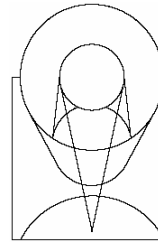




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SPACE TELESCOPE

TECHNICAL REPORT



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<p>Title: NIRCam as a Fine Guidance Sensor for JWST, Operations Concept and Use Cases</p>	<p>Doc #: JWST-STScI-000962 Date: August 15, 2006 Rev: A</p>
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1.0 Abstract

This Technical Report outlines the Operations Concept for using NIRCam as the Fine Guidance Sensor for JWST. Implementation of the concept is explored by using a set of Use Cases for the activities associated with the guide function. We assume that the process of acquiring a guide star in “FineLock” as defined in the FGS-Guider Operations Concept Document is applicable to NIRCam, and as such the Operations Concept and Use Cases defined here are as similar as possible to that of the FGS-Guider. We assume that the NIRCam short wavelength channels will be needed to provide the guide function since the stellar radiance of a typical guide star (M-dwarf) peaks over that bandpass, thereby allowing the use of fainter guide stars than possible with the long wavelength. Use of the SW channels requires that the identification function read all four SCAs. This must be done in parallel to meet constraints imposed by timing and coarse pointing performance, therefore the ICDH memory allocated to the guide function increases by a factor of four for image and reference data storage. We find that for the Acquisition and Track functions, the 31.7 mas pixel scale of the NIRCam SW channel requires 2x2 larger sub arrays, in terms on the number of pixels involved relative to the FGS-Guider, to cover the same patch of sky, the size of which is dictated by ACS coarse pointing performance. This implies longer readout times for the Acquisition and Track windows. The slower Track rate implies 128 msec (8 Hz) updates to the guide star centroid, which may have an impact on ACS design and performance. If the ACS must have 16 Hz centroid updates from the Track function, it will be necessary to implement Track as a two-step function, whereby a transition from a 64x64 array to a 32x32 array is necessary, and is commanded by either the AD or FSW when (coarse) pointing stability permits. We find that the 2x2 format of the 4 SCAs comprising each of the short wavelength channels imposes operational constraints on the ground system to avoid selecting guide stars that may fall near or in the gap between the SCAs for all possible dithers and/or offsets of the visit. However, we assume that small angle maneuvers that cause a guide star image to move from one SCA will be accommodated.

2.0 Introduction

The JWST Guider is tasked with providing guide star centroids to the Attitude Control System (ACS) to facilitate the fine pointing of the Observatory. The instrument must meet or exceed the four critical requirements shown in Table 1. In the baseline design of JWST, these requirements

Table 1. JWST Guider Requirements

Requirement	Description
MR-171	95% Guide Star Availability
MR-365	90% Guide Star Availability following single failure
ISIM-261	16 Hz Guide Star Centroid Update Rate
ISIM-262	Noise Equivalent Angle (3.5 mas per axis, 1σ)

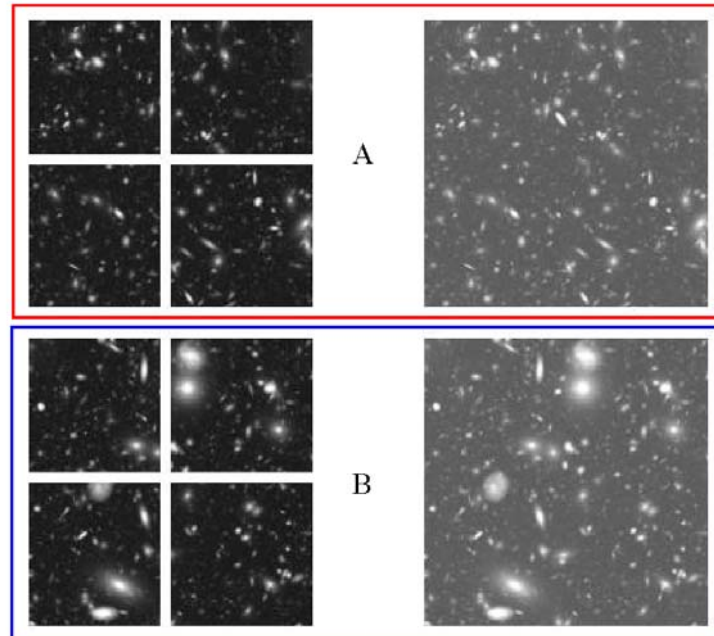


Figure 1. Representative NIRCcam FOV for modules A and B. Each module contains a SW channel (composed of the 4 SCAs on the left) and a co-spatial LW channel (right). Modules A & B each have a 4.7 arcmin² FOV.

are met by deploying a dedicated Fine Guidance Sensor (FGS-Guider), which is a near infrared camera composed of two independent channels, each with a field of view (FOV) exceeding 5.0 arcmin² imaged on to a 2kx2k HgCdTe detector. The instrument makes full use of the detector’s response to achieve a bandpass of 0.6 μ m to 5.0 μ m for maximum sensitivity. The requirements in Table 1, coupled with the areal density and NIR brightness distribution of stars on the sky, require the FGS-Guider to be able utilize guide stars as faint as $J_{AB} < 19.4$ [REF1].

NIRCcam is the prime JWST NIR imager (complemented by the FGS-TFI). NIRCcam has two identical, but independent modules (figure 1), each with a short wavelength (SW) and long wavelength (LW) channel that observe a co-spatial 4.7 arcmin² FOV. The SW channels each employ 4 HgCdTe 2kx2k sensor chip arrays (SCAs) arranged in a 2x2 format with ~5” gap between the detectors. The LW channels each use a single HgCdTe 2kx2k detector.

This Technical Report documents the Operation Concept and Use Cases for using NIRCcam to perform the JWST guide function in the event that the FGS-Guider is not available. Hereafter, “NIRCcam-Guider” refers to the use of NIRCcam as the JWST fine guidance sensor. The concept

outlined in the FGS-Guider Operations Concept Document (ref XXX) provides the backbone for the NIRCcam-Guider Operations Concept, but as will be demonstrated, additional complications are introduced by the 2x2 SCA format of the SW channels and the smaller, 31.7 mas pixel scale.

3.0 Assumptions for Operating NIRCcam as a Guider

The capability of NIRCcam as the JWST Guider is documented in Nelan et al (2006). They concluded that **MR-171** (95% guide star availability) requires use of the SW channels for the guide function since it provides sensitivity to use $J_{AB} < 18.5$ guide stars with the F150W2 filter (which *just* meets **MR-171**; the LW channels are limited to guide stars brighter than $J_{AB} = 17.5$). We therefore assume that the NIRCcam-Guider will nominally use the SW channels, but LW channels must be available for guiding to support WFS&C visits in the event that one of the NIRCcam SW channels is unavailable. Below, we explicitly list the assumptions that inform the specification of the NIRCcam-Guider Operations Concept.

