

## Chapter 32

# NIRSpec Multi-Object Spectroscopy

In this chapter...

### 32.1 Introduction

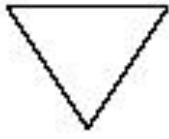
The NIRSpec Multi-Object Spectroscopy (MOS) template is to be used for all observations using the multi-object spectroscopy mode of NIRSpec. NIRSpec MOS observations can be used to study rich fields (e.g. clusters of galaxies), as well as very extended targets (e.g. H II regions). The MOS offers either the option of the standard MSA target acquisition, or to simply take an image to verify pointing during post-analysis. The parameters described in this section are used to specify the Observations for NIRSpec Multi-Object Spectroscopy. More complete descriptions of the detector readout parameters, filters/dispersers, detector characteristics, etc. are available in the [NIRSpec Instrument Handbook](#); see also [Chapter 8](#) of the document for more details on the NIRSpec MSA Planning tool.

The following fields are defined in Chapter 5: Observation Number ([5.1](#)), Observation Label ([5.2](#)), Observation Comments ([5.3](#)), Target Name ([5.4](#)), Observation-Level Special Requirements ([5.5](#)), and On Hold Comments ([5.6](#)), and will not be discussed in this Chapter. Note that for the MSA, the target position refers to the reference point of the MSA apertures, and not to any particular MSA source.

The NIRSpec Multi-Object Spectroscopy **[NRS0115]** template consists of the following parameters:

Field	Details	Values	Notes
Preliminary Direct Image <b>[NRS0116]</b>	specify source of preliminary IR image <b>[NRS0117]</b>		MOS observations cannot be scheduled until this image is obtained
TA_Method <b>[NRS0466]</b>		TACQ or VERIFY_ONLY <b>[NRS0467]</b>	
<b>Target Acquisition</b>			
TACQ Filter <b>[NRS0118]</b>	select filter name	choose from list <b>[NRS0119]</b>	see Table 32-1
TACQ Readout Pattern <b>[NRS0120]</b>	select readout pattern	choose from list <b>[NRS0121]</b>	see Table 32-2
MSA TACQ Configuration Filename(s)	specify filename(s)		if needed

<b>[NRS0122]</b>	<b>[NRS0123]</b>		
Reference Stars <b>[NRS0124]</b>	select targets	choose from list <b>[NRS0125]</b>	
<b>Pointing Verification Image</b>			
Pointing Verification Image Filter <b>[NRS0468]</b>	select filter name	choose from list <b>[NRS0469]</b>	see Table 32-1
Pointing Verification Image Readout Pattern <b>[NRS0470]</b>	select readout pattern	choose from list <b>[NRS0471]</b>	see Table 32-2
Pointing Verification Image Number of Groups <b>[NRS0472]</b>	specify number of groups	number <b>[NRS0473]</b>	
Pointing Verification Image MSA Configuration Filename(s) <b>[NRS0474]</b>	specify filename(s) <b>[NRS0475]</b>		If needed
<b>Confirmation Image</b>			
Obtain Confirmation Image? <b>[NRS0126]</b>	specify if image desired	Yes/No <b>[NRS0127]</b>	optional
Confirmation Readout Pattern <b>[NRS0128]</b>	select readout pattern	choose from list <b>[NRS0129]</b>	see Table 32-2
Confirmation Number of Groups <b>[NRS0130]</b>	specify number of groups	number <b>[NRS0131]</b>	
<b>Science Observation</b>			
Dither Pattern <b>[NRS0132]</b>	select Dither Pattern	choose from list <b>[NRS0133]</b>	see Table 32-3
MSA Science Configuration Filename <b>[NRS0134]</b>	specify filename <b>[NRS0135]</b>		
Science Grating/Filter <b>[NRS0136]</b>	select grating name	choose from list <b>[NRS0137]</b>	see Table 32-4
Science Readout Pattern <b>[NRS0138]</b>	select readout pattern	choose from list <b>[NRS0139]</b>	
Science Number of Groups <b>[NRS0140]</b>	specify number of groups	number <b>[NRS0141]</b>	
Science Number of Integrations <b>[NRS0142]</b>	specify number of integrations	number <b>[NRS0143]</b>	
Automatic Calibration Option <b>[NRS0476]</b>	select Auto Calibration option	DEFAULT, NONE, FLAT, WAVECAL, BOTH <b>[NRS0477]</b>	



*Note that **ALL** parameters listed below are required as part of your Phase I submission, except for the MSA Science and MSA Acquisition Configuration Filenames.*

## 32.2 NIRSpec Multi-Object Spectroscopy

The following parameters are used to define NIRSpec Multi-Object Spectroscopic observations.

