THE NGST INTEGRATED SCIENCE INSTRUMENT MODULE

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47.6"

Overview

We display portions of the baseline design concept for the NGST Integrated Science Instrument Module (ISIM). This ISIM design is under ongoing development for integration with the "Yardstick" and other NGST 8 m architectures that are intended for packaging in an EELV or Ariane 5 meter class fairing. The goals of this activity are to: [1] demonstrate mission science feasibility, [2] assess ISIM engineering and I&T feasibility, [3] assess ISIM cost feasibility, [4] identify ISIM technology challenge areas, [5] identify ISIM/NGST interface constraints, and [6] enable smart customer procurement of the ISIM.

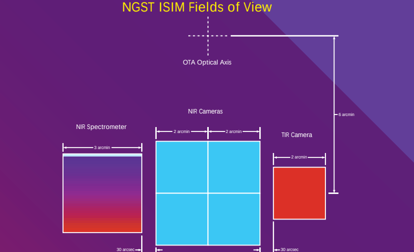
In this poster, we display a snap shot of work in progress including: optical design, opto-mechanical layout, thermal modeling, focal plane array design, detector electronics, and mechanism electronics design. Ongoing progress can be monitored via the ISIM team web site: http://www701.gsfc.nasa.gov/isim/isim.htm

ISIM Baseline Science Instruments

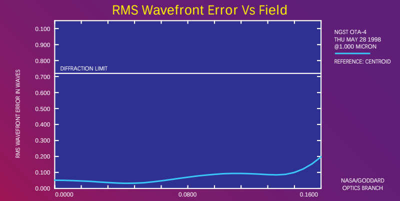
Instrument	Wavelength (µm)	Bandwidth	FPA	Pixel Pitch (µm)	Plate Scale (10^{-3} arc-sec)	Aperture Control (arc-min)
Near-IR Camera (1 of 4[1])	0.6 – 5.3	R = 2, 5 fixed filters, R = 50 - 200 tunable filters	4096 x 4096	27	29	quad-beam divider: four 2 x 2 fields chronograph mask[2]
Near-IR Spectrometer	0.6 – 5.3	R = 300, 3000 gratings	4096 x 4096	27	100	reflective slit mask: 2048 x 2048 micro-mirror array, 100µm pixels
Mid-IR Camera/Spec	5 – 28	broad-band filters, grisms, cross-disperser	1024 x 1024	27	230	slit selection + 2 x 2 camera

1. A quad-beam divider (pyramid mirror) apportions a 4 x 4 arc-min field of view over 4 identical cameras.
2. Holes in pyramid mirror facets used to form simple chronograph.

NGST ISIM Fields of View



RMS Wavefront Error Vs Field

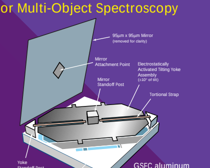


The ISIM instruments are located in an off-axis position. This configuration yields excellent image quality.

MEMS Sensor Optics

GSFC Cryogenic Micro-Mirror Arrays for Multi-Object Spectroscopy

- 30 K operating temperature
- 100 micron pixel pitch
- aluminum surface micro-machining
- low voltage electrostatic actuation
- scalability goal: 2048 x 2048
- first 3 x 3 pixel unit cell demonstrator during Dec 98



Mechanical model for GSFC micro-mirror torsion hinge

The moment needed to produce a given torsion hinge displacement is:

$$T := \frac{K \cdot \theta \cdot G}{l}$$

where θ is the twist angle, G is the modulus of rigidity of the material, l is the length of the torsion hinge, and K is the stiffness factor for the rectangular torsion bar of width 2x and thickness 2y:

$$K := x \cdot y^3 \left[\frac{16}{3} - 3.36 \cdot \frac{y}{x} \left(1 - \frac{y^4}{12 x^4} \right) \right]$$

If the moment is produced by a parallel plate capacitor of area A and gap d, then the force is:

$$F := \frac{\varepsilon \cdot V^2 \cdot A}{2 \cdot d^2}$$

Where ε is the permittivity of free space, and V is the bias voltage.

