ABSTRACT

In this ISR the Proposal Instructions for the NICMOS Science Instrument are described. This report discusses the possible SI configurations, modes, and most of the optional parameters. The optional parameters which support the creation and association of patterns of exposures are discussed in a companion ISR (NICMOS-013).

1. Introduction

The NICMOS proposal instructions define the primary interface between the NICMOS Scientific Instrument (hereafter, SI) and HST observers. These instructions, combined with observatory level instructions, are used on a “proposal logsheet” at the start of the process of obtaining a NICMOS science or calibration observation. Certain engineering operations can also be accomplished through the proposal instructions, via special commanding, or via other means. As such, the proposal instructions are the user interface to NICMOS and present a conceptual “model” of the operation of the SI to observers.

Related Documentation

This ISR documents the present state of the General NICMOS Proposal Instructions. This state is expected to be in effect for Cycle 7 with, probably, some modifications and enhancements becoming available in time for Cycle 8. The quantization of NICMOS exposures time and the resulting tables of permitted exposure times will be presented in a future ISR. The largest departure from past practice in the design of the NICMOS Proposal Instructions is the inclusion of a mechanism to execute sequences of pre-defined “patterns” of observations from a simple syntax on a single proposal logsheet line. This capability is described in “NICMOS Proposal Instructions 2: Patterns and Associations” by J.W. MacKenty and R. Kutina (1996). The “association” of exposures from the proposal stage through to the data calibration and archiving stages is a new development for the SM97 Science Instruments. The broader consequences and overall design of the asso-
cation capability is documented in NICMOS ISR-010 and STIS ISR-016 “Associations of NICMOS and STIS Exposures: an extension of the HST data processing pipeline” (MacKenty, J.W. and Baum, S.A., STScI 1996).

Summary of NICMOS Proposal Instructions

In Table 1 a concise summary of the Proposal Instructions is provided. Those options reserved for STScI (and IDT SMOV activities) are indicated with italics.

Table 1. NICMOS Proposal Instructions Summary

<table>
<thead>
<tr>
<th>Config</th>
<th>Mode</th>
<th>Optional Parameter</th>
<th>Allowed Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIC1, NIC2, NIC3</td>
<td>ACCUM, MULTIACCUM, RAMP</td>
<td>PATTERN</td>
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<td>CHOP-SIZE</td>
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<td>DETECTOR (default), 0.0 - 360 degrees</td>
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<td>NREAD</td>
<td></td>
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<td>MULTIACCUM</td>
<td>SAMP-TIMEi (i = 01 - 25)</td>
<td>0.215 - 8590.0 seconds</td>
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<tr>
<td>RAMP</td>
<td>NSAMP</td>
<td>3 (default) - 255</td>
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<td>CR-ELIMINATION</td>
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<tr>
<td>BRIGHTOBJ</td>
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<td>NIC2</td>
<td>ACQ</td>
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<td></td>
<td></td>
<td>YTILT</td>
<td>0 (default), -176 to +176 steps</td>
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</table>
2. Configurations

NICMOS consists of three independently operated “cameras”; known as Cameras 1, 2, and 3. An observer specifies a particular camera with the Proposal Instructions by the configuration NIC1, NIC2, or NIC3. The generic specification NIC is used to specify instrument level engineering operations (i.e. optical alignment).

The cameras are distinguished by their fields of view, filter sets, and special capabilities. Each camera consists of its own reimaging optics, filter wheel, cold stops, and MgCdTe focal plane array detector and associated readout electronics. Virtually any combination of the three cameras can be operated simultaneously. However, only one camera may be specified on an individual exposure logsheet line (i.e. a single proposal instruction).

**CAMERA1**

Camera 1 (NIC1) provides the highest available spatial resolution with an 11 x 11 arcsecond field of view and 43 mas pixels (equivalent to the WF/PC-1 PC pixel scale). Its filter complement includes broad and medium band filters covering the spectral range from 0.8µm to 1.8µm and narrow band on and off line filters for Paschen α, He I, Fe II, and S III. It is equipped with the short wavelength polarizers (0.81µm to 1.29µm).

**CAMERA2**

Camera 2 (NIC2) provides an intermediate spatial resolution with a 19.2 x 19.2 arcsecond field of view and 75 mas pixels. Its filters include broad and medium band filters covering the spectral range from 0.8µm to 2.45µm. The “Minimum Background” filter which covers 1.4µm to 1.8µm (in which NICMOS is expected to be most sensitive to faint sources) is available in both Cameras 2 and 3. This filter set also includes filters for CO, Brackett γ, H2, Paschen α, HCO2 + C2, and the long wavelength polarizers (1.9µm to 2.1µm). Camera 2 also provides a chronographic mask with a 300 mas diameter.

