NIRSpec MSA Target Acquisition

The NIRSpec target acquisition (MSATA) process uses reference stars to center targets within the MSA, IFU or FS apertures for science observations. In cases where few reference stars are available, it is possible to use other compact sources with relaxed stellarity.

Introduction

> *Parent article: NIRSpec Target Acquisition*
> *See Also: NIRSpec Target Acquisition Recommended Strategies*

The NIRSpec target acquisition (TA) method ***MSATA***[1] will be used for most NIRSpec science observations performed with the micro-shutter assembly (MSA) in the MOS observing mode, and is optionally available for the NIRSpec fixed slits (FS) and IFU observing modes.

During the ***MSATA*** procedure, a set of TA reference objects (typically stars) are observed through the open micro-shutters. Their centroids are calculated and used to accurately correct the initial spacecraft pointing and orientation. The achievable TA performance depends significantly on the relative astrometric knowledge of both the reference stars and the science source positions used to plan the TA and the science. The ***MSATA*** procedure is designed to work best when the relative astrometric accuracy of the target field is in the range of 5 to 50 mas. The optimal TA accuracy of about 20 mas requires a relative astrometric accuracy of 5 mas in the planning catalog.

MSATA is not available for the bright object time-series (BOTS) observing mode because (1) the wide aperture TA available for this template in the JWST Astronomers Proposal Tool (APT) is equally accurate for a single target and takes less time to execute and (2) the required full frame detector readout would likely saturate on any BOTS science sources.

[1] ***Bold italics*** font style indicates parameters, parameter values, and special requirements that are set in the APT GUI.

Operational sequence of *MSATA*

The ***MSATA*** procedure uses a set of reference stars distributed over the MSA quadrants, determines their observed centroids on the detector, and compares them to the desired positions to calculate a small-angle maneuver that adjusts the initial pointing and position angle. The process acquires two exposures to centroid reference stars in order to accurately align the science targets of interest within their apertures. The centroids of 5–20 reference stars will be measured in a full frame imaging exposure obtained through the "all open" MSA quadrants (or a protected configuration to block all operable shutters except those with reference stars) using both detectors NRS1 and NRS2.

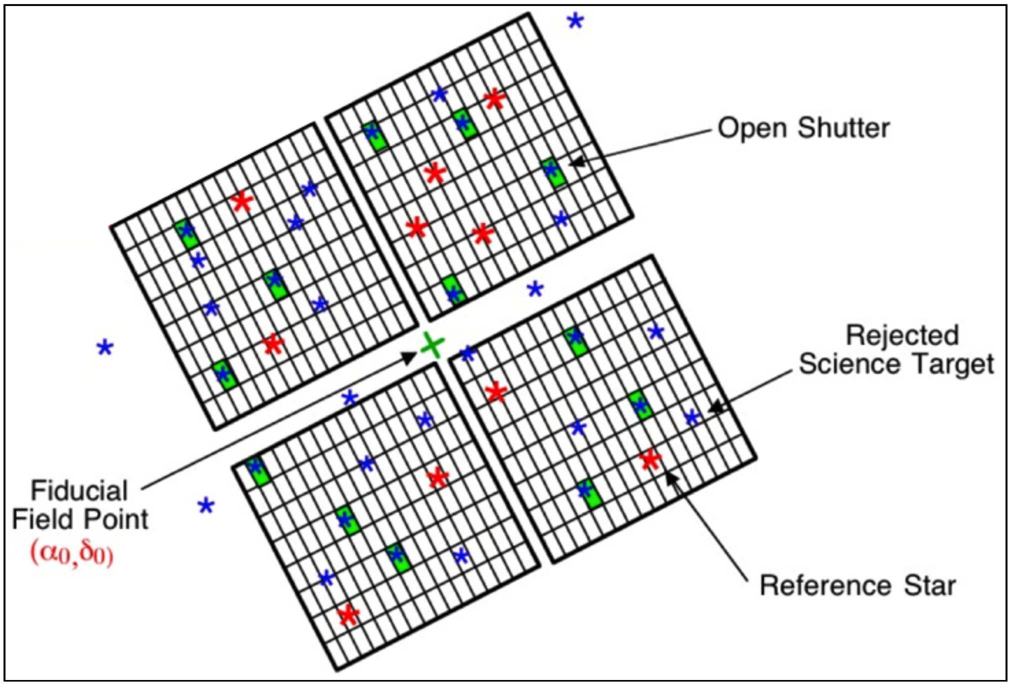
The two exposures are offset by one-half of an MSA shutter "pitch" (the distance between adjacent shutter centers) in both coordinates. This “MSA half facet slew” is necessary to properly derive the location of the reference stars, minimizing the effect of the physical bars between micro-shutters that could otherwise bias the measured positions of the stars. The description of the micro-shutter assembly presents additional information on the MSA structure. The NIRSpec observation planning tool software will preferentially choose reference stars that are not affected by failed closed micro-shutters.

