

Near-Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS)

1. Introduction

The Near-Infrared Camera and Fabry-Perot Spectrometer (NIC-FPS) will provide near-infrared imaging over the wavelength range ~ 1.0 - 2.3 microns and medium-resolution full-field Fabry-Perot (F-P) spectroscopy in the 1.5 - 2.3 micron range. NIC-FPS will allow a wide variety of extragalactic, Galactic, and Solar System observational programs to be conducted. In particular, it will provide a unique northern hemisphere capability by using a cryogenic etalon for obtaining low-background 3D spectral datacubes at ~ 30 km/s spectral resolution of line-emitting objects in the near-IR over a several arcminute field. For near-IR broad-band, medium-band, and narrow-band imaging programs, the F-P etalon can be removed and the instrument can be used as a simple imager.

The construction of NIC-FPS will be completed by members of the Astrophysical & Planetary Sciences (APS) department at the Center for Astrophysics and Space Astronomy (CASA) at the University of Colorado. The instrument is a collaborative effort between scientists at CU, the University of North Carolina, and Rice University. Prof. Gerald Cecil completed the initial instrument design and oversaw the fabrication of several instrument components at UNC. Prof. Patrick Hartigan has purchased the etalon with Rice University funds. Dr. Jon Morse will oversee the completion of the instrument at CU-CASA.

2. Instrument Description

NIC-FPS was originally designed (under the name IRFP) to be used at the $f/7.75$ Cassegrain focus of the CTIO 4m Blanco telescope in conjunction with the 256×256 NICMOS3 detector in the CIRIM near-IR camera. The optical design will be modified (principally the re-imaging optics) to be used on the $f/10$ ARC 3.5m telescope at Apache Point. Figure 1 shows a schematic layout of the NIC-FPS instrument that will be modified for the ARC 3.5m. Light enters the instrument through an entrance window and passes through the filter wheels and a collimating optic. The beam is then folded by a gold-plated flat mirror for passage through the F-P etalon. A second fold flat directs the beam to a set of re-imaging optics that provide aberration control, field flattening, and the proper image scale at the detector. The dewar is based on the Ohio State U. MOSAIC instrument (deployed at MDM), designed by Tom O'Brien and the OSU Instrument group, to whom we are very grateful. The NIC-FPS optical design will be modified for use at a Nasmyth focus (probably port 2) of the ARC 3.5m telescope using a 1024×1024 Hawaii 1 HgCdTe detector array purchased from IR Labs of Tucson. The pixel scale will likely be $0.25 - 0.3$ arcseconds/pixel to take advantage of optimum near-IR seeing conditions at the telescope while providing a field of view (FOV) of diameter up to 5 arcminutes.

Thermal background suppression and control are provided by cooling with LN_2 . NIC-FPS is a *bona fide* dewar that is well-insulated and operates in vacuum. An ionization vacuum gauge is used to monitor dewar pressure. The dewar is an Al cylinder ~ 18 inches in diameter. The LN_2 tank is a half-cylinder welded to the bottom of the optical bench. LN_2 fill and N_2 vent lines connect into the cryotank. The optics and etalon assemblies are mounted on G10 insulator stand-offs to allow the optics to cool slower than the metal parts. Lenses will be mounted in paper-buffered cells, designed by Tom O'Brien, to minimize thermal shock during cooldown. The optical bench and attachments are in turn epoxied to the front plate through a G10 ring. This design should support ~ 12 -hr observation periods, with topping off of the LN_2 cryotank at dusk

