TECHNICAL REPORT

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Title: Observing Proposals for Coarse Phasing JWST using Dispersed Hartmann Sensing	Doc #: JWST-STScI-000957, SM-12 Date: 05 March 2005 Rev:
Authors: Anand Sivaramakrishnan Phone: 410 338 4480	Release Date: October 9, 2006

1.0 Abstract

Observing Proposals (OPs) for the currently baselined method of coarse-phasing the JWST primary mirror (PM), using Dispersed Hartmann Sensing optical elements, are presented here. An alternative method of coarse-phasing the JWST PM using Dispersed Fringe sensing is possible, but is not yet developed from an operational standpoint.

2.0 Introduction

We attempt to capture advances in our plans for Commissioning JWST, as outlined the WFS&S Requirements Allocation Document, (Reference 1). Authoritative descriptions of these processes will eventually be collated in OTE-24 (Contos, to be released in October 2005), but enough detail is currently known about the process to enable a draft Phase 1 proposal for Coarse Phasing to be developed and presented here. The use of OPs will enable the Observation Plan Executive and all its communications and error checking and verification substructure to be used for Commissioning operations.

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3.0 Scope

The scope of this memorandum is to develop a credible Observing Proposal to carry out Coarse Phasing iteration in JWST WFS&C Commissioning. We rely on prior descriptions of the physics and optics involved in Coarse Phasing, as well as data flow descriptions, namely

1. JWST-STScI-000512: "Wavefront Sensing and Control on JWST: embedding the Executive at the Science & Operations Center"
2. STSCI-JWST-TM-2004-0019A: Coarse Phasing JWST, an Operations Concept
3. STSCI-JWST-TM-2003-0022 A: Coarse Phasing JWST using Dispersed Fringe Sensing and Dispersed Hartmann Sensing during Commissioning
4. STScI-JWST-TM-2003-0011 A: Routine JWST Wavefront Sensing and Control
5. NIRCam DRD-OPS-11-JWST-OPS-002843 2003: "NIRCam Operations Concept"
6. STSCI-JWST-TM-2004-0022: "NIRCam Science Data Pipeline Description"
7. STSCI-JWST-TM-2004-0023: "NIRCam Calibration Reference Files"
8. WFS&C Exec-to-S&OC IRCD

4.0 Subsystems and stakeholders

Coarse Phasing algorithms developed by Adaptive Optics Associates (under subcontract to Ball) are described in an earlier Technical Memorandum (STSCI-JWST-TM-2004-0019A). WFS&C operations involve NIRCam on JWST, S&OC Ground systems' DMS, PPS, and FOS systems, the WFS&C Scientist and/or the JWST Project-wide WFSC Team under Prime Contractor leadership, the WFS&C Exec developed by JPL, and the JWST FGS.

5.0 Coarse Phasing 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 STSCI-JWST-TM-2005-nnnn, 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**

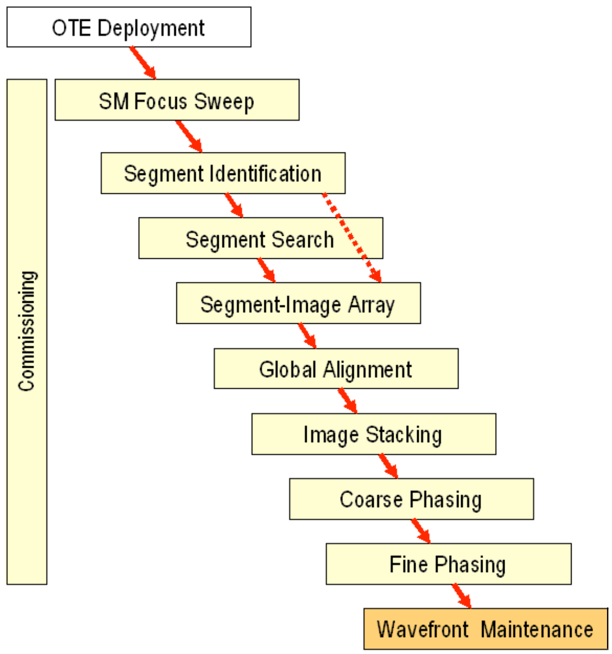

Figure 1: Phases of WFS&C Commissioning (A. Contos, Ball)

OTE-24 (to be released October 2005) 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.

Coarse Phasing occurs at least once during commissioning. The Fine Phasing step of commissioning may involve repeating all steps starting from Coarse Phasing through to another Fine Phasing step, so Coarse Phasing may have to occur twice during commissioning. Reasons for this iteration will be explained in detail when the last Fine Phasing step is described – they have to do with optimizing wavefront quality over the whole of the short wavelength arm of NIRCam used for WFS&C – this final optimization can result in de-phasing the primary enough that it required re-phasing.