### 32.2.1 Preliminary Direct Image

Most NIRSpec MOS observations require a preliminary NIRCcam image, or possible other IR (e.g. HST/WFC3) image, to be obtained. This should be indicated in the template in one of three ways:

- 1) If a NIRCcam image is to be obtained as part of the program, select the "will be done in this program" option, and select the observation which contains the NIRCcam image. You should also place an AFTER OBS BY special requirement on the MOS observation(s) to link the NIRCcam image to the MOS observation(s). **[NRS0144]**.
- 2) If a NIRCcam image is to be obtained external to the program (either as part of a different JWST program or with another observatory), select the "will be obtained external to this program" option. You should also use the ON HOLD special requirement on the observation. **[NRS0145]**.
- 3) If the NIRCcam (or other IR) image is already obtained, select the "is already obtained" option. **[NRS0146]**.

If a pre-image is not required, select the "Not required" option . **[NRS0147]**.

Note that if option 1 or 2 is selected, the NIRSpec MOS observation will NOT be scheduled until the observer has notified STScI that the NIRCcam image has been obtained and analyzed.

Note for developers: If option 1 is selected, APT should ensure that the AFTER OBS BY has a long enough interval to be legal (at least 6 weeks) **[NRS0478]**. If option 2 is selected, APT should ensure that an ON HOLD is present **[NRS0479]**. APT should also verify that at least one of the options is selected **[NRS0480]**.

### 32.2.2 Target Acquisition

TA METHOD **[TA METHOD]** = TACQ **[NRS0145]** (default) **[NRS0323]**,  
VERIFY\_ONLY **[NRS0481]**

Select the target acquisition method to be used. The standard MSA TA is used for observations that require precision of 20 mas RMS, such as when observing many point sources with the MSA or moderately extended sources such as high-redshift galaxies. Pointing Verification can be used for observations that do not require greater precision than 100 mas. Pointing Verification meets the requirements for extended objects such as extended solar system objects (comets, Jovian planets).

Note for developers: TA METHOD is a required parameter **[NRS0482]**. If TACQ is selected, APT should accept Target Acquisition parameters below **[NRS0483]**. If VERIFY\_ONLY is selected, APT should accept Pointing Verification Image parameters below **[NRS0484]**.

### 32.2.21.1 Target Acquisition

If TA METHOD= TACQ then the following parameters are used to define NIRSpec Target Acquisition observations. Note that, after the acquisition is complete, a reference image will be obtained to allow observers to check the status of the acquisition.

### 32.2.21.2 Target Acquisition Filter

Select the name of the TARGET ACQUISITION FILTER **[TACQ FILTER]** (see Table 32-1) you wish to use for target acquisition.

**Table 32-1 Filters Available for NIRSpec Target Acquisition**

Acq. Filter	Center Wavelength $\lambda_0$ ( $\mu\text{m}$ )	Filter Bandpass $\Delta\lambda$ ( $\mu\text{m}$ )	Comment	TACQ	VERIFY_ONLY
F140X	1.4	1.2	broad band	<b>[NRS0149]</b>	<b>[NRS0485]</b>
F110W	1.1	0.2	narrow band	<b>[NRS0150]</b>	<b>[NRS0486]</b>

### 32.2.2.1.2 Acquisition Readout Pattern

**READOUT PATTERN [TACQ PATTERN] = NRS [NRS0151],  
NRSRAPID [NRS0152]**

This field specifies the readout pattern to be used to obtain the acquisition data; see Table 32-2. NRS is used for faint targets, while NRSRAPID is used for bright targets

**Table 32-2 NIRSpec Acquisition Readout Patterns**

Readout Pattern	NGROUP Used	Integration Time	Usage
NRS	3	127.3 <b>[NRS0381]</b>	default pattern for science

NRSRAPID	3	31.8 <b>[NRS0382]</b>	for bright sources
----------	---	-----------------------	--------------------

Note for developers: APT will use these values for calculating the overhead for acquisition exposure times: NINTS=1 **[NRS0330]** and NGROUPS=3 **[NRS0331]**. Also note that while the SUBARRAY is not explicitly given, its value is FULL for the purposes of calculating exposure time **[NRS0341]**.

### 32.2.2.1.3 MSA Acquisition Configuration Filename

When obtaining acquisition data, the default is to have all MSA shutters open **[NRS0157]**. However, if there are bright stars in the field that you wish to mask out during the target acquisition exposure, you can provide an optional **MSA ACQUISITION CONFIGURATION FILENAME** **[NRS0158]** **[TACQ MSAFILE]** which describes the MSA mask to be used to block the light from these stars. This file should be generated by using the MSA Planning tool. If no file is specified, then all shutters will be open.