**CAMERA3**

Camera 3 (NIC3) provides the lowest spatial resolution with a large 51.2 x 51.2 arcsecond field of view and 200 mas pixels. Its includes broad filters covering the spectral range 0.8µm to 2.3µm, medium band filters for the CO band (and an adjacent shorter wavelength continuum region), and narrow band filters for H2, Si VI, Paschen-α, Fe II, and He I. Camera 3 also contains the multi-object spectroscopic capability of NICMOS with grisms covering the wavelength ranges 0.8 - 1.2µm, 1.1 - 1.9µm, and 1.4 - 2.5µm.

3. Modes

NICMOS has six operating modes. Four of these (ACCUM, MULTIACCUM, RAMP, and BRIGHTOBJ) are the science observing modes and can be used with any configuration
(i.e. camera). ACQ mode is limited to use with Camera 2 for the autonomous acquisition of targets and ALIGN mode is limited to the configuration NIC (and is a restricted engineering mode).

**ACCUM**

ACCUM mode generates the simplest basic exposure. It is important to remember that NICMOS does not have a physical shutter mechanism. Instead, the following sequence of operations are performed to obtain an exposure:

- **Array reset:** All pixels are set to “zero”.
- **Array read:** The charge in each pixel is measured and stored in the on-board computer’s memory. This happens as soon as practical after the array reset. In effect, a very short exposure image is stored in memory. Note that it takes a different, but reproducible time from the array reset to access each pixel during the read.
- **Integration:** The NICMOS waits for the period specified for the integration.
- **Array read:** The charge in each pixel is measured and stored in the on-board computer’s memory.
- **Onboard Processing:** The difference between the final and initial array reads is calculated by the NICMOS microprocessor and saved in the NICMOS data buffer for subsequent transfer to the Science Data Formatter, storage by the HST data system, and eventual downlink. This difference is the image data array presented to the observer.

**MULTIACCUM**

MULTIACCUM mode is a variant of ACCUM mode. While consuming the considerably larger quantities of commanding data volume, internal data storage, and downlink bandwidth than the other NICMOS modes, MULTIACCUM mode arguably provides the highest quality scientific data in return.

MULTIACCUM mode consists of an array reset followed by a single readout (identical to the start of the ACCUM mode exposure but without the NREAD optional parameter — see below). Then a sequence of non-destructive array readouts are obtained at observer specified times. All of the readouts, including the initial readout, and stored and downlinked without any onboard processing. Up to 25 readouts can be specified spanning a total integration time from 0.215 seconds to 8590.0 seconds. Since for N readouts, this mode requires the storage and transmission (downlink) of N+1 times the data volume as the ACCUM mode, it can be rather costly. However, current estimates of the anticipated NICMOS observing volume indicate that, with the availability of the 1 Gbit Solid State Recorder (SSR) after the Second Servicing Mission, unrestrained usage of MULTIACCUM mode for the primary NICMOS camera will be sustainable.

The benefits of obtaining observations in MULTIACCUM mode fall into two areas. First, the dynamic range of the observation is greatly increased. Rather than being limited by the
charge capacity of a NICMOS pixel (a few \( \times 10^5 \) electrons), an observation’s dynamic range is in principle limited by the product of the pixel capacity and the ratio of the longest and shortest exposures (8590.0 and 0.215 seconds). In practice, the PSF and internal stray light will probably be the limiting factors. Second, a image can be reconstructed by processing of the stack of readouts to cope with the effects of cosmic ray particle events.

**RAMP**

RAMP mode is a variant of MULTIACCUM mode which carries out a predefined processing of the data within the NICMOS computer and transmits only the resultant image. This provides many of the advantages of MULTIACCUM mode while consuming a considerably smaller quantity of commanding data volume, internal data storage, and downlink bandwidth. RAMP mode is a appropriate option which high dynamic range or cosmic ray cleaned observations are required but the data volume is constrained. It is most useful for internal parallel observations and as a backup capability if data volume becomes an issue.

RAMP mode permits a larger range of sample times than MULTIACCUM (up to 255) but they must be evenly spaced during the integration interval. RAMP mode discontinues the processing on a pixel once that pixel reaches a predefined fraction of the pre-defined saturation level (full well). The result up to that time (and the number of samples which had been collected) are stored and downlinked. The optional parameter CR-ELIMINATION (see below) selects from four available processing modes for the handling of cosmic ray events (detected as a discontinuity in the rate of signal accumulation). It is important to note that RAMP mode uses “on the fly” processing algorithms rather than attempting to collect all of the readouts and subsequently process them. It is able to create an variance array and an array indicating the number of successful samples for each pixel which are downlinked along with the image. The image is represented as the derivative of the signal rather than the total accumulated charge (although no provision to reset a pixel and continue is available). A delay of 30 seconds is placed between the array reset and the first sample to reduce the detector shading effect. This limits the use of RAMP mode to reasonable fainter targets.