6.0 Coarse Phasing Proposals

We present three proposals for Coarse Phasing:

1. Pupil Imaging Lens imaging for pupil alignment
2. Focus-diverse high dynamic range tilt sensing
3. Dispersed Hartmann Sensing driven co-phasing

These proposals, translated by the S&OC PPS into one Visit each, can be used in combination or separately as our plans evolve. We hope to use the same targets for the second and third proposals in this list. If substantial time (a day or more) is devoted to considering what actuation to perform as a result of analyzing the tilt sensing data (obtained during a Visit generated from the second proposal listed), momentum management considerations may dictate losing lock on the target in-between the two Visits.

6.1 Pupil Imaging Proposal

Both NIRCam science imaging and Coarse Phasing with DHS requires a **Pupil Alignment** step using NIRCam's Pupil Imaging Lens (PIL), with the telescope pointed at a bright (K ~ 2, TBD) star. Data to measure the required alignment, the algorithm to produce NIRCam pickoff mirror adjustment, and the commands to effect this alignment are yet to be determined. An aligned pupil results in an image of the PM at a desired location (within tolerance) on a specified NIRCam SCA.

We do not specify here what analysis is performed on the pupil image data this proposal is designed to acquire, nor what commands are created and uplinked to NIRCam to align the pupil inage on the detector when the PIL is in place.

Program No.:751 DRAFT JWST PHASE 1 PROPOSAL

Program title: JWST Primary Mirror Coarse Phasing with DHS – Pupil Imaging

Synopsis: Pupil Imaging to co-phase primary mirror segments using NIRCam

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 measure pupil illumination with NIRCam (Ks=2 TBD)

Instruments and observing configurations:
NIRCam and its filter and pupil wheel elements, FGS operating on co-aligned PSF.
Guide star J magnitude 14 (TBD), guiding box TBD x TBD pixels.

Scheduling requirements or constraints:

NIRCam operational, Primary Mirror latched, Segment Identification and Coarse Alignment achieved, optimal secondary position known or already achieved with Global Alignment procedure, Segment PSFs in "Stacked" configuration (sharing the same pointing), FGS operational at selectable box sizes/loop rates.

Visit scenario:

NIRCam Imaging short wavelength WFSC arm
PIL inserted
Pupil: 1% H_2 2.12 micron
Filter: WFS 1.15-2.25um (wavelength range TBD)

Slew to target
FGS Lock

Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5

Comments:
Unify with Commanding & Project OCD
Unify with OTE-24
Verify health/safety w/NIRCam - image persistence is unlikely to be a problem – PIL and narrow band filter inserted before reaching the target
3 exposures with up the ramp NGROUP1 = 5 to enable CR removal with median filtering
Target star isolation requirements TBD.

Total program time needed (days): N/A

Program written by: Anand Sivaramakrishnan
Date first written: 16 December 2004
As-of date: 3 March 2005

6.2 Focus-diverse High Dynamic Range Tilt Sensing

This proposal mitigates risk of PM segment tilts being out of spec for sufficient fringe contrast to support DHS algorithms processing by the Exec. While unphased PSFs are not amenable to **Misell-Gerchberg-Saxton** (MGS) algorithms (Misell, 1972, Gerchberg & Saxton, 1972) for phase retrieval in general, these algorithms do recover large tilts unambiguously from focus-diverse data (Ohara 2003). With large tilts measured by using data that this OP generates when its visit is executed, corrections to these tilts can be asserted on the JWST PM segments prior to the actual core co-phasing is carried out with DHS fringe sensing. We do not specify where these large tilts are actually corrected (this can be done at the start of the DHS co-phasing visit described in the next subsection, or by an independently executed PM segment pose[1] adjustment). Certainly large tilt corrections can be performed in a standard way using the DHS proposal (as we describe in section 6.4).

Program No.:752 DRAFT 3 JWST PHASE 1 PROPOSAL

Program title: JWST Primary Mirror Coarse Phasing with DHS – Tilt measurement

Synopsis: Segment tilt measurement to co-phase primary mirror segments using NIRCam

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 measure relative piston between segments (Ks=6 TBD)

Instruments and observing configurations:
NIRCam and its filter and pupil wheel elements, FGS operating on co-aligned PSF. Guide star J magnitude 14 (TBD), guiding box TBD x TBD pixels.

