A day in the life of NIRSpec

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Summary

NIRSpec observations will require a complex sequence of calibration and science observations involving precise target acquisitions and at least two sets of dither sequences. This document describes the first version of a spreadsheet that has been created as a tool to analyse the timing and sequencing of these operations for the main observation types anticipated for the instrument. It can be used to examine trades between calibration frequency and overall efficiency for different balances of science observing programmes. In its present form, the spreadsheet represents a day that includes each of the major observation types. In practice, the balance between these types will be determined by the final observing programme. At present, the DRM can be used as a guide to what this balance might be.

1. Purpose and scope

The NGST spectrograph currently undergoing Phase A studies is a multi-object design with two possibilities for aperture construction: a transmissive MEMS with an approximately 2000 x 1000 array of 100 x 200 mas elements or, if such technology is not available on time, a mechanical slit mask offering somewhere between 25 and 50 slits. Such an instrument has operational and calibration requirements that are, in some respects, more complex than those for an imager. In particular, the process of selecting targets, designing optimum masks and acquiring a field with the telescope is a critical driver of several aspects of observatory performance.

The purpose of this document is to elucidate some of the operational issues by anticipating a typical 'day in the life of NIRSpec' and trace through the complete sequence of operations needed to perform different scientific and calibration observations. The specific aims are to:

• estimate overall operational efficiency
• quantify impact of overheads
• derive requirements to maximise operational efficiency

This first survey of an operational scenario is at a relatively high level, i.e., it does not consider the activity of the lowest level subsystems. Rather, it groups a series of events into a logical unit that can be understood by an astronomer familiar with constructing a 'Phase 2' proposal for HST or VLT. The level of detail will be expanded as the instrument and observatory design proceeds. At this stage we do not use the DRM to anticipate the balance of different observation types that might be required to carry out the NGST science programme. This can be done later if necessary.

In what follows, we assume the use of a transmissive MEMS (MSA) in the focal plane, accompanied by a small number of fixed slits. An 'imaging mode' is created by opening all the MSA shutters but it is appreciated that the sources imaged by such a configuration will have their apparent positions and brightnesses modulated by their precise positions with respect to the shutter support structure.

The document consists of this brief explanatory text together with an Excel spreadsheet containing a timed sequence of events divided into blocks representing different observation types. These blocks can be arranged as necessary to represent realistic instrument usage patterns.
2. Observation descriptions

Several different observation types are envisaged with NIRSpec. They consist of those associated with target acquisition, with on-target science integration and with calibration. It is assumed that many of the routine calibrations will be done in parallel with other spacecraft activities but some will require the observation of astronomical sources, i.e., for flux and geometric distortion (including the wavelength dispersion coefficients), or activities that need to be carried out at specific points in an observation sequence - such as the wavelength zero-point determination.

We characterise the observation types as follows:

1. **Target acquisition**
   It is assumed that a NIRCam image will be used as the first step, followed by the use of an offset to transfer of the field to the NIRSpec focal plane. NIRSpec will then be used in 'imaging mode' to verify the field positioning and to perform a peak-up.

2. **Science**
   We assume three basic types of science observation:
   - A **snapshot** using a pre-determined MSA pattern following a simple acquisition sequence with no peak-up. While dithers may be carried out within the MSA pattern, there will be no MSA reconfigurations.
   - A **deep observation** or 'full MSA sequence' following target acquisition and peak-up. Such an observation will involve both dithers within a single MSA configuration and a sequence of MSA reconfigurations following telescope offsets of ~ 10 pixels.
   - A **long-slit** observation using one of the pattern of fixed slits. This will generally follow a full target acquisition and will involve dithering along the slit.

3. **Calibration**
   Many types of calibration observation will need to be developed (see Table 1) but we consider here only examples of those that are time-critical within a science observation and those that need exposure on the sky. Three such observations are considered:
   - **Wavelength zero-point** using an internal source. This is generally triggered after a grating position change if the mechanism is not sufficiently reproducible.
   - **Wavelength dispersion coefficients** determined from either an internal lamp - if a multi-line source can be provided - or an astronomical source such as a planetary nebula. This should be required only infrequently.
   - **Flux/throughput calibration**. This will require the measurement of an astronomical source at an array of different positions across the field.
### Table 1: A summary of NIRSpec calibration types giving their anticipated frequency and requirements for internal lamps or on-sky sources and an indication of whether they should be performed in parallel with other spacecraft activities if this proves to be possible. The specific calibrations mentioned here are marked in colour. (Taken from table 2 of the Calibration Report by Cristiani et al. in prep).

