

HSP

ND-1001A

HSP-Related Acronyms

ACK	Acknowledge Command Processor in NSSC-1
AP	Application Processor
ARS	Area Scan
BAT	Byte Argument Table
BRO	Bright Object Protection Processor in NSSC-1
CVC	Current to Voltage Converter
C&DH	Control and Data Handling (Subsystem)
DAC	Digital-to-Analog Converter
DAS	Deflection Amplifier Subsystem
DCA	Detector Control Assembly
DCF	Data Capture Facility
DEA	Detector Electronics Assembly
DMS	Data Memory Set
DUM	Dump Memory
ELG	Engineering Log Generator Processor in NSSC-1
ET	Engineering Telemetry
FOV	Field Of View
GO	General Observer
GSFC	Goddard Space Flight Center
HSP	High Speed Photometer
HTR	Heater Control Processor in NSSC-1
HV	High Voltage
ICD	Interface Control Document
IDT	Image Dissector Tube
IST	Instrument Science Team
K	For memory, 2^{10} (1024); otherwise, 10^3
Kbps	Kilobits per second
LMSC	Lockheed Missiles and Space Company, Incorporated
MHz	10^6 Hz
MOGS	Mission Operations Ground System
msec	Millisecond
nm	Nanometer (10^{-9} meters or 10 angstroms)
NSSC-1	NASA Standard Spacecraft Computer, Model 1
ODS	Optical Detector Subsystem

OSS	Observation Support System
OTA	Optical Telescope Assembly
PAD	Pulse Amplitude Discriminator
PASS	POCC Application Software Support
PCDS	Power Converter and Distribution Subsystem
PDCR	Preliminary Document Change Request
PDL	Program Design Language
PIT	Processor Interface Table
PMT	Photomultiplier Tube
POCC	Payload Operations Control Center
PODPS	Post-Observation Data Processing System
PORTS	Preliminary Operations Requirements and Test Support
PROM	Programmable Read-Only Memory
QSO	Quasi-Stellar Object
RAM	Random Access Memory (read/write)
RIU	Remote Interface Unit
Sci	Science Institute (Johns Hopkins)
SCP	Single Color Photometry
SDAS	Science Data Analysis Software
SDF	Science Data Formatter
SHP	Standard Header Packet
SI	Science Instrument
SLIB	SOGS (TRW) Library document identifier
SOGS	Science Operations Ground System
SPS	Signal Processing Subsystem
SPSS	Science Planning and Scheduling System
SSC	Science Support Center
SSM	Support Systems Module
SSP	Star/Sky Photometry
ST	Edwin P. Hubble Space Telescope
STOCC	ST Operations Control Center
STSOP	ST Science and Operations Project
TAV	Target Acquisition and Verification (Processor in NSSC-1)
TBD	To be determined
TBT	Telemetry Byte Table

TM	Telemetry
UDL	Unique Data Log
usec	Microsecond
UTC	Universal Time Coordinated
UV	Ultraviolet
V	Conventional first letter for HSP parameters
Vxxx	Abbreviated LMSC ET Measurement ID
V.xxx	Coined Measurement ID (for Science Data)
VAP	Verification and Acceptance Program
X'ab'	Hexadecimal (base 16) value for "ab"
<u>???</u>	Material needing determination/confirmation
:n	Bit number n (1 most significant)

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF HSP NOTEBOOK

The purpose of this High Speed Photometer (HSP) Notebook is to provide a compilation from various sources of factual information on certain aspects of the HSP necessary for design work on the Edwin P. Hubble Space Telescope (ST) Science Operations Ground System (SOGS). The contract for development of SOGS is managed by GSFC, and is performed by TRW. One of the main tasks of SOGS is the receipt, display, manipulation, and calibration of the HSP data (as well as the other instruments on the ST). To perform this task, a thorough understanding is necessary of the various formats in which data is received, where critical processing parameters are in both the science and engineering data streams, and what algorithms are to be applied to calibrate the science data for each instrument configuration.

The intended audience for this HSP Notebook is the TRW SOGS designers, rather than a general collection of diverse groups with equally diverse information desires. Because of its intended audience, there are numerous HSP-related topics that are not included in this Notebook. Section 8 (References) has a list of citations for some source documents on HSP that are in the TRW SOGS Library. Such documents have been assigned serial accession numbers (SLIB numbers) meaningful only to those with access to the TRW Library, so Section 8 provides information on originator, date, and title to identify the material more completely.

The organization of this HSP Notebook is the same as that for the other four ST instruments. After this introductory material, the various types of HSP modes are defined in Section 2 (since they are of major significance to the SOGS design effort). Sections 3 and 4 cover the HSP Science Telemetry and HSP Engineering Telemetry respectively. Algorithms for HSP Calibration, HSP Data Quality/Utility, and HSP Target Acquisition are in Sections 5 to 7 respectively (these relate to what is in Section 10 of the SOGS SE-06-1 specification, SLIB 799). Section 8 has References.

1.2 SUMMARY OF HSP NOTEBOOK UPDATES FOR THIS REISSUE

The changes in this reissue of the HSP Notebook (SLIB 864 was the original issue) are those necessary to reflect the availability of considerably more information on the instrument's performance. This information was obtained from IDT documents, a mid-June 1983 GSFC HSP Operations meeting, review of sample HSP tape data, and the thorough IDT responses to the questions resulting from the tape review. Since new HSP information has been distributed within the SOGS project as it has been obtained, there should be no surprises in the changes that are incorporated in this issue, which include:

1. Addition of numerous instrument details, including the convention for numbering the five HSP sensors. In addition to IDT-generated data, some of these changes were obtained from the ST Science Institute's HSP description in SLIB 1006b (see Section 1.5).
2. The Standard Header Packet locations (from LMSC's SLIB 936) of the HSP engineering telemetry (see Section 4).
3. Reflection of the HSP convention that the Unique Data Log (contrary to most other ST instruments) is sent before the Standard Header Packet on the downlink, as specified by GSFC (see SLIB L58).
4. Changes in the downlink telemetry minor-frame assignments to agree with a new issue of LMSC's DM-02 (SLIB 1089).

A significant area of uncertainty for the HSP centers around the location of parameters in the HSP Unique Data Log. This reissue of the HSP Notebook reflects the same locations as in the previous issue, although this may not be what will be seen in flight (see Section 3.2.2). Two additional areas where (in common with most other ST instruments) uncertainties exist in the material covered in this document are the detailed format of the uplinked area of the Standard Header Packet (alternative sources are cited in Section 3.2.1) and the flight values to be used for the packet format code (see Section 3.2.4).

The updating effort for this HSP Notebook will be a continuous process throughout the duration of the SOGS project. This reissue, however, is the first HSP Notebook change that has been generated since the Revision-2 change

pages (dated 27 February 1983) to the SLIB 864 issue. New information otherwise has been distributed among the TRW SOGS designers by means of SOGS memos. Particularly for those holders of the HSP Notebook outside of TRW, therefore, reliance on this HSP Notebook to reflect the "latest available" (anyplace) set of HSP data continues to be inappropriate.

1.3 INVESTIGATION DEFINITION TEAM

The Principal Investigator for the HSP experiment is:

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1.4 SCIENTIFIC OBJECTIVES

The following information was obtained from SLIB 317:

The HSP will be a scientifically versatile instrument, designed to provide precise, time-resolved photometric observations of rapidly varying sources over time scales as short as 16 usec. Observations in this domain are difficult or impossible to obtain from the ground because of the effect of transmission through the atmosphere. The HSP will provide ultraviolet photometry of faint objects unobservable with previous space instruments and photometry at visible wavelengths with higher precision and to fainter magnitudes than is possible from the ground. The HSP will carry out exploratory ultraviolet polarimetry. It will also provide an important service to other ST instruments by transferring the absolute flux calibrations and photometric systems of bright stars to stars sufficiently faint to be accessible to those instruments. As a minimum, the HSP will be capable of providing data in the following areas:

1. Determination of properties of cataclysmic variables, X-ray bursters, X-ray binaries, gas streams, and accretion disks in compact binary systems;
2. Searches for optical counterparts to radio pulsars;
3. Measurement of time scales of the fastest variability of Seyfert nuclei, BL Lac objects and quasi-stellar objects (QSOs) to determine their characteristic dimensions;
4. Accurate brightness measurements of the zodiacal light and diffuse galactic light;
5. Determination of the wavelength and time dependence of polarization in compact binaries, white dwarfs, nebulae, interstellar dust, QSOs, active galactic nuclei, etc.;
6. Establishment of faint stellar calibration standards, magnitude system transformations, and transfers between previously established photometric sequences and ST targets; and
7. Measurement of the diameter of stars and solar system objects, and determination of the profile of the physical parameters of planetary atmospheres with height using accurate, high-speed observations of stellar occultations by planets, their satellites, minor planets, and the Moon.

1.5 PRINCIPLES OF OPERATION

See SLIB 458 for information on the principles of operation of the complete HSP instrument (including its mechanical layout and a functional block diagram). The material given below emphasizes those HSP aspects that are of particular significance for understanding the nature of its science data, and has been generated using the sources listed in Section 8.1.

The HSP is mechanically the simplest of the SIs on the ST. A major purpose of the HSP is to make fast integrations of the light level of stars (down to 10 usec). This time interval is not available on the ground due to the effects of the atmosphere. One application of the short intervals is to observe what the light curve looks like during occultations. The instrument has an extremely flexible design, allowing it to react to things after they are discovered. It has no moving parts and relies entirely on the fine pointing of the spacecraft to direct the light from a target onto one of its combinations of spectral filters and entrance apertures.

No calibration lamps are in the HSP: its final radiometric calibration will be established by observing stars with known spectral energy distributions. The HSP has two test lamps (both controlled by the same pair of relays in series) whose sole purpose is to do an "aliveness test": it is possible that these lamps will not be used after launch.

The HSP has four independent, magnetically focused and deflected image dissector tubes (IDTs), each mounted behind a plate that holds an assortment of filters and entrance apertures. The IDTs resemble photomultiplier tubes in operation, except they can be made to respond only to photoelectrons coming from the small region of the photocathode on which light is focused. Two of the IDTs have CsTe photocathodes on MgF_2 faceplates and are sensitive from about 120 to 300 nm; the other two have bialkali cathodes on quartz faceplates and are sensitive from about 180 to 700 nm. The photocathode of the IDT is logically subdivided into several areas, each of which can be sampled by controlling the IDT's horizontal and vertical deflection circuitry that is driven by twelve-bit digital-to-analog converters (DACs). The instrument is also equipped with a side-looking photomultiplier tube (PMT)

having a GaAs photocathode. Three of the IDTs (the two CsTe ones and a bialkali tube) are used for photometry. The other bialkali IDT is used for polarimetry, and the photomultiplier along with the bialkali photometry IDT are used for occultation observations. Each IDT takes 16 watts of bus power. It is possible for all five detectors to be on at one time, although no credible observation scheme has been mentioned that would require this.

Detectors are numbered clockwise (when facing in the same direction as the path of incoming light to the instrument), with detector #1 being the forward-facing bialkali-cathode IDT used for polarimetry. The other bialkali-cathode IDT is #3 (used for photometry), and the two CsTe photocathode detectors are #2 and #4. The PMT is referred to as detector #5.

For photometry, light from the ST enters the HSP through one of three holes in its forward bulkhead, and after passing through a filter and aperture is brought to a focus on the dissector photocathode by a relay mirror. The filter/aperture "mechanism" is mounted behind each forward bulkhead entrance hole. Each plate contains 13 filters mounted in two rows (see SLIB 810 for their general characteristics). For each filter plate there is an aperture plate containing apertures arranged in two rows that are positioned directly behind the corresponding rows of filters. Nine of the filters are associated with four apertures: two with diameters of 1 arc second and two with diameters of 0.4 arc seconds. Three more are associated only with three apertures (because of space limitations), and the last filter, of double width, has five associated apertures, including one of 10 arc second diameter for object acquisition. This gives a grand total of 50 apertures and (with no moving parts) 27 different filter/aperture combinations.

Apertures in a given row are 7.5 arc seconds apart so generally one aperture should be suitably located for a background measurement through the same filter. The focal plane is at the exterior aperture location (rather than at the filters). The filter/aperture combination to be used for an observation is established by specifying which aperture is to be used. Notation conventions for these apertures, however, have not yet (see SLIB 1122) been

defined. The ST pointing is not changed; the dissector is simply commanded to collect photoelectrons from the point on the photocathode corresponding to the selected aperture.

To make occultation observations, light from the target object passes through a filter (in this case clear glass) and on through a 1 arc second aperture after which it strikes a beam splitter at 45° to the incident beam. The mirror reflects red light to the photomultiplier via a red glass filter and a Fabry lens. The beam splitter also passes a spectral band in the blue on to a relay mirror and then to a bialkali photometry IDT (detector #3). Occultation observations can therefore be made at about 820 nm and 320 nm simultaneously. Single bandpass occultation observations can also be made with any of the filter/aperture combinations available.

For polarimetric observations, detector #1 (one of the bialkali ones) is used. Light passes through a filter/aperture assembly directly to the IDT (without using a relay mirror). The filter assembly contains only four near UV filters across which are four strips of polarizing material each having its polarizing axis 45° from its neighbor's. The aperture plate contains one arc second apertures only (two for each filter-polarizer combination). Linear polarization is measured by observing through each of the four polarizers in succession.

In the IDT, the resulting photoelectrons from the dissector cathode are magnetically focussed and deflected in the forward section so that the photocurrent is directed through an interior aperture with a size of 180 microns. This corresponds to 1 arc second on the sky for detectors #2, #3, and #4 (the ones using a relay mirror), and 0.65 arc second for detector #1. The deflection-step least increment is about 4.5 microns. This selected aperture connects the forward section of the detector with the 12-stage photomultiplier section. A star image is expected to be about 0.3 arc seconds. These numbers imply that the ten arc-second aperture can be covered adequately by a scan using a rectangular grid with a maximum of 400 points (the figure used for HSP Target Acquisition and Verification, TAV). After the drift area, the multiplier section is entered. The electrical output of

this section is fed through a preamplifier (voltage gain of about 7) that has both a current and a pulse output. This completes the HSP Optical Detector Subsystem (ODS).

The signal next goes to the Detector Electronics Assembly (DEA) that houses a Signal Processing Subsystem (SPS) and a Deflection Amplifier Subsystem (DAS). The DAS is not connected for the PMT, but for logistics reasons is in its DEA. The SPS has a Pulse Amplitude Discriminator (PAD) and a Current to Voltage Converter (CVC). The PAD, after a gain of 36 dB, uses a pulse detector having an eight-bit threshold level (that is specified for the observation). The threshold allows the signal-to-noise ratio to be optimized for any high voltage setting (the high voltage power supplies for the IDTs have an eight-bit command to specify their negative DC voltage). The gain of the tubes is a strong function of the voltage. Under normal conditions, they will be operated with a gain of 10^{**6} . The voltage can be lowered to increase the dynamic range that can be accommodated, or increased to increase the tube's gain.

The pulse output is fed to the Detector Controller, where it is counted to form the digital (photon count) output of the HSP. The CVC is used to process the current output of the ODS. It has a current-to-voltage amplifier (with four settings for gain) followed by a voltage amplifier (gains of 1.0 and 10.0). The gain settings are specified for the observation. The output of the voltage amplifier provides an analog telemetry measurement used to monitor for overcurrent. It is also fed to an analog-to-digital converter in the Detector Controller that generates 12 bits of output, forming (when sampled) the analog output of the HSP. Bright objects are suitable candidates for analog observations, avoiding the inherent problem of the digital observations with their response dead-time under high count rates. The programming capability for the power supplies can be used to extend the dynamic range of the detectors in the analog mode.

All detectors can be operated in either a pulse-counting or current mode (or both). In the pulse-counting mode, data can be taken in integration times as short as about 10 usec, commandable in about 1 usec intervals to longer

times. Delays between successive integrations can be as short as a few microseconds, or zero (since the detectors each have two count chains). Pulses separated by about 50 nsec or more can be separately detected so that count rates of up to 2×10^5 pulses/second can be accommodated with a dead-time correction of no more than 1%. For a broad-band filter, this corresponds roughly to a 10th magnitude star. In the analog mode the CVC measures detector current outputs over a range of 1 nanoamp to 10 microamp full scale. The analog format can be used to observe stars as faint as about 12th magnitude or as bright as 0th magnitude. It is likely to be used for stars brighter than about 10th magnitude.

The shortest observation times range from 4 msec in the 1 nA range to 0.4 msec in the 10 uA range. The minimum time required for the IDT beam to be deflected from one location to another is about one msec. If both star and sky data are required at integration times shorter than this figure, two alternatives are available: take the background observations before and after the high speed data run, or use two dissectors to collect data simultaneously, with integration times for each detector as short as 14 usec (only slightly slower than the shortest 10 usec integration time possible when only one detector is collecting data).

The five identical Detector Controllers perform those functions that relate to a specific detector, i.e., they receive a sequence of parameters and instructions from the System Controller necessary for an observation and science data collection, and do data collection, detector control (for the deflection amplifiers, the power supply, and the threshold for digital and gain for analog measurements), and interfacing with the System Controller. Detector parameters are stored in eight one-byte latches, and a 1.024 MHz clock signal supplies a signal to the ADC and synchronizes sampling start and stop control signals to the two pulse counters.

There are two System Controllers (dual standby redundant), only one of which will be powered at any given time. Each consists of an Intel 8080 microprocessor, memory, and various I/O ports. Direct memory access is provided to allow rapid data transfer through the science and engineering data ports,

and for acquisition of science data from the Detector Controllers and rapid storage in memory. The HSP System Controller performs those functions that are not specific to any one detector or its associated electronics, but rather are essential to overall HSP operation. It is responsible for commands, the serial engineering telemetry, timing, detector operations, science data control (collection, transfer, and storage), and test. Associated with it is a Bus Director (to which all five Detector Controllers interface).

The Bus Director has 8 pages of memory (having 256 eight-bit bytes each), and can carry out a sequence of instructions independently from the microprocessor main program. Bus Director programs are expanded by the HSP microprocessor from data in PROM and command tables, and then loaded into the Bus Director program store memory. The microprocessor can access any given page of the Bus Director as part of its address space. The Bus Director is a simple computer, having up to 255 instructions that contain 4 bits for the operation code and 4 bits for the argument. By uplinking programs using the HSP Store Byte command, special applications can be done. For example, in the normal "byte" mode the minimum count interval is 13-14 usec; by uplinking a special 28-byte Bus-Director program, this can be reduced to about 10 usec. These programs could also be used to cause the generation of special observation sequences (such as two detectors obtaining data truly "simultaneously"), and to produce observation data formats different from those described in this document. Before these special Bus Director programs are used, adequate attention should be paid to the ground processing requirements that they may impose.

The HSP microprocessor has a block of 6K bytes of PROM used for firmware program storage, 4K bytes for system RAM, 16K bytes of RAM for science data buffers, and 4K bytes of RAM for spares. The PROM firmware has a background process that interprets modes and commands, and a foreground process that handles regular repeated tasks such as updating the software clock, sending telemetry, and reading commands from the hardware command queue. The 24K bytes of RAM are divided into 4K blocks of physical memory, labeled blocks A through F. These physical blocks may be mapped such that any physical block

may be in any of six address locations. This mapping normally is invoked during initialization, but can also be done by commands. System RAM has the Data Line Table, a 16-byte array containing the starting addresses of the science data line buffer storage areas.

System RAM also has the Byte Argument Table (BAT) that contains the current values of the arguments of the 160 items relating to HSP serial commands and serial telemetry. The BAT is initialized to the set of values given in SLIB 958. When a command is received by the HSP, its argument is placed in the BAT. The actual actions taken by the instrument are determined by the values stored in the BAT. There is also a Telemetry Byte Table (TBT) from which the data for the telemetry is sent (a software counter is set to the beginning of the table each time a major frame sync pulse is received). This TBT contains the same items as the BAT. When a command altering an item in the first half (first 80 items) of the BAT is received, the entire first half is copied to the TBT. When a detector controller parameter (these are stored in the second half of the BAT) is received, the System Controller writes all the parameters for both the requested detector and the sky detector from the BAT to the detector controller(s), and then reads from them into the TBT. If the values in the BAT (commanded) and TBT (read) disagree, the VERROR flag is set. This flag will become set during the reset sequence if one or more of the Detector Controllers is not powered. Either a reset or a parameter for that Detector Controller must be sent after it has been powered for its latches to be correct.

Science data normally is buffered in the microprocessor RAM, but can be provided from the Bus Director RAM as a backup capability. A maximum of 16 K 8-bit bytes is available for data buffering. Data is collected and buffered one line at a time, and since the normal (but not the only) length of an HSP data line is 960 16-bit words (1920 bytes), this means 8 lines can be accommodated. During a data collection, the buffers are filled and emptied in sequence, and then used over. The science data then interfaces with the Remote Interface Unit (RIU) of the SI C&DH (Control and Data Handling), including the Science Data Formatter (SDF). From the SDF, the data can then be fed to the NSSC-1 SI C&DH computer, to the downlink, or to the tape recorder.

The NSSC-1 has five HSP application processors:

1. TAV, Target Acquisition and Verification, is NSSC-1 processor #41. It is used for Mode II (on-board) target acquisition. Four steps are required:
 - a) Maneuver the ST to point it so the target image falls within a "finding" HSP aperture;
 - b) Use the Area Scan HSP Operation Instrument Mode to scan the aperture, providing a rough image of it as science data (which is then transferred to the NSSC-1);
 - c) Process the scan data to identify possible target objects. Only those objects whose total flux count lies in a preset range are considered, and one of three selection modes can be used to choose the target: brightest, faintest, and only object; and
 - d) Compute an offset vector used to command the ST to do a small slew to place the target in the desired observing aperture. The offset is the sum of the finding-to-observing aperture vector and the target vector.

Several TAV parameters are included in the HSP-Unique Data Log (UDL).

2. HTR, Heater Control, is NSSC-1 processor #42. The HSP does not have any thermostats on their heaters, so this processor is used to maintain HSP temperatures with predictable orbit average power usage. Heat causes thermal distortion in the HSP, but to a first order the relative displacements between apertures are independent of temperature. The HTR processor is activated once each minute, and every 30 activations a new thermal cycle is initialized and the amount of energy used by each of the 9 HSP heaters for this cycle is reset to 0. The energy used is computed by $[E^{**2}]/R$, using the constant heater resistance, a voltage of 28 volts for the ODS heaters, and the measured voltage for the six interface heaters driven from the power bus. Once switched on, the heater remains on until the cumulative amount of energy exceeds a requested amount, until the corresponding temperature exceeds a high limit value, or until the heater switch table indicates the heater should be off. There is also a warmup mode lasting 20 cycles (10 hours), for which the amount of energy needed for each successive cycle is stored in a special array. Heater switching can be inhibited during sensitive observations. A number of the heater parameters are included in the UDL.
3. ELG, Engineering Log Generator, is NSSC-1 processor #43. This processor effects the transmission of the UDL. It gathers the log data, selects the appropriate formats for the SDF, and outputs the UDL.

4. ACK, Acknowledge Command, is NSSC-1 processor #44. Every command that changes the mode of the HSP is acknowledged. In response to the mode change command, the HSP sends an acknowledgement to the SI C&DH as a byte of special engineering data (using a separate port), which this processor monitors every 0.5 seconds, setting a flag indicating that the HSP is ready. The HSP sends a null code until the command can be acknowledged, at which time either a positive or negative acknowledgment code is sent.
5. BRO, Bright Object Protection, is NSSC-1 processor #45. It includes logic to monitor the SSM PIT for flags indicating proximity of the sun or moon, as well as a monitor for excessive detector current in each of the 5 detectors. If any tube current is excessive, the whole instrument is placed in a "safe" condition. The BRO processor is scheduled for activation every 10 seconds.

See SLIB 225, SLIB 233, and SLIB 435 for more details on the NSSC-1 HSP on-board software.

2.0 HSP MODES OF OPERATION

There are three kinds of HSP "modes" that need to be distinguished:

1. Instrument Modes (where control by the HSP electronics causes differences in the measured data due to data-gathering differences);
2. Science Data Modes (settings of Instrument Mode and/or the optics parameters cause different effects); and
3. Ground Software Modes (differences in ground processing that can be a function of the Instrument Mode and/or Science Data Mode).

These modes are treated in separate sections below. Throughout this document, bit 1 is the most significant (or sign) and bit 8 or bit 16 is the least significant (for 8-bit words and 16-bit words respectively). This convention (emphasized in some places by placing a colon before the bit number, as in SLIB 1089) is the same as that used in the other SOGS Instrument Notebooks, as well as in SLIB 340. According to SLIB 797, however, "HSP bits are numbered 0 (LSB) to 15 (MSB). We do not care how anyone else numbers them, but the burden of translating all documents produced by the HSP team will always fall to the parties with conflicting schemes."

The notation "Vxxx" means the LMSC engineering telemetry abbreviated measurement identifier (see Section 4), and "V.xxx" refers to telemetry that lacks an LMSC identifier. Tables 4.2-5 and 4.2-6 list all the HSP telemetry in sequence by the identifier value and by mnemonic, respectively. According to SLIB 797, "All HSP telemetry names and commands have the unique prefix 'V,'" and therefore this is reflected in the mnemonics employed (including those in the science telemetry) in this document.

2.1 HSP INSTRUMENT MODES

Information on the HSP Instrument Modes falls into two categories: that defining the HSP operating mode and that defining the length and format of the science data words.

2.1.1 HSP Operation Instrument Mode

The HSP Operation Instrument Mode has nine allowed values. It is controlled by command VMODE (V200) and telemetered in measurement VTMODE (V500). Execution of a new VMODE command by the HSP firmware takes place only when the HSP is in the IDLE operating mode. If this mode is not IDLE when the new VMODE command is received, then execution of the VMODE command is deferred until the firmware completes the previous mode, thus entering the IDLE mode. The various VTMODE measurement values are:

- 0 IDLE, HSP is awaiting the next VMODE command;
- 1 SCP, Single Color Photometry, for science data;
- 2 SSP, Star/Sky Photometry, for science data;
- 3 ARS, Area Scan, for science data;
- 4 TIM, Reset clock using VCLKSET word (V507), for support;
- 5 DMS, Data Memory Set using VDMSBYT (V573), for test;
- 6 DUM, Dump memory, for test;
- 7 MAP, Reconfigure RAM using VCFGMAP word (V569), for support; and
- 8 BDT, Bus Director RAM test, for test.

V500 values of 1 (SCP), 2 (SSP), 3 (ARS), and 6 (DUM) cause scientific data to be sent, as detailed in Section 3.3. The V500 value of 4 (TIM) is discussed in Section 3.1.1, and the value of 5 (DMS) and 7 (MAP) in Section 3.1.4. The value of 8 (BDT) tests the Bus Director RAM and sends an acknowledgment in V567 (VACKBYT) telling which pages (see SLIB 958) are usable. The test reads and writes alternate bit patterns of X'55' and X'2A' into Bus Director RAM pages.

In HSP test tapes that have been seen, the instrument was in the IDLE mode when the output was produced, and therefore the VTMODE/V500 value in the UDL was 0. Hence the UDL value can not??? necessarily be used to determine the HSP configuration when the accompanying science data was gathered. The value in VACKBYT/V567 (see #2 of Section 3.1.4), however, did reflect the HSP Operation Instrument Mode used to obtain the data, but whether this quantity can be relied upon has not been confirmed???

2.1.2 HSP Data Format Instrument Mode

The HSP Data Format Instrument Mode has five different values to define the length and format of the "HSP words" that are to be transmitted in the science telemetry. It is controlled by command VDFMT, V201, and telemetered

in measurement VDATAFMT (V501). As discussed in Section 3.1, a typical (but not constrained) way of operating the HSP is to divide the science data into lines of 960 16-bit words (or a total of 15360 bits). If this is done, then efficient use of the downlink can be accomplished, and all five HSP formats will have an integral number of HSP words in these 960 16-bit words, as reflected in the definition of the various VDFMT values:

- 1 BYTE, provide the digital counts in eight-bit bytes. For a downlink of 960 16-bit words per line, 1920 BYTE-format HSP words would be sent.
- 2 WORD, provide the digital counts as a pair of eight-bit bytes (a total of 16 bits each). For a downlink of 960 16-bit words per line, 960 WORD-format HSP words would be sent.
- 3 LWRD, provide the digital counts as a triplet of eight-bit bytes (a total of 24 bits each). For a downlink of 960 16-bit words per line, 640 LWRD-format HSP words would be sent.
- 4 ALOG, provide the results as an analog (photocurrent) measurement in a pair of eight-bit bytes with the 12-bit result right justified (top 4 bits of the 16 bits are zero). For a downlink of 960 16-bit words per line, 960 ALOG-format HSP words would be sent.
- 7 ALL, provide both the analog and digital count data in a total of five eight-bit bytes. The first two bytes of each group of 5 have the analog measurement (12 bits, right justified) as for ALOG; the remaining three have a triplet of eight-bit bytes as for LWRD. For a downlink of 960 16-bit words per line, 348 ALL-format HSP words would be sent.

Any Data Format Instrument Mode can be used with any of the three science data Operation Instrument Modes.

The individual bytes in the science words are reversed. This means that the following sequence of data is provided for the defined VDFMT values:

- 1 BYTE has two samples per science data word.
 - a) In the first data word, bits :9-16 have count sample n, and bits :1-8 have sample n+1; and
 - b) In the second data word, bits :9-16 have sample n+2, and bits :1-8 have sample n+3; etc.

- 2 WORD has one sample per science data word.
 - a) In the first data word, bits :9-16 have the high-order byte of count sample n, and bits :1-8 have the low-order byte of sample n; and
 - b) In the second data word, bits :9-16 have the high-order byte of sample n+1, and bits :1-8 have the low-order byte of sample n+1; etc.
- 3 LWRD has two samples per three science data words.
 - a) In the first data word, bits :9-16 have the high-order byte of count sample n, and bits :1-8 have the middle-order byte of sample n;
 - b) In the second data word, bits :9-16 have the low-order byte of sample n, and bits :1-8 have the high-order byte of sample n+1;
 - c) In the third data word, bits :9-16 have the middle-order byte of sample n+1, and bits :1-8 have the low-order byte of sample n+1; and
 - d) In the fourth data word, bits :9-16 have the high-order byte of sample n+2; etc.
- 4 ALOG has 12-bit samples of the CVC output, one sample per science data word.
 - a) In the first data word, bits :9-16 have the high order 4 bits (right justified, leading zeros so bits :9-12 are 0) of count sample n, and bits :1-8 have the low-order 8 bits of sample n; and
 - b) In the second data word, bits :9-16 have the high-order 4 bits (right justified, leading zeros) of sample n+1, and bits :1-8 have the low-order 8 bits of count sample n+1; etc.
- 7 ALL has 24 bits of pulse count data and 12 bits of CVC (analog) output, two samples per five science data words.
 - a) In the first data word, bits :9-16 have the high-order 4 bits (right justified, leading zeros) of analog count sample n, and bits :1-8 have the low-order 8 bits of analog sample n;
 - b) In the second data word, bits :9-16 have the high-order byte of pulse sample n, and bits :1-8 have the middle-order byte of pulse sample n;
 - c) In the third data word, bits :9-16 have the low-order byte of pulse sample n, and bits :1-8 have the high-order 4 bits (right justified, leading zeros) of analog sample n+1;

- d) In the fourth data word, bits :9-16 have the low-order 8 bits of analog sample $n+1$, and bits :1-8 have the high-order byte of pulse sample $n+1$;
- e) In the fifth data word, bits :9-16 have the middle-order byte of pulse sample $n+1$, and bits :1-8 have the low-order byte of pulse sample $n+1$; and
- f) In the sixth data word, bits :9-16 have have the high-order 4 bits (right justified) of analog sample $n+2$, and bits :1-8 have the low-order 8 bits of analog sample $n+2$; etc.

2.2 HSP SCIENCE DATA MODES

The HSP has four Science Data Modes:

- 1 Star Single-Color Time Series,
- 2 Star/Sky Single-Color Time Series,
- 3 Multi-Color Photometry or Polarimetry, and
- 4 Acquisition or Aperture Mapping.

2.2.1 Star Single-Color Time Series Science Data Mode

This Science Data Mode is expected to be the most frequently used HSP mode. Two subdivisions have been defined, a "slow" (typical time resolution of one second) and a "fast" (typical time resolution of 16 usec). The time resolution refers to the length of time during which data is gathered to form a single HSP word (in the format defined by the Data Format Instrument Mode). The single-color time series implies that (after acquisition has been completed) the detector control parameters remain constant, and the detector remains oriented to the given object. The Operation Instrument Mode in this case is SCP. In SLIB 344, it was included with 2.2.2, but to meet one of the objections in SLIB 797 it is identified as a separate one in this document. A typical run length for "slow" would be three hours and for "fast" would be 1000 seconds.

2.2.2 Star/Sky Single-Color Time Series Science Data Mode

This Science Data Mode is similar to 2.2.1, except that the Operation Instrument Mode is SSP. In SLIB 344, it was included with 2.2.1, but to meet one of the objections in SLIB 797 it is identified as a separate one in this document.

2.2.3 Multi-Color Photometry or Polarimetry Science Data Mode

This Science Data Mode makes use of several aperture/filter combinations to observe the same object. Typically a total of four colors might be observed, using 10 seconds per color with a small spacecraft maneuver to position another aperture between them. Because of the maneuver, the data would come down in separate (short) frames, each of which would look like one of those in Section 2.2.1 or 2.2.2. Because of the aperture change, the measurement

attributes (such as integration time) can be different. The HSP Instrument Modes for this Science Data Mode can be the same as discussed in Section 2.2.1. A typical run length would be three hours.

2.2.4 Acquisition or Aperture Mapping Science Data Mode

This Science Data Mode requires the Operation Instrument Mode to be set to ARS (for area scan), and can have any of the word formats defined by the Data Format Instrument Mode. For the typical acquisition application, an area of [10 x 10] arc seconds is sampled, to provide up to 400 points (for a single integration per spatial point). Additional data points would be obtained if more than one integration per point were specified. Another application would be to obtain a full IDT map (180 x 180 pixels). In both cases, integration times are sufficiently long that the 4 Kbps downlink would prove satisfactory.

2.3 HSP GROUND SOFTWARE MODES

There are two HSP Ground Software Modes:

- 1 Target Acquisition and
- 2 Photometry.

Their selection is based on user input to the ground system.

2.3.1 Target Acquisition Ground Software Mode

For the Target Acquisition Ground Software Mode, the Operation Instrument Mode must be set to ARS (for area scan), and the Science Data Mode must be Acquisition or Aperture Mapping (see Section 2.2.4). See Section 7 for the algorithms to be used.

2.3.2 Photometry Ground Software Mode

The Photometry Ground Software Mode will be the most commonly used HSP Ground Software Mode. See Section 2.2.1 for criteria identifying data proper for use in this Ground Software Mode, and Sections 5 and 6 for the algorithms to be used.

WEPIC ND-1002A

WF/PC-Related Acronyms

Å	Angstrom (10^{-10} meter)
ADC	Analog to Digital Converter
CCD	Charge-Coupled Device
CEI	Contract End Item
C&DH	Control and Data Handling (Subsystem)
DCF	Data Capture Facility
DN	Digital Number
ET	Engineering Telemetry
e ⁻	Electron
FGS	Fine Guidance Sensor
FOO	Faint-Object Observation
FOV	Field Of View
GO	General Observer
GSFC	Goddard Space Flight Center
ICD	Interface Control Document
IDT	Investigation Definition Team
IST	Instrument Science Team
K	For memory, 2^{10} (1024); otherwise, 10^3
K spot	Kelsall spot (lamp)
LMSC	Lockheed Missiles and Space Company, Incorporated
MHz	10^6 Hz
MOGS	Mission Operations Ground System
msec	Millisecond
m_V	Apparent visual magnitude
ND	Neutral Density
nm	Nanometer (10^{-9} meters or 10 angstroms)
NSSC-1	NASA Standard Spacecraft Computer, Model 1
OSS	Observation Support System
OTA	Optical Telescope Assembly
PASS	POCC Application Software Support
PC	Planetary Camera
PDCR	Preliminary Document Change Request
PDL	Program Design Language
POCC	Payload Operations Control Center

PODPS	Post-Observation Data Processing System
PORTS	Preliminary Operations Requirements and Test Support
PROM	Programmable Read-Only Memory
RAM	Random Access Memory (read/write)
RIU	Remote Interface Unit
RM	Remote Module
RTI	Real time interrupt
SAA	South Atlantic Anomaly
Sci	Science Institute (Johns Hopkins)
SDAS	Science Data Analysis Software
SDF	Science Data Formatter
SHP	Standard Header Packet
SI	Science Instrument
SLIB	SOGS (TRW) Library document identifier
SOFA	Selectable Optical Filter Assembly
SOGS	Science Operations Ground System
SPSS	Science Planning and Scheduling System
SSC	Science Support Center
SSM	Support Systems Module
ST	Edwin P. Hubble Space Telescope
STOCC	ST Operations Control Center
STSOP	ST Science and Operations Project
SWG	Science Working Group
TBD	To be determined
TEC	Thermoelectric Cooler
TM	Telemetry
usec	Microsecond
UTC	Universal Time Coordinated
UV	Ultraviolet
W	Conventional first letter for WF/PC parameters
Wxxx	Abbreviated LMSC ET Measurement ID
W.xxx	Coined Measurement ID (for spare data)
WFC	Wide Field Camera
WFPC	See WF/PC
WF/PC	Wide Field and Planetary Camera

X'ab' Hexadecimal (base 16) value for "ab"
2DP Two-Dimensional Photometry
2DPP Two-Dimensional Photopolarimetry
2DS Two-Dimensional Spectrophotometry
??? Material needing determination/confirmation
:n Bit number n (1 most significant)

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF WF/PC NOTEBOOK

The purpose of this Wide Field and Planetary Camera (WF/PC) Notebook is to provide a compilation from various sources of factual information on certain aspects of the WF/PC necessary for design work on the Edwin P. Hubble Space Telescope (ST) Science Operations Ground System (SOGS). The contract for development of SOGS is managed by GSFC, and is performed by TRW. One of the main tasks of SOGS is the receipt, display, manipulation, and calibration of the WF/PC data (as well as the other instruments on the ST). To perform this task, a thorough understanding is necessary of the various formats in which data is received, where critical processing parameters are in both the science and engineering data streams, and what algorithms are to be applied to calibrate the science data for each instrument configuration.

The intended audience for this WF/PC Notebook is the TRW SOGS designers, rather than a general collection of diverse groups with equally diverse information desires. Because of its intended audience, there are numerous WF/PC-related topics that are not included in this Notebook. Section 8 (References) has a list of citations for some source documents on WF/PC that are in the TRW SOGS Library. Such documents have been assigned serial accession numbers (SLIB numbers) meaningful only to those with access to the TRW Library, so Section 8 provides information on originator, date, and title to identify the material more completely.

The organization of this WF/PC Notebook is the same as that for the other four ST instruments. After this introductory material, the various types of WF/PC modes are defined in Section 2 (since they are of major significance to the SOGS design effort). Sections 3 and 4 cover the WF/PC Science Telemetry and WF/PC Engineering Telemetry respectively. Algorithms for WF/PC Calibration, WF/PC Data Quality/Utility, and WF/PC Target Acquisition are in Sections 5 to 7 respectively (these relate to what is in Section 10 of the SOGS SE-06-1 specification, SLIB 799). Section 8 has References.

1.2 SUMMARY OF WF/PC NOTEBOOK UPDATES FOR THIS REISSUE

The changes in this reissue of the WF/PC Notebook (SLIB 854 was the original issue) are those necessary to reflect a collection of minor details concerning the instrument's performance. There should be no surprises in the changes that are incorporated in this issue, which include:

1. Some telemetry identifier changes to agree with a new issue of LMSC's DM-02 (SLIB 1089). The most extensive of these reflect the assignments of separate identifiers to different groups of memory-dump words (see Section 4).
2. The Standard Header Packet locations (from LMSC's SLIB 936) of the WF/PC engineering telemetry (see Section 4).
3. Some augmentations of the instrument description obtained from the ST Science Institute's WF/PC description in SLIB 1006b (see Section 1.5).

Two areas where (in common with most other ST instruments) uncertainties exist in the material covered in this document are the detailed format of the uplinked area of the Standard Header Packet (alternative sources are cited in Section 3.2.1) and the flight values to be used for the packet format code (see Section 3.2.4).

The updating effort for this WF/PC Notebook will be a continuous process throughout the duration of the SOGS project. This reissue, however, is the first WF/PC Notebook change that has been generated since the SLIB 854 issue (dated 9 December 1982). New information otherwise has been distributed among the TRW SOGS designers by means of SOGS memos. Particularly for those holders of the WF/PC Notebook outside of TRW, therefore, reliance on this WF/PC Notebook to reflect the "latest available" (anyplace) set of WF/PC data continues to be inappropriate.

1.3 INVESTIGATION DEFINITION TEAM

The Principal Investigator for the WF/PC experiment is:

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Bradford A. Smith, University of Arizona, Tucson, AZ

1.4 SCIENTIFIC OBJECTIVES

The following information was obtained from SLIB 197, SLIB 319, and SLIB L32:

The WF/PC will be a versatile, broadband imaging instrument designed:

1. To provide high angular resolution, photometrically and geometrically accurate, multiband observations of stars and extended sources over the widest field of view possible on the ST with current detectors; and
2. To provide very high angular resolution images of deep-space objects as well as photometrically and geometrically accurate, multiband synoptic images of solar system objects.

It will address a broad variety of problems at an angular resolution unavailable from the ground, over a wavelength range impossible to achieve except in space, and it will reach faintness levels exceeding those achieved by the largest ground-based telescopes. As a minimum, the WF/PC will be capable of providing data of the requisite quality for the proposed investigations in the following areas:

1. Determination of the cosmic distance scale over distances larger by a factor of seven than is possible from the ground;
2. Tests of world models and cosmic evolution;
3. Comparative evolutionary studies of distant and local galaxies;
4. Stellar population studies to very faint levels;
5. High resolution measurement of luminosity profiles of galactic nuclei;
6. Measurement of flux distributions of stars and compact sources;
7. Dynamical studies of proto-stars and supernova remnants;
8. Determination of cloud motions and composition of planetary atmospheres, the dynamical figures of planets, cartography of asteroids and satellites, and the structure of comets; and
9. Astrometric search for extra-solar system planets.

See SLIB 810 for more details.

1.5 PRINCIPLES OF OPERATION

See SLIB 399 for information on the principles of operation of the complete WF/PC instrument (including its mechanical layout and a functional block diagram). The material given below emphasizes those WF/PC aspects that are of particular significance for understanding the nature of its science data, and has been generated using the sources listed in Section 8.1.

The WF/PC occupies the only ST radial bay allocated to scientific instruments (the other three radial bay locations are used for the fine-guidance sensors), and therefore will receive the highest quality images. It has the widest spectral response (from 115 to 1100 nm) of the SIs, is expected to generate more than 90% of the ST science bits, and is also expected to be in use 75% of the time any SI is operating. In an operational sense, the WF/PC is a simple instrument, and does not have autonomous interaction with the spacecraft.

The WF/PC has two cameras, only one of which can operate at a time. The Wide Field Camera (WFC), at f/12.9, has a square field of view (FOV) of about 158 arc seconds (2.63 arc minutes) on a side, the largest field of the SIs. Each of the WFC detector pixels subtends an angle of 0.1 arc second. The WFC scale was chosen to match the pixel size to the telescope blur circle in order to maximize the signal-to-noise ratio for small and point sources, and to provide a wide field. With exposures of a few thousand seconds, the WFC limiting magnitude will be 100 times fainter than the 200-inch telescope photographic limit, and it will be possible to see similar objects ten times farther away with the same resolution and photometric accuracy. The Planetary Camera (PC), at f/30, has a FOV of about 68 arc seconds on a side, and a pixel subtends 0.043 arc second. This scale was chosen to optimize the sampling for high-resolution studies of extended objects such as planets and galaxies. The PC field size is such that any of the planets including Jupiter and Saturn will be imaged in a single exposure. The resolution of detail on Jupiter will approach that in Voyager flyby images about 5 days from the point of closest encounter (a resolution of about 400 kilometers). The FOV of the four detectors in each camera is overlapped slightly to allow the four segments of each picture to be reassembled on the ground.

The input light from the object is deflected into the WF/PC by a near-45° pick-off mirror extending into the central portion of the OTA's beam, and then passes through an aperture. There is an optically afocal aperture cover to block the entrance to the WF/PC optical bench assembly from contaminants on the ground, during launch, and during the early part of the mission. The window cover moves clear of the aperture upon command, and will nominally remain clear throughout the operational life of the WF/PC. Since the afocal cover is MgF and hence UV transparent, the WF/PC can be operated with the aperture cover in place. The light next passes through a two-bladed shutter that controls the exposure time, and then through one or more spectral elements on a set of filter wheels. The shutter is driven by rotary solenoids, and exposure times for subsequent processing are assumed to be those commanded. For the four shortest exposure times, the shutter direction (A to B or B to A) must be monitored to determine the actual exposure length, but according to SLIB L63 this is expected to be an SDAS activity. If engineering data indicates that FGS loss of fine lock occurred, the actual exposure time must be determined, but additional details are TBD (see SLIB 1045 and SLIB L63).

The solenoids (a backup mode to control the shutter is also available) nominally operate to power open the first blade and power close the second blade upon command. Shading is monitored by determining the flight time of each blade. WF/PC exposure times from 0.11 to 10^5 seconds can be set, with 128 values (stored in an array in the WF/PC microprocessor memory) possible over this range. The commands are arranged in a roughly logarithmic fashion, with the minimum dictated by the flight time of the shutter blade and the electrical constraint permitting only one blade activation at a time. When the shutter is closed, the back side of a blade can be illuminated by a set of "calibration" lamps giving a flat-field illumination. These tungsten filament lamps are not suitable for absolute calibration, but instead can be used for short-term monitoring of the WF/PC flat field calibration stability.

The Selectable Optical Filter Assembly (SOFA) has 12 filter wheels in a parallel stack. Each wheel has four filters and one clear cutout, and the full ensemble has 48 filters (a total that includes three gratings and three

polarizers). Each wheel is separately commandable, so any combination of optical elements in separate wheels is possible. All 12 wheels could have filters placed in the optical path (except for focus problems), although in normal operation (see SLIB 1045) only two filters will be used. There are 137 filter combinations that have been identified as being desirable. In response to a single command, two wheels (maximum) can be rotated to the clear position ("home"), and then the desired filter is selected. If two or more filters are desired, separate commands must be sent for each filter. If a different filter in the present wheel is desired, the wheel can be commanded to move directly to the new position (without going via the home position). It is estimated that the filters will be changed every other observation.

After passing through the SOFA, the light beam strikes a shallow figured reflecting pyramid (four-sided) mirror. This pyramid separates the OTA image into four quadrants (a four-part optical mosaic). These optical bundles are then re-imaged by four sets of relay optics onto four separate Charge Coupled Device (CCD) detectors. Each frame of the four-part mosaic overlaps adjacent frames by 5^{+25}_{-0} pixels. The choice of camera is governed by the rotational position (a separation of 45°) of the pyramid. Movement of the pyramid to change cameras is expected to occur less than once a day. The associated CCDs require several hours to cool down (only one set of four can be cooled at one time). The thermal time constant for the WF/PC optical bench is about two days. The pyramid can also be moved forward and rearward (by ± 0.016 inch in steps of about 0.001 inch) for focusing purposes, an activity expected only during initial orbital operations.

The pyramid has a series of 10 micron (a micron is 10^{-6} meter) "pinholes" along its facet intersections, where the reflective coating has been removed. When the pyramid is back-lit by the "K spot" (or "pyramid") lamp, these points are seen as a string of artificial stars (Kelsall spots) in each CCD. In the camera for which the pyramid is set, they run along the two borders of each CCD; in the other, they would run across a CCD at a 45° angle. Since these dots will be in and out of the focal plane, they can be used as a focus

check in addition to allowing the adjacent frames to be aligned for full-field mosaics from the four CCDs. The pyramid also has a neutral density (ND) spot (1.38 arc seconds in diameter) with a suppression ratio of about 1000. A bright star can be placed on the spot so its magnitude is attenuated (without disturbing the quality of the data), permitting sufficiently long exposure times to bring out the fainter background star field. The ND spot is very bright (and will saturate many columns of pixels) when the K spot lamp is on.

The CCD detectors are 800 x 800 pixel devices that are cooled by thermo-electric coolers (TECs) to suppress their dark current. The TEC can cool to -102°C (the lowest regulated temperature). For stability and repeatability, it is anticipated that the -102°C value will be used most of the time. The WF/PC has a thermal radiator (part of the instrument) to dissipate the TEC heat. This radiator is mounted on the side of the ST that will normally be kept away from the sun. The CCDs are microelectronic silicon chips that convert a pattern of incident light into electrical signals, and are squares measuring about 0.6 inch on a side (each pixel has a size of about 15 microns). After an exposure is completed, the integrated charge on each CCD is sampled and fed through a preamplifier and a double-sampling processor. All four CCDs in a given camera are then fed through a multiplexer to a 12-bit analog to digital converter (ADC), scaled for 7.5 ± 1.0 electrons/data number (e^-/DN). The DN is defined to be the numerical intensity value at an individual pixel. The data word for each pixel is increased to 16 bits by the insertion of four leading zeros. The complete CCD readout thus gives an 800 x 800 pixel image of 640,000 words. The reading of each CCD is under external line-trigger commands: it takes a minimum of about 53 seconds to read the four CCDs of a given camera.

An alternative readout scheme is to perform 2x2 pixel summations directly on the CCD chip during readout, a process referred to as "2x2 sum" or "area integration" (in contrast to "full" or "standard" resolution where each pixel is read individually). Although this reduces optical resolution, it increases signal detectivity because the on-chip pixel summing is virtually noiseless. Regardless of the readout scheme, the image data is expanded by

adding ancillary engineering data and a CCD/line number to the start of each line, giving a line length of 802 16-bit words for the standard resolution and 402 16-bit words for area integration. Each quadrant is read out as a complete frame of either 800 or 400 lines (of 802 or 402 words respectively). If more than one CCD (such as the complete FOV that needs four readouts) is required, each quadrant is sent as a separate frame.

As this science data is read out, it is buffered under control of the WF/PC microprocessor. This device controls the gating of signals to the Remote Interface Unit (RIU) of the SI C&DH (Control and Data Handling), including the Science Data Formatter (SDF). From the SDF, the data is fed to the downlink or the tape recorder.

During South Atlantic Anomaly (SAA) passage, the charged particle background will be too high to carry out science exposures. Consequently, all exposures must be ended, and read out, before SAA entry. The readout is essential because an exposed picture in the CCDs will continue to accumulate particle "hits" with the shutter closed. While in the SAA, the CCDs should be in Autoerase mode to minimize charge accumulation.

The WF/PC microprocessor (a single RCA COSMAC 1802) acts as a buffer between the SI C&DH NSSC-1 computer and the WF/PC, and also controls those functions that are common to all CCD detectors, such as filter selection and pyramid position. It receives commands via a logic interface unit from the SI C&DH, decodes them, and generates signals to control the selection of filters, operation of the shutter, operation of the calibration and pyramid lamps, and position of the pyramid. It also initiates the read-out sequence in the selected CCDs. Additional functions are to control the WF/PC engineering telemetry function, output engineering data through the RIU, and output WF/PC health and status information through the RIU. The WF/PC data system architecture has 48 output channels and 32 input channels.

The microprocessor's firmware consists of PROMs organized in pairs, where each pair provides 256 eight-bit bytes. While hardware to support 64 PROMs (8K bytes) is available, the addressing for only the 46 ($23 * 256 = 5888$

bytes or 5.75K) being used has been implemented (readout of the other cells gives zero). The PROM contains an executive and application processors. It incorporates transfers at about 32 selected breakpoints into RAM scratch-pad addresses. In the event of PROM failure, or to modify the effect of what is contained in the PROM software, code can be uplinked to the RAM area that functionally replaces what is in portions of the PROM.

CH.1

The WF/PC microprocessor has a real time interrupt (RTI) loop that is entered every 10 msec (a period derived from the 6.144 MHz SSM clock input by a countdown chain) to do foreground processing. The loop can be connected to up to four external programs that have been uplinked into scratch-pad RAM. This RAM consists of 4K 8-bit bytes, 2K of which is used for science data storage and an engineering data buffer, and the remaining 2K of which is scratch pad for breakpoint processing or interrupt processing. Discrete commands control which half of the RAM is to be used for scratch pad. An internal test of the scratch-pad RAM is performed as a background test, with errors reported on the downlink. This is in addition to the dump of RAM (and PROM) that occurs in the engineering telemetry, as well as the PROM checksum that is performed each engineering-telemetry major frame (once per minute). RAM normally is loaded from PROM during microprocessor initialization.

The WF/PC processes required to make an exposure are divided into five cycles (sometimes called "states"): Infrequent, Prepare, Expose, Readout, and Wait. A single "expose command" will schedule all or any combination of these cycles. The first of these cycles scheduled will begin execution during the first RTI of the engineering telemetry major frame following the receipt of the expose command from the queue, with each of the following scheduled cycles beginning their execution on the first RTI of the major frame following the completion of the previous cycle. The Infrequent and Prepare cycles will always complete their processing inside of one major frame (one minute), while the Expose and Readout cycles may take more than one such frame.

The Infrequent cycle is used to adjust the WF/PC pyramid focus, open or close the aperture seal, and control the TEC cold junction temperature. It always loads the TEC control register first. During the next 11 RTIs it moves the focus motor if that option is selected; during the next 46.96 seconds it

opens or closes the aperture cover if specified by the command. This time period is sufficient to drive the aperture seal firmly against its stops. Each of these three processes is assigned its own slot in the major frame interval, so a given activity (if selected) always occurs at the same RTI.

The Prepare cycle is used to select the proper camera and position the filters. During the first 6.24 seconds of the major frame, it rotates the pyramid (if this option is selected). If the option to clear the filters is selected, the lowest-numbered uncleared filter wheel is located and cleared (starting 9.91 seconds into the frame, and no more than 15.54 seconds will be devoted to this first selected filter). If more than one wheel is in the uncleared position, the next higher numbered uncleared wheel is selected and the next time slot (starting 25.46 seconds into the frame, and lasting no more than 14.72 seconds) is used to clear that wheel. If the option to set a filter is selected, the chosen filter will start moving at 44.6 seconds into the frame and stop (for the maximum of 4 positions) 11.71 seconds later. Due to this time partitioning of the three activities, any combination of them can be scheduled to be executed in a single major frame.

The Expose cycle uses the first 16.4 seconds of the first major frame to erase the CCDs (if that option is selected). As much of the remaining major frame (or frames) is used to effect the exposure as was specified. If an exposure (shutter operation) is not specified, the calibration lamp specification is checked, and the lamps energized if necessary. The Kelsall spot lamp is turned on if specified (regardless of the exposure bit). Both sets of lamps are turned off a maximum of 80 seconds after they were energized (regardless of the time code specified). To determine which of the two shutters should be moved, their current state is examined. If both are opened or closed before the start of the exposure, this is an error condition that is reported on the downlink, and no shutter action is initiated.

Following the Expose cycle, the WF/PC may either enter the Readout cycle, remain in the Expose cycle for multiple exposures at the same wavelength, or enter the Prepare cycle to reposition the filters for multiple wavelength integrations. If the Readout cycle is entered, the CCDs are read (in full

resolution or 2x2 area integration mode as determined by the command). The Wait cycle is entered automatically at instrument power on and at completion of a Readout cycle. It continues until receipt of the next valid command (starting one of the other cycles). During the Wait cycle, the WF/PC micro-processor records serial commands as they are received, decodes commands and sets up the control sequencer, and optionally performs an automatic continuous erasure of the CCDs.

Collection of engineering data for telemetry and processing of stored commands are the only NSSC-1 software functions used by the WF/PC. Storage of relative time command sequences is the only use of the 6144 words of NSSC-1 memory assigned to the WF/PC. At some future time, WF/PC-unique application processors could be developed and input to the NSSC-1 either prior to launch or on orbit, as required.

2.0 WF/PC MODES OF OPERATION

There are three kinds of WF/PC "modes" that need to be distinguished:

1. The Instrument Mode (where control by the WF/PC electronics causes differences in the measured data due to data-gathering differences);
2. The Science Data Modes (settings of the optics parameters cause different effects); and
3. The Ground Software Mode.

These modes are treated in separate sections below. Throughout this document, bit 1 is the most significant (or sign) and bit 8 or bit 16 is the least significant (for 8-bit and 16-bit words respectively). This convention (emphasized in some places by placing a colon before the bit number, as in SLIB 1089) is the same as that used in the other SOGS Instrument Notebooks, and differs from that in some WF/PC information. The notation "Wxxx" means the LMSC engineering telemetry abbreviated measurement identifier (see Section 4), and "W.xxx" refers to telemetry spare words/bits that lack an LMSC identifier. Tables 4.2-6 and 4.2-7 list the WF/PC telemetry in sequence by the identifier value and by mnemonic, respectively.

2.1 WF/PC INSTRUMENT MODE

The only change in WF/PC science formats on orbit occurs when the 2x2 area integration mode of CCD readout (vs. the standard resolution, see Section 1.5) is commanded. This is provided in telemetry measurement WRDUTPT2 (W099), and is controlled by the Prepare/Readout Exposure command. Bit :2 is 1 if in the 2x2 area integration mode, and is 0 if in the full resolution (standard) mode. If the bit is 1, then a science data frame consists of 402 16-bit words in each of 400 lines; if the bit is 0, the frame consists of 802 16-bit words in each of 800 lines. Control of the camera and the CCDs to be read out is also done by this command (see Section 3.1.3).

The WF/PC has two readout modes, namely full resolution of one to four CCDs and area integration of one to four CCDs.

2.2 WF/PC SCIENCE DATA MODES

In a fundamental way, the WF/PC has a single science mode: it acts as a photometric, area imager. By choice of elements from the SOFA that are included in the light beam, however, three distinct photometric modes are permitted:

- 1 Filter Photometry (using wide or narrow band filters);
- 2 Photopolarimetry (using a polarizer plus a 0.25-0.80 micron filter); and
- 3 Spectrophotometry (using a transmission grating plus a blocker).

These are treated in separate sections below.

2.2.1 Filter Photometry Science Data Mode

This WF/PC Science Data Mode, also referred to as Two-Dimensional Photometry (2DP), involves the Prepare, Expose, and Readout cycles described in Section 1.5. The time interval is three minutes plus the exposure time (rounded to the next larger minute). This Science Data Mode will be used to measure the intensity of the target (usually with a filter to allow only certain wavelength photons to be collected by the CCD). Often several exposures through different filters will be taken during one ST pointing.

2.2.2 Photopolarimetry Science Data Mode

This WF/PC Science Data Mode is also referred to as Two-Dimensional Photopolarimetry (2DPP). It involves the cycles listed in Section 2.2.1. By use of linear polarizers, measurement of target polarization properties can be obtained: this is a powerful way to understand the physical processes in such sources. In general, three separate exposures are required (through three polarizer/filter combinations) for each measurement.

2.2.3 Spectrophotometry Science Data Mode

This WF/PC Science Data Mode is also referred to as Two-Dimensional Spectrophotometry (2DS). It too involves the cycles listed in Section 2.2.1. The WF/PC carries three transmission gratings that generate pictures in which each point-source image is spread out into a short spectrum on the CCD. These point sources each have a zero-order image along with a spectrum in the first and second order on nearby pixels.

2.2.4 Other WF/PC Science Data Acquisition Capabilities

There are several other WF/PC science data acquisition capabilities described in SLIB 523 that are briefly summarized below:

1. Faint-Object Observation (FOO) is used when faint objects (implying long exposure times) are observed. Special efforts must be made to remove the time-integrated effects of charged particle (cosmic rays and high-energy protons and neutrons) impacts. The planned procedure is to follow whichever of 2.2.1-2.2.3 is desired for a long exposure time, and then repeat for a short exposure.
2. The ND spot (see Section 1.5) can be used with either camera and any Science Data Mode (as well as FOO) to suppress a selected image. This may require fine tuning of the ST pointing.
3. Multiple images or scan will require the OTA to step and stop, or scan continuously. It will be used to observe bright standards and as an aid for detecting short-period variables. One application would be to observe a "standard" star with the star in different areas of the FOV (a typical number on the ground is 9). Only one readout of the CCDs would be taken. This procedure can be used to achieve higher statistical accuracy and reduce the volume of data on the downlink.
4. A readout of less than 4 CCDs can be done by command (the CCDs are always read in increasing numerical order, but some can be skipped), as an aid in suppressing superfluous data. From the observer's viewpoint, each CCD readout is an independent entity. The Kelsall spots (see Section 1.5) can be used to help with the merging. One reason to merge the four images created by the pyramid splitting is for public relations purposes (there is normally no science justification to do so). Because of edge effects produced by the pyramid reflections and diffractions, there will be a region of about 5 pixels in the neighborhood of the corresponding pyramid edge that will not contain good science data.
5. Flattening for WF/PC data means the removal of the pixel-by-pixel variation in the optical/electrical sensitivity of the instrument. To obtain data for this, a "flat field" (an exposure of a spatially uniform source) obtained through the telescope and filter needs to be observed. Real flat fields are always taken with external light sources (such as the sunlit Earth). The WF/PC internal light sources that illuminate the CCDs can be used to monitor the stability of the flat fields (less the telescope). This internal capability uses a light source that cannot be guaranteed to be stable, and therefore does not provide absolute data on the sensitivity of the CCDs and the performance of the WF/PC internal optics.

6. Dark frames are long exposures that are taken without opening the shutter. They are used to detect CCD counts (the dark current) caused by thermal generation (due to the bulk properties of silicon), as well as the rate of charged particle impacts. At the normal CCD operating temperature, the dark current magnitude is about 0.01 electrons/second/pixel. Typical dark-count exposures will be many hundreds of seconds.
7. Zeroing for WF/PC means the removal of the pixel-by-pixel value of the instrument bias level. Zero frames (also called erase frames and bias frames) are readouts of the CCDs without an exposure (so the dark current is negligible). They are taken by erasing the CCD and reading it out immediately. These frames are used to detect a purposeful bias built into the system to ensure that the ADC input is above zero, and hence to determine the pedestal for a zero signal (these frames, of course, should not be automatically zeroed in the data reduction process).
8. Kelsall spots (see also #4) can be imposed on any type of frame to find focus shifts, relative motions between CCDs, and to aid in registration of four frames (one per CCD) as a celestial scene. Normally, however, a separate frame for them will be taken because of the effect of the ND spot (with the K spot lamp energized, CCD saturation can be caused).

For instrument health reasons, the following actions can also be taken:

1. Close the aperture window if there is evidence of outside contamination.
2. Flush CCD windows of contaminants by elevating the temperature of the detector packages.
3. Turn on heaters to unfreeze a heat pipe.

2.3 WF/PC GROUND SOFTWARE MODE

There is only one WF/PC Ground Software Mode: the Photometry Ground Software Mode. See Sections 5 and 6 for the algorithms to be used in this mode (contrary to some other SIs, there are no algorithms specified for WF/PC Target Acquisition, see Section 7).

HRS ND-1003A

HRS-Related Acronyms

BASD	Ball Aerospace Systems Division (HRS prime contractor)
CVT	Current Value Table
C&DH	Control and Data Handling (Subsystem)
DAC	Digital-to-Analog Converter
DCF	Data Capture Facility
DCP	Delayed Command Processor
DEB	Detector Electronic Box
ET	Engineering Telemetry
ETR	Engineering Trailer (in science data)
FOS	Faint Object Spectrograph
FOV	Field Of View
GC/OST	Ground Control/Observational Sequence Table
GO	General Observer
GSFC	Goddard Space Flight Center
HRS	High Resolution Spectrograph
HVPS	High Voltage Power Supply
ICD	Interface Control Document
IDT	Investigation Definition Team
IST	Instrument Science Team
IUE	International Ultraviolet Explorer
K	For memory, 2^{10} (1024); otherwise, 10^3
LMSC	Lockheed Missiles and Space Company, Incorporated
LVPS	Low Voltage Power Supply
MEB	Main Electronics Box
MHz	10^6 Hz
MOGS	Mission Operations Ground System
msec	Millisecond
nm	Nanometer (10^{-9} meters or 10 angstroms)
NSSC-1	NASA Standard Spacecraft Computer, Model 1
OCT	Observation Control Table
OSS	Observation Support System
OST	Observation Sequence Table
OTA	Optical Telescope Assembly
PASS	POCC Application Software Support

PDCR	Preliminary Document Change Request
PDL	Program Design Language
PHA	Pulse Height Analysis
pi	3.14159...
PIT	Processor Interface Table
POCC	Payload Operations Control Center
PODPS	Post-Observation Data Processing System
PORTS	Preliminary Operations Requirements and Test Support
RIU	Remote Interface Unit
SAA	South Atlantic Anomaly
SAM	Small Angle Maneuver
Sci	Science Institute (Johns Hopkins)
SDAS	Science Data Analysis Software
SDF	Science Data Formatter
SHP	Standard Header Packet
SI	Science Instrument
SLIB	SOGS (TRW) Library document identifier
SOGS	Science Operations Ground System
SPSS	Science Planning and Scheduling System
SSC	Science Support Center
SSM	Support Systems Module
ST	Edwin P. Hubble Space Telescope
STOCC	ST Operations Control Center
STSOP	ST Science and Operations Project
TBD	To be determined
TM	Telemetry
UDL	Unique Data Log
usec	Microsecond
UTC	Universal Time Coordinated
UV	Ultraviolet
V	Volts
X'ab'	Hexadecimal (base 16) value for "ab"
Z	Conventional first letter for HRS parameters
Zxxx	Abbreviated LMSC ET Measurement ID
Z.xxx	Coined Measurement ID (for Science Data)
???	Material needing determination/confirmation

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF HRS NOTEBOOK

The purpose of this High Resolution Spectrograph (HRS) Notebook is to provide a compilation from various sources of factual information on certain aspects of the HRS necessary for design work on the Edwin P. Hubble Space Telescope (ST) Science Operations Ground System (SOGS). The contract for development of SOGS is managed by GSFC, and is performed by TRW. One of the main tasks of SOGS is the receipt, display, manipulation, and calibration of the HRS data (as well as the other instruments on the ST). To perform this task, a thorough understanding is necessary of the various formats in which data is received, where critical processing parameters are in both the science and engineering data streams, and what algorithms are to be applied to calibrate the science data for each instrument configuration.

The intended audience for this HRS Notebook is the TRW SOGS designers, rather than a general collection of diverse groups with equally diverse information desires. Because of its intended audience, there are numerous HRS-related topics that are not included in this Notebook. Section 8 (References) has a list of citations for some source documents on HRS that are in the TRW SOGS Library. Such documents have been assigned serial accession numbers (SLIB numbers) meaningful only to those with access to the TRW Library, so Section 8 provides information on originator, date, and title to identify the material more completely.

The organization of this HRS Notebook is the same as that for the other four ST instruments. After this introductory material, the various types of HRS modes are defined in Section 2 (since they are of major significance to the SOGS design effort). Sections 3 and 4 cover the HRS Science Telemetry and HRS Engineering Telemetry respectively. Algorithms for HRS Calibration, HRS Data Quality/Utility, and HRS Target Acquisition are in Sections 5 to 7 respectively (these relate to what is in Section 10 of the SOGS SE-06-1 specification, SLIB 799). Section 8 has References.

1.2 SUMMARY OF HRS NOTEBOOK UPDATES FOR THIS REISSUE

The changes in this reissue of the HRS Notebook (SLIB 853 was the original issue) are those necessary to reflect the availability of additional information on the instrument's performance. This information was obtained from IDT documents, review of sample HRS tape data, and the IDT responses to the questions resulting from the tape review. Since new HRS information has been distributed within the SOGS project as it has been obtained, there should be no surprises in the changes that are incorporated in this issue, which include:

1. Incorporation of a number of instrument details. In addition to IDT-generated data, some of these changes were obtained from the ST Science Institute's HRS description in SLIB 1006b (see Section 1.5).
2. Data initially discovered from review of HRS tape data, including reversal of the Standard Header Packet/HRS-Unique Data Log sequence at the end of the data if a target acquisition error was encountered and reversal of the detector identification bits in the Engineering Trailer.
3. Some telemetry identifier changes to agree with a new issue of LMSC's DM-02 (SLIB 1089).

Two areas where (in common with most other ST instruments) uncertainties exist in the material covered in this document are the detailed format of the uplinked area of the Standard Header Packet (alternative sources are cited in Section 3.2.1) and the flight values to be used for the packet format code (see Section 3.2.4).

The updating effort for this HRS Notebook will be a continuous process throughout the duration of the SOGS project. This reissue, however, is the first HRS Notebook change that has been generated since the Revision-1 change pages (dated 6 January 1983) to the SLIB 853 issue. New information otherwise has been distributed among the TRW SOGS designers by means of SOGS memos. Particularly for those holders of the HRS Notebook outside of TRW, therefore, reliance on this HRS Notebook to reflect the "latest available" (anyplace) set of HRS data continues to be inappropriate.

1.3 INVESTIGATION DEFINITION TEAM

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1.4 SCIENTIFIC OBJECTIVES

The following information was obtained from SLIB 117 and SLIB 810:

The HRS is being developed for ultraviolet astronomy with the Space Telescope. It will provide a spectral resolution of about 100,000 over a nominal wavelength range of 110-320 nm, together with a spatial resolution of about 0.25 arc seconds. Once a hermetic seal is opened in orbit, only two moving parts, a grating carrousel and a shutter, are required for regular operation of the HRS. On-board calibration should yield accurate relative (1% design goal) and absolute (4% goal) spectrophotometry.

The scientific objectives that drive the HRS design include specific research goals in the areas of: the interstellar medium in our own Galaxy and neighboring galaxies; steady, episodic, and eruptive mass loss from a variety of single and binary stars; the evolution of the outer atmospheres of stars; the abundances of the chemical elements and their relation to stellar evolution; the physical properties of quasars and the bright nuclei of Seyfert galaxies; and the atmospheres of comets, planets, and satellites in the solar system.

In the area of interstellar medium studies, the HRS resolution is adequate (1) to obtain improved estimates of the column densities of interstellar atomic and molecular species, particularly those for which the strongest spectral component is highly saturated; (2) to detect the weak absorption lines of many species that are well below the detection threshold of the Copernicus spacecraft; (3) to measure directly the Doppler broadening of interstellar lines and hence perhaps measure kinetic temperatures in the intercloud medium; (4) to resolve interstellar from circumstellar absorptions in the spectra of nearby late-type stars; (5) to determine the rotational excitation temperature for interstellar molecules such as carbon monoxide; and (6) to isolate absorption features corresponding to physically distinct regions within interstellar clouds and at the boundaries of H II regions.

At a spectral resolution of 20,000, the HRS will be capable of recording ultraviolet spectra of objects about 1000 times fainter than those observed with the IUE. Again choosing interstellar medium science for purposes of illustration, this means that investigations of the following types will be practical: studies of very local gas in the direction of nearby white dwarfs and emission-line stars; studies of very dense interstellar clouds to elucidate molecule formation and the selective depletion of heavy elements; studies of the composition and distribution of the interstellar gas in adjacent spiral arms and the galactic halo; and study of intergalactic gas in the directions of bright galaxy cores and quasars. A detailed investigation of the interstellar media in the Magellanic Clouds will be feasible and could provide basic information on compositional differences between these nearby galaxies and the Milky Way.

See SLIB 810 for more details.

1.5 PRINCIPLES OF OPERATION

See SLIB 521 for information on the principles of operation of the complete HRS instrument (including its mechanical layout and a functional block diagram). The material given below emphasizes those HRS aspects that are of particular significance for understanding the nature of its science data, and has been generated using the sources listed in Section 8.1.

After an entrance port, the light beam from the OTA passes through one of two square entrance apertures (of dimension 0.25 arc second and 2.0 arc second). A motor is used to close the large-slit shutter, with a spring provided to return the shutter to the fail-safe (open) position at loss of motor power. There is no shutter on the small slit. Aperture selection is accomplished by orienting the ST to place the image of the target in the desired aperture. Within the HRS, the light is reflected by a collimator to a carrousel that houses five first-order (medium and low resolution) plane gratings, an echelle (high resolution), and an acquisition mirror used for relaying undispersed images of the entrance aperture to a detector for target acquisition. The HRS is similar to the Faint Object Spectrograph (FOS) on the ST, since both instruments have essentially the same kind of detectors. The main difference between the two instruments is their spectral resolution and wavelength coverage. The detailed format of their scientific data, however, is considerably different.

To use the first-order gratings, the carrousel is commanded to rotate to bring them into the proper position. Two of the five, both having wavelengths ranging from 105 to 170 nm, have nominal resolutions of 20,000 (grating "G-1") and 2,000 (grating "G-5"), and are used with HRS Digicon detector 1 (having a CsI/LiF photocathode/window, identified as "solar-blind"). The other three, all with a nominal spectral resolution of 20,000, are used with HRS Digicon detector 2 (having a CsTe/MgF₂ photocathode/window). For these, grating "G-2" has a range of 115-210 nm, "G-3" covers 160-230 nm, and "G-4" covers 220-320 nm.

To image a selected spectral interval, the rotation of the carrousel must be commanded to a previously tabulated angle. The carrousel is free to rotate continuously in either direction and will slew to a new position in less than 23 seconds for a full 180° rotation. The motor is driven by a 16-bit digital position command that is compared to the encoder position signal. When it nears null, the encoder is switched to an analog mode that permits position control to better than 1.5 arc seconds (see SLIB 234 for more details). The command angular resolution is $[2 \pi/2^{16}]$ or about 19.78 arc seconds, defining the minimum carrousel substep size. This corresponds to about ten pixels at the Digicon.

The echelle provides a nominal resolution of 100,000. It too is rotated into the appropriate position, and depending on the carrousel angle, the echelle relays the dispersed beam to HRS Digicon detector 1 (14 orders are imaged on the detector photocathode) or HRS Digicon detector 2 (12 orders are imaged simultaneously). Selection of the specific order to be measured by the Digicon is done by magnetically deflecting that order in the cross-dispersion ("Y" axis) direction. The "E-A" range (for detector 1) is 105-170 nm, and the "E-B" range (detector 2) is 170-320 nm.

Photoelectrons are accelerated across a nominal 22.5 ± 2.5 KV potential, and then reach a set of 512 diodes used for detection purposes. This voltage is adjustable between 1 and 25 KV, and must (in transitioning from Hold to Operate) be brought up by the execution of about 200 commands per detector, a process taking about 6 minutes. The response of a single diode to such a photoelectron is 5600 electron-hole pairs. The diodes are numbered 1-512 from left to right (increasing X axis direction). Of these diodes, 500 form a linear array aligned parallel to the spectrum order, and serve to record the spectrum or interorder spectrum. These diodes are numbered 7-506 and are spaced 50 microns (a micron is 10^{-6} meter) apart along the HRS's X axis. They are 40 microns wide, and have a height (dimension perpendicular to the dispersion) of 400 microns. Their height corresponds to 2 arc seconds at the ST focal plane, and is twice the diode height in the FOS to permit accurate measurement of the echelle orders in the presence of distortions. When the mirror is used, eight diodes (a width of 400 microns) must be sampled to span the large (2 arc seconds) aperture in the X direction.

The other 12 Digicon diodes serve special purposes. Four corner background diodes (numbered 1 and 2 on the left side and 511 and 512 on the right) are mounted with their long axis (1000 microns) parallel to the X axis; they are 100 microns tall. These diodes may be used to evaluate scattered light during spectral data acquisition. Focus (also referred to as "calibration") diodes on each side of the linear array can be used to generate a field map of the large aperture or check the quality of the Digicon focus. The ones on the left are numbered 4-6. Diode 4, however, is not wired to an amplifier channel (to prevent a wire cross-over to the header) and therefore can never be used. Diode 5 is the upper left diode and diode 6 is the lower left, while diode 507 is the right upper and 508 the right lower. These upper and lower focus diodes are in the form of a square that is 25 microns (0.25 arc seconds projected size) on a side, meaning that the large aperture can be mapped in a $[400/25 =]$ 16 x 16 group of measurements. Although diode 509 is wired and its data appears in the science stream, it is currently not being used by the acquisition software. If the other four available focus diodes are lost due to failures after launch, however, the HRS flight software could be modified to use diode 509 for acquisition.

The remaining two diodes (numbered 3 and 510) are called "radiation" diodes. They are covered with gold foil, are 1040 microns wide by 140 microns high (positioned on the centerline at each end of the array), and do not respond to signal electrons but will respond to high energy particles (cosmic rays). The output of the diode on the right (diode 510) is added to an accumulator each time a line of science data is read, and the result put in the engineering telemetry. The data from the other radiation diode is also accumulated on-board, but is not made available to the engineering telemetry.

