Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

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January 29, 2010

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Systems Presentation

January 29, 2010

GEO-CAPE Mission Overview

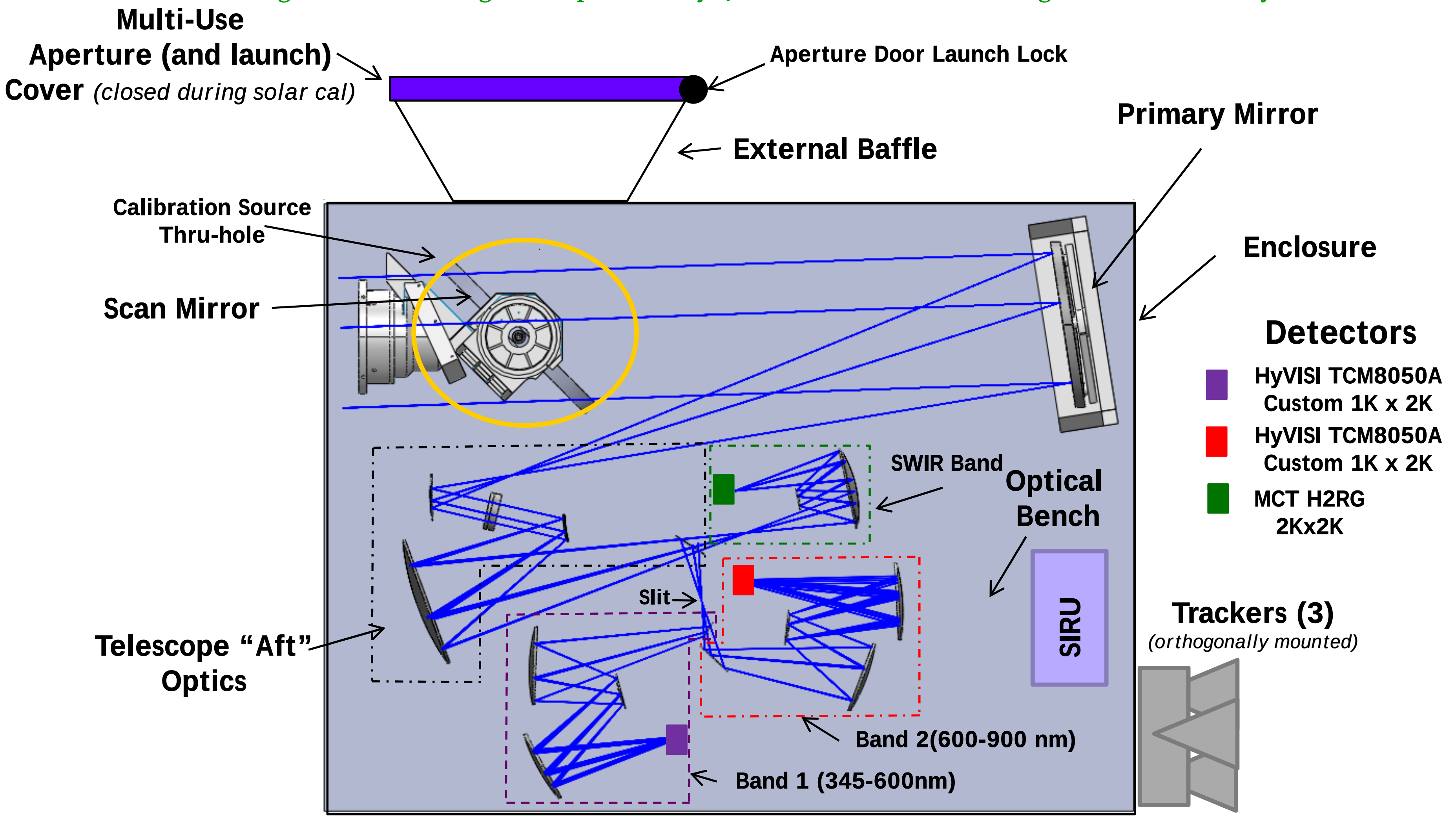
- Mission Configuration A:
  - GEO-CEDI (Coastal Ecosystem Dynamics Imager)
  - GEO-MAC
  - CISR (Compact Imaging Spectro-Radiometer)
- Mission Configuration B:
  - GEO-CEDI only
- Mission Class: B
- Launch Date: 2017
- Launch Vehicle: Undetermined
- Orbit: Geostationary 95W Longitude
- Science FOR: 50N Lat to 45S Lat / ~160W Long to ~30W Long

