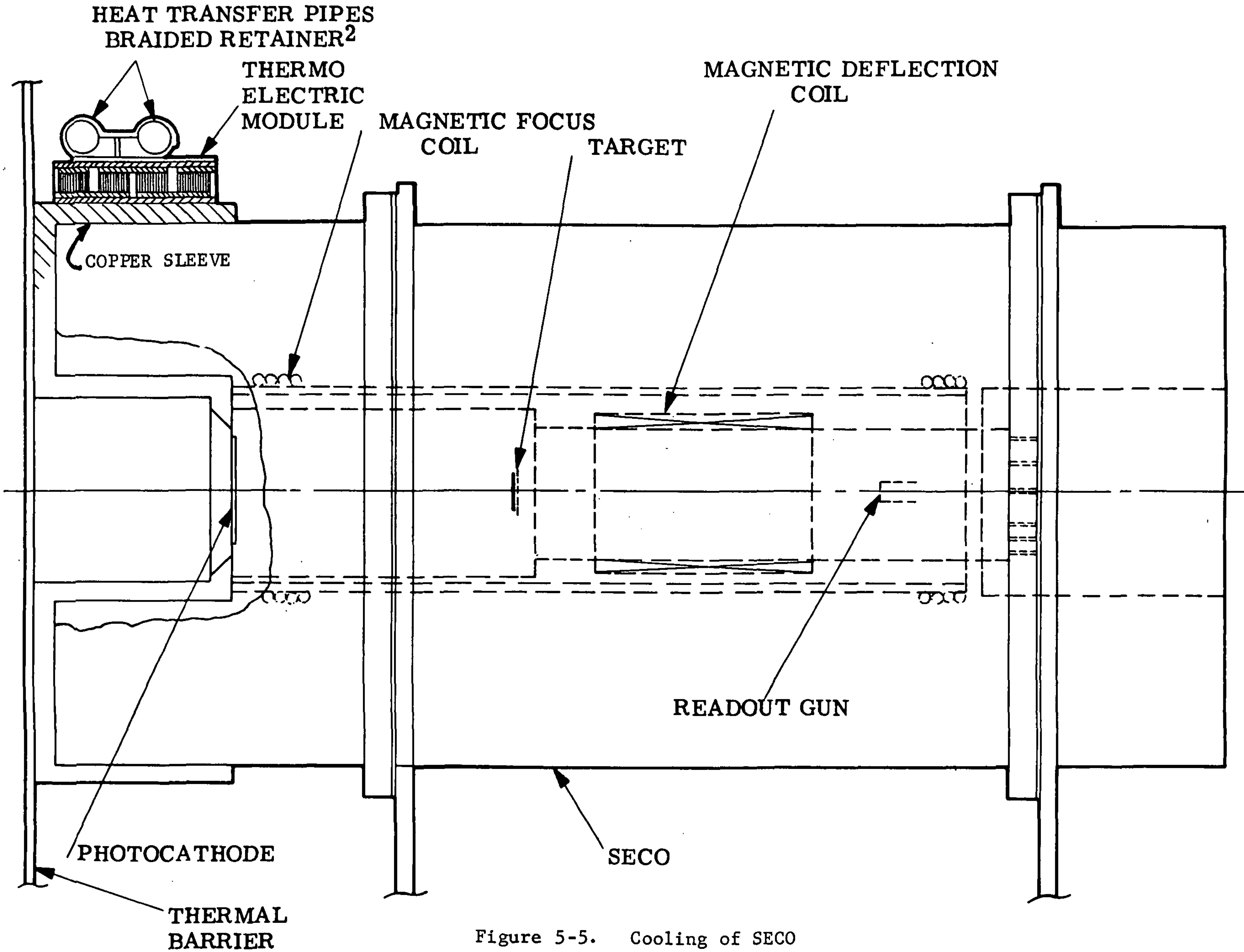


Figure 5-5. Cooling of SECO

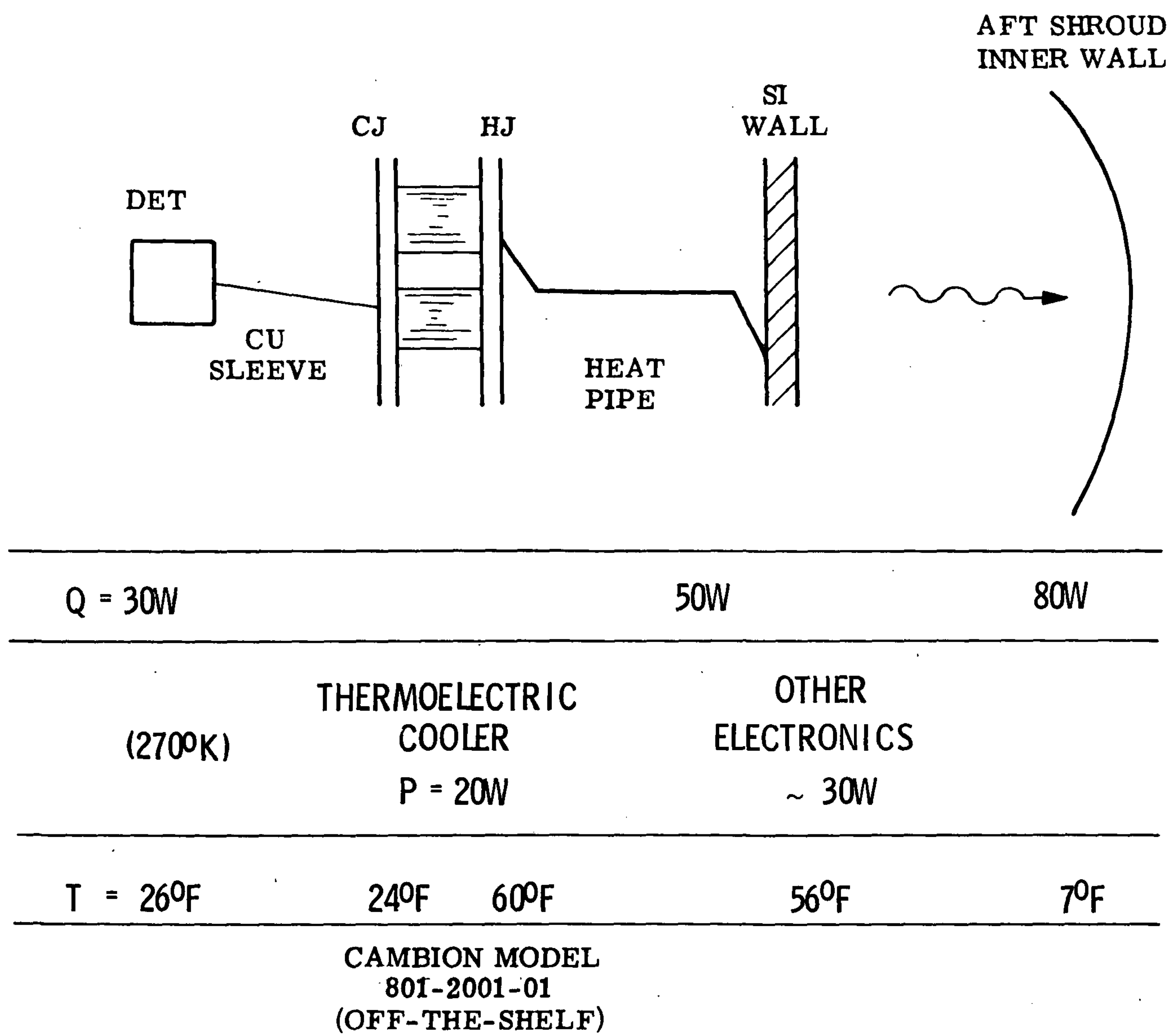


Figure 5-6. Camera Detector Heat Flow

- Similarly isolate the deflection coil from the glass tube limiting the heat leakage to the photocathode from the deflection coil to 2 watts.

With careful design, there is every reason to expect a significant reduction in the heat load to be thermoelectrically removed from the photocathode to provide a 270°K operating temperature.

All calculations shown above are for a "hot" orbit condition. Optical bench control heater power increases slightly as the SSM shroud temperature decreases. The additional heat needed is anticipated to be about 2 - 3 watts for the radial f/24 camera as the aft shroud temperature goes from +7°F to -40°F.

The cooling system power requirement is reduced if a heat pipe is used instead of a heat strap. The heat pipe operates with a much lower temperature gradient than a weight equivalent heat strap and permits the thermoelectric cooler to operate at a much lower temperature level. A preliminary trade-off has shown that a 12-lb. copper heat strap would perform at a level comparable to the 2-lb. heat pipe.

SECTION 6

POWER COMMAND AND DATA HANDLING

6.1 POWER INTERFACE

As noted in Section I, the instrument will operate from a supply of 28VDC ± 5, and will be limited to a maximum orbital average power consumption of 100 watts. The power requirements, broken down by subsystem were summarized in Section II - Table 2-2.

Perkin-Elmer, at the Preliminary Design Review on July 15 and 16, recommended the power interface to the science instruments shown in Figure 6-1. The rationale for this approach was:

1. To avoid a multi-line power interface with the SSM
2. Provide earlier verification of power distribution system and interface.
3. Eliminate the requirement for a SSM PDS simulator during OTA/SI testing

NASA is currently considering the alternative of having the SSM provide all electrical distribution boxes (mounted within the SSM) with the individual science instrument providing any additional control, regulation or sequencing peculiar to the SI through a distributor box mounted within the SI.

6.2 COMMAND INTERFACE

The f/24 Field Camera contains a command decoder, which receives and decodes commands from the SSM's dedicated SI command and data handling system. Commands may be classified as "discrete" or "variable word". Discrete commands are single pulses used to initiate or terminate an event. Variable word commands are multi bit digital streams that specify a setting value, or a position or some other analog variable. The actual setting (to the value specified by a variable word) will be initiated using "load" and "execute" discrete commands.

The camera command concept is illustrated in Fig. 6-2. This system provides maximum operational flexibility with minimum on-board sequencing. A command sequence and requirements list is given in Appendix B.

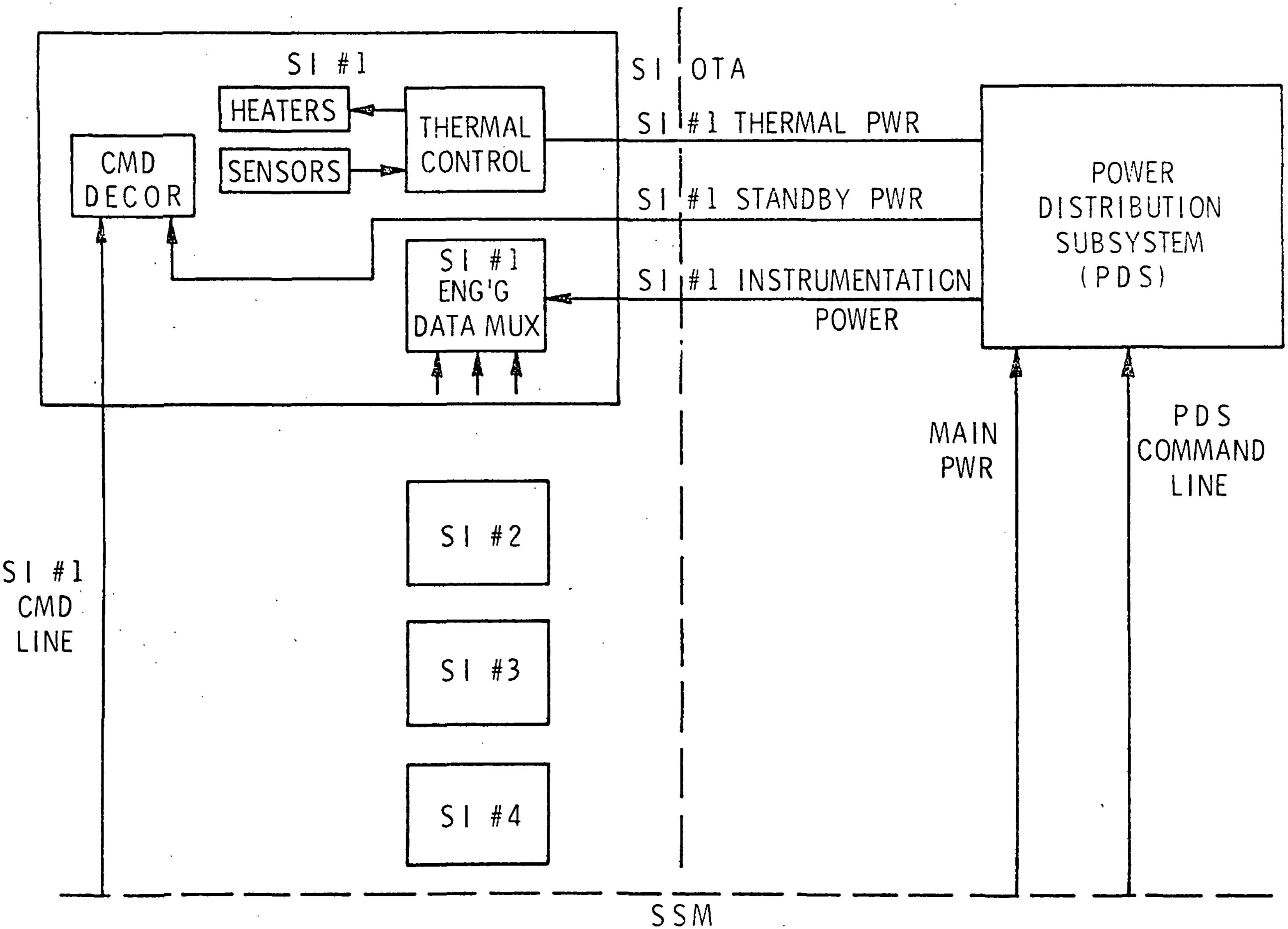


Figure 6-1. Power Interface

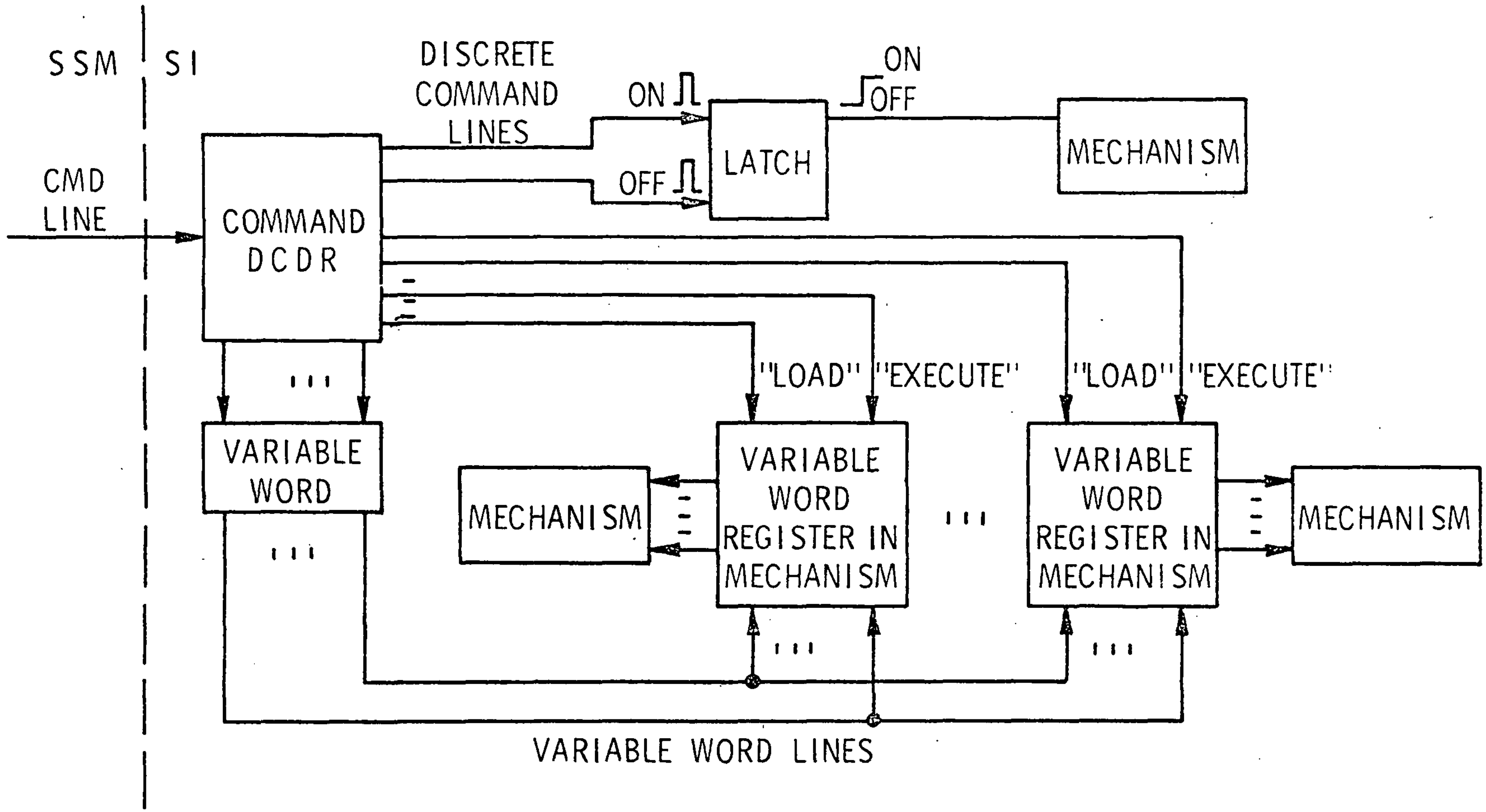


Figure 6-2. Command Concept

6.3 DATA INTERFACE

Data is broadly classified as "engineering" or "science" data, some engineering data being necessary to the scientist to aid in his interpretation and understanding of the science data. Engineering data, indicating the current status of the camera subsystems (filter wheel, shutter, calibration sources, gains, etc.) and identified as "Header" data, is interleaved with the science data and transmitted to ground over the data link.

A general description of the OTA/SI data system philosophy is shown in Fig. 6-3. The instrumentation list is given in Appendix C.

Engineering data is provided by the f/24 Camera instrumentation subsystem, the concept of which is shown in Fig. 6-4. The required sensors, or transducers, form the analog signals which, after buffering and scaling, are multiplexed, digitized and output to the telemetry unit. Header data is also sent to the Data unit for interleaving with science data. Figure 6-5 is a block diagram of the signal processing and data flow of the f/24 Camera. The Camera uses a 2000 x 2000 pixel SEC orthicon detector (SECO). The SECO discharge time for readout of each pixel has not been defined. Utilizing the FID as a guide, the maximum readout rate was selected to be 50 KHz. Multiple readouts may be required to obtain all of the stored charge and thereby improve the signal to noise ratio.

