Instrument Science Report WFC3-2004-02

WFC3 Science Calibration

Summary assessment of December 2003/January 2004 science verification/calibration campaign

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by

I. Neill Reid, STScI

ABSTRACT
We have completed the first set of science calibration tests of the UVIS channel of Wide-Field Camera 3. This document summarises the results of those tests, in terms of both the operational performance and the initial results on scientific performance.

1 Introduction

Wide-Field Camera 3 (WFC3) is scheduled to replace Wide-Field Planetary Camera 2 (WFPC2) during servicing mission 4 (SM4) to the Hubble Space Telescope (HST). WFC3 is in the final stages of assembly at Goddard Space Flight Center (GSFC). The Flight #1 detector has been installed in the UVIS channel together with the control electronics and most ancillary mechanisms, with the exception of the internal calibration sources. These mechanisms, including the camera, can be controlled using the Science Instrument Test System (SITS), providing the first opportunity to obtain full-system data to verify both the instrumental system performance for scientific purposes, and the operational performance of the data acquisition and analysis infrastructure. Since these measurements were obtained under ambient conditions, the detector cannot be cooled to the nominal operating temperature of –83 ^{o}C, and reaches only –74 ^{o}C. These test data are therefore unsuitable for deriving final calibration measurements.

Initially, the intention was to carry out the series of tests documented in the Wide-Field Camera 3 Mini-Calibration Campaign (MiniCal – seeWFC3 ISR 2003-12). However, alignment tests have shown that the detector is offset by ~1 millimetre from the desired location within the flight package, and will need to be re-aligned. As a result only a subset of the Mini-calibration tests were undertaken during this campaign. Nonetheless, the data obtained shed interesting light on system performance.

The scientific results from the tests carried out during the December '03/January '04 Mini-calibration campaign will be discussed in detail in a series of WFC3 SIPT Instrument Science Reports. This report summarises those results, but concentrates more on the operational performance. We give an assessment of lessons learned from this campaign, and discuss possible modifications and extensions of the test procedures for the MiniCal proper.

2 Test Protocol, Operation and Procedures

Figure 1 gives a schematic outline of the command structure and data flow during the December '03 Mini-Cal. The overall concept has been discussed elsewhere (e.g. The WFC3 Science Calibration Plan – WFC3 ISR 2002-07), but the details have undergone subsequent modification, so we provide a brief summary here.

WFC3 is controlled through the SITS, with the instrumental configuration (channel, filter, exposure time, gain, etc) defined either through real-time commanding or using a Science Mission Specification (SMS) procedure. The latter are constructed by the SITS group based on information provided by members of the Science IPT *via* an excel spreadsheet tool. If the test procedure requires use of the CASTLE Optical Stimulus, the appropriate CASTLE configurations are defined through a similar process: Science IPT members provide excel spreadsheets, generated using a custom-built tool, to the CASTLE operators, who use those data to build stimulus control scripts. The SITS and CASTLE are connected through an RIU link (SITS to CASTLE) that can transfer two commands:

1. Move to a new CASTLE configuration
2. Write out a CASTLE Snapshot file providing information on the CASTLE configuration (light source, fibre/flat field, wavelength, bandpass, etc).

The WFC3 data files and the CASTLE configuration file are written to disk, where they are available for access by a local Quick-Look inspection and analysis software system, which adds several parameters to the CASTLE snapshot file, and timestamps the datafiles. The Quick-Look operator maintains a log of the exposures, including comments gleaned from initial inspection. The data are entered in a local database, and are available for inspection by a member of the Science IPT.

The raw datafiles, including the OS snapshot, are transferred to a staging disk where they can be accessed for transfer to STScI. At STScI, the data are processed through the OPUS system, where the appropriate OS snapshot data are added to the header. The resultant files are both ingested into the STScI Data Archiving Distribution System (DADS), where they become available for general access after a period of 12-24 hours, and placed on a dedicated disk for shorter term access by WFC3 Science IPT and SOC members.

