TECHNICAL REPORT

SPACE TELESCOPE SCIENCE INSTITUTE
Operated for NASA by AURA

Title: An Observing Proposal for Secondary Mirror Focus Sweep during Commissioning of JWST	Doc #: JWST-STScI-000956, SM-12 Date: 26 April 2006 Rev:
Authors: Colin Cox and Russ Makidon Phone: 410 3384792	Release Date: October 9, 2006

1.0 Abstract

We present a Phase 1 Observing Proposal (OP) for performing the JWST secondary mirror focus sweep, using one of NIRCam's short wavelength arms. The program can be performed without real-time contact.

2.0 Introduction

We attempt to capture advances in our plans for Commissioning JWST, as outlined in OTE-14a (Contos). Authoritative descriptions of these processes will eventually be collated in OTE-24, but enough detail is currently known about the process to enable a draft Phase 1 proposal for Focus Sweep to be presented here. The use of OPs will enable the S&OC-developed Observation Plan Executive (OPE), designed for routine Science Operations, along with all its communications and error checking and verification infrastructure, to be used for Commissioning operations.

3.0 Scope

The scope of this memorandum is to develop a credible Observing Proposal to execute Segment Identification during JWST WFS&C Commissioning. We rely on prior descriptions of Commissioning operations and NIRCam data flow, namely

1. JWST.2006.170.0024 "WFS&C Requirements Allocation Document"
2. JWST-STScI-000512: "Wavefront Sensing and Control on JWST: embedding the Executive at the Science & Operations Center"
3. STScI-JWST-TM-2003-0011 A: "Routine JWST Wavefront Sensing and Control"
4. NIRCam DRD-OPS-11-JWST-OPS-002843 2003: "NIRCam Operations Concept"
5. STSCI-JWST-TM-2004-0022: "NIRCam Science Data Pipeline Description"

Released via JWST Science and Operations Center Configuration Management Office
Operated by AURA for NASA under Contract NAS5-03127.

6. STSCI-JWST-TM-2004-0023: "NIRCam Calibration Reference Files"
7. JWST-IRD-002996: "WFS&C Exec-to-S&OC IRD"

4.0 Subsystems and stakeholders

Segment Identification algorithms, developed by Ball are described in OTE-14a. WFS&C operations involve NIRCam on JWST, S&OC Ground systems' Data Management System (DMS), Proposal Planning System (PPS), and Flight Operations System (FOS), the WFS&C Scientist and/or the JWST Project-wide WFSC Team under Prime Contractor leadership, the WFS&C Executive software (the "Exec"), developed by JPL, and the JWST Line-of-Sight Control system. The Fine Guidance Sensors are not used at this stage of Commissioning.

5.0 Focus Sweep in the WFS&C Commissioning sequence

Commissioning is currently described in a detailed process flowchart maintained by Acton (Ball) for the different phases of commissioning (see Figure 1 in JWST-STScI-000-512, Sivaramakrishnan et al.). These commissioning stages are summarized at the highest level by the following steps:

Focus Sweep
Segment Identification
if any segments are missing:
    Segment Search
Segment Array
if segment PSFs are confused:
    go back to **Segment Identification**
Global Alignment
Image Stacking
Coarse Phasing
Fine Phasing
Multi-Field Fine Phasing
if PM segment updates are too large:
    go back to **Coarse Phasing**