The address and timing control logic section controls the readout of the pixels and analog to digital conversion of the video signal. Synchronization with the SSM data handling system could be accomplished via this section.

The S/H (sample and hold amplifier) section samples the video signal and holds the signal amplitude while the analog to digital converter (A/D) digitizes the signal to a 10 bit digital word. The serial output word rate will be 500K bits/sec.

The SI data interface control section interfaces with SSM communication and data handling subsystem (C & DH) to transmit the science data.

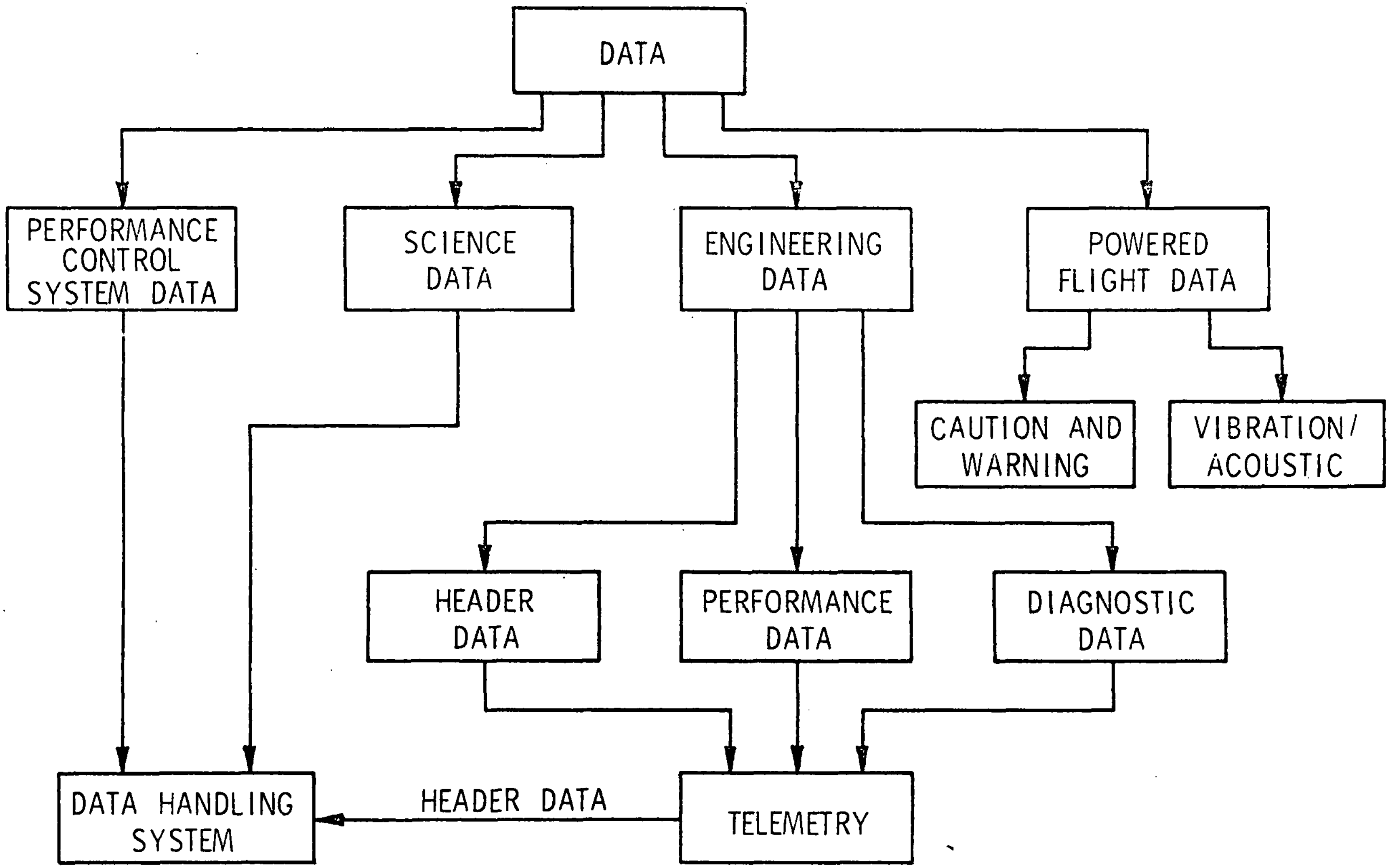


Figure 6-3. Data Terminology and Flow

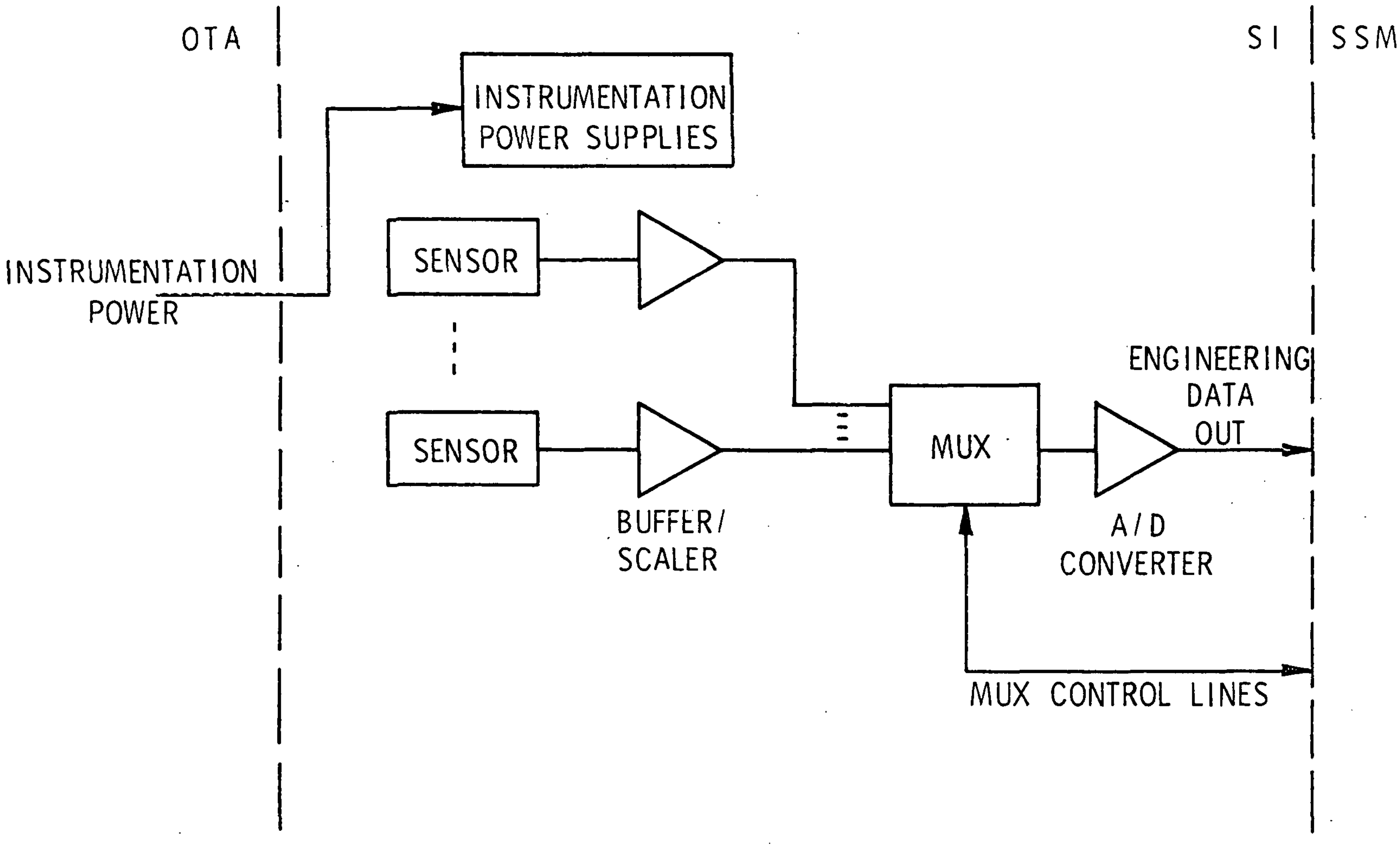
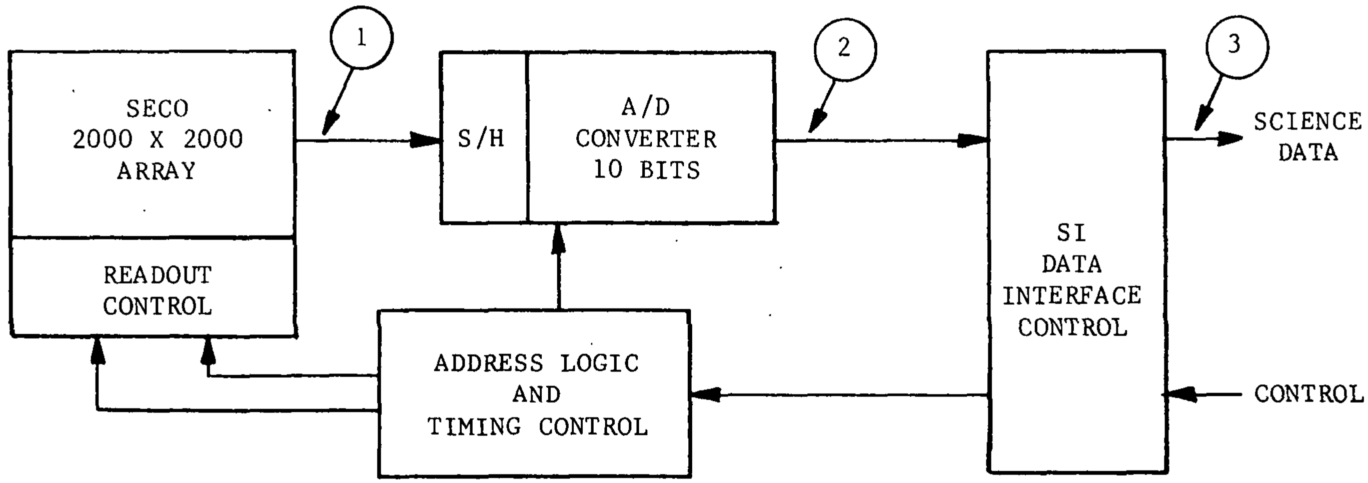


Figure 6-4. SI Engineering Data Concept



	1 ANALOG READOUT RATE	2 DATA RATE AFTER CONVERSION TO 10-BIT ENCODING	3 SCIENCE DATA RATE
DATA RATES BASED ON FIXED SI/SSM TRANSFER RATE	100K SAMPLES/SECOND OR 40 SECONDS/FRAME FOR 4 SAMPLES/PIXEL - 100 SECONDS/FRAME	MAXIMUM RATE 1 MEGABIT PER SECOND	1 MEGABIT PER SECOND
DATA RATES BASED ON DETECTOR REQUIREMENTS	50K SAMPLES/SECOND OR 80 SECONDS/FRAME FOR 4 SAMPLES/PIXEL - 320 SECONDS/FRAME	500K BITS PER SECOND	500K BITS PER SECOND

Figure 6-5. Camera Science Data Flow

SECTION 7

RELIABILITY

7.1 REQUIREMENTS

Revised ST project guidelines define a reliability goal for the f/24 Field Camera of 0.85 for the first year of operations. It is also a requirement that the camera be capable of operation on a nearly full time basis. Since available observational time translates, on average, into about one-half calendar time, the field camera is expected to operate with a duty cycle of approximately 50%.

7.2 RELIABILITY ANALYSIS

The standby (or dormant) failure rate of the instrument has been assumed to be one-tenth of the active failure (planned useage) primarily because of the electrical and electronic components. For an instrument whose duty cycle is D and whose failure rate is λ, the duty cycle failure rate λ_{dc} is determined by the following equation -

$$\lambda_{dc} = \lambda_a (D) + \lambda_s (1 - D)$$

where λ_a = active failure rate

λ_s = standby failure rate

Failure rates are defined for the camera at the module level in Table 7-1. These failure rates were compiled by TRW for Perkin-Elmer earlier in the Phase B study (Reference P-E Report #11880, OTA/SI Conceptual Design Report, 1 April 1974). The main source for failure rates were estimates used on:

- Apollo Telescope Mount (ATM)
- Seasparrow Naval Low Level Light TV Project
- Planning Research Corp. orbital data on Vidicon Tubes*
- EMR Report -
  Failure Rates, Reliability Prediction, Failure Mode Effects and Critical Analysis, Photo multiplier Tube Packaged Assembly
  25 Feb. 1969

The vidicon tube and its high voltage power supply are considered to be the components with the highest failure rate.

*Addendum to Reliability Data from In-Flight Spacecraft 1958-1972, Report #0-1874, Bean & Bloomquist, AD906048L, 30 Nov.1972

TABLE 7-1

FAILURE RATE DATA

FAILURES/BILLIONS HOURS

Subassembly	DC	λa	λs	λdc
Sensor Unit	50%	23500	2350	12925
Command Control Telemetry (CC&T) Elect.	50%	8300	830	4565
Opto/Mechanical Unit	50%	1100	1100	1100
TOTAL	50%	32900	4280	18590

Assuming an exponential failure rate:

$$R = e^{-\lambda_{dc} t}$$

where t = 1 year (8760 hours)
and λ_{dc} is taken from the table,
we find

$$R_t = e^{-0.162848}$$

R_t = .8497 for a 1 year mission

SECTION 8

TEST AND INTEGRATION

8.1 TESTING OF THE FIELD CAMERA

The f/24 Field Camera will be qualified and acceptance tested as a subsystem prior to its integration into the OTA. This testing will follow the plan defined in GSFC Report #X-604-74-290, GSFC Integration, Test and Evaluation Plan for ST Focal Plane Assembly. Major components and subassemblies will undergo development testing as required to support the detailed design. Such testing will include breadboard testing of electronic circuits, temporal stability measurements of calibration sources and sensitivity/uniformity measurements of detector photocathodes.

Test objectives/requirements for each phase (development, subassembly, instrument level and integration with the OTA) are shown in Figure 8-1. Required testing is defined as follows:

Optics

The camera has no re-imaging optics that require critical testing. The major responsibility for image quality falls upon the verification of the OTA performance. However, the pick-off mirror and the filter elements must be tested for reflected and transmitted opd values, respectively. This requires a typical wavefront analyzer unit (collimator interferogram) and standard reduction software to assess wavefront peak to peak and rms data at various wavelengths. This is performed with the elements both unmounted as well as mounted in their system configurations. An extension of the above test unit can be used to measure the reflectivity and transmission of the various elements.

The calibration mirrors must also be tested in an analagous manner. The imaging optics, used to irradiate the photo cathode are required to be of known uniform throughput, but are not required to provide high image quality.

Mechanical

The mechanical testing will include the alignment and repeatability characteristic of the port door, filter, and shutter units as well as stability of the mounting to be used to support the detector.

At the S.I. system level, mechanical tests will be directed toward determining the Field Camera, installed in the radial bay module box

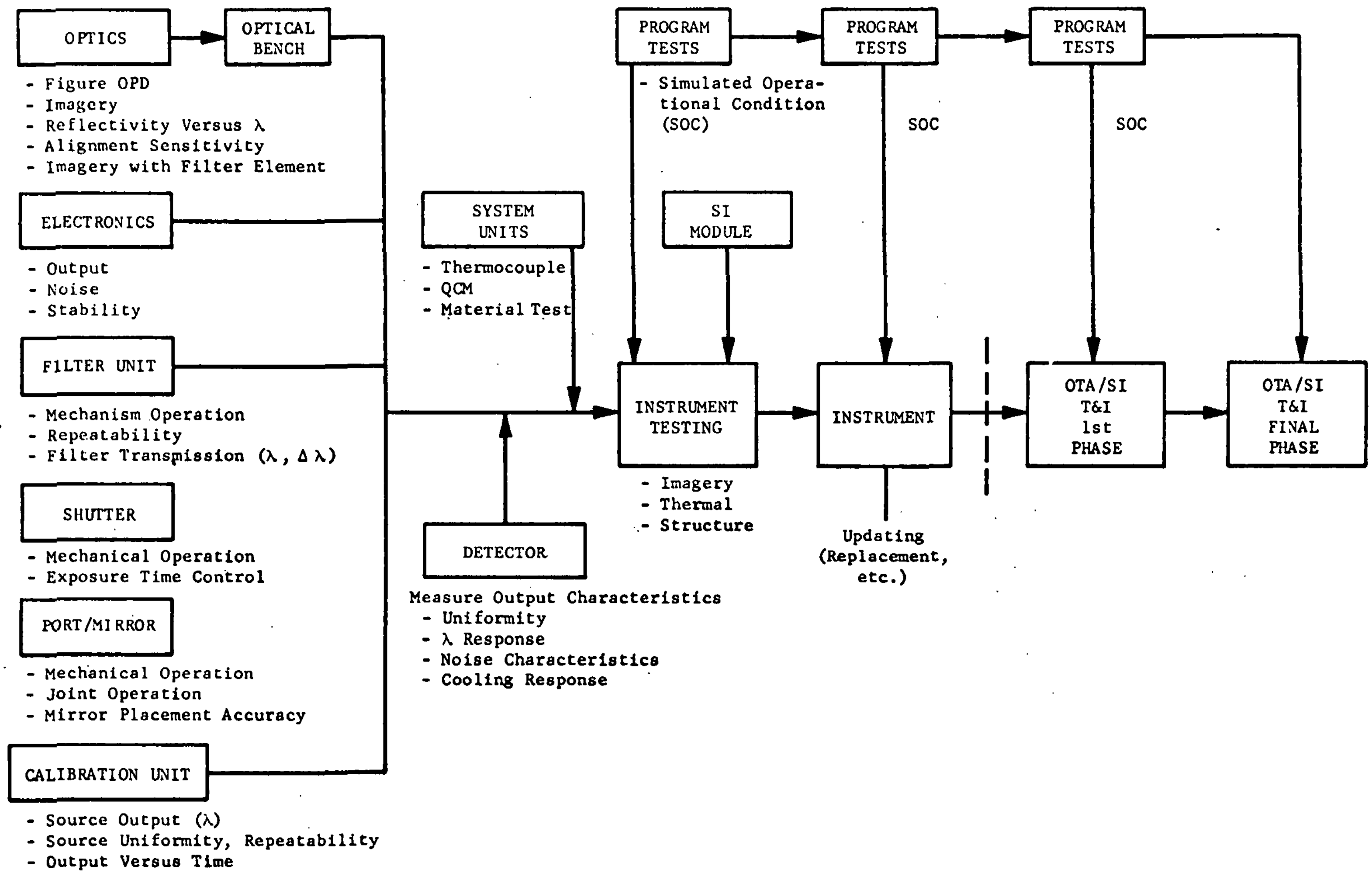


Figure 8-1 Field Camera Integration and Test Flow

is properly aligned, and retains that alignment during vibration and repeated installation/removal cycles on the OTA focal plane structure. The OTA FPS thermal structural unit at GSFC will be used for these tests.