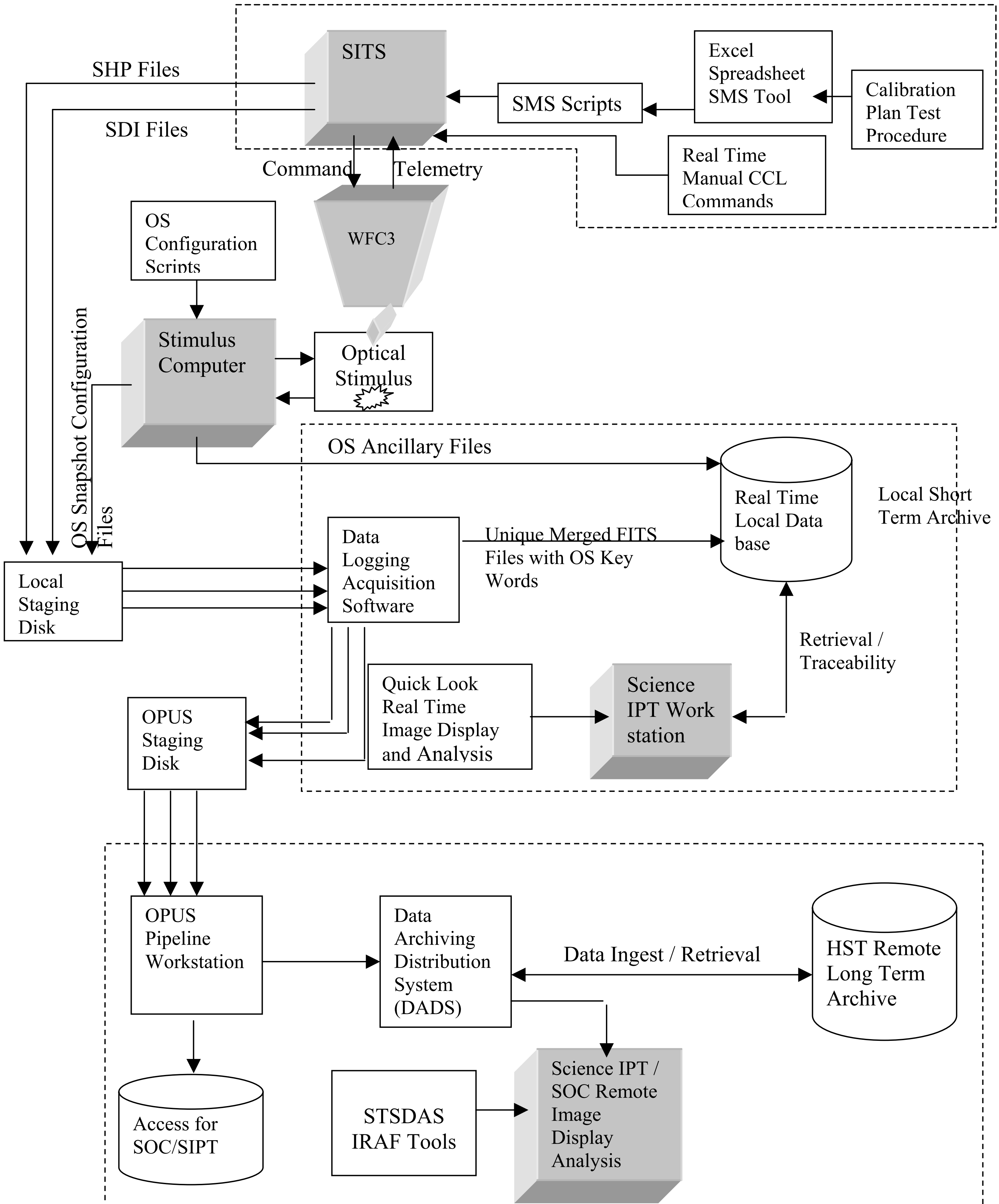

Figure 1: WFC3 Mini-calibration Data Flow

With a very few exceptions, all of the tests undertaken during this calibration campaign were run using SMS procedures rather than real-time SITS commanding. The majority of the SMSs were compiled and verified well in advance of the test campaign, but, in a few cases, new tests and new SMSs were designed in shorter timescales (less than 24 hours) in response to results from the initial tests.

Staffing levels during the December ’03 MiniCal were as follows:

- SITS operators – 2
- SMS production – 1 (B. McLaughlin)
- CASTLE operations – 2-3 (including B. Greeley)
- Quick-Look System - 1
- Science IPT – 1-2 (Reid/Hartig)

Other WFC3 Science IPT members were present intermittently during these tests, in particular, monitoring SITS operations from a separate console. All personnel were located in a section of Room 150.

The original schedule for the test campaign was as follows:

Day	**SMS**	**Procedure**	**PI**	**N_{exp}**	**Elapsed time**
0	VE00S01	Exposure time verification	Kutina/Reid	15	2.5 hours
1	VE07S01	Ghosts inside FOV	Hartig/Brown	48	3.4 hours
	VE07S01	Ghosts outside FOV	Hartig/Brown	40	3.4
	VE01S01	Darks and biases	S. Baggett	4	1.8
2	VE02S05	Image quality	Hartig	64	4.2 hrs
	VE03S01	Throughput – Broad- & medium-band filters	Reid	44	4.2
3	VE05S01	Broad- & medium-band filter flats	Reid	30	5.7 hrs
	VE04S01	System throughput	Reid	24	2.6
4	VE09S04	F218W bandpass measurement at UV12 (220-275 nm)	Reid	30	2.9 hrs
	VE09S05	F225W bandpass measurement at UV12 (220-275 nm)	Reid	30	2.9
	VE09S06	System throughput measurement at UV12 (220-275 nm)	Reid	30	2.9

Based on the initial results, the following modified or new test procedures were added to the campaign.

SMS	Procedure	PI	N_{exp}	Elapsed time
VE04S01A	System throughput	Reid	24	2.6 hrs
VE03S02	System/broadband throughput	Reid	13	1.3
VE05S02	Offset flat fields	Reid	15	1.8
VE07S03	Ghosts in F218W/F225W	Hartig/Brown	34	2
VE07S04	Ghosts in F300X/crosstalk	Brown/Baggett	25	2

The original test procedures are described in detail in the WFC3 MiniCal plan (WFC3 ISR 2003-12); additional test procedures are summarised in Appendix I. As discussed further below, VE04S01A differs from VE04S01 only in the inclusion of commands to dump data.
All measurements were made with WFC3 running on side 2 electronics.

