FOS-UCSD-SE01C
ISSUE:
DATE: October 30,

October 1986
DRAFT

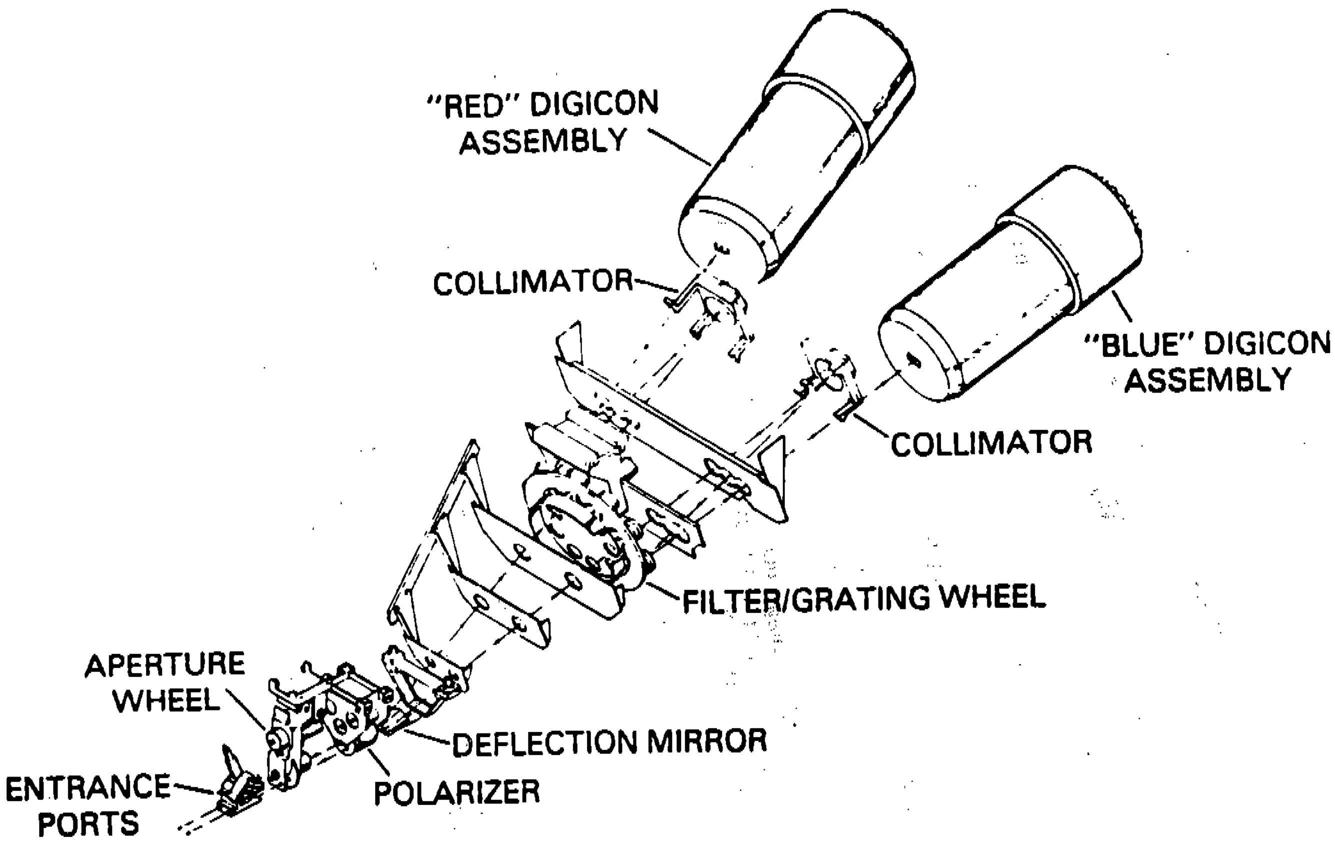
INSTRUMENT DESCRIPTION & USER HANDBOOK
FOR THE
FAINT OBJECT SPECTROGRAPH

ROUGH DRAFT

APPROVED:

UCSD: ______________________ DATE: ____________

GSFC: ______________________ DATE: ____________



3.1.1-1

Figure ~~2.1.1~~. Optical paths in the FOS. See text for discussion.

OPTICAL GEOMETRY

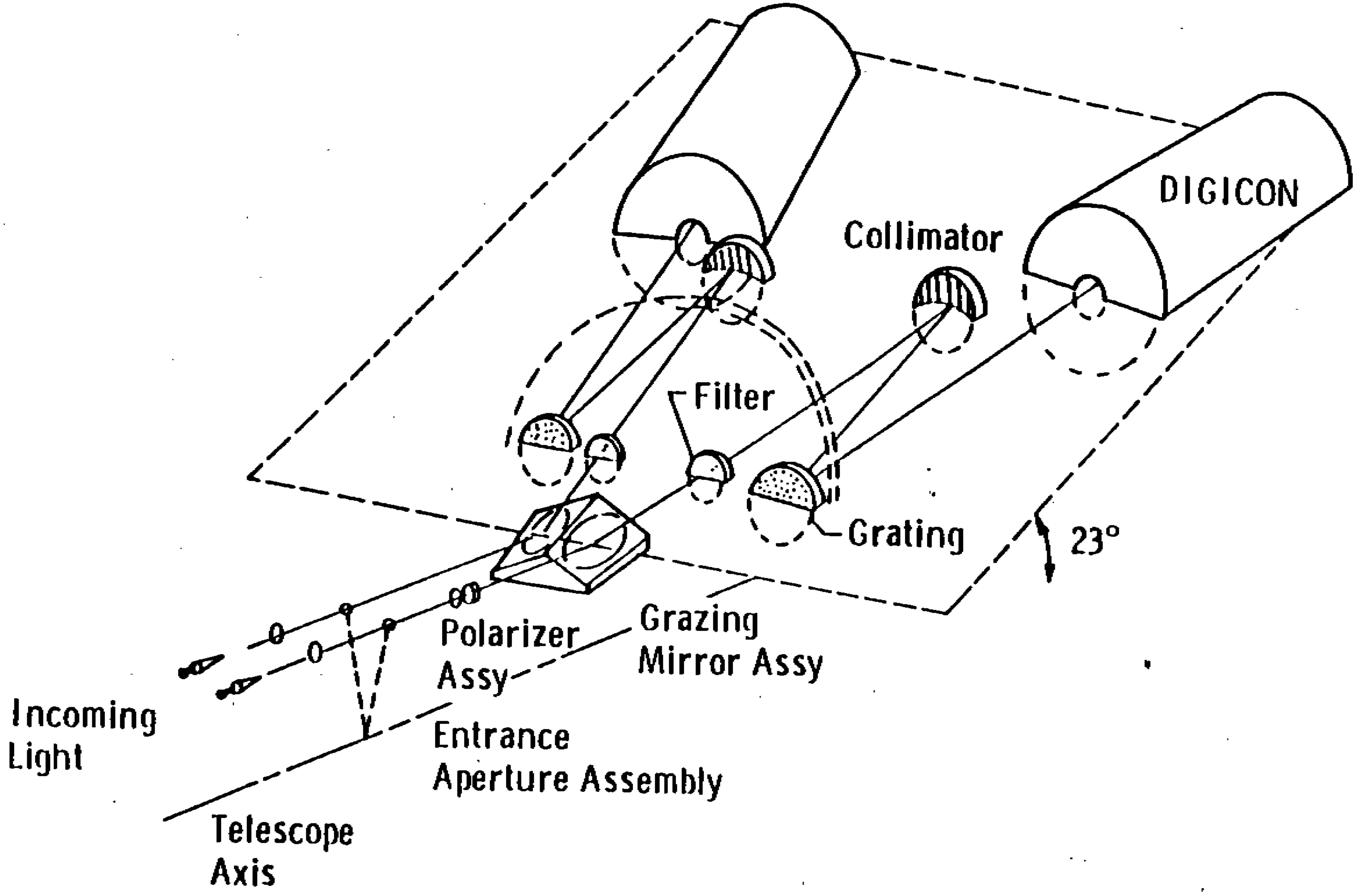


FIGURE 4.1-1

3.1.1-2

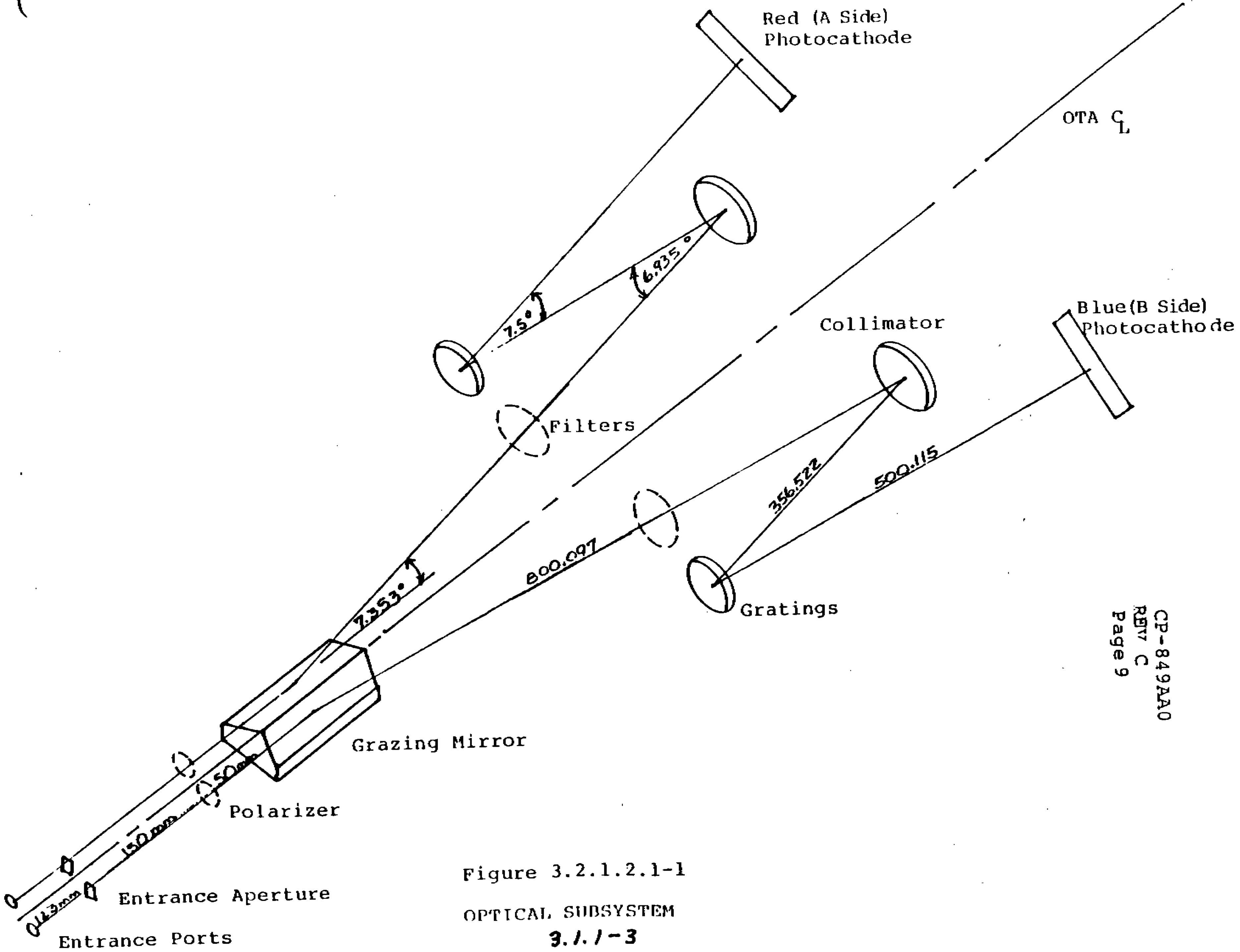


Figure 3.2.1.2.1-1

OPTICAL SUBSYSTEM

3.1.1-3

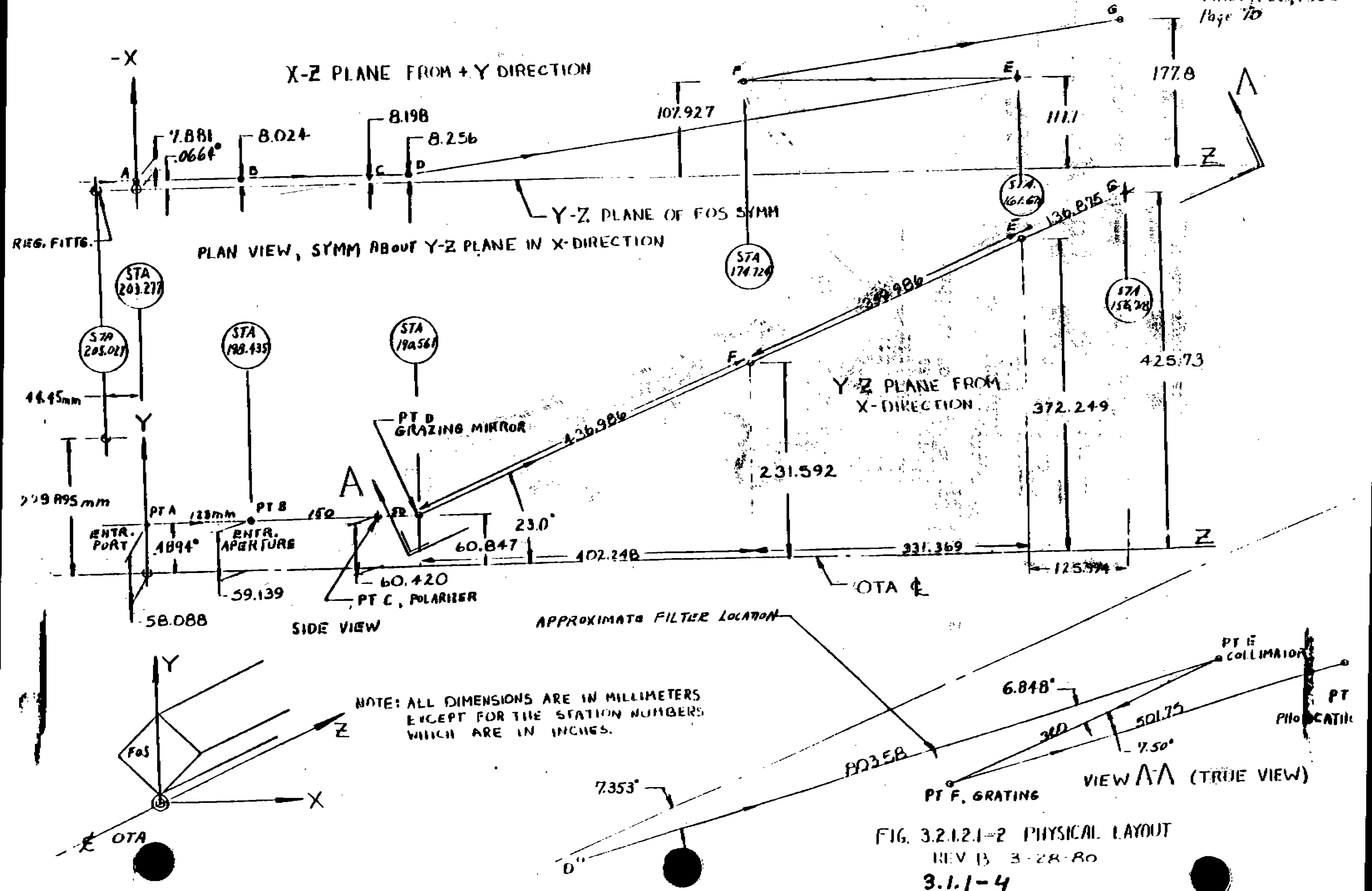


FIG. 3.2.1.2.1-2 PHYSICAL LAYOUT
REV B 3-28-80

TABLE OF CONTENTS

NOTE: Sections 4-7 are incomplete

Notes on Missing Sections.

A. List of Figures.

This will follow the Table of Contents.
Generate a list of figures from the draft when the final version is ready.

B. List of Tables.

To follow the list of figures.
The list of tables should also be done from the final draft.

Page Numbers.

The page numbers have to wait for the text to be typed in a consistent format.

FOS-UCSD-SE01C
ISSUE: FINAL-01
DATE: Oct. 30, 1984

Reference Documents

Information on the FOS is also found in the following reference documents.

Science

1. Faint Object Spectrograph for Space Telescope, Harms, R.J., *et al* Proc. SPIE 183, 74-87, 1979.

2. Faint Object Spectrograph (FOS) Calibration, Harms, R. *et al* Proc. SPIE 331, 268-278, 1982.

3. Astronomical Capabilities of the Faint-Object Spectrograph on Space Telescope, Harms, R.J. and the FOS Science and Engineering Team, in *The Space Telescope Observatory* NASA CP-2244, SS-75, 1982.

4. Calibration and Operation of the Faint Object Spectrograph (FOS) Harms, R. *et al* Proc. SPIE, 445, 410-426, 1983.

5. Faint Object Spectrograph Instrument Handbook, ~~Preliminary,~~ dated ~~12/84~~ 10/85 by Dr. Holland Ford

Instrumentation

1. FOS CEI Specifications, Part II, REVC CP-849AA0 UCSD/MMDA Feb. 22, 1984.

Software and Systems

1. DM-01 Command and Data Lists

2. DM-03D SI C&DH Flight Software User's Manual (IBM 7936288)

3. DM-05C Flight Software Description
   Part I - FOS Microprocessor (Firmware)
   Part II - NSSC-I

4. DM-05D
   Part I - Microprocessor Users Manual
   Part II - NSSC-I Users Manual

Operations

1. ST Constraints and Restrictions Document, SMO-1020

2. Operation Limitations Document, STP-G-OPS-0001

1. INTRODUCTION

The Faint Object Spectrograph (FOS) is designed to allow spectroscopic analysis of physical conditions in faint and often extremely distant astronomical objects. The Edwin P. Hubble Space Telescope (ST) itself provides unprecedented spatial resolution throughout the ultraviolet to near-infrared portion of the spectrum. The excellent image quality is used by the FOS not only to make possible the study of fine structures but also to achieve major improvement in limiting magnitudes by suppressing sky background. As described below, the FOS design is matched to the ST-unique capabilities to provide astronomers a flexible instrument with broad spectral coverage, moderate spectral resolution, ultraviolet spectropolarimetry capability, stable and nearly linear photometric response over a large dynamic range, fine temporal resolution, and extremely low background.

The FOS has been designed and built for use with the Space Telescope to provide digitized spectra of faint astronomical objects over the wavelength range from 115 to 850 nm at resolving powers ($\lambda/\Delta\lambda$) of about 1200 and 200. A variety of concave gratings and prisms are employed to form nearly stigmatic spectra on either of two Digicon photon counting detectors that are optimized for two different but overlapping spectral ranges.

The FOS will address major scientific questions associated with: 1) quasars; 2) nebulosity around or near quasars; 3) nuclei and other active areas in active galaxies; 4) objects in normal galaxies outside the Local Group, including small-scale structure in their central regions; 5) objects in galaxies in the Local Group; and finally, 6) objects in our galaxy. The UV coverage and spatial resolution will also be used for solar system studies such as, for example, obtaining UV spectra of comets, and combining on-going high-spatial-resolution studies of planets and satellites with those of planetary exploration missions. All of these studies will be conducted within the context of understanding the origin, structure, composition, and evolution of our universe.

The list of scientific programs that the FOS will be able to undertake is very large; only a brief outline is given here. First, quasars and galaxies with active (explosive) nuclei raise some of the most exciting questions in both astrophysics and cosmology as well as in cosmogony or the problem of the origin of galaxies. Spectra in the far UV, as well as spectra at all wavelengths in faint nebulosity around quasars, spectroscopy at 0.1 arc sec scale in active galaxies and spectropolarimetry with the FOS should lead to an understanding of just what is happening in these objects where there are enormous outpourings of non-thermal energy from very small volumes. One question to be addressed is whether massive black holes exist in the centers of these galaxies and in quasars.

Study of stars, globular clusters, supernovae, planetary nebulae and other objects in external galaxies will be aimed toward obtaining a more accurate distance scale in the universe (the Hubble scale), toward determining the rate of deceleration of the expanding universe and, hence, what kind of universe we live in, and toward obtaining information on the evolution of galaxies, both chemical and structural. In our own galaxy, the FOS capability for spectropolarimetry and ten millisecond time-resolved spectrophotometry will be particularly important for elucidating the properties of interstellar dust, the extraordinary white dwarfs with very strong magnetic fields, and the rapidly varying, highly evolved stars, X-ray binaries, and pulsars.

2. INSTRUMENT DESCRIPTION

The Faint Object Spectrograph is one of four axial scientific instruments on the Space Telescope. Figure 2.0-1 depicts the main features of the FOS. The instrument is divided into two major compartments: an electronics shelf area above and an optics-plus-detector region below. The entire structure is about 1 x 1 x 2 meters, roughly the size of a phone booth.

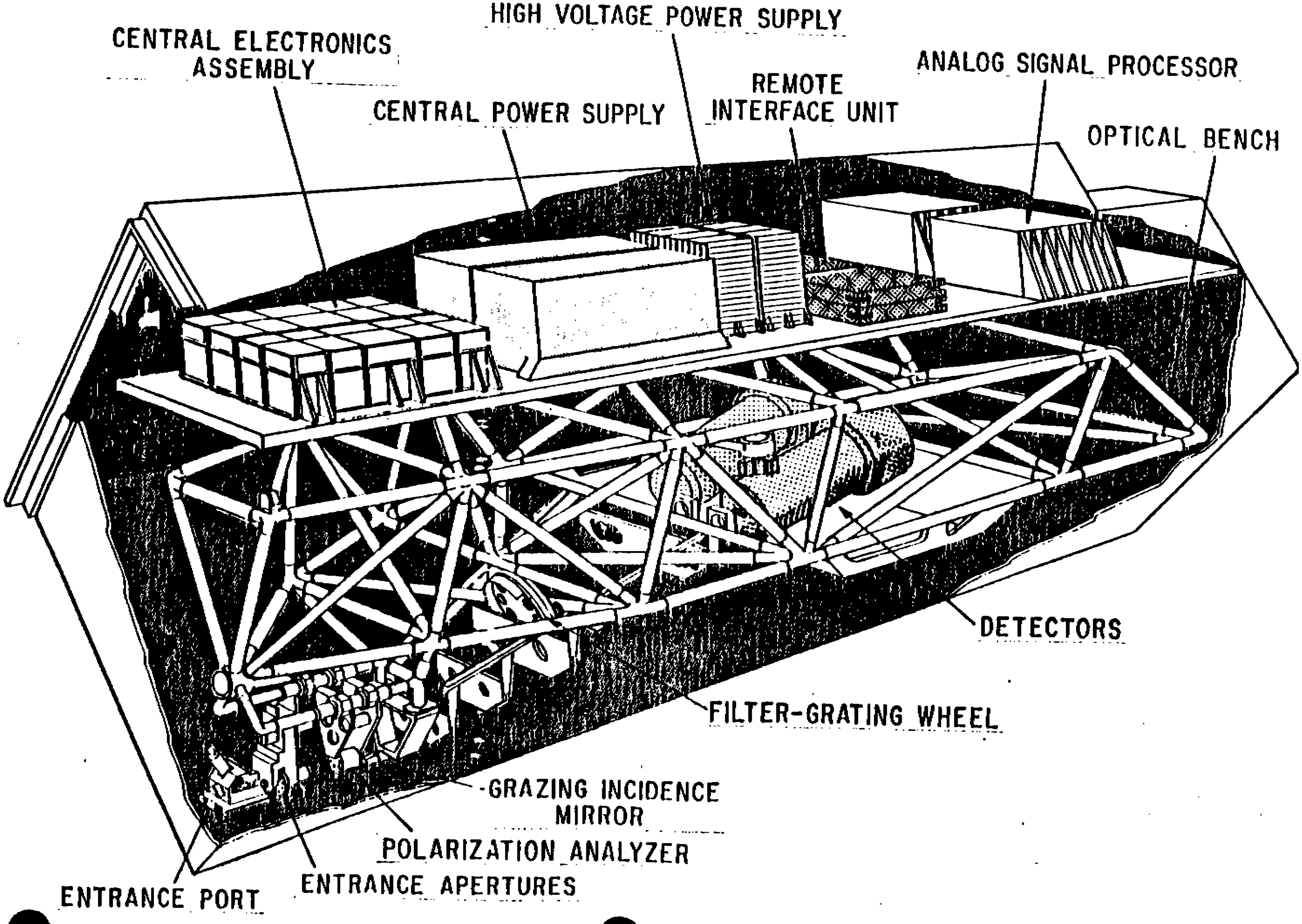
The following subsections will introduce the main FOS components. Detailed descriptions are in section 3.

2.1 Optics. The design of the FOS optics is dominated by the desire to maximize throughput efficiency while utilizing a portion of the ST focal plane as nearly on-axis as possible. The FOS design has eliminated any need to compensate for ST optical distortions, and has reduced to a minimum the number of optical surfaces. For example, a far-ultraviolet photon suffers only 3 reflections in the FOS before reaching a detector (grazing-incidence mirror, collimator, and focusing grating).

Light enters the FOS through a pair of entrance ports (shown at lower left of Figure 2.0-1) located about 60mm = 215 arcseconds off the optical axis of the ST. The light from the object of interest then passes through one of two independent optical paths. The FOS aperture wheel, placed at the ST focal surface, contains twelve sets of single or paired apertures which range in size from 0.1 to 4.3 arcsec projected onto the sky. The optical beam then passes through the polarization analyzer (which includes a clear aperture position). The grazing incidence mirror, a "roof" prism, deflects the beam 22° upward. The reflection is required in order to allow the apertures to be placed near ST optical axis to minimize astigmatism, while meeting packaging constraints within the FOS. The deflected beam passes through an order-sorting filter, for most filter/grating wheel positions, and is then collimated by an off-axis paraboloidal mirror, ~~and~~

The collimated beam is then both dispersed (except for one imaging position) and focused by the selected element on the filter/grating wheel. A nearly stigmatic image is formed on the photocathode of the selected 512-channel Digicon photon detector. The two detectors are optimized for blue (B) and red (A) regions of the 1100-8000Å range, with considerable overlap.

FIGURE 2.0-1
FOS CUTAWAY SHOWING MAJOR COMPONENTS



The entrance part or door mechanism also contains mirrors so that, in its closed position, light from the internal spectral calibration lamps can be shone through the optical path for wavelength calibrations.

The aperture mechanism rotates one of the twelve aperture (upda fig sets into both optical paths. Figure 3.2.2-2 shows and Table 3.2.2-1 lists the various aperture choices provided. The largest aperture, 4.3 arcseconds square, will be used for target acquisition. A variety of apertures from 0.1 arcseconds diameter for spectroscopy of fine spatial structure (e.g. knots in jets such as in M87) to 1.0 arcseconds for spectrophotometry or faint-nebula spectroscopy will enable astronomers to conduct diverse observations with high efficiency. Specialized occulting apertures are intended for the study of faint sources surrounding bright objects, particularly nebulosity surrounding quasars.

The FOS polarization analyzer allows positioning of any of three elements into either optical path: a clear aperture, a thin-waveplate plus Wollaston prism assembly, or a thick-waveplate plus Wollaston prism assembly. One waveplate is permanently located in front of each Wollaston. The polarimeter is designed so that only a single motor is required to rotate the waveplates and to move either of the Wollaston/waveplate pairs from one entrance port to the other or out of the way. A drum, which is only 1.9 inches in diameter, contains the two Wollaston/waveplate pairs. The Wollastons are permanently fixed to the drum, but the waveplates are mounted in rotatable cylinders inside the drum. The waveplate cylinders have a 16-tooth gear on the outside which meshes with a 17-tooth fixed center gear inside the drum. One revolution of the drum rotates the Wollastons by 360°. The waveplates, however, rotate 382.5°. Each rotation of the drum thus increments the position angle of the waveplate fast axis by a net 22.5°. Sixteen rotations of the drum bring the mechanism back to its original configuration.

2.2 Detectors. There are two independent assemblies, one for each optical path. Each detector assembly, consists of a Digicon tube (described in Harms et al., 1979 and references therein), deflection coils, a permanent magnet focus assembly, magnetic shielding, mounting and alignment structure, heat pipes, temperature sensors, hybrid preamplifiers, and connectors.

The two Digicon detector assemblies, designated "red" and "blue", differ only in their photocathode and faceplate materials. The blue detector has a bialkali photocathode (Na_2K KSb) deposited on a magnesium fluoride window to cover the wavelength region 115 nm $< \lambda <$ 500 nm. The photocathode of the red detector, trialkali Na_2 KSb(Cs) deposited on fused silica, provides an extension of sensitivity to the red, covering the range 180 nm $< \lambda <$ 850 nm. To reduce dark background to the extremely low values required for FOS scientific programs (< .002 counts diode $^{-1}$ sec^{-1}), the detectors are cooled to the temperature range -10C to -28C by means of attached heat pipes.

The Digicons operate by accelerating (to 20-25 KeV) photoelectrons emitted by the transmissive photocathode onto a linear array of 512 silicon diodes. The array of the diodes, each measuring 40 microns wide by 200 microns high, is mounted onto a 5 cm diameter ceramic header containing 520 vacuum-tight electrical feedthroughs. The charge pulse generated in each diode is amplified and counted by one of 512 independent electronic channels, beginning with the hybrid preamplifiers physically colocated with each Digicon.

2.3 Control. The FOS receives commands processed through the ST Command and Data Handling (C&DH) computer which controls all ST scientific instrument activity. Internal to the FOS itself are two microprocessor systems, one for each detector system. Each microprocessor (only one can be operating at a given time) controls all the functions needed to operate one side of the FOS such as moving mechanisms, controlling power supplies, scanning the photocathode with the diode array by use of the deflection coils, and accumulating science data. The memory for each microprocessor consists of 24K bytes of read-only memory and 32K bytes of random-access memory. Figure 2.6-1 details the current memory usage (still subject to minor evolution). Storage available for science data integration during an observation is adequate for 12K 16-bit data elements, allowing considerable (but finite!) scanning flexibility with the 512-element diode arrays. ~~(The firmware plot packages have been essential for the development and ground-based testing of the FOS.)~~

2.4 Operating Modes. Because so many FOS parameters are software-selectable under ground-system commands, the possible number of observing configurations truly is astronomical. However, in terms of intended use, the FOS operates in one of six basic modes: 1) target acquisition, 2) spectroscopy, 3) time-resolved, 4) spectropolarimetry, 5) rapid-readout, and 6) time-tagged. Each offers the observer unique advantages (and limitations) for specific purposes.

2.4.1 Target Acquisition Mode. As might be suspected, acquiring an extremely faint astronomical target in a viewing field of maximum size 4.3 arcseconds square using a one-dimensional detector, can be a nontrivial task. The preferred solution, which should become the usual procedure with increasing ST experience in orbit, will be to know target coordinates and possess ST pointing of sufficient accuracy to allow simply commanding the telescope to the proper position to image the object into the desired FOS entrance aperture (Mode III target acquisition). For less benign circumstances, the FOS possesses one position on the filter/grating wheel with a mirror only to provide undispersed images on the detectors as well as onboard software and firmware able to determine small offsets necessary to center a target in a particular FOS aperture, provided that the field is extremely simple (Mode II). If locating the target requires application of more than the most rudimentary intelligence, the onboard software simply maps the field and depends upon the astronomer (working with the ground data display system) to identify the desired target. This manual method, using real-time interaction, is known as Mode I target acquisition. The time to acquire a faint target in a complex field can easily be greater than the exposure time to obtain the spectrum; thus, blind offsetting techniques such as are used at ground-based telescopes will be desirable for increased observing efficiency. It is also possible, though not assured, that one of the two ST cameras can be used to assist in target acquisition for the FOS.

Acquisition of targets for the FOS may be accomplished with Modes I, II, or III. Mode II will be the normal target acquisition scheme for faint objects, but Peakup Mode acquisition capability will also be provided in the NSSC-1 software.

The FOS contains a large (4.3 arcsec) target acquisition aperture and science apertures ranging down to 0.1 arcsec, as well as apertures designed for polarimetry or designed to occult part of the field of view. For MODE II acquisition, the target and any reference objects are positioned in the large aperture based on known or predicted coordinates; or, if the target's coordinates are particularly well known beforehand, a mid-sized aperture may be used. Internal scanning in a non-dispersed mode will provide relative location coordinates to the NSSC-1 for computing offsets to center the target in a smaller aperture. The known offsets of the apertures relative to each other are included in computing the offset required of ST. Aperture offset tables will be built from alignment data obtained before flight, but could require fine tuning with actual on-orbit experience.

Peakup Mode target acquisition will utilize software that will determine peak target intensity with selected integration times while the ST slews slowly. The time of peak intensity will be transmitted to the SSM by the C&DH for return to those coordinates. Since integration times for faint objects necessitate very slow slew rates, it is anticipated that Mode II acquisition will be used much more than Peakup Mode.

2.4.2 Spectroscopy Mode. The most common use of the FOS will probably be in the spectroscopy mode. Any one of ten possible portions (Table 3.1-1) of the ST image can be usefully observed in any of nine spectral regions (Table 3.1-2). Observations may be virtually as brief as desired (shortest snapshot is less than 50 μsec) or as long as the time-allocation committee will approve. For a typical observation, lasting from a few minutes to a few hours, the data is internally integrated in the FOS in software selectable intervals (now planned to be one minute) between each readout to the ground or ST tape recorders. The frequent readouts result in negligible loss of observing efficiency and protect against catastrophic losses of data.

2.4.3 Time Resolved Mode. The time-resolved mode will be used to study objects with known periodicity in about the 50 msec to 100 second range. In this mode, the data is stored in separate memory locations (slices) corresponding to phase, with four to ten samples per full period being typical. Interruptions of data acquisition to read out each frame of data are set by commands to last an integral number of periods so that each frame of an observation has the same correspondence between phase and slice (so long as the period is correctly known!). Thus, all information should be contained in the last frame. Finally, there exist synchronous and asynchronous submodes; these differ only as to whether or not the initial phase angle is explicity locked to the source at the start of the observation (by commanding the start to occur at a specified Universal Time).

2.4.4 Spectropolarimetry Mode. The technique used for spectropolarimetry in the FOS is very similar to that developed for ground-based instruments. A polarizing prism of doubly refractive material is introduced into the spectrophotometer, so as to form twin dispersed images of the slit in opposite senses of polarization at the detector. This analyzer is used at a fixed position, and a waveplate is introduced ahead of it which is turned in 22.5° intervals to analyze for linear and circular polarization. In this way the polarization effects in the dispersing optics following the analyzing prism are of no consequence, and have no effect on the accuracy of the measurement. Two separate waveplates of differing retardation are included in order to allow measurement of linear and circular polarization throughout the ultraviolet region. (It turns out that this allows visible-light operation also.) Any spectral mode may be used with either polarizer waveplate.

2.4.5 Rapid Readout Mode. There are certain astronomical targets where rapid time variability is suspected, but the precise period of variability is unknown, or aperiodic rapid variability is expected. Time-resolved mode is unsuitable for these observations, as the bin folding period must be preset in that mode. Instead, normal FOS data taking is used, but the spectra are read out at very frequent intervals, rather than the approximately 60-sec integration times we anticipate for normal FOS data-taking. The frequency of readout is again set by the observer's requirements, but the shortest possible integration times are limited by various processor overheads. We expect 20 ms is a reasonable estimate of the shortest integrations (the exact minimum overheads are complex because the possibility exists to take "short spectra", ignoring some of the 512 diodes). This rapid-readout capability obviously requires the 1 MHz downlink from ST through TDRSS to the ground (or storage onto magnetic tape within ST).

2.4.6 Time Tagged Mode. The time-tagged mode, probably to be the least used FOS mode, will allow study of the most rapid variability possible using the FOS. Periodic or aperiodic variability on timescales in the range of about 10 microsec to 50 msec are well suited to time-tagged study. In time-tagged mode, each of the FOS accumulators counts the 1.024 MHz spacecraft clock rather than sensor counts. When the first photon arrives in a given channel, this counting freezes and further counts are inhibited in that channel. To be of value, time-tagged mode data must normally be read out at high rates, e.g., the 1 MHz telemetry rates, and will produce a very high data rate during its rare usages (estimated 2%-5% of FOS observing time). Note that this produces far more than 2%-5% of FOS data, however; it may (in competition with rapid-readout mode) produce a majority of FOS data to be reduced. The data outputs are each unsigned integers between 0 and 65,535. The selected accumulation time, for reasonable data, must be long enough to allow proper flight software operation, but be less than the clock overflow period, resulting in a range of allowed periods from about 10 msec to 64 msec. The data obtained in this mode will be similar in format to that obtained by many X-ray experiments.

2.5 Flight Firmware and Software. The FOS contains a pair of microprocessors one located in each CEA (Central Electronic Assembly). There is a CEA for each side of the instrument - one for the red and one for the blue. Only one side and hence only one microprocessor can be active at any given time. The code for the FOS microprocessors is stored in ROM - so they execute or run what is commonly called "firmware". The flight firmware running in the active CEA controls the data acquisition from the Digicon detectors and handles commands that move the spectrograph mechanisms and set up deflections within the Digicons etc. The CEA communicates with the SI C&DH (Control and Data Handling) computer which is a NSSC-1 (NASA Standard Spacecraft Computer - Model 1). The NSSC-1 runs software written for the FOS. In particular there are programs (called "Application Processors") that handle turning on the FOS and Mode 2 target acquisition. Part of the software for the NSSC-1 consists of sequences of commands called "Relative-Time Command Sequences". The NSSC-1 software is loaded into RAM before it is run, so it is proper to call it software. Sequences of commands, "Absolute-Time Command Sequences", to operate the FOS and ST as a scientific instrument in orbit are stored and executed by the NSSC-1. Many of the commands in a typical command sequence are simply sent from the NSSC-1 to the active FOS microprocessor. A schematic of the interface between the NSSC-1 software and FOS firmware is given in figure 2.5-1.

For the FOS, the microprocessor used is a Texas Instruments SBP 9900A, a 16 bit CPU implemented with integrated injection logic. The 64K byte address space of the microprocessor is divided into 24K bytes of ROM, an 8K byte region reserved for memory mapped I/O, and 32K bytes of RAM. A more detailed breakdown of the memory utilization is given in figure 2.5-2. The ROM contains a polyForth operating system, 10 application programs, and some tables that contain parameters for the FOS. The FOS firmware establishes what is basically an interrupt driven system. Apart from servicing interrupts, there are five "background tasks" that are executed in round-robin fashion. One background task handles pulses to the stepper motors that move the FOS mechanisms. So the amount of time required to move an FOS mechanism will depend on the amount of interrupt activity. The firmware also handles FOS data from the Digicons. This data is read from the hardware accumulators to the RAM. And the firmware controls transfer of data from the RAM to the SDF (Science Data Formatter) to be downlinked or stored in the on-board tape recorders.

The FOS software for the NSSC-1 consists of seven "processors". Some of these processors require relative-time command sequences (RTCSs) for their operation. These RTCSs can be considered as part of the software. This software controls "safing", initialization, turn off, housekeeping, and certain kinds of target acquisition. And there are some routines that support these operations by performing functions like the transfer of data from the FOS RAM to the NSSC-1. The "processors" are written in the Caine, Farber, and Gordon PDL language.

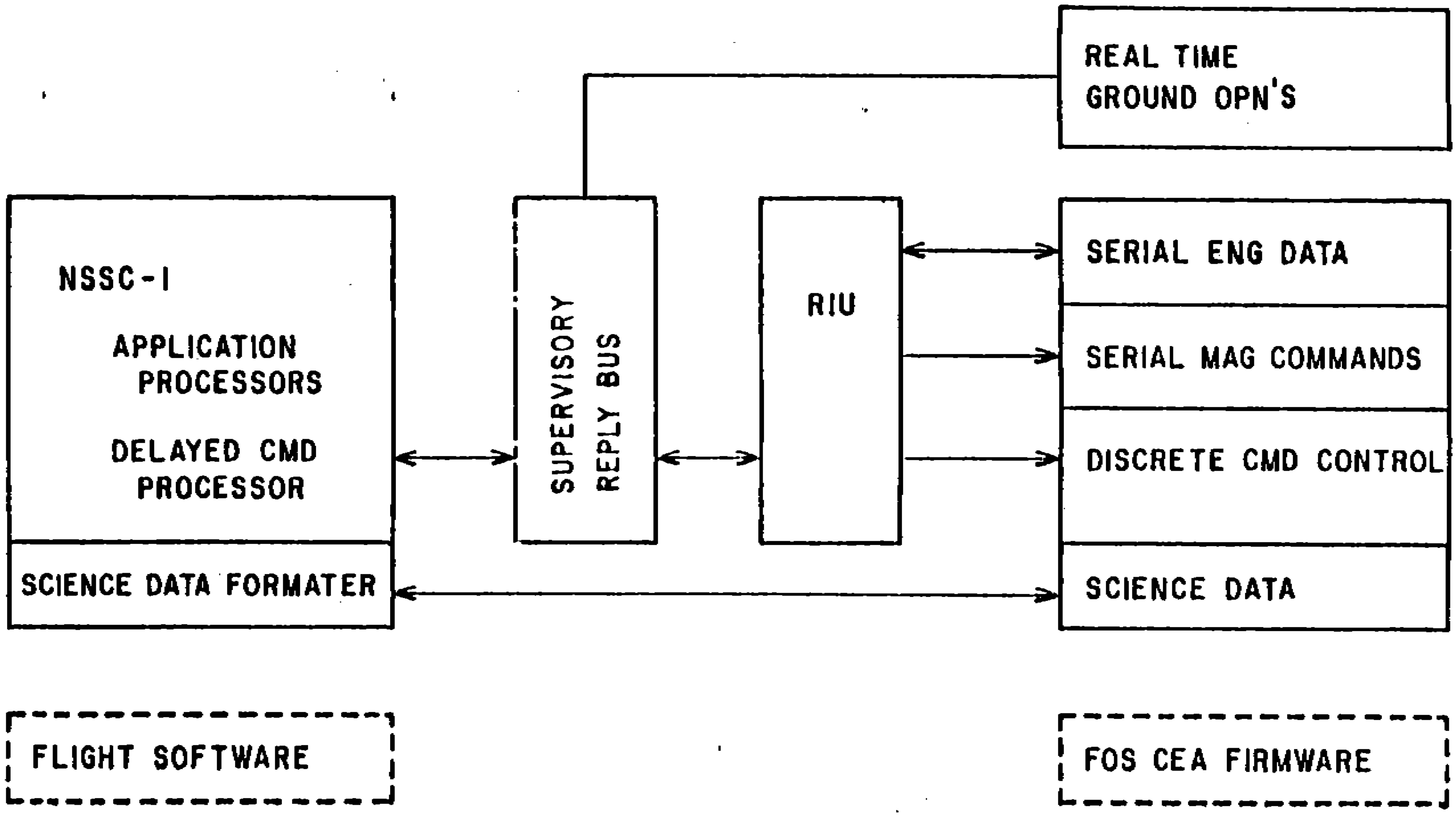


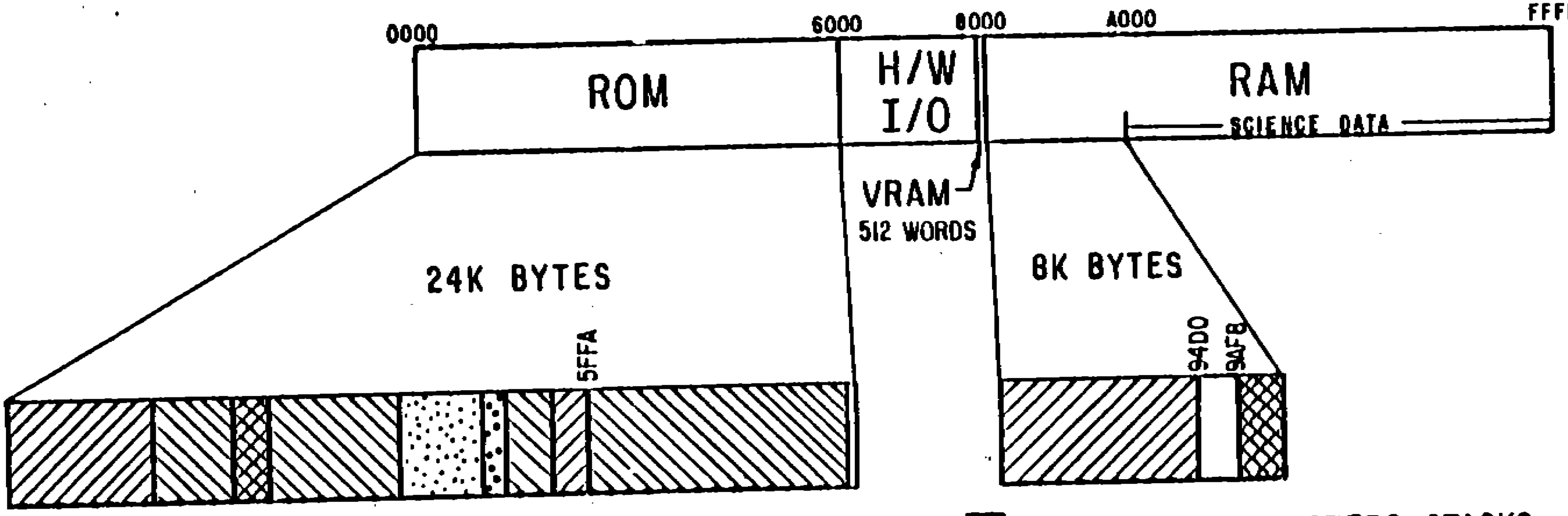
FIGURE ~~2.6-4~~ 2.5-1

FLIGHT FIRMWARE / SOFTWARE INTERFACES

8IRH-II-085A

Figure ~~2.6-1~~ 2.5-2

FOS FLIGHT FIRMWARE MEMORY UTILIZATION



ROM (24K BYTES):

- = FORTH OPERATING SYSTEM 5.2 KBYTES
- = FOS APPLICATION & AIDS 11.8 "
- = DISCRIMINATOR DAC TABLE 1.0 "
- = INTERACTIVE PLOT PACKAGE 2.3 "
- = FOS FORMAT, PLOT, & FIX 0.7 "

23.996 KBYTES

- = UNUSED 6.0 BYTES

RAM (8K BYTES):

- = SYTEM PARAMETERS, STACKS, WORKSPACES, ACQUISITION TABLES, ETC. 5.1 KBYTES
- = DISC. & TELEMETRY TABLES, HEADER, ETC. 1.3 "

6.4 KBYTES

- = UNUSED 1.6 KBYTES

3.1 Optics

The FOS optics were introduced in section 2.1 - this section provides a more detailed description. It is divided into six major headings: 1. Optical Paths, 2. Design, 3. Spectrograph Parameters, 4. Elements, 5. Focus, and 6. Alignment and Tolerances. Section 4 is further divided into subsections for each of the major optical elements. Many of these optical elements are parts of mechanisms with optical, mechanical, and electrical components. For these mechanisms, both the optical and mechanical (3.2) sections of this manual should be consulted. More information can be found in the references. The Faint Object Spectrograph Instrument Handbook by Holland Ford (October 1985 STScI Publication) contains information pertinent to astronomical observations. An appendix to that publication is an article by Allen and Angel about the FOS Spectropolarimeter (originally appeared in 1982, S.P.I.E., 331, 259). The MMC Prime Equipment Detailed Specification Part II (CM-02 CEI CP-849AA0) contains the design values and their tolerances for the optical elements.

3.1.1 Optical Paths. The FOS optics reimage light from the OTA focal surface to the detectors with a magnification of 0.5. The FOS is primarily a spectrograph, but a limited imaging capability is provided over a very small field (4.3 arcseconds square) so that targets may be acquired even when their celestial positions are uncertain by amounts greater than the size of the desired FOS aperture projected onto the sky. Two separate optical paths with the same geometry are provided; one for each of the two detectors, as shown in figure 3.1.1-1. For both paths, a grazing mirror reflects the incoming light onto the collimator mirror. After the grazing mirror, the chief optical rays lie in a plane tipped 23^{o} from the telescope axis. This is illustrated in figure 3.1.1-2. Since the OTA provides an f/24 beam and the collimators are 1000mm from the entrance apertures, a point source of light will produce a 42mm diameter beam of collimated light. Figure 3.1.1-3 shows the optical subsystem and gives dimensions between the optical elements. Figure 3.1.1-4 gives a more detailed physical layout of the FOS optics and defines the coordinate system used in defining the tolerances in the positions of the optical components.

3.1.2 Design. The design of the FOS optics is dominated by the desire to maximize throughput efficiency while utilizing the part of the ST focal plane as nearly on-axis as possible. The FOS design has eliminated any need to compensate for ST optical distortions, and has reduced to a minimum the number of optical surfaces. For example, a far-ultraviolet photon suffers only 3 reflections in the FOS before reaching a detector (grazing incidence mirror, collimator, and focusing grating).

The FOS geometry has been determined from a number of considerations. The entrance ports for the two independent optical paths are located nominally 61mm away from the ST optical axis. This dimension was chosen for two reasons. First, in order to keep optical distortions small, the ports must be close to the ST optical axis. Second, the entrance aperture mechanism and the polarizer mechanism must have clearance. The polarizer mechanism is placed before the grazing incidence mirror. This mirror tips the optical path 23° away from the ST optical axis in order to meet packaging constraints for the elements that are further from the entrance port. The gratings, the spherical mirror substrate for the thin prism, and the camera mirror all have nominal focal lengths of 500mm. This focal length provides a magnification of 0.5 so the Digicon diodes project to 0.35" X 1.4" on the sky. The 0.35" along the spectral dispersion direction provides a good match to the spectroscopically useful apertures with dimensions from 0.25" to 0.5". This matching allows optimal use of the resolution elements available with the Digicon.

3.1.3 Optical Parameters. Table 3.1.3-1 provides a list of the most important spectrograph parameters.

FOS Spectrograph Parameters

OTA Incoming Beam	f/24
Scale at Entrance Apertures	3.58 arcseconds/mm
Collimator Focal Length	1000mm
Focusing Grating Focal Length	500mm
Beam at Digicon	f/12
Scale at Digicon (Imaging)	7.16 arcseconds/mm
Digicon Diode Spacing Center to Center	50μ
Effective Digicon Diode Width	~44μ
Digicon Diode Height	200μ
Projected Diode Spacing X Height	0.35 X 1.4 arcsec

Table 3.1.3-1

3.1.4 Elements

3.1.4.1 Entrance Ports. Two identical entrance ports are located in the forward bulkhead of the FOS, one for each of the two channels. The ports are circular openings 7.37mm in diameter and they are separated by 16mm. The entrance ports are followed by a door mechanism that allows light to enter the FOS when open and prevents light from entering or escaping the FOS when closed. The door mechanism has a mirror that in the closed position reflects light from the internal wavelength calibration lamps onto the FOS entrance apertures. The entrance port in use is selected by pointing the telescope.

The telescope must be pointed to place the astronomical object which will be observed in the entrance port of the optical path to the detector that is active - only one detector will be active at any given time or both detectors will be off.

3.1.4.2 Entrance Apertures. Entrance apertures are located at the OTA focal plane - they define the field of view. Two arrays of primary apertures are located around a wheel such that in each selectable wheel position the same aperture configuration lies on the red and the blue light paths. The apertures are grouped to minimize the distance between the most frequently used apertures. The square and rectangular shaped holes are oriented so that the final image on the Digicon will have the edge of the image parallel or perpendicular to the diode elements. The aperture wheel has twelve primary positions that can be selected. One of these positions is blank and blocks both beams. In case the aperture mechanism fails, a burn wire pinpuller stroke allows torsion springs to rotate the aperture wheel out of the way and brings in a failsafe aperture consisting of a large square hole plus a small square hole. Several different kinds of apertures are available in the eleven non-blank positions of the aperture wheel. There are apertures that consist of a pair of square holes and there are apertures that consist of a single circular hole. Also there is a large square hole for target acquisition and a narrow slit shaped hole and two rectangles with occulting bars through the middle. The apertures are listed in table 3.1.4.2-1 and a schematic representation appears in figure 3.1.4.2-1. This table and figure come from the Faint Object Spectrogaph Instrument Handbook by Holland Ford (1985, STScI). A more mechanical presentation of the apertures is given in section 3.2. Table 3.1.4.2-2 gives measured sizes for the FOS apertures (from Harms et al. 1983, S.P.I.E., 331, 259).

3.1.4.3 Polarimeter Optics. The FOS polarimeter consists of two rotating waveplates each followed by its own Wollaston prism. A rotating polarizer mechanism places either waveplate in either the red or blue optical path. Also there is a clear position used for non-polarimetric spectrophotometry. This same mechanism also rotates the waveplates with respect to the Wollaston prisms. The Wollastons rotate because they are attached to a drum, while the waveplates rotate because they are attached to small cylinders inside the drum. The cylinders are driven by a 16-tooth gear on the outside meshed with a 17-tooth fixed gear in the center of the drum. Each 360^{o} rotation of the drum returns the Wollaston prism back to the same place and orientation but the waveplate in front of the Wollaston has rotated 17/16 of a full circle or 360^{o} plus 22.5^{o}. Thus the same mechanism that inserts the polarimetric apparatus into the optical path also rotates the waveplates in increments of 22.5^{o}.

3.1.4.2-1
Table ~~2.2.1-1~~
FOS Apertures

Designation	Number	Shape	Size (")	Separation (")	Special Purpose
0.3	Single	Round	0.30 dia	NA	Spectroscopy and Spectropolarimetry
0.5	Single	Round	0.50 dia	NA	Spectroscopy and Spectropolarimetry
1.0	Single	Round	1.00 dia	NA	Spectroscopy and Spectropolarimetry
0.1- PAIR	Pair	Square	0.10	3.0	Object and Sky
0.25-PAIR	Pair	Square	0.25	3.0	Object and Sky
0.5- PAIR	Pair	Square	0.50	3.0	Object and Sky
1.0- PAIR	Pair	Square	1.00	3.0	Object and Sky
0.25 × 2.0	Single	Rectangular	0.25 × 2.0	NA	Extended Objects
0.7 × 2.0-BAR	Single	Rectangular	0.70 × 2.0	NA	Surrounding Nebulosity
2.0-BAR	Single	Square	2.0	NA	Surrounding Nebulosity
BLANK	NA	NA	NA	NA	Dark and Particle Events
4.3	Single	Square	4.3	NA	Target Acquisition
Failsafe	Pair	Square	0.5 and 4.3	NA	Target Acquisition and Spectroscopy

The first dimension of rectangular apertures is along the dispersion direction, the second dimension is perpendicular to the dispersion direction. The two apertures with the suffix designation "BAR" are bisected by an occulting bar which is 0.3" wide in the direction perpendicular to the dispersion.

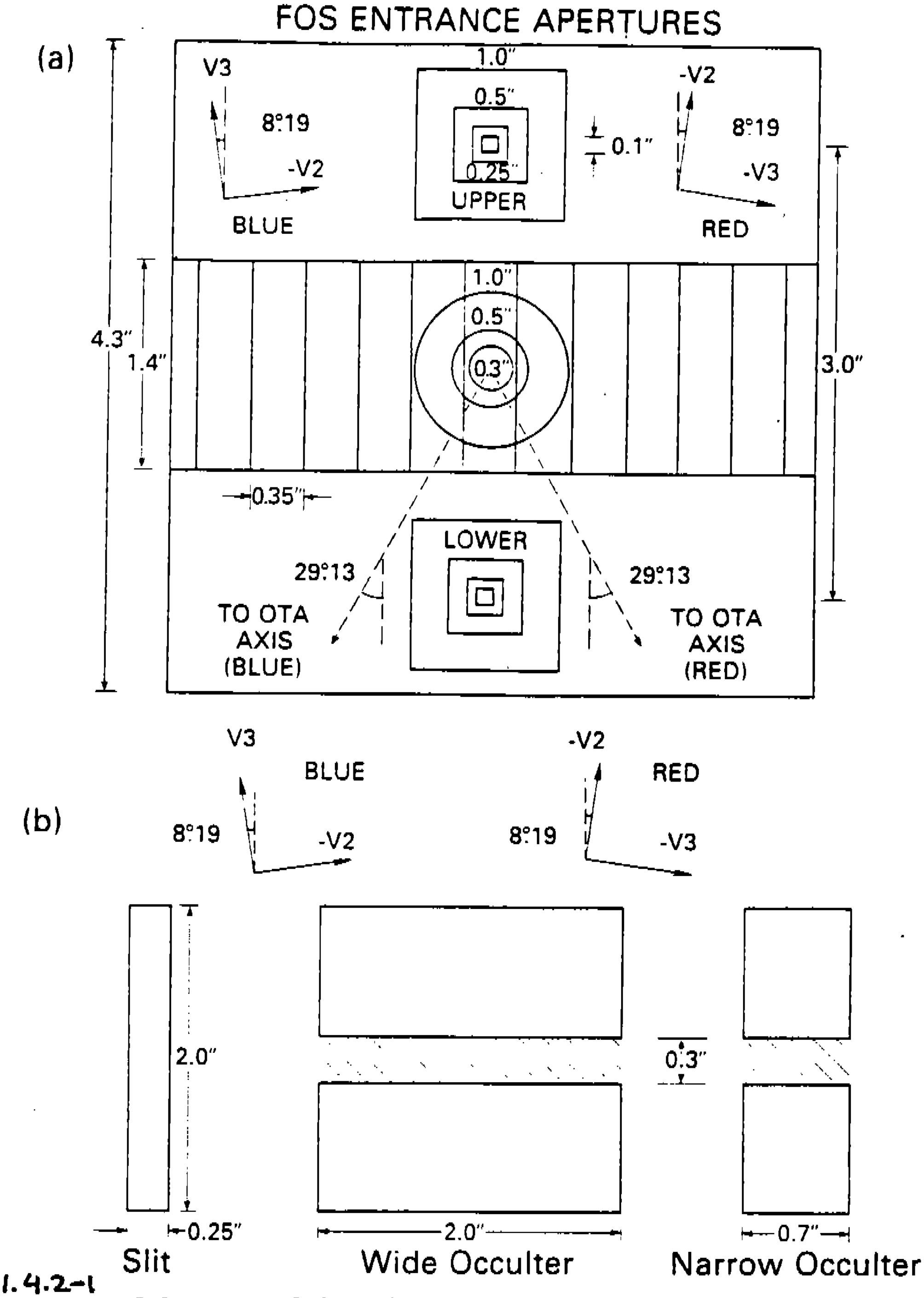


Figure ~~2.2.1-1~~ 3.1.4.2-1 A Schematic of the FOS Apertures projected onto the sky. The upper panel shows the array of 0.35″ × 1.4″ diodes projected across the center of the 4.3″ × 4.3″ target acquisition aperture. The target acquisition aperture and the single circular apertures position to a common center. The pairs of square apertures position to common centers with respect to the target acquisition aperture as shown in the figure. Either the upper aperture (the "A" aperture, which is furtherest from the HST optical axis) or the lower aperture (the "B" aperture, which is closest to the HST optical axis) in a pair can be selected by an appropriate y-deflection in the Digicon detectors. The lower panel shows the three rectangular slits; two of the slits are bisected by an 0.3″ opaque occulting bar. The centers of the three slits position to the center of the target acquisition aperture. The figure shows the orientation of the direction perpendicular to the dispersion in the HST V2, V3 focal plane on the blue and red sides. The FOS x-axis is parallel to the diode array and positive to the right; the y-axis is perpendicular to the diode array and positive toward the upper aperture.

3.1.42-2

Table ~~2.1-1~~. Fos Aperture Sizes

SPECIFICATIONS		BLUE SIDE MEASUREMENTS			RED SIDE MEASUREMENTS	
Aperture	Dimensions* Arcsec	Area Arcsec^2	Area Microscope Arcsec^2	Area + Optical Throughput Arcsec^2	Area Microscope Arcsec^2	Area + Optical Throughput Arcsec^2
A4L	0.1x0.1	.010	.00905	.0186	.01027	.0179
A4U	0.1x0.1	.010	.00855	.0117	.00922	.0139
A3L	0.25x0.25	.063	.0575	.0808	.0581	.0697
A3U	0.25x0.25	.063	.0575	.0685	.0567	.0720
B2	0.3 circular	.071	.0629	.0755	.0670	.0744
B1	0.5 "	.196	.184	.208	.182	.203
A2L	0.5x0.5	.250	.243	.293	.238	.267
A2U	0.5x0.5	.250	.246	.270	.239	.273
C2	0.25x2.0	.500	.475	.489	.482	.576
B3	1.0 circular	.785	.738	.806	.746	.793
C1L	1.0x1.0	1.00	.981	1.06	.988	1.05
C1U	1.0x1.0	1.00	.989	1.06	.985	1.05
C4	0.7x2.0**	1.19	1.18	1.24	1.18	1.26
C3	2.0x2.0**	3.46	3.36	3.57	3.34	3.45
A1	4.3x4.3	18.5	18.6	18.5	18.5	18.5

* First dimension is along dispersion. The second dispersion is perpendicular to dispersion

** With occulter bar that is 0.3 arcsec wide in cross-dispersion direction.

\+ Normalized to aperture A1 = 18.5 arcsec^2

The FOS polarimeter uses a polarizing prism to form two dispersed images of the aperture in opposite senses of polarization at the detector. The orientation of this analyzer is essentially fixed while a waveplate ahead of it is rotated to measure polarization. This geometry makes the polarization measurement independent of polarization effects in the optical path following the polarizing prism. In particular the measurement will not depend on the magnitude or direction of polarization introduced by the grazing mirror and the dispersive elements.