The electrons from the Digicon photocathode are focused by a magnetic field provided by a rare-earth permanent magnet assembly. Electromagnetic deflection coils are provided to allow the desired portion of the photocathode to be imaged on the array. These coils are used to select orders in the echellogram, for substepping during accumulation mode, to sample interorder or other off-spectrum background, and for scanning the field of view during target acquisition. The deflection coils for the X (diode-array) axis and Y

axis are both driven by 12-bit digital-to-analog converters (DACs). The least increment (a deflection step) for the DACs corresponds to 6.25 microns, or [1/8] of the diode spacing (50 microns) for the linear array in the X direction and [1/64] of their height in the Y direction. For the focus diodes, a deflection step corresponds to [1/4] of the 25-micron diode size in both the X and Y directions.

The HRS is provided with two redundant platinum-neon hollow cathode wavelength calibration lamps, each furnished with a dedicated entrance slit. Flat field calibration lamps are also provided. These are redundant low-pressure xenon lamps emitting primarily in a resonance line at 147 nm. They are used as internal standards for diode-to-diode response calibration and photocathode mapping, and as light sources for the operation of locating the photocathode mask edges. Before launch, the irradiance of each xenon lamp will be adjusted to produce about 7000 counts/second/diode due to its illumination of the detector photocathode. One flat field lamp is dedicated to each detector, but the two calibration lamps can be used with either detector. Periodic calibration of the HRS on standard stars is required to support spectrophotometric observations.

The outputs from the diodes in each Digicon are fed to preamplifiers and then to a Detector Electronic Box (DEB). The DEB, in turn, is connected to a Main Electronics Box (MEB). Both the DEB and MEB are configured as dual operationally independent units, with separate sets of electronics dedicated to each detector (only one DEB should be on at any time, but, power permitting, both MEBs will normally be on at all times the HRS is operating). When the HRS transitions from Hold to Operate, one or two orbits are required for stabilization of the electronics (since the optical bench temperature is maintained at $21 \pm 4^\circ\text{C}$ in all modes, it should not cause delays).

The MEB interfaces with the Remote Interface Unit (RIU) of the SI C&DH (Control and Data Handling), including the Science Data Formatter (SDF). A science data line is output from the instrument at the completion of an integration, and when the SDF is ready to accept it. The data can be sent on

the downlink directly ("direct" mode) or to a 524-word buffer in the scratch pad memory portion of the NSSC-1 SI C&DH onboard computer for subsequent processing ("accumulation" mode).

In the DEB, the signal from each diode is shaped in a semi-Gaussian pulse amplifier (the shaping time constant is 1 usec) and then applied to a threshold detector. Each diode path has a separate low-level discriminator with 8 bits of commandable discrimination: the output of the DAC is reconverted to digital form and telemetered as the path's "threshold". The storage registers for the thresholds receive power from a "keep-alive" power supply that remains on even when the instrument power is off. The threshold for diode 4 (the unwired one) is set to 255 so that its output data will always be zero. The outputs from each diode are then counted (after rate limiting using a dead time established by 16 periods of a 2.048 MHz oscillator) in individual hardware accumulators.

The outputs from each diode are also formed into an analog sum, which is compared with a commanded threshold. If the analog-sum result is above the threshold, an "anti-coincidence" circuit inhibits all 512 diode accumulators for about 8 usec. This is done to avoid spurious results if radiation has impinged on the detector faceplate with sufficient energy to cause fluorescence. The number of times the anti-coincidence circuit was activated during the integration is included in the output from the instrument (and used in a data-quality check).

For a given set of magnetic deflections, the segment of the photocathode detected by the 512 diodes can result in the generation of a "line" (also referred to as a "frame") of data. Each line of science data output from the HRS instrument consists of 524 16-bit words (512 accumulator counts, 9 words of "Engineering Trailer" data, and 3 words of zero fill that are loaded by the NSSC-1 computer if the data is processed there) each data-gathering interval. The diode-path accumulator counts are buffered and sent from the DEB to the MEB, where an on-the-fly adder sums them (the result of the sum is used in a data-quality check).

The HRS instrument is designed to gather data at rates up to 20 times per second (50 msec intervals), and this interval can be changed by command in 50-msec steps up to 12.75 seconds. For computer loading reasons, the minimum data gathering interval for data processed in the NSSC-1 is 200 msec (the 50 msec period can be used only for the direct downlink, when the HRS software in the NSSC-1 is bypassed and constant Digicon magnetic deflections are used). The duration of an observation in the direct downlink mode, due to the high data rate, is limited by the available capacity of the ST tape recorder, or by the availability of a real-time link to the ground. If the instrument output is provided in the direct downlink mode, the diode sequence is scrambled (for failure isolation reasons), and hence must be unscrambled using a table that is independent of the Digicon. If the data is processed in the NSSC-1, however, then the diode information appears in the proper diode-number order (which in turn reflects an increasing wavelength with diode number, so lower diode numbers correspond to shorter wavelengths).

Changes in the magnetic deflections from one line to the next are called HRS "substeps". For example, successive lines could alternate in the Y direction between a particular spectral order and the interorder as a means of providing information required for background removal. Other substep purposes are to compensate for the gaps between diodes, to obtain the full HRS spectral resolution, and to smooth out the pixel-to-pixel response. Background and spectral observation data may have different numbers of substeps, and typically only science data is substepped. Substep commands are stored in the HRS Observation Control Table (OCT), which contains the control parameters for an observation. The OCT can hold up to six "substep offset" pairs (X and Y axes) that are applied from a given "initial deflection" pair. A "substep pattern" consists of the data gathered using deflections specified by one of the initial deflection pairs alone, then as augmented by the substep offset pairs (each repeated as specified in a repeat code). The Y deflections for substepped patterns of the bins to be interleaved are expected (within a small tolerance) to be the same.

In addition to these applications of the deflection capability, Digicon deflections can also be used to compensate for the Doppler shift caused by changes in the velocity of the spacecraft with respect to the target. The corrections consist of periodic (once a minute) shifts of the substep pattern along the dispersion direction to compensate for the change in the wavelength of a photon in the observer's frame due to the changing vector of the ST's orbital motion. This correction, which is needed only for the HRS high spectral resolution (100,000) operation, allows the coaddition programs to continue to add counts corresponding to a specific rest-frame wavelength into the same storage bin during a time exposure.

By selecting other initial deflection pairs (up to 5 can be accommodated in the OCT), changes in the X-axis deflection can be specified that amount to integral diode widths. For array storage reasons in the HRS memory, as well as to minimize the amount of science data that must be discarded, initial deflections 2-5 are limited in the X direction to a maximum of 15 diodes from initial deflection 1, must shift the spectrum an integral number of diodes, and shift the spectrum in the direction of increasing diode number (toward the right, meaning that a particular diode sees decreasing wavelengths). This capability can be used to avoid pixel dropouts due to bad or noisy diodes, as well as to average the diode output to smooth performance non-uniformities. The same substep pattern is applied for all initial deflection pairs. Increasing X-deflections can be thought of as moving the diode array in the direction of increasing X-deflection across a stationary image. What actually occurs is that the diode array remains stationary while the image moves in the direction of decreasing X-deflection. Hence with increasing X-deflection, the image is seen by lower-numbered diodes.

The NSSC-1 computer has memory for up to seven 524-word "substep bins" (for the initial deflection pair and for each of the up to six substep offset pairs). All data arising from the up to five initial deflection pairs are "co-added" into bin 1; all from deflections composed of initial deflections plus the first substep offset pair are co-added into bin 2; etc. If more than one initial deflection pair was specified, this implies that the spectral line of interest to the observer was sequentially deflected to be

observed by up to five other diodes in the array. In this case, all data obtained from a particular point on the spectrum is "comb-added" into the same register of the substep storage bin. For example, if an initial deflection value X-axis difference of 16 (2 diodes) was specified, the data from diode 100 for one deflection and diode 102 for the second is comb-added in the same memory cell. This technique means that the downlink information must be considered the output of various "channels" rather than the special case of "diodes" that would apply if there were only one initial deflection pair.

The HRS software in the NSSC-1 is divided into seven processors, several of which in turn have a number of modules included in them (see SLIB 284). The seven processors, in order of decreasing priority (urgency for running), are:

1. DMPSCI, NSSC-1 processor #40, used to coordinate with the flight executive in the dumping of all substep bins in use.
2. DATACQ, NSSC-1 processor #38, used to accept a line of science data from the instrument, check its quality, and call for its unscrambling and storage.
3. CRITCD, NSSC-1 processor #34, used to retrieve and store for science data downlinking ten critical temperature values needed for calibration.
4. MAIN, NSSC-1 processor #36, used for overall HRS observation control.
5. VERIFY, NSSC-1 processor #37, used to verify the receipt of commands sent to the HRS instrument or (for spacecraft pointing) to the spacecraft. The carrousel/SSM interlock, whereby the HRS flight software informs the SSM of imminent carrousel motion, can be enabled or disabled by setting a 1 or 0 (respectively) into the memory cell called CSSMIL.
6. SAFING, NSSC-1 processor #39, used to monitor critical engineering data from the HRS instrument and request issue of the HRS safing sequence when necessary.
7. DOPPLER, NSSC-1 processor #33, used to update the Doppler-shift correction.

According to SLIB 1006b, three more processors are likely to be added. One of them would suspend and resume observations for SAA entrance and exit; the second would turn down high voltages before a bright Earth occultation; and the third would conduct the high voltage turn-on sequence.

To coordinate HRS integration with the 25 msec SI C&DH Delayed Command Processor (DCP) clock, an "event parade" is required, since at any one moment during a science data acquisition observation the following series of events may be occurring:

1. Data is dumped from the instrument accumulators to its output registers, new deflections are transferred from the holding registers to the deflection registers, and data is shifted from the output registers to the SDF and thence to a buffer in the NSSC-1;
2. Data from the instrument is input to the HRS flight software, checked for quality, and co-added into the proper substep bin; and
3. Deflection commands are issued by the DCP and the deflections moved into the HRS deflection holding registers.

According to SLIB L39, however, this design may be changed to go to a two-step event parade.

For monitoring the event parade, six parallel four-element queues are used in the NSSC-1 HRS software. Current items are taken from the head of the queues, and new items placed at their tails. The event parade itself contains three elements, but a fourth element is included for added visibility and ease of processing. The six items are: horizontal and vertical deflections, destination substep bin number, repeat count (how many times the deflections have been re-issued because of bad data quality), number of diodes to shift for comb-addition, and the Doppler shift correction. See SLIB 284 and SLIB 285 for more details on the NSSC-1 HRS on-board software.

2.0 HRS MODES OF OPERATION

There are three kinds of HRS "modes" that need to be distinguished:

1. Instrument Modes,
2. Science Data Modes, and
3. Ground Software Modes.

These modes are treated in separate sections below. Throughout this document, bit 1 is the most significant (or sign) bit and bit 8 or bit 16 is the least significant (for 8-bit words and 16-bit words respectively). The notation "Zxxx" means the LMSC engineering telemetry abbreviated measurement identifier (see Section 4), and "Z.xxx" refers to telemetry that lacks an LMSC identifier. Tables 4.2-7 and 4.2-8 list all the HRS telemetry in sequence by the identifier value and by mnemonic, respectively. Engineering telemetry mnemonics used in this document are, if available, those in SLIB 1089 (without a "Z" first character for consistency with IDT practice).

2.1 HRS INSTRUMENT MODES

Information on the HRS Instrument Modes can be divided into four categories:

- 1 Downlink Source,
- 2 Target Search,
- 3 Target Locate, and
- 4 Detector Source.

These are treated in separate sections below.

2.1.1 Downlink Source Instrument Mode

The science data Downlink Source Instrument Mode can be set to either the HRS instrument itself (the direct downlink mode of operation) or the NSSC-1 computer (the accumulation mode of operation). This is specified by a bit in the OCT, and reflected in measurement Z.120 (INFOa, see Section 3.1 for a discussion of the OCT). A 0 for this bit means that the downlink data is obtained from the NSSC-1 computer and a 1 means that it is obtained directly from the HRS instrument. If the bit is 1, then the order of the diode

information in the 524-word set of science data is "scrambled" (see Table 3.3-1 for the mapping that must be used to convert the downlink information into the proper order for subsequent processing). Measurement Z.252 (ZBINIDZ) can also be used to establish that the data is directly from the instrument (it normally has field map data or the substep bin number in range 1-7, but is zero for data directly from the instrument).

2.1.2 Target Search Instrument Mode

The Target Search Instrument Mode is defined in the OCT, and reflected in measurements Z.153 (MODESb) and Z664 (TSMODE). The mode specifies the nature of phase 3 (target search, see Section 2.2.1) activities required for the HRS Target Acquisition Science Data Mode. In this phase, star-presence checks and/or field maps of the field of view are interspersed with SSM slews in a outward-growing spiral pattern. The individual settings for this Instrument Mode are:

- 1 Spiral dwell scan until star present (flux checked at each dwell),
- 2 Same as 1 with focus-diode field map constructed at each dwell, and
- 3 Full spiral scan (no flux check) with focus diode field map constructed at each dwell.

2.1.3 Target Locate Instrument Mode

The Target Locate Instrument Mode is also defined in the OCT, and reflected in measurements Z.152 (MODESa) and Z665 (TLMODE). The mode specifies the nature of phase 4 (target locate) activities required for the HRS Target Acquisition Science Data Mode. In this phase, a map can be made of the field of view, and the target centered in the large aperture to an accuracy sufficient to place the target in the small aperture with one nominal slew, if desired. The individual settings for this Instrument Mode are:

- 1 Image null balance only,
- 2 Focus diode field map only, and
- 3 Focus diode field map, followed by image null balance.

2.1.4 Detector Source Instrument Mode

The Detector Source Instrument Mode is likewise defined in the OCT, and reflected in measurement Z.100 (CONOF, whose bit 10 is 1 for detector 1, with CsI photocathode; bit 9 is 1 for detector 2, with CsTe photocathode). Measurement Z656 (DEB2) is 1 if detector 2 is on and Z657 (DEB1) is 1 if detector 1 is on. Per SLIB 713a, the source is also contained in measurements Z501 (SYSON1, 1 if data from detector 1) and Z502 (SYSON2, 1 if data from detector 2). To determine unambiguously which detector was used (see SLIB T24) to gather the science data, however, the values in Z.212 and Z.213 of the Engineering Trailer (see Section 3.2.3.3) can be used.

2.2 HRS SCIENCE DATA MODES

The HRS has three major Science Data Modes:

- 1 Target Acquisition,
- 2 Spectroscopy (high, medium, and low resolution), and
- 3 Pulse Height Analysis (PHA).

These are treated in separate sections below.

2.2.1 Target Acquisition Science Data Mode

A target acquisition observation normally consists of searching for a target star presence in the field of view of the instrument (generating field maps if requested). These searches are interspersed with HRS-requested SSM slews in an outward growing spiral pattern until the target star is detected, and centering the star in the large or small HRS aperture. A blind offset to a nearby dimmer star may also be included if requested, including a post-offset peakup on the dimmer star.

Target acquisition has been defined as having four submodes (A1, A2, N1, and N2), depending on the optical configuration and the Digicon that is used. They are described in SLIB 219 (which was reproduced in SLIB 521). Target acquisition is normally accomplished under control of autonomous HRS flight software, and has eight phases (all except the first and last can be optionally executed, constrained to be in ascending numerical order). In addition, a wait-after for ground interaction and continuation can optionally be specified for all but the first and last phases. The individual phases are:

1. Initialization, which is now (per SLIB L39) an empty phase.
2. Deflection calibration, when the offsets of the image of one of the spectral calibration lamps from its nominal position on the diode array are computed. This phase is expected to be used with each target acquisition.
3. Target search, when star-presence checks and/or field maps can be interspersed with SSM slews in an outward growing spiral pattern (see Section 2.1.2 for the Instrument Mode applying to this phase).

4. Target location, when a map can be made of the field of view, and the target centered in the large aperture sufficiently accurately to place the target in the small aperture with one nominal slew, if desired (see Section 2.1.3 for the Instrument Mode applying to this phase).
5. Peakup, when the target is centered in the small aperture.
6. Offset, when a slew is made to another location near the object previously acquired.
7. Post-offset peakup, when the offset target is centered in the small aperture.
8. Flux measurement, when a flux measurement is taken through whichever aperture contains the target, for telemetry as measurement Z.193 (FLUXM).

Measurement Z649 (ACQIND) is 1 if in the Target Acquisition Science Data Mode (and 0 if in one of the other Science Data Modes). Measurement Z651 (TPHAS1) is 0 either if not in Target Acquisition or if in its short-duration initialization phase. A nonzero value means that it has [phase - 1] of the current Target Acquisition phase: a 5 would mean the HRS software is in offset (phase 6), for example. For identifying the science data, measurement Z.001 (DIND) is 2 if the Standard Header Packet (SHP, see Section 3.2.1) is being dumped at the start of a target acquisition observation (it is 3 for the SHP at the end of any observation). Measurement Z.251 (ZCOADDZ) is ≥ 0 for science observations, and is -2 for a target acquisition focus diode field map.

2.2.2 Spectroscopy Science Data Mode

A science data observation normally means the acquisition of one spectral line of interest from the target star. More than one line of interest to the observer may be obtained in one observation if they are close enough together to fall on the 500 data diodes of the diode array simultaneously. Spectroscopy has been defined as having seven dispersive submodes, five of which relate to the five first-order gratings (G-1 through G-4 with a resolution of 20,000 and G-5 with 2,000) and the other two of which relate to using a Digicon with the echelle (E-A and E-B, both with 100,000). See Section 1.5 for the characteristics of the gratings. The submodes are described in SLIB 219 (which was reproduced in SLIB 521). Either of the two HRS entrance apertures can be used in any dispersive submode.

Measurement Z649 (ACQIND) is 0 if in the Spectroscopy (or PHA) Science Data Mode. For identifying the science data, measurement Z.001 (DIND) is 1 if the SHP is being dumped at the start of a Spectroscopy observation (it is 3 for the SHP at the end of any observation), and measurement Z.251 (ZCOADDZ) is \geq 0 for such observations.

2.2.3 PHA Science Data Mode

Pulse Height Analysis (PHA) of the two HRS detectors requires 28,800 commands per detector. PHA is required to detect changes in sensitivity of the detector diodes and the amplifiers, and to determine the proper threshold settings for each of the 512 diode paths per detector to maintain the 1% relative photometric accuracy of the HRS. PHAs are expected to be conducted possibly once a month or less, depending on the drifts in sensitivity caused by the space environment. They can be accomplished using NSSC-1 delayed command processor relative time sequences (5200 words of delayed command memory, see SLIB 764), or by an on-board flight processor requiring 200 words of dedicated memory. The on-board processor method can be used only if sufficient memory resources are available after launch. The PHA processor would send three commands to the HRS detector every 25 msec for 2.4 sec (288 commands), integrate data for one second, and then dump the data via the direct downlink mode for each of the 100 steps in the PHA, thus requiring about 340 seconds per detector.

According to SLIB T24, there is no way to identify PHA data from the science telemetry, since it has the usual format of SHPs, UDLs, and science data.

2.3 HRS GROUND SOFTWARE MODES

There are two HRS Ground Software Modes:

- 1 Target Acquisition and
- 2 Spectroscopy.

Their selection is based on user input to the ground system.

2.3.1 Target Acquisition Ground Software Mode

See Section 2.2.1 for criteria identifying data proper for use in this Ground Software Mode, and Section 7 for the algorithms to be used.

2.3.2 Spectroscopy Ground Software Mode

See Section 2.2.2 for criteria identifying data proper for use in this Ground Software Mode, and Sections 5 and 6 for the algorithms to be used.

FOS ND-1004A

SPACE TELESCOPE
SCIENCE OPERATIONS GROUND SYSTEM

SOGS-ND-1004
FAINT OBJECT SPECTROGRAPH
SOGS NOTEBOOK
28 JANUARY 1984
REVISION A



TRW DSG

SPACE TELESCOPE
SCIENCE OPERATIONS GROUND SYSTEM

SOGS-MD-1004
FAINT OBJECT SPECTROGRAPH
SOGS NOTEBOOK
28 JANUARY 1984
REVISION A



TRW DSG

SPACE TELESCOPE
SCIENCE OPERATIONS GROUND SYSTEM

SOGS-ND-1004

FAINT OBJECT SPECTROGRAPH

SOGS NOTEBOOK

28 JANUARY 1984

REVISION A

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FOREWORD

This volume provides a compilation from various sources of factual information on certain aspects of the Faint Object Spectrograph, one of the five Science Instruments on the Edwin P. Hubble Space Telescope. It is one of a set of such documents prepared by TRW to aid in the design work for the Space Telescope Science Operations Ground System (SOGS).

This document (ND-1004, Revision A) is a reissue of the preliminary FOS SOGS Notebook (ND-1004, 31 December 1982) to incorporate considerable additional instrument information that has become available since the original Notebook was produced.

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FOS-Related Acronyms

ASCII	American Standard Code for Information Interchange
CEA	Central Electronics Assembly
CLPS	Calibration Lamp Power Supply
CPU	Central Processing Unit
C&DH	Control and Data Handling (Subsystem)
DAC	Digital-to-Analog Converter
DCF	Data Capture Facility
ET	Engineering Telemetry
FGWA	Filter/Grating Wheel Assembly
FOS	Faint Object Spectrograph
FOV	Field Of View
GFE	Government Furnished Equipment
GO	General Observer
GSFC	Goddard Space Flight Center
HRS	High Resolution Spectrograph
HVPS	High Voltage Power Supply
ICD	Interface Control Document
IDT	Investigation Definition Team
IEB	Instruction Engineering Bit
IST	Instrument Science Team
K	For memory, 2^{10} (1024); otherwise, 10^3
LED	Light Emitting Diode
LMSC	Lockheed Missiles and Space Company, Incorporated
MEC	Mechanism
MHz	10^6 Hz
MOGS	Mission Operations Ground System
msec	Millisecond
nm	Nanometer (10^{-9} meters or 10 angstroms)
NSSC-1	NASA Standard Spacecraft Computer, Model 1
OSS	Observation Support System
OTA	Optical Telescope Assembly
PASS	POCC Application Software Support
PDCR	Preliminary Document Change Request
PDL	Program Design Language

PIT	Processor Interface Table
POCC	Payload Operations Control Center
PODPS	Post-Observation Data Processing System
PORTS	Preliminary Operations Requirements and Test Support
PROM	Programmable Read-Only Memory
RAM	Random Access Memory (read/write)
RIU	Remote Interface Unit
ROM	Read-Only Memory
RPI	Relay Position Indicator
SCI	Science Institute (Johns Hopkins)
SDAS	Science Data Analysis Software
SDF	Science Data Formatter
SHP	Standard Header Packet
SI	Science Instrument
SLIB	SOGS (TRW) Library document identifier
SMC	Serial Magnitude Command
SOGS	Science Operations Ground System
SPSS	Science Planning and Scheduling System
SSC	Science Support Center
SSM	Support Systems Module
ST	Edwin P. Hubble Space Telescope
STOCC	ST Operations Control Center
STSOP	ST Science and Operations Project
TBD	To be determined
TM	Telemetry
UCSD	University of California, San Diego
usec	Microsecond
UTC	Universal Time Coordinated
UV	Ultraviolet
X'ab'	Hexadecimal (base 16) value for "ab"
Y	Conventional first letter for FOS parameters
Yxxx	Abbreviated LMSC ET Measurement ID
Yxxx _c	Abbreviated LMSC Command ID
Y.xxx	Coined Measurement ID
Y.xxx _c	Coined Command ID
???	Material needing determination/confirmation

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF FOS NOTEBOOK

The purpose of this Faint Object Spectrograph (FOS) Notebook is to provide a compilation from various sources of factual information on certain aspects of the FOS necessary for design work on the Edwin P. Hubble Space Telescope (ST) Science Operations Ground System (SOGS). The contract for development of SOGS is managed by GSFC, and is performed by TRW. One of the main tasks of SOGS is the receipt, display, manipulation, and calibration of the FOS data (as well as the other instruments on the ST). To perform this task, a thorough understanding is necessary of the various formats in which data is received, where critical processing parameters are in both the science and engineering data streams, and what algorithms are to be applied to calibrate the science data for each instrument configuration.

The intended audience for this FOS Notebook is the TRW SOGS designers, rather than a general collection of diverse groups with equally diverse information desires. Because of its intended audience, there are numerous FOS-related topics that are not included in this Notebook. Section 8 (References) has a list of citations for some source documents on FOS that are in the TRW SOGS Library. Such documents have been assigned serial accession numbers (SLIB numbers) meaningful only to those with access to the TRW Library, so Section 8 provides information on originator, date, and title to identify the material more completely.

The organization of this FOS Notebook is the same as that for the other four ST instruments. After this introductory material, the various types of FOS modes are defined in Section 2 (since they are of major significance to the SOGS design effort). Sections 3 and 4 cover the FOS Science Telemetry and FOS Engineering Telemetry respectively. Algorithms for FOS Calibration, FOS Data Quality/Utility, and FOS Target Acquisition are in Sections 5 to 7 respectively (these relate to what is in Section 10 of the SOGS SE-06-1 specification, SLIB 799). Section 8 has References.

1.2 SUMMARY OF FOS NOTEBOOK UPDATES FOR THIS REISSUE

The changes in this reissue of the FOS Notebook (SLIB 865 was the original issue) are those necessary to reflect the availability of considerably more information on the instrument's performance. This information was obtained from a mid-June 1983 GSFC FOS Operations meeting, review of sample FOS tape data, IDT written responses to some of the questions resulting from the tape review, and a valuable meeting held at UCSD with FOS IDT personnel on 24 January 1984. Since new FOS information has been distributed within the SOGS project as it has been obtained, there should be no surprises in the changes that are incorporated in this issue, which include:

1. Addition of numerous instrument details. In addition to IDT-provided data, some of these changes were obtained from the ST Science Institute's FOS description in SLIB 1006b (see Section 1.5).
2. The Standard Header Packet locations (from LMSC's SLIB 936) of the FOS engineering telemetry (see Section 4).
3. The IDT-provided contents of the FOS-unique area of the Standard Header Packet (see Section 3.2.1).
4. Some telemetry identifier changes to agree with a new issue of LMSC's DM-02 (SLIB 1089).
5. Addition of material initially discovered from review of FOS tape data (see SLIB 1106), including the frequent cases in which the downlink packet size differs from the original data-gathering logical grouping, the fact that some crucial downlink instrument time information is in two's complement form, and the fact that some instrument mechanism positions are telemetered in one's complemented Gray code.

Two areas where (in common with most other ST instruments) uncertainties exist in the material covered in this document are the detailed format of the uplinked area of the Standard Header Packet (alternative sources are cited in Section 3.2.1) and the flight values to be used for the packet format code (see Section 3.2.4 for the assigned ranges).

The updating effort for the FOS Notebook will be a continuous process throughout the duration of the SOGS project. This reissue, however, is the first FOS Notebook change that has been generated since the SLIB 865 issue (dated 31 December 1982). New information otherwise has been distributed

among the TRW SOGS designers by means of SOGS memos. Particularly for those holders of the FOS Notebook outside of TRW, therefore, reliance on this FOS Notebook to reflect the "latest available" (anyplace) set of FOS data continues to be inappropriate.

1.3 INVESTIGATION DEFINITION TEAM

The Principal Investigator for the FOS experiment is:

Richard J. Harms, University of California, San Diego, CA.

Co-Investigators are:

Roger Angel, University of Arizona, Tucson, AZ;

Frank Bartko, Martin Marietta Corporation, Denver, CO;

Edward Beaver, University of California, San Diego, CA;

Ralph Bohlin, ST Science Institute, Baltimore, MD;

Margaret Burbidge, University of California, San Diego, CA;

Arthur Davidsen, Johns Hopkins University, Baltimore, MD;

Holland Ford, ST Science Institute, Baltimore, MD; and

Bruce Margon, University of Washington, Seattle, WA.

1.4 SCIENTIFIC OBJECTIVES

The following information was obtained from SLIB 118 and SLIB 810:

The FOS is being 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 of about 1200 and 200. A variety of concave gratings and prisms is 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 quasars; active galaxies; normal, distant, and local group galaxies; a wide class of objects within our own and neighboring galaxies; and objects within our solar system. All of these studies will be conducted within the context of understanding the origin, structure, composition, and evolution of our universe.

Faint objects that will be studied include: 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, e.g., obtaining UV spectra of comets, and combining on-going high-spatial-resolution studies of planets and satellites with those of planetary exploration missions.

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.

1.5 PRINCIPLES OF OPERATION

See SLIB 411 for information on the principles of operation of the complete FOS instrument (including its mechanical layout and a functional block diagram). The material given below emphasizes those FOS aspects that are of particular significance for understanding the nature of its science data, and has been generated using the sources listed in Section 8.1.

Light enters the FOS through a pair of entrance ports. In their closed position (a fail-safe provision is available to force the ports open), the ports reflect light from either of two internal neon-filled spectral calibration lamps used for FOS wavelength calibration. The light from the object of interest then passes through one of two independent optical channels, each of which focuses nearly stigmatic spectral images on the photocathodes of photon-counting Digicon detectors. Selection of the desired optical channel is accomplished by pointing the telescope. These channels differ only in the wavelength sensitivity of their respective detectors. The Digicon output is then processed by a set of electronics (which is different for the two channels), and the resulting scientific data can then be sent on the down-link. The FOS is similar to the High Resolution Spectrograph (HRS) on the ST, since both instruments have essentially the same kind of detectors. The main difference between the two instruments is their spectral resolution and wavelength coverage. The detailed format of their scientific data, however, is considerably different. Only one FOS detector and set of electronics will be operational at a time, depending on the desired bandwidth and the detector range.

Five minutes are required to switch between detectors, and their high voltage settles in about one minute. Such changes (to obtain the desired wavelength coverage) are expected to occur about 10-20% of the time. The overall instrument warmup time is constrained by its mechanical elements. During the first few hours of operation, as the electronics heat the electronics shelf, the enclosure will deform slightly shifting the cross-dispersion position of the optical bench. During this transition, use of the 0.1 arcsec aperture should be restricted to relatively short (3 hour) observations to avoid loss of lock on the target during data acquisition.

The FOS aperture wheel is placed at the ST focal surface. This wheel contains 11 (plus a blank for a light shield) sets of single or paired apertures (ranging in size from 0.1 to 4.3 arc seconds as projected on the sky). As a fail-safe provision, an "arm" command followed by a "fire" puts a pair of fail-safe entrance apertures in the light path. The 4.3 arc-second aperture is used for target acquisition, while the smaller ones (including two with an occulting capability) will allow diverse observations to be conducted efficiently. The individual aperture offsets are fairly close to zero (a calibration table will be available). The apertures for the two detectors, however, have a larger (constant) offset, so if the Digicons are switched a small ST maneuver must be carried out.

After passing through the aperture wheel, the light passes through the polarization analyzer. This device 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. 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 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 that meshes with a 17-tooth fixed center gear inside the drum. One revolution of the drum rotates the Wollastons by 360° and the waveplates by $[17/16 * 360^\circ =] 382.5^\circ$, so each drum rotation increments the position angle of the waveplate fast axis by a net 22.5° (and 16 rotations return the mechanism to its starting configuration). Any of 48 positions (the three elements for any of the 16 rotations) can be commanded. A fail-safe provision causes the assembly to be rotated out of the light paths.

The light next passes (after a grazing incidence mirror) through an order-sorting filter (or a blank hole) in the FOS Filter/Grating Wheel Assembly (FGWA). The light is collimated by an off-axis paraboloidal mirror and reflected back to an element on the FWGA, which in turn both focuses and disperses (except for one imaging position) the beam onto one of the

detectors. The FGWA has ten positions (only five of which have filters). It has six high-resolution (1200) gratings, two low-resolution (200) gratings, a low-resolution (100) prism, and a camera mirror. The FOS's high-resolution gratings resolve, for example, 0.2 nm at a wavelength of 240 nm. Changing gratings will be a fairly common FOS activity (estimated to be done for about half the observations). For interactive observations, the observer might want to look at an object with the prism and then study an interesting area in more detail with a higher-resolution element. Movement of the FGWA does not cause a spacecraft attitude perturbation. The fail-safe provision for the FGWA is a redundant stepper motor to operate the mechanism if the primary motor fails.

There are two independent detector assemblies, one for each optical channel. Each assembly consists of a Digicon tube, deflection coils, a permanent magnet focus assembly, magnetic shielding, mounting and alignment structure, heat pipes, temperature sensors, hybrid preamplifiers, and connectors. The two Digicon assemblies differ only in their photocathode and faceplate material. The red (also referred to as side "A" for "amber", and having a trialkali Digicon) detector covers the range of 180-850 nm, while the blue detector (side "B", having a bialkali Digicon) covers 115-500 nm. There is one LED flat-field lamp for each Digicon (the LED irradiates its corresponding photocathode directly without intervening optical elements).

Each incident photon (with a probability of about 30%) produces about 5000 electrons in the Digicon. These electrons are accelerated through a potential of about 22.5 KV, and then reach a linear array of 512 silicon diodes arranged along the "X" axis of the instrument (FOS axis terminology, although related by a transformation to the ST axes as shown in SLIB 706). These diodes are spaced 50 microns apart along the X axis, and have a size of 40 x 200 microns (a micron is 10^{-6} meter). The wavelength associated with diodes is in monotonic order by diode number, in accordance with the following rules (see SLIB L66):

1. Side A with the prism has shorter wavelengths at lower diode numbers;
2. Side A with elements other than the prism has shorter wavelengths at higher diode numbers; and

3. Side B is the opposite of side A (prism gives shorter wavelengths at higher diode numbers, other elements give shorter wavelengths at lower diode numbers).

The FOS diode numbering convention (see SLIB T30) numbers them from 0 to 511. When using the lower-resolution elements, the spectrum does not cover all 512 diodes, and commands are available to select the diode outputs that are processed and downlinked. The charge pulse generated in each diode is amplified and counted by one of 512 independent electronic channels, beginning with the hybrid preamplifier physically colocated with each Digicon. The signal is next passed through several feet of cable to the FOS Analog Signal Processor.

The electrons from the Digicon photocathode are focused by a magnetic field, and also can be magnetically deflected in the instrument's X axis (the direction of the dispersion) and perpendicular to it (the Y axis). The movement in the Y axis is needed because frequently there are two images on the photocathode (such as a star image and a background sky image), and it is necessary to examine both of them with the diode array. The X and Y axis magnetic deflection coils are both driven by 12-bit digital-to-analog converters (DACs).

The design of the FOS control parameters recognizes that observer-specified deflection parameters must be available that give well-defined observation effects. These observer quantities are specified in terms of "nominal" instrument performance (independent of the potential effects of, for example, component aging and temperature). To allow this interface to exist, nominals are defined based on the original FOS specification values of 32 DAC least increments per diode for deflections in the X direction (to span the diode width of 50 microns) and 256 DAC least increments per diode (to span the diode height of 200 microns) in the Y direction. These figures imply that the maximum nominal Y-axis deflection range in microns is half of the X-axis range. The actual scaling constants (the physical hardware's number of increments for these deflections) can be managed on a "facility" basis, and the observer in most cases should not be concerned about the values actually used during his/her observation. For example, the value of the flight X scaling constant (see SLIB 1106) probably will be about 24 DAC increments/diode-width, but the design-baseline figure of 32 can nevertheless be used to specify the observer's FOS X-axis deflection parameters.

In the FOS Analog Signal Processor, the signal is shaped to a two-microsecond width. Each channel has a separate "low-level" discriminator with 8 bits of commandable discrimination: the setting value is in the DDTBL ("Discriminator DAC/Disabled Diode Table") array available in the FOS-Unique Data Log (see Section 3). Some variations are expected during flight, particularly as the system "ages". This table, therefore, is the appropriate operational source for the status of the FOS diodes. There is no hardware "upper level" discriminator. The low-level discriminator in each channel is followed by a rate limiter (which uses 10 cycles of the 1.024 MHz spacecraft clock) to provide a single-value count output. Without such a device, the same output could result for a low pulse-rate input (where the counts would be precise) and a very high input (where due to "pulse pileup" several pulses would be interpreted as one). For 100,000 pulses/sec input, the device would give 50,000 output, and it provides monotonically decreasing outputs for inputs below that level.

The output of the rate limiter (again for each channel) is fed to a 16-bit hardware accumulator. This accumulator can operate in both the count mode and the timer mode (count is the dominant mode). In the count mode, the accumulator counts the incoming pulses from the rate limiter for an interval controlled by a command; in the timer mode, it counts the 1.024 MHz spacecraft clock, stopping when the first pulse is received. The accumulator, in turn, is fed to a buffer register (one for each channel) where it can be read out while the next sample is being acquired. Each channel (through to the buffer) is independently replicated. For failure isolation reasons (might tolerate 10 "scattered" channels not working, but not as readily 10 consecutive ones), hardware assignments such as pin and circuit partitions are "scrambled"; a "descramble PROM" is used to restore the data to the original channel sequence for the FOS microprocessor. It therefore is unnecessary for the ground software (contrary to the HRS) to compensate for this hardware "scrambling". The downlink data, however, must be rearranged in a monotonic wavelength sequence: this process is referred to as "reordering" or "unscrambling" (see Section 3.2.3.2).

The output of the FOS Analog Signal Processor is fed by two wires (for even and odd channels) to the FOS Central Electronics Assembly (CEA), where the FOS microprocessor and associated electronics are located. As mentioned previously, there are two sets of FOS electronics (including microprocessor systems), but only one can be operating at a given time. The CEA, in turn, interfaces with the Remote Interface Unit (RIU) of the SI C&DH (Control and Data Handling), including the Science Data Formatter (SDF).

The FOS microprocessor, a Texas Instrument SBP 9900A, is a parallel 16-bit monolithic CPU with integrated injection logic and 3 MHz operation (switchable to 1.5 MHz) capability. It has a byte-organized 16-bit memory which "typically" uses word operations. The address space is divided as follows ("X" means hexadecimal and the final character of "E" reflects words rather than bytes):

- X'0000' to X'5FFE' 12K 16-bit words (24K bytes) of read-only memory (ROM);
- X'6000' to X'7FFE' Memory-mapped I/O (SDF, accumulators, etc); and
- X'8000' to X'FFFE' 16K 16-bit words (32K bytes) of random access memory (RAM).

The ROM includes an executive, 10 application programs, and some tables of nominal values required for operation of FOS detectors. These tables can be copied into RAM at initialization. One table has 512 16-bit values for the DDTBL array (channel enable/disable flag and discriminator DAC value); another has Mechanism Control Blocks for each of the four mechanisms (a total of 96 16-bit words, see Section 3.1.4). The two CEA ROMs (side "A" and side "B") are unique with respect to these default table values. The operating system (the FOS microprocessor is programmed in polyFORTH) occupies about 5200 bytes of the 21000 ROM bytes currently assigned.

The FOS RAM consists of eight physical pages of 4K bytes (or 2K words, K = 1024) each, which are relocatable. The logical assigned position of any 4K RAM address space is automatically established during each instrument power on and reset, or can be specified by a serial magnitude command preceding power-on. Four 16-bit words of the FOS-Unique Data Log reflect this "RAM

map". If a defective physical page is encountered, it will be mapped to the X'Fxxx' address area, so that the still-functioning RAM pages will remain in contiguous locations starting with X'8000'.

The first 2 logical RAM pages (addresses X'8000 to X'9FFE', or 8K bytes) are assigned to System Variables and Tables, with the last 965 words of this area used for the FOS-Unique Data Log. The remaining 24K bytes of RAM, starting at byte address X'A000' (or $10 * 16^3 = 40960_{10}$), are used strictly for temporary storage of science data. The maximum possible length of the science information (excluding the Science Header which comes from the FOS-Unique Data Log area) is 6 pages or 12K 16-bit words ($12,288_{10}$ words). The actual number of words that are meaningful, however, and the method for their interpretation, are under control of the FOS microprocessor (using input commands to set the required parameters). The microprocessor stores science data and the Reject Array (which is stored immediately following the last science data) according to observation (data acquisition) parameters; it transmits that data as requested by the values of dump-control parameters set by a separate command. There is no connection between these two (except by convention).

The FOS microprocessor is an interrupt-driven system (with about 10 priority-ranked interrupt levels), so precise answers to timing questions (other than those directly associated with gathering the original observation data) do not exist. For example, if the FOS is doing data acquisition, and the time interval for the accumulators to be open expires, an interrupt is generated to read them out. Since this readout takes longer than 10 msec, it cannot be done while science data is being read out of the FOS data memory (since the SDF interface has a 10 msec timeout). The FOS must therefore stop data gathering while it is feeding science data to the downlink (or the tape recorder), a cyclic process involving the setting of a 16-bit word into an output register, sensing (via an interrupt that is less urgent than that for accumulator readout) that the word has been taken, and loading a new word. The elapsed time for this process to be completed depends on other activity (such as telemetry interrupts) that may also be taking place.

To understand the variability of the mechanism response times, the FOS microprocessor's firmware architecture needs to be recognized. There are five "background tasks" that are executed in a round-robin fashion when an interrupt is not being serviced. These tasks each suspend themselves by a polyFORTH "pause" command that allows the next background task in the sequence to receive CPU time. These background tasks are:

1. The "operator" task that handles the serial magnitude YKEY command. This command can be used in a manner closely analogous to the FORTH reserved word KEY ("Get a single character from the keyboard and push it on the stack").
2. The "terminal interface" task that uses an RS-232 interface. This interface should not be active after launch, although line terminations are being investigated to avoid spurious rubout characters that have been observed in testing.
3. The "data monitoring" task that is used to start target acquisition processing, clear the science data memory (when the proper flags are set), monitor for a data acquisition limit, and similar activities.
4. The "housekeeping" task that computes the ROM checksum, does an abbreviated check of the CPU instruction set, increments a speed-check parameter, and services the serial command watchdog timer (used to confirm that the command link with the NSSC-1 is operational).
5. The "mechanism control" task.

The results of the first three housekeeping-task actions are contained in three 16-bit words in the engineering telemetry:

1. Parameter YERRCHK has the ROM checksum result (which can be compared against the expected value).
2. Parameter YSELFCHK reflects the results of the check of the CPU instruction set. If the expected result is obtained, an "OK" (in ASCII) is set into the parameter; otherwise, the incorrect result of some arithmetic manipulations is stored in the word.
3. Parameter YARITHCK has the value of the speed check parameter. This quantity is reset to zero every 0.5 second. The maximum value observed in a sample set of FOS data was 192.

The elapsed time required to set the FOS mechanisms is determined by logic in the mechanism control background task. This task includes a provision to

delay for one msec of CPU time before doing its polyFORTH "pause". The mechanism timing is defined (as described in Section 3.1.4) by the number of these delays, which are imposed between successive stepper motor phases. The corresponding elapsed time depends on the amount of other FOS microprocessor activity that is taking place. Test cases have been run (for a given environment of microprocessor operation) showing that a delay counter setting of 3 gives about 25 msec; a setting of 23 corresponds to about 100 msec; and a setting of 47 yields 200 msec.

The NSSC-1 has seven FOS processors:

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.
3. Turn Off Processor (YFOFF, processor #27). This processor controls planned FOS turn offs, leaving the FOS with both sides off.
4. Mode 2 Target Acquisition Processor (YFM002, 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.
5. Housekeeping Processor (YFHKPG, processor #30). This processor processes FOS engineering outputs for monitoring FOS health and safety, including Y0VRLITE from the engineering stream.
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 for processing to accomplish both peakup and NSSC-1 controlled Mode 2 target acquisition.

See SLIB 763 for more information on these NSSC-1 processors.

For FOS targeting, the NSSC-1 does a binary search, trying various Y-axis deflections and seeing the effect on the data (as it tries to put the object at the "edge" of the diode array). The FOS operates in response to NSSC-1 commands to set the observation control parameters. Targeting is typically done with the A-1 aperture (4.3 arc seconds) and with the FGWA's CAM (mirror) element. Since the FOS/NSSC-1 science data interface must exist for NSSC-1 targeting, packet format codes (see Section 3.2.4) have been assigned to cover the possibility of downlinking FOS science data from the NSSC-1. This capability, however, is unlikely to be employed; the FOS microprocessor could provide through the NSSC-1 the same information that it normally sends on the downlink directly.

2.0 FOS MODES OF OPERATION

There are three kinds of FOS "modes" that need to be distinguished:

1. Instrument Modes (where control by the FOS electronics causes differences in the measured data due to data-gathering differences);
2. Science Data Modes (settings of Instrument Mode and/or the optics parameters cause different effects); and
3. Ground Software Modes (differences in ground processing that can be a function of the Instrument Mode and/or Science Data Mode).

These modes are treated in separate sections below. Throughout this document, bit 1 is the most significant (or sign) and bit 8 or bit 16 is the least significant (for 8-bit and 16-bit words respectively). The notation "Yxxx" means the LMSC engineering telemetry abbreviated measurement identifier (see Section 4), and "Y.xxx" refers to telemetry that lacks an LMSC identifier. A subscript of "c" with such identifiers means a command ID rather than a measurement ID. Tables 4.2-7 and 4.2-8 list all the FOS commands and telemetry in sequence by the identifier and by mnemonic, respectively.

2.1 FOS INSTRUMENT MODES

The FOS Instrument Mode is defined by engineering telemetry word YACQSYNC/Y535 (see Section 4). This word is loaded by command YACQMODE/Y049_c ("Select Data Acquisition Mode"). The first six bits of the eight-bit word are assigned to the following (the others are spare):

- 1 YYSYNCS/Y.205, Synchronous Start;
- 2 YYTIMTG/Y.206, Time-Tag;
- 3 YYREJRE/Y.207, Reject/-Retry;
- 4 YYTARGA/Y.208, Target Acquisition;
- 5 YYDBLSN/Y.209, Double/-Single Precision Adder; and
- 6 YYAUTPO/Y.210, Automatic Polarizer Sequence.

2.1.1 Synchronous Start Instrument Mode

If this YY SYNC S/Y.205 bit is zero, data acquisition (the first time the FOS Analog Signal Processor's accumulators are turned on to measure outputs from the rate limiters in each channel) starts roughly two seconds after the Begin Data Acquisition command is recognized. The time delay is determined by the (somewhat variable) execution time taken by the FOS microprocessor to complete initialization.

If the bit is one, then a "synchronous start" is performed. This capability would be expected to be used in conjunction with the Time-Resolved Ground Software Mode, but has no impact on the reduction software. After the FOS microprocessor completes its initialization, it drops into a loop to wait for a specified minor frame, and so many oscillator counts (the least increment on the command is 7.8125 usec) after that minor frame begins. At this point, it begins the sampling of the rate limiters in each channel.

The FOS microprocessor initialization (what it does when a Begin Data Acquisition command is acted upon) is set by command YINIT/Y041_c, and reflected in measurement YINTMODE/Y547. Only the first five bits are assigned:

- 1 YYRSMNI/Y.213 is "Resume (no initialization)". The bit is set to cause the FOS microprocessor to "carry on where were." It might be used, for example, after have sent command YENDAC/Y557_c ("End data acquisition at end of pattern").
- 2 YYINHSLT/Y.214 is "Inhibit slice table fill". The FOS microprocessor software has what corresponds to a set of transfer vectors that can control what is done at the start of each slice (see Section 3.1.1.5). The default value (same for all vectors) is set from ROM if the bit is 0; if the bit is 1, the setting from ROM is bypassed (meaning that the vectors could be loaded by command).
- 3 YYINHYDF/Y.215 is "Inhibit Y-deflection table fill". The FOS microprocessor normally computes the DAC Y (and X) 12-bit deflection values (based on the observer-specified control parameters and the DAC scaling) as part of its observation initialization. A value of 0 for this bit means that these computed values for the Y axis should be loaded in the Y-deflection table for use during the observation; if the bit is 1, this loading is bypassed, thus allowing ground-commanded values to be used instead.

- 4 YYINHXDF/Y.216 is "Inhibit X-deflection table fill". See discussion with bit 3, applying similarly to the X axis.
- 5 YYINDFHY/Y.217 is "Do deflection hysteresis pattern at beginning of data acquisition". This pattern currently is expected to be required only at the beginning of each data acquisition. It is in the form of a "big square spiral" that is used for degaussing. Without it, hysteresis effects of the order of a diode width have been seen. Exercise of this option does not have a significant impact on the time line. If it should be necessary to do the pattern before each deflection, the YKEY command (see Section 1.5) could be used to uplink the FOS firmware augmentation.

2.1.2 Time-Tag Instrument Mode

If this YYTIMG/Y.206 bit is zero, the accumulators in the FOS Analog Signal Processor count the output pulses from the rate limiters in each channel. If the bit is one, the accumulators instead count pulses from the 1.024 MHz spacecraft oscillator between "start" and when the first output pulse from the rate limiter is received. This way of operating the instrument is similar to some other current X-ray instrumentation. The bit must be one for the Time-Tagged Ground Software Mode, and zero for the others.

2.1.3 Reject-/Retry Instrument Mode

This YYREJRE/Y.207 bit controls what is to be done if a noise burst is received (above the noise limit value in measurement YNOISELM/Y544). The bit does not control the performance of the rejection logic itself. If YNOISELM is zero, the adder is disabled entirely (and therefore the computation of the overlight sum discussed in Section 2.1.5); a value of X'FFFF' makes the rejection limit unattainable, allowing the adder to still function. If the bit is 1 when Begin Data Acquisition is acted upon, the FOS microprocessor allocates RAM capacity for a Reject Array immediately following the last science data. The bit being 1 means that if a data sample above the noise limit is rejected, FOS should not attempt to retry the measurement. The bit should be 1 for the Time-Resolved, Rapid Readout, and Time-Tagged Ground Software Modes. The Reject Array is downlinked only if so commanded (downlinking, however, is expected to be the normal operating procedure).

If the bit is 0 and a noise burst is received, FOS repeats the measurement with the same value of the beam deflection parameters. The impact of this is that the measurement time tags can slip beyond the expected periods (such as "once/minute" for readouts).

2.1.4 Target Acquisition Instrument Mode

The YYTARGA/Y.208 bit must be 1 for the Target Acquisition Ground Software Mode, and zero for all the others. The FOS microprocessor stops at the end of a set of measurements and puts the newly computed coordinates of the target in the engineering telemetry stream. The NSSC-1 Mode 2 Target Acquisition processor (YFM002, see Section 1.5) uses these coordinates to generate a ST movement request to the SSM.

If the NSSC-1 is doing the targeting (see Section 1.5), this bit is not set. In contrast to the NSSC-1's approach of "looking at data and deciding what to do next," the FOS microprocessor has the approach of "taking data in a gulp and then figuring out from the data where the center is." YTAQIP/Y575 is used to inform the data monitoring background task that the targeting computations must occur. See Section 3.1.5 for the commands and parameters that are associated with FOS targeting.

2.1.5 Double/-Single Precision Adder Instrument Mode

The YYDBLSN/Y.209 bit controls the nature of the addition of the 512-diode output for Y0VRLITE/Y513. For a dim object with an integration time between samples of (for example) 20 msec, a single precision addition (bit set to 0) would be enough (the average output from each of the 2^9 diodes less than 2^6); if the integration time were 10 seconds, however, then a double-precision addition (bit set to 1) to form the 512-diode sum might have to be done. The disadvantage of doing a double precision addition is that additional CPU time is needed, so the sum is under control of this Instrument Mode bit. The bit has no effect on the processing needed for the other information on the downlink. The addition can be disabled (if it is necessary to save CPU time) by setting YNOISELM/Y544 to zero; the adder (and hence computation) is also disabled while FOS science dumps are being performed.

Regardless of how the diode sum is generated, it is added as a 32-bit quantity into YOVLITE/Y513, which therefore has units of "diode counts". The YOVLITE quantity is reset once a minute just after being sampled for insertion in the telemetry. This sampling (as is true for all other multi-byte quantities that are cleared as they are read for telemetry) is set up such that the entire quantity is read and stored in a temporary buffer (while clearing the quantity) at the time of the first byte to occur in the telemetry stream. Hence the entire value as read out in telemetry has an effective sampling time corresponding to the time of the first byte. The set of quantities that are zeroed when they are read, in addition to YOVLITE, includes the following:

1. The words in minor frame 117 and 118 ("DAC" error bits and the bits for YACTMERR, YMECHTOC, and YDATACTL);
2. The target acquisition results contained in YTARXCTR and YTARYCTR (see Section 3.1.5);
3. The serial magnitude error reporting quantities (flags in YSMCERRS and the command in YLASTCMD, see Section 3.1);
4. Bits 6 (YYSAFLKA/Y.202) and 7 (YYSAFTSL/Y.203) in YSAFING; and
5. YREJECTS (see Section 3.1.1.1).

The YOVLITE value is used by the YFHKPG NSSC-1 processor (and can be on the ground) to monitor for excessive light intensity striking the instrument in one of the dispersion modes (it is comparatively ineffective if the mirror is used, since only about five diodes are illuminated then). Viewing the bright earth with the FOS is not allowable (if the mirror were used, a hole could be burned in the cathode); objects with a magnitude of $m_v = 6$ (or brighter) are otherwise of concern for the instrument.

2.1.6 Automatic Polarizer Sequence Instrument Mode

The YYAUTPO/Y.210 bit is used to specify, if 1, that the polarizer should be stepped during the course of the observation. This can be used to cause the polarizer at each slice to move to the next in a series of waveplate angles (the FOS microprocessor waits until the polarizer has reached the new position before taking measurements). Because of data memory capacity constraints, this will probably be used only with a subset of the instrument's

total number of diodes (such as to examine a bright line); the YYINHSLT/Y.214 bit (see Section 2.1.1) is used to inhibit the default loading of the slice table (which is instead filled with commands to do the mechanism movement). The polarizer, of course, can be used even if this FOS Instrument Mode bit is set to 0, so the bit cannot be used to establish that the Spectropolarimetry Ground Software Mode is required.

2.2 FOS SCIENCE DATA MODES

The FOS has four Science Data Modes. They are:

- 1 Imaging,
- 2 Spectrophotometric,
- 3 Time-Resolved Spectrophotometric, and
- 4 Spectropolarimetric.

These classes of science data-taking modes were taken from SLIB 213. An equivalent view of the FOS operating modes could use the six Ground Software Modes (see Section 2.3) defined as such in SLIB 598 but discussed from the observer's viewpoint in SLIB 810. The sequence of presentation in this Section (as suggested in SLIB L64) parallels Sections 2.3.1-2.3.4 respectively. As explained in Section 2.2.3, the Ground Software Modes in Sections 2.3.5 and 2.3.6 are alternatives to Section 2.3.3.

2.2.1 Imaging Science Data Mode

The FOS FGWA has a position with a camera mirror, designed to form a non-dispersed target image on the photocathode. Although the basic purpose of this Science Data Mode is for target acquisition (see Section 2.3.1), it is conceivable that scientific requirements might arise that require data-taking in this Mode.

2.2.2 Spectrophotometric Science Data Mode

It is anticipated that about 90% of the FOS observations will be made in this Science Data Mode (see Section 2.3.2). The observer selects a Digicon sensor and one or more grating settings to provide the desired resolution and wavelength coverage for spectroscopy. The data may later be interpreted photometrically via comparison of the observed count rates with separate external observations of standard stars. Typical exposure times range from about one minute to many hours per selected configuration. The FOS instrument allows a minimum exposure time of about 125 usec (and no maximum exists). Spectra are read out of the FOS microprocessor about every 60 seconds. The frequent readouts result in negligible loss of observing efficiency and protect against catastrophic losses of data.

2.2.3 Time-Resolved Spectrophotometric Science Data Mode

This Science Data Mode is a superset of the Spectrophotometric Mode, with the difference that the science requirements dictate rapid and phase-coherent data acquisition. Several operations options are available in this Science Data Mode. The FOS microprocessor memory may be used to store a number of synchronously phased and co-added spectra (see Section 2.3.3). In a variation of this Mode, when the 1 MHz telemetry downlink (or the on-board tape recorder) is available, there will occasionally be a requirement to transmit each individual 512-diode spectrum (without substepping) as quickly as it is read out, without co-addition (see Section 2.3.5). Programs that involve observations of rapidly varying objects of unknown or unstable periods are an example of candidates for this data-taking Mode. Finally, the Time-Tag Instrument Mode (see Section 2.3.6) permits one additional fast-timing Mode, where the channel accumulators are used to store the number of clock pulses elapsed between an enable pulse and the arrival of the first count in that diode. It is also possible that an observer may occasionally require time-resolved spectropolarimetry, i.e. a combination of the Spectropolarimetric and Time-Resolved Spectrophotometric Science Data Modes.

2.2.4 Spectropolarimetric Science Data Mode

This Science Data Mode is also a superset of the Spectrophotometric Mode. In addition to the sensor, grating, and filter configuration, the observer also specifies one of a pair of waveplates and a sequence of polarizer stepping motions. This can be done using the Automatic Polarizer Sequence Instrument Mode (see Section 2.1.6), but this is not necessary. See Section 2.3.4.

2.3 FOS GROUND SOFTWARE MODES

There are six FOS Ground Software Modes (see SLIB 598):

- 1 Target Acquisition,
- 2 Spectroscopy,
- 3 Time-Resolved,
- 4 Spectropolarimetry,
- 5 Rapid-Readout, and
- 6 Time-Tagged.

It is possible to determine if the FOS science data should be processed using the Target Acquisition Ground Software Mode (the only case in which YYTARGA/Y.208 is 1) or the Time-Tagged Ground Software Mode (the only case in which YYTIMTG/Y.206 is 1). If one of the other four Ground Software Modes (which must have both these bits equal to zero) is necessary, however, the choice (see SLIB T30) cannot be reliably determined from the downlink information (instead, the selection is based on user input). As mentioned in Section 2.2, these could also be considered as FOS operating modes. The order in which the modes are listed is that used by the IDT in SLIB 598 and SLIB 810.

2.3.1 Target Acquisition Ground Software Mode

For the Target Acquisition Ground Software Mode, the Instrument Mode (see Section 2.1.1) must have YYTIMTG/Y.206 equal to 0 and YYTARGA/Y.208 equal to 1. An FOS target acquisition picture will be constructed from a sequence of X-stepped and Y-stepped scans taken in the Imaging Science Data Mode (also referred to as the "direct imaging" mode) with an aperture of size 4.3 arc seconds. See Sections 5 and 7 for references to the processing required.

Faint red targets will usually be acquired and observed on side A, while faint ultraviolet targets imbedded in diffuse red sources will usually be acquired and observed with the bialkali (side B) Digicon. Acquisition on one side and observation on both sides (to get the necessary wavelength range) will be common. In unusual cases, acquisition on one side and observation only on the other will be done.

2.3.2 Spectroscopy Ground Software Mode

For the Spectroscopy Ground Software Mode, the Instrument Mode must have both the YYTIMG/Y.206 and YYTARGA/Y.208 bits equal to 0. This will probably be the most commonly used Ground Software Mode. See Sections 5 and 6 for references to the processing required.

2.3.3 Time-Resolved Ground Software Mode

For the Time-Resolved Ground Software Mode, the Instrument Mode must have both the YYTIMG/Y.206 and YYTARGA/Y.208 bits equal to 0 and the YYREJRE/Y.207 bit equal to 1. This Ground Software Mode will be used to study objects with known periodicity in about the 50 msec to 100 second range, and is expected to generate data comprising 5-10% of all FOS observations (a typical observation might last 60 minutes). Spectra are folded into a predetermined number of time bins (or 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. The YYSYNCS/Y.205 bit will be set if the precise phase of the data is important to the observer (if it is not set, this absolute phase is not important). Ground processing is the same regardless of this bit. See Sections 5 and 6 for references to the processing required.

2.3.4 Spectropolarimetry Ground Software Mode

For the Spectropolarimetry Ground Software Mode, the Instrument Mode must have both the YYTIMG/Y.206 and YYTARGA/Y.208 bits equal to 0. There will usually be 64 spectra taken in a single polarization observation (32 stellar spectra and 32 background spectra). Half of each group will have been taken with the Digicon deflected to $[X_1, Y_1]$ and the other half with it deflected to $[X_2, Y_2]$. The usual configuration will have $[X_1 = X_2]$, but $[Y_1 \neq Y_2]$. It is not necessary to have the YYAUTPO/Y.210 bit set for this Ground Software Mode. See Sections 5 and 6 for references to the processing required.

2.3.5 Rapid-Readout Ground Software Mode

For the Rapid-Readout Ground Software Mode, the Instrument Mode must have both the YYTIMTG/Y.206 and YYTARGA/Y.208 bits equal to 0 and the YYREJRE/Y.207 bit equal to 1. 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. The Time-Resolved Ground Software Mode is unsuitable since the bin folding period (the period of the signal) must be set in advance. Instead, normal FOS data taking is used, but the spectra are read out at very frequent intervals, rather than the approximately 60-second integration times anticipated for normal FOS data-taking. The shortest integration time is estimated to be 20 msec. The rapid-readout capability requires the 1 MHz downlink (or use of the on-board tape recorder). This Ground Software Mode is expected to generate data comprising 2-5% of all FOS observations (a typical observation might last 60 minutes), but a disproportionately large data volume. See Sections 5 and 6 for references to the processing required.

2.3.6 Time-Tagged Ground Software Mode

For the Time-Tagged Ground Software Mode, the Instrument Mode must have the YYTIMTG/Y.206 and YYREJRE/Y.207 bits equal to 1, and the YYTARGA/Y.208 bit equal to 0. This will probably be the least used Ground Software Mode, but will allow study of the most rapid variability possible using the FOS. Periodic or aperiodic variability on timescales in the range of about 10 usec to 50 msec are well-suited to study in this Ground Software Mode, which is expected to generate data comprising 2-5% of FOS observing time, although far more than this percentage of FOS data. A typical observation might last 60 minutes. See Sections 5 and 6 for references to the processing required.

3.0 FOS SCIENCE TELEMETRY

3.1 FOS SCIENCE TELEMETRY OVERVIEW

As stated in SLIB 598:

FOS data arrives in logical units denoted as "frames" at a commandable frequency typically about once per minute. One or more frames constitute an observation, which will have been pre-defined to correspond to a scientifically logical unit of data.

The definition of an "observation", therefore, is significant for understanding how the FOS science data is to be processed. An observation consists of the following:

- a) The NSSC-1 (SI C&DH computer) Standard Header Packet. The transmission of the Standard Header Packet is commanded through the NSSC-1. According to SLIB T23, the YFHKPG NSSC-1 processor can request the SHP every N (a commandable parameter in the NSSC-1 software) major frames when the CEA indicates that it is acquiring data. The YFSDPR NSSC-1 processor issues an SHP for each map that is taken, and Mode 2 Target Acquisition also outputs SHPs. In any event, however, an SHP will be output at the start of each observation.
- b) The FOS-Unique Data Log (from the FOS microprocessor). Prior to the transmission of this log, the science telemetry format is changed to reflect 965 data words per line and one line per telemetry frame (see Section 3.2.4 for definitions of these terms). According to SLIB T23, the UDL may be dumped more frequently than once per observation.
- c) One or more frames of science information (from the FOS microprocessor), each of which can contain a Science Header, a Science Data Array, and a Reject Array. Only the Science Data Array must be present in the data processed in all Ground Software Modes. Prior to the start of transmission of the science information, the science telemetry format is changed to reflect the science information's number of words/line and number of lines/frame.

There are typically many frames of science information in an FOS observation, usually spaced (for telemetry transmission) at one to five-minute centers. As mentioned in Section 1.5, there is no connection between the observation (data acquisition) parameters and the downlink control parameters (except

what may happen to exist if conventions are followed). Further details on the transmission characteristics are provided below:

1. Command YSCIDMP/Y002 (see Section 3.1.2.1) can be used to specify the memory dump start address, the number of words/line, and the number of lines/frame. These quantities are all in the engineering telemetry.
2. The SDF and the FOS microprocessor must be compatible in their expectations of the number of words/line and lines/frame for the telemetry to function.
3. The maximum number of data words/line (see Section 3.2.4) is 965. For some observations (although this is not required), a convention may be used that keeps an association between the SDF (and hence FOS microprocessor) "line" and how the observer thinks of a "line". If this convention happens to be used, a typical FOS line size could be 521 words, corresponding to 512 channels (i.e., all the diodes being used) and an OVRSCN (see Section 3.1.1.3) value of 10.
4. The total number of words per frame can potentially be up to the full 12K words (address X'A000' to X'FFFE') allocated in the FOS RAM to science information (see Section 3.2.3). An integral number of lines must be sent in a frame, however, and all lines in a frame must have the same number of words.
5. In some FOS applications, it may be necessary to reduce the line size to gain speed (would send fewer channels to the ground). Another technique to gain speed would be to eliminate the Science Header. Finally, the most efficient use of the telemetry format requires a line length of $[50 + 61 * n]$ words (n an integer in the [0-15] range, 15 giving 965 words).
6. Because of the characteristics of the FOS/SDF interface (see Section 1.5), the FOS must stop data gathering while it is feeding information to the downlink (or tape recorder).

Control of the FOS instrument can be accomplished by "command sequences" (see SLIB 763 for examples) that are comprised of individual commands. There are three types of FOS-unique commands:

1. Discrete Relay Commands are used to control FOS input power to the various power supplies. They are also used to control critical failsafe hardware, the internal common bus, and science data port cross-strapping.
2. Discrete Logic Commands are used to reset the FOS microprocessor; start, end, and abort data acquisition; reset internal error flags; and select the FGWA motor.

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

The commands in the first two types are listed in Table 3.1-1 (in the order they are presented in SLIB 753, but using the notation of SLIB 1088 that omits the RIU designation), while the Serial Magnitude Commands (in the order shown graphically in SLIB 753, and described in SLIB 683) are listed in Table 3.1-2. These tables also give the section in this document where the command is discussed. The first seven commands in Table 3.1-2 are "Type 3 commands" (having a four-bit command code and a 12-bit data field); all others are "Type 4 commands", which have a four-bit command code, four-bit modifier field, and eight-bit data field.

Bits Y.219-Y.221 in the command error flag word (YSMCERRS/Y649) distinguish between Type 3 and Type 4 commands. Bits Y.223-Y.226 of this word have reference in their definitions to "illegal path". If any of these bits are set, a malfunction of the FOS microprocessor is indicated. There is no combination of normal commands that should cause the indicated path to be taken, since the command parameters are checked before the branching based on them is taken. YSMCERRS and the associated command in YLASTCMD/Y543 are zeroed after being sampled for telemetry (see the list in Section 2.1.5).

For the purposes of this document, the FOS commands (except for most of the Discrete Relay ones, since their functions are self-evident) have been divided into the following categories:

- 1 Loop Control Commands,
- 2 Other Downlink Control Commands,
- 3 Digicon Commands,
- 4 Mechanism Commands,
- 5 Targeting Commands, and
- 6 Miscellaneous Commands.

These commands, with their associated telemetry, are covered in Sections 3.1.1-3.1.6 respectively. Section 3.1.7 lists the major FOS flags and indicators required for processing.

Table 3.1-1 FOS Discrete Commands

<u>Cmd ID</u>	<u>Mnemonic</u>	<u>Role</u>
<u>Discrete Relay Commands</u>		
Y505 _c	YSAFAP	Safe Aperture command. See Section 3.1.4.2
Y507 _c	YSAFED	Safe Entrance Port command. See Section 3.1.4.1
Y515 _c	YSAFPPL	Safe Polarizer command. See Section 3.1.4.3
Y501 _c	YARMAP	Arm Aperture command. See Section 3.1.4.2
Y503 _c	YARMED	Arm Entrance Port command. See Section 3.1.4.1
Y511 _c	YARMPL	Arm Polarizer command. See Section 3.1.4.3
Y579 _c	YBUSS1	A-On, B-Off S1 command.
Y581 _c	YBUSS2	A-On, B-Off S2 command.
Y517 _c	YHVOFF	High Voltage Supply Off command.
Y519 _c	YHVON	High Voltage Supply On command.
Y521 _c	YQSOFF	Quiet Supply Off command.
Y523 _c	YQSON	Quiet Supply On command.
Y525 _c	YLSOFF	Logic Supply Off command.
Y527 _c	YHTON	Heater On command.
Y529 _c	YSDFB4	SDF B4 port to side select command.
Y531 _c	YSDFB2	SDF B2 port to side select command.
Y533 _c	YSDFB3	SDF B3 port to side select command.
Y535 _c	YSDFB1	SDF B1 port to side select command.
Y537 _c	YSDFA4	SDF A4 port to side select command.
Y539 _c	YSDFA2	SDF A2 port to side select command.
Y541 _c	YSDFA3	SDF A3 port to side select command.
Y543 _c	YSDFA1	SDF A1 port to side select command.
Y569 _c	YLS0N	Logic Supply On command.
Y585 _c	YCALS8	Select Calibration Lamp B command. See Section 3.1.6.4
Y583 _c	YCALSA	Select Calibration Lamp A command. See Section 3.1.6.4
Y547 _c	YHTOFF	Heater Off command.
Y577 _c	YCALOF	Spectral Calibration Lamp Off command. See Section 3.1.6.4
Y575 _c	YCALON	Spectral Calibration Lamp On command. See Section 3.1.6.4
Y561 _c	YBLAPR	Blow Aperture command. See Section 3.1.4.2
Y563 _c	YBLENT	Blow Entrance Port command. See Section 3.1.4.1
Y567 _c	YBLPOL	Blow Polarizer command. See Section 3.1.4.3
Y625 _c	YSTBY1	RIUA SBY1 command.
Y627 _c	YSTBY2	RIUA SBY2 command.
<u>Discrete Logic Commands</u>		
Y571 _c	YCMTRA	Select Motor A command. See Section 3.1.4.4
Y573 _c	YCMTRB	Select Motor B command. See Section 3.1.4.4
Y545 _c	YRESET	Reset Microprocessor command. See Section 3.1.6.5
Y549 _c	YRIEBW	Reset IEB/Watchdog command. See Section 3.1.6.5
Y551 _c	Y3MHZ	Select 3.0 MHz Clock command. See Section 3.1.6.5
Y553 _c	Y1:5MZ	Select 1.5 MHz Clock command. See Section 3.1.6.5
Y555 _c	YABACQ	Abort Data Acquisition command. See Section 3.1.2.3
Y557 _c	YENDAC	End Data Acquisition command. See Section 3.1.2.3
Y559 _c	YBEGAC	Begin Data Acquisition command. See Section 3.1.2.3

Table 3.1-2 FOS Serial Magnitude Commands

<u>Cmd ID</u>	<u>Mnemonic</u>	<u>Role</u>
<u>Type 3 Commands</u>		
Y024 _c	YX-DEFL	Set X-deflection amplifier DAC. See Section 3.1.3
Y025 _c	YY-DEFL	Set Y-deflection amplifier DAC. See Section 3.1.3
Y026 _c	YX-BASE	Base value for X deflection computations. See Section 3.1.3
Y027 _c	YY-BASE	Base value for Y deflection computations. See Section 3.1.3
Y028 _c	YX-PITCH	Scaled X-deflection DAC value for one diode width in X. See Section 3.1.3
Y029 _c	YY-PITCH	Scaled Y-deflection DAC value for one diode width in Y. See Section 3.1.3
Y030 _c	YHV_DAC	Set high voltage power supply DAC. See Section 3.1.3
<u>Data Commands</u>		
Y000 _c	YRAMADDR	Load RAM storage address. See Section 3.1.6.3
Y002 _c	YSCIDMP	Set dump parameters. See Section 3.1.2.1
Y004 _c	YTARACQ	Set target acquisition parameters. See Section 3.1.5
Y006 _c	YDISCADDR	Load discriminator at address or set all values. See Section 3.1.6.2
Y008 _c	YLIVETYM	Set accumulator open (live) time. See Section 3.1.1.1
Y010 _c	YDEADTYM	Set accumulator closed (dead) time. See Section 3.1.1.1
Y012 _c	YCHNLEN	Enable/inhibit channel(s). See Section 3.1.6.2
Y014 _c	YREJLIM	Set noise rejection limit. See Section 3.1.1.1
Y016 _c	YACQLIM	Set data acquisition limit. See Section 3.1.2.3
Y018 _c	YSTRWRD	Store next commands as data. See Section 3.1.6.3
Y022 _c	YMECHCAL	Set feedback code for mechanism. See Section 3.1.4
Y023 _c	YSYNC	Set delay for starting synchronous acquisition. See Section 3.1.6.1
Y059 _c	YSCIADDR	Set first RAM address for science data. See Section 3.1.6.5
<u>DAC Commands</u>		
Y031 _c	YDISC	Set discriminator DAC table value. See Section 3.1.6.2
Y032 _c	YREFDAC	Set common discriminator reference DAC. See Section 3.1.6.2
Y033 _c	YFOCUS	Set focus trim DAC. See Section 3.1.3
Y038 _c	YFFCAL	Set LED flat-field lamp on or off. See Section 3.1.6.4
<u>Mechanism Commands</u>		
Y034 _c	YENTRNC	Set entrance port open or closed. See Section 3.1.4.1
Y035 _c	YAPER	Set entrance aperture to position. See Section 3.1.4.2
Y036 _c	YPLZR	Set polarizer mechanism to position. See Section 3.1.4.3
Y037 _c	YFILTER	Set FGWA to position. See Section 3.1.4.4

Table 3.1-2 FOS Serial Magnitude Commands (cont)

<u>Cmd ID</u>	<u>Mnemonic</u>	<u>Role</u>
Y087 _c	YMCHREG	Set mechanism register to drive signal. See Section 3.1.4
Y056 _c	YMCHSTEP	Step mechanism. See Section 3.1.4
<u>Software Parameter Commands</u>		
Y039 _c	YX-STEP	Select number of X deflection steps. See Section 3.1.1.2
Y040 _c	YX-DLY	Spare.
Y041 _c	YINIT	Set initialization mode. See Section 3.1.6.1
Y042 _c	Y1STCHNL	Set first channel to be processed. See Section 3.1.2.2
Y043 _c	YINTS	Set number of sub-integrations per X-step. See Section 3.1.1.1
Y066 _c	YY-RNGE	Set range for Y deflection. See Section 3.1.1.4
Y045 _c	YOUT-CLR	Set readouts/memory clear. See Section 3.1.1.7
Y046 _c	YTAMOD	Set target acquisition mode. See Section 3.1.5
Y047 _c	YY-STEP	Set number of Y deflection steps. See Section 3.1.1.4
Y048 _c	YY-DLY	Spare.
Y049 _c	YACQMODE	Set data acquisition mode. See Section 3.1.6.1
Y050 _c	YCHNLS	Set number of channels to be processed. See Section 3.1.2.2
Y051 _c	Y0VRSCAN	Set number of diodes overscan. See Section 3.1.1.3
Y068 _c	YSLICES	Set number of memory slices. See Section 3.1.1.5
Y053 _c	YCLEAR	Set number of memory clears/acquisition. See Section 3.1.1.8
Y054 _c	YPTRNOUT	Set number of patterns/readout. See Section 3.1.1.6
<u>Diagnostic Commands</u>		
Y052 _c	YRAM-MAP	Map physical to logical RAM page. See Section 3.1.6.5
Y044 _c	YSTOPDMP	Stop science dump. See Section 3.1.2.3
Y055 _c	YMEMCHK	Fill science memory with test pattern. See Section 3.1.6.3
Y058 _c	YKPALVED	Enable/disable autonomous going safe. See Section 3.1.6.5
Y057 _c	YSDERASE	Clear science memory locations. See Section 3.1.6.3
Y070 _c	YSCIACT	Control science data dump. See Section 3.1.2.3
Y071 _c	YKEY	Provide FORTH KEY capability. See Section 3.1.6.5
Y083 _c	YDDCHK	Sample all discriminator DACs. See Section 3.1.6.1
Y084 _c	YEFILL	Sample all serial digital telemetry. See Section 3.1.6.1
Y085 _c	YPAUSE	Set/reset pause acquisition bit. See Section 3.1.2.3
Y086 _c	YRANDOM	Fill science memory with pseudo-random sequence. See Section 3.1.6.3

3.1.1 Loop Control Commands

The FOS microprocessor has a set of control parameters used for its loop control. These parameters are commanded (rather than having the FOS microprocessor adaptively determine them), and all of them are in the engineering telemetry (and hence the Science Header and FOS-Unique Data Log) described in Section 4. In the sequence from the inner-most to outer-most loop, and using the notation of a figure in SLIB 753, these quantities are:

- 1 Number of Integrations (INTS),
- 2 Number of X-Steps per Diode (XSTEPS),
- 3 Number of X-Diodes (OVRSCN),
- 4 Number of Y-Steps (YSTEPS),
- 5 Number of Slices (SLICES),
- 6 Number of Patterns/Readout,
- 7 Number of Readouts/Memory Clear, and
- 8 Number of Memory Clears/Acquisition.