3 Test Program and Results

A baseline set of science calibration measurements were obtained on 3 December 2003, to verify optical stimulus performance, and the first concentrated calibration campaign was undertaken from 10 December to 17 December 2003. Analysis of those data revealed two notable performance issues: bright ghosting in a limited number of filters; and low-level electronic cross-talk between the four CCD amplifiers. Additional calibration measurements to investigate those issues were obtained between 7 January 2004 and 23 January 2004. These included ghost measurements for all of the optical filters. The individual test programs are outlined in further detail below.

3.1 Verif00: Exposure time/CASTLE performance verification – VE00S01

The initial measurements in this calibration campaign were made 3 December 2003. As outlined in the appendix, this SMS is designed to verify, first, that the CASTLE flux levels and WFC3 throughput are in line with expectations, and hence confirm that the exposure times in the calibration SMSs are suitable; and, second, to verify that CASTLE moves between different configurations in the expected manner. This test includes point targets at UV, blue and red wavelengths; throughput measures with the 200-micron extended target; and flat fields taken with the deuterium lamps mounted directly on the integrating, and using the fibre-fed Xe and tungsten lamps in the monochromator.
The overall test was successful – all of the exposures taken using the Xenon and deuterium lamps were successful, with CASTLE moving to the expected configurations within the predicted elapsed time and producing the expected flux. While the point-source and extended source exposures were successful, the flat field exposures were not. This proved to be due to a burnt out tungsten lamp. Once the bulb was replaced, a series of exposures were taken using real time commanding, and the flux levels were confirmed as consistent with predictions.

3.2 Verif07: Ghosts and scattered light – VE07S01 and VE07S02

This test was rated as highest priority, and the two SMSs were run during the first day of the truncated MiniCal, 10 December 2003. Images were taken with the f225W, F336W, F606W and F814W with an unresolved point source (5-micron or 10-micron pinhole) placed at alignment locations UV13, UV14, UV15 and UV16 (close to the centre of each of the four quadrants). The images are taken in pairs: a short-exposure subarray, designed to provide a measure of the effective count-rate; and a full-frame 2x2 binned image, exposed for 50 times longer. The SMS cycled through the 4 filters at each location before moving to the next.

Operational performance:

1 The SMS executed without any errors; however, the second and third F225W exposures were lost due to an error in the OS script. The neutral density filter must be set explicitly to ND0 in the spreadsheet, rather than left blank. Since the previous exposures used the ND3 filter, the point source is barely visible on even the (nominally) highly saturated full-frame images.

2 Scattered light is present in all of the F606W exposures. The steering mirrors move the image of the fibre plate in the focal plane over the CCD, allowing light to scatter in around the edges (giving a nice image of the fibre plate).

3 Light also enters through the (unilluminated) other fibres in both F606W and F814W images. (Two of the F606W images were taken with the HeNe source un-shuttered, and those full-frame images have two bright point sources.) The stimulus and WFC3 require more extensive draping for this test, and it may be necessary to extinguish some of the room lights.

Scientific results:

1 Bright ghosts are present on all of the full-frame images, notably two pairs of double reflections due to the camera optics. These are expected, and are within the specifications.

2 The F225W filter images have significantly stronger ghosts close to the point source. These have can reach flux levels of 10-15% of the flux in the primary image, and the morphology appears to change with location on the image. These do not meet the operational specifications.

3.3 Verif01: Biases and Darks – VE01S01

A short series of full-frame, unpinned darks and biases were taken at the conclusion of operations on 10 December 2003. The CCD was at a temperature of $-73\ ^{o}$C and operating at gain 1.5, the standard setting.

Operational performance:

1. The SMS ran without any problems.
2. Scattered light is clearly present, producing structure in the longer darks.

Scientific results:

1. The readnoise from the four amplifiers, ABCD, measured from both bias frames and overscan in the dark frames, spans the range 3.15 to 3.33 electrons. This is well within the CEI specifications, even at the elevated operating temperature.
2. The dark current ranges from 1.7 to 2.4 electrons/pixel/hour; again, this meets the CEI specification of < 20 electrons/pixel/hour.

3.4 Verif03: Throughput of broad and medium-band filters – VE03S01

The throughput of all broad and medium-band UVIS WFC3 filters was measured on 11 December 2003. The measurements were made using the CASTLE monochromator in double-mode (bandwidth 13 nm), with the wavelength tuned to match the central wavelength of each filter. Extended target sources were produced using the 200-micron fibres, giving as circular 26-pixel diameter image on the detector, with the xenon light source used for measurements at wavelengths shortward of 555 nm and the tungsten lamp at longer wavelengths. Pairs of exposures were taken at each setting, with the flux calibrated after each exposure by offsetting the CASTLE steering mirrors to place the beam on either a photo-multiplier tube (Xe lamp) or silicon photo-diode (tungsten). In the latter case, a circular chopper is also switched on to provide alternating current.
Operational performance:

1 The SMS executed without any apparent errors
2 The repeated flux calibration measurements show differences of much less than 1%, indicating that the CASTLE fluxes are stable to that level, at least over the relatively short timescales involved in these calibration measurements (exposure times range from 5 to 40 seconds).
3 Two sets of measurements – with the F475W and F850LP – were saturated due to errors in the SMS definition – the exposure times were too long.
4 There were two anomalous measurements. In both cases, the first image in a pair had significantly lower flux than the second: F606W, first image is lower by a factor of 1000; F625W, flux is lower by a factor of 2. No apparent anomalies reported by CASTLE.