Both NIRSpec ***MSATA*** images are processed by the onboard software to determine precise locations of the reference stars. These locations are initially measured in pixel coordinates and must be transformed by the software into the distortion-free tangential coordinate system on the sky before they can be compared to the desired sky positions. This coordinate transformation requires precise knowledge of the combined distortion effects of the telescope (Optical Telescope Element; OTE) and NIRSpec, as well as the measured tilt of the NIRSpec target acquisition imaging mirror. The measured centroids of the reference stars will be transformed to sky coordinates and compared with catalog positions expressed in the same sky frame to determine offsets for each reference star and a combined mean pointing offset including a possible roll adjustment.

These quantities are calculated using a least squares methodology. After a sigma-clipping and threshold outlier rejection procedure to determine the mean offset and residuals, the telescope will be offset by the final derived mean slew value. The procedure may be repeated once if the overall offset exceeds a specified threshold (1.1") to improve centering accuracy. Subsequently, a reference image of the centered target field is automatically obtained to conclude the ***MSATA*** operational process. The overall timing to execute ***MSATA*** is estimated to be 1,440 s per science visit in observation planning. This overhead will be revised as new information becomes available.

The available filters for these acquisition images are ***F110W***, ***F140X***, or ***CLEAR***. NIRSpec TA images are always acquired in full frame readout with N_{groups} = 3 and detector readout pattern options of ***NRS,*** **NRSRAPID**, ***NRSRAPIDD1*** and ***NRSRAPIDD2***. The latter two are available for ***MSATA*** only.

Figure 1. Graphical description of NIRSpec *MSATA*



Schematic view of the MSA layout, with target acquisition reference stars shown in red, and science targets (blue) shown in their open MSA shutters (green). Some science targets are not observed because they lie in the same row as other sources (spectral overlap) or because their flux is attenuated by the MSA support grid. The target acquisition process acquires exposures and carefully measures the pointing of the reference stars to correct the pointing and position angle to the best science position.