Two waveplates with different retardations are provided to allow better polarimetric sensitivity for a range of wavelengths near Lyα 1216Å. The relative configuration of the optical elements in the polarimeter drum is shown in figure 3.1.4.3-1 which is shown from inside the spectrograph looking toward the entrance ports. The retardations and efficiencies of the flight waveplates are presented in table 3.1.4.3-1. The retardations are plotted in figure 3.1.4.3-2 and the transmission of the polarimeter is shown in figure 3.1.4.3-3. The table and all of the figures are from the article by Allen and Angel (1982, S.P.I.E., 331, 259.)

High transmission in the ultraviolet was achieved by making the polarimeter optical elements of relatively thin pieces of magnesium fluoride. The clear aperture of the polarimeter is 8mm, the Wollaston prisms are 3.5mm thick and the waveplates are 1.0mm thick. The Wollaston prisms have an internal wedge angle of 20^{o}. This angle was chosen to provide adequate separation of the two images at Lyα, a wavelength where the birefringence of the magnesium fluoride is small.

3.1.4.4 Grazing Incidence Mirror. A single fixed grazing mirror assembly shaped like a roof prism reflects light toward the collimators. The mirror is made of aluminum with a surface coating of Al_2O_3. The angles of incidence and reflectance are 11.8^{o}. The effect of the grazing mirror is to simultaneously deflect both beams 23^{o} away from the OTA optical axis and to deflect one beam left and the other beam right by 7.353^{o}. Figures 3.1.4.4-1 and 3.1.4.4-2 (from Harms et al. 1983, S.P.I.E., 445, 410) show the reflectance of the mirror as a function wavelength for parallel and perpendicular polarized light.

3.1.4.5 Filters. The light path after the grazing incidence mirror passes through the filter-grating wheel assembly. Some of the dispersive elements require order separating filters. These filters are in the f/24 diverging beam between the grazing incidence mirror and the collimator. The clear aperture of the filters is 30mm, and they are mounted 360mm from the collimators. Since the filters are attached to the same wheel as the gratings, the proper filter is

3.1.4.3-1

Table 1. Retardations of the Flight Waveplates

λ(Å)	Waveplate A			Waveplate B		
	δ	Efficiency linear	Efficiency circular	δ	Efficiency linear	Efficiency circular
1175	-108°	.65	.95	-93°	.53	1.00
1200	100°	.59	.98	0°	0	0
1216	215°	.91	.57	90°	.50	1.00
1250	360°	0	0	161°	.97	.33
1300	460°	.59	.98	228°	.83	.74
1350	482°	.76	.85	247°	.70	.92
1400	485°	.79	.82	250°	.67	.94
1450	480°	.75	.87	241°	.74	.87
1500	468°	.65	.95	238°	.76	.85
1600	439°	.85	.98	226°	.85	.72
2537	251°	.66	.94	123°	.77	.86
3650	163°	.98	.29	84°	.45	.99
6328	95°	.54	.99	43°	.13	.68

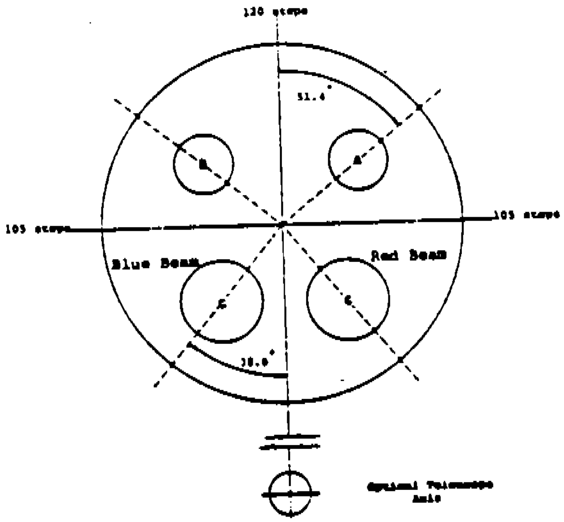


Figure 1. Relative configuration of the optical elements as viewed from inside the FOS in the direction of the entrance ports.

3.1.4.3-1

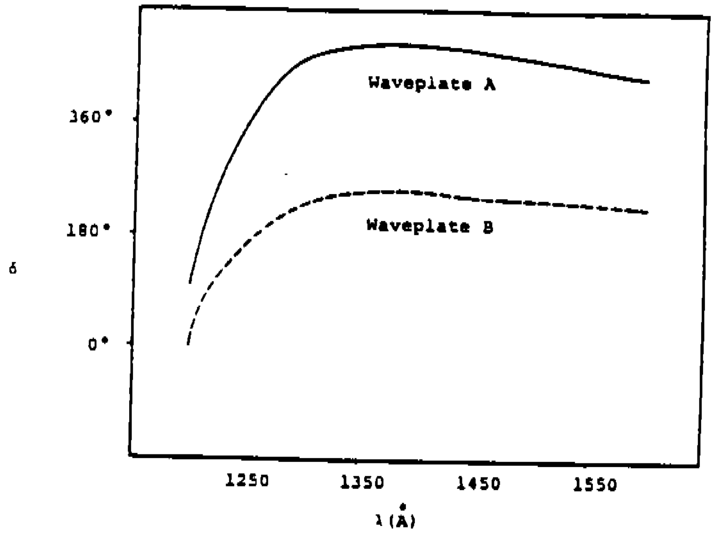


Figure 4. Retardations of the flight waveplates.

3.1.4.3-2

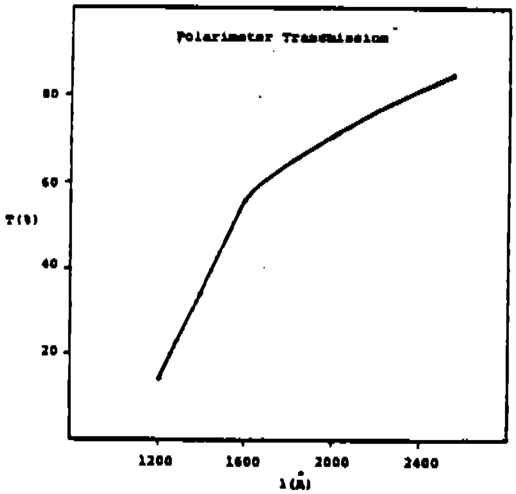


Figure 5. The transmission of the polarimeter as a function of wavelength.

3.1.4.3-3

CALCULATED REFLECTANCE OF ALUMINUM WITH 45 Å Al_2O_3
INCIDENCE ANGLE = 78.5°
COMPARED WITH AVERAGE OF GRAZING MIRRORS

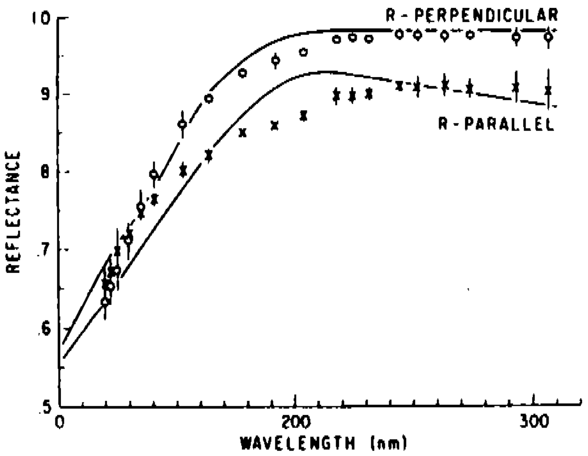


Figure ~~2-1-3~~. Calculated reflectances (curves) versus measured values (points).

3.1.4.4-1

CALCULATED REFLECTANCE OF ALUMINUM WITH 45Å Al_2O_3
INCIDENCE ANGLE = 78.5°
COMPARED WITH AVERAGE OF GRAZING MIRRORS

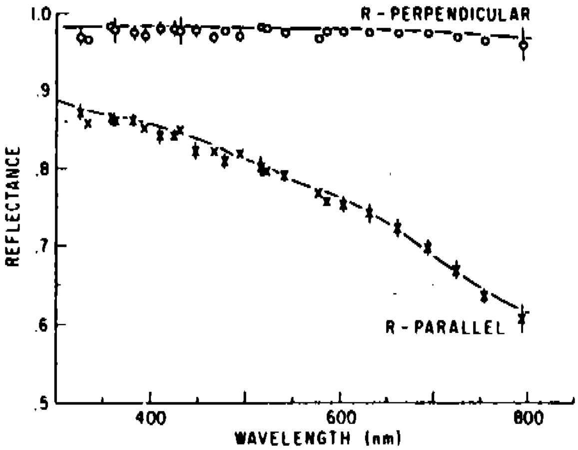
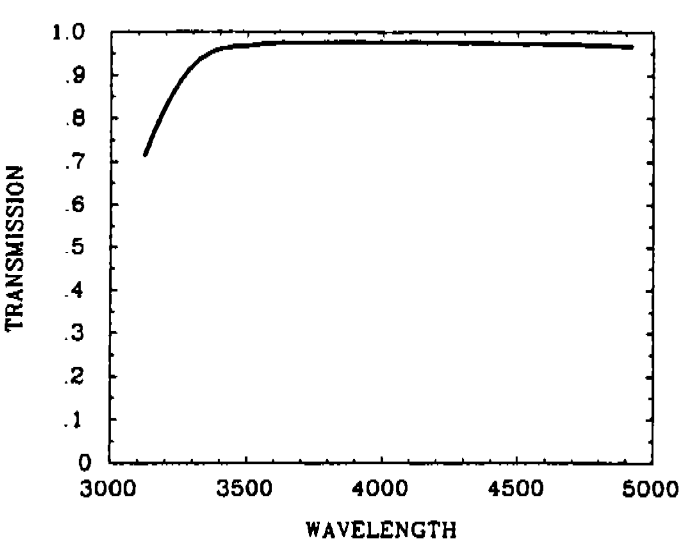


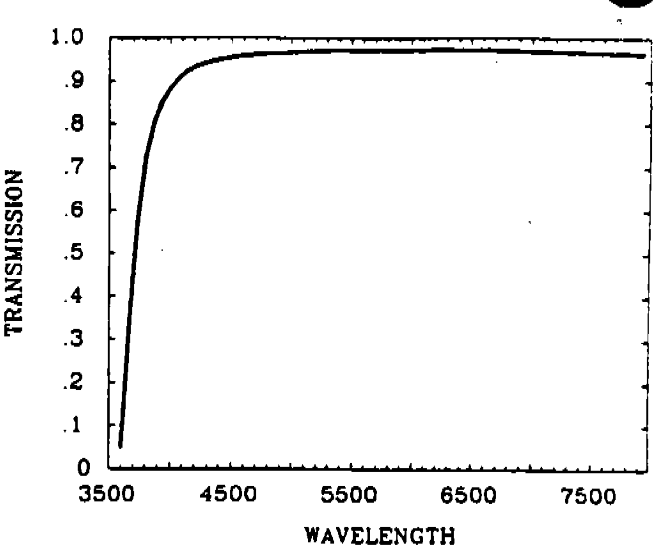
Figure ~~2-1-4~~. Calculated reflectances (curves) versus measured values (points).

3.1.4.4-2

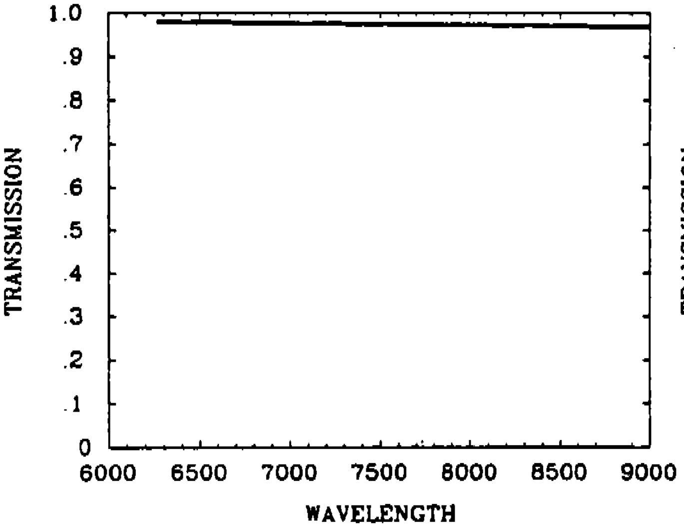
SCHOTT WG305 BLOCKING FILTER



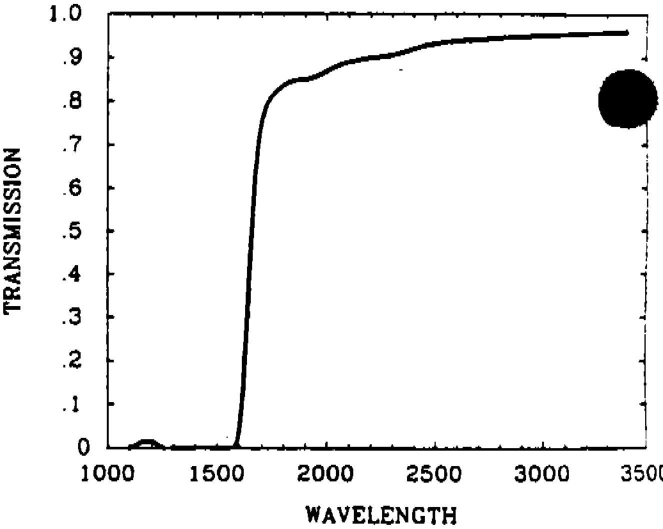
GG375 BLOCKING FILTER



OG530 BLOCKING FILTER



ULTRAVIOLET BLOCKING FILTER



FOS FILTER CALIBRATIONS

3.1.4.5-1

automatically inserted for each grating. The measured filter transmissions are given in figure 3.1.4.5-1 (from Ford, Holland, 1985, Faint Object Spectrograph Instrument Handbook, STScI Publication). Table 3.1.4.8-3 lists the gratings and the associated blocking filters.

3.1.4.6 Collimators. The collimators change the f/24 diverging light bundle into a non-diverging parallel beam that illuminates the focusing gratings. The collimating mirrors are off-axis sections of parabolic surfaces. Each collimator has a clear aperture diameter of 43.5mm. The focal length of the mirror is 1000mm, and its center is 119.6mm away from the axis of rotational symmetry of the paraboloid. The collimators are overcoated with approximately 250Å of magnesium fluoride. The reflectance of this material is shown in figure 3.1.4.6-1.

3.1.4.7 Concave Mirror. A concave mirror is located at one position on the filter-grating wheel assembly. This provides a limited direct imaging capability for target acquisition. This camera mirror is an off axis section of a concave paraboloid with a focal length of 500mm. The center of the off-axis section is 65.1mm from the axis of rotational symmetry. The clear aperture diameter is 43.5mm. Like the collimators, this mirror is overcoated with approximately 250Å of magnesium fluoride and its reflectance can be estimated from figure 3.1.4.6-1.

3.1.4.8 Dispersers. Dispersive elements are located at 9 positions near the outer edge of the filter-grating wheel assembly. The tenth element on this wheel is a concave mirror discussed in section 3.1.4.7 above. The dispersive elements are divided into high ($R = \lambda/\Delta\lambda \approx 1300$) resolution and low ($R = \lambda/\Delta\lambda \approx 250$) resolution groups. Six gratings provide high resolution coverage from 1150Å to 9000Å. Low resolution coverage from 1100Å to 8000Å is provided by two gratings centered at 1600Å and 6000Å and one thin prism to cover the inbetween wavelengths. The prism dispersion is very non-linear. The gratings also focus the light - the substrates all are concave spherical surfaces with nominal focal lengths of 500mm. The thin prism assembly has a spherical mirror with a nominal focal length of 500mm.

The gratings are all blazed for the first inside order. The high resolution gratings are illuminated by the collimator at an angle of 7.5°. The diffracted angles are $\pm 1.47^{\circ}$ from the grating normal. The chief ray angle of incidence on both of the low resolution gratings is 3.475° with a range of diffraction angle from the normal of $2.787 \pm 0.229^{\circ}$. The thin prism is made of UV-grad sapphire. The thin prism assembly, like the gratings, has a minimum clear aperture of 43.5mm.

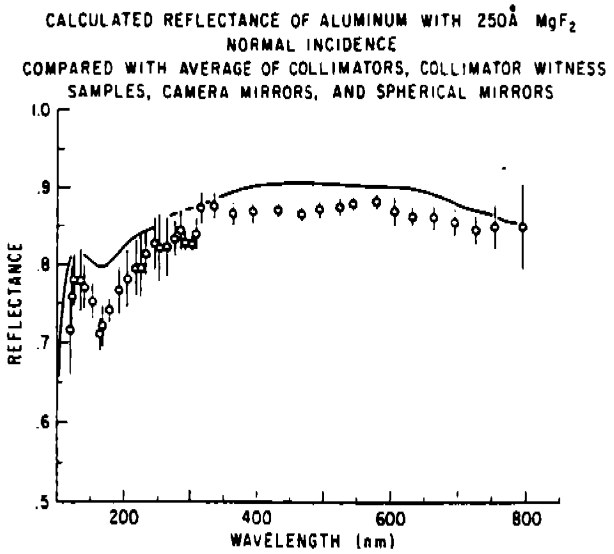


Figure 2.1-5. Calculated reflectances (curve) versus measured values (points).

3.1.4.6-1

All of the high resolution gratings were designed to give approximately the same resolution $R = \lambda/\Delta\lambda = 1300$. So the number of grooves per mm is different - it depends on the central wavelength for each grating. The groove density is given in table 3.1.4.8-1 for the high resolution gratings and in table 3.1.4.8-2 for the low resolution gratings. These tables are from the MMC CM-02 CEI CP-849AA0 document. A list of FOS dispersers with dispersions, wavelength coverage, and the associated blocking filters is given in table 3.1.4.8-3. This table is from the Faint Object Spectrograph Instrument Handbook by Holland Ford (1985, STScI Publication). Also from this reference figure 3.1.4.8-1, the prism efficiency and figure 3.1.4.8-2 grating efficiencies for all eight gratings.

3.1.4.9 Calibration Lamps. The FOS has an internal wavelength calibration system consisting of two lamps and optical elements to transmit the light to the FOS entrance apertures. The entrance apertures are illuminated by mirrors on the back of the entrance port shutter assembly. The entrance apertures cannot be illuminated by the calibration lamps when the entrance ports are open. There is also a flat field lamp for each Digicon. The light from the flat field lamps enters the Digicons directly without any intervening optical elements. These flat field LEDs are mounted on a baffle near the filter grating wheel assembly.

The wavelength calibration lamps are gas filled hollow cathode lamps with magnesium fluoride windows. The cathode of each lamp contains platinum and chromium. The fill gas is neon. The calibration lamps and optical elements are mounted on the forward bulkhead of the FOS.

3.1.4.10 Baffles and Light Traps. Baffles with a low reflectivity coating (reflectivity < 10%) are used to minimize scattered light within the spectrograph. They limit the direct light path between spectrograph elements to the minimum required for the on-axis spectrograph light bundle. The five baffles in the FOS are perforated aluminum sheets coated with black paint. These are best shown in figure 3.1.1-1. Three are located between the grazing incidence mirror and the filter/grating wheel, one around the filter grating wheel and one between the filter/grating wheel and the collimator mirror. A light trap is provided near each Digicon photocathode. These traps are positioned to intercept light reflected from the high resolution gratings in the zeroeth order. This light is not dispersed and the exit angle is equal to the angle of incidence. Although near the photocathodes, the zero order traps do not vignette the light bundles to the Digicons. They are wedge shaped boxes coated with low reflectivity material. Back reflectance from these traps is less than 10^{-6} between 1100Å and 9000Å.

-0 mm). The clear aperture of each grating shall be a circle with a minimum diameter of 43.5 mm. The entire clear aperture shall be ruled, and the grating spacings shall be accurate to $\pm$2 percent. All gratings shall be blazed for the first inside order and have a minimum resolution of 1000. The orientation of the blaze shall be indelibly marked on the edge of the grating substrate. Gratings may be multipartite to meet the required efficiency.

3.1.4.8-1
Table 3.2~~.1.2.1-II~~

HIGH RESOLVING POWER GRATING

#	Name	Groove Density on Grating (± 2%)	Nominal Wavelength Coverage min	avg	max	Min Peak Effic.
-001	H13	1000mm-1	0.104um	0.130um	0.155um	45%
-002	H19	685.7	0.152	0.189	0.226	60%
-003	H27	480.0	0.217	0.270	0.323	60%
-004	H40	327.3	0.318	0.396	0.474	60%
-005	H57	225.0	0.462	0.576	0.690	65%
-006	H78	171.4	0.607	0.766	0.906	70%

SCN 2

c. Low Resolving Power Grating - The grating parameters shall be as defined in Table 3.2.1.2.1-III. The gratings shall be on a fused silica substrate. The substrate shall have a vertex radius of 1000 mm (+6, -0 mm). The clear aperture of each grating shall be a circle with a minimum diameter of 43.5 mm. The entire clear aperture shall be ruled and the grating spacing shall be accurate to $\pm$2 percent. Each grating shall be blazed for the first inside order and have a resolution of 200 $\pm$50 at the average wavelength. The orientation of the blaze shall be indelibly marked on the edge of the grating the blaze shall be indelibly marked on the edge of the grating substrate. Gratings may be multipartite to meet the required efficiency. SCN 2

3.1.4.8-2
Table ~~3.2.1.2.1-III~~

LOW RESOLVING POWER GRATING

#	Name	Groove Density on Grating (± 2%)	Nominal Wavelength Coverage min	avg	max	Min Peak Effic.
-003	L15	144mm-1	0.110um	0.165um	0.220um	30%
-004	L65	40	0.400	0.600	0.800	40%

SCN 2

3.1.4.B-3

Table ~~2.2.3-1~~

FOS Dispersers

			Blue Digicon				
Grating	Diode No.	λ(Å)	Diode No.	λ(Å)	$\Delta\lambda$(Å $Diode^{-1}$)	Max Dev(%)	Blocking Filter
G130H	60	1150[1]	516[7]	1608	1.00	1.2	—
G190H	1	1575	516	2332	1.47	1.5	—
G270H	1	2227	516	3306	2.09	1.4	MgF
G400H	1	3244	516	4827	3.07	1.4	WG 305
G570H	1	4583	516	6885[6]	4.46	1.3	WG 375
G160L	318	1150[1]	516	2523[2]	6.50	2.4	—
G650L	295	3530	373	5500[6]	25.04	2.6	WG 375
PRISM	175	1850[4]	24	5500	—	—	—
			Red Digicon				
G190H	1	2323	516	1573[5]	- 1.45	0.4	—
G270H	1	3293	516	2225	- 2.07	0.4	MgF
G400H	1	4802	516	3237	- 3.04	0.4	WG 305
G570H	1	6849	516	4571	- 4.42	0.4	WG 375
G780H	1	9259	516	6274	- 5.79	0.5	OG 530
G160L	1	2473	126	1600[5]	- 6.96	—	—
G650L	1	8904[3]	205	3770	-25.05	0.6	WG 375
PRISM	497	8950	332	1850	—	—	—

1 The blue Digicon's MgF_2 faceplate absorbs light shortward of 1150Å.

2 The second order overlaps the first order longward of 2300Å.

3 The second order overlaps the first order longward of 7100Å.

4 The sapphire prism absorbs light shortward of 1650 Å; however, because of the large dispersion of the prism at the shortest wavelengths, the effective cutoff is longward of 1650 Å.

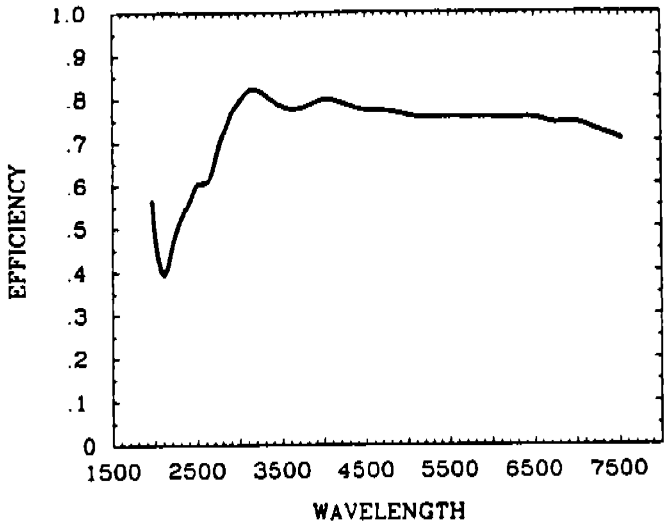
5 The red Digicon's fused silica faceplate strongly absorbs light shortward of 1700 Å.

6 The blue Digicon has little sensitivity longward of 5500 Å.

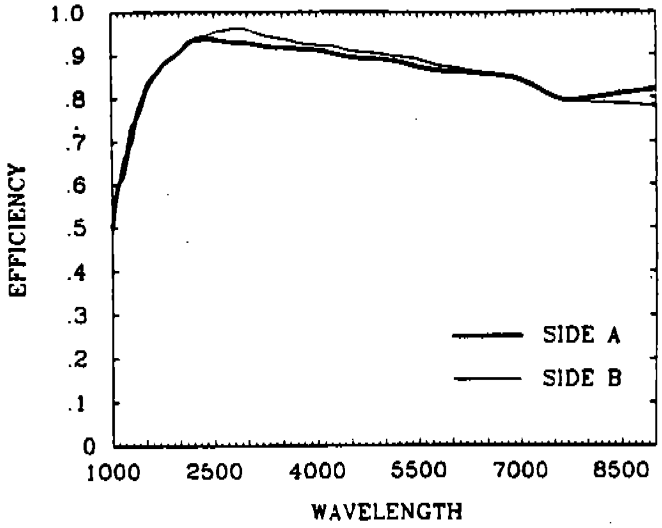
7 The photocathode electron image typically is deflected across 5 diodes, effectively adding 4 diodes to the diode length.

3.1.4.8-1

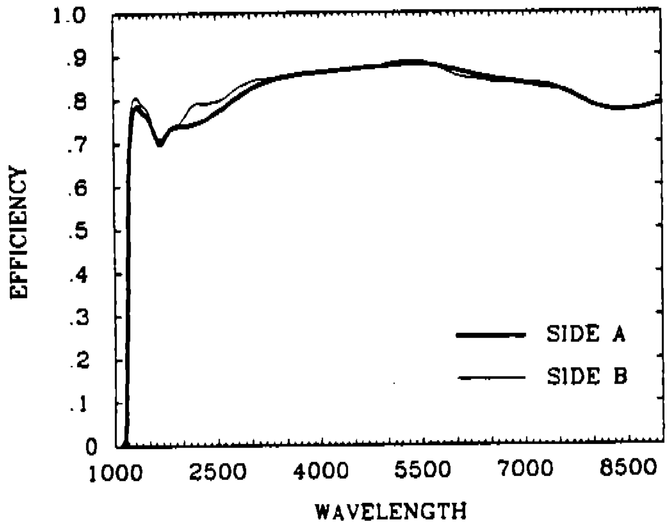
PRISM



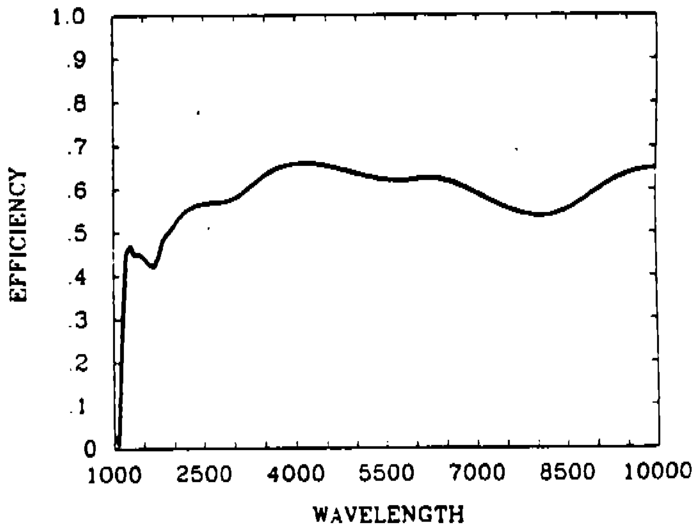
GRAZING INCIDENCE MIRROR



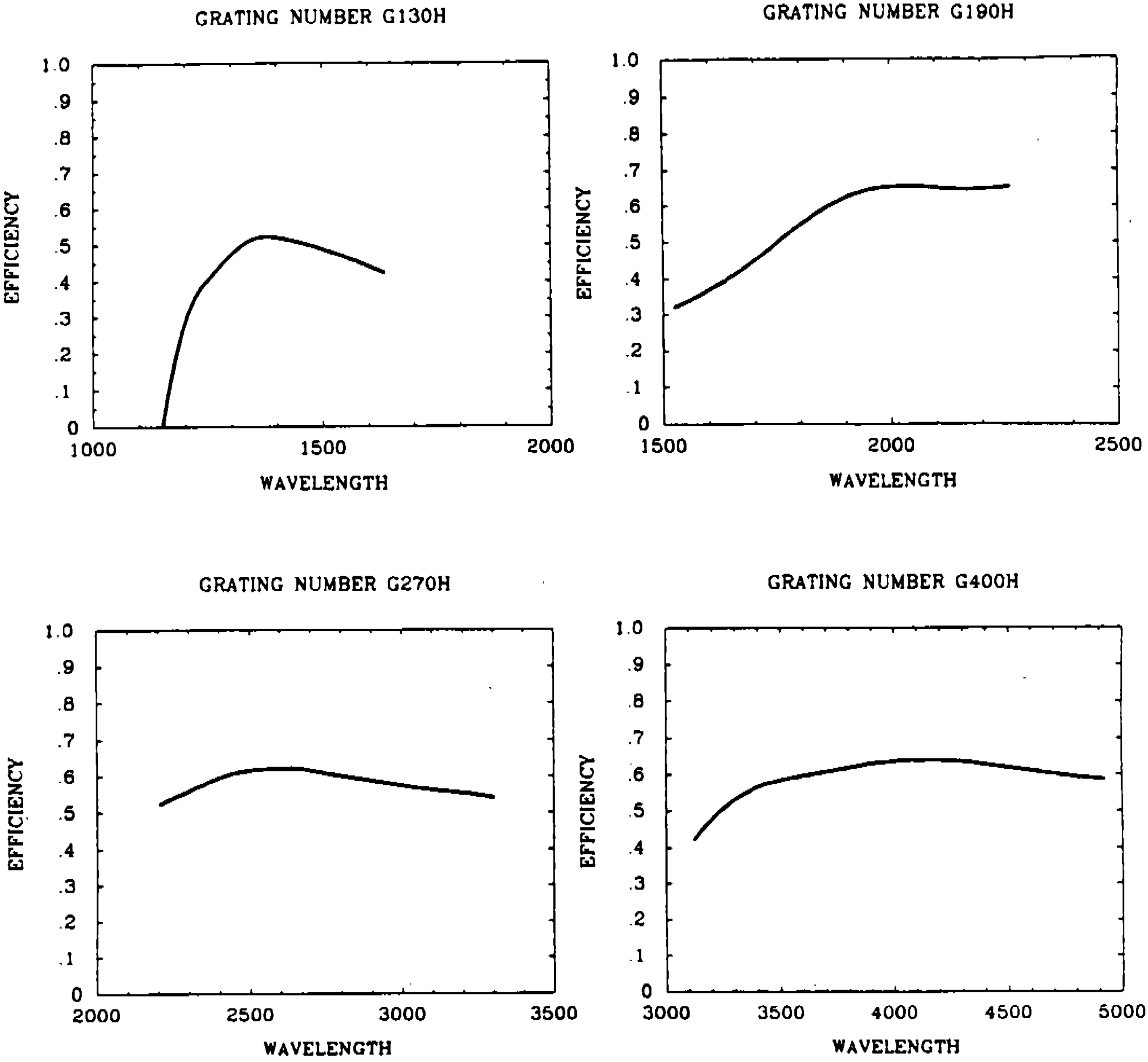
COLLIMATOR



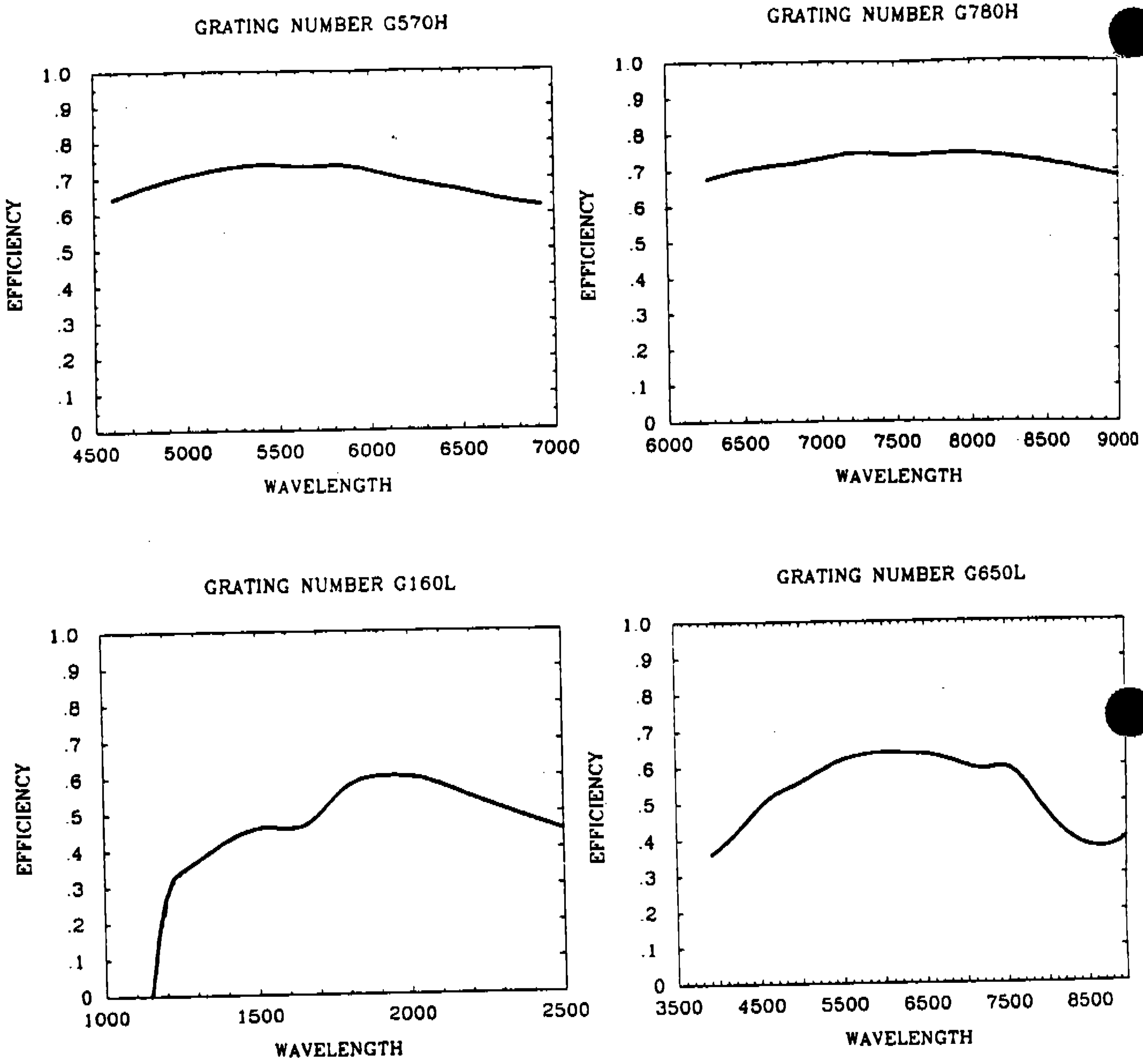
ASSUMED SPACE TELESCOPE EFFICIENCY



FOS COMPONENT CALIBRATIONS



FOS GRATING CALIBRATIONS



FOS GRATING CALIBRATIONS

3.1.5 Optical Focus. Once the FOS is in orbit, the optical focus is fixed - there are no mechanisms for changing the optical focus. Collimator focus is established by means of shimmed adjustments. The collimators are focussed to produce the parallel light beams that illuminate the focusing gratings. The distances between the entrance apertures and the collimators are adjusted to match the focal lengths of the collimators. The Digicon mounts are adjustable. By moving the Digicon along the light path that connects the focusing grating to the Digicon, the focus of images on the photocathode can be varied. Once the proper positions have been established, the FOS will remain in focus provided the alignment tolerances described in section 3.1.6 are not exceeded. Sensitivity to small movements of the optical elements can be estimated from the spacings of the optical elements, the f-ratios of the beams involved, and Digicon diode spacings and aperture dimensions. One way of defining a major change of focus is to consider a defocusing that amounts to one basic resolution element which is about one diode spacing at the Digicons or 50 microns. At the entrance aperture, a diode corresponds to 100microns, and the beam is f/24 - so a major change in focus would result if there were a 2400micron change in the distance from entrance aperture to collimator. At the detector, the beam is f/12 and a resolution element is about 50 microns - a major change in focus would result if the grating to Digicon photocathode distance changed by 600microns. These numbers are more than the combined alignment tolerances given in the next section.

3.1.6 Alignment and Tolerances. The final alignment criteria table from MMC CM-02 CEI CP-849AA0 REV. C is given as table 3.1.6-1. Figure 3.1.1-4 should be consulted for the coordinate system used in the alignment and tolerance specification. Tolerances or alignment envelopes are specified both for the duration of the mission and for a four hour period of observation with the FOS. The alignment envelopes for the entire mission are shown in figure 3.1.6-1 and the short term stability tolerance is shown in figure 3.1.6-2. Tolerances for positional repeatability for the moving mechanisms are given in figure 3.1.6-3. These figures also come from the MMC CM-02 document.

Table 3.1.6-1

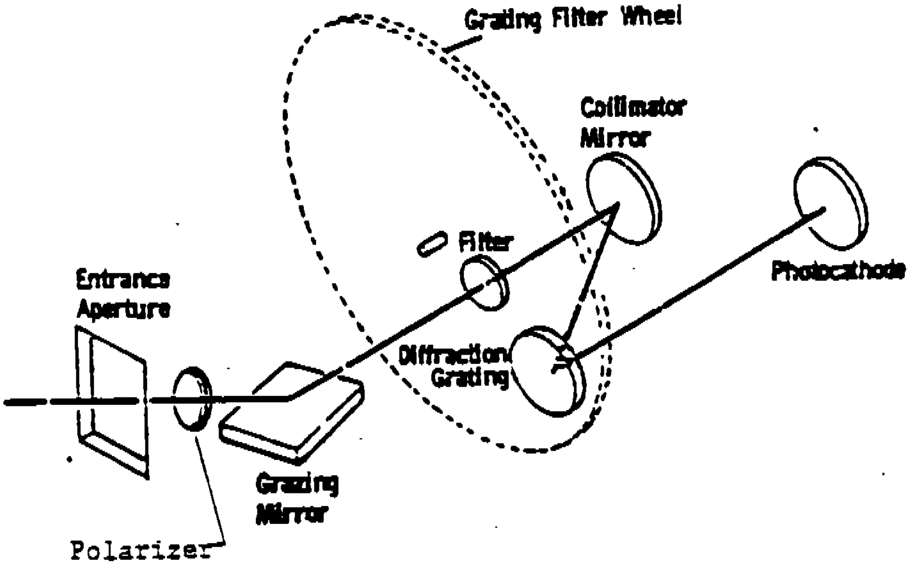
FINAL ALIGNMENT CRITERIA TABLE

ELEMENT	X	Y	Z	θx	θy	θz
	AXIS					
1) Grazing Mirror	← Capture all Light →	→	→	→	→	→
2) Collimator	(Capture all light) →	→	Focus at Aperture ± 100um	←	(Capture all light) →	→
3) Detector/Camera Mirror	Diode 256 ±20 diodes	±250um	↑	↑	↑	Red and Blue Detectors within 0.2°
4) Gratings(Detector) H13(Blue Prime)	Overlap H19, 155nm line at diode ≤510	↑ Deflection Current >1/4 max, <3/4 max	Instrument Profile*. Met with A4 Aperture	Instrument Profile*. Met in top and bottom spectra from A4 Aperture	Instrument Profile*. Met at <diode 100 and >diode 412	↑
H19(Blue Prime)	Overlap H19 and H27	↓	↓	↓	↓	↕
H27(Red Prime ; goal is both)	Overlap H19 and H40	↓	↓	↓	↓	0.2°
H40(Red Prime)	Overlap H27 and H57	↓	↓	↓	↓	↕
H57(Red Prime)	Overlap H40 and H78	↓	↓	↓	↓	↕
H78(Red)	Overlap H57	↓	↓	↓	↓	↕
Prism(Blue Prime)	All Red on Diode Array, Blue to 165nm and longer on Array	↓	↓	↓	Instrument Profile * at right and left of SPECTRA	↓
L15 (Blue Prime)	110nm λ Diode 437 ±25 Diodes	↓	↓	↓	↓	0.6°
L65(Red Prime)	400nm λ at Diode 75 ±25 Diode	↓	↓	↓	↓	0.6°

* The Instrument Profile shall be ≤1.2 diode widths FWHM for the Camera Mirror and for individual, isolated spectral lines.

ENTIRE PAGE SCN2

Element Name	X (um)	Y (um)	Z (um)	θ_X (Radians)	θ_Y (Radians)	θ_Z (Radians)
Entrance Aperture	±200	±200	±100	±2 (-2)	±2 (-2)	±2 (-2)
Grazing Mirror	±1000	±1000	±1000	±2 (-3)	±5 (-3)	±2 (-3)
Collimator	±100	±100	±100	±5 (-4)	±5 (-4)	±2 (-2)
Grating	±100	±100	±100	±2 (-3)	±2 (-3)	±3.5 (-3)
Photocathode	±200	±200	±200	±3.5 (-2)	±8.7 (-3)	±3.5 (-3)
Waveplate	±500	±500	±5000	±6.2 (-3)	±6.2 (-3)	±8.7 (-3)
Wollaston Prism	±500	±500	±5000	±6.2 (-3)	±6.2 (-3)	±4.4 (-3)



Polarizer
Waveplate
Wollaston Prism

(1) The initial alignment position in θ_Z is arbitrary but once established, should be determined to the accuracy specified.

Figure ~~3.2.1.2.1-3~~ 3.1.6-1

Alignment Tolerances - The optical components above must remain within the alignment envelopes specified throughout the orbital lifetime of the instrument during operation.

Element Name	X (um)	Y (um)	Z (um)	θ_X (Radians)	θ_Y (Radians)	θ_Z (Radians)
Entrance Aperture	± 3.0	±3.0	±25	±1(-2)	± 1 (-2)	±1(-2)
Grazing Mirror	±200	±15	±500	±1.5(-5)	± 1.2(-6)	±1(-3)
Collimator	±1.5	±3.8	±25	±7.4(-6)	±3.8(-6)	±1.0(-2)
Grating	±3.0	±7.5	±25	±5.9(-6)	±7.5(-6)	±0.6(-3)
Photocathode*	±10.7	±10.6	±140	±1.7(-4)	±1.6(-4)	±8.5(-4)
1) Photocathode w.r.t. Housing	±7.6	±7.5	±99	±5.1(-5)	±5.0(-5)	±6.0(-4)
2) Housing w.r.t. Optical Axis	±7.6	±7.5	±99	±1.6(-4)	±1.5(-4)	±6.0(-4)
Polarizer						
1) Waveplate	±250	±250	±1000	±3.1(-3)	±3.1(-3)	±6.0 [illegible]
2) Wollaston Prism	±250	±250	±1000	±3.1(-3)	±3.1(-3)	±1.7(-3)

*The total error permitted for the photocathode is allocated to 1) the photocathode with respect to the housing of the detector and 2) the detector housing with respect to the optical axis.

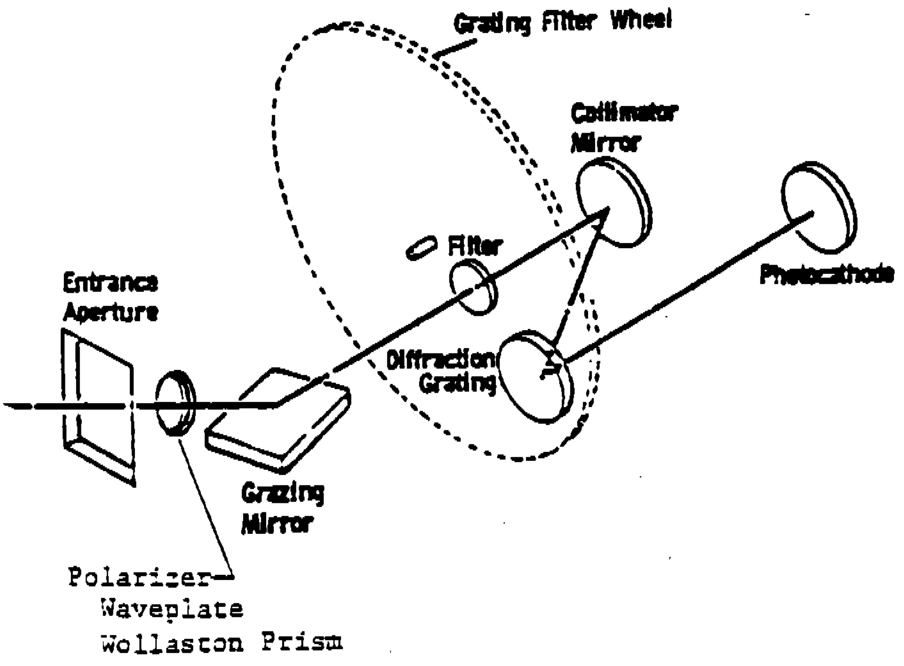


Figure 3.1.6-2 ~~3.2.1.2.1-4~~

Observational Stability - Each component must not deviate more than specified during a four-hour observation.

Element Name	X (um)	Y (um)	Z (um)	θ_X (Radians)	θ_Y (Radians)	θ_Z (Radians)
Entrance Aperture	±6	±6	±25	±1(-2)	±1(-2)	±1(-2)
Gratings	±20	±25	±25	±43(-5)	±4.3(-5)	±3.2(-4
Waveplate	±250	±250	±1000	±16(-3)	±16(-3)	±6.0(-3
Wollaston Prism	±250	±250	±1000	±16(-3)	±16(-3)	±17(-3)

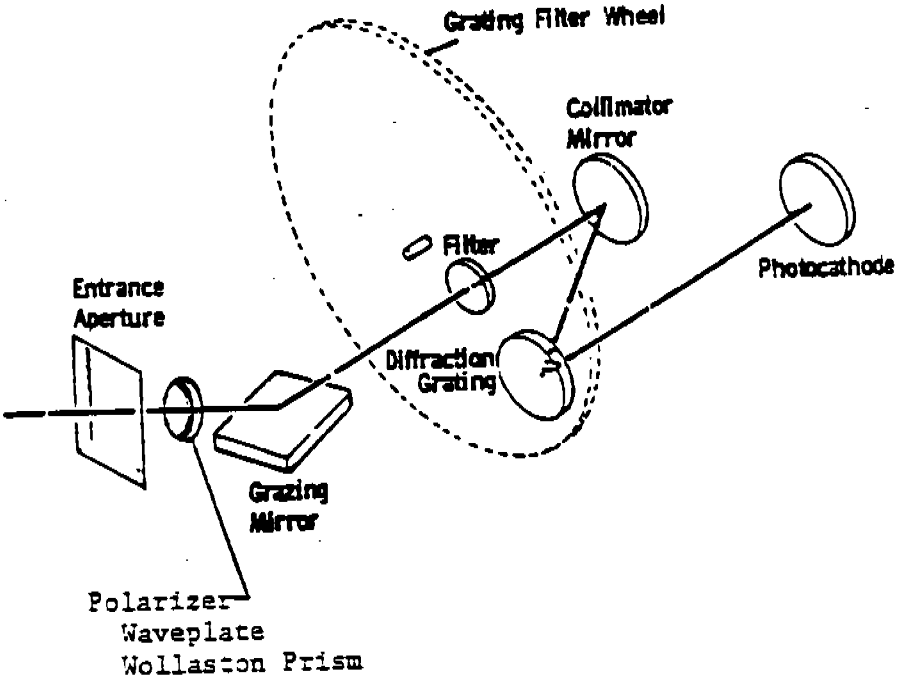


Figure ~~3.2.1.2.1-5~~ 3.1.6-3

Positional Repeatability of Moving Mechanisms - Each mechanism shall maintain the tolerances specified, measured upon return to the original position.

3.2 Mechanical

This section is divided into two major headings: 1. structures and 2. mechanisms. The structures include the enclosure and the optical bench. The mechanisms consist of the entrance port, entrance aperture, polarizer, and filter/grating wheel.

mitting window of magnesium fluoride. The lamps emit spectral lines over a wavelength range from 0.11 to 0.90 micrometers. The radiance of each lamp permits wavelength determinations in an exposure time not to exceed 100 seconds (and generally much less). Wavelength determination is done to better than twenty percent of the instrument profile width. Optical elements are provided to direct light from wavelength lamps into each light path (red and blue). Each lamp is usable with each light path. The calibration lamps and optical elements are all mounted on the forward bulkhead of the FOS enclosure. The flat field LED's are mounted on the baffle near the filter/grating wheel.

Stray light is reduced to the minimum practical level through use of low scattering optical surfaces, careful control of particulate contamination, and attenuation of stray light by baffles, light traps, and surface blackening. Attenuation of undesired grating orders is provided by blocking filters or the digion faceplate along with baffles and zero order light traps. There are five baffles made of perforated aluminum sheets coated with black paint. Three baffles are located between the grazing mirror and the filter/grating wheel, one around the filter/grating wheel and one between the filter/grating wheel and the collimator mirror.

Light traps are installed to prevent zero order light from propagating to the detector. Each trap is a wedge-shaped box whose interior surfaces are low scattering black surfaces. The traps are placed close to the front face of the detector, but do not intrude into the desired light beams going to the photocathode.

3.2.1 ~~4.2~~ Structures

The FOS structural system's primary function is to support the detectors, optical and electrical components through launch and during operation in space. The two major subassemblies are the enclosure and the optical bench. Figure ~~3-1~~ 2.0-1 illustrates the general arrangement.

3.2.1.1 Enclosure

The SI enclosure provides the structural, mechanical, electrical, and thermal interfaces with the OTA. The optical bench is supported at three points inside the enclosure. Electrical components are mounted on the shelf, which also serves to separate the enclosure into optical and electrical compartments. The enclosure is the structure to which the majority of the thermal control components are affixed. An exterior view of the assembly is shown on Figure ~~4.2-1~~ 3.2.1.1-1.

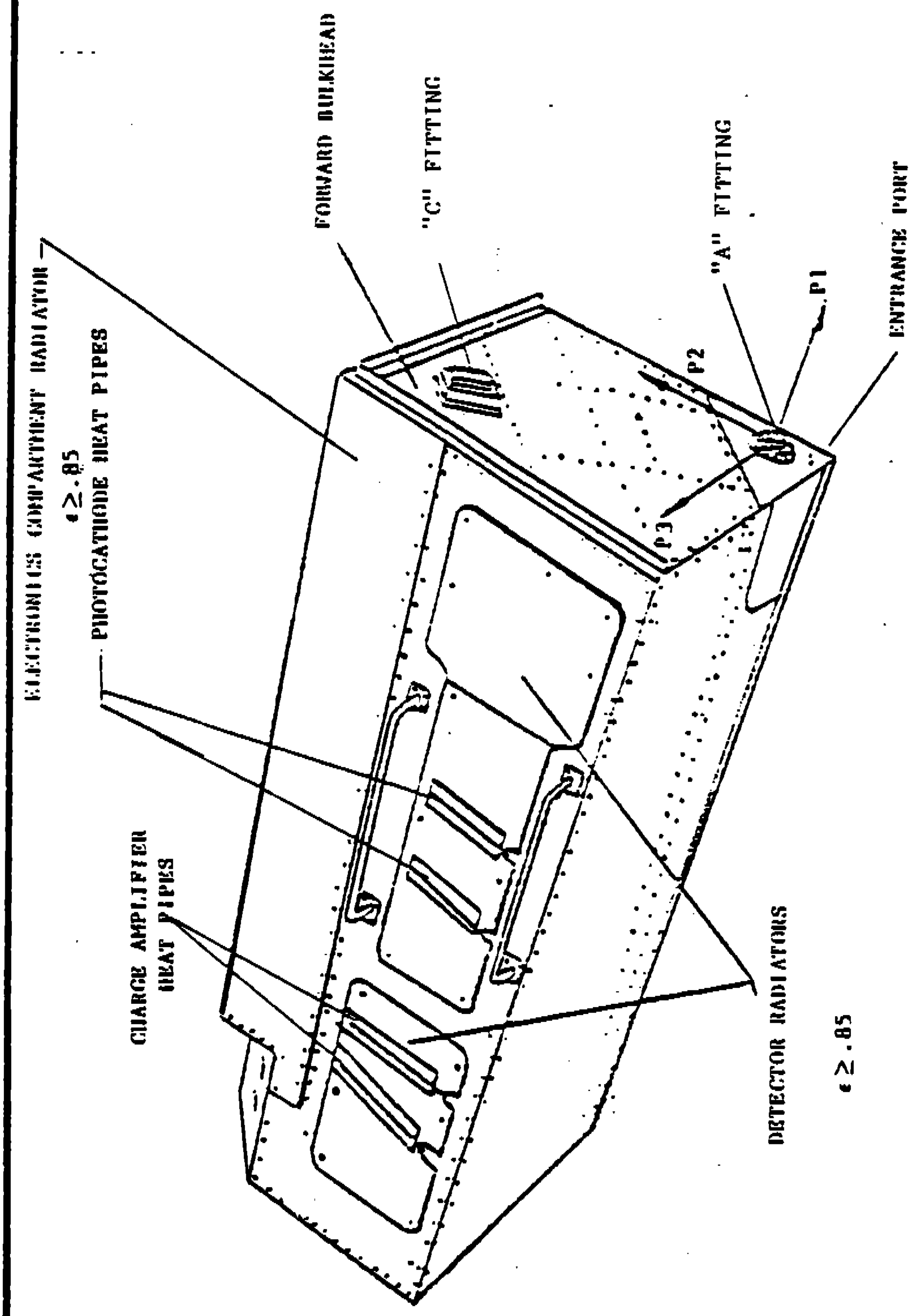


FIGURE 4 FOS EXTERIOR

The enclosure structure consists of fore and aft bulkheads, two longerons, an electronic equipment shelf, fixed and removable side (shear) panels and corner stringers. The forward bulkhead supports the "A" and "C" registration fittings and the forward guide rails. The aft bulkhead supports the "B" registration fitting and aft guide rails. The aft bulkhead also is the location for the aspirating filter-vent.

3.2.1.2 Optical Bench

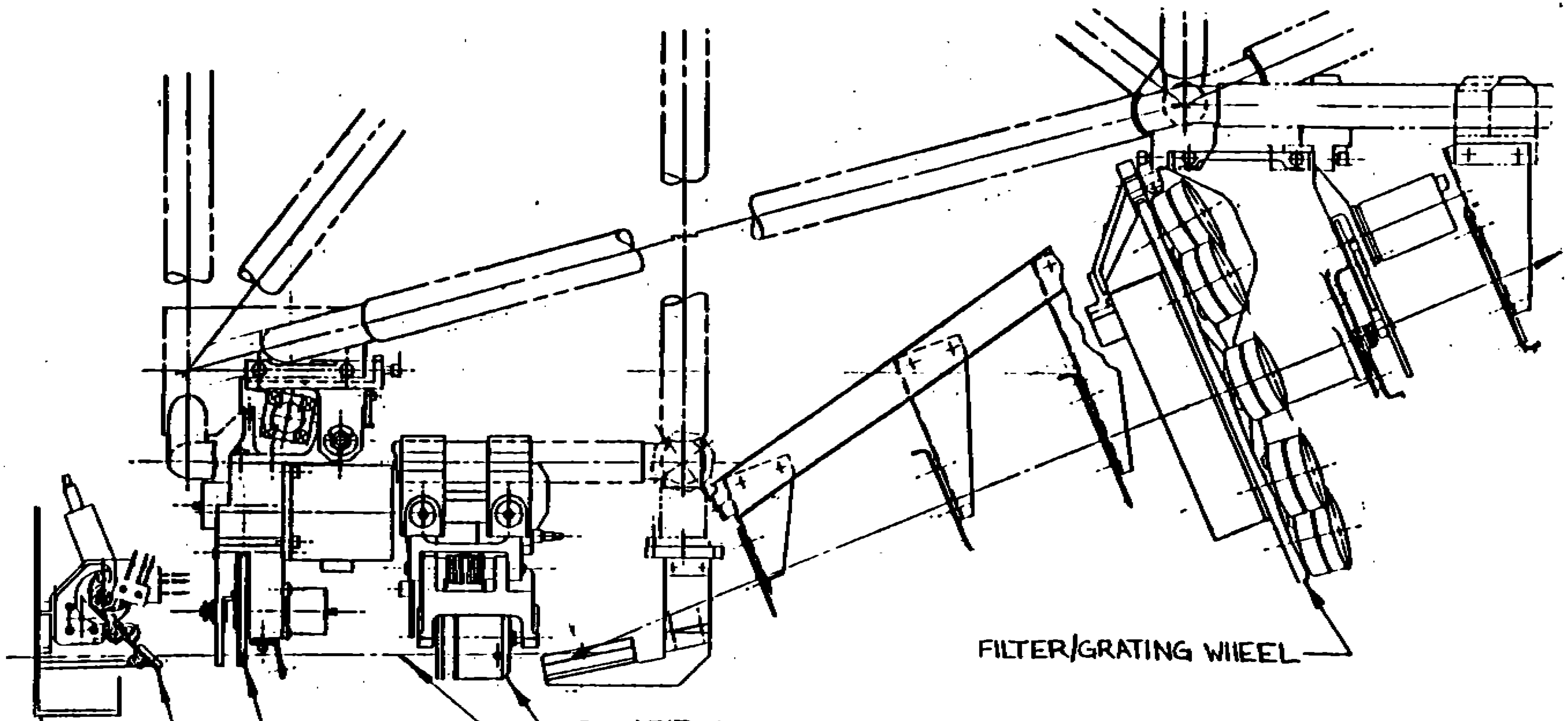
The optical bench is a space truss designed to meet structural stiffness and thermal characteristics requirements. It is a true composite structure in that graphite epoxy tube members are bonded to invar welded tube intersections to form the truss structure. The optical bench is mounted in the enclosure with a statically determinate three-point attachment. The forward end of the bench is attached to the forward bulkhead with a ball/split socket mount that is located in line with the forward spherical registration detent (A fitting). At the forward end, an adjustable linkage is mounted tangentially to obtain optical bench rool adjustment and restraint. The optical bench pitch and yaw adjustments and restaints are effected by two adjustable links attached to the aft end. The two adjustable links are in turn attached to a common point on the aft bulkhead in line with the aft spherical registration detent (B fitting). This mounting technique isolates the optical bench from the enclosure and effects a direct structural connection of the bench to the OTA latch mechanism. Hence, thermal and mechanical instabilities of the enclosure will have minimal effect on the alignment of the optical bench.

3.2.2 4.3 Mechanisms

The FOS mechanisms consist of the entrance port, entrance aperture, polarizer and filter/grating wheel. The general arrangement of the four mechanisms and their location on the FOS structure is shown in Figure 4.3-1. 3.2.2-1

The entrance port mechanism shown in Figure 4.3-2 allows light to enter through both, or closes off, both entrance ports in the forward bulkhead. In the closed position, the mirror on the inboard side of the shutter directs light from the wavelength calibration system to the entrance apertures. The shutter

MECHANISMS



[illegible]URE 4.3-1 3.2.2-1

3.2.2.1 Entrance Port. The entrance port mechanism, which is shown in figure 3.2.2.1-1, allows light to enter through both or closes off both openings in the forward bulkhead. When the entrance ports are closed, a mirror directs light from the wavelength comparison lamps to the entrance apertures. The door is operated by a 90° size 11 stepper motor which drives an eccentric bearing through a 12:1 gear reduction. The entrance door is controlled by the command YENTRNC. The door position is indicated by the telemetry quantity YDOOR (see table 3.6.2-1). The Fail-Safe Mode critical commands YARMED and YBLENT command a burn wire pinpuller to permanently open the door.

