NIRCam Instrument Overview

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ABSTRACT

The Near Infrared Camera (NIRCam) instrument for NASA's James Webb Space Telescope (JWST) is one of the four science instruments installed into the Integrated Science Instrument Module (ISIM) on JWST intended to conduct scientific observations over a five year mission lifetime. NIRCam's requirements include operation at 37 kelvins to produce high resolution images in two wave bands encompassing the range from 0.6 microns to 5 microns. In addition NIRCam is used as a metrology instrument during the JWST observatory commissioning on orbit, during the initial and subsequent precision alignments of the observatory's multiple-segment 6.3 meter primary mirror. JWST is scheduled for launch and deployment in 2012.

This paper is an overview of the NIRCam instrument with pointers to several NIRCam subsystem papers to be presented in the same conference. This paper will introduce and explain at top level the structural, optical, mechanical and thermal subsystems of NIRCam.

Keywords: NIRCam, James Webb, JWST, ISIM

1. INTRODUCTION

1.1 Instrument Overview

The NIRCam instrument for JWST is one of the four science instruments to be installed into the ISIM. NIRCam's requirements include operation at 37 kelvins to produce high resolution images in two wave bands encompassing the range from 0.6 microns to 5 microns. In addition NIRCam is to be used as a metrology instrument during the JWST observatory commissioning on orbit during the precise alignment of the observatory's multiple-segment primary mirror.

1.2 Integrated Science Instrument Module (ISIM)

The ISIM occupies the volume directly behind the JWST primary mirror assembly. It provides the four JWST instruments with the low background radiation and cryogenic environment necessary to conduct mission operations. For NIRCam this means a 37 kelvin thermal environment provided through thermal conduction of heat into the ISIM, and the ISIM's passive radiation to space. NIRCam is connected to the ISIM mechanically with a system of kinematic mounts in the structural form of struts. There are thermal straps connecting the NIRCam optical bench assembly to the ISIM structure and to thermal radiators. Optically the NIRCam pickoff mirrors have access to the volume immediately in front of the prime focus of the JWST optical telescope element (OTE) in order to reflect the observatory's converging f/20 cone of visible and near IR content into NIRCam.

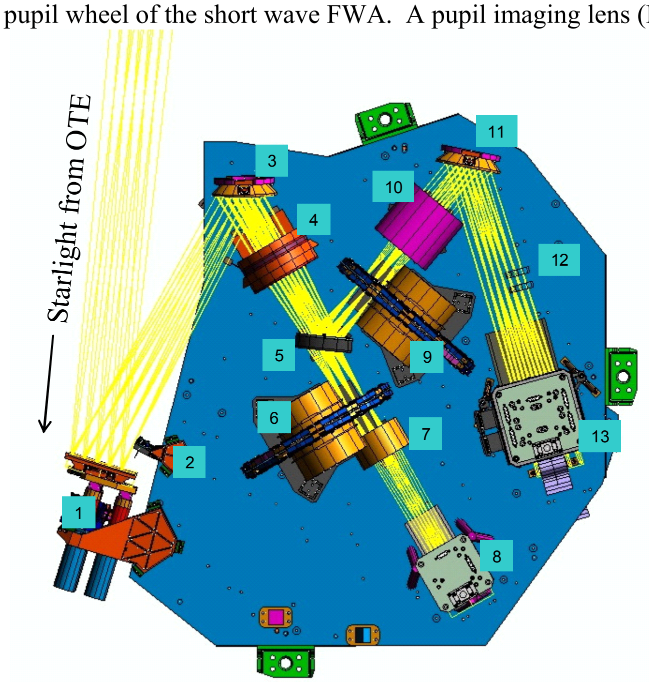
1.3 Science Imaging and Observatory Metrology

In addition to its functions as a JWST science mission imager NIRCam also is used as a metrology instrument during commissioning of the observatory's OTE segmented mirror. During coarse and fine phasing of the mirror segments it is the NIRCam short wave focal plane assembly that is used as the observatory's metrology detector array. NIRCam is outfitted with wavefront sensing (WFS) elements in its filter and pupil wheels. A retractable NIRCam pupil imaging lens (PIL) is inserted into the short wave leg of the optical system in a manner that allows for imaging of the JWST primary mirror segments onto the NIRCam detectors.