Electronics

Electronic subsystems and components will be subject to considerable development testing in support of detail design work, and will confirm design predictions of power consumption, thermal stability, gains, signal to noise ratio, etc.

As individual components and circuit boards are brought together, tests will include vibration, and electromagnetic interference and compatability. Failure modes and back-up systems will be confirmed.

8.2 CAMERA QUALIFICATION & INTEGRATION WITH OTA

As noted in Section 8-1 qualification testing will be conducted at GSFC. Figure 8-2 gives the schedule of key milestones for the instrument design, assembly, and testing as well as its delivery to the OTA contractor for integration. The instrument contractor will provide, starting at month 27 a structural/thermal model of the camera to GSFC. GSFC will integrate this model with a focal plane structure provided by the OTA contractor. This FPS will be, as far as possible, a duplicate of the FPS being designed for the OTA. GSFC will integrate the TSU instrument models into the FPS and conduct a series of tests of this assembly to verify the thermal/structural design of the camera. This testing information will be input to the continuing design of the camera.

The completed Field Camera will be delivered to GSFC at month 44 of the program. GSFC will integrate the SI's (including the Field Camera) into the FPS and again conduct the tests defined in Report #X-604-74-290. This testing program will qualify the individual instruments - at the conclusion of this test sequence they will be certified as accepted flight instruments for delivery to OTA integration. The SI contractor will participate in and support the testing program at GSFC.

Figure 8-3 defines the schedule for the integration of the Field Camera (and all other SI's) into the OTA. Months 60 and 61 are provided for the receiving and inspection of the camera at the OTA integration site. Following acceptance it will be integrated into the OTA by the OTA contractor. The following tests will be conducted on the OTA/SI assembly during the period months 62-68.

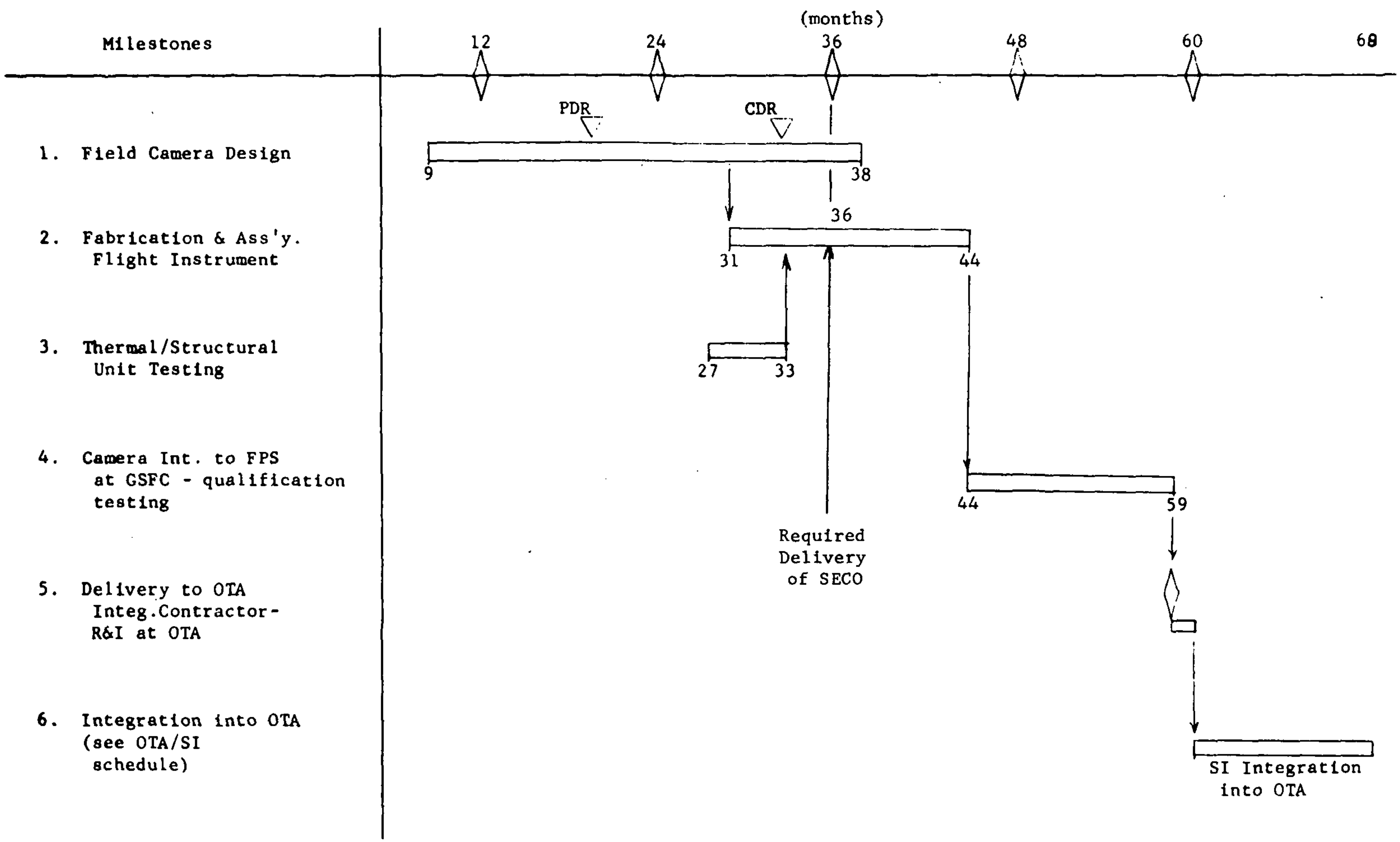


Figure 8-2. f/24 Field Camera Development and Qualification Schedule

C.2

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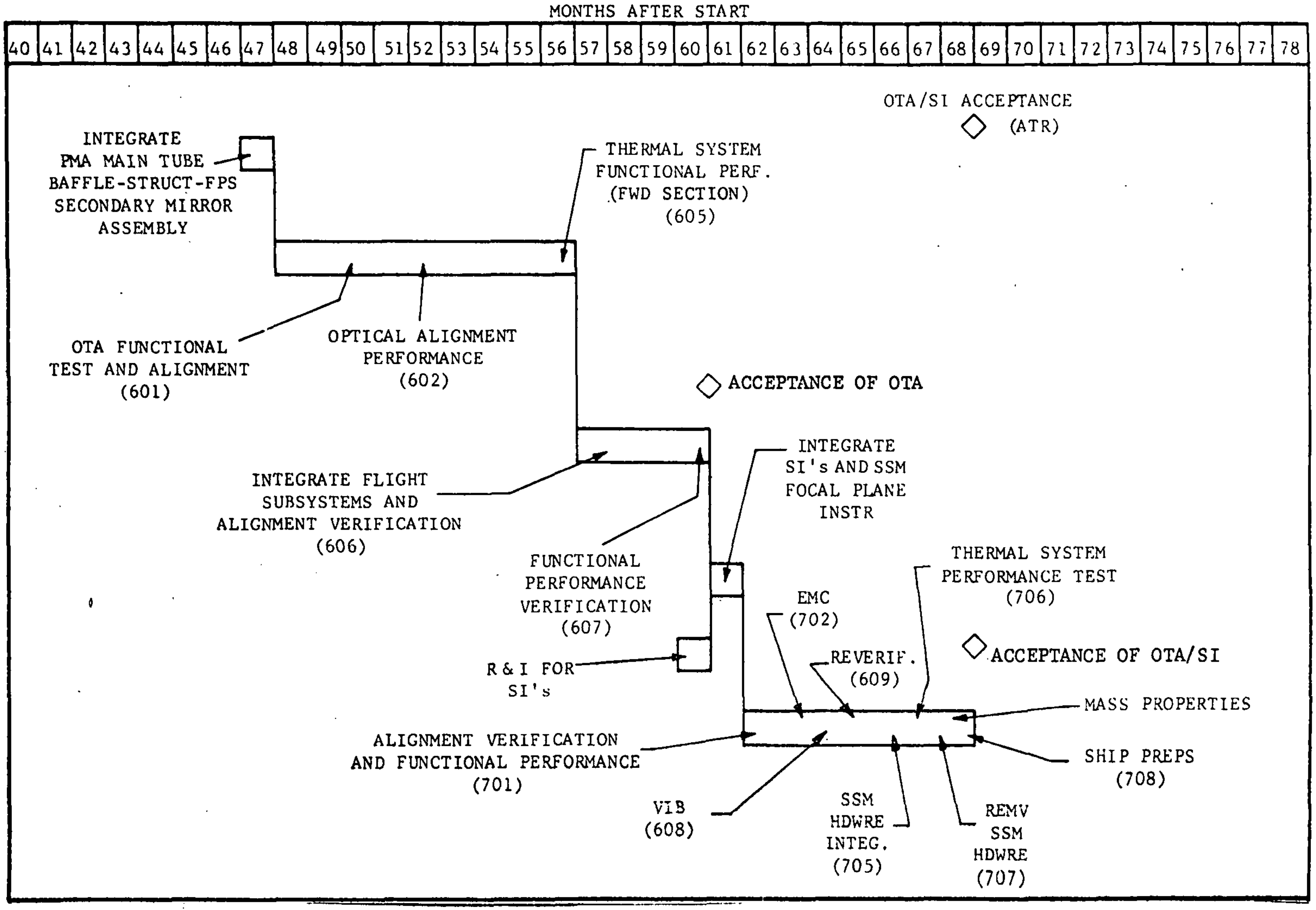

Figure 8-3. OTA and OTA/SI Test Sequence

Test #	Title	Testing/Special Test Equip.
701	Alignment Verification and Functional Performance	The OTA with all science instruments installed will be installed in a thermal/vac test chamber as shown in Fig. 8-4. Using the 72" collimator as shown in Fig. 8-5, the SI's will be verified for alignment and function.
702	EMC	Limited EMC testing will be conducted during Test 701. Test will be limited to monitoring of busses and critical signal lines.
608	Vibration	OTA/SI assembly removed from chamber, subjected to acceptance level vibration.
609	Re-verification of Functional Performance	Return OTA/SI to test chamber and repeat Test 701 to insure system functional after the vibration test.
705	Integration of SSM Hardware	Install SSM Flight Forward Shroud, simulated SSM section and SSM Flight Aft Shroud.
706	Thermal System Performance Test	Test to verify the Optical Performance of OTA/SI under simulated thermal environment. Also to verify thermal interface between SSM and OTA/SI. This includes stability of optical metering truss and power dissipation from the SI area. The test will also verify SI power requirements. Test will be conducted with OTA/SI vertical in test chamber, with 72" collimator input and with thermal simulation of space environment as shown in Fig. 8-4.
707	Removal of SSM Hardware	Following test 706, the SSM Flight hardware is removed.
708	Mass Properties Verification	Verification of Flight OTA/SI.

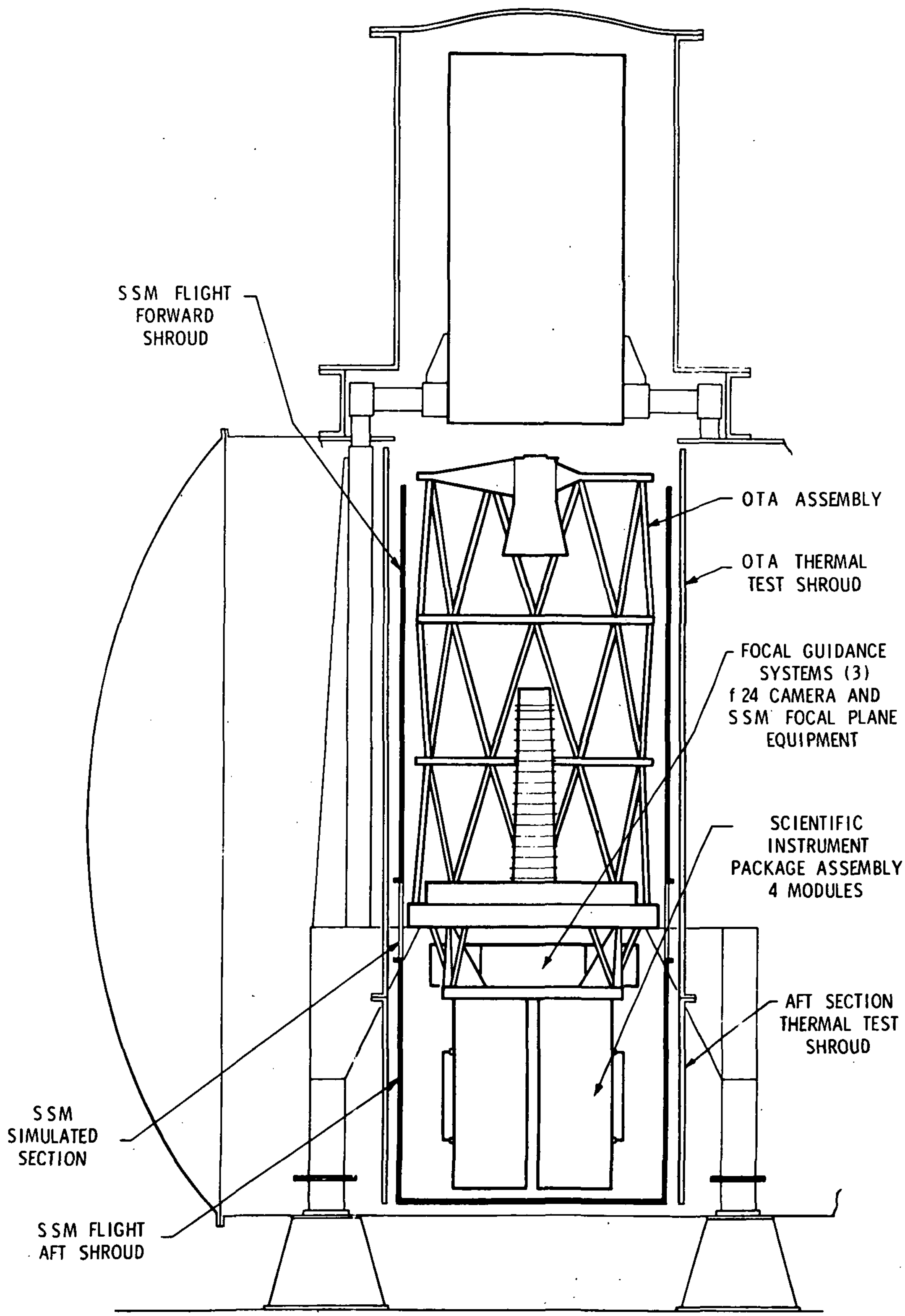

Figure 8-4. OTA/SI Thermal System Performance Test

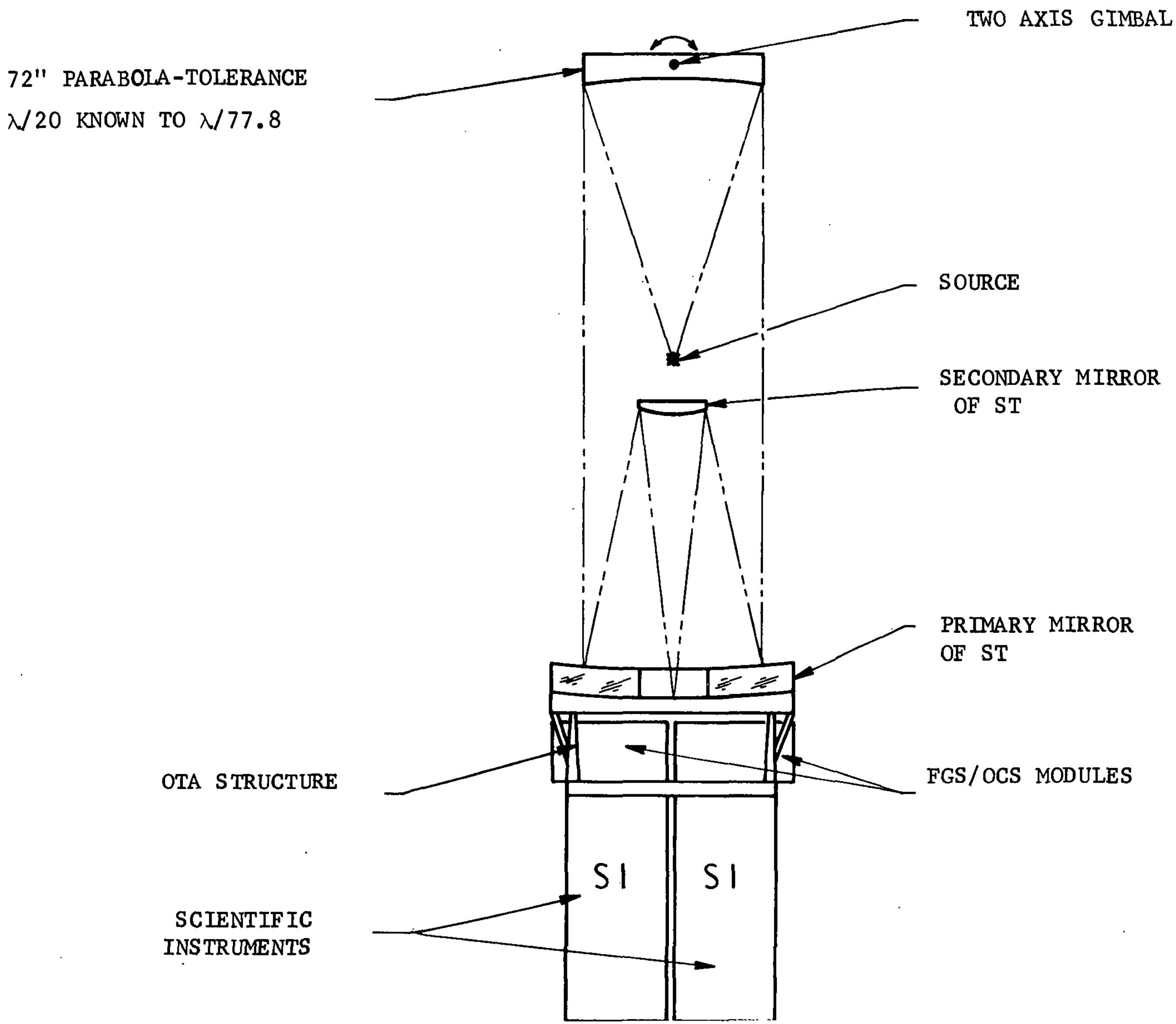

Figure 8-5. 72" Collimator System Test Configuration

Figure 8-6 illustrates the interface conformation sequence for the development/integration of the science instruments. MSFC, as prime contractor, will accept the SI enclosures. They will be supplied to GSFC which will accept/forward the enclosures to the individual contractors. The completed instrument will go to GSFC for environmental/qualification tests as described, and will be accepted by MSFC prior to integration into the OTA.

