NIC-FPS 1-Year Review

Program Overview

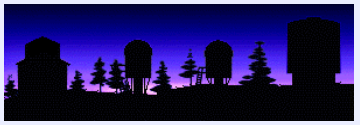
Jon Morse

(CU-CASA)

4 April 2003

CASA-ARL

Boulder, CO



NIC-FPS Personnel

CU-CASA

Mike Shull, Administrative PI
Jon Morse, Instrument PI
Fred Hearty, Opto-Mechanical
Stéphane Béland, Electronics & S/W
Frank Bartko, I&T flow
Bob Sarrazin, Detailed mechanical drawings
Meredith Drosback, Detector characterization
Matthew Pallas, Roverback
Ann Shipley, FEA

Science & Technical Advisory Group

John Bally (CU-CASA)
Erica Ellingson (CU-CASA)
Jason Glenn (CU-CASA)
Erik Wilkinson (CU-CASA)
Al Betz (CU-CASA)
Pat Hartigan (Rice U.)
Jon Holtzman (NMSU/ARC)
John Barentine (ARC Instr Liaison)

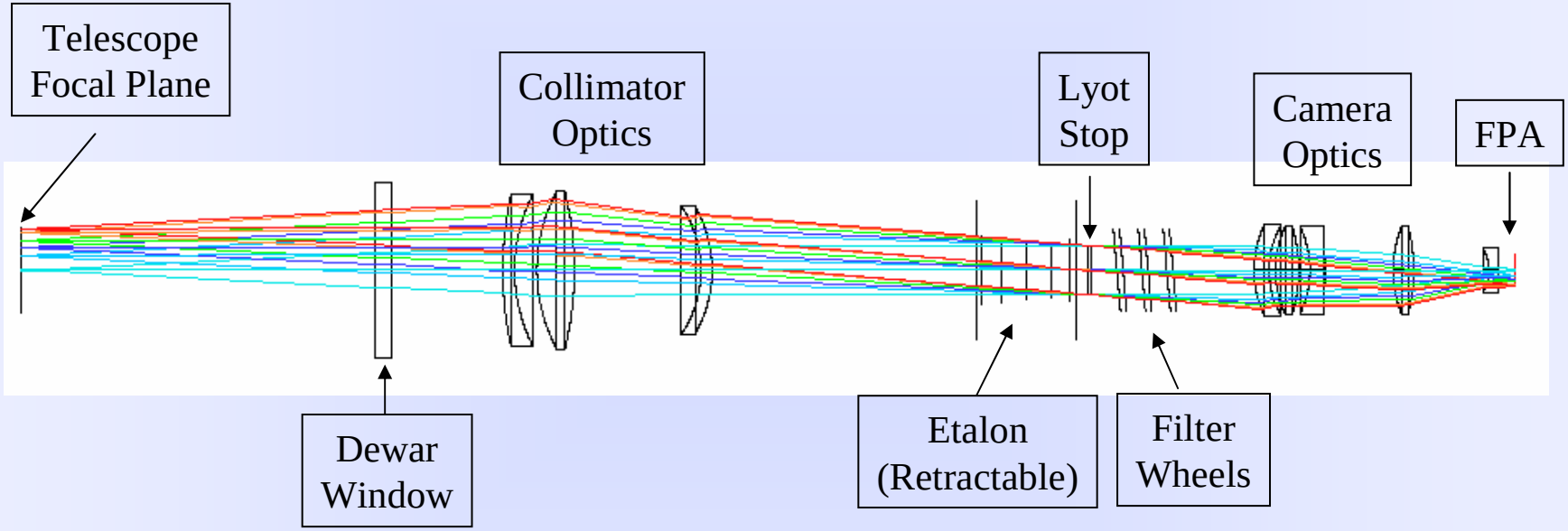
Ball Aerospace

David Fischer, Systems engineering
Chris Stewart, Optical design
Art Olsen, Optical design
Gary Emerson, Opto-mechanical/thermal
Mike Ensminger, Detector testing & characterization

NIC-FPS 1-Year Review

- **Wavelength range:** 0.85 to 2.5 µm
- **Pixel Scale and Field of View:** single image scale
  - Pixel scale of 0.27 ±0.02 arcsec/pixel for H-1RG 1024×1024 HgCdTe detector with 18µm pixel pitch
  - Field of View of 4.58′×4.58′ (6.42′ across diagonal)
- **Optics**
  - High intrinsic Strehl to take advantage of best seeing conditions
  - Minimized and well-characterized image distortion to allow accurate astrometry
  - High system transmission (> 70% at 2 microns)
  - Pupil size is ~80% of F-P etalon 50mm clear aperture
  - Cold optics and Lyot stop to reduce background levels
  - Minimize scattered light and ghost images when viewing point and extended sources

Instrument Optical Design



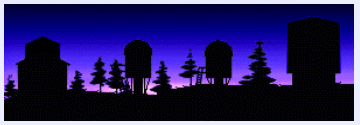
- Optical design by M. Vincent based on preliminary design by C. Stewart (Ball Aerospace), optimized by Janos to ease lens fabrication and mounting
- Optics and lens mounts fabricated and cold tested by Janos for mid-April delivery

NIC-FPS 1-Year Review

ARC Telescope Parameters

Entrance Aperture Diameter	3404.6 mm
Entrance Stop Placement	Primary Mirror
Central Obscuration	780.0 mm diameter
F/#	F/10.35

Camera Design Parameter	Design Value
Wavelength Range	0.85 – 2.5 μm
Pixel Scale	0.27" / pixel (1016 x 1016 HgCdTe)
Pixel Pitch	18.0 μm
System Effective Focal Length	13592 mm
System F/#	3.99
System Field-of-View	4.58' edge-to-edge 6.42' corner-to-corner
NIC-FPS Internal Pupil Diameter	Driven by Etalon (40 mm)
Collimator Magnification Factor	85.115X
Pupil Relief Distance from Collimator Lens 3	301 mm
Transmission including window and Lyot stop (not including filter or etalon)	75 %



NIC-FPS 1-Year Review

NIC-FPS Image Quality

Optical Design Parameter	Design Value
Geometric Distortion	**0.75% at edge 1.6% at corner**
RMS Spot Diameter Performance	**Less than 1 pixel at all wavelengths and fields**
Refocusing Between Filters	**None Required**

80 % Diffraction Encircled Energy Diameters

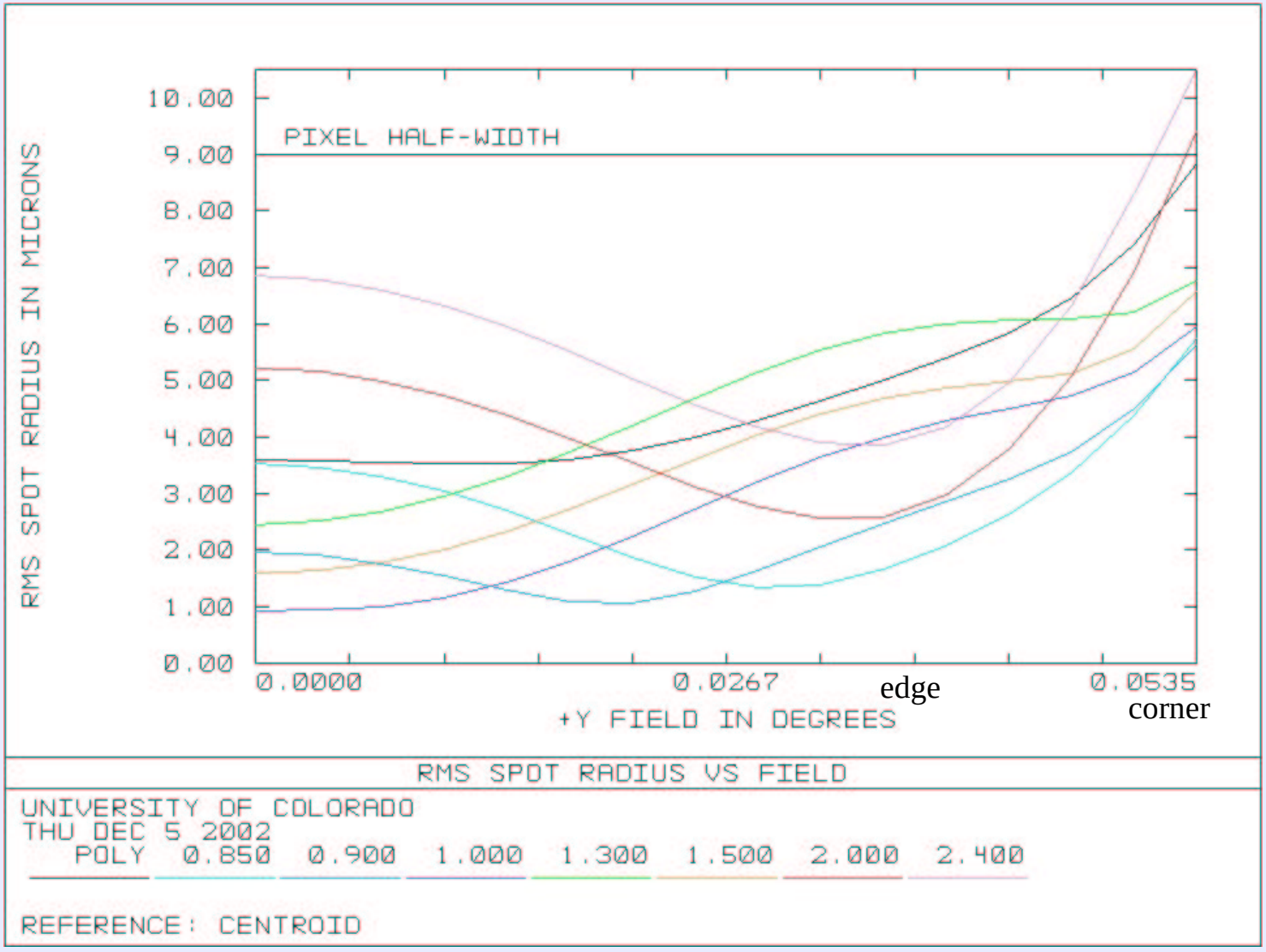
Wavelength (µm)	Best (µm)	Worst (µm)	Diffraction limit (µm)
0.90	11.9	17.4	11.3
1.30	16.7	20.0	16.5
2.00	27.4	37.0	25.2
2.40	32.4	39.7	30.3

Note that the best and worst cases are not necessarily the center and corner fields.
Diameters are for the as designed system.
18 µm pixel size.