2.0 INSTRUMENT ARCHITECTURE

2.1 Instrument Architecture

NIRCam is designed around a compact, lightweight optical system employing refractive triplet lenses. Mass and volume are conserved through a combination of material properties and packaging. Functional redundancy is achieved through the implementation of two complete camera systems, one on each side of the optical bench assembly (figure 1). Each of the two camera modules is divided into a short wave and a long wave imaging system, for a total of four active imagers operating simultaneously. In each imager the entire 0.6 to 5.0 micron waveband is reflected into NIRCam along a common path by a pickoff mirror [1] and is next reflected from a turning flat [3] and through a wideband refractive triplet collimator lens assembly [4]. Separation of the short wave and long wave optical paths is achieved with a dichroic beamsplitter (DBS) [5]. The short wave path uses a reflection from the DBS, while the long wave path includes transmission through the DBS. After separation into two wavebands, further spectral selection is performed with spectral filters in the two filter wheel assemblies (FWA) [6] and [9]. After exiting the filter wheel assembly, the beam is focused through camera lens triplets [7] and [10] onto arrays of detectors in the short- and long-wave focal plane housings [13] and [8]. A coronagraph mask assembly [2] sits just outside the field of view of the short wave detectors, but can be brought into the field of view through the use of a refractive wedge element that is mounted in the pupil wheel of the short wave FWA. A pupil imaging lens (PIL) assembly [12] is inserted during WFS operations.



1	Pick-Off Mirror Assembly
2	Coronagraph
3	First Fold Mirror
4	Collimator Lens Group
5	Dichroic Beamsplitter
6	Long Wave Filter Wheel Assembly
7	Long Wave Camera Lens Group
8	Long Wave Focal Plane Housing
9	Short Wave Filter Wheel Assembly
10	Short Wave Camera Lens Group
11	Short Wave Fold Mirror
12	Pupil Imaging Lens
13	Short Wave Focal Plane Housing
14	ICE Interface Panel
15	FPE Interface Panel

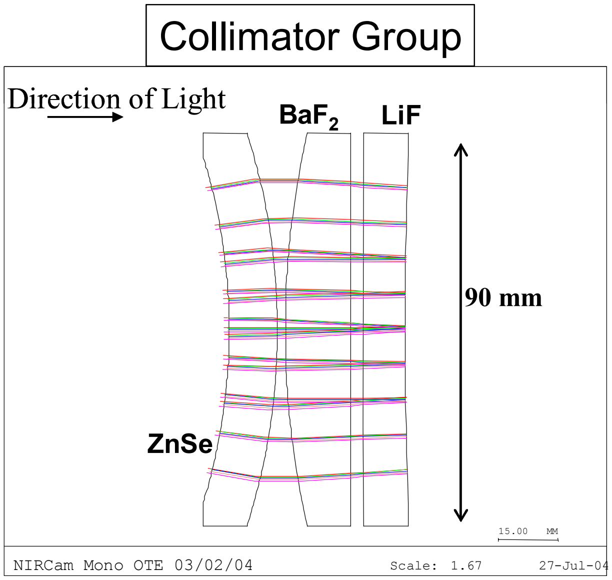
Figure 1. Short-wave and long-wave channels in a NIRCam imager module. An identical module is on the back side.

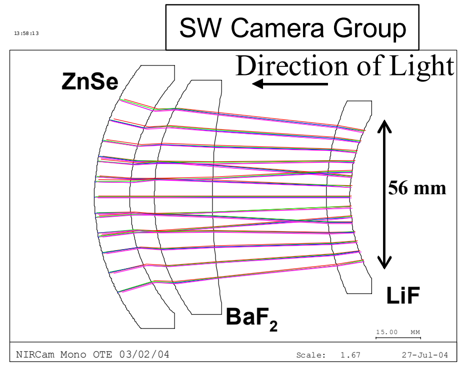
2.2 Instrument Attributes

Each of the two NIRCam short wave imaging channels operates in the wavelength range from 0.6 microns to 2.3 microns. Specific narrowband and wideband wavelength selection within a short wave band is achieved through precision positioning of spectral filters in a twelve-place filter wheel. The short wave triplet camera lens provides an image to a focal plane array (FPA) made up of four single chip arrays (SCAs); each SCA is a 2k by 2k array of mercury-cadmium-telluride (HgCdTe) infrared detectors. Similarly, each of the two long wave channels operates in the waveband from 2.4 microns to 5.0 microns. Specific narrowband and wideband wavelength selection within a long wave band is achieved through precision positioning of spectral filters in a twelve-place filter wheel. The long wave triplet camera lens provides an image to a focal plane array (FPA) made up of one 2k by 2k HgCdTe SCA.

