FOS Cycle 6 Calibration Plan

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ABSTRACT

This instrument report describes in detail the FOS Cycle 6 calibration program in terms of objects and planned observations. Cycle 6 will be the close-out of the FOS, which determines the timing of the FOS calibration measurements. No special calibrations will be performed. Thus, in Cycle 6 we expect to maintain the routine calibration status of the instrument. The total spacecraft time required for the calibration program will be 75(93) orbits of external time and 128 orbits of internal occultation/parallel time. The number of external orbits will depend on the evaluation of a Cycle 5 test to check whether close-out aperture throughput measurements will be necessary.

1. Overview

All characterizations of the FOS performance which have been specifically requested by Cycle 6 GOs can be accommodated as part of several monitoring programs. Therefore, there is no urgent need for special calibration programs.

The routine monitoring proposals are designed to monitor those aspects of the FOS performance that are known to show time variations. The focus test is conducted only once during the cycle, because we know that the variations in the FOS focus are not large and do not affect the photometric accuracy of the data dramatically. The high voltage settings for the diode arrays are also checked once a cycle. Since the FOS detectors are affected by external magnetic fields the location of spectra on the photocathode and the FOS internal background observations will be conducted once every month. Similarly, the stability of the internal wavelength calibrations will be checked once every month. Some FOS detector/disperser combinations have shown temporal variations in their flat field structure during previous cycles. Hence, the spectral flat fields for both FOS blue and red will be calibrated once during the cycle. The absolute photometric calibration of some spectral elements has shown some temporal variations during Cycle 4. We will continue monitoring these aspects of the FOS sensitivity frequently. Flat field and photometry observations are closely coordinated to eliminate duplications as certain photometric observations provide serendipitous flat fields and vice versa. An overview of the calibration plan is given in Table 1. Tables 2 and 3 list which detector/disperser combinations are calibrated. Shaded areas depict those that will be done in Cycle 6.
A summary description of each program is given that includes proposal number, primary targets (if any), detectors, apertures and spectral elements used. A description of target acquisition techniques if required is also given. Also provided are the scientific justification, a description of the observations and the calibration accuracies expected.

Table 1: FOS Cycle 6 Calibration Plan

ID	Proposal Title	Frequency (per cycle)	Estimated Time (orbits) "External"	Estimated Time (orbits) "Internal"	Required Resources (FTE)	Products	Accuracy	Notes
Routine Monitoring Programs								
6910	Focus, X-Pitch, Y-Pitch	1	4		0.05	IMDB		Execute mid cycle.
6911	Discriminator Test	1		4	0.05	IMDB		Execute mid cycle.
6912	Dark Monitoring	7		28	0.1	CDBS	10%	Execute each set once every month
6913 & 6914	Ybase Monitoring and Internal Wavelengths	7		96	0.2	PDB and CDBS	15-25 ybase units and 0.1 diode	Execute once every month. The ybase accuracy is detector dependent.
6916	Photometric Calibration	2	28 (46)		0.1	CDBS	3-10%	Only certain spectral elements will be monitored. The accuracy is aperture dependent.
6915	Spectral Flat Field Calibration	1	24		0.15	CDBS	2%	Only certain spectral elements will be monitored.
6918	Internal External Offset	1	19		0.25	CDBS	0.2 diodes	Internal/external wavelength scale offsets
TOTAL TIME (including all executions)			75 (93)	128	0.90			

Table 2: FOS/BL Cycle 6

	G130H	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
4.3	F	F	F	F	***S***		F		F
1.0	F	F	F	F	S		F		S ***F***
0.5	***S***	***S***	***S***	***S***					
0.3	λ_e F	λ_e F	λ_e F	λ_e F	λ ***S***		λ ***F***	λ	λ
0.25x2.0	***S***								
1.0-PAIR	F	F	F	***F***			F		S
0.5-PAIR		***S***	***S***				***S***		
0.25-PAIR	λ ***S***	λ ***S***	***S***	***S***	λ		λ F		
0.1-PAIR			λ	λ				λ	λ
2.0-BAR									
0.7x2.0-BAR									