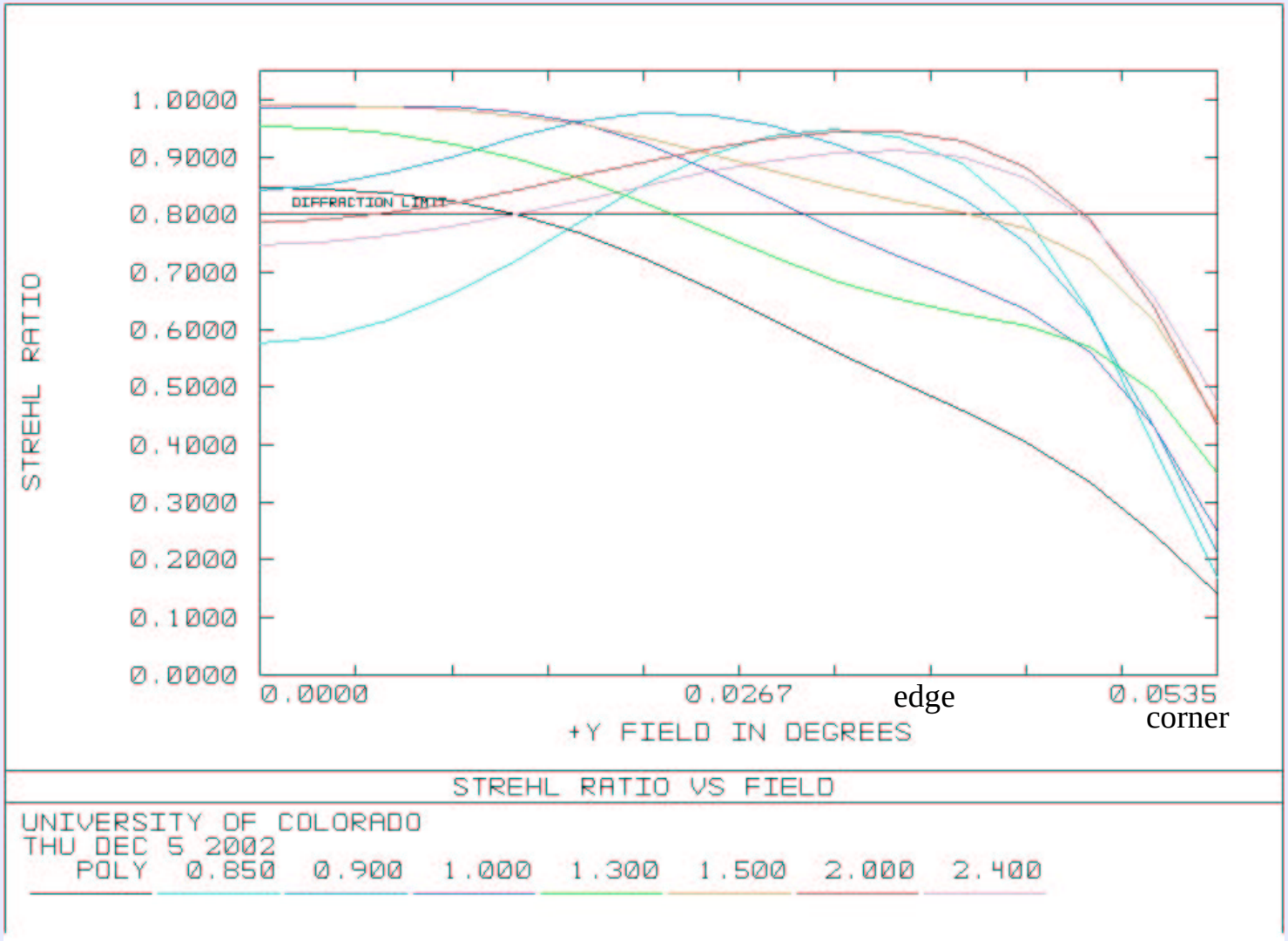
NIC-FPS 1-Year Review

Spot Diagrams

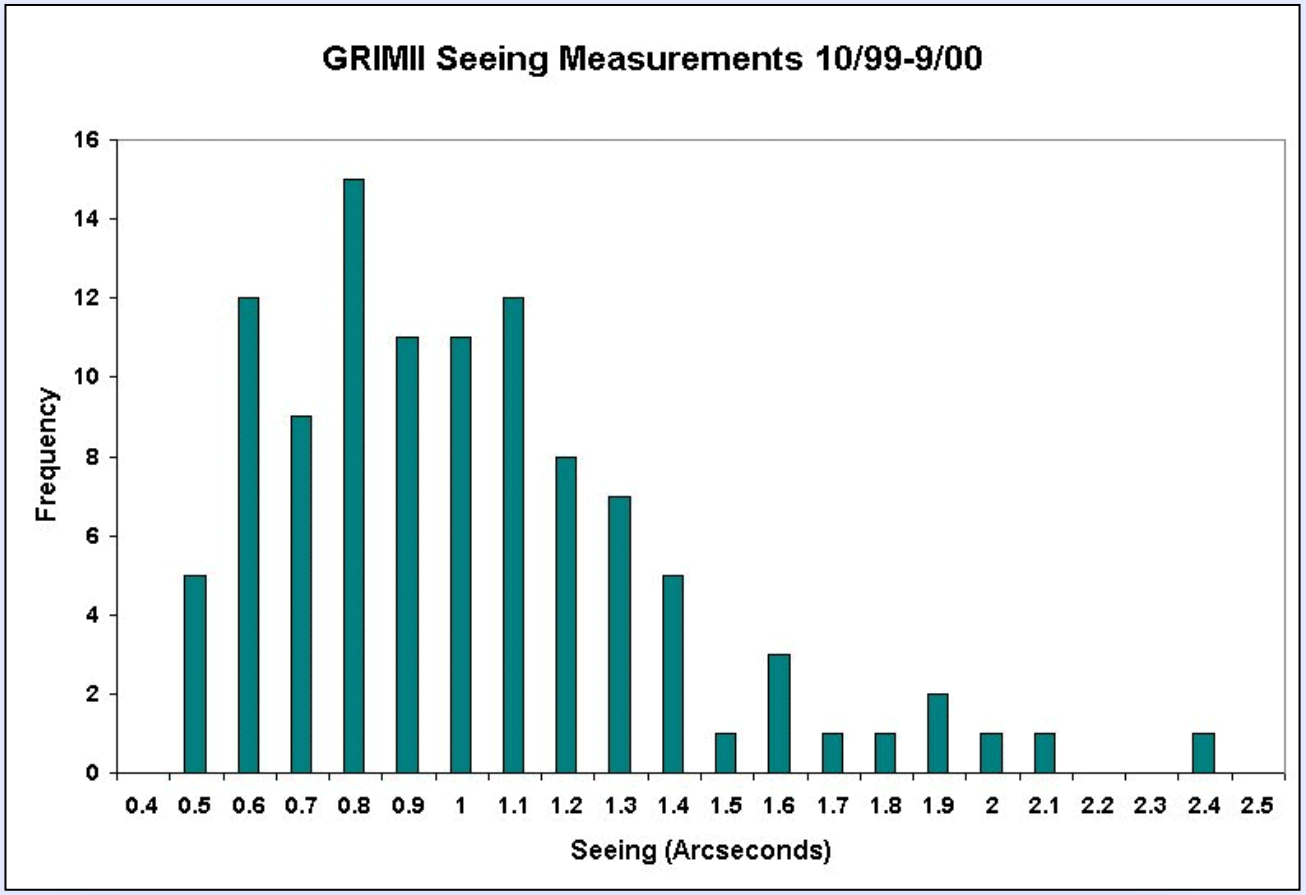
NIC-FPS 1-Year Review



NIC-FPS 1-Year Review



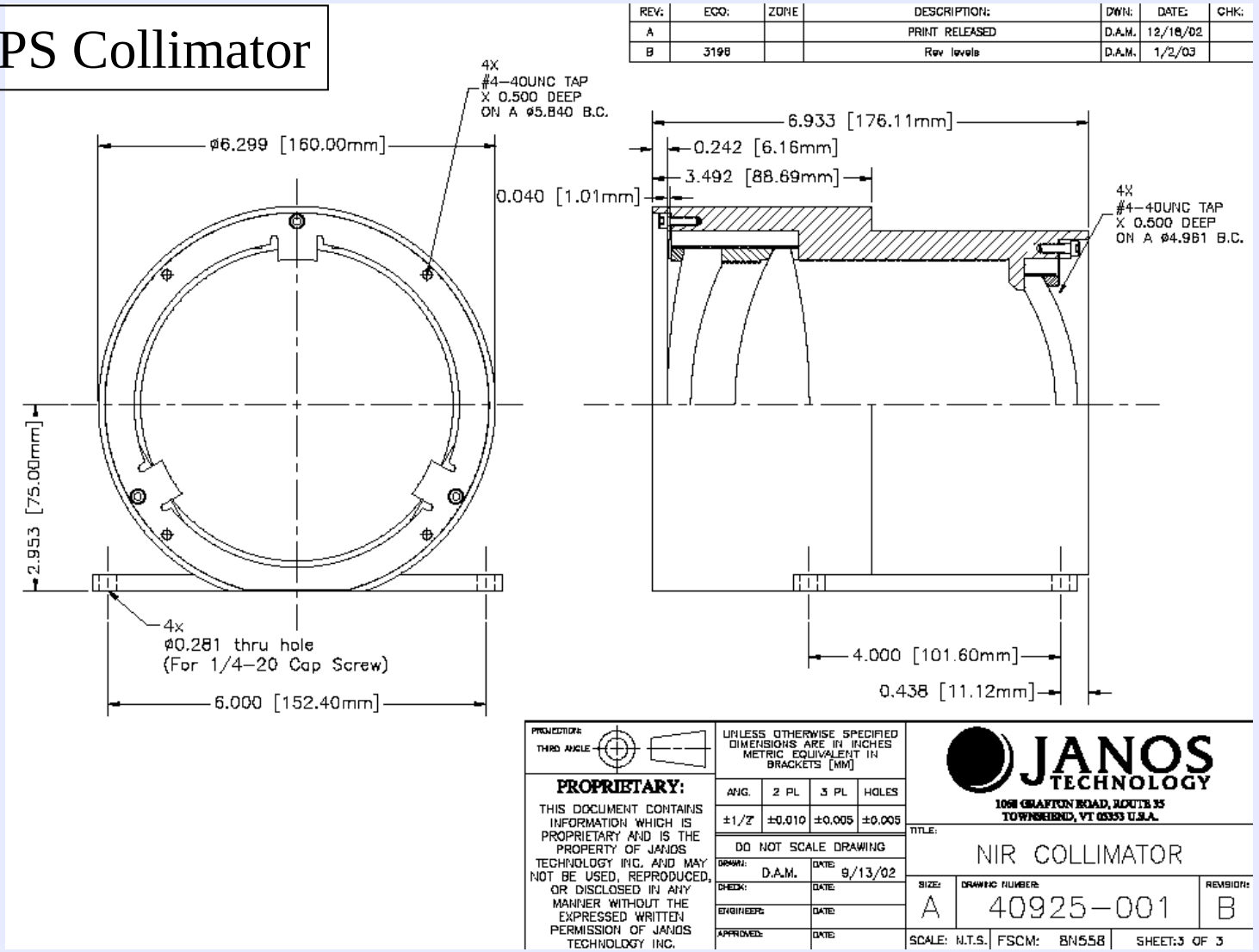
NIC-FPS 1-Year Review



- 1999-2000 GRIM II 2-micron median FWHM seeing is 0.93 arcsec (Barentine, 2002).
- Seeing better than 0.8 arcsec occurs about one night in four.
- 0.5 arcsec seeing occurs about once a month.