Scheduling requirements or constraints:
NIRCam operational, Primary Mirror latched, Segment Identification and Coarse Alignment achieved, optimal secondary position known or already achieved with Global Alignment procedure, Segment PSFs in Stacked configuration (sharing the same pointing), FGS operational at selectable box sizes/loop rates.
Pre-selected named file containing actuator updates must be specified in proposal.

Visit scenario:

NIRCam Imaging short wavelength WFSC arm
Slew to target
FGS Lock

Five defocus settings with weak lenses (exact number is TBD)
using TBD combinations of filter and pupil wheel positions
and narrow band filters

Pupil:Imaging pupil or a WFS Weak Lens – combination 1
Expose TBDs NFRAME1=2, NGROUP1=3

[1] The term "pose" refers to postioning a segment or segments in position or orientation. The term is also used in the field of biometrics, where the instaneous position and orientation of the al or part of the human body is referrred to as the "pose".

Pupil:Imaging pupil or a WFS Weak Lens – combination 2
Expose TBDs NFRAME1=2, NGROUP1=3

Pupil:Imaging pupil or a WFS Weak Lens – combination 3
Expose TBDs NFRAME1=2, NGROUP1=3

Pupil:Imaging pupil or a WFS Weak Lens – combination 4
Expose TBDs NFRAME1=2, NGROUP1=3

Pupil:Imaging pupil or a WFS Weak Lens – combination 5
Expose TBDs NFRAME1=2, NGROUP1=3

Comments:
Unify with OTE-24
Verify health/safety w/NIRCam - image persistence is unlikely to be a problem.
This data is to be processed by Tilt Retrieval algorithms (POC Scott Acton/Paul Atcheson and JPL: Cathy Ohara).
Exposure times are TBD.
NGROUP1 = 3 to enable CR removal with median filtering
Target star (5 magnitudes in 10') and guide star isolation requirements TBD.

Total program time needed (days): 1

Program written by: Anand Sivaramakrishnan
Date first written: 13 January 2004
As-of date: 03 March 2005

6.3 Dispersed Hartmann Sensing inter-segment piston sensing

The following proposal performs corrections for large segment tilts if required (a file containing the actuator commands implementing these segment pose changes is referred to as **P753_CP_DHS_placeholder_1** in the following proposal). Small segment pose changes (as determined from prior analysis of DHS fringe sensing data from this proposal) will reside in a file referred to as **P753_CP_DHS_placeholder_2** below. Details of how these files are generated by the WFS&C Exec, translated and recorded as suggested moves by the Mirror Control Software hosted by the Exec, and linked to the proposal by the use of Activity Descriptor parameters using unique, Visit ID-derived filenames, is described in a separate memorandum JWST-STScI-000512 "Wavefront Sensing and Control on JWST: embedding the Executive at the Science & Operations Center" (Sivaramakrishnan et al.2005)

Program No.:753 DRAFT 1 JWST PHASE 1 PROPOSAL

Program title: JWST Primary Mirror Coarse Phasing with DHS – Piston sensing

Synopsis: Inter-segment piston measurement to co-phase primary mirror segments using NIRCam

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

Basis for exposure time estimates (needed S/N and brightness range):
Sufficient exposure to measure relative piston between segments using fringes between adjacent segments produced by DHS dispersing prisms (Ks=6 TBD)

Instruments and observing configurations:
NIRCam and its filter and pupil wheel elements, FGS operating on co-aligned, possibly co-phased, PSF. Guide star J magnitude 14 (TBD), guiding box TBD x TBD pixels.

Scheduling requirements or constraints:
NIRCam WFSC short wavelength arm operational, Primary Mirror latched, Segment Identification and Coarse Alignment achieved, optimal secondary position known or already achieved with Global Alignment procedure, Segment PSFs in Stacked configuration (sharing the same pointing), FGS operational at selectable box sizes/loop rates.

File **P753_CP_DHS_placeholder_1** and **P753_CP_DHS_placeholder_2** containing actuator updates may be present on-board JWST. The first one will contain commands to correct out-of-spec segment tilts, the second will contain segment piston corrections. Any combination of these two files (neither, one or the other, or both) may be present on board. Typically neither or only one of these files is envisaged to be present on board at any time.