- There are no changes to the NIRCcam (hardware) design. We assume that the wide-bandpass filter F150W2 and F360W2 will be the nominal filters used for guiding with the SW channels and LW channels, respectively,
- Operating one NIRCcam channel as a guider has no effect on, nor is it affected by any other SI, including the other NIRCcam channels that may be operating simultaneously. Therefore, any of the other three NIRCcam channels can be operated independently of the channel executing the guide function.
- When an SW channel is used for guiding, all four SCAs need to be readout by the Identification function to provide sufficient FOV to accommodate the reference stars. This implies a 4-fold increase in data volume to be processed on-board by the identification function. The SCA readouts must occur in parallel due to timing constraints and limitations of coarse pointing performance.
- When an SW channel is used for guiding, the three non-guiding SCAs are *not* used for science or calibration. If not observing the guide star, they are idle after NIRCcam-Guider executes the Identification function. However, an idle SCA can be transitioned via AD command to observe the guide star in the event that a spacecraft slew brings the guide star image into its FOV.
- The two LW NIRCcam channels can be used for guide duty. This is necessary to support WFS&C and NIRCcam SW-science in the event a SW channel is lost.
- For NIRCcam science visits, the ground system selects the module to be used as a guider. For non-NIRCcam visits, both modules are available for guide star selection and onboard acquisition (same as FGS-Guider). Note, NIRCcam science visits are more prone to guide star acquisition failures since fewer guide star candidates are available in-flight.
- All raw data acquired by the NIRCcam-Guider (excluding the Fowler sub samples) and the results of all algorithms executed by NIRCcam-Guider application software (with the exception of the centroid packets), will be sent to the solid-state recorder for storage and eventual downlink. These data will be used to monitor the performance of the NIRCcam-Guider and the ACS. Observers can access these data from the JWST archives to reconstruct, for example, the time series jitter history of the Observatory pointing over the course of a particular science visit.
- The ground system must plan the visit to avoid placing the guide star in or near the gaps between the SW SCAs for all of the visit's possible offset maneuvers.

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4.0 Operation of NIRCam as the JWST Guider

In this section we outline the operation of the NIRCam-Guider informed by (1) the assumptions stated in Section 3, (2) the design of NIRCam, and (3) the pointing performance of the ACS, as specified in JWST Observatory Specifications, while the NIRCam-Guider executes its various functions. We follow as closely as possible the FGS-Guider Operations Concept (REF xxx). However, due to the different plate scales between FGS-Guider and the SW channel of NIRCam-Guider (69 mas pixels vs 31.7 mas pixels, respectively), and the different layout of their focal plane arrays (1 SCA vs, 2x2 SCAs, respectively), significant differences arise. These are summarized in the following section.

4.1 Major Differences in FGS-Guider & NIRCam-Guider, SW-channel Operations

- At high Galactic latitude the areal density of candidate guide stars will be low, on average only 1.8 stars of sufficient brightness will be present in the 4.7 arcmin² FOV of a NIRCam-Guider SW channel (Nelán et al. 2006). Unfortunately, the incompleteness of the JWST guide star catalog (GSC-2) renders it impossible for the ground system to predict the brightness and relative location of all stars detected by the JWST guider in the Identification image. Consequently, 2 faint stars may be predicted while 3 or more may be observed. In order to properly identify which is the guide star, a task which is exacerbated by the 7" 1-sigma coarse pointing error in (V2,V3), the Guider flight software must apply a pattern match algorithm. To improve the likelihood that the ground system can provide the guide star and at least one reference star for the pattern match, the entire 4.7 arcmin² SW FOV is needed, i.e., all four SCAs must be readout to obtain the identification image. The ISIM is required to complete the Identification function in 60 seconds or less. If this requirement holds for the NIRCam-Guider as well, the four SCA's must be readout in parallel. Thus, relative to FGS-Guider, NIRCam-Guider will require 4 times more ICDH memory (to store image data and reference files) when the SW channel is used.
- The ACS will provide a pointing stability of 3" drift and 0.3"/sec drift rate (both values are 3-sigma radial, **OBS-1987** and **OBS-1988** respectively) over the course of the 180 seconds that has been allocated for completion of up to three attempts to identify the guide star (up to 3 sequential executions of the Identification function). Immediately following a successful Identification, the Guider will execute (upon command from the AD) the Acquisition function. To assure that the guide star is within the Acquisition sub array, the array size must be more than approximately twice the size of the 3" pointing stability requirement. The FGS-Guider uses a 128x128 pixel sub array (8.8"x8.8") for the initial acquisition window. For the NIRCam-Guider, the SW channel requires a 256x256 sub array to cover an equivalent patch of sky. The readout time for this subarray challenges the ability of NIRCam-Guider to complete the Acquisition function in less than 15 seconds (**ISIM-599**).
- The ACS will execute small angle offsets (such as a 20" NIRSpec dither) without using guide star centroids with an accuracy of 0.8", 3-sigma per axis (**OBS-TBS3**). The baseline concept calls for the FGS-Guider to "re-acquire" the guide star by executing the Track function, which in turn is required to provide guide star centroids to the ACS at 16 Hz for the initiation of closed loop guidance. The nominal size of the FGS-Guider Track sub array is 32x32 pixels, corresponding to a 2.2"x2.2" window on the sky. This array is to be sampled via a correlated double-sample CDS (Fowler-1) readout at 16 Hz. The

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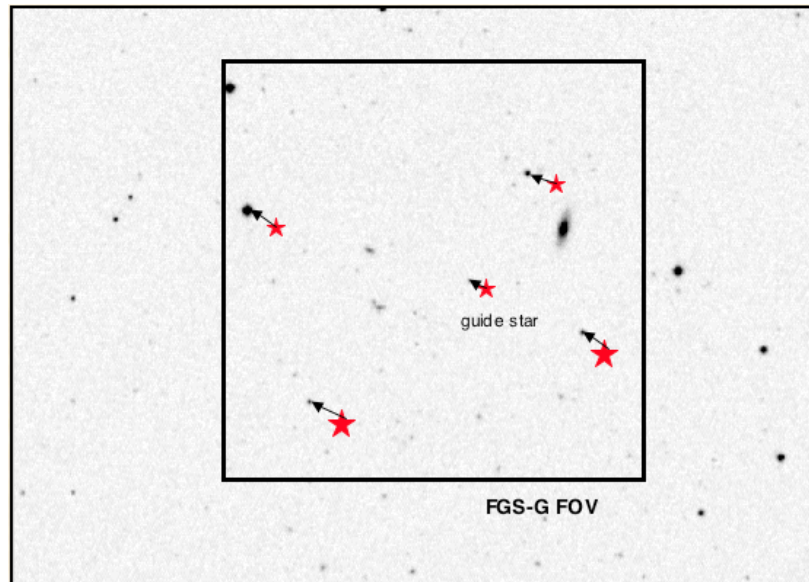