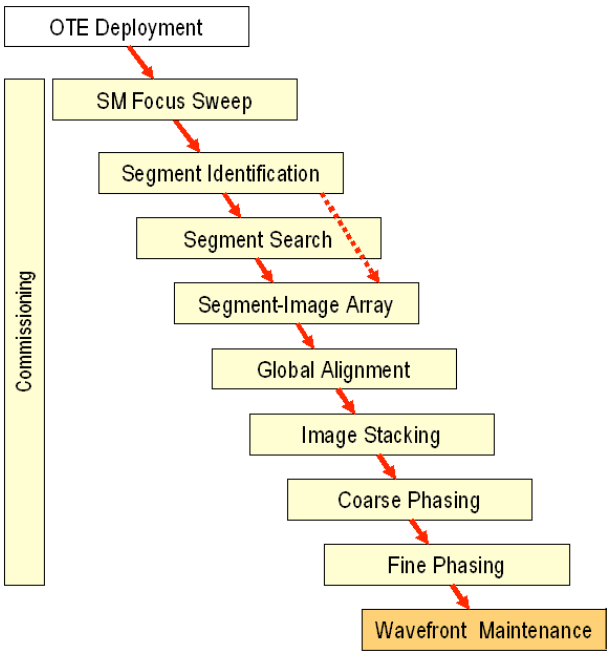

Figure 1: Phases of WFS&C Commissioning (A. Contos, Ball)

OTE-24 will serve as a WFS&C operations concept, especially for commissioning (which is more complex than routine operations). This document will be the main repository for WFS&C operations knowledge (although currently OTE 14a and 14b encapsulate WFS&C processes as we understand them). OTE-24 will include a discussion of preconditions and exit criteria for the phases of WFS&C commissioning, the types of calibrations that are needed to prior to commissioning, and a description of the types of proposals needed – both for success-oriented scenarios as well as for the most likely contingencies, as defined by the Ball WFS&C team.

The Secondary Mirror Focus Sweep will be performed only once during commissioning

6.0 Method For Secondary Mirror Focus Sweep

The method for finding a focus is the traditional one of stepping through focus positions and choosing the best looking image. This idea is complicated by the presence of 18 mirror segments, which, at this stage, will be somewhat independent in position and focus. Each segment image will only be 1/18 as bright as a combined image, and some images may fall outside the field of view.

We will not concern ourselves with the missing segment images at this stage, but simply find the best focus for those visible.

The focusing procedure uses images from NIRCam for which the readiness will have been determined using purely internal checks. According to the commissioning plan this activity will be carried out when the NIRCam has only cooled down to 100°K. Noise levels will be somewhat higher than in normal operating mode. Laboratory measurements were made on the HgCdTe arrays chosen for use in NIRCam and on

the other candididate InSb arrays. (Figer et al, 2003). The HgCdTe dark count rates are lower by about a factor of six at 30°K and by a much larger factor at 80°K. As compare to the InSb detector. The temperature variation is shown in Figure 2. (The units are ADUs/second and to convert to electrons/second we multiply by 1.3.) At 80°K the dark rate is about 1 count per pixel per second and extrapolating to 100°K suggests a dark rate of about 10 to 20 counts per pixel per second. The full well depth is given in the same report as 130000 electrons. The minimum NIRCam exposure time for the full detector array is 10 seconds. For short exposures of 10 seconds, the dark rate will not present a problem.

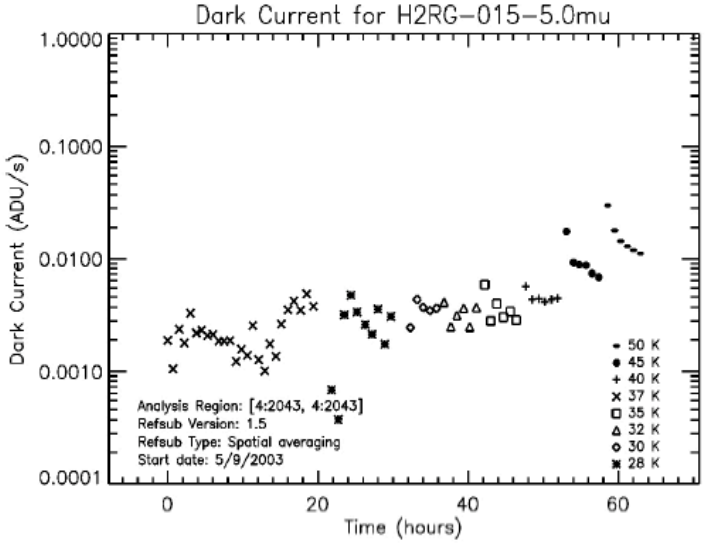

Figure 2: Low temperature dark rates for HgCdTe array. This figure take from Figer et al. 2003.