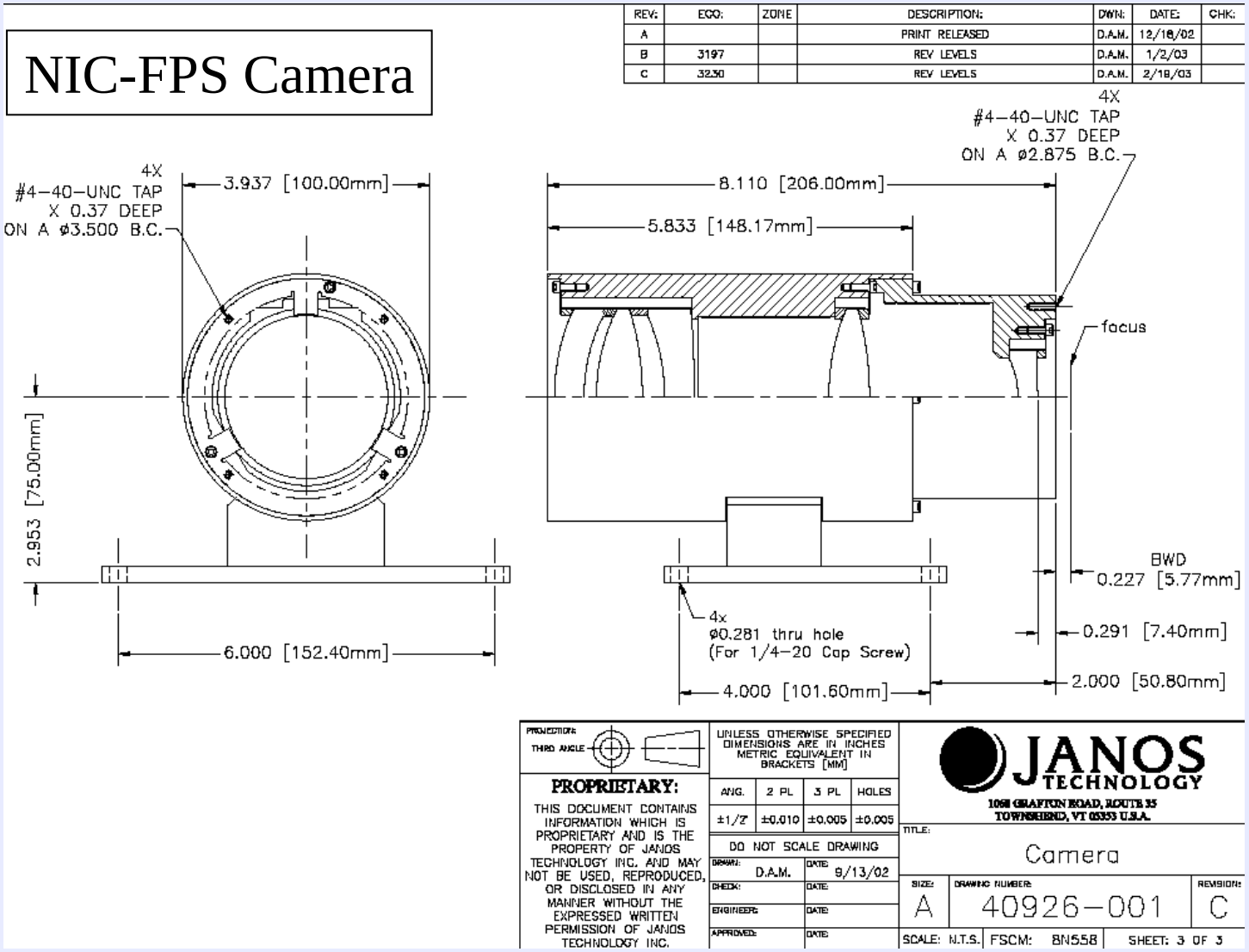
NIC-FPS 1-Year Review

NIC-FPS Collimator



NIC-FPS 1-Year Review

NIC-FPS Camera

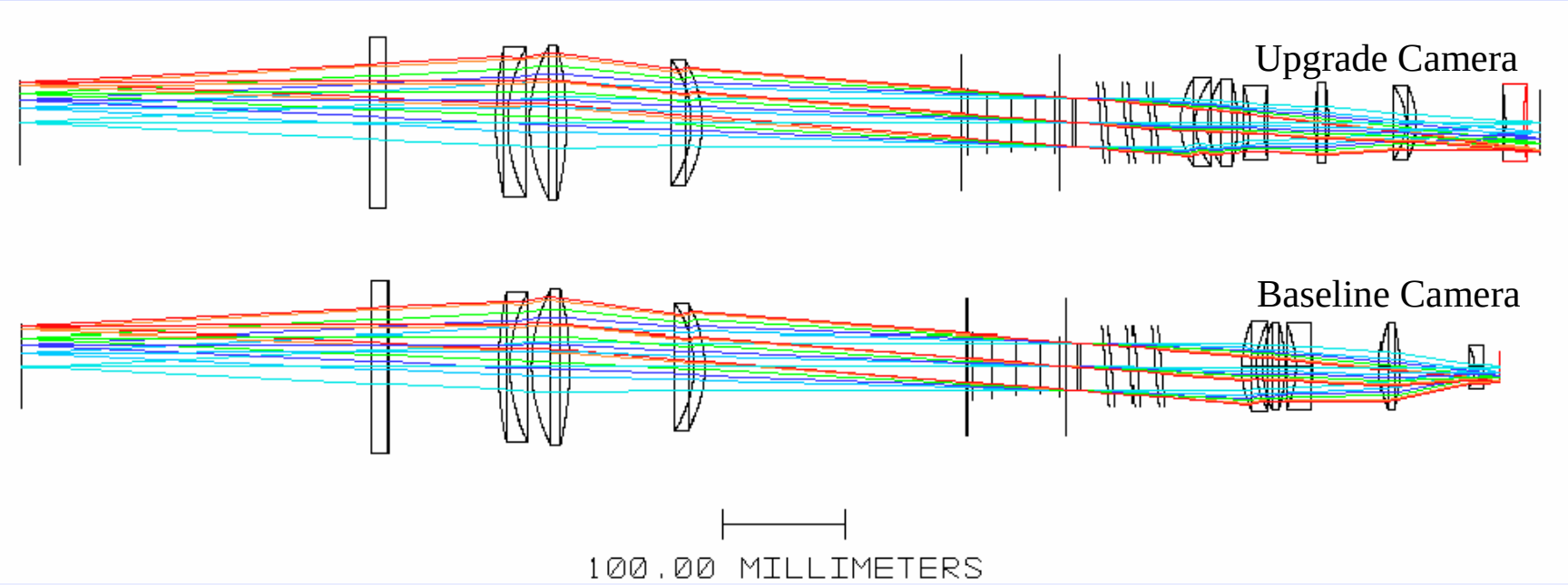


NIC-FPS 1-Year Review

Camera Upgrade

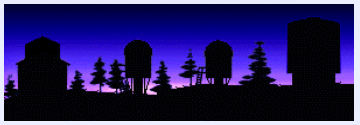
When the seeing at ARC improves to where 0.5” seeing is common, NIC-FPS will be ready.

By replacing the camera and H-1RG detector with a new camera and an H-2RG, the pixel scale can drop from 0.27 to 0.144”/pixel. The field of view would then increase by ~6% with minimal vignetting. At 0.15-0.16”/pixel, the field would be even larger, at the cost of some vignetting in the corners. New camera can fit into the same space, but expanding the length by ~36 mm provides excellent image quality.