Visit scenario:

NIRCam Imaging short wavelength WFSC arm
Slew to target
FGS Lock

initial image before actuation
NFRAME1 frames are averaged together into a single digital image on board
NGROUP1 ‘reads’ are made up the ramp

Pupil: 1% H_2 2.12 micron
Filter: WFS 1.15-2.25um (wavelength range TBD)
Expose 100s (TBD) NFRAME1=1, NGROUP1=3
Expose 100s (TBD) NFRAME1=1, NGROUP1=3
Expose 100s (TBD) NFRAME1=1, NGROUP1=3

this corrects out-of-spec segment tilts if needed

Activity Descriptor: File **P753_CP_DHS_placeholder_1**
If **P753_CP_DHS_placeholder_1** exists:
    # post-actuation sensing
    Expose 100s (TBD) NFRAME1=1, NGROUP1=3
    Expose 100s (TBD) NFRAME1=1, NGROUP1=3
    Expose 100s (TBD) NFRAME1=1, NGROUP1=3

initial DHS sensing prior to actuation
Pupil: DHS 1
Filter: WFS 1.15-2.25um
Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5

Pupil: DHS 2
Filter: WFS 1.15-2.25um
Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5
Expose 100s (TBD) NFRAME1=1, NGROUP1=5

this corrects segment pistons if needed
Activity Descriptor: File **P753_CP_DHS_placeholder_2**
If **P753_CP_DHS_placeholder_2** exists:
    # post-actuation DHS sensing
    Pupil: DHS 1
    Filter: WFS 1.15-2.25um
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5

    Pupil: DHS 2
    Filter: WFS 1.15-2.25um
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5
    Expose 100s (TBD) NFRAME1=1, NGROUP1=5

Comments:
Unify with Commanding & Project OCD, OTE-24.
Verify health/safety w/NIRCam - image persistence is unlikely to be a problem.
This implements a Ball/AOA DHS algorithm (POC Scott Acton/Paul Atcheson/Allan Wirth).
3 exposures with up the ramp NGROUP1 = 5 to enable CR removal with median filtering
Target star isolation requirements TBD.

Total program time needed (days): N/A

Program written by: Anand Sivaramakrishnan
Date first written: 17 December 2004
As-of date: March 3 2005

7.0 Iterating Coarse Phasing steps

The exit gate for Coarse Phasing is specified in OTE-24: it is currently set at the rms measured inter-segment piston (OPD, not surface) being below 1 micron. Coarse Phasing proposals will be executed sequentially, with analysis by the WFS&C Exec and discussion of WFS&C Exec recommended segment pose updates by the WFS&C Team to determine next step.

8.0 Coarse Phasing Data flow, algorithms

Coarse Phasing and tilt retrieval algorithms are not described in this memorandum: please see STSCI-JWST-TM-2004-0019A (Sivaramakrishnan, 2004) for Coarse Phasing data flow, risks, and algorithm details, and Ohara et al (2003) for tilt retrieval with focus-diverse images. The principles used in Coarse Phasing, algorithmic sensitivities, capture ranges, etc. are discussed in STScI-JWST-TM, 2004 (Sivaramakrishnan et al. 2004), STSCI-JWST-TM-2004-0019A, 2004 (Sivaramakrishnan et al. 2004). Exec to S&OC ground systems is defined in WFS&C Exec to S&OC IRCD (being developed by Antczak, 2005).

8.1 WFS&C-specific Calibration Data

Target stars for Coarse Phasing possessing identifiable spectral features in the 1.0 to 2.2 micron wavelength range could provide the wavelength scale zero points for calibration of DHS spectra. This calibration is not part of routine NIRCam science data processing. Alternatively, narrow band filters in this range could be used to calibrate the wavelength scale. Another WFS&C-specific calibration step required is the identification of where DHS spectra actually fall on the detector.

8.2 Algorithm Data Quality Requirements

Noise affects Coarse Phasing piston measurements significantly. The proposals presented here target high frequency cosmic ray noise reduction by taking multiple images. Data inspection and post-pipeline processing to reduce noise even further may still be required by the WFS&C DHS piston-measuring algorithms.

8.3 DHS and/or DFS

Oschmann (2005) will report on the strengths and weaknesses of two methods of coarse phasing JWST, notably DHS and DFS. We do not address comparisons of these methods here. If they are required, DFS proposals can be developed for JWST prior to launch.

9.0 Conclusion

The STScI S&OC Ground System, together with the WFS&C Exec software is capable of using the Proposal Planning System, together with the WFS&C Executive to perform all of the steps involved in Coarse Phasing. The WFS&C Scientist and/or the WFS&C Team will inspect and possibly modify segment pose changes suggested by the Exec after some of the Coarse Phasing visit data are reduced. Using observing proposals prepared beforehand, along with data-driven segment updates created soon after Visit data are downlinked to the DMS and delivered to the Exec is a flexible approach that does not require special tools. We identify extra data processing steps over and above routine NIRCam data pipeline processing for Coarse Phasing data.

10.0 References

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