TECHNICAL MEMORANDUM

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Title: Sample Target Acquisition Scenarios for JWST		Doc #: JWST-STScI-003472 Date: July 3, 2013 Rev: -
Authors: Marshall Perrin, John Stansberry, Tracy Beck, Dean Hines, Rémi Soummer	Phone: 410-338-4789	Release Date: 3 September 2013

1 Introduction

We summarize some typical target acquisition scenarios envisioned for coronagraphy and spectroscopy with JWST NIRCam, MIRI, and NIRSpec. This is intended as a succinct summary of what “typical” target acquisitions could look like, particularly in terms of sequences of events and motions of the observatory with respect to the sky.

This document does not develop or describe in detail the reasoning behind the various acquisition sequences. It’s simply a summary in one document of target acquisition plans previously presented in several other documents as cited below. These are our current baseline plans, and may still be subject to change as operations planning matures before launch.

2 NIRCam Coronagraphy

Requirement: The NIRCam coronagraphs can tolerate up to 30 mas error (2σ radial) in target position after the slew is executed. The observatory allocation is 20 mas of that.

Broadly speaking, NIRCam coronagraphic acquisition works by first imaging one single target star once through a neutral density square, measuring its position, and then commanding one single slew of about 10 arcseconds to position the star behind the occulter. The spot occulters each have a unique target position that is used independent of filter selection. For the bar occulters, the target position varies along the length of the bar based on the central wavelength of the filter. (Longer wavelength observations are conducted closer to the wide end of the bar.)

Target Acquisition Process Summary:

1. User selects desired coronagraphic mask and filter when planning observations
    1. Which ND square to use is determined from that. See Figure 1.
    2. ND spots (named ND*) and round occulters (named M*R) are paired.
    3. There are 2 possible ND spots for each bar occulter (M*B). Which to use depends on filter being used.
2. Acquisition Procedure
    1. Observatory slew to place target behind appropriate ND square. (ND squares are 5” wide). FGS goes to fine guide.

2. Target imaged using 5” subarray
3. Scripts compute image centroid
4. Scripts compute slew to transfer target from current position to desired position behind occulter
5. Scripts command needed slew.
6. After slew, FGS reacquires fine guide.
7. NIRCam science observations are taken.

Slew Description:

1. Typical slew is 10.6” (center of ND square to center of occulter)
   a. Range 7.5” – 14” for round occulters. Depends on initial target position behind ND square
   b. Range 5.5” – 14” for bar occulters. Likewise depends on initial target position, but also affected by filter choice
2. Typical slew is oriented +/- 45º wrt +V3
   a. Sign is fixed for any spot occulter
   b. Sign depends on filter for bar occulters.
   c. The exact orientation angle depends on the initial target position behind the ND square, and for bar occulters also depends a bit on filter.

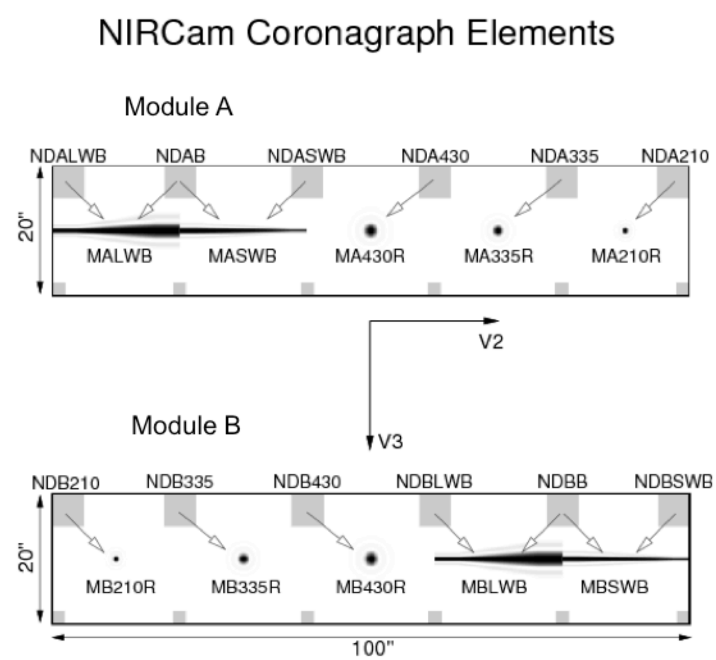

Figure 1: NIRCam coronagraph elements, showing the slews from the ND squares to the coronagraph occulters.

3 NIRSpec Spectroscopy

This section summarizes material from the document “NIRSpec Target Acquisition Requirements”, ESA-JWST-RQ-5071 by Torsten Böker. Please refer to that document for additional details including the error budget developed by the NIRSpec team.

We describe here the baseline procedure for target acquisitions for the MSA. Alternate target acquisition processes for fixed slit and integral field spectroscopy modes are in development but not yet complete. It is expected that they will look broadly similar to the MSA target acquisition procedure described here.