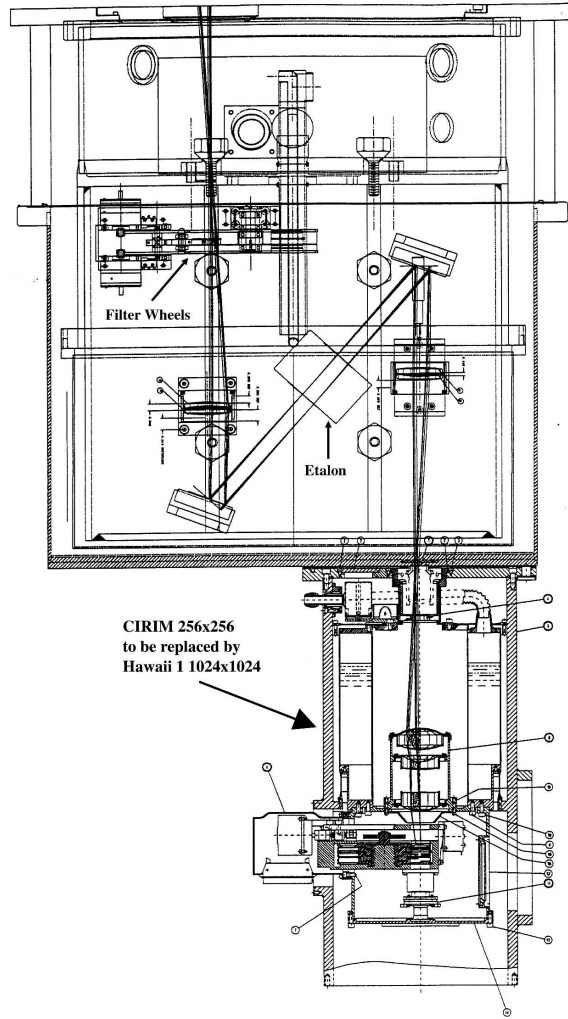


Figure 1: Schematic layout of the NIC-FPS as originally designed for deployment on the CTIO 4m telescope. The filter wheels and etalon are labeled. In addition to modifying the optical design for the ARC 3.5m, we will install a 1024×1024 Hawaii 1 HgCdTe detector array in place of the CIRIM 256×256 array shown here.

and dawn. Mechanical and electrical feedthroughs are provided for power/data cables, connectors from the cryogenic F-P etalon to its CS 100 controller, and a focusing micrometer to the collimator optic.

During the re-design effort, we hope to allow flexibility for upgrading to a 2048×2048 Hawaii 2 HgCdTe chip, provided that the clear apertures of the filters, etalon, mirrors, and lenses will support this. We also will consider making it possible to insert a grism into the beam at the location of the F-P etalon for performing spectroscopy.

3. Sensitivities and Performance

The following table presents NIC-FPS sensitivity estimates for detecting point and extended sources. We assume a seeing-limited point spread function (PSF) of 0.6 arcseconds FWHM, and an imaging scale of 0.3 arcseconds/pixel.

Table 1: NIC-FPS Sensitivity Estimates

Band	λ_{cen} (μm)	$\Delta\lambda$ (μm)	Back-Ground ⁴	Limiting mag or flux ^{5,6}
Z	1.00	0.26	8.1e-2	24.2
J	1.25	0.28	2.3e-1	23.3
H	1.65	0.30	1.4	21.6
K	2.22	0.42	1.5	21.2
Fabry-Perot				
[Fe II]	1.64	0.00016	4.5e-4	9e-18
H ₂ (1-0) S(1)	2.12	0.00021	3.6e-4	5e-18

Table Notes:

1. Seeing-limited PSF of 0.6" FWHM; image scale of 0.3 arcsec/pixel; 3x3 pixel aperture.
2. Throughput efficiency of ~0.33 for imaging through broad-band filters. Throughput efficiency of ~0.30 for Fabry-Perot.
3. Read noise = 15 e⁻/pixel per read (Fowler sampled); dark current 0.1 e⁻/s/pixel.
4. Backgrounds are in units of photons/s/cm² per 3x3 pixel bin in the specified bandpass. F-P backgrounds assume average sky background at λ .
5. For broad-band filters, point source sensitivities are in limiting magnitudes for 5 σ detections in 1 hour.
6. For F-P imaging, extended source sensitivities are in units of ergs/cm²/s per 3x3 pixel bin for 5 σ detection in 1 hour of integration at one etalon gap setting.

4. Instrument Definition Team

An Instrument Definition Team (IDT) of scientists and engineers will be involved in the development of NIC-FPS. The IDT will include the following scientists, plus additional technical and administrative support personnel at CU-CASA: Dr. Jon Morse, Prof. John Bally, Prof. Erica Ellingson, Dr. Erik Wilkinson, Mr. Stephane Beland (CU-CASA), Prof. Gerald Cecil (UNC), Prof. Patrick Hartigan (Rice), and Prof. Jon Holtzman (NMSU, ARC Instrument Scientist).