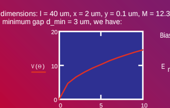
If the capacitor center of effort is located a distance M from the axis of the torsion bar, then the moment T = MF so that:

$$\frac{\varepsilon \cdot V^2 \cdot A}{2 \cdot d^2} = \frac{K \cdot \theta \cdot G}{l \cdot M}$$

Solving for V and taking into account that the mirror is supported by two identical torsion bars, we have that:

$$V(\theta) := \frac{1}{(\varepsilon \cdot A)} \cdot d_n \cdot \sqrt{2} \cdot \sqrt{\left[\varepsilon \cdot A \cdot K \cdot \theta \cdot \frac{G}{(l \cdot M)} \right] \cdot \frac{2\pi}{360}}$$

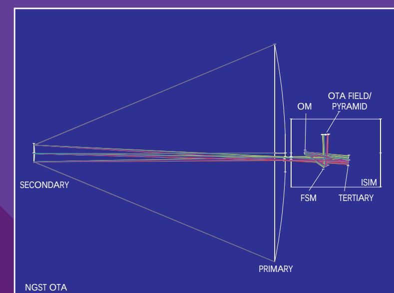
For dimensions: l = 40 um, x = 2 um, y = 0.1 um, M = 12.3 um, average gap d_n = 4.5 um and minimum gap d_min = 3 um, we have:



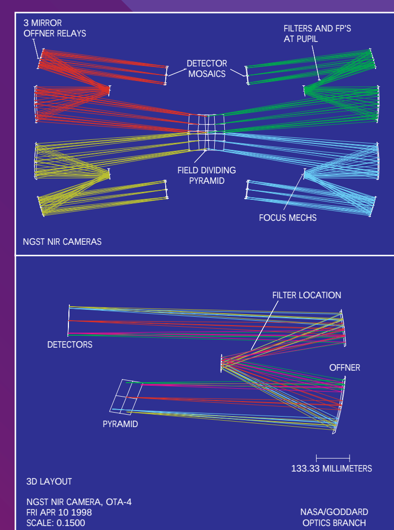
Bias for Θ=10 deg: $V(10) = 14.589 \cdot volt$

$$E_{max} = 4.863 \cdot 10^6 \cdot \frac{volt}{m}$$

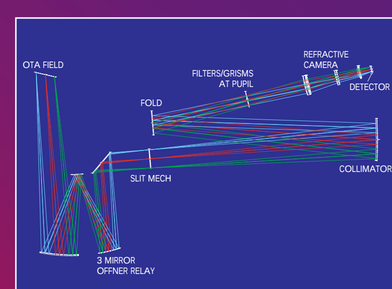
Optical Design



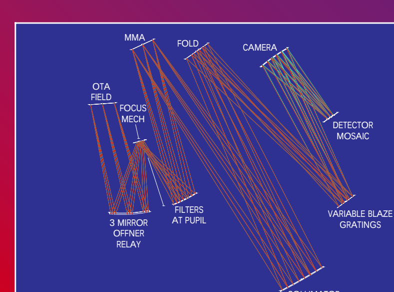
OTA and ISIM system optical schematic



Near-infrared wide field camera optical schematic

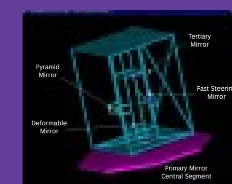


Mid-infrared camera/spectrometer optical schematic. An all reflective design is also under analysis.

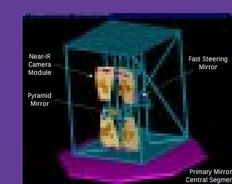


Near-infrared micro-mirror array spectrometer optical schematic.