Table 3: FOS/RD Cycle 6

	G130H	G190H	G270H	G400H	G570H	G780H	G160L	G650L	PRISM
4.3		F	F	F	F	***S***	F	F	***S***
1.0		F	F	F	F	F	F	S	S
0.5		***S***	***S***	***S***	***S***			***S***	***S***
0.3		λ_e F	λ_e F	λ_e F	λ_e F	λ_e ***S***	λ ***S***	λ S	λ S
0.25x2.0		***S***	***S***	***S***	***S***				
1.0-PAIR		F	F	F	F	***S***	F	S	S
0.5-PAIR		***S***	***S***					***S***	
0.25-PAIR		λ F	λ F	***S***	***F***	***S***	λ S	***S***	λ
0.1-PAIR				λ	λ	λ		λ	
2.0-BAR									
0.7x2.0-BAR									

Shaded areas indicates detector/disperser combinations used in Cycle 6 GO programs.
λ: planned internal source wavelength calibration ONLY; λ_e: planned external source and internal source wavelength calibration; **F**: planned flat field calibration; *S*: planned photometric (inverse sensitivity) calibration; ***BOLD-ITALICIZED-UNDERLINED***: contingency calibration in Cycle 6 plan

Proposal ID 6910: FOS Cycle 6 Focus, X-pitch, Y-pitch

Plan

Purpose: A good instrumental focus is the first stage of the data acquisition process and thus impacts all FOS observations. The observations in this proposal will be used to verify the focus, X-pitch, Y-pitch and determine their stability throughout the cycle, since the FOS focus is sensitive to external magnetic fields.

Description: The FOS focus will be determined by obtaining spectra with the 0.1-PAIR aperture, G190H, and the Pt-Ne lamp at various voltages until the maximum voltage is 23.86 kV (blue detector) or 22.8 kV (red detector). Once an optimal HV setting for the focus is determined and updates made to the PDB, a series of spectra at three different X-Bases will be made to determine the corresponding X-Pitch. Additionally, measurements with the TALEDs through the 0.1-PAIR aperture will be used to determine the Y-Pitch. This program may result in an instruction flow change to the detector high voltage setting, the X-pitch value, and the Y-pitch value. The focus will be checked once in this cycle for both FOS detectors.

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 4 orbits

Analysis: 0.05 Full Time Employee (FTE)

Special Requirements: These observations MUST occur during non-SAA impacted orbits. Although this program uses the internal lamp, the observation sequences require NON INT exposures; therefore the test requires pointed external time.

Accuracy: The observations are to verify that the FOS focus has not changed. Thus this proposal aims to maintain the present FOS focus. Small changes in the FOS focus do not affect the photometric quality of the data dramatically.

Products: The analysis will require about 15 days and may lead to an Instructional Management Database (IMDB) update which will occur within one month of the observations. There are no reference files to be delivered. Results of this test will be described in an Instrument Science Report (ISR) within a month of the final analysis.

Proposal ID 6911: FOS Cycle 6 Discriminator Test

Plan

Purpose: Noise and gain are known to be temperature sensitive, and it is therefore likely that some fraction of the channels will experience some change in their optimal discriminator settings on orbit. Hence, the stability of these settings has to be verified. The observations in this proposal will be used to measure the high voltage settings for each diode.

Description: The FOS high voltage will be brought to approximately one-half the nominal operating voltage followed by a 60 seconds wait to allow the high voltage to stabilize. Then observations of the INTFLAT lamp will be obtained.

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 4 occultation/parallel orbits

Analysis: 0.05 FTE

Special Requirements: The detector high voltage will be set to a non-nominal value. Overlight protection will have to be disabled.

Accuracy: If the diodes are not maintained at their optimal high voltage settings, the resultant data tends to look like a noisy diode and compromises the observations. Thus this test is conducted to verify the discriminator settings for each FOS diode.

Products: The analysis will require about 1 month and will lead to an IMDB update which will occur within two months of the observations. There are no reference files to be delivered. Results of this test will be described in an ISR within a month of the final analysis.

Proposal ID 6912: FOS Cycle 6 Dark Monitoring

Plan

Purpose: The FOS is affected by the geo-magnetic field and thus the instrumental background needs to be properly quantified. The error due to an incorrect background file is insignificant in the case of strong sources (number of source counts ≥ number of background counts), but causes substantial errors in the derived flux and spectral shape of weaker sources (number of source counts < number of background counts). The observations in this proposal will be used to measure the internal background as seen by the FOS, as a function of position on the sky, the South Atlantic Anomaly (SAA), and electromagnetic interference (EMI) sources. These data will also allow us to verify the instrumental noise, the derived limiting magnitude, and enable us to determine which channels should be disabled.