8.3 ENVIRONMENTAL CONTROL REQUIREMENTS FOR FIELD CAMERA

Figures 8-7 and 8-8 define the environmental conditions which are required during all ground handling of the Field Camera: assembly, testing, refurbishment and transportation. The importance of the Field Camera to successful ST performance demands a highly reliable design. Because of the long period of ground integration and test, it is critical that high levels of cleanliness and careful control of temperature and humidity be maintained. As integration moves to a higher level and ST system size makes such control more difficult, special effort will be required to provide and use covers to protect the camera when not undergoing actual test or checkout.

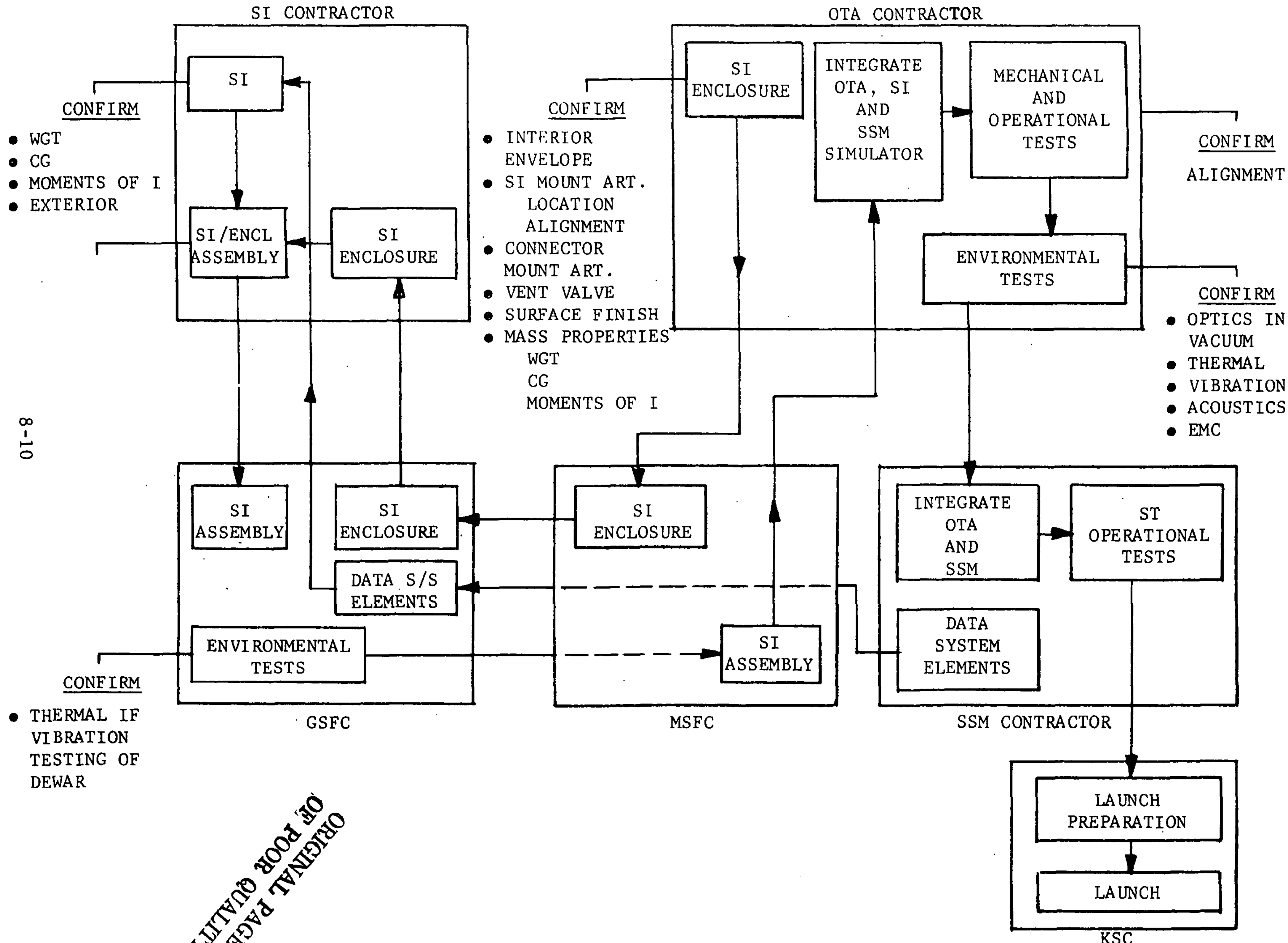

Figure 8.6. OTA/SI Interface Confirmation

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Environmental Parameter		Limits	Max Rate of Change	Remarks
Air Temperature, Ambient Dry Bulb		65°F to 78°F	20°F/Hr	
SI Equipment Temperature		65°F to 78°F	10°F/Hr	For operational requirements, see Paragraph 3.5.6.
Relative Humidity Ambient Air		$<$ 50%	N/A	Note A.
Cleanliness Ambient Air	SI/SI Encl. Integ.	10,000 Max.	N/A	
	OTA/SI Integ.	10,000 Max.	N/A	Fed Std. 209 - See Note B
	SSM Integ.	10,000 Max.	N/A	
Cleanliness SI		Class 200, Level B	N/A	
Cleanliness SI Enclosure Viewing the SI		MIL-STD-1246A	N/A	At the time of integration of the SI with the SI enclosure.

NOTES:

A. During thermal vacuum testing, repressurization shall be controlled to prevent any condensation on OTA/SI surfaces or particulate matter back-stream.

B. During OTA/SI to SSM integration, operations which would expose the interior of the OTA/SI to the ambient environment shall be performed in a Class 10 K environment. Operations which do not expose the OTA/SI interior to the ambient environment may be performed in a Class 100K environment. Appropriate seals and closures on the OTA/SI or plastic tents supplied by HEPA filtered blowers shall be considered as meeting the intent of this requirement.

Figure 8-7. General Environments for the SI Within the SI Enclosure (Handling, Including Factory, Refurbishment)

Environmental Parameter	Limits	Rate of Change - Max	Remarks
Air Temperature, Ambient Dry Bulb	50°F to 90°F	20°F/Hr	
Relative Humidity	$\leq$ 50%	N/A	Note A
Cleanliness - Conditioned Air	100,000		Fed Std 209 - Note B

NOTES:

A. No condensation shall be allowed on any exposed surface of OTA/SI equipment at any time.

B. During transportation, interior of OTA/SI to be closed off to maintain class 10K environment internally while exposed to class 100K environment externally.

Figure 8-8. Transportation Environment Requirements for SI's

APPENDIX A

COMPUTER ANALYSES OF OPTICAL DESIGN

As discussed in Section 3.4, the f/24 Field Camera design incorporates a radial pick-off mirror without corrector and with the SECO photo cathode placed at the best average focus for the field i.e. with focus at the 0.7 diameter of the photo cathode as shown in Figure 3-11. The analyses in this appendix are in support of that design configuration with performance compiled at the on-axis, 50% diameter, 70% diameter and full field positions.

f24 CAMERA OPTICAL PERSCRIPTION

```
LST RC F/24 (LSTRC)

F/ 2.400D 01   FIELD  2X 2.3333D-01 DEG        TARGET F.L. 5.75999D 04

        WAVELENGTHS 6.328000-01 6.328000-01 6.32800D-01
```

NO.	RADIUS	THICKNESS	N3	N4	N5	DEL N	
		0.0	1.000000	1.000000	1.000000	0.0	
* 1	-1.104000D 04	-4.906071D 03	-1.0000000	-1.0000000	-1.0000000	0.0	PRIMARY
ASPH	-2.298500D-03						
* 2	-1.358000D 03	6.406200D 03	1.0000000	1.0000000	1.0000000	0.0	SECONDARY
ASPH	-4.968600D-01						
3	1.000000D 55	0.0	1.0000000	1.0000000	1.0000000	0.0	IMAGE

```
EFL  5.759985D 04   FVD  1.500129D 03   YEP  1.199997D 03

STOP DIAMETER 0.0           POSN.  0.0          AFTER SURF  1
```

```
oooooooooooooooooooooo
oXXXXXX        XXXXXXo
oXXXX            XXXXo
oXXX              XXXo
oXX                XXo
oX                  Xo
oX                  Xo
o                    o
o        XXX         o
o       XXXXX        o
o       XXXXX        o  Central
o       XXXXX        o  Observation
o        XXX         o
o                    o
oX                  Xo
oX                  Xo
oXX                XXo
oXXX              XXXo
oXXXX            XXXXo
oXXXXXX        XXXXXXo
oooooooooooooooooooooo
    5    10    15
```

Evaluation Ray Mask - 204 Rays

f/24 Camera Optical Perscription

- o on axis location
- o best average focus over format (focused at 0.7 zone of image)

*Surface Equation

$$\text{Sag} = \frac{C(y^2 + z^2)}{1 + (1-\epsilon C^2(y^2 + z^2))^{\frac{1}{2}}}$$

$$C = \frac{1}{\text{rad}} \qquad \epsilon = \text{asph.}$$

LST RC F/24 (LSTRC)

NO.	SURFACE	RADIUS	THICKNESS	MD-INDEX	HI-INDEX	LO-INDEX		
WAVELENGTH				0.63280	0.63280	0.63280		
			0.0	1.00000	1.00000	1.00000		
1	ASPHER.	-11040.0000	-4906.0710	-1.00000	-1.00000	-1.00000	AIR	Primary
2	ASPHER.	-1358.0000	6406.1995	1.00000	1.00000	1.00000	AIR	Secondary
3	SPHER.	INF	-0.4800	1.00000	1.00000	1.00000	AIR	Image

TABLE OF ASPHERIC COEFFICIENTS

NO.	E	A(4)	A(6)	A(8)	A(10)
1	-2.2985000D-03	0.0	0.0	0.0	0.0
2	-4.9686000D-01	0.0	0.0	0.0	0.0

FIRST ORDER PARAMETERS ON MERIDIONAL PLANE

OBJECT DSTNCE	ENTR.PUP.DIST	FRST.PPAL.PNT	EQV.FCL.LNGTH	SCND.PPAL.PNT	EXT.PUP.DSTNC	IMAGE DISTNCE
INF	0.0	-416184.061391	57599.854894	-51194.135355	-596.451184	6405.719539
OBJECT HEIGHT	ENTR.PUP.SIZE	OBJT.SPCE.FNO	TRACK LENGTH	IMGE.SPCE.FNO	EXT.PUPL.SIZE	IMAGE HEIGHT
INF	2399.993954	INF	INF	24.000000	291.777113	234.572622
MAGNIFICATION	SEMIANG.FIELD	BACK VTX.DIST	BARREL LENGTH	FRNT.VTX.DIST	SEMIANG.FIELD	DEMAGNIFICATION
0.0	0.233333	INF	-4906.071000	1499.648539	1.919266	INF
APT.STOP SIZE	APT.STOP DIST	FROM SRFCE.NO	*************	FLD.STOP SIZE	FLD.STOP DIST	FROM SRFCE.NO
2399.993954	0.0	1		469.145244	6405.719539	2

FIRST ORDER PARAMETERS

LST RC F/24 (LSTRC)   12:10:41--------09/12/75
CYCLE 0

PERKIN-ELMER

OPTICAL PATH DIFFERENCES (for 204 rays of the evaluation grid)

FIELD CO-ORDS. 0.0 0.0
REF. F.L. 5.760D 04 WAVELENGTH 6.328D-04

1	***	***	***	***	***	***	-0.15	-0.15	-0.15	-0.15	-0.15	***	***	***	***	***	***
2	***	***	***	***	-0.15	-0.13	-0.12	-0.11	-0.11	-0.11	-0.12	-0.13	-0.15	***	***	***	***
3	***	***	-0.16	-0.14	-0.12	-0.10	-0.09	-0.08	-0.08	-0.08	-0.09	-0.10	-0.12	-0.14	-0.16	***	***
4	***	***	-0.14	-0.11	-0.09	-0.08	-0.07	-0.06	-0.06	-0.06	-0.07	-0.08	-0.09	-0.11	-0.14	***	***
5	***	-0.15	-0.12	-0.09	-0.07	-0.06	-0.05	-0.04	-0.04	-0.04	-0.05	-0.06	-0.07	-0.09	-0.12	-0.15	***
6	***	-0.13	-0.10	-0.08	-0.06	-0.04	-0.03	-0.02	-0.02	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	-0.13	***
7	-0.15	-0.12	-0.09	-0.07	-0.05	-0.03	-0.02	***	***	***	-0.02	-0.03	-0.05	-0.07	-0.09	-0.12	-0.15
8	-0.15	-0.11	-0.08	-0.06	-0.04	-0.02	***	***	***	***	***	-0.02	-0.04	-0.06	-0.08	-0.11	-0.15
9	-0.15	-0.11	-0.08	-0.06	-0.04	-0.02	***	***	***	***	***	-0.02	-0.04	-0.06	-0.08	-0.11	-0.15
10	-0.15	-0.11	-0.08	-0.06	-0.04	-0.02	***	***	***	***	***	-0.02	-0.04	-0.06	-0.08	-0.11	-0.15
11	-0.15	-0.12	-0.09	-0.07	-0.05	-0.03	-0.02	***	***	***	-0.02	-0.03	-0.05	-0.07	-0.09	-0.12	-0.15
12	***	-0.13	-0.10	-0.08	-0.06	-0.04	-0.03	-0.02	-0.02	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	-0.13	***
13	***	-0.15	-0.12	-0.09	-0.07	-0.06	-0.05	-0.04	-0.04	-0.04	-0.05	-0.06	-0.07	-0.09	-0.12	-0.15	***
14	***	***	-0.14	-0.11	-0.09	-0.08	-0.07	-0.06	-0.06	-0.06	-0.07	-0.08	-0.09	-0.11	-0.14	***	***
15	***	***	-0.16	-0.14	-0.12	-0.10	-0.09	-0.08	-0.08	-0.08	-0.09	-0.10	-0.12	-0.14	-0.16	***	***
16	***	***	***	***	-0.15	-0.13	-0.12	-0.11	-0.11	-0.11	-0.12	-0.13	-0.15	***	***	***	***
17	***	***	***	***	***	***	-0.15	-0.15	-0.15	-0.15	-0.15	***	***	***	***	***	***

RMS OPD 4.2642D-02 KOUNT 204 AVERAGE -8.9219D-02

NOTES:

1 On axis of Camera (0 Field Position)
2 OPD in wavelengths at 632.8 nm
3 rms opd = .0426λ = λ/23.45
4 Each numeric value corresponds to the opd of a ray entering the pupil at the indicated point

```
LST RC F/24 (LSTRC)                              12:10:46---------09/12/75
CYCLE   0

                               LATERAL ABERRATIONS (on Axis of Camera)

      FIELD CO-ORDS.  0.0          0.0                   REF.F.L.  5.75999D 04
      PRIN.RAY CO-ORDS.  0.0          0.0

DY  1 ****************************************** 0.009  0.009  0.009  0.009  0.009******************************************
DZ  1 ****************************************** -0.002 -0.001 0.0    0.001  0.002******************************************

DY  2 **************************** 0.008  0.008  0.008  0.008  0.008  0.008  0.008  0.008  0.008****************************
DZ  2 **************************** -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005****************************

DY  3 ************** 0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007  0.007**************
DZ  3 ************** -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007**************

DY  4 ************** 0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006  0.006**************
DZ  4 ************** -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007**************

DY  5 ******* 0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005  0.005*******
DZ  5 ******* -0.008 -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007  0.008*******

DY  6 ******* 0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004  0.004*******
DZ  6 ******* -0.008 -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007  0.008*******

DY  7  0.002  0.002  0.002  0.002  0.002  0.002  0.002********************* 0.002  0.002  0.002  0.002  0.002  0.002  0.002
DZ  7 -0.009 -0.008 -0.007 -0.006 -0.005 -0.004 -0.002********************* 0.002  0.004  0.005  0.006  0.007  0.008  0.009

DY  8  0.001  0.001  0.001  0.001  0.001  0.001*********************************** 0.001  0.001  0.001  0.001  0.001  0.001
DZ  8 -0.009 -0.008 -0.007 -0.006 -0.005 -0.004*********************************** 0.004  0.005  0.006  0.007  0.008  0.009

DY  9  0.0    0.0    0.0    0.0    0.0    0.0   *********************************** 0.0    0.0    0.0    0.0    0.0    0.0
DZ  9 -0.009 -0.008 -0.007 -0.006 -0.005 -0.004*********************************** 0.004  0.005  0.006  0.007  0.008  0.009

DY 10 -0.001 -0.001 -0.001 -0.001 -0.001 -0.001***********************************-0.001 -0.001 -0.001 -0.001 -0.001 -0.001
DZ 10 -0.009 -0.008 -0.007 -0.006 -0.005 -0.004*********************************** 0.004  0.005  0.006  0.007  0.008  0.009

DY 11 -0.002 -0.002 -0.002 -0.002 -0.002 -0.002 -0.002*********************-0.002 -0.002 -0.002 -0.002 -0.002 -0.002 -0.002
DZ 11 -0.009 -0.008 -0.007 -0.006 -0.005 -0.004 -0.002********************* 0.002  0.004  0.005  0.006  0.007  0.008  0.009

DY 12 ******* -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004 -0.004*******
DZ 12 ******* -0.008 -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007  0.008*******

DY 13 ******* -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005 -0.005*******
DZ 13 ******* -0.008 -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007  0.008*******

DY 14 ************** -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006 -0.006**************
DZ 14 ************** -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007**************

DY 15 ************** -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007 -0.007**************
DZ 15 ************** -0.007 -0.006 -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005  0.006  0.007**************

DY 16 **************************** -0.008 -0.008 -0.008 -0.008 -0.008 -0.008 -0.008 -0.008 -0.008****************************
DZ 16 **************************** -0.005 -0.004 -0.002 -0.001 0.0    0.001  0.002  0.004  0.005****************************

DY 17 ****************************************** -0.009 -0.009 -0.009 -0.009 -0.009******************************************
DZ 17 ****************************************** -0.002 -0.001 0.0    0.001  0.002******************************************

        rms Spot Size  =   RMS LAT.ABER.   7.36310-03   KOUNT 204
```

NOTES:

1 Lateral aberrations given are for each ray of evaluation grid

2 DY = Ray error in 'Y' direction

3 DZ = Ray error in "Z' direction

4 Dimensions in millimeters

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LST RC F/24 (LSTRC) 09:08:52--------11/24/75
CYCLE 0

MONOCHROMATIC O.T.F.

WAVELENGTH 6.3280D-04 REF.F.L. 5.76000 04 FIELD CO-ORDS. 0.0 0.0

LINES PARALLEL TO RADIAL DIR.