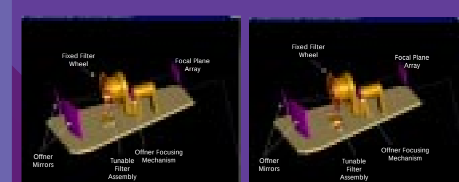
Opto Mechanical Layout



The OTA tertiary mirror, deformable and fast steering mirror assemblies, and pyramid mirror integrate into the ISIM in a modular fashion



The ISIM near-infrared wide field camera employs a pyramid beam divider to apportion a 16 square arc-min field of view over four identical camera modules. Each module utilizes a 4096 x 4096 focal plane array covering 4 square arc-min.



Each camera channel includes a focusing Offner relay, filter wheel, and retractable tunable filter.

Near-infrared camera module with solid model beams

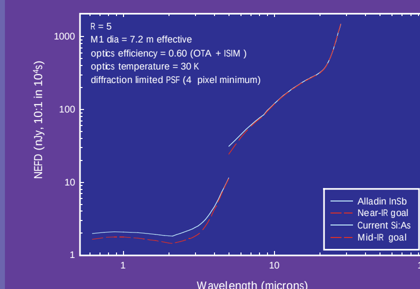
The mid-infrared camera/spectrometer module utilizes a 1024 x 1024 focal plane array and contains selectable slits, filters, and cross-dispersed grisms.

Mid-infrared camera/spectrometer module with solid model beams

The near-ir camera and mid-ir camera modules integrate into the ISIM in a modular fashion. Near-ir spectrometer not shown.

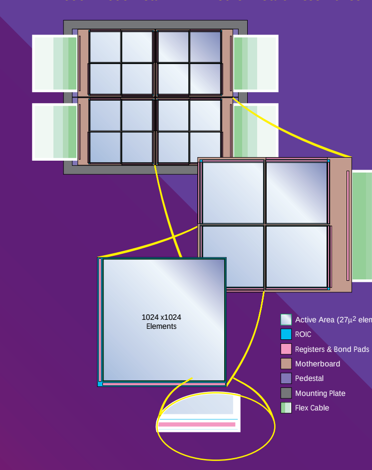
Focal Plane Arrays

Performance Exhibited By Current Detectors Is Near NGST Goals

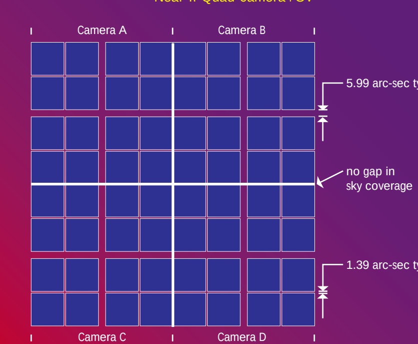


	QE	Read Noise (e) multiple read	Dark Current (e/s)	Operating Temp (K)
Alladin InSb	0.8	15	0.1	30
Near-IR goal	0.8	3	0.02	30
Current Si:As	0.5	8	10	6
Mid-IR goal	0.5	3	1	6