Description: In this program measurements of the instrumental background (dark) will be obtained as internal observations with the FOS in the standard IMAGE mode. The visits in this program have been structured into groups no longer than approximately 30 minutes to facilitate scheduling as interleavers in occultation. The complete program can be scheduled as an interleaver observation and should be repeated every month during the cycle for both FOS detectors.

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 28 occultation orbits. We would require 8 additional occultation orbits if servicing mission should be delayed.

Analysis: 0.1 FTE

Special Requirements: The observations in this program consist of seven sets of four exposures per epoch. An individual set of exposures is specified to be grouped WITHIN 4 DAYS; all observations in such a set should be scheduled on the same calendar, if possible.

Accuracy: We will maintain the accuracy achieved in previous cycles (10%) and hope to improve the background determination to an accuracy of 5%.

Products: The analysis for this program will require about three months. A CDBS update will occur within three months of the final observations if required. There are background reference files (CCS8, BACHFILE) to be delivered. Results of this test will be described in an ISR within a month of the final analysis.

Proposal ID 6913 and 6914: FOS Cycle 6 Location of Spectra and Wavelength Calibration *Plan*

Purpose: The observations in this proposal will be used to monitor both the Y location of spectra and the wavelength scale for all reasonable aperture/disperser/detector combinations. This proposal has the highest priority because our ability to acquire spectra and minimize photometric calibration errors depends on our knowledge of Y-base values.

Description: Two separate monitoring programs (Part 1: location of spectra, and Part 2: internal wavelength calibration) have been combined to minimize the number of turn on and off of the internal calibration lamps.

Part 1: The primary objective of the first part of this proposal is to determine and monitor the Y-base measurements corresponding to the Y-location of spectra for each aperture/disperser/detector combination every month, using the 0.3" aperture and the internal Pt-Ne lamps and TALEDs. The observations will map the face of the photocathode using 24 y-steps and 1 x-step. Although the ideal technique is to obtain Y-base maps for each aperture/disperser/detector combination, the amount of time to perform such measurements is prohibitive. Hence, Y-base maps will be obtained to determine the locations of spectra and the coarse aperture location for the 0.3" aperture for all grating settings in both FOS detectors. Y-bases for all other apertures will be measured once with the G190H or G400H gratings to determine the location of spectra for the single and paired apertures and both detectors. The small number of observations should suffice and the difference in the location of the spectra should be solely due to the offset of single versus paired apertures. This test has to be conducted once every month because previous cycles have shown that the Y-locations of the spectra have drifted with time.

Part 2: The second part of this proposal is to monitor the stability of the FOS wavelength scale. ACCUM mode measurements of the Pt-Ne lamp will be obtained with both FOS detectors for all standard gratings with the 0.3" circular and either the 0.1" or 0.25" paired apertures. The observations taken through the smallest circular (0.3") aperture will be used to determine accurate wavelength scales for all disperser/detector combinations. The WAVECAL lamp has a fairly constant output, so that these data are a secondary monitor of any changes in the FOS internal sensitivity.

The visits in this program have been structured into groups no longer than approximately 25 minutes to facilitate scheduling as interleavers in occultation. It is necessary to conduct this program many times during the cycle since we know from previous cycles that the Y-location of the spectra has drifted with time, and to check the stability of the FOS wavelength scale. The complete program can be scheduled as an interleaver observation and should be repeated every month for a total of 96 occultation periods. Separate proposals are submitted for the FOS red detector (6914) and for the FOS blue detector (6913).

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 96 occultation orbits. We would require 32 additional occultation orbits if servicing mission should be delayed.

