Chapter 10

FGS Data Structures

In This Chapter...

This chapter describes how to identify and interpret the contents of FGS data files. An FGS dataset received from the Archive contains information from all three FGSs, plus some supporting data on the spacecraft itself. These files arrive in FITS format and need to be converted to GEIS format as described in Chapter 2 before processing.

10.1 Engineering Telemetry Data

The FGS is unique among HST's science instruments in that its data downlink is carried on the engineering data stream rather than the science data stream. FGS data are transmitted with the engineering data because the FGSs are controlled by the spacecraft's housekeeping computer, consistent with their primary role as part of the pointing control system. While the contents of the downlink for the other science instruments depend upon the specifics of that instrument, the contents and rates of the FGS data are determined by the engineering telemetry format.

The fundamental FGS data of interest for astrometry and guiding are:

- The photon counts from the four photomultiplier tubes.
- The instantaneous values of the two Star Selector servo angles.
- The twelve status flag bits.

The first two items are sampled every 25 msec, while the status flag bits are reported every 150 msec for the FN format (100 msec for HN). Additional FGS mnemonics present in the telemetry either can be reconstructed from those listed above or are of interest only to the system engineering staff.

When an FGS is operated as an astrometer, the Astrometry and Engineering Data Processing (AEDP) system, part of HST's ground support system at Goddard Space Flight Center (GFSC), extracts specific FGS mnemonics from the engineering telemetry and builds the astrometry data products. These are similar to the GEIS format files produced for the other science instruments (see Chapter 2 for more on GEIS file format). This system also accesses the Mission Support Schedule (MSS) and inserts additional information into various header keywords necessary for proper identification and interpretation of the associated data files.

As of late November 1997, generation of the astrometry data products will become the task of OMS's AST subsystem at STScI. The Astrometry and Engineering Data Processing system will then be phased out.

10.2 FGS Astrometry Files

Each FGS astrometry observation generates header and data files (`.a*h/.a*d`) for all three FGSs whenever any one FGS, generally FGS 3, is used as an astrometer. The contents of the data files for the guiding FGSs, generally FGS 1 and 2, record the photometry and positions of the two guide stars. The contents of the header files contain both information common to all FGSs and information specific to the FGS associated with that file, such as the values assigned to uplinked control parameters.

File Description

The data from the FGS mnemonics included in the astrometry subset are extracted from the telemetry stream and organized into groups. The data are grouped by type and mnemonic (e.g., group 5 contains the positions of star selector A). The GEIS data file for a given FGS contains 17 groups of data of which only seven are of interest for astrometry science data processing. The other ten groups continue to exist for traditional and historic reasons. We anticipate that later versions of the OMS AST subsystem will generate data files with only the necessary seven data groups.

Each individual FGS astrometry observation produces one GEIS header and data file pair for each of the three FGSs. A typical FGS POSITION mode observing sequence or *visit* consists of an HST orbit filled with observations of several stars, usually the science target and a few reference stars. Therefore, each visit will yield a number of GEIS file sets for three FGSs, each set corresponding to an observation of an individual star. These file sets contain all the FGS tracking and photometry data from the time interval when the specific observation was made.

The rootnames of FGS data sets adhere to the IPPPSSOOT convention described in Chapter 2. The first letter is always an F, identifying the file as FGS data, and the last letter is an M, indicating that the data were merged real time and tape recorded. For example, an FGS observation might be named `f42n0203m`. If

5 individual FGS observations were made in this hypothetical visit, their rootnames would be f42n0201m, f42n0202m, f42n0203m, f42n0204m, and f42n0205m. The 02 in each case is the visit number, which is important to note because all observations from a given visit must pass through the data reduction pipeline together (see Chapter 3). The two digits following the visit number give the observation numbers, in the sequence they were obtained.

For each observation, there should be six files, one header-data pair for each FGS. Data from the first observation will appear in the following files

Header	Data	Sensor
f42n0201m.a1h	f42n0201m.a1d	FGS 1
f42n0201m.a2h	f42n0201m.a2d	FGS 2
f42n0201m.a3h	f42n0201m.a3d	FGS 3

In this example, if FGS 3 is the astrometer and measures the position of a star in exposure id = F42N0201M, then the f42n0201m.a3h and f42n0201m.a3d files contain the astrometry data. The guide star data gathered during this astrometry observation are recorded into files f42n0201m.a1h, f42n0201m.a1d and f42n0201m.a2h, f42n0201m.a2d for FGS 1 and FGS 2 respectively.