4096 x 4096 Near-Ir FPA Mother Board Assemblies

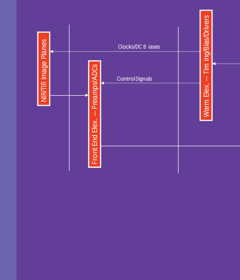


Near-Ir Quad-Camera FOV

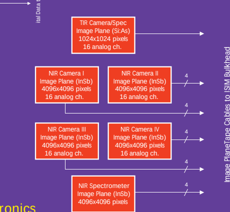


Electronics Design

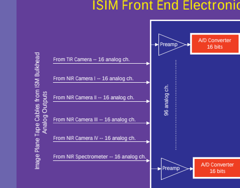
ISIM Detector Electronics Overview



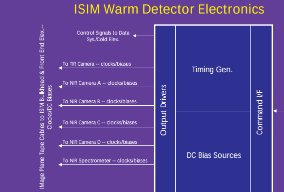
ISIM Focal Plane Arrays



ISIM Front End Electronics



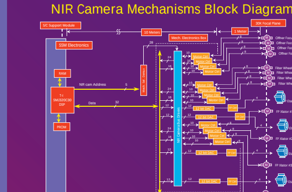
ISIM Warm Detector Electronics



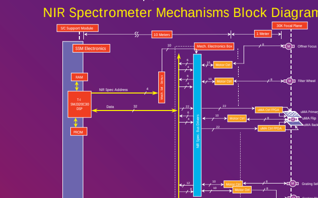
Functional Blocks

- Focal Plane Arrays
  - near-ir, mid-ir hybridized detectors/ROICs
  - driven by warm electronics
  - analog outputs to front end electronics
- Front End Electronics
  - preamplifiers, analog-to-digital converters, digital multiplexers
  - driven by FPAs and warm electronics
  - digital outputs to ISIM data system
- Warm Electronics
  - command interface, timing generators, DC bias sources and drivers
  - driven by ISIM computer via command interface
  - control outputs to FPA and front end electronics

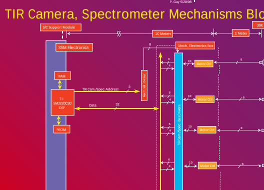
NIR Camera Mechanisms Block Diagram



NIR Spectrometer Mechanisms Block Diagram

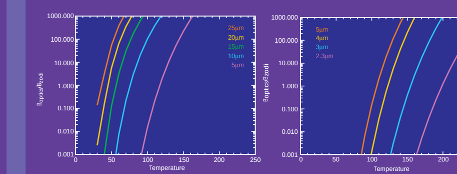


TIR Camera, Spectrometer Mechanisms Block Diagram



Thermal Design

ISIM Cooling Requirements



ISIM optical bench temperature as a function of thermal background power relative to the Zodical light at various wavelengths.

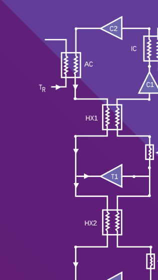
Creare Miniature Turbo-brayton Cooler

Key Features

- Vibration Free
- Robust gas bearings ensure long life
- Low mass, highly efficient, easy to integrate
- Ideal for use with radiatively cooled heat sink

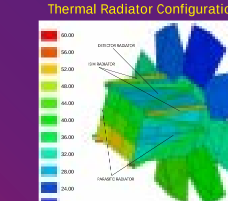
Status

- 5 watt, 65 Kelvin engineering model on life test
  - 215 watt input power too large for NASA applications
- 35 K/60 K cooler under development
  - 125 watt input power with 300 K heat sink
- 4-10 K cooler under development
  - Less than 60 watt input power with 220 K heat sink
  - Available for flight by 2000

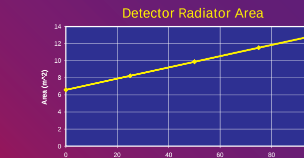
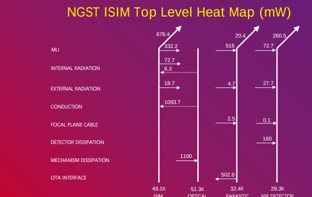
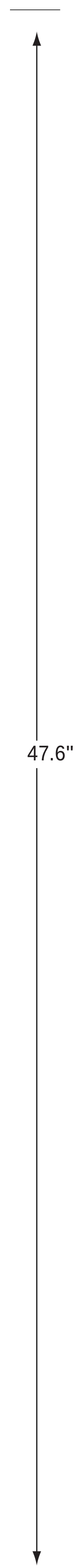


C - compressor
AC - aftercooler
IC - intercooler
HX - recuperator
T_R - rejection temperature
Q_P - primary load
T_P - primary temperature
Q_S - secondary load
T_S - secondary temperature
T1 - warm turbine
T2 - cold turbine

Thermal Radiator Configuration



Detector Radiator Area



NGST ISIM Top Level Heat Map (mW)