Analysis: 0.2 FTE

Special Requirements: None

Accuracy:

Part 1: The Y-locations of the spectra on the photocathode affect both the binary acquisition strategy and the FOS photometric accuracy. The scatter in the location of the blue side spectra seems to be time dependent and the 1σ accuracy we hope to achieve is $\pm$ 10 YBASE units. The scatter in the location of spectra on the red side is random and the 1σ accuracy we hope to achieve is $\pm$ 20 YBASE units. These accuracies will allow a 1σ binary acquisition accuracy of 0.08″ for the FOS/BL detector and 0.12″ for the FOS/RD detector. The photometric accuracy in the 4.3″ and the 1.0″ apertures is affected the most because the size of the aperture is $\geq$ to the size of the diode array and not all the photons in the point spread function are collected. Further, this is not a simple matter of losing a percentage of light, but the effect is also wavelength dependent. On average a YBASE uncertainty of 20 YBASES leads to $\leq$ 3% photometric uncertainty in the 1.0″ aperture. The loss could be larger for extended objects. Our accuracy requirement for this program is $\pm$ 15 YBASE units for the blue side, $\pm$ 25 YBASE units for the red side.

Part 2: The dominant error in the wavelength accuracy for a typical FOS spectrum is due to the filter grating wheel non-repeatability of the order of 0.35 diodes. FOS spectra have a limiting accuracy of 0.03 diodes, due to the non-linearity of the diode array, if there is no motion of the filter grating wheel. Our accuracy requirement for this program is 0.1 diode

Products: The analysis of Part 1 of the proposal will require about 2.5 months throughout the cycle. A PDB updates will be made at least once during the cycle and more often if required. There are no reference files to be delivered for the location of spectra part of the proposal. Results of Part 1 will be described in an ISR within a month of the final analysis. The analysis of Part 2 of the proposal will require about 2.5 months throughout the cycle. The analysis of the internal wavelength calibration will lead to an update of the Calibration Database System (CDBS). There are wavelength calibration reference files (CCS6) to be delivered. Results of Part 2 will be described in an ISR within a month of the final analysis.

Proposal ID 6915: FOS Cycle 6 Spectral Flat Field Calibration

Plan

Purpose: Some FOS detector/disperser combinations have shown temporal variations in their flat field and need to be monitored to achieve good FOS data calibration accuracy. This set of observations will produce additional flat field calibrations appropriate to the Cycle 6 time period.

Description: High S/N spectra will be obtained for G191-B2B, which has a relatively featureless spectrum and which has been the primary target for earlier flat field observations. There will be two visits using multi-stage peak-up acquisitions for excellent centering (0.04"). Flat field observations will be made through the 4.3", 1.0", 1.0-PAIR-A, and 0.3" apertures. All usable detector/disperser combinations will be calibrated. These observations also double as inverse sensitivity measurements and must be scheduled in the designated time period. On two other occasions three red side spectral elements will be monitored with the 1.0" aperture in the companion proposal 6916.

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 24 orbits

Analysis: 0.15 FTE

Special Requirements: It is imperative that these observations be scheduled in the requested fall 1996 time frame, in order to coordinate with all other FOS flat field and inverse sensitivity observations.

Accuracy: FOS superflats show that there are few strong features (greater than 5% deviation from unity). The typical flat field deviations are of the order of 1-2% about the mean value of unity. There may be some time dependence which needs to be quantified. The flat field corrections are only intended to remove photocathode granularity typically on the scale of 10 pixels or less. We expect to obtain accuracies of 2% deviation from the mean value of unity, while our goal is to achieve an accuracy of 1% deviation from the mean value of unity. Higher precision requires simultaneous flat field calibration observations, so that the science target illuminates the same portion of the photocathode as the calibration observations.

Products: The analysis will require about three months. A CDBS update will occur within 3 months after the final observations. There are flat field reference files (FLnHFILE) to be delivered. Results of this test will be described in an ISR within a month of the final analysis.

Proposal ID 6916: FOS Cycle 6 Photometric Monitor

Plan

Purpose: The observations in this proposal will be used to determine the absolute photometric calibration of both FOS detectors, and to determine the aperture throughputs. Many of the observations in this program also provide simultaneous flat fields, and determine the stability of the instrument.

Description: A measurement of the absolute sensitivity of both FOS detectors will be performed using the UV standard star BD+28D4211. All the highest priority gratings (6 blue detector and 8 red detector-grating combinations) will be used with the 4.3" and 1.0" apertures. To assure registration of the spectrum on the diode array, the stars will be observed at 3 Y-bases with an 8-10 micron separation. Most of the spectra will be obtained in the 4.3" and 1.0" apertures.