**BRIGHTOBJ**

An inherent consequence of the methods of operating the NICMOS array detectors in the ACCUM, MULTIACCUM, and RAMP modes is a minimum possible exposure time set by the time required to readout the array. For a very bright object, the time between the reset of a pixel, its initial, and final readouts may be sufficiently long that the pixel saturates. Although the detector arrays are multiplexed by division into four quadrants, each pixel in a 128 x 128 pixel quadrant must be sampled in some order (note that these is no transfer of charge as is done in a CCD -- this is limited by the addressing of pixels and the number of amplifiers).
The solution adopted to this problem for NICMOS is the provision of a bright object mode. In BRIGHTOBJ mode, an ACCUM sequence of operations is performed on one pixel at a time (actually four pixels -- one per quadrant). That is, the pixel is reset, read, integrated, and read again with the difference between the final and initial readouts being stored as the measured signal. Since this is done for each pixel in turn, it is an extremely slow process. The observation time is approximately $16384 \times (128^2)$ the exposure time. It is possible, in the worst case, for a single BRIGHTOBJ mode exposure to use most of an orbit. Observers are strongly advised to consider the trade-off between relatively long BRIGHTOBJ mode exposures (which take the longest time) and short ACCUM mode exposures (perhaps using a filter and camera combination with lower throughput).

Note that BRIGHTOBJ mode exposures are very sensitive to the quality of the pointing of HST. They should not be obtained using GYRO guiding mode. Although they are still susceptible to cosmic rays, events should be very rare as the integration time per pixel is quite short.

**ACQ**

The ACQ (acquisition) mode is only available for Camera 2. This is an autonomous (on board or Mode 2) target acquisition mode in support of the chronographic mask. The target is positioned by a normal pointing (i.e. to within a couple of arcseconds) at the NIC2-ACQ aperture (see NICMOS ISR-007 “NICMOS Aperture Definitions and Coordinate System Conventions”, J.W. MacKenty and R. Kutina, 1996). An acquisition image is obtained (and stored for subsequent downlink). The centroid of the target (brightest object in the $128 \times 128$ acquisition region centered on the NIC2-ACQ aperture is determined by an algorithm executed by the NICMOS computer. (Note that this requires the use of a flat field array stored onboard in the NICMOS computer’s memory -- no color information is available to this algorithm). The telescope is this repositioned via a SAM to position the target’s centroid at the NIC2-CORON aperture (behind the chronographic mask). This mode must be used in conjunction with the observatory level special requirement “ONBOARD ACQ FOR.”

**ALIGN**

This engineering mode permits the movement of the NICMOS Pupil Alignment Mirror (PAM). This element has x and y tilt motions to position the HST OTA pupil (primary mirror image) properly onto the NICMOS corrective mirror to compensate for the spherical aberration present in the OTA primary mirror. This element also provides a piston motion to adjust the NICMOS focal plane to the OTA focal plane (which is set by the needs of the other SIs aboard HST -- primarily the WFPC2). No science datasets are generated by this mode and it is not available to observers.
4. Optional Parameters

Patterns and Associations
These optional parameters are described in NICMOS ISR-013 “NICMOS Proposal Instructions II: Patterns and Associations” by J.W. MacKenty and R. Kutina (1996).

Optional Parameters which apply to multiple modes
These parameters apply to the ACCUM, MULTIACCUM, and RAMP modes only.
• READOUT = x (where x = FAST (default) or SLOW)
  This parameter selects the timing pattern used to perform the detector array readouts. It is expected that the default FAST option will be generally suitable for most observers. A FAST detector readout requires 0.215 seconds and a SLOW readout requires 3.44 seconds.
• FOMXPOS = x (where x = -26.0 to +26.0 arcseconds; default = 0.0)
• FOMYPOS = y (where y = -26.0 to +26.0 arcseconds; default = 0.0)
  The NICMOS has a Field Offset Mirror (FOM) which can reposition the NICMOS focal plane relative to the HST focal plane. This permits internal dithering and limited chopping over a 26 arcsecond radius region (i.e. the radial motion of the FOM is limited to 26.0 arcseconds). This element is located prior to the individual camera’s re-imaging optics and therefore moves the focal plane (images) in all three NICMOS cameras simultaneously and by equal amounts.