FREQ	THEOR	MTF	REAL	IMAG	PHASE
5.00	0.861	0.851	0.851	0.0	0.0
10.00	0.722	0.693	0.693	0.0	0.0
15.00	0.591	0.548	0.548	0.0	0.0
20.00	0.468	0.426	0.426	0.0	0.0
25.00	0.387	0.357	0.357	0.0	0.0
30.00	0.344	0.321	0.321	0.0	0.0
35.00	0.313	0.290	0.290	0.0	0.0
40.00	0.288	0.261	0.261	0.0	0.0
45.00	0.225	0.205	0.205	0.0	0.0
50.00	0.143	0.133	0.133	0.0	0.0
55.00	0.084	0.081	0.081	0.0	0.0
60.00	0.037	0.036	0.036	0.0	0.0

204 MASK POINTS

204 RAYS OUT OF 204

NOTES:

1 On axis of Camera (0 Field Position)

2 Freq. = Frequency in line pairs per millimeter

3 Theor. = Theoretical diffraction limited MTF at 632.8 nm

4 MTF = Actual computed system MTF including diffraction in the flat photocathode surface plane of the detector

LST RC F/24 (LSTRC) 12:11:13--------09/12/75
CYCLE 0

FIELD 0.0 0.0 REF.F.L.*********

X.Y.Z SHIFTS 0.0 0.0 0.0

PERCENTAGES EXCLUDE VIGNETTING 0.0 %

RADIUS	PERCENTAGE	Y-REF	Z-REF	Y-BOUND
2.500000D-03	0.0	0.0	0.0	1.000000D 10
5.000000D-03	19.60784			
7.500000D-03	52.94118			
1.000000D-02	100.00000			
1.250000D-02	100.00000			
1.500000D-02	100.00000			
1.750000D-02	100.00000			
2.000000D-02	100.00000			
2.250000D-02	100.00000			
2.500000D-02	100.00000			

NOTES:

1 On axis of Camera
2 Geometrical encircled energy
3 Radius = Spot radius
4 Percentage = Percentage enclosed energy

LST RC F/24 (LSTRC) 12:11:49--------09/12/75
CYCLE 0

PERKIN-ELMER

OPTICAL PATH DIFFERENCES (204 rays)

FIELD CO-ORDS. 1.243D-02 0.0
REF. F.L. 5.760D 04 WAVELENGTH 6.328D-04

1	******	******	******	******	******	******	-0.11	-0.11	-0.10	-0.11	-0.11	******	******	******	******	******	******
2	******	******	******	******	-0.11	-0.10	-0.09	-0.08	-0.08	-0.08	-0.09	-0.10	-0.11	******	******	******	******
3	******	******	-0.12	-0.10	-0.09	-0.07	-0.07	-0.06	-0.06	-0.06	-0.07	-0.07	-0.09	-0.10	-0.12	******	******
4	******	******	-0.10	-0.08	-0.07	-0.06	-0.05	-0.04	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.10	******	******
5	******	-0.11	-0.09	-0.07	-0.05	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.05	-0.07	-0.09	-0.11	******
6	******	-0.10	-0.08	-0.06	-0.04	-0.03	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	******
7	-0.12	-0.09	-0.07	-0.05	-0.03	-0.02	-0.01	******	******	******	-0.01	-0.02	-0.03	-0.05	-0.07	-0.09	-0.12
8	-0.11	-0.09	-0.06	-0.05	-0.03	-0.02	******	******	******	******	******	-0.02	-0.03	-0.05	-0.06	-0.09	-0.11
9	-0.11	-0.09	-0.06	-0.04	-0.03	-0.02	******	******	******	******	******	-0.02	-0.03	-0.04	-0.06	-0.09	-0.11
10	-0.11	-0.09	-0.06	-0.05	-0.03	-0.02	******	******	******	******	******	-0.02	-0.03	-0.05	-0.06	-0.09	-0.11
11	-0.12	-0.09	-0.07	-0.05	-0.03	-0.02	-0.01	******	******	******	-0.01	-0.02	-0.03	-0.05	-0.07	-0.09	-0.12
12	******	-0.10	-0.08	-0.06	-0.04	-0.03	-0.02	-0.02	-0.01	-0.02	-0.02	-0.03	-0.04	-0.06	-0.08	-0.10	******
13	******	-0.11	-0.09	-0.07	-0.05	-0.04	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04	-0.05	-0.07	-0.09	-0.11	******
14	******	******	-0.10	-0.08	-0.07	-0.06	-0.05	-0.04	-0.04	-0.04	-0.05	-0.06	-0.07	-0.08	-0.10	******	******
15	******	******	-0.12	-0.10	-0.09	-0.07	-0.07	-0.06	-0.06	-0.06	-0.07	-0.07	-0.09	-0.10	-0.12	******	******
16	******	******	******	******	-0.11	-0.10	-0.09	-0.08	-0.08	-0.08	-0.09	-0.10	-0.11	******	******	******	******
17	******	******	******	******	******	******	-0.11	-0.11	-0.10	-0.11	-0.11	******	******	******	******	******	******

RMS OPD 3.16690-02 KOUNT 204 AVERAGE -6.61540-02

NOTES:

1 0.5 Field position of camera

2 opd in wavelengths at 632.8 nm

3 rms opd = .03167λ = λ/31.58

4 Each numeric value corresponds to the opd of a ray entering the pupil at the indicated point.

LST RC F/24 (LSTRC) 12:11:53--------09/12/75
CYCLE 0

LATERAL ABERRATIONS (0.5 Field Position of Camera)

FIELD CO-ORDS. 1.24300D-02 0.0 REF.F.L. 5.75999D 04
PRIN.RAY CO-ORDS. 1.24951D 01 0.0

DY 1							0.007	0.007	0.007	0.007	0.007						
DZ 1							-0.002	-0.001	0.0	0.001	0.002						
DY 2					0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006				
DZ 2					-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004				
DY 3			0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005		
DZ 3			-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005		
DY 4			0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004		
DZ 4			-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005		
DY 5		0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
DZ 5		-0.006	-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005	0.006	
DY 6		0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	0.003	
DZ 6		-0.006	-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005	0.006	
DY 7	0.002	0.002	0.002	0.002	0.002	0.002	0.002				0.002	0.002	0.002	0.002	0.002	0.002	0.002
DZ 7	-0.007	-0.006	-0.005	-0.005	-0.004	-0.003	-0.002				0.002	0.003	0.004	0.005	0.005	0.006	0.007
DY 8	0.001	0.001	0.001	0.001	0.001	0.001						0.001	0.001	0.001	0.001	0.001	0.001
DZ 8	-0.007	-0.006	-0.005	-0.005	-0.004	-0.003						0.003	0.004	0.005	0.005	0.006	0.007
DY 9	0.000	0.000	0.000	0.000	0.000	0.000						0.000	0.000	0.000	0.000	0.000	0.000
DZ 9	-0.007	-0.006	-0.005	-0.005	-0.004	-0.003						0.003	0.004	0.005	0.005	0.006	0.007
DY 10	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001						-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
DZ 10	-0.007	-0.006	-0.005	-0.005	-0.004	-0.003						0.003	0.004	0.005	0.005	0.006	0.007
DY 11	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002				-0.002	-0.002	-0.002	-0.002	-0.002	-0.002	-0.002
DZ 11	-0.007	-0.006	-0.005	-0.005	-0.004	-0.003	-0.002				0.002	0.003	0.004	0.005	0.005	0.006	0.007
DY 12		-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	
DZ 12		-0.006	-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005	0.006	
DY 13		-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	
DZ 13		-0.006	-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005	0.006	
DY 14			-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004		
DZ 14			-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005		
DY 15			-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005	-0.005		
DZ 15			-0.005	-0.005	-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004	0.005	0.005		
DY 16					-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006				
DZ 16					-0.004	-0.003	-0.002	-0.001	0.0	0.001	0.002	0.003	0.004				
DY 17							-0.007	-0.007	-0.007	-0.007	-0.007						
DZ 17							-0.002	-0.001	0.0	0.001	0.002						

rms Spot Size = RMS LAT.ABER. 5.46360-03 KOUNT 204

Ref. notes on page A-5

LST RC F/24 (LSTRC) 09:09:04--------11/24/75
CYCLE 0

MONOCHROMATIC O.T.F.

WAVELENGTH 6.3280D-04 REF.F.L. 5.76000 04 FIELD CO-ORDS. 1.2430-02 0.0

	LINES PARALLEL TO RADIAL DIR.						LINES PARALLEL TO TANGENTIAL DIR.				
FREQ	THEOR	MTF	REAL	IMAG	PHASE		THEOR	MTF	REAL	IMAG	PHASE
5.00	0.861	0.855	0.855	0.0	0.0	*	0.861	0.856	0.856	-0.000	-0.000
10.00	0.722	0.705	0.705	0.0	0.0	*	0.722	0.707	0.707	-0.000	-0.000
15.00	0.591	0.566	0.566	0.0	0.0	*	0.591	0.569	0.569	-0.000	-0.000
20.00	0.468	0.443	0.443	0.0	0.0	*	0.468	0.446	0.446	-0.000	-0.000
25.00	0.387	0.369	0.369	0.0	0.0	*	0.387	0.371	0.371	-0.000	-0.000
30.00	0.344	0.331	0.331	0.0	0.0	*	0.344	0.332	0.332	-0.000	-0.000
35.00	0.313	0.299	0.299	0.0	0.0	*	0.313	0.301	0.301	-0.000	-0.000
40.00	0.288	0.272	0.272	0.0	0.0	*	0.288	0.274	0.274	-0.000	-0.000
45.00	0.225	0.213	0.213	0.0	0.0	*	0.225	0.215	0.215	-0.000	-0.001
50.00	0.143	0.137	0.137	0.0	0.0	*	0.143	0.138	0.138	-0.000	-0.001
55.00	0.084	0.082	0.082	0.0	0.0	*	0.084	0.082	0.082	-0.000	-0.001
60.00	0.037	0.037	0.037	0.0	0.0	*	0.037	0.037	0.037	-0.000	-0.001

204 MASK POINTS

204 RAYS OUT OF 204

NOTES:

1 0.5 Field position of camera

2 Reference notes 2, 3 and 4, page A-6

LST RC F/24 (LSTRC)　　　　12:12:21--------09/12/75
CYCLE 0

FIELD 0.0124 0.0　　REF.F.L.*********

X.Y.Z SHIFTS 0.0　0.0　0.0

PERCENTAGES EXCLUDE VIGNETTING 0.0 %

RADIUS	PERCENTAGE	Y-REF	Z-REF	Y-BOUND
2.500000D-03	1.96078	0.0	0.0	1.000000D 10
5.000000D-03	39.21569			
7.500000D-03	100.00000			
1.000000D-02	100.00000			
1.250000D-02	100.00000			
1.500000D-02	100.00000			
1.750000D-02	100.00000			
2.000000D-02	100.00000			
2.250000D-02	100.00000			
2.500000D-02	100.00000			

NOTES:

1 0.5 Field position of camera

2 Geometrical encircled energy

3 Radius = Spot radius

4 Percentage = Percentage enclosed energy

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LST RC F/24 (LSTRC)                                  12:12:58--------09/12/75
CYCLE    0

                     OPTICAL PATH DIFFERENCES

          FIELD CO-ORDS.  2.487D-02  0.0
      REF. F.L.  5.760D 04      WAVELENGTH  6.328D-04

 1 ************************************  0.02  0.02  0.02  0.02  0.02************************************
 2 ************************  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01************************
 3 ************  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01************
 4 ************  0.00  0.00  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.00  0.00************
 5 ****** -0.00 -0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00 -0.00 -0.00******
 6 ****** -0.00 -0.00 -0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00 -0.00 -0.00 -0.00******
 7  -0.01 -0.01 -0.00 -0.00 -0.00 -0.00  0.00******************  0.00 -0.00 -0.00 -0.00 -0.00 -0.01 -0.01
 8  -0.01 -0.01 -0.00 -0.00 -0.00 -0.00****************************** -0.00 -0.00 -0.00 -0.00 -0.01 -0.01
 9  -0.01 -0.01 -0.01 -0.00 -0.00 -0.00****************************** -0.00 -0.00 -0.00 -0.01 -0.01 -0.01
10  -0.01 -0.01 -0.00 -0.00 -0.00 -0.00****************************** -0.00 -0.00 -0.00 -0.00 -0.01 -0.01
11  -0.01 -0.01 -0.00 -0.00 -0.00 -0.00  0.00******************  0.00 -0.00 -0.00 -0.00 -0.00 -0.01 -0.01
12 ****** -0.00 -0.00 -0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00 -0.00 -0.00 -0.00******
13 ****** -0.00 -0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00  0.00 -0.00 -0.00******
14 ************  0.00  0.00  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.00  0.00************
15 ************  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01************
16 ************************  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01  0.01************************
17 ************************************  0.02  0.02  0.02  0.02  0.02************************************

                RMS OPD   6.9958D-03   KOUNT 204     AVERAGE   3.1200D-03
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NOTES:

1 0.7 Field position of camera

2 opd in wavelengths at 632.8 nm

3 rms opd = .007λ = λ/142.94

4 Each numeric value corresponds to the opd of a ray entering the pupil at the indicated point.

PERKIN-ELMER

LST RC F/24 (LSTRC) 12:13:03--------09/12/75
CYCLE 0

LATERAL ABERRATIONS (0.7 Field Position of Camera)

FIELD CO-ORDS. 2.48700D-02 0.0 REF.F.L. 5.75999D 04
PRIN.RAY CO-ORDS. 2.50004D 01 0.0

DY 1							-0.001	-0.001	-0.001	-0.001	-0.001						
DZ 1							-0.000	-0.000	0.0	0.000	0.000						
DY 2					-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001				
DZ 2					-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000				
DY 3			-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001		
DZ 3			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000		
DY 4			-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001		
DZ 4			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000		
DY 5		-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001	
DZ 5		-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
DY 6		-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	
DZ 6		-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
DY 7	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000				-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
DZ 7	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000				0.000	0.000	0.000	0.000	0.000	0.001	0.001
DY 8	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000						-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
DZ 8	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000						0.000	0.000	0.000	0.000	0.001	0.001
DY 9	0.000	0.000	0.000	0.000	0.000	0.000						0.000	0.000	0.000	0.000	0.000	0.000
DZ 9	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000						0.000	0.000	0.000	0.000	0.001	0.001
DY 10	0.000	0.000	0.000	0.000	0.000	0.000						0.000	0.000	0.000	0.000	0.000	0.000
DZ 10	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000						0.000	0.000	0.000	0.000	0.001	0.001
DY 11	0.000	0.000	0.000	0.000	0.000	0.000	0.000				0.000	0.000	0.000	0.000	0.000	0.000	0.000
DZ 11	-0.001	-0.001	-0.000	-0.000	-0.000	-0.000	-0.000				0.000	0.000	0.000	0.000	0.000	0.001	0.001
DY 12		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	
DZ 12		-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
DY 13		0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	
DZ 13		-0.001	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000	0.001	
DY 14			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
DZ 14			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000		
DY 15			0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001		
DZ 15			-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000	0.000	0.000		
DY 16					0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001				
DZ 16					-0.000	-0.000	-0.000	-0.000	0.0	0.000	0.000	0.000	0.000				
DY 17							0.001	0.001	0.001	0.001	0.001						
DZ 17							-0.000	-0.000	0.0	0.000	0.000						

RMS Spot Size = RMS LAT.ABER. 7.5840D-04 KOUNT 204

Ref. Notes on page A-5

LST RC F/24 (LSTRC) 09:09:17--------11/24/75
CYCLE 0

MONOCHROMATIC O.T.F.

WAVELENGTH 6.32800-04 REF.F.L. 5.7600D 04 FIELD CO-ORDS. 2.487D-02 0.0

	LINES PARALLEL TO RADIAL DIR.						LINES PARALLEL TO TANGENTIAL DIR.				
FREQ	THEOR	MTF	REAL	IMAG	PHASE		THEOR	MTF	REAL	IMAG	PHASE
5.00	0.861	0.861	0.861	0.0	0.0	*	0.861	0.861	0.861	-0.000	-0.000
10.00	0.722	0.721	0.721	0.0	0.0	*	0.722	0.721	0.721	-0.000	-0.000
15.00	0.591	0.591	0.591	0.0	0.0	*	0.591	0.590	0.590	-0.000	-0.000
20.00	0.468	0.468	0.468	0.0	0.0	*	0.468	0.468	0.468	-0.000	-0.000
25.00	0.387	0.387	0.387	0.0	0.0	*	0.387	0.386	0.386	-0.000	-0.000
30.00	0.344	0.344	0.344	0.0	0.0	*	0.345	0.344	0.344	-0.000	-0.000
35.00	0.313	0.313	0.313	0.0	0.0	*	0.313	0.313	0.313	-0.000	-0.001
40.00	0.288	0.288	0.288	0.0	0.0	*	0.288	0.287	0.287	-0.000	-0.001
45.00	0.225	0.225	0.225	0.0	0.0	*	0.226	0.225	0.225	-0.000	-0.001
50.00	0.143	0.143	0.143	0.0	0.0	*	0.143	0.143	0.143	-0.000	-0.001
55.00	0.084	0.084	0.084	0.0	0.0	*	0.084	0.084	0.084	-0.000	-0.001
60.00	0.037	0.037	0.037	0.0	0.0	*	0.037	0.037	0.037	-0.000	-0.002

204 MASK POINTS

204 RAYS OUT OF 204

NOTES:

1 0.7 Field position of camera

2 Ref. notes 2, 3 and 4, page A-6

LST RC F/24 (LSTRC) 12:13:26--------09/12/75
CYCLE 0

FIELD 0.0249 0.0 REF.F.L.*********

X,Y,Z SHIFTS 0.0 0.0 0.0

PERCENTAGES EXCLUDE VIGNETTING 0.0 %

RADIUS	PERCENTAGE	Y-REF	Z-REF	Y-BOUND
2.50000D-03	100.00000	0.0	0.0	1.00000D 10
5.00000D-03	100.00000			
7.50000D-03	100.00000			
1.00000D-02	100.00000			
1.25000D-02	100.00000			
1.50000D-02	100.00000			
1.75000D-02	100.00000			
2.00000D-02	100.00000			
2.25000D-02	100.00000			
2.50000D-02	100.00000			

NOTES:

1 0.7 Field position of Camera

2 Geometrical encircled energy

3 Radius = Spot radius

4 Percentage = Percentage enclosed energy

LST RC F/24 (LSTRC) --------09/12/75
CYCLE 0

OPTICAL PATH DIFFERENCES (204 rays)

FIELD CO-ORDS. 3.517D-02 0.0
REF. F.L. 5.760D 04 WAVELENGTH 6.328D-04

1	******	******	******	******	******	******	0.19	0.19	0.18	0.19	0.19	******	******	******	******	******	******
2	******	******	******	******	0.17	0.16	0.15	0.14	0.14	0.14	0.15	0.16	0.17	******	******	******	******
3	******	******	0.18	0.15	0.14	0.12	0.11	0.11	0.10	0.11	0.11	0.12	0.14	0.15	0.18	******	******
4	******	******	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.07	0.08	0.09	0.10	0.12	0.14	******	******
5	******	0.14	0.12	0.10	0.08	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.08	0.10	0.12	0.14	******
6	******	0.12	0.10	0.08	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.06	0.08	0.10	0.12	******
7	0.14	0.11	0.08	0.06	0.04	0.03	0.02	******	******	******	0.02	0.03	0.04	0.06	0.08	0.11	0.14
8	0.13	0.10	0.07	0.05	0.03	0.02	******	******	******	******	******	0.02	0.03	0.05	0.07	0.10	0.13
9	0.13	0.10	0.07	0.05	0.03	0.02	******	******	******	******	******	0.02	0.03	0.05	0.07	0.10	0.13
10	0.13	0.10	0.07	0.05	0.03	0.02	******	******	******	******	******	0.02	0.03	0.05	0.07	0.10	0.13
11	0.14	0.11	0.08	0.06	0.04	0.03	0.02	******	******	******	0.02	0.03	0.04	0.06	0.08	0.11	0.14
12	******	0.12	0.10	0.08	0.06	0.04	0.03	0.03	0.03	0.03	0.03	0.04	0.06	0.08	0.10	0.12	******
13	******	0.14	0.12	0.10	0.08	0.06	0.05	0.05	0.05	0.05	0.05	0.06	0.08	0.10	0.12	0.14	******
14	******	******	0.14	0.12	0.10	0.09	0.08	0.07	0.07	0.07	0.08	0.09	0.10	0.12	0.14	******	******
15	******	******	0.18	0.15	0.14	0.12	0.11	0.11	0.10	0.11	0.11	0.12	0.14	0.15	0.18	******	******
16	******	******	******	******	0.17	0.16	0.15	0.14	0.14	0.14	0.15	0.16	0.17	******	******	******	******
17	******	******	******	******	******	******	0.19	0.19	0.18	0.19	0.19	******	******	******	******	******	******

RMS OPD 4.7597D-02 KOUNT 204 AVERAGE 9.5457D-02

NOTES:

1 Full Field position of camera
2 opd in wavelengths at 632.8 nm
3 rms opd = .0476λ = λ/21.01
4 Each numeric value corresponds to the opd of a ray entering the pupil at the indicated point.