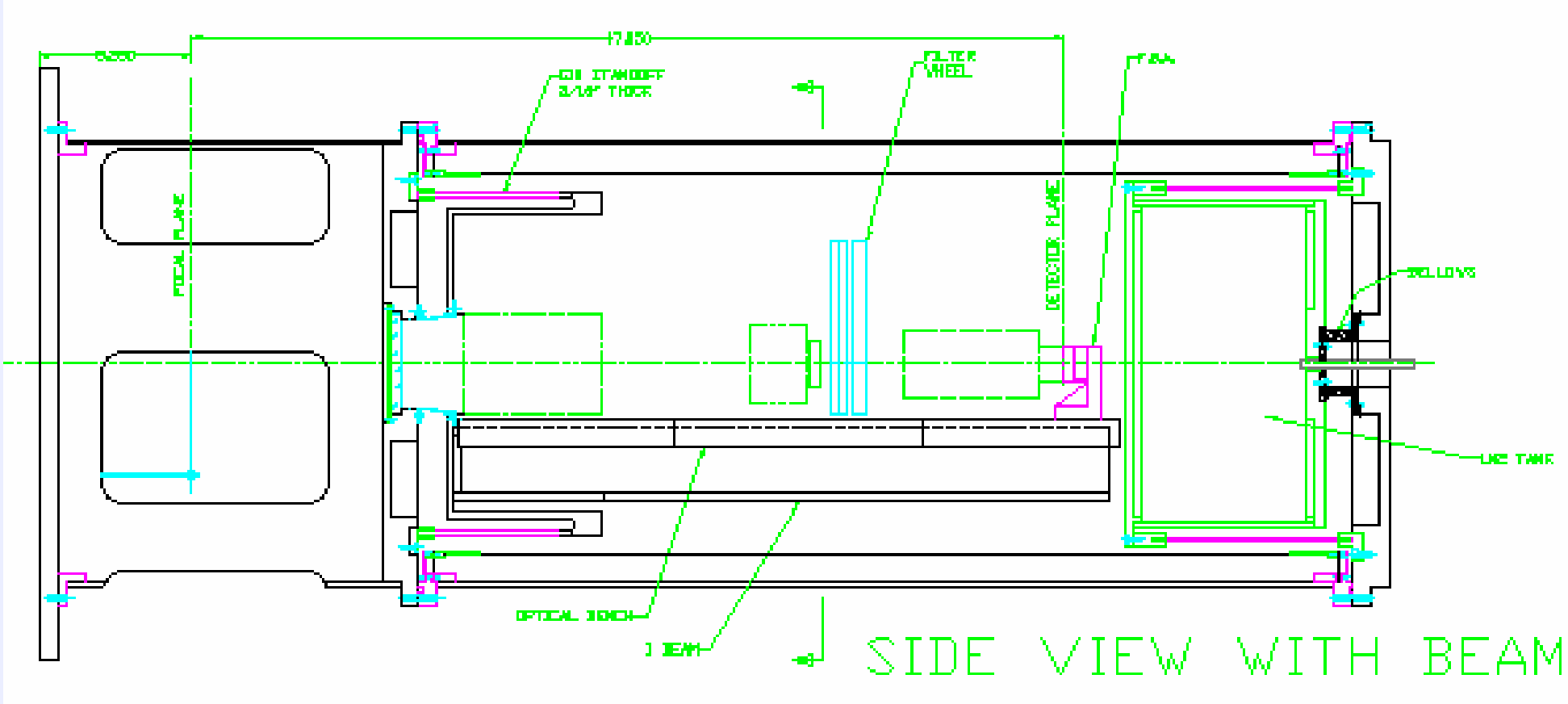


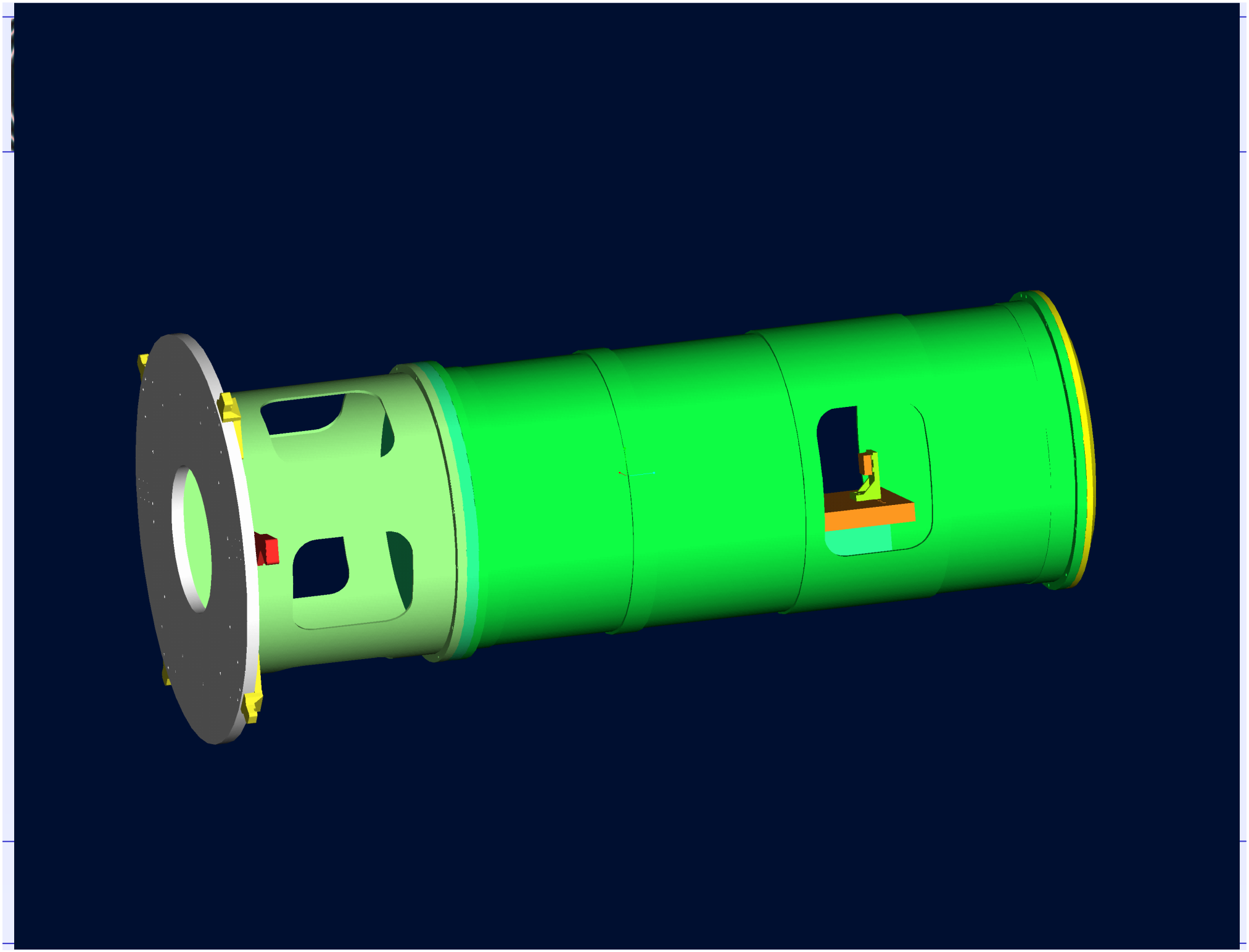
NIC-FPS 1-Year Review

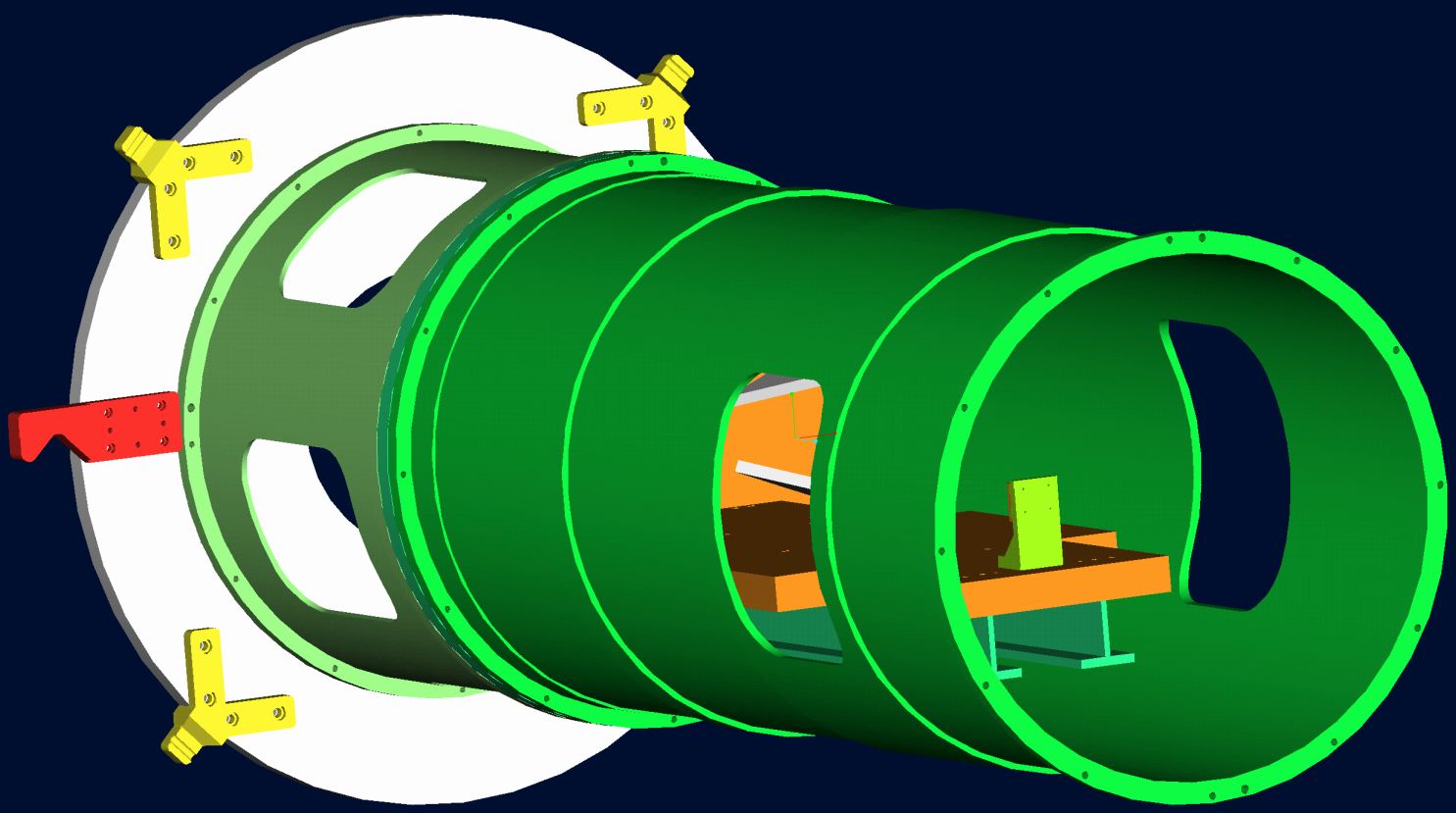
- **Dewar & optical bench**
  - "Access architecture" for alignment and maintenance
  - Cool detector to ~77K using LN2
  - Cool optics to <220K to reduce background
  - Cool optics to ~77K with LN2 for ease of implementation and to reduce thermal gradients/mechanical distortions
  - Cryogen hold time >24 hours (goal of >48 hours)
  - Minimize vibration environment for etalon
  - Baseline mounting to Nasmyth port 2
  - External calibration sources
- **Cryo Mechanisms (minimum set)**
  - 3 motorized filter wheels with 7 slots each in collimated beam
    - 3 clear slots (1 per wheel), 1 blocker, 17 science filter slots
  - 1 motorized arm/stage to remove etalon for direct imaging

