1. PREAMBLE

The purpose of this note is to describe the expected operational and calibration status of the Faint Object Camera at completion of Science Verification.

The FOC SV plan consists of 16 separate tests. It has been designed to accomplish a number of specific objectives which include: the location of the camera apertures and determination of the plate scale to facilitate modes I, II and III target acquisition; the acquisition of calibration data to support Routine Science Data Processing (RSDP, i.e. the pipeline); and the acquisition of data for non-routine FOC analyses such as polarization, speckle imaging and UBV photometry. In addition to meeting these goals, the SV plan has been designed to allow a thorough check-out of the overall scientific performance of the FOC and its operational status.

First, in §2, we describe briefly the individual SV tests. Next, in §3 and §4, we discuss the completeness and level of confidence in the operational performance of the FOC, and in §5 and §6 we detail the calibration status which is expected by the end of SV. The reader should be aware of two additional documents, the HST SV catalog SV-1020, released May 9, 1986, which contains a detailed description of the FOC plan, and an ST ScI ISB calibration report, issued Jan. 1986, which lists the correspondence between individual SV tests and the RSDP calibration files.

Finally, §7 gives an overview of the expected status of FOC after SV, for the reader in a hurry, or for future general observers who are not necessarily familiar with all the details given early but who need some information to help in their planning of HST observing programs. Such a summary may be useful, for example, for inclusion in a future ST ScI Newsletter.
2. THE FOC SV PLAN

The FOC SV plan is divided into two parts: the SV minimum plan - an agreed set of tasks that will be completed by the end of the SV period, and an SV delta plan - additional tests that may be accomplished if time is available. The 16 tests or activities that constitute the plan are:

1. (1505) Stability - tests geometric stability during the turn-on period,
2. (1506) Detector focus - optimizes the focus of both image tube and TV camera,
3. (1507) Optical Focus - checks optical focus, verification of filter thicknesses and parameter data base,
4,4 (1508, 1509) Linearity* - performance of detector for point source and flat field exposures at various illumination levels,
5. (1510) Plate scale/distortion - determines arcsec/pixel and scale of optical distortions,
6. (1511) Absolute Sensitivity* - measures f/96 sensitivity from 1215 to 5500 Å,
7,7 (1512) Background - determines particle and geocoronal radiation levels,
8. (1513, 1514) F/48 Spectrograph - sensitivity and wavelength calibrations,
9,9 (1515, 1516) Relative calibration* - determines spatial DQE with wavelength using flat fields,
10. (1517) Mode II target acquisition - tests on-board acquisition,
11. (1518) Visible photometry† - calibrates UBV photometric filters,
12. (1519) Objective prisms - determines offsets, sensitivity and wavelength calibrations,
13. (1520) PSF* - determines point spread function with wavelength, mainly f/288,
14. (1521) Polarization† - calibrates three polarizers in f/96,
15. (1522) Filter leak† - determines red leak of ultraviolet filters,

EXPLANATORY NOTES: The first column gives the FOC IDT number associated with each test. (The letter i indicates that the source is internal to the FOC. A number of these tests require both external and internal sources, hence the use of a dual numbering scheme.) The second column gives the corresponding ST ScI PEP catalogue number.

* lowest priority exposures are in SV delta plan.
† entire test in SV delta plan.
During the SV period, most of these tests will be executed for both f/48 and f/96 optical chains and for f/288 where appropriate. The SV timeline is being organized to allow observational work to take place on one detector at a time over a ∼2 - 4 day period, during which time the FOC will be the prime instrument. A number of the monitoring tests, especially 1 and 3, will be repeated during each on-cycle. Hence, data will be received in batches throughout the entire SV period.

3. OPERATIONAL CAPABILITIES OF THE FOC AT END OF SV

3.1.1 APERTURE LOCATIONS - The central locations (in SDS and V2, V3 coordinates), orientations, plates scales and vignetting functions will be established for both f/96 and f/48 apertures: determined initially in OV and then by SV FOC-5.