The desired target position for NIRSpec spectroscopy is determined by measuring the apparent centroids of a set of reference stars, between 8 and 20 stars typically. In any one exposure with unknown position offset, it’s almost certain that several of these stars will be blocked by the MSA shutter grid causing errors in their measured centroids. For this reason the NIRspec acquisition process takes two images offset by half a shutter grid width and analyzes both to ensure accurate centroids are used when computing the final slew.

Requirement: “In order to guarantee that the slit losses occurring at the MSA can be well-calibrated, the placement of the science targets within their respective shutter must be controlled to better than 10% of the shutter width which corresponds to a target acquisition error no larger than 20 mas.”

Target Acquisition Process Summary:

1. When planning observations, user defines desired MSA mask position relative to the sky.
2. Telescope slew to target field.
3. FGS goes to Fine Guide via standard procedure
   - After entering fine guidance mode, the target should be positioned to an accuracy of 1 arcsecond (1-sigma, radial)
   - Error budget assumes 5.0 mas for target drift during the acquisition process.
4. NIRSpec takes internal lamp image to calibrate the imaging mirror position.
5. NIRSpec acquires an image of the sky
6. Spacecraft slew of 120 mas in ‘NIRSpec x direction’ (=41.5 deg counterclockwise from +V3), 250 mas in ‘NIRSpec y direction’ (=131.5 deg counterclockwise from +V3).
   - Error budget assumes 5.0 mas for dither slew execution.
   - *Note: For the fixed slit and IFU target acq procedures still in development, it is likely that a different slew will be used here. Requirements are not yet finalized but the offset is expected to be of order 0.3 to 0.5 arcseconds.*
7. NIRSpec acquires another image of the sky
8. Both images are processed to derive required slew to precisely position science target(s)
   - The size of this slew will depend upon the accuracy with which the spacecraft has positioned the initial field. If the spacecraft meets the 1 arcsecond, 1 sigma accuracy noted above in step 3, the slew here should be of that size.
9. The resulting slew is sent to ACS and the spacecraft slew occurs.

- Error budget assumes 5.0 mas for slew execution.

10. Confirmation image taken.
11. NIRSpec proceeds to science observations.

4 MIRI Coronagraphy

Four Quadrant Phase Mask (4QPM)

- Optic induces 180deg phase difference in quadrants for narrow band-pass
- Enables ~1lambda/D inner working angle
- Require very precise centering of target on vertex of quadrants
- Tolerance ≤ 5 mas (single axis, 1sigma)
- It is more important that the pointing is repeatable than that the absolute pointing is centered. Reference star subtraction alignment dominates the errors (see figures below)

Lyot

- Standard Lyot with ~6lambda/D inner working angle
- Only used for 23µm band
- Tolerance is ≤ 20mas (single axis, 1sigma)

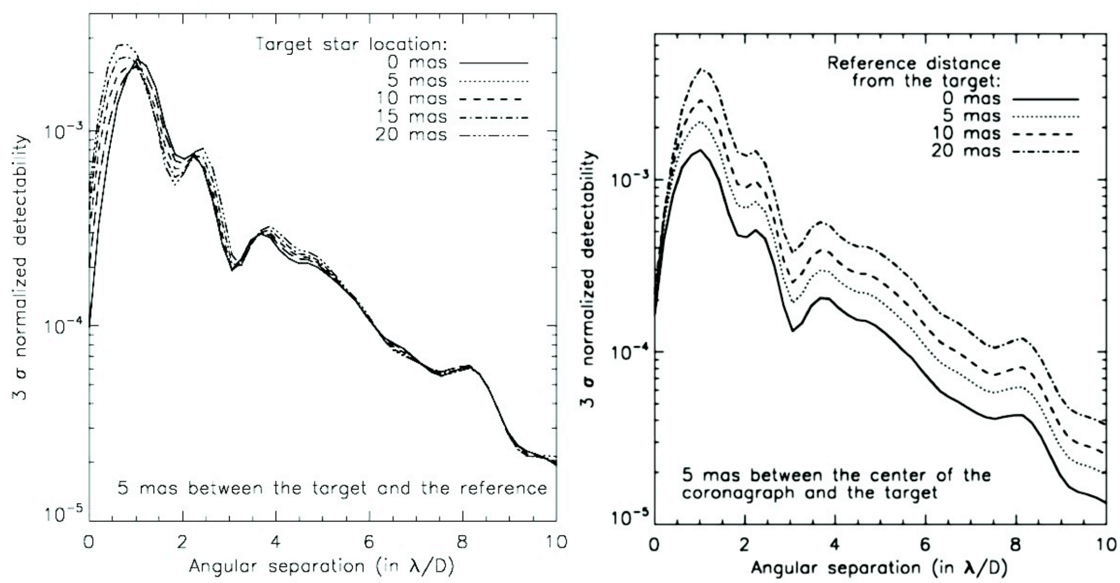

Figure 2: The ultimate contrast is dominated by the offset between the target and reference point-sources

What is the motivation of the 4QPMs?