Fig 2. Guide star identification. The NIRCcam-Guider FSW identifies the guide star by application of a recognition algorithm that compares the predicted (red stars) vs. observed relative positions of the guide star and reference field stars. The arrows indicate the difference between the predicted and observed locations of the guide star and the reference stars in a NIRCcam-Guider SW-channel FOV. (I'll update the diagram to apply to NIRCcam SW channels –EN)

equivalent window for NIRCcam, as dictated by **OBS-TBS3**, requires use of a 64x64 pixel sub array, which can't be processed via CDS in less than 64 msec (takes more than 81 msec). Thus, use of NIRCcam as a guider imposes a slower control law for the ACS as the guider executes the Track function. To stay synchronized with the ACS 64 msec minor-frame time, the NIRCcam-Guider SW-channels would likely be operated with 128 msec cycles while executing the Track function. If the ACS can not make use of 128 msec (8 Hz) guide star centroid updates, it will be necessary to implement Track as a two-step function as described below. *Note, the Track Use Case presented in this document assumes the 8 Hz updates will suffice.*

4.2 NIRCcam-Guider Operating Modes

The NIRCcam-Guider will have three operating modes, Off, Standby, and Operate. There will be five functions performed under Operate; Identification, Acquisition, Track, Fine Guiding, and Calibration. The NIRCcam-Guider enters these modes and executes these functions upon receipt of commands from the ICDH. In Off, the NIRCcam-Guider (hardware) is powered down and does not send telemetry. In Standby, flight application software is running and the NIRCcam-Guider is ready to transition to Operate to execute any commandable function. The NIRCcam-Guider flight software (FSW) actively controls all physical, electrical, and detector conditions to which the NIRCcam-Guider performance is sensitive. The NIRCcam-Guider FSW shall be capable of sending telemetry and receiving commands, calibration data, reference data, and software updates. Standby can be entered from only from Operate. The functions under Operate are discussed in the following subsections.

4.3 Identification

In response to a command from the AD, the NIRCcam-Guider will image the sky in a specific FOV (Nominally the AD issues this command after the Observatory has slewed to *and settled* at a desired attitude). The NIRCcam-Guider FSW will identify the guide star by application of a recognition algorithm that compares the observed versus predicted relative positions of the guide star and selected reference field stars (Fig. 2). The predicted position (in local detector space, distortion corrected coordinates) and magnitude (over the NIRCcam-Guider pass band, for either the SW or LW channel) of each star will be provided to the NIRCcam-Guider FSW by the AD. The recognition algorithm will accommodate as many as 10 reference stars, if available (such a large number of reference stars may be needed in crowded fields). The identification image is obtained with the Observatory held in coarse guide mode (gyros and star trackers). To minimize image smearing, each of the SW SCAs is simultaneously read out in a ripple down fashion using thirty-two 64x2048 pixel sub arrays (or strips) with 1-second exposures, each of which is read twice to facilitate correlated double sample (CDS) processing. The 1-second exposure time allows the NIRCcam-Guider to observe bright stars ($13 < J_{AB} < 17$) which would otherwise saturate in the ~ 10 seconds (minimum time) required for a full frame readout of an SCA.

The NIRCcam-Guider FSW records the location of each detected source that falls within a predicted magnitude range (set by the AD). When all of the strips have been processed, the FSW applies a recognition algorithm to these objects to identify the guide star (figure 4). The criteria for success requires the guide star to be identified, classified as a point source (to the extent possible under coarse guiding), and observed to be sufficiently bright for the NIRCcam-Guider to deliver a useful NEA.

Upon exiting the Identification function, for both successful and failed outcomes, the NIRCcam-Guider FSW reports the results to the AD. For a successful guide star identification, the NIRCcam-Guider FSW also reports the star's brightness and location in the NIRCcam-Guider FOV (along with data quality indicators) to the AD. The AD commands the NIRCcam-Guider to Standby.

4.4 Acquisition

The NIRCcam-Guider initiates the Acquisition function upon command from the AD. The AD provides the position of the guide star (in local detector coordinates) and its magnitude (or equivalent count rate) in the NIRCcam-Guider pass band (determined from the identification image or from a previous acquisition within the same visit). The NIRCcam-Guider FSW configures the appropriate SCA's FPE to obtain image data at 1 Hz from a **256x256** pixel (8.1"x8.1") sub array centered on the guide star. An updated position of the guide star is determined by the NIRCcam-Guider FSW and is reported to the AD approximately every 1 second. As the position of the guide star stabilizes to under 0.1"/sec, the NIRCcam-Guider FSW re-configures the FPE to reposition (if necessary) and reduce the size of the sub array ultimately to (nominally) 64x64 pixels (2.2"x2.2") with 1 Hz readouts. The outcome (successful or not) of the Acquisition function is reported to the AD and the NIRCcam-Guider. The AD transitions the NIRCcam-Guider to Standby mode.

Note that in crowded fields the NIRCcam-Guider FSW must be tolerant of faint neighbors ($\delta m_{AB} < 3$) that may also appear in the initial 8.1"x8.1" acquisition sub array.

4.5 Track

Upon successful completion the acquisition function, the AD nominally commands the NIRCcam-Guider FSW to execute the Track function. The FSW configures the FPE to center a 64x64 pixel sub array (refer to Section 4.1) on the guide star (to the extent possible with discrete pixels), extracts image data from the sub array, and computes the guide star's undistorted position every **128 msec** (compared to 64 msec for FGS-Guider). These centroids are made available to the ACS via telemetry packets for line of sight stabilization of the spacecraft.

Every 128 msec the NIRCcam-Guider FSW re-configures the FPE to re-center the 64x64 pixel sub array on the previously observed location of the guide star. This allows NIRCcam-Guider to "track" the guide star's image as it moves in its FOV, as will be the case when the ACS fine points the Observatory to remove residual pointing errors at the end of small angle maneuvers or to observe moving targets.