LST RC F/24 (LSTRC)   12:14:06--------09/12/75
CYCLE 0

LATERAL ABERRATIONS (Full Field Position of Camera)

FIELD CO-ORDS. 3.517000-02 0.0   REF.F.L. 5.759990 04
PRIN.RAY CO-ORDS. 3.535450 01 0.0

DY 1							-0.012	-0.012	-0.012	-0.012	-0.012						
DZ 1							0.002	0.001	0.0	-0.001	-0.002						
DY 2					-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010	-0.010				
DZ 2					0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004				
DY 3			-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009	-0.009		
DZ 3			0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006		
DY 4			-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007	-0.007		
DZ 4			0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006		
DY 5		-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	-0.006	
DZ 5		0.007	0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	
DY 6		-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	-0.004	
DZ 6		0.007	0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	
DY 7	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003				-0.003	-0.003	-0.003	-0.003	-0.003	-0.003	-0.003
DZ 7	0.008	0.007	0.006	0.005	0.004	0.003	0.002				-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	-0.008
DY 8	-0.001	-0.001	-0.001	-0.001	-0.001	-0.001						-0.001	-0.001	-0.001	-0.001	-0.001	-0.001
DZ 8	0.008	0.007	0.006	0.005	0.004	0.003						-0.003	-0.004	-0.005	-0.006	-0.007	-0.008
DY 9	0.000	0.000	0.000	0.000	0.000	0.000						0.000	0.000	0.000	0.000	0.000	0.000
DZ 9	0.008	0.007	0.006	0.005	0.004	0.003						-0.003	-0.004	-0.005	-0.006	-0.007	-0.008
DY 10	0.001	0.001	0.001	0.001	0.001	0.001						0.001	0.001	0.001	0.001	0.001	0.001
DZ 10	0.008	0.007	0.006	0.005	0.004	0.003						-0.003	-0.004	-0.005	-0.006	-0.007	-0.008
DY 11	0.003	0.003	0.003	0.003	0.003	0.003	0.003				0.003	0.003	0.003	0.003	0.003	0.003	0.003
DZ 11	0.008	0.007	0.006	0.005	0.004	0.003	0.002				-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	-0.008
DY 12		0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	
DZ 12		0.007	0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	
DY 13		0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	
DZ 13		0.007	0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006	-0.007	
DY 14			0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007	0.007		
DZ 14			0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006		
DY 15			0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009		
DZ 15			0.006	0.005	0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004	-0.005	-0.006		
DY 16					0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.010				
DZ 16					0.004	0.003	0.002	0.001	0.0	-0.001	-0.002	-0.003	-0.004				
DY 17							0.012	0.012	0.012	0.012	0.012						
DZ 17							0.002	0.001	0.0	-0.001	-0.002						

RMS Spot Size = RMS LAT.ABER. 7.99600-03 KOUNT 204

Ref. Notes on page A-5

LST RC F/24 (LSTRC) 09:09:39--------11/24/75
CYCLE 0

MONOCHROMATIC O.T.F.

WAVELENGTH 6.3280D-04 REF.F.L. 5.7600D 04 FIELD CO-ORDS. 3.517D-02 0.0

	LINES PARALLEL TO RADIAL DIR.						LINES PARALLEL TO TANGENTIAL DIR.				
FREQ	THEOR	MTF	REAL	IMAG	PHASE		THEOR	MTF	REAL	IMAG	PHASE
5.00	0.861	0.853	0.853	0.0	0.0	*	0.861	0.845	0.845	-0.000	-0.000
10.00	0.722	0.700	0.700	0.0	0.0	*	0.722	0.676	0.676	-0.000	-0.000
15.00	0.591	0.558	0.558	0.0	0.0	*	0.591	0.524	0.524	-0.000	-0.000
20.00	0.468	0.435	0.435	0.0	0.0	*	0.469	0.402	0.402	-0.000	-0.000
25.00	0.387	0.364	0.364	0.0	0.0	*	0.387	0.340	0.340	-0.000	-0.000
30.00	0.344	0.327	0.327	0.0	0.0	*	0.345	0.308	0.308	-0.000	-0.000
35.00	0.313	0.295	0.295	0.0	0.0	*	0.313	0.277	0.277	-0.000	-0.000
40.00	0.288	0.267	0.267	0.0	0.0	*	0.288	0.247	0.247	-0.000	-0.001
45.00	0.225	0.209	0.209	0.0	0.0	*	0.226	0.193	0.193	-0.000	-0.001
50.00	0.143	0.135	0.135	0.0	0.0	*	0.143	0.127	0.127	-0.000	-0.001
55.00	0.084	0.082	0.082	0.0	0.0	*	0.085	0.079	0.079	-0.000	-0.001
60.00	0.037	0.037	0.037	0.0	0.0	*	0.037	0.036	0.036	-0.000	-0.002

NOTES:

1 Full Field Position of Camera

2 Reference notes 2, 3 and 4, page A-6

LST RC F/24 (LSTRC)   12:14:28--------09/12/75
CYCLE   0

FIELD   0.0352   0.0   REF.F.L.*********

X.Y.Z SHIFTS 0.0   0.0   0.0

PERCENTAGES EXCLUDE VIGNETTING   0.0 %

RADIUS	PERCENTAGE	Y-REF	Z-REF	Y-BOUND
2.50000D-03	0.0	0.0	0.0	1.00000D 10
5.00000D-03	14.70588			
7.50000D-03	46.07843			
1.00000D-02	82.35294			
1.25000D-02	100.00000			
1.50000D-02	100.00000			
1.75000D-02	100.00000			
2.00000D-02	100.00000			
2.25000D-02	100.00000			
2.50000D-02	100.00000			

NOTES:

1 Full Field Position of Camera

2 Geometrical encircled energy

3 Radius = Spot Radius

4 Percentage = Percentage enclosed energy

*** OTFGEN PROGRAM ***

APERTURE TYPE = INTRFRGM

DATE = 11/19/75
TIME = 12:58:13

FMAX = 0.57
DF = 0.03

STREHL RATIO = 0.84
OUTPUT FILENAME = DUM

OBSCURATION RATIO = 0.310

INTERFEROGRAM FILENAME = WAVEF

NUM	X-MOD	PHASE	Y-MOD	PHASE	MAP OF 1ST & 2ND QUADRANTS
31	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
30	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
29	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
28	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
27	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
26	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
25	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
24	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
23	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
22	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
21	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
20	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
19	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
18	0.015	0.0	0.015	0.0	0000000000000000000000000000001111100000000000000000000000000000
17	0.039	0.0	0.039	0.0	0000000000000000000000000111111111111100000000000000000000000000
16	0.077	0.0	0.077	0.0	0000000000000000000000001111111111111111100000000000000000000000
15	0.117	0.0	0.117	0.0	0000000000000000000000111111122222111111100000000000000000000000
14	0.161	0.0	0.161	0.0	0000000000000000000011111122222222222211111100000000000000000000
13	0.208	0.0	0.208	0.0	0000000000000000000111112222222222222222111110000000000000000000
12	0.250	0.0	0.250	0.0	0000000000000000001111222223333333333222221111000000000000000000
11	0.278	0.0	0.278	0.0	0000000000000000011112222333333333333332222111100000000000000000
10	0.299	0.0	0.299	0.0	0000000000000000011122233333333333333333332221110000000000000000
9	0.317	0.0	0.317	0.0	0000000000000000011122233333334444433333332221110000000000000000
8	0.335	0.0	0.335	0.0	0000000000000000111122333334444444444433333221111000000000000000
7	0.357	0.0	0.357	0.0	0000000000000000111222333344444444444444433332221110000000000000
6	0.404	0.0	0.404	0.0	0000000000000011112233334444444444444444433332211110000000000000
5	0.482	0.0	0.482	0.0	0000000000000011122223334444455555555444443332221110000000000000
4	0.584	0.0	0.584	0.0	0000000000000011122333344445566666655444433332211100000000000000
3	0.694	0.0	0.694	0.0	0000000000000011122333344455677777655444333322111000000000000000
2	0.811	0.0	0.811	0.0	0000000000000111222333444456788988765444433322211100000000000000
1	0.927	0.0	0.927	0.0	0000000000000111222333444456789*98765444433322211100000000000000
0	1.000	0.0	1.000	0.0	000000000000011122233344445679***976544443332221110000000000000

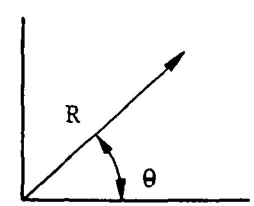
FFT ARRAY SIZE = 64

COMPUTE TIME = 3.97 SECS

20 Cycles/mm

NOTES:

1 On axis of camera
2 Digital Contour Map of MTF
3 R = Frequency ≈ 4 ℓp/mm per step
θ = Line Orientation, Azimuth



```
*** VERIFY PROGRAM ***   12:58:58   11/19/75   ***

NPTS = 48      MAX VALUE =  8.417E-01      FILENAME = PFILE
NREC = 48      MIN VALUE =  0.0
               TOTAL SUM =  1.431E 01
```

X	F(X)	Y	F(Y)
-23.	0.000	23.	0.000
-22.	0.000	22.	0.000
-21.	0.000	21.	0.000
-20.	0.000	20.	0.000
-19.	0.000	19.	0.000
-18.	0.000	18.	0.000
-17.	0.001	17.	0.001
-16.	0.002	16.	0.002
-15.	0.001	15.	0.001
-14.	0.000	14.	0.000
-13.	0.001	13.	0.001
-12.	0.001	12.	0.001
-11.	0.000	11.	0.000
-10.	0.002	10.	0.002
-9.	0.004	9.	0.004
-8.	0.004	8.	0.004
-7.	0.015	7.	0.015
-6.	0.040	6.	0.040
-5.	0.042	5.	0.042
-4.	0.008	4.	0.008
-3.	0.049	3.	0.049
-2.	0.296	2.	0.296
-1.	0.661	1.	0.661
0.	0.842	0.	0.842
1.	0.661	-1.	0.661
2.	0.296	-2.	0.296
3.	0.049	-3.	0.049
4.	0.008	-4.	0.008
5.	0.042	-5.	0.042
6.	0.040	-6.	0.040
7.	0.015	-7.	0.015
8.	0.004	-8.	0.004
9.	0.004	-9.	0.004
10.	0.002	-10.	0.002
11.	0.000	-11.	0.000
12.	0.001	-12.	0.001
13.	0.001	-13.	0.001
14.	0.000	-14.	0.000
15.	0.001	-15.	0.001
16.	0.002	-16.	0.002
17.	0.001	-17.	0.001
18.	0.000	-18.	0.000
19.	0.000	-19.	0.000
20.	0.000	-20.	0.000
21.	0.000	-21.	0.000
22.	0.000	-22.	0.000
23.	0.000	-23.	0.000
24.	0.000	-24.	0.000

Digital Plot of PSF

```
      111
    1111111
  11111111111
  1111   1111
 1111 111 1111
 111 13331 111
111 1367631 111
111 1379731 111
111 1367631 111
 111 13331 111
 1111 111 1111
  1111   1111
  11111111111
    1111111
      111
```

NOTES:

1 On axis of camera

2 Diffraction Point Spread Function

3 X or Y (8.21 = Airy Radius)

*** NRE PROGRAM 12:59:28 11/19/75 ***

INPUT FILENAME = PFILE INPUT FILESIZE = 48 X 48

APERTURE TYPE = RECT (3) Xw = 5.53

Yw = 5.53

X	NRF(X)	Y	NRE(Y)	
-20.	3.68E-04	19.	7.16E-04	00000000000000000000000000000000000000000
-19.	7.16E-04	18.	1.23E-03	00000000000000000000000000000000000000000
-18.	1.23E-03	17.	1.37E-03	00000000000000000000000000000000000000000
-17.	1.37E-03	16.	1.36E-03	00000000000000000000000000000000000000000
-16.	1.36E-03	15.	1.76E-03	00000000000000000000000000000000000000000
-15.	1.76E-03	14.	1.91E-03	00000000000000000000000000000000000000000
-14.	1.91E-03	13.	1.45E-03	00000000000000000000000000000000000000000
-13.	1.45E-03	12.	1.77E-03	00000000000000000000000000000000000000000
-12.	1.77E-03	11.	3.06E-03	00000000000000000000000000000000000000000
-11.	3.06E-03	10.	4.64E-03	00000000000000000000000000000000000000000
-10.	4.64E-03	9.	1.09E-02	00000000000000000000000000000000000000000
-9.	1.09E-02	8.	2.62E-02	00000000000000000000000000000000000000000
-8.	2.62E-02	7.	4.13E-02	00000000000000000000000000000000000000000
-7.	4.13E-02	6.	4.60E-02	00000000000000000000000000000000000000000
-6.	4.60E-02	5.	6.43E-02	00000000000000000011111000000000000000000
-5.	6.43E-02	4.	1.46E-01	00000000000000001122222110000000000000000
-4.	1.46E-01	3.	3.02E-01	00000000000000001234443210000000000000000
-3.	3.02E-01	2.	4.73E-01	00000000000000012357775321000000000000000
-2.	4.73E-01	1.	5.89E-01	00000000000000012478987421000000000000000
-1.	5.89E-01	0.	6.27E-01	00000000000000012479997421000000000000000
0.	6.27E-01	-1.	5.89E-01	00000000000000012478987421000000000000000
1.	5.89E-01	-2.	4.73E-01	00000000000000012357775321000000000000000
2.	4.73E-01	-3.	3.02E-01	00000000000000001234443210000000000000000
3.	3.02E-01	-4.	1.46E-01	00000000000000001122222110000000000000000
4.	1.46E-01	-5.	6.43E-02	00000000000000000011111000000000000000000
5.	6.43E-02	-6.	4.60E-02	00000000000000000000000000000000000000000
6.	4.60E-02	-7.	4.13E-02	00000000000000000000000000000000000000000
7.	4.13E-02	-8.	2.62E-02	00000000000000000000000000000000000000000
8.	2.62E-02	-9.	1.09E-02	00000000000000000000000000000000000000000
9.	1.09E-02	-10.	4.64E-03	00000000000000000000000000000000000000000
10.	4.64E-03	-11.	3.06E-03	00000000000000000000000000000000000000000
11.	3.06E-03	-12.	1.77E-03	00000000000000000000000000000000000000000
12.	1.77E-03	-13.	1.45E-03	00000000000000000000000000000000000000000
13.	1.45E-03	-14.	1.91E-03	00000000000000000000000000000000000000000
14.	1.91E-03	-15.	1.76E-03	00000000000000000000000000000000000000000
15.	1.76E-03	-16.	1.36E-03	00000000000000000000000000000000000000000
16.	1.36E-03	-17.	1.37E-03	00000000000000000000000000000000000000000
17.	1.37E-03	-18.	1.23E-03	00000000000000000000000000000000000000000
18.	1.23E-03	-19.	7.16E-04	00000000000000000000000000000000000000000
19.	7.16E-04	-20.	3.68E-04	00000000000000000000000000000000000000000
20.	3.69E-04	-21.	2.80E-04	00000000000000000000000000000000000000000

Digital map of convolution

NOTES:

1 On Axis of Camera

2 Detector PSF Convolution

3 25μ detector

4 X or Y (8.21 = 1 Airy Radius)

MAX VALUE OF 0.627 AT X = 0. Y = 0. = Ensquared Energy (includes diffraction at 632.8nm)

CENTRAL 5 X 5 ARRAY =

3.65E-01	4.47E-01	4.73E-01	4.47E-01	3.65E-01
4.47E-01	5.54E-01	5.89E-01	5.54E-01	4.47E-01
4.73E-01	5.89E-01	6.27E-01	5.89E-01	4.73E-01
4.47E-01	5.54E-01	5.89E-01	5.54E-01	4.47E-01
3.65E-01	4.47E-01	4.73E-01	4.47E-01	3.65E-01