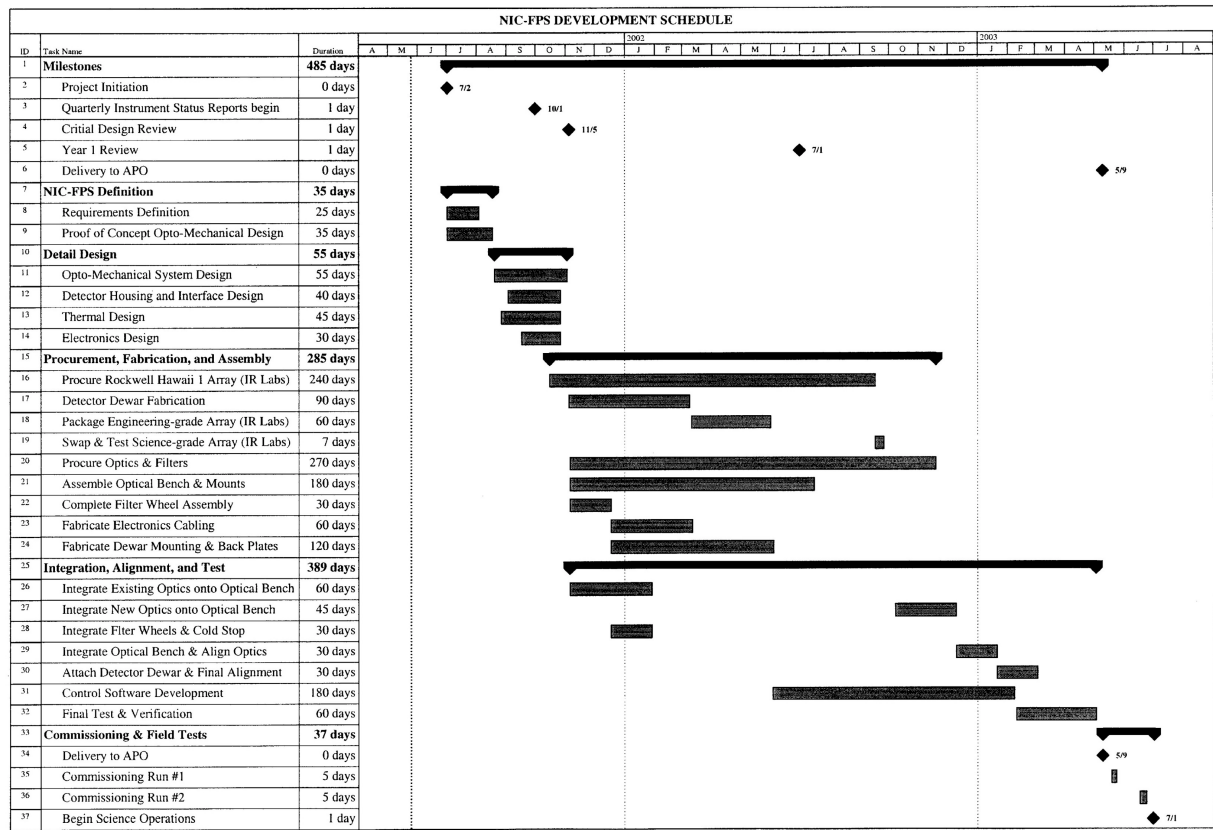
The IDT will be responsible for overseeing the completion of the re-design effort (based on scientific, technical, and programmatic inputs); the definition of the mechanical and operational interfaces to the telescope; the procurement, assembly, and integration of the instrument components (except for the new Hawaii 1 array, which will be assembled and integrated at IR Labs); and the instrument testing prior to delivery to the observatory. Upon instrument delivery, the IDT will provide adequate documentation and training of ARC personnel in the instrument hardware and software operations.

The PI (Morse) is designated as the Point of Contact for NIC-FPS. During the design, assembly, and testing phase, the PI will make quarterly reports on the instrument status and schedule to the ARC Board. After delivery, the PI will be the primary contact for information regarding instrument operations, maintenance, and repair.

5. Schedule, Budget Items, and Facilities

Figure 2 shows the NIC-FPS development schedule, with milestones identified that include project initiation on 1 July 2001, a Critical Design Review (CDR) in November 2001, engineering runs to commission the instrument during Spring 2003, and commencement of science observations by July 2003. Scientists from CU-APS (Shull, Stocke, Green) and other ARC member institutions will be invited to serve on the review panel for the CDR.

When viewing the schedule of activities, please bear in mind that the original optical design for deployment at the CTIO 4m is mature; our task is to modify this design to accommodate the ARC 3.5m. Secondly, many long-lead components have already been



fabricated: construction of the main dewar was completed at UNC; the main dewar was vacuum-tested at UNC; mechanical and electrical feedthroughs were completed at UNC; the optics mounts have been fabricated and the existing optics were successfully cooled in the O'Brien cells; the construction of the filter wheels (2 wheels with 9 slots each) has been completed at CTIO and the filter wheel components are being shipped to CU. Early in the re-design process, we expect to make one or more site visits to APO to verify the instrument mounting scheme.

NIC-FPS development will be supported entirely from internal CU funds. Major budget items include procurement and packaging of the Hawaii 1 array from IR Labs of Tucson (~\$200k), lenses (~\$10k ea.), filters (~\$3-5k ea.), cables, control computer, and in-kind contributions of other materials, equipment, and labor to support the design modifications, integration, alignment, and test. As previously noted, the F-P etalon (\$63k) has been purchased by Dr. Hartigan and the etalon controller (~\$40k) will be provided through Drs. Cecil and Hartigan. To accomplish this project, CU-CASA will employ its infrastructure located at the Astrophysics Research Laboratory (ARL), which is located in the East Campus Research Park of CU's Boulder campus. ARL is a 25,000 sq-ft facility dedicated to the design, development, integration, and test of airborne, space-borne, and ground-based astronomical instrumentation. The facility is divided into office space for the technical staff and multiple lab areas where such projects as the testing of the *HST-COS* gratings and flight detector, UV sounding rocket program, and X-ray and IR instrumentation development are undertaken. In addition to the program specific lab areas, ARL houses a machine shop, electronics development area, precision cleaning lab, and 800 sq-ft class 1000 Integration and Test cleanroom. The NIC-FPS project will be assigned its own clean area in the main high bay, and will have access to all the precision optical alignment equipment and ancillary tooling necessary to assemble the instrument.