The locations of the f/96 coronographic fingers and f/48 slit-template will be established in both SDS and V2, V3 coordinates: determined initially in OV and then by SV FOC-16 (both f/96 and f/48) and SV FOC-8 (for f/48).

3.1.2 TARGET ACQUISITION - use and verification of modes I (fully interactive), II (on-board) and III (dead-reckoning).

3.1.3 MECHANISMS - use and verification of filters in f/96 and f/48 image modes,
- use and verification of f/48 spectrograph in both blocking-filter and echelette modes,
- use and verification of LEDs, both optical relays,
- use and verification of shutters, both optical relays,
- use and verification of mirror refocus mechanism, both optical relays.

3.2 CONFIDENCE LEVELS

By the end of the SV minimum plan, we have a high level of confidence that those items listed under 3.1.1 and 3.1.3 will be achieved. For FOC target acquisition (3.1.2) the situation is a little more complicated.

Recall that for the FOC we need to acquire targets in either the f/48 or f/96 large aperture or behind one of the f/96 coronographic fingers or on the f/48 slit. We expect to use mode III target acquisition for the large apertures and have a high level of confidence that this will have been achieved by the end of OV. Mode III will also be useful for placing extended sources on the f/48 slit, where precise location (i.e., on a scale of an arcsec, or
so) is not important, and we have a high level of confidence that this will be achieved in SV. We also have a high confidence level that mode I target acquisition will be achieved for both f/96 fingers and the f/48 slit by the end of SV.

Point-source, mode III target acquisition to the 0.8 finger has a high level of confidence of being achieved by the end of SV, and that for the 0.4 finger and f/48 slit a medium level confidence. Mode II target acquisition to the 0.8 finger has a medium level of confidence of being achieved by the end of SV, the 0.4 finger and f/48 slit a low level of confidence.

4. OPERATIONAL PARAMETERS OF THE FOC AT END OF SV

The following is a list of operational parameters that will be determined by the end of science verification.

4.1.1 Optimal detector-focus settings - to be determined in OV and repeated if necessary in SV FOC i2 - both relays.

4.1.2 Optimal optical-focus settings for filter imaging - to be determined in SV FOC 3, both relays.

4.1.3 Optimal Settings of LED Exposure Levels - to be determined in SV FOC 4.

4.1.4 Count rate limitations for point source and flat field exposures for both relays, and various camera formats - to be determined using SV FOC 4, i4.

4.1.5 Effect of SAA on FOC background levels, for both relays - to be determined using SV FOC i7.

4.1.6 Effect of ultraviolet airglow lines on FOC background levels, for both relays - to be determined using SV FOC 7.

4.1.7 Geometric stability of FOC relays after turn on - to be determined using SV FOC i1, and throughout a relay cycle, using repeated flat field exposures.

4.2 LEVEL OF COMPLETENESS

It is expected that all the necessary parameters will have been evaluated by the end of the SV FOC minimum plan, apart from item 4.1.4 above. This item will 75% complete by end of the minimum plan and 100% at the end of the delta plan.
5. CALIBRATION DATA REQUIRED TO SUPPORT RSDP

A description of the RSDP calibrations and their detailed relationship to the SV FOC plan is given elsewhere (ST Sci Instrument Science Report: FOC Calibration Report No. 9, Jan 1986). Here we list only the FOC RSDP reference files as defined by TRW and their expected level of completion at the end of SV.

The pipeline requires a total of eight different reference files, and their selection depends upon whether the FOC exposure is a normal or spectrograph image or a flat field calibration image. One correction, the intensity transfer function is expected to be turned off in the pipeline, although knowledge of the linearity of the instrument is needed for planning purposes.

5.1 BACKGROUND: the detector dark count - but expected to be dominated by the in-orbit background. Will be assessed by SV FOC i1, and i7; 100% complete at end of minimum plan. The background is expected to vary smoothly and slowly over the faceplate of the detector—hence the calibration files can be produced by averaging counts over many pixels. The expected error associated with such a file should be ~5% or less.