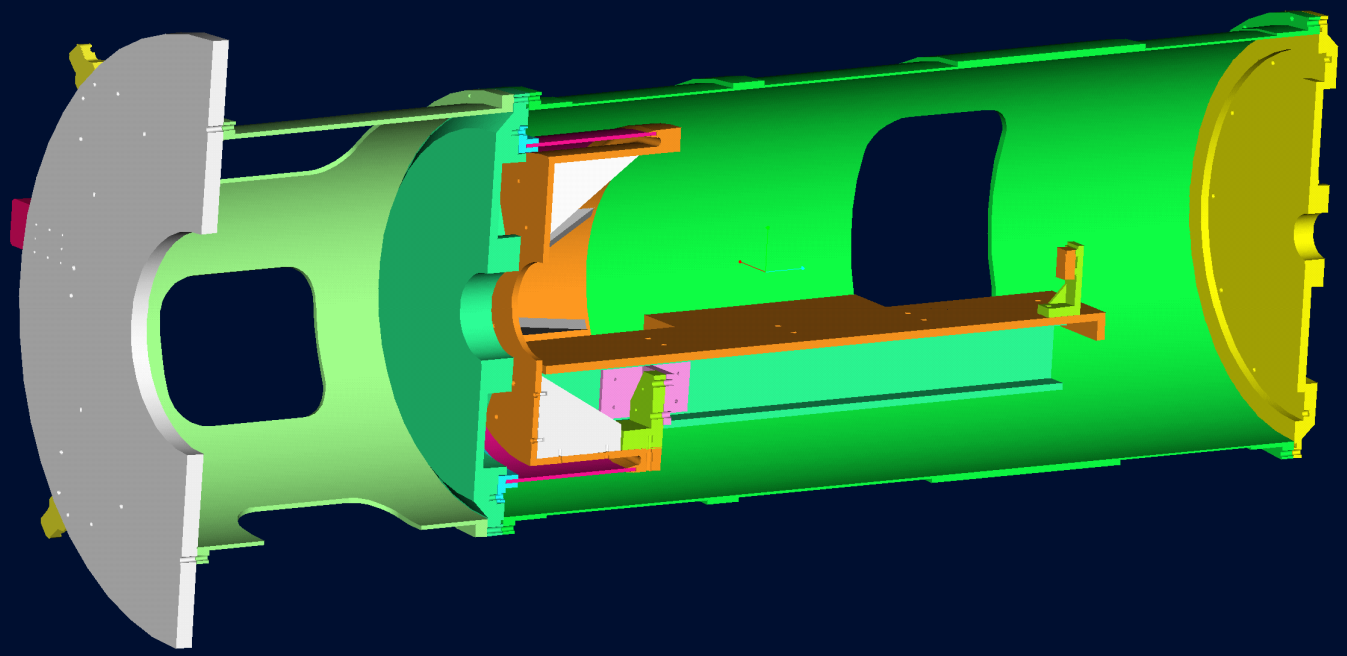


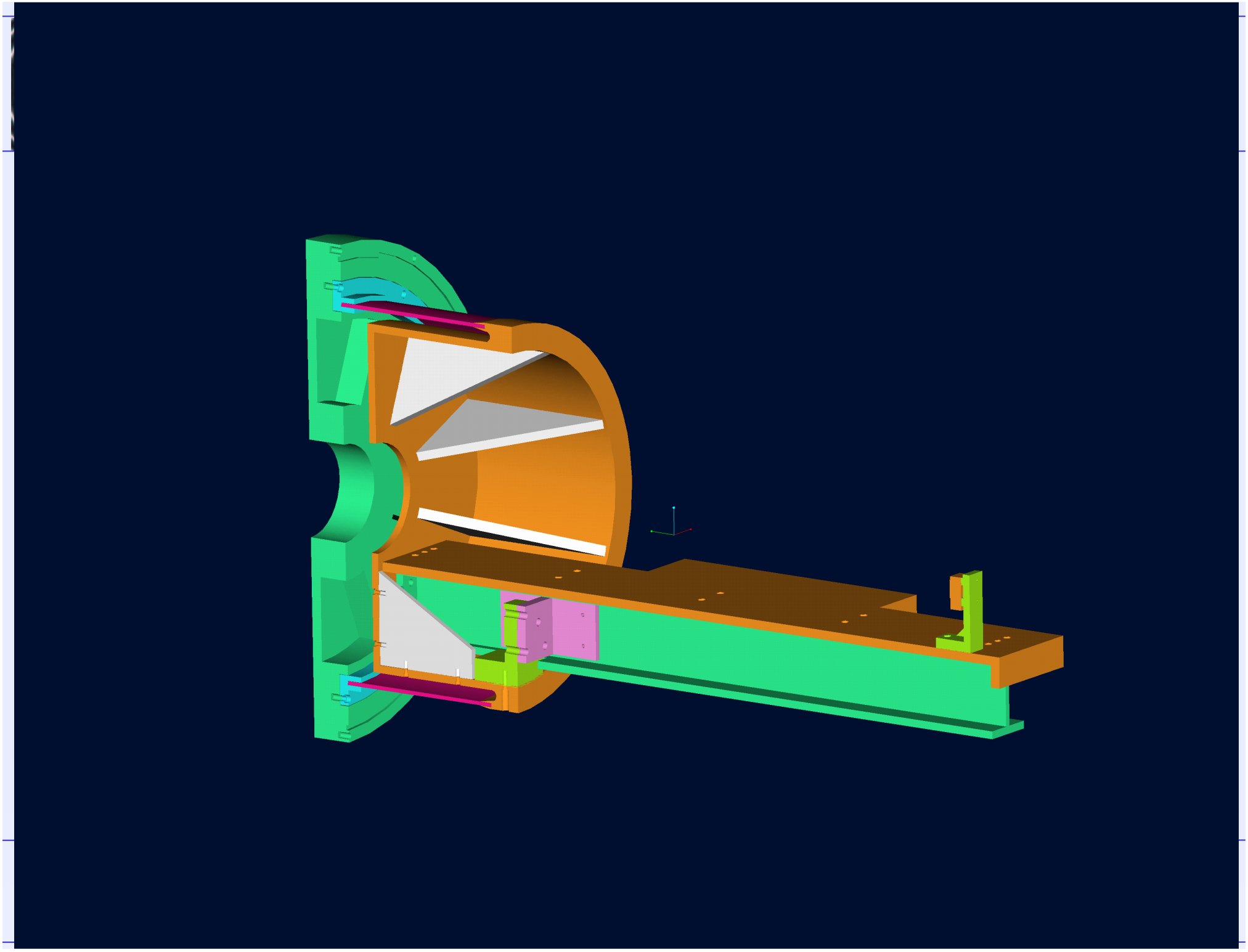
NIC-FPS 1-Year Review











CASA Facilities and Equipment

- NIC-FPS assembly and test to be done at CASA's Astrophysical Research Lab
- A NIC-FPS instrument area has been allocated for the duration of the program

Electronics bench and test area

Class 10,000 clean tent (10'x12') with I&T table

NIC-FPS 1-Year Review

Science Capabilities:

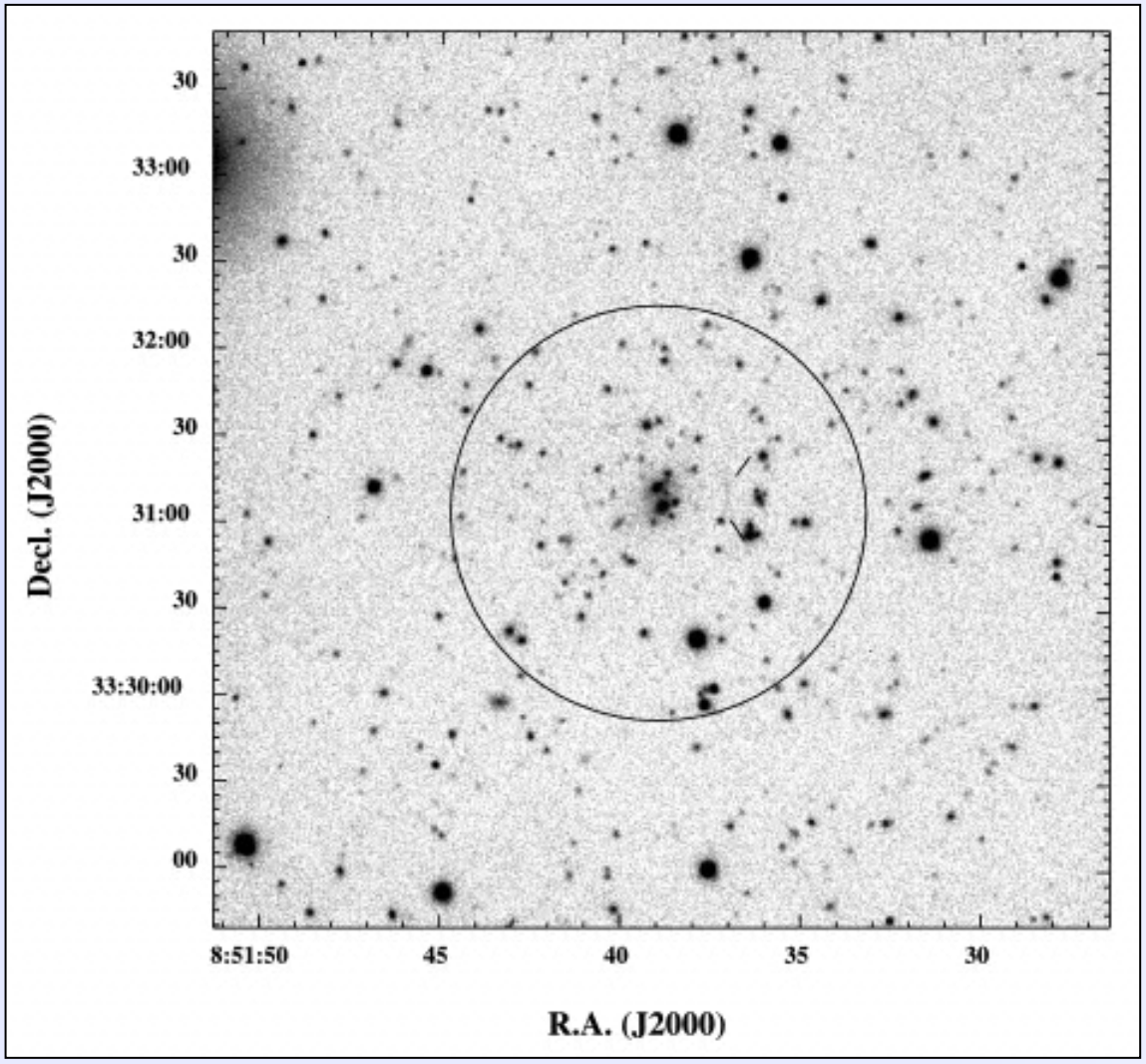
- zJHK imaging (e.g., SDSS follow-up)
- narrow-band imaging
- Fabry-Perot kinematics