In principle, the starting channel and number of channels sampled could be considered as loop "0" (see Section 3.1.2.2). To the end of this list could also be added (conceptually, since of course it is not an explicit parameter) the quantity "Number of Acquisitions/Space Telescope Lifetime". Once the FOS microprocessor falls out of the "8" loop, aside from setting bit YNDAIP/Y571 it takes no further action pending another "Begin Data Acquisition" (command YBEGAC/Y559_c) that initiates the whole process again. Since these loop control parameters are so significant to FOS operation, they are discussed in detail below.

3.1.1.1 Number of Integrations (INTS)

INTS, the number of integrations, controls the number of open time/close time pairs of FOS Analog Signal Processor samples of the output from the rate limiter that are done. It is commanded by YINTS/Y043_c and telemetered in YINTEG/Y546. A zero value means that 256 of these sub-integrations should be performed for each XSTEPS (see Section 3.1.1.2) value.

The accumulator "open time" (interval during which accumulator counting is enabled) is specified by command YLIVETYM/Y008_c in units of 7.8125 usec (8 periods of the 1.024 MHz spacecraft oscillator). Although the command

specifies this time directly, the telemetered value in YLIVEHI/Y585 and YLIVELO/Y586 is (due to the nature of the hardware) in two's complement form. To convert the downlink value to the "true" time in microseconds, the 16-bit value can be converted to decimal, subtracted from 2^{16} (65536), and then multiplied by 7.8125.

The time interval is controlled by the spacecraft clock (and a high-urgency interrupt) rather than being dependent on FOS microprocessor background computing delay times (see Section 1.5). The minimum reasonable accumulator open time is about 3 msec (since a telemetry sync interrupt can take a couple of milliseconds to service). In special cases, the telemetry could be disabled, thus reducing the minimum to the about 800 clock ticks (781.25 usec) that are needed to service the interrupt. Since 16 bits are allocated, a maximum of 512 msec can be set for the time during which the accumulators are to count the FOS rate limiter outputs.

Similarly, the accumulator "close time" (interval during which accumulator counting is disabled) is specified by command YDEADTYM/Y010_c in the same units (7.8125 usec). The telemetered value in YDEADHI/Y587 and YDEADLO/Y588) again is in two's complement form. The accumulators are inhibited every timer cycle to allow for data readout. Other uses of the capability include while the magnetic deflection system is moving the beam to a new position or if, for some other reason, a "garbage" output would otherwise be expected. To allow for the FOS microprocessor computations, the sum of the accumulator live and dead times must be above a value that depends on the instrument mode (30 msec is a good rule of thumb). If the accumulated count per integration is large, then the Double/-Single Precision Adder Instrument Mode bit must be set to 1 (see Section 2.1.5).

A major application of INTS is to minimize the amount of data lost due to transients, since the FOS hardware can respond to relay glitches and could reasonably be expected in 512 msec to take cosmic ray "hits". If, rather than a single 512-msec interval, had 10 intervals of about 51 msec, then editing in the FOS microprocessor could detect inputs above a burst noise rejection limit (command YREJLIM/Y014_c, telemetered in YNOISELM/Y544) and

reject them. For a faint object with an interval of 25-50 msec, the limit probably will be set to 2, since the overwhelming probability is a count of zero. A zero value for YREJLIM disables the adder entirely (and therefore the computation of the overnight sum, see Section 2.1.5), while a value of -1 (X'FFFF') makes the rejection limit unattainable (allowing the adder to still function). Rejection is of the complete sample from all channels for that particular interval: this is accompanied either by a "retry" or by an update of the Reject Array (the latter would be chosen if the time phasing of the measurements was critical). If YYREJRE/Y.207 is 1, the Reject Array is updated. The count of the number of rejects (cleared each time the value is sampled, see SLIB T30) is given in 16-bit measurement YREJECTS/Y652, which is incremented regardless of whether the Reject Array is being used. There is no limit in the FOS microprocessor software on the number of times a given measurement can be retried.

3.1.1.2 Number of X-Steps per Diode (XSTEPS)

The 12-bit FOS Digicon X-axis DAC deflection control has a nominal scaling (see Section 1.5) of 32 least increments per X-axis diode width. The parameter XSTEPS (command YX-STEP/Y039_C, telemetered in YXSTEPS/Y524) specifies the number of steps to be done over a single diode's width. For example, [XSTEPS = 4] would cause a measurement "at" the diode, then at [diode+0.25], [diode+0.50], and [diode+0.75]. Steps go in the +X direction. Expected values for XSTEPS are 1, 2, 4, 8, and 16 (with 4 the typical value). There is no restriction that the quantity be a power of 2, however. A setting of 32 for XSTEPS is considered unreasonable, 16 gets to noise, 8 is overkill, 4 is about right, and 2 is coarse.

For speed reasons, the FOS microprocessor for a given scan of the diode-path buffer registers increments its RAM channel counters at successive addresses. This means that, for a given XSTEPS-controlled offset (such as for [diode +0.50]), all the channel readouts are grouped together. For subsequent processing, however, it is necessary to arrange the information in meaningful wavelength order, so that the readouts must progress [element], [element +0.25], [element+0.50], and [element+0.75], followed by the next element's result for the four XSTEPS-controlled offsets. This reordering (or unscrambling) process is covered in Section 3.2.3.2.

3.1.1.3 Number of X-Diodes (OVRSCN)

XSTEPS controls the fractional diode X-axis step logic. OVRSCN (command YOVRSCAN/Y051_c, telemetered in YOVRSCAN/Y530) controls the number of integral X-axis diodes over which the X-axis deflection process is continued. For example, if [XSTEPS = 4] and [OVRSCN = 3], then a total of 12 successive X-axis measurements, each spaced (after the first) by 0.25 diode, would be taken. In the FOS microprocessor, the memory cell boosted from diode #3's output for the first of these 12 measurements would be boosted from diode #4's output for the fifth measurement, and from diode #5's output for the ninth, since (for perfect deflection hardware performance) these samples reflect a light stimulus of identical wavelength. It is this process that causes the FOS RAM cells to contain "element" information (in contrast to "channel" data that they would have in the special case of [OVRSCN = 1]). See Section 3.2.3.2 for the arrangement of the resulting words in FOS memory.

Having [OVRSCN > 1] causes a filtering on the output of the various diodes, as well as permitting compensation for a failed channel (that otherwise would produce a "gap" in the spectrum data). A commanded value of 0 is interpreted to be 256, but hardware limits meaningful use to values from 1 to 128. Although a value of 64 has been run, a more typical value is 10. Due to the OVRSCN parameter, the data at either end of the sampled group of channels must be compensated to recognize (even if the Reject Array is not involved) that fewer samples are collected for them.

3.1.1.4 Number of Y-Steps (YSTEPS)

The OVRSCN parameter is the last of the group of parameters controlling the FOS microprocessor's looping for the X axis. YSTEPS (command YY-STEP/Y047_c, telemetered in YYSTEPS/Y528) is used to control the deflection in the Y direction (perpendicular to the X-axis dispersion direction). A typical value is 2, allowing one value to be for the object and the other to reflect a sky background. A commanded value of 0 is interpreted to be 256.

In the FOS design, the X and Y axes were kept as symmetrical as possible. Deflections for both start at a "base" value (YXBASE and YYBASE in Section 3.1.3), and in both there is the concept of a "deflection range" and the

"number of steps in that range." The deflection range for X is defined to be one diode width, whereas for Y it is determined by a command. The number of steps for X is given by XSTEPS (see Section 3.1.1.2), and for Y it is YSTEPS. Since for X the steps are counted including the first point ([XSTEPS = 2] provides a measurement "at" the diode and at [diode + 0.5], with subsequent offsets controlled by OVRSCN as described in Section 3.1.1.3), a similar procedure is followed for the Y axis.

The YY-RNGE/Y066_c command (telemetered in YRANGE/Y555) selects the range over which the Y deflection is to occur: for N YSTEPS, the bottom [(N-1)/N] fraction of the full area will be covered. Hence in the frequently useful case where need only two different Y deflections, YYBASE gives the first value, and [YRANGE/2] gives the offset for the second. This means that YRANGE must be set to twice the second Y value's desired offset from YYBASE. The scaling of YY-RNGE is such that a parameter value of 128 corresponds to the full nominal deflection capability, implying (since the DAC is 12 bits) that must scale the information by 2⁵. Successive nominal increments are offset (always in the +Y direction) by:

$$(YRANGE * 32)/YSTEPS.$$

As discussed in Section 1.5, the observer can set the FOS deflection parameters based on the design-nominal deflection scaling; the actual values loaded into the DACs are scaled by the FOS microprocessor (using YXPITCH and YYPITCH discussed in Section 3.1.3).

3.1.1.5 Number of Slices (SLICES)

SLICES (command YSLICES/Y068_c, telemetered in YMSLICES/Y576) is the final FOS microprocessor control parameter impacting the choice of RAM storage cells. It is used to cause a repetition (in a different area of the memory) of the XSTEPS-OVRSCN-YSTEPS collection of data. One application of the parameter is to segment the data for subsequent processing in the Time-Resolved Ground Software Mode to permit study of objects with known periodicity (each "slice" corresponds to a predicted phase). Another use of SLICES is in conjunction with the Automatic Polarizer Sequence Instrument Mode (see Section 2.1.6). A commanded value of 0 is interpreted to be 256. If a value above 1 is needed,

typical settings are 4-8, with maximum expected value of 20. Alternatively, a large value of SLICES could be used with a small value for the number of channels to analyze aperiodic or unknown-period time variability.

3.1.1.6 Number of Patterns/Readout

The collection of data over the selected number of elements (including the effect of OVRSCN), for each XSTEP, for each YSTEP, and then for each SLICE constitutes a group of FOS RAM data that is referred to as a "pattern". Its physical significance, however, is merely a set of contiguous FOS microprocessor RAM cells. Patterns/readout (command YPTRNOUT/Y054_c, telemetered in YPTRNS/Y577) determines how many collection pattern sequences (for each XSTEP, for each YSTEP, and then for each SLICE, each sequence incrementing the same FOS microprocessor RAM cells at the corresponding point) occur before a "frame" of science information is telemetered. A commanded value of 0 is interpreted as 256. A typical setting would be to cause a readout about once per minute. Comparatively frequent readouts are desirable to ensure against loss of data (due to data transmission problems), as well as to help permit compensation for possible radiation-induced transients in the FOS RAM (manual checks could reveal where an excessive discontinuity occurred). If the Reject Array is not used, the actual transmission period of the information can be variable, depending on the number of retries that are triggered by the burst noise rejection limit commanded by YREJLIM/Y014_c (see Section 3.1.1.1).

3.1.1.7 Number of Readouts/Memory Clear

Readouts/memory clear (command YOUT-CLR/Y045_c, telemetered in YREADCYC/Y548) is used to determine how often the RAM cells reflecting the counts accumulated for each element are reset. Doing the readouts without memory clears means that a subsequent readout would have sufficient data to do the processing. If, for example, do a readout every 5 minutes, the readout after 60 minutes, if successful, would reflect all the data measurement results gathered for that hour. For high input rates or long sampling intervals, however, it is necessary to reset the RAM science information (with a nominal starting address of X'A000') cells to zero periodically so that the analysis will not be complicated by overflow of the 16-bit RAM word (see also command

YACQLIM/Y016_c in Section 3.1.2.3). If, for instance, there is a 5 hour observation, the specification might be to reset the memory every hour. This means that the analysis activity eventually would have to retrieve the final frame within each hour for processing, combining the counts with the corresponding ones in the other four hours. Clearing occurs after the last readout in the sequence. A commanded value of 0 would result in indefinitely long observations (continuing until otherwise stopped). If the time phasing of the measurements is critical, this quantity should have a value of 1, since the phasing cannot be guaranteed across the readout interval.

3.1.1.8 Number of Memory Clears/Acquisition

Memory clears/acquisition (command YCLEAR5/Y053_c, telemetered in YREADCYL/Y548) is the final criterion determining when an "observation" is completed (with memory clears every hour, it would be set to 5 if the desired length of the complete observation was 5 hours). As with the other times, the values are "nominal" if the Reject Array is not used, because of the possibility of retries. A commanded value of 0 would result in indefinitely long observations (continuing until otherwise stopped).

3.1.2 Other Downlink Control Commands

As mentioned previously, the FOS science information is basically a dump of an area of the FOS microprocessor memory. In addition to the loop control quantities discussed in Section 3.1.1, commands in the following categories also control the output:

- 1 Dump Parameter Command,
- 2 Channel Selection Commands, and
- 3 Acquisition/Dump Commands.

These are discussed in the following sections.

3.1.2.1 Dump Parameter Command

Command YSCIDMP/Y002_c can be used to specify the memory dump start address, the number of words per line, and the number of lines per frame. Depending on a command parameter, only the last two, or only the last, quantity can also be set by the same basic command. These quantities are telemetered in YMDDMPADR/Y550, YWRDSSLIN/Y551, and YLINSFRM/Y552 respectively.

As discussed in Section 3.2.3, the memory dump start address typically will be set to cause transmission of one line (YWRDSLIN) of Science Header data before the Science Data itself, although this constraint is not enforced by the on-board software.

The number of words/line is a maximum of 965 (a limit imposed by other ST systems, see Section 3.2.4), but for some observations probably will be set to:

$$M = CHNLS + OVRSCN - 1,$$

where CHNLS is the number of channels to be processed (see Section 3.1.2.2) and OVRSCN is the overscan parameter (see Section 3.1.1.3). For typical values of [CHNLS = 512] and [OVRSCN = 10], therefore, [M = 521]. There is no constraint on the operation of the FOS that requires this convention to be observed, since the downlinking process is fundamentally a dump of a part of the FOS microprocessor's memory, and therefore need have no simple relationship to the deflection sequence when the data was gathered.

The number of lines/frame that are required can be determined from:

$$N = SHL + #SL + #STL,$$

where SHL is the number of lines for the Science Header (=1, see Section 3.2.3), #SL is the number of Science Lines, and #STL is the number of Science Trailer Lines. The value for #SL is determined from:

$$#SL = XSTEPS * YSTEPS * SLICES,$$

where XSTEPS, YSTEPS, and SLICES are discussed in Sections 3.1.1.2, 3.1.1.4, and 3.1.1.5 respectively. Note that the parameters in Sections 3.1.1.6-3.1.1.8 do not impact the format of the output. Finally, the value for #STL is determined from:

$$#STL = [(WRA + M - 1)/M],$$

where WRA is the number of words in the Reject Array (if it is needed, see Section 3.2.3.3), a truncated division is used, and M is the number of words/line computed above. WRA is given by:

$$WRA = XSTEPS * OVRSCN * YSTEPS * SLICES,$$

where the parameters have already been cited.

3.1.2.2 Channel Selection Commands

The first channel in the detector array to be processed is selected by command Y1STCHNL/Y042_c (telemetered in Y1STCHNL/Y531). The first physical channel is numbered #0, and the actual channel to be used is given by two times the data field (in both the command and the telemetry). Hence before being used in computations, the value must be multiplied by 2.

CHNLS, the number of channels in the detector array to be processed, is specified by command YCHNLS/Y050_c (telemetered in YNUMCHNL/Y532). The actual number of channels to be used is given by two times the data field (in both the command and the telemetry), except that a value of 0 means all 512 channels. Before being used in computations, these compensations must be made.

3.1.2.3 Acquisition/Dump Commands

There are several commands provided to control data acquisition and dumping. They include:

1. YBEGAC/Y559_c, used to Begin Data Acquisition. When it is received, telemetry bit YYBEGNDA/Y.227 is set 1 (the bit is zeroed when it is read out as part of minor frame 118, see Section 2.1.5).
2. YENDAC/Y557_c, used to End Data Acquisition (at the end of the next pattern). When it is received, telemetry bit YYENODA/Y.228 is set 1 (the bit is zeroed when it is read out).
3. YABACQ/Y555_c, used to Abort Data Acquisition immediately. When it is received, telemetry bit YYABRTDA/Y.229 is set 1 (the bit is zeroed when it is read out).
4. YPAUSE/Y085_c, used to Pause Data Acquisition (without disturbing the data acquisition counters). The same command is used to resume data acquisition. When a pause is in progress, telemetry bit YPIP/Y573 is set 1.
5. YACQLIM/Y016_c, used to set the data acquisition limit (if any datum exceeds this peak limit, acquisition is ended at the next readout opportunity). Although this could give the FOS a capability similar to the "exposure meter" method of operating the HRS, it is not planned for use. The high-order byte of the value is telemetered in YDATALIM/Y549 (there is no down-link monitoring available of the value of the low byte).
6. YSTOPDMP/Y044_c, used to stop a science dump immediately and disable further automatic science dumps. Telemetry bit YSDIP/Y584 is set if a science dump is in progress.

7. YSCIACT/Y070, used to activate an immediate science data dump and disable or enable automatic science data dumps. Telemetry bit YSDIP/Y584 is set if a science dump is in progress.

3.1.3 Digicon Commands

There are eight commands provided to control the various Digicon DACs, as well as to provide data-base values for the FOS microprocessor to be used for its DAC-related computations. All except YFOCUS are "Type 3" commands in Table 3.1-2, meaning that they have a 12-bit data field. These commands are:

1. YX-DEFL/Y024 sets the X-deflection amplifier DAC to the 12-bit command value. After loading, the DAC is read and YXDACERR/Y558 is set if an error is found. The DAC readback is in YXDAC/Y553. Both the command and the readback have the actual hardware setting (they are not impacted by YXPITCH).
2. Similarly, YY-DEFL/Y025 sets the Y-deflection amplifier DAC (YYDACERR/Y559 is set if an error is found on readback). The DAC readback is in YYDAC/Y521.
3. YX-BASE/Y026 sets the base deflection value for X deflection table computations to the 12-bit command value. The quantity is telemetered in YXBASE/Y523. The value is scaled using the nominal 32 DAC increments/diode width (see Section 1.5). Negative values are expressed in two's complement form (sign extension occurs for the YXBASE telemetry value).
4. Similarly, YY-BASE/Y027 sets the base deflection value for Y deflection table computations (see Section 3.1.1.4). This quantity is telemetered in YYBASE/Y527. The value is scaled using the nominal 256 DAC increments/diode height (see Section 1.5). Negative values are expressed in two's complement form (sign extension occurs for the YYBASE telemetry value).
5. YX-PITCH/Y028 uses the 12-bit command value to set the scaled X-deflection DAC value which when added to the current deflection will produce one diode width deflection in the X direction. It is telemetered in YXPITCH/Y522. The least significant bit of this quantity corresponds to [1/64] of a DAC increment. For example, a value of X'0600' (decimal 1536) means that [1536/64 =] 24 DAC increments are required to deflect the beam by one diode width. This quantity is used to scale the other X-axis control parameters so they can be provided assuming the nominal 32 DAC increments/width (a YXPITCH value of X'0800').
6. Similarly, YY-PITCH/Y029 sets the value for the Y axis (telemetered in YYPITCH/Y526) necessary to produce one diode's height deflection. The least significant bit of this quantity corresponds to [1/8] of a DAC increment. For example, a value

of X'0800' (decimal 2048) means that [2048/8 =] 256 Y-axis increments are required to span the diode's height. This quantity is used to scale the other Y-axis control parameters so they can be provided assuming the nominal 256 DAC increments/height.

7. YHVDAC/Y030 sets the high voltage power supply DAC to the right-most 10 bits of the command value. After loading, the DAC is read and YHVDACER/Y561 set if an error is found. The readback is in YHVDACR8/Y520. The instrument gain is a weak function of the high voltage (which ranges 18-25 KV). The voltage value is expected to be changed only rarely (such as to compensate for component aging effects).
8. YFOCUS/Y033 sets the focus trim DAC to the command value. After loading, the DAC is read and YFDACERR/Y560 set if an error is found. The readback is in YFOCUSR8/Y519.

YXDAC/Y553 and YYDAC/Y521 can be used to monitor the deflection voltages during the observation. Since the DAC has 12 bits, only the bottom 12 bits of these words are set. Negative values are expressed in two's complement form, meaning that if the 12-bit value corresponds to decimal 2048 or more, the "true" value is obtained by subtracting 4096. See SLIB 1106 for values from a sample FOS tape.

3.1.4 Mechanism Commands

There are four FOS mechanisms that can be controlled by commands:

- 1 Entrance Port Mechanism,
- 2 Entrance Aperture Mechanism,
- 3 Polarizer Mechanism, and
- 4 Filter/Grating Wheel Mechanism.

Two FOS mechanisms cannot be moved at the same time. If the second one is commanded before the first is done, the instrument ignores the second command. Hence it is necessary to allow sufficient time between the commands so they are all acted upon. In addition to commands dedicated to each of these mechanisms (see below), there are also commands that can be used with any of the mechanisms (selected by a command field with values of 1, 2, 3, and 5 respectively for the mechanisms listed above). These general mechanism commands include:

1. YMCHCAL/Y022_c provides the value of a mechanical calibration index and another parameter as the new feedback code for the mechanism position specified by the index.
2. YMCHREG/Y087_c loads the mechanism register with the specified data field (a four-bit field giving the motor phase drive signals for the four-phase motor, with 1 being on and 0 being off).
3. YMCHSTEP/Y056_c steps the indicated mechanism in either the clockwise ("forward") or counter-clockwise direction by 2^{**n} steps (n is 4 bits, and if a value of 15 is specified, the mechanism motion is stopped).

The YDMECH/Y.005_c command (which filled the science data memory area starting at X'A000' with mechanism encoder values by moving the indicated mechanism forward or backward) has been deleted from the system because it locked out other serial magnitude commands. This command (whose effects could be provided via the YKEY command if necessary) was used to see if the mechanism is "sticking".

Each mechanism has a Mechanism Control Block that is included in the parameters with the UDL (see Section 3.2.2). The layout of each of these blocks is as follows:

1. Word 1 is the current relative step position. It is set to 0 when the FOS microprocessor is reset and incremented or decremented with each step from then. The value determines which phases of the stepper motor are active (it is an index into the mechanism motor phase table, modulo the number of table entries). Since the timing of its clearing with respect to the current motor phase is not unique, specific values are not necessarily repeated for a given physical position of the mechanism.
2. Word 2 is the address of a table in memory giving the stepper motor phase table (the phase sequence of the stepper motor). This table typically has four entries (and probably will be the same for all mechanisms). It could be changed if motor torque requirements, for example, made it necessary.
3. Word 3 has the number of times that the mechanism background task (see Section 1.5) should be entered, do a delay loop that nominally occupies a millisecond, and then hand over control to the next background task in the round-robin sequence. After completion of the required number of delays, the stepper motor phase is changed. For large values, one test showed that the real-time delay is about four times the value in this word. The in-flight times that elapse between any pair of motor steps is heavily dependent on the interrupt activity (for example, servicing a telemetry sync interrupt requires 2 msec).
4. Word 4 is the time-out count, generally set to four more (for the end point) than the total number of steps in a complete cycle. When this setting procedure is used, the values are 36 for the entrance port, 16004 for the aperture, 6724 for the polarizer, and 364 for the FGWA. The mechanism time-out code is telemetered in YMECHTOC/Y566 (reset when it is read, see Section 2.1.5). The three bits in YMECHTOC are set to 1 for the entrance port, 2 for the aperture, 3 for the polarizer, and 5 for the FGWA (this internal numbering system is reflected in a number of places in the FOS hardware). A value for the three bits of 0 means that there is no problem.
5. Word 5 is the dead band for the aperture and polarizer mechanisms (it must be set zero for the entrance port and FGWA). Each hexadecimal digit of this 16-bit quantity is treated separately, and represents the negative and positive allowed deviations for the high and low encoders respectively. For example, an aperture value of X'0112' would mean [-0, +1] for the high encoder and [-1, +2] for the low encoder (see Section 3.1.4.2).

6. Word 6 is the number of encoder map entries (starting with word 7). Values are 2 for the entrance port, 12 for the aperture, 48 for the polarizer, and 10 for the FGWA, meaning that their total control-block sizes are 8, 18, 54, and 16 respectively, for a grand total of 96 words (see Table 3.2-2).
7. Word 7 is the first encoder map entry (the total number of entries is specified in word 6).
8. Word 8 (and subsequent words if needed) complete the encoder map.

Information on each of the individual mechanisms is provided in the following sections.

3.1.4.1 Entrance Port Mechanism

An entrance port assembly is provided at the point where light enters the FOS from the OTA. The assembly allows light to enter through both or neither opening in the bulkhead. The circular entrance ports are 0.290 ± 0.010 inches in diameter. The close direction is "forward" (the sense of the command is "go backwards until open") for the general mechanism commands. The entrance port is capable of 20,000 cycles (open and close is one cycle) during a five-year on-orbit life. In the closed position, a mirror is introduced to direct light from the wavelength calibration system to the entrance apertures. As a fail-safe provision, a burn-wire pin puller opens the shutter.

Command YENTRNC/Y034_c is used to set the entrance port open or closed (depending on the argument in the data field). The position is indicated in the telemetry by YDOOR/Y503, with values of 01₂ for open and 10₂ for closed. The 00₂ value means "between". Words 7 and 8 of the Entrance Port Mechanism Control Block have X'40' for open and X'80' for closed respectively, corresponding to the YDOOR/Y503 bits shifted left 6 places. For the fail-safe provision, command YARMED/Y503_c is used to arm the pin puller, YSAFED/Y507_c to safe it, and YBLENT/Y563_c to blow the pin puller. The armed/safe status is telemetered (1 means armed) in YENTFRPI/Y124.

The entrance port has a 90° stepper motor with a 10:1 reduction (meaning that it takes 9°/step). A total movement of 288° is required to open or close the port, meaning [288/9 =] 32 motor steps. Contrary to the polarizer and aperture mechanisms (which use pin encoders that can give spurious readings if their mechanisms are run "too fast"), the entrance port can be run at its advertised speed, which is a nominal 6.4 seconds for opening or closing (32 steps at 200 msec/step). On a sample tape (see SLIB 1106), word 3 of the Entrance Port Mechanism Control Block was set to 47 (which corresponds to about 200 msec, see Section 1.5). A time allocation of 10 seconds is considered (see SLIB T30) a good nominal upper limit, and 30 seconds is probably an absolute maximum.

3.1.4.2 Entrance Aperture Mechanism

Two arrays of primary apertures are located around a wheel such that in each selectable wheel position the same aperture configuration lies in both the "A" (red) and "B" (blue) paths. The light path is selected by pointing the ST. The apertures are grouped to minimize the distance between the most frequently used apertures. The mechanism is capable of 30,000 aperture repositioning operations (averaging 90° each) during the five-year on-orbit life. Each aperture consists of a single hole or a pair of holes, with each hole being either round, square, or rectangular. Table 3.1-3 lists the FOS apertures that are available. A burn-wire pin puller allows torsion springs to rotate the aperture wheel out of the light paths, and causes a pair of fail-safe apertures to be placed in the paths.

Command YAPER/Y035_c is used to set the entrance aperture to the position (1-12) specified, and also indicates whether the direction is forward (defined as towards the bottom of the list in Table 3.1-3, such as from B-1 to B-2) or backward. The decimal command values for the individual aperture IDs to command them in the forward direction are given in the "Fwd Cmd" column of Table 3.1-3. For the fail-safe provision, command YARMAP/Y501_c is used to arm the pin puller, YSAFAP/Y505_c to safe it, and YBLAPR/Y561_c to blow the pin puller. The armed/safe status is telemetered (1 means armed) in YAPRFRPI/Y123.

Table 3.1-3 FOS Apertures

<u>ID</u>	<u>Fwd Cmd</u>	<u>Hex T/M</u>	<u>Hex Map</u>	<u>Description</u>
B-1	1	4C E2	0016	Single, round, 0.5 arc second. Used in polarimetry.
B-2	2	6D 63	E3E8	Single, round, 0.3 arc second. Used in polarimetry.
B-3	3	62 18	E98A	Single, round, 1.0 arc second. Used in polarimetry.
B-4	4	67 35	EF8C	Blank. Used as light shield (and for dark count measurement).
A-1	5	F6 0A	0EA6	Single, square, 4.3 arc second. Used in target acquisition.
A-2	6	E1 83	1477	Pair, square, 0.5 arc second, 3.0 arc second separation (distance between pair centers). Used with object and sky.
A-3	7	E3 90	1A4A	Pair, square, 0.25 arc second, 3.0 arc second separation. Used with object and sky.
A-4	8	CF E9	201B	Pair, square, 0.1 arc second, 3.0 arc second separation. Used with object and sky.
C-1	9	0F 00	3F35	Pair, square, 1.0 arc second, 3.0 arc second separation. Used with object and sky.
C-2	10	98 FB	4507	Single, rectangular, 0.25 x 2.0 arc second (in-dispersion and cross-dispersion respectively). Used with extended objects.
C-3	11	91 4A	4809	Single, square, 2.0 arc second, with 0.3 arc second wide occulter bar in cross-dispersion direction. Used with faint sources surrounding bright objects.
C-4	12	36 01	51AB	Single, rectangular, 0.7 x 2.0 arc second (in-dispersion and cross-dispersion respectively), with 0.3 arc second wide occulter bar in cross-dispersion direction. Used with faint sources surrounding bright objects.
FS-1	--	----	---	Single (Fail-safe aperture), square, 0.5 arc second, 4.4 arc second separation from FS-2. Used with target acquisition and spectroscopy.
FS-2	--	----	---	Single (Fail-safe aperture), square, 4.3 arc second, 4.4 arc second separation from FS-1. Used with target acquisition and spectroscopy.

Two eight-bit pin contact encoders (giving a one's complement Gray code output) are used to monitor the position of the aperture wheel. These are telemetered in measurement YAPERPOS/Y505. The telemetered values corresponding to individual aperture IDs are given in the "Hex T/M" column of Table 3.1-3 (obtained from SLIB L55). If the fail-safe mechanism provision is activated, the encoders remain connected and hence could read the same value as they did when the mechanism was in the optical path.

Since non-zero dead bands are allowed for the aperture (word 5 of the Aperture Mechanism Control Block), the downlink values need to be converted to the "binary" form given in the control block's encoder map (the map values corresponding to the "Hex T/M" column are quoted in the "Hex Map" column of Table 3.1-3). This conversion involves taking the one's complement of the downlink value, and then converting each byte (since the encoders are independent) separately from Gray to binary. For example, aperture B-1 has a nominal downlinked value of X'4CE2'. The conversion to the encoder map value can be done as follows:

1. Take the one's complement of the telemetered value (replace ones with zeros and conversely, subtract from X'FFFF', or the equivalent), meaning that X'4CE2' becomes X'8310'.
2. Convert the first two hexadecimal digits of the result from Gray to binary as shown below. The "Working" row is the "Result" row shifted right one place; the Result row is the sum (without carries) of the original value and the Working row (the exclusive OR, or equivalent):

X'83'	= 1011 0011
Working	= <u>110 1110</u>
Result	= 1101 1101 = X'0D'

3. Repeat the process for the other two digits of the result:

X'1D'	= 0001 1101
Working	= <u>000 1011</u>
Result	= 0001 0110 = X'16'

4. The final result is X'0016', the encoder map entry in Table 3.1-3 for aperture B-1.

Since the encoder pins drag, the encoder value can jitter (as well as exhibit a hysteresis-type effect). Consequently, a non-zero deadband for the low-encoder output (word 5 of the mechanism control block) is provided. A change

of a motor step (which gives several encoder increments) corresponds to about 0.1 diode, so is not significant for most observations. In addition, the high encoder at each desired aperture position is not necessarily near the middle of its range, so it could change value "near" the point where the desired aperture is located. Position ambiguities that in principle could result from this situation, however, have not yet been observed.

To establish the Aperture Mechanism Control Block encoder map values, a test was run using the capabilities of the former YDMECH command (see Section 3.1.4) to examine the encoder behavior near the desired aperture positions. This test, for example, found for position B-4 a encoder output corresponding to a map value of X'F08C'. This location, however, was close to the high encoder's transition from X'EF'. Hence the map value for B-4 in Table 3.1-3 is X'EF8C', but the dead band in word 5 of the Aperture Mechanism Control Block (see SLIB 1106) is set to X'0112' (allowing -0 and +1 count deviation in the high encoder). The FOS microprocessor will therefore recognize X'F08C' as a "match" for the B-4 encoder position. All these values, of course, are after convert the raw encoder output that is on the downlink (take one's complement and convert each byte from Gray to binary).

The aperture drive takes 16000 steps for a complete revolution. The originally specified speed was 7.4 msec/step for the motor, and since apertures are less than 180° apart (8000 steps), this gives a figure of $[7.4 * 8 =]$ 59.2 seconds (probably where the 70-second figure in SLIB 706 came from). If the motor is run at this speed, however, the encoder pin readings because of "pin bounce" would not give a valid result. A better figure, allowing adequate encoder readings, is 25 msec/step, giving about 200 seconds for 180° (probably where the five-minute figure in SLIB T23 came from). The pin bounce problem does not physically damage the hardware, so one FOS aperture positioning procedure could be to step the wheel rapidly by a specified number of steps (using a low value for the dwell time in control block word 3), and then increase the dwell time and command the aperture to a specific opening (the mode in which the FOS microprocessor uses the encoder outputs).

As had been determined from a least-squares fit, each aperture position is displaced from its neighbor by 382 motor steps (since the full 180° has 21 slots, this is in good agreement with a theoretical value of [8000/21 =] 380.95 steps). At 25 msec/step, this separation could be covered in about 9.55 seconds. The physical layout of the aperture wheel, however, has (for example) apertures [B-1, B-2, B-3, and B-4] for side "A", followed by [B-1, B-2, B-3, and B-4] for side "B" before reach the [A-1, A-2, A-3, and A-4] for side "A". Hence if start with B-1 on side "A" and step the wheel by [4 * 382] steps, will get a illegal side "A" location.

3.1.4.3 Polarizer Mechanism

The FOS has a polarizer assembly with two sets of polarizer elements designed for different but overlapping spectral ranges. Each set of polarizer elements consists of a rotatable waveplate followed by a dedicated Wollaston prism. Either set of polarizer elements can be placed in either the "A" (red) or "B" (blue) light path, and either or both light paths can also be left clear. Each waveplate is rotatable with respect to its Wollaston prism in increments of 22.5°. The fail-safe provision is a burn-wire pin puller allowing torsion springs to rotate the polarizer out of the light paths. The mechanism is capable of rotating through one 22.5° increment of the waveplate 10^5 times during the five-year on-orbit life. It is also capable of operating up to one-third of the time for up to eight hours.

Command YPLZR/Y036_C is used to set the polarizer mechanism to the position (1-48) specified, moving either forward (direction of increasing position number) or backward. Each of the two polarizers have 16 positions, as does the "clear" position. The decimal command value is the same as the position number quoted in Table 3.1-4. Polarizer "A" is thicker than Polarizer "B", and "Polarizer C" means "clear" (on both sides). The drum (see Section 1.5) is driven by a 90° permanent magnet stepper motor. The polarizer has 6720 motor steps for a complete "revolution". In these 6720 steps, the outer unit moves 16 revolutions (so 420 steps are required to move the drum one revolution). During these 420 steps, the inner unit moves (relatively) by 22.5° (such as from polarizer position A03 to A04). The setting quoted in SLIB 1106 for the Polarizer Mechanism Control Block word 5 corresponds to a real

Table 3.1-4 FOS Polarizer Information

<u>Pos</u>	<u>ID</u>	<u>Encoder Map For Side A (Hex)</u>	<u>Encoder Map For Side B (Hex)</u>
01	C01	87 C6	87 C6
02	A01	77 82	65 6C
03	B01	09 0F	F7 FA
04	C02	87 B6	87 B6
05	A02	77 72	65 5C
06	B02	09 FF	F7 EA
07	C03	87 A6	87 A6
08	A03	77 62	65 4C
09	B03	09 EF	F7 DA
10	C04	87 96	87 96
11	A04	77 52	65 3C
12	B04	09 DF	F7 CA
13	C05	87 86	87 86
14	A05	77 42	65 2C
15	B05	09 CF	F7 BA
16	C06	87 76	87 76
17	A06	77 32	65 1C
18	B06	09 BF	F7 AA
19	C07	87 66	87 66
20	A07	77 22	65 0C
21	B07	09 AF	F7 9A
22	C08	87 56	87 56
23	A08	77 12	65 FC
24	B08	09 9F	F7 8A
25	C09	87 46	87 46
26	A09	77 02	65 EC
27	B09	09 8F	F7 7A
28	C10	87 36	87 36
29	A10	77 F2	65 DC
30	B10	09 7F	F7 6A
31	C11	87 26	87 26
32	A11	77 E2	65 CC
33	B11	09 6F	F7 5A
34	C12	87 16	87 16
35	A12	77 D2	65 8C
36	B12	09 5F	F7 4A
37	C13	87 06	87 06
38	A13	77 C2	65 AC
39	B13	09 4F	F7 3A
40	C14	87 F6	87 F6
41	A14	77 B2	65 9C
42	B14	09 3F	F7 2A
43	C15	87 E6	87 E6
44	A15	77 A2	65 8C
45	B15	09 2F	F7 1A
46	C16	87 D6	87 D6
47	A16	77 92	65 7C
48	B16	09 1F	F7 0A

time of about 30 msec/step, meaning that about 12.6 seconds would be used for this 22.5° movement. The Automatic Polarizer Sequence Instrument Mode can be used to move the polarizer to successive positions and take data in individual slices (see Section 2.1.6).

Two eight-bit pin encoders provide a unique output for each position of the polarizer. One revolution of the drum rotates encoder A 5 times and encoder B 5.0625 times (in 16 cycles, A rotates 80 times and B 81 times). Encoder A is telemetered in YPLRZPOS HI/Y507a, and is also (see SLIB L66) referred to as the "slow" or "relative positions" encoder. It changes by $[(5 * 2^8)/420]$, or about 3.04762, bits per motor step. Encoder B is telemetered in YPLRZPOS LO/Y507b, and is also referred to as the "fast" or "waveplate angle" encoder. It changes by $[(5.0625 * 2^8)/420]$, or about 3.08571, bits per motor step. Both encoders increase with a CCW rotation of the drum (as viewed from inside the FOS in direction of the entrance ports).

The Polarizer Mechanism Control Block default encoder map values (which can be updated during flight) corresponding to the individual positions are given in hexadecimal in Table 3.1-4. To convert the downlink information to the form given in Table 3.1-4, it is necessary to take the one's complement of the downlink information (in YPLRZPOS/Y507) and then convert each byte separately from Gray to binary (the process is the same as required for the aperture position information, see Section 3.1.4.2). The Polarizer Mechanism Control Block deadband (see SLIB 1106) was set to X'1112' on a sample tape, meaning the high encoder (after conversion to binary) had a tolerance of ± 1 count and the low encoder a tolerance of [-1 +2] counts. If the fail-safe mechanism provision is activated, there is no distinctive encoder value that appears on the downlink (the encoders remain connected).

The FOS only has one set of polarizer encoders, but the readouts from them are different for the two sides. This is accommodated by having different Polarizer Mechanism Control Blocks for the red (side A) and blue (side B) ROMs in their respective CEAs. For example, if position 2 is commanded for side A and then the FOS is switched to side B, the X'77 82' encoder map value will indicate that the polarizer is at position 2 on side A, and side B may

be blocked. The IDT has pointed out (see SLIB L64) that powering down the FOS while the polarizer is moving between standard positions will cause confusion as to what command should be sent next and thus should be avoided. In the last two columns of Table 3.1-4, the first two hexadecimal digits are for YPLRZPOS HI (encoder A) and the other two are for YPLRZPOS LO (encoder B).

For the fail-safe provision, command YARMPL/Y511_c is used to arm the polarizer pin puller, YSAFPL/Y515_c to safe it, and YBLPOL/Y567_c to blow the pin puller. The armed/safe status is telemetered (1 means armed) in YPOLFRPI/Y130.

3.1.4.4 Filter/Grating Wheel Mechanism

The filter/grating wheel is a rotatable wheel providing the support structure for the filter and dispersion optics. It allows transmission of the light bundle through the appropriate filter or blank hole. After striking a collimating mirror, the light is reflected back to one of the dispersion elements or the camera mirror on the wheel, and then to one of the detectors. The wheel has ten equally spaced positions. Each position places a set of optical elements in each of the two light paths. The mechanism is capable of 54,000 repositionings of 90° each during the five-year on-orbit life. Accurate positioning is determined by a spring-loaded ball bearing cam detent. The FGWA has a 90° stepper motor with a 90:1 reduction gear, so each step corresponds to 1°. With a step delay setting corresponding to 100 msec (see SLIB 1106), this means that the wheel can move 180° in about 18 seconds (there are no encoder pin-bounce problems). A redundant stepper motor operates the mechanism if the primary motor fails.

There are 6 high-resolution gratings, two low-resolution gratings, a prism, and a mirror mounted on the FGWA. Table 3.1-5 gives their characteristics (the resolution is measured at the central wavelength), in the sequence given in SLIB 810. Five order blocking filters are used (the other five elements have a blank hole) to attenuate grating orders higher than the first to the greatest practical extent consistent with high transmittance of the desired first order (they are not used for the shortest wavelengths where the Digicon faceplates block higher-order light).

Table 3.1-5 FOS FGWA Elements

<u>Number</u>	<u>Type</u>	<u>ID</u>	<u>Resolu-</u> <u>tion</u>	<u>Filter</u>	<u>Wavelength</u> <u>(nm)</u>	<u>Side A</u>	<u>Side B</u>		
						<u>Cmd</u>	<u>Encod</u>	<u>Cmd</u>	<u>Encod</u>
-001	Grating	H13	1200	---	110-164	9	A	4	B
-002	Grating	H19	1200	---	153-228	7	7	2	9
-003	Grating	H27	1200	FH27	221-329	6	E	1	C
-004	Grating	H40	1200	FH40	319-474	10	6	5	3
-005	Grating	H57	1200	FH57	459-683	8	5	3	0
-006	Grating	H78	1200	FH78	626-931	4	8	9	A
-003	Grating	L15	200	---	115-230	1	C	6	E
	Prism	PRI	100	---	250-700	3	D	8	5
-004	Grating	L65	200	FL65	400-800	2	9	7	7
	Mirror	CAM	1	---	110-900	5	3	10	6

Command YFILTER/Y037_c is used to specify the FGWA position desired (in the range 1-10). Due to the mechanical layout of the FGWA, the element in the blue (side B) path is displaced 5 positions from the one for the red (side A) path: for example, command (and position) "1" puts element L15 in the red path; command "6" puts it in the blue path. Command YCMTRA/Y571_c is used to select motor "A" and command YCMTRB/Y573_c to select motor "B". The selected motor is indicated by measurement YCMTRST/Y101 (a 0 means B and a 1 means A).

The position of the wheel is read by a LED/phototransistor array and a coded cylinder. The four bits of the FGWA position are in telemetry measurement YFGWAPOS/Y506, and is given (in hexadecimal) in the "Encod[er]" columns of Table 3.1-5.

3.1.5 Targeting Commands

The FOS microprocessor has a capability (see Section 2.1.4) to do on-board targeting, using commands YTARACQ/Y004_c (which sets target acquisition parameters) and YTAMODE/Y046_c. Their roles, as well as the resulting downlink quantities, are summarized below:

1. YTARACQ/Y004_c, if N (in the command) is 2, provides the upper and lower target acquisition limits; if N is 1, only the lower window limit is provided. The 16-bit upper limit is telemetered in YTAMAX/Y650 and the lower limit in YTAMIN/Y651.

Both are in units of counts for a single data word. These values define the thresholds for processing the results of the FOS scan.

2. YTAMODE/Y046 specifies the target acquisition mode, and is telemetered in YTAMODE/Y515. This parameter controls the nature of the FOS targeting computations that are carried out. If it is zero, the results are not to be loaded; if $\neq 0$, then a peak value is found in X (changes, except perhaps to filter points, are not anticipated in this area). A value of 1 means locate using the top of the diode array; of 2 means use the bottom; and of 3 means find the peak in Y (similar to what done in X).
3. The 16-bit measurement YTARXCTR/Y510 has the high-order 4 bits giving information about the star field encountered. Bit 1 is set 1 if the target acquisition process was valid (this bit is expected to be reassigned). Bit 2 is set 1 to mean "crowded field", signifying that a second relative maximum (between YTAMAX and YTAMIN) was detected that was too far from the first (the computations are abandoned). Bit 3 is set 1 to mean "bright object(s)", signifying that at least one data word with a value above YTAMAX was found. Bit 4 is initialized to 1, meaning "faint field". It is reset 0 if a data word above YTAMIN is found.

If the target acquisition process was valid, the 12 low-order bits represent the value to which one would set YXBASE (see Section 3.1.3) to center the chosen image on the "center" diode (presently defaults to diode #256). This setting is computed based on the nominal 32 DAC increments/diode width.

4. The 16-bit measurement YTARYCTR/Y511 has the high-order 4 bits equal to the number of computation results that are included in the average target center reported (with an upper limit of 15). If a second (or subsequent) relative maximum is found within a tolerance of the current estimate (as well as between YTAMIN and YTAMAX), this value is merged with the current estimate and the counter is incremented. If the value is outside the tolerance, bit 2 of YTARXCTR is set instead.

If the target acquisition process was valid, the 12 low-order bits represent the value to which one would set YYBASE (see Section 3.1.3) to center the target image on the row of diodes in the Y direction. This setting is computed based on the nominal 256 DAC increments/diode height.

Information is not put in the downlink registers until after the computations are complete. YTARXCTR and YTARYCTR are zeroed (see Section 2.1.5) after being put on the downlink. The NSSC-1 uses these words to determine if the results are of sufficient validity; if so, the spacecraft is moved to cause the required centering to take place.

3.1.6 Miscellaneous Commands

In addition to the commands discussed above, there are several other commands that are also significant for operation of the FOS. These include:

- 1 Observation Initialization Commands,
- 2 Channel Control Commands,
- 3 FOS Microprocessor Memory Commands,
- 4 Light Source Commands, and
- 5 Internal FOS Microprocessor Commands.

These commands are described in the following sections.

3.1.6.1 Observation Initialization Commands

The observation initialization commands would be expected to be sent (if necessary) before the actual observation is begun. These commands are:

1. YSYNC/Y023_C is used to specify the time when the observation should start if YYSYNCS/Y.205 (see Section 2.1.1) is set. A 16-bit parameter specifies the fine delay (in units of 7.8125 usec), and another parameter gives the starting minor frame (in range 0-119). Note that this start time is not included on the downlink. In addition, the FOS use of the "take data flag" in the PIT has (according to SLIB T23) not yet been determined, but may impact this time. The YPAUSE/Y085 command (see Section 3.1.2.3) can be used to suspend and subsequently resume an observation, so an NSSC-1 processor might look at the PIT flag and generate the proper FOS commands if desired.
2. YINIT/Y041_C is used to specify the initialization to be performed by the Start Data Acquisition command (YBEGAC/Y559_C). Only the first five bits are assigned, and the quantity is telemetered in YINTMODE/Y547 (see Section 2.1.1 for a description of the bits).
3. YACQMODE/Y049_C is used to select the data acquisition mode. Only the first six bits are assigned, and the quantity is telemetered in YACQSYNC/Y535 (see Section 2.1 for a description of the bits).
4. YDDCHK/Y083_C is used to read, rewrite, and check all the discriminator DACs and store the result in the DDTBL array at X'9AF3'. This array is included in the FOS-Unique Data Log (see Section 3.2.2). This command can take up to 2 seconds to perform, and any commands received in that interval will be ignored. The FOS microprocessor first checks for an error in

readback, using all eight bits. If any difference exists, bit YDDACERR/Y563 is set (it is reset when sampled for telemetry). In addition, the most significant seven bits of the readback value are set in bits 2-8 of the array (otherwise, those bits are set 0).

5. YEFILL/Y084, is used to sample all the serial digital telemetry (SI Word 8) quantities and place their values in the engineering subcom table. This table is included in the FOS-Unique Data Log (see Section 3.2.2).

3.1.6.2 Channel Control Commands

There are four commands that can be used to control the performance of the individual channels. They are:

1. YDISCADDR/Y006, used either to load the discriminator address (for a later command) or to set all discriminator values to the low 8 bits of the command. As discussed in Section 1.5, the discriminator is used to establish the threshold below which the diode output is suppressed.
2. YCHNLEN/Y012, used to enable a channel, inhibit a channel, or inhibit/enable all channels.
3. YDISC/Y031, used to load the discriminator DAC table (at the address initialized by YDISCADDR/Y006) with the data field. After loading the table, the discriminator address is incremented by one.
4. YREFDAC/Y032, used to load the common discriminator reference DAC with the data field. After loading, the DAC is read back and YDRDACER/Y562 set 1 if an error is found.

3.1.6.3 FOS Microprocessor Memory Commands

There are five commands that can be used to set cells of the FOS microprocessor memory. They are:

1. YRAMADDR/Y000, used to specify a 16-bit RAM storage address. The address is telemetered in YRAMADDR/Y545. The initialization value for this word is X'A000'.
2. YSTRWRD/Y018, used to specify that the following N (in the command) words should be stored as data. The starting address specified by YRAMADDR/Y545 is incremented by 2 after each word.
3. YMEMCHK/Y055, used to fill memory (beginning at the start of the science data area) with a specified test pattern.

4. YSDERASE/Y057, used to set all memory locations from X'A000' to X'FFFE' to zero.
5. YRANDOM/Y086, used to fill the science data memory array (starting at X'A000') with a pseudo-random sequence (whose parameters are specified as part of the command).

3.1.6.4 Light Source Commands

There are two internal light sources associated with the FOS: a calibration source and a LED flat-field source. They are controlled as described below:

1. Command YCALON/Y575, is used to turn on the spectral calibration lamp and YCALOF/Y577, to turn it off. Its status is in telemetry measurement YCALRPI/Y102 (0 means on and 1 means off). Calibration lamp "A" is selected by YCALSA/Y583, and "B" by YCALSB/Y585. The lamp selection is telemetered in YCALSEL/R/Y133 (a 0 is B and a 1 is A).
2. Command YFFCAL/Y038, is used to set the LED flat-field lamp on or off (there is only one LED per Digicon). Telemetry measurement YFFCPWR/Y580 is 1 if the lamp power is on.

Measurement YCDACERR/Y578 has an identification in SLIB 1089 of "Calibration DAC readback error." The notation "DAC" is somewhat of a misnomer for this bit, but arises due to the design of the FOS microprocessor interfaces. A common set of code is used to load the "real" DACs, as well as the three-bit register associated with this bit. That register has the two power control bits for the descrambling PROMs, as well as the bit used to control the calibration flat-field lamp. Any time the bit controlling the flat-field lamp is updated, the two bits for the PROMs are reasserted; if a readback of the resulting three bits disagrees with what was specified, then bit YCDACERR/Y578 is set.

3.1.6.5 Internal FOS Microprocessor Commands

The commands given in this section are associated with the operation of the FOS microprocessor. They are:

1. YSCIADDR/Y059, is used to specify the first RAM address for science data processing. Except for failure or reprogramming situations, this address is expected to be X'A000'. Changes to this quantity (note that it is not on the downlink) should be carefully coordinated with the ground processing that must be accomplished.

2. YRAM-MAP/Y052_c maps the physical RAM page specified in the command to the address range specified by the logical page. Each page has a capacity of 2K 16-bit words. The map information is in RAMMAP/Y.402 of the FOS-Unique Data Log.
3. YKPALVED/Y058_c enables/disables autonomous going safe. It controls the value of YYSAFED/Y.204. If YYSAFED is 1, then if YYSAFLKA/Y.202 or YYSAFTSL/Y.203 are found set then a "safe" transition is initiated. YYSAFLKA is set by the housekeeping background task (see Section 1.5) if lose the keep-alive Serial Magnitude Command. This bit (in common with YYSAFTSL that is set if lose telemetry sync) may indicate valid auto safing conditions even if auto safe mode transitions are disabled (YYSAFED/Y.204 is zero).
4. YKEY/Y071_c is normally used to provide a FORTH KEY capability (see the operator background task description in Section 1.5). If its data field is an ASCII "ACK" (X'06'), however, the operator task clears a keep-alive counter that is incremented each major frame by the housekeeping background task. The NSSC-1 normally sends YKEY with a data field of X'06' once a minute; if the counter gets above a threshold (typically 2), then YYSAFLKA/Y.202 is set.
5. YRESET/Y545_c causes a computer reset to take place. If a reset is commanded, telemetry bit YYRSETMP/Y.230 is set 1 (the bit is zeroed when it is read out as part of minor frame 118).
6. YRIEBW/Y549_c causes the Instruction Engineering Bit (set when the microprocessor attempts to fetch an instruction from a non-resident RAM memory space) to be reset to 0. The watchdog timer error bit is also reset. These bits are telemetered in YINSENG/Y104 and YWTCHDOG/Y103 respectively.
7. Y3MHZ/Y551_c is used to select the 3.0 MHz clock rate (the normal operation mode) for the microprocessor. If this rate is selected, telemetry bit YCLKMON/Y134 is 0.
8. Y1.5MZ/Y553_c is used to select the 1.5 MHz clock rate (the "slow mode") for the microprocessor. If this rate is selected, telemetry bit YCLKMON/Y134 is 1.

3.1.7 Major FOS Flags and Indicators

Table 3.1-6 summarizes the major FOS flags and indicators used in the FOS equations of SLIB 799 (see Sections 5-7), together with their telemetry notations. The "Equation" column gives the notation in SLIB 799 (or SLIB 598) for the quantity; the "Byte" column indicates (as in SLIB 799) the byte number in the "header data list" (origin of 0 at the start of the engineering telemetry material, 16-bit word 902 of the FOS-Unique Data Log in Section 3.2.2).

Table 3.1-6 Major FOS Flags and Indicators

<u>Equation</u>	<u>T/M ID</u>	<u>Byte</u>	<u>Mnemonic</u>	<u>Role</u>
Detector	Y.201	1	YYPATH	Bit is 0 for red and 1 for blue.
NDISP	Y506	8	YFGWAPOS	FGWA encoder position.
Aperture	Y505	9-10	YAPERPOS	Aperture position. Downlinked value in one's complement Gray code.
Waveplate	Y507	11-12	YPLRZPOS	Polarizer position. Downlinked value in one's complement Gray code.
X-base	Y523	48-49	YXBASE	X base.
NXSTEPS	Y524	50	YXSTEPS	X step.
NYSTEPS	Y528	57	YYSTEPS	Y step.
NSLICES	Y576	59	YMSLICES	Number of memory slices.
NSCAN	Y530	60	Y0VRSCAN	Overscan.
1STCHNL	Y531	61	Y1STCHNL	First channel to be processed. Multiply telemetry value by 2 to obtain true number.
NCHNLS	Y532	62	YNUMCHNL	Number of channels to be processed. Multiply telemetry value by 2 to obtain true number (if value is 0, use 512).
LIVETIME	Y585	63	YLIVEHI	Accumulator open time (units of 7.8125 usec in two's complement).
	Y586	63	YLIVEL0	
DEADTIME	Y587	65	YDEADHI	Accumulator close time (units of 7.8125 usec in two's complement).
	Y588	66	YDEADLO	
ACQ MODE	Y535	67	YACQSYNC	Acquisition mode.
INTS	Y546	110	YINTEG	Number of integrations/X-step.
NPAT	Y577	111	YPTRNS	Number of patterns per readout.
NREAD	Y.406	122-123	NREAD	Readout number.

3.2 FOS SCIENCE TELEMETRY MODE-INDEPENDENT INFORMATION

For FOS, the science telemetry information is basically the same regardless of the Instrument Mode (the arrangement of information in the FOS micro-processor RAM memory causes the detailed layout of the Science Data Array to vary, but this is only an indirect consequence of the Science Data Mode and Instrument Mode). As discussed in Section 3.1, the set of data comprising a FOS observation consists of:

1. One or more NSSC-1 Standard Header Packets;
2. One or more FOS-Unique Data Logs; and
3. One or more frames of science information, each of which can consist of a Science Header, a Science Data Array, and a Reject Array.

These topics are covered in Sections 3.2.1-3.2.3. The science telemetry protocol that requires division of the science information into "Packets", each of which in turn is divided into "Segments", is covered in Section 3.2.4. All words in this discussion are 16 bits long (bits numbered from 1, the most significant, to 16), and are positive numbers.

3.2.1 FOS-Related Quantities in Standard Header Packet

By ST convention, the NSSC-1 computer generally sends a Standard Header Packet (SHP) to mark the beginning of an observation. For FOS, several SHPs may be sent during the course of a given observation. The 965 data words (see Section 3.2.4 for the ancillary data that consumes another 59 words) in this SHP have the following divisions:

<u>Words</u>	<u>Assignment</u>
1	In bits 1-8, the SI identification (for FOS, a value of X'DC').

In bits 9-16, the observation number. This number is the same as in the science data's ancillary word 11 (this ancillary word is zero for the SHP). It is incremented with each observation that is taken, and is one of the parameters that must be specified when configuring the CU/SDF for data readout. There is no need for this number to be in any way related to the data in words 801-805 of the SHP.

<u>Words</u>	<u>Assignment</u>
131-259	FOS Current Value Table (total of 129 words).
260-800	Assigned to other functions.
801-802	Forward linked value of FOS Program Number (per SLIB L38), total of 32 bits.
803-804.0	Forward linked value of FOS Observation Set Number (per SLIB L38) in word 803 and bits 1-8 of word 804, total of 24 bits.
804.5-805	Forward linked value of FOS Observation Number (per SLIB L38) in bits 9-16 of word 804 and in word 805, total of 24 bits. This word should not be confused with what is in bits 9-16 of data word 1 in the SHP.
806-820	Assigned to other functions.
821-830	UTC time correlation constants (per SLIB L38).
831-877	Assigned to other functions.
878-899	FOS Unique Data (total of 22 words).
900-965	Assigned to other functions.

Words 801-805 and 821-830 are in a 60-word SHP area (encompassing data words 796-855) that are assigned to "forward link data". There are several different proposals concerning what should be in this area, including SLIB L38 ("Proposal A" in SLIB 936), a second version defined as "Proposal B" in SLIB 936, and a third version described in SLIB L68. Which one will be used in flight is T80.

The information in the FOS Current Value Table reflects the last-sampled versions of some Engineering Telemetry (see Section 4) values. For FOS data processing purposes, all the necessary data is available elsewhere, such as in the FOS-Unique Data Log. For FOS, only words 131-168 of the Current Value Table are occupied (words 169-259 are spares that are set 0). These words are used for the FOS analog and bilevel telemetry (see Tables 4.2-1 and 4.2-2).

The 22 words assigned to the FOS-Unique data in the SHP are described in Table 3.2-1 (which uses data obtained from SLIB L66). Despite the similar notation, these words should not be confused with the FOS-Unique Data Log described in Section 3.2.2. These SHP words are assigned to the storage of information from the NSSC-1 processors that support FOS. The 22 words can have five possible sets of information, as defined by YYSHUID/Y.001 (which is always in the first word of the 22). Depending on YYSHUID, the total number of words used ranges from 4 to 19, with the unused words retaining previous values (rather than being zeroed or otherwise filled).

The different values that are established for YYSHUID, and the source of data and resulting occupied words, are summarized below:

1. A value for YYSHUID of 1 means data is from the NSSC-1 YFHKPG FOS Housekeeping Processor (processor #25, see Section 1.5). Only words 878-881 are used.
2. A value of 2 means data is from the NSSC-1 YFM002 FOS Mode 2 Target Acquisition Processor (#28). Words 878-890 are used.
3. A value of 3 means data is from the NSSC-1 YFSDPR FOS Science Data Processor (#31), module YFBSC1 (binary search 1). Words 878-893 are used.
4. A value of 4 means data is from the NSSC-1 YFSDPR Processor, module YFBSC2 (binary search 2). Words 878-896 are used (words 893-896 are not valid unless [YEDGE = 1]).
5. A value of 5 means data is from the NSSC-1 YFSDPR Processor, module YFPKUP (search for maximum or minimum counts). Words 878-885 are used.

Table 3.2-1 FOS-Unique Data in SHP

<u>SHP Wd</u>	<u>Meas ID</u>	<u>Contents</u>
<u>YYSHUID = 1</u>		
878	Y.001	YYSHUID, Identifier for FOS-Unique SHP data. See text.
879	Y600	YSTBUF, Number of FOS status buffer entries. Measured since last time the counter reset.
880	Y.002	YYNXTSB, Next available message position in status buffer. Per SLIB L66, is word #3 of SI C&DH Engineering; per SLIB T30, has SLIB 1089 measurement ID M10J213A.
881	Y.003	YYSBST, FOS single-bit status items. Per SLIB L66, is word #111 of SI C&DH Engineering; per SLIB T30, has SLIB 1089 measurement IDs M12X4248-M12X4318. This is AN (see Section 4.3) format word 250/37, having SI2 (FOS) information. Using SLIB 204 definitions (related to SLIB 1089), bit :1 means time code update not sent (no window); bit :2 means not authorized to use selected science data buffer; bits :3 and :4 are spare; bit :5 means line length from SDF disagrees with application program request; bit :6 means no application program request between science data lines; bit :7 means a science data request to the NSSC-1, but no storage available; and bit :8 means science data transfer cancelled.
<u>YYSHUID = 2</u>		
878	Y.001	YYSHUID, Identifier for FOS-Unique SHP data. See text.
879	Y.004	YMAP, Map number. Has the map number for the next set of data processed.
880	Y.005	YM2MAP, Maximum maps. Ground-settable maximum number of maps permitted.
881	Y624	YTACMP, Mode 2 Target acquisition completion indicator. A 1 means complete.
882	Y622	YGIVUP, Mode 2 target acquisition error indicator.
883	Y.006	YFM2CF, Count rate window change for next data set. A 4 means lower level of counting rate lowered; a 5 means upper level of counting rate raised.
884	Y.007	YYNMINOR, Minor frame number. Per SLIB L66, is "IBM standard quantity, number of minor frame #24, 84 offset from MJF time".

Table 3.2-1 FOS-Unique Data in SHP (cont)

<u>SHP Wd</u>	<u>Meas ID</u>	<u>Contents</u>
885	Y.008	YFXCTR, X-offset to center. Is in scaled microns, range \pm 19200. Least increment is [1/32] micron.
886	Y.009	YFYCTR, Y-offset to center. Is in scaled microns, range \pm 19200. Least increment is [1/32] micron.
887	Y.010	YYFVCTR2 HI, V2 component of ST slew request HI.
888	Y.010	YYFVCTR2 LO, V2 component of ST slew request LO.
889	Y.011	YYFVTCR3 HI, V3 component of ST slew request HI.
890	Y.011	YYFVTCR3 LO, V3 component of ST slew request LO.
		<u>YYSHUID = 3</u>
878	Y.001	YYSHUID, Identifier for FOS-Unique SHP data. See text.
879	Y621	YFRCTR, Count frames for part 1 of YFSDPR processor.
880	Y.012	YPKCT1, Objects found in field. It is the total for all frames since the frame counter was set to 1. It is the number of objects in the current data set, as determined by the peak finder module.
881	Y.013	YYCHPK1, First channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
882	Y.014	YYCHPK2, Second channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
883	Y.015	YYCHPK3, Third channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
884	Y.016	YYCHPK4, Fourth channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
885	Y.017	YPPINV, Preplanned branch status. Gives the request status. A 1 means FOS will wait for ground-invoked command; a 2 (initialization value) means no preplanned branch available (from SLIB L66, "to get one, set YPPB=1").

Table 3.2-1 FOS-Unique Data in SHP (cont)

<u>SHP Wd</u>	<u>Meas ID</u>	<u>Contents</u>
886	Y.018	YRSINV, Raster scan request status. Has value of 1 when search in progress. A value of 2 means allow a four arc second search (if nothing found, and no branch available, does a "Maltese cross search"). This search pattern starts at center, then 9:00, 3:00, 12:00, 6:00, 10:30, 1:30, 4:30, and 7:30. If it fails, YGIVUP/Y622 is set. Finally, a value of 3 or more means that the four arc second search is not allowed.
887	Y.019	YBASKP, Y base for current data. Y base used by FOS to acquire current data. Has a range of + 256 about a (nominal) zero value, and is 11 bits plus sign (right justified with sign extended).
888	Y.020	YNBCTR, Brightness rank. Gives rank (range 1-12) of object chosen for binary search.
889	Y.021	Y0BSJ, Peak matrix number. Gives location in 12-element array of peaks, 4x3 part of map.
890	Y.022	YBSM, Channel number of peak. Gives channel number for the diodes sampled (# diode number) of peak chosen for binary search.
891	Y.023	YNMAX, Number of counts in peak. Value is integrated above mean sky.
892	Y.024	YNMEAN, Counts in mean sky.
893	Y.025	YYARI1, Sky variance.

YYSHUID = 4

878	Y.001	YYSHUID, Identifier for FOS-Unique SHP data. See text.
879	Y.026	YGPCTR, Previous value of binary search step counter. Value ranges 1-6.
880	Y.012	YPKCTL, Objects found in field. It is the total for all frames since the frame counter was set to 1. It is the number of objects in the current data set, as determined by the peak finder module.
881	Y.013	YYCHPK1, First channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.

Table 3.2-1 FOS-Unique Data in SHP (cont)

<u>SHP Wd</u>	<u>Meas ID</u>	<u>Contents</u>
882	Y.014	YYCHPK2, Second channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
883	Y.015	YYCHPK3, Third channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
884	Y.016	YYCHPK4, Fourth channel where peak found. Channel number where qualifying peak found. Maximum is four, can be less. Array not zeroed out.
885	Y.017	YPPINV, Preplanned branch status. Gives the request status. A 1 means FOS will wait for ground-invoked command; a 2 (initializatian value) means no preplanned branch available (from SLIB L66, "to get one, set YPPB=1").
886	Y.018	YRSINV, Raster scan request status. Has value of 1 when search in progress. A value of 2 means allow a four arc second search (if nothing found, and no branch available, does a "Maltese cross search"). This search pattern starts at center, then 9:00, 3:00, 12:00, 6:00, 10:30, 1:30, 4:30, and 7:30. If it fails, YGIVUP/Y622 is set. Finally, a value of 3 or more means that the four arc second search is not allowed.
887	Y.019	YBASKP, Y base for current data. Y base used by FOS to acquire current data. Has a range of + 256 about a (nominal) zero value, and is 11 bits plus sign (right justified with sign extended).
888	Y620	YFM2FL, Action indicator for YFM2PR module. A value of 2 means Y base is going to increase for the next frame; a value of 3 means it is going to decrease.
889	Y.027	YEDGE, Result of edge test. A value of 1 means target is on edge (binary search successful); a value of 2 means target on diode array; and a value of 3 means target off diode array. Values in words 893-896 not valid unless [YEDGE = 1].
890	Y.028	YNTARG, Counts in target channels. Gives number of counts in channels where target is or should be, integrated above mean sky.
891	Y.024	YNMEAN, Counts in mean sky.
892	Y.025	YYARI1, Sky variance.

Table 3.2-1 FOS-Unique Data in SHP (cont)

<u>SHP Wd</u>	<u>Meas ID</u>	<u>Contents</u>
893	Y.010	YYFVCTR2, V2 component of ST slew request. Scaling is TBD.
894	Y.011	YYFVTCR3, V3 component of ST slew request. Scaling is TBD.
895	Y.008	YFXCTR, X-offset to center. Is in scaled microns, range \pm 19200. Least increment is [1/32] micron.
896	Y.009	YFYCTR, Y-offset to center. Is in scaled microns, range \pm 19200. Least increment is [1/32] micron.

YYSHUID = 5

878	Y.001	YYSHUID, Identifier for FOS-Unique SHP data. See text.
879	Y630	YFDWCT, Dwell counter for FPKUP. Ranges from 1 to YDWELS, dependent on dwell scan set up for SSM.
880	Y.029	YACSAV HI, Historic counts HI. Gives largest or least counts from dwell so far. Initialized to 0 to search for maximum and to the largest largest NSSC-1 integer to search for minimum.
881	Y.029	YACSAV LO, Historic counts LO. See YACSAV HI.
882	Y.030	YFUTT HI, Saved dwell time HI. Time of day corresponding to YACSAV.
883	Y.030	YFUTT LO, Saved dwell time LO. See YFUTT HI.
884	Y.031	YACACC HI, Number of counts in this dwell HI.
885	Y.031	YACACC LO, Number of counts in this dwell LO.

3.2.2 FOS-Unique Data Log Contents

There are 965 data words in the FOS-Unique Data Log. These words are stored in the FOS microprocessor RAM in the area immediately preceding address 'A000', which as explained in Section 1.5 is the beginning of the Science Data Array storage area. The data in the FOS-Unique Data Log is shown in Table 3.2-2.

Table 3.2-2 FOS-Unique Data Log

<u>Words</u>	<u>Assignment</u>
1-225	YSPR/Y.400, Spare (total of 225 16-bit words, starting at address X'9876'). Since these words lie in the upper part of the RAM area allocated to System Tables, some of them may contain such information as FORTH (the language for the FOS microprocessor) dictionary data. There is no need to provide a data reduction/analysis capability for these words, but it should be realized that they will not necessarily be zero.
226-233	YYEPMC/Y.409, Entrance Port Mechanism Control Block (see Section 3.1.4.1).
234-251	YYAPMC/Y.410, Aperture Mechanism Control Block (see Section 3.1.4.2).
252-305	YYPLMC/Y.411, Polarizer Mechanism Control Block (see Section 3.1.4.3).
306-321	YYFGMC/Y.412, FGWA Mechanism Control Block (see Section 3.1.4.4).
322-833	DDTBL/Y.401, Discriminator DAC/Disabled Diode Table, total of 512 16-bit words, starting at address X'9AF8'. Contains discriminator and channel enable information for each channel. Bit 1 is 1 to inhibit use of the channel and is 0 to enable it. Bits 2-8 are the seven most significant bits of the readback from the DAC used to set the low-level discriminator in the FOS Analog Signal Processor for that channel if an error was encountered (see Section 3.1.6.1). Bits 9-16 have the eight bits reflecting the desired setting of the DAC. This array can be set by command YDOCHK/Y083 _c .
834-837	RAMMAP/Y.402, RAM map (total of 4 16-bit words starting at address X'9EF8'). Has the logical mapping for each of the 8 physical pages of RAM memory (8 bits each). The information provided is the logical page number for each physical page (in range 0-7). Note that only the three least significant bits of each byte are actually used.

Table 3.2-2 FOS-Unique Data Log (cont)

<u>Words</u>	<u>Assignment</u>
838-901	ASCIIHD/Y.403, ASCII header (total of 64 16-bit words starting at address X'9F00'). Used for observer comments. According to SLIB L72, the area is presently used by Digital Equipment Corporation Ground Support Equipment (no immediate plans for flight use have been made, although such use is not precluded). On an FOS test tape (see SLIB 1106), the values for the plain-text character sequence "ABCD", for example, would have appeared in sequential 16-bit words as X'4241' and X'4443', namely with the bytes in each 16-bit word "reversed". There is no explicit initialization of the cells (X'FFFF' was observed on the test tape).
902-961	Total of 60 16-bit words starting at X'9F80'. They contain an image of the serial digital data (SI word 8) in engineering telemetry for each minor frame (see Section 4). Each 16-bit word has two consecutive eight-bit minor frame readouts. Word number is given by: $WN = 902 + [SI/2],$ where SI is the SI subframe number (range 0-119). If SI is even, then bits 1-8 have the data; otherwise, bits 9-16 have it. The value of WN (with a ".5" to indicate bits 9-16) is shown in the tables of Section 4.2 in the "UDL" column. New values are loaded into this area as they are placed in the engineering telemetry. Command YEFILL/Y084 can be used to fill all these words from their current values, rather than waiting for the 60-second major frame time (see Section 4) to elapse. This command probably will be issued before the FOS-Unique Data Log is telemetered at the start of the observation.
962.0	MIF/Y.404, minor frame number, in bits 1-8 of word 962 (address X'9FF8').
962.5	MAF/Y.405, major frame number, in bits 9-16 of word 962 (address X'9FF9'). This number is counted since the last FOS reset.
963	NREAD/Y.406, readout number (16-bit word at address X'9FFA'). This quantity is used in the processing of the data results (Section 10.2.2.1.1 of SLIB 799), and is a count of the actual number of readouts that have taken place during the current observation. The number returned is the [count - 1]. When telemetered as part of the FOS-Unique Data Log at the start of the observation, therefore, the value is not meaningful (probably a residual value related to the previous observation). Typical value at startup is X'7A78' ("subframe" 122 and 123).

Table 3.2-2 FOS-Unique Data Log (cont)

<u>Words</u>	<u>Assignment</u>
964	NMEMCLR/Y.407, memory clear number (16-bit word at address X'9FFC'). This quantity is a count of the number of memory clears that have taken place during the current observation. The number returned is the [count - 1]. When telemetered as part of the FOS-Unique Data Log at the start of the observation, therefore, the value is not meaningful (probably a residual value related to the previous observation). Typical value at startup is X'7C7D' ("subframe" 124 and 125).
965	YSPR/Y.408, spare (16-bit word at X'9FFE'). Typical value is X'7EFF' ("subframe" 126 and 255).

3.2.3 FOS Science Data Contents

For FOS, the material telemetered in each frame of science information is merely a dump of a set of RAM (or ROM, if so specified) cells from the FOS microprocessor, as discussed in Section 3.1. The FOS science downlink may also include several SHPs and UDLs for a given observation. Commands are used to control the logical partitioning of the RAM in the FOS microprocessor. The values actually used are available in the engineering telemetry (and hence in the FOS-Unique Data Log and the Science Header), thus allowing the information to be interpreted. Since the red and blue Digicon devices are processed by separate FOS hardware, measurement YYPATH/Y.201 (0 for the "A" or amber/red channel and 1 for the "B" or blue channel) can be used to determine the source of the data. As discussed in Section 1.5, there is no connection between the observation (data acquisition) and downlink dump parameters except that which might be established by conventions.

The number of words/line is given in measurement YWRDSLIN/Y551, the number of lines/frame in YLINSFRM/Y552, and the starting memory dump byte address in YMDDMPADR/Y550. The Instrument Mode is defined by YACQSYNC/Y535 (individual bits are in Y.205 through Y.210, see Section 2.1). With these quantities, it is possible to determine the major features of the science frame:

1. In general, the memory dump address will be set to cause transmission of one line's worth (YWRDSLIN) of Science Header data before the Science Data itself. This means that:

$$YMDDMPADR = X'A000' - 2 * YWRDSLIN,$$

where the factor of 2 is because YWRDSLIN is in units of 16-bit words, not bytes. If this relationship is true, then a Science Header appears at the start of each science frame. The constant X'A000' is the start of the Science Data Array. Although this constant can be updated by a command, such an update (see #1 of Section 3.1.6.5) should be done only after careful coordination with the ground processing.

2. If YMDDMPADR = X'A000', this means that there is no Science Header.
3. If YYREJRE/Y.207 (the Reject/-Retry bit) is 1, this means that there is a Reject Array needed for processing of the data. The Reject Array is stored immediately after the Science Data Array in the FOS memory. As noted in Section 2.1.3, however, its transmission is not controlled by this bit).

3.2.3.1 Science Header

The information in the Science Header for the science frame, if it is transmitted, is the same as the latter portion of the FOS-Unique Data Log (with, however, updates to reflect the changing data values as the material is telemetered). By FOS convention, there is one line (YWRDSLIN words) of the Science Header transmitted, so the last YWRDSLIN words of the FOS-Unique Data Log appear as the Science Header. For example, if [YWRDSLIN = 521], this means that the last 521 words (or words 445-965) of the Log are sent. More importantly, if [YWRDSLIN \geq 63], a complete image of the Serial Digital engineering telemetry data will be available in the Science Header. Caution must be exercised, however, in using the data in the Science Header to control processing, for reasons explained in Section 4.1.

3.2.3.2 Science Data Array

Commands are provided to the FOS microprocessor to control the sampling of the diode-path registers and the arrangement of data in its RAM memory from where it is subsequently telemetered. These commands, with their command mnemonic, data base ID, engineering telemetry slot, and role are summarized in Table 3.2-3.