5.2 INTENSITY TRANSFER BACKGROUND: the linearity of the FOC. Will be determined by SV FOC i4 and i4; 75% complete at end of minimum plan, 100% by end of delta plan. For the pipeline, the plan requires the linearity to be determined for each individual pixel per image, and for different camera formats. The expected error associated with such a file will be ~10% or better. However, the current baseline is to publish details of the linearity in the handbook rather than use it as a correction in the pipeline. In this case the linearity will be deduced by averaging over many pixels and so can be established to ~1% or better. It is known, but not well studied, that the linearity of the FOC is very source dependent: for point source illumination it can achieve much higher count rates than for flat field illumination, perhaps by as much as a factor of 5–10.

5.3 FIRST UNIFORM DE: flat fields at different wavelengths. Will be determined by SV FOC i9 and i9; 25% complete at end of SV minimum plan, 50% by end of delta plan.

For wavelengths longward of 2000 Å, either Earth or on-board LED exposures will be used for both f/96 and f/48. However, shortward of 2000 Å a major difficulty is to find astronomical sources that are good flat fields and have adequate flux in the UV. SV test 9 is designed to search for such a field in Orion, using the f/48 detector and, if found, to take flat field exposures at 1400 Å (f/96 and f/48) and 1900 Å (f/96 only). The goal of the work is to obtain a total of at least ~1000 counts per wavelength interval. In the optical
and near UV the flat field images can be smoothed, but in the far UV (< 2000 Å) there is a lot of very fine structure preventing much smoothing. The expected error associated with such files should be ~5-7% in the optical and near UV and 10% or possibly worse in the far UV.

5.4 SECOND UNIFORM DE: the inverse sensitivity of each camera. Will be determined from SV FOC 6 for the f/96 relay and is expected to be 75% complete by end of the minimum plan and 100% by end of delta plan. Will be determined indirectly from SV FOC 8 for the f/48 relay, and will be 100% complete by end of SV minimum plan. (Further work beyond SV, using very faint standards established by HST, will subsequently be used to recalibrate the f/48 relay.) The expected error associated with such files should be ~10% for the f/96 relay, and 10-25% for the f/48.

5.5 GEOMETRIC DISTORTION CORRECTION: Will be determined by SV FOC 5 and i1; 100% complete by end of SV minimum plan. In the f/96 relay, geometrically-corrected FOC images of unsaturated, well-exposed point sources, taken closely in time with LED exposures for reseau calibration, should permit relative astrometry (i.e. positional measurements within the same image) to an accuracy of ~0.005 arcsec, excluding extraneous factors such as OTA jitter.

5.6 RESEAU: Can be established and monitored by all SV activities; 100% complete by end of SV minimum plan. Individual reseau positions should be located to within a 1/10 of a pixel i.e. ~0.002 arcsec for f/96.

5.7 RESEAU MARK MODEL: established by FOC i1, i4 and i9; 100% complete by end of SV minimum plan.

5.8 SPECTROGRAPH DE: the inverse sensitivity of the f/48 spectrograph, established by FOC 8; 100% complete by end of SV minimum plan. The expected error associated with such a file should be between 5% (visible and near UV) and 10% (far UV).

6. OTHER CALIBRATIONS EXPECTED TO BE AVAILABLE AT THE END OF SCIENCE VERIFICATION

Additional calibrations that lie outside the present scope of the pipeline process but which are required for the analysis of FOC images include,
6.1 Wavelength calibration of the f/48 spectrograph. Established by SV FOC 8, 100% complete at end of minimum plan. Wavelength uncertainty should be in the image of 15 km/sec.

6.2 UBV photometric calibration. Established by SV FOC 11, not in the minimum plan but will be accomplished in the delta plan. (Laboratory data on the filter transmission curves are available from the ground calibration, allowing a preliminary analysis of the characteristics of the photometric filters.) The goal of the calibration is to tie in the FOC broad band filters to the Johnson standard system to within 10% uncertainty. This goal is unlikely to be achieved by the end of SV given the many uncertainties in the calibration but should be achieved in the steady state.