Group Structure and Group Contents

Each data file contains the same number of data groups (17) and each group is of the same size, having the same number of samples. The duration of the observation and the rate of the most frequently read out mnemonic determine the sizes of the groups for a particular observation (the photon counts and star selector positions are readout 40 times per second). If an observation spans 100 seconds, then each data group will have:

$$100 * 40 = 4000 \text{ samples}$$

Some groups, such as the flags/status bits group, are readout less frequently (once every 150 msec). In this situation the valid data are packed from the beginning and the remaining 5/6 of the group is padded with fill data.

For FGS astrometry science data processing, the groups of interest in each GEIS data file are groups 1 through 6 and group 17. Table 10.1 lists the contents of these groups. :

Table 10.1: Groups in FGS GEIS Files

Group	Contents	Description	Sample Period
1	PMTXA	Photon counts, channel A, *x*-axis	25 msec
2	PMTXB	Photon counts, channel B, *x*-axis	25 msec
3	PMTYA	Photon counts, channel A, *y*-axis	25 msec
4	PMTYB	Photon counts, channel B, *y*-axis	25 msec
5	SSENCA	Star selector A encoder position	25 msec
6	SSENCB	Star selector B encoder position	25 msec
17	FLAGS/STATUS BITS	Indicates specific activity of FGS	150 msec

Groups 1 through 4 contain the photometry data for the 5" x 5" patch of sky observed by the FGS. If the FGS is guiding and tracking its guide star, then it registers the photon counts from the guide star. If the FGS is operating as an astrometer, there will be an astrometric target in its instantaneous field of view (IFOV) only after the IFOV has slewed to the target's position and the FGS has successfully acquired the star. While the slew is underway, the FGS records the sky background and serendipitous field stars. These background data are used in the data reduction pipeline.

Groups 5 and 6 record the position (to 0.6 mas) of the IFOV in the FGS's pickle and therefore in the HST focal plane. If the FGS is guiding, the measured position of the guide star is fed into the Pointing Control System so that the spacecraft's pointing can be maintained or corrected. These guide star data are used in the pipeline processing discussed in Chapter 11.

The flags/status bits group records the value of the 12 flags and indicators, each of which is a single bit which is either set (=1) or not set (=0). If the FGS is guiding and is tracking its guide star in FineLock, then the FineLock, DataValid, and Star Presence flags will be set (=1) and all others not set (=0). The astrometer FGS will display a sequence of flags/status bits settings which reflects the current activity of the FGS. If the FGS is to be operated in POSITION mode, then the following sequence of flag/status bits would be displayed for a successful acquisition:

Table 10.2: Status/Flag Bits

SSM	SR	CT	FL	DV	SP	Action
ON						Slewing the IFOV to star's location
	ON					Begin spiral search for star
	ON				ON	Spiral search located star
		ON			ON	Star detected, begin CoarseTracking
		ON		ON	ON	CoarseTracking successful
			ON		ON	Attempt FineLock acquisition
			ON	ON	ON	Tracking star in FineLock

The flags and status bits have the following meanings when set to 1:

- ***SSM***: FGS under control of DF 224 computer.
- ***SR***: FGS in autonomous (FGE) control, performing a spiral search .
- ***CT***: FGS in CoarseTrack mode.
- ***FL***: FGS in FineLock mode, if DV=0, then in WalkDown phase, if DV=1, then tracking in FineLock.
- ***DV***: CoarseTrack or FineLock was successful.
- ***SP***: Star presence, photon counts summed from all four PMTs fell within the commanded range (LOCOUNT < PMTSUM < HICOUNT).

When determining the position of an astrometric object observed in FineLock, the data of interest to the astrometry pipeline are:

- The slew to the star's expected location (provides background data).
- The WalkDown to FineLock (provides critical PMT data to better locate interferometric null) and to support FGS photometry.
- The FineLock tracking of the object (provides the FGS's measured location of star in focal plane).

More details on interpreting and making use of the FGS data are provided in the sections "Plate Overlays" on page 13-3 and "Resolving Structure with TRANSFER Mode" on page 13-5.