- Characterizing exoplanets
- Provides superior inner working angle (~l/D) compared to Lyot (~6 l/D)

What is the primary driver for maximum contrast?

- Centering on the vertex of the 4QPM?
- Matching the position of the target and reference on the 4QPM?
- Both, but matching the target and reference more important!

Heavily dependent on the accuracy of the telescope slew

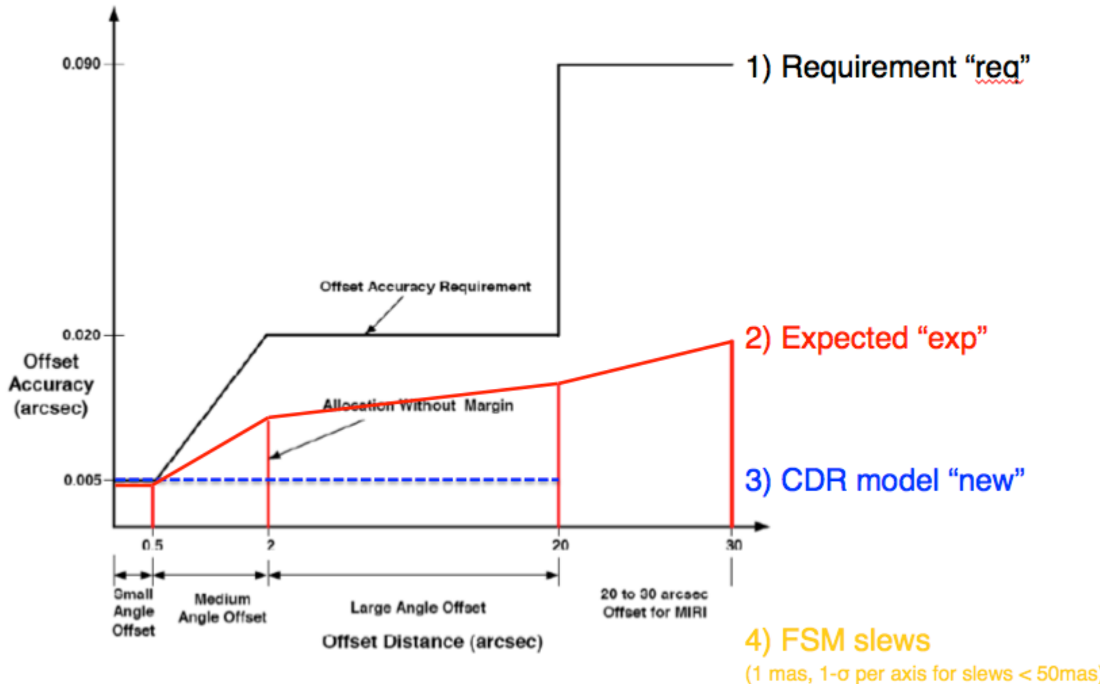

Figure 3: comparison of various estimate of the slew accuracy. The TA scenario described here assumes "CDR estimates" of the slew accuracy.

Target Acquisition (TA)

- Description of TA herein is strictly confined to the centroiding and slew, not the details of the TA filter selection or the detailed algorithms
- No timing estimates are provided
- **The TA scenarios described here assume CDR slew accuracy estimates (5mas slew accuracy constant up to 20 arcsec slews)**

LYOT TARGET ACQUISITION

- Place target in 64pix x 64pix Region of Interest (ROI) with far edge ≤ 20 arcsec from center of coronagraph
- Find centroid
- Slew telescope to place object in center of Lyot "spot"
- Take science images
- Repeat process from opposite side to mitigate against latent images in the ROI

FQPM TARGET ACQUISITION

- Detailed TA is still under development
- Place target in 64pix x 64pix Region of Interest (ROI) with far edge ≤ 20 arcsec from center of coronagraph
- Find centroid

- Slew telescope to place object into a second ROI that is located 4 arcsec from the vertex of the 4QPM
- Find Centroid
- Slew telescope to place object into the vertex of the 4QPM
- Take science images
- Repeat process from opposite side to mitigate against latent images in the ROIs

OPTIONAL CORONAGRAPHIC DITHER PATTERN

- Optional small dither pattern for coronagraphic TA
  - Include a small sub-pixel dither pattern (e.g. 3x3 pattern 10-50mas side) centered around the final position obtained after TA, while remaining under fine guidance (FSM slews).
  - This pattern can be used with any coronagraph but mostly driven by MIRI FQPM
  - This pattern can be used both on the target and on the reference stars, but is more likely to be used on the reference star only
- This dither pattern is an optional feature for coronagraphy that can improve the performance of the coronagraph (up to a factor 10) for some more challenging targets