There are presently several concerns regarding the use of this mechanism and its availability or limiting rules for observers have not yet been determined. Motion of the FOM will result in some change to the HST generated (mainly thermal) radiation reaching the detectors. It appears likely that moving the telescope rather than the FOM for observations at thermally limited wavelengths will result in a superior background subtraction. The primary circumstances in which the FOM may prove advantageous is the dithering of images which the NICMOS is operated in parallel with another SI and therefore is not permitted to control the pointing of HST.
• LAMP = x (where x = NONE (default), FLAT1, FLAT2, FLAT3)
  NICMOS contains three internal calibration lamps. There are available only as an engineering mode (i.e. they are not available to observers). Note that these images include the sky background (the lamps are outside of the filter wheel) and therefore HST will generally require a pointed observation of a blank (dark) region in conjunction with lamp observations.
Optional parameters which apply to specific modes

**ACCUM**
- NREAD = n (where n = 1 to 25; default = 1)
This parameter modifies the sequence of operations during an ACCUM exposure to reduce the effective readout noise of the array detectors. Since each readout is non-destructive of the accumulated signal, it is possible to rapidly obtain a set of ‘n’ readouts at both the start and finish of the integration. The difference of the average of the finish and starting readouts is then computed and transmitted as the image.

**MULTIACCUM**
- SAMP-TIMEi = t (where i = 01 to 25 and t = 0.215 to 8590.0 seconds)
The observer may supply from 1 to 25 integration times. These reflect the total integration time since the initial readout of the detector array. The times must be monotonically increasing. Specifying only a single time is equivalent to an ACCUM mode observation with NREAD = 1.
For example, the specification:
SAMP-TIME01 = 2.0, SAMP-TIME02=9.0,
SAMP-TIME03=60.0, SAMP-TIME04=1000.0
will return five images to the observer corresponding to 0, 2, 9, 60, and 1000 seconds of accumulated integration.

**RAMP**
- NSAMP = n (where n = 3 to 255; default = 3)
The sets the number of array readouts done during the integration. For example, if NSAMP= 4 and the requested exposure duration was 1000 seconds, then images with integration times of 250, 500, 750, and 1000 seconds will be processed with the RAMP mode algorithms by the NICMOS onboard computer. The final downloaded image will reflect the signal to noise ratio of the 1000 second integration except for those pixels for which an exception occurs.

The minimum RAMP mode sample times are determined by the speed of the NICMOS computer. When only one camera is operated in RAMP mode, at least 5 seconds per sample is required. For two or three cameras operating in parallel and in RAMP mode, the 10 or 15 seconds per sample are required. For example, if Camera 1 is being operated in ACCUM mode while Cameras 2 and 3 are in RAMP mode, a 1000 second exposure in Camera 2 must have NSAMP <=100.
• **CR-ELIMINATION = x** (where x = CONTINUE (default), RETAIN, MARK, NONE)

There are four available algorithms for handling statistically significant a discontinuity in the derivative of the signal in each pixel.

CONTINUE: the single sample which fails the test is excluded from the calculation of the derivative and the calculation continues for that pixel on the subsequent sample.

RETAIN: the last “good” value for the derivative is retained (and subsequently down-linked). The later samples for that pixel are ignored.

MARK: the pixel is flagged (set to zero in the number of sample array) but processing continues including the suspect sample.

NONE: no processing based on changes in the slope is performed. But note that the saturation processing described above is *always* performed.

**ALIGN**

• **FOCUS = n** (where n = -4097 to +4097 steps; default = 0)

This parameter moves the PAM by ‘n’ steps in its piston (focus) axis. All of the ALIGN mode motions are relative to a nominal zero position. This zero position is set via real-time commanding permitting the execution of preplanned scans of the mechanism (interleaved with actual exposures) without knowledge of the absolute position of the mechanism at the time the stored commanding (proposal) is created.

• **XTILT= n** (where n = -176 to +176; default = 0)

• **YTILT= n** (where n = -176 to +176; default = 0)

These parameters move the PAM by ‘n’ steps in x or y axis tilt. These steer the OTA pupil image relative to the NICMOS correction mirror.

**5. Notes and Acknowledgments**

The controlling documents for the capabilities of the NICMOS are (will be) the Cycle 7 Call for Proposals (CP), the Cycle 7 Phase 2 Proposal Instructions (Phase2 PI), and the NICMOS Instrument Handbook. These proposal instructions have been previously described in a series of memos by Ray Kutina. Many people have contributed to the definition and development of the NICMOS Proposal Instructions. We particularly acknowledge the contributions of David Axon, Vicki Balzano, and Glenn Schneider.