3.2.2.2 Entrance Aperture Wheel The aperture wheel mechanism accurately places any of twelve pairs (B4 is blank) of apertures into operating position in the two light paths. The mechanism is shown in figure 3.2.2.2-1 and the apertures are described in Table 3.2.2.2-1. The size and orientation of the apertures is illustrated in figure 3.2.2.2-2 (and figure 3.1.4.2-1). They are arranged around the perimeter of a wheel (as shown in Fig. 3.6.2.2-1) which is driven through a two stage 80:1 antibacklash gear reduction by a 1.8° size 23 stepper motor. The command YAPER moves the aperture wheel. Two 8-pin contact encoders provide unique output (YAPERPOS) for each position of the aperture wheel. The select codes and return telemetry codes are given in table 3.2.2.2-1. The down-linked values (listed as Hex T/M in table 3.2.2.2-1) must be converted to mapped codes by taking the one's complement and then converting each byte from Gray to binary. The encoder values are not exact, there is normally a non-zero dead band value stored in the mechanism control block (see section 3.6.3.2). Each encoder has both a positive and negative deadband, and these must be used in interpreting the telemetry returned from this mechanism. The slow encoder may produce ambiguous positions as the instrument ages. A single revolution of the fast encoder moves the slow encoder by a small amount - this angle is close to the deadband and error tolerance of the slow encoder. So with age and vibration, the aperture wheel may move to a "ghost" position that is one full turn of the fast encoder away from a true position. One possible solution, if there are ambiguities, is to change the operation to allow counting of motor steps to a certain tolerance before the physical encoder value is compared to the encoder value in the mechanism table and positioning is completed. In FAIL-SAFE mode, commanded by critical commands YARMAP and YBLAPR, a burn wire pinpuller stroke allows torsion springs to rotate the aperture wheel out of, and a pair of failsafe apertures into, the light paths. The failsafe apertures are 4.3" square and 0.5" square, separated by 4.4" and are the same on each detector side (A and B).

The apertures are not uniformly spaced around the aperture wheel itself. The time required to move from one aperture to another depends on the direction chosen. This is explained in a note to Table 3.6.5-1 and a schematic of the aperture spacing in time units is given in Figure 3.6.5.2-1.

Expected mechanism lifetime is 30,000 rotations averaging 90°. This is for the aperture wheel motor (ref. section 4.7).

ENTRANCE PORT

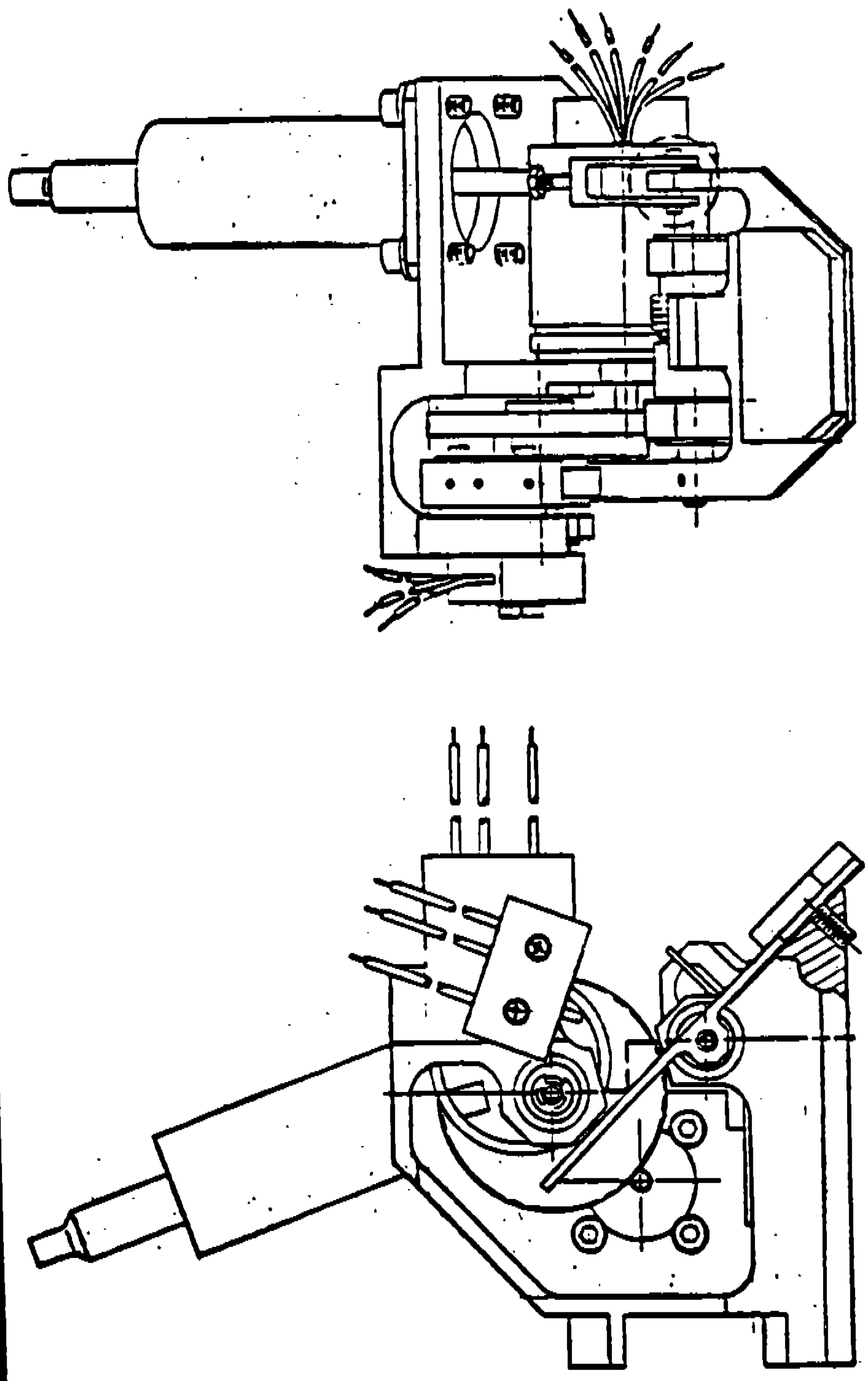


FIGURE 4.3-2

ENTRANCE APERTURE - CROSS SECTION

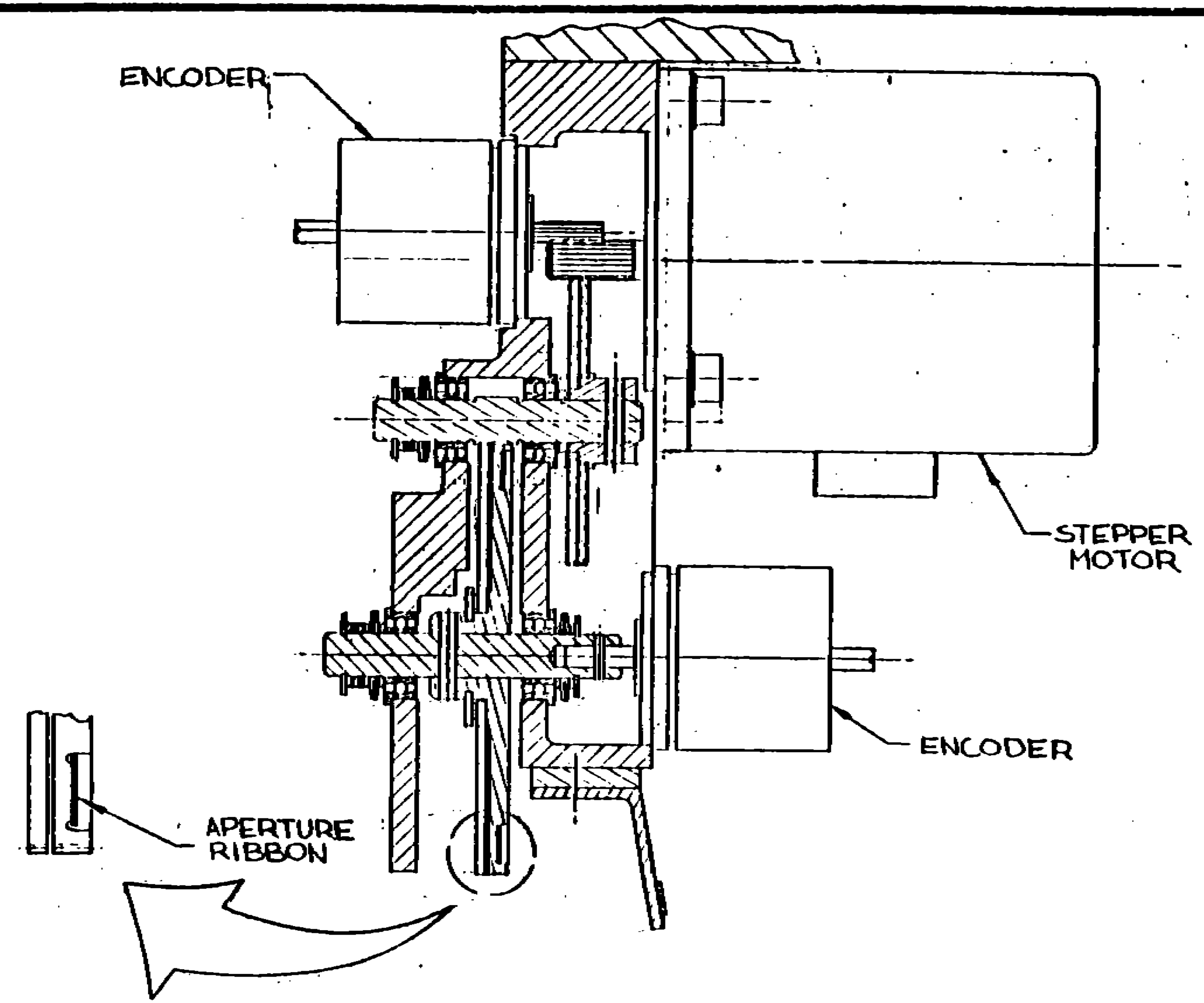


FIG. 4.3-3

POLARIZER

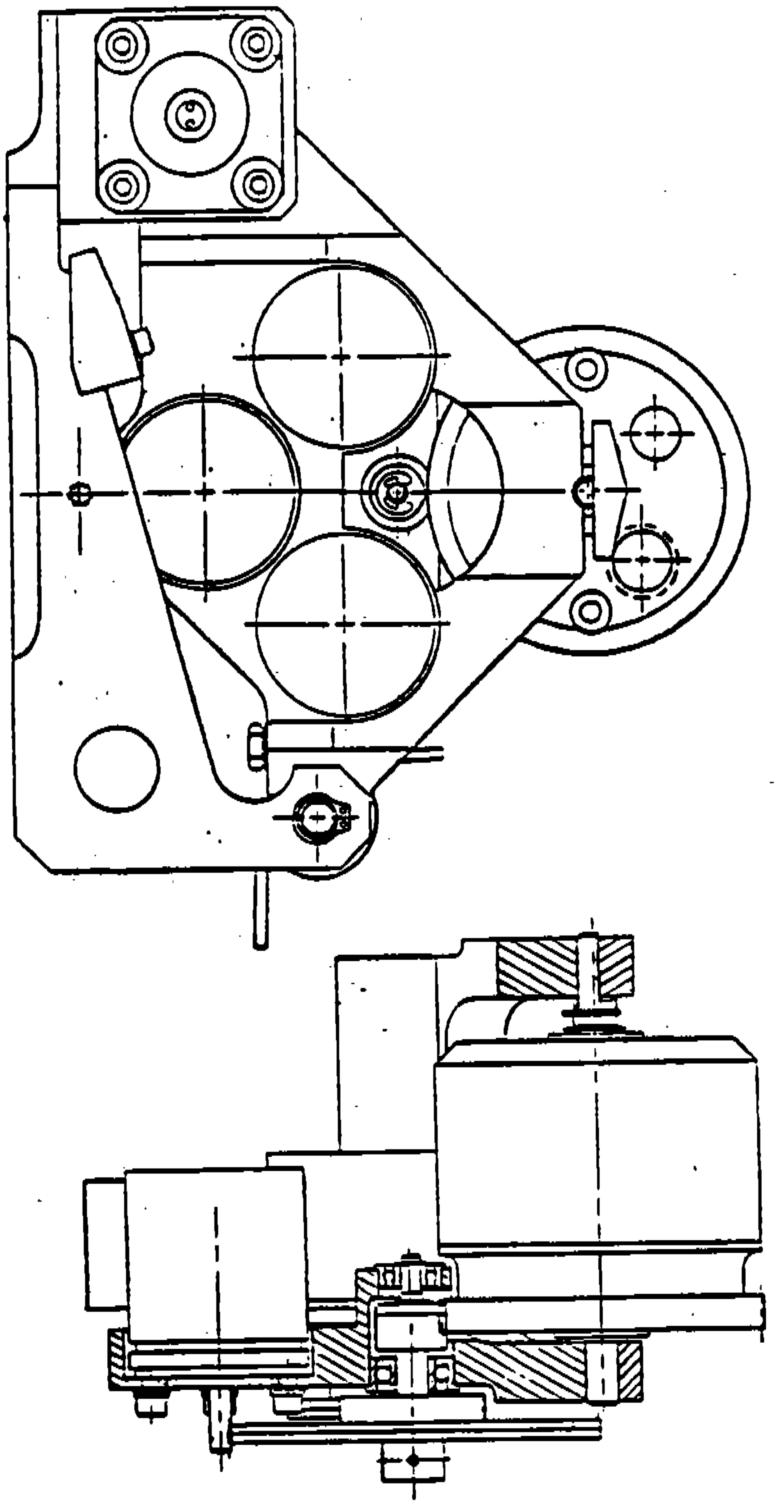


FIGURE 3.2.2.3-1

3.2.2.3 Polarizer. The polarizer mechanism, shown in figures 3.2.2.3-1 and 3.2.2.3-2, places two waveplate/Wollaston prism pairs in the two light paths or places openings in the light paths and rotates each waveplate in 22.5° increments with respect to its Wollaston prism. The Wollaston prisms are mounted in a rotating cylinder drive through a two stage 105:1 antibacklash gear reduction by a 90° size 11 stepper motor. The waveplates are mounted to a gear within the cylinder in such a way that one revolution of the cylinder results in 1 1/16 revolution of the waveplates with respect to the Wollaston prisms. The command to set the polarizer is YPLZR. Position indication is provided by two 8 bit pin contact encoders which provide a unique output (YPLRZPOS) for each position of the polarizer. Table 3.2.2.3-1 gives the mapped-encoder values for each of the 48 positions of the polarizer that the command YPLZR controls. Encoder values are stored in the polarizer mechanism control block (see section 3.6.3.2). Different values are stored for the two independent optical path/electronic groups side A and side B. This was done so that the command values sent up to the FOS have the same meaning for both sides in the sense that each value positions a specified optical element and angle into the currently active beam independent of which beam is active. Also this means that there are a minimum number of command values each corresponding to a non-blocked position of the polarizer. The down-linked encoder values must be converted to mapped values by taking the one's complement and then converting each byte separately from Gray to binary. The encoder values are not exact, normal operation is anticipated with a non-zero deadband for the polarizer mechanism. Fail safe mode is by means of critical commands YARMPL and YBLPOL, which cause a burn-wire pinpuller to allow torsion springs to rotate the polarizer permanently out of the light paths.

Polarizer lifetime is expected to be 100,000 motor increments of 22.5° (ref. section 4.7).

Table 3.2.2.3-1 FOS Polarizer Command and Encoder Values

~~Table 3.1-4 FOS Polarizer Information~~

CMD ~~Pos~~	ID	Encoder Map For Side A (Hex)	Encoder Map For Side B (Hex)
01	C01	B7 C6	B7 C6
02	A01	77 82	65 6C
03	B01	09 0F	F7 FA
04	C02	B7 B6	B7 B6
05	A02	77 72	65 5C
06	B02	09 FF	F7 EA
07	C03	B7 A6	B7 A6
08	A03	77 62	65 4C
09	B03	09 EF	F7 DA
10	C04	B7 96	B7 96
11	A04	77 52	65 3C
12	B04	09 DF	F7 CA
13	C05	B7 86	B7 86
14	A05	77 42	65 2C
15	B05	09 CF	F7 BA
16	C06	B7 76	B7 76
17	A06	77 32	65 1C
18	B06	09 BF	F7 AA
19	C07	B7 66	B7 66
20	A07	77 22	65 0C
21	B07	09 AF	F7 9A
22	C08	B7 56	B7 56
23	A08	77 12	65 FC
24	B08	09 9F	F7 8A
25	C09	B7 46	B7 46
26	A09	77 02	65 EC
27	B09	09 8F	F7 7A
28	C10	B7 36	B7 36
29	A10	77 F2	65 DC
30	B10	09 7F	F7 6A
31	C11	B7 26	B7 26
32	A11	77 E2	65 CC
33	B11	09 6F	F7 5A
34	C12	B7 16	B7 16
35	A12	77 D2	65 BC
36	B12	09 5F	F7 4A
37	C13	B7 06	B7 06
38	A13	77 C2	65 AC
39	B13	09 4F	F7 3A
40	C14	B7 F6	B7 F6
41	A14	77 B2	65 9C
42	B14	09 3F	F7 2A
43	C15	B7 E6	B7 E6
44	A15	77 A2	65 8C
45	B15	09 2F	F7 1A
46	C16	B7 D6	B7 D6
47	A16	77 92	65 7C
48	B16	09 1F	F7 0A

POLARIZER - CROSS SECTION

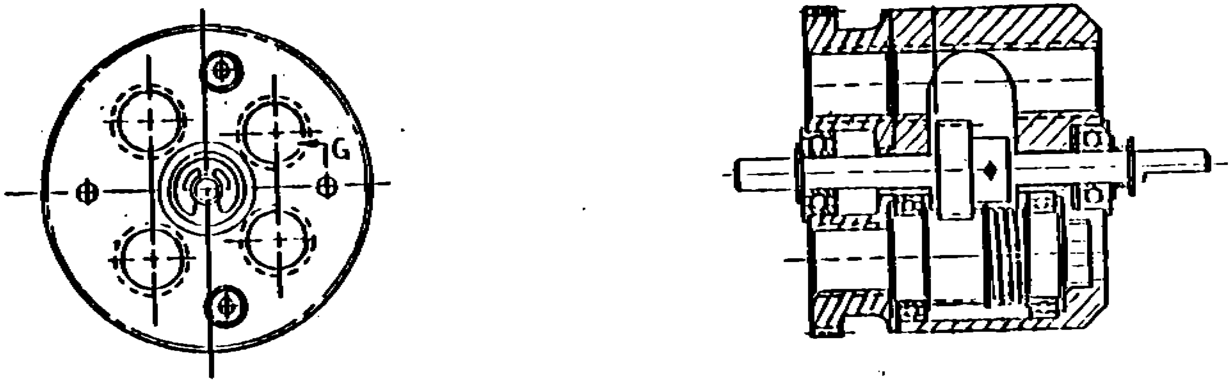


FIGURE 2.2.3-2

FILTER/GRATING WHEEL

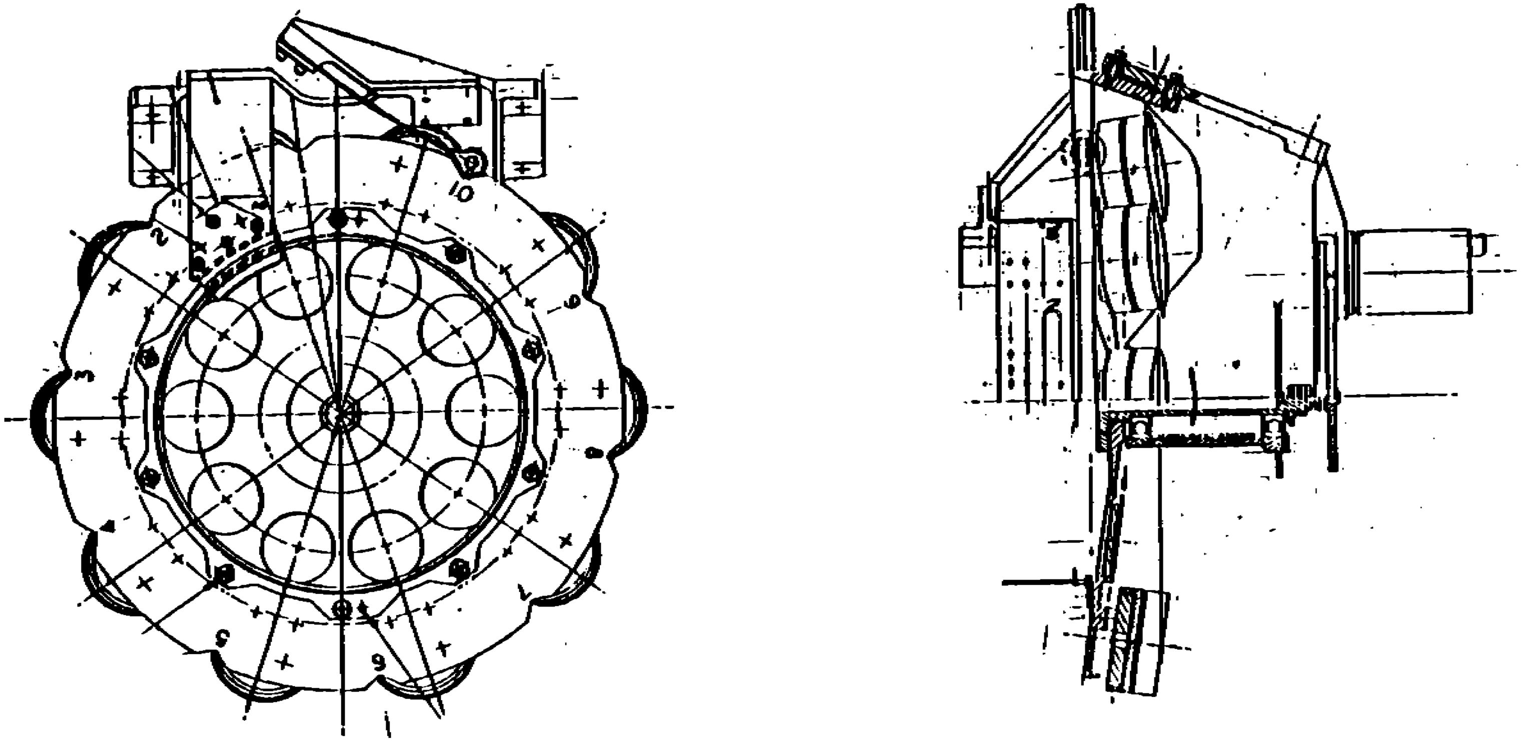


FIGURE 4-3-6

3.2.2.4 ~~3.2.4~~ Filter Grating Wheel Assembly. The FGWA shown in figure 3.2.2.4-1 accurately places a selected set of optical elements (grating or prism and attendant filter) into either (but not both) of the two light paths. The FGWA is driven through a two stage 90:1 gear reduction by one of two redundant size 15 stepper motors, and accurate positioning is determined by a spring loaded ball bearing cam detent. Position indication is by means of a LED/Phototransistor array and coded cylinder which provide a signal to stop the motor and a unique output for each position of the wheel (YFGWAPOS). Fail-Safe Mode is by means of the redundant stepper motor which operates the mechanism if the primary motor fails. Motor lifetime is expected to be 54,000 rotations of 90° for each motor (ref. section 4.7). These rotations were assumed to be in both directions, which may not be true if a preferred rotation direction is used to avoid FGWA seating repeatability problems. Current FGWA uncertainty results in a 50 micron image shift on the digicon diodes, or approximately 1/3 arcsecond. Tests are planned for drive and seating techniques to reduce this non-repeatability. Table 3.2.2.4-1 lists the optical elements on the FGWA with command and encoder values. Figure 3.2.2.4-2 shows a schematic of their arrangement.

Table 3.2.2.4-1 ~~3.2.4-1~~

FOS FGWA Elements

Type	Grating ID Old	Grating ID New	Resolution	Filter	Wavelength (nm)	Side A Cmd	Side A Encod	Side B Cmd	Side B Encod
Grating	H13	G130H	1200	----	110-164	9	A	4	B
Grating	H19	G190H	1200	----	153-228	7	7	2	9
Grating	H27	G270H	1200	FH27	221-329	6	E	1	C
Grating	H40	G400H	1200	FH40	319-474	10	6	5	3
Grating	H57	G570H	1200	FH57	459-683	8	5	3	D
Grating	H78	G780H	1200	FH78	626-931	4	B	9	A
Grating	L15	G160L	200	----	115-230	1	C	6	E
Prism	PRI	PRISM	100	----	250-700	3	D	8	5
Grating	L65	G650L	200	FL65	400-800	2	9	7	7
Mirror	CAM	~~CAMRA~~ MIRROR	1	----	110-900	5	3	10	6

4.6 3.3 Thermal

The thermal control subsystem uses a passive design augmented with heat pipes and electric heaters to maintain the instrument components within the required temperature limits. The design is cold-biased to permit temperature control within the desired range by a combination of radiators and electric heaters. The concept is illustrated in Figures 4.6-1 3.3-1 and 4.6-2. 3.3-2.

The FOS instrument has been divided into optics and electronics compartments which are thermally isolated to the maximum extent feasible.

3.3.1 Optics Compartment - The optics compartment contains the optical bench, the optical elements, the two detector assemblies with the charge amplifiers, the optics mechanisms, and the calibration sources with their power supply.

The interior of the compartment is insulated with multilayer insulation blankets. The blankets are formed by ten layers of perforated double aluminized mylar, 1/4-mil thick, alternated with dacron net spacers. A polyester screen cloth is used as a filter to prevent any particle trapped within the insulation from escaping during ascent venting. Aluminized kapton sheet, 2-mil thick, forms the insulation covers. For stray light control, the insulation side facing the interior of the compartment is painted black.

The compartment optical bench and components are maintained at 16°C ± 4°C with a redundant electric heater system. Film heaters are attached to six aluminum panels located at the inboard sides of the FOS facing the optical bench structure, three panels per side. Each panel is approximately 24 by 9 inches, and is temperature controlled by a sensor located on the panel. The heater power requirements are approximately 38 watts for the cold operating conditions.

The detectors' photocathodes are maintained at low temperature ($\leq$ -8°C) to satisfy the detector dark count requirements. This is accomplished with heat pipes that transfer thermal energy from the detector assemblies to radiators located on the FOS sides facing the SSM walls.

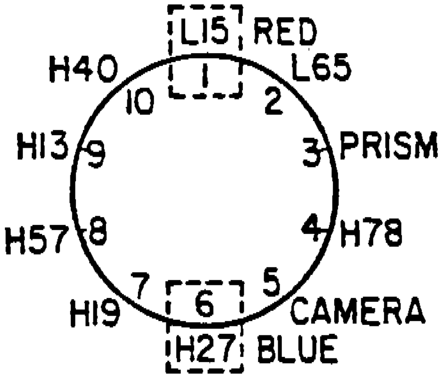


FIGURE ~~3.2.4-1~~ 3.2.2.4-2

DISPOSITION OF THE OPTICAL ELEMENTS AROUND THE FGWA

~~3.3 Thermal Design: TBD~~

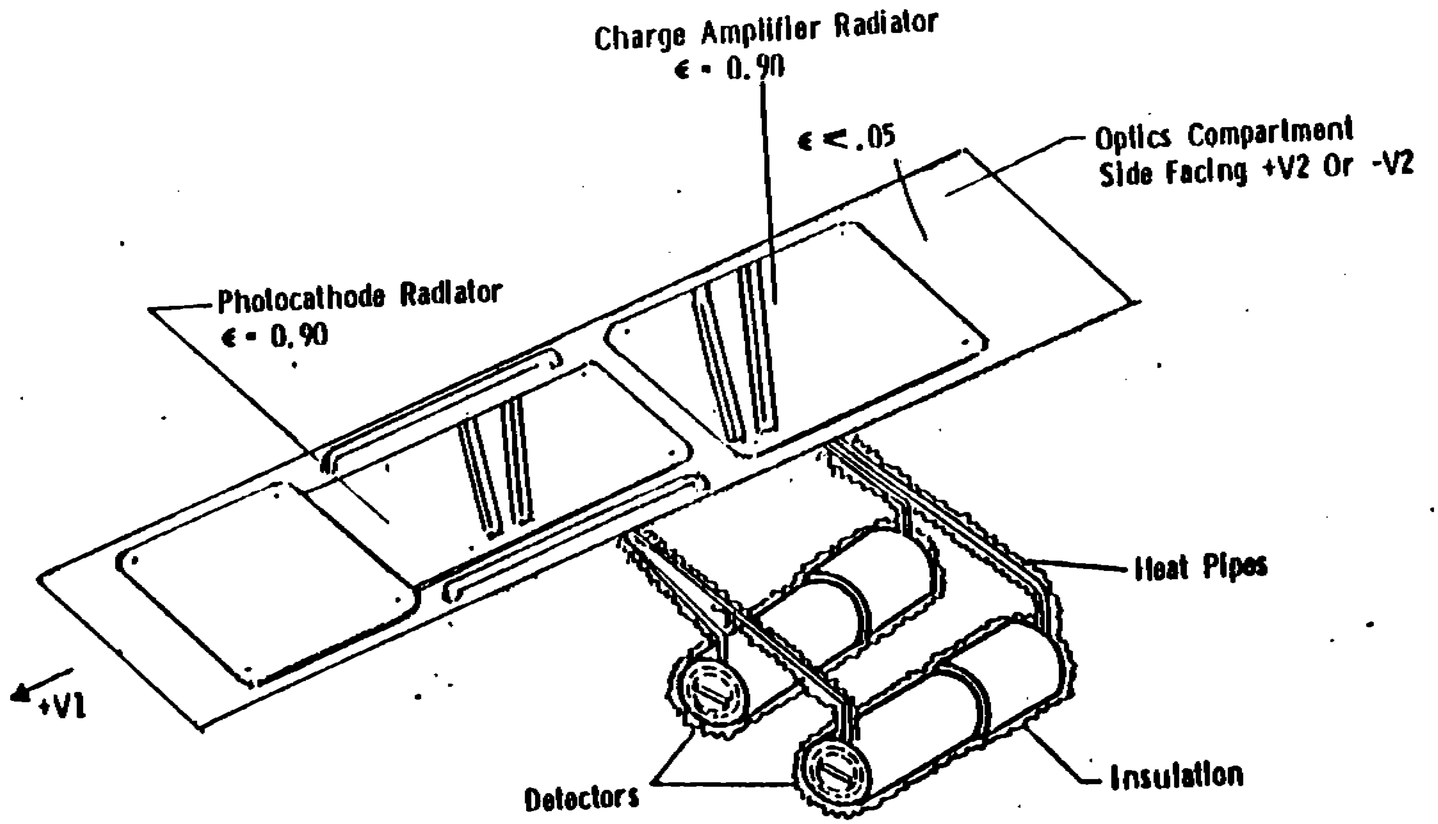
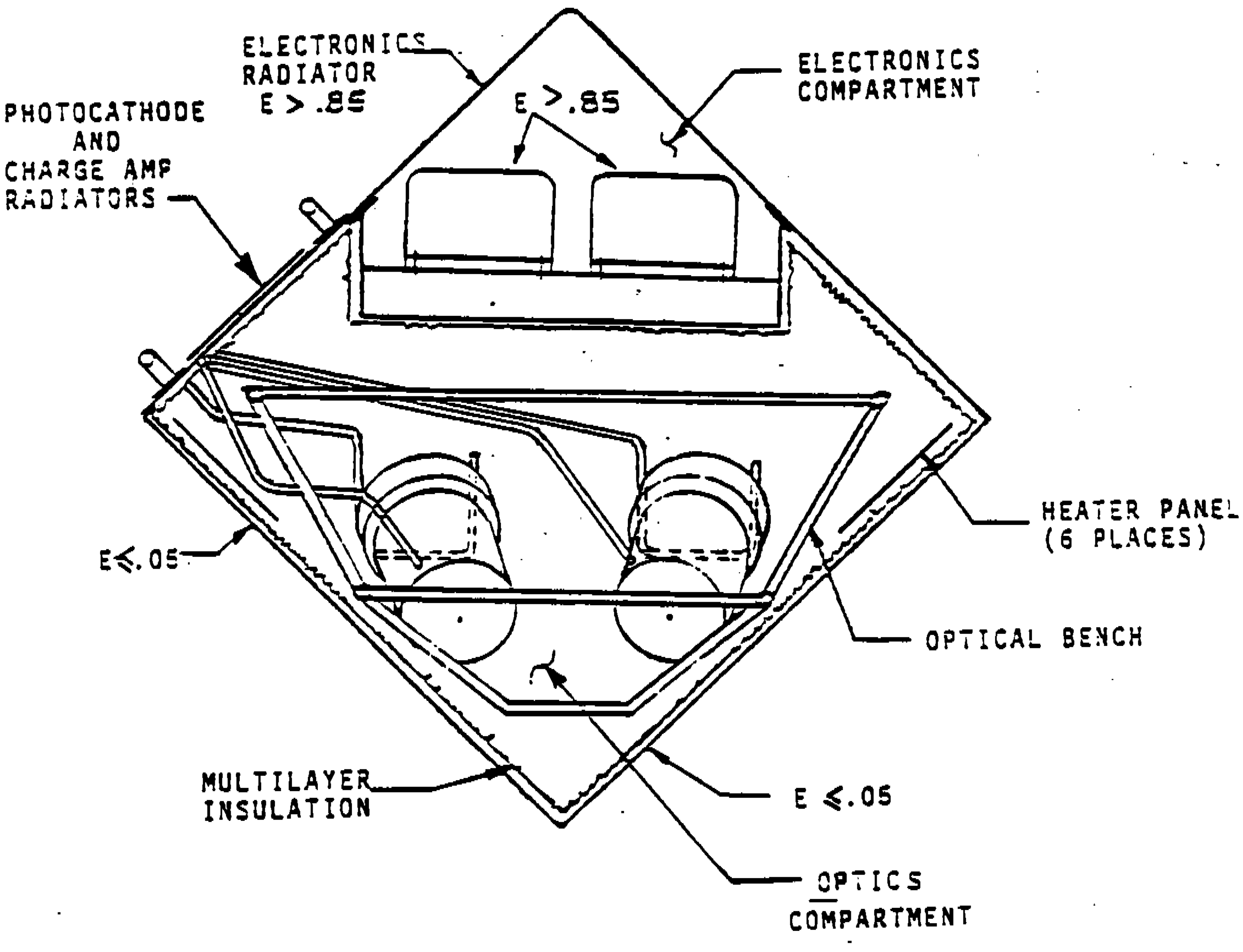


Figure ~~4.6-2~~ 3.3-2 DETECTOR THERMAL CONTROL

3.3-1
FIGURE ~~4.6-1~~

THERMAL CONTROL SUBSYSTEM



VIEW LOOKING AFT

The temperature of the detector assembly components, (digicon, permanent magnets, deflection coils, and charge amplifier) during the FOS operating modes are within the specified range; therefore, no heater power is required for these modes.

For monitoring of the thermal performance of the compartment components, sensors are located at the main mechanical interfaces with the OTA, at the optical bench attach links, and on some critical optics components. In addition, sensors will monitor the temperature near the photocathode, diode array, coil assemblies, and charge amplifiers.

3.3.2 Electronics Compartment - The electronics compartment contains all the support electronics required for the operation of the FOS including the SI C&DH Remote Interface Units.

The electronic boxes are attached to an aluminum structural shelf and radiate the internally generated heat through the covers to the compartment radiators. The compartment dissipation is approximately 100 watts. No additional heater power is required while the electronics is operated during hot or cold operating modes.

4.7 Ground Support and Test Equipment

The Ground Support Equipment (GSE) for the FOS consists of the Interim Electrical GSE (IGSE) and mechanical GSE.

IGSE - The FOS IGSE is capable of exercising the FOS via the command interfaces and verifying the correct instrument performance via the science data interface and the engineering data interface. Figure 4.7-1 shows a block diagram of the IGSE. The heart of the IGSE is the Texas Instruments FS990 Microprocessor Development system which is mounted in a desk type console along with the floppy disk, CRT, keyboard and printer.

The IGSE hardware simulates the command, Engineering Data and Science Data interfaces of the SI C&DH as defined in the SI to SI C&DH IBM No. 7936229. The Programmable Power Supply is programmable from the FS990 and can be programmed from 0 to 32 volts dc.

3.3.2 A schematic of the design configuration is presented in Figure ~~4.6-2~~. The two detectors are coupled with four heat pipes to two separate radiators: the photocathode end of the detectors to one radiator and the charge amplifier end to the other. This arrangement, with a separate path for the charge amplifier heat dissipation (approximately eight watts), minimizes the impact of the digicon/charge amplifier configuration constraints upon the photocathode temperatures. The charge amplifiers, housed within the detector magnetic shields, are mounted as close as feasible to the diode array side of the digicons and are thermally coupled through 520 electric wires to the diode array.

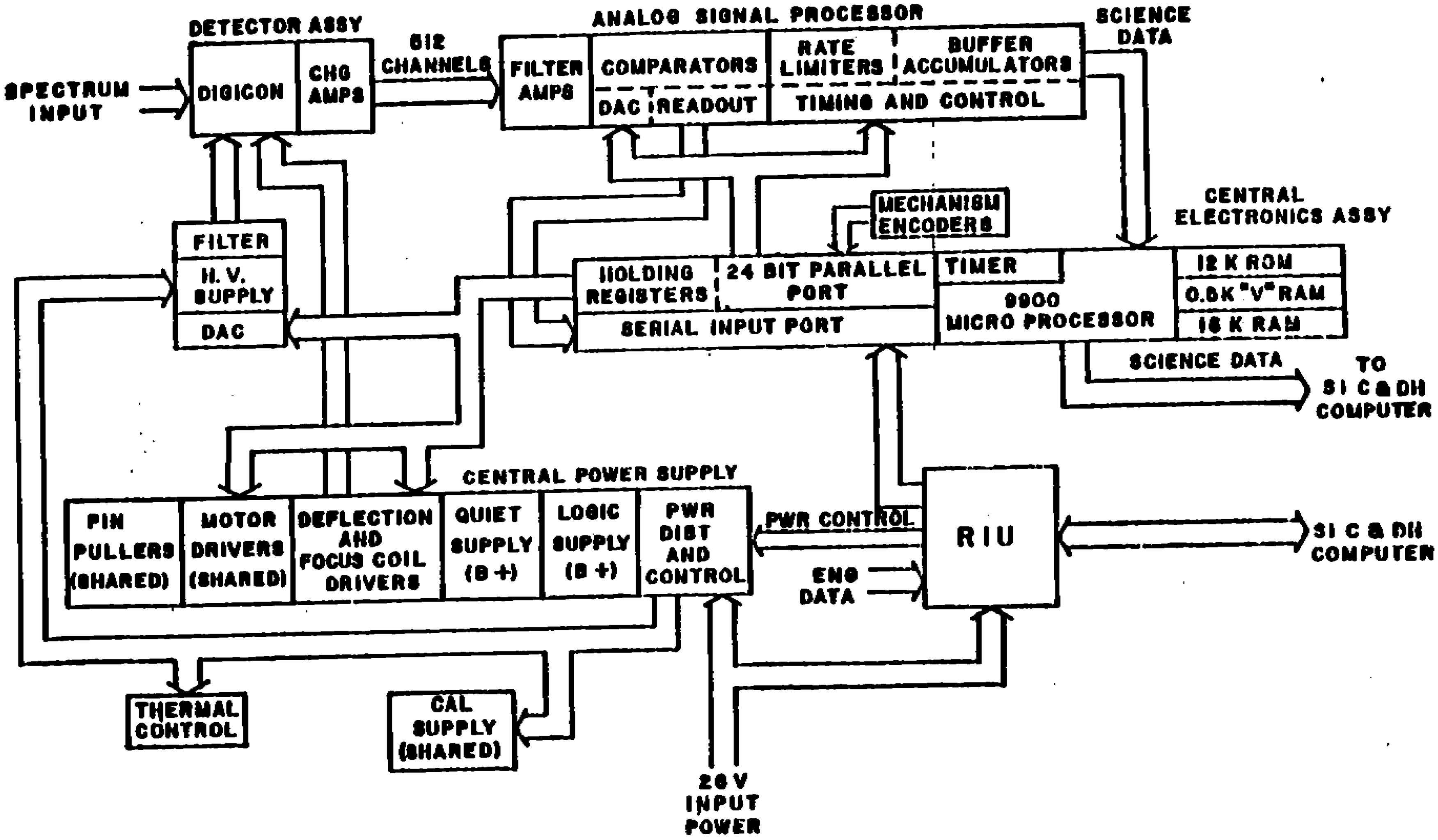
At the photocathode end of the digicon, eight beryllium oxide rods and a beryllium oxide cylinder connect the digicon ceramic body to a flange external to the pole piece. A ring-shaped saddle, to which the evaporator zone of the heat pipe is permanently attached, is bolted to the flange and forms a nonpermanent joint between the heat pipe and the detector.

At the charge amplifier side, the coupling to the heat pipe evaporator zone is through two rectangular saddles attached to the hybrids board supports extended through the detector aft cover. This joint, as in the case of the photocathode end, is also of nonpermanent type.

The heat pipes are made of internally-grooved aluminum tubing 5/16 inches in diameter, with ammonia as the working fluid. They extend from the detectors (evaporator side of the heat pipe) to the radiators (condenser side) with lengths in the 40-70 inch range. Bends along the pipe length permit the contraction of the pipes without applying undesirable loads to the detectors. The bends along the pipe length are all contained in one plan to permit the verification of the zero-g heat pipe performance.

For ground testing, boiler reflux operation of the heat pipes is obtained within the FOS +P1 axis inclined 9.75 degrees from the veritical, in the P1 - P2 plane.

The radiators, one 2.6 ft^2 for the charge amplifier and the other 4 ft^2 for the photocathode temperature control, are located on the FOS P3 side facing the +V2 SSM wall. The radiators are thermally isolated from the FOS structure with multilayer insulation and standoffs. The thermal standoffs also provide the electrical isolation of the radiators from the FOS main structure required to satisfy the single point ground requirement.



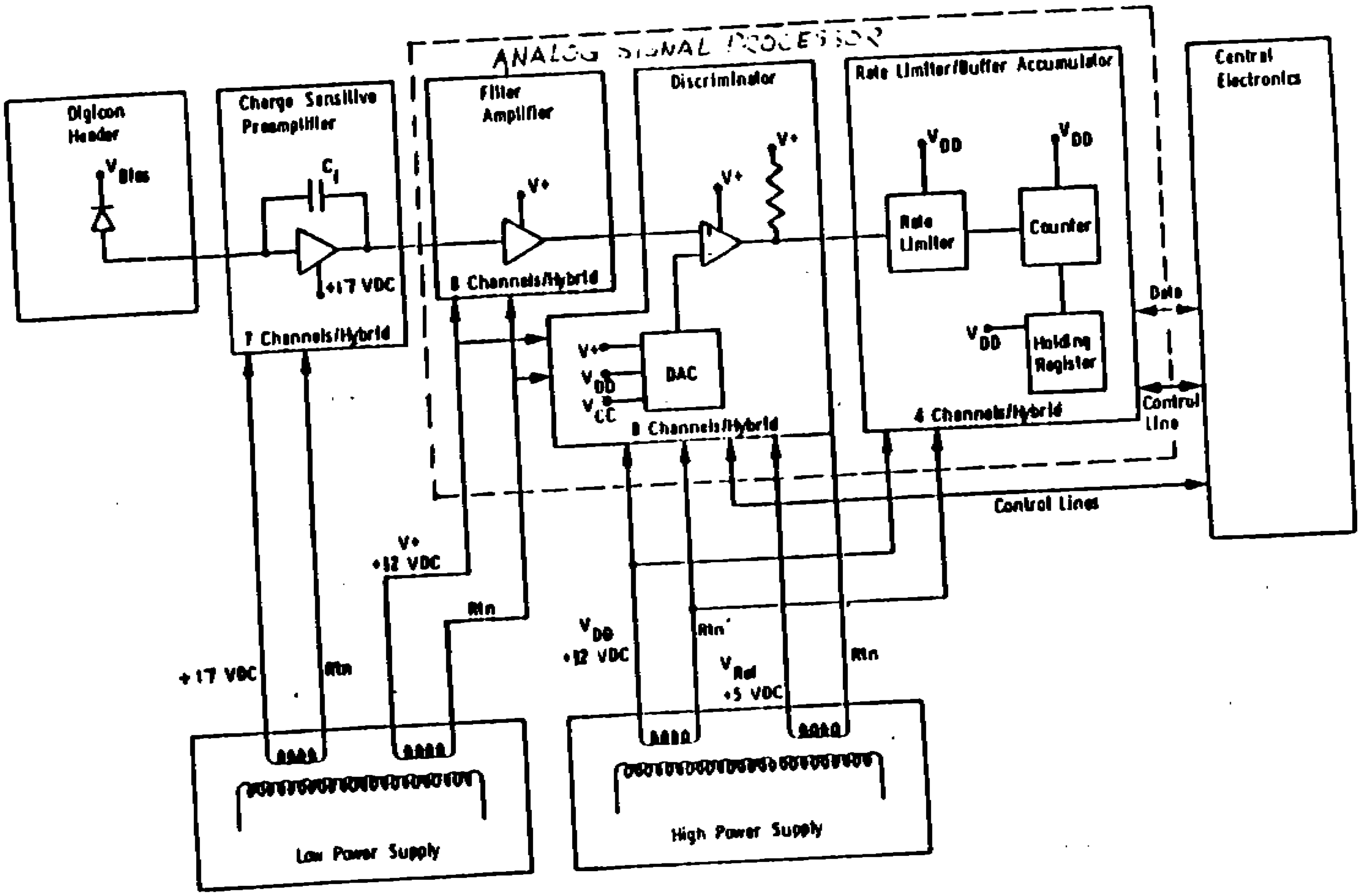
F. O. S. ELECTRICAL BLOCK DIAGRAM

FIGURE ~~4.5-1~~ 3.4-1

3.4 Electrical.

The electrical section of this manual is divided into two major subsections, 1.) electronic subassemblies and 2.) power. The FOS electronics consist of two Analog Signal Processors (ASP), two Central Electronics Assemblies (CEA), two High Voltage Power Supplies (HVPS), one Calibration Lamp Supply (CLPS), two Remote Interface Units (RIU), one Expander Unit (EU) and the Cable Harness Assembly. The physical location of these components is shown in figure 2.0-1. Figure 3.4-1 is a block diagram of the system. The power section gives details on the distribution and control of electrical power and a summary of the power usage of the FOS.

SCN2



3.4.1.1-1
Figure ~~3.2.1.2.6-2~~ Analog Signal ProcessING

A block diagram is given in figure 3.4.1.1-1

3.4.1 Electronic Subassemblies

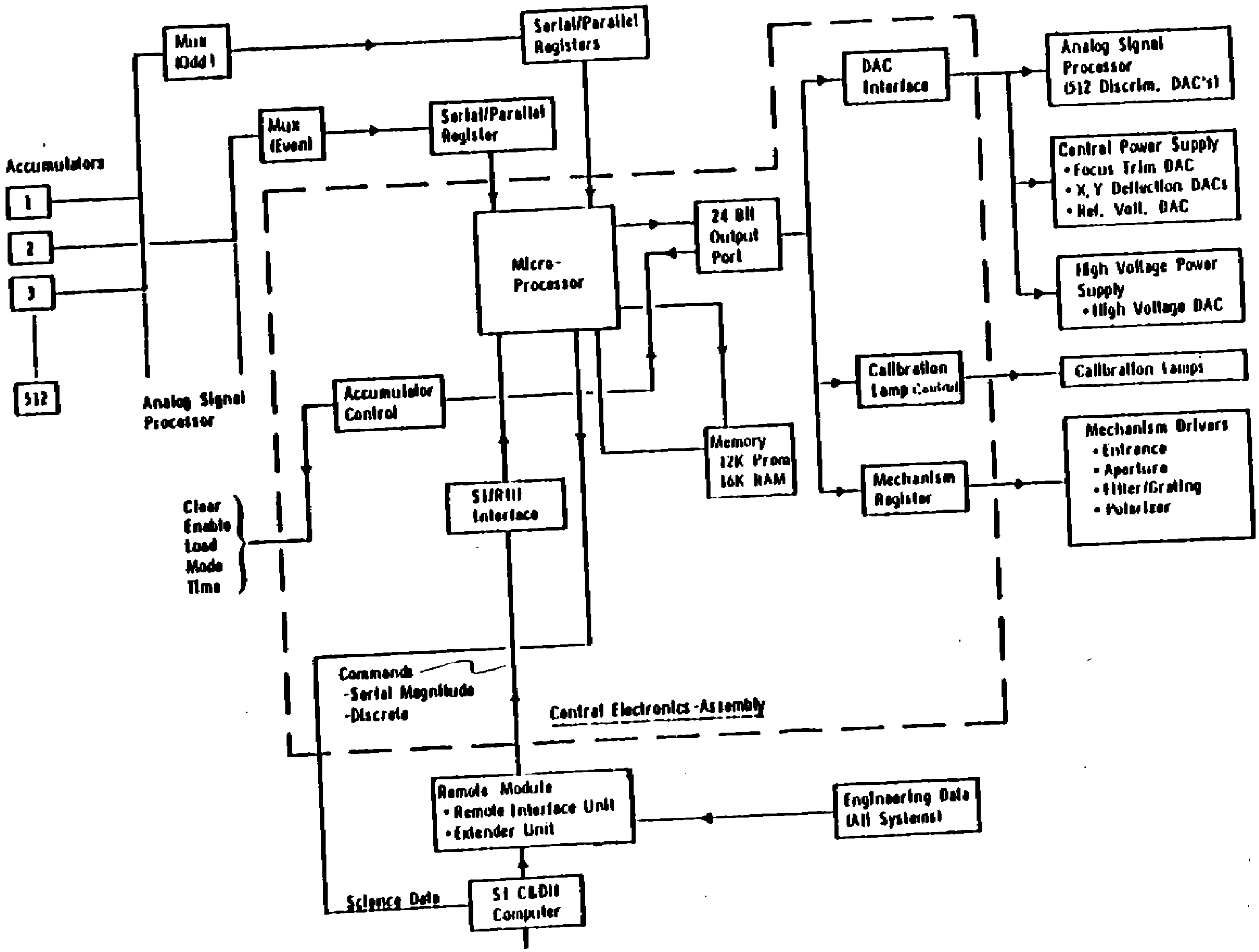
3.4.1.1 Analog Signal Processing - Signals from the detector are processed into usable forms and transmitted to the CEA. The signal processing is performed by five types of circuits: 1) charge sensitive preamplifier, 2) filter amplifier, 3) comparator, 4) rate limiter/buffer accumulator, and 5) serial to parallel converter. The charge sensitive preamplifier circuits are located in the detector adjacent to the digicon header, and the other four (4) types are located in the ASP.

3.4.1.1.1 Charge Sensitive Preamplifier - The Charge Sensitive Preamplifier circuits are located adjacent to the digicon header and provide the electronic interface to the digicon tube. The anode of each diode in the digicon is connected to the input of a charge amplifier. Each amplifier converts the equivalent of 5250 electrons ($8x10^{-16}$ coulombs) to an output pulse with a peak of 4.5 mv.

3.4.1.1.2 Filter Amplifier - The Filter Amplifier takes the output of the charge amplifier and amplifies and shapes it to an approximate gaussian-shaped pulse of about 250 mv amplitude.

3.4.1.1.3 Comparator - The Comparator circuit converts the analog signals, from the filter amplifier, into digital signals to be used by the Rate Limiter/Buffer Accumulator. The conversion is accomplished by feeding the analog signal into a comparator. The comparator threshold is obtained from a Digital to Analog Converter which is controlled from the Central Electronics Assembly. The programmable threshold is used to match the channels during instrument calibration.

3.4.1.1.4 Rate Limiter/Buffer Accumulator - The Rate Limiter is used to introduce a known dead time of 9.77 $\pm$ 1.0 microseconds into the ASP. The accumulator/buffer is designed for two modes of operation - count and time resolved. In the count mode, the output pulses from the rate limiter are counted for a selected period of time. In the time resolved mode, the elapsed time from the start of the sample period to the first pulse is measured in the accumulator. At the end of a sample period, the contents of the accumulators are transferred into the buffers and are then read sequentially by the Central Electronics Assembly. The mode and sample period are controlled from the Central Electronics Assembly.



3.4.1.2-1
Fig. 3.2.1.2.6-3 Central Electronics Assembly

3.4.1.1.5 Serial to Parallel Converter - The output of the selected accumulator channel is routed to the input of the serial to Parallel Converter where it is shifted serially into a 16-bit shift register. The output of the shift register is available to be read by the microprocessor.

3.4.1.2 Central Electronics Assembly - The Central Electronics Assembly (CEA) provides the primary interface between the FOS and the SI Control and Data Handling system of the ST. Commands are received by way of the RIU. Science data is transmitted from the CEA to the Science Data Formatter, and Engineering data is transmitted to the RIU.

The CEA consists of a microprocessor, memory, 24-bit output port Digital to Analog Converter (DAC) interface, mechanism and flat field calibration lamp control, accumulator control, and the SI C&DH Interfaces. A block diagram of the CEA is given in figure 3.4.1.2-1

3.4.1.2.1 Microprocessor - The microprocessor used is a 16-bit monolithic central processing unit fabricated with Integrated Injection Logic (I^2L). The microprocessor has a 16-bit word length with the capability of directly addressing 32 K words. The microprocessor clock is 3 Mhz, but can be reduced to 1.5 Mhz if the microprocessor chip degrades with life or radiation.

3.4.1.2.2 Memory - The CEA includes 12 K words of Programmable Read-Only-Memory (PROM) which contains the instrument firmware and fixed operating parameters. There is also 16 K words of Read/Write Memoray (RAM) which is used for storing science and engineering data, variable operating parameters and scratch pad memory. The RAM is assigned addresss space locations in blocks of 2 K words. An additional block of 512 addresses is assigned to the virtual RAM (VRAM) which is a 16-bit register which may be loaded and read by the microprocessor. This allows the execution of up to 512 identical instructions without the use of memory.

~~3.4.4~~ 3.4.1.2.3 24-Bit Output Port - This is an output port used for microprocessor communication with the DACs and for control of the flat-field calibration lamp and mechanism drivers. This port consists of ten address bits, 12 data bits and two control bits.

3.4.1.3.1 Power Conditioning for ASP and CEA - There are two power supplies in the CPS, each electrically isolated from input power and from each other. The logic supply furnishes the necessary power for all the logic elements in the CEA and the ASP. The quiet supply furnishes power to all the sensitive analog circuits in the ASP and also to the deflection and focus coil driver circuits.

Power Distribution and Control - Figure 4.5-2 shows the FOS power distriubtion. The switching is performed by magnetically latching relays controlled from the RIU using discrete commands. → moved to pow

3.4.1.3.2 Pin Puller - Each CPS contains circuits which perform the pin puller functions. Two discrete commands are required to fire any pin puller. The ARM command enables power to the actual pin puller electronics through a latching relay. A FIRE command then causes a current pulse of sufficient magnitude and duration to flow through the selected pin puller. The latching relay is normally in the SAFE position which prohibits the FIRE command from activating the current pulse.

3.4.1.3.3 Motor Drivers - The four mechanisms are operated by DC stepper motors containing four motor coils each. The control for the motors originates in the CEA and is transfered to the CPS as CMOS level signals. Each motor receives an individual enable command, and the four phase control signals are common to all motors. The control signals are optically isolated from the power switching circuits in the CPS.

3.4.1.3.4 Deflection and Focus Coil Drivers - There are three coil driver circuits in each CPS for driving the X and Y deflection coils and the trim focus coil. Each driver circuit is a programmable current source controlled from the CEA.

3.4.1.3.5 Thermal Controllers - Circuits are provided in the CPS to control the heaters in the optics compartment and on the bulkhead. These circuits monitor the temperature at the heater locations and turn the corresponding heater on or off by way of solid state switching components. The turn on and turn off times are controlled to prevent electromagnetic interference.

3.4.1.2.4 DAC Interface - The DAC interface provides a method of loading and reading the DAC control registers. The registers are loaded through the 24-bit port, and are read serially. The DACs include 512 Discriminator DACs - 8-bits each; the Focus Trim Coil DAC - 8-bits; X & Y Deflection DACs - 12-bits each; Discriminator Reference DAC - 8-bits; and High Voltage Control DAC - 10-bits.

3.4.1.2.5 Mechanism and Flat Field Calibration Lamp Control - The FOS mechanisms are controlled by the microprocessor through an 8-bit mechanism register. This register is loaded from the 24-bit port. Three of the bits are used to select the mechanism to be enabled, while 4-bits are the four phase signals to the motors. The eighth bit is not used. Position feedback from the mechanisms is read serially by the microprocessor.

The flat field calibration lamp is turned on and off by the microprocessor through the 24-bit port.

3.4.1.2.6 Accumulator Control - The accumulators in the ASP are controlled from the microprocessor throught the 24-bit port. The control signals clear, enable and inhibit the counter, select the operating mode and transfer data to the output buffers. In addiion, there is an Enable/Inhibit signal for each channel which is loaded through the 24-bit port to force the output of any malfunctioning channels to zero.

3.4.1.2.7 SI C&DH Interfaces - The CEA provides the interfaces to the SI C&DH for receiving serial commands, transmitting science data and transmitting serial engineering data. The command and engineering data interfaces are to the Remote Interface Units (RIU) of the SI C&DH system while the science data is transmitted to the Science Data Formatter (SDF). The RIUs are located in the FOS as shown in Figure 3-1 and the SDF is external to the FOS. The characteristics of these interfaces are in accordance with the SI to SI C&DH ICD, IMB No. 7936229.

3.4.1.3 Central Power Supply - The CPS contains the power distribution and control circuits for the FOS and the power conditioning circuits for the ASP and the CEA. In addition, the CPS contains the control and monitoring circuits for the pin pullers, motor drivers, deflection and focus coils and thermal controllers.

3.4.2 Power.

3.4.2.1 Distribution and Control. Figure 3.4.2-1 shows the FOS power distribution. The switching is performed by magnetically latching relays controlled from the RIU using discrete commands.

3.4.2.2 Usage. Table 3.4.2.2-1 provides a summary of FOS power usage and figure 3.4.2.2-1 shows the FOS power profile.

3.4.1.4 High Voltage Power Supply - The High Voltage Power Supply (HVPS) converts power from the input power bus to a regulated, filtered voltage output for the Detector Subsystem. The HVPS output is controlled from the CEA by way of a 10-bit digital command. The output voltage is programmable from 0 to -25,100 volts in 24.4 volt increments. The HVPS provides engineering data monitoring of its output voltage, output current and temperature.

3.4.1.5 Calibration Lamp Power Supply - The Calibration Lamp Power Supply (CLPS) converts power from the FOS common bus to a current-stabilized DC output suitable for starting and operating the calibration lamp. The CLSP is capable of greater than 400 volts DC for starting the lamp and then regulates the current at 10 ma ± 20%. The CLPS provides engineering data monitoring of its output voltage, output current and temperature.

3.1.4.6 Remote Modules - The FOS command and engineering data interfaces are supplied by two Remote Modules (RM). Each RM consists of one RIU and half of the EU. The characteristics of the RM are described in the SI to SI C&DH ICD IBM No. 7936229.