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Internal lamp</th>
<th>Astronomical source</th>
<th>Parallel</th>
</tr>
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<tbody>
<tr>
<td>Bias</td>
<td>daily</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Dark current</td>
<td>2/yr - weekly</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Readout noise</td>
<td>2/yr - weekly</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Hot Pixels</td>
<td>weekly - daily</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Gain</td>
<td>2/yr - monthly</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Linearity</td>
<td>2/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Latent Image</td>
<td>once + occasional</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Focus</td>
<td>monthly</td>
<td>Y</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>MEMS maps</td>
<td>1-2/yr</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Astrometry/distortion</td>
<td>1-2/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Spectral Trace</td>
<td>1-2/yr</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Dispersion Coeffs</td>
<td>1-2/yr</td>
<td>N?</td>
<td>Y?</td>
<td>N</td>
</tr>
<tr>
<td>Wavelength ZP</td>
<td>1/setup</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Flat Field - local</td>
<td>daily-monthly</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Flux/throughput</td>
<td>1-2/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Line Spread Function</td>
<td>1/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Contrast</td>
<td>1/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Image Anomalies</td>
<td>1/yr</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

### 3. Spreadsheet description

The [EXCEL spreadsheet](#) is divided into seven worksheets that are explained briefly below:

1. Assumptions & efficiency

   This contains a list of assumed times for the various operations listed in the following sheets. It also calculates the 'on-target/open-shutter' efficiency for this particular sequence of observations.

2. Proposal phases

   The proposal solicitation, review and refinement process follows very much the pattern used for HST. For the case of NIRSpec MOS observations, however, there will be a requirement to tune the slit mask designs once the exact date, and hence spacecraft roll angle, are known. This introduces a 'Phase 3' process.

3. Deep observation
This will be the normal operational mode for the bulk of NIRSpec observations. It is the most complex in terms of MSA operations and telescope dither patterns. There are four logical elements:

- **setup**
  
  This assumes that NIRCam will be used for the initial field acquisition. While this exposure is being made, a wavelength zero-point observation is carried out with NIRSpec in parallel.

- **first dither position**
  
  After a target peak-up using NIRSpec, the first science exposure is taken at the first dither position.

- **dither without MSA reconfiguration**
  
  This exposure is repeated several times with small telescope motions to move the targets within the first aperture mask array.

- **dither with reconfiguration**
  
  The above dither sequence is then repeated several times after reconfiguration of the MSA pattern to move the slits by ~10 pixels on the detector.

The sequence will generally be repeated (excluding the target acquisition but possibly including a peak-up) for each wavelength range. In the case of R1000 observations, there are three such settings.

4. **Snapshot observation**

A snapshot observation is a simpler, quicker version of the deep observation. It includes a target acquisition using NIRCam and a wavelength ZP calibration but excludes a peak-up sequence. Dithers are carried out only within a single MSA configuration. Again, the whole sequence, excluding acquisition, would be repeated for different wavelength settings.

5. **Long-slit observation**

A long-slit (single object) observation can be carried out using either one of the fixed slits in the NIRSpec focal plane or using a special MSA configuration. If the former (assumed here), there are obviously no MSA (re)configurations but dithers are carried out along the slit. If the latter, it becomes possible to perform MSA reconfigurations for small (~10 pixel) slews as in the 'deep observation'.

6. **Flux calibration**

The aim here is to obtain the spectrum of a flux calibration source at a number of widely-spaced positions in the FOV. The sequence is similar to that for a deep observation except the telescope dithers are larger (a significant fraction of the FOV) and the individual exposures are shorter. The MSA only needs to be configured once since the array of slits can remain open throughout the sequence. Again, the sequence, excluding acquisition, would be repeated for different wavelength ranges.

7. **Ground processing**

4. **Conclusions**
This is a first attempt to visualise the sequence of operations that are required to carry out the major observation types envisaged for NIRSpec. The overall shutter-open efficiency, especially for deep observations, can be quite high. There are a number of uncertainties regarding the need for, and the frequency of, certain operations. For example:

- Is more than a single peak-up needed for a deep observation?
- Is a wavelength zero-point calibration needed after each change of wavelength range?
- Can certain operations be carried out in parallel?
- How precisely can the position transfer be made between the NIRCam and the NIRSpec fields of view?
- What is the optimum balance between dithers with and without MSA reconfiguration?
- We assume that it is more efficient to complete an entire dither sequence for each wavelength setting. This also minimises the number of grating settings.

We expect this analysis to be revised continuously through the instrument design and construction phases.