2.2.1 Refractive Optics

The NIRCam refractive triplet lenses (figure 2) in the collimator group, in the short wave camera group and in the long wave camera group are each made up of a lithium fluoride (LiF), a barium fluoride (BaF_2) and a zinc selenide (ZnSe) singlet lens. The largest refractive elements in NIRCam are on the order of 90mm clear aperture diameter. The lens surfaces are spherical except for one mild aspheric surface in each triplet. Each lens element is mounted as a singlet, and is thermally cycled and tested prior to assembly into its respective triplet.





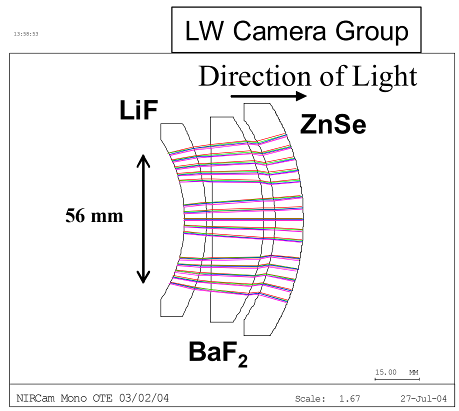


Figure 2. NIRCam Triplet Lens Assemblies

2.2.2 Redundant Optical Modules

Figure 3 shows the two redundant NIRCam imager modules (modules A and B). Although they are functionally redundant mirror-image layouts, the A and B modules are not operated one at a time, but rather simultaneously in order to provide science mode imaging from two adjacent patches of sky.

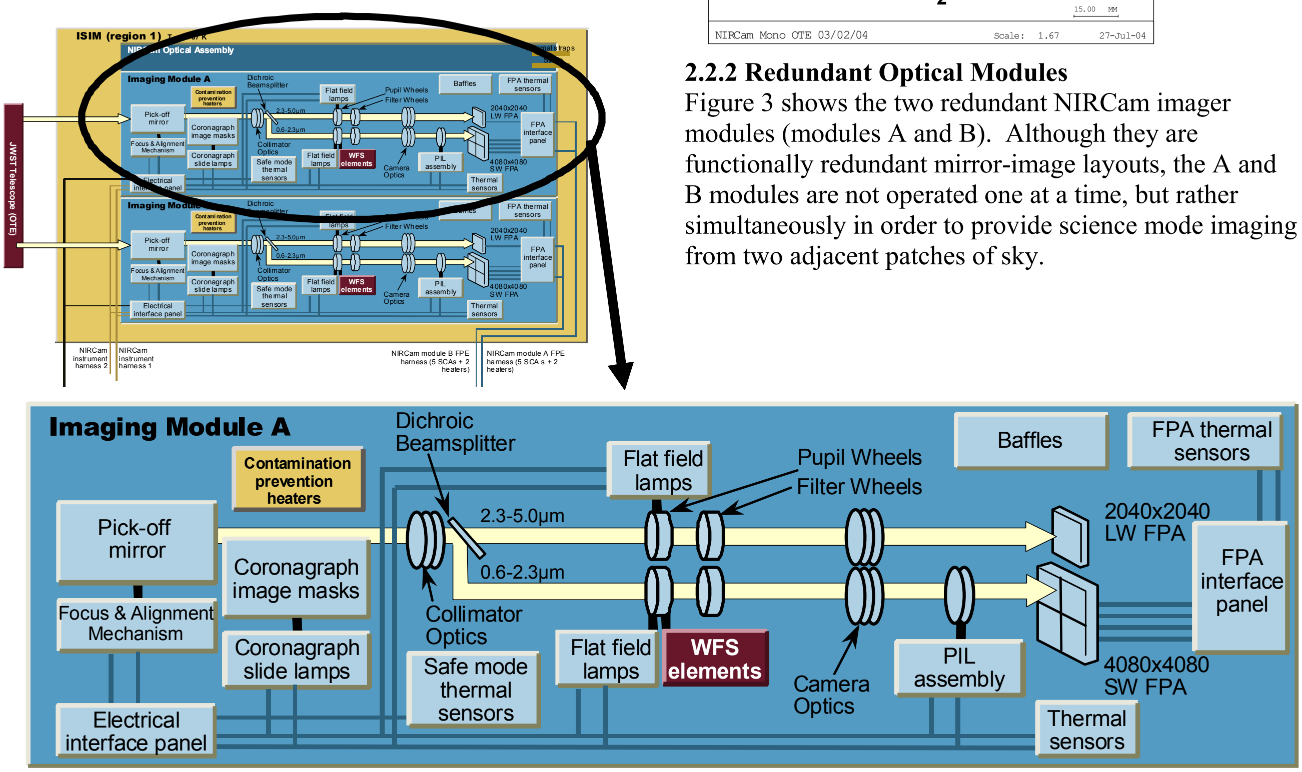


Figure 3 Short-wave and long-wave channels in a NIRCam imager module

During normal science mode operation, there are two adjacent (2.2 arcminute)^2 fields of view being observed in both the short wave and the long wave bands. Figure 4 shows the geometries of the four NIRCam spectral channels. Within Module A, the short wave image covers the same area of the sky as the long wave image, but the short wave image has twice the linear resolution (using four SCAs instead of one SCA as in the long wave channel). Similarly, the B module produces a short wave image with twice the resolution of the long wave image, while observing the same area of the sky. Note that in the figure the two star fields (short wave and long wave) in an imager module are identical.