Galaxy Clusters

- Cluster evolution; stellar pops
- Cluster core radius of 1 h^{-1} Mpc corresponds to ~4 arcmin at z = 0.5

Example:

- X-ray selected galaxy cluster from Lewis et al. (2002)
- KPNO 2.1 m 1800s Gunn r exposure
- T1KA with 0.305”/pix
- Cluster at redshift z ~ 0.45
- Circle is 0.5 h^{-1} Mpc radius centered on BCG
- Note arcuate lensed galaxies

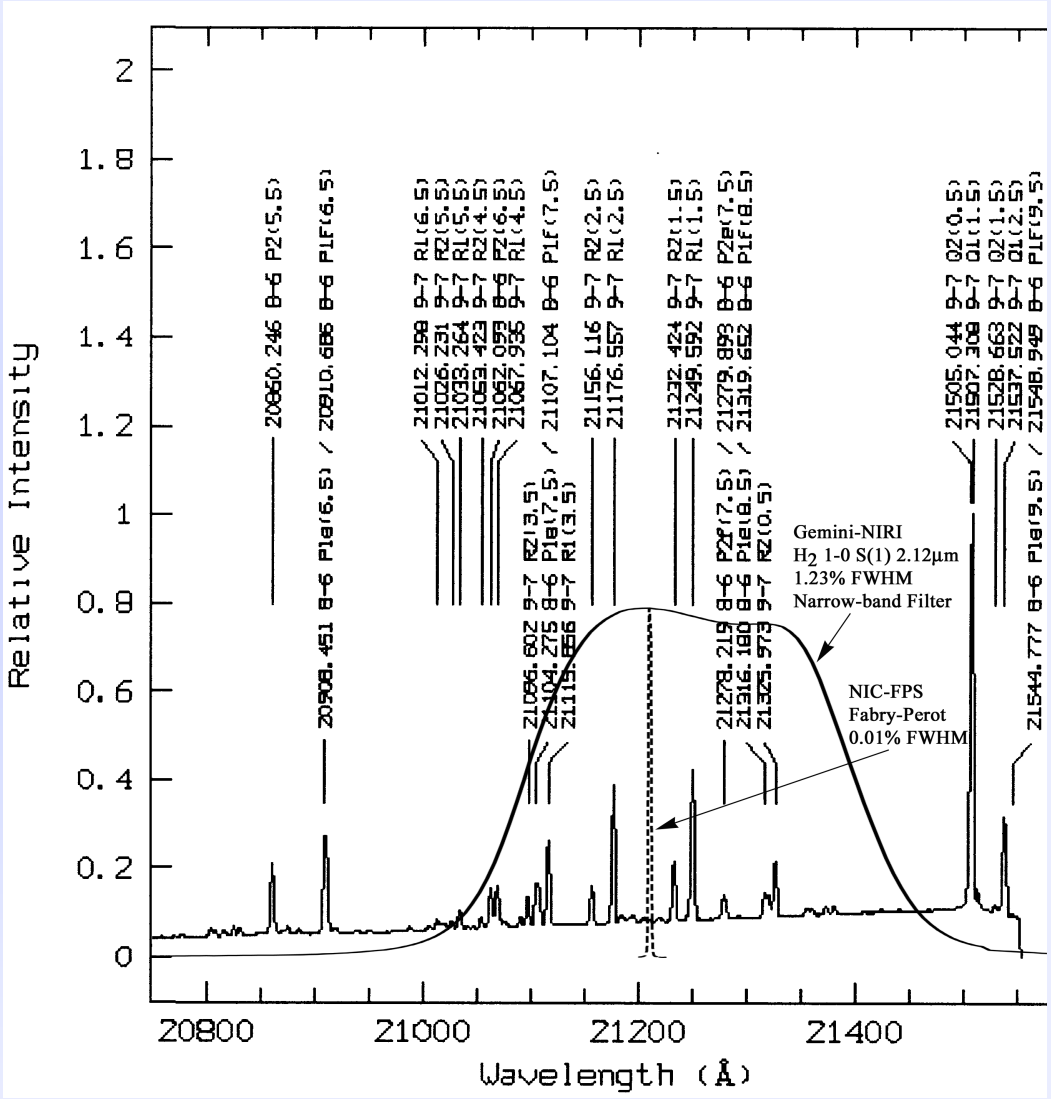


NIC-FPS 1-Year Review

• The cryogenic Fabry-Perot etalon offers R~10,000 full-field imaging of selected diagnostic features (e.g., H_2, [Fe II], Br-γ, [Si VI], etc.) with sky background over 100 times lower than conventional ~1% narrowband imaging.

• Sky backgrounds between OH airglow lines will be in the 1-10 photons/s/pixel range, depending on wavelength.

• Signal-to-noise calculation shows that for a faint (10^{-17} ergs/cm^2/s) 1 arcsec uniform monochromatic source at 2.12µm, ARC+NIC-FPS will achieve S/N ~ 3.6 in 1000 s while Gemini+NIRI (f/6 mode) achieves S/N ~ 0.65!!

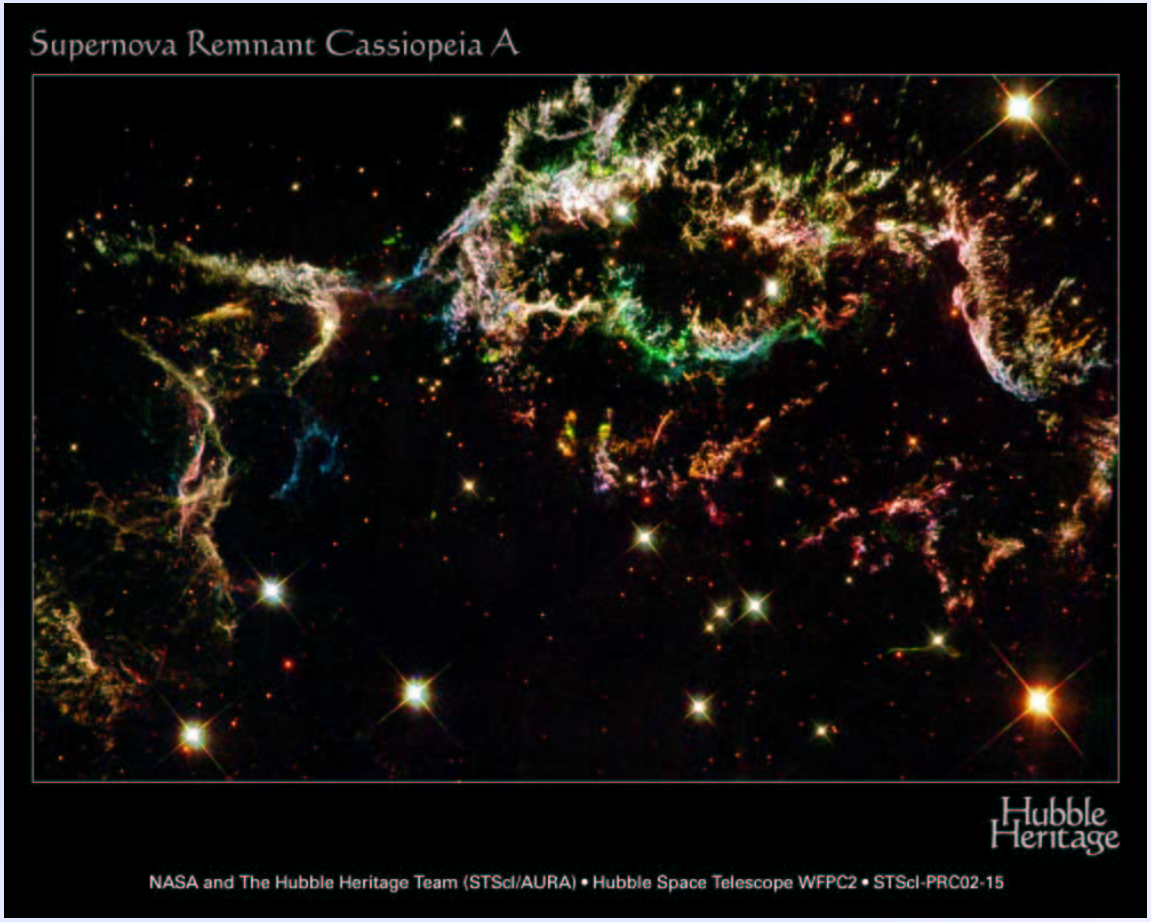


Galactic Nebulae

- H II regions, protostellar jets/outflows,
PNe, LBVs, SNRs, nova shells, etc.
- Morphologies, kinematics; radiative shocks, photoionized gas, dust
- 6 pc subtends ~4 arcmin at D = 5 kpc

Example:

- Cas A supernova remnant
- SN ~1680, D ~ 3.4 kpc
- Main shell diameter ~4 arcmin
- High-extinction sight-line
- Probe Fe distribution and kinematics plus other tracers of nucleosynthesis
- Forward/reverse shock physics