~~3.4 Power.~~

TABLE ~~3.4-1~~ 3.4.2.2-1

FOS Power Usage

	AVERAGE HOT	AVERAGE COLD	PEAK INCREMENT OVER AVERAGE
CHARGE AMPLIFIERS	8.0	8.0	
SIGNAL PROCESSOR	21.5	21.5	
CENTRAL ELECTRONICS	34.3	34.3	
Y+Z DEFLECTION DRIVERS	2.2	2.2	1.0
FOCUS DRIVERS	.5	.5	N/A USED UNDER MALFUNCTION
POWER SUPPLY LOSS	29.0	29.0	
HEATER POWER	6+1 FOR DRIVERS	26+5 FOR DRIVERS	19.2(33.7)
MECHANISMS	.58(.76)	.58(.76)	15.2(19.6)
HV SUPPLY	4.5	4.5	
CAL SUPPLY	.72	.72	8.3
RIU	4.3(4.9)	4.3(4.9)	2.4
TOTAL WATTAGE USED	113(114)	137(138)	45.9(65.0)

1. BASED ON TYPICAL PLUS 10% INCLUDING EFFECTS OF WORST CASE TEMPERATURE (-40°C)

2. ALL POWER AT NOMINAL 28V EXCEPT (XX) INDICATES INPUT POWER AT +32V

3. AVERAGE IS BASED ON OPERATING PROFILE FOR CALIBRATION AND A FORTY-MINUTE OBSERVATION SEQUENCE

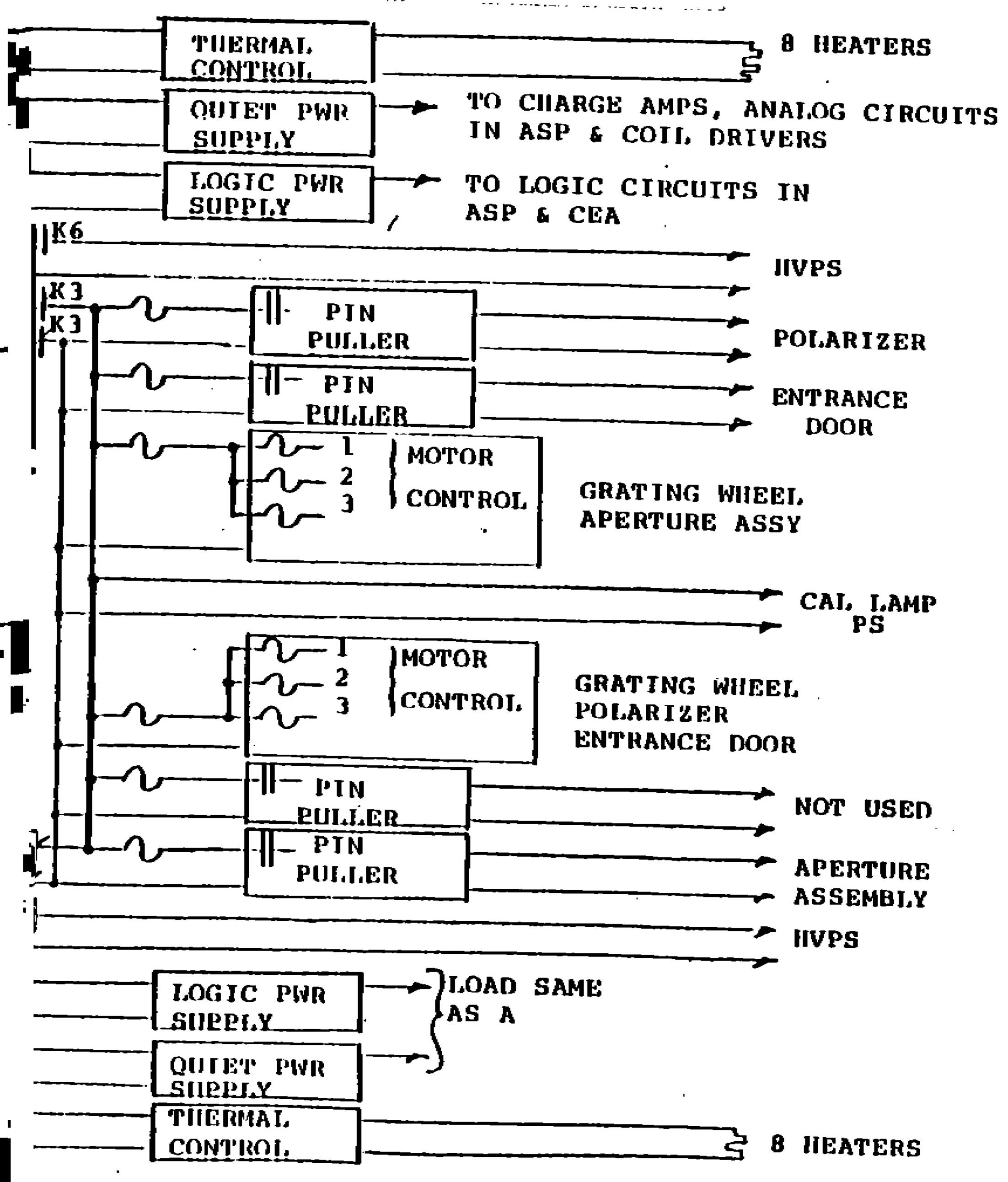


FIGURE 4.5-2 FOS …ER SWITCHING/DISTRIBUTION

3.5 Detectors

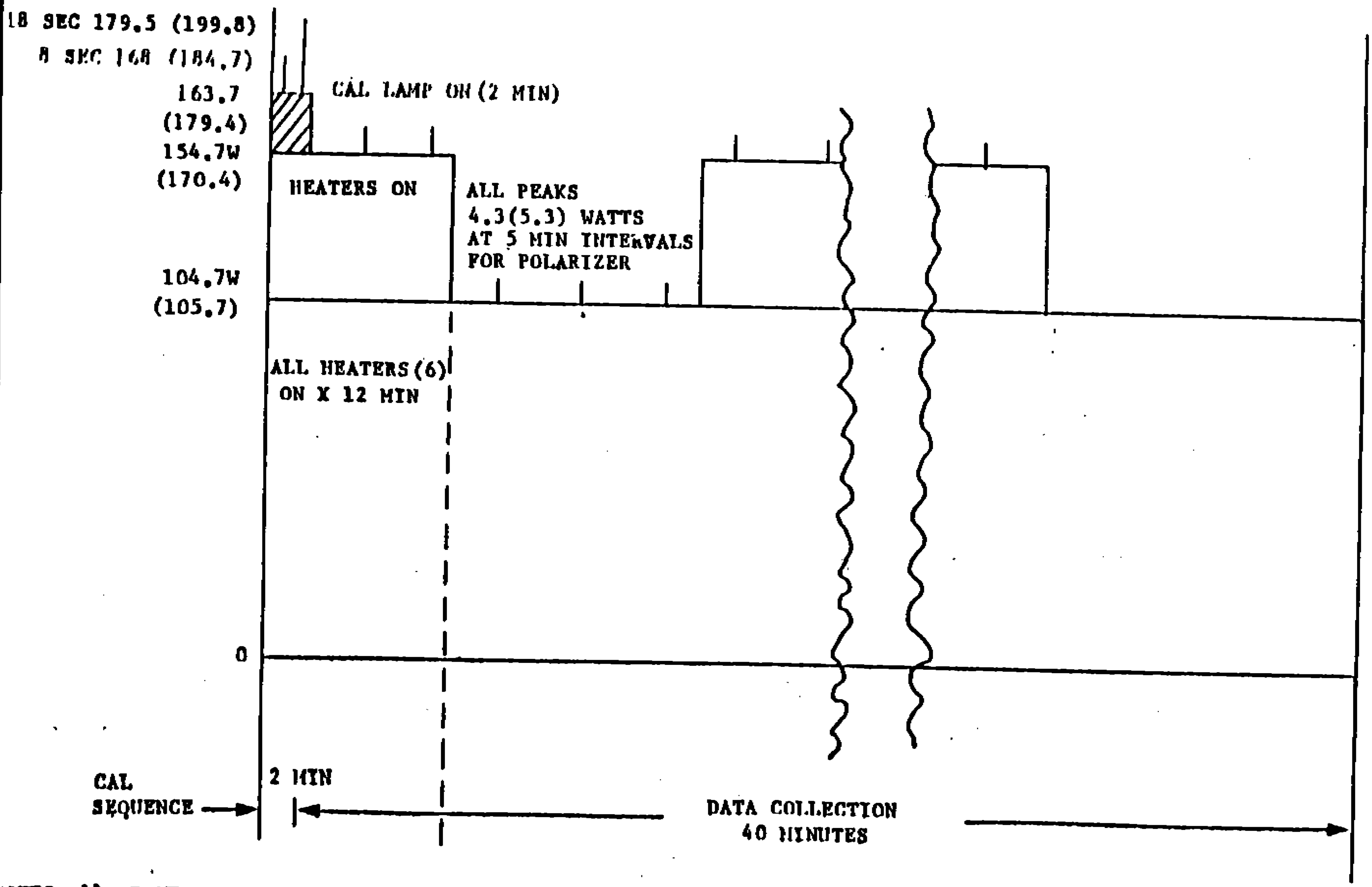
The detector subsystem interfaces with the optical subsystem to perform the photoelectron transfer from the light input to output pulses from the charge amplifiers which are sensed by the filter amplifiers of the Analog Signal Processor. The major components and subassemblies of the detector subsystem are shown on Figure 3.5-1

The detector subsystem consists of two detector assemblies. These assemblies differ only in the photocathode type and faceplate material used. In all other respects, they are identiccal. Each detector assembly consists of a digicon tube, deflection coils, a permanent magnet focus assembly, magnetic shielding, structural details for mounting, joining, and aligning the individual components, temperature sensors, and electrical connectors.

The real image of the optical spectrum is focused onto the photocathode of the detector assembly. The photon flux in this image causes, with a known probability, the emission of a photoelectron flux with the same spatial variation as the photon flux. This photoelectron flux is accelerated in the electric field to an energy of about 22.5 kilovolts. A magnetic field parallel to the electric field reimages this photoelectron flux onto a monolithic array of 512 silicon photodiodes. These 512 diodes are arranged in a single row and preserve the spatial information present in the optical image. The photoelectron energy is absorbed when the particle strikes the silicon diode. This absorbed energy results in a charge pulse of about $8x10^{-16}$ coulomb or more depending on the electric field strength. These charge pulses are amplified by the charge amplifiers. Since the optical image may appear at more than one location on the photocathode, magnetic deflection coils are available to shift the photoelectron flux in the two directions orthogonal to the optical axis. This permits counting photoelectrons from a substantial area of the cathode. The major components of the detector assembly are:

3.5.1 Digicon - The digicon is the basic photodetector. It includes a vacuum envelope, an optical faceplate on which the photocathode is deposited, a diode array, a header on which the diode array is mounted and which provides 520 electrical feedthroughs, a high voltage cable, a set of accelerator rings, encapsulation for high voltage insulation, and a tube housing.

Figure 3.4-1 FOS POWER PROFILE
3.4.2.2-1



NOTES: 1) POWER AT COLD TEMP AND 28V DC EXCEPT (XX) AT 32 VDC

2) RIU PEAKS OF 2.4W (ESTIMATED) AND X+Y DEFLECTION OF 1.0 AMP ASSUMED TO BE UNDER ONE SE[illegible] ARE NOT SHOWN

The digicon tube body is a brazed assembly of 96% alumina rings and copper accelerator rings. The tube header is attached to the tube body by a copper cold weld of the header and body copper flanges. The window is sealed to the tube body after cathode generation by means of hot indium-bismuth seal.

A resistive potential divider is connected to the accelerator rings. The individual resistors are distributed around the tube circumference to avoid concentrating the dissipated heat on one side of the tube. A maximum of 0.4 watts is dissipated at the normal operating level of 22,500 volts. A lead will be brought out from the voltage divider near the anode. This lead serves as a voltage readout monitor during ground testings. The transfer characteristic is about 2.5 volts out for 25,000 volts in. The tube and resistive divider is encapsulated to prevent high voltage breakdown.

Beryllium oxide parts are deeply embeded into the encapsulant in order to conduct heat from the divider axially to the heat sink which is attached to a heat pipe. On the outer surface of the tube housing is an electrostatic shield.

Na_2KSb (For bialkali is: Na_2KSb) trialkali $Na_xKSb(Cs)$

There are two types of digicons used in the FOS which differ only in their faceplate and photocathode materials. The photocathodes are ~~KCsSb~~ (bialkali) on UV grade magnesium fluoride and Na_2 KSb(Cs) (trialkali) on fused silica (Suprasil I). The minimum quantum efficiency as a function of wavelength for these cathodes is shown on Figure ~~4-4-2~~. 3.5. Photocathode uniformity is expected to be as good as ± 5%. The expected thermionic emission for these cathodes is shown in Figure ~~4-4-3~~ 3.5. as a function of temperature. The emission is expressed in terms of counts/sec/diode. The maximum allowable dark count rate per diode is also shown.

The tube header consists of a multilayer ceramic and dielectric substrate with wirebond pads on two levels. Metallization for wirebond pads and conductive traces is electroless gold plated over thick film tungsten. A copper flange is brazed onto the outer circumference of the top ceramic layer for attachment to the tube. There are 512 wire bond pads arranged in two rows, 128 per row, on each side of the diode array die attach pad. Each wire bond pad is four mils wide, located on eight mil centers. There are 520 silver solder pads brazed to the bottom ceramic layer. In addition to 512 signal feedthrough, there are four common connections and four ground connections.

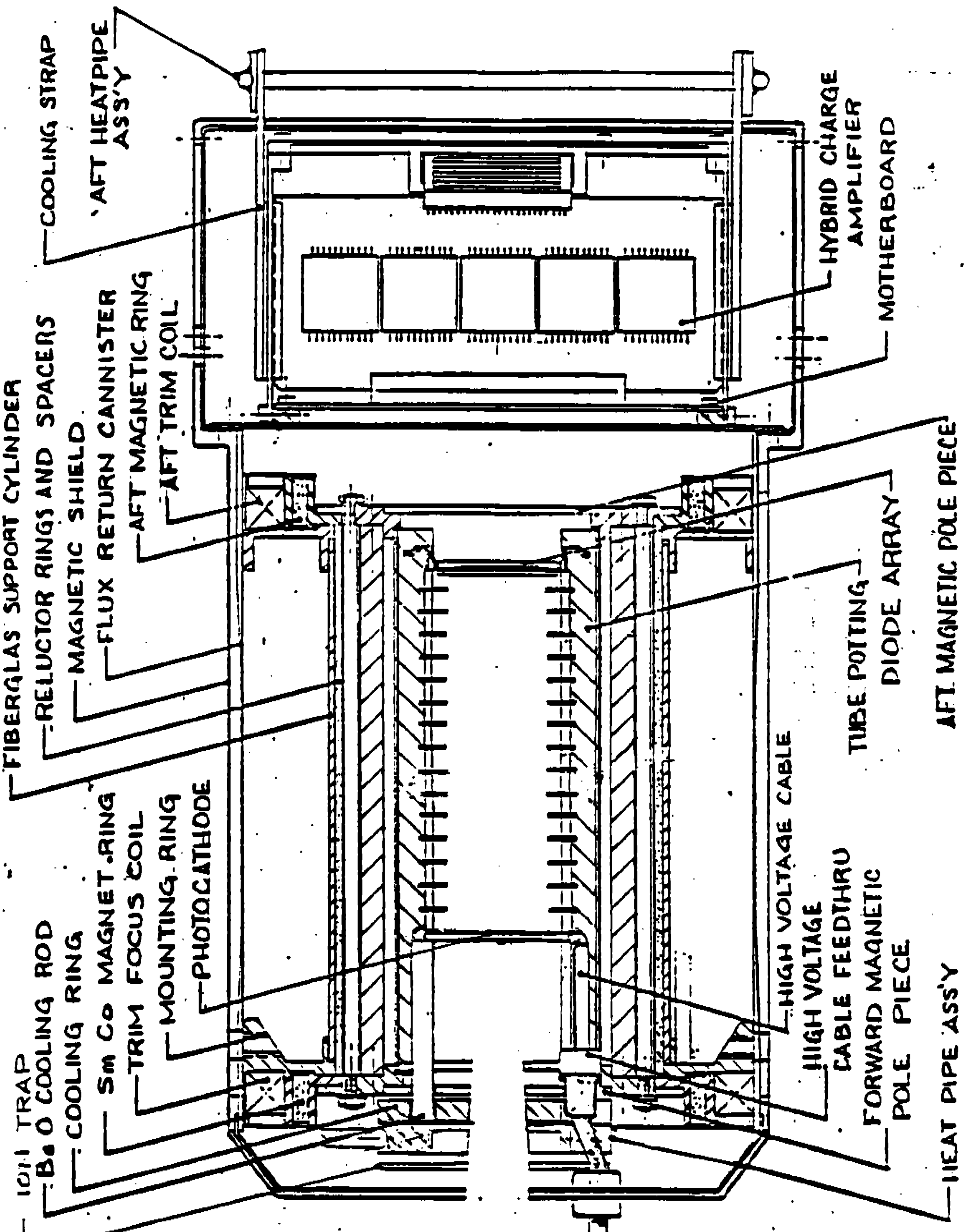


FIGURE 4-3.5-1
DETECTOR SUBSYSTEM

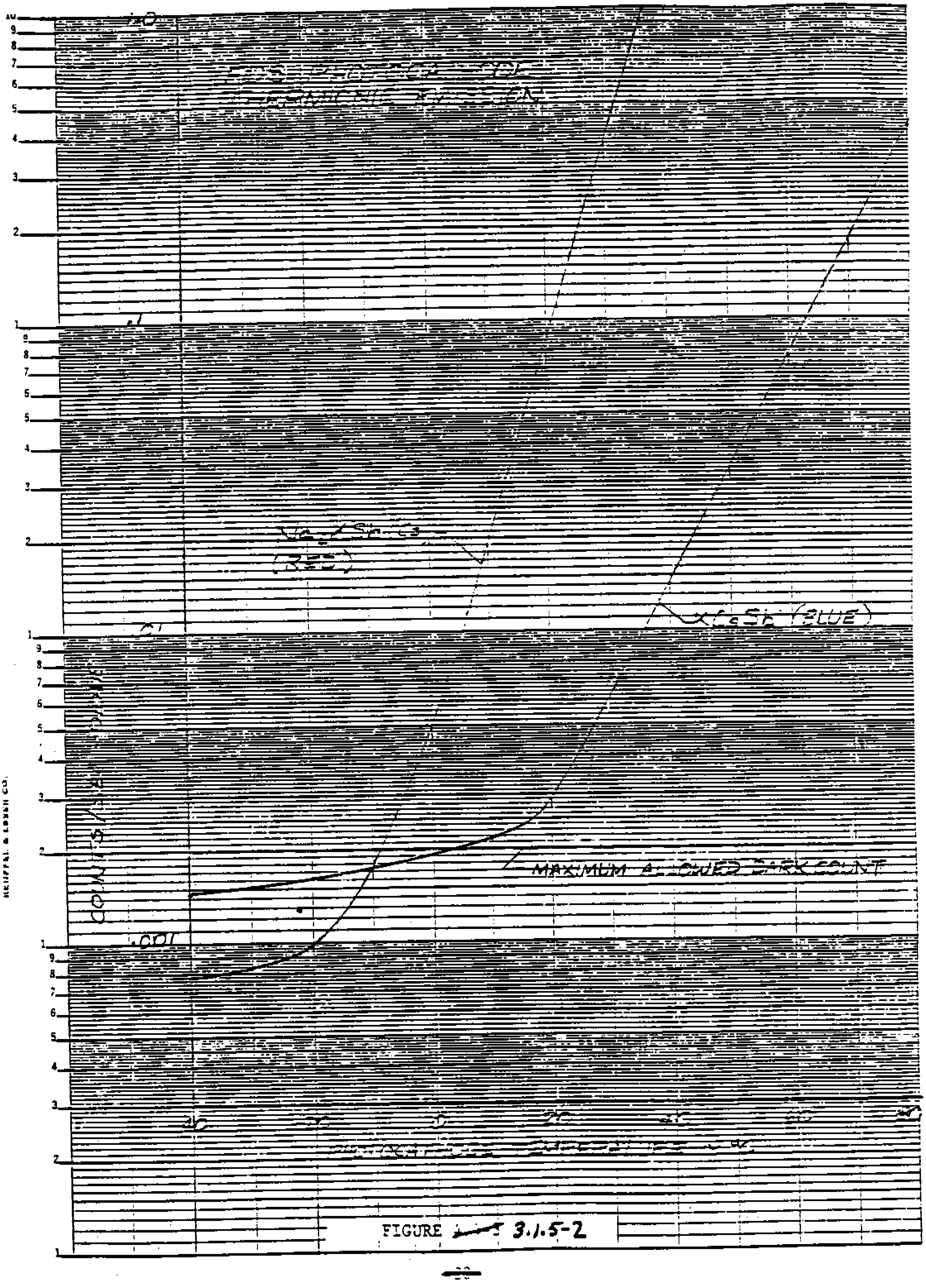

XCsSb (BLUE)
MAXIMUM ALLOWED DARK COUNT
.001
SEMI-LOGARITHMIC 46 6013
KEUFFEL & ESSER CO.

FIGURE 3.1.5-2

UPDATE THIS FIGURE WITH A MORE RECENT VERSION FROM BILL BAITY.

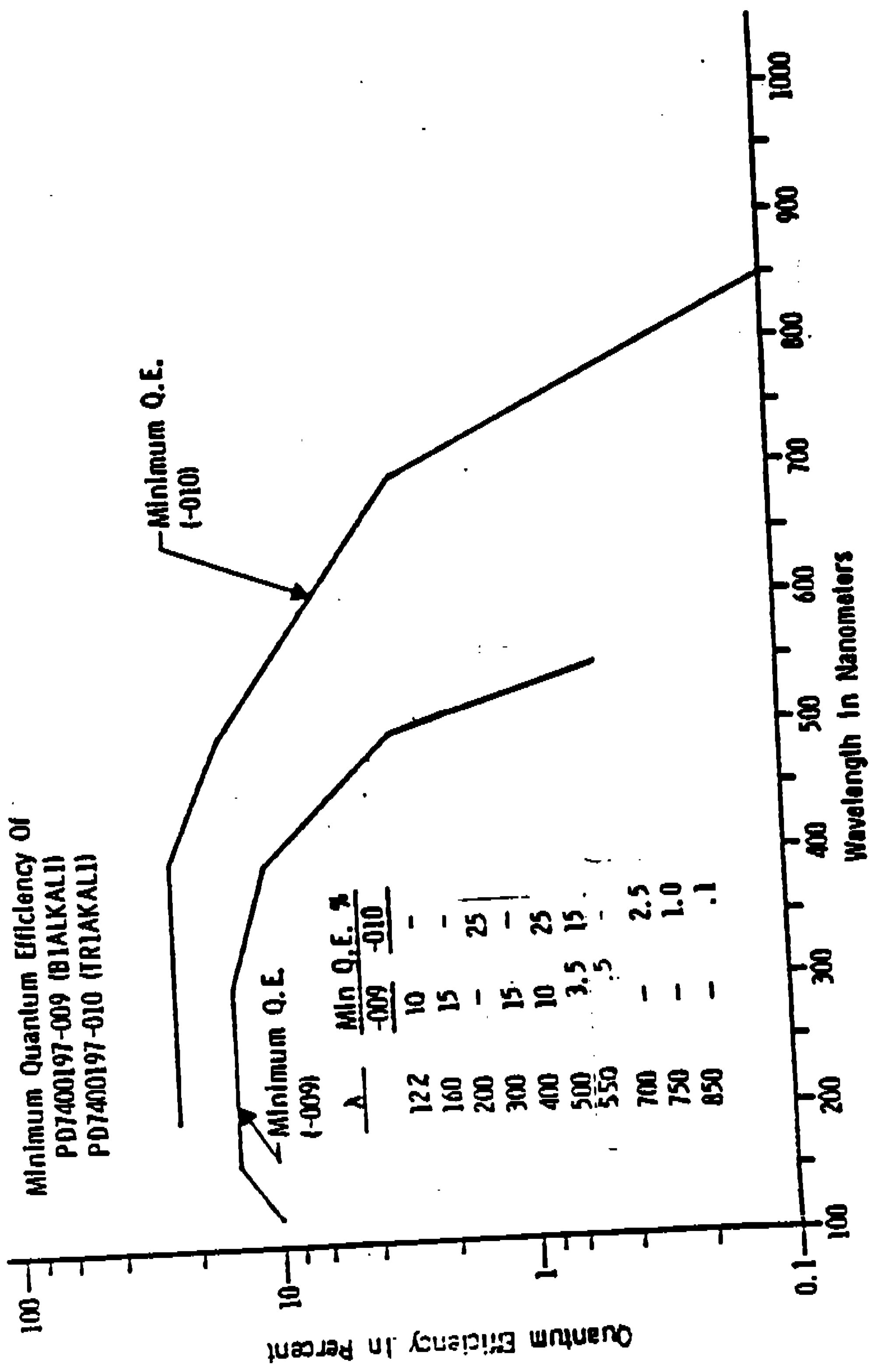


FIGURE ~~1.1.2~~ 3.5.1-1 DETECTOR QUANTUM EFFICIENCY

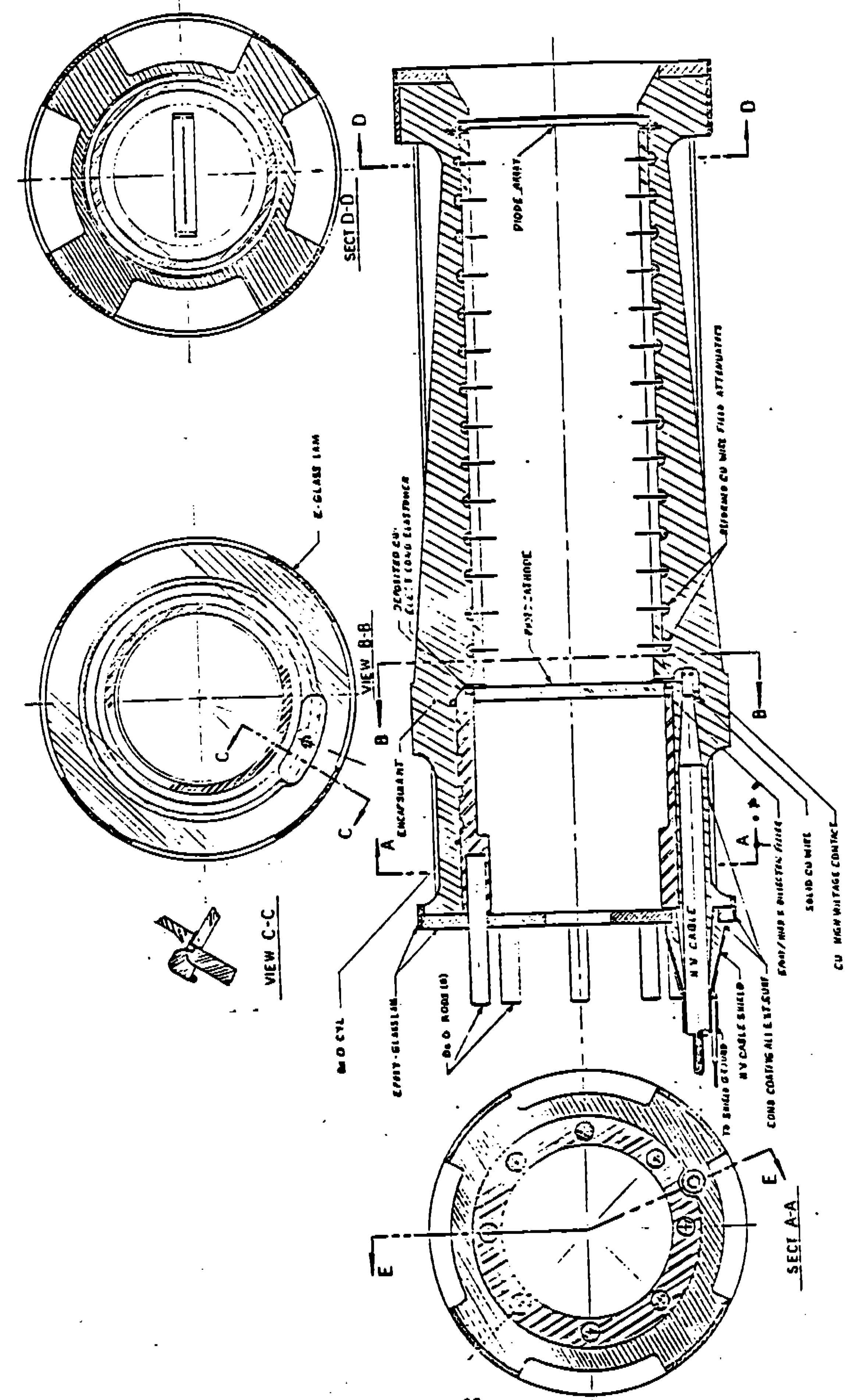


FIGURE 3.5.1-3 FOS DIGICON CONCEPT

The diode array is a monolithic silicon device approximately 1.2 inches long. The width is chosen to keep wire lengths about 0.100 or less. The device has 512 diode elements in a single row. Each element is 40 by 200 microns and has a 50 micron center-to-center spacing with adjacent elements. The silicon from which the device is made has a bulk resistivity of about 10 ohm-cm and is normally biased to produce a depletion width of about five microns. The device is to be bonded onto the header using a gold-silicon eutectic. One mil aluminum wirebonds are installed using a thermosonic bonder. One hundred percent prestress screening will be employed to weed out weak bonds.

A digicon schematic is shown in Figure ~~4.4-4~~. 3.5.1-3

3.5.2 Deflection Coils - Around the digicon is mounted a pair of orthogonal deflection coils. The rotational orientation of these coils is such that the resulting photoelectron deflections are either in the dispersion direction or orthogonal to it. These coils are completely encapsulated.

3.5.3 Permanent Magnet Focus Assembly - The major structure of the detector subsystem is part of the PMFA. This assembly includes the permanent magent rings (2), the reluctor rings, the flux return cannister, the magnetic shield, and the trim focus coil.

3.5.4 Charge Amplifier Assembly - Figure ~~4.4-1~~ 3.5-1 also shows the charge amplifier circuit boards physically mounted in their operating location although these components are considered to be part of the electrical subsystem.

The detector subsystem also contains temperature sensors and provides for conductive cooling of the charge amplifier assembly and the photocathode.

the CEA adjusts the magnetic deflections within the active digicon to properly sample the spectrum or spectra present on the photocathode of the digicon. The actual magnetic deflections within the digicons depend both on the loop commands and the deflection base and pitch values.

3.6 Commands.

3.6.1 Overview of FOS Commands. Commands sent to the FOS are used to control the spectrograph mechanisms and the Digicon detectors. The data format depends on the parameters used to set up and read out the detector. There are a large number of "modes" in which the FOS can operate. Some of these "modes" are described in section 2.4. Because the individual parameters are set by command, new "modes" are possible to respond to in-orbit conditions and unusual observing opportunities. There are many combinations of parameters that don't do anything useful, so the parameters have to be chosen with care.

The FOS commands can be divided into three groups, 1. Discrete Relay, 2. Discrete Logic, and 3. Serial Magnitude. All of the commands come through the RIU as shown in figure 2.5-1 ~~3.6.1-1~~, but the "Discrete" commands directly operate the FOS while "Serial" commands are sent to the active CEA (internal microprocessor) for interpretation and execution. A good example is the High Voltage Power Supply (HVPS). A Discrete Relay Command is used to turn on the HVPS while the voltage is set by a serial magnitude command. The Discrete Relay Commands operate magnetically latched relays while the Discrete Logic Commands provide logic level signals. In general:

Discrete Relay Commands are used to:
- control input power to the various power supplies,
- control critical failsafe hardware,
- control the internal common bus, and
- control science data port cross strapping.

Discrete Logic Commands are used to:
- reset the internal microprocessor,
- start, end, and abort data acquisition,
- reset internal error flags, and
- select filter grating wheel motor.

Serial Magnitude Commands are used to:
- initialize hardware parameters,
- control mechanisms,
- set up and control science data acquisition,
- set up and control science data readout, and
- perform diagnostics.

One of the most important functions of the FOS microprocessors (the CEA) is the control of the data acquisition loop. The commands that control this loop are eight software related commands - these commands are discussed in a separate section under the general heading of serial magnitude commands. As the data acquisition loop is executed,

TABLE 3.6.2-1
FOS Commands by Mnemonic
with Telemetry Verification Info

Command Mnemonic	Type[1]	ID	Execute Time (sec)	Telemetry	Notes	Value	Significance
YABACQ-X	DL	Y555c		YYABRTDA	2	1	Abort Data Acquisition cmd
YACQLIM	SDC	Y016c	.05	YDATALIM		8/16 bits	Set data acq. limit
YACQMODE	SSP	Y049c	.05	YACQSYNC		8 bit	Set data acq. mode
YAPER	SME	Y035c	**	YAPERPOS		16 bit	Set entrance aper. to p
YARMAP-X	DR	Y501c		YAPRFRPI		0	Arm aperture cmd
YARMED-X	DR	Y503c		YENTFRPI		0	Arm entrance port cmd
YARMPL-X	DR	Y511c		YPOLFRPI		0	Arm polarizer cmd
YBEGAC-X	DL	Y559		YYBEGNDA	3	1	Begin data acq. cmd (start)
YBLAPR-X	DR	Y561c		No TLM		--	Blow aperture cmd
YBLENT-X	DR	Y563c		No TLM		--	Blow entrance cmd
YBLPOL-X	DR	Y567c		No TLM		--	Blow polarizer cmd
YBUSS1-X	DR	Y579c		Y1BUSRPI		1	A-On, B-Off 28S1. 0=B-On/A-Off
YBUSS2-X	DR	Y581c		Y2BUSRPI		1	A-On, B-Off 28S2. 1=B-Off/A-On
YCALOF-X	DR	Y577c		YCALRPI		1	Spectral calib. lamp off cmd
YCALON-X	DR	Y575c		YCALRPI		0	Spectral calib. lamp on cmd -extension = lamp,
YCALSA-X	DR	Y583c		YCALSELR		1	Select calib. lamp A cmd
YCALSB-X	DR	Y585c		YCALSELR		0	Select calib. lamp B cmd
YCHNLEN	SDC	Y012c	1.5	No TLM		--	Enable/inhibit channel(s)
YCHNLS	SSP	Y050c	.05	YNUMCHNL		8 bit coded	Set # of chnls to be processed
YCLEARS	SSP	Y053c	.05	YMCLEARS		8 bit	Set # of memory clears/acq.
YCMTRA-X	DL	Y571		YCMTRST		1	Select (FGWA) carrousel motor A cmd
YCMTRB-X	DL	Y573		YCMTRST		0	Select motor B cmd
YDATA	ST1	Y---c		No TLM		--	Type 1 cmd: 16 bit data field for prev. SDC
YDDCHK	SDI	Y083c	4	YDDACERR		8 bit coded	Sample all discr. DACs (takes ≤2 sec)
YDEADTYM	SDC	Y010c	.05	YDEAD HI+LO		16 bit	Set accumulator closed (dead) time
YDISC	SDA	Y031c	.05	YDRDACER		0 = ok 1 = error	Set discriminator DAC table value
YDISCADR	SDC	Y006c	1.5	YDDACERR		8 bit coded	Load discr. at address or set all values
YEFILL	SDI	Y084c	.5	See UDL		TBD	Sample all serial digital telemetry
YENDAC-X	DL	Y557		YYENDDA	3	1	End data acquisition cmd (Escape)

Maybe consistent depends on how busses arranged

?

3.6.2 FOS Command List. Table 3.6.2-1 gives a list of all FOS commands, alphabetized by mnemonic, together with their 4-character identifier and a short description of their function. This table also shows telemetry verifier mnemonics and, where possible, the readout which will follow from issuing the command. Critical commands, time criticality and pre-requisite commands are identified in later sections.

YRANDOM	SDI	Y086c	10	No TLM		--	Fill sci. memory with pseudo-random seq
YREFDAC	SDA	Y032c	.05	YDRDACER		1=error	Set common disc. reference DAC
YREJLIM	SDC	Y014c	.05	YNOISELM	HI+LO	16 bit	Set noise rejection limit
YRESET-X	DL	Y545		YRESETMP	**	0	Reset microprocessor cmd
YRIEBW	DL	Y549		YINSENG		0	Reset Instruction Eng. Bit/watchdog cmd
				YWTCHDOG		0	(1=error)
YSAFAP-X	DR	Y505c		YAPRFRPI		1	Safe aperture cmd
YSAFED-X	DR	Y507c		YENTFRPI		1	Safe entrance door = disarm cmd
YSAFPL-X	DR	Y515c		YPOLFRPI		1	Safe polarizer cmd
YSCIACT	SDI	Y070c	.05	YSDIP	3	1	Immediate sci data dump, 0=auto dump
YSCIADDR	SDC	Y059c	.05	Not TLM!		--	Set first RAM address for sci data
YSCIDMP	SDC	Y002c	.05	YMDMPADR	HI+LO	16 bit	Set sci dump parameters
				YWRDSLIN	HI+LO	16 bit	
				YLINSFRM	HI+LO	16 bit	
YSDERASE	SDI	Y057c	.5	No TLM		all 0	Clear sci memory locations
YSDFA1-X	DR	Y543c		Y4SDFPRT		0	Reset CEA B Y4 relay to SDF port 2
YSDFA2-X	DR	Y539c		Y1SDFPRT		0	Reset CEA A Y1 relay to SDF port 2
YSDFA3-X	DR	Y541c		Y4SDFPRT		1	Set CEA B Y4 relay to SDF port 1
YSDFA4-X	DR	Y537c		Y1SDFPRT		1	Set CEA A Y1 relay to SDF port 1
YSDFB1-X	DR	Y535c		Y3SDFPRT		0	Reset CEA B Y3 relay to SDF port 2
YSDFB2-X	DR	Y531c		Y2SDFPRT		0	Reset CEA A Y2 relay to SDF port 2
YSDFB3-X	DR	Y533c		Y3SDFPRT		1	Set CEA B Y3 relay to SDF port 1
YSDFB4-X	DR	Y529c		Y2SDFPRT		1	Set CEA A Y2 relay to SDF port 1
YSLICES	SSP	Y068c	.05	YMSLICES		8 bit	Set # of memory slices
YSTBY1-X	DR	Y625c		YRIUS2		01	RIUA SBY1 cmd (bit 2=RIUB status)
YSTBY2-X	DR	Y627c		YRIUS2		10	RIUA SBY2 cmd
YSTOPDMP	SDI	Y044c	.05	YSDIP	3	1 to 0	Stop science dump
YSTRWRD	SDC	Y018c	.05	No TLM		--	Store next cmds as data
YSYNC	SDC	Y023c	.05	No TLM		--	Set delay for starting synch acq
YTAMOD	SSP	Y046c	.05	YTAMODE		*TBD*	Set target acquisition mode
YTARACQ	SDC	Y004c	.05	YTAMAX(UL)		16 bit	Set target acquisition parameters
				YTAMIN(LL)		16 bit	
YX-BASE	ST3	Y026c	.05	YXBASE	HI+LO	12 bit	Base value for X defl comp

** Verifies only for 1 mjf

YENTRNC	SME	Y034c	15	YDOOR	0 = between 1 = open 2 = closed 3 = invalid	Set entrance door open or closed
YFFCAL	SDA	Y038c	.05	YFFCPWR YCDACERR	1=on 1=error	Set LED flat-field lamp on or off
YFILTER	SME	Y037c	10	YFGWAPOS	4 bit coded	Set FGWA to position
YFOCUS	SDA	Y033c	.05	YFOCUSRB YFDACERR	8 bit 1=error	Set focus trim DAC
YHTOFF-X	DR	Y547c		YHTRRPI	1	Heater off cmd
YHTON-X	DR	Y527c		YHTRRPI	0	Heater on cmd
YHVDAC	ST3	Y030c	.05	YHVDACRB YHVDACER	10 bit 1=error	Set high voltage pwr supply DAC
YHVOFF-X	DR	Y517c		YHVRPI	1	High voltage supply off
YHVON-X	DR	Y519c		YHVRPI	0	High voltage supply on c
YIGON-X	DR	Y600c		YAIONRPI YBIONRPI	0 1	Ion gauge on
YIGOFF-X	DR	Y601c		YAIONRPI YBIONRPI	0 1	Ion gauge off
YINIT	SSP	Y041c	.05	YINTMODE	5 bits	Set initialization mode
YINTS	SSP	Y043c	.05	YINTEG	8 bit	Set # of sub-integrations per x-step
YKEY	SDI	Y071c	***	YKEEP	=0 if X'06' sent	Provide FORTH KEY capability
YKPALVED	SDI	Y058c	.05	YYSAFED	1/0	Enable/disable autonomous going safe
YLIVETYM	SDC	Y008c	.05	YLIVE HI+LO	16 bits	Set accumulator open (live) time
YLSOFF-X	DR	Y525c		YLSRPI	1	Logic supply off cmd
YLSON-X	DR	Y569c		YLSRPI	0	Logic supply on cmd
YMCHREG	SME	Y087c	.05	See UDL	*TBD*	Set mech. register to drive signal
YMCHSTEP	SME	Y056c	.05	See UDL	*TBD*	Step mechanism
YMECHCAL	SDC	Y022c	.05	See UDL	*TBD*	Set feedback code for mechanism
YMEMCHK	SDI	Y055c	.5	No TLM	--	Fill sci. memory with test pattern
YOUT-CLR	SSP	Y045c	.05	YREADCYC	8 bit	Set readouts/memory clear
YOVRSCAN	SSP	Y051c	.05	YOVRSCNX	8 bit	Set # of diodes x overscan (Note TLM name change)
YPAUSE	SDI	Y085c	.05	YPIP 3	1=paused	Set/reset pause acq. bit
YPLZR	SME	Y036c	20	YPLRZPOS HI+LO	16 bit	Set polarizer mech. to position
YPTRNOUT	SSP	Y054c	.05	YPTRNS	8 bit	Set # of patterns/readout
YQSOFF-X	DR	Y521c		YQSRPI	1	Quiet supply off cmd
YQSON -X	DR	Y523c		YQSRPI	0	Quiet supply on cmd
YRAMADDR	SDC	Y000c	.05	YRAMADR HI+LO	16 bit	Load RAM storage address (Note TLM name change)
YRAM-M	SDI	Y052c	.05	See UDL	D*	Map physical to logical RAM pa

inconsistent

? the FOS SOGs Lists a YIONRPI (Vac. gauge power RPI)

3.6.3 Serial Magnitude Commands.

3.6.3.1 Serial Magnitude Command Table. The bit patterns used for the serial magnitude commands are given in table 3.6.3.1-1. Type 4 commands of subtype "DATA" are followed by one or more type 1 commands (pure data fields). The table shows the maximum number of type 1 commands that follow each of these commands. The actual number is given in the type 4 command data field and must correspond exactly to the number of type 1 commands that follow. If the numbers do not match, data fields will be interpreted as other types of commands or other types of commands will be interpreted as data fields. Although the CEA checks to make sure that the maximum number of allowed type 1 commands that follow is not exceeded, the actual number of type 1 commands sent should be carefully controlled. Appendix D gives a further listing of type 4 commands and includes a description of each. Figure 3.6.3.1-1 shows the bit arrangement for the serial magnitude command error report flags.

If more than one unit is sending commands to the FOS, care must be taken that the commands are not randomly interleaved. The type 4 command of subtype "DATA" and its associated type 1 commands (pure data fields) must arrive in sequence without insertions.

YX-DEFL	ST3	Y024c	.05	YXDAC HI+LO YXDACERR 1=error	12 bit	Set X-defl amplifier DAC
YX-FILW	SSP	Y040c		--	12 bit	Spare
YX-PITCH	ST3	Y028c	.05	YXPITCH HI+LO	12 bit	Scaled X-defl DAC val. for 1 diode
YX-STEP	SSP	Y039c	.05	YXSTEPS	8 bit	Select number of X defl steps
YY-BASE	ST3	Y027c	.05	YYBASE HI+LO	12 bit	Base value for Y defl comp
YY-DEFL	ST3	Y025c	.05	YYDAC HI+LO	12 bit	Set Y-defl amplifier DAC
YY-FILW	SSP	Y048c		--	--	Spare
YY-PITCH	ST3	Y029c	.05	YYPITCH HI+LO	12 bit	Scaled Y-defl DAC val. for 1 diode
YY-RNGE	SSP	Y066c	.05	Y-RNGE	8 bit	Set range for Y defl
YY-STEP	SSP	Y047c	.05	YYSTEPS	8 bit	Set number of Y defl steps
Y1STCHNL	SSP	Y042c	.05	YSTCHNL	8 bit	Set first channel to be processed
Y1:5MZ-X	DL	Y553		YCLKMON	1	Select 1.5 MHz clock cmd
Y3MHZ-X	DL	Y551		YCLKMON	0	Select 3.0 MHz clock cmd

Notes

1) Command Types

DR Discrete Relay
DL Discrete Logic
ST3 Serial Type 3
SDC Serial Data Cmds
SDA Serial DAC Cmds
SME Serial Mechanism Cmds
SSP Serial Software Parameter
SDC Serial Diagnostic Cmds

2) Discrete commands Y------ -X are cross-strapped and may be issued by either RIU; ex. YABACQ-A and YABACQ-B. The ID values listed are for side A; the B value is 1 higher.

3) This command sets the indicated telemetry bit for only 1 mnf, so it probably won't be read out. Do not depend on this telemetry for verification.

4) This command is verified only for 1 mjf. <-- which cmd(s)?

5) Related to "de-rats' nesting" of diode leads and digicon by "descramble proms". Status only, no command.

MSB → LSB

ILLEGAL 3 TYPE CMD-CODE	ILLEGAL 4 TYPE CMD-CODE	ILLEGAL 4 TYPE MODIFIER	DATA COMMAND OVERFLOW	DATA COMMAND ILLEGAL PATH	SYNST COMMAND ILLEGAL PATH	MECHICAL COMMAND ILLEGAL PATH	SCIDMP COMMAND ILLEGAL PATH

MINOR FRAME 95

SERIAL MAGNITUDE COMMAND ERROR REPORT FLAGS

81GS-11-084

FIGURE ~~3.6.2-1~~ 3.6.3.1-1

TABLE .2.1-1

FOS SERIAL MAGNITUDE COMMAND FORMATS

← COMMAND CODE →

TYPE 3 COMMANDS	YX-DEFL 1 0 0 0	YY-DEFL 1 0 0 1	YX-BASE 1 0 1 0	YY-BASE 1 0 1 1	YX-PITCH 1 1 0 0	YY-PITCH 1 1 0 1	YHVDAC 1 1 1 0	UNUSED 1 1 1 1

TYPE 4 COMMANDS (MODIFIER)		UNUSED 0 0 0 0	DATA * 0 0 0 1	DAC 0 0 1 0	MECH 0 0 1 1	S/W PARAMETERS 0 1 0 0	S/W PARAMETERS 0 1 0 1	DIAG 0 1 1 0	UNUSED 0 1 1 1
00	0		YRAMADDR (1)	YDISC	YENTRNC	YX-STEP	YY-STEP	YRAM-MAP	
01	1		YSCIDMP (2,3)	YREFDAC	YAPER	YXFILWID	YYFILWID	YSTOPDMP (Ø)	
02	2		YTARACQ (1,2)	YFOCUS	YPLZR	YINIT	YACQMODE	YMEMCHK	
03	3		YDISCADR (1)	YFFCAL	YFILTER	YISTCHNL	YCHNLS	YKPALVED	
04	4		YLIVETYM (1)		YMCHREG	YINTS	YOVRSCAN	YSDERASE (Ø)	
05	5		YDEADTYM (1)		YMCHSTEP	YY-RNGE	YSLICES	YSCIACT	
06	6		YCHNLEN (2) 1			YOUT-CLR	YCLEARS	YKEY	
07	7		YREJLIM (1)			YTAMODE	YPTRNOUT	YDDCHK (Ø)	
10	8		YACQLIM (1)			YSPARE48	YSPARE58	YEFILL (Ø)	
11	9		YSTRWRD (2) 256			YSPARE 49	YSPARE59	YPAUSE	
12	A		YSPARE1A			YSPARE4A	YSPARE5A	YRANDOM	
13	B		YMECHCAL (1) 97			YSPARE4B	YSPARE5B	YTA (Ø)	
14	C		YSYNC (1,2)			YSPARE4C	YSPARE5C		
15	D		YSCIADDR (1)			YSPARE4D	YSPARE5D		
16	E					YSPARE4E	YSPARE5E		
17	F					YSPARE4F	YSPARE5F		

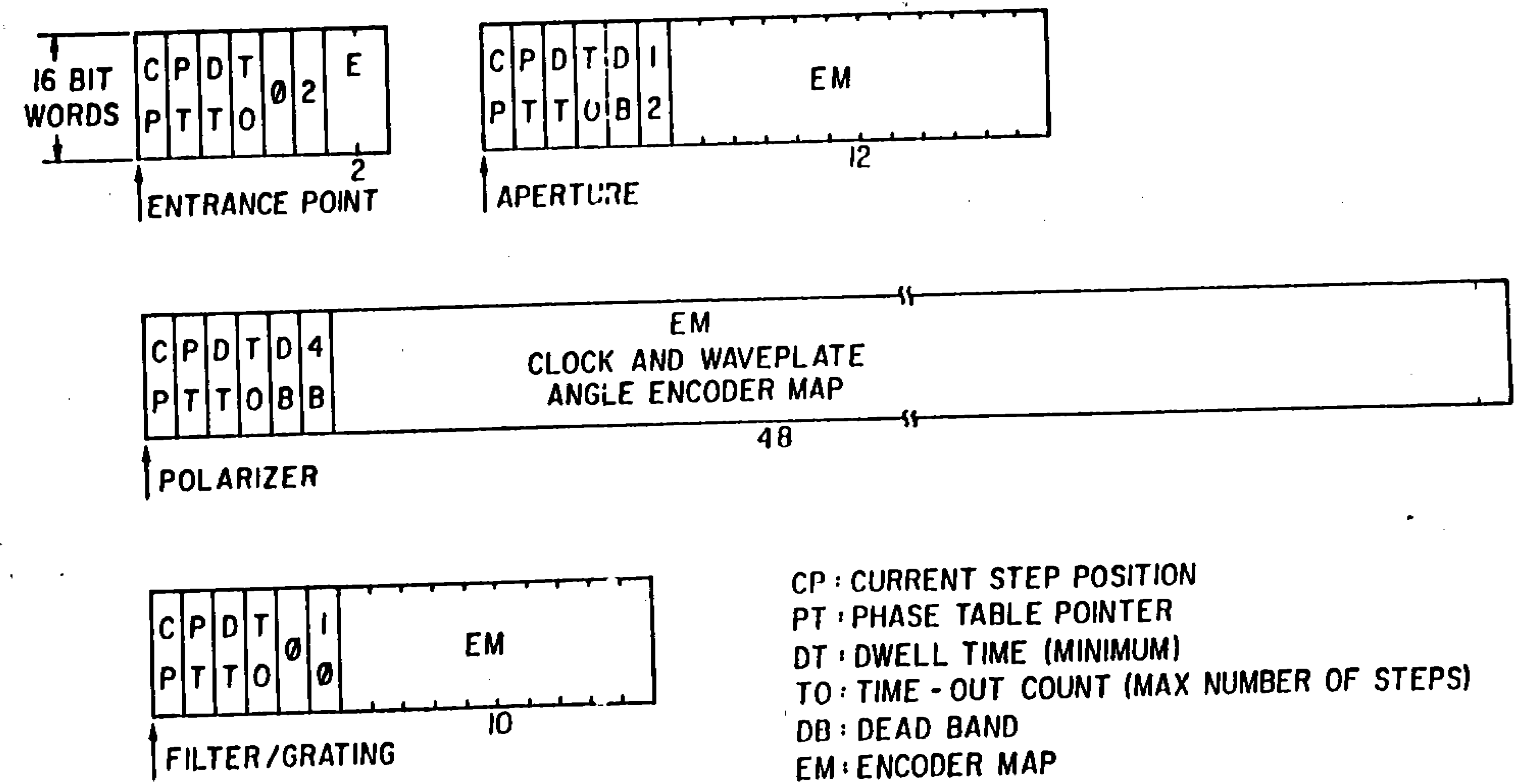
*NOTE 1

NOTE 1: (MAXIMUM
A TYPE 4 COMMAND FOLLOWED BY ONE OR MORE TYPE 1 COMMANDS) NUMBER OF C[...] INCLUDED IN PARENTHESES
0 = 256)
→ AS MANY NEEDED, UP TO 256
0 = 256

MSB Ø ... LSB 15

			COMMAND TYPE
COMMAND CODE	12 bit DATA FIELD		3
COMMAND CODE	MODIFIER	8 bit DATA FIELD	4
16 bit DATA FIELD			1

Change MAX to 97 for YMECHAL + 1 for YCHNLEN



CP : CURRENT STEP POSITION
PT : PHASE TABLE POINTER
DT : DWELL TIME (MINIMUM)
TO : TIME - OUT COUNT (MAX NUMBER OF STEPS)
DB : DEAD BAND
EM : ENCODER MAP

FIGURE 2.8-1- 3.6.3.2-1

FOS MECHANISM CONTROL BLOCK

85WB-11-001

3.6.3.2 Mechanism Control. Serial magnitude commands are used to control the four FOS mechanisms. The data field sent with the command gives the position code and a direction of travel for the mechanism. The four mechanism commands are YENTRNC, YAPER, YPLZR, and YFILTER for the entrance port, enrance aperture, polarizer, and filter/grating wheel respectively. The bit patterns appear in table 3.6.3.1-1 and in appendix D. There are also general mechanism commands, YMECHCAL, YMCHREG, YMCHSTEP, that allow each stepper motor to be controlled if necessary.

Two FOS mechanisms cannot be moved at the same time. If a second mechanism command arrives before a previous mechanism command has time to finish, the second command is ignored. The mechanisms move under the control of a background task, so the total time required for any move depends somewhat on how busy the CEA is. The amount of time that should be allowed between for various mechanism commands is given in section 3.6.6.1.

The CEA actually controls the individual phases of the stepper motors step by step. For each mechanism, a Mechanism Control Block stored in the RAM area of the CEA contains a pointer to a phase table and dead band and encoder map information. These blocks are shown in figure 3.6.3.2-1. The default values are loaded from PROM at power up but table load commands (see section 3.~~XX~~ 3.6.4) can be used to change these values.

3.6.3.2.1 Entrance Port. The command is YENTRNC (see appendix D), the direction is 0 (forward) to close. The dead band should be set to zero in the Motor Control Block and running the mechanism at the full rated motor speed does not cause problems for the position readback.

3.6.3.2.2 Entrance Aperture. The command that controls aperture position is YAPER and forward (coded 0) is defined in the direction of increasing command position code - see table 3.2.2.2-1. So a "forward" command direction should be used to move from B-1 (position 1) to B-2 (position 2) for example. The "forward" direction for this example will take about 15 seconds while "backward" will take about 300 seconds (see Figure 3.6.5.2-1). An optimum sequence of moves should be employed to avoid turning the aperture wheel completely because it takes so much time. Also a sequence of moves will have to be used if it is found in calibration that the aperture positions repeat better when the final position is approached always from one direction.

3.6.3.2.3 Polarizer. The polarizer mechanism is commanded with YPLZR - the command position table is given in 3.2.2.3-1. Forward is defined as being in the direction of increasing command position numbers. There are 16 unique positions for each of the two waveplate/Wollaston prism combinations. This

3.6.4 ~~2.8~~ FOS Table Loads

3.6.4.1 ~~2.8.1~~ FOS Data Tables. Data operational data tables reside within the first 8K bytes of RAM. These tables total 608 16-bit words. Default values reside in ROM and are automatically transferred to these RAM tables during CEA power-on and reset. Any item of these RAM tables may be changed by ground command to correct for inaccuracies of the default values stored in ROM.

Discriminator DAC Table (Channel Calibration Factors)
512 16-bit words, one word per discriminator

(1) High Order Byte contains channel enable/disable flag (high order bit 0/1 = ENA/DIS)
(2) Low Order Byte contains 8-bit discrininator DAC value

The remaining 7 bits of (1) represent the 7 most significant bits of the discriminator DAC value when different from ROM (else 0). These bits result from a hardware diagnostic test internal to FOS and are not loaded from the ground.

The Discriminator DAC Table is located with the 8K byte control area system of RAM at CEA byte address 9AF8 HEX.

Mechanism Control Block
96 16-bit words - format shown in Figure ~~C-4~~ 3.6.3.2-1
The mechanism control block is located at CEA address TBD HEX.

The mechanism control block contains fields which are changed by the FOS during operations. Thus, verification of data loads to this table must be done immediately following the load command process.

Note TBD on location of Mech. control block results from the 22.5^{o} rotation increments of the waveplate relative to its prism. There are also 16 clear positions - they are equivalent in terms of non-polarimetric observations. The position numbers are coded such that an increment in position number by one gives the next valid position rotating forward.

3.6.3.2.4 Filter/Grating Wheel. The YFILTER command controls the Filter/Grating Wheel position as given in table 3.2.2.4-1. The position command number is different for side A and side B. There are also commands for choosing the drive motor, these are YCMTRA and YCMTRB. Two motors are included in order to provide a FAIL-SAFE mode because there is no preferred position for the Filter/Grating Wheel. The Filter/Grating Wheel assembly positions in a repeatable manner only if rotated into position from the same direction, otherwise there is a shift of as much as 100 microns or 2 diode spacings.

where mech cal index includes (1) the word count offset into the mechanism control block where the load of the data commands is to begin (CP of Figure C-4 is offset 0) and (2) an indicator of which mechanism control block is to be loaded.

The offset is automatically incremented by 1 for each new data command following.

3.6.4.2 ~~2.8.2~~ FOS Table Load Commands. The following represents RAM table load command sequences. Each sequence includes a unique combination of FOS command types.

Channel ENABLE/DISABLE

Command mnemonics

Y2S01601 channel enable/disable
Y2S0XXXX data

where data	= 001000 (octal)	enables all 512 channels
	= 101000	disables all 512 channels
	= 000YYY	enables single channel YYY
	= 100YYY	disables single channel YYY

Each data command above must be preceeded by the channel enable/disable command.

Discriminator DAC table load

Y2S01301	discrimination load request
Y2S0XXXX	data word
Y2S020XX	discriminator value to be loaded

where tne data word includes the 8-bit address (relative to the start of the discriminator table) of the load value or, if 9th low order bit is set, the data word indicates that ALL entries of the discriminator table are to be loaded with the value of the next command. If an address is provided in the data word command, multiple discriminator values may be loaded within the same command string for consecutive placement within the table.

Mechanism Control Block table load:

Y2S01BXX	number of commands following
Y2S0XXXX	mech cal index
Y2S0XXXX	data to be loaded

3.6.6 Stored Command Sequences. Because the ST spacecraft and FOS will not be in communication with the ground at all times, routine operation of the instrument will be by means of stored command sequences. The NSSC-1 computer stores and executes these commands. The command sequences can contain relative timing information (in other words commands like fixed time delays) or there can be ties to the spacecraft clock. If only relative time type of commands are included, then the effect of the command sequence is independent of the absolute date and time when the sequence is initiated. Several "Relative-Time Command Sequences" (RTCSs) have been written for the FOS. Creating sequences of FOS Commands is similar in concept to programming some computers using a Job Control Language. In both situations a sequence of rather high level commands is saved for later execution as a single entity. The RTCSs are part of the NSSC-1 software but unlike the "processors" (the NSSC-1 software programs) they are not written in the Caine, Farber, and Gordon PDL language and are not converted to machine code.

3.6.6.1 Absolute-Time Command Sequences. Commands can be executed at a predetermined count of the spacecraft clock. If the command specifies a time less than the current count of the spacecraft clock, the computer must be reset or the clock must be reset otherwise the system will wait until the clock wraps around through zero which can take several years. In the testing phase of the ST, command sequences are sometimes repeated by resetting the spacecraft clock to a time just prior to the execution time requested for the first command. Absolute-Time Command Sequences are written without branches or jumps, and the minimum time delays that are included are of order one second. Like all command sequences, they are tested on a program that models the response of the ST and the SI's.

3.6.6.2 Relative-Time Command Sequences. Some Relative-Time Command Sequences (RTCSs) have been written to control the FOS during target acquisition and initialization. These sequences interact heavily with the NSSC-1 processors and together with the processor perform the desired function. A list of the RTCSs for the FOS is given in table 3.6.6.2-1.

3.6.5 Real Time Commanding. The FOS can be commanded in real time when the spacecraft has a communication link with the ground. Since the TDRSS satellite communication link will probably be available only during certain portions of each orbit, the FOS will normally operate under control of stored command sequences. The only real-time commands anticipated in normal operations are commands to position the telescope after an interactive mode target acquisition. Interactive real-time target acquisition is possible either by using the FOS or the WFC to obtain a picture of a region of sky around the target. This picture is down-linked and the astronomer marks his target in real-time. Offsets from the current telescope position to the target position are calculated and uplinked. A stored command sequence is normally running even during this process. A pre-programmed branch and delay allow the interactive target acquisition to take place. Some default offsets are used in case no information is up-linked and the stored command sequence proceeds. It is anticipated that interactive target acquisition will not be used often. This is because it requires more time than other target acquisition methods and it requires scheduling when the TDRSS communnication channel is available. Other than target acquisition, real time commands will probably only be used for special tests of the FOS in case of anomalous behaviour or failure and to obtain engineering information.

3.6.7 Command Execution Times

3.6.7.1 Serial Magnitude Command Timing. Response time depends upon command issued. See "Execute Time" column in Table 3.6.2-1 and the SMC timing list below.

Given the interrupt structure, it is not possible to make a definitive statement regarding the length of time required for actual execution of a serial magnitude command as a lower level interrupt can be kept pending by a higher level interrupt. However, the following list gives times that we feel will work most of the time.