Scientific results:

1 The throughput for each filter was measured by using aperture photometry to sum the total flux in each extended image, subtracting the background and using the gain of 1.5 to convert from DN to electrons. The CASTLE flux measurements are given as photon/second, so the ratio (allowing for quantum effects) gives the throughput. The results are consistent with expectations and meet the CEI specifications.
2 Of particular note, the UV throughput meets the CEI specifications.

3.5 Verif04: System throughput – VE04S01, VE04S01A and VE03S02

The system throughput for WFC3 (optics and detector, but no filter) is measured by setting the SOFA to CLEAR and, with the 200-micron target and double monochromator, stepping the stimulus in wavelength from 200 to 1000 nm. This test was initially run on 11 December 2003. That test was not successful, since the SITS failed to command the WFC3 SOFA to move to CLEAR, so all measurements were made with the F225W filter in place. That error in commanding was corrected, and the test was run again on 15 December 2003.
Operational performance:

1 The initial version of VE04S01 did not make any provision for early data dumps – all data were dumped at the conclusion of the SMS (2 hour duration). VE04S01A

corrects this problem, by including forced data dumps at intervals of approximately 30 minutes.
2 VE04S01A ran smoothly, without any apparent errors.
3 Significant anomalies were apparent in the throughput measurements made using the tungsten lamp – the measured throughputs were *lower* by a factor of two than those derived with the filter in place.

Prompted by the latter result, a new SMS, VE03S02, was constructed and compiled on 16 December 2003 and run on 17 December 2003. As outlined in the appendix, this cycles through six broadband filters, taking throughput measurements with the filter alternately in place and removed. As in all other throughput tests, the 200-micron extended source is used in combination with the double monochromator, tuned to match the central wavelength of the filter in question.

Operational performance:

1 The last three exposures in the SMS (second F606W and both F814W) failed due to CASTLE taking significantly longer than expected to re-configure. This was due to a problem accessing excel spreadsheet data and is being corrected.
2 The successful exposures taken with the tungsten lamp have the expected throughput ratio between filter/no-filter, but are significantly lower than expected, based both on *a priori* predictions and previous measurements (VE03S01). Investigation showed that these anomalies are due to a combination of two sources: first, the chopper used in calibrating the flux from the tungsten lamp was incorrectly triggered during the on-chip exposures, cutting the actual incident flux by a factor of 2.1; second, the tungsten lamp, installed on 3 December, was in the final stages of failure.

Scientific results:

1 The relative throughput with and without filters is consistent with expectations, and with CEI specifications, for all measurements made with the Xenon lamp.
2 Once allowance is made for the anomalies outlined above, the throughput measurements with the tungsten lamp are consistent with expectation and the CEI specifications.

3.6 Verif02: Encircled Energy – VE02S05

This SMS measures the encircled energy distribution of a point source at four wavelengths (225, 336, 633 and 810 nm) and at four locations (UV13, UV14, UV15 and UV16). The stimulus is operated in double monochromator mode with the Xenon lamp and 5-micron pinhole (225, 336 nm), with the HeNe laser and the LD810 laser diode. The original version of this SMS was compiled and run on 11 December, but execution was aborted when it was realised that the SMS lacked wait times for CASTLE to re-configure. The SMS was revised accordingly, and run on 12 December 2003.

Operational performance:

1 The first attempt to run the SMS on that date was aborted due to the CASTLE chopper having drifted into the CASTLE beam. This problem arose because the chopper had been in an unpowered state for >24 hours.
2 The SMS was re-started after re-setting the chopper and ran successfully.

Scientific results:

1 The encircled energy measurements are well within CEI specifications at all wavelengths
2 Dark frames taken immediately after saturated images show no evidence for persistence.

3.7 Verif05: Flat fields – VE05S01 and VE05S02

The original SMS, VE05S01, acquires a single flat field exposure in each broad- and medium-band filter, and searches for pinholes in the F218W, F225W, F300X, F275W and F280N filters by illuminating each with 600 nm wavelength flats, generated by the tungsten lamp and monochromator in single-mode (130 nm bandwidth). This SMS was run on 15 December 2003.
Operational performance:
1 The deuterium lamps switched on and then off for both F218W and F225W flats due to CASTLE commanding errors
2 The flux from the Xe lamp was reduced by a factor of ~2 due to the chopper partly obscuring the beam. However, flux levels were still adequate at ~9-10K

Scientific results:
1. An optical flare-like feature is present on all frames, although at a level of much less than 1%. This feature is also present in data taken at Ball before the flight package was shipped to GSFC.
2. At least 25 doughnuts were identified on the frames, with 2 distinct families (by size). All appear to be present in every filter, indicating they are on the camera optics.
3. The pinhole checks were made by illuminating the F218W, F225W, F300X, F275W and F280N with a 600 nm wavelength (130 nm bandwidth) flat; there is an obvious doughnut in the F280N flat, but nothing evident (at least at first inspection) in the other filters

SMS VE05S02 was compiled on 16 December 2003 to determine whether the structure of the flare-like feature depends on how the detector is illuminated. The CASTLE steering mirrors were used to centre flat fields on different locations on the chip.
Operational performance:
1 SMS executed without any problems.