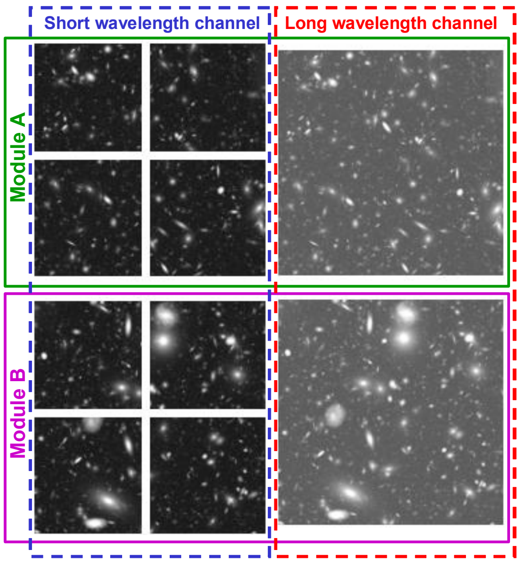


Figure 4. NIRCam focal plane array coverage on the sky

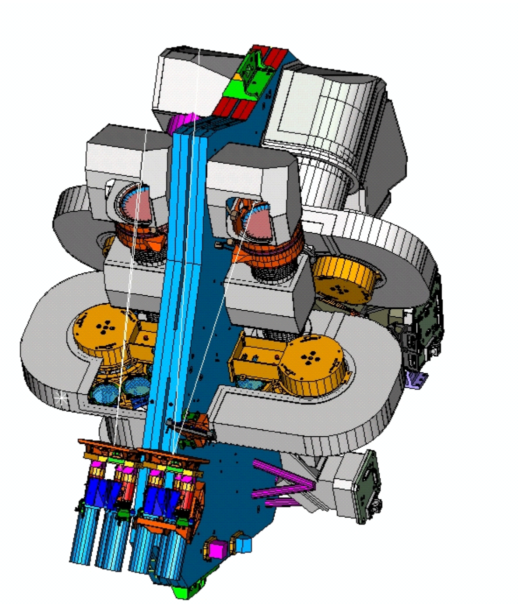


Figure 5 A side and B side NIRCam imager modules

Figure 5 shows the two NIRCam imager modules. The B module is shown on the left and the A module is on the right. The optical trains are laid out as mirror images, resulting in placement of each subsystem within a module directly opposite its counterpart subsystem in the other module. In this view the converging f/20 optical cone from the JWST OTE enters the picture from above and is reflected by the two POM assemblies into their respective A and B imager modules.

2.2.3 Operation in Two Wave Bands

Figure 6 is a schematic diagram of the optical system for a NIRCam imager module. Each of the three triplet lens groups is capable of transmitting the entire 0.6 to 5.0 micron broadband near infrared spectral content. It is the spectral separation imparted by the DBS that results in the division of the short and long wave bands. In the course of performing science mission observations the short wave and long wave filter wheel assemblies are positioned so as to select individual narrowband or wideband spectral filters for inclusion in the optical path. In addition to its filter wheel, each FWA (figure 7) contains a separately selectable 12 position pupil wheel to provide a variety of elements very near intermediate focus in the optical path including weak lenses and WFS elements as well as optical wedges for coronagraphic imaging and pinholes for use in pupil imaging or with the FWA internal calibration radiation sources. In the volume designated “to SW FPA” in the figure, a pupil imaging lens assembly (figure 8) is used for placing an image of the JWST segmented primary telescope mirror onto the short wave FPA. During science observations NIRCam produces a short wave image with an overlapping registered long wave image from the same segment of the sky. At the same time, the other imager module is producing a short wave and a registered long wave image from the adjacent patch of sky.