*** OTFGEN PROGRAM ***

APERTURE TYPE = INTRFRGM

DATE = 11/19/75
TIME = 13:04:12

FMAX = 0.57
DF = 0.03

STREHL RATIO = 0.87
OUTPUT FILENAME = DUM

OBSCURATION RATIO = 0.310

INTERFEROGRAM FILENAME = WAVEF

NUM	X-MOD	PHASE	Y-MOD	PHASE	MAP OF 1ST & 2ND QUADRANTS
31	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
30	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
29	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
28	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
27	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
26	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
25	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
24	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
23	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
22	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
21	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
20	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
19	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
18	0.015	0.0	0.015	0.00	0000000000000000000000000011111000000000000000000000000000000000
17	0.039	0.0	0.039	0.0	0000000000000000000000000011111111111110000000000000000000000000
16	0.078	0.0	0.078	0.0	0000000000000000000000000111111111111111100000000000000000000000
15	0.119	0.0	0.120	0.0	0000000000000000000000011111122222111111100000000000000000000000
14	0.166	0.0	0.167	0.0	0000000000000000000001111112222222222221111110000000000000000000
13	0.216	0.0	0.218	0.0	0000000000000000000011111222222333222222211111000000000000000000
12	0.260	0.0	0.261	0.0	0000000000000000000111122222333333333332222111100000000000000000
11	0.288	0.0	0.290	0.0	0000000000000000001111222333333333333333222111100000000000000000
10	0.309	0.0	0.310	0.0	0000000000000000001112223333333444333333322211100000000000000000
9	0.326	0.0	0.328	0.0	0000000000000000011122233344444444444443333222110000000000000000
8	0.345	0.0	0.347	0.0	0000000000000000111122333344444444444444333322111100000000000000
7	0.368	0.0	0.370	0.0	0000000000000001112233334444444444444444433332211100000000000000
6	0.419	0.0	0.422	0.0	0000000000000001111223334444444555444444443332211110000000000000
5	0.499	0.0	0.502	0.0	0000000000000011122333344444555555554444433332211100000000000000
4	0.600	0.0	0.603	0.0	0000000000000011122333444445566666554444433322111000000000000000
3	0.707	0.0	0.709	0.0	0000000000000011122333444455677777765544443332211100000000000000
2	0.818	0.0	0.819	0.0	0000000000000111222333444456788988765444433322211100000000000000
1	0.929	0.0	0.929	0.0	0000000000000111223333444556789*987655444333322111000000000000
0	1.000	0.0	1.000	0.0	000000000000011122333344455679***976554443333221110000000000000

FFT ARRAY SIZE = 64

COMPUTE TIME = 3.92 SECS

20 Cycles/mm

NOTES:

1 0.5 Field position of camera
2 Digital Contour Map of MTF
3 Ref. notes on page A-20

A-23

ORIGINAL PAGE IS
OF POOR QUALITY

*** VERIFY PROGRAM *** 13:05:04 11/19/75 ***

```
NPTS = 48        MAX VALUE =  8.678E-01        FILENAME = PFILE
NREC = 48        MIN VALUE =  0.0
                 TOTAL SUM =  1.431E 01
```

X	F(X)	Y	F(Y)
-23.	0.000	23.	0.000
-22.	0.000	22.	0.000
-21.	0.000	21.	0.000
-20.	0.000	20.	0.000
-19.	0.000	19.	0.000
-18.	0.000	18.	0.000
-17.	0.001	17.	0.001
-16.	0.002	16.	0.002
-15.	0.001	15.	0.001
-14.	0.000	14.	0.000
-13.	0.001	13.	0.001
-12.	0.001	12.	0.001
-11.	0.000	11.	0.000
-10.	0.001	10.	0.001
-9.	0.003	9.	0.002
-8.	0.002	8.	0.002
-7.	0.014	7.	0.014
-6.	0.040	6.	0.040
-5.	0.041	5.	0.041
-4.	0.007	4.	0.006
-3.	0.050	3.	0.048
-2.	0.305	2.	0.304
-1.	0.682	1.	0.681
0.	0.868	0.	0.868
1.	0.682	-1.	0.682
2.	0.305	-2.	0.304
3.	0.050	-3.	0.044
4.	0.007	-4.	0.005
5.	0.041	-5.	0.041
6.	0.040	-6.	0.040
7.	0.014	-7.	0.014
8.	0.002	-8.	0.002
9.	0.003	-9.	0.002
10.	0.001	-10.	0.001
11.	0.000	-11.	0.000
12.	0.001	-12.	0.001
13.	0.001	-13.	0.001
14.	0.000	-14.	0.000
15.	0.001	-15.	0.001
16.	0.002	-16.	0.002
17.	0.001	-17.	0.001
18.	0.000	-18.	0.000
19.	0.000	-19.	0.000
20.	0.000	-20.	0.000
21.	0.000	-21.	0.000
22.	0.000	-22.	0.000
23.	0.000	-23.	0.000
24.	0.000	-24.	0.000

Digital Plot of PSF

```
           1
        1111111
      11111111111
      1111   1111
     1111 111 1111
     111 13331 111
    111 1367631 111
    111 1379731 111
    111 1367631 111
     111 13331 111
     1111 111 1111
      1111   1111
      11111111111
        1111111
           1
```

NOTES:

1 0.5 Field position of camera

2 Diffraction Point Spread Function

3 X or Y (8.21 = 1 Airy Radius)

PERKIN-ELMER

*** NRE PROGRAM 13:05:34 11/19/75 ***

INPUT FILENAME = PFILE INPUT FILESIZE = 48 X 48

APERTURE TYPE = RECT XW = 5.53
YW = 5.53

X	NRE(X)	Y	NRE(Y)	
-20.	3.12E-04	19.	6.65E-04	00000000000000000000000000000000000000000
-19.	6.77E-04	18.	1.22E-03	00000000000000000000000000000000000000000
-18.	1.22E-03	17.	1.40E-03	00000000000000000000000000000000000000000
-17.	1.40E-03	16.	1.42E-03	00000000000000000000000000000000000000000
-16.	1.41E-03	15.	1.82E-03	00000000000000000000000000000000000000000
-15.	1.81E-03	14.	1.98E-03	00000000000000000000000000000000000000000
-14.	1.97E-03	13.	1.48E-03	00000000000000000000000000000000000000000
-13.	1.48E-03	12.	1.55E-03	00000000000000000000000000000000000000000
-12.	1.59E-03	11.	2.32E-03	00000000000000000000000000000000000000000
-11.	2.44E-03	10.	3.32E-03	00000000000000000000000000000000000000000
-10.	3.56E-03	9.	9.23E-03	00000000000000000000000000000000000000000
-9.	9.62E-03	8.	2.47E-02	00000000000000000000000000000000000000000
-8.	2.51E-02	7.	3.96E-02	00000000000000000000000000000000000000000
-7.	4.02E-02	6.	4.38E-02	00000000000000000000000000000000000000000
-6.	4.46E-02	5.	6.24E-02	00000000000000000000000000000000000000000
-5.	6.34E-02	4.	1.47E-01	00000000000000000112221100000000000000000
-4.	1.48E-01	3.	3.08E-01	00000000000000001234443210000000000000000
-3.	3.09E-01	2.	4.85E-01	00000000000000001357775310000000000000000
-2.	4.85E-01	1.	6.05E-01	00000000000000002478987420000000000000000
-1.	6.05E-01	0.	6.44E-01	00000000000000002479997420000000000000000
0.	6.44E-01	-1.	6.05E-01	00000000000000002478987420000000000000000
1.	6.05E-01	-2.	4.85E-01	00000000000000001357775310000000000000000
2.	4.85E-01	-3.	3.08E-01	00000000000000001234443210000000000000000
3.	3.09E-01	-4.	1.47E-01	00000000000000000112221100000000000000000
4.	1.48E-01	-5.	6.25E-02	00000000000000000000000000000000000000000
5.	6.34E-02	-6.	4.38E-02	00000000000000000000000000000000000000000
6.	4.46E-02	-7.	3.97E-02	00000000000000000000000000000000000000000
7.	4.02E-02	-8.	2.47E-02	00000000000000000000000000000000000000000
8.	2.51E-02	-9.	9.30E-03	00000000000000000000000000000000000000000
9.	9.62E-03	-10.	3.32E-03	00000000000000000000000000000000000000000
10.	3.56E-03	-11.	2.32E-03	00000000000000000000000000000000000000000
11.	2.44E-03	-12.	1.55E-03	00000000000000000000000000000000000000000
12.	1.59E-03	-13.	1.48E-03	00000000000000000000000000000000000000000
13.	1.48E-03	-14.	1.98E-03	00000000000000000000000000000000000000000
14.	1.97E-03	-15.	1.82E-03	00000000000000000000000000000000000000000
15.	1.81E-03	-16.	1.42E-03	00000000000000000000000000000000000000000
16.	1.41E-03	-17.	1.40E-03	00000000000000000000000000000000000000000
17.	1.40E-03	-18.	1.22E-03	00000000000000000000000000000000000000000
18.	1.22E-03	-19.	6.66E-04	00000000000000000000000000000000000000000
19.	6.77E-04	-20.	3.00E-04	00000000000000000000000000000000000000000
20.	3.12E-04	-21.	2.28E-04	00000000000000000000000000000000000000000

Digital map of convolution

NOTES:
1 0.5 Field position of camera
2. Detector PSF convolution
3 25μ detector
4 X or Y (8.21 = 1 Airy Radius

MAX VALUE OF 0.644 AT X = 0. Y = 0. = Ensquared Energy (includes diffraction at 632.8 nm)

CENTRAL 5 X 5 ARRAY =					
	3.73E-01	4.57E-01	4.85E-01	4.57E-01	3.73E-01
	4.58E-01	5.69E-01	6.05E-01	5.69E-01	4.58E-01
	4.85E-01	6.05E-01	6.44E-01	6.05E-01	4.85E-01
	4.58E-01	5.69E-01	6.05E-01	5.69E-01	4.58E-01
	3.73E-01	4.58E-01	4.85E-01	4.58E-01	3.73E-01

*** OTFGEN PROGRAM ***

APERTURE TYPE = INTRFRGM

DATE = 11/19/75
TIME = 13:11:57

FMAX = 0.57
DF = 0.03

STREHL RATIO = 0.90
OUTPUT FILENAME = DUM

OBSCURATION RATIO = 0.310

INTERFEROGRAM FILENAME = WAVEF

NUM	X-MOD	PHASE	Y-MOD	PHASE	MAP OF 1ST & 2ND QUADRANTS
31	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
30	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
29	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
28	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
27	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
26	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
25	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
24	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
23	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
22	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
21	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
20	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
19	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
18	0.015	0.0	0.015	0.00	0000000000000000000000000000011111000000000000000000000000000000
17	0.040	0.0	0.040	0.00	0000000000000000000000000111111111111100000000000000000000000000
16	0.079	0.0	0.079	0.00	0000000000000000000000011111111111111111000000000000000000000000
15	0.123	0.0	0.123	0.00	0000000000000000000000111111222221111110000000000000000000000000
14	0.173	0.0	0.173	0.0	0000000000000000000011111222222222222211111000000000000000000000
13	0.228	0.0	0.228	0.0	0000000000000000001111122222333322222111110000000000000000000000
12	0.274	0.0	0.274	0.0	0000000000000000001111222233333333332222111100000000000000000000
11	0.302	0.0	0.302	0.0	0000000000000000111122233333333333333332221111000000000000000000
10	0.322	0.0	0.322	0.0	0000000000000000111222333444444444433332221110000000000000000000
9	0.340	0.0	0.339	0.0	0000000000000001112223344444444444443332221110000000000000000000
8	0.359	0.0	0.359	0.0	0000000000000011112233344444444444444333221111000000000000000000
7	0.384	0.0	0.383	0.0	0000000000000011122333444444444444444443332211100000000000000000
6	0.440	0.0	0.440	0.0	0000000000000111222233444444455554444444332221110000000000000000
5	0.524	0.0	0.524	0.0	0000000000000111223334444455566655544444333221110000000000000000
4	0.623	0.0	0.623	0.0	0000000000000111223344444556677766555444443322111000000000000000
3	0.725	0.0	0.724	0.0	0000000000000111223344444566778776654444433221110000000000000000
2	0.828	0.0	0.828	0.0	0000000000000111223334444556788988765544443332211100000000000000
1	0.932	0.0	0.932	0.0	000000000000011122333444456788 9*98876544443332211100000000000000
0	1.000	0.0	1.000	0.0	000000000000011122333444456789***98765444433322111000000000000000

FFT ARRAY SIZE = 64

COMPUTE TIME = 4.07 SECS

20 Cycles/mm

NOTES:

1 0.7 Field position of camera

2 Digital Contour Map of MTF

3 Ref. notes on page A-20

```
*** VERIFY PROGRAM ***   13:12:40   11/19/75   ***

NPTS = 48      MAX VALUE =  8.990E-01     FILENAME = PFILE
NREC = 48      MIN VALUE =  0.0
               TOTAL SUM =  1.431E 01
```

X	F(X)	Y	F(Y)
-23.	0.000	23.	0.000
-22.	0.000	22.	0.000
-21.	0.000	21.	0.000
-20.	0.000	20.	0.000
-19.	0.000	19.	0.000
-18.	0.000	18.	0.000
-17.	0.001	17.	0.001
-16.	0.002	16.	0.002
-15.	0.001	15.	0.001
-14.	0.000	14.	0.000
-13.	0.001	13.	0.001
-12.	0.001	12.	0.001
-11.	0.000	11.	0.000
-10.	0.001	10.	0.001
-9.	0.001	9.	0.001
-8.	0.000	8.	0.000
-7.	0.013	7.	0.013
-6.	0.040	6.	0.040
-5.	0.041	5.	0.041
-4.	0.004	4.	0.004
-3.	0.049	3.	0.049
-2.	0.315	2.	0.315
-1.	0.706	1.	0.706
0.	0.899	0.	0.899
1.	0.706	-1.	0.707
2.	0.315	-2.	0.315
3.	0.049	-3.	0.049
4.	0.004	-4.	0.004
5.	0.041	-5.	0.041
6.	0.040	-6.	0.041
7.	0.013	-7.	0.013
8.	0.000	-8.	0.000
9.	0.001	-9.	0.001
10.	0.001	-10.	0.001
11.	0.000	-11.	0.000
12.	0.001	-12.	0.001
13.	0.001	-13.	0.001
14.	0.000	-14.	0.000
15.	0.001	-15.	0.001
16.	0.002	-16.	0.002
17.	0.001	-17.	0.001
18.	0.000	-18.	0.000
19.	0.000	-19.	0.000
20.	0.000	-20.	0.000
21.	0.000	-21.	0.000
22.	0.000	-22.	0.000
23.	0.000	-23.	0.000
24.	0.000	-24.	0.000

Digital Plot of PSF

```
          1
       1111111
     11111111111
     1111   1111
    1111 111 1111
    111 13431 111
    11 1367631 11
   111 1479741 111
    11 1367631 11
    111 13431 111
    1111 111 1111
     1111   1111
     11111111111
       1111111
          1
```

NOTES:

1 0.7 Field position of camera

2 Diffraction Point Spread Function

3 X or Y (8.21 = 1 Airy Radius)

*** NRE PROGRAM 13:13:11 11/19/75 ***

INPUT FILENAME = PFILE INPUT FILESIZE = 48 X 48

APERTURE TYPE = RECT XW = 5.53
YW = 5.53

X	NRE(X)	Y	NRE(Y)	
-20.	2.25E-04	19.	6.14E-04	0000000000000000000000000000000000000000
-19.	6.13E-04	18.	1.21E-03	0000000000000000000000000000000000000000
-18.	1.21E-03	17.	1.43E-03	0000000000000000000000000000000000000000
-17.	1.43E-03	16.	1.48E-03	0000000000000000000000000000000000000000
-16.	1.48E-03	15.	1.90E-03	0000000000000000000000000000000000000000
-15.	1.90E-03	14.	2.08E-03	0000000000000000000000000000000000000000
-14.	2.09E-03	13.	1.54E-03	0000000000000000000000000000000000000000
-13.	1.54E-03	12.	1.35E-03	0000000000000000000000000000000000000000
-12.	1.35E-03	11.	1.57E-03	0000000000000000000000000000000000000000
-11.	1.55E-03	10.	1.99E-03	0000000000000000000000000000000000000000
-10.	1.95E-03	9.	7.76E-03	0000000000000000000000000000000000000000
-9.	7.70E-03	8.	2.33E-02	0000000000000000000000000000000000000000
-8.	2.32E-02	7.	3.83E-02	0000000000000000000000000000000000000000
-7.	3.82E-02	6.	4.21E-02	0000000000000000000000000000000000000000
-6.	4.20E-02	5.	6.14E-02	0000000000000000000000000000000000000000
-5.	6.13E-02	4.	1.49E-01	0000000000000000011222110000000000000000
-4.	1.49E-01	3.	3.16E-01	0000000000000000123444321000000000000000
-3.	3.15E-01	2.	4.99E-01	0000000000000000135777531000000000000000
-2.	4.99E-01	1.	6.24E-01	0000000000000000247398742000000000000000
-1.	6.24E-01	0.	6.65E-01	0000000000000000247999742000000000000000
0.	6.65E-01	-1.	6.24E-01	0000000000000000247398742000000000000000
1.	6.24E-01	-2.	4.99E-01	0000000000000000135777531000000000000000
2.	4.99E-01	-3.	3.16E-01	0000000000000000123444321000000000000000
3.	3.16E-01	-4.	1.50E-01	0000000000000000011222110000000000000000
4.	1.49E-01	-5.	6.15E-02	0000000000000000000000000000000000000000
5.	6.13E-02	-6.	4.22E-02	0000000000000000000000000000000000000000
6.	4.20E-02	-7.	3.83E-02	0000000000000000000000000000000000000000
7.	3.82E-02	-8.	2.33E-02	0000000000000000000000000000000000000000
8.	2.32E-02	-9.	7.76E-03	0000000000000000000000000000000000000000
9.	7.70E-03	-10.	2.00E-03	0000000000000000000000000000000000000000
10.	1.95E-03	-11.	1.58E-03	0000000000000000000000000000000000000000
11.	1.55E-03	-12.	1.35E-03	0000000000000000000000000000000000000000
12.	1.35E-03	-13.	1.54E-03	0000000000000000000000000000000000000000
13.	1.54E-03	-14.	2.08E-03	0000000000000000000000000000000000000000
14.	2.09E-03	-15.	1.90E-03	0000000000000000000000000000000000000000
15.	1.90E-03	-16.	1.48E-03	0000000000000000000000000000000000000000
16.	1.48E-03	-17.	1.43E-03	0000000000000000000000000000000000000000
17.	1.43E-03	-18.	1.21E-03	0000000000000000000000000000000000000000
18.	1.21E-03	-19.	6.16E-04	0000000000000000000000000000000000000000
19.	6.13E-04	-20.	2.25E-04	0000000000000000000000000000000000000000
20.	2.26E-04	-21.	1.73E-04	0000000000000000000000000000000000000000

Digital map of convolution

NOTES:

1 0.7 Field position of camera

2 Detector PSF Convolution

3 25μ detector

4 X or Y (8.21 = 1 Airy Radius)

MAX VALUE OF 0.665 AT X = 0. Y = 0. Ensquared Energy (includes diffraction at 632.8 nm)