If the ACS requires 16 Hz updates to the guide star centroid before such data are useful for pointing control, it will be necessary to execute the Track function in two steps. The 64x64 pixel subarray is used initially to allow the NIRCcam-Guider to locate and "lock on" to the guide star, while the Observatory remains under coarse guiding control (star trackers and gyros). Once the guide star's centroid stabilizes to a value (provided to the NIRCcam-Guider FSW by the AD), the NIRCcam-Guider FSW transitions the track box to a 32x32 pixel subarray with 16 Hz centroid updates, and the ACS initiates Fine Guidance. To avoid an open ended (long) wait for the transition from the 64x64 to the 32x32 pixel subarrays, the AD will set a time limit for the transition to occur.

The AD interprets the centroid data reported by the Track function to determine when it is appropriate to transition to the Fine Guide function. This will be when further repositioning of the sub array is not required, i.e., when the location of the sub array is optimal for observing the guide star at its desired position. In the event of a Track function failure (i.e., loss of the guide star image), the NIRCcam-Guider FSW informs the AD and commands the instrument to Standby.

Operating the NIRCcam-Guider via the Track function with an 8x8 pixel sub array may be necessary when JWST observes Solar System (moving) targets (depending upon exposure time and the target's angular velocity). Due to the overhead of reprogramming the FPE every 64 msec, the actual "exposure" time spent observing the guide star will not be as long as when NIRCcam-Guider executes the Fine Guide function to observe a stationary guide star. Also, the read noise will be somewhat higher since fewer Fowler samples can be obtained (we expect simple CDS for the readout scheme). Therefore, the reduced signal-to-noise ratio of the photometric data may yield a larger NEA when faint guide stars are used. Thus, to achieve the necessary NEA, the use of faint guide stars may need to be avoided.

4.6 Fine Guidance

The AD commands the NIRCcam-Guider to transition from the Track function and to the Fine Guide function when the guide star image is within 1/2 pixel (~16 mas) of where it needs to be for the subsequent science observation. The NIRCcam-Guider FSW programs the FPE to observe the guide star with an 8x8 pixel subarray, extracts the image data, and computes the guide star's centroid for each 64 msec interval. The centroids (and ancillary data) are sent to the CTP for ACS ingest via telemetry packets with a latency of less than 40 msec. The NIRCcam-Guider continues processing data in this manner, from the same 8x8 pixel sub array, until commanded by the AD to transition to Standby.

4.7 Calibration

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The Calibration function provides the means for the NIRCcam-Guider to obtain the data required by the ground system for calibrating geometric distortion, intra-pixel non-uniformity, flat field response, bias, defective pixel maps, photometric response, and PSF characterization across its FOV. When necessary, these data will be obtained for one channel while another channel observes a guide star in its FOV. It is possible that the “Calibration function” may be implemented as a variant of the Identification function with exposure control parameters set appropriately.

5.0 NIRCcam-Guider Data

To facilitate the routine monitoring of NIRCcam-Guider and ACS performance, and to provide observers with a detailed time series history of the Observatory’s pointing during science exposures, the ICDH will have the capability to provide *all data from the NIRCcam SCAs* to configurable telemetry filters which select data for the real time and solid state recorder (SSR) telemetry streams (with the exception of the intermediate Fowler readouts and Fowler subtracted sub arrays). The results of all algorithms executed by the NIRCcam-Guider FSW to process guider data will also be available to the telemetry filters. Thus, the images obtained by the identification function, the time series of the large window and small window images obtained by the acquisition function, as well as the “postage stamp” images generated during Track and Fine Guidance can be accessed by the telemetry filters, as can the detector coordinates and NIRCcam-Guider magnitude of each object found during guide star identification. The time series centroids of the guide star (from Acquisition, Track, and Fine Guidance functions) that are provided to the ACS can also be recorded on the SSR. All flags and status mnemonics can be stored for downlink, along with all engineering housekeeping data and logged state transitions. The contents of the memory reserved for the NIRCcam-Guider FSW can be made available to the telemetry filters in the event that these data are to be downlinked.

6.0 Use Cases

This section contains the NIRCcam-Guider Use Cases for all of the NIRCcam-Guider functions relating to the guide function. These have been developed as “deltas” from the FGS-Guider Use cases. The differences that are specific to the NIRCcam-Guider are highlighted in **bold green**. Error paths are highlighted as **red**. The major differences between FGS-Guider and NIRCcam-Guider Use Cases are:

- The need to readout & process data from the SW channel’s 4 SCAs for the Identification function. This represents a 4-fold increase in image data and reference data volume.
- The need for a 256x256 pixel subarray for the initial Acquisition Function window. The second window size is a 64x64 pixel subarray. This compares with 128x128 and 32x32 subarrays used by the FGS-Guider to observe the same patch of sky, the size of which is dictated by ACS coarse pointing control performance.
- The need to use a 64x64 pixel subarray for the Track Function to observe the required 2.2”x2.2” patch of sky. This implies a slower update rate of the guide star centroid (8 Hz vs. 16 Hz for FGS-Guider). We assume that the ACS can accommodate the 8 Hz rate.
- It falls upon the ground system to select guide stars that have no chance of being near or falling within the gaps between the SW channel SCAs, no matter what target acquisition or dither offsets may occur during the visit. The Uses Cases implicitly assume this.

NIRCam-Guider Use Cases

Identification:

Pre-condition: Vehicle has maneuvered to best attitude for identifying guide star. Attitude is maintained by Coarse Pointing Control (Star Trackers and Gyros).

1. AD commands NIRCam FSW to set function to IDENTIFICATION
2. NIRCam FSW sends centroid packet to indicate ID function to CTP
Contents of centroid packet are to be defined by ISIM/CTP ICD.
3. NIRCAM FSW sends ID transition success telemetry indication

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends ID transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed function transition, ID attempt aborted”
- NIRCAM FSW remains in the STANDBY function
- AD terminates with failure indication

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends ID transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed function transition, ID attempt aborted”
- NIRCAM FSW remains in the STANDBY function
- AD terminates with failure indication

4. AD provides NIRCAM FSW with the number of reference stars (up to 10) expected to be present in the FOV.
5. NIRCAM FSW sends reference star count command success telemetry indication.
6. NIRCAM FSW sends number of reference stars expected via telemetry.