Most serial magnitude commands should be allowed 50 msec to execute at 3 MHz or 100 msec at the 1.5 MHz clock rate. The serial magnitude commands in Table 3.6.7.1-1 require more than 50 msec, or more than 100 msec at the 1.5 MHz clock rate.

Table 3.6.~~[illegible]~~ 6.2-1

FOS ~~Real~~ Relative-Time Command Sequences (RTCSs)

(SEQNOM?)

IBM NAME	FOS NAME	FUNCTION
	1) 21	FOS Autonomous Safing
	22	Initialization Side A FOS
	23	Initialization Side B FOS
	24	Initiate FOS Payload Safing
	2) 26	FOS Turn Off
	28	Target Acquisition (Contents variable, can be no-op for direct astron. intervention)
	29	FOS Keep-Alive
	30	FOS Fail-Safe Disarm
	FOS SEQ1	NSSC-1 Controlled Mode 2 Target Acquisition (stored in FOS portion of NSSC-1 Memory)
	FOS SEQ2	FOS Controlled Mode 2 Target Acquisition (stored in FOS portion of NSSC-1 memory)

NOTES:

1) Some of our numbers (21-24) have also been used by HRS (despite not using up their own set)

2) There are gaps in the FOS name sequencing - FOS was initially assigned numbers 21 through 30; some of the missing numbers have been used in the past for ground testing and 1 or 2 may be needed for flight operations.

3) RTCS names XX are called YFXXCD in the software (new 3-15?).

There's a note on the previous version. A ? next to the Keep Alive.

~~FGWA positioning problems.~~

*** YKEY - After a YKEY/15 (<CR>) command, one must wait for a response of 'ok' in the firmware status bytes before sending further YKEY commands, other than YKEY/06 which is the keepalive command. Also of note: The CEA should be given fewer than eighty YKEY commands at a time before sending a YKEY/15.

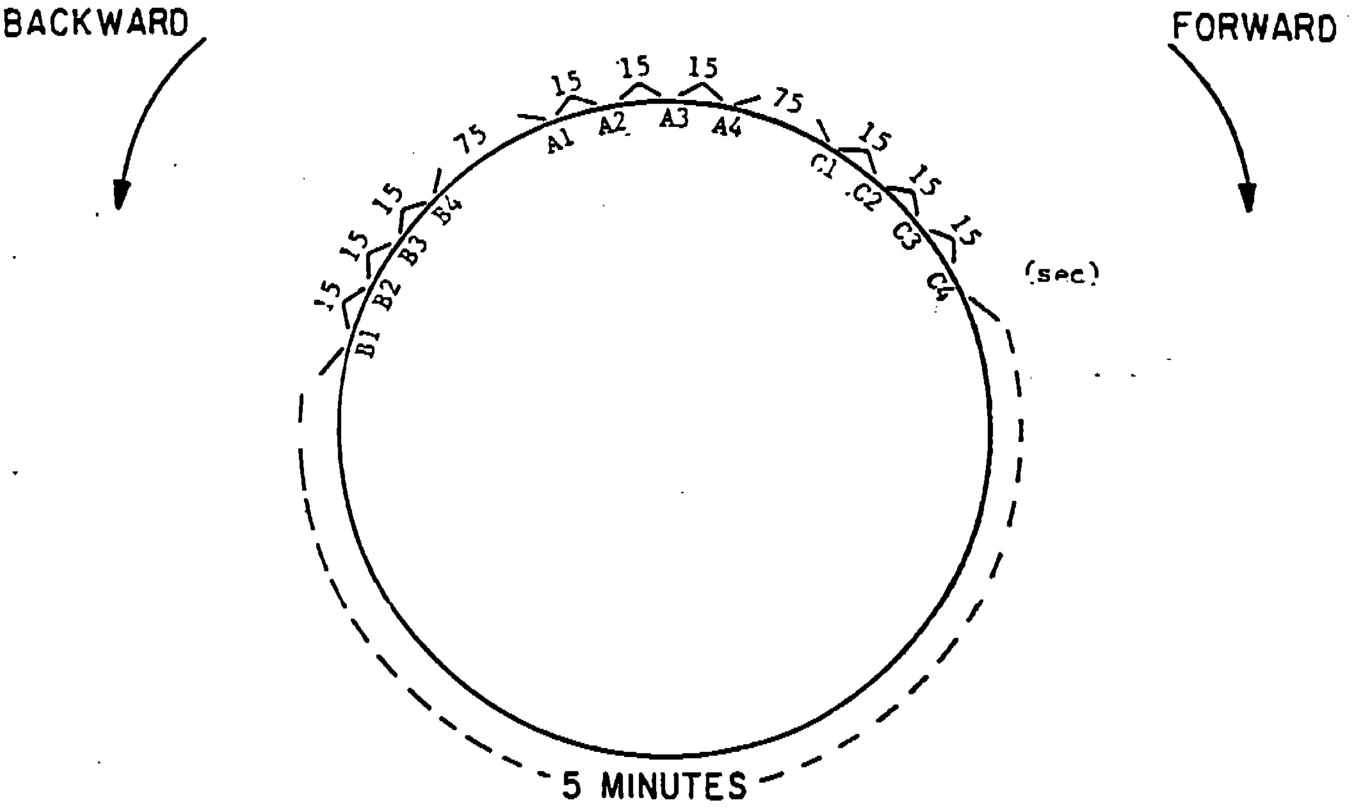


Figure 3.6.~~5.2.1 6.1.1~~ 7.1-1
FOS Aperture Wheel Travel Times

Max wrong way = $(9 \times 15_5) + (2 \times 75_5) + 5$ min.
135 + 150 + 300 = 585 sec.

Max right way = 135 + 150 = 285 sec.

Min right way = 15 sec.

Table ~~3.6.5.2.1~~ ~~3.6.6.1-1~~ 3.6.7.1-1

FOS Commands Requiring > 50 msec to Execute

YAPER*	**
YPLZR*	20 seconds between successive positions
YFILTER*	10 seconds between successive positions
YENTRNC*	15 seconds
YKEY	***
YCHNLEN	50 msec for one
	1500 msec to enable all channels
YDDCHK	4 seconds
YDISCADR	50 msec for one
	1500 msec to set all discriminators
YEFILL	500 msec
YMEMCKH	500 msec
YRANDOM	10 seconds
YSDERASE	500 msec for all of memory
	100 msec for default area of memory

* The time allocations given for these commands are the times necessary to actually move each mechanism. Only one mechanism can move at a time. However, other serial magnitude commands may be issued 50 msec after sending the mechanism commands.

** The aperture mechanism has 12 positions which are not evenl spaced around the aperture wheel itself. Therefore, the timing between positions is dependent upon what position it is currently at and which position it will be moved to. Figure 3.6.~~5.2~~7.1-1 shows the orientation of the 12 positions and the length of time suggested to allow for movement from one to another in seconds. It is recommende that the operator manage the direction of aperture movement as the 5 minutes required to move forward from C4 to B1 would be a waste of operation time. In addition, extra commands and time may be require to drive in to final position from a given direction to avoid ~~ESUA~~ positioning problems. ~~In addition, extra commands and time may be required to drive in to final position from a given direction to~~

data acquisition parameters. Note: In synchronous start mode this command could require up to 62 seconds, execution time plus up to one MF to wait for the appropriate start time.

Science Data - Generated once for each science data word transferred. Response time is 40 s, except at the end of a line of science data when the response time is < 100 s, and at the end of a science data frame when response will likely be < 1 ms.

μ check

Put in
μS for units

3.6.7.2 Microprocessor Interrupt Levels. Microprocessor interrupts listed in order of decreasing priority. A higher priority interrupt will suspend processing of any lower priority interrupts. All response times assume uninterrupted CPU processing time.

Reset - Generated by YRESET-A and YRESET-B ~~and YRESET-B~~ commands, and by applying power to the logic supply (YLSON-A and YLSON-B). It takes about 2 seconds (Breadboard Timing Measurement, ~~or~~ BTM) of execution time before the CEA is ready to accept more commands. Note: Telemetry synch requires a Major Frame (MF) start and then 1 minute, 120 minor frames (mf), until the next MF start to achieve all valid data within the current value table. [NCR 87 carries with it a CCR which describes the procedure for issuing a YRESET-A or YRESET-B command during normal FOS operation.]

Telemetry (TLM) - Generated once for each mf. Maximum response time is 2 milliseconds (ms).

Abort Acquisition - Generated by YABACQ-A or YABACQ-B command. Response time is a "few" (<10) milliseconds.

End Acquisition - Generated by YENDAC-A or YENDAC-B commands. Response time is < 3 ms.

Accumulators Closed - Generated by timer countdown indicating that the accumulators have closed. Response time can vary depending upon the acquisition mode bits set by default or by the most recent YACQMODE command. Response time will be < 30 ms.

Accumulators Open - Generated by timer countdown indicating that the accumulators have opened. Response time is roughly 120 microseconds (s) if it is not kept pending by an accumulators closed interrupt.

Begin Acquisition - Generated by YBEGAC-A or YBEGAC-B command. Response time will likely be 2 seconds or less, dependent somewhat on

Table 3.6.10-1

FOS Pre-Operation Commands

DATA BASE #	MNEMONIC	DESCRIPTION
Y527	YHTON-A	Turn on power to heater
Y528	YHTON-B	Turn on power to heater
Y547	YHTOFF-A	Turn off power to heater
Y548	YHTOFF-B	Turn off power to heater

3.6.11 Safing Commands.

As long as the FOS is operational, a safe mode can be achiev by executing the following commands to set HV to zero and close the entrance door (requires approximately 7 sec to execute):

YHVDAC/000

YENTRNC/200

3.6.8 Critical Commands. The FOS commands in Table 3.6.8-1 are critical since once they are executed the failsafe action is irreversible. Execution of these commands on orbit must be approved by the FOS Principal Investigator.

TABLE 3.6.8-1

FOS Critical Commands

DATE BASE #	MNEMONIC	DESCRIPTION
Y561	YBLAPR-A	Blow Aperture Failsafe
Y562	YBLAPR-B	Blow Aperture Failsafe
Y563	YBLENT-A	Blow Entrance Door Failsafe
Y564	YBLENT-B	Blow Entrance Door Failsafe
Y567	YBLPOL-A	Blow Polarizer Failsafe
Y568	YBLPOL-B	Blow Polarizer Failsafe
Y501	YARMAP-A	Arm Aperture Failsafe
Y502	YARMAP-B	Arm Aperture Failsafe
Y503	YARMED-A	Arm Entrance Door Failsafe
Y504	YARMED-B	Arm Entrance Door Failsafe
Y511	YARMPL-A	Arm Polarizer Failsafe
Y512	YARMPL-B	Arm Polarizer Failsafe

3.6.9 Time Criticality of Commands

3.6.10 Prerequisite Commands.

3.6.10.1 Preoperation Commands. The FOS heater power should b turned on at least 3 hours prior to operation. Heater power commands are as follows:

3 TBD
SECTIONS

available for the engineering data stream. The FOS specific telemetry occupies a small part of the total engineering telemetry that is generated by the ST. The engineering telemetry has many different formats for different spacecraft operations. The normal SI data telemetry mode (a mode called AN) is emphasized in the following sections. More information about the engineering telemetry can be found in the LHMSC document DM-02 - this contains a complete list of all engineering telemetry items and a breakdown of every format showing which words are assigned to a given SI or OTA subassembly.

The SHP that is transmitted on the science data stream contains only a small amount of information specific to the FOS. In particular it contains a few words that relate to the calculations done for the target acquisition process. For example, whenever a mode II target acquisition is done, a SHP is output. This SHP will contain a flag that indicates if the target acquisition was successful and if not, a code that indicates why it failed (field too crowded, etc.). The SHP is a maximally long line - it consists of 965 16 bit words. For transmission, like other things on the science data stream, it is loaded into a "packet" that contains 16 segments each 64 words long. The number of segments per packet is determined by the number of words in the line. Each segment contains 3 words of segment header adding up to 48 words on this example. The first segment contains an additional 11 words called a packet header. Thus the total is 965 + 48 + 11 = 1024 which accounts for every word in the 16 segments each 64 words long.

The FOS UDL is also a maximally long line - there are 965 words. The FOS UDL is a copy of 965 words within the FOS microprocessor RAM address space. This region of RAM contains the mechanism control blocks, the Discriminator DAC/Disabled Diode Table, an image of the serial digital data (duplicating the items serially transmitted by the engineering telemetry) and a few more items. Like the SHP, the FOS UDL will be loaded into a "packet" that contains 16 segments each 64 words long.

The Science Header Line has a line length equal to the other science lines. It is a copy of the upper part of the RAM area that maps into the FOS UDL. For example, if the science data lines are 517 words long, then the Science Header Line will contain the uppermost 517 words of the FOS UDL. Following the Science Header Line are the science data lines. The Science Header Line and each science data line is loaded into a "packet". The lines may or may not be packed into optimally small packets.

A summary of the information sent back from the FOS is given in table 3.7.1-1. The science header line, science lines and science trailer lines are usually transmitted in that order

3.7 Data and Telemetry Processing.

3.7.1 Overview of FOS Data and Telemetry Processing. This section deals with the information that is sent back from the FOS, it describes the formats used, and it describes the processing that is done by the CEA and the NSSC-1 computers. Data from the FOS is used by the CEA and the NSSC-1 in order to implement certain target acquisition modes. The most important process controlled by the CEA is the storage and co-addition of FOS on-target science data. The scientific data from the spectrograph has a format that is determined by user selectable parameters. This data is returned in the "science stream" which also contains engineering data and header information needed to interpret the spectrograph counts. The contents of the science stream depend on what is requested. Independent items in the science data stream include the "Standard Header Packet" (SHP), the FOS Unique Data Log (UDL), and the science data frames. The science data frames typically contain a science header line and several science data lines. The header line is optional but will usually be present and the science data lines will be sometimes followed by several science trailer lines. For transmission purposes, the science data stream is broken into segments that are 64 16 bit words long. The segments are grouped into packets of variable length - the length is usually chosen such that a packet contains one science data line. The segment/packet structure also adds its own headers above and beyond the information being transferred. Thus for example, the first line of a science frame, the science header line is considered data to the segment/packet structure and a segment header and packet header will be added. The contents of the SHP, UDL, and science frames are normally discussed assuming the routine removal of the segment/packet structure and the associated headers has been accomplished.

Engineering data is sent back by a stream independent from the science stream. The information in the engineering telemetry unique to the FOS and the information in the FOS UDL overlap but are not exactly the same. In particular the FOS UDL is usually generated after the FOS is commanded to update the information. The engineering data stream is designed to use less bandwidth during normal operation than the science data stream. A sub-commutation scheme is used so that some data items are sampled much more often than others. This scheme allows one telemetry data location within a minor frame on successive minor frames to hold different pieces of information. Minor frames are assembled into major frames so that within a major frame each data item is sampled at least once. Part of the processing done by the FOS microprocessor involves this commutation of telemetry items. A counter is initialized when a major frame signal is detected and incremented with each minor frame signal. This counter acts as an index to control which telemetry item is updated and made

Table 3.7.1.-1
Summary of FOS Telemetry

A. Engineering Stream - FOS Engineering Telemetry - Normal Format AN. See section 3.7.3.2 for subcommutation table and 3.7.4 for format list.

B. Science Stream - segment/packet structure see 3.7.5.1 for an example.

1. SHP - mostly ST information - some FOS specific items including failure/success of target acquisition.
2. UDL - important parameters for FOS, generated by copying a contiguous section of FOS CEA memory.
3. Science Header Line - typically precedes each science pattern. A copy of upper part of same memory area used for UDL.
4. Science Lines - the number of lines varies, depends on xsteps, ysteps, and slices see 3.7.3.2
5. Science Trailer Lines - reject array.

and constitute a single frame. How the SHP's and UDL's are mixed in with the science lines in the science stream depends on when requests were sent for SHP's and UDL's. Also some operations automatically generate a SHP. A complete list of individual FOS telemetry items is given in appendix B. This list gives the location for each item in the engineering stream, the SHP and the UDL. Most items appear in both the engineering and the science telemetry - the update times might differ somewhat.

5. Housekeeping Processor (YFHKPG, processor #30). This processor processes FOS engineering outputs for monitoring FOS health and safety, including YOVRLTMB|YOVRLTLB (see Section 2.1.5) from the engineering stream. YFHKPG can also initiate the periodic transmission of Standard Header Packets (see Section 3.2.1).

6. Science Data Storage Processor (YFSDST, processor #31). This processor provides the services required to transfer science data from the FOS into the NSSC-1.

7. Science Data Processor (YFSDPR, processor #32). This processor operates in conjunction with YFSDST to accomplish both binary search and peakup/peakdown target acquisition (depending on a control flag). It also causes the NSSC-1 Standard Header Packet and the FOS science data buffer in the NSSC-1 to be output.

Table 3.7.2-1

FOS Applications Processors

Processor	Associated RTCSs	Purpose	Comments
25	21	Autonomous Safing	Designed to Operate Once.
26	22 or 23	Turn On	
27	26	Turn Off	
28		Mode II Targ. Acq.	Independent (every 30 sec)
(There is nc #29 at present)			
30	29+30	Housekeeping	Scheduled, always operating (every 15 sec)
31		Sci. Data Storage	Not Scheduled. can operate indefinitely.
32	28	Sci. Data Processing	

3.7.2 <u>On-Board Processing - NSSC-1</u>. There are seven "processors" that have been written for the NSSC-1. These are listed in table 3.7.2-1 with their associated RTCS's. The organization of this software is given in figure 3.7.2-1. Detailed flow charts of the modules and their major subsections are available in section 3.8 (the NSSC-1 software section). Basically the NSSC-1 processors take care of turning the FOS on and off and do calculations necessary to support target acquisition. Brief descriptions of the seven processors are given below. Flow charts for the processors are in the NSSC-1 software section - 3.8.

1. Autonomous Safing Processor (YFASAF, processor #25). This processor completes and emulates the internal FOS safe state, so that the FOS is put in a safe mode while preserving the microprocessor contents.

2. Initialization Processor (YFINIT, processor #26). This processor brings one side of the FOS experiment to a state of readiness for the acceptance of operational parameters. Since this processor does not control the FOS heaters, any commands required to bring the FOS into the temperature range required for operation should precede YFINIT execution.

3. Turn Off Processor (YFOFF, processor #27). This processor controls planned FOS turn offs, leaving the FOS with both sides off.

4. Mode II Target Acquisition Processor (YFMOD2, processor #28). This processor performs a single centering operation for each period when execution is enabled. It uses YTARXCTR and YTARYCTR (see Section 3.1.5) to determine what should be fed to the SSM for movement, and also causes the NSSC-1 Standard Header Packet to be output. This processor is used when target identification, isolation, and location is done in the FOS microprocessor (without bringing raw science data into the NSSC-1).

3.7.3 On Board Processing (TBD).

3.7.3.1 Engineering Telemetry Subcommutation (TBD).

Figure 3.7.3.1-1 shows the basic major frame - minor frame breakdown for ST engineering telemetry. Table 3.7.3.1-1 explains the subcommutation done by the FOS CEA. This pattern is synchronized by the major frame interrupt, the minor frame interrupt increments a counter that is used to index the telemetry item. Figure 3.7.3.1-2 provides a breakdown of the three bytes of the subcommutated engineering telemetry that contain the discrete command error log.

3.7.3.2 Science Data Format(TBD).

Figure 3.7.3.2-1 illustrates the science data organization used when FOS data is recorded or transmitted. Figure 3.7.3.2-2 gives detailed information on the science data format including packing of the science data lines into the segment/packet structure that is common to all items transmitted via the science stream.

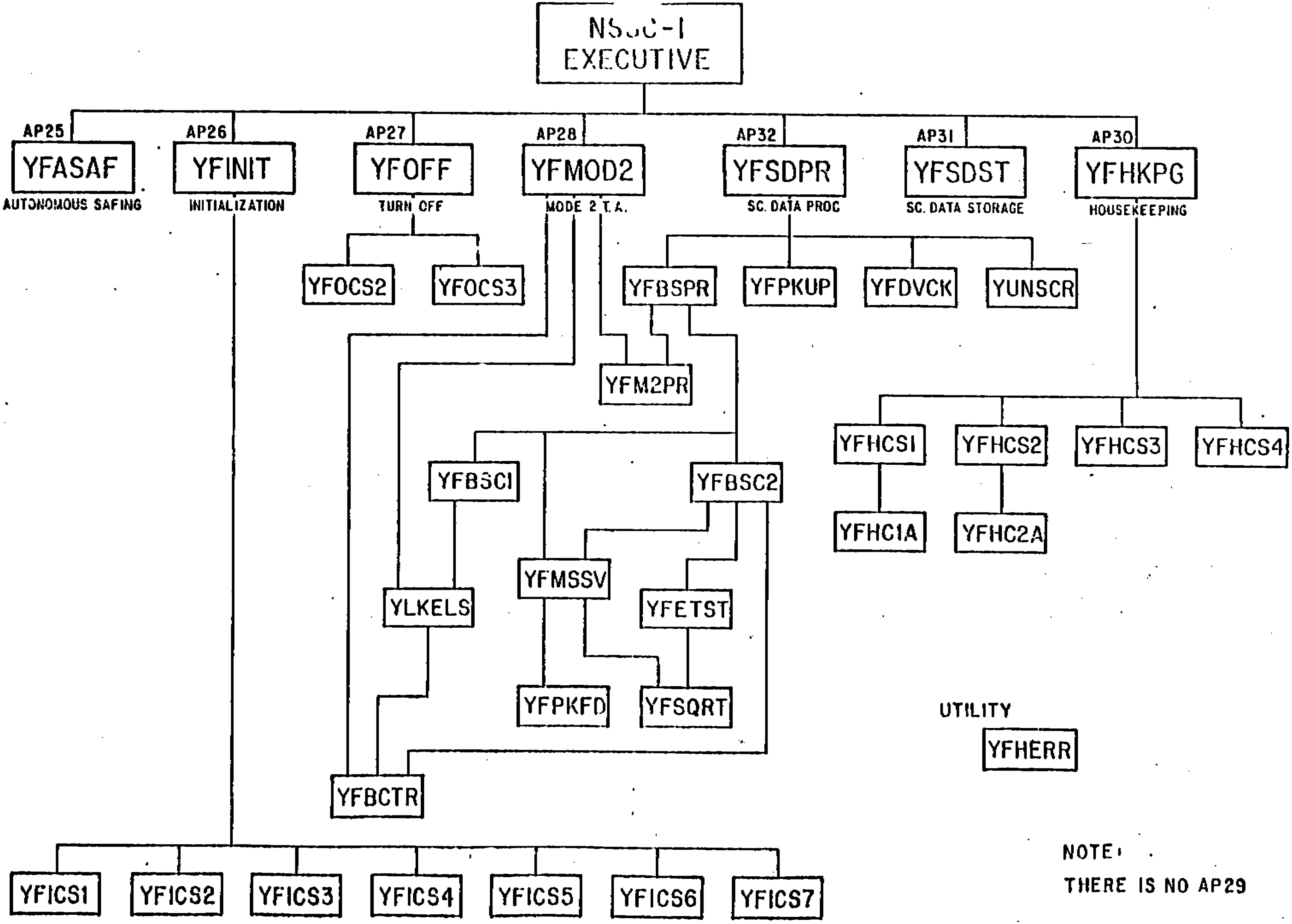


FIGURE 2-6-5 3.7.2-1

FOS SOFTWARE FUNCTIONAL ORGANIZATION

FOS WORD 8 SERIAL ENGINEERING INTERNAL SUB-COMMUTATOR DATA LIST

0 Y500 YENGSYNC	1 Y501 YFIRMVER	2 Y502 YERRCHK HI	3 Y502 YERRCHK LO	4 Y551 YWRDSLIN HI	5 Y551 YWRDSLIN LO	6 Y552 YLINSFRM HI	7 Y552 YLINSFRM LO
8 *Y506, Y504, Y503	9 Y505 YAPERPOS HI	10 Y505 YAPERPOS LO	11 Y507 YPLRZPOS HI	12 Y507 YPLRZPOS LO	13 Y553 YXDAC HI	14 Y553 YXDAC LO	15 YXFILW
16 Y510 YTARXCTR HI	17 Y510 YTARXCTR LO	18 Y511 YTARYCTR HI	19 Y511 YTARYCTR LO	20 Y650 YTAMAX HI	21 Y650 YTAMAX LO	22 Y513 YOVRLITE MS	23 Y513 YOVRLITE NMS
24 Y513 YOVRLITE NLS	25 Y513 YOVRLITE LS	26 Y514 YSAFING	27 Y515 YTAMODE	28 Y516 YSPEED HI	29 Y516 YSPEED LO	30 Y517 YSELFCHK HI	31 Y517 YSELFCHK LO
32 Y518 YDREFDAC	33 Y519 YFOCUSRB	34 -* Y520, Y579 Y580, Y581	35 Y520 YHVDACRB LO	36 Y521 YYDAC HI	37 Y521 YYDAC LO	38 *Y506, Y504, Y503	39 Y505 YAPERPOS HI
40 Y505 YAPERPOS LO	41 Y507 YPLRZPOS HI	42 Y507 YPLRZPOS LO	43 Y553 YXDAC HI	44 Y553 YXDAC LO	45 YYFILW	46 Y522 YXPITCH HI	47 Y522 YXPITCH LO
48 Y523 YXBASE HI	49 Y523 YXBASE LO	50 Y524 YXSTEPS	51 Y652 YREJECTS HI	52 Y555 YRANGE	53 Y526 YYPITCH HI	54 Y526 YYPITCH LO	55 Y527 YYBASE HI
56 Y527 YYBASE LO	57 Y528 YYSTEPS	58 Y652 YREJECTS LO	59 Y576 YMSLICES	60 Y530 YOVRSCAN	61 Y531 Y1STCHNL	62 Y532 YNUMCHNL	63 Y533 YLIVETYM HI
64 Y533 YLIVETYM LO	65 Y534 YDEADTYM HI	66 Y534 YDEADTYM LO	67 Y711 YAQMD	68 *Y506, Y504, Y503	69 Y505 YAPERPOS HI	70 Y505 YAPERPOS LO	71 Y507 YPLRZPOS HI
72 Y507 YPLRZPOS LO	73 Y553 YXDAC HI	74 Y553 YXDAC LO	75	76 Y510 YTARXCTR HI	77 Y510 YTARXCTR LO	78 Y511 YTARYCTR HI	79 Y513 YTARYCTR LO
80 Y651 YTAMIN HI	81 Y651 YTAMIN LO	82 Y536 YFWSTAT1 HI	83 Y536 YFWSTAT1 LO	84 Y537 YFWSTAT2 HI	85 Y537 YFWSTAT2 LO	86 Y538 YFWSTAT3 HI	87 Y538 YFWSTAT3 LO
88 Y539 YFWSTAT4 HI	89 Y539 YFWSTAT4 LO	90 Y540 YFWSTAT5 HI	91 Y540 YFWSTAT5 LO	92 Y541 YFWSTAT6 HI	93 Y541 YFWSTAT6 LO	94 Y542 YMCLEARS	95 Y649 YSMCERRS
96 Y543 YLASTCMD HI	97 Y543 YLASTCMD LO	98 *Y506, Y504, Y503	99 Y505 YAPERPOS HI	100 Y505 YAPERPOS LO	101 Y507 YPLRZPOS HI	102 Y507 YPLRZPOS LO	103 Y553 YXDAC HI
104 Y553 YXDAC LO	105	106 Y544 YNOISELM HI	107 Y544 YNOISELM LO	108 Y545 YRAMADDR HI	109 Y545 YRAMADDR LO	110 Y546 YINTEG	111 Y577 YPTRNS
112 Y547 YINTMODE	113 Y548 YREADCYC	114 Y549 YDATALIM	115 Y550 YMDMPADR HI	116 Y550 YMDMPADR LO	117 **Y563 - Y556	118 *+Y570 - Y564	119 +*Y575 - Y571

*WORD 8 MINOR FRAME 8, 38, 68, 98

DATA BASE#	MNEMONIC	BITS△
Y506	YFGWAPOS	4-1
Y504	YFGWASTR	5
Y503	YDOOR	8-7

** WORD 8 MINOR FRAME 117

DATA BASE#	MNEMONIC	BITS△
Y548	YCDACERR	5
Y563	YDDACERR	3
Y562	YDRDACER	8
Y561	YHVDACER	7
Y560	YFDACERR	2
Y559	YYDACERR	6
Y558	YXDACERR	4
Y556	YSPRBIT1	1

*+ WORD 8 MINOR FRAME 118

DATA BASE#	MNEMONIC	BITS△
Y570	YRESETMP	8
Y569	YABORTDA	7
Y568	YENDDA	6
Y567	YBEGINDA	5
Y566	YMECHTOC	4-3
Y565	YMCHTOER	2
Y564	YACTMERR	1

+* WORD 8 MINOR FRAME 119

DATA BASE#	MNEMONIC	BITS△
Y575	YSPRNIB1	8-5
Y574	YSPRBIT6	4
Y573	YSPRBIT5	3
Y572	YSPRBIT4	2
Y571	YSPRBIT3	1

-* WORD 8 MINOR FRAME 34

DATA BASE	MNEMONIC	BITS△
Y579	YDPRMPWR	2-1
Y580	YHVSPAR	3
Y581	YFFCPWR	4
Y520	YHVDACRB HI	8-7

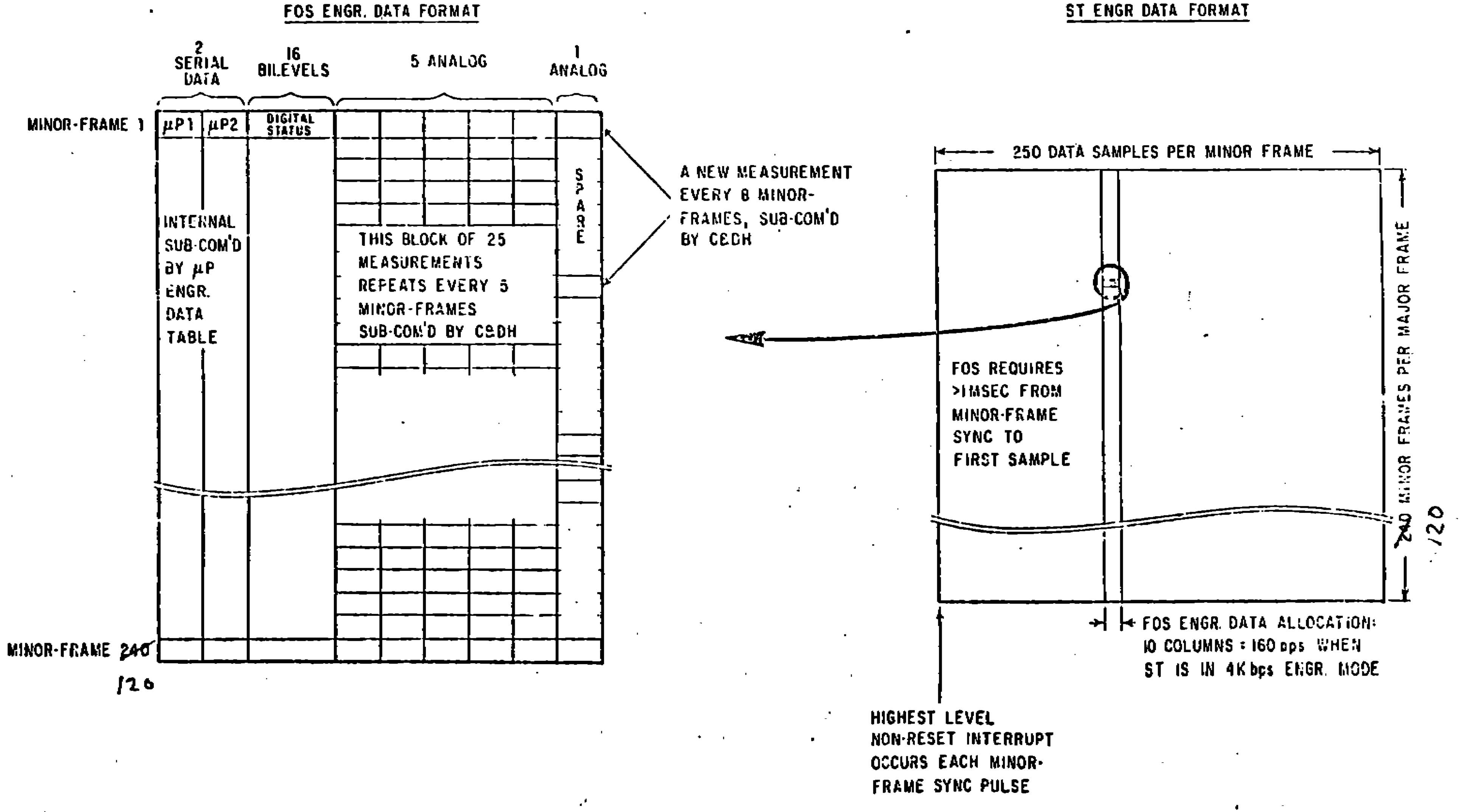
DISCRETE COMMAND/ERROR LOG

△ BIT 1 IS MSB
BIT 8 IS LSB

~~FIGURE II 3.9.2-2~~

Table 3.7.3.1-1

FOS ENGINEERING TELEMETRY UTILIZATION



7969-11-003A

Figure 3.7.3.1-1

UCSD FOS SCIENCE DATA STORAGE

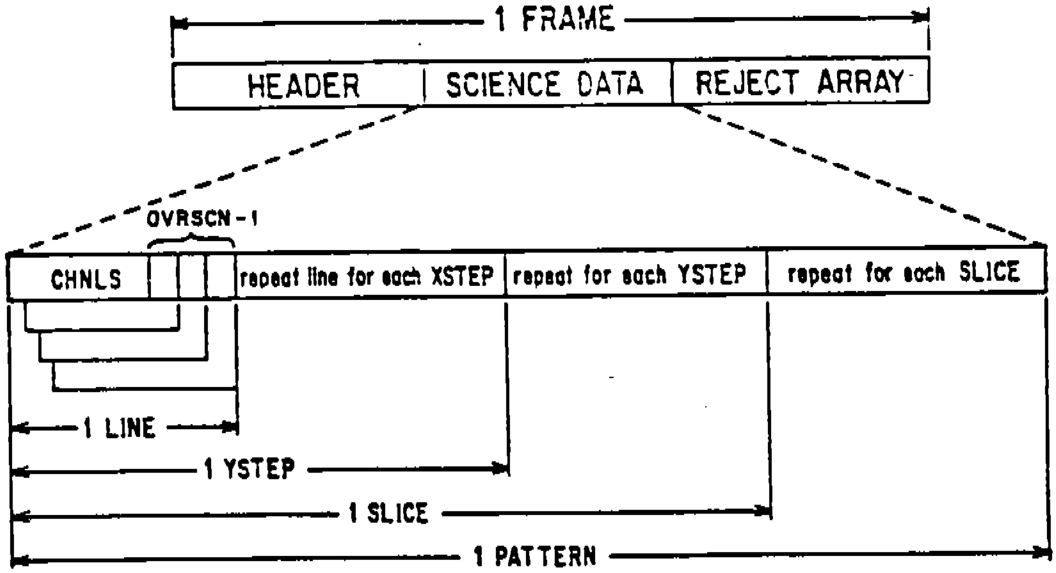
1) Order of operations in flight microprocessor, from innermost loop out:

1 PATTERN {
- INTEGRATIONS (INTS)
- XSTEPS
- OVRSCN
- YSTEPS
- SLICES

}

- PATTERNS / READOUT
- READOUTS / MEMORY CLEAR
- MEMORY CLEARS / ACQUISITION

2) Order of data transmission



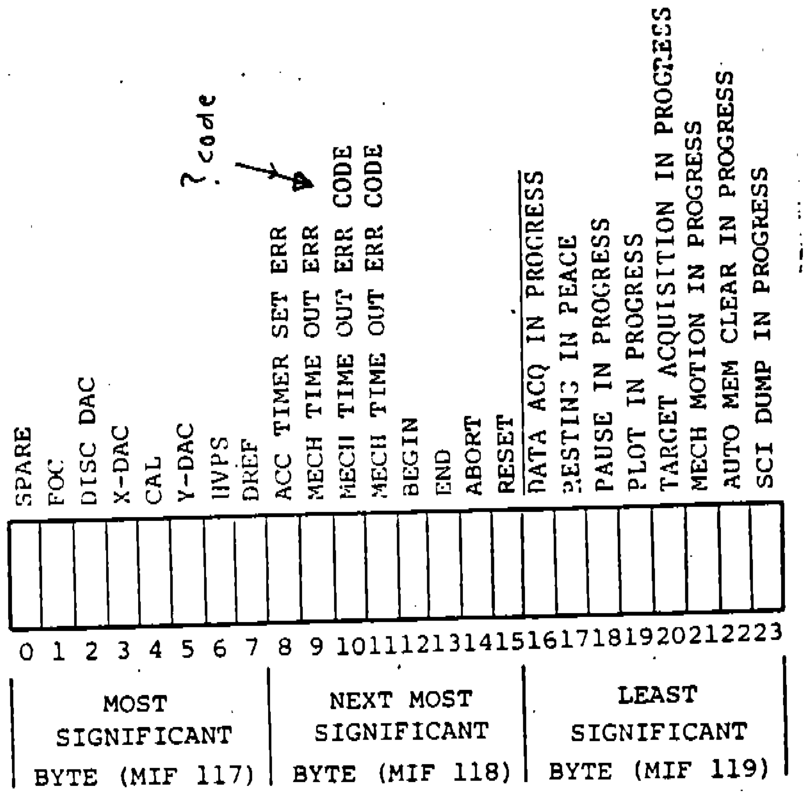
84WB-11-003

FIGURE ~~3.6.1-1~~ 3.7.3.2-1

UCSD FOS SCIENCE DATA STORAGE

there is an explanation in FOS SOGs of this pattern

DISCRETE COMMAND ERROR LOG
24 Bits



11-5000F

~~FIGURE 5.2-2~~

Figure 3.7.3.1-2

3.7.~~5.2~~ 3.3 Packet Format Codes. The packet format code is an 8-bit, user-defined number indicating the type of FOS data containe the packet. Table 3.7.~~5.2~~ 3.3-1 lists the specific (hex code) numbers f the science data which will be downlinked from the FOS.

The assignment of Packet Format Codes is done for the purpos of classifying data by type for processing/archival. The Packet Fo Codes will not restrict the use of the FOS M x N format in any way.

The Packet Format Codes should be used to determine default processing/archival only. An observer should have the capability of over-riding the defaults in order to process/archive a particular observation as if it had some other Packet Format Code.

Table 3.7.~~5.2~~ 3.3-1 Packet Format (Hex) Codes

FOS DATA TYPE	PACKET FORMAT CODE
Memory dump	D0
Memory dump from Autonomous Safing processor	D1
Unique log	10
Calibration data (no cal; direct)	
Internal wave-length calibration	20
External wave-length calibration	21
Spectrophotometric standard calibration	22
Polarimetry standard polarized calibration	23
Polarimetry standard unpolarized calibration	24
Calibration Data (Calibrate; direct)	
Internal wave-length calibration	40
External wave-length calibration	41
Spectrophotometric standard calibration	42

UCSD FAINT OBJECT SPECTROGRAPH M x N SCIENCE DATA FORMAT

A Science Frame contains a Science Header, a complete Science Data Array S, and a Reject Array R if necessary.

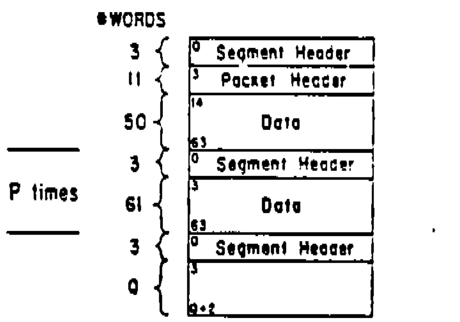
M = Number of words per line. N = Number of lines per frame.

S = Science Data Array with elements S_{ijkl}
where i varies from 1STCHNL to (1STCHNL + CHNLS + OVRSCN −2)
j varies from 1 to XSTEPS
k varies from 1 to YSTEPS
l varies from 1 to SLICES

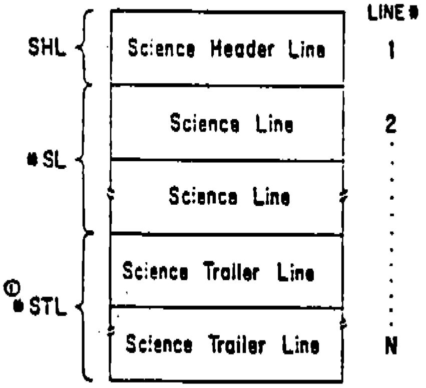
R = Reject Array with elements R_{jmkl}
where j, k and l are the same subscripts as the Science Data Array S and m varies from 1 to OVRSCN.

By definition:
XSTEPS = Number of X deflection substeps, YSTEPS = Number of Y deflection steps, OVRSCN = Number of channels overscanned; 1STCHNL = First channel in detector array to be processed, CHNLS = Number of channels to be processed, SLICES = Number of data acquisition slices.

TYPICAL SCIENCE LINE



TYPICAL SCIENCE FRAME



N = Number of lines per frame.
= SHL + #SL + #STL
where
SHL = 1
#SL = Number of Science Lines.
= (XSTEPS)(YSTEPS)(SLICES)
① #STL = Number of Science Trailer Lines.

$$= \left\lceil \frac{WRA}{M} \right\rceil_{③}$$

where
WRA = Words in reject array.
= (XSTEPS)(OVRSCN)(YSTEPS)(SLICES)

M = words/line = (CHNLS + OVRSCN − 1)
= 50 + 61 P + Q

where $P = \left\lfloor \frac{M-50}{61} \right\rfloor_{②}$ and $Q = \text{Rem } \frac{M-50}{61}$

#SEG = Number of segments per line.

$$= \left\lceil \frac{M-50}{61} \right\rceil_{③} + 1$$

NOTE:
① #STL will generally = 0 for non time resolved modes.
② Greatest integer ≤ quotient.
③ Least integer ≥ quotient.

FIGURE ~~3.6.1-2~~ 3.7.3.2-2
UCSD FOS M x N Science Data Format

3.7.4 FOS Engineering Telemetry A basic reference for engineering telemetry is DM-02 ST Instrument Program and Component List from LMSC (LMSC 4171850G). This reference explains the formats that are available for engineering telemetry. The formats differ in telemetry rate and in minor frame length and in the number of minor frames per major frame. The minor frames are separated by 24-bit telemetry sync words. A major frame is the period in which all data is sampled at least once. The basic formats are given in table 3.7.4-1 (based on LMSC DM-02):

Table 3.7.4-1

Format	Minor Fr Length (8-bit words)	Minor Fr pr Major Frame	Trnsm. Speed Kbps	Format Prog./ Fixed	Purpose
A/AN/AF	250	120	4	Prog	Normal ST Telem.
F/FN/FF	200	1200	32	Prog	OTA Diagnostic
P/PN/PF	200	1200	32	Prog	PCS Diagnostic
C	125	20	0.5	Prog	Deployment
D	125	20	4	Fix	Autonomous Safemode
E	125	20	0.5	Fix	Retrieval
T/TN/TF	200	1200	32	Prog	Test/General Purpose
Q/QN/QF	200	1200	32	Prog	SSM Flight Software Test

Note: AN implies Normal SI Data, AF Fixed SI Data etc.

The normal mode anticipated for FOS operations is format AN.

(Table 3.7.3.3-1 Cont'd)

Polarimetry standard polarized calibration	43
Polarimetry standard unpolarized calibration	44
Science Data (Direct)	
Spectroscopy	60
Spectropolarimetry	61
Time-tagged	62
Rapid readout	63
Time-resolved synchronous	64
Time-resolved asynchronous	65
Firmware Target Acquisition (Image Mode) Raw	70
Firmware Target Acquisition (Image Mode) Filtered	71
Science Data (Processed)	
NSSC-1 Binary Search (Image m	80
NSSC-1 Peakup (Image mode)	81
ST Data Types	
Standard Header Packet	AA
Executive States Buffer	BB
NSSC-1 Dump	DD
Fill	FF

Bill, there was a note in draft "need addition for double-buffered? See Rich/Tom ?-P
Tom: useful

All these numbers are up-linked prior to observation

ND 4007 p00
Table 4.2.1 ref ?

TABLE 3.7.5.1-1

FOS STANDARD HEADER PACKET (SHP) STRUCTURE
(per ND-1004)

WORD (bits 8, 16)		
1	ID | OBS	ID = X'DC' for FOS OBS = observation # = # in ancillary data ≠ word 8045-805
	//////////////	
131–259	FOS current Value Table	129 words (last sampled versions of some Eng. Telemetry). Only words 131-168 are used. See ~~Table 4.2.1 (ND 4007)~~ appendix B.
	//////////////	
801–802	FOS Prog. No. (fwd linked value)	
803–804	FOS Observ. Set No	≠ OBS in word 1 above
804–805	FOS Observ. No.	
	//////////////	
878–899	FOS Data	22 words ≠ FOS Unique Data Log --> See Section 3.7.5.1 (from NSSC-1 processors used to support FOS; ex. Target Acquisition.
	//////////////	
965		

		Ancillary Data (14 words) (from Table 3.2-2)
0	Sync X'03BB'	Sync pattern 24 bits
1	Sync X'2E' | Segment No.	Segment 0-15 (64 16-bit words = 1 segment of a packet or a line 965 max words)
2	Packet count	# of non-filler packets output by SI C&DH
3	Source ID | Mission ID X'3A'	Source ID = X'DC' for FOS, 0 for SHP
4	Coded Packet Length | Secondary Header Length	CPL: '30', '40', '48', '50', '54', '58', '56', '60', '62', etc (1, 2, 3, 4, 5, 6, 7, 8, 9); SHL: X'10' = 16_{10}
5	Packet Format | Source ID Parity	Packet format code: See Table ~~3.7.5.2-1~~ 3.7.3.3-1; Source ID parity: SHP- 0, FOS-X'A7'
6	Frame Start Ct.	0 for SHP
7	Line Count	0 for single line (965 16-bit words)
8	Time msbits	
9	Time nmsbits	
10	Time lsbits 0	
11	Undef. | 11 Obs Nb	= SHP wd 1 bits 9-16
12	Packets/frame	= 1 for SHP and FOS UDL
13	Wds/packet	= 965 (X'365') for SHP and FOS UDL
14–15	Data or fill as req. in last packet	Fill = X'5569'
63		

3.7.5 Standard Header Packet (SHP). The NSSC-1 computer usually marks the beginning of an observation by transmitting a Standard Header Packet (SHP). One purpose of this is to provide data necessary to calculate an accurate starting time for the observation. The SHP's are transmitted as part of the science data stream. The FOS processors running in the NSSC-1 can also generate requests for a SHP. This can be done at fixed time intervals by setting a NSSC-1 memory cell with the time interval. This memory cell is read by the housekeeping processor. Also the target acquisition processors generate requests for SHP's in order to transmit to the ground the results of the target acquisition.

3.7.5.1 FOS SHP Structure. The SHP is transmitted as part of the science data stream - it constitutes a maximal length line or 965 16 bit words. Like all the telemetry on the science data stream, the SHP is embedded in a segment/packet structure that adds telemetry information. Each packet contains up to 16 segments each of which consist of 64 16 bit words. The first segment in a packet contains 14 words of ancillary data (a 3 word segment header and a 11 word packet header) and 50 words of transmitted information or fill. Subsequent segments within a packet contain a 3 word segment header and 61 words of transmitted information or fill. The SHP structure after the packet/segment structure has been removed is shown if figure 3.7.5.1-1 as well as a summary of the ancillary data.

The SHP includes some of the FOS engineering telemetry - the items can be found by looking at the SHP column in appendix B. These engineering items are available either in the engineering stream or the FOS UDL and they will normally be obtained from these sources rather than the SHP. The SHP also contains binary data that relates to the results of target acquisition. The next section summarizes this and appendix C gives a detailed description of the FOS-unique words.

TABLE 3.7.5.2-1
FOS - DEDICATED WORDS IN STANDARD HEADER PACKET (SHP)

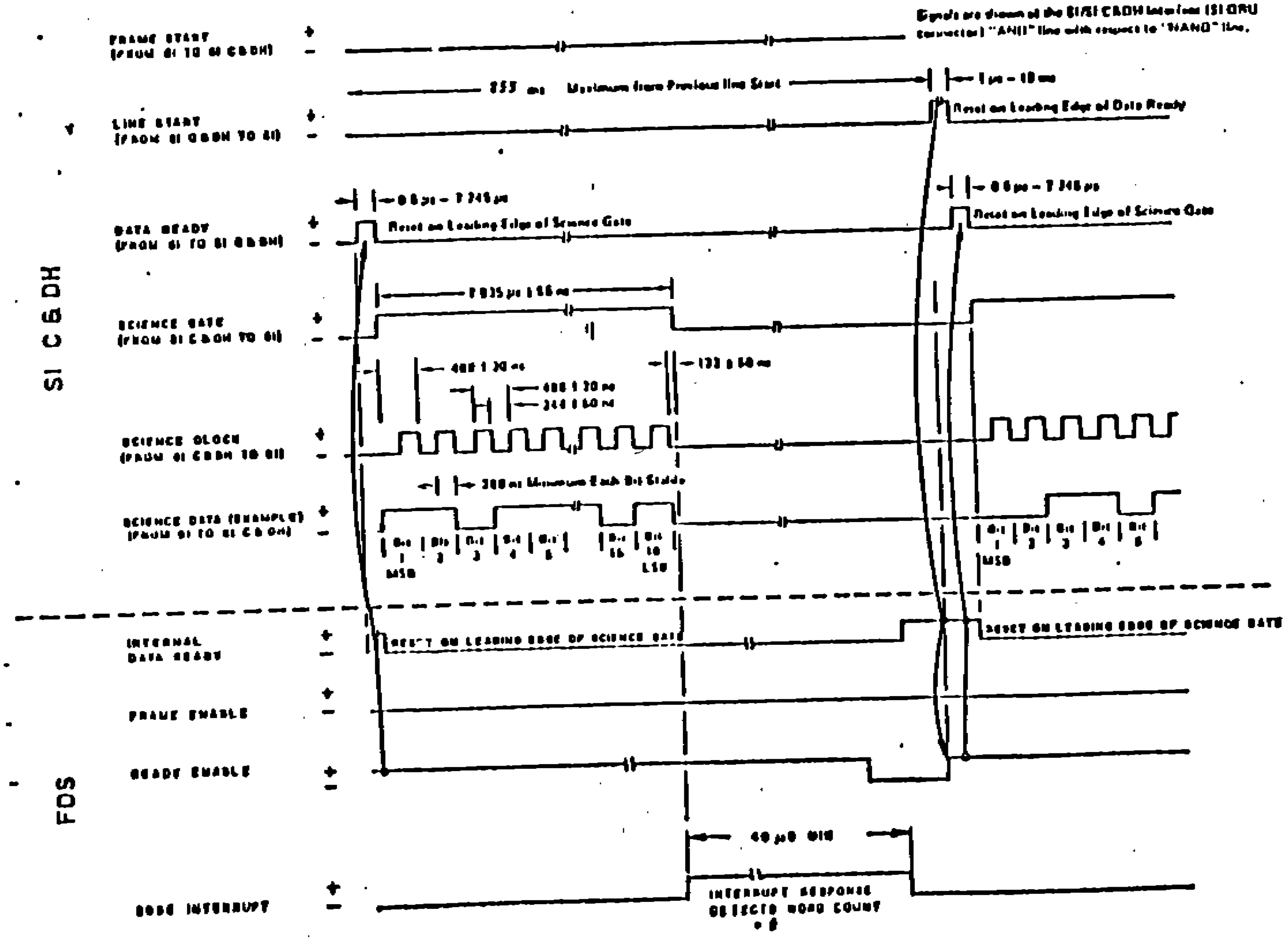
#	1	SHP #	2	3	4	5
1	1	878	2	3	4	5
2	YSTBUF	879	YTACMP	YGIVUP	YTACMP	YTACMP
3	SRUFPTRH	880	YGIVUP	YFRCTR	YGIVUP	YFDCWT
4	Wd#111 SIC&DH	881	YFM2CF	YFOUND.	YGPCTR	YDWELS
5		882	NMINOR	Pk. Ch. 1	YPKCT1	YACSAV-1
6		883	YFXCTR	Pk. Ch. 2	Pk. Ch. 1	YACSAV-2
7		884	YFYCTR	Pk. Ch. 3	Pk. Ch. 2	YFPUTT-1
8		885	YFVCTR(1)-1	Pk. Ch. 4	Pk. Ch. 3	YFPUTT-2
9		886	YFVCTR(1)-2	YPPB	Pk. Ch. 4	YACACC-1
10		887	YFVCTR(2)-1	YPPINV	YBASKP	YACACC-2
11		888	YFVCTR(2)-2	YRSINV	YFM2FL	
12		889	YPPB	YRSMVS	YEDGE	
13		890	YPPINV	YSCNUM	YNTARG	
14		891	YRSINV	YBASKP	YNMEAN	
15		892	YRSMVS	YNBCTR	YVARI1	
16		893	YSCNUM	YOBSJ	YFVCTR(1)-1	
17		894	YTALIM	YBSM	YFVCTR(1)-2	
18		895	YTACNT	YNMAX	YFVCTR(2)-1	
19		896	NEDM4	YNMEAN	YFVCTR(2)-2	
20		897	NEDM2	YVARI1	YFXCTR	
21		898	YFM2ST	YFM2FL	YFYCTR	
22		899	YTAMOD			
	HK PROCESSOR #30 YFHKPG		MODE 2 T.A. PROCESSOR #28 YFMOD2	SCIENCE PROCESSOR #32 YFSDPR	SCIENCE PROCESSOR #32 YFSDPR	SCIENCE PROCESSOR YFSDPR

? FOS SOGS
doesn't show entry
for Housekeeping
processor

3.7.5.2 FOS Unique Data in the Standard Header Packet

Table 3.7.5.2-1 shows the arrangement of the 22-word FOS-dedicated area. The content of the FOS 22-word unique area is dependent on the reason for dumping the SHP (normal observation, target acquisition, etc.) and on the Application Processor requestin the SHP. The first word is a number which uniquely defines the forma of the other 21 words. A detailed description of the FOS-unique wor may be found in Appendix C.

SCIENCE DATA TRANSFER TIMING BETWEEN LINES



Note 1: Maximum times shown assume average transmission rates are 1.024 Mbps from SI to CU/SDF, 1.024 Mbps from CU/SDF to SSM, and 32 Kbps to/from the NSSC-I. Times are proportionally longer for lower transmission rates.

Note 2: SI C&DH disconnects if SI fails to respond within 10 ms.

FIGURE 3.7.6.2-2

3.7.6 Telemetry Synchronization

3.7.6.1 Engineering Data. Engineering data is synchronized the telemetry by the Major and Minor Frame Signal. Science data is transferred to the CU/SDF asynchronously.

3.7.6.2 Science Data. The FOS uses a general N lines per frame by M words per line science data output format, where N and M a specified by serial magnitude command and must always correspond to t current CU/SDF settings.

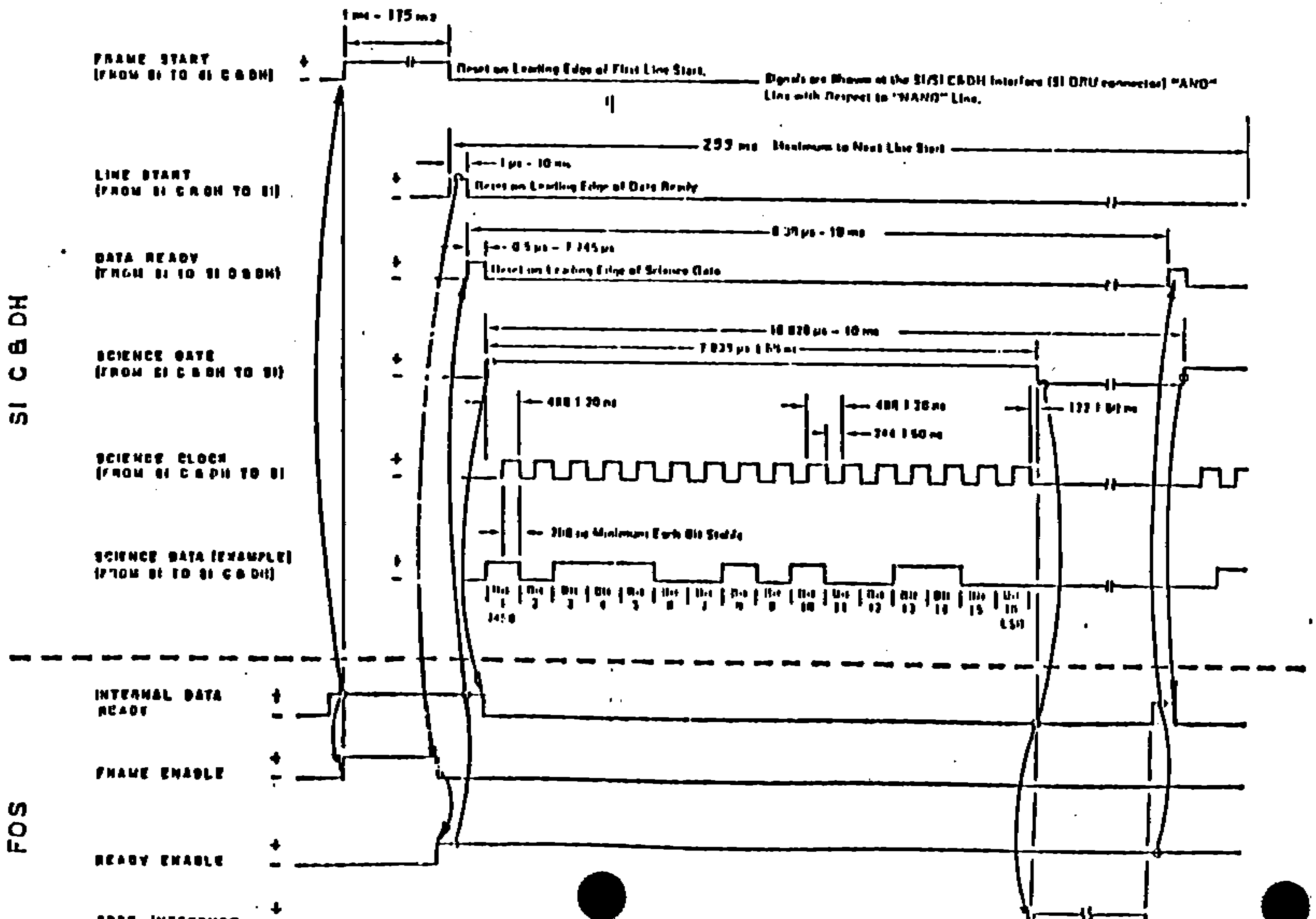
The FOS science data output timing is controlled by an interrupt to the microprocessor whenever a word of science data is re out of the FOS by the CU/SDF. The word to word timing is determined the "loading" of the microprocessor in tasks other than the science output task and in general is not known; however, the lower bound is by the number of instructions in the science data output task and the microprocessor clock speed (commandable to either 1.5MHz or 3.0MHz, 3.0MHz normal) and is approximately 400,000 bits/sec. The timing relation between the FOS and the CU/SDF is shown in Figure 3.7.6.2-1 Figure 3.7.6.2-2.

3.8 <u>NSSC-1 Software (Application Processors).</u> The functional organization of FOS software (NSSC-1 resident processors) is shown in Figure 3.8-1, while the operation of each processor or major sub-case and its attendant command sequence(s) is shown in Figures 3.8-2 through 3.8-9, arranged by increasing processor number. Also flow charts for the processors appear as Figures 3.8-10 through 3.8-27.