Table 3.2-3 FOS Commands with Data Format Impact

<u>Command</u>	<u>Eng'g TM</u>	<u>Command Role</u>
YINTS/ Y043 _c	YINTEG/ Y546	Set number of integrations per X-Step. See Section 3.1.1.1.
Y1STCHNL/ Y042 _c	Y1STCHNL/ Y531	Load first channel to be processed. See Section 3.1.2.2.
YCHNLS/ Y050 _c	YNUMCHNL/ Y532	Set number of channels processed. See Section 3.1.2.2.
YX-STEP/ Y039 _c	YXSTEPS/ Y524	Load number of X-Steps. See Section 3.1.1.2.
Y0VRSCAN/ Y051 _c	Y0VRSCAN/ Y530	Set channel overscan number. See Section 3.1.1.3.
YY-STEP/ Y047 _c	YYSTEPS/ Y528	Load number of Y-Steps. See Section 3.1.1.4.
YSLICES/ Y068 _c	YMSLICES/ Y576	Set number of memory slices. See Section 3.1.1.5.

As previously discussed, the FOS microprocessor memory has a dedicated area of memory for science information, and it is from this area of memory that the Science Data Array is telemetered. Consecutive cells in the memory are loaded with successive channel outputs, starting with the Y1STCHNL channel and ending with:

$$\text{OMEG} = \text{Y1STCHNL} + \text{YCHNLS} + \text{Y0VRSCAN} - 2$$

(sum of true first channel, [true number of channels - 1], and [overscan number - 1]). This gives a total of:

$$M = \text{YCHNLS} + \text{Y0VRSCAN} - 1$$

data values for the inner-most loop of the sampling process. For some FOS observations (see Section 3.1.2.1), this could be the line length (YWRDSLIN/ Y551), although this constraint is not imposed by the instrument. Cells in the "middle" of the science array are normally incremented by the output of Y0VRSCAN diodes. For example, word 107 (counting from 0) for [Y0VRSCAN = 5] would be incremented by the output of diode 103 (counting from 0), then diode 104, then 105, then 106, and finally 107 as successively larger offsets (controlled by Y0VRSCAN) are used. Similarly, word 4 would be incremented by diodes 0, 1, 2, 3, and 4 in that order. Word 0 is incremented (by diode 0) only at the "final" offset. See SLIB 1106 for examples.

If $[YX\text{-}STEP} > 1]$, the next M words in the FOS microprocessor RAM reflect an X offset (done by the magnetic focusing hardware) so as to allow the diodes to sense spectrographic information for a slightly offset group of wavelengths. For example, if $[YX\text{-}STEP} = 2]$ and $[M = 10]$, and using Fortran indexing, then the FOS microprocessor RAM cells would have to be sampled in the sequence:

1,11, 2,12, 3,13, 4,14, 5,15, 6,16, 7,17, 8,18, 9,19, 10,20

in order to present the data in a monotonic wavelength sequence. As mentioned in Section 1.5, the relationship between diode number and wavelength is different for the two detectors and also depends on the optical element in use. Similarly, if $[YX\text{-}STEP} = 4]$, then points would have to be read as:

1,11,21,31, 2,12,22,32, 3,13,23,33, ...

where again the grouping indicates that, for example, points [1,11,21,31] are all read from the same diode, but with different magnetic deflection values. Since the telemetry is of successive RAM cells, however, this unshuffling must be done as part of the ground processing.

After reading the data for the channels a total of YX-STEP times, the FOS instrument can deflect the beam in the Y axis direction (perpendicular to the diode array) and generate exactly the same information. Continuing the example, if $[YY\text{-}STEP} = 3]$ then the RAM would have words 1-40 for the first collection (interleaved as described above), words 41-80 for the second, and words 81-120 for the third Y-axis step. Words 1, 11, 21, 31, 41, 51, 61,...111 would all contain information from the Y1STCHNL diode.

Finally, to gather data for some Ground Software Modes (such as Time-Resolved), the complete set of measurements must be repeated several times, as controlled by the YSLICES command. For $[YSLICES} = 4]$, but otherwise the above scenario, words 1-120 would have the first slice, 121-240 the second, 241-360 the third, and 361-480 the fourth slice. In this situation, the total size of the FOS "pattern" would reflect a Science Data Array length of 480 words.

Using the command (and engineering telemetry) values previously presented, the Science Data Array in the FOS microprocessor can also be visualized as having elements

$$S_{i,j,k,l}$$

where:

- i varies from Y1STCHNL to [Y1STCHNL + YCHNLS + YOVRSCAN - 2],
- j varies from 0 to [YX-STEP - 1],
- k varies from 0 to [YY-STEP - 1], and
- l varies from 0 to [YSLICES - 1].

Using the values previously presented, and having [Y1STCHNL = 0], the first element would be $S_{0,0,0,0}$ and the last $S_{9,3,2,3}$, for a total of $[10*4*3*4=]$ 480 words.

3.2.3.3 Reject Array

If the YYREJRE/Y.207 (see Section 2.1.3) bit is 1, then the Reject Array is used to count the number of rejected measurements (the output from all 512 channels is ignored, rather than being used to update the FOS microprocessor RAM). As discussed in Section 2.1.3, the actual use of the rejection logic is controlled by the threshold value. The process for using the Reject Array is given in Section 10.2.2.1.1.1 of SLIB 799. The array has the general form:

$$NR_{j,m,k,l}$$

where:

- j varies from 0 to [YX-STEP - 1],
- m varies from 0 to [YOVRSCAN - 1],
- k varies from 0 to [YY-STEP - 1], and
- l varies from 0 to [YSLICES - 1].

The only parameter different from the normal science data is "m". Contrary to the Science Data Array, no rearrangement prior to subsequent use is necessary.

The Reject Array is stored in the FOS microprocessor immediately after the Science Data Array. There is no constraint imposed that it be telemetered starting with a separate downlink packet. All packets must have the same number of words: those after the end of the Reject Array are not meaningful for the current observation, and should be ignored.

3.2.4 Arrangement of Science Data into Packets

The FOS science data, in common with the other ST instruments, is divided for telemetry interface purposes into "lines" and "frames". A "line" is a maximum of 965 16-bit words of science data, and a "frame" is a collection of one or more "lines". A set of one or more "frames" constitutes an "observation". The number of words in a line, and the number of lines in a frame, must be consistent between the SDF and the originating SI. The complete interface involves a six-signal protocol.

For transmission purposes, a line of data is accommodated in a "packet", which in turn is divided into from 1 to 16 "segments" (each of which has 64 16-bit words). In the first segment (by ST convention, "segment 0"), 50 data words are available to the user, with the other 14 occupied by ancillary information; in the other segments, 61 data words are available to the user. Since each segment of a packet must contain exactly 64 words, words of fill may be required to complete the last segment in the packet. These words are all set to X'5569'. For subsequent processing, it would be expected that the data words would be extracted from the individual segments. The data locations quoted in this document, therefore, assume that the transmission-protocol ancillary words have been removed and the data words compacted.

The information in the ancillary (non-data) words is defined in SLIB 204 and SLIB L65, and summarized in Table 3.2-4. Following the convention of SLIB 204, segments are numbered 0-15 and words 0-63. Words 0-2 are reflected in all segments, while words 3-13 are only in the first segment (segment 0). As elsewhere in this document, bits are numbered 1-16 (1 is most significant).

Table 3.2-4 Packet Ancillary Data

<u>Word</u>	<u>Significance</u>
0	Top 16 bits of sync pattern, X'0588'.
1	Bottom 8 bits of sync pattern, X'2E', in bits 1-8 of the word.
	Segment number of this segment (range 0-15) in bits 9-16 of the word.

Table 3.2-4 Packet Ancillary Data (cont)

<u>Word</u>	<u>Significance</u>
2	Packet count (a running 16-bit count of the number of non-filler packets output by the SI C&DH).
3	Source ID in bits 1-8 of the word. For FOS, value is X'DC'. When the SHP is sent, the value in this byte is 0.
	Mission ID in bits 9-16 of the word. Value is X'3A'.
4	Coded packet length in bits 1-8 of the word (units of segments). Values are X'30'(1 segment), X'40'(2), X'48'(3), X'50'(4), X'54'(5), X'58'(6), X'5C'(7), X'60'(8), X'62'(9), X'64'(10), X'66'(11), X'68'(12), X'6A'(13), X'6C'(14), X'6E'(15), X'70'(16). For the SHP and the FOS Unique Data Log, 16 segments are required. The number of segments required for science data depends on the specified number of words (see Section 3.1.2.1).
	Secondary header length in bits 9-16 of the word (number of 8-bit bytes in words 6-13 of segment 0). Value is decimal 16, or X'10'.
5	Packet format code in bits 1-8 of the word. For the SHP, a value of X'AA' is used, and for NSSC-1 Executive Status Buffer dumps, a value of X'88'. The FOS UDL has values (from SLIB L64 and SLIB L67) in the range X'10' to X'1F'. The FOS science data (directly from the instrument) has values in the range X'60' to X'7F'; if the data comes through the NSSC-1, the format code has values of X'80' to X'9F'. Finally, memory dumps have values in the range X'D1' to X'DF' (excluding X'D0').
	See SLIB L67 for the significance of other values; the ones to be used during flight (within the above ranges) are TBD.
	Source ID parity in bits 9-16 of the word. For FOS, value is X'A7'. When the SHP is sent, the value is 0.
6	Frame start count (a running 16-bit counter of the number of Frame Start signals received from the SI that is the source of the data in the packet). The count is kept in the SDF hardware, and when the SDF is reset, this counter is also reset. When the SHP is sent (or if FOS data is sent via the NSSC-1), the value in this word will be 0. For data sent from the instrument itself (UDL, science, and dump data), this word can be non-zero (it is incremented in conjunction with the transmission of each UDL as well as for each frame of science/dump data).

Table 3.2-4 Packet Ancillary Data (cont)

<u>Word</u>	<u>Significance</u>
7	Line count. For multi-line formats, the number of the line of science data contained in the packet, starting at 0. It is always zero for the SHP and UDL. For science and dump data, it ranges from 0 to one less than the packets/frame contained in ancillary data word 12 (hence it is always zero for single-line formats).
8	The most significant 16 bits of time code value, the space-craft time of transmission of the Line Start signal or start of the DMA transfer that produced the data for the packet. Words 8 and 9 together correspond to the NSSC-1 held space-craft clock with a least increment of 125.000 msec. The entire 42 bits (including word 10) represent the SDF clock with a least increment of 125/1.024 usec (122.0703125 usec).
9	The next most significant 16 bits of time code value (see word 8).
10	The least significant 10 bits of time code value (left justified). See word 8. Bits 11-16 are 0.
11	Observation number. Bits 1-8 of this word are zero. For the FOS UDL and science data, bits 9-16 have the value that is also contained in bits 9-16 of data word 1 of the SHPs (see Section 3.2.1) that are associated with the observation. In the SHP, this complete word is 0.
12	Number of packets per frame. This is the number of packets that the SI C&DH outputs as a result of the invocation of this format. It is 1 for the Standard Header Packet and FOS-Unique Data Log. The value for FOS science data is down-linked in YLINSFRM/Y552 (see Section 3.1.2.1). Since the line count in ancillary data word 7 starts at 0, this word 12 value is one greater than the final (last packet in frame) value in word 7.
13	Number of data words per packet. Has number of data words (as opposed to ancillary or fill words) in each packet of the frame of which this packet is a part. The maximum value is 965 (X'3C5'), the value for the Standard Header Packet and the FOS-Unique Data Log. The value for FOS science data is downlinked in YWRDSLIN/Y551 (see Section 3.1.2.1).

4.0 FOS ENGINEERING TELEMETRY

4.1 FOS ENGINEERING TELEMETRY OVERVIEW

The FOS engineering telemetry consists of four types of data:

1. Analog data (such as temperatures and voltages),
2. Bilevel data (contact closures),
3. Serial digital data (from the FOS microprocessor), and
4. Digital data from the FOS NSSC-1 processors.

All ST Engineering Telemetry measurements have an associated eight-character LMSC (SLIB 1089) measurement identifier, as well as an abbreviated (but still unique) four-character identifier. The full eight-character identifier is divided into five fields:

1. Field 1, the first character, identifies the major ST element. A "Y" is assigned to the FOS.
2. Field 2, characters 2-3, identify the component code. For FOS, the reserved codes are:

01	MEC
02	CEA
03	CPS
04	Signal Processor
05	HVPS
06	PSA (not used)
07	PSB (not used)
08	CLPS
09	RIU A
10	RIU B
11	General FOS.

3. Field 3, character 4, is a letter code for the measurement parameter. For FOS, values of C (current), H (position), J (logic status/computer address), Q (counters/quantity), T (temperature), V (voltage), W (time), X (bilevel/multilevel), and Z (spare) are used.
4. Field 4, characters 5-7, uniquely identifies each measurement within the category identified by Field 1. For FOS, the numbers are further divided:

101-134	Bilevel
301-338	Analog
500-589	Serial Digital Data
600-648	Data from NSSC-1 Processors (in word 9)
649-652	Serial Digital Data.

For the purposes of this document, the numbering system in this field has been extended to include those parameters that are not otherwise identified. To avoid ambiguity (while still permitting useful presentation in numerical order), these extensions have been made as fractions, using the following assignments:

- .001-.031 FOS-Unique data in SHP (see Section 3.2.1)
- .201-.230 Divisions in word 8 (words already assigned)
- .400-.412 Quantities in FOS-Unique Data Log (Section 3.2.2)
- .648 Spares in word 9.

It should be noted that commands are also identified with similar notations:

- 000_c-087_c Serial magnitude commands
- 501_c-627_c Discrete commands.

5. Field 5, character 8, is an indicator of ground processing required. Values for FOS are:

- A Analog (where have calibration curve) or conversion to numerical value;
- B Bilevels (single bits): each of the two states can have an equivalent English statement (8 characters maximum); and
- D Multi-level data having a maximum of up to 32 discrete output states (otherwise as for B).

Solely for presentation purposes in this document, a lower-case alphabetical suffix (a, b, c, etc.) has been added to Field 5 to distinguish successive parts of the Serial Digital Data requiring more than eight bits to telemeter ("a" is appended to the most significant part, "b" to the next most, etc.).

The abbreviated measurement identifier uses Fields 1 and 4.

As mentioned in Section 3.2.3.1, users of the engineering telemetry information must be aware of the sampling done internally by the FOS microprocessor for control purposes, as well as that done by the microprocessor for output of the Serial Digital Data. The FOS command philosophy is based on an "Arm and Fire" technique, whereby the necessary commands to set up the parameters are carried out (such as those used for FOS microprocessor loop control). A "Fire" command (or, more precisely, Begin Data Acquisition, YBEGAC/Y559_c) is used to start the actual activity. There is a command to abort the data acquisition immediately (YABACQ/Y555_c), or to end data acquisition at the end of the pattern (YENDAC/Y557_c). See Section 3.1.2.3.

At the start of data acquisition, the FOS microprocessor (in an activity that takes a total of a couple of seconds) samples many of the commanded parameters (such as the INTS, XSTEPS, and OVRSCN controls for the X-axis activity) from their telemetered cells and puts them into other cells for use throughout the observation. The telemetered cells, however, will reflect any subsequent command activity (a primary purpose of telemetering them, of course, is for command verification). The commands whose data is sampled in this fashion are called "Software Parameter Commands" in Table 3.1-2. For data reduction purposes, it would be more conservative to sample these parameters from the FOS-Unique Data Log information.

Some commands, however (such as $YREJLIM/Y014_c$, the one controlling the burst noise level for rejecting an integration value from the diodes' accumulators) are in the "Data Commands" category in Table 3.1-2, meaning that they can be updated "on the fly" and will have an effect. Although these commands do not impact the partitioning of the RAM memory, they can impact the processing. One example is $YLIVETIM/Y008_c$ and $YDEADTYM/Y010_c$, the commands used to control the diode-path accumulator sampling interval: these cells are specified in SLIB 598 for alternative use in reducing time-tagged data. The "Data" category commands, therefore, should be obtained from the Science Header if possible. It is expected (see SLIB 814) that the observer will take care not to change parameters or issue data commands during an acquisition, since such changes can result in meaningless data.

The memory area preceding the X'A000' address (the nominal address where the Science Data Array starts) has the image of the Serial Digital Data. Individual bytes in this area are loaded at the same time that they are presented to the telemetry, meaning the 120 bytes comprising this data (for "normal" telemetry, see Section 4.3) take a minute to get refreshed. Because of this delay, command $YEFILL/Y104_c$ will probably be used to sample all 120 values and place them in this area of memory. An expected command sequence, therefore, would be to abort the previous acquisition activity, provide the YEFILL command, and then generate the NSSC-1 Standard Header Packet and the FOS-Unique Data Log information.

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The sequence of FOS engineering telemetry flow through the ST systems is shown in Figure 2 of SLIB 1089.

4.2 ENGINEERING TELEMETRY OUTPUT FROM FOS

The FOS Engineering Telemetry is described in this section from the viewpoint of the FOS instrument (and, therefore, documentation). The actual structure of the engineering telemetry stream (major frames, minor frames, subcommutation, and related matters) is discussed in Section 4.3.

Four kinds of telemetry are provided: Analog, Bilevel, Serial Digital, and Digital from FOS NSSC-1 processors. The tables on the following pages provide a summary of the telemetry assignments arranged in different sequences and formats for ease of reference (they are derived from the same basic set of data). The following information is supplied:

1. Table 4.2-1 lists the FOS Analog Telemetry sequenced by abbreviated TM identifier. The "SHP" column gives the SHP (Current Value Table area, see Section 3.2.1) location where the value is stored, with the ".5" meaning that it is in the low 8 bits of the word.
2. Table 4.2-2 lists the FOS Bilevel Telemetry sequenced by abbreviated TM identifier. The SHP column has the same significance as for Table 4.2-1.
3. Table 4.2-3 lists the FOS Analog and Bilevel Telemetry sequenced by plug and pin connection (for checking against other interface documentation).
4. Table 4.2-4 lists the FOS Serial Digital Telemetry sequenced by abbreviated TM identifier. The FOS-Unique Log word location ("UDL" column) is determined as described in Section 3.2.2.
5. Table 4.2-5 provides the same information as in Table 4.2-4, but sequenced by location.
6. Table 4.2-6 lists the FOS NSSC-1 Processor Digital Telemetry sequenced by their identifier (equivalent to sequencing by location). See Section 1.5 for NSSC-1 processor identifications. The "SHP" column refers to the word location in the Standard Header Packet. The subscripts in this column reflect the conditions under which the quantity appears (the value of YYSHUID/Y.001, see Section 3.2.1).
7. Table 4.2-7 lists all the FOS commands and telemetry sequenced by their abbreviated command (with subscript "c") or TM identifier. The "SHP" column is the same as for Table 4.2-6 (no subscript means the quantity does not depend on YYSHUID/Y.001), and the "UDL" column gives the location in the FOS-Unique Data Log.

8. Table 4.2-8 provides the same information as in Table 4.2-7, but sequenced by mnemonic. It should be noted that the sort sequence is not an ASCII one (numbers are after letters, for example).

In these tables, the notation a/b:c-d in the WD/SF column implies that the quantity is in FOS output engineering telemetry word #a (range 0-9), subframe slot b (range 0 to [length - 1]), and bits c-d (bit 1 is most significant and bit 8 is least significant). See Section 4.3 for additional information on the engineering telemetry.

Table 4.2-1 FOS Analog Telemetry by ID

<u>TM ID</u>	<u>WD/SF</u>	<u>SHP</u>	<u>Significance</u>
Y301	7/0	145.5	Y10BTMP, Optical Bench Temperature Location 1.
Y302	7/1	146.5	Y20BTMP, Optical Bench Temperature Location 2.
Y303	7/2	147.5	Y30BTMP, Optical Bench Temperature Location 3.
Y304	7/3	148.5	Y40BTMP, Optical Bench Temperature Location 4.
Y305	7/4	149.5	YPCATMP, Photocathode A Temperature.
Y306	7/5	150.5	YPAMATMP, Pre-Amp Assembly A Temperature.
Y307	7/6	151.5	YPMFATMP, Permanent Magnet Focus Assembly A Temperature.
Y308	7/7	152.5	Y10ATMP, Optics Area Temperature Location 1.
Y309	7/8	153.5	Y20ATMP, Optics Area Temperature Location 2.
Y310	7/9	154.5	YSIGPTMP, Signal Processor Temperature.
Y311	7/10	155.5	YCEATMP, Central Electronics Temperature.
Y312	7/11	156.5	YDOORTMP, Entrance Door Mechanism Temperature.
Y313	7/12	157.5	YAPERTMP, Aperture Mechanism Temperature.
Y314	7/13	158.5	YPOLRTMP, Polarizer Mechanism Temperature.
Y315	7/14	159.5	YFGMATMP, Filter/Grating Wheel Motor A Temperature.
Y316	7/15	160.5	YHV TMP, High Voltage Supply Temperature.
Y318	7/18	163.5	YCPSTMP, Central Power Supply Temperature.
Y319	0/0	131.5	YHV VLT, High Voltage Supply Voltage.
Y320	6/0	137.5	YCALVLT, Calibration Lamp Supply Voltage.
Y321	2/0	133.5	YXDEFCUR, X-Deflection Coil Driver Current.
Y322	3/0	134.5	YYDEFCUR, Y-Deflection Coil Driver Current.
Y323	4/0	135.5	YTRMFCUR, Trim Focus Coil Driver Current.
Y324	5/0	136.5	YDSCRVLT, Discriminator Reference Voltage.
Y325	1/0	132.5	YHVCUR, High Voltage Supply Current.
Y326	7/16	161.5	YARIUTMP, RIU-A Temperature.
Y327	7/17	162.5	YBRIUTMP, RIU-B Temperature.
Y328	0/1	138.5	YCLSCUR, Calibration Lamp Supply Current.
Y329	7/19	164.5	YFGMBTMP, Filter/Grating Wheel Motor B Temperature.
Y330	7/20	165.5	YPCBTMP, Photocathode B Temperature.
Y331	7/21	166.5	YPAMB TMP, Pre-Amp Assembly B Temperature.
Y332	5/1	143.5	Y8VQPSV, Plus 8 Volt Quiet Power Supply Voltage.
Y333	7/22	167.5	YPMFBTMP, Permanent Magnet Focus Assembly B Temperature.
Y334	7/23	168.5	YXYDFTMP, X Y Deflection Focus DAC Temperature.
Y337	6/1	144.5	Y5VLPSV, Plus 5 Volt Logic Power Supply Voltage.
Y338	2/1	140.5	YANASPAR, Analog Spare.

Table 4.2-2 FOS Bilevel Telemetry by ID

<u>TM ID</u>	<u>WD/SF</u>	<u>SHP</u>	<u>Significance</u>
Y101	3/1:8	141.5	YCMTRST, Carrousel Motor Status. A 0 is B and a 1 is A. See Section 3.1.4.4
Y102	4/1:6	142.5	YCALRPI, Calibration Lamp Supply RPI. A 0 is on and 1 is off. See Section 3.1.6.4
Y103	3/1:3	141.5	YWTCHDOG, Watchdog Timer Status. A 0 is OK and 1 is error. See Section 3.1.6.5
Y104	3/1:4	141.5	YINSENG, Instruction Engineering Bit Status. A 0 is OK and 1 is error. See Section 3.1.6.5
Y105	3/1:1	141.5	YRESETST, Reset Status. A 0 is reset and a 1 is not reset
Y106	3/1:5	141.5	YODSCRAM, Descramble PROM Power Status Odd. A 0 is off and 1 is on
Y107	3/1:6	141.5	YEDSCRAM, Descramble PROM Power Status Even. A 0 is off and 1 is on
Y117	4/1:5	142.5	YHVRPI, High Voltage Relay Position. A 0 is HVON (on) and 1 is HVOF (off)
Y118	1/1:8	139.5	YHTRRPI, Heater Control Relay Position. A 0 is HTON (on) and 1 is HTOF (off)
Y119	4/1:3	142.5	YQSRPI, Quiet Supply Relay Position. A 0 is +QPS (on) and 1 is -QPS (off)
Y120	4/1:4	142.5	YLSRPI, Logic Supply Relay Status. A 0 is +LPS (on) and 1 is -LPS (off)
Y121	4/1:7	142.5	Y1BUSRPI, Common Bus Relay #1 Status. A 0 is B On/A Off1 and a 1 is A On/B Off1
Y122	4/1:8	142.5	Y2BUSRPI, Common Bus Relay #2 Status. A 0 is B On/A Off2 and a 1 is A On/B Off2
Y123	1/1:5	139.5	YAPRFRPI, Aperture Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.2
Y124	1/1:6	139.5	YENTFRPI, Entrance Door Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.1
Y125	1/1:1	139.5	Y1SDFPRT, SD CEA A K1-K6 Status. A 0 is A8 and 1 is AA
Y126	1/1:2	139.5	Y2SDFPRT, SD CEA A K7-K11 Status. A 0 is A8 and 1 is AA
Y127	1/1:3	139.5	Y3SDFPRT, SD CEA B K1-K6 Status. A 0 is B8 and 1 is BA
Y128	1/1:4	139.5	Y4SDFPRT, SD CEA B K7-K11 Status. A 0 is B8 and 1 is BA
Y130	1/1:7	139.5	YPOLFRPI, Polarizer Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.3
Y131	4/1:1-2	142.5	YRIUS2, RIU Standby Status. Bit 1 is for RIU A and bit 2 for RIU B. A 0 means STBY1 and a 1 means STBY2
Y133	3/1:7	141.5	YCALSEL, Calibration Lamp Select RPI. A 0 is B and a 1 is A. See Section 3.1.6.4
Y134	3/1:2	141.5	YCLKMON, Microprocessor Clock Monitor. A 0 is 3 MHz and 1 is 1.5 MHz. See Section 3.1.6.5

Table 4.2-3 FOS Analog/Bilevel Telemetry by Plug-Pin

<u>Wiring</u>	<u>Mnemonic</u>	<u>TM ID</u>	<u>Significance</u>
P2-20	YHVVLT	Y319	High Voltage Supply Voltage
P2-21	YHVCUR	Y325	High Voltage Supply Current
P2-22	YDSCRVLT	Y324	Discriminator Reference Voltage
P2-23	Y8VQPSV	Y332	Plus 8 Volt Quiet Power Supply Voltage
P2-24	YANASPAR	Y338	Analog Spare
P2-34	YFGMATMP	Y315	Filter/Grating Wheel Motor A Temperature
P2-35	Y408TMP	Y304	Optical Bench Temperature Location 4
P2-36	Y108TMP	Y301	Optical Bench Temperature Location 1
P2-37	YFGMBTMP	Y329	Filter/Grating Wheel Motor B Temperature
P2-38	YPAMATMP	Y306	Pre-Amp Assembly A Temperature
P2-39	YPAMBTMP	Y331	Pre-Amp Assembly B Temperature
P2-40	YPMFBTMP	Y333	Permanent Magnet Focus Assembly B Temperature
P2-41	YXYDFTMP	Y334	X Y Deflection Focus DAC Temperature
P5-34	YARIUTMP	Y326	RIU-A Temperature
P5-35	YBRIUTMP	Y327	RIU-B Temperature
P5-36	YCPSTMP	Y318	Central Power Supply Temperature
P5-37	Y208TMP	Y302	Optical Bench Temperature Location 2
P5-38	YSIGPTMP	Y310	Signal Processor Temperature
P5-39	YHVTMP	Y316	High Voltage Supply Temperature
P5-40	YPCATMP	Y305	Photocathode A Temperature
P5-41	YPCBTMP	Y330	Photocathode B Temperature
P6-11-12	YRIUS2	Y131	RIU Standby Status
P6-13	YQSRPI	Y119	Quiet Supply Relay Position
P6-14	YLSRPI	Y120	Logic Supply Relay Status
P6-15	YHVRPI	Y117	High Voltage Relay Position
P6-16	YCALRPI	Y102	Calibration Lamp Supply RPI
P6-17	Y18USRPI	Y121	Common Bus Relay #1 Status
P6-18	Y2BUSRPI	Y122	Common Bus Relay #2 Status
P6-31	Y1SDFPRT	Y125	SD CEA A K1-K6 Status
P6-32	Y2SDFPRT	Y126	SD CEA A K7-K11 Status
P6-33	Y3SDFPRT	Y127	SD CEA B K1-K6 Status
P6-34	Y4SDFPRT	Y128	SD CEA B K7-K11 Status
P6-35	YAPRFRPI	Y123	Aperture Failsafe Arm/Safe Status
P6-36	YENTFRPI	Y124	Entrance Door Failsafe Arm/Safe Status
P6-37	YPOLFRPI	Y130	Polarizer Failsafe Arm/Safe Status
P6-38	YHTRRPPI	Y118	Heater Control Relay Position
P6-51	YXDEFCUR	Y321	X-Deflection Coil Driver Current
P6-52	YTRMFCUR	Y323	Trim Focus Coil Driver Current
P6-53	YYDEFCUR	Y322	Y-Deflection Coil Driver Current
P6-54	YCALVLT	Y320	Calibration Lamp Supply Voltage
P6-55	YCLSCUR	Y328	Calibration Lamp Supply Current
P6-56	Y5VLPSV	Y337	Plus 5 Volt Logic Power Supply Voltage
P6-60	YPMFATMP	Y307	Permanent Magnet Focus Assembly A Temperature
P6-61	Y10ATMP	Y308	Optics Area Temperature Location 1
P6-62	Y20ATMP	Y309	Optics Area Temperature Location 2
P6-63	Y308TMP	Y303	Optical Bench Temperature Location 3
P6-64	YCEATMP	Y311	Central Electronics Temperature
P6-65	YDOORTMP	Y312	Entrance Door Mechanism Temperature
P6-66	YAPERTMP	Y313	Aperture Mechanism Temperature

Table 4.2-3 FOS Analog/Bilevel Telemetry by Plug-Pin (cont)

<u>Wiring</u>	<u>Mnemonic</u>	<u>TM ID</u>	<u>Significance</u>
P6-67	YPOLRTMP	Y314	Polarizer Mechanism Temperature
P6-70	YRESETST	Y105	Reset Status
P6-71	YCLKMON	Y134	Microprocessor Clock Monitor
P6-72	YWTCHDOG	Y103	Watchdog Timer Status
P6-73	YINSENG	Y104	Instruction Engineering Bit Status
P6-74	YODSCRAM	Y106	Descramble PROM Power Status Odd
P6-75	YEDSCRAM	Y107	Descramble PROM Power Status Even
P6-76	YCALSELR	Y133	Calibration Lamp Select RPI
P6-77	YCMTRST	Y101	Carrousel Motor Status

Table 4.2-4 FOS Serial Digital Data by ID

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y.201	8/1:8	902.5	YYPATH, Path identification. A 0 is "A" (amber or red) and 1 is "B" (blue). See Section 3.2.3.
Y.202	8/26:6	915	YYSAFLKA, Auto safe due to loss of keep-alive SMC. See Section 3.1.6.5
Y.203	8/26:7	915	YYSAFTSL, Auto safe due to loss of telemetry sync. See Section 3.1.6.5
Y.204	8/26:8	915	YYSAFED, Auto safing enabled/disabled. See Section 3.1.6.5
Y.205	8/67:1	935.5	YYSYNCS, Synchronous start instrument mode. See Section 2.1.1
Y.206	8/67:2	935.5	YYTIMITG, Time-Tag instrument mode. See Section 2.1.2
Y.207	8/67:3	935.5	YYREJRE, Reject/-Retry instrument mode. See Section 2.1.3
Y.208	8/67:4	935.5	YYTARGA, Target acquisition instrument mode. See Section 2.1.4
Y.209	8/67:5	935.5	YYDBLSN, Double/-Single precision adder instrument mode. See Section 2.1.5
Y.210	8/67:6	935.5	YYAUTPO, Automatic polarizer sequence instrument mode. See Section 2.1.6
Y.211	8/67:7	935.5	YYSPR, Spare bit.
Y.212	8/67:8	935.5	YYSPR, Spare bit.
Y.213	8/112:1	958	YYRSMNI, Resume (no initialization). See Section 2.1.1
Y.214	8/112:2	958	YYINHSLT, Inhibit slice table fill. See Section 2.1.1
Y.215	8/112:3	958	YYINHYDF, Inhibit Y-deflection table fill. See Section 2.1.1
Y.216	8/112:4	958	YYINHXDF, Inhibit X-deflection table fill. See Section 2.1.1
Y.217	8/112:5	958	YYINDFHY, Do deflection hysteresis pattern at beginning of data acquisition. See Section 2.1.1
Y.218	8/112:6-8	958	YYSPR, Spare bits.
Y.219	8/95:1	949.5	YYILT3CC, Illegal Type-3 command code. See Section 3.1
Y.220	8/95:2	949.5	YYILT4CC, Illegal Type-4 command code. See Section 3.1
Y.221	8/95:3	949.5	YYILT4MO, Illegal Type-4 command modifier. See Section 3.1
Y.222	8/95:4	949.5	YYDCMOF, Data command overflow.
Y.223	8/95:5	949.5	YYDCMIP, Data command illegal path. See Section 3.1
Y.224	8/95:6	949.5	YYSSCIP, Synchronous start command illegal path. See Section 3.1
Y.225	8/95:7	949.5	YYTAWCIP, Target acquisition window command illegal path. See Section 3.1
Y.226	8/95:8	949.5	YYSDCIP, Science dump command illegal path. See Section 3.1
Y.227	8/118:5	961	YYBEGNDA, Begin data acquisition command flag. A 1 means begin. See Section 3.1.2.3

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y.228	8/118:6	961	YYENDDA, End data acquisition command flag. A 1 means end. See Section 3.1.2.3
Y.229	8/118:7	961	YYABRTDA, Abort data acquisition command flag. A 1 means abort. See Section 3.1.2.3
Y.230	8/118:8	961	YYRSETMP, Reset microprocessor command flag. A 1 means reset. See Section 3.1.6.5
Y500	8/0	902	YENGSYNC, MP serial engr data packet sync. Value is X'A5'
Y501	8/1	902.5	YFIRMVER, Firmware version number. Has Y.201
Y502	8/2	903	YERRCHK HI, Firmware check character HI. See Section 1.5
Y502	8/3	903.5	YERRCHK LO, Firmware check character LO. See Section 1.5
Y503	8/8:7-8	906	YDOOR, Entrance door position. See Section 3.1.4.1
Y503	8/38:7-8	921	YDOOR, Entrance door position. See Section 3.1.4.1
Y503	8/68:7-8	936	YDOOR, Entrance door position. See Section 3.1.4.1
Y503	8/98:7-8	951	YDOOR, Entrance door position. See Section 3.1.4.1
Y504	8/8:5	906	YFGWASTR, FGWA encoder strobe bit.
Y504	8/38:5	921	YFGWASTR, FGWA encoder strobe bit.
Y504	8/68:5	936	YFGWASTR, FGWA encoder strobe bit.
Y504	8/98:5	951	YFGWASTR, FGWA encoder strobe bit.
Y505	8/9	906.5	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
Y505	8/10	907	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
Y505	8/39	921.5	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
Y505	8/40	922	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
Y505	8/69	936.5	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
Y505	8/70	937	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
Y505	8/99	951.5	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
Y505	8/100	952	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
Y506	8/8:1-4	906	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y506	8/38:1-4	921	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y506	8/68:1-4	936	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y506	8/98:1-4	951	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y507	8/11	907.5	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
Y507	8/12	908	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y507	8/41	922.5	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
Y507	8/42	923	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
Y507	8/71	937.5	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
Y507	8/72	938	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
Y507	8/101	952.5	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
Y507	8/102	953	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
Y508	8/8:6	906	YFGWASP, FGWA spare.
Y508	8/38:6	921	YFGWASP, FGWA spare.
Y508	8/68:6	936	YFGWASP, FGWA spare.
Y508	8/98:6	951	YFGWASP, FGWA spare.
Y509	8/15	909.5	YMECHSPR, Mechanism spares. Typical value X'0F' (subframe)
Y509	8/45	924.5	YMECHSPR, Mechanism spares. Typical value X'2D' (subframe)
Y509	8/75	939.5	YMECHSPR, Mechanism spares. Typical value X'48' (subframe)
Y509	8/105	954.5	YMECHSPR, Mechanism spares. Typical value X'69' (subframe)
Y510	8/16	910	YTARXCTR HI, Target Acq X-center HI. See Section 3.1.5
Y510	8/17	910.5	YTARXCTR LO, Target Acq X-center LO. See Section 3.1.5
Y510	8/76	940	YTARXCTR HI, Target Acq X center HI. See Section 3.1.5
Y510	8/77	940.5	YTARXCTR LO, Target Acq X center LO. See Section 3.1.5
Y511	8/18	911	YTARYCTR HI, Target Acq Y-center HI. See Section 3.1.5
Y511	8/19	911.5	YTARYCTR LO, Target Acq Y-center LO. See Section 3.1.5
Y511	8/78	941	YTARYCTR HI, Target Acq Y center HI. See Section 3.1.5
Y511	8/79	941.5	YTARYCTR LO, Target Acq Y center LO. See Section 3.1.5
Y513	8/22	913	Y0VRLITE B1, Overlight sum MS byte. Total of 32 bits (see Section 2.1.5)
Y513	8/23	913.5	Y0VRLITE B2, Overlight sum NMS byte. Total of 32 bits (see Section 2.1.5)
Y513	8/24	914	Y0VRLITE B3, Overlight sum NLS byte. Total of 32 bits (see Section 2.1.5)
Y513	8/25	914.5	Y0VRLITE B4, Overlight sum LS byte. Total of 32 bits (see Section 2.1.5)

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y514	8/26	915	YSAFING, Auto safe mode transition. Has Y.202-Y204 (bits 1-5 unused). Bits 6-7 zeroed when sampled
Y515	8/27	915.5	YTAMODE, Target acquisition mode. See Section 3.1.5
Y516	8/28	916	YARITHCK HI, Arithmetic self-check (speed) results HI. See Section 1.5
Y516	8/29	916.5	YARITHCK LO, Arithmetic self-check (speed) results LO. See Section 1.5
Y517	8/30	917	YSELFCHK HI, Processor self-check results HI. See Section 1.5
Y517	8/31	917.5	YSELFCHK LO, Processor self-check results LO. See Section 1.5
Y518	8/32	918	YDREFDAC, Discriminator reference DAC.
Y519	8/33	918.5	YFOCUSRB, Focus trim coil DAC readback. See Section 3.1.3
Y520	8/34:7-8	919	YHVDACRB HI, High voltage DAC readback HI. See Section 3.1.3
Y520	8/35	919.5	YHVDACRB LO, High voltage DAC readback LO. See Section 3.1.3
Y521	8/36	920	YYDAC HI, Y DAC readback HI. See Section 3.1.3
Y521	8/37	920.5	YYDAC LO, Y DAC readback LO. See Section 3.1.3
Y522	8/46	925	YXPITCH HI, X deflection pitch between diodes HI. See Section 3.1.3
Y522	8/47	925.5	YXPITCH LO, X deflection pitch between diodes LO. See Section 3.1.3
Y523	8/48	926	YXBASE HI, X deflection base HI. See Section 3.1.3
Y523	8/49	926.5	YXBASE LO, X deflection base LO. See Section 3.1.3
Y524	8/50	927	YXSTEPS, X deflection sub-steps. See Section 3.1.1.2
Y526	8/53	929.5	YYPITCH HI, Y deflection pitch between diodes HI. See Section 3.1.3
Y526	8/54	929	YYPITCH LO, Y deflection pitch between diodes LO. See Section 3.1.3
Y527	8/55	929.5	YYBASE HI, Y deflection base HI. See Section 3.1.3
Y527	8/56	930	YYBASE LO, Y deflection base LO. See Section 3.1.3
Y528	8/57	930.5	YYSTEPS, Y deflection sub steps. See Section 3.1.1.4
Y530	8/60	932	Y0VRSCAN, X deflection overscan. See Section 3.1.1.3
Y531	8/61	932.5	Y1STCHNL, First channel to be processed. See Section 3.1.2.2
Y532	8/62	933	YNUMCHNL, Number of channels to be processed. See Section 3.1.2.2
Y535	8/67	935.5	YACQSYNC, Acquisition mode. Has Y.205-Y.212
Y536	8/82	943	YFWSTAT1 HI, Firmware status group 1 HI. Typically ASCII (interpretation depends on use)
Y536	8/83	943.5	YFWSTAT1 LO, Firmware status group 1 LO. Typically ASCII (interpretation depends on use)
Y537	8/84	944	YFWSTAT2 HI, Firmware status group 2 HI. Typically ASCII (interpretation depends on use)

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y537	8/85	944.5	YFWSTAT2 LO, Firmware status group 2 LO. Typically ASCII (interpretation depends on use)
Y538	8/86	945	YFWSTAT3 HI, Firmware status group 3 HI. Typically ASCII (interpretation depends on use)
Y538	8/87	945.5	YFWSTAT3 LO, Firmware status group 3 LO. Typically ASCII (interpretation depends on use)
Y539	8/88	946	YFWSTAT4 HI, Firmware status group 4 HI. Typically ASCII (interpretation depends on use)
Y539	8/89	946.5	YFWSTAT4 LO, Firmware status group 4 LO. Typically ASCII (interpretation depends on use)
Y540	8/90	947	YFWSTAT5 HI, Firmware status group 5 HI. Typically ASCII (interpretation depends on use)
Y540	8/91	947.5	YFWSTAT5 LO, Firmware status group 5 LO. Typically ASCII (interpretation depends on use)
Y541	8/92	948	YFWSTAT6 HI, Firmware status group 6 HI. Typically ASCII (interpretation depends on use)
Y541	8/93	948.5	YFWSTAT6 LO, Firmware status group 6 LO. Typically ASCII (interpretation depends on use)
Y542	8/94	949	YMCLEAR, Memory clears/data acquisition. See Section 3.1.1.8
Y543	8/96	950	YLASTCMD HI, Last command at SMC error HI. See Section 3.1
Y543	8/97	950.5	YLASTCMD LO, Last command at SMC error LO. See Section 3.1
Y544	8/106	955	YNOISELM HI, Burst noise rejection limit HI. See Section 3.1.1.1
Y544	8/107	955.5	YNOISELM LO, Burst noise rejection limit LO. See Section 3.1.1.1
Y545	8/108	956	YRAMADOR HI, RAM address pointer HI. See Section 3.1.6.3
Y545	8/109	956.5	YRAMADOR LO, RAM address pointer LO. See Section 3.1.6.3
Y546	8/110	957	YINTEG, Number of integrations/X-step. See Section 3.1.1.1
Y547	8/112	958	YINTMODE, Initialization mode. Has Y.213-Y.218
Y548	8/113	958.5	YREADCYC, Readouts/memory clear. See Section 3.1.1.7
Y549	8/114	959	YDATAHIM, High byte of acquisition limit. See Section 3.1.2.3
Y550	8/115	959.5	YMDMPADR HI, Memory dump address HI. See Section 3.1.2.1
Y550	8/116	960	YMDMPADR LO, Memory dump address LO. See Section 3.1.2.1
Y551	8/4	904	YWRDSLIN HI, Words per line HI. See Section 3.1.2.1
Y551	8/5	904.5	YWRDSLIN LO, Words per line LO. See Section 3.1.2.1
Y552	8/6	905	YLINSFRM HI, Lines per frame HI. See Section 3.1.2.1
Y552	8/7	905.5	YLINSFRM LO, Lines per frame LO. See Section 3.1.2.1

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y553	8/13	908.5	YXDAC HI, X DAC readback HI. See Section 3.1.3
Y553	8/14	909	YXDAC LO, X DAC readback LO. See Section 3.1.3
Y553	8/43	923.5	YXDAC HI, X DAC readback HI. See Section 3.1.3
Y553	8/44	924	YXDAC LO, X DAC readback LO. See Section 3.1.3
Y553	8/73	938.5	YXDAC HI, X DAC readback HI. See Section 3.1.3
Y553	8/74	939	YXDAC LO, X DAC readback LO. See Section 3.1.3
Y553	8/103	953.5	YXDAC HI, X DAC readback HI. See Section 3.1.3
Y553	8/104	954	YXDAC LO, X DAC readback LO. See Section 3.1.3
Y555	8/52	928	YRANGE, Y range. See Section 3.1.1.4
Y556	8/117:1	960.5	YSPRBIT1, Spare bit. All bits in word zeroed when sampled
Y558	8/117:4	960.5	YXDACERR, X DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y559	8/117:6	960.5	YYDACERR, Y DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y560	8/117:2	960.5	YFDACERR, Focus DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y561	8/117:7	960.5	YHVDACER, HV DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y562	8/117:8	960.5	YDRDACER, Discriminator reference DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.2
Y563	8/117:3	960.5	YDDACERR, Discriminator DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.1
Y564	8/118:1	961	YACTMERR, Accumulator timer set error. A 0 is OK and a 1 is error
Y566	8/118:2-4	961	YMECHTOC, Mechanism time-out code. See Section 3.1.4
Y567	8/118:5-8	961	YDATACTL, Data control commands. Has Y.227-Y.230
Y571	8/119:1	961.5	YNDAIP, Data acquisition not in progress. A 1 means not in progress. See Section 3.1.1
Y572	8/119:2	961.5	YRIP, Resting in peace.
Y573	8/119:3	961.5	YPIP, Pause in progress. A 1 means pause in progress. See Section 3.1.2.3
Y574	8/119:4	961.5	YCPIP, CEA plot in progress. A 1 means plot in progress
Y575	8/119:5	961.5	YTAQIP, Target acquisition in progress. A 1 means acquisition in progress. See Section 2.1.4
Y576	8/59	931.5	YMSLICES, Number of memory slices. See Section 3.1.1.5
Y577	8/111	957.5	YPTRNS, Patterns per readout. See Section 3.1.1.6
Y578	8/117:5	960.5	YCDACERR, Calibration DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.4
Y579	8/34:1-2	919	YDPRMPWR, Descramble PROM power status. A 00 is off, 01 is even, 10 is odd, and 11 is both
Y580	8/34:4	919	YFFCPWR, Flat field cal lamp power. A zero is off and a 1 is on. See Section 3.1.6.4
Y581	8/34:3	919	YHVSPAR, Spare bit.

Table 4.2-4 FOS Serial Digital Data by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>Significance</u>
Y582	8/119:6	961.5	YMMIP, Mechanism motion in progress. A 1 means motion in progress
Y583	8/119:7	961.5	YAMCIP, Auto memory clear in progress. A 1 means clear to be done (interface with data monitoring background task)
Y584	8/119:8	961.5	YSDIP, Science dump in progress. A 1 means dump in progress. See Section 3.1.2.3
Y585	8/63	933.5	YLIVEHI, Accumulator open time high byte. See Section 3.1.1.1
Y586	8/64	934	YLIVELO, Accumulator open time low byte. See Section 3.1.1.1
Y587	8/65	934.5	YDEADHI, Accumulator close time high byte. See Section 3.1.1.1
Y588	8/66	935	YDEAOLO, Accumulator close time low byte. See Section 3.1.1.1
Y589	8/34:5-6	919	YSPARE, Spare.
Y649	8/95	949.5	YSMCERRS, Serial magnitude command error report flags. Has Y.219-Y.226. Word zeroed when sampled
Y650	8/20	912	YTAMAX HI, Upper Target/Acq Window HI. See Section 3.1.5
Y650	8/21	912.5	YTAMAX LO, Upper Target/Acq Window LO. See Section 3.1.5
Y651	8/80	942	YTAMIN HI, Lower Target/Acq Window HI. See Section 3.1.5
Y651	8/81	942.5	YTAMIN LO, Lower Target/Acq Window LO. See Section 3.1.5
Y652	8/51	927.5	YREJECTS HI, Number of adder rejects HI. See Section 3.1.1.1
Y652	8/58	931	YREJECTS LO, Number of adder rejects LO. See Section 3.1.1.1

Table 4.2-5 FOS Serial Digital Data by Location

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/0	902	Y500	YENGSYNC, MP serial engr data packet sync. Value is X'A5'
8/1	902.5	Y501	YFIRMVER, Firmware version number. Has Y.201
8/1:8	902.5	Y.201	YYPATH, Path identification. A 0 is "A" (amber or red) and 1 is "B" (blue). See Section 3.2.3
8/2	903	Y502	YERRCHK HI, Firmware check character HI. See Section 1.5
8/3	903.5	Y502	YERRCHK LO, Firmware check character LO. See Section 1.5
8/4	904	Y551	YWRDSLIN HI, Words per line HI. See Section 3.1.2.1
8/5	904.5	Y551	YWRDSLIN LO, Words per line LO. See Section 3.1.2.1
8/6	905	Y552	YLINSFRM HI, Lines per frame HI. See Section 3.1.2.1
8/7	905.5	Y552	YLINSFRM LO, Lines per frame LO. See Section 3.1.2.1
8/8:1-4	906	Y506	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
8/8:5	906	Y504	YFGWASTR, FGWA encoder strobe bit.
8/8:6	906	Y508	YFGWASP, FGWA spare.
8/8:7-8	906	Y503	YDOOR, Entrance door position. See Section 3.1.4.1
8/9	906.5	Y505	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
8/10	907	Y505	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
8/11	907.5	Y507	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
8/12	908	Y507	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
8/13	908.5	Y553	YXDAC HI, X DAC readback HI. See Section 3.1.3
8/14	909	Y553	YXDAC LO, X DAC readback LO. See Section 3.1.3
8/15	909.5	Y509	YMECHSPR, Mechanism spares. Typical value X'0F' (subframe)
8/16	910	Y510	YTARXCTR HI, Target Acq X-center HI. See Section 3.1.5
8/17	910.5	Y510	YTARXCTR LO, Target Acq X-center LO. See Section 3.1.5
8/18	911	Y511	YTARYCTR HI, Target Acq Y-center HI. See Section 3.1.5
8/19	911.5	Y511	YTARYCTR LO, Target Acq Y-center LO. See Section 3.1.5
8/20	912	Y650	YTAMAX HI, Upper Target/Acq Window HI. See Section 3.1.5
8/21	912.5	Y650	YTAMAX LO, Upper Target/Acq Window LO. See Section 3.1.5
8/22	913	Y513	Y0VRLITE 81, Overlight sum MS byte. Total of 32 bits (see Section 2.1.5)
8/23	913.5	Y513	Y0VRLITE 82, Overlight sum NMS byte. Total of 32 bits (see Section 2.1.5)

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/24	914	Y513	Y0VRLITE B3, Overlight sum NLS byte. Total of 32 bits (see Section 2.1.5)
8/25	914.5	Y513	Y0VRLITE B4, Overlight sum LS byte. Total of 32 bits (see Section 2.1.5)
8/26	915	Y514	YSAFING, Auto safe mode transition. Has Y.202-Y204 (bits 1-5 unused). Bits 6-7 zeroed when sampled
8/26:6	915	Y.202	YYSAFLKA, Auto safe due to loss of keep-alive SMC. See Section 3.1.6.5
8/26:7	915	Y.203	YYSAFTSL, Auto safe due to loss of telemetry sync. See Section 3.1.6.5
8/26:8	915	Y.204	YYSAFED, Auto safing enabled/disabled. See Section 3.1.6.5
8/27	915.5	Y515	YTAMODE, Target acquisition mode. See Section 3.1.5
8/28	916	Y516	YARITHCK HI, Arithmetic self-check (speed) results HI. See Section 1.5
8/29	916.5	Y516	YARITHCK LO, Arithmetic self-check (speed) results LO. See Section 1.5
8/30	917	Y517	YSELFCHK HI, Processor self-check results HI. See Section 1.5
8/31	917.5	Y517	YSELFCHK LO, Processor self-check results LO. See Section 1.5
8/32	918	Y518	YDREFDAC, Discriminator reference DAC.
8/33	918.5	Y519	YFOCUSURB, Focus trim coil DAC readback. See Section 3.1.3
8/34:1-2	919	Y579	YDPRMPWR, Descramble PROM power status. A 00 is off, 01 is even, 10 is odd, and 11 is both
8/34:3	919	Y581	YHYSPLR, Spare bit.
8/34:4	919	Y580	YFFCPWR, Flat field cal lamp power. A zero is off and a 1 is on. See Section 3.1.6.4
8/34:5-6	919	Y589	YSPARE, Spare.
8/34:7-8	919	Y520	YHVDACRB HI, High voltage DAC readback HI. See Section 3.1.3
8/35	919.5	Y520	YHVDACRB LO, High voltage DAC readback LO. See Section 3.1.3
8/36	920	Y521	YYDAC HI, Y DAC readback HI. See Section 3.1.3
8/37	920.5	Y521	YYDAC LO, Y DAC readback LO. See Section 3.1.3
8/38:1-4	921	Y506	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
8/38:5	921	Y504	YFGWASTR, FGWA encoder strobe bit.
8/38:6	921	Y508	YFGWASP, FGWA spare.
8/38:7-8	921	Y503	YDOOR, Entrance door position. See Section 3.1.4.1
8/39	921.5	Y505	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
8/40	922	Y505	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
8/41	922.5	Y507	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
8/42	923	Y507	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/43	923.5	Y553	YXDAC HI, X DAC readback HI. See Section 3.1.3
8/44	924	Y553	YXDAC LO, X DAC readback LO. See Section 3.1.3
8/45	924.5	Y509	YMECHSPR, Mechanism spares. Typical value X'2D' (subframe)
8/46	925	Y522	YXPITCH HI, X deflection pitch between diodes HI. See Section 3.1.3
8/47	925.5	Y522	YXPITCH LO, X deflection pitch between diodes LO. See Section 3.1.3
8/48	926	Y523	YXBASE HI, X deflection base HI. See Section 3.1.3
8/49	926.5	Y523	YXBASE LO, X deflection base LO. See Section 3.1.3
8/50	927	Y524	YXSTEPS, X deflection sub-steps. See Section 3.1.1.2
8/51	927.5	Y652	YREJECTS HI, Number of adder rejects HI. See Section 3.1.1.1
8/52	928	Y555	YRANGE, Y range. See Section 3.1.1.4
8/53	928.5	Y526	YYPITCH HI, Y deflection pitch between diodes HI. See Section 3.1.3
8/54	929	Y526	YYPITCH LO, Y deflection pitch between diodes LO. See Section 3.1.3
8/55	929.5	Y527	YYBASE HI, Y deflection base HI. See Section 3.1.3
8/56	930	Y527	YYBASE LO, Y deflection base LO. See Section 3.1.3
8/57	930.5	Y528	YYSTEPS, Y deflection sub steps. See Section 3.1.1.4
8/58	931	Y652	YREJECTS LO, Number of adder rejects LO. See Section 3.1.1.1
8/59	931.5	Y576	YMSLICES, Number of memory slices. See Section 3.1.1.5
8/60	932	Y530	Y0VRSCAN, X deflection overscan. See Section 3.1.1.3
8/61	932.5	Y531	Y1STCHNL, First channel to be processed. See Section 3.1.2.2
8/62	933	Y532	YNUMCHNL, Number of channels to be processed. See Section 3.1.2.2
8/63	933.5	Y585	YLIVEHI, Accumulator open time high byte. See Section 3.1.1.1
8/64	934	Y586	YLIVELO, Accumulator open time low byte. See Section 3.1.1.1
8/65	934.5	Y587	YDEADHI, Accumulator close time high byte. See Section 3.1.1.1
8/66	935	Y588	YDEADLO, Accumulator close time low byte. See Section 3.1.1.1
8/67	935.5	Y535	YACQSYNC, Acquisition mode. Has Y.205-Y.212
8/67:1	935.5	Y.205	YYSYNCS, Synchronous start instrument mode. See Section 2.1.1
8/67:2	935.5	Y.206	YYTIMTG, Time-Tag instrument mode. See Section 2.1.2
8/67:3	935.5	Y.207	YYREJRE, Reject/-Retry instrument mode. See Section 2.1.3

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/67:4	935.5	Y.208	YYTARGA, Target acquisition instrument mode. See Section 2.1.4
8/67:5	935.5	Y.209	YYDBLSN, Double/-Single precision adder instrument mode. See Section 2.1.5
8/67:6	935.5	Y.210	YYAUTPO, Automatic polarizer sequence instrument mode. See Section 2.1.6
8/67:7	935.5	Y.211	YYSPR, Spare bit.
8/67:8	935.5	Y.212	YYSPR, Spare bit.
8/68:1-4	936	Y506	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
8/68:5	936	Y504	YFGWASTR, FGWA encoder strobe bit.
8/68:6	936	Y508	YFGWASP, FGWA spare.
8/68:7-8	936	Y503	YDOOR, Entrance door position. See Section 3.1.4.1
8/69	936.5	Y505	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
8/70	937	Y505	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
8/71	937.5	Y507	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
8/72	938	Y507	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
8/73	938.5	Y553	YXDAC HI, X DAC readback HI. See Section 3.1.3
8/74	939	Y553	YXDAC LO, X DAC readback LO. See Section 3.1.3
8/75	939.5	Y509	YMECHSPR, Mechanism spares. Typical value X'48' (subframe)
8/76	940	Y510	YTARXCTR HI, Target Acq X center HI. See Section 3.1.5
8/77	940.5	Y510	YTARXCTR LO, Target Acq X center LO. See Section 3.1.5
8/78	941	Y511	YTARYCTR HI, Target Acq Y center HI. See Section 3.1.5
8/79	941.5	Y511	YTARYCTR LO, Target Acq Y center LO. See Section 3.1.5
8/80	942	Y651	YTAMIN HI, Lower Target/Acq Window HI. See Section 3.1.5
8/81	942.5	Y651	YTAMIN LO, Lower Target/Acq Window LO. See Section 3.1.5
8/82	943	Y536	YFWSTAT1 HI, Firmware status group 1 HI. Typically ASCII (interpretation depends on use)
8/83	943.5	Y536	YFWSTAT1 LO, Firmware status group 1 LO. Typically ASCII (interpretation depends on use)
8/84	944	Y537	YFWSTAT2 HI, Firmware status group 2 HI. Typically ASCII (interpretation depends on use)
8/85	944.5	Y537	YFWSTAT2 LO, Firmware status group 2 LO. Typically ASCII (interpretation depends on use)
8/86	945	Y538	YFWSTAT3 HI, Firmware status group 3 HI. Typically ASCII (interpretation depends on use)
8/87	945.5	Y538	YFWSTAT3 LO, Firmware status group 3 LO. Typically ASCII (interpretation depends on use)

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/88	946	Y539	YFWSTAT4 HI, Firmware status group 4 HI. Typically ASCII (interpretation depends on use)
8/89	946.5	Y539	YFWSTAT4 LO, Firmware status group 4 LO. Typically ASCII (interpretation depends on use)
8/90	947	Y540	YFWSTAT5 HI, Firmware status group 5 HI. Typically ASCII (interpretation depends on use)
8/91	947.5	Y540	YFWSTAT5 LO, Firmware status group 5 LO. Typically ASCII (interpretation depends on use)
8/92	948	Y541	YFWSTAT6 HI, Firmware status group 6 HI. Typically ASCII (interpretation depends on use)
8/93	948.5	Y541	YFWSTAT6 LO, Firmware status group 6 LO. Typically ASCII (interpretation depends on use)
8/94	949	Y542	YMCLEARs, Memory clears/data acquisition. See Section 3.1.1.8
8/95	949.5	Y649	YSMCERRs, Serial magnitude command error report flags. Has Y.219-Y.226. Word zeroed when sampled
8/95:1	949.5	Y.219	YYILT3CC, Illegal Type-3 command code. See Section 3.1
8/95:2	949.5	Y.220	YYILT4CC, Illegal Type-4 command code. See Section 3.1
8/95:3	949.5	Y.221	YYILT4MO, Illegal Type-4 command modifier. See Section 3.1
8/95:4	949.5	Y.222	YYDCMOF, Data command overflow.
8/95:5	949.5	Y.223	YYDCMIP, Data command illegal path. See Section 3.1
8/95:6	949.5	Y.224	YYSSCIP, Synchronous start command illegal path. See Section 3.1
8/95:7	949.5	Y.225	YYTAWCIP, Target acquisition window command illegal path. See Section 3.1
8/95:8	949.5	Y.226	YYSDCIP, Science dump command illegal path. See Section 3.1
8/96	950	Y543	YLASTCMD HI, Last command at SMC error HI. See Section 3.1
8/97	950.5	Y543	YLASTCMD LO, Last command at SMC error LO. See Section 3.1
8/98:1-4	951	Y506	YFGWAPOS, Filter/Grating Wheel Assembly position. See Section 3.1.4.4
8/98:5	951	Y504	YFGWASTR, FGWA encoder strobe bit.
8/98:6	951	Y508	YFGWASP, FGWA spare.
8/98:7-8	951	Y503	YDOOR, Entrance door position. See Section 3.1.4.1
8/99	951.5	Y505	YAPERPOS HI, Aperture position HI. See Section 3.1.4.2
8/100	952	Y505	YAPERPOS LO, Aperture position LO. See Section 3.1.4.2
8/101	952.5	Y507	YPLRZPOS HI, Polarizer position HI. See Section 3.1.4.3
8/102	953	Y507	YPLRZPOS LO, Polarizer position LO. See Section 3.1.4.3
8/103	953.5	Y553	YXDAC HI, X DAC readback HI. See Section 3.1.3
8/104	954	Y553	YXDAC LO, X DAC readback LO. See Section 3.1.3

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
3/105	954.5	Y509	YMECHSPR, Mechanism spares. Typical value X'69' (subframe)
3/106	955	Y544	YNOISELM HI, Burst noise rejection limit HI. See Section 3.1.1.1
3/107	955.5	Y544	YNOISELM LO, Burst noise rejection limit LO. See Section 3.1.1.1
3/108	956	Y545	YRAMADDR HI, RAM address pointer HI. See Section 3.1.6.3
3/109	956.5	Y545	YRAMADDR LO, RAM address pointer LO. See Section 3.1.6.3
3/110	957	Y546	YINTEG, Number of integrations/X-step. See Section 3.1.1.1
3/111	957.5	Y577	YPTRNS, Patterns per readout. See Section 3.1.1.6
3/112	958	Y547	YINTMODE, Initialization mode. Has Y.213-Y.218
3/112:1	958	Y.213	YYRSMNI, Resume (no initialization). See Section 2.1.1
3/112:2	958	Y.214	YYINHSLT, Inhibit slice table fill. See Section 2.1.1
3/112:3	958	Y.215	YYINHYDF, Inhibit Y-deflection table fill. See Sec- tion 2.1.1
3/112:4	958	Y.216	YYINHXDF, Inhibit X-deflection table fill. See Sec- tion 2.1.1
3/112:5	958	Y.217	YYINDFHY, Do deflection hysteresis pattern at begin- ning of data acquisition. See Section 2.1.1
3/112:6-8	958	Y.218	YYSPR, Spare bits.
3/113	958.5	Y548	YREADCYC, Readouts/memory clear. See Section 3.1.1.7
3/114	959	Y549	YDATALIM, High byte of acquisition limit. See Sec- tion 3.1.2.3
3/115	959.5	Y550	YMDMPADR HI, Memory dump address HI. See Section 3.1.2.1
3/116	960	Y550	YMDMPADR LO, Memory dump address LO. See Section 3.1.2.1
3/117:1	960.5	Y556	YSPRBIT1, Spare bit. All bits in word zeroed when sampled
3/117:2	960.5	Y560	YFDACERR, Focus DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
3/117:3	960.5	Y563	YDDACERR, Discriminator DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.1
3/117:4	960.5	Y558	YXDACERR, X DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
3/117:5	960.5	Y578	YCDACERR, Calibration DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.4
3/117:6	960.5	Y559	YYDACERR, Y DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
3/117:7	960.5	Y561	YHYDACER, HV DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
3/117:8	960.5	Y562	YDRDACER, Discriminator reference DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.2

Table 4.2-5 FOS Serial Digital Data by Location (cont)

<u>WD/SF</u>	<u>UDL</u>	<u>TM ID</u>	<u>Significance</u>
8/118:1	961	Y564	YACTMERR, Accumulator timer set error. A 0 is OK and a 1 is error
8/118:2-4	961	Y566	YMECHTOC, Mechanism time-out code. See Section 3.1.4
8/118:5-8	961	Y567	YDATACTL, Data control commands. Has Y.227-Y.230
8/118:5	961	Y.227	YYBEGNDA, Begin data acquisition command flag. A 1 means begin. See Section 3.1.2.3
8/118:6	961	Y.228	YYENDDA, End data acquisition command flag. A 1 means end. See Section 3.1.2.3
8/118:7	961	Y.229	YYABRTDA, Abort data acquisition command flag. A 1 means abort. See Section 3.1.2.3
8/118:8	961	Y.230	YYRSETMP, Reset microprocessor command flag. A 1 means reset. See Section 3.1.6.5
8/119:1	961.5	Y571	YNDAIP, Data acquisition not in progress. A 1 means not in progress. See Section 3.1.1
8/119:2	961.5	Y572	YRIP, Resting in peace.
8/119:3	961.5	Y573	YPIP, Pause in progress. A 1 means pause in progress. See Section 3.1.2.3
8/119:4	961.5	Y574	YCPIP, CEA plot in progress. A 1 means plot in progress
8/119:5	961.5	Y575	YTAQIP, Target acquisition in progress. A 1 means acquisition in progress. See Section 2.1.4
8/119:6	961.5	Y582	YMMIP, Mechanism motion in progress. A 1 means motion in progress
8/119:7	961.5	Y583	YAMCIP, Auto memory clear in progress. A 1 means clear to be done (interface with data monitoring background task)
8/119:8	961.5	Y584	YSDIP, Science dump in progress. A 1 means dump in progress. See Section 3.1.2.3

Table 4.2-6 FOS NSSC-1 Processor Telemetry by ID

<u>TM ID</u>	<u>WD/SF</u>	<u>SHP</u>	<u>Significance</u>
Y600	9/0	879 ₁	YSTBUF, Number of FOS status buffer entries. Measured since last time the counter reset
Y601	9/1		YONOFF, FOS on/off indicator. Is 1 if FOS successfully turned off via YFOFF; otherwise 2
Y602	9/2		YFINST, Status of INIT processor. Is 1 if YFINIT executing, 2 if terminated on error, 4 if termination normal
Y603	9/3		YFSDST, Science data storage status. Is 1 if YFSDST executing, 2 if terminated on error, 4 if termination normal
Y604	9/4		YFPRST, Science data processing status. Is 1 if YFSDPR executing, 2 if terminated on error, 4 if termination normal
Y605	9/5		YSPRO, Spare 0.
Y606	9/6		YLINCT, Line number within a frame.
Y607	9/7		YFHKST, Housekeeping status. Is 1 if YFHPKG executing, 2 if terminated on error, 4 if disabled by another processor
Y608	9/3		YFASST, Autonomous safe status. Is 1 if YFASAF executing, 2 if terminated abnormally, 4 if termination normal
Y609	9/9		YFTOST, Turn off status. Is 1 if YFOFF executing, 2 if terminated abnormally, 4 if termination normal
Y610	9/10		YFL81, Data items 1-8. FOS limit check flags 81
Y611	9/11		YFL169, Data items 9-16. FOS limit check flags 82
Y612	9/12		YFL241, Data items 17-24. FOS limit check flags 83
Y613	9/13		YFL322, Data items 25-32. FOS limit check flags 84
Y614	9/14		YDISCT, Counts main frame discrete log errors. Counter for consecutive major frames in which discrete command log error indicated
Y615	9/15		YSMECT, Counts main frame magnitude command errors. Counter for consecutive major frames in which a serial magnitude command error reported
Y616	9/16		YKEEP, Counts main frame keep alive failures. Counter of consecutive major frames in which FOS serial ED fails keep-alive test
Y617	9/17		YFLGCT, Counts main frame limit check failures. Counter for consecutive major frames in which same FOS limit check failed
Y618	9/18		YSFFLG, Autonomous safe flag. Is 1 if YFASAF has been invoked by application processor, 2 if not invoked
Y619	9/19		YTOFLG, Turn off flag. Is 1 if YFOFF has been invoked by application processor, 2 if not invoked
Y620	9/20	888 ₄	YFM2FL, Action indicator for YFM2PR module. See Section 3.2.1
Y621	9/21	879 ₃	YFRCTR, Count frames for part 1 of YFSDPR processor.
Y622	9/22	882 ₂	YGIYUP, Mode 2 target acquisition error indicator.
Y623	9/23		YGPCTR, Count frames for part 2 of YFSDPR processor.

Table 4.2-6 FOS NSSC-1 Processor Telemetry by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>SHP</u>	<u>Significance</u>
Y624	9/24	881 ₂	YTACMP, Mode 2 Target acquisition completion indicator. A 1 means complete
Y625	9/25		YFM2ST, Mode 2 target acquisition processor status. Is 1 if YFMOD2 executing, 2 if terminated abnormally, 4 if termination normal
Y626	9/26		YSPR1, Spare 1.
Y627	9/27		YSPR2, Spare 2.
Y628	9/28		YFPKST, Peak-up target acquisition processor status.
Y629	9/29		YFPUCT, Counter of frames/dwell during FPKUP.
Y630	9/30	879 ₅	YFDWCT, Dwell counter for FPKUP. See Section 3.2.1
Y631	9/31		YOV81, 8 LSBs accumulated YOVRILITE.
Y632	9/32		YOV169, Next 8 LSBs accumulated YOVRILITE.
Y633	9/33		YOV241, Next 8 LSBs accumulated YOVRILITE.
Y634	9/34		YOV322, 8 MSBs accumulated YOVRILITE.
Y635	9/35		YSPR3, Spare 3.
Y636	9/36		YSPR4, Spare 4.
Y637	9/37		YSPR5, Spare 5.
Y638	9/38		YFSCTR, Number of tests by FHKPG where fail-safe armed. Counter indicating number of tests since YHKPG was initialized where fail-safe RPI was armed
Y639	9/39		YERCTR, Consecutive major frames with error check error. Counter indicating consecutive major frames in which an error check error is indicated
Y640	9/40		YFWCTR, Consecutive major frames with firmware version error. Counter indicating consecutive major frames in which a firmware version error is indicated
Y641	9/41		YMFCCT, Counter of major frame fail-safe RPI test.
Y642	9/42		Major frame counter used for fail-safe RPI test
Y643	9/43		YMFECT, Counter of major frame output for data log.
Y644	9/44		Major frame counter tested for output of SHPs
Y645	9/45		YSAFCR, Consecutive major frames gone safe autonomously. Number of consecutive major frames in which FOS indicated it has gone safe autonomously
Y646	9/46		YOVCTR, Counter of failed YOVRILITE sum tests. Number of consecutive major frames in which FOS overlight sum test has failed
Y647	9/47		YSCCTR, Counter of failed self-check tests. Number of consecutive major frames in which the FOS has failed the self-check test
Y648	9/48		YSPCTR, Counter of speed check errors. Counter indicating consecutive major frames in which a speed check error is indicated
Y648	9/49		YSPR6, Spare 6.
Y648	9/50		YSPR7, Spare 7.
Y648	9/51		YSPR8 81, Spare.
Y648	9/52		YSPR8 82, Spare.
Y648	9/53		YSPR8 83, Spare.
			YSPR8 84, Spare.
			YSPR8 85, Spare.

Table 4.2-6 FOS NSSC-1 Processor Telemetry by ID (cont)

<u>TM ID</u>	<u>WD/SF</u>	<u>SHP</u>	<u>Significance</u>
Y.648	9/54	YSPR8	86, Spare.
Y.648	9/55	YSPR8	87, Spare.
Y.648	9/56	YSPR8	88, Spare.
Y.648	9/57	YSPR8	89, Spare.
Y.648	9/58	YSPR8	810, Spare.
Y.648	9/59	YSPR8	811, Spare.

Table 4.2-7 All FOS Commands and Telemetry by ID

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y.001	YYSHUID	/		878	Identifier for FOS-Unique SHP data. See Section 3.2.1
Y.002	YYNXTSB	/		880 ₁	Next available message position in status buffer. See Section 3.2.1
Y.003	YYSBST	/		881 ₁	FOS single-bit status items. See Section 3.2.1
Y.004	YMAP	/		879 ₂	Map number. See Section 3.2.1
Y.005	YM2MAP	/		880 ₂	Maximum maps. See Section 3.2.1
Y.006	YFM2CF	/		883 ₂	Count rate window change for next data set. See Section 3.2.1
Y.007	YYNMINOR	/		884 ₂	Minor frame number. See Section 3.2.1
Y.008	YFXCTR	/		885 ₂ 895 ₄	X-offset to center. See Section 3.2.1
Y.009	YFYCTR	/		886 ₂ 896 ₄	Y-offset to center. See Section 3.2.1
Y.010	YYFVCTR2	/		893 ₂ 894 ₄	V2 component of ST slew request. See Section 3.2.1
Y.010	YYFVCTR2 HI	/		887 ₂	V2 component of ST slew request HI.
Y.010	YYFVCTR2 LO	/		888 ₂	V2 component of ST slew request LO.
Y.011	YYFVCTR3	/		894 ₂ 894 ₄	V3 component of ST slew request. See Section 3.2.1
Y.011	YYFVCTR3 HI	/		889 ₂	V3 component of ST slew request HI.
Y.011	YYFVCTR3 LO	/		890 ₂	V3 component of ST slew request LO.
Y.012	YPKCT1	/		885 ₂ 880 ₄	Objects found in field. See Section 3.2.1
Y.013	YYCHPK1	/		881 ₃ 881 ₄	First channel where peak found. See Section 3.2.1
Y.014	YYCHPK2	/		882 ₃ 882 ₄	Second channel where peak found. See Section 3.2.1
Y.015	YYCHPK3	/		883 ₃ 883 ₄	Third channel where peak found. See Section 3.2.1
Y.016	YYCHPK4	/		884 ₃ 884 ₄	Fourth channel where peak found. See Section 3.2.1
Y.017	YPPINV	/		885 ₃ 885 ₄	Preplanned branch status. See Section 3.2.1
Y.018	YRSINV	/		886 ₃ 886 ₄	Raster scan request status. See Section 3.2.1
Y.019	YBASKP	/		887 ₃ 887 ₄	Y base for current data. See Section 3.2.1
Y.020	YNBCTR	/		888 ₃	Brightness rank. See Section 3.2.1
Y.021	YB8SJ	/		889 ₃	Peak matrix number. See Section 3.2.1
Y.022	YBSM	/		890 ₃	Channel number of peak. See Section 3.2.1
Y.023	YNMAX	/		891 ₃	Number of counts in peak. See Section 3.2.1
Y.024	YNMEAN	/		892 ₃ 891 ₄	Counts in mean sky.
Y.025	YVARI1	/		893 ₃ 892 ₄	Sky variance.
Y.026	YGPCTR	/		879 ₄	Previous value of binary search step counter. See Section 3.2.1
Y.027	YEDGE	/		889 ₄	Result of edge test. See Section 3.2.1
Y.028	YNTARG	/		890 ₄	Counts in target channels. See Section 3.2.1
Y.029	YACSAV HI	/		880 ₅	Historic counts HI. See Section 3.2.1
Y.029	YACSAV LO	/		881 ₅	Historic counts LO. See Section 3.2.1
Y.030	YFUTT HI	/		882 ₅	Saved dwell time HI. See Section 3.2.1
Y.030	YFUTT LO	/		883 ₅	Saved dwell time LO. See Section 3.2.1
Y.031	YACACC HI	/		884 ₅	Number of counts in this dwell HI.
Y.031	YACACC LO	/		885 ₅	Number of counts in this dwell LO.