Error Path 4.1 – command parameter verification fails

- NIRCAM FSW sends reference star count failure telemetry indication (invalid parameter value)

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- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM failed FPE configuration, ID termination started”
- AD releases SCEP(s) as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates ID activity with failure indication

Error Path 15.2 – FPE hardware issue

- NIRCAM FSW sends FPE setup failure telemetry indication (hardware problem)
- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM FPE hardware error, ID termination started”
- AD releases SCEP(s) as specified in SCEP(s) Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

19. AD commands NIRCAM FSW to begin image collection

20. NIRCAM FSW sends hardware command for detector image readback (setup SCE to grab image, sends FPE controls)

Image read out from detector and transferred to the SCEP(s)

21. NIRCAM FSW sends image collection start telemetry indication

Error Path 19.1 – command parameter verification fails

- NIRCAM FSW sends image collection start failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM exposure command failed, ID termination started”
- AD releases SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

Error Path 19.2 – FPE hardware issue

- NIRCAM FSW sends image collection start failure telemetry indication (hardware problem)
- NIRCAM FSW sends an error event message
“ _____ ”

- AD sends error event message “NIRCAM FPE hardware error, ID termination started”
- AD issues Data Acq exposure termination command.
- AD releases SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

22. *** NIRCAM FSW requests Data Acq to extract pixel correction data from FPAP memory for current strip **for each SCA (4, if SW channel)**

23. Data Acq notifies NIRCAM FSW that file is ready **for SCA(n)**

24. Data Acq sends telemetry notification to NIRCAM FSW that pixel correction data ready after each strip (**for each SCA**)

Error Path 19.3 – Data Acq does not extract pixel correction data

- NIRCAM FSW sends guide star identification failure telemetry indication (pixel correction data not extracted)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM data transfer incomplete, ID termination started”
- AD issues Data Acq exposure termination command.
- AD releases SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

25. NIRCAM FSW commands Data Acq to extract image strip data from FPAP memory

26. Data Acq notifies NIRCAM FSW that file is ready **for each SCA**

Error Path 19.4 – Data Acq does not extract image **data for each commanded SCA**

- NIRCAM FSW sends guide star identification failure telemetry indication (no image data)
- NIRCAM FSW sends an error event message “_____”
- AD sends error event message “NIRCAM data transfer incomplete, ID termination started”
- AD issues Data Acq exposure termination command.
- AD releases SCEPs as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

27. NIRCAM FSW performs Image Processing, Subtraction and Correction

NOTE: There is a distortion correction table in SBC memory

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28. NIRCAM FSW performs star identification (detects star/non-star find objects **within specific magnitude ranges**)
29. NIRCAM FSW deletes files created by identification process
 - *** Repeat steps 22 – 29 for each of the 32 strips
30. FPEs goes to continuous flush (idle)
31. NIRCAM FSW does Pattern recognition
 - Match stars found versus provided reference star list
32. NIRCAM FSW sends centroid packet to CTP to report guide star location. **This is to be in “ideal” (distortion-corrected) NIRCAM-Guider coordinates.**
33. NIRCAM FSW sends image collection success telemetry indication
34. NIRCAM FSW sends guide star identification success telemetry indication

Error Path 19.5 – Guide star cannot be identified (1st or 2nd try)

- NIRCAM FSW sends guide star identification failure telemetry indication (no guide star identified)
- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM failed to identify guide star, ID termination started”
- AD executes Function Retry use case.

Error Path 19.6 – Guide star cannot be identified (3rd try)

- NIRCAM FSW sends guide star identification failure telemetry indication (no guide star identified)
- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM failed to identify guide star, ID termination started”
- AD releases SCEP(s) as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

Error Path 19.7 – Centroid calculation exceeds allotted time (1st or 2nd try)

- NIRCAM FSW sends guide star identification failure telemetry indication (ID did not complete)
- NIRCAM FSW sends an error event message
“ _____ ”
- AD sends error event message “NIRCAM guide star centroid calculation timed out, ID termination started”
- AD executes Function Retry use case.

Error Path 19.8 – Centroid calculation exceeds allotted time (3rd try)

- NIRCAM FSW sends guide star identification failure telemetry indication (ID did not complete)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM guide star centroid calculation timed out, ID termination started”
- AD releases SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

35. NIRCAM FSW sends guide star location telemetry (for AD)

36. AD commands Data Acq to release **all previously allocated** SCEP(s).

37. Data Acq sends telemetry indicating that SCEP(s) was released.

Error Path 36.1 – Data Acq unable to release **all** SCEPs

- Data Acq sends SCEP release failure telemetry indication
- AD issues error event message “NIRCAM data transfer incomplete, ID termination started”
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

38. AD commands NIRCAM FSW to set function to STANDBY.

39. NIRCAM FSW sends STANDBY transition success telemetry indication.

Error Path 38.1 – command parameter verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, ID termination started”
- AD terminates with failure indication

Error Path 38.2 – command sequence verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, ID termination started”
- AD terminates with failure indication

40. AD terminates Identification process with success indication.

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Acquisition:

Precondition:

- (1) Following large vehicle slew to guide star identification (ID) attitude and successful ID

OR

- (2) Following large vehicle slew to ID attitude, successful ID, successful initial acquisition, slew to science attitude

OR

- (3) Following a return from a small angle maneuver (SAM) once Fine-lock was achieved on guide star – Vehicle at guide star acquisition attitude

1. AD commands NIRCAM FSW to set function to ACQ

2. NIRCAM FSW sends centroid packet to indicate ACQ function to CTP

NOTE: A centroid packet is created once at the start of ACQ and then once for every centroid calculation.

3. NIRCAM FSW sends ACQ transition success telemetry indication

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends ACQ transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed function transition, ACQ attempt aborted”
- NIRCAM FSW remains in STANDBY
- AD terminates with failure indication

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends ACQ transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message
“_____”
- AD sends error event message “NIRCAM FSW failed function transition, ACQ attempt aborted ”
- NIRCAM FSW remains in STANDBY
- AD terminates with failure indication

4. AD provides NIRCAM FSW with parameters for the current guide star location and count rate (as obtained from Identification function or calculated from input parameters for guide star at science attitude). **Parameters indicate which SCA, and ideal coordinates with that SCA.**

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- AD terminates with failure indication

- AD obtains SpaceWire address for 2nd SCEP from telemetry.
- AD commands NIRCAM FSW to configure FPE for Acquisition. AD provides ideal starting subarray coordinates, DAQ telemetry slot numbers and SCEP Spacewire addresses. FPE is configured for both 256 x 256 and 64 x 64 subarrays.
NOTE: The NIRCAM FSW must retrieve the data from FPAP memory into a file (as is done in ID mode) even after the subarray size is reduced later in this use case.
- NIRCAM FSW sends FPE Control Commands (set up FPE for acquisition)
 - Channel selection FOV A or FOV B, **SCA_ID**
 - SCA window size selection
 - Integration time selection and readout pattern parameters
- NIRCAM FSW reads FPE status telemetry
- NIRCAM FSW sends FPE setup complete telemetry indication

Error Path 12.1 – command parameter verification fails

- NIRCAM FSW sends FPE setup command failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM failed FPE configuration, ACQ termination started”
- AD releases each SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

Error Path 12.2 – hardware problem

- NIRCAM FSW sends FPE setup command failure telemetry indication (hardware problem)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM FPE hardware error, ACQ termination started”
- AD releases each SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

- AD commands NIRCAM FSW to begin image collection
Summary of actions taken in response to this command:
Array readout of initial (1st SCEP) subarray, followed by image extraction, image processing and correction and guide star location and quality check. The process

is repeated starting with a readout of the final (2nd SCEP) subarray. The results of the guide star acquisition attempt are reported via telemetry.