? Need text for Dongo S/W Charts

FIGURE 3.7.6.2-1

SCIENCE DATA TRANSFER TIMING AT START OF TRANSFER



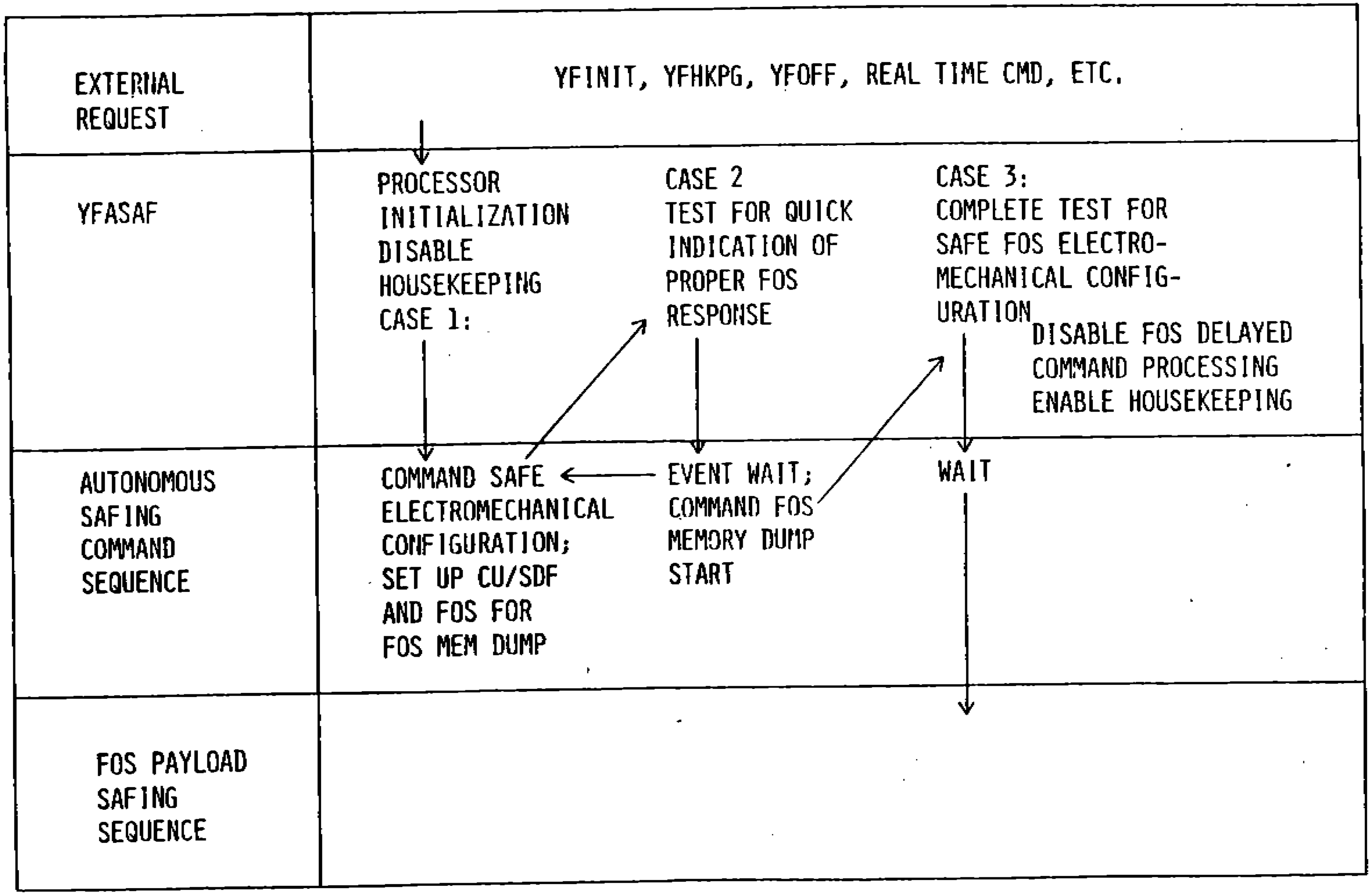
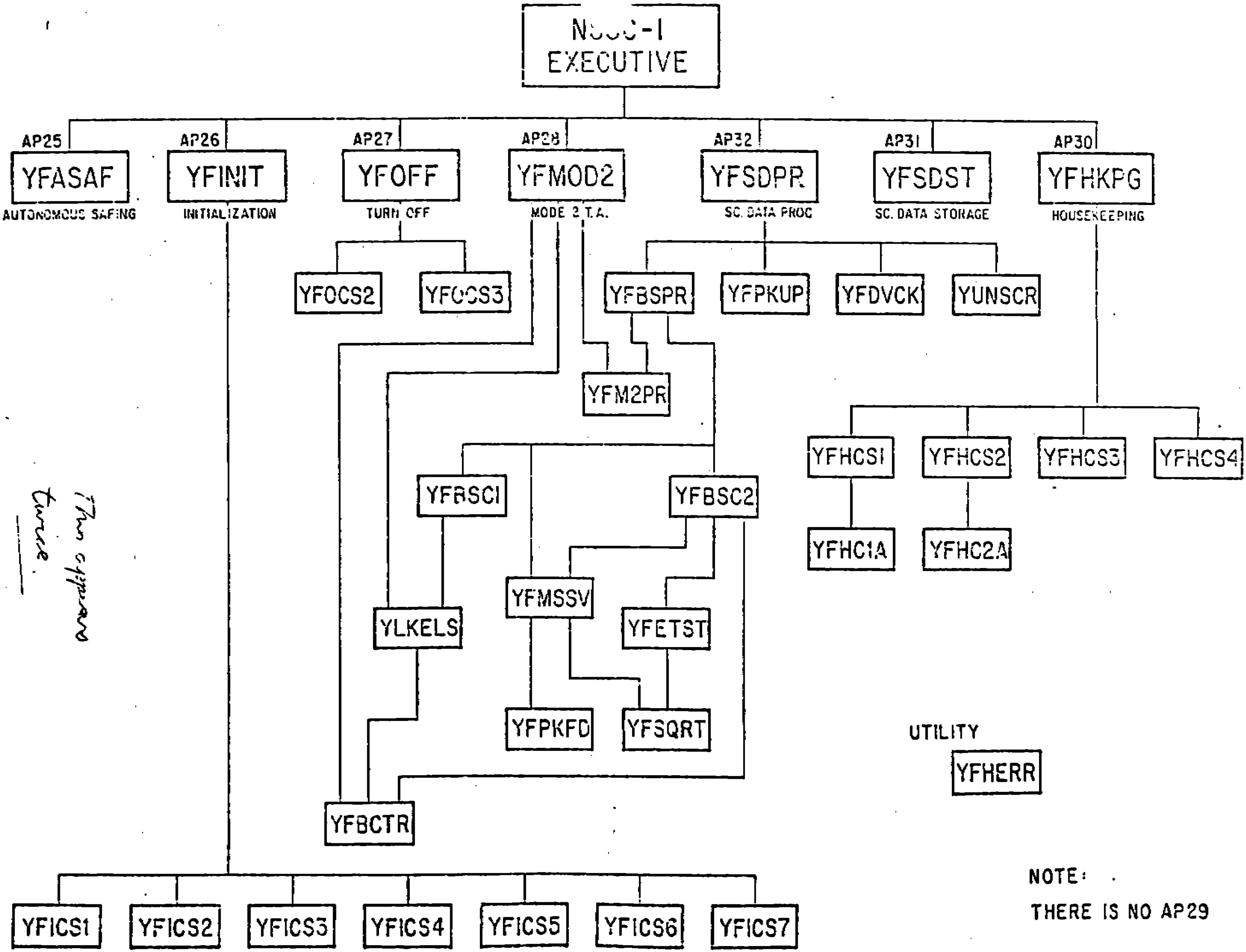


FIGURE 3.8-2

AP25 - YFASAF OPERATION

82GP-11-021



This appears twice.

_URE 3.8-1

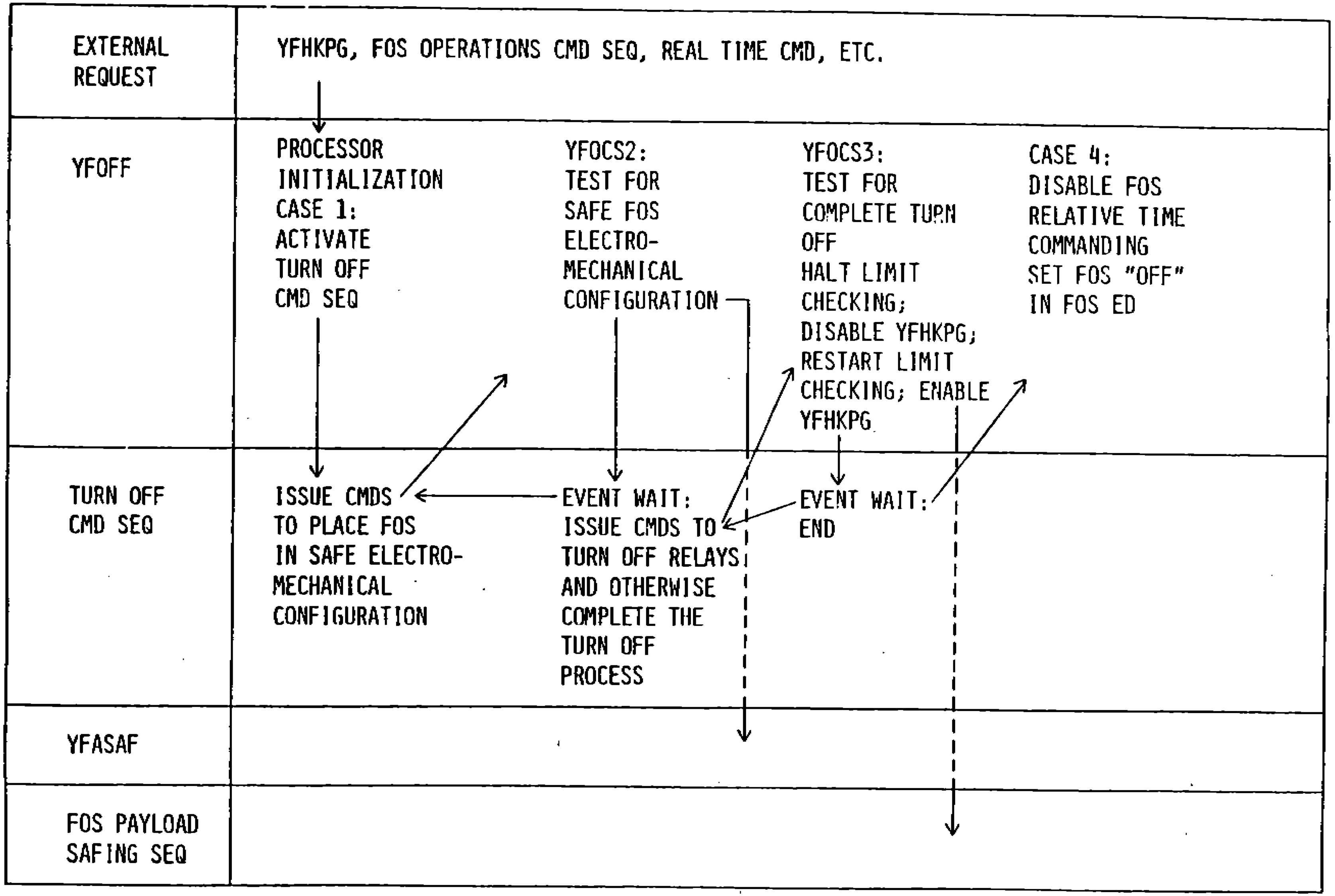


FIGURE 3.8-4

AP27 - <u>YFOFF OPERATION</u>

82GP-011-015

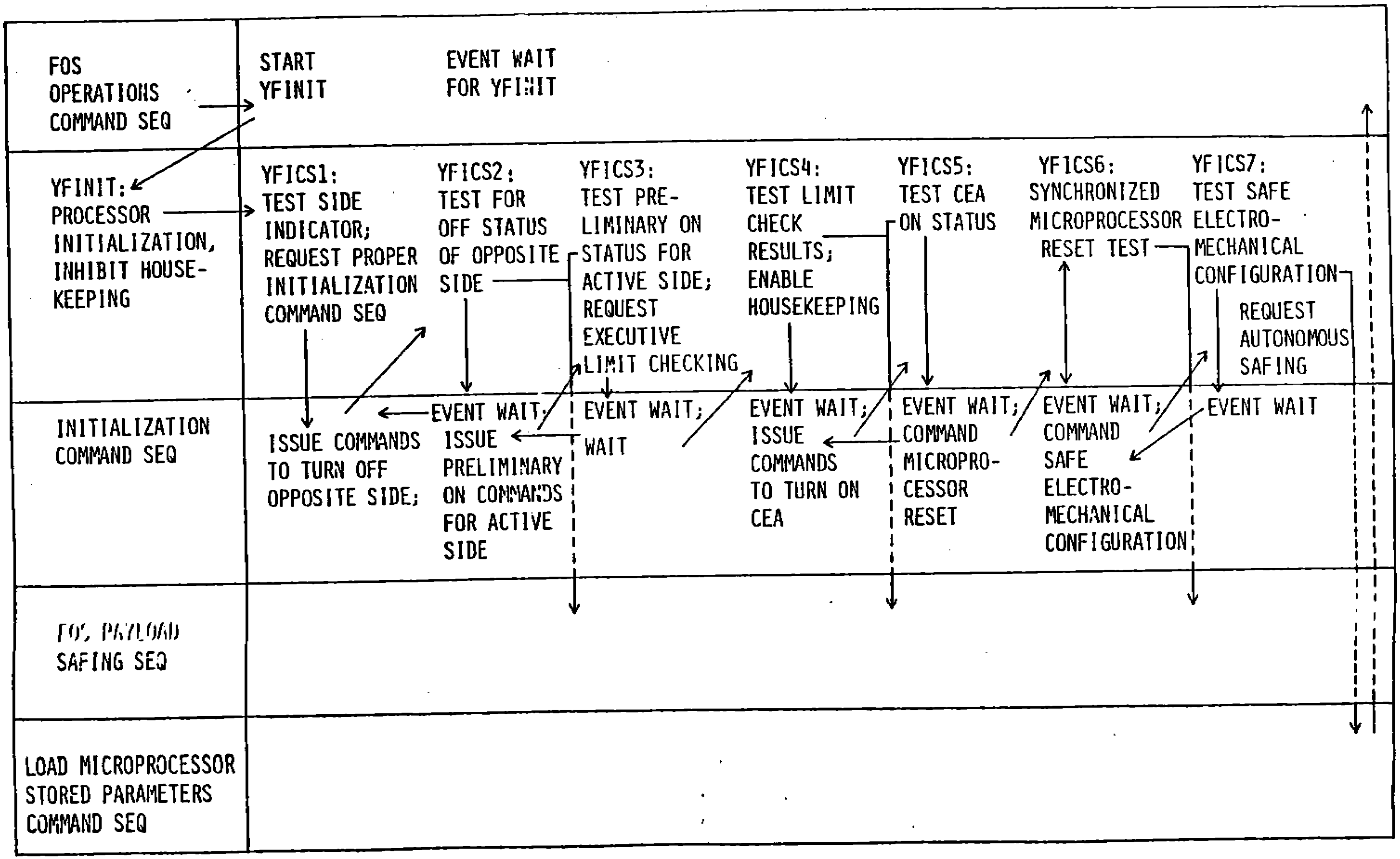


FIGURE 3.8-3

AP26 - YFINIT OPERATION

82GP-11-

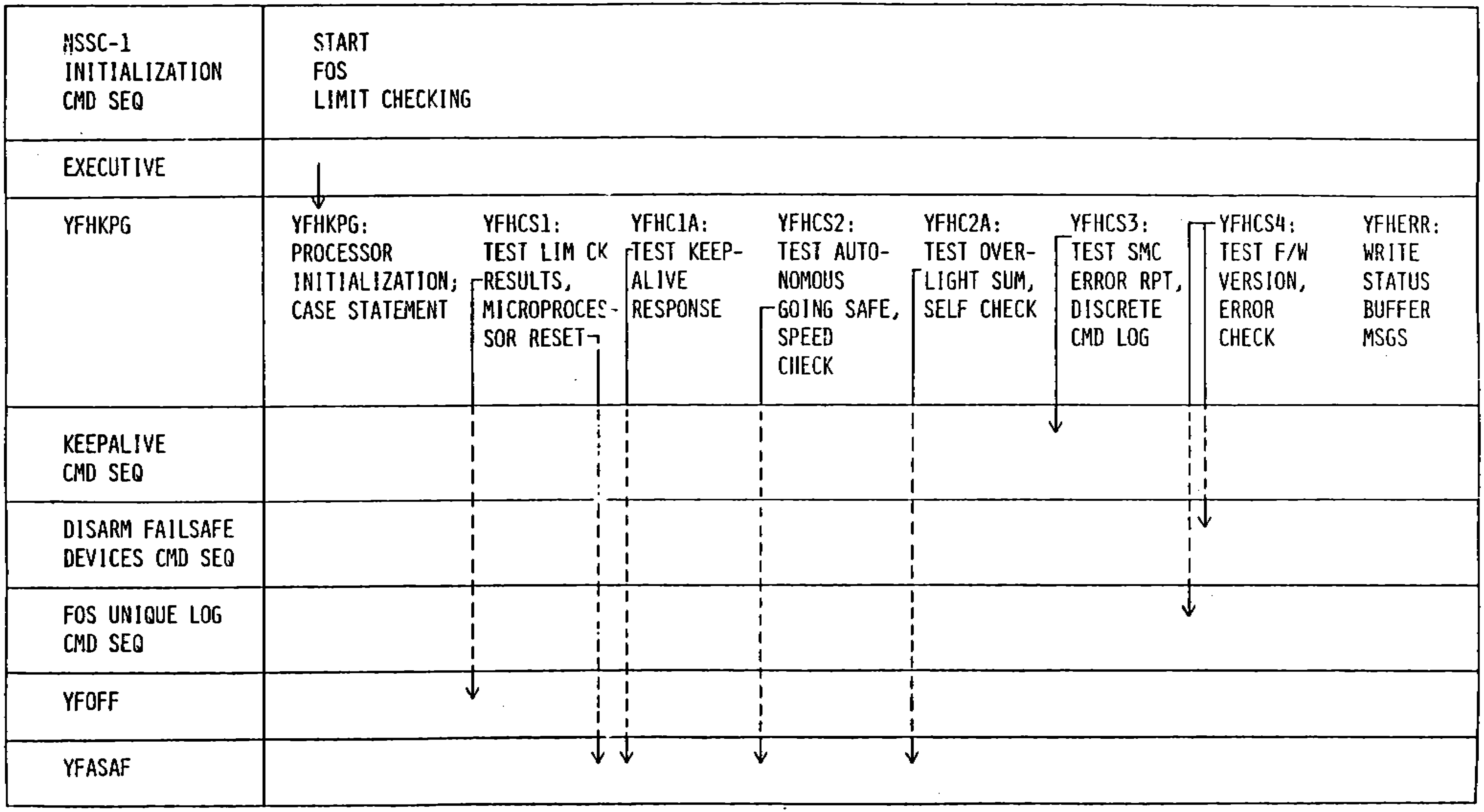


FIGURE 3.8-6

AP30 - YFHKPG OPERATION

82GP-OH-019A

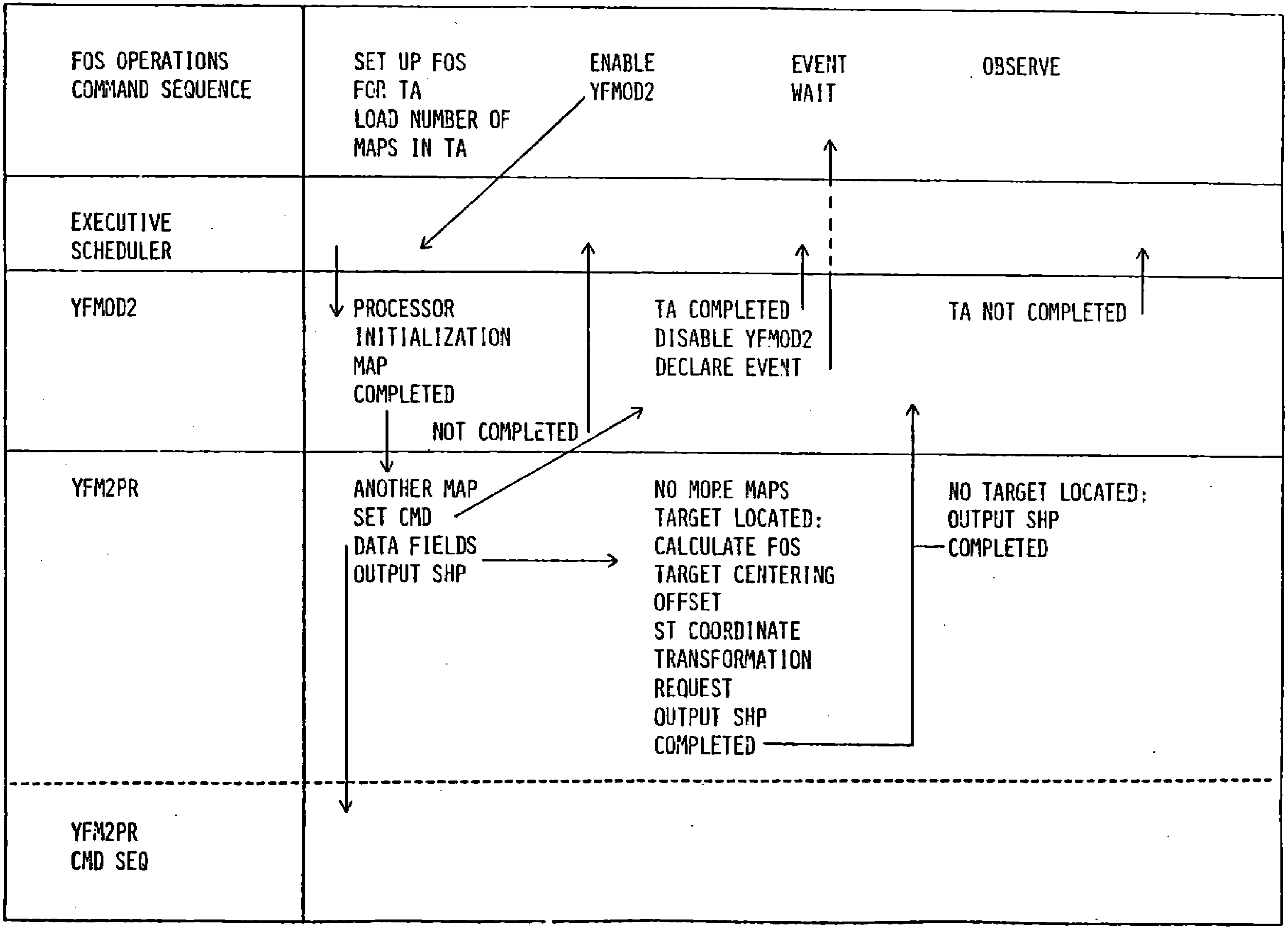

FOS OPERATIONS COMMAND SEQUENCE
SET UP FOS FOR TA LOAD NUMBER OF MAPS IN TA
ENABLE YFMOD2
EVENT WAIT
OBSERVE
EXECUTIVE SCHEDULER
YFMOD2
PROCESSOR INITIALIZATION MAP COMPLETED
NOT COMPLETED
TA COMPLETED DISABLE YFMOD2 DECLARE EVENT
TA NOT COMPLETED
YFM2PR
ANOTHER MAP SET CMD DATA FIELDS OUTPUT SHP
NO MORE MAPS TARGET LOCATED: CALCULATE FOS TARGET CENTERING OFFSET ST COORDINATE TRANSFORMATION REQUEST OUTPUT SHP COMPLETED
NO TARGET LOCATED: OUTPUT SHP COMPLETED
YFM2PR CMD SEQ

FIGURE 3.8-5

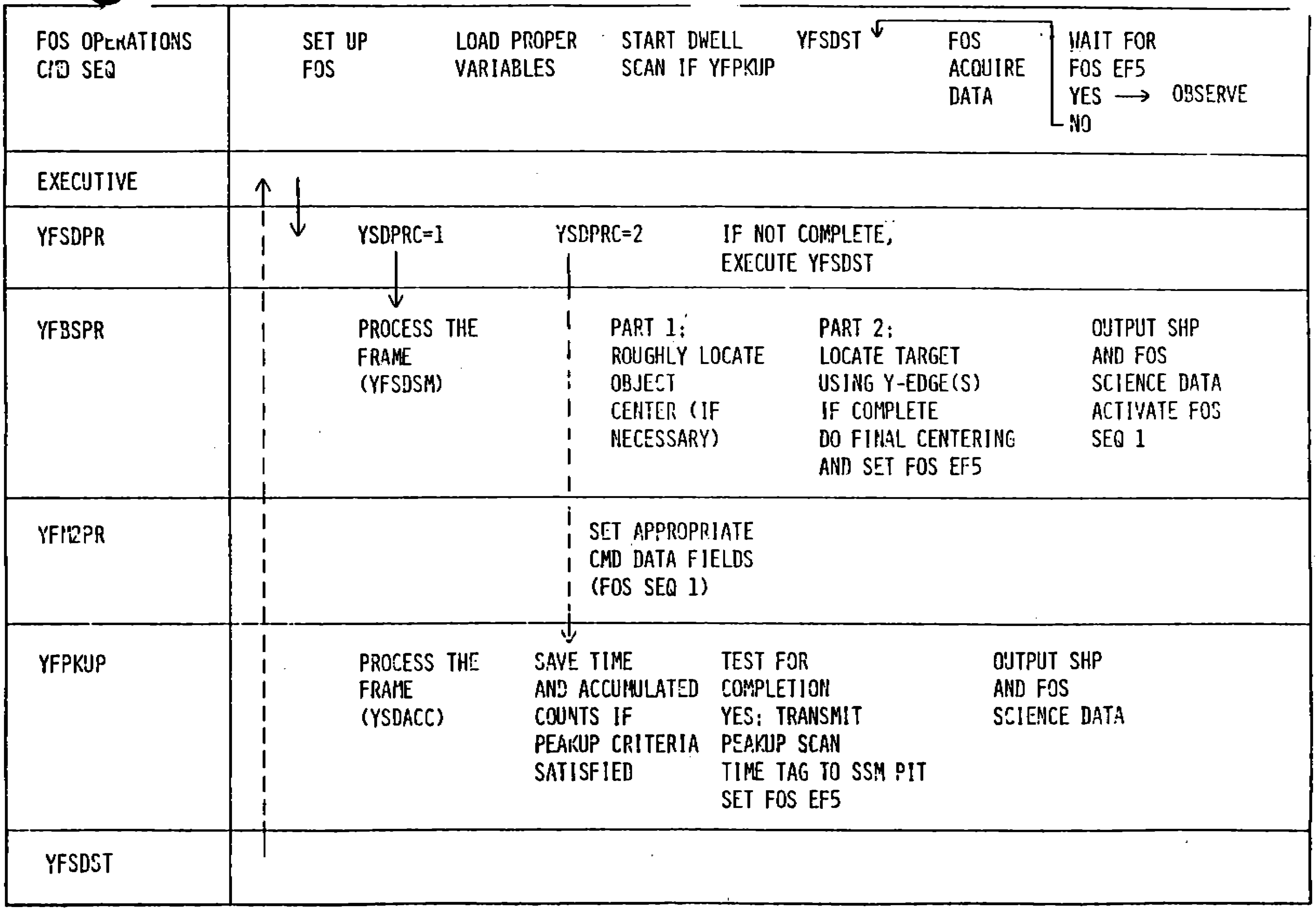


FIGURE 3.8-8

AP32 - YFSDPR OPERATION

82GP-II-017B

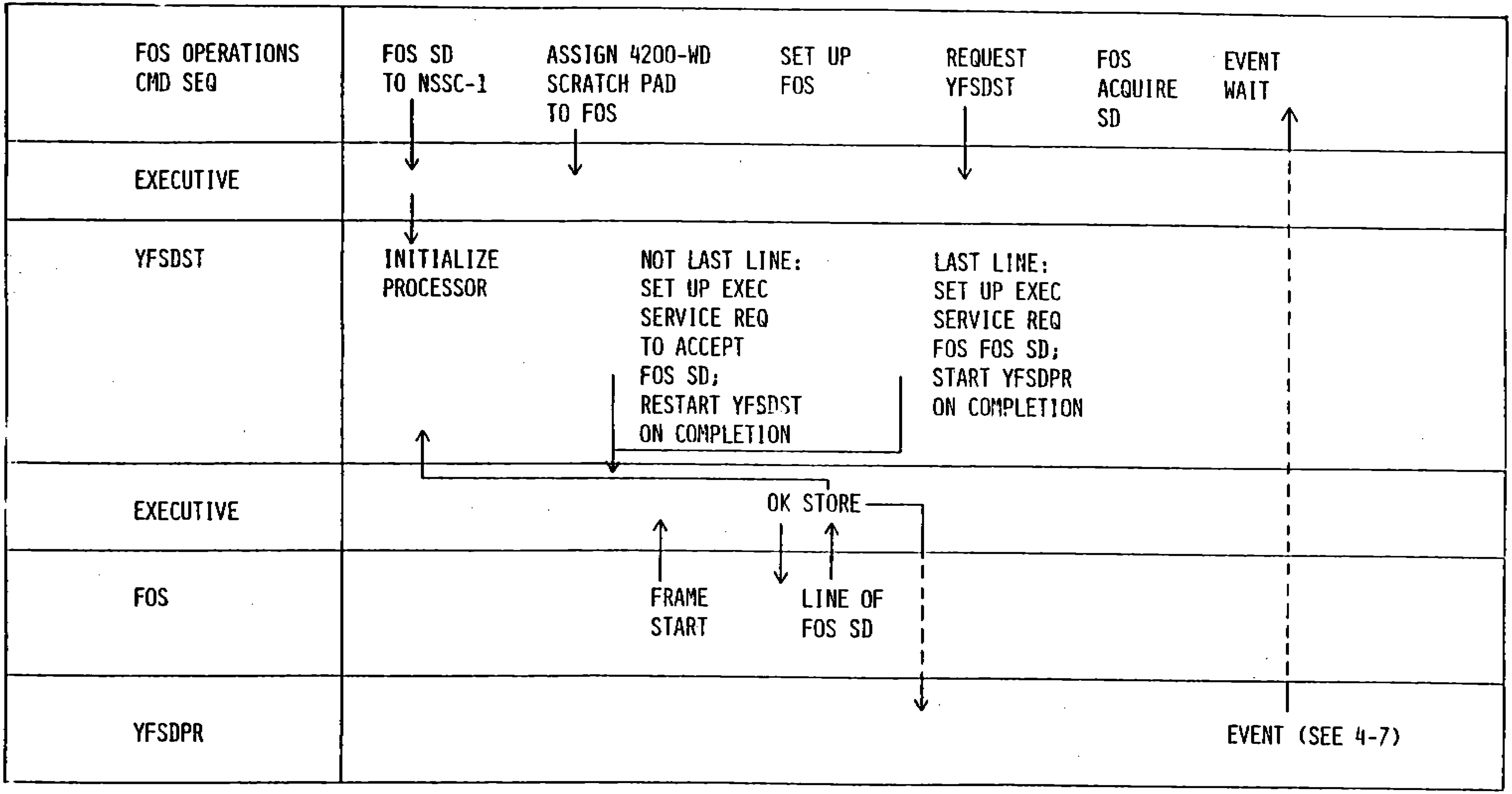


FIGURE 3.8-7

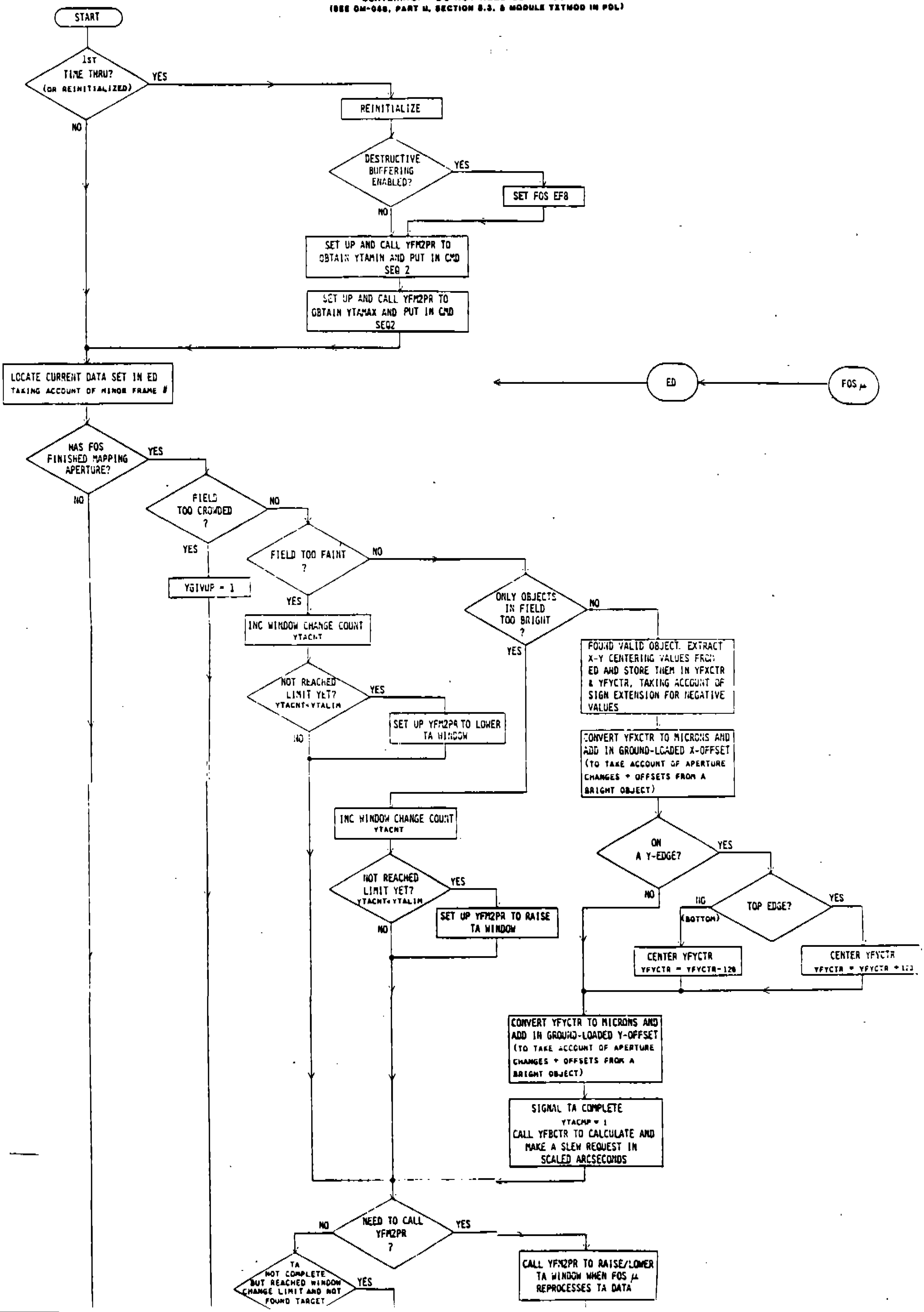
AP31 - YFSDST OPERATION

82GP-11-018A

FIGURE 3.8-10a

YFMOD2
MAY 15, 1985

COMPLETE FIRMWARE TA (AP28). FOSμ HAS CALCULATED (OR IS CALCULATING) TA PARAMETERS AND PUT THEM IN ED. ANALYZE TA PARAMETERS IN ED & PERFORM CENTERING. DO NOT NEED SO IN NSSC-1.
(SEE OM-048, PART II, SECTION 8.3, & MODULE TXTMOD IN POL)



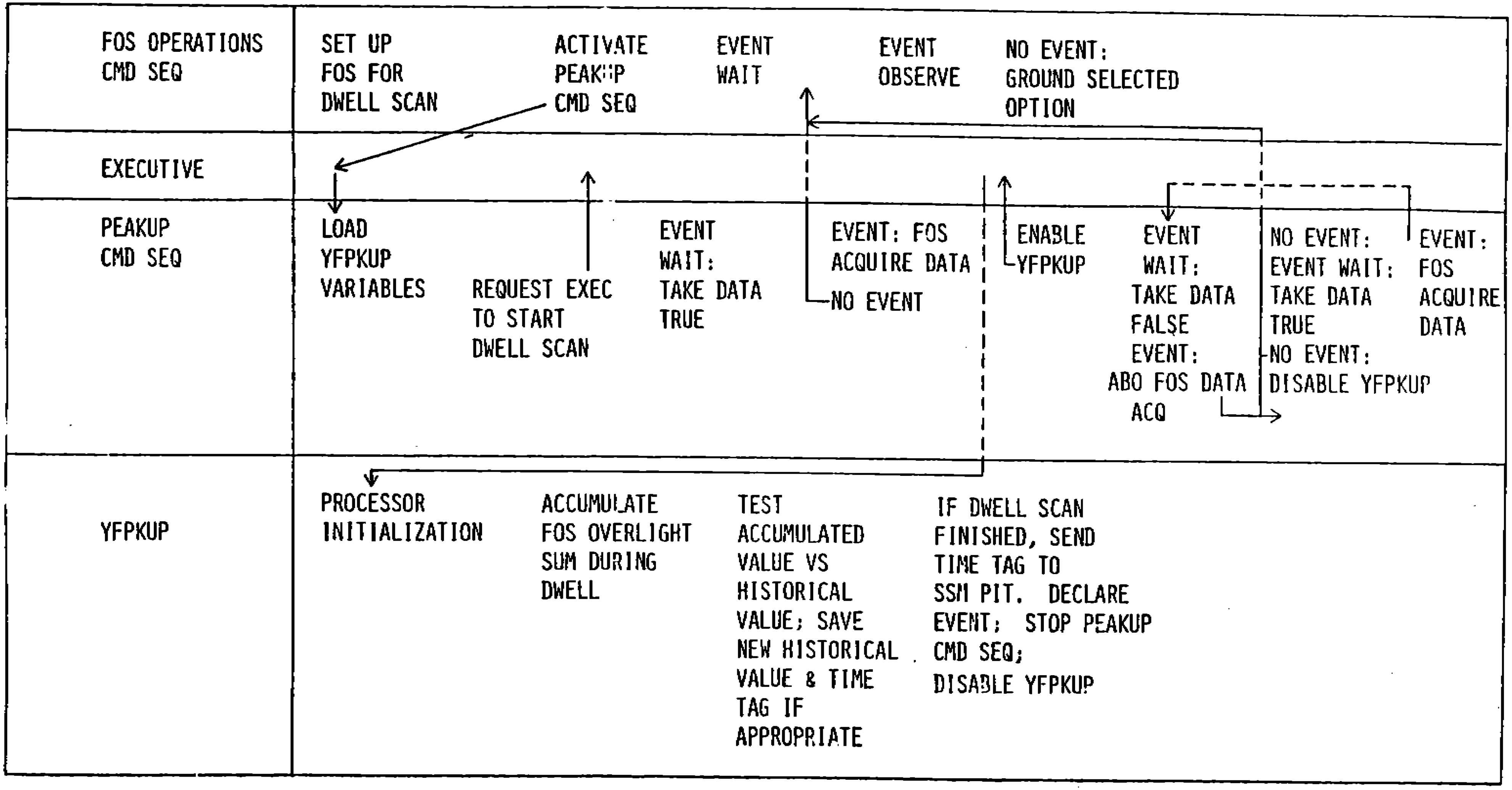


FIGURE 3.8-9

YFPKUP OPERATION

82GP-11-020

FIGURE 3.8-11

YFSDPR

SCIENCE DATA PROCESSOR (AP32) OUTLINE BLOCK DIAGRAM (HIGHLY OVER-SIMPLIFIED) ONLY FOR GENERAL IMPRESSION AND HOW MAIN MODULES FIT TOGETHER

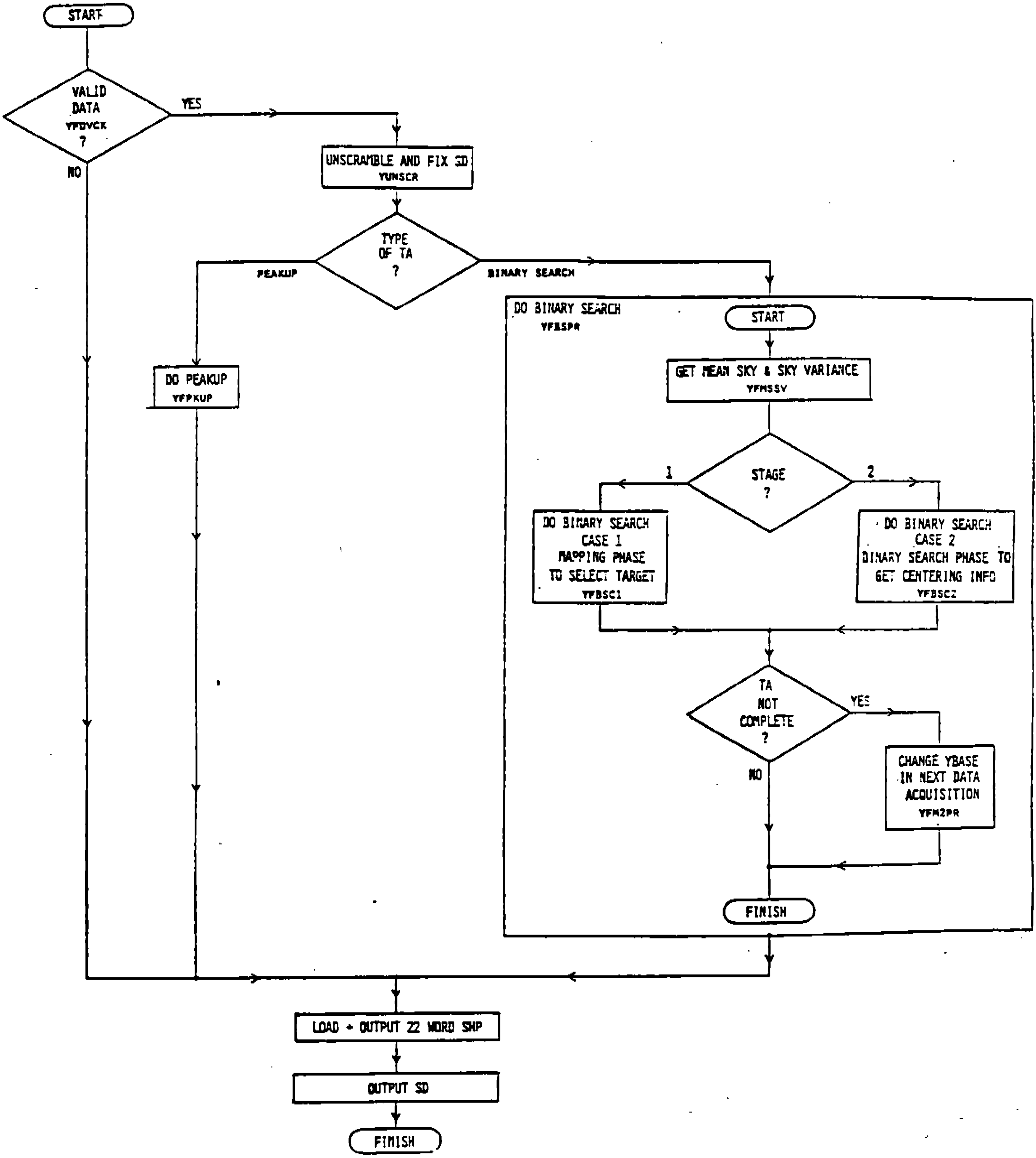


FIGURE 3.8-10b

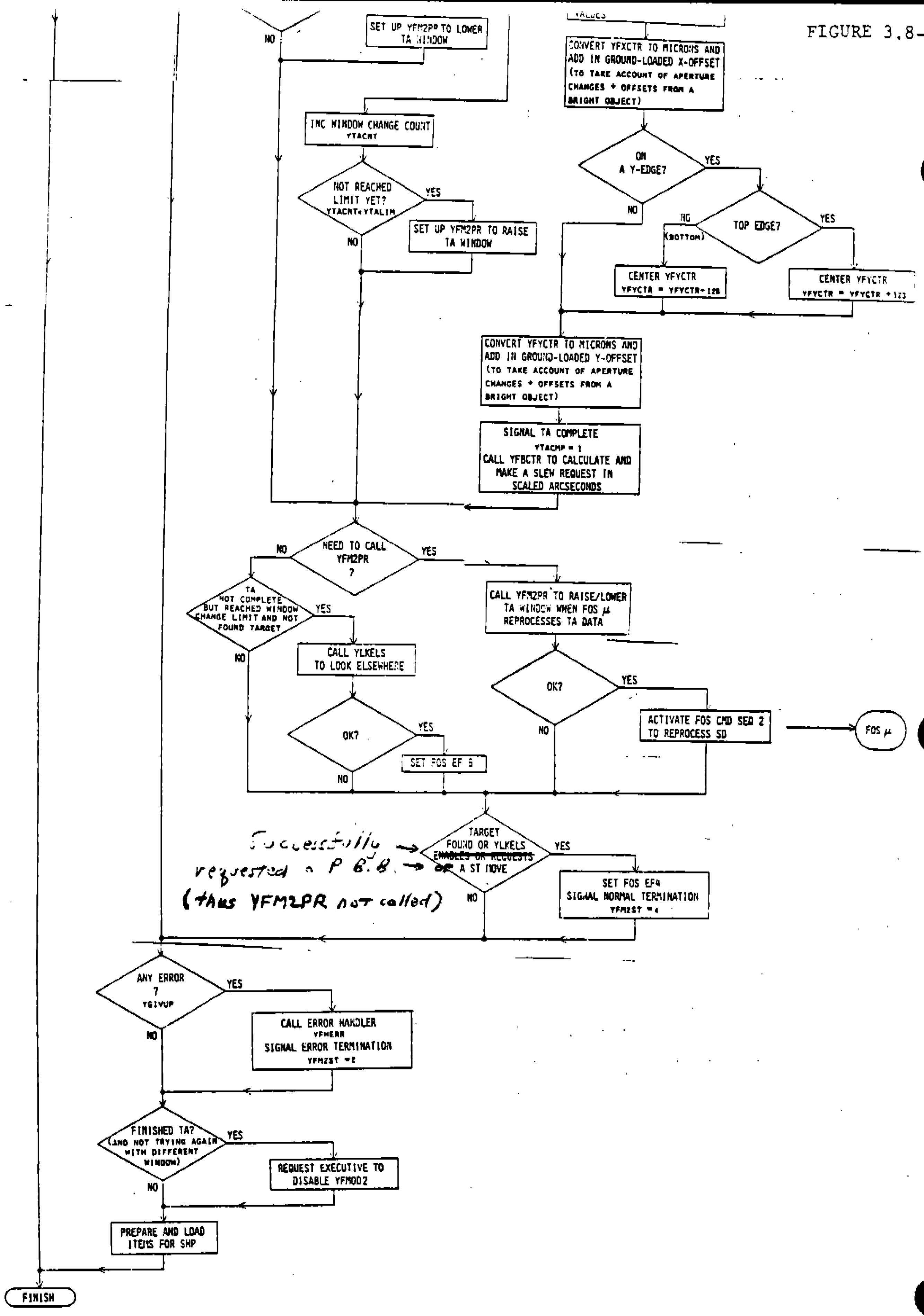


FIGURE 3.8-13

YFPKUP

MAY 15, 1985

PEAKUP MODE TARGET ACQUISITION PROCESSING

PEAKUP TO BRIGHTEST SPOT OR DOWN TO FAINTEST SPOT (OCCULTING APERTURES)

FIND MIN/MAX COUNT TOTAL & TIME FOR IT

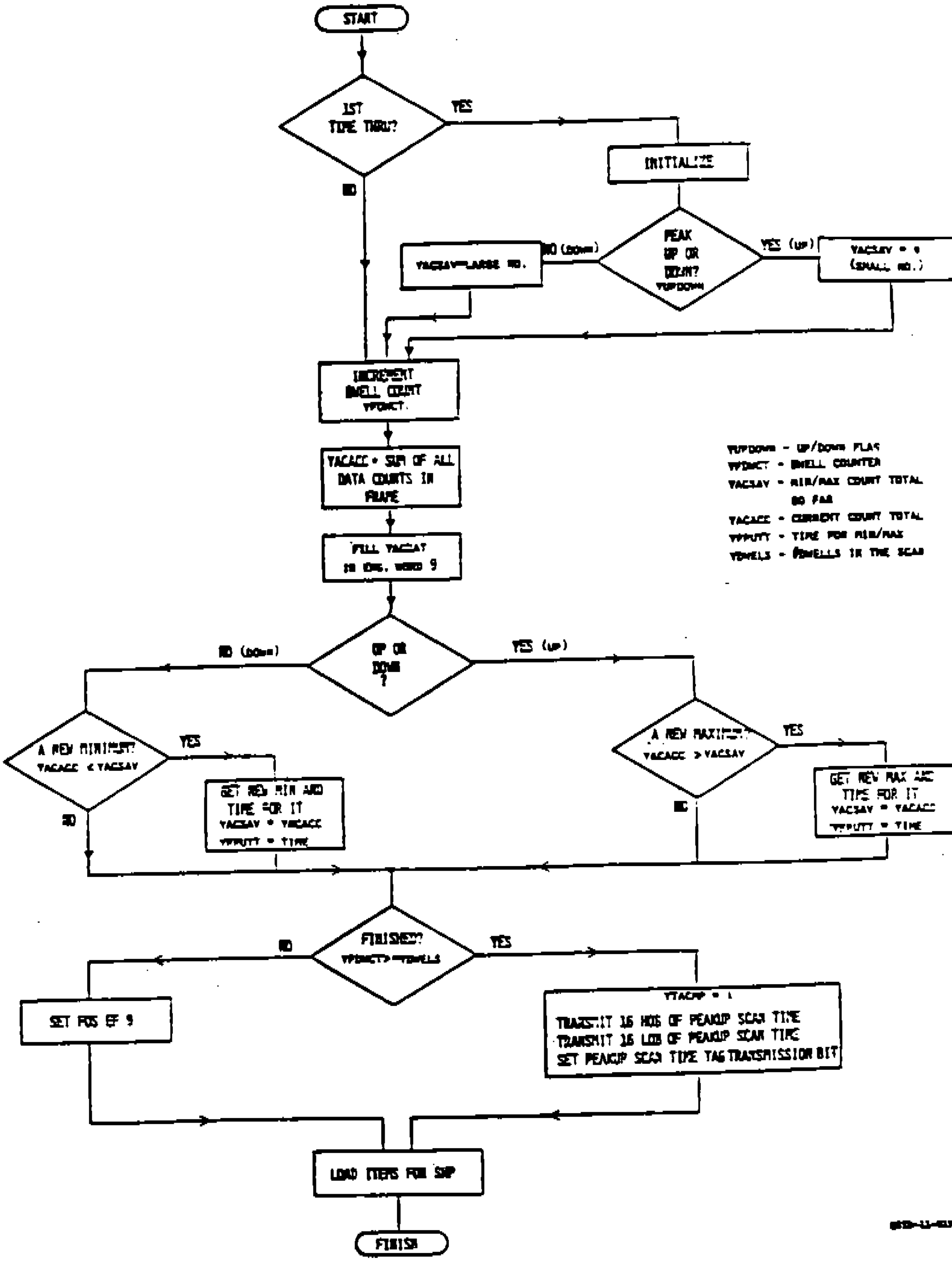
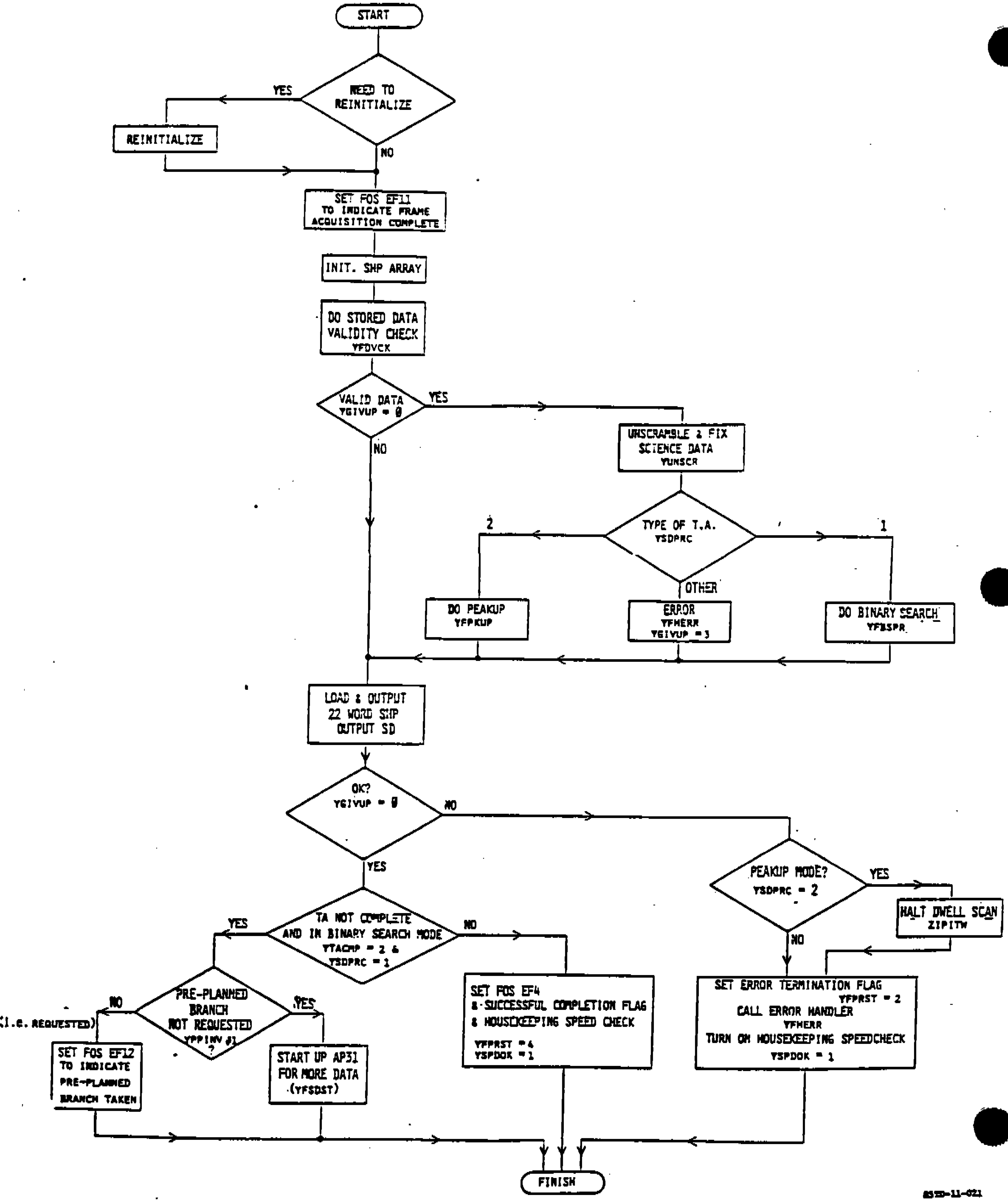


FIGURE 3.8-12

YFSDPR

MAY 15, 1985

SCIENCE DATA PROCESSOR AP 32



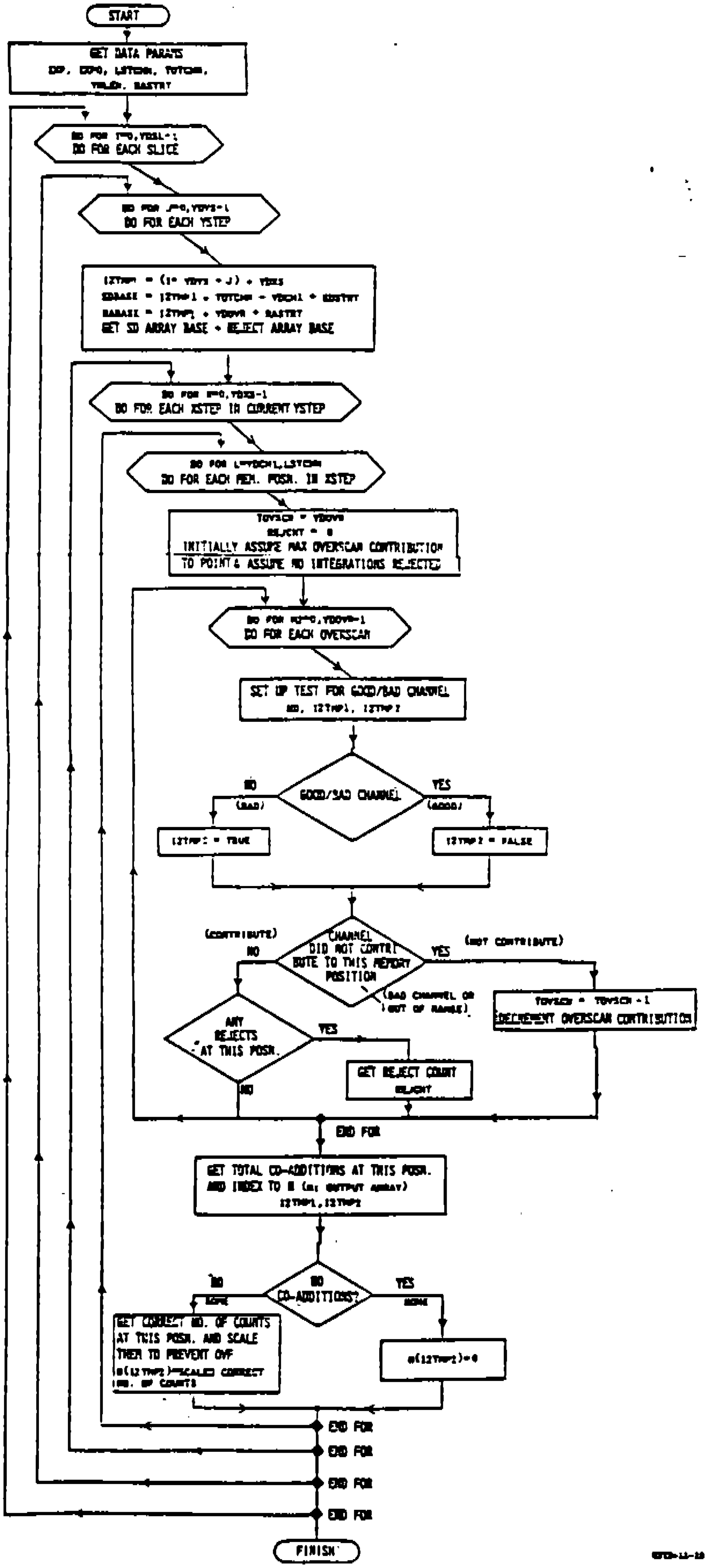
85SD-11-021

FIGURE 3.8-15

YUNSCR

MAY 16, 1986

UNSCRAMBLE AND FIX SCIENCE DATA
LOGICALLY REORDER DATA TO BE MORE AMENABLE FOR PROCESSING AND "FIX" FOR BAD CHANNELS & BURST NOISE REJECTIONS (i.e. FIX OVERSCAN & REJECT EFFECTS) WRITE RESULTS IN ANOTHER SECTION OF SCRATCH-PAD MEMORY (ARRAY B) SCALE TO PREVENT OVERFLOW.