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>IDL</u>	<u>SHP</u>	<u>Significance</u>
Y.201	YYPATH	8/1:8	902.5		Path identification. A 0 is "A" (amber or red) and 1 is "B" (blue). See Section 3.2.3
Y.202	YYSAFLKA	8/26:6	915		Auto safe due to loss of keep-alive SMC. See Section 3.1.6.5
Y.203	YYSAFTSL	8/26:7	915		Auto safe due to loss of telemetry sync. See Section 3.1.6.5
Y.204	YYSAFED	8/26:8	915		Auto safety enabled/disabled. See Section 3.1.6.5
Y.205	YYSYNCS	8/67:1	935.5		Synchronous start instrument mode. See Section 2.1.1
Y.206	YYTMTG	8/67:2	935.5		Time-Tag instrument mode. See Section 2.1.2
Y.207	YYREJRE	8/67:3	935.5		Reject-/Retry instrument mode. See Section 2.1.3
Y.208	YYTARGA	8/67:4	935.5		Target acquisition instrument mode. See Section 2.1.4
Y.209	YYDBLSN	8/67:5	935.5		Double/-Single precision adder instrument mode. See Section 2.1.5
Y.210	YYAUTPO	8/67:6	935.5		Automatic polarizer sequence instrument mode. See Section 2.1.6
Y.211	YYSPR	8/67:7	935.5		Spare bit.
Y.212	YYSPR	8/67:8	935.5		Spare bit.
Y.213	YYRSMNI	8/112:1	958		Resume (no initialization). See Section 2.1.1
Y.214	YYINHSLT	8/112:2	958		Inhibit slice table fill. See Section 2.1.1
Y.215	YYINHYDF	8/112:3	958		Inhibit Y-deflection table fill. See Section 2.1.1
Y.216	YYINHXDF	8/112:4	958		Inhibit X-deflection table fill. See Section 2.1.1
Y.217	YYINDFHY	8/112:5	958		Do deflection hysteresis pattern at beginning of data acquisition. See Section 2.1.1
Y.218	YYSPR	8/112:6-3	958		Spare bits.
Y.219	YYILT3CC	8/95:1	949.5		Illegal Type-3 command code. See Section 3.1
Y.220	YYILT4CC	8/95:2	949.5		Illegal Type-4 command code. See Section 3.1
Y.221	YYILT4MD	8/95:3	949.5		Illegal Type-4 command modifier. See Section 3.1
Y.222	YYDCMOF	8/95:4	949.5		Data command overflow.
Y.223	YYDCMIP	8/95:5	949.5		Data command illegal path. See Section 3.1
Y.224	YYSSCIP	8/95:6	949.5		Synchronous start command illegal path. See Section 3.1
Y.225	YYTAWCIP	8/95:7	949.5		Target acquisition window command illegal path. See Section 3.1
Y.226	YYSDCIP	8/95:8	949.5		Science dump command illegal path. See Section 3.1
Y.227	YYBEGINDA	8/118:5	961		Begin data acquisition command flag. A 1 means begin. See Section 3.1.2.3
Y.228	YYENDDA	8/118:6	961		End data acquisition command flag. A 1 means end. See Section 3.1.2.3
Y.229	YYABRTDA	8/118:7	961		Abort data acquisition command flag. A 1 means abort. See Section 3.1.2.3

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y.230	YYRSETMP	8/118:3	961		Reset microprocessor command flag. A 1 means reset. See Section 3.1.6.5
Y.400	YSPR	/	1		Spare (225 words). See Section 3.2.2
Y.401	OOTBL	/	322		Discriminator DAC/Disabled Diode Table (512 words). See Section 3.2.2
Y.402	RAMMAP	/	834		RAM map (4 words). See Section 3.2.2
Y.403	ASCIIH0	/	838		ASCII header (64 words). See Section 3.2.2
Y.404	MIF	/	962		Minor frame number (8 bits). See Section 3.2.2
Y.405	MAF	/	962.5		Major frame number (8 bits). See Section 3.2.2
Y.406	NREAD	/	963		Readout number (16 bits). See Section 3.2.2
Y.407	NMEMCLR	/	964		Memory clear number (16 bits). See Section 3.2.2
Y.408	YSPR	/	965		Spare word.
Y.409	YYEPMC	/	226		Entrance Port Mechanism Control Block (8 words). See Section 3.2.2
Y.410	YYAPMC	/	234		Aperture Mechanism Control Block (18 words). See Section 3.2.2
Y.411	YYPLMC	/	252		Polarizer Mechanism Control Block (54 words). See Section 3.2.2
Y.412	YYFGMC	/	306		FGWA Mechanism Control Block (16 words). See Section 3.2.2
Y.648	YSPR8 81	9/49			Spare.
Y.648	YSPR8 82	9/50			Spare.
Y.648	YSPR8 83	9/51			Spare.
Y.648	YSPR8 84	9/52			Spare.
Y.648	YSPR8 85	9/53			Spare.
Y.648	YSPR8 86	9/54			Spare.
Y.648	YSPR8 87	9/55			Spare.
Y.648	YSPR8 88	9/56			Spare.
Y.648	YSPR8 89	9/57			Spare.
Y.648	YSPR8 810	9/58			Spare.
Y.648	YSPR8 811	9/59			Spare.
Y000 _c	YRAMADDR	/			Load RAM storage address. See Section 3.1.6.3
Y002 _c	YSCIDMP	/			Set dump parameters. See Section 3.1.2.1
Y004 _c	YTARACQ	/			Set target acquisition parameters. See Section 3.1.5
Y006 _c	YDISCADDR	/			Load discriminator at address or set all values. See Section 3.1.6.2
Y008 _c	YLIVETYM	/			Set accumulator open (live) time. See Section 3.1.1.1
Y010 _c	YDEADTYM	/			Set accumulator closed (dead) time. See Section 3.1.1.1
Y012 _c	YCHNLEN	/			Enable/inhibit channel(s). See Section 3.1.6.2
Y014 _c	YREJLIM	/			Set noise rejection limit. See Section 3.1.1.1
Y016 _c	YACQLIM	/			Set data acquisition limit. See Section 3.1.2.3

Table 4.2-7 All FDS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y018 _c	YSTRWD	/			Store next commands as data. See Section 3.1.6.3
Y022 _c	YMECHCAL	/			Set feedback code for mechanism. See Section 3.1.4
Y023 _c	YSYNC	/			Set delay for starting synchronous acquisition. See Section 3.1.6.1
Y024 _c	YX-DEFL	/			Set X-deflection amplifier DAC. See Section 3.1.3
Y025 _c	YY-DEFL	/			Set Y-deflection amplifier DAC. See Section 3.1.3
Y026 _c	YX-BASE	/			Base value for X deflection computations. See Section 3.1.3
Y027 _c	YY-BASE	/			Base value for Y deflection computations. See Section 3.1.3
Y028 _c	YX-PITCH	/			Scaled X-deflection DAC value for one diode width in X. See Section 3.1.3
Y029 _c	YY-PITCH	/			Scaled Y-deflection DAC value for one diode width in Y. See Section 3.1.3
Y030 _c	YHV_DAC	/			Set high voltage power supply DAC. See Section 3.1.3
Y031 _c	YDISC	/			Set discriminator DAC table value. See Section 3.1.6.2
Y032 _c	YREFDAC	/			Set common discriminator reference DAC. See Section 3.1.6.2
Y033 _c	YFOCUS	/			Set focus trim DAC. See Section 3.1.3
Y034 _c	YENTRNC	/			Set entrance port open or closed. See Section 3.1.4.1
Y035 _c	YAPER	/			Set entrance aperture to position. See Section 3.1.4.2
Y036 _c	YPLZR	/			Set polarizer mechanism to position. See Section 3.1.4.3
Y037 _c	YFILTER	/			Set FGA to position. See Section 3.1.4.4
Y038 _c	YFFCAL	/			Set LED flat-field lamp on or off. See Section 3.1.6.4
Y039 _c	YX-STEP	/			Select number of X deflection steps. See Section 3.1.1.2
Y040 _c	YX-DLY	/			Spare.
Y041 _c	YINIT	/			Set initialization mode. See Section 3.1.6.1
Y042 _c	Y1STCHNL	/			Set first channel to be processed. See Section 3.1.2.2
Y043 _c	YINTS	/			Set number of sub-integrations per X-step. See Section 3.1.1.1
Y044 _c	YSTOPDMP	/			Stop science dump. See Section 3.1.2.3
Y045 _c	YOUT-CLR	/			Set readouts/memory clear. See Section 3.1.1.7
Y046 _c	YTAMOD	/			Set target acquisition mode. See Section 3.1.5
Y047 _c	YY-STEP	/			Select number of Y deflection steps. See Section 3.1.1.4

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>IDL</u>	<u>SHP</u>	<u>Significance</u>
Y048	YY-DLY	/			Spare.
Y049 _c	YACQMODE	/			Set data acquisition mode. See Section 3.1.6.1
Y050 _c	YCHNLS	/			Set number of channels to be processed. See Section 3.1.2.2
Y051 _c	Y0VRSCAN	/			Set number of diodes overscan. See Section 3.1.1.3
Y052 _c	YRAM-MAP	/			Map physical to logical RAM page. See Section 3.1.6.5
Y053 _c	YCLEARs	/			Set number of memory clears/acquisition. See Section 3.1.1.8
Y054 _c	YPTRNOUT	/			Set number of patterns/readout. See Section 3.1.1.6
Y055 _c	YMEMCHK	/			Fill science memory with test pattern. See Section 3.1.6.3
Y056 _c	YMCHSTEP	/			Step mechanism. See Section 3.1.4
Y057 _c	YSDERASE	/			Clear science memory locations. See Section 3.1.6.3
Y058 _c	YKPALVED	/			Enable/disable autonomous going safe. See Section 3.1.6.5
Y059 _c	YSCIADDR	/			Set first RAM address for science data. See Section 3.1.6.5
Y066 _c	YY-RNGE	/			Set range for Y deflection. See Section 3.1.1.4
Y068 _c	YSLICES	/			Set number of memory slices. See Section 3.1.1.5
Y070 _c	YSCIACT	/			Control science data dump. See Section 3.1.2.3
Y071 _c	YKEY	/			Provide FORTH KEY capability. See Section 3.1.6.5
Y083 _c	YDDCHK	/			Sample all discriminator DACs. See Section 3.1.6.1
Y084 _c	YEFTILL	/			Sample all serial digital telemetry. See Section 3.1.6.1
Y085 _c	YPAUSE	/			Set/reset pause acquisition bit. See Section 3.1.2.3
Y086 _c	YRANDOM	/			Fill science memory with pseudo-random sequence. See Section 3.1.6.3
Y087 _c	YMCHREG	/			Set mechanism register to drive signal. See Section 3.1.4
Y101	YCMTRST	3/1:3		141.5	Carousel Motor Status. A 0 is B and a 1 is A. See Section 3.1.4.4
Y102	YCALRPI	4/1:6		142.5	Calibration Lamp Supply RPI. A 0 is on and 1 is off. See Section 3.1.6.4
Y103	YWTCHDOG	3/1:3		141.5	Watchdog Timer Status. A 0 is OK and 1 is error. See Section 3.1.6.5
Y104	YINSENG	3/1:4		141.5	Instruction Engineering Bit Status. A 0 is OK and 1 is error. See Section 3.1.6.5

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>IDL</u>	<u>SHP</u>	<u>Significance</u>
Y105	YRESETST	3/1:1		141.5	Reset Status. A 0 is reset and a 1 is not reset
Y106	YODSCRAM	3/1:5		141.5	Descramble PROM Power Status Odd. A 0 is off and 1 is on
Y107	YEDSCRAM	3/1:6		141.5	Descramble PROM Power Status Even. A 0 is off and 1 is on
Y117	YHVRPI	4/1:5		142.5	High Voltage Relay Position. A 0 is HVON (on) and 1 is HVOF (off)
Y118	YHTRRPI	1/1:8		139.5	Heater Control Relay Position. A 0 is HTON (on) and 1 is HTOF (off)
Y119	YQSRPI	4/1:3		142.5	Quiet Supply Relay Position. A 0 is +QPS (on) and 1 is -QPS (off)
Y120	YLSRPI	4/1:4		142.5	Logic Supply Relay Status. A 0 is +LPS (on) and 1 is -LPS (off)
Y121	Y1BUSRPI	4/1:7		142.5	Common Bus Relay #1 Status. A 0 is B On/A Off1 and a 1 is A On/B Off1
Y122	Y2BUSRPI	4/1:8		142.5	Common Bus Relay #2 Status. A 0 is B On/A Off2 and a 1 is A On/B Off2
Y123	YAPRFRPI	1/1:5		139.5	Aperture Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.2
Y124	YENTFRPI	1/1:6		139.5	Entrance Door Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.1
Y125	Y1SDFPRT	1/1:1		139.5	SD CEA A K1-K6 Status. A 0 is AB and 1 is AA
Y126	Y2SDFPRT	1/1:2		139.5	SD CEA A K7-K11 Status. A 0 is AB and 1 is AA
Y127	Y3SDFPRT	1/1:3		139.5	SD CEA B K1-K6 Status. A 0 is BB and 1 is BA
Y128	Y4SDFPRT	1/1:4		139.5	SD CEA B K7-K11 Status. A 0 is BB and 1 is BA
Y130	YPOLFRPI	1/1:7		139.5	Polarizer Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.3
Y131	YRIUS2	4/1:1-2		142.5	RIU Standby Status. Bit 1 is for RIU A and bit 2 for RIU B. A 0 means STBY1 and a 1 means STBY2
Y133	YCALSELR	3/1:7		141.5	Calibration Lamp Select RPI. A 0 is B and a 1 is A. See Section 3.1.6.4
Y134	YCLKMON	3/1:2		141.5	Microprocessor Clock Monitor. A 0 is 3 MHz and 1 is 1.5 MHz. See Section 3.1.6.5
Y301	Y108TMP	7/0		145.5	Optical Bench Temperature Location 1.
Y302	Y208TMP	7/1		146.5	Optical Bench Temperature Location 2.
Y303	Y308TMP	7/2		147.5	Optical Bench Temperature Location 3.
Y304	Y408TMP	7/3		148.5	Optical Bench Temperature Location 4.
Y305	YPCATMP	7/4		149.5	Photocathode A Temperature.
Y306	YPAMATMP	7/5		150.5	Pre-Amp Assembly A Temperature.
Y307	YPMFATMP	7/6		151.5	Permanent Magnet Focus Assembly A Temperature.
Y308	Y10ATMP	7/7		152.5	Optics Area Temperature Location 1.
Y309	Y20ATMP	7/8		153.5	Optics Area Temperature Location 2.
Y310	YSIGPTMP	7/9		154.5	Signal Processor Temperature.
Y311	YCEATMP	7/10		155.5	Central Electronics Temperature.
Y312	Y000RTMP	7/11		156.5	Entrance Door Mechanism Temperature.
Y313	YAPERTMP	7/12		157.5	Aperture Mechanism Temperature.
Y314	YPOLRTMP	7/13		158.5	Polarizer Mechanism Temperature.

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y315	YFGMATMP	7/14		159.5	Filter/Grating Wheel Motor A Temperature.
Y316	YHVTMP	7/15		160.5	High Voltage Supply Temperature.
Y318	YCPSTM	7/18		163.5	Central Power Supply Temperature.
Y319	YHWLT	0/0		131.5	High Voltage Supply Voltage.
Y320	YCALVLT	6/0		137.5	Calibration Lamp Supply Voltage.
Y321	YXDEFCUR	2/0		133.5	X-Deflection Coil Driver Current.
Y322	YYDEFCUR	3/0		134.5	Y-Deflection Coil Driver Current.
Y323	YTRMFCLR	4/0		135.5	Trim Focus Coil Driver Current.
Y324	YDSCRVLT	5/0		136.5	Discriminator Reference Voltage.
Y325	YHVCLR	1/0		132.5	High Voltage Supply Current.
Y326	YARIUTMP	7/16		161.5	RIU-A Temperature.
Y327	YBRIUTMP	7/17		162.5	RIU-B Temperature.
Y328	YCLSLUR	0/1		138.5	Calibration Lamp Supply Current.
Y329	YFGMBTMP	7/19		164.5	Filter/Grating Wheel Motor B Temperature.
Y330	YPCBTMP	7/20		165.5	Photocathode B Temperature.
Y331	YPAMB TMP	7/21		166.5	Pre-Amp Assembly B Temperature.
Y332	Y8VQPSV	5/1		143.5	Plus 8 Volt Quiet Power Supply Voltage.
Y333	YPMFB TMP	7/22		167.5	Permanent Magnet Focus Assembly B Temperature.
Y334	YXYDFTMP	7/23		168.5	X Y Deflection Focus DAC Temperature.
Y337	Y5VLP SV	6/1		144.5	Plus 5 Volt Logic Power Supply Voltage.
Y338	YANASPAR	2/1		140.5	Analog Spare.
Y500	YENGSYNC	8/0	902		MP serial engr data packet sync. Value is X'AS'
Y501	YFIRMV ER	8/1	902.5		Firmware version number. Has Y.201
Y501 _c	YARMAP	/			Arm Aperture command. See Section 3.1.4.2
Y502	YERRCHK HI	8/2	903		Firmware check character HI. See Section 1.5
Y502	YERRCHK LO	8/3	903.5		Firmware check character LO. See Section 1.5
Y503	YDOOR	8/8:7-8	906		Entrance door position. See Section 3.1.4.1
Y503	YDOOR	8/38:7-8	921		Entrance door position. See Section 3.1.4.1
Y503	YDOOR	8/68:7-8	936		Entrance door position. See Section 3.1.4.1
Y503	YDOOR	8/98:7-8	951		Entrance door position. See Section 3.1.4.1
Y503 _c	YARMED	/			Arm Entrance Port command. See Section 3.1.4.1
Y504	YFGIASTR	8/8:5	906		FGIA encoder strobe bit.
Y504	YFGIASTR	8/38:5	921		FGIA encoder strobe bit.
Y504	YFGIASTR	8/68:5	936		FGIA encoder strobe bit.
Y504	YFGIASTR	8/98:5	951		FGIA encoder strobe bit.
Y505	YAPERPOS HI	8/9	906.5		Aperture position HI. See Section 3.1.4.2
Y505	YAPERPOS LO	8/10	907		Aperture position LO. See Section 3.1.4.2
Y505	YAPERPOS HI	8/39	921.5		Aperture position HI. See Section 3.1.4.2
Y505	YAPERPOS LO	8/40	922		Aperture position LO. See Section 3.1.4.2
Y505	YAPERPOS HI	8/69	936.5		Aperture position HI. See Section 3.1.4.2
Y505	YAPERPOS LO	8/70	937		Aperture position LO. See Section 3.1.4.2
Y505	YAPERPOS HI	8/99	951.5		Aperture position HI. See Section 3.1.4.2
Y505	YAPERPOS LO	8/100	952		Aperture position LO. See Section 3.1.4.2
Y505 _c	YSAFAP	/			Safe Aperture command. See Section 3.1.4.2
Y506	YFGWPOS	8/8:1-4	906		Filter/Grating Wheel Assembly position. See Section 3.1.4.4

Table 4.2-7 All FDS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y506	YFGWAPOS	8/38:1-4	921		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y506	YFGWAPOS	8/68:1-4	936		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y506	YFGWAPOS	8/98:1-4	951		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
Y507	YPLRZPOS HI	8/11	907.5		Polarizer position HI. See Section 3.1.4.3
Y507	YPLRZPOS LO	8/12	908		Polarizer position LO. See Section 3.1.4.3
Y507	YPLRZPOS HI	8/41	922.5		Polarizer position HI. See Section 3.1.4.3
Y507	YPLRZPOS LO	8/42	923		Polarizer position LO. See Section 3.1.4.3
Y507	YPLRZPOS HI	8/71	937.5		Polarizer position HI. See Section 3.1.4.3
Y507	YPLRZPOS LO	8/72	938		Polarizer position LO. See Section 3.1.4.3
Y507	YPLRZPOS HI	8/101	952.5		Polarizer position HI. See Section 3.1.4.3
Y507	YPLRZPOS LO	8/102	953		Polarizer position LO. See Section 3.1.4.3
Y507 ^c	YSAFED	/			Safe Entrance Port command. See Section 3.1.4.1
Y508	YFGWASP	8/3:6	906		FGWA spare.
Y508	YFGWASP	8/38:6	921		FGWA spare.
Y508	YFGWASP	8/68:6	936		FGWA spare.
Y508	YFGWASP	8/98:6	951		FGWA spare.
Y509	YMECHSPR	8/15	909.5		Mechanism spares. Typical value X'0F' (subframe)
Y509	YMECHSPR	8/45	924.5		Mechanism spares. Typical value X'2D' (subframe)
Y509	YMECHSPR	8/75	939.5		Mechanism spares. Typical value X'48' (subframe)
Y509	YMECHSPR	8/105	954.5		Mechanism spares. Typical value X'69' (subframe)
Y510	YTARXCTR HI	8/16	910		Target Acq X-center HI. See Section 3.1.5
Y510	YTARXCTR LO	8/17	910.5		Target Acq X-center LO. See Section 3.1.5
Y510	YTARXCTR HI	8/76	940		Target Acq X center HI. See Section 3.1.5
Y510	YTARXCTR LO	8/77	940.5		Target Acq X center LO. See Section 3.1.5
Y511	YTARYCTR HI	8/18	911		Target Acq Y-center HI. See Section 3.1.5
Y511	YTARYCTR LO	8/19	911.5		Target Acq Y-center LO. See Section 3.1.5
Y511	YTARYCTR HI	8/78	941		Target Acq Y center HI. See Section 3.1.5
Y511	YTARYCTR LO	8/79	941.5		Target Acq Y center LO. See Section 3.1.5
Y511 ^c	YARML	/			Arm Polarizer command. See Section 3.1.4.3
Y513 ^c	YOVRLITE B1	8/22	913		Overlight sum MS byte. Total of 32 bits (see Section 2.1.5)
Y513	YOVRLITE B2	8/23	913.5		Overlight sum MMS byte. Total of 32 bits (see Section 2.1.5)
Y513	YOVRLITE B3	8/24	914		Overlight sum MLS byte. Total of 32 bits (see Section 2.1.5)
Y513	YOVRLITE B4	8/25	914.5		Overlight sum LS byte. Total of 32 bits (see Section 2.1.5)
Y514	YSAFTNG	8/26	915		Auto safe mode transition. Has Y.202-Y204 (bits 1-6 unused). Bits 6-7 zeroed when sampled
Y515	YTAMODE	8/27	915.5		Target acquisition mode. See Section 3.1.5

Table 4.2-7 A11 FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UD</u>	<u>SHP</u>	<u>Significance</u>
Y515 _c	YSAFPL	/			Safe Polarizer command. See Section 3.1.4.3
Y516	YARITHCK HI	8/28	916		Arithmetic self-check (speed) results HI. See Section 1.5
Y516	YARITHCK LO	8/29	916.5		Arithmetic self-check (speed) results LO. See Section 1.5
Y517	YSELFCHK HI	8/30	917		Processor self-check results HI. See Section 1.5
Y517	YSELFCHK LO	8/31	917.5		Processor self-check results LO. See Section 1.5
Y517 _c	YHVOFF	/			High Voltage Supply Off command.
Y518 _c	YOREFDAC	8/32	918		Discriminator reference DAC.
Y519	YFOCUSRB	8/33	918.5		Focus trim coil DAC readback. See Section 3.1.3
Y519 _c	YHVON	/			High Voltage Supply On command.
Y520 _c	YHVDACRB HI	8/34:7-8	919		High voltage DAC readback HI. See Section 3.1.3
Y520	YHVDACRB LO	8/35	919.5		High voltage DAC readback LO. See Section 3.1.3
Y521	YYDAC HI	8/36	920		Y DAC readback HI. See Section 3.1.3
Y521	YYDAC LO	8/37	920.5		Y DAC readback LO. See Section 3.1.3
Y521 _c	YQSOFF	/			Quiet Supply Off command.
Y522 _c	YXPITCH HI	8/46	925		X deflection pitch between diodes HI. See Section 3.1.3
Y522	YXPITCH LO	8/47	925.5		X deflection pitch between diodes LO. See Section 3.1.3
Y523	YXBASE HI	8/48	926		X deflection base HI. See Section 3.1.3
Y523	YXBASE LO	8/49	926.5		X deflection base LO. See Section 3.1.3
Y523 _c	YSON	/			Quiet Supply On command.
Y524 _c	YXSTEPS	8/50	927		X deflection sub-steps. See Section 3.1.1.2
Y525	YLSOFF	/			Logic Supply Off command.
Y526 _c	YYPITCH HI	8/53	928.5		Y deflection pitch between diodes HI. See Section 3.1.3
Y526	YYPITCH LO	8/54	929		Y deflection pitch between diodes LO. See Section 3.1.3
Y527	YYBASE HI	8/55	929.5		Y deflection base HI. See Section 3.1.3
Y527	YYBASE LO	8/56	930		Y deflection base LO. See Section 3.1.3
Y527 _c	YHTON	/			Heater On command.
Y528 _c	YYSTEPS	8/57	930.5		Y deflection sub steps. See Section 3.1.1.4
Y529 _c	YSDFB4	/			SDF 34 port to side select command.
Y530 _c	YOVRS CAN	8/60	932		X deflection overscan. See Section 3.1.1.3
Y531	Y1STCHNL	8/61	932.5		First channel to be processed. See Section 3.1.2.2
Y531 _c	YSDFB2	/			SDF 32 port to side select command.
Y532 _c	YNUMCHNL	8/62	933		Number of channels to be processed. See Section 3.1.2.2
Y533 _c	YSDFB3	/			SDF 33 port to side select command.
Y535 _c	YACQSYNC	8/67	935.5		Acquisition mode. Has Y.205-Y.212
Y535 _c	YSDFB1	/			SDF 31 port to side select command.

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UD</u>	<u>SHP</u>	<u>Significance</u>
Y536	YFWSTAT1 HI	8/82		943	Firmware status group 1 HI. Typically ASCII (interpretation depends on use)
Y536	YFWSTAT1 LO	8/83		943.5	Firmware status group 1 LO. Typically ASCII (interpretation depends on use)
Y537	YFWSTAT2 HI	8/84		944	Firmware status group 2 HI. Typically ASCII (interpretation depends on use)
Y537	YFWSTAT2 LO	8/85		944.5	Firmware status group 2 LO. Typically ASCII (interpretation depends on use)
Y537 ^c	YSDFA4	/			SDF A4 port to side select command.
Y538 ^c	YFWSTAT3 HI	8/86		945	Firmware status group 3 HI. Typically ASCII (interpretation depends on use)
Y538	YFWSTAT3 LO	8/87		945.5	Firmware status group 3 LO. Typically ASCII (interpretation depends on use)
Y539	YFWSTAT4 HI	8/88		946	Firmware status group 4 HI. Typically ASCII (interpretation depends on use)
Y539	YFWSTAT4 LO	8/89		946.5	Firmware status group 4 LO. Typically ASCII (interpretation depends on use)
Y539 ^c	YSDFA2	/			SDF A2 port to side select command.
Y540 ^c	YFWSTAT5 HI	8/90		947	Firmware status group 5 HI. Typically ASCII (interpretation depends on use)
Y540	YFWSTAT5 LO	8/91		947.5	Firmware status group 5 LO. Typically ASCII (interpretation depends on use)
Y541	YFWSTAT6 HI	8/92		948	Firmware status group 6 HI. Typically ASCII (interpretation depends on use)
Y541	YFWSTAT6 LO	8/93		948.5	Firmware status group 6 LO. Typically ASCII (interpretation depends on use)
Y541 ^c	YSDFA3	/			SDF A3 port to side select command.
Y542 ^c	YMCLEAR	8/94		949	Memory clears/data acquisition. See Section 3.1.1.8
Y543	YLASTCMD HI	8/96		950	Last command at SMC error HI. See Section 3.1
Y543	YLASTCMD LO	8/97		950.5	Last command at SMC error LO. See Section 3.1
Y543 ^c	YSDFA1	/			SDF A1 port to side select command.
Y544 ^c	YNOISELM HI	8/106		955	Burst noise rejection limit HI. See Section 3.1.1.1
Y544	YNOISELM LO	8/107		955.5	Burst noise rejection limit LO. See Section 3.1.1.1
Y545	YRAMADDR HI	8/108		956	RAM address pointer HI. See Section 3.1.6.3
Y545	YRAMADDR LO	8/109		956.5	RAM address pointer LO. See Section 3.1.6.3
Y545 ^c	YRESET	/			Reset Microprocessor command. See Section 3.1.6.5
Y546	YINTEG	8/110		957	Number of integrations/X-step. See Section 3.1.1.1
Y547	YINTMODE	8/112		958	Initialization mode. Has Y.213-Y.218
Y547 ^c	YHTOFF	/			Heater Off command.
Y548	YREADCYC	8/113		958.5	Readouts/memory clear. See Section 3.1.1.7
Y549	YDATALIM	8/114		959	High byte of acquisition limit. See Section 3.1.2.3
Y549 ^c	YRIEBW	/			Reset IEB/Watchdog command. See Section 3.1.6.5

Table 4.2-7 All FDS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y550	YMDMPADR HI	8/115	959.5		Memory dump address HI. See Section 3.1.2.1
Y550	YMDMPADR LO	8/116	960		Memory dump address LO. See Section 3.1.2.1
Y551	YWDOSLIN HI	8/4	904		Words per line HI. See Section 3.1.2.1
Y551	YWDOSLIN LO	8/5	904.5		Words per line LO. See Section 3.1.2.1
Y551 _c	Y3MHz	/			Select 3.0 MHz Clock command. See Section 3.1.6.5
Y552	YLINSFRM HI	8/6	905		Lines per frame HI. See Section 3.1.2.1
Y552	YLINSFRM LO	8/7	905.5		Lines per frame LO. See Section 3.1.2.1
Y553	YXDAC HI	8/13	908.5		X DAC readback HI. See Section 3.1.3
Y553	YXDAC LO	8/14	909		X DAC readback LO. See Section 3.1.3
Y553	YXDAC HI	8/43	923.5		X DAC readback HI. See Section 3.1.3
Y553	YXDAC LO	8/44	924		X DAC readback LO. See Section 3.1.3
Y553	YXDAC HI	8/73	938.5		X DAC readback HI. See Section 3.1.3
Y553	YXDAC LO	8/74	939		X DAC readback LO. See Section 3.1.3
Y553	YXDAC HI	8/103	953.5		X DAC readback HI. See Section 3.1.3
Y553	YXDAC LO	8/104	954		X DAC readback LO. See Section 3.1.3
Y553 _c	Y1.5MHz	/			Select 1.5 MHz Clock command. See Section 3.1.6.5
Y555	YRANGE	8/52	928		Y range. See Section 3.1.1.4
Y555 _c	YABACQ	/			Abort Data Acquisition command. See Section 3.1.2.3
Y556	YSPR8ITI	8/117:1	960.5		Spare bit. All bits in word zeroed when sampled
Y557 _c	YENDAC	/			End Data Acquisition command. See Section 3.1.2.3
Y558	YXDACERR	8/117:4	960.5		X DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y559	YYDACERR	8/117:6	960.5		Y DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y559 _c	YBEGAC	/			Begin Data Acquisition command. See Section 3.1.2.3
Y560	YFDACERR	8/117:2	960.5		Focus DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y561	YHVDACER	8/117:7	960.5		HV DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
Y561 _c	YBLAPR	/			Blow Aperture command. See Section 3.1.4.2
Y562 _c	YORDACER	8/117:8	960.5		Discriminator reference DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.2
Y563	YDDACERR	8/117:3	960.5		Discriminator DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.1
Y563 _c	YBLENT	/			Blow Entrance Port command. See Section 3.1.4.1
Y564	YACTMERR	8/118:1	961		Accumulator timer set error. A 0 is OK and a 1 is error
Y566	YMECHTOC	8/118:2-4	961		Mechanism time-out code. See Section 3.1.4
Y567	YDATACTL	8/118:5-8	961		Data control commands. Has Y.227-Y.230
Y567 _c	YBLPOL	/			Blow Polarizer command. See Section 3.1.4.3
Y569 _c	YLSON	/			Logic Supply On command.

Table 4.2-7 A11 FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y571	YNDAIP	8/119:1	961.5		Data acquisition not in progress. A 1 means not in progress. See Section 3.1.1
Y571 _c	YCMTRA	/			Select Motor A command. See Section 3.1.4.4
Y572 _c	YRIP	8/119:2	961.5		Resting in peace.
Y573	YPIP	8/119:3	961.5		Pause in progress. A 1 means pause in progress. See Section 3.1.2.3
Y573 _c	YCMTRB	/			Select Motor B command. See Section 3.1.4.4
Y574 _c	YCP IP	8/119:4	961.5		CEA plot in progress. A 1 means plot in progress.
Y575	YTAQIP	8/119:5	961.5		Target acquisition in progress. A 1 means acquisition in progress. See Section 2.1.4
Y575 _c	YCALON	/			Spectral Calibration Lamp On command. See Section 3.1.6.4
Y576	YMSLICES	8/59	931.5		Number of memory slices. See Section 3.1.1.5
Y577	YPTRNS	3/111	957.5		Patterns per readout. See Section 3.1.1.6
Y577 _c	YCALOF	/			Spectral Calibration Lamp Off command. See Section 3.1.6.4
Y578	YCDACERR	8/117:5	960.5		Calibration DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.4
Y579	YDPRMPWR	8/34:1-2	919		Descramble PROM power status. A 00 is off, 01 is even, 10 is odd, and 11 is both
Y579 _c	YBUSS1	/			A-On, B-Off S1 command.
Y580 _c	YFFCPWR	8/34:4	919		Flat field cal lamp power. A zero is off and a 1 is on. See Section 3.1.6.4
Y581	YHVSPAR	8/34:3	919		Spare bit.
Y581 _c	YBUSS2	/			A-On, B-Off S2 command.
Y582 _c	YMMIP	8/119:6	961.5		Mechanism motion in progress. A 1 means motion in progress
Y583	YAMCIP	8/119:7	961.5		Auto memory clear in progress. A 1 means clear to be done (interface with data monitoring background task)
Y583 _c	YCALSA	/			Select Calibration Lamp A command. See Section 3.1.6.4
Y584	YSDIP	8/119:8	961.5		Science dump in progress. A 1 means dump in progress. See Section 3.1.2.3
Y585	YLIVEHI	8/63	933.5		Accumulator open time high byte. See Section 3.1.1.1
Y585 _c	YCALSB	/			Select Calibration Lamp B command. See Section 3.1.6.4
Y586	YLIVEL0	8/64	934		Accumulator open time low byte. See Section 3.1.1.1
Y587	YDEADHI	8/65	934.5		Accumulator close time high byte. See Section 3.1.1.1
Y588	YDEADLO	8/66	935		Accumulator close time low byte. See Section 3.1.1.1
Y589	YSPARE	8/34:5-6	919		Spare.
Y600	YSTBUF	9/0		879 ₁	Number of FOS status buffer entries. Measured since last time the counter reset

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y601	YONOFF	9/1			FOS on/off indicator. Is 1 if FOS successfully turned off via YFOFF; otherwise 2
Y602	YFINST	9/2			Status of INIT processor. Is 1 if YINIT executing, 2 if terminated on error, 4 if termination normal
Y603	YFSDST	9/3			Science data storage status. Is 1 if YFSDST executing, 2 if terminated on error, 4 if termination normal
Y604	YFPRST	9/4			Science data processing status. Is 1 if YFSDPR executing, 2 if terminated on error, 4 if termination normal
Y605	YSPRO	9/5			Spare 0.
Y606	YLINCT	9/6			Line number within a frame.
Y607	YHKST	9/7			Housekeeping status. Is 1 if YHPKG executing, 2 if terminated on error, 4 if disabled by another processor
Y608	YFASST	9/8			Autonomous safe status. Is 1 if YFASAF executing, 2 if terminated abnormally, 4 if termination normal
Y609	YFTOST	9/9			Turn off status. Is 1 if YFOFF executing, 2 if terminated abnormally, 4 if termination normal
Y610	YFL81	9/10			Data items 1-8. FOS limit check flags 81
Y611	YFL169	9/11			Data items 9-16. FOS limit check flags 82
Y612	YFL241	9/12			Data items 17-24. FOS limit check flags 83
Y613	YFL322	9/13			Data items 25-32. FOS limit check flags 84
Y614	YDISCT	9/14			Counts main frame discrete log errors.
Y615	YSMECT	9/15			Counter for consecutive major frames in which discrete command log error indicated
Y616	YKEEP	9/16			Counts main frame magnitude command errors.
Y617	YFLGCT	9/17			Counter for consecutive major frames in which a serial magnitude command error reported
Y618	YSFFLG	9/18			Counts main frame keep alive failures.
Y619	YTOFLG	9/19			Counter of consecutive major frames in which FOS serial ED fails keep-alive test
Y620	YFM2FL	9/20		888 ₄	Counts main frame limit check failures.
Y621	YFRCTR	9/21		379 ₃	Counter for consecutive major frames in which same FOS limit check failed
Y622	YGINUP	9/22		882 ₂	Autonomous safe flag. Is 1 if YFASAF has been invoked by application processor, 2 if not invoked
Y623	YGPCTR	9/23			Turn off flag. Is 1 if YFOFF has been invoked by application processor, 2 if not invoked
					Action indicator for YFM2PR module. See Section 3.2.1
					Count frames for part 1 of YFSDPR processor.
					Mode 2 target acquisition error indicator.
					Count frames for part 2 of YFSDPR processor.

Table 4.2-7 A11 FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>DL</u>	<u>SHP</u>	<u>Significance</u>
Y624	YTACMP	9/24		881 ₂	Mode 2 Target acquisition completion indicator. A 1 means complete
Y625	YFM2ST	9/25			Mode 2 target acquisition processor status. Is 1 if YFM02 executing, 2 if terminated abnormally, 4 if termination normal
Y625 _c	YSTBY1	/			RIUA SBY1 command.
Y625 _c	YSPR1	9/26			Spare 1.
Y627	YSPR2	9/27			Spare 2.
Y627 _c	YSTBY2	/			RIUA SBY2 command.
Y628	YFPKST	9/28			Peak-up target acquisition processor status.
Y629	YFPUCT	9/29			Counter of frames/dwell during FPKUP.
Y630	YFDWCT	9/30		879 ₅	Dwell counter for FPKUP. See Section 3.2.1
Y631	YOV81	9/31			8 LSBs accumulated YOVLITE.
Y632	YOV169	9/32			Next 8 LSBs accumulated YOVLITE.
Y633	YOV241	9/33			Next 8 LSBs accumulated YOVLITE.
Y634	YOV322	9/34			8 MSBs accumulated YOVLITE.
Y635	YSPR3	9/35			Spare 3.
Y636	YSPR4	9/36			Spare 4.
Y637	YSPR5	9/37			Spare 5.
Y638	YFSCTR	9/38			Number of tests by FPKG where fail-safe armed. Counter indicating number of tests since YPKG was initialized where fail-safe RPI was armed
Y639	YERCTR	9/39			Consecutive major frames with error check error. Counter indicating consecutive major frames in which an error check error is indicated
Y640	YFWCTR	9/40			Consecutive major frames with firmware version error. Counter indicating consecutive major frames in which a firmware version error is indicated
Y641	YMFCT	9/41			Counter of major frame fail-safe RPI test. Major frame counter used for fail-safe RPI test
Y642	YMFCT	9/42			Counter of major frame output for data log. Major frame counter tested for output of SHPs
Y643	YSAFCR	9/43			Consecutive major frames gone safe autonomously. Number of consecutive major frames in which FOS indicated it has gone safe autonomously
Y644	YOVCTR	9/44			Counter of failed YOVLITE sum tests. Number of consecutive major frames in which FOS overnight sum test has failed
Y645	YSCCTR	9/45			Counter of failed self-check tests. Number of consecutive major frames in which the FOS has failed the self-check test
Y646	YSPCTR	9/46			Counter of speed check errors. Counter indicating consecutive major frames in which a speed check error is indicated

Table 4.2-7 All FOS Commands and Telemetry by ID (cont)

<u>ID</u>	<u>Mnemonic</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
Y647	YSPR6	9/47			Spare 6.
Y648	YSPR7	9/48			Spare 7.
Y649	YSMCERRS	8/95		949.5	Serial magnitude command error report flags. Has Y.219-Y.226. Word zeroed when sampled
Y650	YTAMAX HI	8/20		912	Upper Target/Acq Window HI. See Section 3.1.5
Y650	YTAMAX LO	8/21		912.5	Upper Target/Acq Window LO. See Section 3.1.5
Y651	YTAMIN HI	8/80		942	Lower Target/Acq Window HI. See Section 3.1.5
Y651	YTAMIN LO	8/81		942.5	Lower Target/Acq Window LO. See Section 3.1.5
Y652	YREJECTS HI	8/51		927.5	Number of adder rejects HI. See Section 3.1.1.1
Y652	YREJECTS LO	8/58		931	Number of adder rejects LO. See Section 3.1.1.1

Table 4.2-8 A11 FOS Commands and Telemetry by Mnemonic

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>WL</u>	<u>SHP</u>	<u>Significance</u>
ASCIIH0	Y.403	/	838		ASCII header (64 words). See Section 3.2.2
DTBL	Y.401	/	322		Discriminator DAC/Disabled Diode Table (512 words). See Section 3.2.2
MAF	Y.405	/	962.5		Major frame number (8 bits). See Section 3.2.2
MIF	Y.404	/	962		Minor frame number (8 bits). See Section 3.2.2
NMEMCLR	Y.407	/	964		Memory clear number (16 bits). See Section 3.2.2
NREAD	Y.406	/	963		Readout number (16 bits). See Section 3.2.2
RAMMAP	Y.402	/	834		RAM map (4 words). See Section 3.2.2
YABACQ	Y555 _c	/			Abort Data Acquisition command. See Section 3.1.2.3
YACACC HI	Y.031	/		884 ₅	Number of counts in this dwell HI.
YACACC LO	Y.031	/		885 ₅	Number of counts in this dwell LO.
YACQLM	Y016 _c	/			Set data acquisition limit. See Section 3.1.2.3
YACQMODE	Y049 _c	/			Set data acquisition mode. See Section 3.1.6.1
YACQSYNC	Y535	8/67	935.5		Acquisition mode. Has Y.205-Y.212
YACSAV HI	Y.029	/		880 ₅	Historic counts HI. See Section 3.2.1
YACSAV LO	Y.029	/		881 ₅	Historic counts LO. See Section 3.2.1
YACTMERR	Y564	8/118:1	961		Accumulator timer set error. A 0 is OK and a 1 is error
YAMCIP	Y583	8/119:7	961.5		Auto memory clear in progress. A 1 means clear to be done (interface with data monitoring background task)
YANASPAR	Y338	2/1		140.5	Analog Spare.
YAPER	Y035 _c	/			Set entrance aperture to position. See Section 3.1.4.2
YAPERPOS HI	Y505	8/9	906.5		Aperture position HI. See Section 3.1.4.2
YAPERPOS HI	Y505	8/39	921.5		Aperture position HI. See Section 3.1.4.2
YAPERPOS HI	Y505	8/69	936.5		Aperture position HI. See Section 3.1.4.2
YAPERPOS HI	Y505	8/99	951.5		Aperture position HI. See Section 3.1.4.2
YAPERPOS LO	Y505	8/10	907		Aperture position LO. See Section 3.1.4.2
YAPERPOS LO	Y505	8/40	922		Aperture position LO. See Section 3.1.4.2
YAPERPOS LO	Y505	8/70	937		Aperture position LO. See Section 3.1.4.2
YAPERPOS LO	Y505	8/100	952		Aperture position LO. See Section 3.1.4.2
YAPERTMP	Y313	7/12		157.5	Aperture Mechanism Temperature.
YAPRFRPI	Y123	1/1:5		139.5	Aperture Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.2
YARITHCK HI	Y516	8/28	916		Arithmetic self-check (speed) results HI. See Section 1.5
YARITHCK LO	Y516	8/29	916.5		Arithmetic self-check (speed) results LO. See Section 1.5
YARIUTMP	Y326	7/16		161.5	RIU-A Temperature.
YARMAP	Y501 _c	/			Arm Aperture command. See Section 3.1.4.2
YARMED	Y503 _c	/			Arm Entrance Port command. See Section 3.1.4.1

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

Mnemonic	ID	WD/SF	UDL	SHP	Significance
YARMP	Y511	/			Arm Polarizer command. See Section 3.1.4.3
YBASQP	Y.019	/			Y base for current data. See Section 3.2.1
YBEGAC	Y559 _c	/	887 ₃	887 ₄	Begin Data Acquisition command. See Section 3.1.2.3
YBLAPR	Y561 _c	/			Blow Aperture command. See Section 3.1.4.2
YBLENT	Y563 _c	/			Blow Entrance Port command. See Section 3.1.4.1
YBLPOL	Y567 _c	/			Blow Polarizer command. See Section 3.1.4.3
YBRIUTMP	Y327 _c	7/17		162.5	RIU-B Temperature.
YBSM	Y.022	/		890 ₃	Channel number of peak. See Section 3.2.1
YBUSS1	Y579 _c	/			A-On, B-Off S1 command.
YBUSS2	Y581 _c	/			A-On, B-Off S2 command.
YCALOF	Y577 _c	/			Spectral Calibration Lamp Off command. See Section 3.1.6.4
YCALON	Y575 _c	/			Spectral Calibration Lamp On command. See Section 3.1.6.4
YCALRPI	Y102	4/1:6		142.5	Calibration Lamp Supply RPI. A 0 is on and 1 is off. See Section 3.1.6.4
YCALSA	Y583 _c	/			Select Calibration Lamp A command. See Section 3.1.6.4
YCALSB	Y585 _c	/			Select Calibration Lamp B command. See Section 3.1.6.4
YCALSLR	Y133	3/1:7		141.5	Calibration Lamp Select RPI. A 0 is B and a 1 is A. See Section 3.1.6.4
YCALVLT	Y320	6/0		137.5	Calibration Lamp Supply Voltage.
YCDACERR	Y578	8/117:5	960.5		Calibration DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.4
YCEATMP	Y311	7/10		155.5	Central Electronics Temperature.
YCHNLEN	Y012 _c	/			Enable/inhibit channel(s). See Section 3.1.6.2
YCHNLS	Y050 _c	/			Set number of channels to be processed. See Section 3.1.2.2
YCLEARS	Y053 _c	/			Set number of memory clears/acquisition. See Section 3.1.1.3
YCLKMON	Y134	3/1:2		141.5	Microprocessor Clock Monitor. A 0 is 3 MHz and 1 is 1.5 MHz. See Section 3.1.6.5
YCLSLCR	Y328	0/1		138.5	Calibration Lamp Supply Current.
YCMTRA	Y571 _c	/			Select Motor A command. See Section 3.1.4.4
YCMTRB	Y573 _c	/			Select Motor B command. See Section 3.1.4.4
YCMTRST	Y101 _c	3/1:8		141.5	Carousel Motor Status. A 0 is B and a 1 is A. See Section 3.1.4.4
YCP IP	Y574	8/119:4	961.5		CEA plot in progress. A 1 means plot in progress
YCPSTMP	Y318	7/18		163.5	Central Power Supply Temperature.
YDATACTL	Y567	8/118:5-8	961		Data control commands. Has Y.227-Y.230
YDATALIM	Y549	8/114	959		High byte of acquisition limit. See Section 3.1.2.3
YDDACERR	Y563	8/117:3	960.5		Discriminator DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.1

Table 4.2-3 All FDS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YDDCHK	Y083 _c	/			Sample all discriminator DACs. See Section 3.1.6.1
YDEADHI	Y587	8/65	934.5		Accumulator close time high byte. See Section 3.1.1.1
YDEADLO	Y588	8/66	935		Accumulator close time low byte. See Section 3.1.1.1
YDEADTYM	Y010 _c	/			Set accumulator closed (dead) time. See Section 3.1.1.1
YDISC	Y031 _c	/			Set discriminator DAC table value. See Section 3.1.6.2
YDISCADR	Y006 _c	/			Load discriminator at address or set all values. See Section 3.1.6.2
YDISCT	Y614	9/14			Counts main frame discrete log errors. Counter for consecutive major frames in which discrete command log error indicated
YDOOR	Y503	8/8:7-8	906		Entrance door position. See Section 3.1.4.1
YDOOR	Y503	8/38:7-8	921		Entrance door position. See Section 3.1.4.1
YDOOR	Y503	8/68:7-8	936		Entrance door position. See Section 3.1.4.1
YDOOR	Y503	8/98:7-8	951		Entrance door position. See Section 3.1.4.1
YDOORTMP	Y312	7/11		156.5	Entrance Door Mechanism Temperature.
YDPRMPWR	Y579	8/34:1-2	919		Descramble PROM power status. A 00 is off, 01 is even, 10 is odd, and 11 is both
YDRCACER	Y562	8/117:8	960.5		Discriminator reference DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.6.2
YDREFDAC	Y518	8/32	918		Discriminator reference DAC.
YDSCRVLT	Y324	5/0		136.5	Discriminator Reference Voltage.
YEDGE	Y.027	/		889 ₄	Result of edge test. See Section 3.2.1
YEDSCRAM	Y107	3/1:6		141.5	Descramble PROM Power Status Even. A 0 is off and 1 is on
YEFLILL	Y084 _c	/			Sample all serial digital telemetry. See Section 3.1.6.1
YENDAC	Y557 _c	/			End Data Acquisition command. See Section 3.1.2.3
YENGSYNC	Y500	8/0	902		MP serial engr data packet sync. Value is X'A5'
YENTFRPI	Y124	1/1:6		139.5	Entrance Door Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.1
YENTRNC	Y034 _c	/			Set entrance port open or closed. See Section 3.1.4.1
YERCTR	Y639	9/39			Consecutive major frames with error check error. Counter indicating consecutive major frames in which an error check error is indicated
YERRCHK HI	Y502	8/2	903		Firmware check character HI. See Section 1.5
YERRCHK LO	Y502	8/3	903.5		Firmware check character LO. See Section 1.5
YFASST	Y608	9/8			Autonomous safe status. Is 1 if YFASAF executing, 2 if terminated abnormally, 4 if termination normal

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YFDACERR	Y560	8/117:2	960.5		Focus DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
YFDWCT	Y630	9/30		879 ₅	Dwell counter for FPKUP. See Section 3.2.1
YFFCAL	Y038 _c	/			Set LED flat-field lamp on or off. See Section 3.1.6.4
YFFCPWR	Y580	8/34:4	919		Flat field cal lamp power. A zero is off and a 1 is on. See Section 3.1.6.4
YFGMATMP	Y315	7/14		159.5	Filter/Grating Wheel Motor A Temperature.
YFGMBTMP	Y329	7/19		164.5	Filter/Grating Wheel Motor B Temperature.
YFGWAPOS	Y506	8/8:1-4	906		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
YFGWAPOS	Y506	8/38:1-4	921		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
YFGWAPOS	Y506	8/68:1-4	936		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
YFGWAPOS	Y506	8/98:1-4	951		Filter/Grating Wheel Assembly position. See Section 3.1.4.4
YFGWASP	Y508	8/8:6	906		FGWA spare.
YFGWASP	Y508	8/38:6	921		FGWA spare.
YFGWASP	Y508	8/68:6	936		FGWA spare.
YFGWASP	Y508	8/98:6	951		FGWA spare.
YFGWASTR	Y504	8/8:5	906		FGWA encoder strobe bit.
YFGWASTR	Y504	8/38:5	921		FGWA encoder strobe bit.
YFGWASTR	Y504	8/68:5	936		FGWA encoder strobe bit.
YFGWASTR	Y504	8/98:5	951		FGWA encoder strobe bit.
YHKST	Y607	9/7			Housekeeping status. Is 1 if YFHPKG executing, 2 if terminated on error, 4 if disabled by another processor
YFILTER	Y037 _c	/			Set FGWA to position. See Section 3.1.4.4
YFINST	Y602 _c	9/2			Status of INIT processor. Is 1 if YINIT executing, 2 if terminated on error, 4 if termination normal
YFIRMVER	Y501	8/1		902.5	Firmware version number. Has Y.201
YFLGCT	Y617	9/17			Counts main frame limit check failures.
					Counter for consecutive major frames in which same FOS limit check failed
YFL169	Y611	9/11			Data items 9-16. FOS limit check flags 32
YFL241	Y612	9/12			Data items 17-24. FOS limit check flags 33
YFL322	Y613	9/13			Data items 25-32. FOS limit check flags 34
YFL31	Y610	9/10			Data items 1-8. FOS limit check flags 31
YFM2CF	Y.006	/	383 ₂		Count rate window change for next data set. See Section 3.2.1
YFM2FL	Y620	9/20		388 ₄	Action indicator for YFM2PR module. See Section 3.2.1
YFM2ST	Y625	9/25			Mode 2 target acquisition processor status. Is 1 if YFM02 executing, 2 if terminated abnormally, 4 if termination normal
YFOCUS	Y033 _c	/			Set focus trim DAC. See Section 3.1.3
YFOCUSRB	Y519 _c	8/33		918.5	Focus trim coil DAC readback. See Section 3.1.3

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YFPKST	Y628	9/28			Peak-up target acquisition processor status.
YFPRST	Y604	9/4			Science data processing status. Is 1 if YFSOPR executing, 2 if terminated on error, 4 if termination normal.
YFPUCT	Y629	9/29			Counter of frames/dwell during FPKUP.
YFRCTR	Y621	9/21			Count frames for part 1 of YFSOPR processor.
YFSCTR	Y638	9/38		879 ₃	Number of tests by FHPKG where fail-safe armed. Counter indicating number of tests since YFHPKG was initialized where fail-safe RPI was armed
YFSOST	Y603	9/3			Science data storage status. Is 1 if YFSOST executing, 2 if terminated on error, 4 if termination normal
YFTOST	Y609	9/9			Turn off status. Is 1 if YFOFF executing, 2 if terminated abnormally, 4 if termination normal
YFUTT HI	Y.030	/		882 ₅	Saved dwell time HI. See Section 3.2.1
YFUTT LO	Y.030	/		883 ₅	Saved dwell time LO. See Section 3.2.1
YFWCTR	Y640	9/40			Consecutive major frames with firmware version error. Counter indicating consecutive major frames in which a firmware version error is indicated
YFWSTAT1 HI	Y536	8/82		943	Firmware status group 1 HI. Typically ASCII (interpretation depends on use)
YFWSTAT1 LO	Y536	8/83		943.5	Firmware status group 1 LO. Typically ASCII (interpretation depends on use)
YFWSTAT2 HI	Y537	8/84		944	Firmware status group 2 HI. Typically ASCII (interpretation depends on use)
YFWSTAT2 LO	Y537	8/85		944.5	Firmware status group 2 LO. Typically ASCII (interpretation depends on use)
YFWSTAT3 HI	Y538	8/86		945	Firmware status group 3 HI. Typically ASCII (interpretation depends on use)
YFWSTAT3 LO	Y538	8/87		945.5	Firmware status group 3 LO. Typically ASCII (interpretation depends on use)
YFWSTAT4 HI	Y539	8/88		946	Firmware status group 4 HI. Typically ASCII (interpretation depends on use)
YFWSTAT4 LO	Y539	8/89		946.5	Firmware status group 4 LO. Typically ASCII (interpretation depends on use)
YFWSTAT5 HI	Y540	8/90		947	Firmware status group 5 HI. Typically ASCII (interpretation depends on use)
YFWSTAT5 LO	Y540	8/91		947.5	Firmware status group 5 LO. Typically ASCII (interpretation depends on use)
YFWSTAT6 HI	Y541	8/92		948	Firmware status group 6 HI. Typically ASCII (interpretation depends on use)
YFWSTAT6 LO	Y541	8/93		948.5	Firmware status group 6 LO. Typically ASCII (interpretation depends on use)
YFXCTR	Y.008	/		385 ₂ 395 ₄	X-offset to center. See Section 3.2.1
YFYCTR	Y.009	/		386 ₂ 396 ₄	Y-offset to center. See Section 3.2.1
YGIVUP	Y622	9/22		382 ₂	Mode 2 target acquisition error indicator.

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

Mnemonic	ID	WD/SF	UDL	SHP	Significance
YGPCTR	Y.026	/		879 ₄	Previous value of binary search step counter. See Section 3.2.1
YGPCTR	Y623	9/23			Count frames for part 2 of YFSDPR processor.
YHTOFF	Y547	/			Heater Off command.
YHTON	Y527 _c	/			Heater On command.
YHTRRPI	Y118 _c	1/1:8		139.5	Heater Control Relay Position. A 0 is HTON (on) and 1 is HTOF (off)
YHVCLR	Y325	1/0		132.5	High Voltage Supply Current.
YHVDAC	Y030 _c	/			Set high voltage power supply DAC. See Section 3.1.3
YHVDAKER	Y561	8/117:7		960.5	HV DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
YHVDACRB HI	Y520	8/34:7-8		919	High voltage DAC readback HI. See Section 3.1.3
YHVDACRB LO	Y520	8/35		919.5	High voltage DAC readback LO. See Section 3.1.3
YHVOFF	Y517	/			High Voltage Supply Off command.
YHVON	Y519 _c	/			High Voltage Supply On command.
YHVRPI	Y117 _c	4/1:5		142.5	High Voltage Relay Position. A 0 is HVON (on) and 1 is HVOF (off)
YHVSAR	Y581	8/34:3		919	Spare bit.
YHVTEMP	Y316	7/15		160.5	High Voltage Supply Temperature.
YHVOLT	Y319	0/0		131.5	High Voltage Supply Voltage.
YINIT	Y041	/			Set initialization mode. See Section 3.1.6.1
YINSENG	Y104 _c	3/1:4		141.5	Instruction Engineering Bit Status. A 0 is OK and 1 is error. See Section 3.1.6.5
YINTEG	Y546	8/110		957	Number of integrations/X-step. See Section 3.1.1.1
YINTMODE	Y547	8/112		958	Initialization mode. Has Y.213-Y.218
YINTS	Y043 _c	/			Set number of sub-integrations per X-step. See Section 3.1.1.1
YKEEP	Y616	9/16			Counts main frame keep alive failures.
YKEY	Y071 _c	/			Counter of consecutive major frames in which FOS serial ED fails keep-alive test
YKPALVED	Y058 _c	/			Provide FORTH KEY capability. See Section 3.1.6.5
YLASTCMD HI	Y543	8/96		950	Enable/disable autonomous going safe. See Section 3.1.6.5
YLASTCMD LO	Y543	8/97		950.5	Last command at SMC error HI. See Section 3.1
YLINCT	Y606	9/6			Last command at SMC error LO. See Section 3.1
YLINNSFRM HI	Y552	8/6		905	Line number within a frame.
YLINNSFRM LO	Y552	8/7		905.5	Lines per frame HI. See Section 3.1.2.1
YLIYEH	Y585	8/63		933.5	Lines per frame LO. See Section 3.1.2.1
YLIYEL0	Y586	8/64		934	Accumulator open time high byte. See Section 3.1.1.1
YLIYETYM	Y008 _c	/			Accumulator open time low byte. See Section 3.1.1.1
					Set accumulator open (live) time. See Section 3.1.1.1

Table 4.2-3 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>IDL</u>	<u>SHP</u>	<u>Significance</u>
YLSOFF	Y525	/			Logic Supply Off command.
YLSON	Y569 _c	/			Logic Supply On command.
YLSRPI	Y120 _c	4/1:4		142.5	Logic Supply Relay Status. A 0 is +LPS (on) and 1 is -LPS (off)
YMAP	Y.004	/		879 ₂	Map number. See Section 3.2.1
YMCREG	Y087 _c	/			Set mechanism register to drive signal. See Section 3.1.4
YMCSTEP	Y056 _c	/			Step mechanism. See Section 3.1.4
YMCLEAR	Y542	8/94		949	Memory clears/data acquisition. See Section 3.1.1.8
YMDMPADR HI	Y550	8/115		959.5	Memory dump address HI. See Section 3.1.2.1
YMDMPADR LO	Y550	8/116		960	Memory dump address LO. See Section 3.1.2.1
YMECHCAL	Y022 _c	/			Set feedback code for mechanism. See Section 3.1.4
YMECHSPR	Y509	8/15		909.5	Mechanism spares. Typical value X'0F' (subframe)
YMECHSPR	Y509	8/45		924.5	Mechanism spares. Typical value X'2D'
YMECHSPR	Y509	8/75		939.5	(subframe)
YMECHSPR	Y509	8/105		954.5	Mechanism spares. Typical value X'48'
YMECHSPR	Y509	8/118:2-4		961	(subframe)
YMECHTOC	Y566				Mechanism time-out code. See Section 3.1.4
YMEMCHK	Y055 _c	/			Fill science memory with test pattern. See Section 3.1.6.3
YMFCT	Y641	9/41			Counter of major frame fail-safe RPI test. Major frame counter used for fail-safe RPI test
YMFCT	Y642	9/42			Counter of major frame output for data log.
YMMIP	Y582	8/119:6		961.5	Major frame counter tested for output of SHPs
					Mechanism motion in progress. A 1 means motion in progress
YMSLICES	Y576	8/59		931.5	Number of memory slices. See Section 3.1.1.5
YM2MAP	Y.005	/		880 ₂	Maximum maps. See Section 3.2.1
YNECTR	Y.020	/		888 ₃	Brightness rank. See Section 3.2.1
YDAIP	Y571	8/119:1		961.5	Data acquisition not in progress. A 1 means not in progress. See Section 3.1.1
YNMAX	Y.023	/		891 ₃	Number of counts in peak. See Section 3.2.1
YNMEAN	Y.024	/		892 ₃	Counts in mean sky.
YNOISELM HI	Y544	8/106		955	Burst noise rejection limit HI. See Section 3.1.1.1
YNOISELM LO	Y544	8/107		955.5	Burst noise rejection limit LO. See Section 3.1.1.1
YNTARG	Y.028	/		890 ₄	Counts in target channels. See Section 3.2.1
YLMCHNL	Y532	8/62		933	Number of channels to be processed. See Section 3.1.2.2
YOBSSJ	Y.021	/		889 ₃	Peak matrix number. See Section 3.2.1
YDSCRAM	Y106	3/1:5		141.5	Descramble PROM Power Status Odd. A 0 is off and 1 is on

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YONOFF	Y601	9/1			FOS on/off indicator. Is 1 if FOS successfully turned off via YOFF; otherwise 2
YOUT-CLR	Y045 _c	/			Set readouts/memory clear. See Section 3.1.1.7
YOVCTR	Y644	9/44			Counter of failed YOVLITE sum tests. Number of consecutive major frames in which FOS overlight sum test has failed
YOVLITE B1	Y513	8/22	913		Overlight sum MS byte. Total of 32 bits (see Section 2.1.5)
YOVLITE B2	Y513	8/23	913.5		Overlight sum MMS byte. Total of 32 bits (see Section 2.1.5)
YOVLITE B3	Y513	8/24	914		Overlight sum NLS byte. Total of 32 bits (see Section 2.1.5)
YOVLITE B4	Y513	8/25	914.5		Overlight sum LS byte. Total of 32 bits (see Section 2.1.5)
YOVRS CAN	Y530	8/60	932		X deflection overscan. See Section 3.1.1.3
YOVRS CAN	Y051 _c	/			Set number of diodes overscan. See Section 3.1.1.3
YOV169	Y632	9/32			Next 8 LSBs accumulated YOVLITE.
YOV241	Y633	9/33			Next 8 LSBs accumulated YOVLITE.
YOV322	Y634	9/34			8 MSBs accumulated YOVLITE.
YOV81	Y631	9/31			8 LSBs accumulated YOVLITE.
YPAMATMP	Y306	7/5	150.5		Pre-Amp Assembly A Temperature.
YPAMB TMP	Y331	7/21	166.5		Pre-Amp Assembly B Temperature.
YPAUSE	Y085 _c	/			Set/reset pause acquisition bit. See Section 3.1.2.3
YPCATMP	Y305	7/4	149.5		Photocathode A Temperature.
YPCBTMP	Y330	7/20	165.5		Photocathode B Temperature.
YPIP	Y573	8/119:3	961.5		Pause in progress. A 1 means pause in progress. See Section 3.1.2.3
YPKCTI	Y.012	/	380 ₃ 380 ₄		Objects found in field. See Section 3.2.1
YPLRZPOS HI	Y507	8/11	907.5		Polarizer position HI. See Section 3.1.4.3
YPLRZPOS HI	Y507	8/41	922.5		Polarizer position HI. See Section 3.1.4.3
YPLRZPOS HI	Y507	8/71	937.5		Polarizer position HI. See Section 3.1.4.3
YPLRZPOS HI	Y507	8/101	952.5		Polarizer position HI. See Section 3.1.4.3
YPLRZPOS LO	Y507	8/12	908		Polarizer position LO. See Section 3.1.4.3
YPLRZPOS LO	Y507	8/42	923		Polarizer position LO. See Section 3.1.4.3
YPLRZPOS LO	Y507	8/72	938		Polarizer position LO. See Section 3.1.4.3
YPLRZPOS LO	Y507	8/102	953		Polarizer position LO. See Section 3.1.4.3
YPLZR	Y036 _c	/			Set polarizer mechanism to position. See Section 3.1.4.3
YPMFATMP	Y307	7/6	151.5		Permanent Magnet Focus Assembly A Temperature.
YPMFB TMP	Y333	7/22	167.5		Permanent Magnet Focus Assembly B Temperature.
YPOLFRPI	Y130	1/1:7	139.5		Polarizer Failsafe Arm/Safe Status. A 0 is Arm and 1 is Safe. See Section 3.1.4.3
YPOLRTMP	Y314	7/13	158.5		Polarizer Mechanism Temperature.
YPPINV	Y.017	/	385 ₃ 385 ₄		Preplanned branch status. See Section 3.2.1
YPTRNOUT	Y054 _c	/			Set number of patterns/readout. See Section 3.1.1.6

Table 4.2-3 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YPTRNS	Y577	8/111	957.5		Patterns per readout. See Section 3.1.1.6
YOSOFF	Y521 ^c	/			Quiet Supply Off command.
YOSON	Y523 ^c	/			Quiet Supply On command.
YQSRPI	Y119 ^c	4/1:3		142.5	Quiet Supply Relay Position. A 0 is +QPS (on) and 1 is -QPS (off)
YRAMADDR	Y000	/			Load RAM storage address. See Section 3.1.6.3
YRAMADDR HI	Y545 ^c	8/108	956		RAM address pointer HI. See Section 3.1.6.3
YRAMADDR LO	Y545	8/109	956.5		RAM address pointer LO. See Section 3.1.6.3
YRAM-MAP	Y052 ^c	/			Map physical to logical RAM page. See Section 3.1.6.5
YRANDOM	Y086 ^c	/			Fill science memory with pseudo-random sequence. See Section 3.1.6.3
YRANGE	Y555	8/52	928		Y range. See Section 3.1.1.4
YREADCYC	Y548	8/113	958.5		Readouts/memory clear. See Section 3.1.1.7
YREFDAC	Y032 ^c	/			Set common discriminator reference DAC. See Section 3.1.6.2
YREJECTS HI	Y652	8/51	927.5		Number of adder rejects HI. See Section 3.1.1.1
YREJECTS LO	Y652	8/58	931		Number of adder rejects LO. See Section 3.1.1.1
YREJLIM	Y014 ^c	/			Set noise rejection limit. See Section 3.1.1.1
YRESET	Y545 ^c	/			Reset Microprocessor command. See Section 3.1.6.5
YRESETST	Y105	3/1:1		141.5	Reset Status. A 0 is reset and a 1 is not reset
YRIEBW	Y549 ^c	/			Reset IEB/Watchdog command. See Section 3.1.6.5
YRIP	Y572	8/119:2	961.5		Resting in peace.
YRIUS2	Y131	4/1:1-2		142.5	RIU Standby Status. Bit 1 is for RIU A and bit 2 for RIU B. A 0 means STBY1 and a 1 means STBY2
YRSINV	Y.018	/		886 ₃ 886 ₄	Raster scan request status. See Section 3.2.1
YSAFAP	Y505 ^c	/			Safe Aperture command. See Section 3.1.4.2
YSAFCR	Y643 ^c	9/43			Consecutive major frames gone safe autonomously. Number of consecutive major frames in which FOS indicated it has gone safe autonomously
YSAFED	Y507 ^c	/			Safe Entrance Port command. See Section 3.1.4.1
YSAFTNG	Y514	8/26	915		Auto safe mode transition. Has Y.202-Y204 (bits 1-5 unused). Bits 6-7 zeroed when sampled
YSAFPL	Y515 ^c	/			Safe Polarizer command. See Section 3.1.4.3
YSCCTR	Y645 ^c	9/45			Counter of failed self-check tests. Number of consecutive major frames in which the FOS has failed the self-check test
YSCIACT	Y070 ^c	/			Control science data dump. See Section 3.1.2.3

Table 4.2-8 A11 FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YSCIADDR	Y059 ^c	/			Set first RAM address for science data. See Section 3.1.6.5
YSCIDMP	Y002	/			Set dump parameters. See Section 3.1.2.1
YSDERASE	Y057 ^c	/			Clear science memory locations. See Section 3.1.6.3
YSDFA1	Y543	/			SDF A1 port to side select command.
YSDFA2	Y539 ^c	/			SDF A2 port to side select command.
YSDFA3	Y541 ^c	/			SDF A3 port to side select command.
YSDFA4	Y537 ^c	/			SDF A4 port to side select command.
YSDFB1	Y535 ^c	/			SDF B1 port to side select command.
YSDFB2	Y531 ^c	/			SDF B2 port to side select command.
YSDFB3	Y533 ^c	/			SDF B3 port to side select command.
YSDFB4	Y529 ^c	/			SDF B4 port to side select command.
YSDIP	Y584 ^c	8/119:8		961.5	Science dump in progress. A 1 means dump in progress. See Section 3.1.2.3
YSELFCHK HI	Y517	8/30		917	Processor self-check results HI. See Section 1.5
YSELFCHK LO	Y517	8/31		917.5	Processor self-check results LO. See Section 1.5.
YSFFLG	Y618	9/18			Autonomous safe flag. Is 1 if YFASAF has been invoked by application processor, 2 if not invoked
YSIGPTMP	Y310	7/9		154.5	Signal Processor Temperature.
YSLICES	Y068 ^c	/			Set number of memory slices. See Section 3.1.1.5
YSMCERRS	Y649	8/95		949.5	Serial magnitude command error report flags. Has Y.219-Y.226. Word zeroed when sampled
YSMECT	Y615	9/15			Counts main frame magnitude command errors.
YSPARE	Y589	8/34:5-6		919	Counter for consecutive major frames in which a serial magnitude command error reported Spare.
YSPCTR	Y646	9/46			Counter of speed check errors. Counter indicating consecutive major frames in which a speed check error is indicated
YSPR	Y.400	/		1	Spare (225 words). See Section 3.2.2
YSPR	Y.408	/		965	Spare word.
YSPRBIT1	Y556	8/117:1		960.5	Spare bit. All bits in word zeroed when sampled
YSPR0	Y605	9/5			Spare 0.
YSPR1	Y626	9/26			Spare 1.
YSPR2	Y627	9/27			Spare 2.
YSPR3	Y635	9/35			Spare 3.
YSPR4	Y636	9/36			Spare 4.
YSPR5	Y637	9/37			Spare 5.
YSPR6	Y647	9/47			Spare 6.
YSPR7	Y648	9/48			Spare 7.
YSPR8 B1	Y.648	9/49			Spare.
YSPR8 B10	Y.648	9/58			Spare.
YSPR8 B11	Y.648	9/59			Spare.

Table 4.2-3 A11 FOS Commands and Telemetry by Mnemonic (cont)

Mnemonic	ID	WD/SF	LDL	SHP	Significance
YSPR8 B2	Y.648	9/50			Spare.
YSPR8 B3	Y.648	9/51			Spare.
YSPR8 B4	Y.648	9/52			Spare.
YSPR8 B5	Y.648	9/53			Spare.
YSPR8 B6	Y.648	9/54			Spare.
YSPR8 B7	Y.648	9/55			Spare.
YSPR8 B8	Y.648	9/56			Spare.
YSPR8 B9	Y.648	9/57			Spare.
YSTBUF	Y600	9/0	879 ₁		Number of FOS status buffer entries. Measured since last time the counter reset
YSTBY1	Y625 _c	/			RIUA SBY1 command.
YSTBY2	Y627 _c	/			RIUA SBY2 command.
YSTOPDMP	Y044 _c	/			Stop science dump. See Section 3.1.2.3
YSTRWD	Y018 _c	/			Store next commands as data. See Section 3.1.6.3
YSYNC	Y023 _c	/			Set delay for starting synchronous acquisition. See Section 3.1.6.1
YTACIP	Y624	9/24	881 ₂		Mode 2 Target acquisition completion indicator. A 1 means complete
YTAMAX HI	Y650	8/20	912		Upper Target/Acq Window HI. See Section 3.1.5
YTAMAX LO	Y650	8/21	912.5		Upper Target/Acq Window LO. See Section 3.1.5
YTAMIN HI	Y651	8/80	942		Lower Target/Acq Window HI. See Section 3.1.5
YTAMIN LO	Y651	3/81	942.5		Lower Target/Acq Window LO. See Section 3.1.5
YTAMOD	Y046 _c	/			Set target acquisition mode. See Section 3.1.5
YTAMODE	Y515	8/27	915.5		Target acquisition mode. See Section 3.1.5
YTAQIP	Y575	8/119:5	961.5		Target acquisition in progress. A 1 means acquisition in progress. See Section 2.1.4
YTARACQ	Y004 _c	/			Set target acquisition parameters. See Section 3.1.5
YTARXCTR HI	Y510	8/16	910		Target Acq X-center HI. See Section 3.1.5
YTARXCTR HI	Y510	8/76	940		Target Acq X center HI. See Section 3.1.5
YTARXCTR LO	Y510	8/17	910.5		Target Acq X-center LO. See Section 3.1.5
YTARXCTR LO	Y510	8/77	940.5		Target Acq X center LO. See Section 3.1.5
YTARYCTR HI	Y511	8/18	911		Target Acq Y-center HI. See Section 3.1.5
YTARYCTR HI	Y511	8/78	941		Target Acq Y center HI. See Section 3.1.5
YTARYCTR LO	Y511	8/19	911.5		Target Acq Y-center LO. See Section 3.1.5
YTARYCTR LO	Y511	8/79	941.5		Target Acq Y center LO. See Section 3.1.5
YTOFLG	Y619	9/19			Turn off flag. Is 1 if YFOFF has been invoked by application processor, 2 if not invoked
YTRMFCLR	Y323	4/0	135.5		Trim Focus Coil Driver Current.
YVARI1	Y.025	/	893 ₃ 892 ₄		Sky variance.
YWDOSLIN HI	Y551	8/4	904		Words per line HI. See Section 3.1.2.1
YWDOSLIN LO	Y551	8/5	904.5		Words per line LO. See Section 3.1.2.1
YWTCHDOG	Y103	3/1:3	141.5		Watchdog Timer Status. A 0 is OK and 1 is error. See Section 3.1.6.5
YXBASE HI	Y523	8/48	926		X deflection base HI. See Section 3.1.3
YXBASE LO	Y523	3/49	926.5		X deflection base LO. See Section 3.1.3

Table 4.2-8 A11 FOS Commands and Telemetry by Mnemonic (cont)

Mnemonic	ID	WD/SF	UDL	SHP	Significance
YXDACERR	Y558	8/117:4	960.5		X DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
YXDAC HI	Y553	8/13	908.5		X DAC readback HI. See Section 3.1.3
YXDAC HI	Y553	8/43	923.5		X DAC readback HI. See Section 3.1.3
YXDAC HI	Y553	8/73	938.5		X DAC readback HI. See Section 3.1.3
YXDAC HI	Y553	8/103	953.5		X DAC readback HI. See Section 3.1.3
YXDAC LO	Y553	8/14	909		X DAC readback LO. See Section 3.1.3
YXDAC LO	Y553	8/44	924		X DAC readback LO. See Section 3.1.3
YXDAC LO	Y553	8/74	939		X DAC readback LO. See Section 3.1.3
YXDAC LO	Y553	8/104	954		X DAC readback LO. See Section 3.1.3
YXDEFCUR	Y321	2/0		133.5	X-Deflection Coil Driver Current.
YXPITCH HI	Y522	8/46	925		X deflection pitch between diodes HI. See Section 3.1.3
YXPITCH LO	Y522	8/47	925.5		X deflection pitch between diodes LO. See Section 3.1.3
YXSTEPS	Y524	8/50	927		X deflection sub-steps. See Section 3.1.1.2
YXYDFTMP	Y334	7/23		168.5	X Y Deflection Focus DAC Temperature.
YX-BASE	Y026 _c	/			Base value for X deflection computations. See Section 3.1.3
YX-DEFL	Y024 _c	/			Set X-deflection amplifier DAC. See Section 3.1.3
YX-DLY	Y040 _c	/			Spare.
YX-PITCH	Y028 _c	/			Scaled X-deflection DAC value for one diode width in X. See Section 3.1.3
YX-STEP	Y039 _c	/			Select number of X deflection steps. See Section 3.1.1.2
YYABRTDA	Y.229	8/118:7	961		Abort data acquisition command flag. A 1 means abort. See Section 3.1.2.3
YYAPMC	Y.410	/	234		Aperture Mechanism Control Block (18 words). See Section 3.2.2
YYAUTPO	Y.210	8/67:6	935.5		Automatic polarizer sequence instrument mode. See Section 2.1.6
YYBASE HI	Y527	8/55	929.5		Y deflection base HI. See Section 3.1.3
YYBASE LO	Y527	8/56	930		Y deflection base LO. See Section 3.1.3
YYBEGENDA	Y.227	8/118:5	961		Begin data acquisition command flag. A 1 means begin. See Section 3.1.2.3
YYCHPK1	Y.013	/	881 ₃ 881 ₄		First channel where peak found. See Section 3.2.1
YYCHPK2	Y.014	/	882 ₃ 882 ₄		Second channel where peak found. See Section 3.2.1
YYCHPK3	Y.015	/	883 ₃ 883 ₄		Third channel where peak found. See Section 3.2.1
YYCHPK4	Y.016	/	884 ₃ 884 ₄		Fourth channel where peak found. See Section 3.2.1
YYDACERR	Y559	8/117:6	960.5		Y DAC readback error flag. A 0 is OK and a 1 is error. See Section 3.1.3
YYDAC HI	Y521	8/36	920		Y DAC readback HI. See Section 3.1.3
YYDAC LO	Y521	8/37	920.5		Y DAC readback LO. See Section 3.1.3

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YYDBLSN	Y.209	8/67:5	935.5		Double/-Single precision adder instrument mode. See Section 2.1.5
YYDCMIP	Y.223	8/95:5	949.5		Data command illegal path. See Section 3.1
YYDCMOF	Y.222	8/95:4	949.5		Data command overflow.
YYDEFCUR	Y322	3/0	134.5		Y-Deflection Coil Driver Current.
YYENDDA	Y.228	8/118:6	961		End data acquisition command flag. A 1 means end. See Section 3.1.2.3
YYEPMC	Y.409	/	226		Entrance Port Mechanism Control Block (8 words). See Section 3.2.2
YYFGMC	Y.412	/	306		FGNA Mechanism Control Block (16 words). See Section 3.2.2
YYFVCTR2	Y.010	/	893 ₄		Y2 component of ST slew request. See Section 3.2.1
YYFVCTR2 HI	Y.010	/	887 ₂		Y2 component of ST slew request HI.
YYFVCTR2 LO	Y.010	/	888 ₂		Y2 component of ST slew request LO.
YYFVTCR3	Y.011	/	894 ₄		Y3 component of ST slew request. See Section 3.2.1
YYFVTCR3 HI	Y.011	/	889 ₂		Y3 component of ST slew request HI.
YYFVTCR3 LO	Y.011	/	890 ₂		Y3 component of ST slew request LO.
YYILT3CC	Y.219	8/95:1	949.5		Illegal Type-3 command code. See Section 3.1
YYILT4CC	Y.220	8/95:2	949.5		Illegal Type-4 command code. See Section 3.1
YYILT4MO	Y.221	8/95:3	949.5		Illegal Type-4 command modifier. See Section 3.1
YYINDFHY	Y.217	8/112:5	958		Do deflection hysteresis pattern at beginning of data acquisition. See Section 2.1.1
YYINHSLT	Y.214	8/112:2	958		Inhibit slice table fill. See Section 2.1.1
YYINHXDF	Y.216	8/112:4	958		Inhibit X-deflection table fill. See Section 2.1.1
YYINHYDF	Y.215	8/112:3	958		Inhibit Y-deflection table fill. See Section 2.1.1
YYNMINDR	Y.007	/	884 ₂		Minor frame number. See Section 3.2.1
YYNXTSB	Y.002	/	880 ₇		Next available message position in status buffer. See Section 3.2.1
YYPATH	Y.201	8/1:8	902.5		Path identification. A 0 is "A" (amber or red) and 1 is "B" (blue). See Section 3.2.3
YYPITCH HI	Y526	8/53	928.5		Y deflection pitch between diodes HI. See Section 3.1.3
YYPITCH LO	Y526	8/54	929		Y deflection pitch between diodes LO. See Section 3.1.3
YYPLMC	Y.411	/	252		Polarizer Mechanism Control Block (54 words). See Section 3.2.2
YYREJRE	Y.207	8/67:3	935.5		Reject/Retry instrument mode. See Section 2.1.3
YYRSETMP	Y.230	8/118:8	961		Reset microprocessor command flag. A 1 means reset. See Section 3.1.6.5
YYRSVNI	Y.213	8/112:1	958		Resume (no initialization). See Section 2.1.1
YYSAFED	Y.204	8/26:8	915		Auto safing enabled/disabled. See Section 3.1.6.5

Table 4.2-8 All FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>UDL</u>	<u>SHP</u>	<u>Significance</u>
YYSAFLKA	Y.202	8/26:6	915		Auto safe due to loss of keep-alive SMC. See Section 3.1.6.5
YYSAFTSL	Y.203	8/26:7	915		Auto safe due to loss of telemetry sync. See Section 3.1.6.5
YYSBST	Y.003	/		881 ₁	FOS single-bit status items. See Section 3.2.1
YYSDCIP	Y.226	8/95:8	949.5		Science dump command illegal path. See Section 3.1
YYSHUID	Y.001	/		878	Identifier for FOS-Unique SHP data. See Section 3.2.1
YYSPR	Y.211	8/67:7	935.5		Spare bit.
YYSPR	Y.212	8/67:8	935.5		Spare bit.
YYSPR	Y.218	8/112:6-8	958		Spare bits.
YYSSCIP	Y.224	8/95:6	949.5		Synchronous start command illegal path. See Section 3.1
YYSTEPS	Y528	8/57	930.5		Y deflection sub steps. See Section 3.1.1.4
YYSYNCS	Y.205	8/67:1	935.5		Synchronous start instrument mode. See Section 2.1.1
YYTARGA	Y.208	8/67:4	935.5		Target acquisition instrument mode. See Section 2.1.4
YYTAWCIP	Y.225	8/95:7	949.5		Target acquisition window command illegal path. See Section 3.1
YYTMTG	Y.206	8/67:2	935.5		Time-Tag instrument mode. See Section 2.1.2
YY-BASE	Y027 _c	/			Base value for Y deflection computations. See Section 3.1.3
YY-DEFL	Y025 _c	/			Set Y-deflection amplifier DAC. See Section 3.1.3
YY-DLY	Y048	/			Spare.
YY-PITCH	Y029 _c	/			Scaled Y-deflection DAC value for one diode width in Y. See Section 3.1.3
YY-RNGE	Y066 _c	/			Set range for Y deflection. See Section 3.1.1.4
YY-STEP	Y047 _c	/			Set number of Y deflection steps. See Section 3.1.1.4
Y1BUSRPI	Y121	4/1:7		142.5	Common Bus Relay #1 Status. A 0 is B On/A Off1 and a 1 is A On/B Off1
Y10ATMP	Y308	7/7		152.5	Optics Area Temperature Location 1.
Y10BTMP	Y301	7/0		145.5	Optical Bench Temperature Location 1.
Y1SDPRT	Y125	1/1:1		139.5	SD CEA A K1-K6 Status. A 0 is A8 and 1 is AA
Y1STCHNL	Y531	8/61		932.5	First channel to be processed. See Section 3.1.2.2
Y1STCHNL	Y042 _c	/			Set first channel to be processed. See Section 3.1.2.2
Y1:SMZ	Y553 _c	/			Select 1.5 MHz Clock command. See Section 3.1.6.5
Y2BUSRPI	Y122	4/1:8		142.5	Common Bus Relay #2 Status. A 0 is B On/A Off2 and a 1 is A On/B Off2
Y20ATMP	Y309	7/8		153.5	Optics Area Temperature Location 2.
Y20BTMP	Y302	7/1		146.5	Optical Bench Temperature Location 2.