Scientific results:
1 No significant changes were apparent in the flare pattern

3.8 Verif09: Bandpass measurements of F218W/F225W – VE09S04 and VE09S05

The filter bandpasses are measured using the double monochromator, 200-micron target and the Xenon lamp, taking a series of throughput measurements at wavelengths from 200 to 275 nm. The measurements are made at alignment location UV12, in the corner near amplifier B. The tests were run on 16 December 2003.
Operational performance:

1. Several measurements of the F218W filter were lost through configuration problems with CASTLE – the central wavelength did not change. As a result, we lack measurements between 215 and 235 nm.
2. The F225W measurements were completed without any problems.

Scientific results:

1. The bandpass measured for the F225W filter is consistent with expectations and the filter specifications.
2. Both sets of measurements reveal the presence of ghost images in relatively close proximity to the extended source. In both cases, the ghosts are relatively weak at shorter wavelengths (< 240 nm), but increase in prominence rapidly at longer wavelengths, contributing up to 30% of the flux in the primary source at the 275 nm. These features may be associated with the filter construction – both are air-gap filters.

The identification of wavelength dependence in the relative strengths of ghost images led to these tests being extended to include both the F300X and F606W filters. The relevant measurements were made between 14 January 2004 and 20 January 2004, and were executed without problems.

3.9 Verif07: Ghosts and crosstalk – VE07S03 and VE07S04

Prompted by the results from VE07S01, VE07S02, VE09S04 and VE09S05, two additional SMSs were compiled in 16 December to examine ghost morphology as a function of location on the F218W, F225W and F300X filters, and to determine whether crosstalk is dependent on the gain setting. All ghost measurements were made using the 5-micron pinhole and white light; the crosstalk measurements are full-frame, 2x2 binned images, with the point source centred at location UV13. Both SMSs were run on 17 December 2003.

Operational performance:

1. The measurement at location UV13 with the F218W filter was not successful due to an error in constructing the SMS – data were read out centred on UV16. This error was corrected in real time by the CASTLE group (modifying the stimulus script to match the SITS SMS), and data were collected at all locations for F225W and F300X.
2. The initial measurements with the F218W filter had lower flux than anticipated due to an error in setting the ND filters in the OS script – again, this was corrected by the CASTLE group during the procedure.
3. SMS VE07S03 specified two sets of measurements, in F218W and then in F225W. Both sets of measurements were taken in F218W due to a commanding error from SITS.
4. The intention was to include one measurement of F656N in VE07S04, but, due to an error in constructing the SMS, those data were not obtained. The filter was left at F300X.

Scientific results:

1. The F300X filter shows a similar type of reflection as the F218W and F225W filters, albeit with different detailed morphology.

2. All of the ghosts show significant change in morphology with location on the detector
3. Crosstalk is present at all four gain settings.

As noted in the introduction to this section, the discovery of significant ghosts in at least three of the airgap filters led to tests being extended to include all of the UVIS filter set, together with more extensive measurements of filters F214W, F225W and F300X. Those tests were completed between 7 January and 23 January 2004.

4 Lessons Learned

Overall, the December '03 MiniCal was extremely successful:

- The SMS-based approach ensured that data were taken efficiently and provided a reliable record of exposures taken for each test. The availability of a simple schedule also made it easy to communicate simple changes in plans, even at long distance, when those were necessary.
- Good communications prevailed among the on-site groups.
- Revised and new SMSs and OS control scripts were generated with a turnaround of only 10-12 hours.
- The good agreement between predicted and observed DN levels in most exposures indicates that the CASTLE Exposure Time Calculator is well matched to operational performance.
- The quick-look system worked well, providing both qualitative inspection and rudimentary analysis tools.
- Data transfer to STScI generally went smoothly, although there were some hiccups due to *planned* downtime at STScI.
- Initial analysis of the datasets by STScI PIs was completed within 1-2 days

The generally smooth operations can be ascribed, at least in part, to the interface tests carried out on several occasions throughout 2003.

There were also operational areas that should receive some attention in designing the next MiniCalibration campaign:

- The work environment in room 150 was extremely cramped
- Dump early and often – with many of the SMS routines using sub-arrays, it is possible to construct a 5 hour SMS that will only fill the buffer and produce automatic data dumps once or twice. This is both inefficient use of potential analysis time, and could lead to wastage if there are errors in the SMS definition or operation.
- We need to understand and deal with the reasons for the short lifetime of the tungsten lamps.
- Exposures in some SMSs were lost because the CASTLE configuration times were inaccurate
- Protocols should be established within the SIPT for validating SMS/OS spreadsheets generated at short notice in response to preliminary test results.
- The full daily logs should be transferred daily from GSFC to STScI for circulation among SIPT (and SOC) members.