17. *** NIRCAM FSW sends command for detector image readback (set up SCE to grab image, sends FPE controls)
Image read out on detector and transferred to the SCEP
18. NIRCAM FSW sends image collection start telemetry indication

Error Path 16.1 – command parameter verification fails

- NIRCAM FSW sends image collection start failure telemetry indication (invalid parameter value in exposure command)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM exposure command failed, ACQ termination started”
- AD releases each SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

Error Path 16.2 – hardware problem

- NIRCAM FSW sends image collection start failure telemetry indication (FPE hardware problem)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “FPE hardware error, ACQ termination started”
- AD issues Data Acq exposure termination command for each of the two SCEPs.
- AD releases each SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

19. NIRCAM FSW commands Data Acq to extract pixel correction data into an SBC file
20. Data Acq notifies NIRCAM FSW that file is ready

Error Path 16.3 – pixel correction data not extracted

- NIRCAM FSW sends acquisition failure telemetry indication (no pixel correction data)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM data transfer incomplete, ACQ termination started”

- AD issues Data Acq exposure termination command for each of the two SCEPs.
 - AD releases each SCEP as specified in SCEP Release Following Error use case.
 - AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
 - AD terminates with failure indication
21. Data Acq receives interrupt that image data ready and sends data to SSR.
 22. Data Acq notifies NIRCAM FSW that data is available for transfer
 23. NIRCAM FSW commands Data Acq to extract image data into SBC memory
 24. Data Acq notifies NIRCAM FSW that file is ready

Error Path 16.4 – image data not extracted

- NIRCAM FSW sends acquisition failure telemetry indication (image data not extracted)
 - NIRCAM FSW sends error event message “_____”
 - AD sends error event message “NIRCAM data transfer incomplete, ACQ termination started”
 - AD issues Data Acq exposure termination command for each of the two SCEPs.
 - AD releases each SCEP as specified in SCEP Release Following Error use case.
 - AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
 - AD terminates with failure indication
25. ***NIRCAM FSW accesses image and pixel correction data
 26. NIRCAM FSW performs Image Processing, Subtraction and Correction
 27. NIRCAM FSW performs Centroid Position Determination and quality check
 28. NIRCAM FSW performs telemetry processing (sending information to CTP)
-- The centroid packet
 29. NIRCAM FSW sends guide star location telemetry (for AD)
*** Steps 25 – 29 are performed for each of the four integrations in an Acquisition exposure.
 30. NIRCAM FSW deletes image files created by acquisition process
 31. NIRCAM FSW reconfigures FPE for second subarray size (2nd SCEP).
*** Steps 17 – 30 are repeated for second subarray, then execution continues at step 32.

32. Upon exit NIRCAM FSW verifies all files created by acquisition process are deleted.
33. NIRCAM FSW sends image collection success telemetry indication
34. NIRCAM FSW sends acquisition completion telemetry indication.

Error Path 16.5 – guide star not acquired (1st or 2nd attempt)

- NIRCAM FSW sends acquisition failure telemetry indication (guide star not acquired)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM failed to acquire guide star, ACQ termination started”
- AD executes Function Retry use case.

Error Path 16.6 – guide star not acquired (3rd attempt)

- NIRCAM FSW sends acquisition failure telemetry indication (guide star not acquired)
- NIRCAM FSW sends error event message “_____”
- AD sends error event message “NIRCAM failed to acquire guide star, ACQ termination started”
- AD releases each SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

35. AD extracts last guide star position from NIRCAM telemetry to use in offset calculation.
36. AD commands Data Acq to release 1st SCEP.
37. Data Acq sends telemetry indicating that SCEP was released.

Error Path 36.1 – Data Acq unable to release SCEP

- Data Acq sends SCEP release failure telemetry indication
- AD issues error event message “NIRCAM data transfer incomplete, ACQ termination started”
- AD releases 2nd SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

38. AD commands Data Acq to release 2nd SCEP.

39. Data Acq sends telemetry indicating that SCEP was released.

Error Path 38.1 – Data Acq unable to release SCEP

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- Data Acq sends SCEP release failure telemetry indication
- AD issues error event message “NIRCAM data transfer incomplete, ACQ termination started”
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

40. AD commands NIRCAM FSW to set function to STANDBY.

41. NIRCAM FSW sends STANDBY transition success telemetry indication.

Error Path 40.1 – command parameter verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, ACQ termination started”
- AD terminates with failure indication

Error Path 40.2 – command sequence verification fails

- NIRCAM FSW sends ACQ transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, ACQ termination started”
- AD terminates with failure indication

42. AD terminates with success indication.

Tracking:

Pre-condition: Vehicle maneuvered to the vicinity of the next science attitude.

Usage: 1. Preparatory for fine lock.

2. For moving targets.

1. AD commands NIRCAM FSW to set function to TRACK
2. NIRCAM FSW send TRACK transition success telemetry indication

NOTE: centroid packet does not yet indicate TRACK

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends TRACK transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends TRACK transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

3. AD commands Data Acq to set up **1st SCEP** for continuous readouts with readout pattern parameters, window size subarray (**64x64**). **AD provides DAQ telemetry slot number to be associated with the SCEP.**
4. Data Acq send config setup complete telemetry indication

Error Path 3.1 – SCEP configuration fails

- Data Acq sends SCEP configuration failure telemetry indication
- AD sends error event message “NIRCAM request for FPAP configuration failed, ACQ termination started”
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case
- AD terminates with failure indication

5. AD commands Data Acq to configure 2nd SCEP with a subarray size of 8x8.

AD provides DAQ telemetry slot number to be associated with the SCEP.

6. Data Acq sends config complete telemetry indication

Error Path 5.1 – SCEP configuration fails

- Data Acq sends SCEP configuration failure telemetry indication
- AD sends error event message “NIRCAM request for FPAP configuration failed, ACQ termination started”

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- AD issues Data Acq exposure termination command for 1st SCEP.
- AD releases 1st SCEP as specified in SCEP Release Following Error use case.
- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication

7. AD obtains SpaceWire address for 2nd SCEP from telemetry.

8. AD commands NIRCAM FSW to configure FPE for Track. AD provides ideal starting subarray coordinates, DAQ telemetry slot numbers and SCEP Spacewire addresses. FPE is configured for both the 64 x 64 and the 8 x 8 subarrays.