Expected Accuracy of *MSATA*

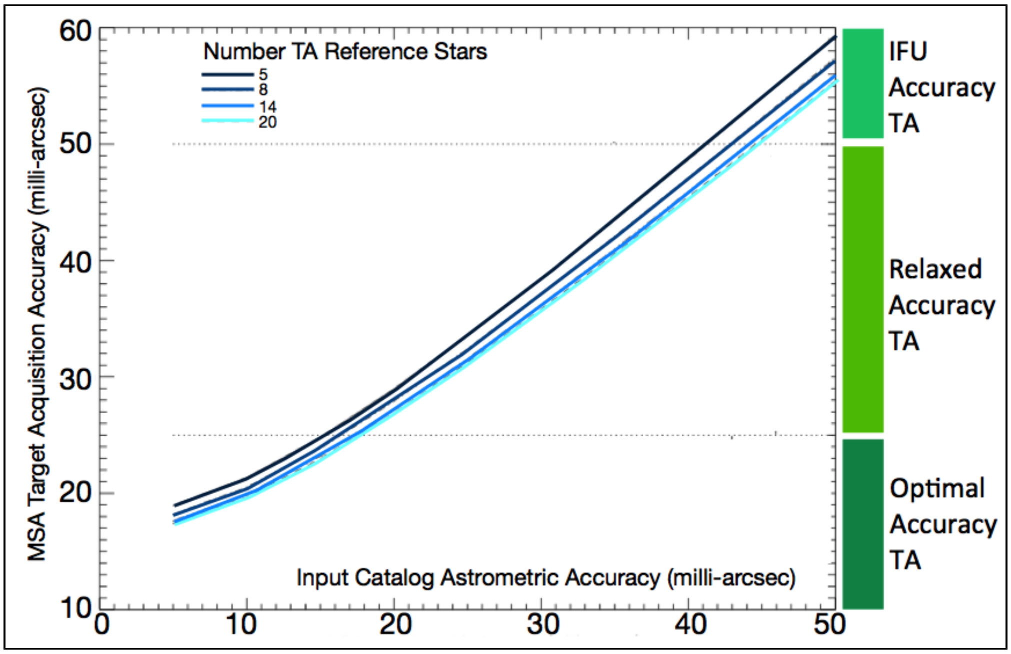
Figure 2 shows the NIRSpec target acquisition planning uncertainty as a function of input catalog astrometric accuracy, derived and updated from the estimated error budget definition.

If target acquisition uses 5 or more reference stars, the estimated NIRSpec acquisition accuracy will be better than ~20 mas (<1/10 shutter width) if the input planning catalog astrometric accuracy is 5–10 mas. The estimated delivered TA accuracies of better than 25 mas (called optimal TA) are achieved only if planning catalog astrometry is better than about 15 mas for all reference stars and science sources. Delivered estimated TA accuracy of 25–50 mas is possible to achieve using input relative astrometry with 15–40 mas accuracy.

An estimated TA accuracy level of 50 mas is 1/4 of an MSA shutter width (or 0.2" FS width), and this would result in very significant flux calibration (i.e., slit loss) uncertainty and probable degradation in wavelength calibration accuracy. Hence, this TA regime (called NIRSpec “relaxed accuracy TA”) should primarily be used for MSA science on very extended sources and use cases that can tolerate a reduced flux calibration accuracy. A TA accuracy beyond 50 mas is recommended primarily for IFU mode observations. (Nevertheless, ***WATA*** is usually preferred over ***MSATA*** for IFU observations.)

Table 1 describes these ***MSATA*** accuracy classifications based on input astrometric accuracies for reference stars and science targets. The Astronomer's Proposal Tool (APT) planning interface with the MSA Planning Tool requests an astrometric catalog accuracy, and these ***MSATA*** classifications are presented to users when target acquisition is defined in visits.

Figure 2. Expected accuracy of the NIRSpec MSATA process as a function of planning catalog accuracy



Expected NIRSpec target acquisition accuracy as a function of input planning catalog (relative) astrometric accuracy. The multiple curves show the expected accuracy for the number of reference stars used in MSATA, from 5 to 20.

Table 1. Description of the "optimal," "relaxed accuracy," and "IFU only" categories used to describe the accuracies achieved in MSATA

Accuracy classification	Input catalog astrometric accuracy (mas)	Estimated TA accuracy (mas)
Optimal	<15	<25
Relaxed accuracy	15–35	25–50
IFU only	>35	50–60

Approximate brightness limits for *MSATA*

The brightness limits for the reference stars in ***MSATA*** observations are defined by the instrument filter used to acquire the images, and the detector readout pattern used for the exposures (IRS2 readout patterns are not used for ***MSATA*** or ***WATA***.) All NIRSpec TA exposures are acquired with Ngroups = 3 (specified using the ***Acq Groups/Int*** parameter in APT), which also defines the achieved brightness range. Table 2 provides the approximate limiting AB magnitudes of sources that might be used for ***MSATA***, and the corresponding instrument settings. Values are provided for a source with a S/N equal to 20 and for a source near saturation, and for all available TA filters. These are estimated values based on ground test results and are subject to change.