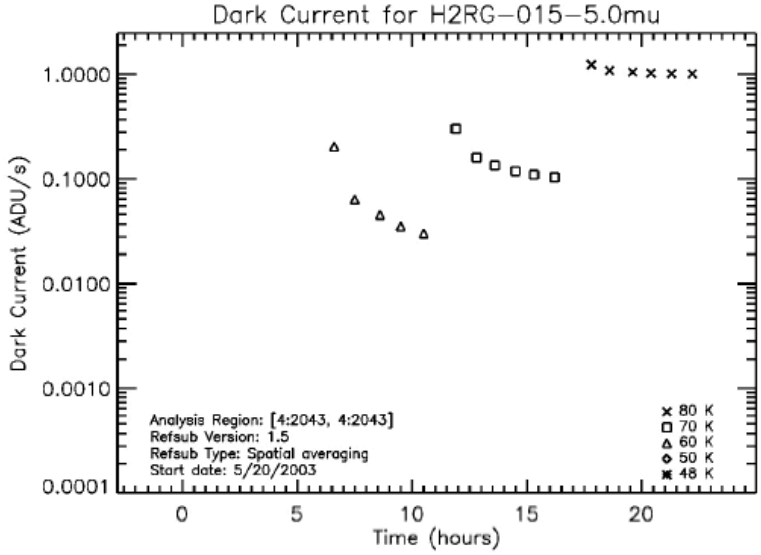

Figure 3: Dark currents at higher temperatures for HgCdTe array. This illustration is also copied from Figer et al.

A 10^{th} magnitude star would give an incident flux of about

4.5×10^5 photons $s^{-1}.m^2.\mu m^{-1}$. The OTE collection area is 25 m^2 comprised of 18 segments. We assume an OTE efficiency of 75%, a NIRCam transmission efficiency of about 65% and a DQE near 80%. The F212N filter would have a bandpass of 0.02 μm and a peak throughput of about 80%. Combining all these factors gives an estimated count rate for each segment of 4000 photons.s^{-1} of which approximately 10% would fall in the brightest pixel. So a 10 second exposure would give at most 4000 counts in any pixel for a well-focused segment.

At the start of the focus sweep the secondary mirror is within 1.2 mm of its nominal focus position. For the focal ratio of f/18, using the formula $2\lambda.(\text{f-number})^2$ the depth of field is close to 1mm, so any segment image in the field should be bright enough to be seen through some part of the sweep.

The method will be to perform a coarse sweep of about twenty steps of 100μ and then examine the images. The two brightest images will then straddle the best focus position and a finer sweep in 10μ steps can be performed in the range covered by these. Since each segment will focus at different positions, one way of selecting the global best focus would be to take the mean best focus position of all visible segments.

The instructions for each sweep consist of a set of mirror commands and NIRCam exposure definitions. After the images from the first sweep have been examined, mirror parameters for the next sweep are loaded for the next sweep. The turnaround time for this will be two or three days. A final measurement at the best focus position will be taken at the next opportunity.

7.0 Secondary Mirror Focus Sweep Proposal

This proposal, translated by the S&OC PPS into a Visit, will be used to perform the focusing of the secondary mirror.

Program No.:7xx DRAFT JWST PHASE 1 PROPOSAL

Program title: JWST Secondary Mirror Focus Sweep

Synopsis: Find initial focus position of secondary mirror

Sample and sky coverage:
pre-selected isolated star in continuous observing zone

Basis for exposure time estimates (needed S/N and brightnesses):
Sufficient exposure to detect star in 10-100s exposures but not saturate detector with signal or noise.
Exposure times are TBD. 10 s exposures are placeholders being the minimum value for full-frame readout
Short exposures mitigate possible pointing instability and minimizes CR contamination.
PSF estimated from expected defocus and aberrations.
Persistent image transients limit target star brightness.

NFRAME1 = 1 low SNR trades speed of execution vs. read noise
NGROUP1 = 2 assists CR rejection, and increases photometric dynamic range of the imaging.

Instruments and observing configurations:
NIRCam operational, star trackers operational.
No FGS lock assumed.