NOTE: The NIRCAM FSW must retrieve the data from FPAP memory into a file (as is done in ID mode) even after the subarray size is reduced later in this use case.

9. AD provides NIRCAM FSW with parameters for the current guide star location and magnitude. **(Includes SCA-ID, and predicted ideal detector coordinates.)**

10. NIRCAM FSW sends guide star parameter command success telemetry indication

Error Path 9.1 – command parameter verification fails

- NIRCAM FSW sends guide star parameter command failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 5.2 – command sequence verification fails

- NIRCAM FSW sends guide star parameter command failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

11. AD commands NIRCAM FSW to setup FPE for Track

12. NIRCAM FSW sends FPE Control Commands (set up FPE for Tracking)

Channel selection FOV A or FOV B

SCA_ID

FPA Array window size selection **(and location in ideal coordinates)**

Integration time selection and readout parameter values

13. NIRCAM FSW reads FPE status telemetry

14. If current pixel correction data is not sufficient to cover the track range, NIRCAM FSW commands Data Acq to extract pixel correction data into SBC file

15. Data Acq notifies NIRCAM FSW that file is ready

16. NIRCAM FSW sends FPE setup complete telemetry indication

Error Path 14.1 – command parameter verification fails

- NIRCAM FSW sends FPE setup failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 14.2 – command sequence verification fails

- NIRCAM FSW sends FPE setup failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 14.3 – FPE hardware issue

- NIRCAM FSW sends FPE setup failure telemetry indication (hardware problem)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW returns to STANDBY
- AD stops using the affected detector, and skips to next guide star, if available, or to next visit that uses the another NIRCAM detector **for guiding.**

Error Path 14.4 – Data Acq does not extract data

- NIRCAM FSW sends FPE setup failure telemetry indication (no correction data)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

17. AD commands NIRCAM FSW to begin image collection

**18. NIRCAM FSW sends command for detector image readback (setup SCE to grab image, sends FPE controls)

Image readout on detector and reconstruction performed on SCEP

19. Data Acq receives interrupt that image data ready and forwards image data to NIRCAM FSW in a telemetry packet.

20. Data Acq sends data to SSR, if necessary

NOTE: When the subarray is 32 x 32 or smaller and continuous readouts are being done, Data Acq will send the actual data pixels in telemetry. This telemetry packet will NOT be in the PRD. It is for internal ISIM communications only.

21. NIRCAM FSW accesses image from telemetry and accesses pixel correction data from SBC file

Error Path 17.1 – Image data telemetry does not arrive for N cycles

- NIRCAM FSW sends image collection failure telemetry indication (no image data from ISIM)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY

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- AD skips to next guide star, if available, or to next visit

22. NIRCAM FSW performs Image Processing, Subtraction and Correction

23. NIRCAM FSW performs Centroid Position Determination and quality check

Error Path 21.1 – Guide star could not be found for M cycles

- NIRCAM FSW sends image collection failure telemetry indication (no guide star found)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 21.2 – Guide star quality is bad for P cycles

- NIRCAM FSW sends FINEGUIDE failure telemetry indication (bad guide star quality)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star if at visit start, else skips to next visit

24. NIRCAM FSW performs telemetry processing

25. NIRCAM FSW sends centroid packet to indicate TRACK function to CTP

It is assumed that the CTP/ACS can make use of 32 Hz (128 ms) guide star centroid updates to being closed loop guiding. *If not*, it will be necessary to modify Track such along the lines of:

- 1. AD requests SCEP#1 and FPE setup for 64x64 pixel subarray**
 - 2. AD requests SCEP#2 and FPE setup for 32x32 pixel subarray**
 - 3. AD requests SCEP#3 and FPE setup for 8x8 subarray in preparation for FINEGUIDE.**
- In this case the NIRCAM-Guider transitions from 64x64 to 32x32 track box (either by AD command or by autonomous FSW) when centroid is “sufficiently stable” to reliably acquired in the 32x32 window. 16 Hz updates are then possible and the Use Case.**
-
-

26. CTP enables fine guidance control and begins FSM management

27. CTP sets fine guidance control telemetry value to ‘ENABLE’ and the Close Loop Control telemetry value to ‘CONTROL’ (in telemetry packet for event-driven operations)

28. When CTP determines that Fine Lock has been achieved, then it sets the Close Loop Control telemetry value to “SETTLED” (in telemetry packet for event-driven operations)

29. NIRCAM FSW sends image collection track started telemetry indication (after first time through)

30. NIRCAM FSW performs new window position determination and reconfigures FPE

If target is outside the region of the pixel correction file:

31. NIRCAM FSW deletes current pixel correction file

32. NIRCAM FSW commands Data Acq to extract another pixel correction file

33. Data Acq notifies NIRCAM FSW that file is ready

Error Path 32.1 – Data Acq does not extract data

- NIRCAM FSW sends image collection failure telemetry indication (no correction data)
- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

Go to ** (an infinite loop with cycle time = **128ms, see note above about 64 msec updates**)

34. AD commands NIRCAM FSW to transition to STANDBY or to FINEGUIDE (see next use case) when time to stop tracking guide star

35. Upon exit, NIRCAM FSW deletes all obsolete files created by tracking process

Error Path 34.1 – Fine Lock never achieved

If AD does not see Close Loop Control = SETTLED after X seconds:

- AD commands NIRCAM FSW to transition to STANDBY
- AD skips to next guide star, if available, or to next visit

35. If going to STANDBY, AD commands Data Acq to complete data transfer to SSR

36. If going to STANDBY, AD commands Data Acq to release SCEP

Fine Guiding:

Pre-condition: Vehicle at science attitude, have successfully completed Track function having subarray size and readout parameters required for fine guiding already setup.

NOTE: NIRCAM FSW is in TRACK function and guide star centroids are being generated every 64 (**128**) msec.

NOTE: CTP has determined that the vehicle attitude is less than ~1/2 pixel (**3-sigma, 16 mas***) of desired position and has set the Close Loop Control telemetry value to “SETTLED” to indicate that the ACS is ready for the Fine Guide transition. The FSM will be near its null position.