- STScI OPUS and CISD need to keep WFC3 requirements in mind when planning internet outages and/or system downtime, and need to maintain better communications with the WFC3 SIPT.
- Daily science reports need to be circulated among the full WFC3 teams
- Goddard is a long way from Freeland, MD – several SIPT members need to negotiate the Baltimore beltway. Staffing and test operation plans should take this into account.

Scientifically, the current Mini-Calibration Plan should be re-assessed in light of the results from the initial test program, and modified as necessary to explore some of the scientific issues raised.

5 Conclusions

We have completed the first set of science calibration tests of the UVIS channel of Wide-Field Camera 3. The infrastructure for undertaking these tests worked well. The preliminary scientific results indicate that the encircled energy distribution, dark current, read-noise level, throughput and flat-field uniformity are all well within specifications. In most filters, reflective ghosts are present at the expected level; however, at least there of the air-gap filters show ghosts at a much higher intensity than anticipated. In addition, cross-talk between amplifiers is clearly present. The latter two issues will receive close attention in the near future, and the MiniCal Plan should be modified to investigate these areas of performance in more detail during the next calibration campaign.

6 Appendix I: new test procedures

We summarise the main characteristics of each of the new SMS procedures undertaken during the December ’03 MiniCal. All save VE00S01 fall under the auspices of a test outlined in the WFC3 MiniCal Plan.

6.1 VERIF03: Throughput, broad and mediumband filters

TITLE: Throughput of the UVIS broad- and mediumband filters

CATEGORY: UVIS channel performance verification

P.I.: I.N. Reid

REVISION DATE: 16 Dec 2003

PURPOSE:
To determine the absolute throughput of a subset of the broad- band filters available in the WFC3/UVIS channel.

OS CONFIGURATION:
200-micron point target generated by fibre bundle linked to monochromator, operating in double mode, with bandwidth of 13 nm. The light source and monochromator will be set to match the appropriate wavelength range of the individual filters.

SITS COMMAND MODE: SMS

SITS SMS/OS SCRIPT NAMES:
Ve03s02; ve03c02

DETAILED TEST PROGRAM:
500-square subarray images are taken of the extended image produced by the 200-micron point target, centred on a defined aperture. Bias frames are taken at the start and conclusion of the full sequence of exposures. The OS is in double monochromator mode, with the wavelength tuned to match the central wavelength of the filter being tested. Exposure times are derived from the CASTLE ETC and are set to give ~30,000 e^-/pixel. Two exposures are taken consecutively at each wavelength setting – the first with the filter in position, the second with the SOFA in CLEAR position. This provides a direct measurement of the absolute throughput and the filter transmission. The images are centred on point UV16: X=1170, Y=1172

EXPOSURES:

Filter	OS central wavelength	OS configuration	Exposure time (secs)	No. of exposures
F225W	225 nm	UVPT1/Xe/DoubleUV/noND	5	3
CLEAR	225	UVPT1/Xe/UV/no ND	5	3

F336W	336	UVPT1/Xe/UV/ND2	4	3
CLEAR	336	UVPT1/Xe/UV/ND2	4	3
F438W	438	UVPT1/Xe/DoubleUVis/ND3	25	3
CLEAR	438	UVPT1/Xe/DoubleUVis/ND3	25	3
F555W	555	VISIRPT1/QTH/DoubleUVis/ND2	8	3
CLEAR	555	VISIRPT1/QTH/DoubleUVis/ND2	8	3
F606W	606	VISIRPT1/QTH/DoubleUVis/ND2	9	3
CLEAR	606	VISIRPT1/QTH/DoubleUVis/ND3	9	3
F814W	814	VISIRPT1/QTH/DoubleUVis/ND2	6	3
CLEAR	814	VISIRPT1/QTH/DoubleUVis/ND2	6	3

TOTAL ELAPSED TIME:
ve03s01 – 0.1 hrs exposure time, 1.5 hrs elapsed time

QUICK-LOOK VERIFICATION:
Each exposure should be inspected visually – there should be no significant non-uniformities or structure. The spot image should be unsaturated.

ANALYSIS:
The data will be processed using the standard WFC3-UVIS IPT pipeline analysis. Determine the total counts by aperture photometry of the spot produced by the 200-micron fibre-bundle. Standard routines in the *apphot* package in IRAF will be adequate for this purpose.

6.2 Verif05: Flat fields – photometric filters

TITLE: Flat field response for UVIS photometric filters

CATEGORY: UVIS channel performance verification

P.I.: I.N. Reid

REVISION DATE: 16 Dec 2003

PURPOSE:
To obtain reference flat fields for initial on-orbit calibration, and to identify cosmetic defects in either filters or CCD detectors.