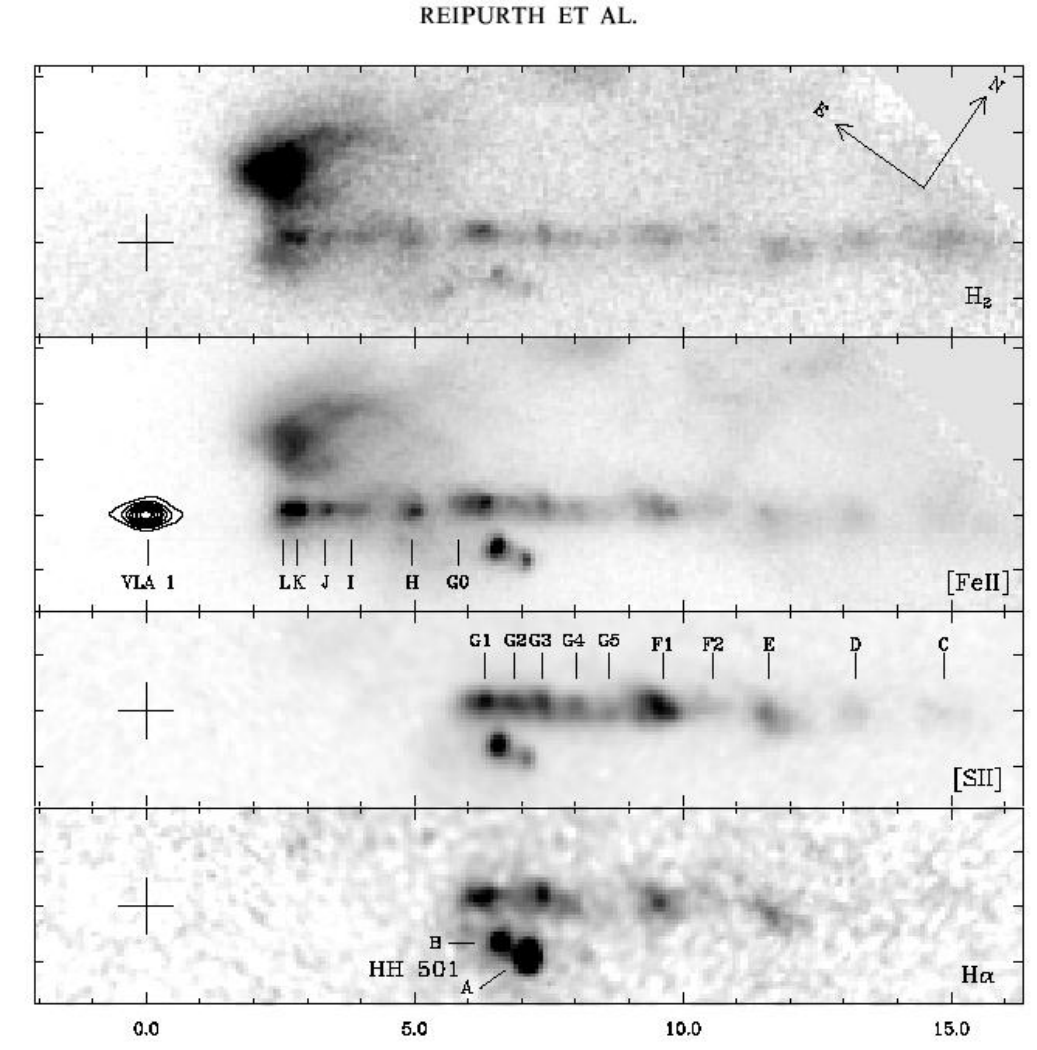


Fesen et al. (2001,2002)

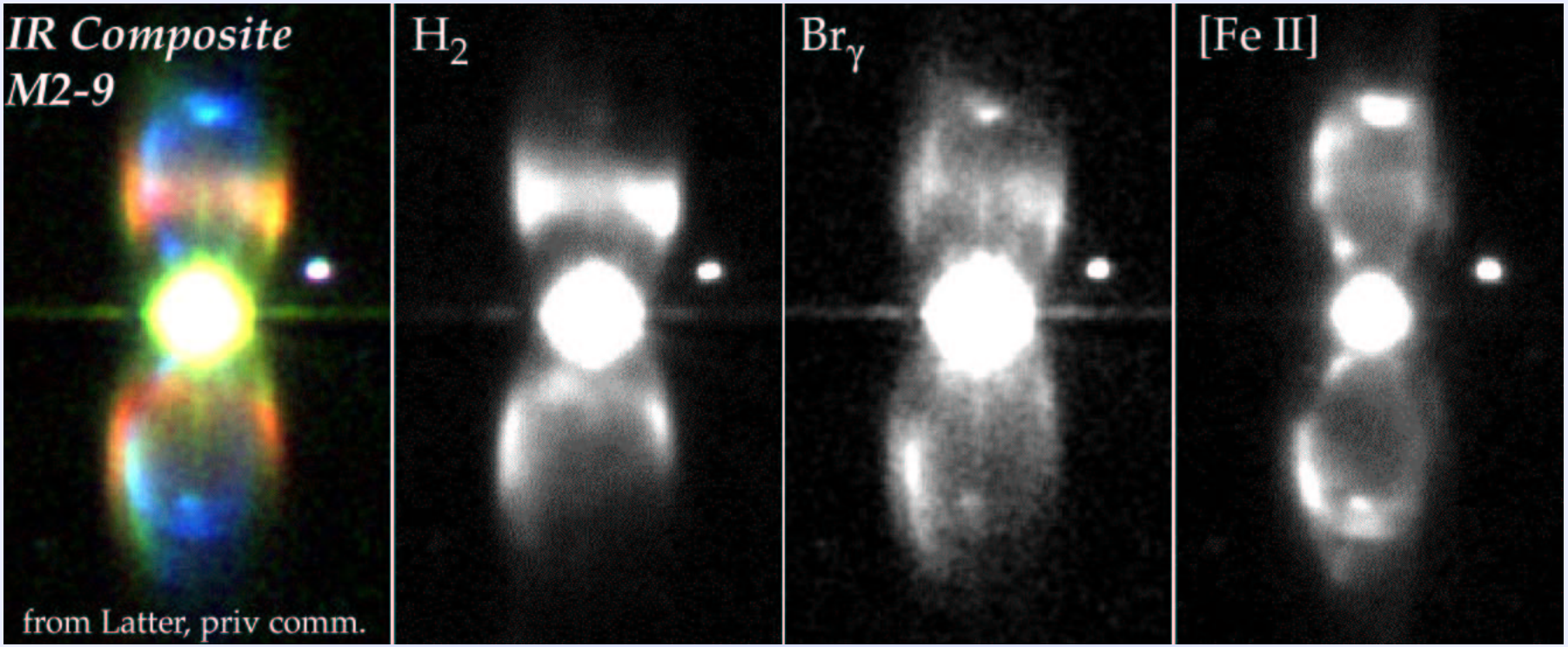
NIC-FPS 1-Year Review

Example: The value of the near-IR

- HH 1 protostellar jet can be traced much closer to the source in [Fe II]λ1.64 microns than in optical lines such as Hα or [S II].
- H_2 traces interactions with ambient molecular cloud material (or may even be present in high-velocity jet).



NIC-FPS 1-Year Review



Planetary nebulae, proto-planetary nebulae, symbiotic stars, etc.

Filters

- Three 7-slot filter wheels provide 17 slots for science filters
- Nominal filter size 65 mm diam. × 5 mm thick, 5° tilt
- Filters in-hand

	Central	1/2-power cut-on	1/2-power cut-off	Ave %T	OoB reject
– MKO J	1.25	1.178	1.330	89	<1e-5
– MKO H	1.63	1.496	1.784	93	<5e-6
– MKO K_S	2.15	1.991	2.309	94	~1e-5

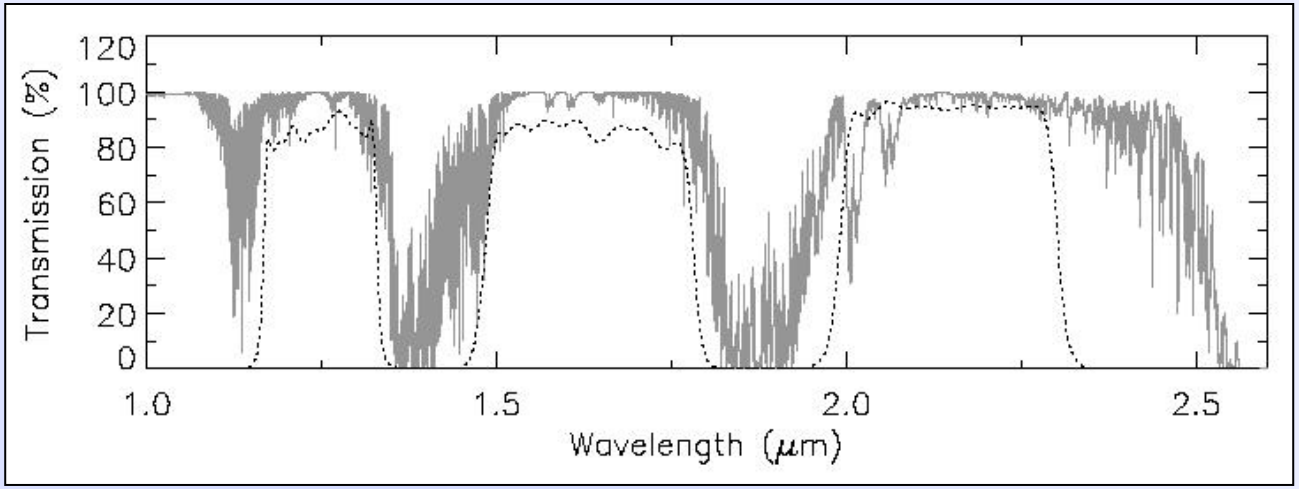
- Hi-pri Filters

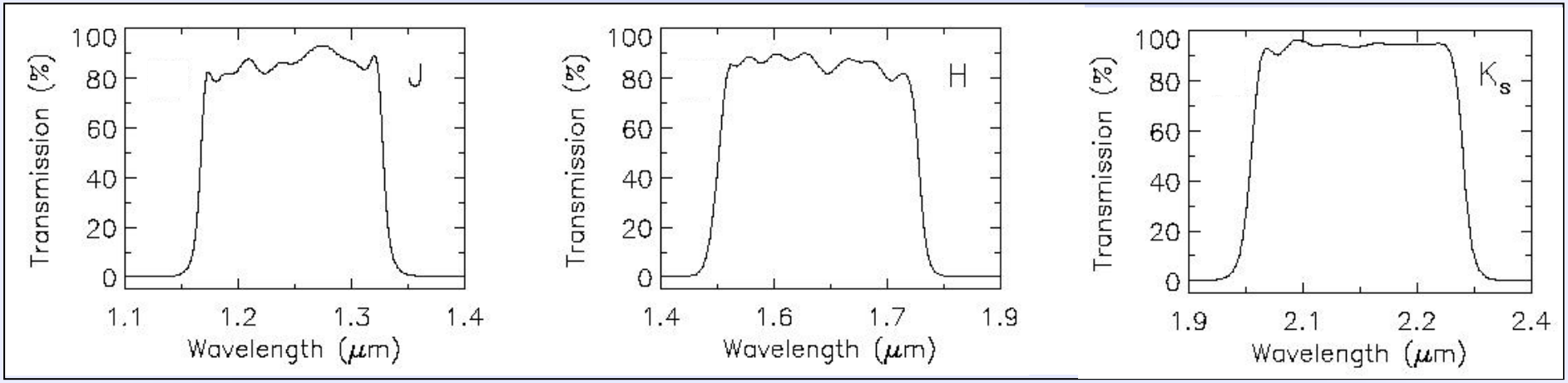
	Central	Cut-on	Cut-off
– [Fe II]	1.644	1.639	1.649
– H_2 1-0 S(1)	2.122	2.117	2.127
– z	1.01	0.90	1.12
– [Fe II] red/cont.	1.652	1.647	1.657
– H_2 red/cont.	2.13	2.125	2.135