*** It may challenge ACS to employ 128 msec (8 Hz) guide star centroids to “fine point” to the Observatory to within 5 mas (1-sigma).**

1. AD commands NIRCAM FSW to set function to FINEGUIDE

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends FINEGUIDE transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends FINEGUIDE transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

2. NIRCAM FSW sends FPE Control Commands (set up FPE for Fine-Guide)

Channel selection FOV A or FOV B

SCA_ID

FPA Array window size **and location (ideal coordinates)**

Integration time selection and readout parameter values

3. NIRCAM FSW reads FPE status telemetry

4. NIRCAM FSW sends command for detector image readback (setup SCE to grab image, sends FPE controls)

Image readout on detector and reconstruction performed on SCEP

**5. Data Acq gets interrupt that image data ready and forwards image data to NIRCAM FSW (in a telemetry packet)

6. NIRCAM FSW accesses image from telemetry and accesses pixel correction data from SBC files

Error Path 6.1 – Image data telemetry does not arrive for N cycles

- NIRCAM FSW sends FINEGUIDE failure telemetry indication (no image data from ISIM)

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- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star, if available, or to next visit

7. NIRCAM FSW performs Image Processing, Subtraction and Correction

8. NIRCAM FSW performs Centroid Position Determination applying the distortion correction as specify by an on-board table, and does a quality check

NOTE: quality check includes a magnitude check, a location check, and a PSF check

Error Path 8.1 – Guide star could not be found for **M** cycles

- NIRCAM FSW sends FINEGUIDE failure telemetry indication (no guide star found)
- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star if at visit start, else skips to next visit

Error Path 8.2 – Guide star quality is bad for **P** cycles

- NIRCAM FSW sends FINEGUIDE failure telemetry indication (bad guide star quality)
- NIRCAM FSW sends an error event message “ _____ ”
- NIRCAM FSW deletes obsolete files
- NIRCAM FSW returns to STANDBY
- AD skips to next guide star if at visit start, else skips to next visit

9. NIRCAM FSW sends centroid packet to indicate FINEGUIDE function to CTP

10. NIRCAM FSW sends FINEGUIDE transition success telemetry indication after **Q** cycles based upon **TBD** characteristics

Go to ** (an infinite loop) with Data Acq periodically transferring image data sets to the SSR

11. AD commands NIRCAM FSW to terminate fine guiding prior to visit termination time or prior to a vehicle offset by requesting a transition to STANDBY

12. NIRCAM FSW deletes obsolete files created by fine guiding process

13. AD commands Data Acq to complete data transfer to SSR

14. AD commands Data Acq to release SCEP

Standby:

Pre-condition: NIRCAM FSW could be in any function

1. AD commands NIRCAM FSW to set function to Standby
 - OR NIRCAM FSW automatically transitions exiting error condition
2. NIRCAM FSW sends centroid packet to indicate Standby function to CTP if previous function was

ID, ACQ, TRACK, FINEGUIDE

3. If ACS was in Close Loop Control, then CTP will stop control

function

4. CTP sends telemetry notification that attitude control has

stopped

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- NIRCAM FSW enters STANDBY
- AD skips to next guide star, if available, or to next visit

Calibration:

Flight software should not need to know the purpose of calibration

AD commands Data Acq to set up an SCEP or two SCEPs
 Question: can both guiders be commanded simultaneously?

AD commands NIRCAM FSW to configure FPE for Calibration
 NIRCAM FSW sends FPE Control Commands (set up FPE(s) for calibration)
 Channel selection FOV A and/or FOV B
 FPA Array window size selection
 Integration time selection and readout pattern parameters

NIRCAM FSW reads FPE status telemetry
 AD receives setup complete notice from Data Acq and NIRCAM FSW
 AD commands NIRCAM to setup internal lamp ON depending on type of calibration
 NIRCAM FSW sends control command to turn Calibration internal lamp ON
 NIRCAM FSW notifies AD that lamp is ON
 AD commands NIRCAM FSW to adjust Focus Mechanism depending on type of calibration
 NIRCAM FSW sends ICE control command to adjust focus mechanism depending on type of calibration
 NIRCAM FSW notifies AD that Focus Mechanism move was successful
 AD commands NIRCAM FSW to begin image collection
 NIRCAM FSW sends command for detector image readback (setup SCE to grab image, sends FPE controls)
 Image readout on detector and reconstruction performed on SCEP(s)
 Data Acq gets interrupt that image data ready and forwards image data to SSR.
 NIRCAM FSW performs telemetry processing (status data to AD and IC&DH (for health and safety monitoring))
 Data Acq and NIRCAM FSW notify AD that data transfer is complete
 AD commands NIRCAM to setup internal lamp OFF depending on type of calibration
 NIRCAM FSW notifies AD that lamp is OFF

SCEP Release Following Error:

Precondition: Error occurs while NIRCAM FSW is executing a function and a SCEP has been configured and associated with a DAQ telemetry slot.

1. AD commands Data Acq to release a SCEP.
2. Data Acq sends telemetry indicating that SCEP was released.

Error Path 1.1 – Data Acq unable to release SCEP

- Data Acq sends SCEP release failure telemetry indication
- AD issues error event message “NIRCAM data transfer incomplete, <function> termination continued”

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Note: The value of the symbol <function> is determined by the function that is currently being executed by the NIRCAM FSW. It is “ID” for the Identification function and “ACQ” for the Acquisition function.

STANDBY Transition Following Error:

Precondition: Error occurs while NIRCAM FSW is executing a function.

1. AD commands NIRCAM FSW to set function to STANDBY.
2. NIRCAM FSW sends STANDBY transition success telemetry indication.

Error Path 1.1 – command parameter verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid parameter value)
- NIRCAM FSW sends an error event message “_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, <function> termination continued”

Error Path 1.2 – command sequence verification fails

- NIRCAM FSW sends STANDBY transition failure telemetry indication (invalid NIRCAM state)
- NIRCAM FSW sends an error event message “_____”
- AD sends error event message “NIRCAM FSW failed to enter STANDBY, <function> termination continued”

Note: The value of the symbol <function> is determined by the function that is currently being executed by the NIRCAM FSW. It is “ID” for the Identification function and “ACQ” for the Acquisition function.

Function Retry:

Precondition: NIRCAM FSW function fails and fewer than 3 attempts have been made to complete it.

1. AD commands Data Acq to release SCEP as specified in SCEP Release Following Error use case.

Error Path 1.1 – Error during release of SCEP

- AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.
- AD terminates with failure indication.

2. AD commands NIRCAM FSW to set function to STANDBY as specified in STANDBY Transition Following Error use case.

Error Path 2.1 – Error during STANDBY transition.

- AD terminates with failure indication.

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3. AD sends event message “<function> termination complete, <function> retry started”.

Function is retried starting from step 1 of the function’s use case.

Note: The value of the symbol <function> is determined by the function that is currently being executed by the NIRCAM FSW. It is “ID” for the Identification function and “ACQ” for the Acquisition function.