6.3 Objective Prisms - wavelength and photometric calibration. Established by FOC 12; 100% complete at end of SV minimum plan. Prisms are rather crude spectroscopic devices, and are not intended to serve as precise spectrophotometric devices: expect errors of the order 25% or larger.

6.4 Point Spread Function. Established initially through tests such as FOC 6 (minimum plan), then by test FOC 13 (delta plan); 100% complete by end of SV delta plan. The goal is to establish the PSF to a high photometric accuracy (~3%).

6.5 Polarization capability. Established through test FOC 14. Not in SV minimum plan, but will be accomplished in the delta plan. The goal of the SV delta plan is to establish the polaroid orientations to within 10%. The instrumental polarization will be derived to an uncertainty of ~3% after SV.

6.6 Filter Leak Measurement. Test FOC 15 will help to confirm the values for the FOC filter red leaks. Not in SV minimum plan, but will be accomplished in the delta plan. (Laboratory data on the filter transmission curves are available from the ground calibration, allowing a reasonably detailed analysis of the filter characteristics.)

7. OVERVIEW

By the end of SV, both the f/96 and f/48 optical relays, along with the f/288 apodizer, will be commissioned and available to the general observer. If required, detector optimization will be performed early on in SV. During the SV phase, the overall stability of the detector and optical relay, and the sensitivity of the camera to background radiation will be assessed.
By the end of SV, mode III target acquisition for both point and extended sources will be available for the f/96 and f/48 apertures, and for extended sources for the f/48 slit—where precise positioning is not required. Mode I acquisition will be available to maneuver a target behind one of the f/96 coronographic fingers or onto the slit—where precise positioning is important. The reader should bear in mind that mode I is a fully-interactive target acquisition that is performed in real-time. It requires TDRSS support to allow both downlink and uplink commands, and presumably will be scheduled only on rare occasions. The alternative to mode I acquisition for placing objects behind the finger or on the slit is mode II—an on-board acquisition procedure. By the end of SV, there is a medium level of confidence that mode II target acquisition will be available for the 0.8 finger and a low confidence level that it will be available for the 0.4 finger or the f/48 slit.

There are two important calibrations that are required to allow GOs to assess feasibility of their programs and calculate accurate exposure times; these calibrations are linearity and absolute sensitivity. By the end of SV, the absolute sensitivity of the f/96 relay, including the f/288 apodizer, will be established to within ~10% over the wavelength range 1215–5500 Å; the sensitivity of the f/48 camera will be deduced from observations taken through the f/48 spectrograph, and consequently will have a larger uncertainty, ~10–25%, over the same wavelength range. By the end of SV, the linearity of the f/96 detector to point source and uniform illumination for most camera formats will be well established to within 5–10%. That for the f/48 detector will have to be bootstrapped to f/96 because the former does not carry attenuators.

Throughout the SV phase, data will be taken for use in production of the calibration reference files needed for RSDP processing. However, it is most unlikely that all the necessary files will be obtained, especially for the flat field correction which requires a uniform extended-source that is also bright in the ultraviolet. Additionally, the RSDP process, as currently designed, requires a very high degree of geometric stability of the instrument for precise registration of the astronomical image with the calibration image as well as for the geometric correction itself. Hence there is a low level of confidence that the RSDP process will yield fully geometrically-calibrated FOC data, by the end of SV.

Additional calibrations that will be available by the end of SV include a wavelength calibration for the f/48 spectrograph and a wavelength and photometric correction for the objective prisms. The point spread function for f/96 and f/288 at various wavelengths will be adequately studied by the end of SV. Calibrations of the Johnson U, B and V filters, and the FOC polarizing filters, are unlikely to be available by the end of SV. The Strömgren u, b, v and y filters are not being exercised in the SV plan.