Depending on the results of a test in Cycle 5 (program 6202) of absolute throughput stability, aperture throughputs may be calibrated with all usable dispersers for the 4.3", 0.5", 0.3", 1.0-PAIR-A, and 0.25-PAIR-A apertures. This contingent calibration would require a total of 18 additional external orbits. A multi-stage peakup of the standard star should provide excellent centering (0.04").

Fraction of GO/GTO Programs Supported: 100%

Resources:

Observation: 28(46) Orbits

Analysis: 0.1 FTE

Special Requirements: None

Accuracy: The dominant error in the photometry is due to miscentering of the target in the aperture, and the aperture size. Other potential sources of error are (1) decline in the FOS sensitivity, (2) flat fields, (3) change in telescope focus, (4) location of spectra, (5) thermal breathing, (6) jitter, (7) GIM, and (8) calibration system offsets. The internal repeatability of the FOS is 1-2%. The photometric calibration of a typical FOS spectrum is accurate to ~3-10% for the large apertures, depending on the many factors given above, and progressively worse for the smaller apertures. We expect to obtain accuracies of 5% for the large apertures and 15% for the small apertures, while our goal is to achieve an accuracy of 3% for the large apertures.

Products: The analysis will require about one month. The CDBS update will occur within one month of the final observations. There are average inverse sensitivity reference files and tables (AISHFILE and CCSA, CCSB, CCSC, and CCSD) to be delivered. Results of this test will be described in an ISR within a month of the final analysis.

Proposal ID 6918: FOS Cycle 6 Wavelength Calibration: Internal/External Offsets

Plan

Purpose: The observations in this program will be used to determine the wavelength offsets between internal and external light sources.

Description:

Part 1: The observations in the first part of this proposal will determine the FOS wavelength scale for all commonly used disperser/detector combinations. In this test, we will obtain spectra of external and internal wavelength calibration sources, and compare the resulting channel versus wavelength relationships to search for any offset between the two. The external objects, as well as the internal Pt-Ne lamp, will be observed through the 0.3" aperture, in the standard FOS ACCUM mode. The primary velocity target, NGC 6833, has insufficient lines in the G130H spectral region, so a second target (HD 207757) is required for this grating. Both sources are observed with sufficient RED and BLUE spectral elements in order to place all observations on the same velocity system. Internal sources make up a small fraction of the exposure time and must be acquired at the same time as the external sources, so they can NOT be scheduled as parallel observations. Derived wavelength offsets can be applied to the polynomial fit of pixel number versus wavelength determined from the lines in the internal Pt/Cr-Ne lamp.

Part 2: The observations with GHRS will allow us to compare the FOS and GHRS wavelength scales. This part of the test will also determine the impact of light from wavelengths longer than 3000 Å scattered off the FOS UV gratings. HD 207757 will be observed with the FOS UV gratings, which will be compared with HRS Side 1 observations.

Fraction of GO/GTO Programs Supported: 100% of the programs will be affected by the wavelength calibration part of the proposal, ~60% by the scattered light measurements.

Resources:

Observation: 19 orbits

Analysis: 0.25 FTE

Special Requirements: For the wavelength calibration part of the proposal, the internal sources make up a small fraction of the exposure time and must be acquired at the same time as the external sources, so they can NOT be scheduled as parallel observations.

The filter grating wheel MUST NOT be moved between the external and internal observations. Internal Pt/Cr-Ne lamp observations must immediately follow each external observation.

Accuracy: The wavelength calibration accuracy is affected by the errors in the zero point of the wavelength scale. These offsets can be calculated to ±0.2 diodes for the FOS. In a typical FOS observation, which is not accompanied by a wavelength calibration, the wavelength error is dominated by the non-repeatability of the filter-grating wheel. The error is of the order of 0.35 diodes. In an FOS observation accompanied by a wavelength calibration, with no intervening filter-grating wheel motion, the limiting wavelength accuracy is roughly 0.1 diodes. We expect to obtain accuracies of 0.2 diodes, while our goal is to achieve an accuracy 0.1 diodes.

Products: The analysis will require about 2 months for the wavelength calibration. Wavelength offsets found between internal and external sources will need to be incorporated into the dispersion coefficients used by the PODPS pipeline. The analysis of the wavelength calibration data will thus lead to a CDBS update which will occur within 2 months after the final observations. There are wavelength calibration reference files (CCS6) to be delivered. Results of this analysis will be described in an ISR within two months of the execution of the test.