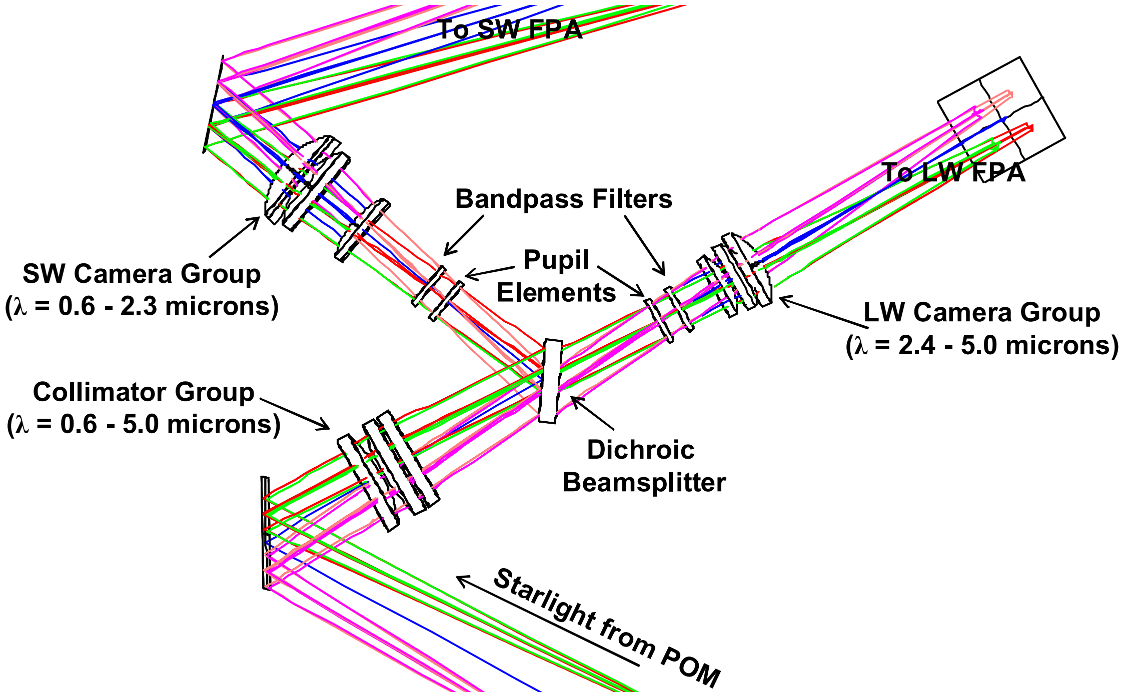


Figure 6. Schematic Diagram of the short wave and long wave optical paths within a NIRCam imager module

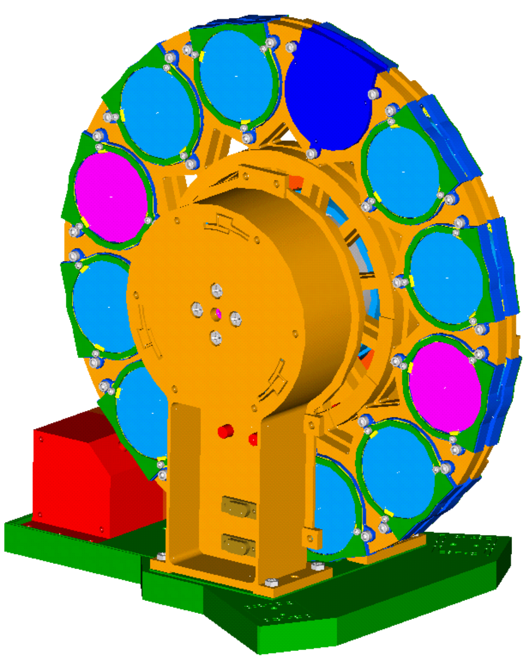


Figure 7. Filter Wheel Assembly (FWA)

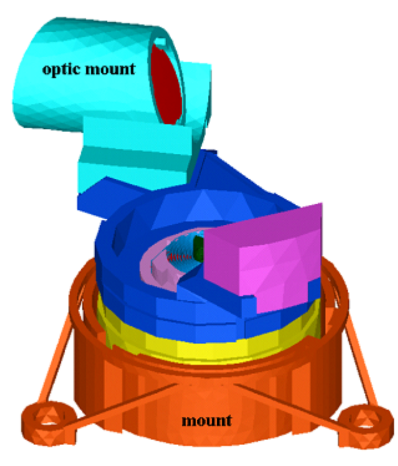


Figure 8. Pupil Imaging Lens (PIL) Assembly

2.2.4 Intermediate Pupil to Accommodate Wavefront Sensing Elements

Within each filter wheel assembly (FWA) there are two independent wheels. One wheel houses 12 filters, while the other wheel houses 12 assorted pupil elements. As part of the complement of pupil elements in each short wave channel FWA there are the optical elements and weak lenses required for coarse and fine phasing of the OTE primary mirror segments. Some of the pupil elements are associated with the use of internal IR calibration sources as well as transmissive wedges used to shift the coronagraphic mask images onto the detector arrays.