### 32.2.2.1.4 Reference stars

Specify the reference stars **[REFSTARS]** (minimum of 8 **[NRS0159]**, maximum of 20 **[NRS0160]**) to be used for analysis of the target acquisition image from those previously entered (see Section 3.3).

Note for developers: the user will choose from a multi-selection window from 8-20 of the reference stars available in the proposal. Ideally this list will be trimmed to only include those in the same region of the sky as the science target, but that is a later requirement. The maximum (20) is a hard limit **[NRS0161]**, but for now make the minimum (8) a warning only **[NRS0162]** (the limit is hard for real usage, but Vicki needs to support fewer stars for testing).

### 32.2.2.2 Pointing Verification Image

If TA METHOD= VERIFY\_ONLY then the following parameters are used to define the NIRSpec Pointing Verification Image exposure. This is an image of the MSA field that will be taken after all science exposures and auto calibrations in each visit have completed. This exposure can be used to determine the exact pointing of every exposure within the observation.

#### 32.2.2.2.1 Pointing Verification Image Filter

Select the name of the **POINTING VERIFICATION IMAGE FILTER** **[POINTING FILTER]** (see Table 32-1) you wish to use for direct image **[see Table 32-1]**.

#### 32.2.2.2.2 Pointing Verification Image Readout Pattern

**POINTING VERIFICATION IMAGE READOUT PATTERN [POINTING PATTERN] = NRS [NRS0487], NRSRAPID [NRS0488]**

This field specifies the readout pattern to be used to obtain the acquisition data; see Table 32-2.

#### 32.2.2.2.3 Pointing Verification Image Number of Groups

**POINTING VERIFICATION IMAGE NUMBER OF GROUPS [POINTING NGROUPS]** specifies the number of groups in an integration **[NRS0489]**.

#### 32.2.2.2.4 Pointing Verification Image MSA Configuration Filename

When obtaining pointing image data for pointing knowledge, the default is to have all MSA shutters open **[NRS0490]**. However, if there are bright stars in the field that you wish to mask out during the pointing image exposure, you can provide an optional **POINTING VERIFICATION IMAGE MSA CONFIGURATION FILENAME [POINTING MSAFILE] [NRS0491]** which describes the MSA mask to be used to block the light from these stars. This file should be generated by using the MSA Planning tool. If no file is specified, then all shutters will be open.

Note for developers: APT will use these values for calculating the overhead for pointing image exposure times: NINTS=1 **[NRS0492]**. Also, while the SUBARRAY is not explicitly given, its value is FULL for the purposes of calculating exposure time **[NRS0493]**.

### 32.2.3 Optional Confirmation Image

The following parameters are used to define an *optional* confirmation image.

#### 32.2.3.1 Obtain Confirmation Image?

**OPTIONAL CONFIRMATION IMAGE [CONFIRM] = YES [NRS0163], NO [NRS0164] (default) [NRS0165]**

If desired, an optional confirmation image can be obtained. This image will be acquired with the first science filter **[NRS0166]**, and will be used to help flux-calibrate the NIRSpec science data; see the [NIRSpec Instrument Handbook](#) for details. If you wish to obtain this image (which will be obtained after every target acquisition), select YES.

Note for developer: a checkbox instead of Yes/No parameter is acceptable.

### 32.2.3.2 Confirmation Readout Pattern

**READOUT PATTERN** [**CONFIRM PATTERN**] = NRS [**NRS0167**]  
(default) [**NRS0168**], NRSRAPID [**NRS0169**]

This field specifies the readout pattern to be used to obtain the optional confirmation image; see Table 32.2

### 32.2.3.3 Confirmation Number of Groups

**NUMBER OF GROUPS** [**CONFIRM NGROUPS**] specifies the number of groups in an integration.

Note for developer: NINTS = 1 [**NRS0171**] Also note that while the SUBARRAY is not explicitly given, its value is FULL for the purposes of calculating exposure time [**NRS0342**]

## 32.2.4 Science Observation

The following parameters are used to define NIRSpec MOS science observations.

### 32.2.4.1 Dither Pattern

Most observations with JWST will require dithering. Select the **DITHER PATTERN** [**DITHER PATTERN**] from those listed in Table 32-3.