Table 4.2-8 A11 FOS Commands and Telemetry by Mnemonic (cont)

<u>Mnemonic</u>	<u>ID</u>	<u>WD/SF</u>	<u>IDL</u>	<u>SHP</u>	<u>Significance</u>
Y2SDFPRT	Y126	1/1:2		139.5	SD CEA A K7-K11 Status. A 0 is AB and 1 is AA
Y3MHZ	Y551 _C	/			Select 3.0 MHz Clock command. See Section 3.1.6.5
Y308TMP	Y303	7/2		147.5	Optical Bench Temperature Location 3.
Y3SDFPRT	Y127	1/1:3		139.5	SD CEA B K1-K6 Status. A 0 is BB and 1 is BA
Y408TMP	Y304	7/3		148.5	Optical Bench Temperature Location 4.
Y4SDFPRT	Y128	1/1:4		139.5	SD CEA B K7-K11 Status. A 0 is BB and 1 is BA
Y5VLPSP	Y337	6/1		144.5	Plus 5 Volt Logic Power Supply Voltage.
Y8VQPSV	Y332	5/1		143.5	Plus 8 Volt Quiet Power Supply Voltage.

4.3 LMSC'S ORGANIZATION OF FOS TELEMETRY

Section 4.2 provided the data for the engineering telemetry as presented by the FOS instrument. This section treats the data as it is actually sent on the downlink. To understand the downlink material, it is first necessary to establish the general features of the engineering telemetry (see the LMSC information in SLIB 1089 for more details).

Although there are several different basic telemetry formats available on the ST, the engineering telemetry format reflected in this section is:

Format AN: 4 KBPS Programmable Format.

According to SLIB 1089, "The purpose of this format is to provide telemetry data during normal day-to-day operations." The fact that it is "Programmable" means (again from SLIB 1089) "The structure or data content can be changed in flight by ground commands. Such changes will require careful planning, coordination, and ST program approval."

The following definitions apply to engineering telemetry:

1. A major frame is the period in which all data in the format is sampled at least once (barring a few exceptions that do not apply to FOS). The major frame for Format AN requires 120 minor frames.
2. A minor frame is the period from the start of one telemetry sync word to the next. The minor frame length for Format AN is 250 eight-bit words.
3. A subframe is a group or list of measurements that are sampled sequentially, one per minor frame, until each measurement in the group has been sampled once. The list is then repeated. Each subframe is assigned to a specific minor frame location, and as a result the measurements in the subframe will appear in that word location, one after another, in a fixed sequence. If the subframe length is 2, for example, this means that every other minor frame will contain another sample of the data (and it will be sampled 60 times in the Format AN major frame).

Since Format AN has 250 eight-bit words (or 2000 bits) per minor frame, and since its rate is 4 KBPS, this means that it takes $[2000/(4 * 10^3) =] 0.5$ second to send a minor frame, and $[120 * 0.5 =] 60$ seconds to send a major frame.

Of the 250 eight-bit words in the Format AN minor frame, the complete SI C&DH is allocated 64. Of these 64, ten are allocated to each of the 5 SIs and the remaining to the SI C&DH itself. The 10 FOS words, with the SI word numbers (0-9) used in Section 4.2, the C&DH (0-63) telemetry word number, the corresponding minor frame word number (1-250), the subframe length, and the assignments are given in the following table:

<u>SI #</u>	<u>C&DH</u>	<u>Minor Frame</u>	<u>Subframe Length</u>	<u>Assignment</u>
0	18	80	2	Y319, Y328
1	19	83	2	Y325, bilevels
2	21	88	2	Y321, Y338 (spare)
3	22	92	2	Y322, bilevels
4	24	100	2	Y323, bilevels
5	25	103	2	Y324, Y332
6	27	111	2	Y320, Y337
7	28	112	24	Y301-Y316 etc (temperatures)
8	30	120	120	Serial Digital Telemetry
9	47	192	60	Y600-Y648

Table 4.3-1 shows the LMSC telemetry information (using the same data as in Section 4.2) arranged by LMSC abbreviated ID (the same sequence as in SLIB 1089). The information differs from Section 4.2 in that subframe numbers begin with one, not zero, and the minor frame word numbers reflect the assignment in the Format AN telemetry.

It should be realized that the "official" source of information on telemetry data eventually must be the ST project data base rather than the material on the following pages.

Table 4.3-1 FOS Engineering Telemetry

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y11X101B	92/2:8	Carrousel Motor Status	YCMTRST
Y08X102B	100/2:6	Calibration Lamp Supply RPI	YCALRPI
Y02X103B	92/2:3	Watchdog Timer Status	YWTCHDOG
Y02X104B	92/2:4	Instruction Engineering Bit Status	YINSENG
Y02X105B	92/2:1	Reset Status	YRESETST
Y04X106B	92/2:5	Descramble PROM Power Status Odd	Y0DSCRAM
Y04X107B	92/2:6	Descramble PROM Power Status Even	YEDSCRAM
Y03X117B	100/2:5	High Voltage Relay Position	YHVRPI
Y03X118B	83/2:8	Heater Control Relay Position	YHTRRPI
Y03X119B	100/2:3	Quiet Supply Relay Position	YQSRPI
Y03X120B	100/2:4	Logic Supply Relay Status	YLSRPI
Y03X121B	100/2:7	Common Bus Relay #1 Status	Y1BUSRPI
Y03X122B	100/2:8	Common Bus Relay #2 Status	Y2BUSRPI
Y03X123B	83/2:5	Aperture Failsafe Arm/Safe Status	YAPRFRPI
Y03X124B	83/2:6	Entrance Door Failsafe Arm/Safe Status	YENTFRPI
Y02X125B	83/2:1	SD CEA A K1-K6 Status	Y1SDFPRT
Y02X126B	83/2:2	SD CEA A K7-K11 Status	Y2SDFPRT
Y02X127B	83/2:3	SD CEA B K1-K6 Status	Y3SDFPRT
Y02X128B	83/2:4	SD CEA B K7-K11 Status	Y4SDFPRT
Y03X130B	83/2:7	Polarizer Failsafe Arm/Safe Status	YPOLFRPI
Y09X131D	100/2:1-2	RIU Standby Status	YRIUS2
Y08X133B	92/2:7	Calibration Lamp Select RPI	YCALSELR
Y02X134B	92/2:2	Microprocessor Clock Monitor	YCLKMON
Y11T301A	112/1	Optical Bench Temperature Location 1	Y10BTMP
Y11T302A	112/2	Optical Bench Temperature Location 2	Y20BTMP
Y11T303A	112/3	Optical Bench Temperature Location 3	Y30BTMP
Y11T304A	112/4	Optical Bench Temperature Location 4	Y40BTMP
Y11T305A	112/5	Photocathode A Temperature	YPCATMP
Y11T306A	112/6	Pre-Amp Assembly A Temperature	YPAMATMP
Y11T307A	112/7	Permanent Magnet Focus Assembly A Temperature	YPMFATMP
Y11T308A	112/8	Optics Area Temperature Location 1	Y10ATMP
Y11T309A	112/9	Optics Area Temperature Location 2	Y20ATMP
Y04T310A	112/10	Signal Processor Temperature	YSIGPTMP
Y02T311A	112/11	Central Electronics Temperature	YCEATMP
Y01T312A	112/12	Entrance Door Mechanism Temperature	YDOORTMP
Y01T313A	112/13	Aperture Mechanism Temperature	YAPERTMP
Y01T314A	112/14	Polarizer Mechanism Temperature	YPOLRTMP
Y01T315A	112/15	Filter/Grating Wheel Motor A Temperature	YFGMATMP
Y05T316A	112/16	High Voltage Supply Temperature	YHVTMP
Y03T318A	112/19	Central Power Supply Temperature	YCPSTMP
Y05V319A	80/1	High Voltage Supply Voltage	YHVLT
Y08V320A	111/1	Calibration Lamp Supply Voltage	YCALVLT
Y03C321A	88/1	X-Deflection Coil Driver Current	YXDEFCUR
Y03C322A	92/1	Y-Deflection Coil Driver Current	YYDEFCUR
Y03C323A	100/1	Trim Focus Coil Driver Current	YTRMFCUR
Y03V324A	103/1	Discriminator Reference Voltage	YDSCRYLT
Y05C325A	83/1	High Voltage Supply Current	YHVCUR
Y09T326A	112/17	RIU-A Temperature	YARIUTMP

Table 4.3-1 FOS Engineering Telemetry (cont)

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y10T327A	112/18	RIU-B Temperature	YBRIUTMP
Y08C328A	80/2	Calibration Lamp Supply Current	YCLSCUR
Y01T329A	112/20	Filter/Grating Wheel Motor B Temperature	YFGMBTMP
Y11T330A	112/21	Photocathode B Temperature	YPCBTMP
Y11T331A	112/22	Pre-Amp Assembly B Temperature	YPAMBTMP
Y03V332A	103/2	Plus 8 Volt Quiet Power Supply Voltage	Y8VQPSV
Y11T333A	112/23	Permanent Magnet Focus Assembly B Temperature	YPMFBTMP
Y03T334A	112/24	X Y Deflection Focus DAC Temperature	YXYDFTMP
Y03V337A	111/2	Plus 5 Volt Logic Power Supply Voltage	YSVLPSV
Y11Z338A	88/2	Analog Spare	YANASPAR
Y02J500A	120/1	MP serial engr data packet sync	YENGSYNC
Y02Q501A	120/2	Firmware version number	YFIRMVER
Y02J502Aa	120/3	Firmware check character HI	YERRCHK HI
Y02J502Ab	120/4	Firmware check character LO	YERRCHK LO
Y02X503D	120/9:7-8	Entrance door position	YDOOR
Y02X503D	120/39:7-8	Entrance door position	YDOOR
Y02X503D	120/69:7-8	Entrance door position	YDOOR
Y02X503D	120/99:7-8	Entrance door position	YDOOR
Y02X504B	120/9:5	FGWA encoder strobe bit	YFGWASTR
Y02X504B	120/39:5	FGWA encoder strobe bit	YFGWASTR
Y02X504B	120/69:5	FGWA encoder strobe bit	YFGWASTR
Y02X504B	120/99:5	FGWA encoder strobe bit	YFGWASTR
Y02H505Aa	120/10	Aperture position HI	YAPERPOS HI
Y02H505Ab	120/11	Aperture position LO	YAPERPOS LO
Y02H505Aa	120/40	Aperture position HI	YAPERPOS HI
Y02H505Ab	120/41	Aperture position LO	YAPERPOS LO
Y02H505Aa	120/70	Aperture position HI	YAPERPOS HI
Y02H505Ab	120/71	Aperture position LO	YAPERPOS LO
Y02H505Aa	120/100	Aperture position HI	YAPERPOS HI
Y02H505Ab	120/101	Aperture position LO	YAPERPOS LO
Y02H506A	120/9:1-4	Filter/Grating Wheel Assembly position	YFGWAPOS
Y02H506A	120/39:1-4	Filter/Grating Wheel Assembly position	YFGWAPOS
Y02H506A	120/69:1-4	Filter/Grating Wheel Assembly position	YFGWAPOS
Y02H506A	120/99:1-4	Filter/Grating Wheel Assembly position	YFGWAPOS
Y02H507Aa	120/12	Polarizer position HI	YPLRZPOS HI
Y02H507Ab	120/13	Polarizer position LO	YPLRZPOS LO
Y02H507Aa	120/42	Polarizer position HI	YPLRZPOS HI
Y02H507Ab	120/43	Polarizer position LO	YPLRZPOS LO
Y02H507Aa	120/72	Polarizer position HI	YPLRZPOS HI
Y02H507Ab	120/73	Polarizer position LO	YPLRZPOS LO
Y02H507Aa	120/102	Polarizer position HI	YPLRZPOS HI
Y02H507Ab	120/103	Polarizer position LO	YPLRZPOS LO
Y02Z5088	120/9:6	FGWA spare	YFGWASP
Y02Z5088	120/39:6	FGWA spare	YFGWASP
Y02Z5088	120/69:6	FGWA spare	YFGWASP
Y02Z5088	120/99:6	FGWA spare	YFGWASP
Y02Z509A	120/16	Mechanism spares	YMECHSPR
Y02Z509A	120/46	Mechanism spares	YMECHSPR

Table 4.3-1 FOS Engineering Telemetry (cont)

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y02Z509A	120/76	Mechanism spares	YMECHSPR
Y02Z509A	120/106	Mechanism spares	YMECHSPR
Y02H510Aa	120/17	Target Acq X-center HI	YTARXCTR HI
Y02H510Ab	120/18	Target Acq X-center LO	YTARXCTR LO
Y02H510Aa	120/77	Target Acq X center HI	YTARXCTR HI
Y02H510Ab	120/78	Target Acq X center LO	YTARXCTR LO
Y02H511Aa	120/19	Target Acq Y-center HI	YTARYCTR HI
Y02H511Ab	120/20	Target Acq Y-center LO	YTARYCTR LO
Y02H511Aa	120/79	Target Acq Y center HI	YTARYCTR HI
Y02H511Ab	120/80	Target Acq Y center LO	YTARYCTR LO
Y02Q513Aa	120/23	Overlight sum MS byte	Y0VRLITE B1
Y02Q513Ab	120/24	Overlight sum NMS byte	Y0VRLITE B2
Y02Q513Ac	120/25	Overlight sum NLS byte	Y0VRLITE B3
Y02Q513Ad	120/26	Overlight sum LS byte	Y0VRLITE B4
Y02J514A	120/27	Auto safe mode transition	YSAFING
Y02J515A	120/28	Target acquisition mode	YTAMODE
Y02J516Aa	120/29	Arithmetic self-check (speed) results HI	YARITHCK HI
Y02J516Ab	120/30	Arithmetic self-check (speed) results LO	YARITHCK LO
Y02J517Aa	120/31	Processor self-check results HI	YSELFCHK HI
Y02J517Ab	120/32	Processor self-check results LO	YSELFCHK LO
Y02J518A	120/33	Discriminator reference DAC	YDREFDAC
Y02J519A	120/34	Focus trim coil DAC readback	YFOCUSRB
Y02Y520Aa	120/35:7-8	High voltage DAC readback HI	YHYDACRB HI
Y02Y520Ab	120/36	High voltage DAC readback LO	YHYDACRB LO
Y02J521Aa	120/37	Y DAC readback HI	YYDAC HI
Y02J521Ab	120/38	Y DAC readback LO	YYDAC LO
Y02H522Aa	120/47	X deflection pitch between diodes HI	YXPITCH HI
Y02H522Ab	120/48	X deflection pitch between diodes LO	YXPITCH LO
Y02H523Aa	120/49	X deflection base HI	YXBASE HI
Y02H523Ab	120/50	X deflection base LO	YXBASE LO
Y02Q524A	120/51	X deflection sub-steps	YXSTEPS
Y02H526Aa	120/54	Y deflection pitch between diodes HI	YYPITCH HI
Y02H526Ab	120/55	Y deflection pitch between diodes LO	YYPITCH LO
Y02H527Aa	120/56	Y deflection base HI	YYBASE HI
Y02H527Ab	120/57	Y deflection base LO	YYBASE LO
Y02Q528A	120/58	Y deflection sub steps	YYSTEPS
Y02H530A	120/61	X deflection overscan	Y0VRSCAN
Y02J531A	120/62	First channel to be processed	Y1STCHNL
Y02Q532A	120/63	Number of channels to be processed	YNUMCHNL
Y02W535A	120/68	Acquisition mode	YACQSYNC
Y02J536Aa	120/33	Firmware status group 1 HI	YFWSTAT1 HI
Y02J536Ab	120/84	Firmware status group 1 LO	YFWSTAT1 LO
Y02J537Aa	120/85	Firmware status group 2 HI	YFWSTAT2 HI
Y02J537Ab	120/36	Firmware status group 2 LO	YFWSTAT2 LO
Y02J538Aa	120/87	Firmware status group 3 HI	YFWSTAT3 HI
Y02J538Ab	120/88	Firmware status group 3 LO	YFWSTAT3 LO
Y02J539Aa	120/89	Firmware status group 4 HI	YFWSTAT4 HI
Y02J539Ab	120/90	Firmware status group 4 LO	YFWSTAT4 LO

Table 4.3-1 FOS Engineering Telemetry (cont)

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y02J540Aa	120/91	Firmware status group 5 HI	YFWSTAT5 HI
Y02J540Ab	120/92	Firmware status group 5 LO	YFWSTAT5 LO
Y02J541Aa	120/93	Firmware status group 6 HI	YFWSTAT6 HI
Y02J541Ab	120/94	Firmware status group 6 LO	YFWSTAT6 LO
Y02Q542A	120/95	Memory clears/data acquisition	YMCLEAR
Y02J543Aa	120/97	Last command at SMC error HI	YLASTCMD HI
Y02J543Ab	120/98	Last command at SMC error LO	YLASTCMD LO
Y02J544Aa	120/107	Burst noise rejection limit HI	YNOISELM HI
Y02J544Ab	120/108	Burst noise rejection limit LO	YNOISELM LO
Y02J545Aa	120/109	RAM address pointer HI	YRAMADDR HI
Y02J545Ab	120/110	RAM address pointer LO	YRAMADDR LO
Y02Q546A	120/111	Number of integrations/X-step	YINTEG
Y02J547A	120/113	Initialization mode	YINTMODE
Y02Q548A	120/114	Readouts/memory clear	YREADCYC
Y02J549A	120/115	High byte of acquisition limit	YDATALIM
Y02J550Aa	120/116	Memory dump address HI	YMDMPADR HI
Y02J550Ab	120/117	Memory dump address LO	YMDMPADR LO
Y02Q551Aa	120/5	Words per line HI	YWRDSLIN HI
Y02Q551Ab	120/6	Words per line LO	YWRDSLIN LO
Y02Q552Aa	120/7	Lines per frame HI	YLINSFRM HI
Y02Q552Ab	120/8	Lines per frame LO	YLINSFRM LO
Y02J553Aa	120/14	X DAC readback HI	YXDAC HI
Y02J553Ab	120/15	X DAC readback LO	YXDAC LO
Y02J553Aa	120/44	X DAC readback HI	YXDAC HI
Y02J553Ab	120/45	X DAC readback LO	YXDAC LO
Y02J553Aa	120/74	X DAC readback HI	YXDAC HI
Y02J553Ab	120/75	X DAC readback LO	YXDAC LO
Y02J553Aa	120/104	X DAC readback HI	YXDAC HI
Y02J553Ab	120/105	X DAC readback LO	YXDAC LO
Y02J555A	120/53	Y range	YRANGE
Y02Z556B	120/118:1	Spare bit	YSPRBIT1
Y02X558B	120/118:4	X DAC readback error flag	YXDACERR
Y02X559B	120/118:6	Y DAC readback error flag	YYDACERR
Y02X560B	120/118:2	Focus DAC readback error flag	YFDACERR
Y02X561B	120/118:7	HY DAC readback error flag	YHVDACER
Y02X562B	120/118:8	Discriminator reference DAC readback error flag	
Y02X563B	120/118:3	Discriminator DAC readback error flag	YDRDACER
Y02X564B	120/119:1	Accumulator timer set error	YDDACERR
Y02X566D	120/119:2-4	Mechanism time-out code	YACTMERR
Y02X567D	120/119:5-8	Data control commands	YMECHTOC
Y02X571B	120/120:1	Data acquisition not in progress	YDATACTL
Y02X572B	120/120:2	Resting in peace	YNDAIP
Y02X573B	120/120:3	Pause in progress	YRIP
Y02X574B	120/120:4	CEA plot in progress	YPIP
Y02X575B	120/120:5	Target acquisition in progress	YCPIP
Y02Q576A	120/60	Number of memory slices	YTAQIP
Y02Q577A	120/112	Patterns per readout	YMSLICES
Y02X578B	120/118:5	Calibration DAC readback error flag	YPTRNS
			YCDACERR

Table 4.3-1 FOS Engineering Telemetry (cont)

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y02X5790	120/35:1-2	Descramble PROM power status	YDPRMPWR
Y02X5808	120/35:4	Flat field cal lamp power	YFFCPWR
Y02Z5818	120/35:3	Spare bit	YHVSAR
Y02X5828	120/120:6	Mechanism motion in progress	YMMIP
Y02X5838	120/120:7	Auto memory clear in progress	YAMCIP
Y02X5848	120/120:8	Science dump in progress	YSDIP
Y02W585A	120/64	Accumulator open time high byte	YLIVEHI
Y02W586A	120/65	Accumulator open time low byte	YLIVELO
Y02W587A	120/66	Accumulator close time high byte	YDEADHI
Y02W588A	120/67	Accumulator close time low byte	YDEADLO
Y02Z589A	120/35:5-6	Spare	YSPARE
Y11Q600A	192/1	Number of FOS status buffer entries	YSTBUF
Y11X601D	192/2	FOS on/off indicator	YONOFF
Y11J602D	192/3	Status of INIT processor	YFINST
Y11J603D	192/4	Science data storage status	YFSDST
Y11J604D	192/5	Science data processing status	YFPRST
Y11Z605A	192/6	Spare 0	YSPRO
Y11Q606A	192/7	Line number within a frame	YLINCT
Y11J607D	192/8	Housekeeping status	YFHKST
Y11J608D	192/9	Autonomous safe status	YFASST
Y11J609D	192/10	Turn off status	YFTOST
Y11J610A	192/11	Data items 1-8	YFL81
Y11J611A	192/12	Data items 9-16	YFL169
Y11J612A	192/13	Data items 17-24	YFL241
Y11J613A	192/14	Data items 25-32	YFL322
Y11Q614A	192/15	Counts main frame discrete log errors	YDISCT
Y11Q615A	192/16	Counts main frame magnitude command errors	YSMECT
Y11Q616A	192/17	Counts main frame keep alive failures	YKEEP
Y11Q617A	192/18	Counts main frame limit check failures	YFLGCT
Y11J618D	192/19	Autonomous safe flag	YSFFLG
Y11J619D	192/20	Turn off flag	YTOFLG
Y11J620D	192/21	Action indicator for YFM2PR module	YFM2FL
Y11Q621A	192/22	Count frames for part 1 of YFSDPR processor	YFRCTR
Y11J622D	192/23	Mode 2 target acquisition error indicator	YGIYUP
Y11Q623A	192/24	Count frames for part 2 of YFSDPR processor	YGPCTR
Y11J624D	192/25	Mode 2 Target acquisition completion indicator	YTACMP
Y11J625D	192/26	Mode 2 target acquisition processor status	YFM2ST
Y11Z626A	192/27	Spare 1	YSPR1
Y11Z627A	192/28	Spare 2	YSPR2
Y11J628D	192/29	Peak-up target acquisition processor status	YFPKST
Y11Q629A	192/30	Counter of frames/dwell during FPKUP	YPUCT
Y11Q630A	192/31	Dwell counter for FPKUP	YFDWCT
Y11Q631A	192/32	8 LSBs accumulated YOVRILITE	YOV81
Y11Q632A	192/33	Next 8 LSBs accumulated YOVRILITE	YOV169
Y11Q633A	192/34	Next 8 LSBs accumulated YOVRILITE	YOV241
Y11Q634A	192/35	8 MSBs accumulated YOVRILITE	YOV322
Y11Z635A	192/36	Spare 3	YSPR3
Y11Z636A	192/37	Spare 4	YSPR4
Y11Z637A	192/38	Spare 5	YSPR5

Table 4.3-1 FOS Engineering Telemetry (cont)

<u>Full ID</u>	<u>Location</u>	<u>Significance</u>	<u>Mnemonic</u>
Y11Q638A	192/39	Number of tests by FHKPG where fail-safe armed	YFSCTR
Y11J639D	192/40	Consecutive major frames with error check error	YERCTR
Y11J640D	192/41	Consecutive major frames with firmware version error	YFWCTR
Y11Q641A	192/42	Counter of major frame fail-safe RPI test	YMFCCT
Y11Q642A	192/43	Counter of major frame output for data log	YMFECT
Y11Q643A	192/44	Consecutive major frames gone safe autonomously	YSAFCR
Y11Q644A	192/45	Counter of failed YOVRILITE sum tests	YOVCTR
Y11Q645A	192/46	Counter of failed self-check tests	YSCCTR
Y11Q646A	192/47	Counter of speed check errors	YSPCTR
Y11Z647A	192/48	Spare 6	YSPR6
Y11Z648A	192/49	Spare 7	YSPR7
Y11J649A	120/96	SMC error report flags	YSMCERRS
Y11Q650Aa	120/21	Upper Target/Acq Window HI	YTAMAX HI
Y11Q650Ab	120/22	Upper Target/Acq Window LO	YTAMAX LO
Y11Q651Aa	120/81	Lower Target/Acq Window HI	YTAMIN HI
Y11Q651Ab	120/82	Lower Target/Acq Window LO	YTAMIN LO
Y11Q652Aa	120/52	Number of adder rejects HI	YREJECTS HI
Y11Q652Ab	120/59	Number of adder rejects LO	YREJECTS LO

5.0 FOS CALIBRATION ALGORITHMS

The FOS Calibration Algorithms are divided into a set used in all FOS Ground Software modes (Sections 5.1-5.3) and those used in the Spectroscopy, Time-Resolved, Spectropolarimetry, Rapid-Readout, and Time-Tagged Ground Software Modes (Sections 5.4-5.8 respectively). Only those in Sections 5.1-5.3 are used in the Target Acquisition Ground Software Mode (see SLIB 799 Section 10.2.2.1). The following sections are arranged in the same sequence as SLIB 799 Section 10.2.2. Also included is the FOS data reformatting specified in SLIB 799 Section 10.1.3.

5.1 FOS DATA REFORMATTING

See SLIB 799 Section 10.1.3.

5.2 STANDARD CASE REDUCTIONS, CONVERT RAW COUNTS TO COUNT RATES

See SLIB 799 Section 10.2.2.1.1.1.

5.3 STANDARD CASE REDUCTIONS, REORDER SCIENCE DATA

See SLIB 799 Section 10.2.2.1.1.2.

5.4 SPECTROSCOPY MODE REDUCTIONS

See SLIB 799 Section 10.2.2.1.2.

5.5 TIME-RESOLVED MODE REDUCTIONS

See SLIB 799 Section 10.2.2.1.3.

5.6 SPECTROPOLARIMETRY MODE REDUCTIONS

See SLIB 799 Section 10.2.2.1.4.

5.7 RAPID-READOUT MODE REDUCTIONS

See SLIB 799 Section 10.2.2.1.5.

5.8 TIME-TAGGED MODE REDUCTIONS

See SLIB 799 Section 10.2.2.1.6.

6.0 FOS DATA QUALITY/UTILITY ALGORITHMS

The FOS Data Quality/Utility Algorithms are used in the Spectrographic Ground Software Modes (all except Target Acquisition). The following sections are arranged in the same sequence as SLIB 799 Section 10.3.2.

6.1 SYNCHRONOUS STACKING OF DATA

See SLIB 799 Section 10.3.2.1.

6.2 ESTIMATION OF LINE INTENSITIES AND EQUIVALENT WIDTHS

See SLIB 799 Section 10.3.2.2.

6.3 DISPLAY OF HISTOGRAMS OF SELECTED POINTS OF THE SPECTRA

See SLIB 799 Section 10.3.2.3 (use standard SOGS image utility).

6.4 DETERMINATION OF LINE CENTERS

See SLIB 799 Section 10.3.2.4.

6.5 WAVELENGTH CALIBRATION ROUTINE

See SLIB 799 Section 10.3.2.5.

7.0 FOS TARGET ACQUISITION ALGORITHMS

The FOS Target Acquisition Algorithms are used solely in the Target Acquisition Ground Software Mode. The following sections are arranged in the same sequence as in SLIB 799 Section 10.4.2.

7.1 PICTURE CONSTRUCTION INPUT SCANS

See SLIB 799 Section 10.4.2.1.1.

7.2 PICTURE CONSTRUCTION UNRESTORED PICTURES

See SLIB 799 Section 10.4.2.1.2.

7.3 PICTURE CONSTRUCTION RESTORED PICTURES

See SLIB 799 Section 10.4.2.1.3.

7.4 PICTURE CONSTRUCTION GENERALIZED PICTURE CONSTRUCTION

See SLIB 799 Section 10.4.2.1.4.

7.5 CENTROIDING OBSERVER INTERACTIVE

See SLIB 799 Section 10.4.2.2.1.

7.6 CENTROIDING GROTH ALGORITHM

See SLIB 799 Section 10.4.2.2.2.

7.7 IMAGE CORRELATION

See SLIB 799 Section 10.4.2.3.

7.8 CROSS-CORRELATION OF COMPLEX IMAGE

See SLIB 799 Section 10.4.2.3.1.

8.0 REFERENCES

This section has three divisions: the first gives a summary of the significant sources used for earlier sections of this document; the second gives sources for other topics not covered in this document; and the third provides information on some SOGS Library documents (SLIB IDs) having information on FOS.

8.1 MAJOR NOTEBOOK SOURCES

FOS data in Section 1 was taken from SLIB L64, SLIB L66, SLIB L69, SLIB L72, SLIB T23, SLIB T30, SLIB 118, SLIB 706, SLIB 739, SLIB 763, SLIB 767, SLIB 810, SLIB 814, SLIB 1006b, and SLIB 1106. SOGS Notebook plans are based on SOGS-300-82-273 (dated 30 July 1982).

Data in Section 2 was taken from SLIB L02, SLIB L64, SLIB L72, SLIB T25, SLIB T30, SLIB 598, SLIB 706, SLIB 767, SLIB 810, SLIB 814, and SLIB 1006b.

Data in Section 3 was taken from SLIB L37, SLIB L38, SLIB L55, SLIB L64, SLIB L65, SLIB L66, SLIB L67, SLIB L72, SLIB T23, SLIB T25, SLIB T30, SLIB 204, SLIB 259, SLIB 598, SLIB 683, SLIB 706, SLIB 739, SLIB 753, SLIB 763, SLIB 767, SLIB 810, SLIB 814, SLIB 936, SLIB 1088, SLIB 1089, and SLIB 1106.

Data in Section 4 was taken from SLIB L66, SLIB L72, SLIB T30, SLIB 598, SLIB 683, SLIB 739, SLIB 753, SLIB 763, SLIB 767, SLIB 814, SLIB 936, SLIB 1088, and SLIB 1089.

Data in Sections 5-7 was taken from SLIB 799 and SLIB 814.

8.2 OTHER TOPICS

The following lists some of the FOS-related subjects omitted from this Note-book. The SLIB references are suggested as a starting point for future study of the topics indicated:

<u>Topic</u>	<u>SLIB References</u>
Algorithm Discussion	SLIB 411
Analysis Software	SLIB 411
Commands	SLIB 683, SLIB 1088
FOS Hardware Requirements	SLIB 706
FOS Microprocessor Memory	SLIB 739
FOS Overview	SLIB 810
FOS Tape Analysis	SLIB 1106
Mission Operations Requirements	SLIB 932
NSSC-1 FOS Processor Design	SLIB 763
Operational Considerations for FOS	SLIB 411
Operations Concept Analysis	SLIB 732
Prototype Software	SLIB 411
Scenarios using FOS	SLIB 731
SHP Contents	SLIB 936
SI C&DH Performance Specification	SLIB 530
SI Overview	SLIB 110, SLIB 595
SI-to-SI C&DH ICD, FOS Appendix	SLIB 753

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8.3 SLIB REFERENCES

Given on the following pages are identifications of the SLIB documents cited in this document, as well as a selection of other TRW SOGS Library FOS-unique documents. They are in the following formats:

Table 8.3-1 is a list in order by SLIB number;

Table 8.3-2 is the same list, but arranged by descending date (most recent document first); and

Table 8.3-3 is the same list, but arranged in alphabetical order by title.

The cutoff date for the TRW SOGS Library material in this issue was the logged accessions for the week ending 27 January 1984.

Table 8.3-1 FOS References by SLIB Number

L02	820316	FOS Data Reduction Requirements, from U.Washington.
L04	820308	FOS Constraints and Restrictions, from UCSD.
L19	820406	Preliminary FOS Requirements for SOGS, from UCSD.
L20	820322	FOS Requirements for SOGS Support, from UCLA (Ford).
L25	820528	List of FOS Algorithms for SOGS, from UCSD.
L26	8104xx	Reducing Scanner Data (program documentation), from UCLA (Grandi).
L27	820412	Polarimetry Calibration Requirements for FOS, from U.Arizona.
L37	821101	DCF Observation Number, from Doxsey (ST Sci).
L38	821028	SHP Uplink Data Transfer, from Doxsey (ST Sci).
L55	830623	FOS Mechanism Information, from UCSD (Strein).
L64	830928	Review of TRW ST SI Notebook, from UCSD (Randall).
L65	831206	SI C&DH Questions, November 22, 1983, from IBM (Campbell).
L66	831206	SOGS Concerns with FOS Test Tape and Other Matters, from UCSD (Baity).
L67	821130	ST Packet Format Code Assignments, from OAO (Wilbur).
L68	831109	Definition of SHP Ground Uplink Format, from J. Hennessy.
L69	831115	Naming of the Space Telescope, from MSFC.
L72	840117	Preliminary Answers to TRW Questions Raised by FOS Data Tape, from UCSD (Hier).
T14	820429	Minutes of SOGS-FOS-00TL-STSOP Telecon of 29 April '82 on FOS Algorithms (AI T81 and T82), from SOGS.
T23	830623	Notes from GSFC/ST Sci Meetings 14-16 June 1983, from SOGS.
T25	830623	Results of FOS Question Discussion at GSFC on 16 June 1983, from SOGS.
T30	840126	Answers to Questions on FOS Data, from SOGS.
028	8003xx	DM-04, Ground Test Software for FOS (S/W Mgt Plan and Requirements), from UCSD.
046	8003xx	DM-03, SI Ground Test Software Requirements Document for FOS, from UCSD.
101	79xxxx	Testing of ST 512-channel Digicon, from SPIE.
103	80xxxx	State of Art ST Digicon Performance Data, from SPIE.
104	79xxxx	ST Digicon, from SPIE.
110	79xxxx	ST Scientific Instruments, from SPIE.
118	79xxxx	FOS for the ST, from SPIE.
204	810807	SI & C&DH Command and Data Lists, from IBM.
213	790330	SI Operations and Data Mgt Requirements for FOS, from UCSD.
214	800522	DM-04C, Preliminary Ground Test Software Design (PDL) Document, from UCSD.
215	790718	DM-04, Preliminary Ground Test Software Requirements for UCSD FOS, from UCSD.
216	800320	DM-05C, Software Design Document for FOS for ST, from UCSD.
218	800714	Systems Description of Faint Object Spectrograph, Rev. A, from Martin.
220	800722	DRM Inputs for FOS, from UCSD.
224	770708	UC/MMC FOS Proposal for the ST, from UCSD.
259	8005xx	FOS Critical Design Review, from Martin.
262	790525	Prime Equipment Detail Spec, Pt. 2, Performance Design, and Verification Requirements for FOS, from Martin.
326	811221	FOS Ground Test Software Data Base, from .
343	811216	FOS Operations (Meeting Handout), from UCLA (H. Ford).

Table 8.3-1 FOS References by SLIB Number (cont)

356 8202xx FOS Bimonthly Review, from UCSD.
397 820303 FOS SI Data Base (printout), from UCSD.
411 820305 ST FOS Requirements Notebook, from SOGS.
439 800401 DM-01, SI Command and Data Lists for FOS, from Martin.
453 82xxxx Performance of Spectropolarimeter for ST FOS, from Allen & Angel.
529 820504 OSS Scenario FOS, from CTA.
530 820325 Performance Spec for the SI C&DH Subsystem of the ST, from GSFC.
560 820524 A Brief Description of the FOS Eng'g TM, from ORI.
561 820524 Format and Content of FOS Science Data Output, from ORI.
563 7901xx Operations and Data Management Plan for FOS, from UCSD.
595 8207xx The ST, from Scientific American.
598 8206xx FOS Data Requirements for SOGS, from UCSD.
630 790411 FOS System Performance Summary, from Martin.
633 8009xx FOS 512-Channel Digicon Detector Performance Data, Paper #290-28, from UCSD.
634 7909xx DM-05, Preliminary FOS NSSC-1 SW Requirements Document for FOS, Section B, from UCSD.
656b 820715 FOS Science Data Modes and Formats, from UCSD.
683 820804 FOS Serial Magnitude Command Definitions, from UCSD.
706 810825 FOS Prime Equipment Detail Spec, Pt. 2: Performance, Design, and Verification Requirements, from UCSD.
731 820830 SOGS Simulation Requirements Based on Operational Scenarios, from CTA.
732 820830 ST SOGS Operations Concept Analysis, from CTA.
733 820823 FOS Quality Utility Algorithms, from UCLA.
739 8208xx SI/NSSC-1 Memory to SATS Interface Requirements Document (Preliminary), from GSFC.
753 820920 FOS Unique Appendix to SI/SI C&DH ICD, Rev. C, from UCSD.
763 8208xx DM-05, Flight Software for FOS, Section C, Pt. II, SW Design (PDL) Document Rev. E, from UCSD.
767 820807 Notes on FOS Briefing by G. Schmidt (SOGNOR-12), from SOGS.
769 820715 FOS Science Data Modes and Formats, from UCSD.
799 821029 SE-06-1 SOGS Design Manual Requirements Section (updated through PDCR-015, plus PDCR-020), from SOGS.
810 8208xx The ST Observatory (10 papers), from Sci.
814 821104 UCSD Comments on FOS SOGS Notebook, from UCSD.
865 821231 FOS SOGS Notebook, from SOGS.
932 8301xx SMO-1000, ST Mission Operations Functional Requirements, Rev. B, from LMSC.
936 830307 Standard Header Packet Definition Document, Rev. A, from LMSC.
1006b 830506 SO-07, Final Science Operations Concept, Part 2, from SCI.
1088 830425 DM-01, ST Command List (LMSC 4171849F), from LMSC.
1089 830425 DM-02, ST Instrumentation Program and Component List (LMSC 4171850G), from LMSC.
1106 831012 Analysis of Parts of FOS 20-22 March 1983 SI Data Tape, from SOGS.

Table 8.3-2 FOS References by Descending Date

T30	840126	Answers to Questions on FOS Data, from SOGS.
L72	840117	Preliminary Answers to TRW Questions Raised by FOS Data Tape, from UCSD (Hier).
L65	831206	SI C&DH Questions, November 22, 1983, from IBM (Campbell).
L66	831206	SOGS Concerns with FOS Test Tape and Other Matters, from UCSD (Baity).
L69	831115	Naming of the Space Telescope, from MSFC.
L68	831109	Definition of SHP Ground Uplink Format, from J. Hennessy.
1106	831012	Analysis of Parts of FOS 20-22 March 1983 SI Data Tape, from SOGS.
L64	830928	Review of TRW ST SI Notebook, from UCSD (Randall).
L55	830623	FOS Mechanism Information, from UCSD (Strein).
T23	830623	Notes from GSFC/ST Sci Meetings 14-16 June 1983, from SOGS.
T25	830623	Results of FOS Question Discussion at GSFC on 16 June 1983, from SOGS.
1006b	830506	SO-07, Final Science Operations Concept, Part 2, from SCI.
1088	830425	DM-01, ST Command List (LMSC 4171849F), from LMSC.
1089	830425	DM-02, ST Instrumentation Program and Component List (LMSC 4171850G), from LMSC.
936	830307	Standard Header Packet Definition Document, Rev. A, from LMSC.
932	8301xx	SMO-1000, ST Mission Operations Functional Requirements, Rev. B, from LMSC.
865	821231	FOS SOGS Notebook, from SOGS.
L67	821130	ST Packet Format Code Assignments, from OAO (Wilbur).
814	821104	UCSD Comments on FOS SOGS Notebook, from UCSD.
L37	821101	DCF Observation Number, from Doxsey (ST Sci).
799	821029	SE-06-1 SOGS Design Manual Requirements Section (updated through PDCR-015, plus PDCR-020), from SOGS.
L38	821028	SHP Uplink Data Transfer, from Doxsey (ST Sci).
753	820920	FOS Unique Appendix to SI/SI C&DH ICD, Rev. C, from UCSD.
731	820830	SOGS Simulation Requirements Based on Operational Scenarios, from CTA.
732	820830	ST SOGS Operations Concept Analysis, from CTA.
733	820823	FOS Quality Utility Algorithms, from UCLA.
767	820807	Notes on FOS Briefing by G. Schmidt (SOGNOR-12), from SOGS.
683	820804	FOS Serial Magnitude Command Definitions, from UCSD.
739	8208xx	SI/NSSC-1 Memory to SATS Interface Requirements Document (Preliminary), from GSFC.
763	8208xx	DM-05, Flight Software for FOS, Section C, Pt. II, SW Design (PDL) Document Rev. E, from UCSD.
810	8208xx	The ST Observatory (10 papers), from Sci.
656b	820715	FOS Science Data Modes and Formats, from UCSD.
769	820715	FOS Science Data Modes and Formats, from UCSD.
595	8207xx	The ST, from Scientific American.
598	8206xx	FOS Data Requirements for SOGS, from UCSD.
L25	820528	List of FOS Algorithms for SOGS, from UCSD.
560	820524	A Brief Description of the FOS Eng'g TM, from ORI.
561	820524	Format and Content of FOS Science Data Output, from ORI.
529	820504	OSS Scenario FOS, from CTA.
T14	820429	Minutes of SOGS-FOS-DOTL-STSOP Telecon of 29 April '82 on FOS Algorithms (AI T81 and T82), from SOGS.

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Table 8.3-2 FOS References by Descending Date (cont)

L27 820412 Polarimetry Calibration Requirements for FOS, from U.Arizona.
L19 820406 Preliminary FOS Requirements for SOGS, from UCSD.
530 820325 Performance Spec for the SI C&DH Subsystem of the ST, from GSFC.
L20 820322 FOS Requirements for SOGS Support, from UCLA (Ford).
L02 820316 FOS Data Reduction Requirements, from U.Washington.
L04 820308 FOS Constraints and Restrictions, from UCSD.
411 820305 ST FOS Requirements Notebook, from SOGS.
397 820303 FOS SI Data Base (printout), from UCSD.
356 8202xx FOS Bimonthly Review, from UCSD.
453 82xxxx Performance of Spectropolarimeter for ST FOS, from Allen & Angel.
326 811221 FOS Ground Test Software Data Base, from .
343 811216 FOS Operations (Meeting Handout), from UCLA (H. Ford).
706 810825 FOS Prime Equipment Detail Spec, Pt. 2: Performance, Design, and Verification Requirements, from UCSD.
204 810807 SI & C&DH Command and Data Lists, from IBM.
L26 8104xx Reducing Scanner Data (program documentation), from UCLA (Grandi).
633 8009xx FOS 512-Channel Digicon Detector Performance Data, Paper #290-28, from UCSD.
220 800722 DRM Inputs for FOS, from UCSD.
218 800714 Systems Description of Faint Object Spectrograph, Rev. A, from Martin.
214 800522 DM-04C, Preliminary Ground Test Software Design (PDL) Document, from UCSD.
259 8005xx FOS Critical Design Review, from Martin.
439 800401 DM-01, SI Command and Data Lists for FOS, from Martin.
216 800320 DM-05C, Software Design Document for FOS for ST, from UCSD.
028 8003xx DM-04, Ground Test Software for FOS (S/W Mgt Plan and Requirements), from UCSD.
046 8003xx DM-03, SI Ground Test Software Requirements Document for FOS, from UCSD.
103 80xxxx State of Art ST Digicon Performance Data, from SPIE.
634 7909xx DM-05, Preliminary FOS NSSC-1 SW Requirements Document for FOS, Section B, from UCSD.
215 790718 DM-04, Preliminary Ground Test Software Requirements for UCSD FOS, from UCSD.
262 790525 Prime Equipment Detail Spec, Pt. 2, Performance Design, and Verification Requirements for FOS, from Martin.
630 790411 FOS System Performance Summary, from Martin.
213 790330 SI Operations and Data Mgt Requirements for FOS, from UCSD.
563 7901xx Operations and Data Management Plan for FOS, from UCSD.
101 79xxxx Testing of ST 512-channel Digicon, from SPIE.
104 79xxxx ST Digicon, from SPIE.
110 79xxxx ST Scientific Instruments, from SPIE.
118 79xxxx FOS for the ST, from SPIE.
224 770708 UC/MMC FOS Proposal for the ST, from UCSD.

Table 8.3-3 FOS References by Title

1106 831012 Analysis of Parts of FOS 20-22 March 1983 SI Data Tape, from SOGS.

T30 840126 Answers to Questions on FOS Data, from SOGS.

560 820524 A Brief Description of the FOS Eng'g TM, from ORI.

L37 821101 DCF Observation Number, from Doxsey (ST Sci).

L68 831109 Definition of SHP Ground Uplink Format, from J. Hennessy.

439 800401 DM-01, SI Command and Data Lists for FOS, from Martin.

1088 830425 DM-01, ST Command List (LMSC 4171849F), from LMSC.

1089 830425 DM-02, ST Instrumentation Program and Component List (LMSC 4171850G), from LMSC.

046 8003xx DM-03, SI Ground Test Software Requirements Document for FOS, from UCSD.

214 800522 DM-04C, Preliminary Ground Test Software Design (POL) Document, from UCSD.

028 8003xx DM-04, Ground Test Software for FOS (S/W Mgt Plan and Requirements), from UCSD.

215 790718 DM-04, Preliminary Ground Test Software Requirements for UCSD FOS, from UCSD.

216 800320 DM-05C, Software Design Document for FOS for ST, from UCSD.

763 8208xx DM-05, Flight Software for FOS, Section C, Pt. II, SW Design (POL) Document Rev. E, from UCSD.

634 7909xx DM-05, Preliminary FOS NSSC-1 SW Requirements Document for FOS, Section B, from UCSD.

220 800722 DRM Inputs for FOS, from UCSD.

561 820524 Format and Content of FOS Science Data Output, from ORI.

356 8202xx FOS Bimonthly Review, from UCSD.

L04 820308 FOS Constraints and Restrictions, from UCSD.

259 8005xx FOS Critical Design Review, from Martin.

L02 820316 FOS Data Reduction Requirements, from U.Washington.

598 8206xx FOS Data Requirements for SOGS, from UCSD.

118 79xxxx FOS for the ST, from SPIE.

326 811221 FOS Ground Test Software Data Base, from .

L55 830623 FOS Mechanism Information, from UCSD (Strain).

343 811216 FOS Operations (Meeting Handout), from UCLA (H. Ford).

706 810825 FOS Prime Equipment Detail Spec, Pt. 2: Performance, Design, and Verification Requirements, from UCSD.

733 820823 FOS Quality Utility Algorithms, from UCLA.

L20 820322 FOS Requirements for SOGS Support, from UCLA (Ford).

656b 820715 FOS Science Data Modes and Formats, from UCSD.

769 820715 FOS Science Data Modes and Formats, from UCSD.

683 820804 FOS Serial Magnitude Command Definitions, from UCSD.

397 820303 FOS SI Data Base (printout), from UCSD.

865 821231 FOS SOGS Notebook, from SOGS.

630 790411 FOS System Performance Summary, from Martin.

753 820920 FOS Unique Appendix to SI/SI C&DH ICD, Rev. C, from UCSD.

633 8009xx FOS 512-Channel Digicon Detector Performance Data, Paper #290-28, from UCSD.

L25 820528 List of FOS Algorithms for SOGS, from UCSD.

T14 820429 Minutes of SOGS-FOS-DOTL-STSOP Telecon of 29 April '82 on FOS Algorithms (AI T81 and T82), from SOGS.

L69 831115 Naming of the Space Telescope, from MSFC.

Table 8.3-3 FOS References by Title (cont)

T23	830623	Notes from GSFC/ST Sci Meetings 14-16 June 1983, from SOGS.
767	820807	Notes on FOS Briefing by G. Schmidt (SOGNOR-12), from SOGS.
563	7901xx	Operations and Data Management Plan for FOS, from UCSD.
529	820504	OSS Scenario FOS, from CTA.
453	82xxxx	Performance of Spectropolarimeter for ST FOS, from Allen & Angel.
530	820325	Performance Spec for the SI C&DH Subsystem of the ST, from GSFC.
L27	820412	Polarimetry Calibration Requirements for FOS, from U.Arizona.
L72	840117	Preliminary Answers to TRW Questions Raised by FOS Data Tape, from UCSD (Hier).
L19	820406	Preliminary FOS Requirements for SOGS, from UCSD.
262	790525	Prime Equipment Detail Spec, Pt. 2, Performance Design, and Verification Requirements for FOS, from Martin.
L26	8104xx	Reducing Scanner Data (program documentation), from UCLA (Grandi).
T25	830623	Results of FOS Question Discussion at GSFC on 16 June 1983, from SOGS.
L64	830928	Review of TRW ST SI Notebook, from UCSD (Randall).
799	821029	SE-06-1 SOGS Design Manual Requirements Section (updated through PDCR-015, plus PDCR-020), from SOGS.
L38	821028	SHP Uplink Data Transfer, from Doxsey (ST Sci).
L65	831206	SI C&DH Questions, November 22, 1983, from IBM (Campbell).
213	790330	SI Operations and Data Mgt Requirements for FOS, from UCSD.
204	810807	SI & C&DH Command and Data Lists, from IBM.
739	8208xx	SI/NSSC-1 Memory to SATS Interface Requirements Document (Preliminary), from GSFC.
932	8301xx	SMO-1000, ST Mission Operations Functional Requirements, Rev. B, from LMSC.
L66	831206	SOGS Concerns with FOS Test Tape and Other Matters, from UCSD (Baity).
731	820830	SOGS Simulation Requirements Based on Operational Scenarios, from CTA.
1006b	830506	SO-07, Final Science Operations Concept, Part 2, from SCI.
936	830307	Standard Header Packet Definition Document, Rev. A, from LMSC.
103	80xxxx	State of Art ST Digicon Performance Data, from SPIE.
104	79xxxx	ST Digicon, from SPIE.
411	820305	ST FOS Requirements Notebook, from SOGS.
L67	821130	ST Packet Format Code Assignments, from OAO (Wilbur).
110	79xxxx	ST Scientific Instruments, from SPIE.
732	820830	ST SOGS Operations Concept Analysis, from CTA.
218	800714	Systems Description of Faint Object Spectrograph, Rev. A, from Martin.
101	79xxxx	Testing of ST 512-channel Digicon, from SPIE.
595	8207xx	The ST, from Scientific American.
810	8208xx	The ST Observatory (10 papers), from Sci.
314	821104	UCSD Comments on FOS SOGS Notebook, from UCSD.
224	770708	UC/MMC FOS Proposal for the ST, from UCSD.

FOC ND-1005A

FOC-Related Acronyms

ADC	Analog to Digital Converter
BAe	British Aerospace
CAM	Coronographic Apodizer Mechanism
CEHT	Camera Electrical High Tension (Unit)
CEM	Camera Electronics Module
CEU	Camera Electronics Unit
CIAR	Command Interrupt Application Routine
CM	Camera Module
CPS	Camera Power Supply
CU	Calibration Unit
C&DH	Control and Data Handling (Subsystem)
DCF	Data Capture Facility
DHU	Detector Head Unit (#1 f/48, #2 f/96)
DICU	Data Handling Interface and Control Unit
EBA	Electronics Bay Assembly
EBS	Electron Bombarded Silicon
EHT	Electrical High Tension
ESA	European Space Agency
ESTEC	European Space Research and Technology Centre
ET	Engineering Telemetry
FITS	Flexible Image Transport System
FOC	Faint Object Camera
FOV	Field Of View
FPLA	Field Programmable Logic Array
FWM	Filter Wheel Mechanism
GO	General Observer
GRT	Ground Related Time
GSFC	Goddard Space Flight Center
HP	High Power (Command)
HRA	High Resolution Apodizer
ICD	Interface Control Document
IDT	Investigation Definition Team
IEHT	Intensifier Electrical High Tension (Unit)
ILS	Interrupteur a Lame Souple (switch having a flexible metal strip)

IST Instrument Science Team
K For memory, 2^{10} (1024); otherwise, 10^3
KV Kilovolts
KV Kilovolts
LED Light Emitting Diode
LMSC Lockheed Missiles and Space Company, Incorporated
LP Low Power (Command)
mA Milliamperes
Mbs Megabits per second
MDE Mechanism Drive Electronics
MHz 10^6 Hz
ML Memory Load Command
mm Millimeter
MOGS Mission Operations Ground System
msec Millisecond
NG Generated by NSSC-1
nm Nanometer (10^{-9} meters or 10 angstroms)
NOG Generated by NSSC-1 and OBC
NSSC-1 NASA Standard Spacecraft Computer, Model 1
OBC On-Board Computer (in FOC)
OBDH On-Board Data Handling
OBE Optical Bench Enclosure
OG Generated by OBC
ORW OBC Request Word
OSS Observation Support System
OTA Optical Telescope Assembly
O/O On/Off Command
PASS POCC Application Software Support
PCU Power Conditioning Unit
PDA Photon Detector Assembly
PDCR Preliminary Document Change Request
PDL Program Design Language
PMA Permanent Magnet Assembly
POCC Payload Operations Control Center
PODPS Post-Observation Data Processing System

PORTS	Preliminary Operations Requirements and Test Support
PRL	Pattern Recognition Logic
PRU	Pattern Recognition Unit
PSS	Payload Safing Sequence
QCM	Quartz Crystal Monitor
RAL	Rutherford Appleton Laboratory
RAM	Random Access Memory (read/write)
RFM	Refocusing Mechanism
RIU	Remote Interface Unit
RMU	Radiation Monitoring Unit
ROM	Read-Only Memory
RTCS	Relative Time Command Sequence
RTU	Remote Terminal Unit
Sci	Science Institute (Johns Hopkins)
SDAS	Science Data Analysis Software
SDF	Science Data Formatter
SDS	Science Data Store
SHM	Shutter Mechanism
SHP	Standard Header Packet
SI	Science Instrument
SLIB	SOGS (TRW) Library document identifier
SMM	Spectrographic Mirror Mechanism
SOGS	Science Operations Ground System
SPSS	Science Planning and Scheduling System
SSC	Science Support Center
SSM	Support Systems Module
ST	Edwin P. Hubble Space Telescope
STOCC	ST Operations Control Center
STR	Science Tape Recorder
STSOP	ST Science and Operations Project
TBD	To be determined
TCE	Thermal Control Electronics
TM	Telemetry
TRIM	Time Resolution Imaging Mode
UDL	Unique Data Log

usec Microsecond
UTC Universal Time Coordinated
VICAR Video Image Communication and Retrieval (for image processing)
VPU Video Processing Unit
WF/PC Wide Field and Planetary Camera
X Conventional first letter for FOC parameters
XXXX Abbreviated LMSC ET Measurement ID
X.xxx Coined Measurement ID
X'ab' Hexadecimal (base 16) value for "ab"
??? Material needing determination/confirmation

1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF FOC NOTEBOOK

The purpose of this Faint Object Camera (FOC) Notebook is to provide a compilation from various sources of factual information on certain aspects of the FOC necessary for design work on the Edwin P. Hubble Space Telescope (ST) Science Operations Ground System (SOGS). The contract for development of SOGS is managed by GSFC, and is performed by TRW. One of the main tasks of SOGS is the receipt, display, manipulation, and calibration of the FOC data (as well as the other instruments on the ST). To perform this task, a thorough understanding is necessary of the various formats in which data is received, where critical processing parameters are in both the science and engineering data streams, and what algorithms are to be applied to calibrate the science data for each instrument configuration.

The intended audience for this FOC Notebook is the TRW SOGS designers, rather than a general collection of diverse groups with equally diverse information desires. Because of its intended audience, there are numerous FOC-related topics that are not included in this Notebook. Section 8 (References) has a list of citations for some source documents on FOC that are in the TRW SOGS Library. Such documents have been assigned serial accession numbers (SLIB numbers) meaningful only to those with access to the TRW Library, so Section 8 provides information on originator, date, and title to identify the material more completely.

The organization of this FOC Notebook is the same as that for the other four ST instruments. After this introductory material, the various types of FOC modes are defined in Section 2 (since they are of major significance to the SOGS design effort). Sections 3 and 4 cover the FOC Science Telemetry and FOC Engineering Telemetry respectively. Algorithms for FOC Calibration, FOC Data Quality/Utility, and FOC Target Acquisition are in Sections 5 to 7 respectively (these relate to what is in Section 10 of the SOGS SE-06-1 specification, SLIB 799). Section 8 has References.

1.2 SUMMARY OF FOC NOTEBOOK UPDATES FOR THIS REISSUE

The changes in this reissue of the FOC Notebook (SLIB 931 was the original issue) are those necessary to reflect a collection of minor details concerning the instrument's performance. There should be no surprises in the changes that are incorporated in this issue, which include:

1. Deletion of most non-administrative references to "SOGS" to avoid the implication that this document defines the characteristics of the SOGS software.
2. Some telemetry identifier changes to agree with a new issue of LMSC's DM-02 (SLIB 1089).
3. Some augmentations of the instrument description obtained from the ST Science Institute's FOC description in SLIB 1006b (see Section 1.5).
4. Additional details concerning some of the downlink parameters obtained from new FOC IDT publications.
5. A table giving the LMSC DM-02 engineering telemetry IDs and the corresponding values in an FOC IDT document (SLIB 1035).
6. The FOC command summary in Section 3.1.7 of the previous issue has been deleted (because of the extensive changes made in the new LMSC DM-01 document, SLIB 1088).

Two areas where (in common with most other ST instruments) uncertainties exist in the material covered in this document are the detailed format of the uplinked area of the Standard Header Packet (alternative sources are cited in Section 3.2.1) and the flight values to be used for the packet format code (see Section 3.2.4).

The updating effort for this FOC Notebook will be a continuous process throughout the duration of the SOGS project. This reissue, however, is the first FOC Notebook change that has been generated since the SLIB 931 issue (dated 24 February 1983). New information otherwise has been distributed among the TRW SOGS designers by means of SOGS memos. Particularly for those holders of the FOC Notebook outside of TRW, therefore, reliance on this FOC Notebook to reflect the "latest available" (anyplace) set of FOC data continues to be inappropriate.

1.3 INSTRUMENT SCIENCE TEAM

The Chairman of the FOC Instrument Science Team is:

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I. R. King, University of California, Berkeley

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G. Weigelt, Physikalisches Institut, Erlangen-Nurnberg

R. N. Wilson, European Southern Observatory, Munchen.

Huw D. Hopkins (ESTEC at Noordwijk) is the ESA Operations Coordinator, Robin J. Laurance (also at Noordwijk) is the FOC Project Manager, and Michel Verdant is the ESA representative at GSFC. J. Chris Blades and Frank Paresce are ESA ST Science Institute representatives.

1.4 SCIENTIFIC OBJECTIVES

The following information was obtained from SLIB 482 and SLIB 297:

The FOC scientific objectives include the following observations and measurements:

1. Physics of minor planets;
2. Search for a planet around Barnard's Star;
3. Search for massive black holes in globular clusters;
4. Ionization structure of shock waves in the interstellar medium;
5. High-spatial-resolution studies of Herbig Haro objects;
6. Spectrography of active nuclei of galaxies;
7. Coma cluster distance moduli;
8. Search for and study of optical emission associated with the radio lobes of double radio galaxies;
9. Velocity dispersion and mass densities in the central regions of normal and compact elliptical galaxies;
10. Objective prism surveys of high latitude X-ray sources; and
11. Stellar content of globular clusters.

Typical specific scientific objectives of the FOC are:

- a) Observations of RR Lyrae stars, cepheids, bright supergiants, globular clusters, and giant HII regions as distance indicators out to expansion velocities > 10 km/sec;
- b) Resolution of spectroscopic and astrometric binaries to establish fundamental stellar masses;
- c) Detailed studies of shock fronts, condensing gas clouds, and the relationship of young stars to the gas around them in regions of star formation;
- d) Optical identification of faint X-ray sources; and
- e) Search for direct evidence of quasars or BL Lac objects in the extraordinary bright nuclei of faint galaxies.

1.5 PRINCIPLES OF OPERATION

See SLIB 414 for information on the principles of operation of the complete FOC instrument (including its mechanical layout and a functional block diagram). The material given below emphasizes those FOC aspects that are of particular significance for understanding the nature of its science data, and has been generated using the sources listed in Section 8.1.

The FOC is the SI supplied by the European Space Agency (ESA) for the ST. The instrument consists of two main elements: the Photon Detector Assembly (PDA) for which British Aerospace (BAe) is responsible, and the Camera Module (CM) that is the responsibility of the FOC contractor (Dornier System GmbH in Friedrichshafen, with Matra-Espace in Toulouse as co-contractor). The latter contract covers the overall FOC system design, verification, and calibration. ESA also is contributing the solar arrays for the ST. In return for their contributions, ESA has been allocated a minimum of 15% of the observing time. The primary purpose of the FOC is to exploit the full optical power of the ST. It will detect the faintest objects visible with the telescope and will record images having the finest angular resolution attainable with the optical system from 115 nm to the visible. Rather than being redundant with the Wide Field and Planetary Camera (WF/PC), the FOC is complementary to that device: for example, the FOC has a higher spatial resolution, but the WF/PC has a larger field of view. The two cameras are designed to be sufficiently similar in function to ensure that an operable camera of some kind will be among the initial ST operational instruments, even if a camera were to fail in orbit.

The FOC contains two complete and independent cameras, each with its own optical path and detector system. Only one optical relay can be operational at one time; switchover may require 24 hours for full thermal stabilization. The baseline mode of FOC operation is at f/96, in which its 25-micron² (a micron is 10^{-6} meter, and the dimension is referred to the input surface of the detector) pixels subtend 0.022 arc seconds on the sky. In this mode, the field of view (FOV) of the FOC is limited (for full resolution) to about 11.2 x 11.2 arc seconds by the size of its data store. The FOC design includes a second independent camera (expected to be used less often) operating at f/48

that doubles these subtended angles, at the cost of angular resolution. Several different pixel scan formats can be specified by the observer to achieve other coverages. The useful photocathode area is 25.6 x 25.6 square millimeter, corresponding to 1024 x 1024 normal-size pixels.

Selection of the optical train (and hence focal ratio) to be used for the input light from the object is accomplished by maneuvering the ST so as to place the object in the correct entrance aperture. Beyond the aperture for each optical train, the beam passes through a Shutter Mechanism (SHM, which also has a mirror to allow use of the Calibration Unit), and then is relayed by several mirrors and focused onto a detector's first stage photocathode. The SHM is normally controlled by a torquer, but can also be controlled by an electromagnet to move it out of the optical path. The electromagnet is intended to be a backup method of operation, so probably would only be used in failure recovery situations. It is not an error condition to have both shutters open, although for stray light reasons it may be better to avoid this configuration.

In the f/96 train, four filter wheels, each with 12 positions (including a clear one), are provided for selectable bandpass, neutral density, and polarizing filters, as well as objective prisms. The filter wheels are controlled by the Filter Wheel Mechanism (FWM), and take about a minute to make a complete revolution. In the f/48 train, only two wheels, each with 8 positions (including a clear one), are provided. Each filter wheel takes 48 cycles to complete a full circle, meaning the f/48 wheel has 6 cycles between positions and the f/96 wheel has 4 cycles. A user command can move the wheel one cycle at a time, but after initialization the normal method of movement will be by a macro command that specifies the position value. The wheel position is monitored by ILS (a French acronym for "Interrupteur a Lame Souple," crudely translated as "switch [having a] flexible metal strip") sensors that give a zero output between the valid wheel positions. No backup wheel movement capability is available.

To compensate for optical path changes due to filter selection and FOC internal instability, a Refocusing Mechanism (RFM) is provided in each optical path that moves one of the mirrors. The RFM normally moves over a range of ± 8 mm, taking about 96 seconds to move over this complete range. Focus changes are in units of cycles of 0.083 mm, where each physical cycle requires four electrical steps of the associated motor.

The f/96 optical path is provided with a coronographic and high resolution facility. This capability will be used to observe faint objects or extended structure near bright sources. It consists of two fixed opaque fingers, 0.4 and 0.8 arc seconds wide (on the sky), located in the ST focal plane close to the corners of the FOV. These masks are used by imaging in the corners of the FOV. There is also an apodizer mask (that eliminates scattered light) mounted on a small removable Cassegrain telescope that can be inserted into the relayed exit pupil. This equipment functions to block bright source photons diffracted by the ST secondary mirror and support structure, as well as to magnify the prime focal ratio by a factor of three (to f/288, so pixels subtend about 0.0075 arc second, the nominal ST pointing stability). It is called the High Resolution Apodizer (HRA), and is moved by the Coronographic Apodizer Mechanism (CAM). The CAM is normally controlled by a torquer, but the HRA can also be moved out of the path by an electromagnet (as a backup). Since the mechanisms are independent, it is possible to use either one of the fingers at f/96 or the 0.8 arc-second finger mask with the f/288 Cassegrain. The f/288 image is formed in the [512 x 512] "upper left" part of the [1024 x 1024] area of the tube.

The f/48 optical path has a spectrographic facility. This makes use of a fixed slit (0.1 x 20 arc seconds on the sky) that is adjacent to the f/48 aperture used for field imaging. The FOC Spectrographic Mirror Mechanism (SMM) inserts a convex mirror into the beam, diverting it to a fixed spherical grating before it reaches the f/48 detector. In common with the SHM and CAM, the SMM is normally controlled by a torquer, but can be moved out of the path by an electromagnet. The desired image order (among nominal values of 360-540 nm, 180-270 nm, and 120-180 nm for orders 1-3 respectively)

can be selected by order-sorting filters controlled by the FWM, and positioning of the ST is used to place the target object on the slit. Filters are also provided to allow several orders to be observed at the same time (a useful capability if an element's emission lines having widely separated wavelengths are of interest). The spectrographic dispersion occurs in the direction of the frame scan. Depending on the object position and time of the year, it may take several months before an observation at a particular position angle is feasible (the roll angle of the ST is constrained by the required orientation of the solar arrays to sunlight).

The two FOC detectors are photon-counting devices of identical design. Each consists of a three-stage image intensifier that is optically coupled by a relay lens system to an electron bombarded silicon (EBS) low-light television camera tube. The intensifier has a total gain of about $[1.3 \times 10^5]$, and employs a trim coil (in conjunction with a Permanent Magnet Assembly, or PMA) for focusing of its electron beams. Light gain is achieved by converting input photons into photoelectrons in a photocathode, accelerating the photoelectrons in an electric field, and reconvertng the photoelectrons into photons in a phosphor screen (which is optically coupled to the input photocathode of the next stage).

The FOC detectors are characterized by high photocathode quantum efficiencies (referred to as "Detective Efficiency") in the blue and ultraviolet, as well as low background dark current. In operation, the EBS tube detects a phosphorescent burst at the output of the intensifier (corresponding to an individual photoevent on the first-stage photocathode). The tube's storage target is scanned in a raster format, the central position of the burst is measured by the Pattern Recognition Unit (PRU) of the PDA's Video Processing Unit (VPU), and a memory cell in the Science Data Store (SDS) associated with that pixel is incremented by 1. The image in the SDS gradually builds up during exposures (which may last several hours), and can be read in a non-destructive way at any intermediate time. All scientific data produced by the PDA is fed to the SDS (there is no real-time recovery of scientific data via telemetry during normal operation).

The speed of the EBS tube and the VPU limits the linear range of pulse counting to about 0.6 counts/pixel/second in the full [512 x 512] format. This rate results in non-linearity at the single pixel level of better than 10%, correctable to a photometric accuracy of about 1%. The on-board Calibration Unit and a set of reseau marks will allow in-flight calibration of photometric response and of geometric distortion at the single pixel level. The reseau marks are in the form of a [17 x 17] grid, each [75 x 75] microns ([3 x 3] normal pixels), etched onto the surface of the first photocathode of each detector. These reseau marks are only used with flat-field calibration images (shutters closed), since they cannot normally be detected in celestial images.

Higher rates of up to 3 counts/pixel/second can be corrected with decreasing accuracy. Brighter objects can be observed by using attenuators (in the f/96 optical path) or by reducing the field format so that a given pixel can be sampled more frequently. In the [64 x 64] pixel format at full resolution, the 10% photometric accuracy limit is about 190 counts/pixel/second. One application of this higher data rate would be for the Time Resolution Imaging Mode (TRIM) to search for optical counterparts to radio pulsars or variable X-ray sources. This application would use exposure times much shorter than 100 seconds. All the necessary TRIM hardware is implemented and has been tested, while the software needed to make it available to the user may be added later, depending in part on the interest shown by astronomers in the capability.

Although each detector has a format of [1024 x 1024] pixels, the SDS can hold only 2^{18} (or 256K) 16-bit data words (the equivalent of an area of [512 x 512] pixels). The observer has several controls for using this storage capacity effectively:

1. The starting pixel can be specified with a least increment corresponding to 0.25 pixel both horizontally and vertically. Some telemetry monitoring, however, provides it with a least increment of 32 pixels.
2. The number of pixels per line can be specified to be 512, 256, 128, or 64.
3. The number of lines per frame can be specified to be 1024, 512, 256, 128, or 64.

4. The number of bits per word can be specified to be 16 or 8.
5. By using the "one-dimensional zoom" capability, the size of a pixel in the line-scan direction can be increased from 25 microns to 50 microns (giving a pixel size of 50 x 25 microns and a total line size of 512 pixels). The size in the frame-scan direction is fixed at 25 microns.

By FOC convention, however, not all the possible formats are expected to be employed. Instead, only the following six formats (all of which make use of the full SDS memory) are defined in FOC specifications:

1. Square ("full") scan, 512 pixels/line x 512 lines/frame (16 bits);
2. Square scan, 256 pixels x 256 lines (16 bits);
3. Square scan, 128 pixels x 128 lines (16 bits);
4. Square scan, 64 pixels x 64 lines (16 bits);
5. Rectangular scan, 256 pixels x 1024 lines (16 bits); and
6. Rectangular scan, 512 pixels x 1024 lines (8 bits).