2.3 Region 1 Hardware (37 kelvins)

Figure 9 illustrates the optical path from the pickoff mirror and turning flat through the refractive collimator group and on to the DBS. The filter wheels are not shown, but the long wave channel involves transmission through the DBS and the long wave filter wheel, then through the long wave camera triplet and on to the long wave focal plane array. The short wave channel includes a reflection from the DBS, then through the short wave FWA (not shown) and through the short wave camera lens to the short wave detector array. During the metrology mode operations, the pupil imaging lens may be inserted into the optical path between the short wave camera lens and the short wave focal plane.

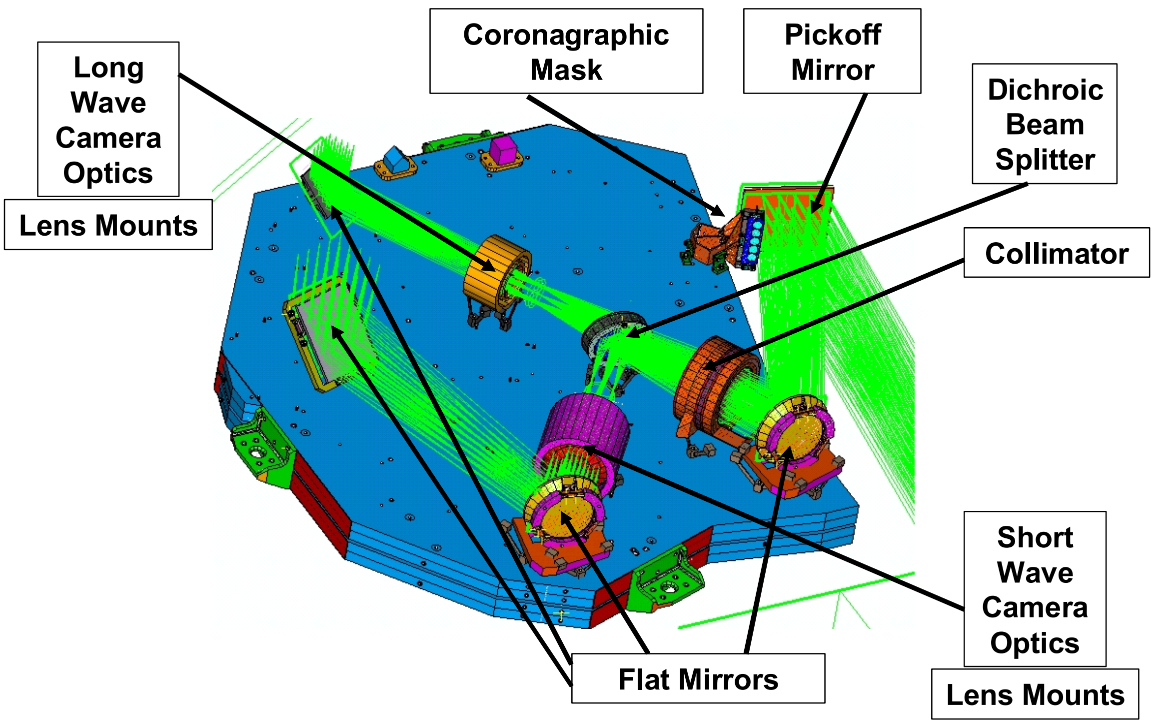


Figure 9. Imager optical train on the optical bench

2.4 Opto-Mechanical Subsystems

2.4.1 Optical Bench Assembly (OBA) and Mechanisms

The two NIRCam imager modules A and B are each built upon an optical bench and the two benches A and B are bolted together. Each of the two benches uses a bonded sandwich construction made up of two flat lightweighted sheets of grade I220H beryllium (Be). Figure 10 shows a lightweighted Be plate with the machined-out pockets and the remaining ribs. Two such Be plates are bonded together to form an optical bench.