**Table 32-3 Dither Patterns Available for NIRSpec MOS Spectroscopy**

Dither Pattern	Description	
dither1-TBD	short description1	[ <b>NRS0172</b> ]
dither2-TBD	short description2	[ <b>NRS0173</b> ]
dither3-TBD	short description3	[ <b>NRS0174</b> ]

### 32.2.4.2 MSA Science Configuration Filename

Specify the **MSA SCIENCE CONFIGURATION FILENAME** [**MSAFILE**], which contains the mapping of the status of each shutter (open or closed). [**NRS0153**] This file is generated from the NIRSpec Observation Planning tool (see Chapter 8). There can be many such files, depending on the extent of the **DITHER PATTERN** [**NRS0175**].

It is not clear if the Dither and Configuration information is entered here or elsewhere.

### 32.2.4.3 Science Grating/Filter

For each grating/filter that you use, specify the name of the grating/filter and the exposure duration parameters (Readout Pattern, Number of Groups, and Number of Integrations)

Note for developers: users can specify one or more combinations of the parameters below.

**[NRS0176]**

#### 32.2.4.3.1 Grating/Filter Name

Select the name of the **GRATING/FILTER** **[GRATING, FILTER]** (see Table 32-4) you wish to use for the science observations.

**Table 32-4 Grating/Filters Available for NIRSpec MOS Observations**

Grating/Filter	Center Wavelength $\lambda_0$ ( $\mu\text{m}$ )	Filter Bandpass $\Delta\lambda$ ( $\mu\text{m}$ )	Resolution	Comment
G140M/F070LP	0.95	0.5	~1000	<b>[NRS0177]</b>
G140M/F100LP	1.40	0.8	~1000	<b>[NRS0178]</b>
G235M/F170LP	2.35	1.3	~1000	<b>[NRS0179]</b>
G395M/F290LP	3.95	2.1	~1000	<b>[NRS0180]</b>
G140H/F070LP	0.95	0.5	~2700	<b>[NRS0181]</b>
G140H/F100LP	1.40	0.8	~2700	<b>[NRS0182]</b>
G235H/F170LP	2.35	1.3	~2700	<b>[NRS0183]</b>
G395H/F290LP	3.95	2.1	~2700	<b>[NRS0184]</b>
PRISM/CLEAR	2.8	4.4	~100	<b>[NRS0185]</b>

#### 32.2.4.3.2 Science Readout Pattern

**READOUT PATTERN** **[READOUT PATTERN]** = NRS **[NRS0186]**  
(default) **[NRS0187]**, NRSRAPID **[NRS0188]**

This field specifies the readout pattern to be used to obtain the science data. NRS is used for faint targets, while NRSRAPID is used for bright targets.

#### 32.2.4.3.3 Science Number of Groups

**NUMBER OF GROUPS** **[NGROUPS]** specifies the number of groups in an integration **[NRS0384]**.



#### 32.2.4.3.4 Science Number of Integrations

**NUMBER OF INTEGRATIONS** [**NINTS**] field specifies the number of times the integration is repeated [**NRS0385**].

Note to developers: while the **SUBARRAY** is not explicitly given, its value is **FULL** for the purposes of calculating exposure time [**NRS0343**]

#### 32.2.5 Autocal Exposure(s)

The following parameters are used to define *optional* autocal exposure(s). Wavelength calibrations are used to compensate for the inaccuracy of the grating wheel sensors during data analysis. Flat calibrations provide a measure of MSA shutter throughput with the combination of shutters and gratings that are actually used to obtain the science data and would be used when the user's spectrophotometric accuracy requirements are strict, and/or early in the mission to build a database of shutter throughputs for calibration purposes.

**AUTO CALIBRATION OPTION** [**AUTOCAL**] = **DEFAULT** [**NRS0154**] (default) [**NRS0155**], **NONE** [**NRS0156**], **FLAT** [**NRS0324**], **WAVECAL** [**NRS0325**], **BOTH** [**NRS0326**]

This parameter specifies whether automatic flat or wavelength calibration exposure(s) will be acquired after all science exposure readouts have been obtained for each grating/filter combination.

If **DEFAULT** is chosen, then the current operational recommendation (see [Section X.X of the NIRSpec Instrument Handbook](#) for the current recommendation) will be used.

If **NONE** is chosen, then no automatic flat or wavelength calibration exposures will be obtained.

If **FLAT**, **WAVECAL**, or **BOTH** is chosen, the lamp used (see [Section X.X of the NIRSpec Instrument Handbook](#) for the choice of lamp) and the exposure time for calibration will be compatible with the selected science grating. Specifying **BOTH** will result in taking flat and wavelength calibrations during the observation.

Note to developer: if **AUTOCAL** is not **NONE** [**NRS0508**] (or **DEFAULT** if the default value is **NONE** [**NRS0509**]), then the observation should get an implicit **NO PARALLEL** special requirement attached.