YFDVCX

MAY 15, 1985

**STORED DATA VALIDITY CHECK.
CHECK IF HEADER INFORMATION PRESENT
AND EXTRACT NECESSARY PARAMETERS.
ALSO CHECK CORRECT
AMOUNT OF DATA TRANSFERRED.**

FIGURE 3.8-14

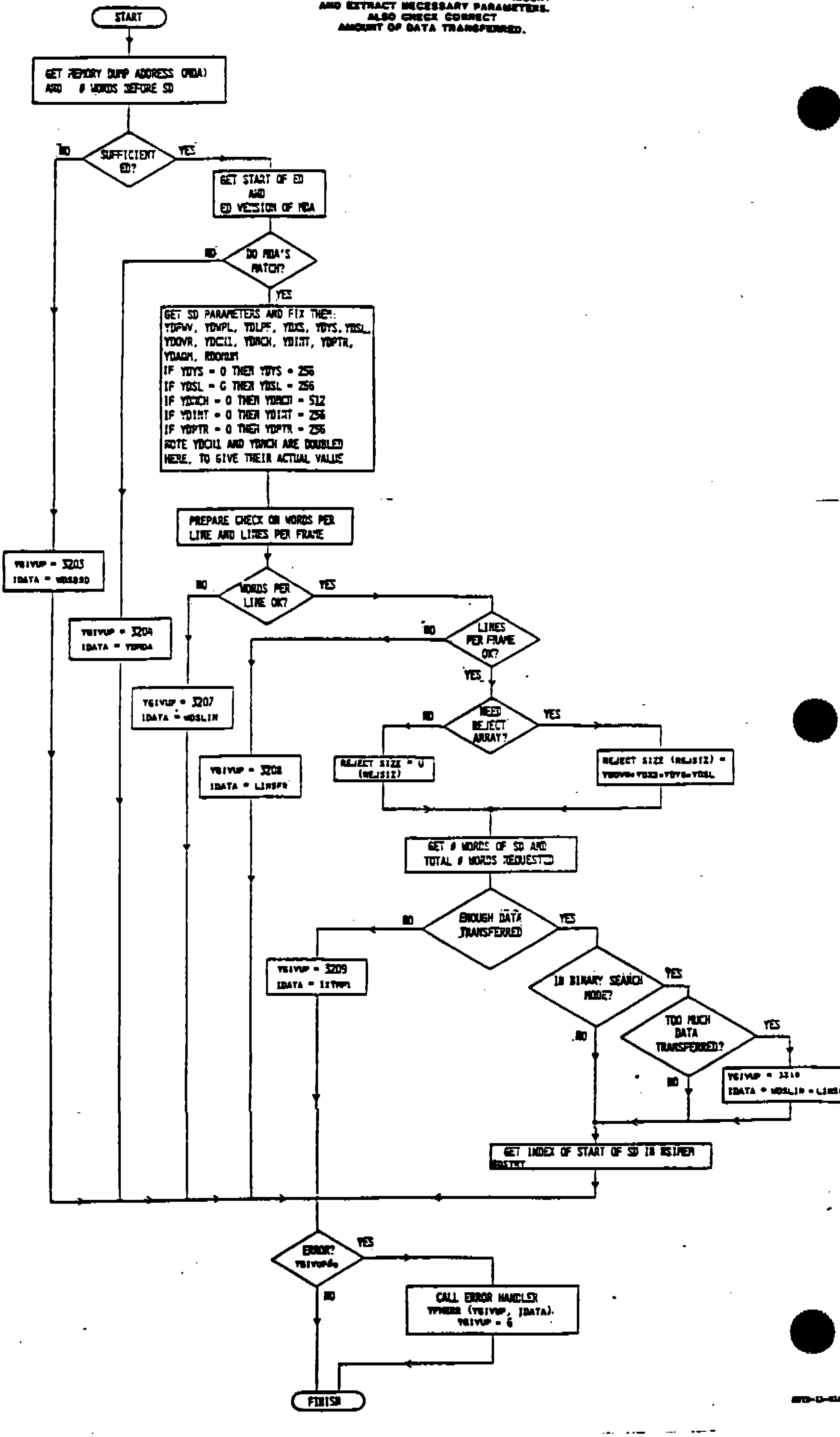


FIGURE 3.8-17

YFM2PR
MAY 15, 1985
CHANGE VARIABLES IN FOS STORED COMMAND SEQUENCES

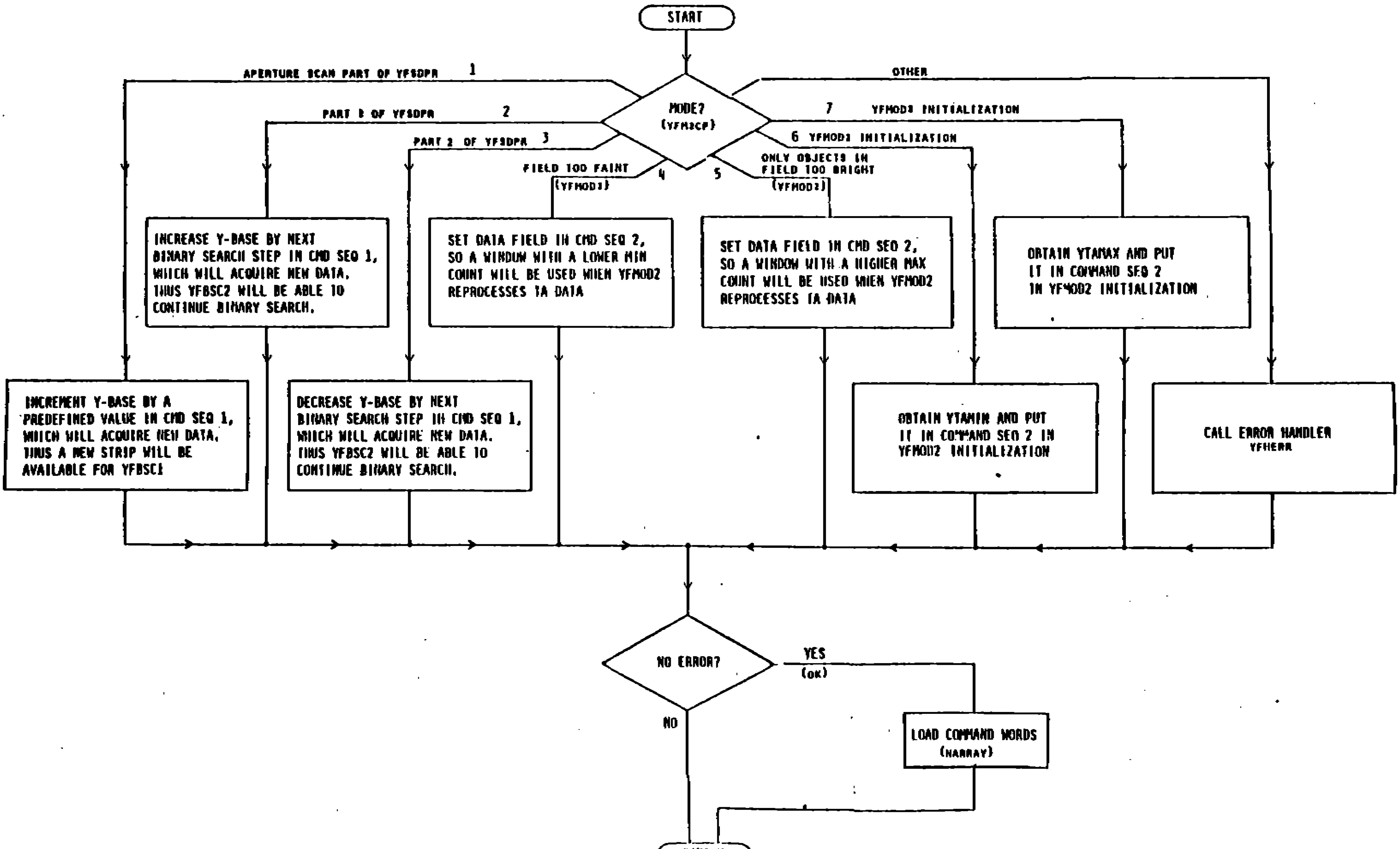


FIGURE 3.8-16

YFBSPR

MAY 15, 1985

BINARY SEARCH TA (TOP MODULE)

1. SELECT A TARGET FROM THE FIELD VIA A MAPPING PROCESS

2. ACQUIRE CENTERING INFORMATION FOR THE SELECTED TARGET

(SEE MODULE TXTSDF IN PDL)

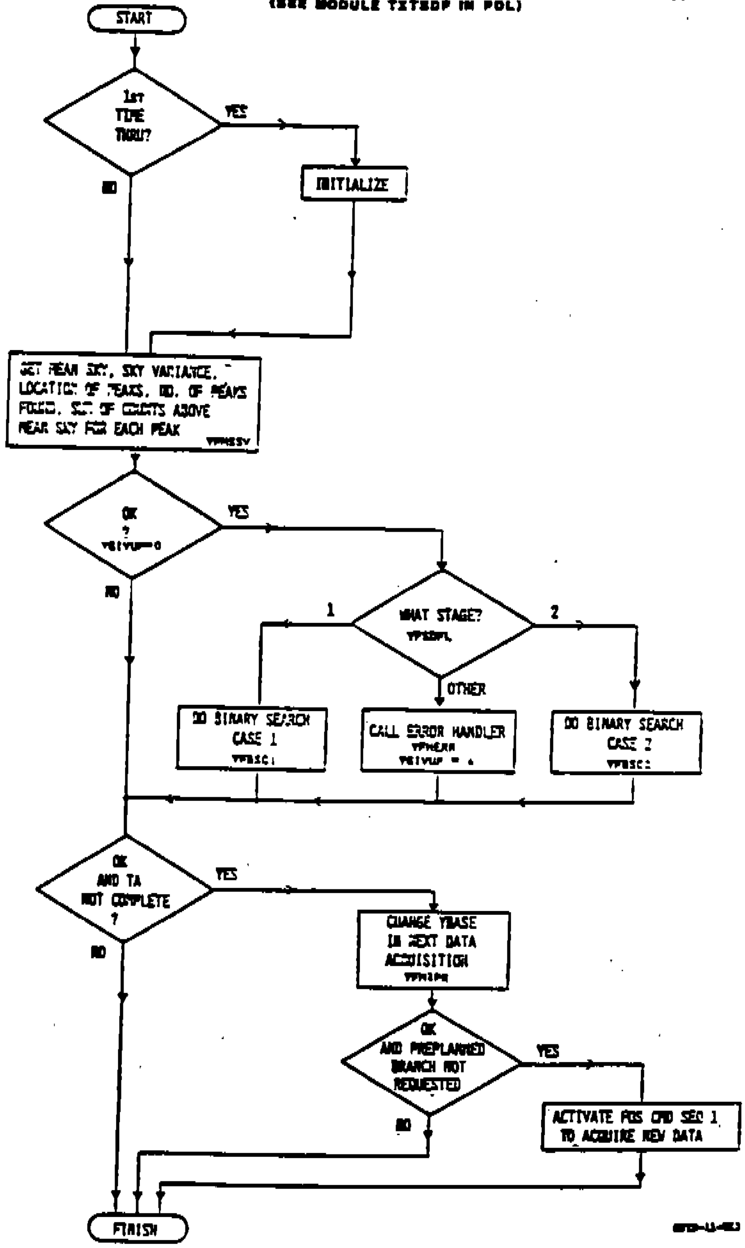


FIGURE 3.8-18b

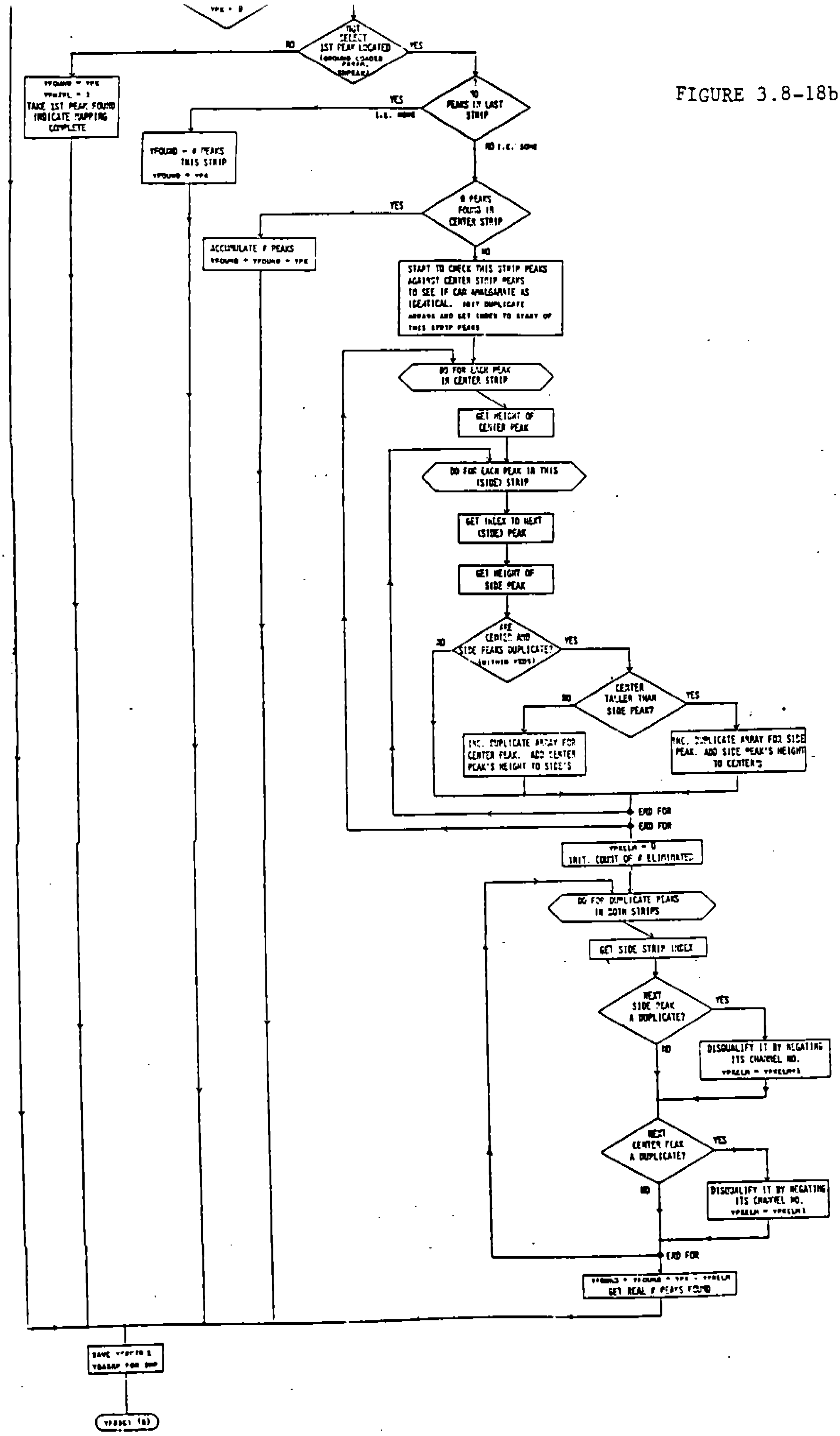


FIGURE 3.8-18a

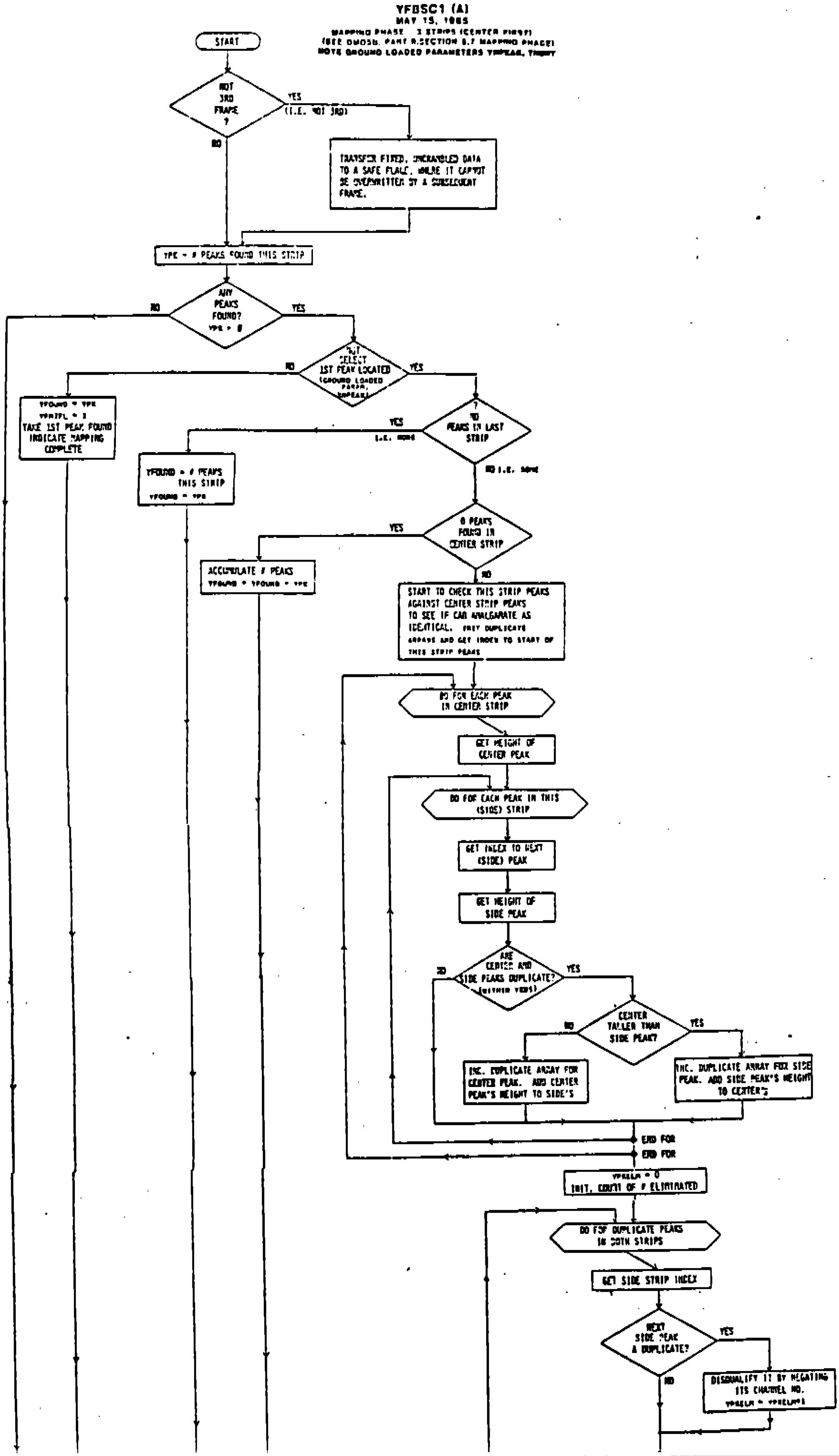
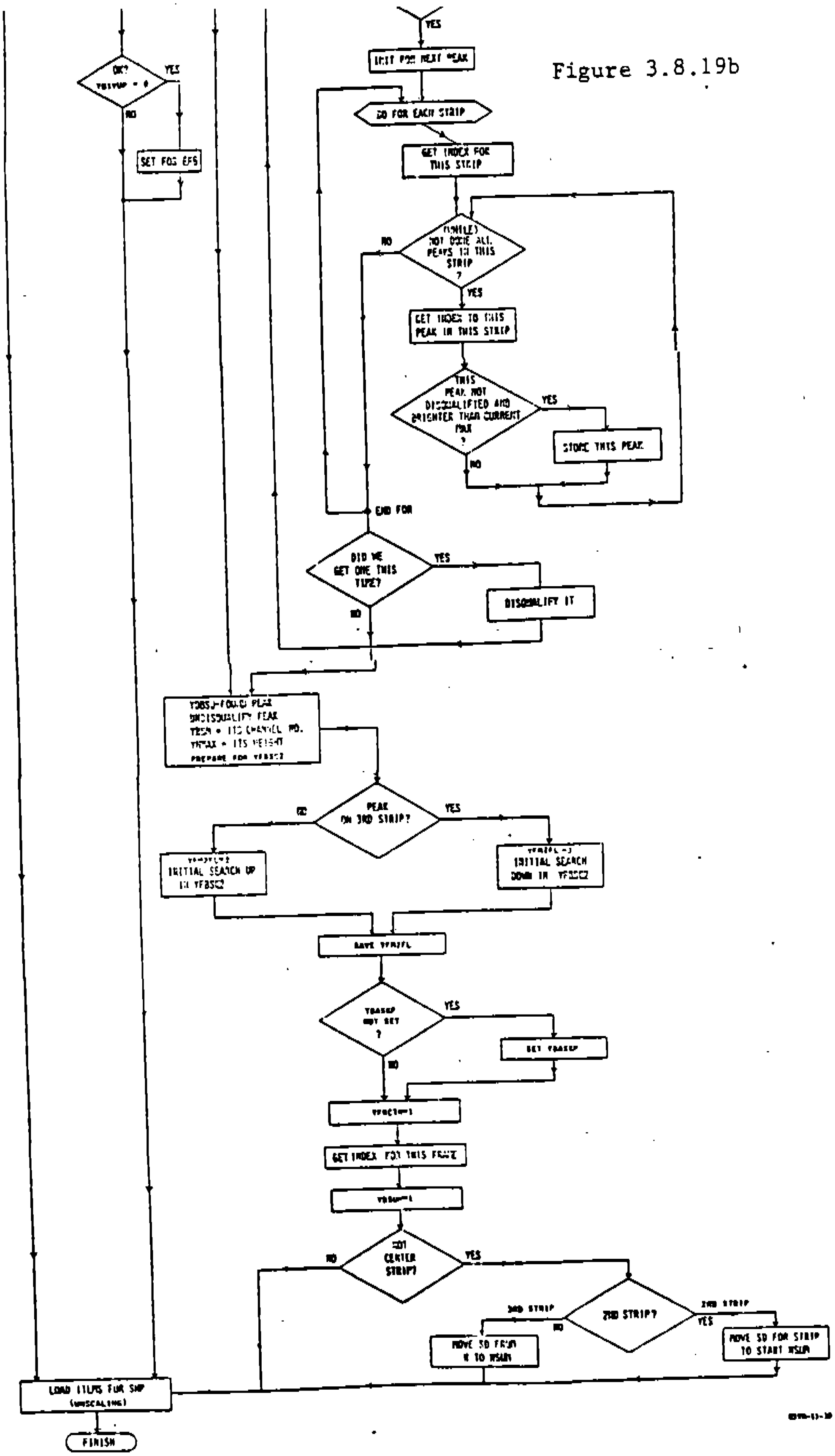


Figure 3.8.19b



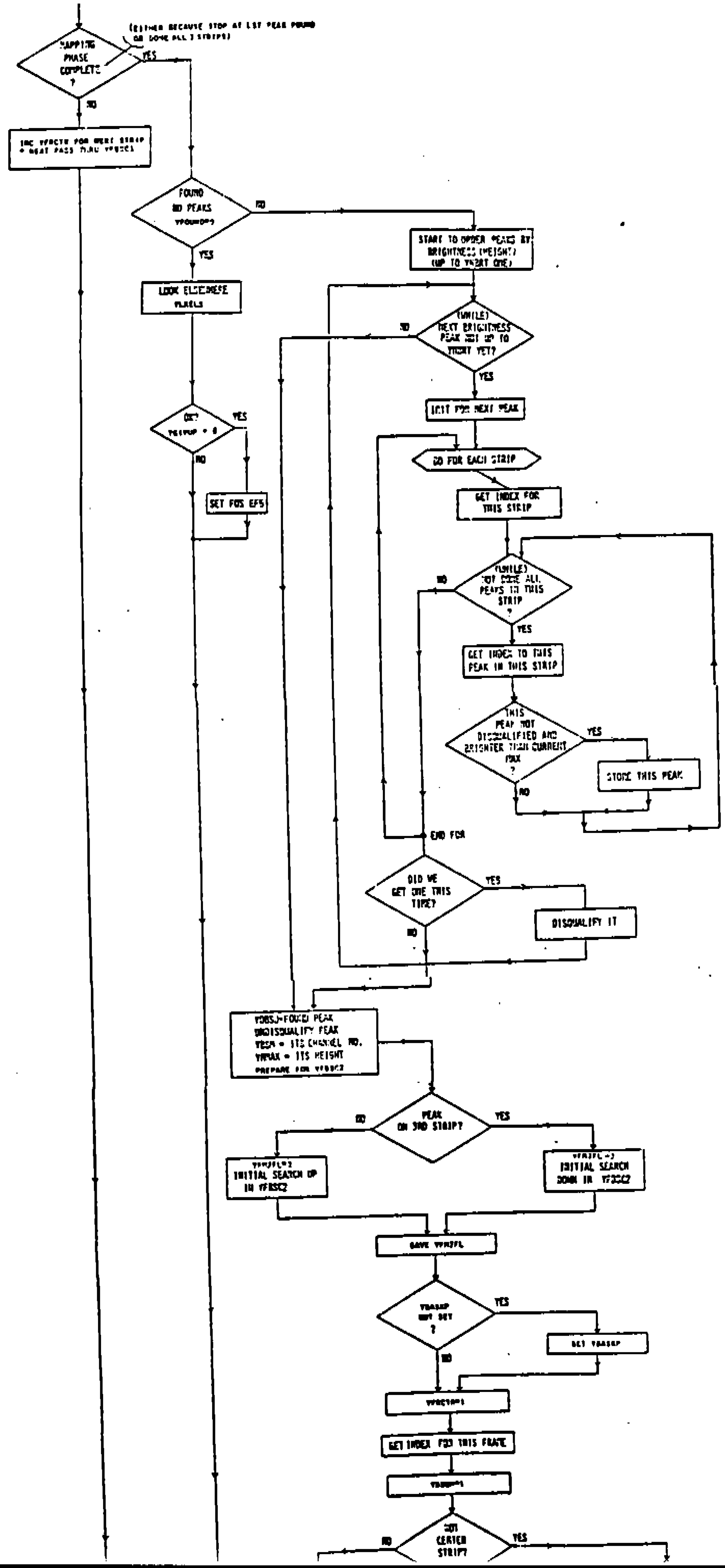
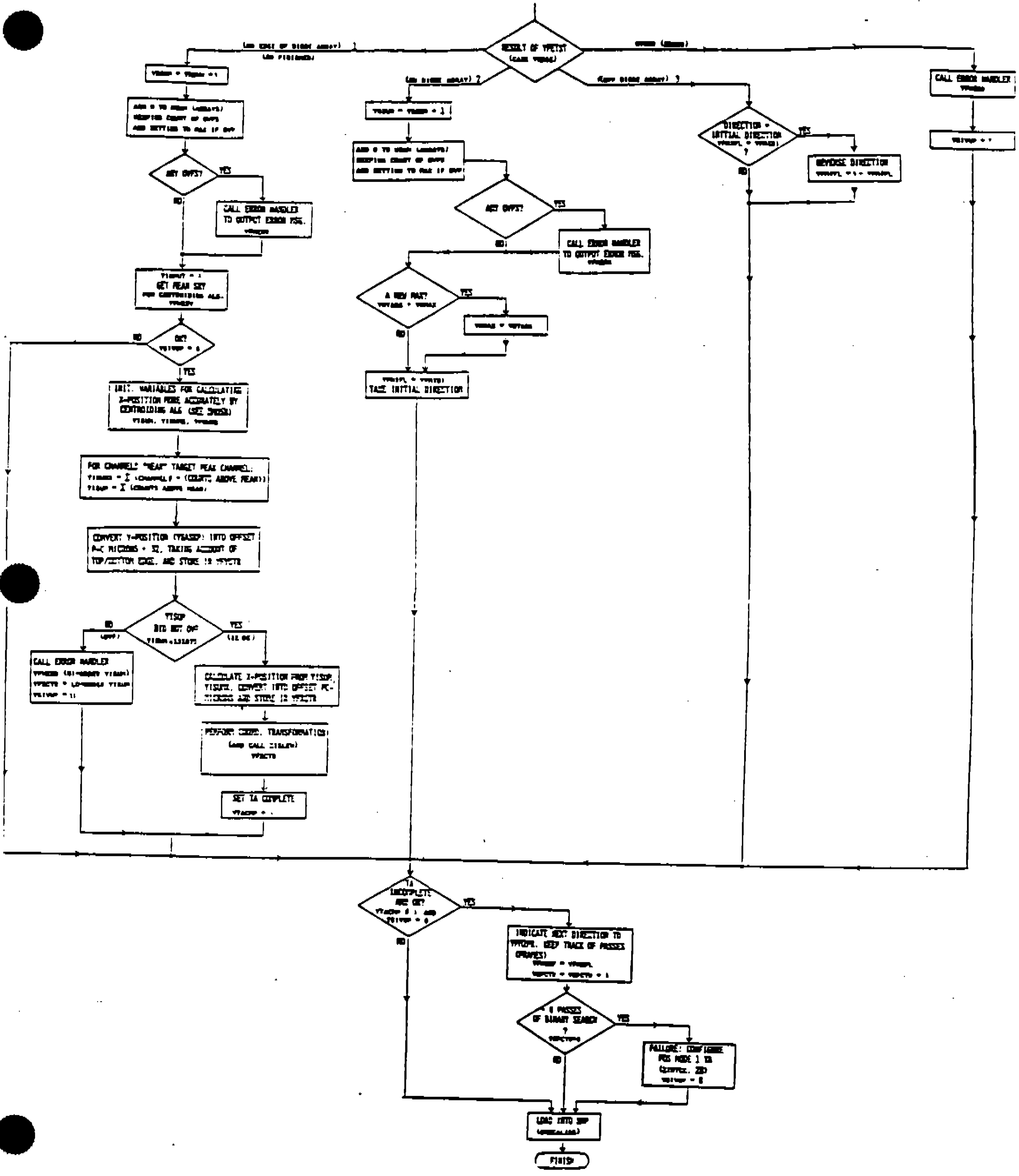

YES
NO
FOUND NO PEAKS
YES
START TO ORDER PEAKS BY BRIGHTNESS (HEIGHT)
LOOK ELSEWHERE
(WHILE) NEXT BRIGHTNESS PEAK NOT UP TO YET?
YES
NO
SET FOS EFS
GO FOR EACH STRIP
GET INDEX FOR THIS STRIP
YES
GET INDEX TO THIS PEAK IN THIS STRIP
YES
STORE THIS PEAK
NO
END FOR
DID WE GET ONE THIS TIME?
YES
DISQUALIFY IT
NO
PEAK ON 3RD STRIP?
NO
YES
INITIAL SEARCH UP IN YFDSC2
INITIAL SEARCH DOWN IN YFDSC2
YES
NO
GET INDEX FOR THIS FRAME
CENTER STRIP?
NO
YES

FIGURE 3.8-21

YFBSC2 (B) (Continued)



YFBSC2 (A)

MAY 15, 1985

BINARY SEARCH (SEE DM-058, PART II, SECTION 5.7)
FIND VALUE FOR YBASE AND THEN YFXCTR, YFYCTR

FIGURE 3.8-20

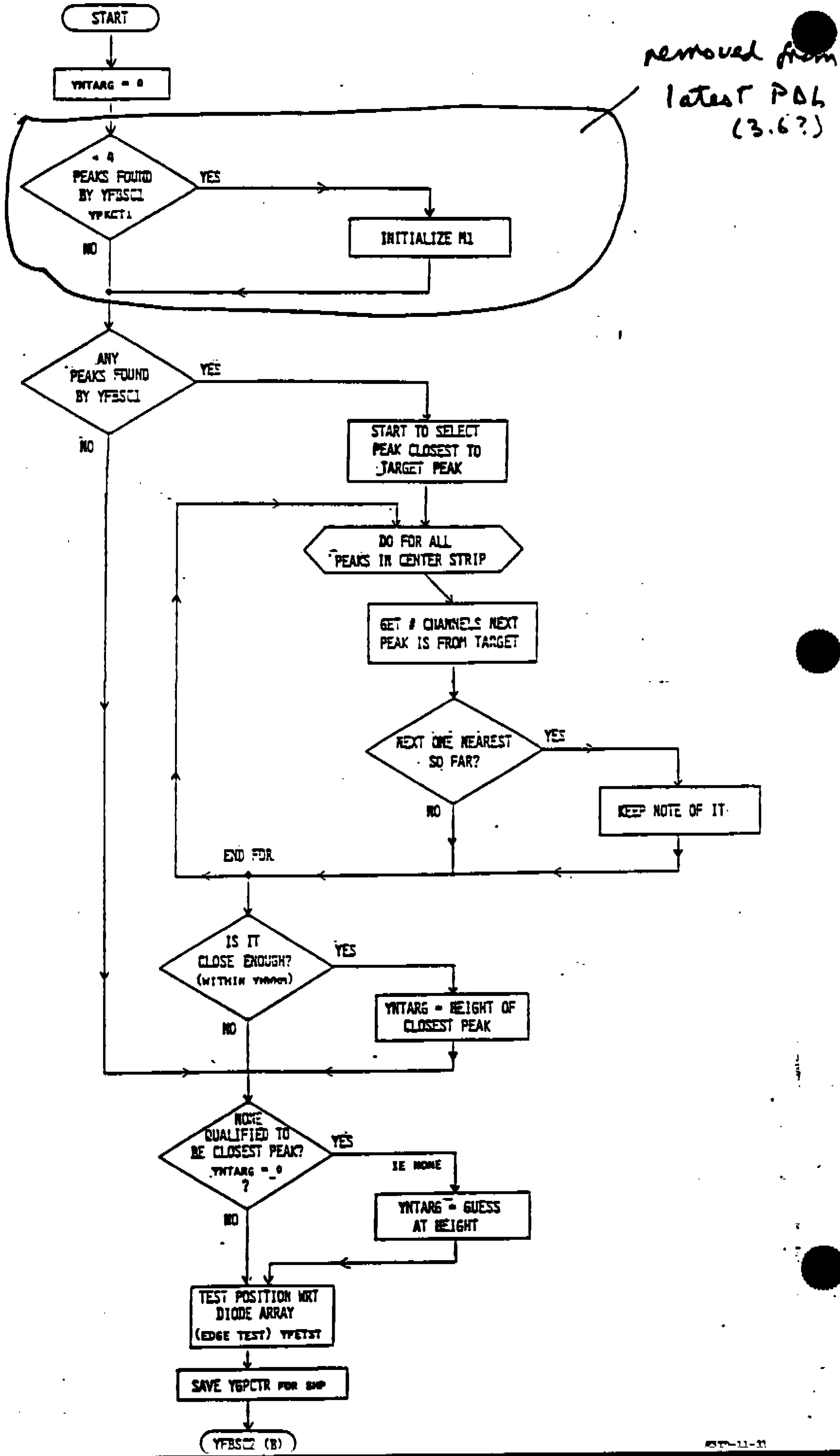
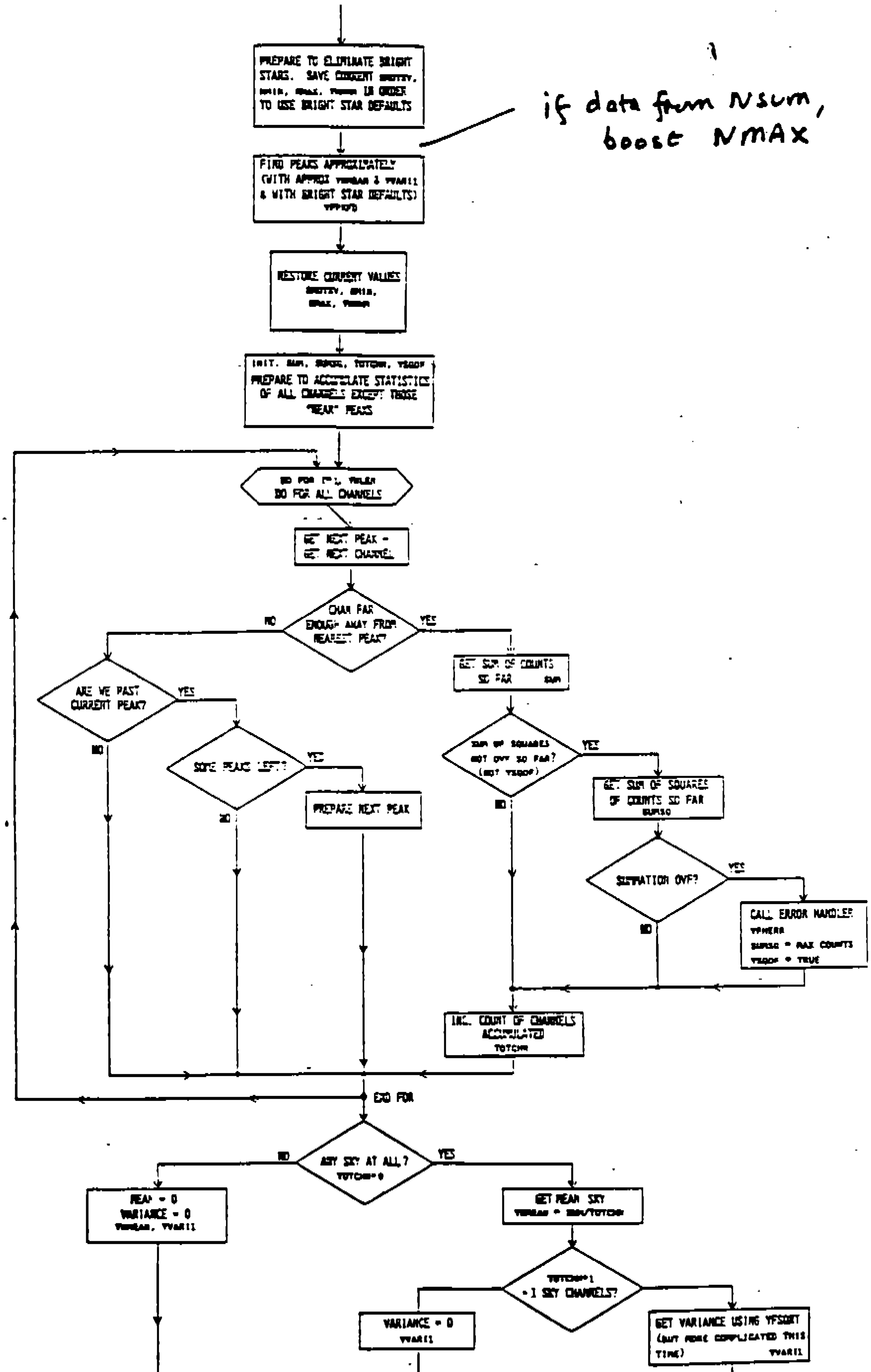


FIGURE 3.8-23

YFMSSV (B) (Continued)



if data from Nsum, boost NMAX

FIGURE 3.8-22

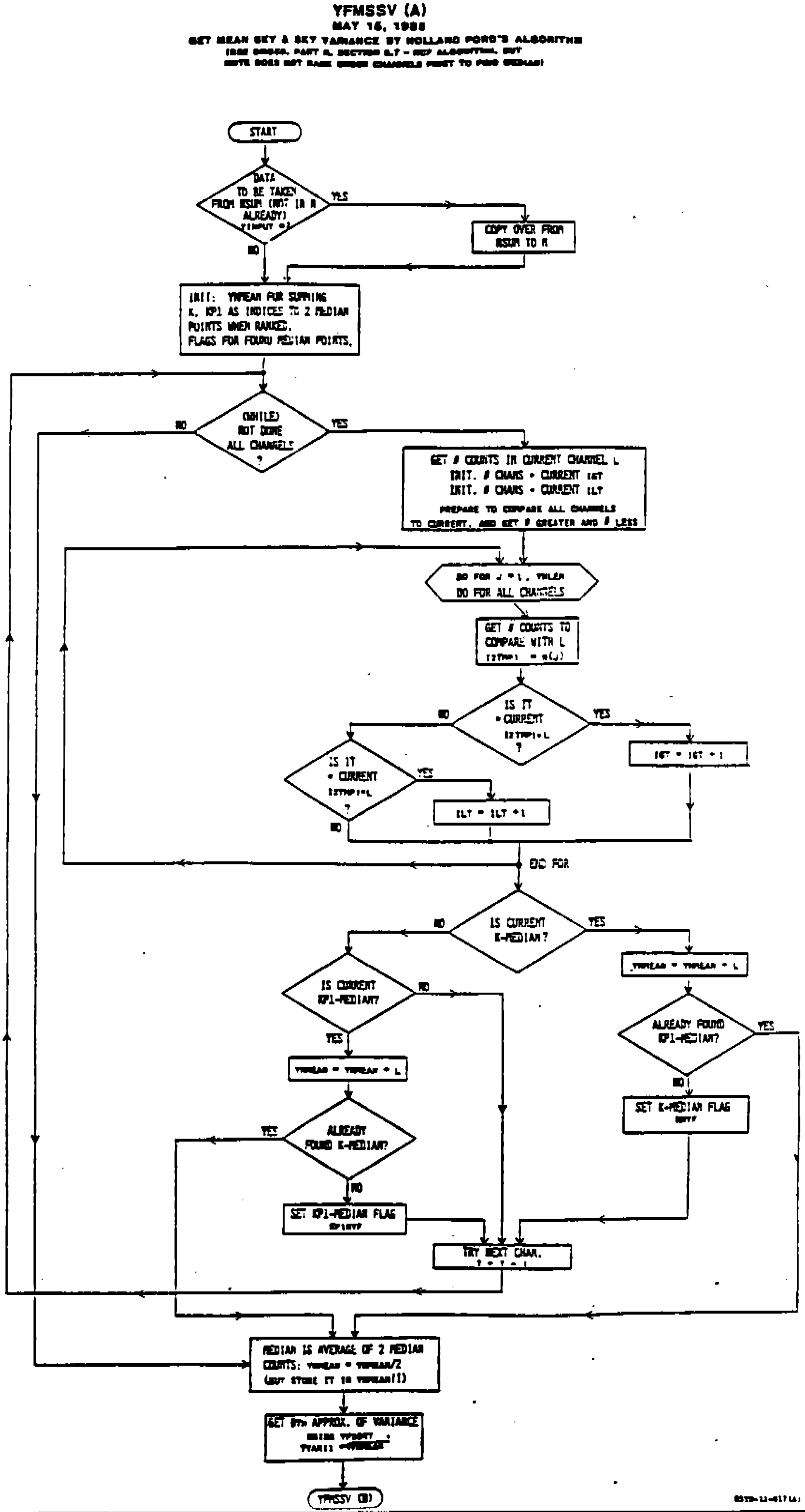

YFMSSV (A)
MAY 15, 1985
GET MEAN SKY & SKY VARIANCE BY HOLLAND FORD'S ALGORITHM
START
DATA TO BE TAKEN FROM RSUM (NOT IN R ALREADY)
YES
NO
COPY OVER FROM RSUM TO R
(WHILE) NOT DONE ALL CHANNELS ?
NO
YES
DO FOR ALL CHANNELS
END FOR
IS CURRENT K-MEDIAN?
IS CURRENT KP1-MEDIAN?
ALREADY FOUND KP1-MEDIAN?
ALREADY FOUND K-MEDIAN?
SET K-MEDIAN FLAG
SET KP1-MEDIAN FLAG
TRY NEXT CHAN.
YFMSSV (B)

FIGURE 3.8-25

YFPKFD

MAY 15, 1985

(SEE DMOSS, PART II SECTION 5.7 "PEAK FINDING ALGORITHM - NCF")

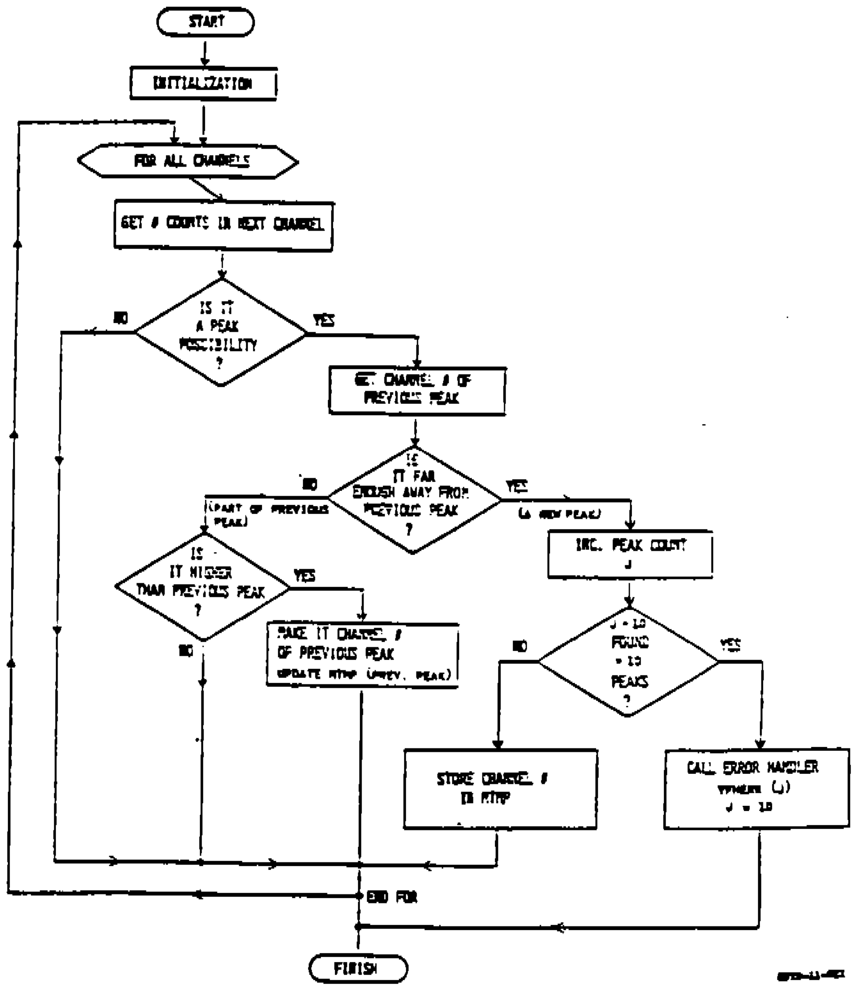


FIGURE 3.8-24

YFMSSV (C) (Continued)

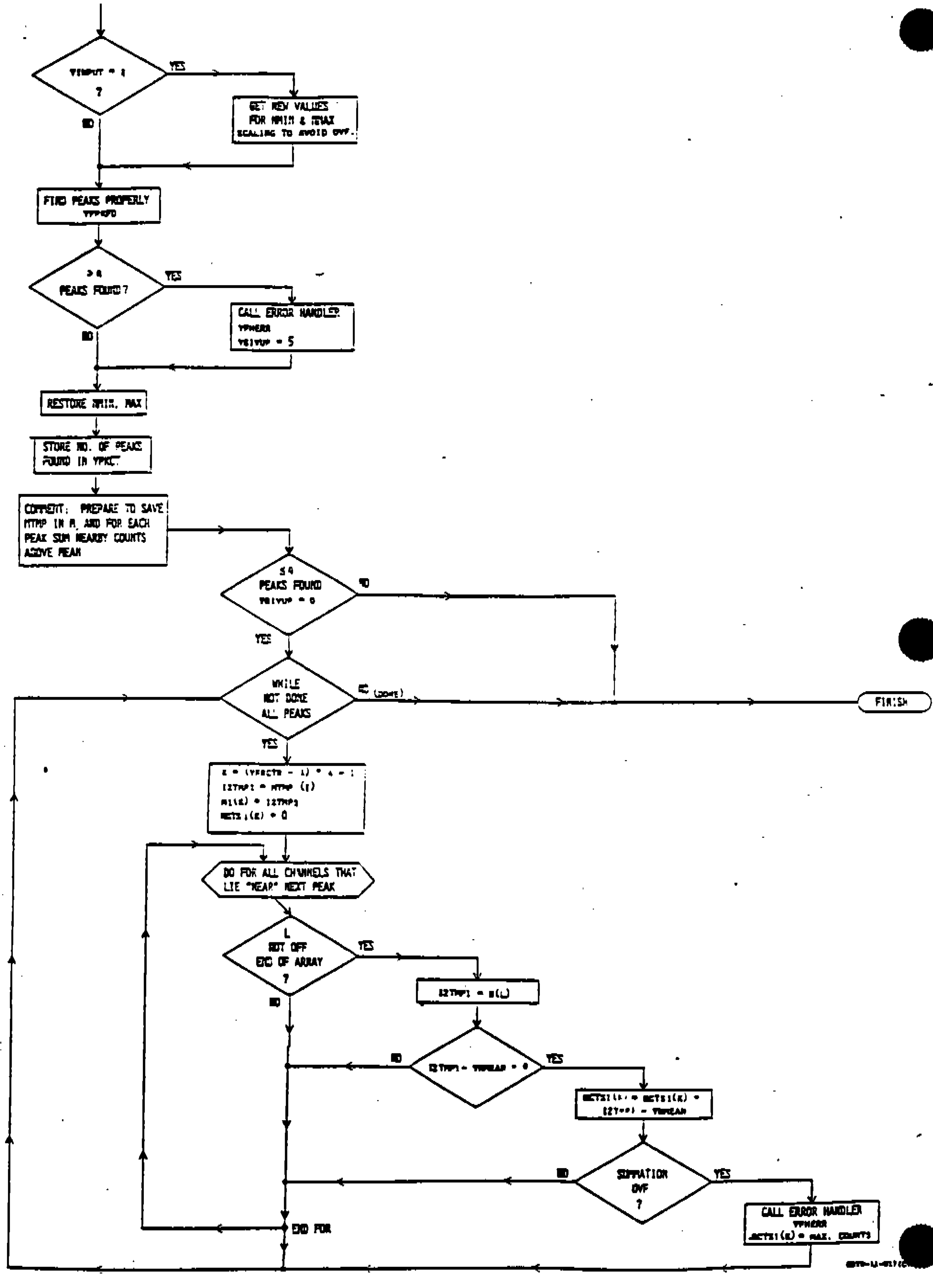
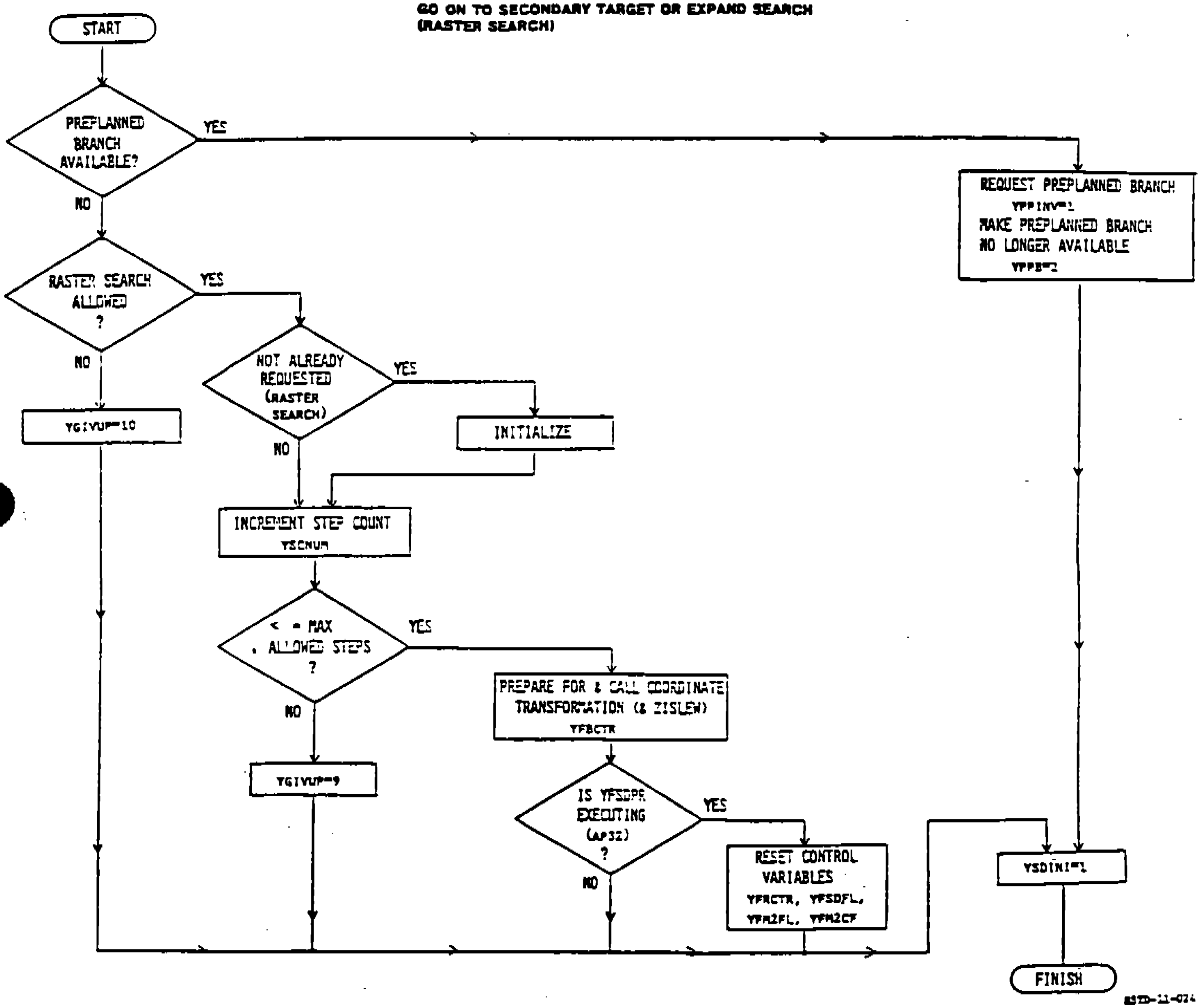


FIGURE 3.8-27

YLKELS

MAY 15, 1985

LOOK ELSEWHERE
GO ON TO SECONDARY TARGET OR EXPAND SEARCH
(RASTER SEARCH)



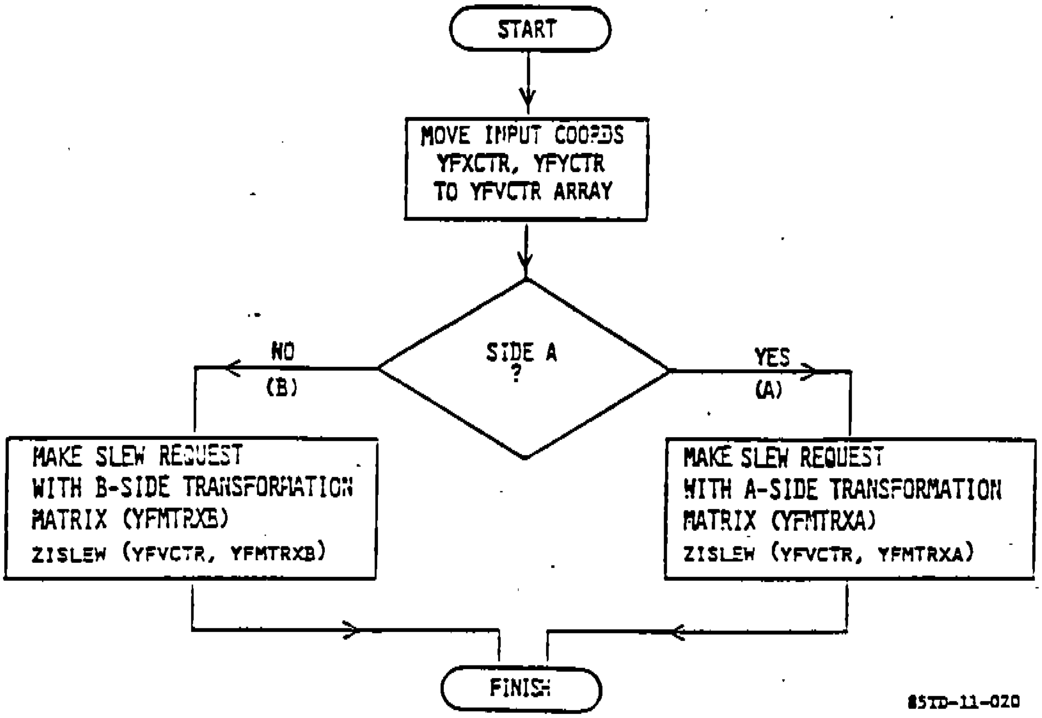
ESD-11-074

FIGURE 3.8-26

YFBCTR

MAY 15, 1985

TRANSFORM CENTERING COORDS (YFXCTR, YFYCTR) FROM MICRONS AT THE PHOTOCATHODE TO SCALED ARC-SECONDS AT THE APERTURE, AND REQUEST ST SLEW (SEE FOS USER's MANUAL AND PDL).

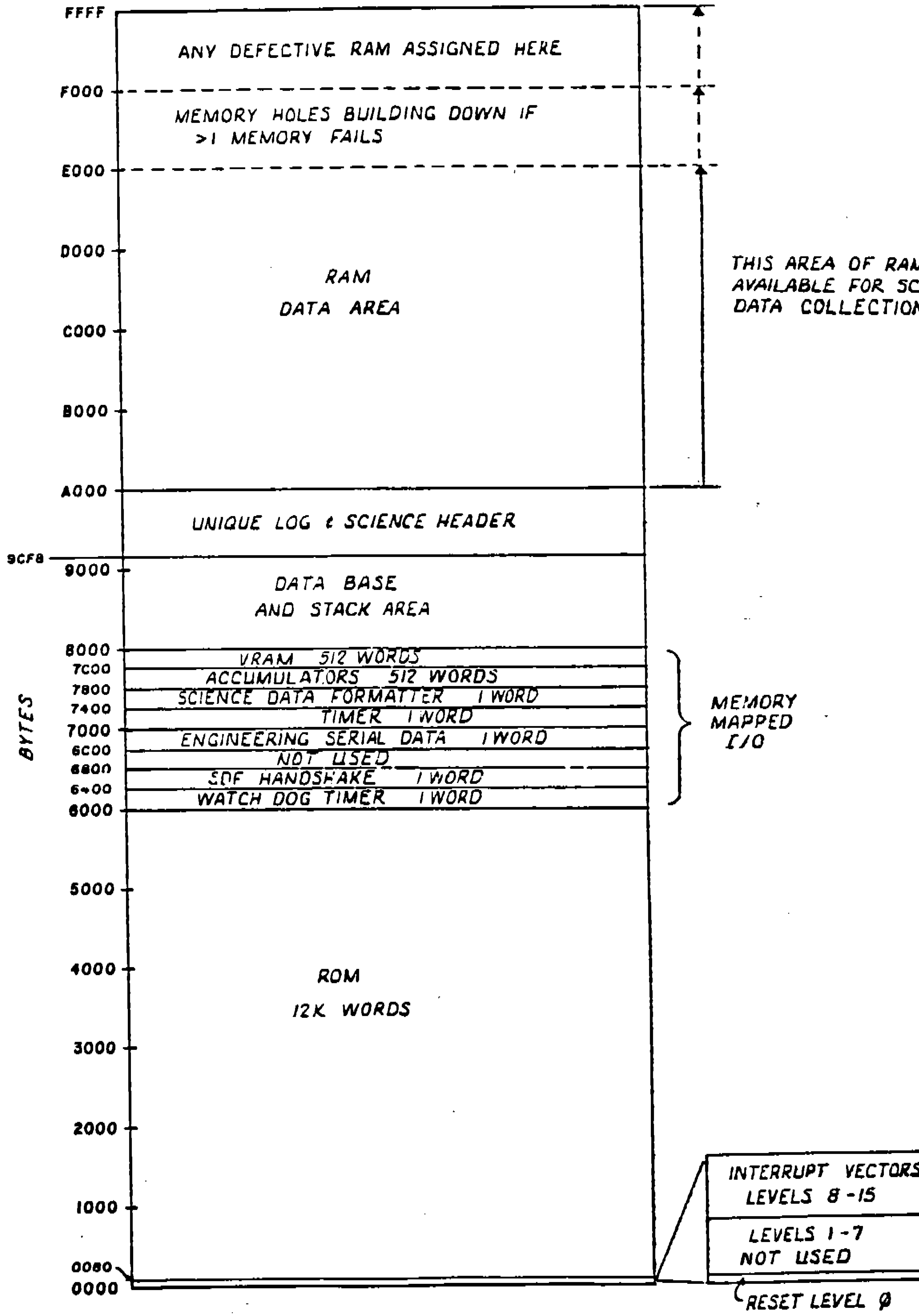


85TD-11-020

FIGURE ~~2.6-2~~ 3.9-1

FOS MICROPROCESSOR MEMORY USE DETAILS

FIRMWARE MEMORY MAP



7903-11-0708

3.8 <u>FOS Microprocessor Firmware (TBD)</u>.
The text for this section remains TBD.

Figure 3.9-1 provides a memory map - also see Figure 2.5-1.
Figure 3.9-2 shows the interrupt structure.
Figure 3.9-3 shows the firmware structure.