CENTRAL 5 X 5 ARRAY =

3.82E-01	4.71E-01	4.99E-01	4.71E-01	3.82E-01
4.71E-01	5.86E-01	6.24E-01	5.86E-01	4.71E-01
4.99E-01	6.24E-01	6.65E-01	6.24E-01	4.99E-01
4.71E-01	5.86E-01	6.24E-01	5.86E-01	4.71E-01
3.83E-01	4.71E-01	4.99E-01	4.71E-01	3.83E-01

*** OTFGEN PROGRAM ***

APERTURE TYPE = INTRFRGM   DATE = 11/19/75
TIME = 13:17:57

FMAX = 0.57   STREHL RATIO = 0.83
DF = 0.03   OUTPUT FILENAME = DUM

OBSCURATION RATIO = 0.310   INTERFEROGRAM FILENAME = WAVEF

NUM	X-MOD	PHASE	Y-MOD	PHASE	MAP OF 1ST & 2ND QUADRANTS
31	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
30	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
29	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
28	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
27	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
26	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
25	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
24	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
23	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
22	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
21	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
20	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
19	0.000	0.0	0.000	0.0	0000000000000000000000000000000000000000000000000000000000000000
18	0.015	0.0	0.015	0.00	0000000000000000000000000000011111000000000000000000000000000000
17	0.039	0.0	0.039	0.00	0000000000000000000000000111111111111100000000000000000000000000
16	0.077	0.0	0.075	0.00	0000000000000000000000011111111111111111000000000000000000000000
15	0.118	0.0	0.113	0.00	0000000000000000000000111111112221111111100000000000000000000000
14	0.164	0.0	0.154	0.00	0000000000000000000011111122222222222111111000000000000000000000
13	0.213	0.0	0.197	0.0	0000000000000000000111112222222222222221111100000000000000000000
12	0.255	0.0	0.236	0.0	0000000000000000001111222223333333332222211110000000000000000000
11	0.284	0.0	0.265	0.0	0000000000000000011112222333333333333322221111000000000000000000
10	0.305	0.0	0.286	0.0	0000000000000000011122233333333333333333222111000000000000000000
9	0.322	0.0	0.304	0.0	0000000000000000111222333333333333333333322211100000000000000000
8	0.341	0.0	0.322	0.0	0000000000000001111223333333444444433333332211110000000000000000
7	0.363	0.0	0.342	0.0	0000000000000001112223333444444444444433332221110000000000000000
6	0.413	0.0	0.384	0.0	0000000000000011112233334444444444444443333221111000000000000000
5	0.492	0.0	0.458	0.0	0000000000000011122233344444455555444444333222111000000000000000
4	0.593	0.0	0.551	0.0	0000000000000011122333344445566666554444333322111000000000000000
3	0.701	0.0	0.676	0.0	0000000000000011122333444455677777655444433322111000000000000000
2	0.815	0.0	0.800	0.0	0000000000000111222333444456788888765444433322211100000000000000
1	0.928	0.0	0.923	0.0	0000000000000111223333444456789*98765444433332211100000000000000
0	1.000	0.0	1.000	0.0	000000000000011122333344455679***97655444333322111 00000000000000

FFT ARRAY SIZE = 64

COMPUTE TIME = 4.01 SECS

20 Cycles/mm

NOTES:

1 Full field position of camera

2 Digital Contour Map of MTF

3 Ref. notes on page A-20

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ORIGINAL PAGE IS OF POOR QUALITY

```
*** VERIFY PROGRAM ***   13:18:34   11/19/75   ***

NPTS = 48        MAX VALUE =  8.274E-01       FILENAME = PFILE
NREC = 48        MIN VALUE =  0.0
                 TOTAL SUM =  1.431E 01
```

X	F(X)	Y	F(Y)
-23.	0.000	23.	0.000
-22.	0.000	22.	0.000
-21.	0.000	21.	0.000
-20.	0.000	20.	0.000
-19.	0.000	19.	0.000
-18.	0.000	18.	0.000
-17.	0.001	17.	0.001
-16.	0.002	16.	0.001
-15.	0.001	15.	0.001
-14.	0.000	14.	0.000
-13.	0.001	13.	0.001
-12.	0.001	12.	0.001
-11.	0.000	11.	0.000
-10.	0.001	10.	0.002
-9.	0.003	9.	0.005
-8.	0.003	8.	0.006
-7.	0.014	7.	0.017
-6.	0.039	6.	0.041
-5.	0.041	5.	0.045
-4.	0.005	4.	0.017
-3.	0.042	3.	0.060
-2.	0.285	2.	0.299
-1.	0.648	1.	0.653
0.	0.827	0.	0.827
1.	0.648	-1.	0.653
2.	0.285	-2.	0.300
3.	0.042	-3.	0.060
4.	0.005	-4.	0.017
5.	0.041	-5.	0.045
6.	0.039	-6.	0.041
7.	0.014	-7.	0.017
8.	0.003	-8.	0.006
9.	0.003	-9.	0.005
10.	0.001	-10.	0.002
11.	0.000	-11.	0.000
12.	0.001	-12.	0.001
13.	0.001	-13.	0.001
14.	0.000	-14.	0.000
15.	0.001	-15.	0.001
16.	0.002	-16.	0.001
17.	0.001	-17.	0.001
18.	0.000	-18.	0.000
19.	0.000	-19.	0.000
20.	0.000	-20.	0.000
21.	0.000	-21.	0.000
22.	0.000	-22.	0.000
23.	0.000	-23.	0.000
24.	0.000	-24.	0.000

Digital Plot of PSF

```
       111
     1111111
   11111111111
   11111111111
  1111 111 1111
  111 13331 111
  11 1257521 11
 111 1379731 111
  11 1257521 11
  111 13331 111
  1111 111 1111
   11111111111
   11111111111
     1111111
       111
```

NOTES:

1 Full field position of camera

2 Diffraction Point Spread Function

3 X or Y (8.21 = 1 Airy Radius)

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*** NRE PROGRAM 13:19:03 11/19/75 ***

INPUT FILENAME = PFILE   INPUT FILESIZE = 48 X 48

APERTURE TYPE = RECT   Xw = 5.53
Yw = 5.53

X	NRE(X)	Y	NRE(Y)	
-20.	3.27E-04	19.	7.94E-04	0000000000000000000000000000000000000000
-19.	6.77E-04	18.	1.26E-03	0000000000000000000000000000000000000000
-18.	1.20E-03	17.	1.36E-03	0000000000000000000000000000000000000000
-17.	1.36E-03	16.	1.33E-03	0000000000000000000000000000000000000000
-16.	1.37E-03	15.	1.71E-03	0000000000000000000000000000000000000000
-15.	1.78E-03	14.	1.85E-03	0000000000000000000000000000000000000000
-14.	1.94E-03	13.	1.46E-03	0000000000000000000000000000000000000000
-13.	1.47E-03	12.	2.08E-03	0000000000000000000000000000000000000000
-12.	1.67E-03	11.	4.07E-03	0000000000000000000000000000000000000000
-11.	2.67E-03	10.	6.54E-03	0000000000000000000000000000000000000000
-10.	3.83E-03	9.	1.34E-02	0000000000000000000000000000000000000000
-9.	9.67E-03	8.	2.92E-02	0000000000000000000000000000000000000000
-8.	2.47E-02	7.	4.54E-02	0000000000000000000000000000000000000000
-7.	3.93E-02	6.	5.18E-02	0000000000000000000000000000000000000000
-6.	4.31E-02	5.	7.13E-02	0000000000000000001111100000000000000000
-5.	6.03E-02	4.	1.52E-01	0000000000000000112222211000000000000000
-4.	1.41E-01	3.	3.04E-01	0000000000000000123444321000000000000000
-3.	2.96E-01	2.	4.69E-01	0000000000000000135777531000000000000000
-2.	4.66E-01	1.	5.82E-01	0000000000000000247898742000000000000000
-1.	5.81E-01	0.	6.18E-01	0000000000000000247999742000000000000000
0.	6.19E-01	-1.	5.82E-01	0000000000000000247898742000000000000000
1.	5.81E-01	-2.	4.70E-01	0000000000000000135777531000000000000000
2.	4.66E-01	-3.	3.04E-01	0000000000000000123444321000000000000000
3.	2.96E-01	-4.	1.52E-01	0000000000000000112222211000000000000000
4.	1.41E-01	-5.	7.14E-02	0000000000000000001111100000000000000000
5.	6.03E-02	-6.	5.18E-02	0000000000000000000000000000000000000000
6.	4.31E-02	-7.	4.54E-02	0000000000000000000000000000000000000000
7.	3.93E-02	-8.	2.92E-02	0000000000000000000000000000000000000000
8.	2.47E-02	-9.	1.35E-02	0000000000000000000000000000000000000000
9.	9.67E-03	-10.	6.56E-03	0000000000000000000000000000000000000000
10.	3.83E-03	-11.	4.08E-03	0000000000000000000000000000000000000000
11.	2.67E-03	-12.	2.09E-03	0000000000000000000000000000000000000000
12.	1.67E-03	-13.	1.46E-03	0000000000000000000000000000000000000000
13.	1.47E-03	-14.	1.85E-03	0000000000000000000000000000000000000000
14.	1.94E-03	-15.	1.71E-03	0000000000000000000000000000000000000000
15.	1.78E-03	-16.	1.33E-03	0000000000000000000000000000000000000000
16.	1.37E-03	-17.	1.37E-03	0000000000000000000000000000000000000000
17.	1.36E-03	-18.	1.26E-03	0000000000000000000000000000000000000000
18.	1.20E-03	-19.	7.95E-04	0000000000000000000000000000000000000000
19.	6.77E-04	-20.	4.62E-04	0000000000000000000000000000000000000000
20.	3.27E-04	-21.	3.47E-04	0000000000000000000000000000000000000000

Digital map of convolution

MAX VALUE OF 0.618 AT X = 0. Y = 0.   **Ensquared Energy (includes diffraction at 632.8 nm)**

CENTRAL 5 X 5 ARRAY =

3.61E-01	4.43E-01	4.69E-01	4.43E-01	3.61E-01
4.40E-01	5.47E-01	5.82E-01	5.47E-01	4.40E-01
4.66E-01	5.81E-01	6.18E-01	5.81E-01	4.66E-01
4.40E-01	5.47E-01	5.82E-01	5.47E-01	4.40E-01
3.61E-01	4.43E-01	4.70E-01	4.43E-01	3.61E-01

NOTES:

1 Full field position of camera

2 Diffraction Point Spread Function

3 X or Y (8.21 = 1 Airy Radius)

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APPENDIX B

f/24 FIELD CAMERA

COMMAND SEQUENCE AND REQUIREMENTS LIST

COMMAND SEQUENCES AND COMMAND REQUIREMENTS

COMMAND SEQUENCE - f/24 FIELD CAMERA

SEQUENCE	FUNCTION
Instrumentation Mode	Instrumentation system only On
Thermal Control	Bring instrument on-line to thermal operating temperature
Standby	LVPS on
	Instrumentation system on
	Command System On
	TLM System On
Acquisition Initialize	N/A
Acquisition Execute	N/A
Calibrate Initialize	Set variables (mechanisms, voltages, readout rate, exposure time)
	Select lamp
Calibrate Execute	Expose, store, transfer
Operate Initialize	Set variables (as in calibrate initialize)
	Open port door
Operate Execute	Expose, store, transfer

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COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
(1) Instrumentation Mode			
FC Instrumentation Power On			1
FC Instrumentation Power Off			1
(1) Thermal Control			
FC Thermal Power On			1
FC Thermal Power Off			1
Standby			
(1) FC Standby Power On			1
(1) FC Standby Power Off			1
FC Main Power On			1
FC Main Power Off			1
Acquisition Initialize	N/A		
Acquisition Execute	N/A		
(1) Via Power Distribution Subsystem (PDS)			

COMMAND REQUIREMENT - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Calibrate Initialize			
Filter Wheel #1	8	3	
Filter Wheel #2	8	3	
Filter Wheel #3	8	3	
Exposure Time	10 msec to 1 hour	16	
SECO Readout Rate	256	8	
Port Door Close			1
Shutter Open			1
Shutter Close			1
Calibrate Lamp 1 Select			1
Calibrate Lamp 2 Select			1
Calibrate Voltage	1000	10	
Wall Voltage	256	8	
Photocathode Voltage	256	8	
Target Voltage	256	8	

COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Calibrate Initialize (continued)			
Focus Current	256	8	
Beam Current	256	8	
Alignment Current	50	6	
Heater Current	64	6	
Photocathode PS Current	100	7	
Deflection Line (X) Current	256	8	
Deflection Frame (Y) Current	256	8	
Erase Lamp Current	50	6	
Target Prepare			1
Target Normal			1
Target Pulsed			1
Scan Size	tbd	8	
G4	Hi/Lo/Zero		3
G3 Focus	256	8	
G2	On/Off		2
G1	Hi/Lo		2
Amplifier Gain	256	8	
Load (one for each variable word)			20
Execute (one for each variable word)			20

COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Calibrate Execute			
Calibrate Start			1
Transfer Start			1
Transfer Stop			1
Erase Lamp Exposure			1
Exposure Interrupt			1
Exposure Restart			1

COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Operate Initialize			
All calibrate initialize commands			
Less			
(Port door close)			
(Shutter open)			
(Shutter close)			
(Calibrate Lamp 1 select)			
(Calibrate Lamp 2 select)			
Plus			
Port door open			1

COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Operate Execute			
Operate Start			1
Transfer Start			1
Transfer Stop			1
Erase Lamp Exposure			1
Exposure Interrupt (shutter close)			1
Exposure Restart (shutter open)			1

COMMAND REQUIREMENTS - f/24 FIELD CAMERA

COMMAND	STEPS	BITS/ VARIABLE WORD	DISCRETE COMMANDS
Contingency Commands			
Filter wheel #1 retract			1
Filter wheel #2 retract			1
Filter wheel #3 retract			1
Port door retract			1
Shutter retract			1
Lamps off			1
Reserve		40	15

APPENDIX C

f/24 FIELD CAMERA

INSTRUMENTATION LIST

INSTRUMENTATION LIST - f/24 FIELD CAMERA

SIGNAL DESCRIPTION	SIGNAL TYPE	RANGE	ANALOG ACCURACY	NUMBER OF BITS	SAMPLE RATE (EACH BIT)
Main Power Monitor	D	on/off		1	1 sps (1)
Main Power Voltage	A	tbd	1%	8	1 sps (1)
Main Power Current	A	tbd	1%	8	tbd (3)
Thermal mode	D	on/off		1	1 sps (1)
Standby mode	D	on/off		1	1 sps (1)
Calibrate mode	D	on/off		1	1 sps (1)
Operate mode	D	on/off		1	1 sps (1)
Filter Wheel #1	D	9 positions		9	1 sps (2)
Filter Wheel #2	D	9 positions		9	1 sps (2)
Filter Wheel #3	D	9 positions		9	1 sps (2)
Calibrate Lamp #1 select	D	on/off		1	1 sps (2)
Lamp #1	D	on/off		1	1 sps (1)
Calibrate Lamp #2 select	D	on/off		1	1 sps (2)
Lamp #2	D	on/off		1	1 sps (1)
Port door	D	open/close/retract		3	1 sps (1)
Exposure time setting	D	as commanded		16	1 sps (1)
Exposure time elapsed	D	msec-hours	usec	32	1 sps (2)
Shutter	D	open/close		2	1 sps (2)
Calibrate lamp voltage setting	D	as commanded		10	1 sps (2)
Calibrate lamp voltage reading	A	tbd	1%	8	1 sps (1)

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INSTRUMENTATION LIST - f/24 FIELD CAMERA

SIGNAL DESCRIPTION	SIGNAL TYPE	RANGE	ANALOG ACCURACY	NUMBER OF BITS	SAMPLE RATE (EACH BIT)
Alignment Current Setting	D	as commanded		6	1 sps (2)
Alignment Current Reading	A	tbd	1%	7	1 sps (1)
Wall voltage setting	D	as commanded		10	1 sps (2)
Wall voltage reading	A	tbd	1%	8	1 sps (1)
Photocathode voltage setting	D	as commanded		10	1 sps (2)
Photocathode voltage reading	A	tbd	1%	8	1 sps (1)
Target voltage setting	D	as commanded		10	1 sps (2)
Target voltage reading	A	tbd	1%	8	1 sps (1)
Focus current setting	D	as commanded		10	1 sps (2)
Focus current reading	A	tbd	1%	8	1 sps (1)
Beam current setting	D	as commanded		7	1 sps (2)
Beam current reading	A	tbd	1%	8	1 sps (1)
Heater current setting	D	as commanded		7	1 sps (2)
Heater current reading	A	tbd	1%	8	1 sps (1)
Photocathode PS current setting	D	as commanded		7	1 sps (2)
Photocathode PS current reading	A	tbd	1%	8	1 sps (1)
Deflection Line (X) current setting	D	as commanded		7	1 sps (2)

INSTRUMENTATION LIST - f/24 FIELD CAMERA

SIGNAL DESCRIPTION	SIGNAL TYPE	RANGE	ANALOG ACCURACY	NUMBER OF BITS	SAMPLE RATE (EACH BIT)
Deflection Line (X) current reading	A	tbd	1%	8	1 sps (1)
Deflection Frame (Y) current setting	D	as commanded		7	1 sps (2)
Deflection Frame (Y) current reading	A	tbd	1%	8	1 sps (1)
Erase lamp current setting	D	as commanded		6	1 sps (2)
Erase lamp current reading	A	tbd	1%	8	1 sps (1)
Erase lamp	D	on/off		1	1 sps (1)
Erase lamp light level	A	tbd	1%	8	tbd (1)
G4 voltage	A	tbd	1%	8	1 sps (2)
G3 voltage	A	tbd	1%	8	1 sps (2)
G2 voltage	A	tbd	1%	8	1 sps(2)
G1 voltage	A	tbd	1%	8	1 sps(2)
SECO readout rate setting	D	as commanded		8	1 sps (2)
SECO readout rate reading	A	tbd	1%	8	tbd (1)
Target	D	prepare/normal/pulsed		3	1 sps (2)
Scan size setting	D	as commanded		8	1 sps (2)
Scan size reading	A	tbd	1%	8	tbd (1)
Scan	D	on/off		1	tbd (1)

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INSTRUMENTATION LIST - f/24 FIELD CAMERA

SIGNAL DESCRIPTION	SIGNAL TYPE	RANGE	ANALOG ACCURACY	NUMBER OF BITS	SAMPLE RATE (EACH BIT)
Thermal sensors (20 X 8 bits)	A	tbd	.1 - .25°C	160	1 sps (1)
LVPS voltages (6 X 8 bits)	A	tbd	1%	48	1 sps (1)
LVPS currents (6 X 8 bits)	A	tbd	1%	48	tbd (3)
Reserve for final design definition				64	
Reserve for diagnostics				64	
(Requirements for the reserves are currently being developed.)					

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