OS CONFIGURATION:
Diffuse, flat-field illumination generated by the monochromator, operated in white light mode (2 mirrors). The Xenon lamp, together with either the UVIS or VIS monochromator optics, will be used for wavelengths λ<500 nm; the QTH lamp, together with the IR monochromator, will be used at longer wavelengths.

SITS COMMAND MODE: SMS

SITS SMS/OS SCRIPT NAMES:
ve05s02; ve05c02

DETAILED TEST PROGRAM:
A series of flat field images will be taken using the F606W filter. The steering mirrors on CASTLE will be used to steer the centre of the image to 10 positions across the chip, with the aim of searching for positionally-dependent sources of anomalous illumination. The exposure times are set to give ~ 30,000 DN. No neutral density filters are used with the OS in any of these measurements.

EXPOSURES:

SMS	Filter	OS Configuration	OS location	Exposure time (secs)	Comments
ve05s02	F606W	VISIR/mirror/QTH	UV00	30	fibre-fed
	F606W		UV13	30	
	F606W		UV14	30	
	F606W		UV15	30	
	F606W		UV16	30	fibre-fed
	F606W		UV04	30	
	F606W		UV06	30	
	F606W		UV07	30	
	F606W		UV08	30	
	F606W		UV09	30	
	F606W		UV10	30	

	F606W		UV11	30	
	F606W		UV12	30	

TOTAL ELAPSED TIME:
ve05s02 – 0.2 hrs exposure time, 2 hrs elapsed time

QUICK-LOOK VERIFICATION:
Each exposure should be inspected visually – there should be no significant non-uniformities or structure.
The background level on the chip should be 10,000-30,000 counts for flat fields.
The background level on the overscan should be a few hundred counts.

ANALYSIS:
The data will be processed initially using the standard WFC3-UVIS IPT pipeline analysis.
Fourier analysis will be used to search for correlated image structure and differencing will be used to identify filter-specific defects. Reference flat fields will be generated by combining individual images using appropriate filters. The goal is to provide <1% accuracy flat fields in all filters.

6.3 Verif07: Optical ghosts

TITLE: Optical ghosts in the WFC3 UVIS Camera

CATEGORY: UVIS channel performance verification

P.I.: T. Brown/G. Hartig

REVISION DATE: 17 Dec 2003

PURPOSE:
To identify and characterise artefacts produced by internal reflections in the WFC3 optics.

OS CONFIGURATION :
Point source generated by fibre linked to monochromator, operating in broadband mode.

SOFTWARE REQUIREMENTS :
IDL and/or IRAF routines to view the images and measure positions and profiles for any detected artifacts.

COMMAND MODE : SMS

SITS SMS/OS SCRIPT NAMES:
ve07s03, ve07s04, ve07s05, ve07s06, ve07s07, ve07s08, ve07s09, ve07s10, ve07s11, ve07s12; ve07c03, ve07c04...ve07c12

PROGRAM/EXPOSURES :
The initial set of ghost measurements made using SMS ve07s01 and ve07s02 showed strong features in the vicinity of the point source for the two UV air-gap filters, F218W and F225W. In addition, cross-talk was detected in the full-frame exposures. The SMS routines outlined here are designed to examine the morphology of the anomalous reflections as a function of location, sampling all of the remaining UVIS filters. The exposure sequence for two SMSs are listed in full below - the remaining SMSs sampled the following filters:
ve07s05 – filters F275W, F555W (8 positions per filter)
ve07s06 – filters F336W, F390W, F438W, F475W (4 positions per filter: UV13, UV14, UV15, UV16 – 10 second + 100 second pairs)
ve07s07 – filters F350LP, F475X, F600LP, F625W (4 positions)
ve07s08 – filters F775W, F850LP, F763M, F845M (4 positions)
ve07s09 – filters F390M, F410M, F467M, F547M (4 positions)
ve07s10 – filters F621M, F689M, F280N, F343N (4 positions)
ve07s11 – filters F373N, F395N, F469N, F487N (4 positions)
ve07s12 – filters F502N,F588N,F631N,F645N (4 positions)
ve07s13 – filters F656N,F657N,F658N,F665N (4 positions)

ve07s14 – filters F673N,F680N,F953N,FQ924N,FQ937N,FQ906N,FQ889N (4 positions for full filters, 1 position for each quad)
ve07s15 – filters FQ243N, FQ378N, FQ232N, FQ437N, FQ436N, FQ492N, FQ422N, FQ387N, FQ672N,FQ674N,FQ575N,FQ508N,FQ727N,FQ750N,FQ634N,FQ619N (1 position for each quad)
ve07s16 – F225W, vary CASTLE focus
ve07s17 – F606W, vary CASTLE focus
ve07s18 - F225W, through focus ghosts
ve07s19 - F280N,F225W,FQ243N,FQ232N
800-square sub-array image, centred on the appropriate aperture, are taken for all of the ghost images; full frame exposures with 2x2 binning are acquired for the cross-talk test.

VARIANTS :
A revised version of ve07s04 should include positional measurements of anomalous reflections with F656N, the only other air-gap filter. The cross-talk test should be expanded as a separate SMS.