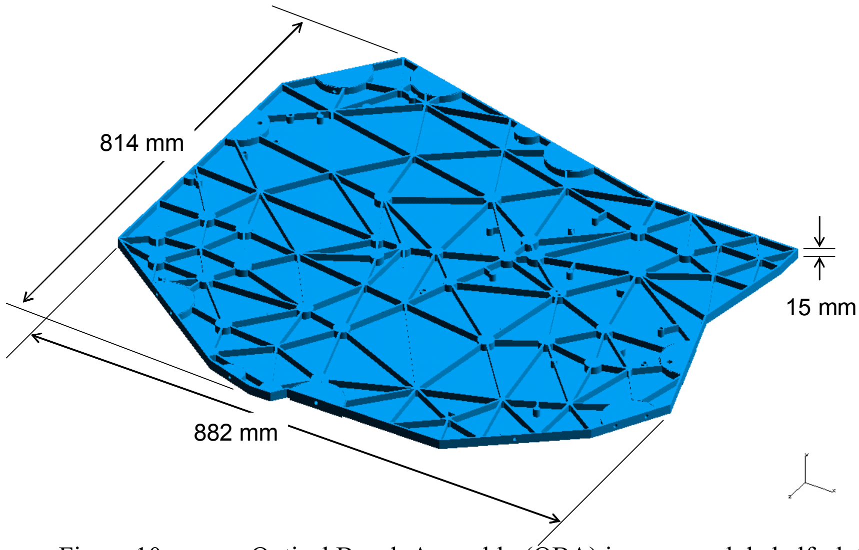
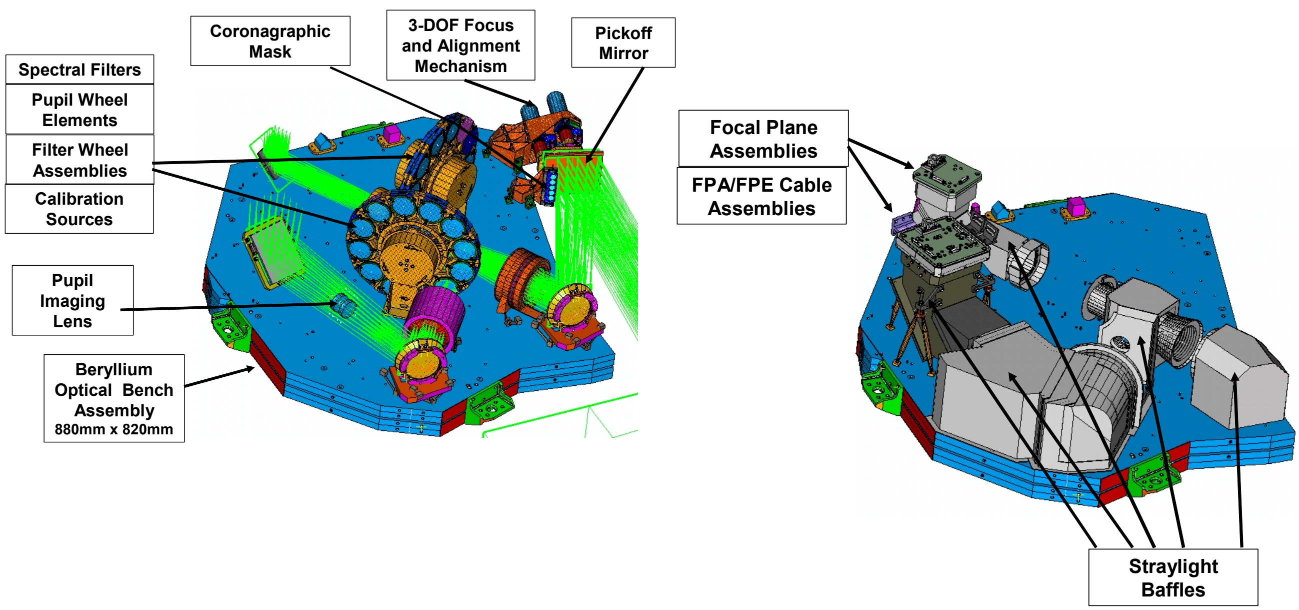


Figure 10. Optical Bench Assembly (OBA) imager module half-plate

2.4.2 Focal Plane Housings and Baffles

NIRCam's FPA housings and optical baffles (right side of figure 11) are designed to suppress stray light from the optical trains and to shield the FPAs from radiation damage. Each FPA housing uses a flat mirror surrounded by titanium to reflect the incoming image up and onto the downward-facing detectors. The FPA housings thus provide a 4 pi steradian shield for the FPAs.

Figure 11. OBA Mechanisms and Baffles



2.4.3 Thermal Subsystem

NIRCam depends upon passive cooling through heat conduction into the ISIM. Besides the necessity of rejecting heat from the mechanisms, detectors, heaters and radiant sources, one of the greatest concerns is parasitic thermal conduction of heat from warmer areas of the ISIM through the large number of electrical connecting wires. Special materials are used for the wiring to achieve high thermal conductivity while providing adequate electrical conductivity. Careful temperature monitoring and power management are used to keep NIRCam within its thermal operating limits.