Scheduling requirements or constraints:
NIRCam operational and cool enough (about 100°K) to avoid excessive noise rate, or too rapid filling of the detector full well. Primary Mirror latched, Acquisition and First Light accomplished.
A minimum of 8 (TBD) segment images visible - Requirement to be placed on Initial acquisition
WFS&C Exec-created filenames TBD are available to Flight Operations System

Visit scenario:

NIRCam Imaging short wavelength WFS&C arm [A or B, TBD]
Slew to target
Filter: F210M
Pupil: Imaging pupil

Activity Descriptor: File **P7xx_SMsweep_placeholder_01**
If **P7xx_SMsweep_placeholder_01** exists:

> Expose 10s (TBD) NFRAME1=1, NGROUP1=2
> Move secondary mirror 100 microns in positive direction
> Repeat 10 times
> Repeat same sequence in opposite direction.
>
> Data from this series of observations returned to ground for review.
> Two best images chosen.

Activity Descriptor: File **P7xx_SMsweep_placeholder_02**
If **P7xx_SMsweep_placeholder_02** exists:

> Repeat observation 10 times using 10 micron displacements between the two best positions found in first session.

Activity Descriptor: File **P7xx_SMsweep_placeholder_03**
If **P7xx_SMsweep_placeholder_03** exists:

> Take single image at best focus position found.

Comments:
Verify health/safety w/NIRCam - image persistence is unlikely to be a problem.
Dynamic range can be increased by increasing exposure time.
Target star and guide star isolation requirements TBD.

Risks and contingencies:
Image not visible:
Segment images too defocussed/abberated to be detected in images (TBR)
If so repeat first group displaced 0.8 mm from initial set in one direction and if this should fail, attempt another set 0.8m in the other direction. At this point we would have scanned a range of 2.6 mm, greatly exceeding the specified initial position accuracy
Total program time needed (days): 7, allowing for receipt of data and preparation of mirror commands.

Program written by: Colin Cox
Date first written: February 10th 2006
As-of date: March 23rd 2006

7.1 WFS&C-specific Calibration Data

Routine NIRCam science data processing will suffice.

Dark subtraction. CR rejection

7.2 Algorithm Requirements

Analysis will consist of calculating signal strengths above background.

8.0 Conclusion

The STScI S&OC Ground System, together with the WFS&C Exec software is capable of using the Proposal Planning System and other S&OC subsystems, together with the WFS&C Executive to perform all of the steps involved in Secondary Mirror Focus Sweep. No extra data processing steps over and above routine NIRCam data pipeline processing are needed.

9.0 References

Antczak, T. "WFS&C Exec to S&OC IRD" JWST-IRD-002996 2005
Atcheson, P. D. "Wavefront Sensing and Control Verification Plan" DRD-OTE-14b 2004
Contos, A. "Wavefront Sensing and Control Requirements Allocation" DRD-OTE-14a (also referred to as JWST-RQMT-002017) 2005
Contos, A. DRD-OTE-24 (in preparation) 2005
McCullough, P. M. "NIRCam Operations Concept", NIRCam DRD-OPS-11-JWST-OPS-002843 2003
McCullough, P., Rhoads, J., Figer, D., Kelly, D. and Rieke, M. "NIRCam Calibration Reference Files" STSCI-JWST-TM-2004-0023 2004
McCullough, P., Figer, D., Rhoads, J., Kelly, D. and Rieke, M. "NIRCam Science Data Pipeline Description" STSCI-JWST-TM-2004-0022 2004

Figer, D. F., Rauscher, B, J., Regan, M. W., Morse, E. Balleza, J., Bergeron, L., Stockman, H. S., "Independent Testing of JWST Detector Prototypes, SPIE-5167-29, August 2003.

Sivaramakrishnan, A., Krist, J. E., Makidon, R. B., Henry, R., and Atcheson, P. D. "Routine JWST Wavefront Sensing and Control" STSCI-JWST-TM-2003-001 2003.

Sivaramakrishnan, A., Makidon, R. B., Henry, R., Balzano, V., and Burns, L. "Wavefront Sensing and Control on JWST: embedding the Executive at the Science & Operations Center", JWST-STScI-00512 2005