In all cases, the full 256K 16-bit words (4×2^{20} bits) of active SDS memory are sent on the downlink. For formats 2, 3, and 4 (which do not completely fill the SDS), several versions (called "subimages") of the exposure are accumulated because the SDS stores data assuming a 512 x 512 scan format. The resulting subimages are not identical copies, but have statistical variations. If 8 bits/pixel are used, the data is interleaved in the memory, and hence has to be decommutated and rearranged to gain a normal image line representation. Note that 8-bit words are required for format 6 because of the memory capacity.

Although these six formats are the only ones included in the instrument specification, other formats can also be produced by the instrument. The camera, for example, will scan 64 pixels/line and 1024 lines/frame if so commanded. Pre-launch calibration information, however, is only expected to be obtained for a few "observation formats" (defined to be not only the number of pixels/line and lines/frame, but also the starting point for these samples). These include a centered [512 x 512] and a centered [256 pixels x 1024 lines]. Since, contrary to most other ST instruments, the FOC sensors

are not discrete elements, it is unlikely that subsets of a complete [1024 x 1024] set of calibration information could be successfully employed to process individual images obtained from portions of this overall field. One application of the FOC's capability to have various "observation formats" is for on-board target acquisition; for scientific observations, however, it has been speculated that 90% of them will use [512 x 512] centered; 98% of them will have a starting pixel that reflects the monitoring quantization of 32 pixels.

The CM includes structure, optics, mechanisms, electronics, and the On-Board Data Handling (OBDH) System. The OBDH is an assembly of components that interface with all subsystems of the FOC for operational control, monitoring, and gathering of science and engineering data. Included in the OBDH are the Remote Terminal Unit (RTU) and the Data Handling Interface and Control Unit (DICU) to provide data links between the SI C&DH and the CM/PDA, the FOC On-Board Computer (OBC) for interpretation of macro commands and generation of command sequences to control the FOC modes, and the SDS to process and store the image data gathered during an exposure. The DICU is the central part of the FOC OBDH, and can be operated in Direct Access (no data exchange between OBC and DICU is possible) or Normal Access (no direct data exchange between the RTU and the RIU via the DICU is possible). Other support electronics include the CM Power Conditioning Unit (PCU), the Thermal Control Electronics (TCE), and the Mechanism Drive Electronics (MDE). All CM electronics (except the OBC) are redundant. The backup to the OBC is the NSSC-1 SI C&DH on-board computer (with the DICU operated in Direct Access).

The PDA consists of two independent detector chains serving the two optical paths of the FOC. It converts the focal-plane image of the FOC into electrical signals for further processing. By FOC convention, references to "xxx1" are to the f/48 optical-path hardware and to "xxx2" are to the f/96 hardware. Switching between detectors can be done quickly, but thermal stabilization can take as long as 24 hours. To meet the image stability requirements, the internal surfaces of the load-carrying structure that enclose the FOC optical bench are actively thermally controlled with a stability of better than 0.5° C. Temperatures should not drift significantly during an exposure, nor should there be a temperature gradient inside the optical bench.

The PDA can be subdivided into a pair of Detector Head Units (DHU-1 for the f/48 path and DHU-2 for the f/96 path, each with an image "Intensifier Section" and a TV "Camera Section") and the following major electronic units:

1. A single Power Conditioning Unit (PCU) that provides all voltages required by the PDA and the Calibration Unit (CU). The CM also has a PCU.
2. Two Camera Electronic Units (CEUs) that provide the necessary drives and operating potentials to the camera tubes, as well as the current for the focus and alignment coils, deflection coil scan waveforms, and trimcoil.
3. Two Video Processing Units (VPUs) that contain most of the PDA electronics. Each VPU implements the externally commanded operational modes of the detectors, and has the PRU for centroiding of photon events and rejection of false events, a Histogram Test Unit, and electronics for interfacing with other FOC subsystems.
4. Two Intensifier Electrical High Tension (IEHT) boxes that provide nominal 12 KV and 36 KV for the DHU Intensifier Sections.
5. Two Camera Electrical High Tension (CEHT) boxes that provide a nominal -12 KV for the imaging part of the EBS camera tube in the DHU Camera Section.

There is no cross-strapping between the two redundant DHU chains at any intermediate point or at the PDA/CM interface.

The video signal from the TV camera preamplifier is received by the VPU analog processing block. This signal is a line-by-line scan of an image containing a number of photon events as well as noise and ion events. Some 10-25% of the photon events can be expected to be partially overlapping at the upper limit of the PDA intensity range, but for the vast majority of the time non-overlapping events will be received. It should be recognized that no picture content is contained in a single frame of the TV scan (all that is registered is a number of events randomly distributed in the frame). The picture information is only detected by counting the arrival rate of the photons at each pixel location, and this counting is done by the SDS.

As an event is scanned by several lines of the TV raster, an approximately gaussian-shaped pulse is produced in the video line. The pulse increases in both height (or amplitude) and width (or extent) on successive lines until the maximum is crossed, and then decreases again. The VPU analog processing block produces two signals: a Peak Signal and an Extent Signal. The Peak Signal is a digital transition that corresponds (within certain limits) to the instant of maximum amplitude of the video signal: this defines the location of the center of photons in the line scan direction. The hardware uses a zero-crossing detector: since these devices are sensitive to high frequency noise, an arming level circuit (set by a four-bit arming threshold command) is incorporated. This arming level voltage must be exceeded before a zero crossing (and hence the peak of an event) may be detected. The Extent Signal is a digital state that corresponds to the times for which the video signal amplitude exceeds a preset threshold: it is used to detect the end of an event (in the frame-scan direction) and also to define the horizontal extent of events. A four-bit extent threshold command is used to set the amplitude gate.

The VPU digital processing block operates on these Peak and Extent Signals in such a way that the two-dimensional digital patterns they represent are turned into a bit stream representing the centroids (centers in two dimensions) of valid photon events. Events from one to eight pixels in diameter can be detected in all single patterns and most two-event overlapping patterns. Within the range of events that can be detected, the accepted sizes are programmed into a Field Programmable Logic Array (FPLA). The Pattern Recognition Logic (PRL) analyses the event vertical and horizontal extents to distinguish the type of pattern present, which is then either accepted or rejected according to the photon acceptance criteria. A wide range of event sizes and overlapping conditions can be recognized and their centers determined. See SLIB 802 for the details of the mechanization.

The video signal processed by the PRU will be delayed with respect to the original camera signals due to several components (including cable and amplifiers). If no action were taken to correct for this "loop delay", the picture would be shifted to the right with the left edge being black and the

corresponding image lost from the right edge. To compensate for this, the logic is run several pixels behind the line scan. The delay can be adjusted on the ground in the range of 4-8 pixels, and a further adjustment of -1 to +2 pixels is provided by a two-bit loop delay command (giving a total control of from 3 to 10 pixels).

In addition to the normal pattern recognition mode for the PRU, the PDA has two other capabilities that are implemented in separate FPLAs. One is Zoom, in which the size of events is effectively halved in the horizontal direction. Selection of Zoom also impacts the CEU (gain switching in the deflection coil drive circuits). The other is Histogram, whose FPLA examines the horizontal and vertical event extent information to give a coded output that defines the event category present (if any). This gives a separate coded word for overlapping events whereas in the other two FPLAs events of the same size are classified the same regardless of the total size of the overlapping events in which they are contained. Switching between these modes imposes the only requirement for power switching within the VPU. The relay to be operated is selected by a memory load command and latched by application of an on/off command.

The PDA also has a Histogram Test Unit with a Histogram/Ratemeter capability. When this unit is running, no data is sent to the SDS; instead, the PDA's output is in the engineering telemetry (ET). For the Histogram option, the PDA counts the number of times a particular event category is observed (the output of the Histogram FPLA) in a specified time interval. This data together with a code for the event category is telemetered to ground, and the unit steps through all 48 event categories. The non-zero length of time over which the event count data is collected can be varied from 3-1023 PDA scan frames (each 30 msec), and the cycle through the event types is repetitive. By monitoring the count data over a number of cycles, a histogram can be built up. Analysis of the count histogram of event categories will enable the settings of various PDA parameters (such as high voltages, focus current, and thresholds) to be determined to achieve a sharp electrical focusing of the detector. There is not yet enough experience to establish how the PDA electrical parameters drift with time (currently, it is anticipated that they

will be verified at the beginning of major observation periods). For the Ratemeter option, one of 16 event types, each corresponding to a valid photon detection, can be selected, and counts collected over the specified time interval. Since insufficient power is available to operate the Histogram Test Unit at the same time as the main VPU, a change-over relay is used to minimize components.

The Calibration Unit contains seven Light Emitting Diodes (LEDs): two red, two yellow, two green, and one blue. The LED that is selected for operation can be set to 256 intensity levels (including the near-minimum default intensity). The light from the CU is sent to each DHU by using the mirrors mounted on the back of the CM shutters, both of which must be closed prior to use of the CU (the fact that both shutters are closed can be used to conclude that the image is a flat-field one). The CU is capable of illuminating simultaneously both calibration mirrors. It will be used to monitor the pixel-to-pixel variations of the FOC throughput, the intensity transfer function, and the spectral response. Absolute calibration of the FOC will be provided by periodic observations of standard star fields.

There is also a Radiation Monitoring Unit (RMU) associated with the CU: data from this device requires complex off-line long-term processing and must be routed to ESTEC for eventual analysis. It measures the total radiation flux received by its sensing element when in the exposure mode (as it is when the PDA-PCU is on). It is in the read mode when the CU is on. The CU electronics also houses two Quartz Crystal Monitors (QCMs) used for contamination monitoring. The choice of which one is energized is determined by a bit in the memory load command word.

The CM's SDS has the capacity to accept an image of [512 pixels x 512 lines] (16-bit word mode) or [512 pixels x 1024 lines] (8-bit mode) to be scanned and recorded at any one time. The cycle time of the data store accepts a camera scan rate of 10M pixels/second (this rate is maintained for all formats). The PDA generates an increment command for every pixel scanned in which a photon event has been detected. The increment commands of four sequential pixels are grouped together and transmitted in parallel. For

normal operation, it is expected that averaged over one line scan of 512 pixels there will be less than one incrementation per six pixels; averaged over one scan of a full frame of 256K (512 * 512) pixels there is expected to be less than one incrementation per ten pixels. Readout of 256K pixels occurs in less than 30 msec; of 4K (64 * 64) pixels in less than 520 usec.

There are two sets of SDS electronics (SDS-1 and SDS-2), with unit 1 dedicated to the f/48 optical path and unit 2 to the f/96 path. The SDS memory is physically divided into 22 modules of 16K 16-bit data words each (holding 32 words from each of 512 lines), but only 16 modules are active at any given time. These 16 modules are accessed in sequence to reduce the requirements on memory cycle time. Each SDS word has 22 bits, with the extra 6 bits being used for "single-bit" error correction and "two-bit" error detection. Included in the engineering telemetry are bits set for each logical module if an error of one of these types occurs (as well as a count of the unrecoverable errors). If more than 6 SDS memory modules fail, the memory can still be operated in a reduced data mode. In this case, zeros will appear in the downlink for those modules that are not available. Data loss occurs from the "right-hand" side, so if only 15 modules are up, would get for the [512 x 512] format words 0-479 for each of the 512 PDA lines.

The SDS can be operated in either the normal imaging mode or the SDS dump mode, so it is necessary to interrupt the pixel increment commands from the PDA to read out the SDS memory to the downlink. For long exposures, readouts will be taken about every 20-30 minutes (the concern previously expressed about magnetic effects requiring a readout every five minutes no longer is applicable). Each readout has a dump of the 256K 16-bit words of SDS memory, and hence contains $4M$ data bits ($M = 2^{20}$). Readout of science data is normally done under control of the NSSC-1, which controls the gating of signals to the Remote Interface Unit (RIU) of the SI C&DH (Control and Data Handling), including the Science Data Formatter (SDF). From the SDF, the data is fed to the downlink or the tape recorder. For target acquisition, however, the science data is dumped to the NSSC-1 (which uses the information in a [64 pixels x 60 lines] image to calculate the location of the "point"

with the maximum count number). On-board target acquisition data looks like other data, and is read in the [128 x 128] format. The NSSC-1 uses the middle 64 pixels of each 128 in PDA lines 32-91 (see SLIB 1062 for details).

The operation of the FOC is normally controlled by macro commands that are sent from the ground to the SSM and then to the Stored Command Processor of the NSSC-1. Decoding of the commands is done by the NSSC-1 and/or the FOC OBC. These macro commands include sets of parameters (see Section 3.1) to specify the detailed execution of a specific FOC task, and most have absolute time tags. With the aid of these macrocommands, the inflight software operates like table-controlled software. Onboard activities are performed strictly according to the scheduled time sequences, which must take the normal execution time of the associated task into consideration. The advantage of this concept is the clear relationship between the preplanned macrocommands from the ground and their execution onboard. The macro commands are spaced in time so that no interference between them is anticipated. User commands can also be sent directly to the FOC hardware, but these are not expected to be used except during initialization and in contingency situations.

By using the DICU capability, the FOC can be operated in either "Normal Access" or "Direct Access". Normal Access is defined as that access where the inflight software of the FOC OBC mainly controls the function of the FOC; Direct Access is defined as that access where the FOC OBC is switched off (possibly due to failure or power reasons) and the FOC-unique software running in the NSSC-1 exclusively controls the FOC. Thus the NSSC-1 provides redundancy in the event that the OBC fails (ROM errors or insufficient "good" RAM blocks). The FOC's onboard computer (OBC) has 2K 16-bit words of internal ROM (operating system and interrupt handler), 8K words of internal RAM, and 8K words of externally packaged ROM (for application processors). The OBC RAM is divided into eight 1K memory blocks that are relocatable: 6K is required for variables, tables, scratch pad, and science data storage, while 2K is spare. Each time the FOC is initialized, the operating system does a self-test of each 1K block, and only the good blocks are used. The

full 18K of OBC memory can be dumped via the science link, and four consecutive words can be selected for dumping as part of the engineering telemetry. A checksum of the ROM can be initiated by a macro command, and a bit is set in the engineering telemetry to reflect the results.

In Normal Access, the NSSC-1 is responsible for: thermal control, monitoring RIU data, engineering data transmission, power switching, computer access switching, interfacing with the OBC, FOC-Unique Data Log generation, science data handling, and target acquisition. In Direct Access, it also must assume responsibility for: exposure control, monitoring RTU data, mechanism setting, SDS mode selection, PDA mode selection, PDA electrical parameter assignment, calibration source setting, and SDS module selection.

The NSSC-1 has seven FOC processors (defined as software components handled by the task management function of the NSSC-1 system software). In order of decreasing (less urgent) priority, they are:

1. Special Engineering Data Snap Action that sends requests to the NSSC-1 system software to sample engineering data.
2. Engineering Data Processor RTU (XFPMEDT), responsible for the generation of the last 240 ET (out of 300) words, the FOC-Unique Data Log, servicing of dump requests, and handling the temperature flag logic for the high-voltage supplies (which should not be turned on unless their temperature is above -10°C). This is NSSC-1 processor #10.
3. Thermal Control Processor (XFPTCTR), activated every 15 seconds to calculate (based on ground-supplied parameters) the power to be dissipated by the heater mats in the OBE and EHT boxes. Four-bit output commands to 13 individual heaters are generated for the TCE. These commands are referred to as "D-Values", and set a voltage value from which (E/R) the corresponding power can be computed (see SLIB 792). There are two control ranges of the TCE (narrow and broad), with the broad range normally used only during non-operational flight modes (it is needed due to the long time constant of the optical bench). This is NSSC-1 processor #11.
4. Engineering Data Processor RIU (XFPMEDI), responsible for the generation of the first 60 (out of 300) ET words in the output stream. This is NSSC-1 processor #12.

5. FOC Internal Safing Processor (XFPMSAF), responsible for monitoring FOC temperatures to detect hazardous situations. This is NSSC-1 processor #13, which runs every 15 seconds. The safing sequence that is invoked is determined by the optical train in use.
6. Macro Command Processor (XFPHMAC), responsible for determining where a macro command should be executed and calling the appropriate routine. This is NSSC-1 processor #14.
7. Target Acquisition Processor (XFPQTAP), which determines the position of a target object and requests a slew of the ST. This is NSSC-1 processor #9.

See SLIB 1010 and SLIB 1062 for more details on the FOC NSSC-1 application processors.

2. FOC MODES OF OPERATION

There are three kinds of FOC "modes" that need to be distinguished:

1. Instrument Modes, where control by the FOC electronics causes differences in the measured data due to data gathering differences;
2. Science Data Modes, where settings of the optics or electronic parameters cause different effects; and
3. Ground Software Modes (differences in ground processing that can be a function of the Instrument Mode and/or Science Data Mode).

These modes are treated in separate sections below. Throughout this document, bit 1 is the most significant (or sign) and bit 8 or bit 16 is the least significant (for 8-bit words and 16-bit words respectively). The notation "XXXX" (XXX a set of three digits) means the LMSC engineering telemetry abbreviated measurement identifier (see Section 4), and "X.XXX" refers to telemetry that lacks an LMSC identifier. Tables 4.2-7 and 4.2-8 list all the FOC telemetry in sequence by the identifier value and by mnemonic, respectively.

Mnemonics quoted in this document are (if applicable) generally those in LMSC's SLIB 1089, as are the measurement identifiers. Mnemonics for telemetry having the "X.XXX" form of identifier also have their first two characters set to "XX", and were coined for referencing convenience purposes in this document (they are not official FOC notations). A number of the FOC quantities were given different measurement identifiers in SLIB 1035. Table 4.3-2 gives the FOC telemetry in the format of SLIB 1035, and Table 4.3-3 gives a cross-reference table relating LMSC (SLIB 1089) and FOC (SLIB 1035) identifiers. For consistency with the other SOGS Notebooks, however, LMSC identifiers are used elsewhere in this Notebook.

2.1 FOC INSTRUMENT MODES

In FOC documentation, the term "mode" is often used to refer to the power supply configuration (such as hold; low voltage; and high voltage operational, data collect, and data ready). Although this approach is appropriate from an operational viewpoint, these "modes" do not control the form of the

information provided on the science downlink. As discussed in Section 1.5, the data on the science downlink results from a dump of the 256K 16-bit words of the SDS memory: this dump is always made from the first word in the memory to the last word. The original storage of information in this memory can be specified by the observer using several parameters that are in both the Engineering Telemetry (ET) stream and in the FOC-Unique Data Log.

The quantities controlling the format of SDS data storage are:

- 1 Pixels/Line;
- 2 Lines/Frame; and
- 3 Bits/Pixel.

These are treated in separate sections below.

2.1.1 Pixels/Line Instrument Mode

There are four possibilities for the number of pixels (data storage elements of 16 or 8 bits) per line. Their coded values, and the associated true number, in the macro command (see Section 3.1.3) are:

- A value of 0 means 512 pixels/line;
- A value of 1 means 256 pixels/line;
- A value of 2 means 128 pixels/line; and
- A value of 3 means 64 pixels/line.

To obtain the value of this instrument mode, it is first necessary to establish which optical path (f/48 or f/96) is being used. There are several quantities that could be used for this purpose. For example, the measurement considered most satisfactory by the IDT (see SLIB T20) is the AC converter current, which is measurement XCONV1AC/X346 for f/48 and XCONV2AC/X347 for f/96. Using these currents, if the f/48 value is above a data base threshold, it can be concluded that the f/48 detector is being used, and the f/96 information can be ignored. If the f/48 measurement is below the threshold, but the f/96 measurement is above a different threshold, then it can be concluded that the f/96 detector is being used. If neither measurement is above the threshold, there is insufficient information to determine the optical path from these AC currents.

If the f/48 optical path is being used, the value of the pixels/line (coded as shown above) is in X48PXPLN/X544 (the result from the VPU); if the f/96 optical path is being used, the VPU value is in X96PXPLN/X628. The value from the NSSC-1 (the result of the echo of command ML VP-01 to the VPU) is in XCCVPPXL/X642 (likewise coded as shown above).

The command to the CEU is XCCCUPXL/X636, with a inverted significance: values of 0-3 are for 64, 128, 256, and 512 pixels/line respectively. The CEU value is also reflected in XCU1PPLN/X395 for the CEU-1 (f/48) path and XCU2PPLN/X468 for the CEU-2 (f/96) path. These CEU values are "analog step functions", having discrete values (in the approximate range of 0-255) depending on which of the four allowed values are being processed.

2.1.2 Lines/Frame Instrument Mode

There are five possibilities for the number of lines per frame, where the number of data storage elements in a line is defined in 2.1.1 and a "frame" is a complete scan of the EBS tube target area of interest. Their coded values, and the associated true number, are:

- A value of 0 means 512 lines/frame;
- A value of 1 means 256 lines/frame;
- A value of 2 means 128 lines/frame;
- A value of 3 means 64 lines/frame; and
- A value of 4 means 1024 lines/frame.

If the f/48 optical path is being used (see Section 2.1.1), the value of the VPU's lines/frame is in X48LNPFR/X542; if the f/96 path is being used, the value is in X96LNPFR/X626. The value from the NSSC-1 (the result of the echo of command ML VP-01 to the VPU) is also on the downlink (in XCCVPLNF/X640).

2.1.3 Bits/Pixel Instrument Mode

Contrary to the previous two FOC Instrument Mode specifications, the control of the Bits/Pixel Instrument Mode lies not with the PDA hardware but with the SDS itself. The two possible values are 16 bits/pixel (expected to be the one normally used) and 8 bits/pixel. Determination of the value from the

telemetry is a two-step process: it is first necessary to determine which set of Science Data Store electronics (SDS-1 or SDS-2) is energized, and then examine the appropriate bit in SDSn Address Register B:

1. One way (see SLIB T20) of determining which SDS electronics is energized is from the housekeeping voltages. For example, if the SDS-1 voltage (XSDS1VLT/X332) is above a data base threshold, the SDS-1 parameters can be used (and SDS-2 can be ignored); otherwise, if the SDS-2 voltage (XSDS2VLT/X333) is above a different data base threshold, the SDS-2 parameters can be used. Note that the SDS-1 electronics are associated with the f/48 optical path and the SDS-2 electronics with the f/96 optical path. If neither voltage is above its respective threshold, there is insufficient information to determine the active SDS electronics from these voltages.
2. If SDS-1 is controlling, use XSD1MODE/X100; if SDS-2 is controlling, use XSD2MODE/X180. The selected bit is 0 for 16 bits/pixel and 1 for 8 bits/pixel.

If the Pixels/Line Instrument Mode reflects a value of 512 pixels/line and the Lines/Frame Instrument Mode reflects 1024 lines/frame, then the Bits/ Pixel Instrument Mode should reflect 8 bits/pixel. If it does not, the complete image does not fit in the 256K words (512K bytes) of the SDS memory.

2.2 FOC SCIENCE DATA MODES

The FOC (in common with the WF/PC) fundamentally has a single science data mode: it acts as a photometric, area imager. By choice of the light-beam elements and SDS controls, however, three distinct photometric modes can be defined:

- 1 Direct Imaging;
- 2 Spectroscopy; and
- 3 Time Resolution Imaging.

These modes are treated in separate sections below.

2.2.1 Direct Imaging Science Data Mode

The Direct Imaging Science Data Mode can be used with the f/48 and f/96 optical paths. Both paths have the option of inserting filters (four wheels in the f/96 path, and two in the f/48 path) into the light beam. In addition, the f/96 path has the option (by suitable ST pointing) of using coronographic masks, as well as imaging at f/288 by using the HRA that is inserted in the path by the CAM (see Section 1.5).

2.2.2 Spectroscopy Science Data Mode

The Spectroscopy Science Data Mode can only be employed with the f/48 optical path. It typically would be used with the FOC Lines/Frame Instrument Mode specifying 1024 lines/frame (the frame direction is that of the spectrum dispersion). The Pixels/Line Instrument Mode typically is either 256 or 512, either with or without the one-dimensional zoom (see Section 1.5) provision. To enable this mode, the SMM is used to insert a relay mirror into the beam (see Section 1.5). Establishing the location of the SMM from the telemetry requires a two-step process: it is first necessary to determine which set of mechanism electronics (MDE-1 or MDE-2) is energized, and then examine the appropriate bit in MDEn TM word 3:

1. One way (see SLIB T20) of determining which set of MDE electronics is energized is from the housekeeping voltages. For example, if the MDE-1 voltage (XMDE1VLT/X330) is above a data base threshold (about 5 telemetry counts, where one count is 0.02 volts), then the MDE-1 electronics are being used, and the MDE-2 outputs can be ignored. Otherwise, if the MDE-2

voltage (XMDE2VLT/X331) is above a different data base threshold, the MDE-2 electronics are being used. If neither voltage is above its respective threshold, there is insufficient information to determine the active MDE electronics from these voltages.

2. If MDE-1 is on, XMDE1SMM/X528 can be used to determine the SMM position; if MDE-2 is on, XMDE2SMM/X612 can be used. Each of these measurements has two bits: a value of 10₂ means the SMM is out-of-beam (bit XXDE1SM0/X.320 or XXDE2SM0/X.420 = 1) and a value of 01₂ (bit XXDE1SM1/X.321 or XXDE2SM1/X.421 = 1) means it is in-beam. The bits could both be 0 (for one telemetry sample) while the mechanism is moving; if they both are 1, this is an error condition.

Since it only takes about 125 msec to move the SMM "flip-flop" mechanism, the telemetry sample of the "busy" bit (XM1TQRAC/X705 for MDE-1 and XM2TQRAC/X715 for MDE-2) probably will miss the brief setting of the bit (for normal operation).

2.2.3 Time Resolution Imaging Science Data Mode

The Time Resolution Imaging Science Data Mode (referred to by the acronym "TRIM") causes the SDS to be divided into 16 separate blocks of 16K (16-bit) words each. Successive photon events determined by the PDA only impact one of these blocks (rather than causing additional subimages to be formed as discussed in Section 3.3). The selected block is sequenced cyclically at a predetermined frequency to examine the behavior of a regularly variable astronomical object, and the period of the cycle is set to that of the observed object. TRIM operation is expected to be done only for FOC Pixels/Line and Lines/Frame Instrument Mode settings of [128 x 128] or [64 x 64] (for the latter case, would get 4 subimages), and in the 16-bit Bits/Pixel Instrument Mode. If SDS-1 is controlling (see Section 2.1.3), TRIM enable is specified by XSD1TRIM/X092 being 1; if SDS-2 is controlling, then it is specified by XSD2TRIM/X172 being 1. Changes from one block to the next are accomplished by externally loading the 4 most significant bits of the line address in SDS Address Register A (see Section 3.3.1). As discussed in Section 1.5, all the necessary hardware for TRIM is provided for the FOC and has been tested; the NSSC-1 software may be added at a later date.

2.3 FOC GROUND SOFTWARE MODES

There are two FOC Ground Software Modes:

- 1 Photometry; and
- 2 Spectrographic.

Their selection is based on user input to the ground system.

2.3.1 Photometry Ground Software Mode

For the Photometry Ground Software Mode, the FOC Science Data Mode must be Direct Imaging or Time Resolution Imaging (see Sections 2.2.1 and 2.2.3). If TRIM is used, the images from the individual SDS memory blocks must be processed individually. See Section 5 for references to the processing required.

2.3.2 Spectrographic Ground Software Mode

For the Spectrographic Ground Software Mode, the FOC Spectroscopy Science Data Mode must be active (see Section 2.2.2). See Section 6 for references to the processing required.

GOLDBERG

NASA Contractor Report 3374

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CONTRACT NAS8-32902
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National Aeronautics
and Space Administration

**Scientific and Technical
Information Branch**

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INTRODUCTION

We have calculated the probabilities for finding a suitable pair of Guide Stars (GS) in the Fine Guidance System (FGS) of the Space Telescope using the Weistropp north galactic pole star catalog (Weistropp 1972) and classical data on bright star counts (see especially Seares *et al.* 1925 and Bahcall and Soneira 1980). Many of the considerations and techniques discussed here are relevant for other space astronomy missions. The data are discussed fully in Appendix A of this report (which is a section of a paper by Bahcall and Soneira 1981 on the distribution of bright stars). The available observational data are rather limited but are in good agreement with each other. The definition of our task in this report is contained in Appendix B.

The most important conclusion from this report is that the acquisition probability for guide stars can be greatly increased if the FGS will allow the second member of a guide star pair to be appreciably fainter than the primary (bright) guide star.

a) GS Selection Requirements

The requirements for GS selection that we have used are:

1. Each FGS detector sees an area of sky $\Omega = 69.2$ square arcmin. The geometry for the 3 detectors is shown in figure 1 (which is taken from Groth 1978).
2. The sensitivity of the GS detector may be modeled as a constant between 4660 \AA to 7000 \AA , and zero outside this range. (This color sensitivity of the GS detector is similar

Not true

FINE GUIDANCE SYSTEM FOCAL PLANE ARRANGEMENT

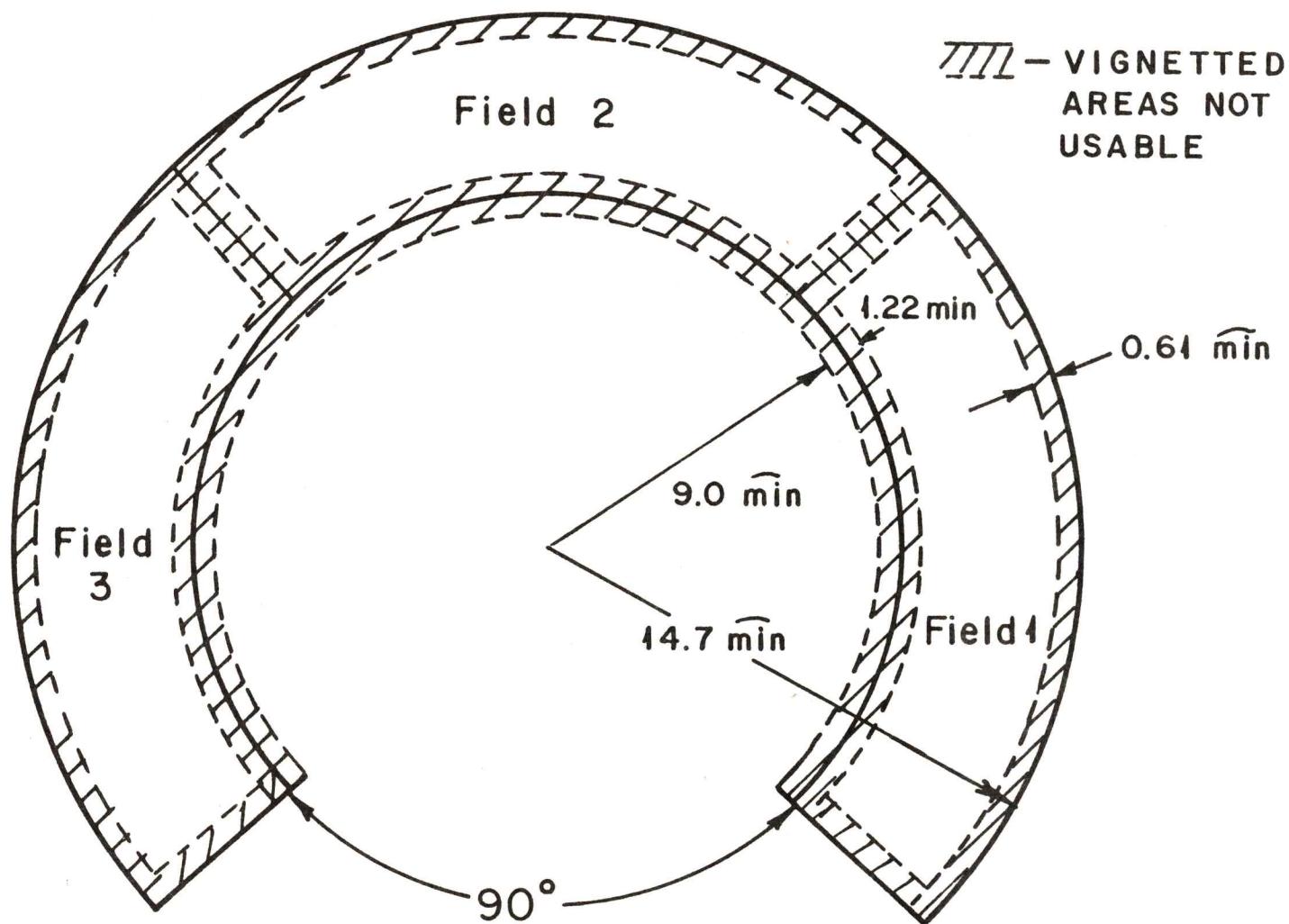


Fig. 1

to the Visual band, but has a factor of 2.7 greater energy throughput and 2.8 greater photon throughput for the color distribution of stars brighter than $V = 14.0$; see Bahcall and Soneira 1981, § III. For $V = 15$, the energy and photon throughputs are 2.7 and 2.9, respectively.)

3. The magnitude range from the primary and secondary guide stars ($i = 1, 2$) is $9 \leq m_V < m_i$, where $14 \leq m_1 \leq 15$ and $(m_2 - m_1)$ could in some designs be as large as 2 magnitudes.

4. Stars closer than $\theta_e = 1.0$ arcmin to a guide star must have a magnitude separation greater than $\Delta m = 0.5$ mag.

5. A pair of guide stars must be separated by at least $\theta_s = 13.5$ arcmin.

b) Analytic Calculation

An analytic statistical treatment of the selection criteria is useful for gaining an understanding of the GS probabilities. (Calculations using Monte Carlo methods are more accurate and, in some ways, more convenient.)

The probability $P = P(\ell, b, m)$ of finding at least one suitable GS pair in the direction (ℓ, b) with apparent magnitudes brighter than $m = m_1 = m_2$ is given to high accuracy by:

$$P(\ell, b, m) = P_1^3 + (2Q + 1)P_1^2(1 - P_1) , \quad (1)$$

with:

$$P_1 = \frac{1}{\beta} \left[1 - e^{-\beta} \mathcal{N}_\Omega \right] \quad (2)$$

$$\Omega = 1 - \sum_{i=1}^{\infty} \sum_{j=1}^{\infty} P_i P_j (1 - \Omega_1)^{ij} , \quad (3)$$

$$P_i = \frac{(\mathcal{N}_\Omega)^i}{i!} e^{-\mathcal{N}_\Omega} , \quad (4)$$

$$\beta = 1 + (10^{\alpha \Delta m} - 1) \frac{\Omega_e}{\Omega} , \text{ assuming} , \quad (5)$$

$$\mathcal{N} = C 10^{\alpha m} , \text{ } \alpha \text{ and } C \text{ constants} , \quad (6)$$

$$\mathcal{N}' = \mathcal{N} (1 - \gamma \mathcal{N}_\Omega) , \quad (7)$$

$$\gamma = \frac{1}{2} \left(10^{\alpha \Delta m} - 10^{-\alpha \Delta m} \right) \frac{\Omega_e}{\Omega} . \quad (8)$$

$\mathcal{N} = \mathcal{N}(\ell, b, m)$ is the number of stars per solid angle brighter than magnitude m satisfying requirement 3 above;

\mathcal{N}' is \mathcal{N} after the application of requirement 4;

Ω is the solid angle seen by one FGS detector, ($\Omega = 69.2$ square arcmin, requirement 1);

θ_e is the minimum angular distance of any star to a GS with a magnitude difference less than Δm ($\theta_e = 1.0$ arcmin, requirement 4);

$\Omega_e = \pi \theta_e^2$ is the area enclosed by θ_e ($\Omega_e = 3.1$ square arcmin);

Δm is the minimum magnitude difference allowed for a star closer than θ_e to a GS. ($\Delta m = 0.5$ mag, requirement 4);

θ_s is the minimum angular separation for a pair of GSS ($\theta_s = 13.5$ arcmin, requirement 5);

$Q_1 = Q_1(\theta_s)$ is the (ensemble average) probability that a single pair of GSs, each star having a randomly chosen position within its GS field, are separated by an angular distance $> \theta_s$.

Q_1 for adjacent detector fields is given by the following expression:

$$Q_1 = \frac{\int_{\Delta\theta}^{90^\circ - \Delta\theta} d\theta \int_{R_1}^{R_2} dr_2 \int_{R_1}^{R_2} r_1 r_2 f(\theta, r_1, r_2) dr_1}{\int_{\Delta\theta}^{90^\circ - \Delta\theta} d\theta \int_{R_1}^{R_2} dr_2 \int_{R_1}^{R_2} r_1 r_2 dr_1} , \quad (9)$$

$$f = \frac{180^\circ - \Delta\theta - \phi - \theta}{90^\circ - 2\Delta\theta} , \quad 0 \leq f \leq 1 , \quad (10)$$

$$\phi = \cos^{-1} \left[\frac{r_1^2 + r_2^2 - \theta_s^2}{2r_1 r_2} \right] , \quad (11)$$

where: $R_1 = 10.22$, $R_2 = 14.09$, $\Delta\theta = 2.873^\circ$. R_1 , R_2 and $\Delta\theta$ define the non-vignetted detector area. A numerical integration gives $Q_1 = 0.735$. For non-adjacent GS fields,

$$Q_1 = 1.0;$$

a is the logarithmic (base 10) slope of the star counts near m. ($\alpha \approx 0.32$ from the Weistroop data);

β is the correction factor expressing the probability that a GS is rejected due to proximity of another star less than θ_e and Δm away [$\beta = 1.020$];

P_1 is the probability of finding at least one GS in one FGS field satisfying requirement 4;

P_i is the Poisson probability distribution;

The above formulae are approximate for the following reasons:

1. They assume that stars are randomly distributed and therefore ignore star clustering. (Our results suggest that this assumption introduces a $\sim 1\%$ overestimate in P);
2. \mathcal{N} is assumed to be exactly an exponential. (This is also an excellent approximation introducing a negligible error);
3. Correction factors due to finite boundaries are ignored in the calculation of β and γ . (This is also an excellent approximation.)

Formulae (1) - (11) were used to calculate the probability of acquiring a GS pair in the memorandum in Appendix B, which describes our definition of the task.

From the Weistroop (1972, 1980) data, the surface density of stars with $9.0 \leq m_v < 14.0$ is 71.5 stars per square degree. The mean number of stars per detector is 1.37. Then $P_1 = 0.74$ and $Q \approx 0.954$ so that $P = 0.41 + 0.41 = 0.82$.

Note that although the single pair form factor, $Q_1 \approx 0.75$, the actual form factor $Q \approx 0.95$ because there are many possible combinations of GS pairs when there is more than one GS per field.

The $\theta_e / \Delta m$ constraint has only a minor effect on P . For $m_v = 14.0$ mag,

$$P \sim 0.84 \left[1 - 0.020 \left(\frac{\Delta m}{0.5} \right) \theta_e^2 \right] . \quad (12)$$

For $m_v > 14$, the influence of θ_e and Δm on P decreases monotonically with increasing m_v .

The above value for P is calculated for the Weistroop field centered at $\ell = 65.5^\circ$, $b = 85.5^\circ$ (SA 57). At $m_v = 14$ mag, the star density is expected to be at a minimum slightly away from the Galactic pole in the direction of the galactic anti-center $\ell = 180^\circ$, $b = 80^\circ$. (This is based on the galactic model of Bahcall and Soneira 1980; there is no direct data presently available to confirm this point.) The minimum is not expected to be at the pole because of the galactic spheroidal bulge contribution to the star counts. For $\ell = 180^\circ$, $b < 80^\circ$ the increasing star density from the disk overcomes the decrease from the spheroid. Figure 2 is an isodensity contour plot of the integrated star counts to $m_v = 14$ mag for $b \geq 20^\circ$ calculated from the Bahcall and Soneira model (assuming a Sandage obscuration model, see paper I). (For $m_v > 14$ the counts increase like $10^{0.32m}$, with only a slight dependence of the slope on latitude and longitude.) The model predicts that the integrated star density to $m_v = 14$ in the direction $\ell = 180^\circ$, $b = 80^\circ$ is $3\frac{1}{2}\%$ smaller than in the direction $\ell = 65.5^\circ$, $b = 85.5^\circ$. (For $m_v = 15$, the value is $4\frac{1}{2}\%$). This reduces the mean number of stars per detector to 1.32 and $P = 0.80$. Near $m_v = 14$, $P \approx 0.5(1+0.45n)$, where n is the mean number of stars per detector. This approximation is accurate to a few percent for n between 1.0 and 1.8 corresponding to the magnitude interval $13.65 \leq m \leq 14.35$.

c) Monte Carlo Calculation

The GS probabilities have also been calculated using a Monte Carlo simulation. The stars in each FGS field were dis-

$$\begin{aligned}
 m &= -2.5 \log B \\
 &\quad 0.32(-2.5 \log B) \\
 N &= 10 \\
 &\quad = B^{-0.8}
 \end{aligned}$$



Fig. 2

tributed randomly; the number of stars in each field was chosen from a Poisson distribution with a specified mean number of stars per field and magnitudes were assigned randomly according to a distribution function that results in a number-magnitude relation that increases as $10^{\alpha m}$. The stars were then processed through an algorithm that implements the GS selection requirements (section A, above). This procedure simulates an ST pointing. In order to accumulate good statistics on the distribution of GS pairs, the procedure was repeated several thousand times. The results of this method agree with the analytic calculation to within the statistical uncertainties. Because the results are almost identical to the analysis on the real Weistrop data, we defer discussion to the next section.

d) GS Selection with the Weistrop Data

The Weistrop survey area is ~ 700 times larger than the area of one FGS field and since there are 984 stars brighter than $m_v = 14$ in the catalog, there is a sufficient data base for accurately determining GS statistics empirically near the pole (assuming, of course, the Weistrop field is representative of the star density at its galactic latitude and longitude).

The only significant difference between the results for the Monte Carlo calculation (§ c) and the Weistrop data is the GS rejection due to the proximity of another star: for the random case at $V = 14^m$ it is 2% and, for the Weistrop data it is 3%. The larger rejection factor in the Weistrop data is due to star clustering. The Weistrop catalog presum-

ably identifies all stars that are separated by more than the seeing disk, $\lesssim 2$ arcsec (Weistroop 1980); hence only very compact binaries (which may be a problem for the FGS) are missed. (The anticorrelation length for the measured stellar positions is ~ 6 arcsec. The absolute positions of the stars are accurate to ~ 1 arcmin, Weistroop 1980.)

We present in Table 1, GS probabilities for the following combinations of (m_1, m_2) : (14,14), (14,14.5), (14,15), (14.5,14.5), (14.5, 15.0), (15.0, 15.0), and (13,15). For each of these pairs of magnitudes we list $n_i = \mathcal{N}_{(m_i)} \Omega$, the mean number of stars per detector, and several GS probability distributions: $P_1(n)$ and $P_2(n)$ are the probabilities for finding n primary or secondary stars per FGS detector before application of any selection constraints; $P_s(n)$ is the probability for finding n suitable secondary guide stars for a primary guide star; and $P_p(n)$ is the probability for finding n suitable guide star pairs per ST pointing.

For the "standard" case of $m_1 = m_2 = 14$, $P_p(>1)$; i.e., the probability of finding at least one suitable GS pair is 0.80, and $P_p(>2) = 0.55$. (This latter value is important for considering backup GS pairs if close binaries are a problem.) For (14,14.5), $P_p(>1) = 0.91$ and $P_p(>10) = 0.35$. Hence allowing the secondary GSs to be 1/2 mag dimmer than the primaries brings about a dramatic increase in the probability of acquiring a suitable GS pair. For (14,15), $P_p(>1) = 0.97$ and $P_p(>1) = 0.87$ for (13,15). Note that for $\mathcal{N}_2 \gg \mathcal{N}_1$ P_s follows closely the Poisson distribution for a mean density of $\frac{2}{3}(2\Omega_1 + 1)n_2$ and $P_p(>1) \sim 1 - e^{-3n_1}$

For $\mathcal{N}_2 \gg \mathcal{N}_1$, the number distribution of GS pairs, P_p , can be significantly reduced if any of the primary Guide Stars is a close binary system. The probability of finding n candidate primary GSs in the three FGS fields taken together is then the statistic of most practical interest because we are virtually guaranteed of finding a secondary GS for each candidate primary GS since $\mathcal{N}_2 \gg \mathcal{N}_1$. This statistic (a Poisson distribution for a mean density of $3n_1$) is presented in Table 2 for each of the limiting magnitudes considered in this paper.

As in section b), the "worst case" probabilities need to be corrected from the direction $\ell = 65.5^\circ$, $b = 85.5^\circ$ to the density minimum at $\ell = 180^\circ$, $b = 80^\circ$. For the "standard" case of $m_1 = m_2 = 14$, $P_p(\geq 1)$ is then 0.79.

Approximate estimates for the GS probabilities for directions other than the galactic pole can be obtained from figure 2 by matching the surface densities \mathcal{N} for a given direction (ℓ, b) as closely as possible to the entries in Table 1. For $\mathcal{N} \gtrsim 100$ stars per deg^2 , corresponding to $m_v \approx 14.5^{\text{mag}}$ at the galactic pole, the probability of acquiring a suitable pair of Guide Stars is $\gtrsim 95\%$, sufficiently high to be of little concern. Appropriate Guide Stars will nearly always be available ($P_p(\geq 1) \geq 0.95$) for all galactic latitudes and longitudes below $b \sim 40^\circ$ if $m_1 = m_2 \geq 14^{\text{m}}$ (see Figure 2 and Table 1).

e) Conclusion

The probability for acquiring a suitable pair of Guide Stars in the direction of minimum star density ($\ell = 180^\circ$,

$b = 80^\circ$) is estimated in this report to be 0.79 when both Guide Stars are required to be brighter than $m_v = 14^m$, somewhat less than the design specification of 0.85. (The acquisition probability will be further reduced if there are a significant number of close binaries with angular separation $\lesssim 2$ arcsec.) In order to meet the design specification with the same brightness limit for both the primary and secondary Guide Stars, one would require $m_1 = m_2 = 14.25$ Visual magnitudes.

If, however, the secondary Guide Star is allowed to be dimmer than the primary, then there can be a significant improvement in the acquisition probability. For $m_1 = 14.0^m$ and $m_2 = 14.5^m$, the Guide Star acquisition probability is 0.90. If we use the maximum allowed brightness difference between the primary and secondary Guide Stars, 2 magnitudes, then the primary star need only be brighter than 13th magnitude (Visual) in order to meet the design specification in the direction of the density minimum near the galactic pole.

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TABLE 1. Guide Star Probability Distributions *

$m_1 = 14.0$	$m_2 = 14.0$	$m_1 = 14.0$	$m_2 = 14.5$	$m_1 = 14.0$	$m_2 = 15.0$
$n_1 = 1.37$	$n_2 = 1.37$	$n_1 = 1.37$	$n_2 = 1.89$	$n_1 = 1.37$	$n_2 = 2.56$
$\mathcal{N}_1 = 71.5$	$\mathcal{N}_2 = 71.5$	$\mathcal{N}_1 = 71.5$	$\mathcal{N}_2 = 98.3$	$\mathcal{N}_1 = 71.5$	$\mathcal{N}_2 = 133$

n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p
0	0.254	0.254	0.113	0.195	0	0.254	0.151	0.052	0.086	0	0.254	0.077	0.018	0.032
1	0.348	0.348	0.236	0.115	1	0.348	0.286	0.137	0.057	1	0.348	0.198	0.067	0.026
2	0.238	0.238	0.262	0.139	2	0.238	0.270	0.212	0.081	2	0.238	0.253	0.134	0.047
3	0.109	0.109	0.196	0.090	3	0.109	0.170	0.211	0.073	3	0.109	0.216	0.181	0.046
4	0.037	0.037	0.111	0.092	4	0.037	0.080	0.173	0.079	4	0.037	0.138	0.181	0.054
5	0.010	0.010	0.052	0.057	5	0.010	0.030	0.110	0.060	5	0.010	0.071	0.159	0.046
6	0.002	0.002	0.020	0.062	6	0.002	0.010	0.058	0.065	6	0.002	0.030	0.111	0.044
7		0.007	0.043		7		0.003	0.029	0.047	7		0.011	0.073	0.048
8		0.002	0.039		8		0.001	0.011	0.057	8		0.004	0.040	0.053
9		0.001	0.029		9			0.004	0.050	9		0.001	0.021	0.047
10		0.027			10			0.001	0.041	10			0.009	0.044
11		0.018			11			0.001	0.035	11			0.004	0.035
12		0.018			12				0.040	12			0.002	0.040
13		0.013			13				0.032	13			0.001	0.039
14		0.012			14				0.026	14				0.034
15		0.011			15				0.018	15				0.029
16		0.007			16				0.020	16				0.035
17		0.006			17				0.015	17				0.027
18		0.006			18				0.015	18				0.028
≥ 19		0.023			≥ 19				0.105	≥ 19				0.247

* See page 10 for definitions.

TABLE 1. Guide Star Probability Distributions* (Continued)

$m_1 = 14.5$		$m_2 = 14.5$		$m_1 = 14.5$		$m_2 = 15.0$		$m_1 = 15.0$		$m_2 = 15.0$				
n_1	\mathcal{N}_1	n_2	\mathcal{N}_2	n_1	\mathcal{N}_1	n_2	\mathcal{N}_2	n_1	\mathcal{N}_1	n_2	\mathcal{N}_2			
0	98.3	0	98.3	0	98.3	0	133	0	133	0	133			
n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p
0	0.151	0.151	0.051	0.080	0	0.151	0.077	0.019	0.026	0	0.077	0.077	0.017	0.023
1	0.286	0.286	0.137	0.052	1	0.286	0.198	0.077	0.018	1	0.198	0.198	0.067	0.014
2	0.270	0.270	0.207	0.073	2	0.270	0.253	0.144	0.041	2	0.253	0.253	0.132	0.033
3	0.170	0.170	0.210	0.071	3	0.170	0.216	0.183	0.039	3	0.216	0.216	0.177	0.031
4	0.080	0.080	0.174	0.073	4	0.080	0.138	0.175	0.052	4	0.138	0.138	0.183	0.041
5	0.030	0.030	0.113	0.052	5	0.030	0.071	0.149	0.036	5	0.071	0.071	0.161	0.033
6	0.010	0.010	0.061	0.064	6	0.010	0.030	0.108	0.054	6	0.030	0.030	0.114	0.042
7	0.003	0.003	0.030	0.046	7	0.003	0.011	0.070	0.040	7	0.011	0.011	0.075	0.038
8	0.001	0.001	0.012	0.058	8	0.001	0.004	0.040	0.052	8	0.004	0.004	0.041	0.045
9			0.004	0.046	9		0.001	0.020	0.046	9	0.001	0.001	0.019	0.033
10			0.002	0.046	10			0.009	0.048	10			0.009	0.042
11			0.001	0.032	11			0.004	0.041	11			0.004	0.033
12				0.042	12			0.002	0.042	12			0.002	0.041
13				0.032	13				0.032	13			0.001	0.030
14				0.029	14				0.035	14			0.038	
15				0.025	15				0.035	15			0.034	
16				0.023	16				0.026	16			0.029	
17				0.016	17				0.029	17			0.034	
18				0.017	18				0.025	18			0.027	
≥ 19				0.125	≥ 19				0.286	≥ 19			0.360	

* See page 10 for definitions.

TABLE 1. Guide Star Probability Distributions* (Concluded)

$$\begin{array}{ll}
 m_1 = 13 & m_2 = 15 \\
 n_1 = 0.684 & n_2 = 2.56 \\
 \mathcal{N}_1 = 35.6 & \mathcal{N}_2 = 133
 \end{array}$$

n	p_1	p_2	p_s	p_p
0	0.505	0.077	0.019	0.131
1	0.345	0.198	0.065	0.046
2	0.118	0.253	0.140	0.076
3	0.027	0.216	0.187	0.078
4	0.005	0.138	0.181	0.086
5	0.001	0.071	0.154	0.059
6		0.030	0.110	0.062
7		0.011	0.071	0.055
8		0.004	0.039	0.051
9		0.001	0.020	0.050
10			0.010	0.039
11			0.003	0.036
12			0.001	0.036
13			0.001	0.025
14				0.024
15				0.021
16				0.024
17				0.015
18				0.013
≥ 19				0.077

* See page 10 for definitions.

TABLE 2. Number Distribution of Primary Guide Stars For All Three Detectors.

n	$m_o = 13.0$ $n_1 = 0.684$	$m_o = 13.5$ $n_1 = 0.980$	$m_o = 14.0$ $n_1 = 1.37$	$m_o = 14.5$ $n_1 = 1.89$	$m_o = 15.0$ $n_1 = 2.56$
0	0.128	0.053	0.016	0.003	0.000
1	0.264	0.155	0.067	0.020	0.004
2	0.270	0.228	0.139	0.055	0.014
3	0.185	0.224	0.190	0.105	0.035
4	0.095	0.165	0.195	0.148	0.067
5	0.039	0.097	0.160	0.168	0.103
6	0.013	0.047	0.110	0.159	0.132
7	0.004	0.020	0.064	0.129	0.144
8	0.001	0.007	0.033	0.091	0.139
9		0.002	0.015	0.058	0.118
10		0.001	0.006	0.033	0.091
11			0.002	0.017	0.063
12			0.001	0.008	0.041
13				0.003	0.024
14				0.001	0.013
15				0.001	0.007
16					0.003
17					0.001
18					0.001
≥ 19					

APPENDIX A

II. BRIGHT-STAR DENSITY

A. The Best Available Data

The principal source of data that we used for the bright ($\lesssim 16^{\text{mag}}$) star densities in paper I was Seares et al. (1925), who list star counts in the direction of the north Galactic pole for magnitudes in the range $4 \leq m_v \leq 18$. The original data from some of the star catalogs used by Seares et al. had large systematic errors (up to 2 magnitudes) that Seares and his collaborators tried to remove. However, a scale error in the "corrected" magnitudes was discovered by Stebbins, Whitford and Johnson (1950). The corrections of Stebbins et al. were applied in paper I, but it was conceivable that some systematic errors remained.

Modern counts of bright star densities have been rare. In paper I, the brightest recent star counts considered were those of Brown (1979). Brown measured integrated star counts in several fields near the north Galactic pole in the magnitude range $17 \leq m_v \leq 20.5$. (The counts of Tyson and Jarvis (1979) extend to 13^{th} magnitude; however, stellar images brighter than 17^{th} magnitude were saturated and hence required an indirect magnitude measurement.)

In this paper we consider additionally star counts from 9^{th} to 16^{th} magnitude obtained from the data of Weistropp (1972, 1980) that was kindly made available to us in the form of

the original computer tape and printout. The Weistroop catalog comes from a field of area 13.5 square degrees, centered on SA57 in the direction of the north Galactic pole. There are 2989 stars in her catalog brighter than $V = 16$ (244 brighter than $V = 12$). The catalog extends to $V = 20$, but magnitude uncertainties appear to increase significantly dimward of 16th magnitude (Faber et al. 1976; Weistroop 1980; King 1980).

According to Weistroop (1980), the magnitude errors for $V \leq 16$ are $\pm 0.12^m$ (one standard deviation). A comparison by Faber et al. 1976 of the Weistroop photographic magnitudes, V_W , to photoelectric magnitudes, V_{PE} , for 23 stars with $V \leq 16$ gives $\langle V_W - V_{PE} \rangle = -0.02 \pm 0.09$. (Systematic errors resulting from minor differences between the photographic and photoelectric pass bands are of concern here only when estimating B-V colors, see below.) King (1980) has compared his own photographic photometry to that of Weistroop. His results for 16 stars with $V \leq 16$ is $\langle V_W - V_K \rangle = +0.01 \pm 0.09$. These estimates all yield a magnitude uncertainty $\sim \pm 0.1^m$. The zero point and magnitude scale appear to be well established for $V \leq 16$.

Figure 1 displays a compilation of all the available differential star densities (number of stars per magnitude per square degree) in the direction of the north Galactic pole (see paper I). The solid curve is the density predicted by our standard Galaxy model of paper I, including a separate contribution from giants (see below). In Table 1 we list the total integrated star counts (stars brighter than the

specified magnitudes limit) for the Weistrop data, the Seares et al. data as reduced to the Visual band in paper I, the calculated densities from our standard Galaxy model (see below), and the densities tabulated in Allen (1973).

B. Allen's Recommended Densities

The star densities listed in Allen (1963, 1973) are typically more than 40% larger than the densities listed above and in paper I for $m \geq 13$. Allen's results have been used as the basis for considering the performance of the Guide Star System for the Space Telescope (see, e.g., Groth 1978). Because of the importance of the Guide Star System for the entire Space Telescope Observatory, it is necessary to examine the origin of the discrepancies between Allen's numbers and the other results given in Table 1. (Allen 1973 notes that his star densities are 25% larger than the Landolt-Börnstein Tables [Scheffler and Elsässer 1965], his reference number 6, although the same sources were used.) The sources listed by Allen are Seares et al. (1925), Seares and Joyner (1928), and van Rhijn (1929). The Seares and Joyner paper examines star counts for $b \leq 70^\circ$, and thus is not relevant for the present discussion. The van Rhijn paper combines star count data of Seares et al. and the Harvard-Durchusterung survey.

A comparison of the Seares et al. and van Rhijn counts in the international photographic band with corresponding counts listed in Allen (1973), shows that Allen must have re-reduced the data introducing small changes, ~10%, (generally) upward in the bright star densities.

Counts in the Visual band are desired for many purposes.

In order to transform the photographic band counts into the Visual band, Bahcall and Soneira (1980) used the color equation in Seares et al. Allen used the following (incorrect) conversion from m_{pg} to m_v :

$$\mathcal{N}_{(\leq m_v)} = \mathcal{N}_{(\leq m_{pg})} \times \left(\frac{\text{total number of stars brighter than } m_v \text{ from } b=0^\circ \text{ to } 90^\circ}{\text{corresponding number for } m_{pg}} \right) \quad (1)$$

This conversion is more incorrect at higher galactic latitudes, since most of the bright stars are counted near the plane of the disk and stellar type (i.e., color) changes systematically with Galactic latitude.

The net discrepancy is unexpectedly large ($>40\%$) between, on the one hand, either the modern star counts in V (Weistropp 1972, 1980) or the older Seares et al. (1925) data as reduced in paper I, and, on the other hand, the star densities tabulated by Allen (1973). In order to illustrate where in the analysis of Allen the errors appear to have originated, we divide the transformation into several steps. For specificity, we consider the star density in the Visual band at 14th magnitude for which Allen cites 102 stars deg⁻². Part of the error appears to result from the different manner in which Allen combined each of the three (tabulated) quantities needed in equation 2 from his two sources. If we apply Allen's transformation (equation 1) to just the Seares et al. data alone, we obtain 94 stars deg⁻². (Van Rhijn tabulates only 2 of the 3 quantities, so it is not possible to perform the Allen transformation solely with van Rhijn's data.) If the band transformation is calculated

using the correct color equation described in Seares et al., the density further decreases to 82 stars deg^{-2} . Finally, if the magnitude corrections of Stebbins, Whitford, and Johnson (1950) are applied to the Seares et al. data (as in paper I), we obtain 71 stars deg^{-2} brighter than 14th Visual magnitude in the direction of the north Galactic pole. Weistroop counted 73.5 stars deg^{-2} ; the Bahcall-Soneira Galaxy model predicts 70.4 stars deg^{-2} brighter than $V = 14$. Hence, it appears that Allen's result can be accounted for by 3 systematic errors, each of order 10%, that add "fortuitously" in the same direction.

C. Theoretical Model

In calculating the star counts for the bright apparent magnitudes considered here using the Bahcall-Soneira Galaxy model, it is necessary to separate the contribution of the stars on the giant branch from the more common main sequence stars which completely dominate the counts at faint magnitudes (see § IIa of paper I for a detailed discussion of this point). The giants were not included separately in paper I.

The differential star counts for the giants peak at 11th mag, where they contribute about 20% to the total counts; by 13th mag their contribution has fallen to 3%. We take the fraction of stars, f , on the main sequence in the plane of the disk to be

$$f = \begin{cases} 0.44 \times \exp \left[0.00015(M+8)^{3.5} \right], & M < 3.7 \\ 1, & M \geq 3.7 \end{cases}, \quad (2)$$

which accurately fits the data of Sandage (1957), Schmidt (1959) and McCuskey (1966). A scale height of 250 pc is adopted for the giants (see paper I).

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TABLE 1. TOTAL INTEGRATED STAR DENSITIES

V	PER SQUARE DEGREE							
	9	10	11	12	13	14	15	16
Weistrop	1.9	3.7	7.6	18	37	74	135	224
Seares <u>et al.</u> ^a	1.2	3.3	8.0	18	36	71	134	216
Bahcall-Soneira Model	1.5	3.5	7.7	16	34	70	138	254
Allen	1.4	3.6	9.1	21	49	102	186	347

^a Reduced to the Visual band in paper I.

FIGURE CAPTIONS

FIGURE 1: Differential star densities \mathcal{A} per magnitude per square degree for the Galactic pole. The solid curve is the density predicted by the standard Galaxy model of paper I assuming no obscuration at the pole and including a separate contribution from giants (see § II c). Data from Seares et al. (1925) as reduced to the Visual-band in paper I are plotted as filled-circles, data from Weistroop (1972, 1980) are plotted as filled-triangles, data from Brown (1979) corrected to the pole (see paper I) are plotted as filled-squares, data from Kron (1978) are plotted as open triangles, data from Tyson and Jarvis (1979) are plotted as open circles, and data from Peterson et al. (1979) as open squares. For conversions between magnitude systems, see paper I (and § III).

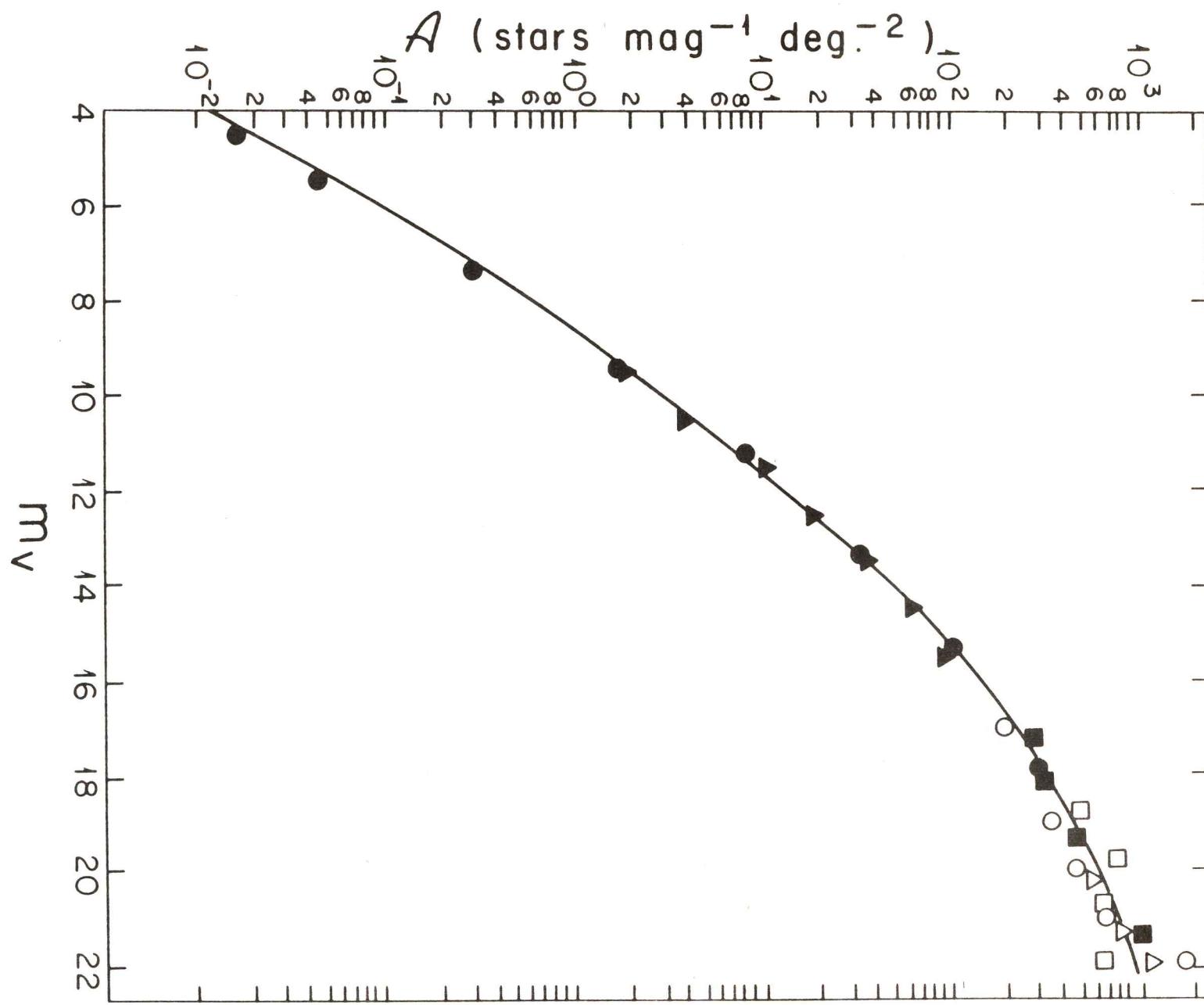


Fig. 1

APPENDIX B

THE INSTITUTE FOR ADVANCED STUDY

PRINCETON, NEW JERSEY 08540

Telephone-609-924-4400

SCHOOL OF NATURAL SCIENCES

February 13, 1980

MEMORANDUM

To: C. R. O'Dell and W. Jeffreys
From: John N. Bahcall and Raymond Soneira
Subject: Guide-star probabilities.

We are undertaking to supply more accurate estimates for the probabilities of finding guide stars in the FGS. The purpose of this preliminary note is to inform you of the scope of our activity and to present some general numbers. We also wish to indicate our summary of the problem so that you can correct any misunderstandings we may have before we complete a lot of numerical work.

Definition of the Problem

1. Each FGS detector has an area of 69.2 arcmin squared.
2. The magnitude limit is presently specified as $9 \leq m_v \leq X$ where X is in the range 14 to 14.5. (The lower limit, $m_v = 9$, will not be important numerically for our purposes.)
3. The separation of the two required guide stars must exceed 13.5 arcmin.
4. For nearby stars within 1 arcmin of a guide star, the separation in magnitude must be at least 0.5^m . For a guide star of magnitude X , the exclusion applies to magnitude $X \pm 0.5^m$.
5. The sensitivity of the detector may be modeled as constant between 4660 \AA to 7000 \AA , and zero outside this range. The detector really requires a fixed number of photons per square centimeter per second in this band.

Scope of Our Activity

- A. Probabilities. We will calculate probabilities for a convenient grid in latitude and longitude of finding two guide stars in the FGS within the limiting magnitude range of 2 (above) for $X = 14.0$ to 14.5 , in steps of 0.1. For these calculations, we shall use the model star densities in our Paper I¹. We will calculate the corrections to these proba-

C. R. O'Dell & W. Jeffreys -2-

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bilities due to constraints (3) and (4) above. We will make similar calculations for m_v^B .

B. Color Correction. The detector sensitivity is not that of any standard astronomical band. Stars of the same visual magnitude will have different photon fluxes in this band. We will normalize our results to an A0 V star, assuming it has the limiting visual magnitude X of constraint 2 above. Then we will reevaluate the photon fluxes for all stars close to magnitude X using their known intrinsic spectra and our estimate of the relative probabilities of stars of different types from Paper I. This will lead to revised color-corrected estimates of the probabilities of finding guide stars in the FGS.

C. Star Clumping. The bright star N-point correlation function is not known, but it may not be accurate to assume, as in all previous calculations we have seen, that bright stars are Poisson distributed on the sky. We will measure the departures from a Poisson distribution using the star data for 13.5 square degrees near SA57 by Dr. D. Weistroop². We will correct all the above probabilities for the effect of star clumping, if appreciable.

Initial Results

We have completed an initial set of calculations for part A above. We find the following.

- a. The minimum star density is slightly displaced from the pole. It actually occurs at $\ell = 180^\circ$, $b = 80^\circ$.
- b. At the minimum, we find from Paper I:

$$N(m_v \leq 14.0) = 65 \text{ per square degree.}$$

Subsequent to the writing of Paper I, we have verified our overall normalization (originally based on Seares *et al.*³ and recalibrated in 1950 using photoelectric standards by Stebbins *et al.*⁴) for the star densities by independent comparisons with data of D. Weistroop and I. King⁵ for SA57 (latitude 86°). Our results agree with theirs to an accuracy of about 10 percent in the range $m_v = 14$ to 15.

c. The probabilities given in the DRM and by Ed Groth in his recent report are based on Allen's Astrophysical Quantities⁶. Allen uses an ad hoc and incorrect conversion from m_{pg} to m_v , i.e.,

$$N(m_v) = N(m_{pg}) \left(\frac{\text{total number of stars brighter than } m_v \text{ from } b=0^\circ \text{ to } 90^\circ}{\text{corresponding number for } m_{pg}} \right).$$

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of interest) since most of the bright stars are counted near the plane of the disk and stellar type (i.e., color) changes systematically with Galactic latitude. Comparable errors, fortuitously all in the same direction, arise from a magnitude error (uncorrected for by Allen) in the Seares et al. counts and by Allen's curious reanalysis of the primary star count data. At the pole, Allen gives

$$N(m_v) = 102 \text{ per degree squared},$$

or a factor of 1.6 more than our estimate of 66.5 at the pole.

d. Two other numbers of interest (at the minimum) are:

$$N_v(m_v \leq 14.5) = 93.5 \text{ per square degree and}$$

$$N_v(m_v \leq 15.0) = 132 \text{ per square degree.}$$

e. Criterion 3 above reduces the probability of finding Guide stars by about four percent in adjacent detectors (zero otherwise) and criterion 4 makes a further reduction of about two percent near the poles (3 percent at lower latitudes). The net reduction of the overall probability near the Galactic poles from these criteria is about three percent.

f. The probability of successful Guide star acquisition at the pole is (ignoring color corrections, star clumping and close binaries),

$$0.75 \text{ at } m_v = 14.0$$

$$0.90 \text{ at } m_v = 14.5$$

$$0.95 \text{ at } m_v = 15.0.$$

g. At $\ell = 0^\circ$, $b = 20^\circ$, $m_v = 14.0$, the corresponding probability is 0.995.

¹ Bahcall, J.N., and Soneira, R.M. 1980, "The Universe at Faint Magnitudes: I. Models for the Galaxy and the Predicted Star Counts," Ap.J. (Supplement), in press. (Paper I).

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The probability of acquiring suitable guide stars is greatly increased if the FGS can allow an appreciable difference between the (bright) primary GS limiting magnitude and the (fainter) secondary GS limiting magnitude.			
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Preliminary Report to the Space Telescope Working Group:

May 5 - 6, 1980

GUIDE STAR PROBABILITIES

by

Raymond M. Soneira and John N. Bahcall
Institute for Advanced Study, Princeton, N.J. 08540

ABSTRACT

Probabilities are calculated for acquiring suitable Guide Stars (GS) with the Fine Guidance System (FGS) of the Space Telescope. The constraints of the FGS are reviewed. The available data on bright star densities are summarized and a previous error in the literature is corrected. Separate analytic and Monte Carlo calculations of the probabilities are described. A simulation of Space Telescope pointing is carried out using the Weistroop catalog of bright stars. Sufficient information is presented so that the probabilities of acquisition can be estimated as a function of position in the sky. The importance is emphasized of having an appreciable difference between the (bright) primary GS limiting magnitude and the (fainter) secondary GS limiting magnitude.

INTRODUCTION

We have calculated the probabilities for finding a suitable pair of Guide Stars (GS) in the Fine Guidance System (FGS) of the Space Telescope using the Weistroop north galactic pole star catalog (Weistroop 1972) and classical data on bright star counts (see especially Seares et al. 1925 and Bahcall and Soneira 1980). The data are discussed fully in Appendix A of this report (which is a preliminary draft of a section of a paper by Bahcall and Soneira 1981 on the distribution of bright stars). The available observational data are rather limited but are in good agreement with each other.

a) GS Selection Requirements

The requirements for GS selection that we have used are:

1. Each FGS detector sees an area of sky $\Omega = 69.2$ square arcmin. The geometry for the 3 detectors is shown in figure 1 (which is taken from Groth 1978).
2. The sensitivity of the GS detector may be modeled as a constant between 4660 \AA to 7000 \AA , and zero outside this range. (This color sensitivity of the GS detector is similar to the Visual band, but has a factor of 2.7 greater throughput for the color distribution of stars brighter than $V = 14.0$.)
3. The magnitude range from the primary and secondary guide stars ($i = 1,2$) is $9 \leq m_V < m_i$, where $14 \leq m_1 \leq 15$ and $(m_2 - m_1)$ could in some designs be as large as 2 magnitudes.
4. Stars closer than $\theta_e = 1.0$ arcmin to a guide star must have a magnitude separation greater than $\Delta m = 0.5$ mag.

FINE GUIDANCE SYSTEM FOCAL PLANE ARRANGEMENT

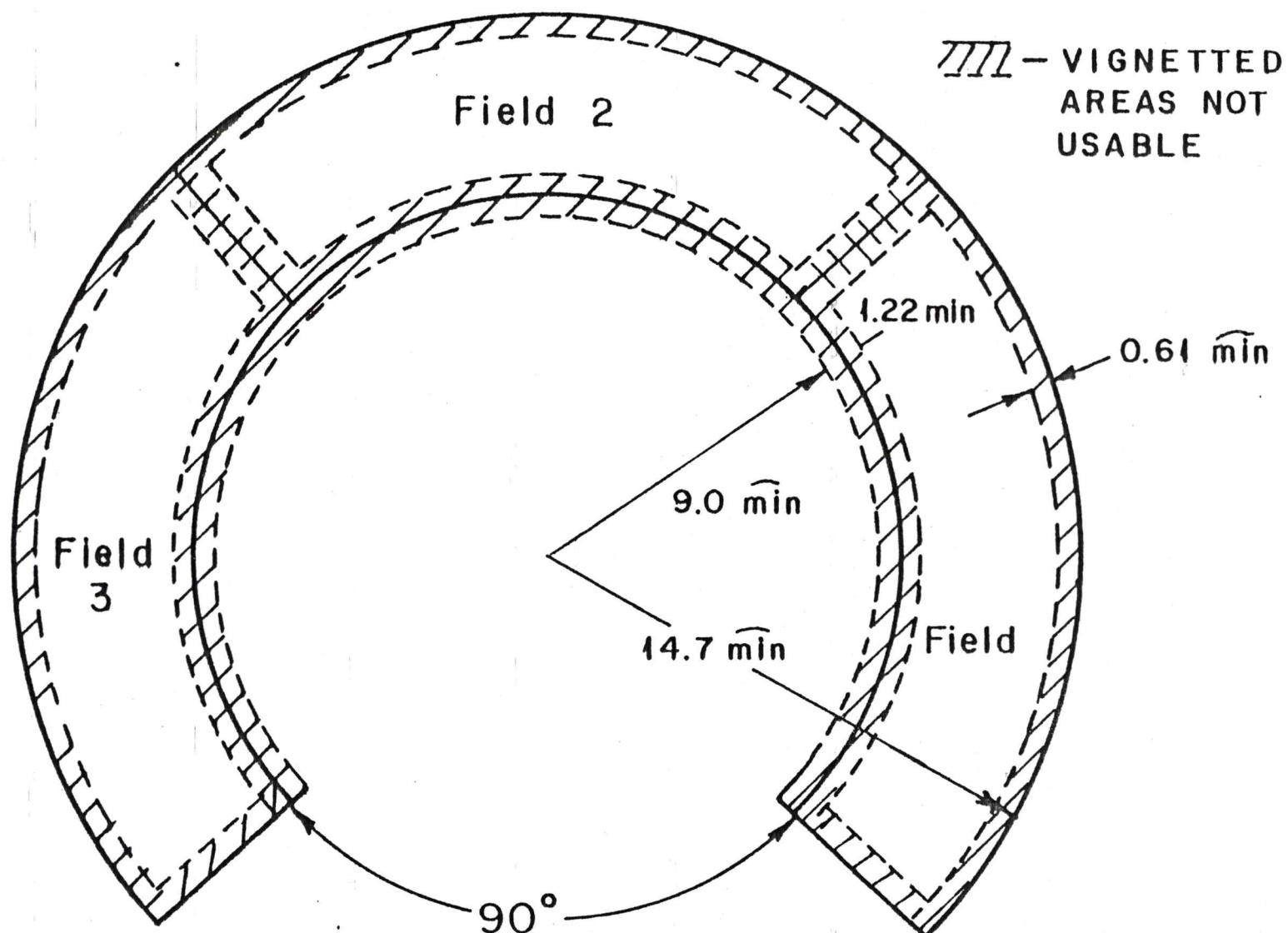


Fig. 1

5. A pair of guide stars must be separated by at least $\theta_s = 13.5$ arcmin.

b) Analytic Calculation

An analytic statistical treatment of the selection criteria is useful for gaining an understanding of the GS probabilities. (Calculations using Monte Carlo methods are more accurate and, in some ways, more convenient.)