2.4.4 Optical Sources

Within each filter wheel are contained optical sources for calibration operations. Both outward-projected and inward-projected sources are used to verify field flatness and image positions. The sources are tungsten lamps with glass envelopes. Also, the coronagraphic mask assemblies are populated with light emitting diodes used to generate position registration information when imaged onto the FPAs.

2.4.5 Focus and Alignment Mechanism (FAM)

The FAM (figure 12) provides tip, tilt and piston adjustments for the pickoff mirror. The FAM employs three motor driven length adjusters with position sensors to precisely control the focus, azimuth and elevation of the images for the NIRCam FPAs.

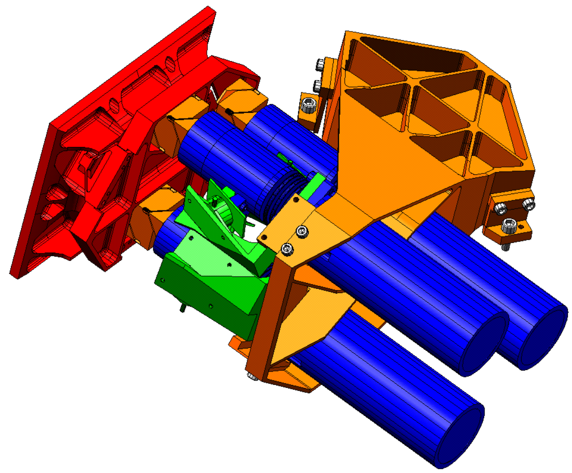


Figure 12.
Focus and Alignment
Mechanism (FAM)

2.5 Region 2 Hardware (NIRCam Electronics)

2.5.1 Focal Plane Electronics (FPE) at 290 kelvins

Data from the FPAs is transferred by the FPE to the ISIM computer through a SpaceWire bus. The FPE provides temperature sensing and control, and power conditioning for the FPAs.

2.5.2 Instrument Control Electronics (ICE) at 290 kelvins

The NIRCam instrument control electronics provide power conditioning and regulation, control for the FAM, FWA and PIL mechanisms, temperature and position sensor power, and housekeeping and telemetry management. The ICE uses a IEEE 1553 bus to communicate with the ISIM computer.

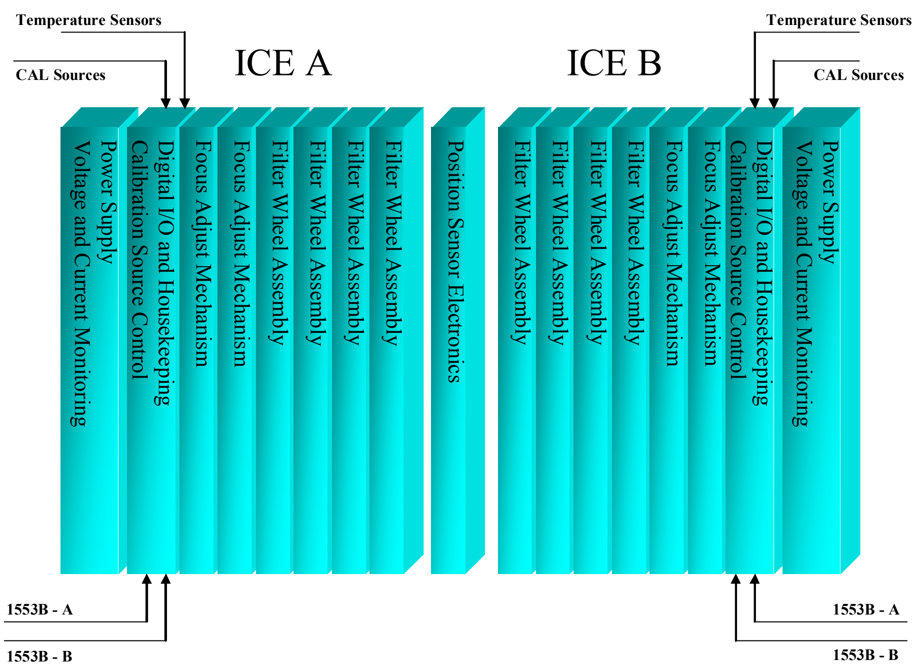


Figure 13. NIRCam Instrument Control Electronics

3.0 Summary

The NIRCam program is in its critical design review (CDR) phase. All major long-lead procurements have been initiated. Subsystem and component risk reduction and verification testing has been conducted on critical hardware items. Instrument development is scheduled to continue through completion and delivery of the ETU and flight instruments late in 2007 and 2008.

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