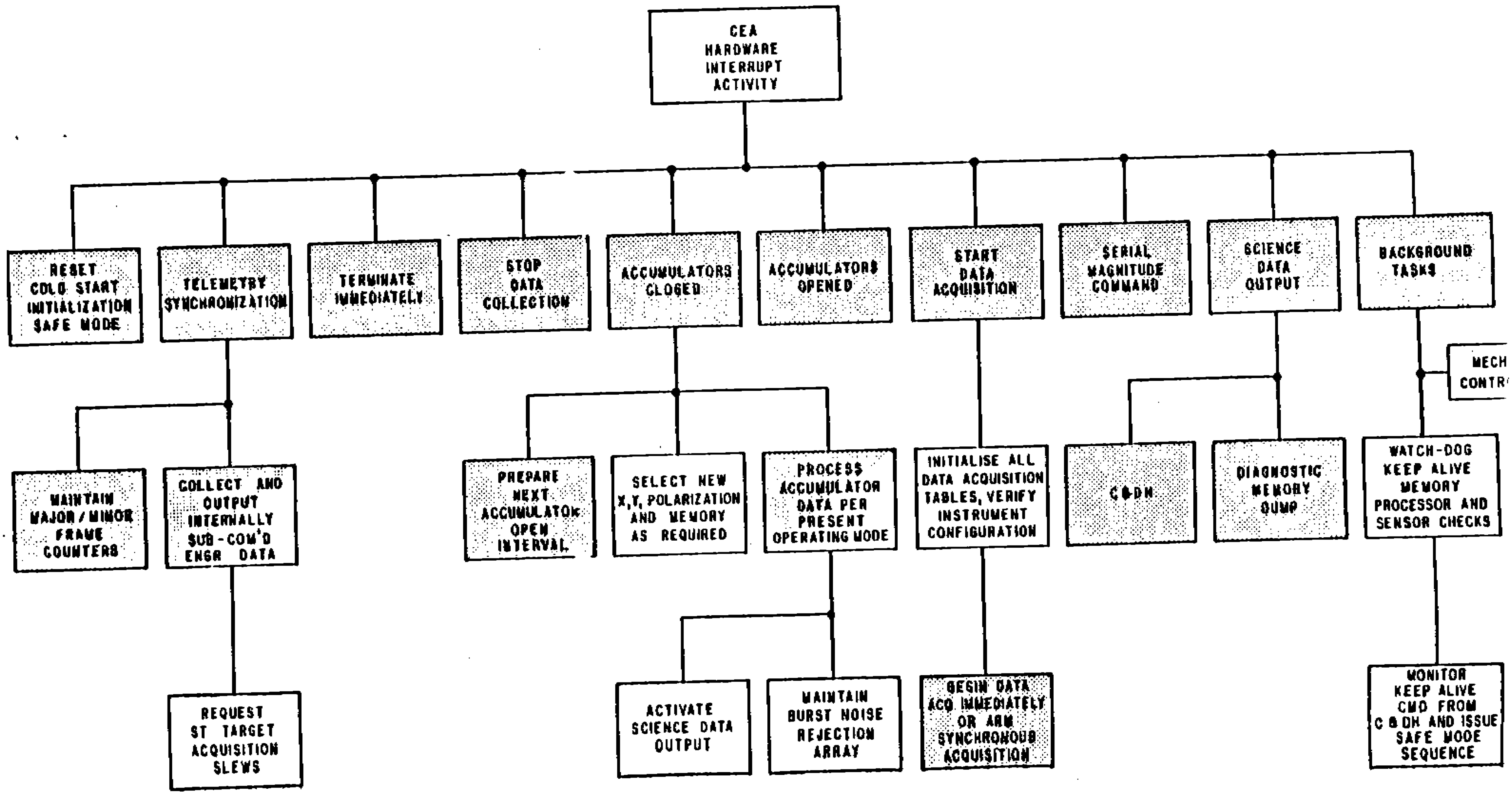


FIGURE ~~2.6-3~~ 3.9-3

FOS FIRMWARE STRUCTURE

T008-11-041E

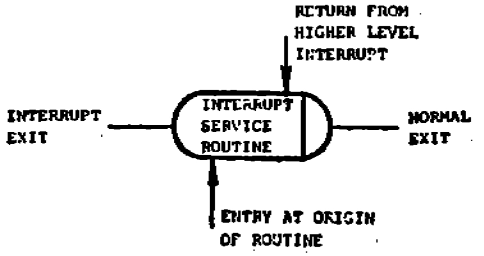
FOS μP INTERRUPT ACTIVITY DIAGRAM

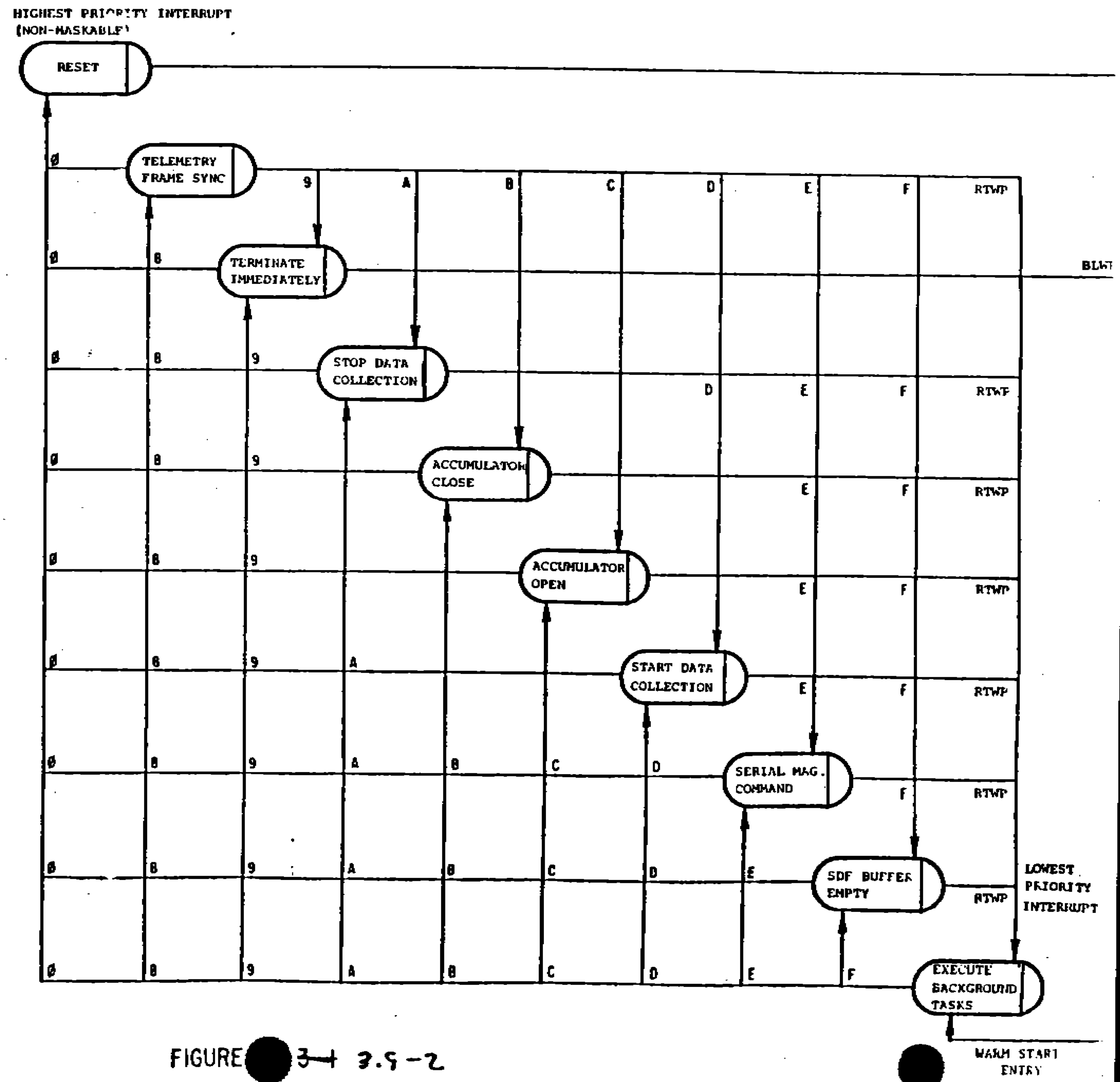
CONTROL DESIGNATION	CONTROL DESCRIPTION
0	POWER ON/OFF C&DH BILEVEL
8	MAJOR FRAME SYNC PULSE MINOR FRAME SYNC PULSE
9	C&DH BILEVEL TERMINATE IMMEDIATELY PRESENTOPERATION
A	C&DH BILEVEL STOP DATA COLLECTION AT END OF PATTERN
B	ACCUMULATOR TIMING CIRCUIT CLOSED ACCUMULATORS
C	ACCUMULATOR TIMING CIRCUIT OPENED ACCUMULATORS
D	C&DH BILEVEL START DATA COLLECTION ON MARK
E	C&DH SERIAL MAGNITUDE COMMAND READY IN BUFFER
F	SDF SCIENCE DATA OUTPUT BUFFER EMPTY
BLWP	SBP 9900 OP CODE: BRANCH AND LOAD WORKSPACE POINTER
RTWP	SBP 9900 OP CODE: RETURN WORKSPACE POINTER

CONTROL DESIGNATOR 0 IS THE HIGHEST LEVEL INTERRUPT

CONTROL DESIGNATOR F IS THE LOWEST LEVEL INTERRUPT

INTERRUPT LEVELS 1 THROUGH 7 NOT USED





7805-II-004C

FIGURE 3-1 3.5-2

3.10.2

~~2.7~~ FOS MEMORY DUMPS. The FOS instrument includes two microprocessors, each known as a Central Electronics Assembly (CEA). Each CEA is associated with a unique FOS detector. The CEA memory for each detector is unique and requires individual load, dump, and verify support. A master image for each CEA must be maintained by the ground. Care must be taken to verify an FOS memory dump against the appropriate CEA master image.

Each CEA includes 24K bytes of ROM and 32K bytes of RAM. The first 8K bytes of RAM consist of system parameters, work spaces, and data tables. The remaining 24K bytes of RAM are used for temporary storage of science data. An FOS memory map is shown in Figure 2.6-1.

The hardware I/0 section of CEA memory between byte addresses 6000 and 8000 HEX (of Figure 5-6) contains dynamic data updated and utilized by the FOS flight hardware. This area will not be loaded or verified by the ground.

The FOS provides the capability to selectively dump any area of FOS ROM/RAM by serial magnitude command from the ground. The ground request provides a start address for the dump along with a word count in the form of words per line and lines per frame. The SDF format for FOS SD downlink must be configured to match the FOS memory dump words per line and lines per frame.

For purposes of verifying FOS memory and table loads only a full 32K 16-bit words CEA dump will be issued. This will minimize the number of master and dump files to be maintained. There are no memory addresses included in the downlink dump data.

An FOS memory dump requires the following commands:

YSTOPDMP Disable any active automatic dump

YSCIAET Science data dump request

where X = binary 11 for special area dump with 3 data

9.10.1

~~2.5~~ Data Rates. The FOS science data rates are summarized in Table 2.5-1. The FOS engineering data rate is 160 bits/sec..

TABLE 2.5-1

FOS SCIENCE DATA RATES

MODE	AVERAGE SCIENCE DATA RATE (bits/sec)		
	MIN	TYPICAL	MAX
Normal Integration	0	2 K	0.4 M
Time Resolved	0	40 K	0.4 M
Target Acquisition	0	4 K	0.4 M
Memory Dump	0	20 K	0.4 M

~~2.6 Flight Firmware.~~

as 64K bytes by FOS. The rightmost byte, of FOS dump data, is the least significant byte. Although the 4K words hardware I/O area is included in the dump data, this area is not to be verified against a master and is of no value on a print. Addressing is as follows:

FOS Memory	FOS Addresses (Decimal Bytes)
12K ROM words	0-24575
4K H/W I/O words	24576-32767
4K System RAM words	32768-40959
12K SD RAM words	40960-65535

FOS CEA memory dumps will be assembled and maintained as temporary ground system files. Selective on-line comparison of specific byte address areas of a dump image to the corresponding areas of the appropriate master CEA image will be provided by the ground system. Discrepancies between the two images will be made available to the test conductor/operator controller and as printer output in Hex. A pring of selected addresses and contents in Hex of the dump image may be necessary following table loads to the FOS.

commands following

Y2S0XXXX data commands (3) associated with dump request

XXXX = 0000	Dump Start Address (0)
XXXX = 0200	Words/Line (512 decimal)
XXXX = 0040	Lines/Frame (64 decimal)

Y2S065XX activate science dump

where XX = 1 for dump immediate

Only the operational CEA may be dumped.

The FOS memory dump occurs in the SD packets as consecutive words of memory. The ground system will extract the FOS dump data from the SD packet overhead to develop a binary image of CEA memory. The identity of which CEA memory dump is received by the ground is available in the SD dump stream as the LSB of FOS dump byte address 9F81 (HEX) 0-CEA A, 1=CEA B. The operational CEA (also useful to determine the dumped CEA) can be known from ED element Y09X131D -- 2 bits: 10 = CEA A, 01 = CEA B.

Packet header parameters for the FOS memory dump are:

Packet Length	Hexadecimal 62
Packet Format Code	Hexadecimal Dx (x TBS by FOS)
Line Count	Hexadecimal 0000-003F
Observation Number	Set at dump time by ground
Number of Packets per Frame	Hexadecimal 0040
Number of Data Words per Packet	Hexadecimal 0200
Fill	26 words of fill (5569 HEX) occur in the 9th segment of each packet.

The FOS memory dump will consist of 32K 16-bit words addressed

7.10.6 ~~2.9.3~~ Microprocessor Speed Check. A microprocessor speed check is performed to verify acceptable performance of the operational CEA. The speed check routine is a background FOS task which increments a counter each time the task is called. The counter is reset to 0 with each minor frame pulse (every 1/2 second). Thus the speed check value represents the number of times this task is called. Under normal test connditions the speed check value should be between 300 to 320. The value will drop rapidly during high periods of CEA activity (e.g., high command activity or high data acquisition.)

3.10.3 ~~2.9~~ FOS Operational CEA Identification. The FOS operational CEA is identified within the engineering data stream every minor frame 0 within FOS word 8 Y02J500A, Eng Data Sync, bit 7 0/1 = A/B). The firmware version number of the operational CEA is in minor frame 1 FOS word 8 Y02Q501A, Firmware Version No. 1.

3.10.4 ~~2.9.1~~ ROM Checksum. The ROM checksum is the arithmetic sum of all ROM bytes in a 16-bit counter with overflow permitted. This algorithm will be routinely performed as a background task during CEA operations. The correct checksum value for each CEA firmware version will be provided for inclusion in the test and operations ground systems data bases. Downlinked values are provided in ED as follows:

Y02J502A	FOS word 8	minor frame 3	(HOB)
		minor frame 4	(LOB)
Y02Q501A	FOS word 8	minor frame 2	
		7 MSB firmware version	
		1 LSB 0/1 = A/B	

3.10.5 ~~2.9.2~~ FOS Instruction Test. A ROM instruction test is an FOS internal arithmetic algorithm performed on all ROM instruction code. The anticipated result is burned into the ROM. If the algorithm produces the anticipated result, the ASCII value "OK" is downlinked, as follows:

Y02J517A	FOS word 8	minor frame 31	(HOB)	"O"
		minor frame 32	(LOB)	"K"

4.1.3.2 Leaving INTS = 1, make P/R.O. as high as necessary, if can't get high enough, boost INTS, if still too low, adjust LT.

4.2 FOS Sensitivity. The material in this section is taken from a paper by Harms, et al. Proc. SPIE, 445, pp. 410-426, 1983. The most basic criterion for FOS scientific capability is the faintness limit for which a good quality spectrum (adequate signal-to-noise, appropriate spectral resolution, coverage of relevant spectral features) can be obtained in an observation of reasonable duration. As described in Section 4.2.1, several factors are important in achieving such a capability: the ST optical efficiency and image quality, and the FOS optical and detector efficiencies, spectral resolution, and instrumental noise.

In Section 4.2.2, we present other system characteristics of the FOS useful for planning particular observations. Measured data for instrumental stability and repeatability, quality of optical alignment, and degree of internal scattered light are described.

4.2.1 Fundamental Spectrographic Capability. The ST is an f/24 Cassegrainian telescope with a primary mirror 2.4 meters in diameter. Figure 4.2-1 illustrates the anticipated optical efficie[ncy] and, equivalently, effective aperture area for the ST. The through[put] includes the effects of obscuration (just under 10% in area) and tw[o] reflections by magnesium fluoride overcoated aluminized mirrors. Measured reflectances at Perkin-Elmer indicate the ST efficiency wi[ll] meet or exceed these specified values.

4. OBSERVATION PLANNING

4.1 Nominal Observational Philosophy. Following are the steps involved in choosing parameters for a no-time-resolved observation. These steps will differ somewhat for various types of observing modes, but the general ideas embodied herein may be applicable. The definition of FOS terms is given in section 2.

4.1.1 Initial choices-basic instrument set-up consistent with desired science: select X-STEPS, Y-STEPS, OVERSCAN, number of channels, acquisition mode, acquisition limit (if desired) etc.

4.1.2 Considering the expected count rate for a given target, and desirability of not overflowing memory (2^{16} counts): choose how often readouts, memory clears and acquisitions should occur in terms of time, taking into account other factors such as total desired observing time and the current orbit of the ST. Section 4.2 presents details concerning the FOS sensitivity.

4.1.3 Juggle the remaining free parameters; live and dead times, INTS, and PATTERNS/READOUT, to be consistent with instrument capabilities and the following considerations:

Time between readouts, Tro, is given by

Tro = (LT + DT) x INTS x [X-STEPS x OVERSCAN x Y-STEPS x SLICES] x PATTERNS/R.O.

and the terms in the [ ] are already set.

4.1.3.1 Set alive and dead times (LT, DT) to ensure a high duty cycle (LT/(LT + DT)) but with a relatively short (default 100 ms) livetime in order to keep efficiency high in noisy cases and to get good temporal sampling of all deflection positions (this is also the reason for keeping INTS low). The exact mix in this tradeoff depends on the objects to be studied and the observer's preferences.

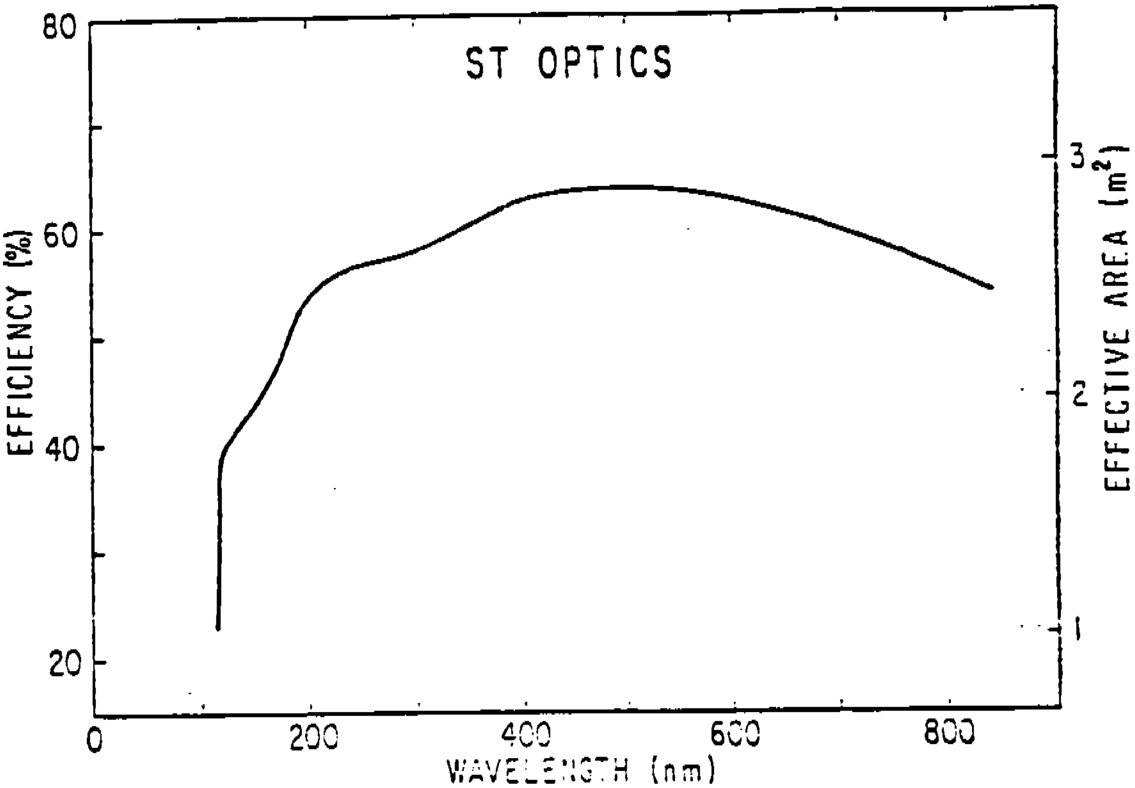


Figure 4.2.1-1
Optical Throughput of the Space Telescope Based on Specified Performance of Primary & Secondary Mirrors

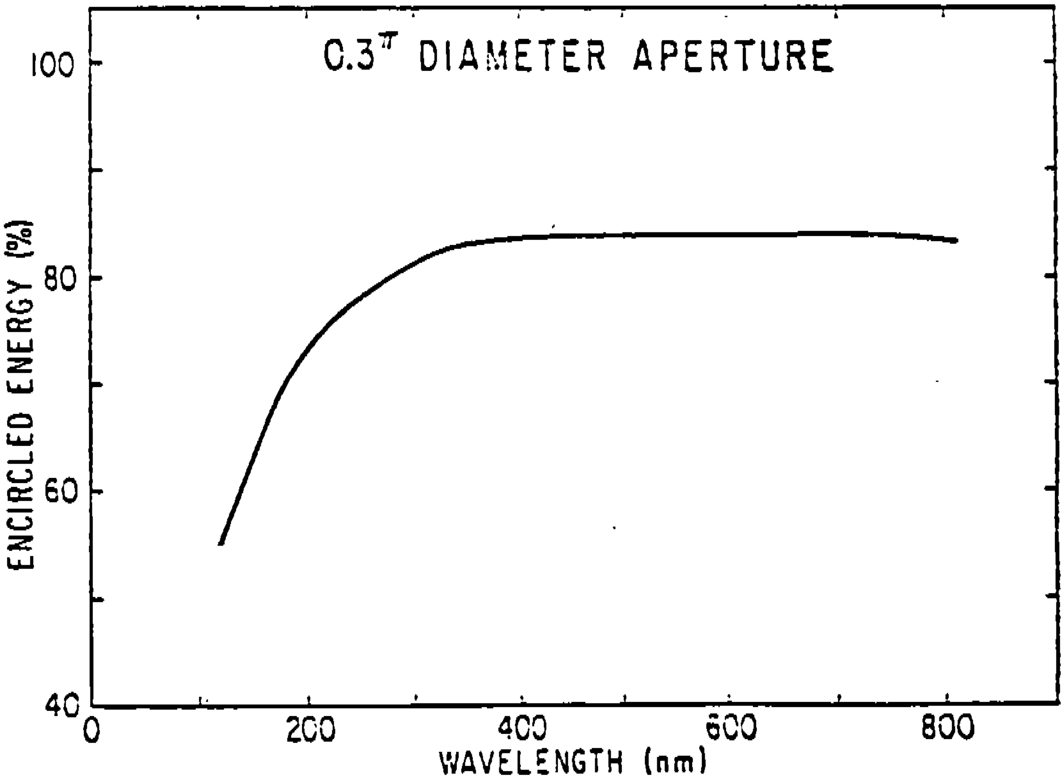


Figure 4.2.1-2
Fraction of Light from ST Calculated to Enter FOS through a 0.3 arcsec Diameter Entrance Aperture

Based upon measurements of the primary and secondary mirror quality as well as the specified ST pointing stability of 7 milliarcseconds RMS accuracy, Dr. Schroeder (calc. presented to STSWG 26-27 October 1982) has computed several measures of expected image quality. Figure 4.2.1-2 displays the fraction of light which will enter the FOS through its 0.3 arcsecond diameter aperture based on these calculations. Because use of this entrance aperture maintains nearly the full FOS spectral resolution, yet admits most of the available light from the target while keeping the sky background low (0.07 square arcseconds), it should be frequently chosen for observations of stellar-like images. Figures 4.2-3 through 4.2-6 present the efficiencies calculated to result using the 0.3 arcsecond aperture. Figure 4.2-7 summarizes the system efficiencies of the ST plus FOS for the low (R 250) and high (R 1300) resolution combinations. The prism, in particular, will be very useful for initial spectra of very faint sources in order to determine object classification and the spectral regions of interest for more detailed study.

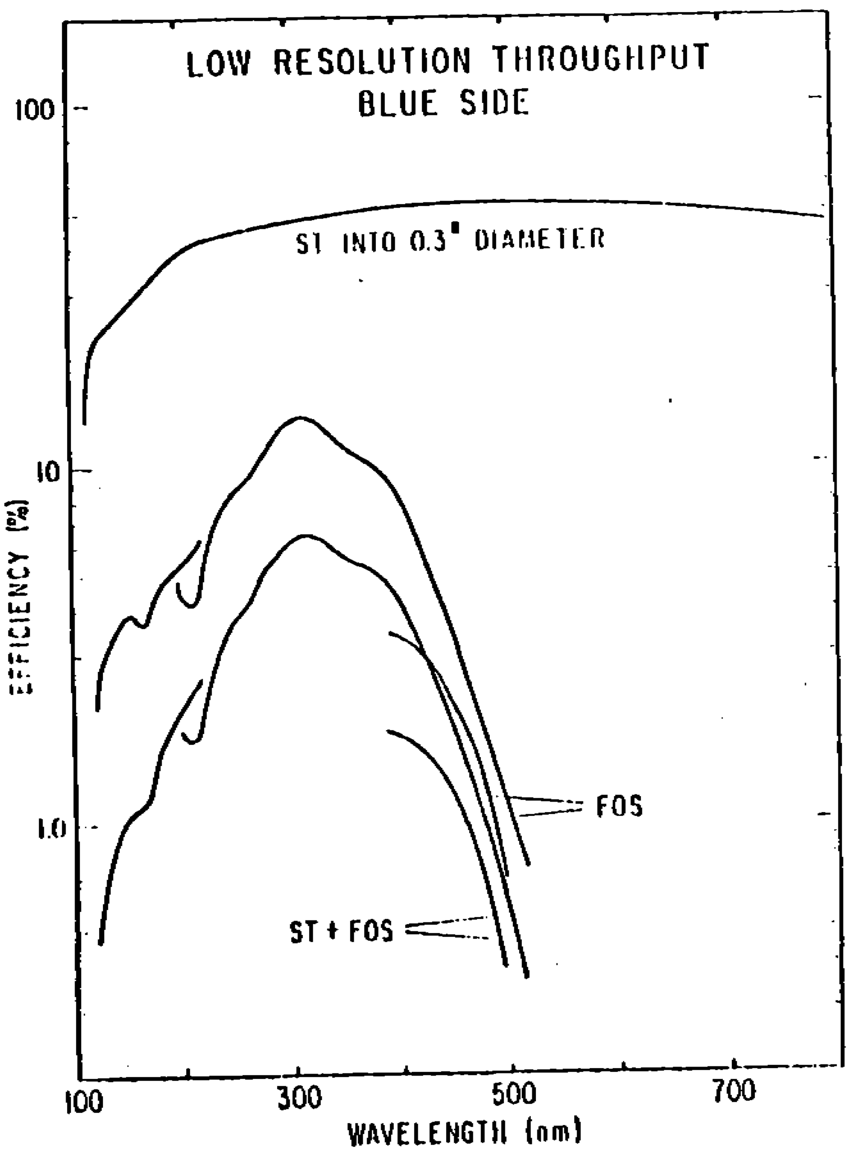


Figure 4.2.1-5
Computed Efficiencies for Observations at R ≈ 250 Using the (New) Blue Detector

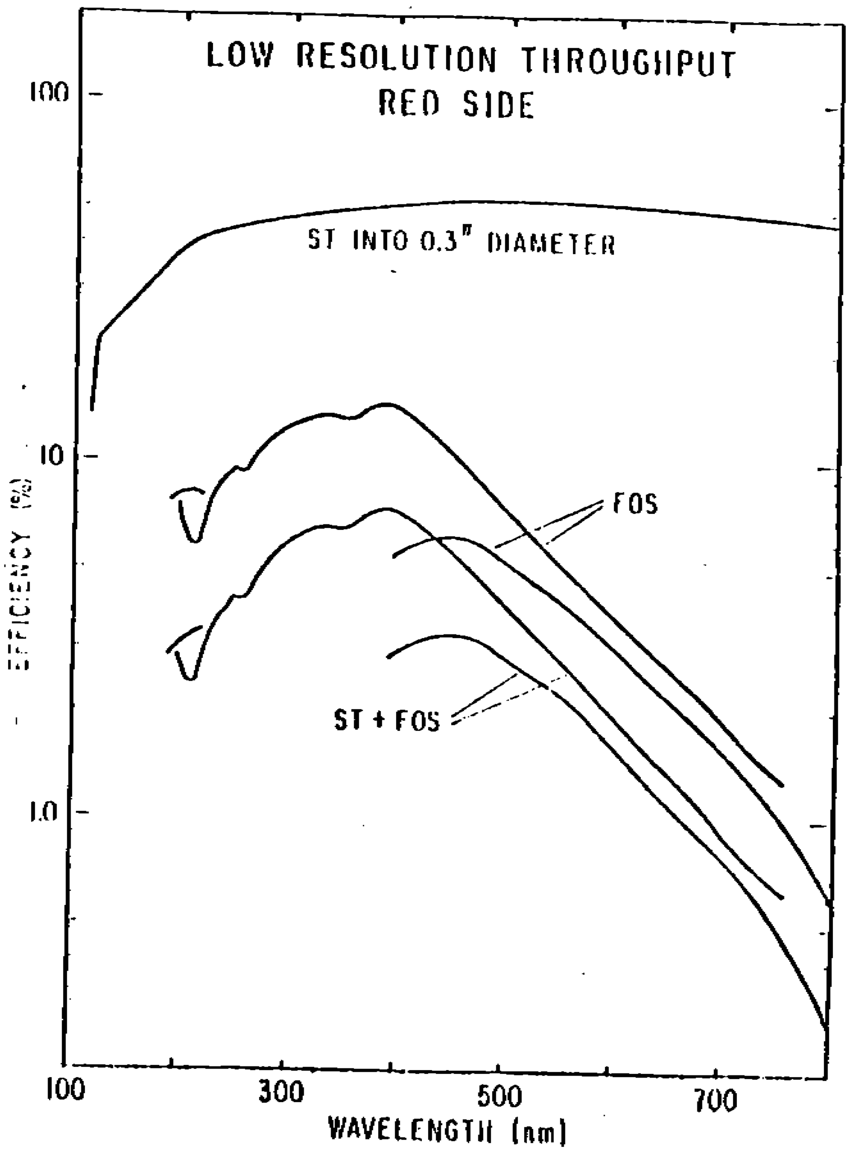


Figure 4.2.1-6
Computed Efficiencies for Observations at R ≈ 250 Using the (New) Red Detector

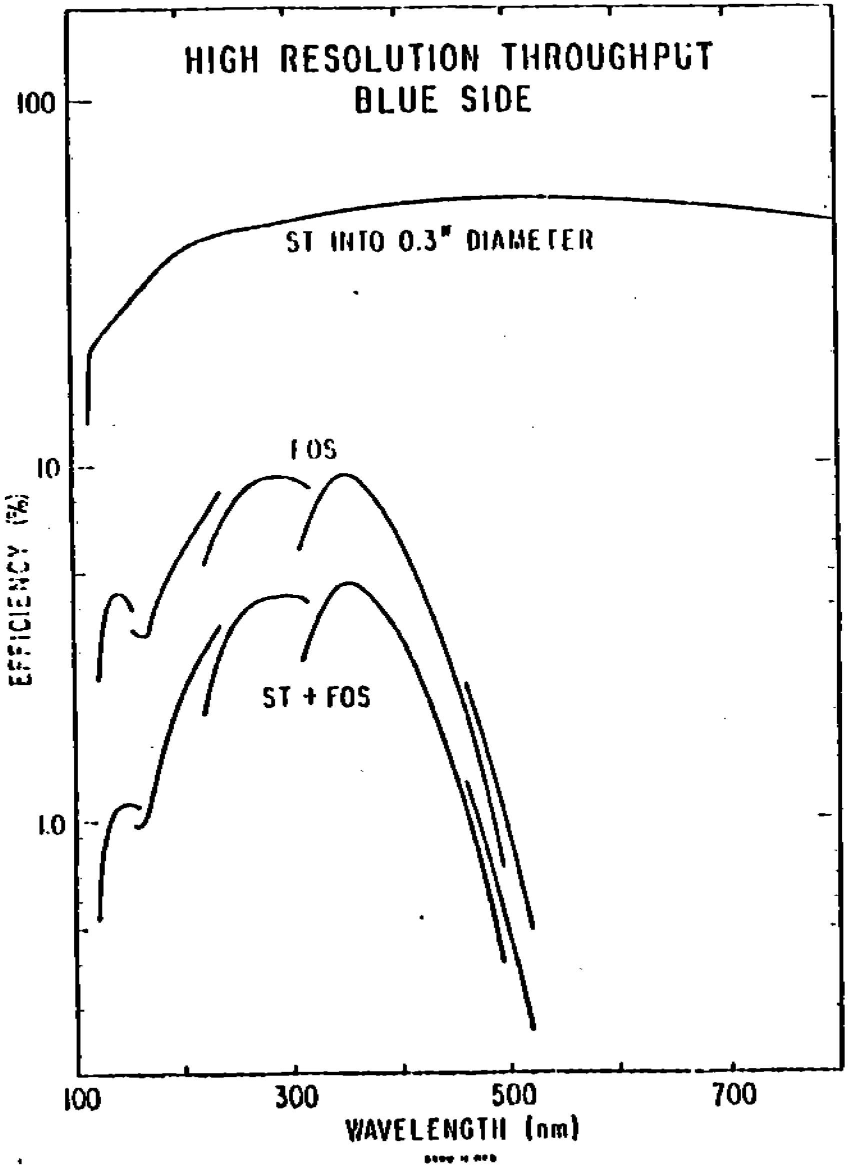


Figure 4.2.1-3
Co ted Efficiencies for Observations at R 300 Using the (New) Blue Detector

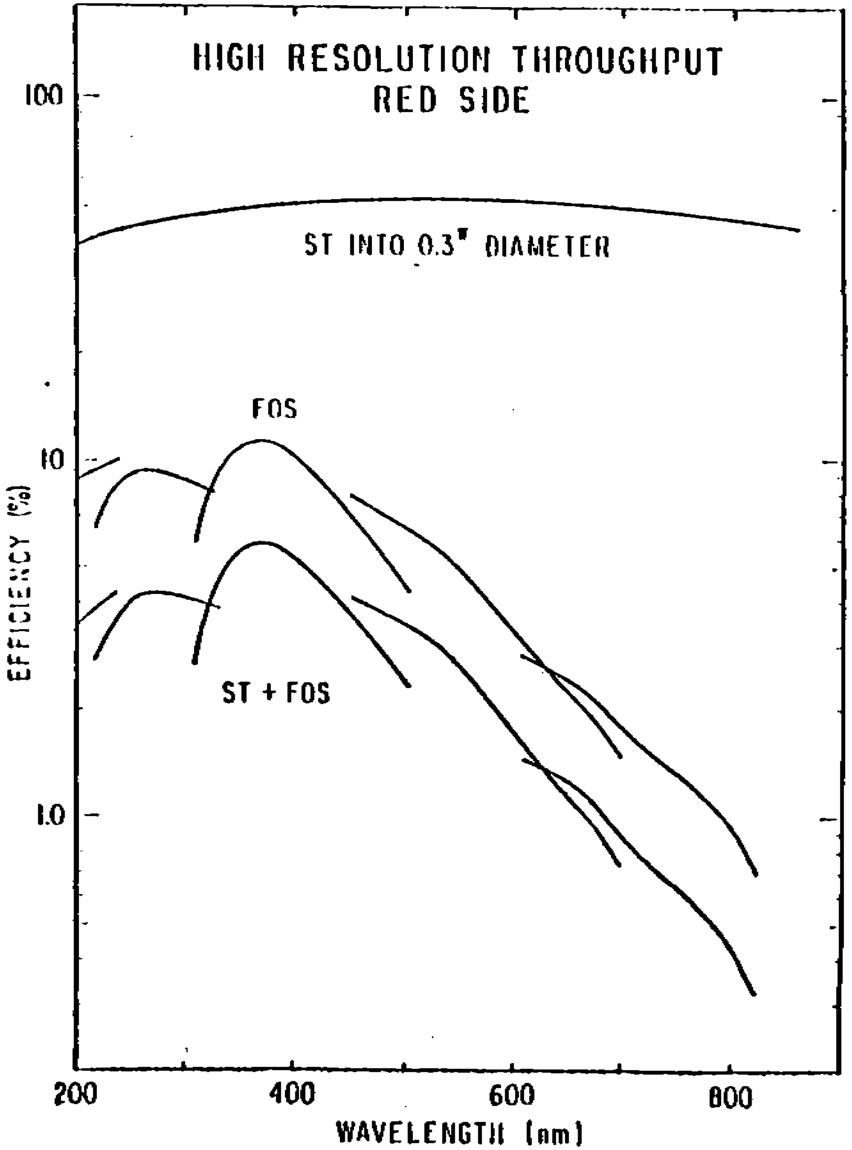


Figure 4.2.1-4
Computed Efficiencies for Observations at R ≈ 1300 Using the (New) Red Detec

Both sky and instrumental background strongly limit the faintness of targets which it is practical to observe, because the time required to achieve a needed signal-to-noise ratio increases a the square of the source faintness once the target signal is much weaker than the total background rate. The excellent image quality provided by the ST is the major factor allowing reduction of sky background; typical visible-band (where the sky plus scattered sunlight is worst) sky background is between magnitude 25 and 26 through a 0.3 arcsecond diameter aperture. Great effort has also g into reducing the FOS instrumental background. The detectors are cooled with heat pipes connected to radiators in order to maintain photocathodes at less than -10 degrees Centigrade; thermionic emiss then produces less than 0.001 count/sec/diode dark noise. The FOS also uses the 512 diodes as their own anticoincidence detectors in order to reject count bursts caused by energetic charged particles striking the detector windows. By these means, we expect the instrument background to be less than 0.002 counts/second/diode so long as the ST is outside the South Atlantic Anomaly.

As a practical illustration of faint target performance, le us consider a one hour observation of an object producing a signal 0.01 count/second/diode. In the absence of any background, a spect with S/N = 6 would be received, more than sufficient for many scientific purposes. Through the 0.3 arcsecond aperture, the sky signal would be entirely negligible except around 500 nm using the prism disperser. Instrument noise at 0.002 counts/second/diode wou amount to around 7 counts/diode. The resulting spectrum would have signal-to-noise ratio about 5 for each resolution element except ne = 500 nm in the prism mode, where sky contamination reduces the spectral quality to S/N 3 to 4. Figures 4.2.1-8 and 4.2.1-9 illustrate the limiting magnitudes for the observations discussed above. As an example of just how faint these targets can be, we mention that the brightness of Comet Halley when first recovered us a charged-coupled-device detector at the Palomar 5-meter (200 inch) telescope was about 23.5 visual magnitude. Had the ST and FOS been operational in orbit, we could have obtained its spectrum throughou

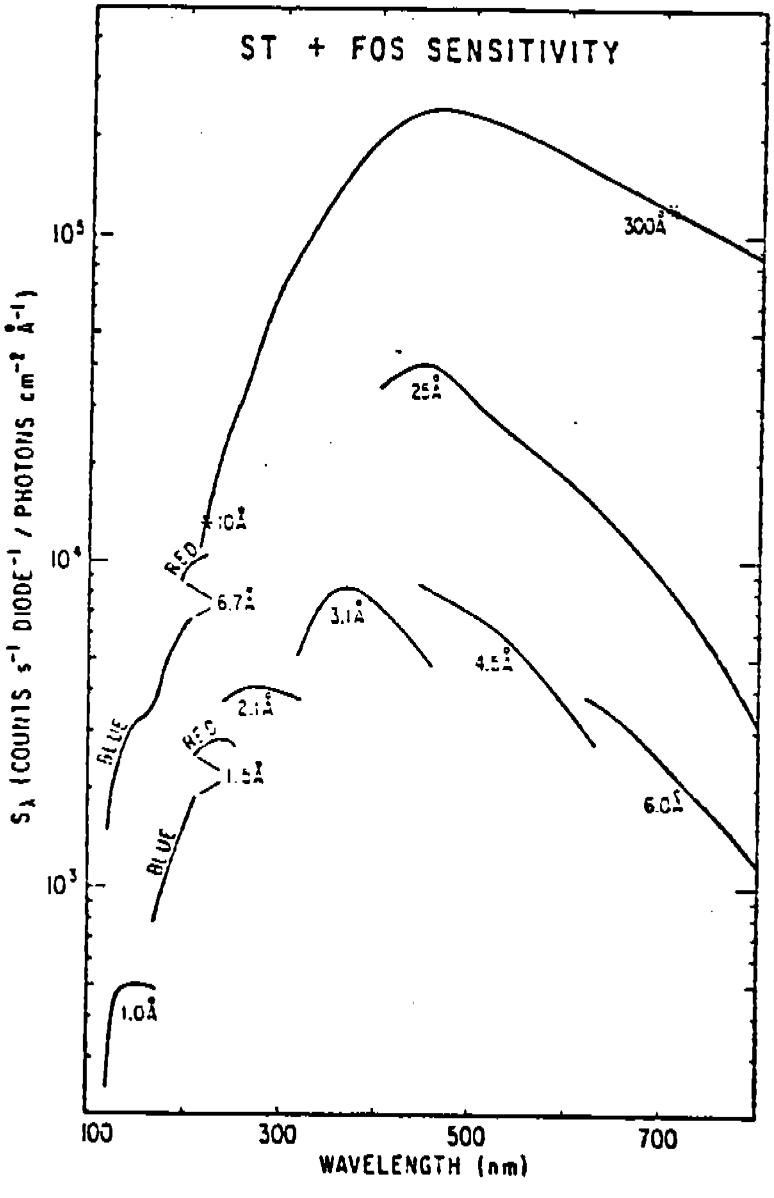


Figure 4.2.1-7
Summary of Systems Efficiency Expected On Orbit for all Spectroscopic Modes of FOS. Numbers Lebeling the Curves Refer to the Wavelength Resolution in Angstroms for Each Mode. Note that the Prism Dispersion Varies from 10 Angstroms/pixel near $\lambda = 220$ nm to 300 Angstroms/pixel near 700 nm.

much of the visible region in less than one hour at low resolution, and even have taken a good-quality R 1300 spectrum in several hou It is reasonable to assume that many of the targets astronomers wil select to observe are so faint that as of today not even an image o them exists.

4.1.2 Other Performance Measures. Repeatability and stability of spectra affect operational efficiency, accuracy of derived wavelengths, and photometric accuracy. Because the FOS reimages its received light, repeatability and stability performanc enters twice: at the ST focal surface in which (we hope) lie the FO entrance apertures and at the detector windows onto which the entra aperture images are focused. At the instrument level only the seco set of (FOS-internal) repeatability and stability performance can b measured. Lack of repeatability and stability of the FOS apertures the ST focal surface would cause errors in the part of the sky look at by the FOS -- partially to fully missed targets, or smearing of intended target and sky across the entrance aperture. The result i good spectrum of the wrong thing. Lack of FOS internal repeatabili and stability, on the other hand, would produce a poor spectrum of correct portion of the sky.

Thermal vacuum measurements of internal stability showed no detectable motion of the spectral image over several hours when the temperature remained constant. The offset in position between the worst case cold operational and hot operational temperatures expect in orbit were only 15 to 20 microns, indicating that the FOS spectr images will be stable for observations of many hours.

Image locations should also repeat after motions of the entrance aperture mechanism (selecting another aperture, then returning to the original) and when returning to a given filter-grating wheel position. The repeatability of spectral locations following aperture motions to and from the most distant apertures was unmeasurably small, far less than 5 microns. However motions of the filter-grating wheel did produce measurable offsets.

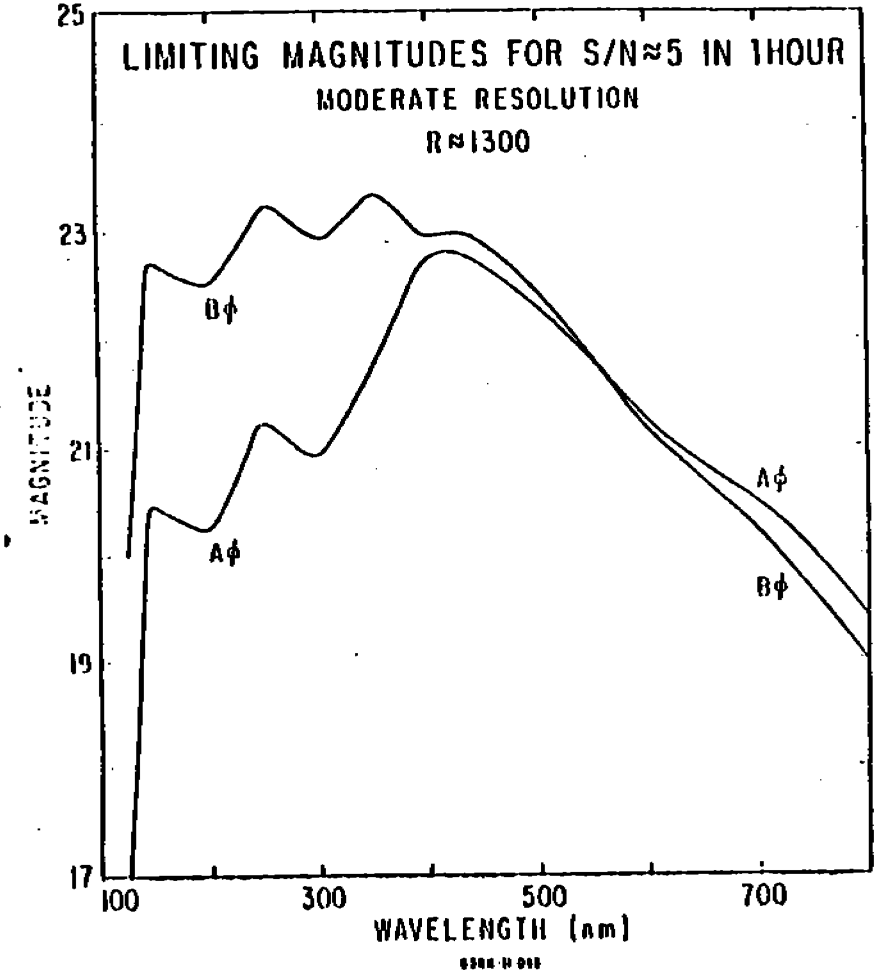


Figure 4.2.1-8
Limiting Visible-Band Magnitudes for Pointlike Sources with AO and BO Spectral Distributions. Spectral Dispersions Range from 1 Angstrom/Pixel at the UV End to 6 Angstroms/Pixel in the Red.

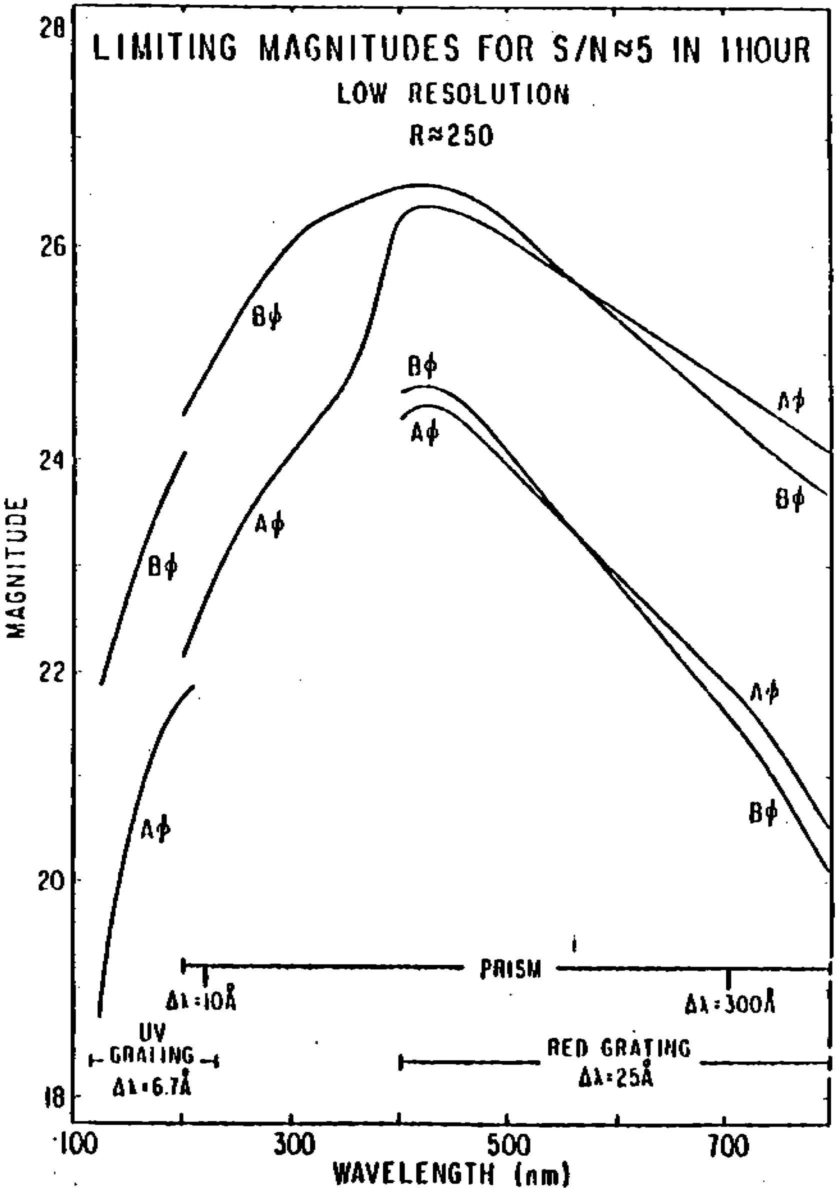


Figure 4.2.1-9
Limiting Visible-Band Magnitudes for Unresolved Sources with AO and BO Spectral Distributions. Dispersions (Angstroms/Pixel) are Noted

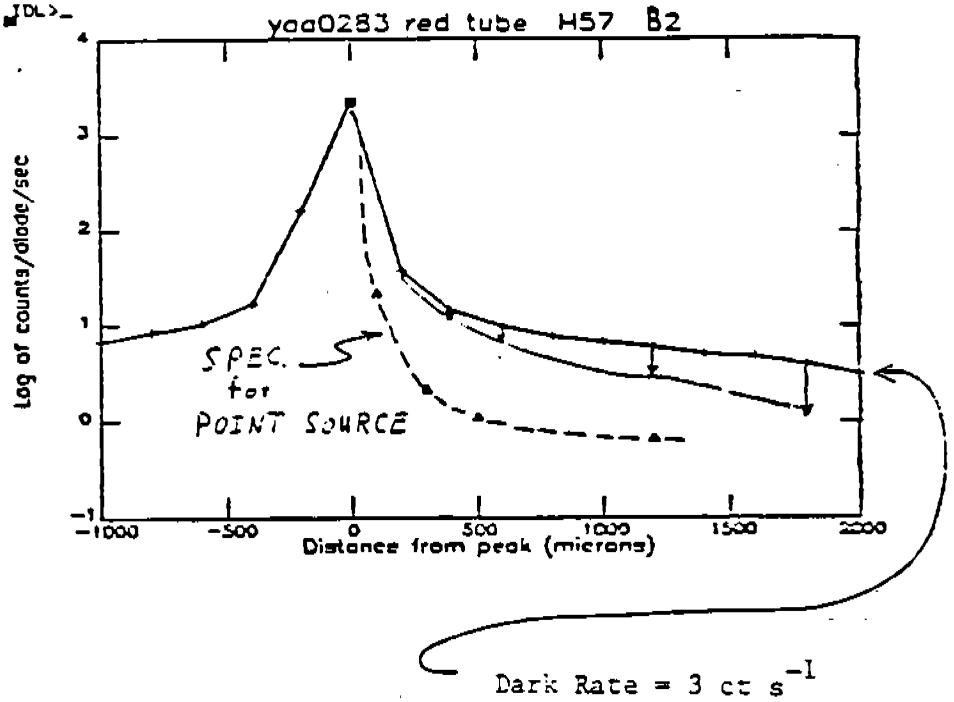


Figure 4.1.2-1
Light Scattered Perpendicularly to a Continuum Source

The normal operation is to approach a given grating position always from the same direction, resulting in image repeatability around 10 microns or 0.2 pixel. This implies that extremely accurate wavel determination will require calibration spectra after selection of th desired disperser. Finally, rotation of the filter-grating wheel in the reverse direction should be avoided, as this produces an offset as much as 100 microns (equal to 2 full pixels) in the spectral imag

The FOS produces one-dimensional spectra which must be accurately aligned with the one-dimensional array of diodes forming the detector anode. A great deal of effort went into aligning every disperser and both detectors to within 0.1 degrees (worst case) of o another. This results in spectra which can be centered in all the diode elements simultaneously to within ± 25 microns (out of a full diode height of 200 microns). Such precise alignment was essential achieve acceptable photometric performance without having to reduce the FOS sensitivity drastically by requiring multiple scans to obtai all the light.

Scattered light measurements of the FOS optical component suggest that scattered light within a spectrum will not greatly limi identification of weak spectral features. The scattered light data from the instrument level calibration are not yet fully analyzed; however, it is clear from an initial look that scattered light intensity drops (from the peak of unresolved isolated emission line) by three to four orders of magnitude within one millimeter. As expected, light intensity perpendicular to the dispersion direction falls off at least as rapidly as along the dispersion (Fig. 4.1.2-1)

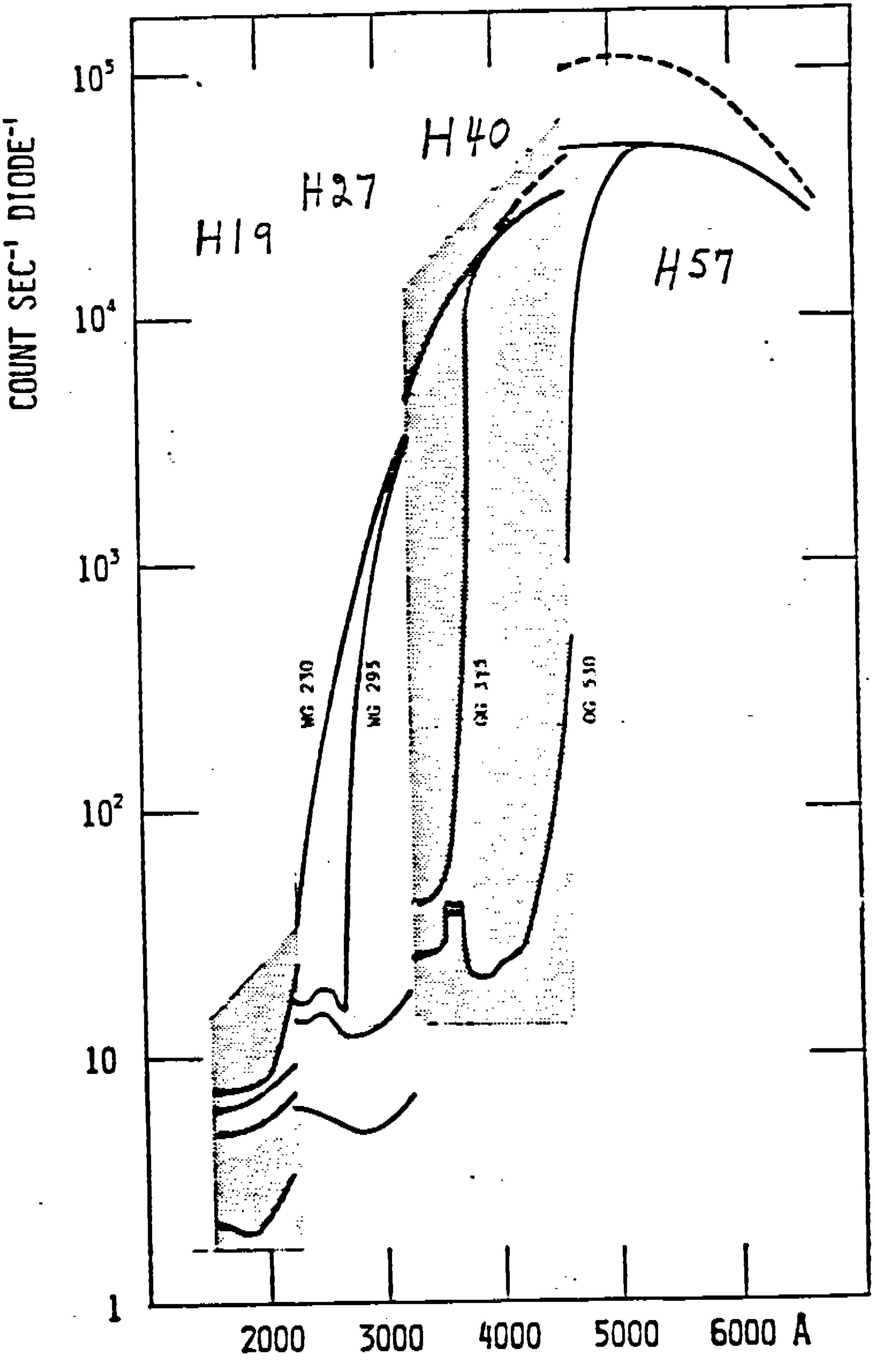


Figure 4.1.2-2
Scattered Light, Tungsten Lamps and High Resolution Filters

Scattering of off-spectral-band light is expected to be r severe during ultraviolet spectroscopy of red targets, where internally scattered unwanted red light may contaminate the spectrum. Instrument level tests were conducted using a tungsten lamp at T 2800^{o}K with various cutoff filters (WG230, WG295, GG395, and OG530, see Fig. 4.1.2-2). Since the current red detector has preferentiall lost red response, the measured sensitivity to scattered red light lies between what will be the on-orbit effects using the blue and re detectors. The count rates (counts/second/pixel) in the ultraviolet spectra (with R 1300) due to scattered visible light were quite uniform and at most 2 x 10^{-4} times the average rates in the visible spectra. As indicated in Figure 4.1-7, the sensitivity (S) for the ST + FOS in the ultraviolet is less than in the visible; for the R 1300 modes, the sensitivity ratios (visible to UV) are approximately 20 at = 125 nm, near 5 at = 200 nm, and about 2 at = 300 nm. From this, we calculate that scattered light will significantly affe targets with color temperatures cooler than about 2000^{o}K for spectra near 300 nm, 4000^{o}K near 200 nm, and nearly 8000^{o}K at Lyman . T for far ultraviolet spectroscopy of cool objects, use of the High Resolution Spectrograph with its solar-blind digicon detectors will often be preferable to use of the FOS.

Note that the FOS digicons are expected to be replaced in la 1984 or early 1985, and that new measurements will have to be made. We may reasonably expect the results to be equal to or better than those shown here.

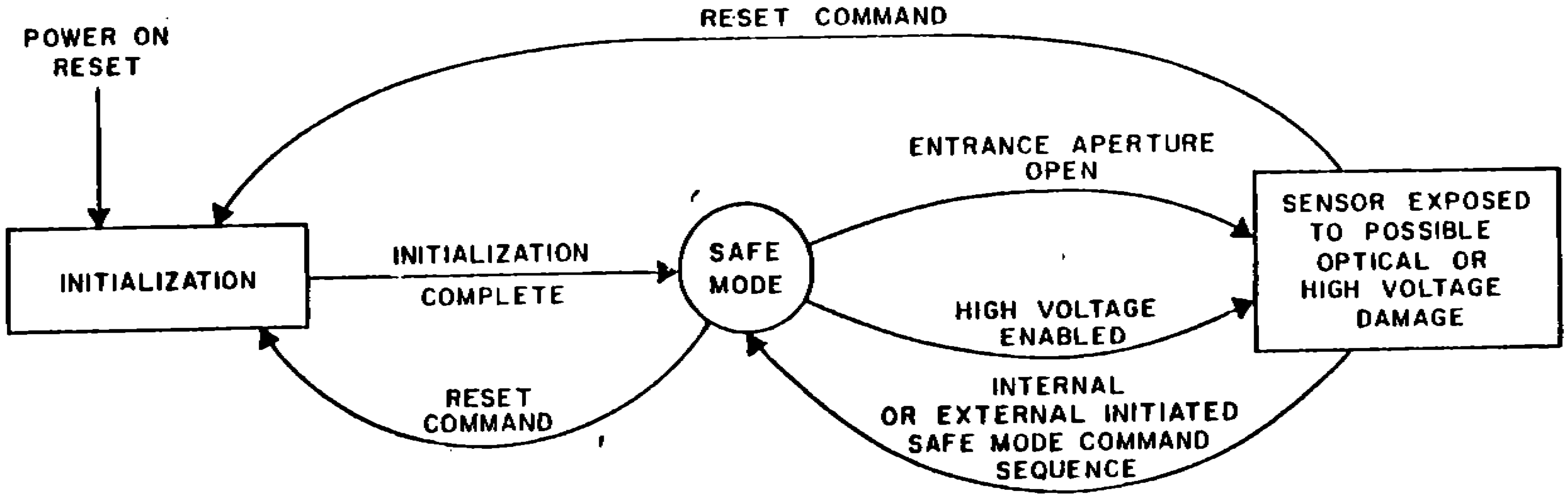


FIGURE 4.3-1
SAFE MODE TRANSITION DIAGRAM

79GS-11-040A

4.3 Routine Mode Transitions.

4.3.1 Transitions To and From Hold. The following relativ time command sequences (RTCSs) are used in routine status changes.

TABLE 4.3.1-1

FOS Routine Status Change RTCSs

RTCS	FUNCTION	DURATION (sec)
YOFHD	Off to Hold	?
YIOFHD	To Hold From Any Initial State	131
YHDLV	Hold to Low Voltage	136
YINIT	One Side to Readiness for Parameters	131
YOPHD	Operate to Hold	125-965
YHDOF	Hold to Off	2
YOFFP	Operate to Off	62.3 - 123

The Safe Mode Transition diagram is shown in Figure 4.3-1. Stat diagrams for the Remote Interface Units are shown in Figures 4.3-2 4.3-3.

4.3.2 Transitions To and From Other Standard Modes. Note that observational modes are in section 4.4, safing transitions are in section 7.1.

4.3.3 Utility Real Time Command Sequences.

YENRTS	Enables the RTCSs Used	<28
YDISRTS	Disables the RTCSs Used	<19
YLDPAR	"Includes" Default Local and Global Parameters	0
YINSEQ	"Includes" RTCSs Used	?