The probability $P = P(\ell, b, m)$ of finding at least one suitable GS pair in the direction (ℓ, b) with apparent magnitudes brighter than $m = m_1 = m_2$ is given to high accuracy by:

$$P(\ell, b, m) = P_1^3 + (2Q + 1)P_1^2(1 - P_1) , \quad (1)$$

with:

$$P_1 = \frac{1}{\beta} \left[1 - e^{-\beta} \mathcal{N}_\Omega \right] , \quad (2)$$

$$Q = 1 - \sum_{i=1}^{\infty} \sum_{j=1}^{\infty} P_i P_j (1 - Q_1)^{ij} , \quad (3)$$

$$P_i = \frac{(\mathcal{N}_\Omega)^i}{i!} e^{-\mathcal{N}_\Omega} , \quad (4)$$

$$\beta = 1 + (10^{\alpha \Delta m} - 1) \frac{\Omega e}{\Omega} , \text{ assuming} , \quad (5)$$

$$\mathcal{N} = C 10^{\alpha m} , \alpha \text{ and } C \text{ constants} , \quad (6)$$

$$\mathcal{N}' = \mathcal{N} (1 - \gamma \mathcal{N}_\Omega) , \quad (7)$$

$$\gamma = \frac{1}{2} \left(10^{\alpha \Delta m} - 10^{-\alpha \Delta m} \right) \frac{\Omega_e}{\Omega} \quad . \quad (8)$$

$\mathcal{N} = \mathcal{N}(\ell, b, m)$ is the number of stars per solid angle brighter

than magnitude m satisfying requirement 3 above;

\mathcal{N}' is \mathcal{N} after the application of requirement 4;

Ω is the solid angle seen by one FGS detector, ($\Omega = 69.2$ square arcmin, requirement 1);

θ_e is the minimum angular distance of any star to a GS with a magnitude difference less than Δm ($\theta_e = 1.0$ arcmin, requirement 4);

$\Omega_e = \pi \theta_e^2$ is the area enclosed by θ_e ($\Omega_e = 3.1$ square arcmin);

Δm is the minimum magnitude difference allowed for a star closer than θ_e to a GS. ($\Delta m = 0.5$ mag, requirement 4);

θ_s is the minimum angular separation for a pair of GSs ($\theta_s = 13.5$ arcmin, requirement 5);

$Q_1 = Q_1(\theta_s)$ is the (ensemble average) probability that a single pair of GSs, each star having a randomly chosen position within its GS field, are separated by an angular distance $> \theta_s$.

Q_1 for adjacent detector fields is given by the following expression:

$$Q_1 = \frac{\int_{\Delta\theta}^{90^\circ - \Delta\theta} d\theta \int_{R_1}^{R_2} dr_2 \int_{R_1}^{R_2} r_1 r_2 f(\theta, r_1, r_2) dr_1}{\int_{\Delta\theta}^{90^\circ - \Delta\theta} d\theta \int_{R_1}^{R_2} dr_2 \int_{R_1}^{R_2} r_1 r_2 dr_1} \quad , \quad (9)$$

$$f = \frac{180^\circ - \Delta\theta - \phi - \theta}{90^\circ - 2\Delta\theta} \quad , \quad 0 \leq f \leq 1 \quad , \quad (10)$$

$$\phi = \cos^{-1} \left[\frac{r_1^2 + r_2^2 - \theta_s^2}{2r_1 r_2} \right] \quad (11)$$

where: $R_1 = 10.22$, $R_2 = 14.09$, $\Delta\theta = 2.873^\circ$. R_1 , R_2 and $\Delta\theta$ define the man-vignetted detector area. A numerical integration gives $Q_1 = 0.735$. For non-adjacent GS fields, $Q_1 = 1.0$;

α is the logarithmic (base 10) slope of the star counts near m. ($\alpha \approx 0.32$ from the Weistroop data);

β is the correction factor expressing the probability that a GS is rejected due to proximity of another star less than θ_e and Δm away [$\beta = 1.020$];

P_1 is the probability of finding at least one GS in one FGS field satisfying requirement 4;

P_i is the Poisson probability distribution;

The above formulae are approximate for the following reasons:

1. They assume that stars are randomly distributed and therefore ignore star clustering. (Our preliminary results suggest that this assumption introduces a $\sim 1\%$ overestimate in P);

2. \mathcal{N} is assumed to be exactly an exponential. (This is also an excellent approximation introducing a negligible error);

3. Correction factors due to finite boundaries are ignored in the calculation of β and γ . (This is also an excellent approximation.)

Formulae (1) - (11) were used to calculate the probability of acquiring a GS pair in the memorandum in Appendix A.

From the Weistroop data, the surface density of stars with $9.0 \leq m_v < 14.0$ is 71.5 stars per square degree. The mean number of stars per detector is 1.37. Then $P_1 = 0.74$ and $Q \approx 0.954$ so that $P = 0.41 + 0.41 = 0.82$.

Note that although the single pair form factor, $Q_1 \approx 0.75$, the actual form factor $Q \approx 0.95$ because there are many possible combinations of GS pairs when there is more than one GS per field.

The $\theta_e / \Delta m$ constraint has only a minor effect on P . For $m_v = 14.0$ mag,

$$P \sim 0.84 \left[1 - 0.020 \left(\frac{\Delta m}{0.5} \right) \theta_e^2 \right] . \quad (12)$$

For $m_v > 14$, the influence of θ_e and Δm on P decreases monotonically with increasing m_v .

The above value for P is calculated for a field centered at $\ell = 65.5^\circ$, $b = 85.5^\circ$. At $m_v = 14$ mag, the star density is expected to be at a minimum in the direction of the galactic anticenter $\ell = 180^\circ$, $b = 80^\circ$. (This is based on the galactic model of Bahcall and Soneira 1980; there is no direct data presently available to confirm this point.) The minimum is not expected to be at the pole because of the galactic spheroidal bulge contribution to the star counts. For $\ell = 180^\circ$, $b < 80^\circ$ the increasing star density from the disk overcomes the decrease from the spheroid. Figure 2 is an isodensity contour plot of the integrated star counts to $m_v = 14$ mag for $b \geq 20^\circ$ calculated

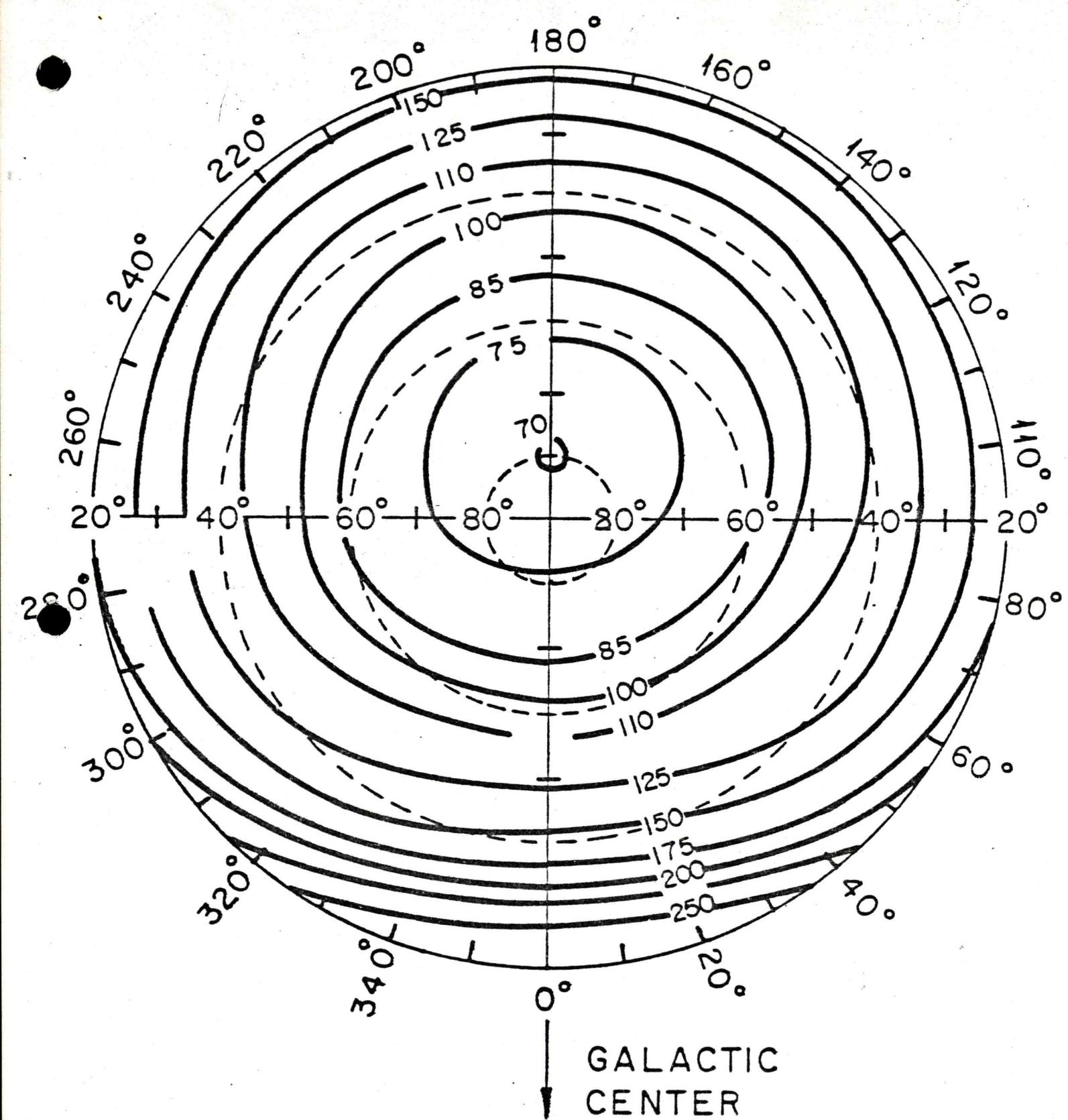


Fig. 2

from the Bahcall and Soneira model (assuming a Sandage obscuration model, see paper I). (For $m_v > 14$ the counts increase like $10^{0.32m}$, with only a slight dependence of the slope on latitude and longitude.) The model predicts that the integrated star density to $m_v = 14$ in the direction $\ell = 180^\circ$, $b = 80^\circ$ is $3\frac{1}{2}\%$ smaller than in the direction $\ell = 65.5^\circ$, $b = 85.5^\circ$. (For $m_v = 15$, the value is $4\frac{1}{2}\%$). This reduces the mean number of stars per detector to 1.32 and $P = 0.80$. Near $m_v = 14$, $P \approx 0.5(1+0.45n)$, where n is the mean number of stars per detector. This approximation is accurate to a few percent for n between 1.0 and 1.8 corresponding to the magnitude interval $13.65 \leq m \leq 14.35$.

c) Monte Carlo Calculation

The GS probabilities have also been calculated using a Monte Carlo simulation. The stars in each FGS field were distributed randomly; the number of stars in each field was chosen from a Poisson distribution with a specified mean number of stars per field and magnitudes were assigned randomly according to a distribution function that results in a number-magnitude relation that increases as $10^{\alpha m}$. The stars were then processed through an algorithm that implements the GS selection requirements (section A, above). This procedure simulates an ST pointing. In order to accumulate good statistics on the distribution of GS pairs, the procedure was repeated several thousand times. The results of this method agree with the analytic calculation to within the statistical uncertainties. Because the results are almost identical to the analysis on the real Weistroop data, we defer discussion to the next section.

d) GS Selection with the Weistrop Data

The Weistrop survey area is ~ 700 times larger than the area of one FGS field and since there are 984 stars brighter than $m_v = 14$ in the catalog, there is a sufficient data base for accurately determining GS statistics empirically near the pole (assuming, of course, the Weistrop field is representative of the star density at its galactic latitude and longitude).

The only significant difference between the results for the Monte Carlo calculation (§ c) and the Weistrop data is the GS rejection due to the proximity of another star: for the random case at $V = 14^m$ it is 2% and, for the Weistrop data it is 3%. The larger rejection factor in the Weistrop data is due to star clustering. The Weistrop catalog presumably identifies all stars that are separated by more than the seeing disk, $\lesssim 2$ arcsec (Weistrop 1980); hence only very compact binaries (which may be a problem for the FGS) are missed. (The anticorrelation length for the measured stellar positions is ~ 6 arcsec. The absolute positions of the stars are accurate to ~ 1 arcmin, Weistrop 1980.)

We present in Table 1, GS probabilities for the following combinations of (m_1, m_2) : (14,14), (14,14.5), (14,15), (14.5,14.5), (14.5, 15.0), (15.0, 15.0), and (13,15). For each of these pairs of magnitudes we list $n_i = \mathcal{N}(m_i)\Omega$, the mean number of stars per detector, and several GS probability distributions: $P_1(n)$ and $P_2(n)$ are the probabilities for finding n primary or

secondary stars per FGS detector before application of any selection constraints; $P_s(n)$ is the probability for finding n suitable secondary guide stars for a primary guide star; and $P_p(n)$ is the probability for finding n suitable guide star pairs per ST pointing.

For the "standard" case of $m_1 = m_2 = 14$, $P_p(\geq 1)$, i.e., the probability of finding at least one suitable GS pair is 0.80, and $P_p(\geq 2) = 0.55$. (This latter value is important for considering backup GS pairs if close binaries are a problem.) For (14,14.5), $P_p(\geq 1) = 0.91$ and $P_p(\geq 10) = 0.35$. Hence allowing the secondary GSs to be 1/2 mag dimmer than the primaries brings about a dramatic increase in the probability of acquiring a suitable GS pair. For (14,15), $P_p(\geq 1) = 0.97$ and $P_p(\geq 1) = 0.87$ for (13,15). (Note that for $\mathcal{N}_2 \gg \mathcal{N}_1$ P_s follows closely the Poisson distribution for a mean density of $\frac{2}{3}(2\mathcal{N}_1+1)n_2$ and $P_p(\geq 1) \sim 1 - e^{-3n_1}$.)

As in section b), the "worst case" probabilities need to be corrected from the direction $\ell = 65.5^\circ$, $b = 85.5^\circ$ to the density minimum at $\ell = 180^\circ$, $b = 80^\circ$. For the "standard" case of $m_1 = m_2 = 14$, $P_p(\geq 1)$ is then 0.79.

Approximate estimates for the GS probabilities for directions other than the galactic pole can be obtained from figure 2 by matching the surface densities \mathcal{N} for a given direction (ℓ, b) as closely as possible to the entries in Table 1. For $\mathcal{N} \gtrsim 100$ stars per deg^2 , corresponding to $m_v \approx 14.5^{\text{mag}}$ at the galactic pole, the probability of acquiring a suitable pair of Guide Stars is $\gtrsim 95\%$, sufficiently high to be of little concern. Appropriate Guide Stars will nearly always be available

$(P_p(\geq 1) \geq 0.95)$ for all galactic latitudes and longitudes below $b \sim 40^\circ$ if $m_1 = m_2 \geq 14^m$ (see Figure 2 and Table 1).

e) Conclusion

The probability for acquiring a suitable pair of Guide Stars in the direction of minimum star density ($\ell = 180^\circ$, $b = 80^\circ$) is estimated in this report to be 0.79 when both Guide Stars are required to be brighter than $m_v = 14^m$, somewhat less than the design specification of 0.85. (The acquisition probability will be further reduced if there are a significant number of close binaries with angular separation ≤ 1 arcsec.) In order to meet the design specification with the same brightness limit for both the primary and secondary Guide Stars, one would require $m_1 = m_2 = 14.25$ Visual magnitudes.

If, however, the secondary Guide Star is allowed to be dimmer than the primary, then there can be a significant improvement in the acquisition probability. For $m_1 = 14.0^m$ and $m_2 = 14.5^m$, the Guide Star acquisition probability is 0.90. If we use the maximum allowed brightness difference between the primary and secondary Guide Stars, 2 magnitudes, then the primary star need only be brighter than 13^{th} magnitude (Visual) in order to meet the design specification in the direction of the density minimum near the galactic pole.

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TABLE 1. Guide Star Probability Distributions *

$$\begin{aligned}m_1 &= 14.0 \\n_1 &= 1.37 \\\mathcal{N}_1 &= 71.5\end{aligned}$$

$$\begin{aligned}m_2 &= 14.0 \\n_2 &= 1.37 \\\mathcal{N}_2 &= 71.5\end{aligned}$$

$$\begin{aligned}m_1 &= 14.0 \\n_1 &= 1.37 \\\mathcal{N}_1 &= 71.5\end{aligned}$$

$$\begin{aligned}m_2 &= 14.5 \\n_2 &= 1.89 \\\mathcal{N}_2 &= 98.3\end{aligned}$$

$$\begin{aligned}m_1 &= 14.0 \\n_1 &= 1.37 \\\mathcal{N}_1 &= 71.5\end{aligned}$$

$$\begin{aligned}m_2 &= 15.0 \\n_2 &= 2.56 \\\mathcal{N}_2 &= 133\end{aligned}$$

n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p
0	0.254	0.254	0.113	0.195	0	0.254	0.151	0.052	0.086	0	0.254	0.077	0.018	0.032
1	0.348	0.348	0.236	0.115	1	0.348	0.286	0.137	0.057	1	0.348	0.198	0.067	0.026
2	0.238	0.238	0.262	0.139	2	0.238	0.270	0.212	0.081	2	0.238	0.253	0.134	0.047
3	0.109	0.109	0.196	0.090	3	0.109	0.170	0.211	0.073	3	0.109	0.216	0.181	0.046
4	0.037	0.037	0.111	0.092	4	0.037	0.080	0.173	0.079	4	0.037	0.138	0.181	0.054
5	0.010	0.010	0.052	0.057	5	0.010	0.030	0.110	0.060	5	0.010	0.071	0.159	0.046
6	0.002	0.002	0.020	0.062	6	0.002	0.010	0.058	0.065	6	0.002	0.030	0.111	0.044
7		0.007	0.043		7		0.003	0.029	0.047	7		0.011	0.073	0.048
8		0.002	0.039		8		0.001	0.011	0.057	8		0.004	0.040	0.053
9		0.001	0.029		9			0.004	0.050	9		0.001	0.021	0.047
10		0.027			10			0.001	0.041	10			0.009	0.044
11		0.018			11			0.001	0.035	11			0.004	0.035
12		0.018			12				0.040	12			0.002	0.040
13		0.013			13				0.032	13			0.001	0.039
14		0.012			14				0.026	14				0.034
15		0.011			15				0.018	15				0.029
16		0.007			16				0.020	16				0.035
17		0.006			17				0.015	17				0.027
18		0.006			18				0.015	18				0.028
≥19		0.023			≥19				0.105	≥19				0.247

* See pages 7 and 8 for definitions.

TABLE 1. Guide Star Probability Distributions* (Continued)

$m_1 = 14.5$	$m_2 = 14.5$	$m_1 = 14.5$	$m_2 = 15.0$	$m_1 = 15.0$	$m_2 = 15.0$									
$n_1 = 1.89$	$n_2 = 1.89$	$n_1 = 1.89$	$n_2 = 2.56$	$n_1 = 2.56$	$n_2 = 2.56$									
$\mathcal{N}_1 = 98.3$	$\mathcal{N}_2 = 98.3$	$\mathcal{N}_1 = 98.3$	$\mathcal{N}_2 = 133$	$\mathcal{N}_1 = 133$	$\mathcal{N}_2 = 133$									
n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p
0	0.151	0.151	0.051	0.080	0	0.151	0.077	0.019	0.026	0	0.077	0.077	0.017	0.023
1	0.286	0.286	0.137	0.052	1	0.286	0.198	0.077	0.018	1	0.198	0.198	0.067	0.014
2	0.270	0.270	0.207	0.073	2	0.270	0.253	0.144	0.041	2	0.253	0.253	0.132	0.033
3	0.170	0.170	0.210	0.071	3	0.170	0.216	0.183	0.039	3	0.216	0.216	0.177	0.031
4	0.080	0.080	0.174	0.073	4	0.080	0.138	0.175	0.052	4	0.138	0.138	0.183	0.041
5	0.030	0.030	0.113	0.052	5	0.030	0.071	0.149	0.036	5	0.071	0.071	0.161	0.033
6	0.010	0.010	0.061	0.064	6	0.010	0.030	0.108	0.054	6	0.030	0.030	0.114	0.042
7	0.003	0.003	0.030	0.046	7	0.003	0.011	0.070	0.040	7	0.011	0.011	0.075	0.038
8	0.001	0.001	0.012	0.058	8	0.001	0.004	0.040	0.052	8	0.004	0.004	0.041	0.045
9		0.004	0.046		9		0.001	0.020	0.046	9	0.001	0.001	0.019	0.033
10		0.002	0.046		10			0.009	0.048	10			0.009	0.042
11		0.001	0.032		11			0.004	0.041	11			0.004	0.033
12		0.042			12			0.002	0.042	12			0.002	0.041
13		0.032			13				0.032	13			0.001	0.030
14		0.029			14				0.035	14			0.038	
15		0.025			15				0.035	15			0.034	
16		0.023			16				0.026	16			0.029	
17		0.016			17				0.029	17			0.034	
18		0.017			18				0.025	18			0.027	
≥ 19		0.125			≥ 19				0.286	≥ 19			0.360	

* See pages 7 and 8 for definitions.

TABLE 1. Guide Star Probability Distributions* (Concluded)

$$\begin{array}{ll}
 m_1 = 13 & m_2 = 15 \\
 n_1 = 0.684 & n_2 = 2.56 \\
 \mathcal{N}_1 = 35.6 & \mathcal{N}_2 = 133
 \end{array}$$

n	p_1	p_2	p_s	p_p
0	0.505	0.077	0.019	0.131
1	0.345	0.198	0.065	0.046
2	0.118	0.253	0.140	0.076
3	0.027	0.216	0.187	0.078
4	0.005	0.138	0.181	0.086
5	0.001	0.071	0.154	0.059
6		0.030	0.110	0.062
7		0.011	0.071	0.055
8		0.004	0.039	0.051
9		0.001	0.020	0.050
10			0.010	0.039
11			0.003	0.036
12			0.001	0.036
13			0.001	0.025
14				0.024
15				0.021
16				0.024
17				0.015
18				0.013
≥ 19				0.077

* See pages 7 and 8 for definitions.

APPENDIX A

II. BRIGHT-STAR DENSITY

a) The Best Available Data

The principal source of data that we used for the bright star densities in paper I was Seares et al. (1925), which lists star counts in the direction of the Galactic pole for magnitudes in the range $4 \leq m_v \leq 18$. The original data from some of the star catalogs used by Seares et al. had large systematic errors (up to 2 magnitudes) that Seares and his collaborators tried to remove. However, a scale error in the magnitudes was discovered by Stebbins, Whitford and Johnson (1950). The corrections of Stebbins et al. were applied in paper I, but it was conceivable that some systematic errors remained.

Modern counts of bright star densities have been rare. In paper I, the brightest recent star counts considered were those of Brown (1979). Brown measured integrated star counts in several fields near the Galactic pole in the magnitude range $17 \leq m_v \leq 20.5$. (The counts of Tyson and Jarvis (1979) extend to 13th magnitude; however, stellar images brighter than 17th magnitude were saturated and hence required an indirect magnitude measurement.)

In this paper we consider additionally star counts from 9th to 16th magnitude obtained from the data of Weistropp (1972) that was kindly made available to us in the form of the original computer tape and printout. The Weistropp catalog comes from a field of area 13.3 square degrees, centered in SA57 in the direction of the Galactic pole. There are 2989 stars in her catalog.

brighter than $V = 16$. The catalog extends to $V = 20$, but magnitude uncertainties appear to increase significantly dimward of 16th magnitude (Faber et al. 1976; Weistroop 1980; King 1980).

According to Weistroop (1980), the magnitude errors for $V \leq 16$ are $\pm 0.12^m$ (one standard deviation). A comparison by Faber et al. 1976 of the Weistroop magnitudes, V_W , to photoelectric magnitudes, V_{PE} , for 23 stars with $V \leq 16$ gives $\langle V_W - V_{PE} \rangle = -0.02 \pm 0.09$. King (1980) has compared his own photometry to that of Weistroop. His results for 16 stars with $V \leq 16$ is $\langle V_W - V_K \rangle = +0.01 \pm 0.09$. These estimates all yield a magnitude uncertainty $\sim \pm 0.1^m$. The zero point and magnitude scale appear to be well established for $V \leq 16$.

Figure 1 displays a compilation of all the available differential star densities (number of stars per magnitude per square degree) in the direction of the Galactic pole (see paper I). The solid curve is the density predicted by our standard Galaxy model of paper I, including a separate contribution from giants (see below). In Table 1 we list the total integrated star counts (stars brighter than the specified magnitudes limit) for the Weistroop data, the Seares et al. data as reduced to the Visual band in paper I, the calculated densities from our standard Galaxy model (see below), and the densities tabulated in Allen (1973).

In calculating the star counts for the bright apparent magnitudes considered here using the Bahcall-Soneira Galaxy model, it is necessary to separate the contribution of the stars on the giant branch from the more common main sequence stars

which completely dominate the counts at faint magnitudes (see § IIa of paper I for a detailed discussion of this point). The giants were not included separately in paper I.

The differential star counts for the giants peak at 11th mag, where they contribute about 20% to the total counts; by 13th mag their contribution has fallen to 3%. We take the fraction of stars, f , on the main sequence to be

$$f = \begin{cases} 0.44 \times \exp [0.00015(M+8)^{3.5}] , & M < 3.7 , \\ 1 , & M \geq 3.7 , \end{cases} \quad (1)$$

which accurately fits the data of Sandage (1957), Schmidt (1959) and McCuskey (1966). A scale height of 250pc is adopted for the giants (see paper I).

b) Allen's Recommended Densities

The star densities listed in Allen (1963, 1973) are typically more than 40% larger than the densities listed above and in paper I for $m \geq 13$. Allen's results have been used as the basis for considering the performance of the Guide Star System for the Space Telescope (see, e.g., Groth 1978).

Because of the importance of the Guide Star System for the entire Space Telescope Observatory, it is necessary to examine the origin of the discrepancies between Allen's numbers and the other results given in Table 1. (Allen 1973 notes that his star densities are 25% larger than the Landolt-Börnstein Tables [Scheffler and Elsässer 1965], his reference number 6, although the same sources were used.) The sources listed by Allen are

Seares et al. (1925), Seares and Joyner (1928), and van Rhijn (1929). The Seares and Joyner paper examines star counts for $b \leq 70^\circ$, and thus is not relevant for the present discussion. The van Rhijn paper combines star count data of Seares et al. and the Harvard-Durchusterung survey.

A comparison of the Seares et al. and van Rhijn counts in the international photographic band with corresponding counts listed in Allen (1973), shows that Allen must have re-reduced the data introducing small changes, ~10%, (generally) upward in the bright star densities.

Counts in the Visual band are desired for many purposes. In order to transform the photographic band counts into the Visual band Bahcall and Soneira (1980) used the color equation in Seares et al. Allen used the following (incorrect) conversion from m_{pg} to m_v :

$$\mathcal{N}(\leq m_v) = \mathcal{N}(\leq m_{pg}) \times \left(\frac{\text{total number of stars brighter than } m_v \text{ from } b=0^\circ \text{ to } 90^\circ}{\text{corresponding number for } m_{pg}} \right) \quad (2)$$

This conversion is more incorrect at higher galactic latitudes, since most of the bright stars are counted near the plane of the disk and stellar type (i.e., color) changes systematically with Galactic latitude.

The net discrepancy is unexpectedly large (>40%) between, on the one hand, either the modern star counts in V (Weistropp 1972, 1980) or the older Seares et al. (1925) data as reduced in paper I, and, on the other hand, the star densities tabulated by Allen (1973). In order to illustrate where in the analysis of Allen the errors appear to have originated, we divide the

transformation into several steps. For specificity, we consider the star density in the Visual band at 14th magnitude for which Allen cites 102 stars deg⁻². Part of the error appears to result from the different manner in which Allen combined each of the three (tabulated) quantities needed in equation 2 from his two sources¹. If we apply Allen's transformation (equation 2) to just the Seares et al. data alone, we obtain 94 stars deg⁻². (Van Rhijn tabulates only 2 of the 3 quantities, so it is not possible to perform the Allen transformation solely with his data.) If the band transformation is calcualted using the correct color equation described in Seares et al., the density further decreases to 82 stars deg⁻². Finally, if the magnitude corrections of Stebbins, Whitford, and Johnson (1950) are applied to the Seares et al. data (as in paper I), we obtain 71 stars deg⁻² brighter than 14th Visual magnitude in the direction of the Galactic pole. Weistroop counted 73 stars deg⁻²; the Bahcall-Soneira Galaxy model predicts 70.4 stars deg⁻² brighter than V = 14. Hence, it appears that Allen's result can be accounted for by 3 systematic errors, each of order 10%, that add "fortuitously" in the same direction.

¹ See Table 2.

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TABLE 1. TOTAL INTERATED STAR DENSITIES

PER SQUARE DEGREE

V	9	10	11	12	13	14	15	16
Weistroop	1.9	3.7	7.6	18	37	74	135	224
Seares <u>et al.</u> ^a	1.2	3.3	8.0	18	36	71	134	216
Bahcall-Soneira Model	1.5	3.5	7.7	16	34	70	138	254
Allen	1.4	3.6	9.1	21	49	102	186	347

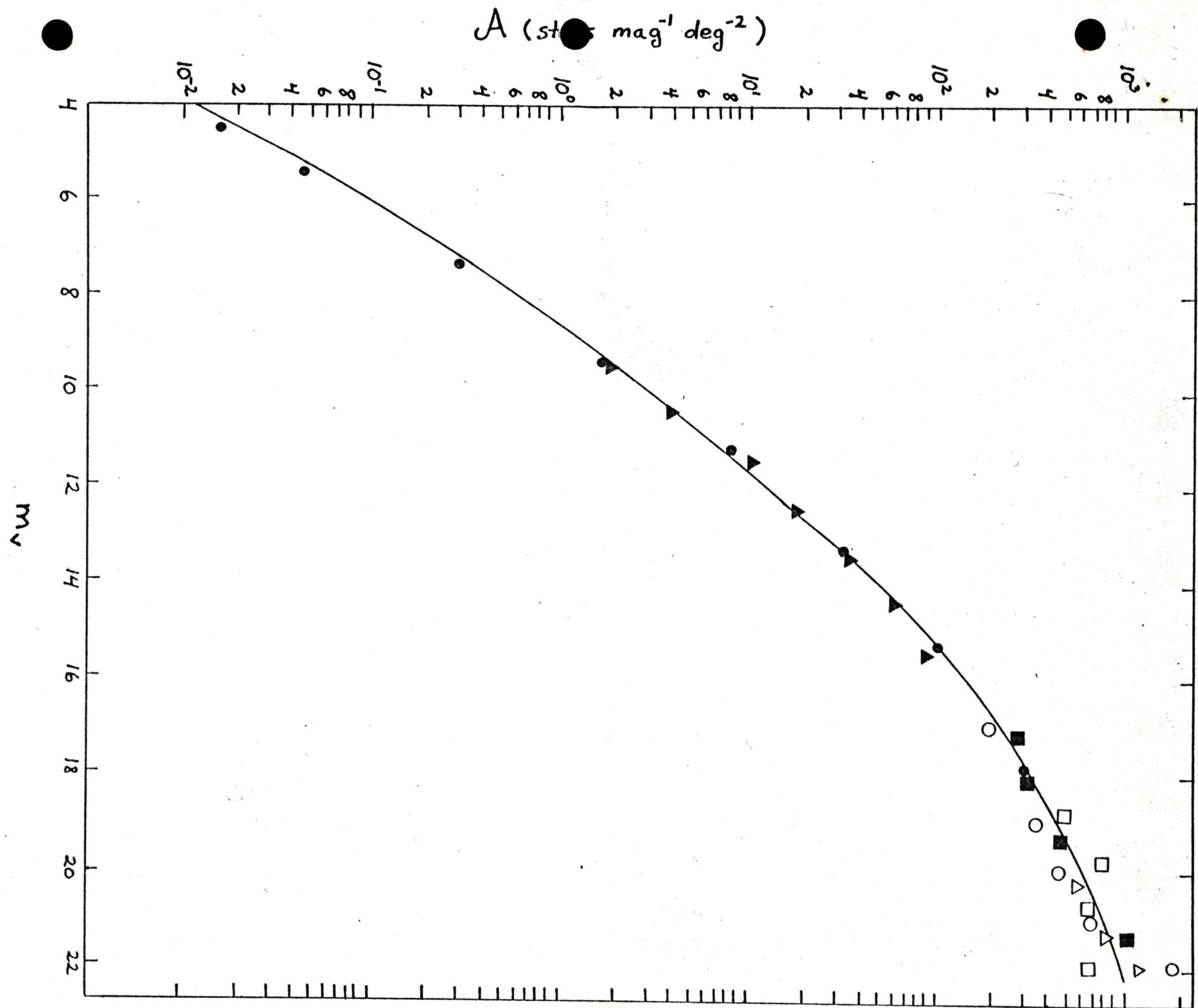
^a Reduced to the Visual band in paper I.

TABLE 2. STAR DENSITY DATA

m	$\log[\mathcal{N}_{pg}(90^\circ)]$			$\log[\mathcal{N}_{pg}(0^\circ-90^\circ)]$			$\log[\mathcal{N}_v(0^\circ-90^\circ)]$		
	Allen	Seares et al.	van Rhijn	Allen	Seares et al.	van Rhijn	Allen	Seares et al.	
10	0.27	0.257	0.25	0.62	0.604	0.64	0.91	0.895	
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14	1.71	1.646	1.70	2.26	2.196	2.30	2.56	2.525	
15	1.97	1.940	1.98	2.62	2.559	2.68	2.94	2.891	
16	2.24	2.211	2.26	2.98	2.905	3.04	3.29	3.235	

CAPTION FOR FIGURE 1

Differential star densities \mathcal{A} per magnitude per square degree for the Galactic pole. The solid curve is the density predicted by the standard Galaxy model of paper I assuming no obscuration at the pole and including a separate contribution from giants (see text). Data from Seares et al. (1925) as reduced to the Visual-band in paper I are plotted as filled-circles, data from Weistroop (1972) are plotted as filled-triangles, data from Brown (1979) corrected to the pole (see paper I) are plotted as filled-squares, data from Kron (1978) are plotted as open triangles, data from Tyson and Jarvis (1979) are plotted as open circles, and data from Peterson et al. (1979) as squares. For magnitude system conversions, see paper I.



OUTLINE

1. SUMMARY OF DATA ON BRIGHT STARS
2. CHARACTERISTICS OF THE FINE GUIDANCE SYSTEM (FGS)
3. ANALYTIC CALCULATION
4. MONTE CARLO SIMULATION
5. GUIDE STAR ACQUISITION WITH THE WEISTROP CATALOG
6. NUMERICAL RESULTS
7. OTHER CALCULATIONS ?

DATA ON BRIGHT STARS

$$9 \leq m_V \leq 16$$

1. WEISTROP CATALOGUE :

2989 STARS / $13.3 \text{ } \square^2$ in SA 57

$\Delta m_V \approx 0.1^m$ (FABER ET. AL., KING).

2. SEARES ET. AL. (1925)

($\sim 10^2 - 10^3$)

STEBBINS, WHITFORD, and JOHNSON
(1950) CORRECTION

3. GALAXY MODEL (PAPER I)

4. ALLEN (1973)

COLOR EQUATION X

STEBBINS, ET. AL. CORRECTION X

COMBINED DIFFERENT SOURCES X

Table 1 .Total Interated Star Densities
Per Square Degree

m_V	9	10	11	12	13	14	15	16
Weistrop	1.9	3.7	7.6	18	37	74	135	224
Seares et al. ^a	1.2	3.3	8.0	18	36	71	134	216
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Allen	1.4	3.6	9.1	21	49	102	186	347

^a

Reduced to the Visual band in paper I

GUIDE STAR SELECTION CHARACTERISTICS

1. 3 DETECTORS : $\Omega = 69.2$ SQ. ARC MIN.
2 GUIDE STARS
2. COLOR SENSITIVITY
UNITY BETWEEN $4660 \text{ \AA} - 7000 \text{ \AA}^{\circ}$
ZERO OUTSIDE
3. MAGNITUDE RANGE :
 $9 \leq m_V \leq m_i$; $14 \leq m_j \leq 15$
(?) $|m_2 - m| \leq 2^m$ (?)
4. MINIMUM ACCIDENTAL SEPARATION : θ_e
 $\theta_e \leq 1 \text{ ARC MIN} \Rightarrow \Delta m \geq 0.5^m$
5. MINIMUM SEPARATION OF GUIDE
STARS : 13.5 ARC MIN
2 DETECTORS

FINE GUIDANCE SYSTEM FOCAL PLANE ARRANGEMENT

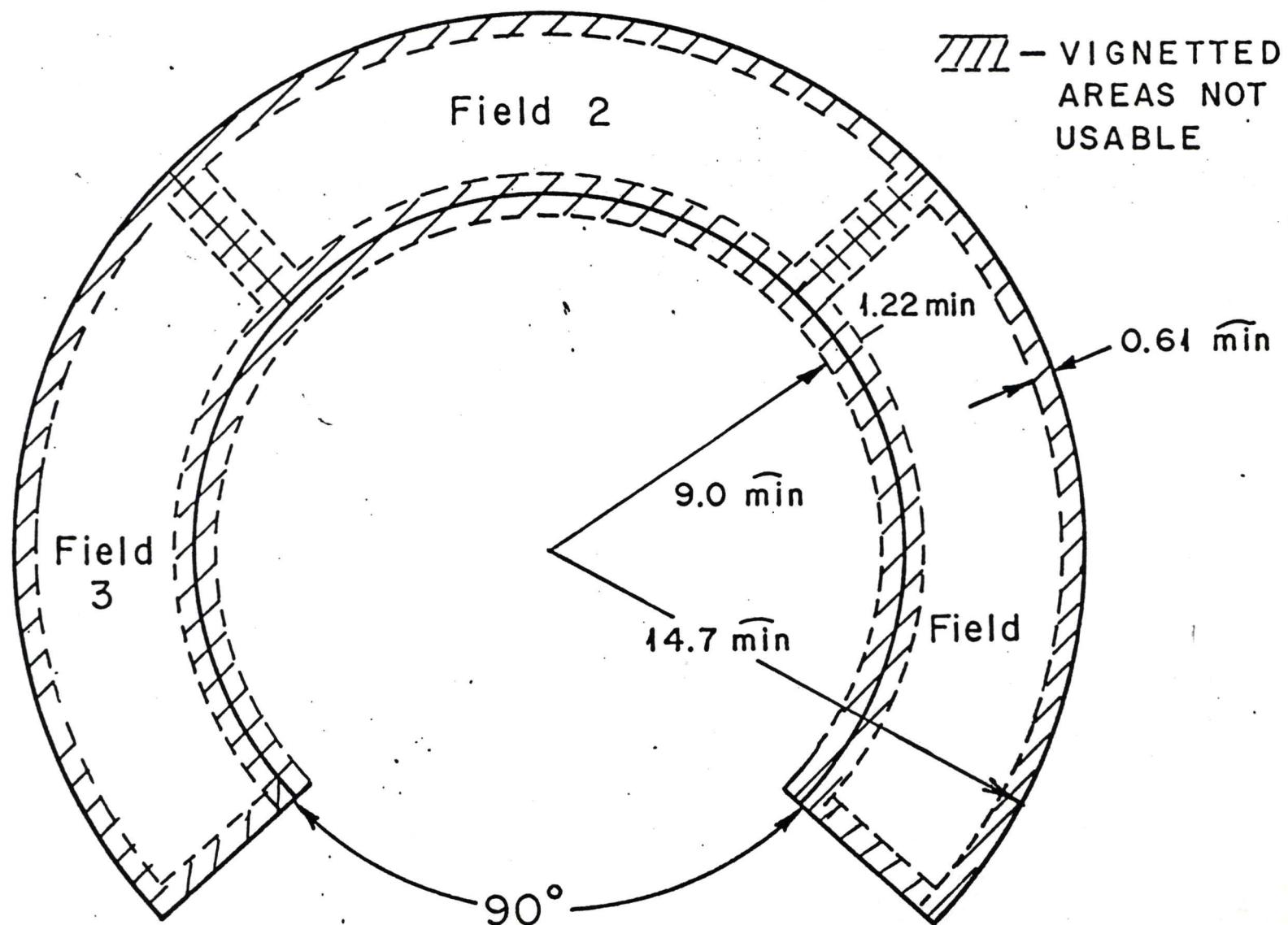


Fig. 1

ANALTIC CALCULATION

ASSUMPTIONS : $m_1 = m_2$

NO COLOR CORRECTION $[\sim 10^{32}(0.04)]$

POISSON STATISTICS.

$$N(n) = C 10^{\gamma m}$$

INCLUDES : EXACT GEOMETRY

FINITE Θ_e

MINIMUM SEPARATION
(2 DETECTORS)

MONTE CARLO SIMULATION

EXACT MOCK-UP

but

(PROGRAM DOES NOT YET INCLUDE
CORRELATION FUNCTIONS)

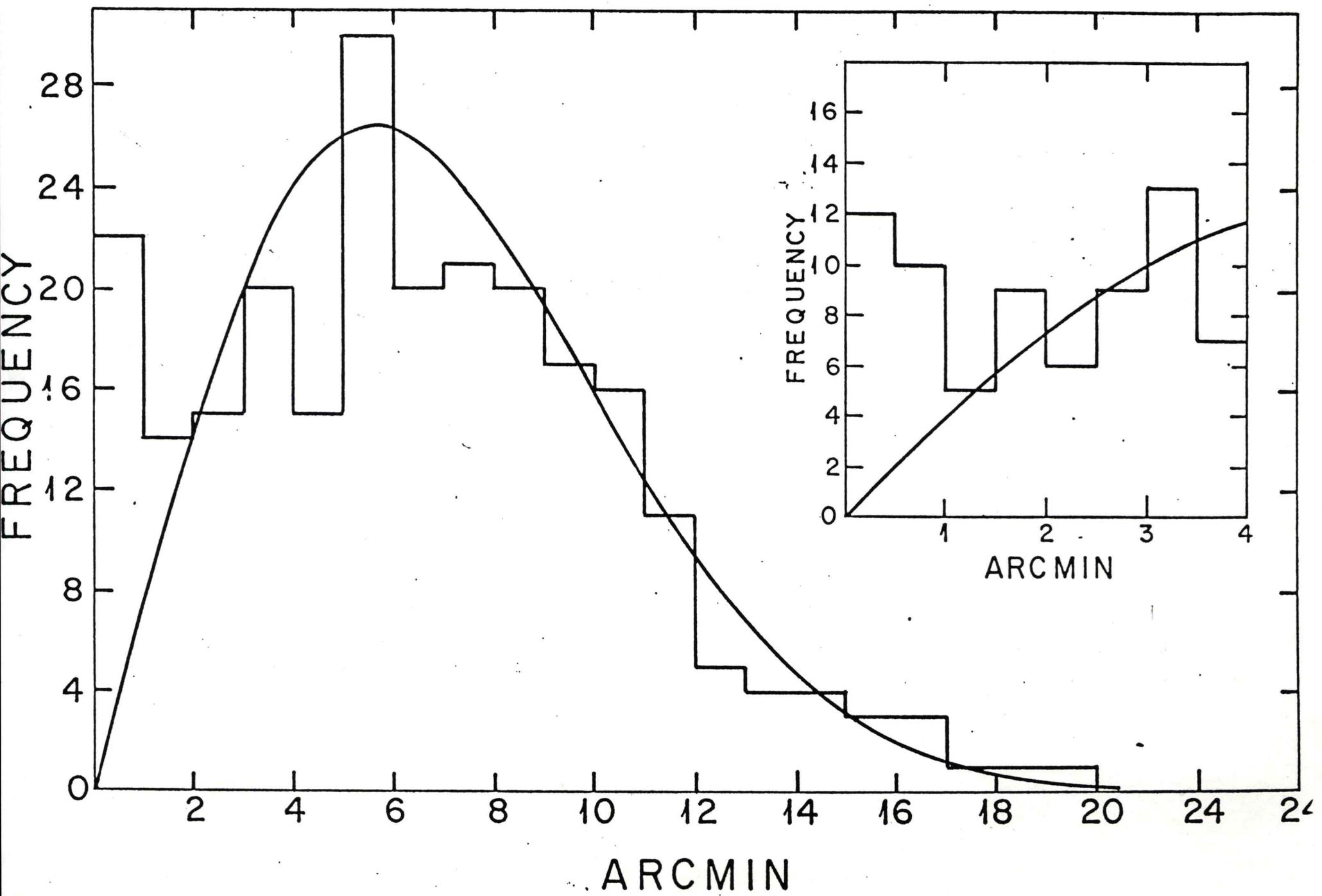
GUIDE - STAR ACQUISITION

WITH THE WEISTROP

CATALOG

AREA $\sim 7 \times 10^{+2} \Omega_{FGS}$

AGREES WITH : ANALYTIC,
CALCULATION AND MONTE
CARLO SIMULATION (EXCEPT
REJECTION RATE GREATER :
 $\sim 1\%$)



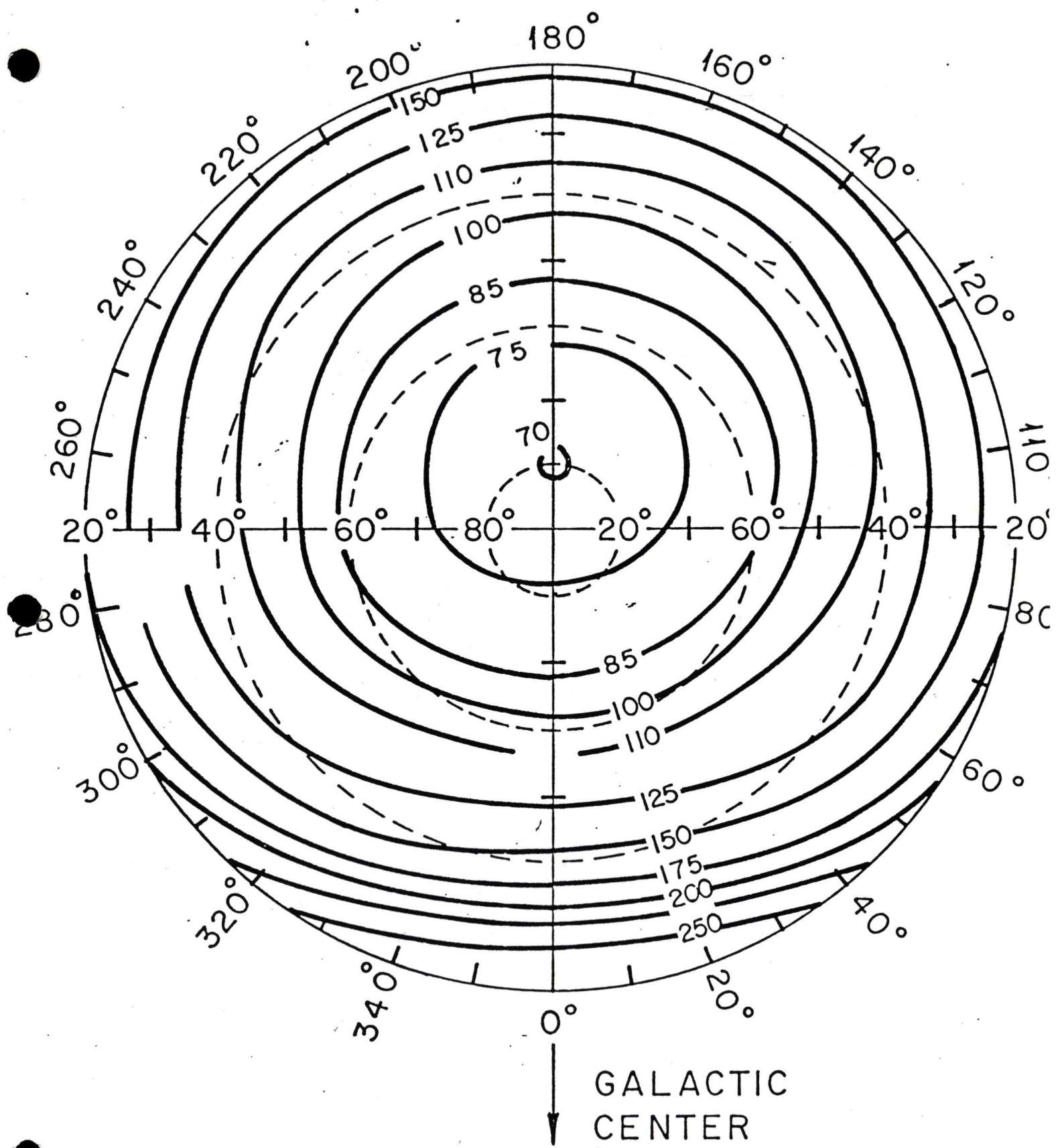
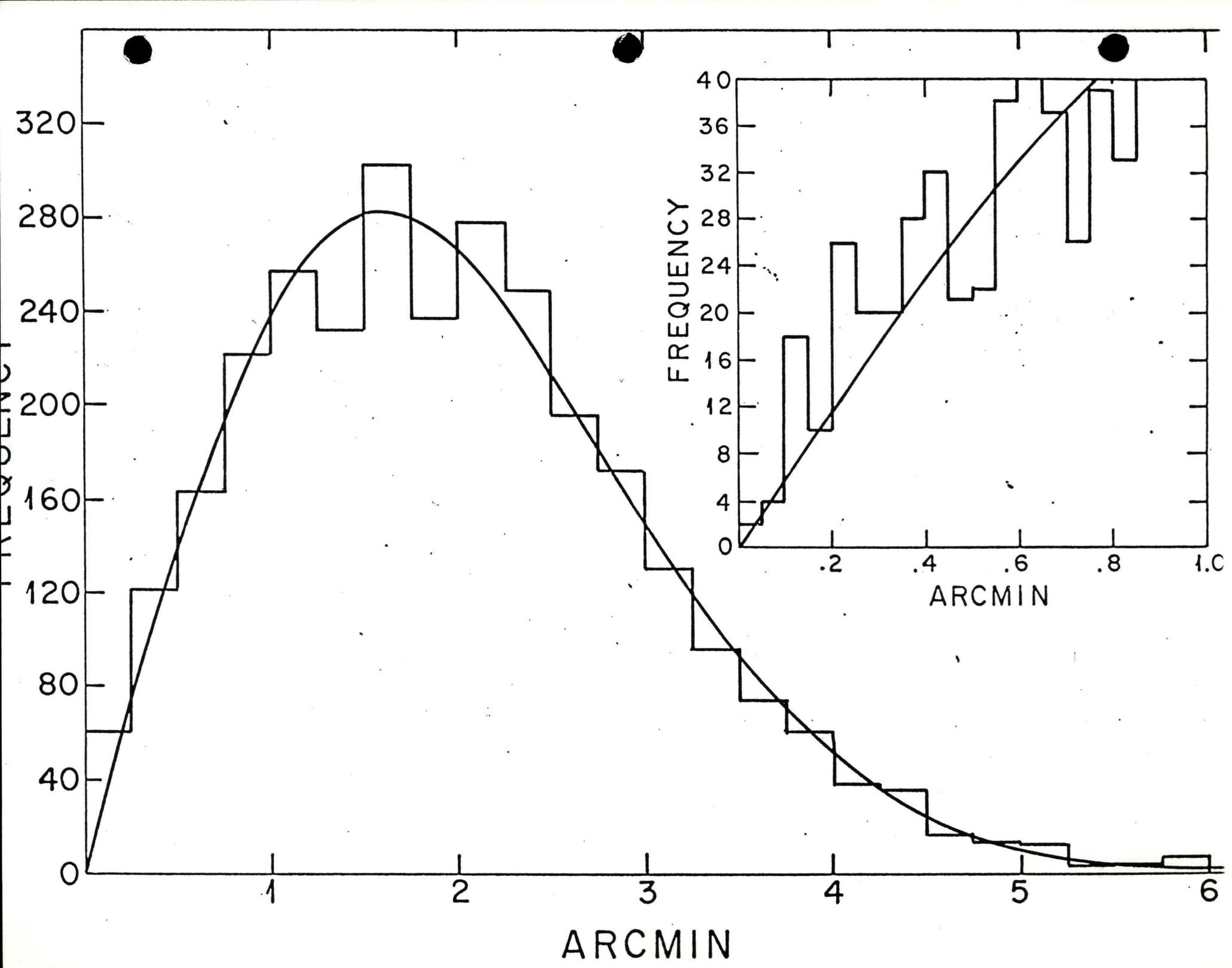


Fig. 2



PROBABILITES

1. STAR DENSITIES $N(m, \lambda, b)$:

CONTOUR MAP: FIGURE 2

PAPER I : TABLE B2

2. TABLE 1: $(m_1, m_2) = (14, 14), (14, 14.5), (14, 15), (14.5, 15.0), (13, 15)$

$n_i, P_1(n), P_2(n)$

$P_s(n)$

$P_p(n)$ \leftarrow

3. Examples:

$m_1 = m_2 = 14: P_p(\geq 1) = 0.80, P_p(\geq 2) = 0.55$

$m_1 = m_2 = 14.25: P_p(\geq 1) = 0.85$

$m_1 = 14, m_2 = 14.5: P_p(\geq 1) = 0.91, P_p(\geq 10) = 0.3$

$m_1 = 13, m_2 = 15: P_p(\geq 1) = 0.87$

QUESTIONS :

PHOTON COUNTING OR ENERGY
COUNTING ?

INCLUDED WIDER BAND - WIDTH ?

CONCLUSIONS

- NO SEVERE (NEW) PROBLEMS

MAGNITUDE DIFFERENCE BETWEEN
PRIMARY AND SECONDARY
GUIDE STARS COULD BE VERY
IMPORTANT.

TABLE 1. Guide Star Probability Distributions* (Continued)

 $m_1 = 14.5$
 $n_1 = 1.89$
 $\mathcal{N}_1 = 98.3$
 $m_2 = 14.5$
 $n_2 = 1.89$
 $\mathcal{N}_2 = 98.3$
 $m_1 = 14.5$
 $n_1 = 1.89$
 $\mathcal{N}_1 = 98.3$
 $m_2 = 15.0$
 $n_2 = 2.56$
 $\mathcal{N}_2 = 133$
 $m_1 = 15.0$
 $n_1 = 2.56$
 $\mathcal{N}_1 = 133$
 $m_2 = 15.0$
 $n_2 = 2.56$
 $\mathcal{N}_2 = 133$

n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p	n	p_1	p_2	p_s	p_p
0	0.151	0.151	0.051	0.080	0	0.151	0.077	0.019	0.026	0	0.077	0.077	0.017	0.023
1	0.286	0.286	0.137	0.052	1	0.286	0.198	0.077	0.018	1	0.198	0.198	0.067	0.014
2	0.270	0.270	0.207	0.073	2	0.270	0.253	0.144	0.041	2	0.253	0.253	0.132	0.033
3	0.170	0.170	0.210	0.071	3	0.170	0.216	0.183	0.039	3	0.216	0.216	0.177	0.031
4	0.080	0.080	0.174	0.073	4	0.080	0.138	0.175	0.052	4	0.138	0.138	0.183	0.041
5	0.030	0.030	0.113	0.052	5	0.030	0.071	0.149	0.036	5	0.071	0.071	0.161	0.033
6	0.010	0.010	0.061	0.064	6	0.010	0.030	0.108	0.054	6	0.030	0.030	0.114	0.042
7	0.003	0.003	0.030	0.046	7	0.003	0.011	0.070	0.040	7	0.011	0.011	0.075	0.038
8	0.001	0.001	0.012	0.058	8	0.001	0.004	0.040	0.052	8	0.004	0.004	0.041	0.045
9			0.004	0.046	9		0.001	0.020	0.046	9	0.001	0.001	0.019	0.033
10			0.002	0.046	10			0.009	0.048	10			0.009	0.042
11			0.001	0.032	11			0.004	0.041	11			0.004	0.033
12			0.042		12			0.002	0.042	12			0.002	0.041
13			0.032		13				0.032	13			0.001	0.030
14			0.029		14				0.035	14				0.038
15			0.025		15				0.035	15				0.034
16			0.023		16				0.026	16				0.029
17			0.016		17				0.029	17				0.034
18			0.017		18				0.025	18				0.027
≥ 19			0.125		≥ 19				0.286	≥ 19				0.360

* See pages 7 and 8 for definitions.

TABLE 1. Guide Star Probability Distributions* (Concluded)

$$\begin{array}{ll}
 m_1 = 13 & m_2 = 15 \\
 n_1 = 0.684 & n_2 = 2.56 \\
 \mathcal{N}_1 = 35.6 & \mathcal{N}_2 = 133
 \end{array}$$

n	P_1	P_2	P_s	P_p
0	0.505	0.077	0.019	0.131
1	0.345	0.198	0.065	0.046
2	0.118	0.253	0.140	0.076
3	0.027	0.216	0.187	0.078
4	0.005	0.138	0.181	0.086
5	0.001	0.071	0.154	0.059
6		0.030	0.110	0.062
7		0.011	0.071	0.055
8		0.004	0.039	0.051
9		0.001	0.020	0.050
10			0.010	0.039
11			0.003	0.036
12			0.001	0.036
13			0.001	0.025
14				0.024
15				0.021
16				0.024
17				0.015
18				0.013
≥ 19				0.077

* See pages 7 and 8 for definitions.

APPENDIX A

II. BRIGHT-STAR DENSITY

a) The Best Available Data

The principal source of data that we used for the bright star densities in paper I was Seares et al. (1925), which lists star counts in the direction of the Galactic pole for magnitudes in the range $4 \leq m_v \leq 18$. The original data from some of the star catalogs used by Seares et al. had large systematic errors (up to 2 magnitudes) that Seares and his collaborators tried to remove. However, a scale error in the magnitudes was discovered by Stebbins, Whitford and Johnson (1950). The corrections of Stebbins et al. were applied in paper I, but it was conceivable that some systematic errors remained.

Modern counts of bright star densities have been rare. In paper I, the brightest recent star counts considered were those of Brown (1979). Brown measured integrated star counts in several fields near the Galactic pole in the magnitude range $17 \leq m_v \leq 20.5$. (The counts of Tyson and Jarvis (1979) extend to 13th magnitude; however, stellar images brighter than 17th magnitude were saturated and hence required an indirect magnitude measurement.)

In this paper we consider additionally star counts from 9th to 16th magnitude obtained from the data of Weistropp (1972) that was kindly made available to us in the form of the original computer tape and printout. The Weistropp catalog comes from a field of area 13.3 square degrees, centered in SA57 in the direction of the Galactic pole. There are 2989 stars in her catalog.

brighter than $V = 16$. The catalog extends to $V = 20$, but magnitude uncertainties appear to increase significantly dimward of 16th magnitude (Faber et al. 1976; Weistroop 1980; King 1980).

According to Weistroop (1980), the magnitude errors for $V \leq 16$ are $\pm 0.12^m$ (one standard deviation). A comparison by Faber et al. 1976 of the Weistroop magnitudes, V_W , to photoelectric magnitudes, V_{PE} , for 23 stars with $V \leq 16$ gives $\langle V_W - V_{PE} \rangle = -0.02 \pm 0.09$. King (1980) has compared his own photometry to that of Weistroop. His results for 16 stars with $V \leq 16$ is $\langle V_W - V_K \rangle = +0.01 \pm 0.09$. These estimates all yield a magnitude uncertainty $\sim \pm 0.1^m$. The zero point and magnitude scale appear to be well established for $V \leq 16$.

Figure 1 displays a compilation of all the available differential star densities (number of stars per magnitude per square degree) in the direction of the Galactic pole (see paper I). The solid curve is the density predicted by our standard Galaxy model of paper I, including a separate contribution from giants (see below). In Table 1 we list the total integrated star counts (stars brighter than the specified magnitudes limit) for the Weistroop data, the Seares et al. data as reduced to the Visual band in paper I, the calculated densities from our standard Galaxy model (see below), and the densities tabulated in Allen (1973).

In calculating the star counts for the bright apparent magnitudes considered here using the Bahcall-Soneira Galaxy model, it is necessary to separate the contribution of the stars on the giant branch from the more common main sequence stars

which completely dominate the counts at faint magnitudes (see § IIa of paper I for a detailed discussion of this point). The giants were not included separately in paper I.

The differential star counts for the giants peak at 11th mag, where they contribute about 20% to the total counts; by 13th mag their contribution has fallen to 3%. We take the fraction of stars, f , on the main sequence to be

$$f = \begin{cases} 0.44 \times \exp [0.00015(M+8)^{3.5}] & M < 3.7 \\ 1 & M \geq 3.7 \end{cases}, \quad (1)$$

which accurately fits the data of Sandage (1957), Schmidt (1959) and McCuskey (1966). A scale height of 250pc is adopted for the giants (see paper I).

b) Allen's Recommended Densities

The star densities listed in Allen (1963, 1973) are typically more than 40% larger than the densities listed above and in paper I for $m \geq 13$. Allen's results have been used as the basis for considering the performance of the Guide Star System for the Space Telescope (see, e.g., Groth 1978).

Because of the importance of the Guide Star System for the entire Space Telescope Observatory, it is necessary to examine the origin of the discrepancies between Allen's numbers and the other results given in Table 1. (Allen 1973 notes that his star densities are 25% larger than the Landolt-Börnstein Tables [Scheffler and Elsässer 1965], his reference number 6, although the same sources were used.) The sources listed by Allen are

Seares et al. (1925), Seares and Joyner (1928), and van Rhijn (1929). The Seares and Joyner paper examines star counts for $b \leq 70^\circ$, and thus is not relevant for the present discussion. The van Rhijn paper combines star count data of Seares et al. and the Harvard-Durchusterung survey.

A comparison of the Seares et al. and van Rhijn counts in the international photographic band with corresponding counts listed in Allen (1973), shows that Allen must have re-reduced the data introducing small changes, ~10%, (generally) upward in the bright star densities.

Counts in the Visual band are desired for many purposes. In order to transform the photographic band counts into the Visual band Bahcall and Soneira (1980) used the color equation in Seares et al. Allen used the following (incorrect) conversion from m_{pg} to m_v :

$$\mathcal{N}(\leq m_v) = \mathcal{N}(\leq m_{pg}) \times \frac{\text{total number of stars brighter than } m_v \text{ from } b=0^\circ \text{ to } 9}{\text{corresponding number for } m_{pg}} \quad (2)$$

This conversion is more incorrect at higher galactic latitudes, since most of the bright stars are counted near the plane of the disk and stellar type (i.e., color) changes systematically with Galactic latitude.

The net discrepancy is unexpectedly large ($\geq 40\%$) between, on the one hand, either the modern star counts in V (Weistropp 1972, 1980) or the older Seares et al. (1925) data as reduced in paper I, and, on the other hand, the star densities tabulated by Allen (1973). In order to illustrate where in the analysis of Allen the errors appear to have originated, we divide the

transformation into several steps. For specificity, we consider the star density in the Visual band at 14th magnitude for which Allen cites 102 stars deg⁻². Part of the error appears to result from the different manner in which Allen combined each of the three (tabulated) quantities needed in equation 2 from his two sources¹. If we apply Allen's transformation (equation 2) to just the Seares et al. data alone, we obtain 94 stars deg⁻². (Van Rhijn tabulates only 2 of the 3 quantities, so it is not possible to perform the Allen transformation solely with his data.) If the band transformation is calculated using the correct color equation described in Seares et al., the density further decreases to 82 stars deg⁻². Finally, if the magnitude corrections of Stebbins, Whitford, and Johnson (1950) are applied to the Seares et al. data (as in paper I), we obtain 71 stars deg⁻² brighter than 14th Visual magnitude in the direction of the Galactic pole. Weistroop counted 73 stars deg⁻²; the Bahcall-Soneira Galaxy model predicts 70.4 stars deg⁻² brighter than V = 14. Hence, it appears that Allen's result can be accounted for by 3 systematic errors, each of order 10%, that add "fortuitously" in the same direction.

¹ See Table 2.

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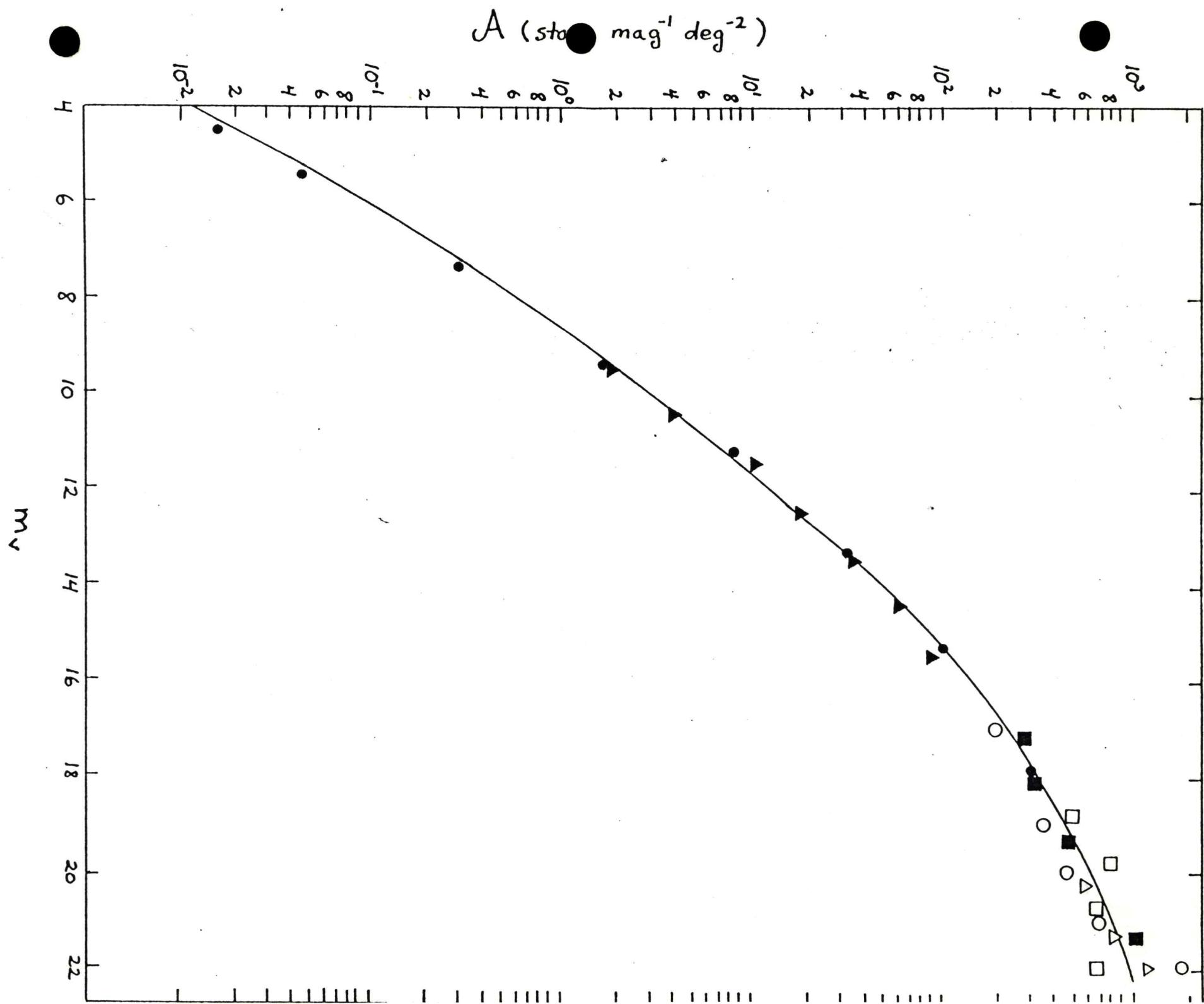
^a Reduced to the Visual band in paper I.

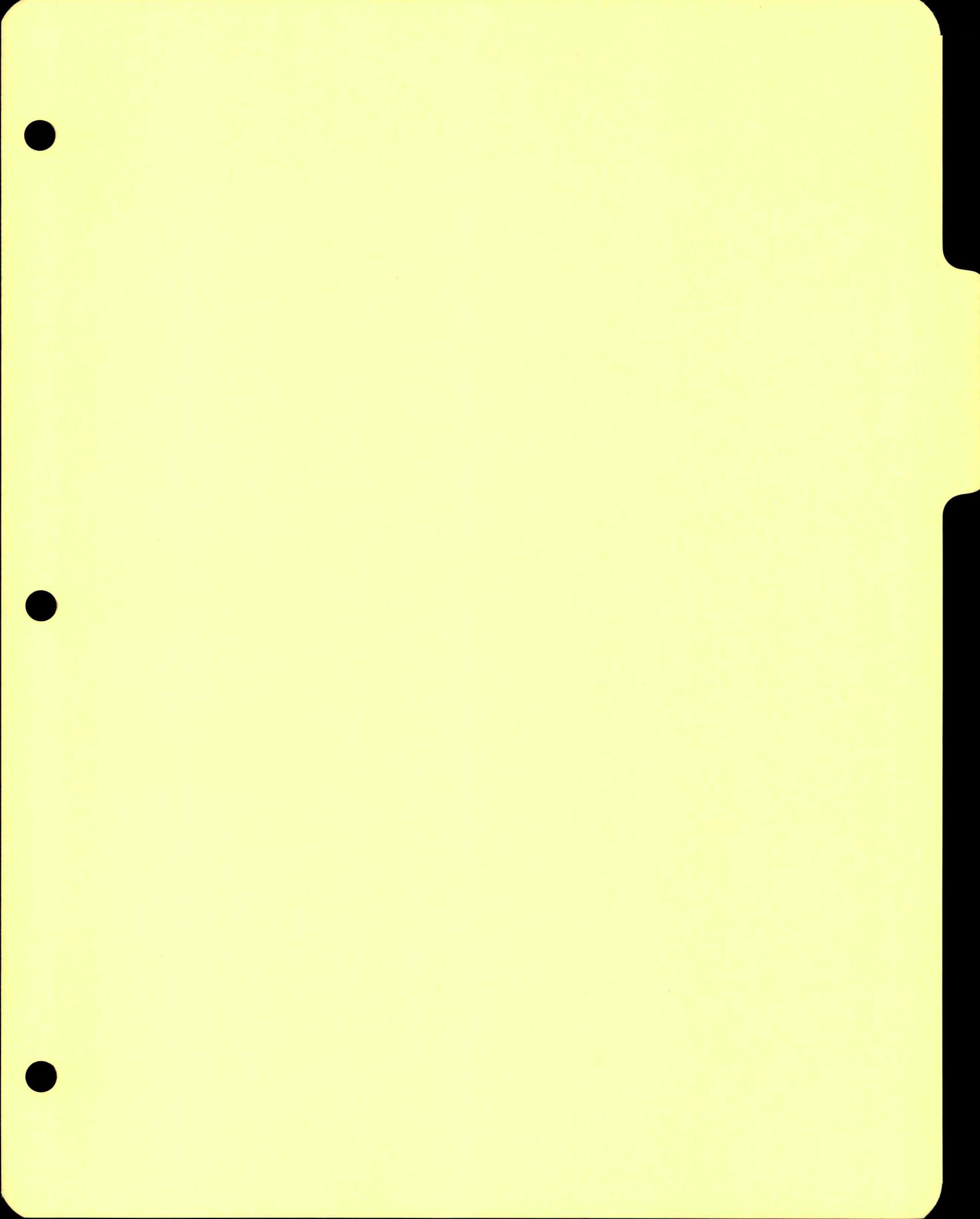
TABLE 2. STAR DENSITY DATA

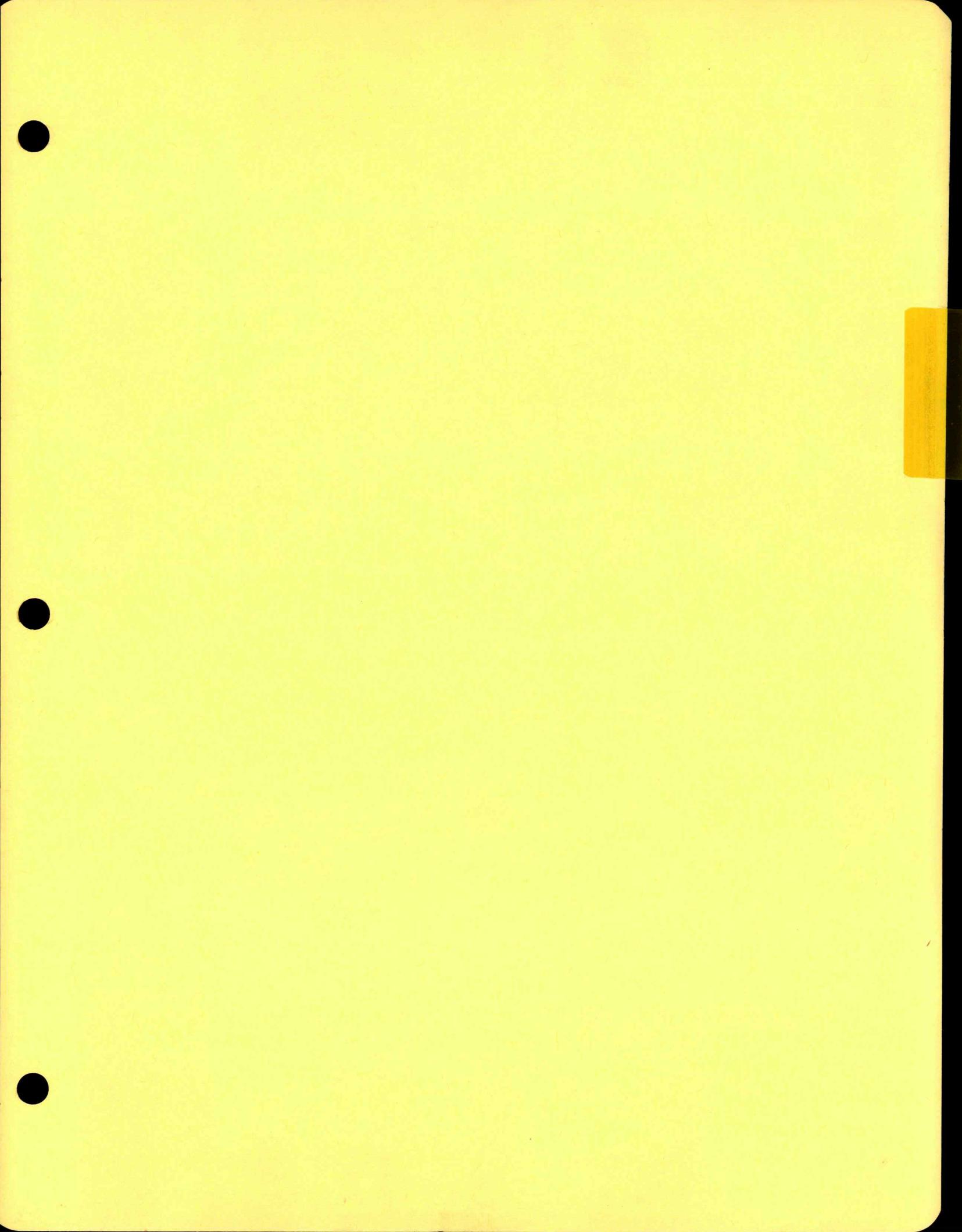
m	$\log [\mathcal{N}_{pg}(90^\circ)]$			$\log [\mathcal{N}_{pg}(0^\circ-90^\circ)]$			$\log [\mathcal{N}_v(0^\circ-90^\circ)]$	
	Allen	Seares <u>et al.</u>	van Rhijn	Allen	Seares <u>et al.</u>	van Rhijn	Allen	Seares <u>et al.</u>
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CAPTION FOR FIGURE 1

Differential star densities \mathcal{A} per magnitude per square degree for the Galactic pole. The solid curve is the density predicted by the standard Galaxy model of paper I assuming no obscuration at the pole and including a separate contribution from giants (see text). Data from Seares et al. (1925) as reduced to the Visual-band in paper I are plotted as filled-circles, data from Weistroop (1972) are plotted as filled-triangles, data from Brown (1979) corrected to the pole (see paper I) are plotted as filled-squares, data from Kron (1978) are plotted as open triangles, data from Tyson and Jarvis (1979) are plotted as open circles, and data from Peterson et al. (1979) as squares. For magnitude system conversions, see paper I.







50.01

S.O.W. MISSION
MNGMT.

TECH. APPROACH

TECH. PROPOSAL
MISSION MANAGEMENT