EXPOSURES:

SMS	Filter	OS Configuration	OS location	Exposure time (secs)	Comments
ve07s03	F218W	UV5micron pinhole /mirror/Xe/no ND	UV07	10	near full-well
	F218W		UV07	100	10x full-well
	F218W		UV08	10	
	F218W		UV08	100	
	F218W		UV11	10	
	F218W		UV11	100	
	F218W		UV12	10	
	F218W		UV12	100	
	F218W		UV13	10	
	F218W		UV13	100	
	F218W		UV14	10	
	F218W		UV14	100	
	F218W		UV15	10	
	F218W		UV15	100	
	F218W		UV16	10	
	F218W		UV16	100	
	F225W		UV07	10	
	F225W		UV07	100	
	F225W		UV08	10	
	F225W		UV08	100	
	F225W		UV11	10	
	F225W		UV11	100	
	F225W		UV12	10	
	F225W		UV12	100	

	F225W		UV13	10	
	F225W		UV13	100	
	F225W		UV14	10	
	F225W		UV14	100	
	F225W		UV15	10	
	F225W		UV15	100	
	F225W		UV16	10	
	F225W		UV16	100	

SMS	**Filter**	**OS Configuration**	**OS location**	**Exposure time (secs)**	**Comments**
ve07s04	F300X	UV5micron pinhole /mirror/Xe/ND 1	UV07	10	near full-well
	F300X		UV07	100	10x full-well
	F300X		UV08	10	
	F300X		UV08	100	
	F300X		UV11	10	
	F300X		UV11	100	
	F300X		UV12	10	
	F300X		UV12	100	
	F300X		UV13	10	
	F300X		UV13	100	
	F300X		UV14	10	
	F300X		UV14	100	
	F300X		UV15	10	
	F300X		UV15	100	
	F300X		UV16	10	
	F300X		UV16	100	
	F300X	no ND	UV13	1	full-frame, gain=1
	F300X		UV13	100	
	F300X		UV13	1	full-frame, gain=1.5
	F300X		UV13	100	
	F300X		UV13	1	full-frame, gain=2
	F300X		UV13	100	
	F300X		UV13	1	full-frame, gain=4
	F300X		UV13	100	

TOTAL TIME :
0.5 hrs exposure time; 1.8 – 2.2 hrs elapsed time for each SMS

ANALYSIS :
Inspect the images for ghosts and other artifacts; determine the profiles, relative intensities and potential persistence of these artifacts.

6.4 VERIF00: Exposure time/CASTLE verification

TITLE: Verification of CASTLE performance

CATEGORY: UVIS channel performance verification

P.I.: I.N. Reid

REVISION DATE: 03 Dec 2003

PURPOSE:
To verify the flux levels, and corresponding WFC3 exposure times, produced for a representative set of CASTLE configurations.

OS CONFIGURATION:
5-micron/10-micron/200-micron point targets generated by fibre bundle linked to monochromator, operating in double mode, with bandwidth of 13 nm, and white-light mirror mode; flat fields produced by

SITS COMMAND MODE: SMS

SITS SMS/OS SCRIPT NAMES:
ve00s01; ve00c01

DETAILED TEST PROGRAM:
200-square subarray images are taken of the point-source and 200-micron point targets; full frame unpinned images are taken for the three flat fields. The OS cycles through a range of configurations. Exposure times are derived from the CASTLE ETC and are set to give ~30,000 e^-/pixel.

EXPOSURES:

Filter	**OS central wavelength**	**OS configuration**	**Exposure time (secs)**	**Test**
F225W	225 nm	5-micron/Xe/DoubleUV/noND	20	PSF-UV
F336W	336	5-micron/Xe/DoubleUV/no ND	10	PSF-blue
F225W	mirror	5-micron /Xe/Mirror/	4	
F606W	mirror	10-micron/Xe/UV/ND3	2	
F547M	547	UVPT1/Xe/DoubleUVis/ND3	40	
F410M	mirror	Xe/no ND	100	full-frame flat
F555W	555	VISIRPT1/QTH/DoubleVis/ND2	8	
F555W	555	VISIRPT1/QTH/DoubleVis/ND2	2	Gain=1.0
F555W	555	VISIRPT1/QTH/DoubleVis/ND2	2	Gain=1.5
F555W	555	VISIRPT1/QTH/DoubleVis/ND2	2	Gain=2.0

F555W	555	VISIRPT1/QTH/DoubleVis/ND2	2	Gain=4.0
F814W	814	VISIRPT1/QTH/DoubleIR/ND2	6	
F814W	Mirror	QTH/Mirror/VisIR	100	Full-frame flat
F275W		D_2 lamps	240	Full-frame flat
F814W		LD810	1	

TOTAL ELAPSED TIME:
ve00s01 – 0.4 hrs exposure time, 2.5 hrs elapsed time

QUICK-LOOK VERIFICATION:
Each exposure should be inspected visually – there should be no significant non-uniformities or structure. The images should be unsaturated.

ANALYSIS:
The data will be processed using the standard WFC3-UVIS IPT pipeline analysis. Determine the total counts by aperture photometry of the spot produced by the 200-micron fibre-bundle. Standard routines in the *apphot* package in IRAF will be adequate for this purpose.