NIC-FPS 1-Year Review

- MKO Broad-band Filter Set

- Compatible photometric system
- 65 mm diameter also used at CTIO-ISPI and elsewhere



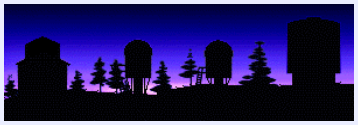


NIC-FPS 1-Year Review

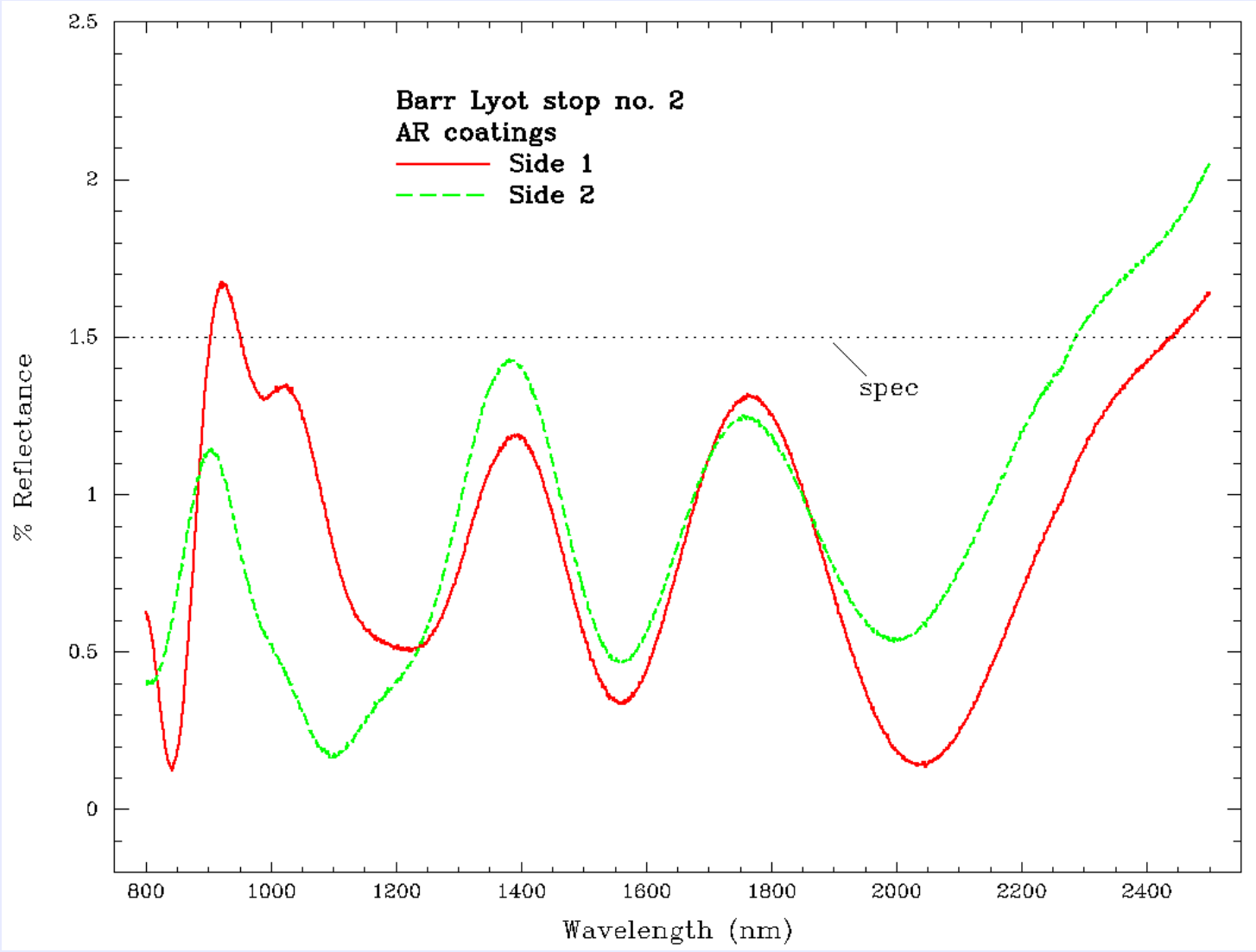
ARC to furnish z-band filter(s) from CFI funds.

Proposed ATI Filter Set. Narrow-band/Order-sorting Filter List

Species	Central λ (μm)	Configuration	Notes
H_2	2.12126	v=1-0 S(1)	Shocks/Fluorescence
H_2-cont	2.12975	v=1-0 S(1)	Redshifted
H_2	2.2471	v=2-1 S(1)	Shocks/ Fluorescence
[Fe II]	1.25668	$^6D_{9/2} - {}^4D_{7/2}$	Extinction
[Fe II]	1.59947	$^4F_{7/2} - {}^4D_{3/2}$	Electron Density
[Fe II]	1.64355	$^4F_{9/2} - {}^4D_{7/2}$	Cooling Gas
[Fe II]-cont	1.65012	$^4F_{9/2} - {}^4D_{7/2}$	Redshifted
Br γ	2.1655	n=7 → 4	Photoionization, Shocks
Br γ-cont	2.1742	n=7 → 4	Redshifted
[Si VI]	1.965	$^2P_{3/2} - {}^2P_{2/2}$	Hot Gas
[Si VI]-cont	1.973	$^2P_{3/2} - {}^2P_{2/2}$	Redshifted
Y-band	1.03	–	[S II]1.03μm, He I 1.08μm, z > 7 QSOs, BDs

NIC-FPS 1-Year Review



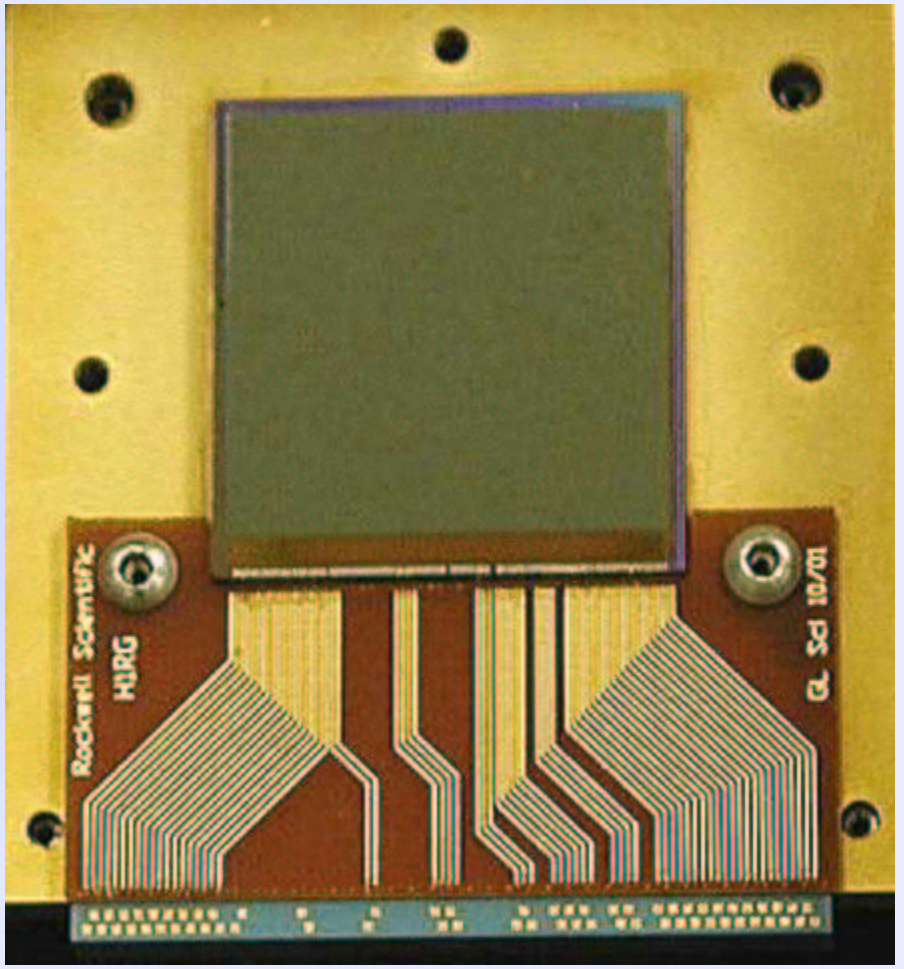
NIC-FPS 1-Year Review

Detector:

- Rockwell/Hawaii-1RG MBE 1024×1024 HgCdTe 0.85-2.5µm

  - Several enhancements over Hawaii-1, such as reference pixels and selectable postage-stamp readout

  - Rockwell in-house testing indicates excellent QE, read noise, and dark current performance



NIC-FPS 1-Year Review

NSF ATI proposal submitted 9/2/02 (reviewed April 2003):

- Highly leveraged proposal for materials that enable our *unique* medium-resolution cryogenic F-P mode
  - New CS-100 etalon controller needed to increase performance and establish team ownership (current CS-100 borrowed from UH)
  - Narrowband filters with widths matched to etalon FSR ($\Delta\lambda \sim 0.4\%$)
- Team members from CU, Rice, APO, UWash, UNC
- Aside from CS-100, purchasing filters via NSF grant builds margin in instrument budget
- Proposed 2-year grant, predominantly for equipment purchases
  - Total request $348k
  - Filters ($160k), CS-100 ($57k), support for FH and SB
  - Barr quote for narrowband filters is ~$13k apiece ([Fe II], H_2, Br γ, …)