In addition to the ***NRSRAPID*** and ***NRS*** readout patterns described in the NIRSpec detector readout patterns pages, ***MSATA*** has two additional detector patterns available called ***NRSRAPIDD1*** and ***NRSRAPIDD2***. These two patterns were added to more efficiently observe the magnitude range achievable for NIRSpec in the ***MSATA*** images, particularly for TA in extragalactic deep fields. The ***NRSRAPIDD1*** and ***NRSRAPIDD2*** patterns are available only with the ***CLEAR*** filter.

Table 2. Brightness ranges for NIRSpec *MSATA* filter and readout pattern options

Readout mode	S/N = 20			Saturation		
	F110W	***F140X***	***CLEAR***	***F110W***	***F140X***	***CLEAR***
NRSRAPID	22.0	23.0	23.8	19.5	20.6	21.3
NRSRAPIDD1			24.5			21.9
NRSRAPIDD2			24.9			22.2
NRS	24.1	25.1	25.7	21.0	22.1	22.8

Limiting bright and faint magnitudes for target acquisition reference stars. All values are given in AB magnitudes; subtract 0.7 for approximate J-band magnitude values (Vega magnitudes). Readout Patterns ***NRSRAPIDD1*** and ***NRSRAPIDD2*** are only used with the ***CLEAR*** filter for TA exposures. All TA exposures are acquired with N_{groups} = 3.

Observation Planning for *MSATA*

In the MOS, IFU and FS science templates, ***MSATA*** is an option for target acquisition. ***MSATA*** is expected to be the common target acquisition method for the NIRSpec MOS science mode. In all cases, the NIRSpec science observations will be defined in a standard way via the Astronomer's Proposal Tool (APT). The ***MSATA*** parameters are defined using a planning catalog with reference stars, ingested in the MSA Planning Tool (MPT).

NIRSpec ***MSATA*** parameters, including reference stars and exposure specifications, cannot typically be completely defined at proposal submission. Science observations with the NIRSpec MSA, FS or IFU that include target acquisition using the ***MSATA*** methodology must be oriented observations, but the orient does not need to be specified with the proposal submission. Rather, the final execution orientation will be assigned after proposal acceptance, and observers will be asked to re-submit with fully defined TA parameters. (Science observations that seek to restrict the aperture position angle are allowed at proposal submission, but discouraged. Ideally, if an orient constraint is desired, a range of angles no smaller than 30 observable degrees is recommended.)

NIRSpec ***MSATA*** parameters, including reference stars and exposure specifications, can only be planned after fixed orients are assigned to a NIRSpec MOS program, or for FS or IFU programs using the MSATA method. Execution orients are assigned by the JWST long range plan (LRP) and communicated to teams after proposals are accepted by the JWST time allocation committee.

The observation planning parameters for observations that use NIRSpec ***MSATA*** are defined both at the observation and visit level in the APT program. In order to properly define NIRSpec ***MSATA***, the catalog used to plan MOS science observations must include reference stars. Even IFU or FS science observations that use ***MSATA*** must have an available catalog of reference stars in the wider area covered by the MSA. In any case, the catalog must have columns containing the brightness in the NIRSpec target acquisition filters for each potential reference star. (To prevent catalog ingest errors, it is also advised to provide this information for all sources in the catalog.) After the science observation is planned, the observer must select a reference star bin for each *visit*. When a visit is highlighted in the hierarchical editor of APT, APT will create a representation of the MSA with selected reference stars. The reference stars have been grouped based on brightness bins defined for the various instrument filter and readout pattern combinations (see Table 2). Each selection, if multiple are presented, contains the brightest stars in the bin, up to a maximum of 20. The bins are ordered by those containing the most reference stars.

For a science program that seeks to use this MSA-based target acquisition process for any NIRSpec observing mode, the proposal should be submitted with an ON HOLD Special Requirement in APT that says "***On Hold for Orient Assignment***".