FITS Header Keywords

The GEIS header files for FGS data contain keywords that will help to interpret the data files. The most important keywords contained in the header files are:

```
NAXIS    :    number of dimensions in the data file (=1 of FGS)
NAXIS1   :    number of samples (or pixels) in each data group
GCOUNT   :    number of groups in the data file (=17 for FGS)
BITPIX   :    bits/pixel (=32 for FGS)
DATATYPE:     datatype (= 32 bit integer for FGS)
FGSID    :    identifies astrometer FGS
FGSNO    :    identifies FGS associated with this header file
```

```
PASTMODE:    observing mode, POSITION or TRANSFER
AUTOS   :   actual start time of observation (Universal time)
PRAV1   :    predicted right ascension of HST's V1 axis
PDECV1  :    predicted declination of HST's V1 axis
PROLLV3 :    predicted roll orientation of HST
PRATGT  :    predicted right ascension of target
PDECTGT :    predicted declination of target
PX_POS  :    HST state vector (position and velocity) at
PY_POS  :    beginning of observation (at PUTOS)
PZ_POS  :
PX_VEL  :
PY_VEL  :
PZ_VEL  :
CAST_FLT:    filter used for the observation.
```

The values assigned to these keywords are used in the calibration pipeline processing discussed in Chapter 11. To print an entire header to the screen, you can use the IRAF **imheader** task as in the following example:

```
cl> imheader f42n0201m.a1h long+ | page
```

10.3 Relationship to Phase II Request

Associated with each astrometry observation is the Support Schedule file, with suffix `.dmh`. This product is generated at STScI by the Science Planning and Support System (SPSS). It is a GEIS header file with no associated data file. Contained within are keywords and values which repeat some of the information in the FGS header files, such as the HST state vector. More importantly, the contents of this file can be used to map a specific FGS observation to the proposal's Phase II exposure log sheet. The proposal ID, PI identifier, target name, proposal type, proposal title, and exposure logsheet line are among the entries. The only keyword used by the astrometry pipeline is the value of DGESTAR to determine which guiding FGS was tracking the dominant guide star. Observers should review the contents of both the `.a3h` and `.dmh` files, which can be done using **imheader** as above.

10.4 Jitter Files

Since about October 1994 the Observatory Monitoring System (OMS) has been populating the STScI data archives with the Observation Logs (see Chapter 2 and Appendix C). They are of secondary use for the processing of FGS astrometry data because the guide star data are directly available to the astrometry pipeline. The item of interest in the `*.jih` file is the OMS computed HST roll angle. Recall that the `.a*h` header files contain the predicted roll angle. The details of how the telescope is pointed on the sky reveal that the roll angle is not set by the pointing control system using FGS data, rather it is set using less accurate fixed head star tracker data. Whatever roll angle results is then maintained by the roll guide star. OMS uses the FGS data, guide star RA, Dec, and HST/FGS alignment matrices to compute the actual roll of the telescope, which can differ from the predicted roll by as much as 0.4 degrees. The more accurate OMS roll angle is best used for the final computation of astrometric parallaxes and binary star position angles.

See the OMS documentation on the Web where the accuracies of roll calculation, etc. are discussed. The URL is:

```
http://www.stsci.edu/ftp/instrument_news/Observatory/
taps.html
```


10.5 SMS Support Data

The FGS is unique among the science instruments onboard HST in that its total field of view (the pickle) is large and therefore sensitive to the effects of differential velocity aberration (DVA), the field-dependent shifts of star positions owing to the telescope’s component of motion in the direction it is pointing. It is possible to maintain the pointing of HST so that the effects of DVA can be compensated for, but only at one place in the focal plane—the *alignment point*. Because typical FGS astrometry programs measure the relative positions of stars spread widely throughout the pickle, there can be at most only one star that will not suffer from DVA. Although this effect is potentially large, up to 20 mas, it is relatively simple to correct for this aberration. The algorithm requires HST's V1 pointing, V3 roll, and state vector, all obtained from the `.a*h` header files, plus the specification of the alignment point. The alignment point data for all FGS observations are stored in a reference library maintained by the STScI FGS staff. The data originate from the Science Mission Schedule (SMS) and are automatically extracted and entered into this library. The astrometry pipeline accesses this library when the differential velocity aberration connection is made.