Primary Science Requirements

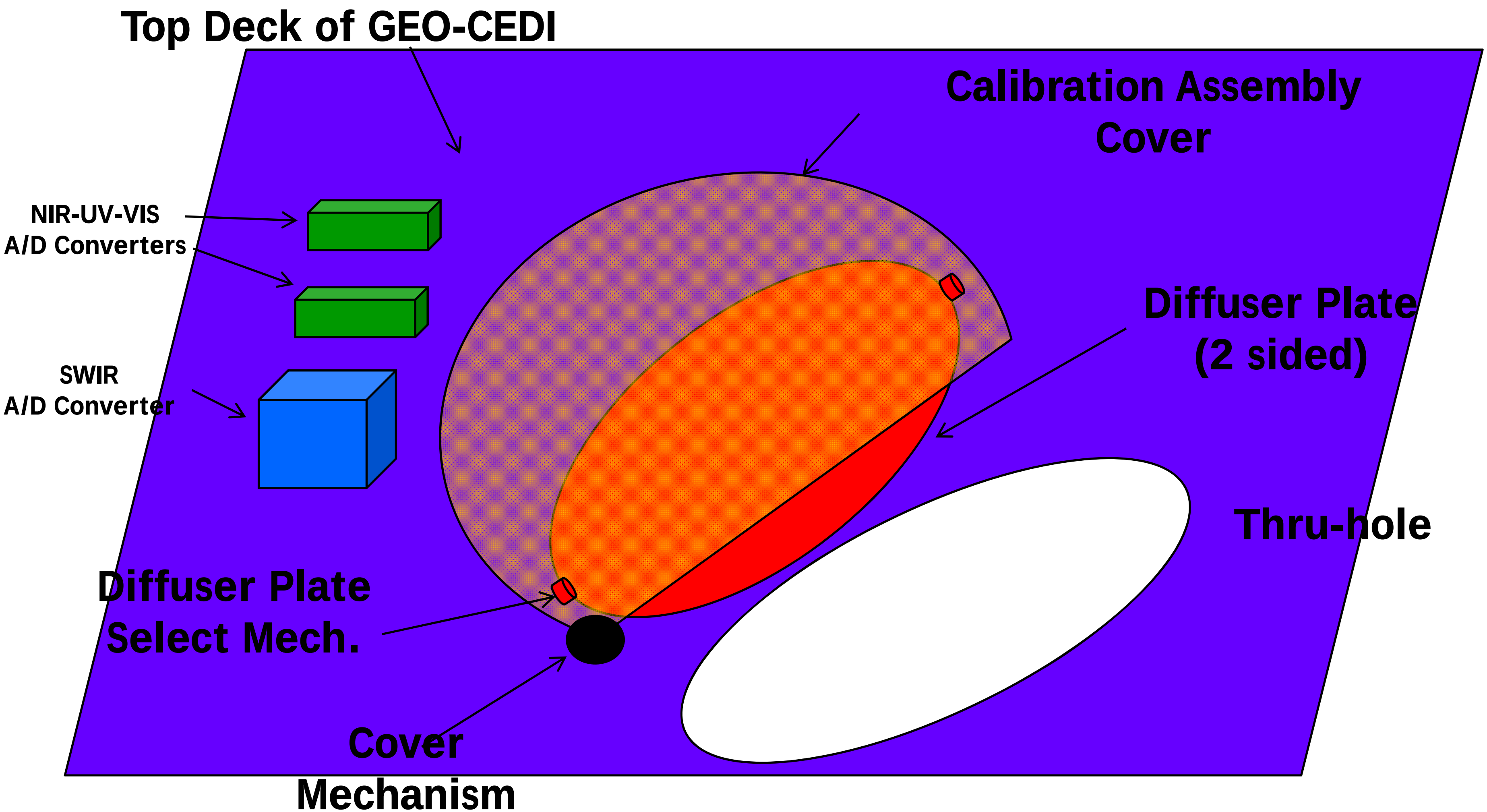
- **Scan of U.S. Coastal Water 3x day during daylight hours**
  - Other Regions of Interest from 50 N Lat to 45 S Lat
- **Spatial resolution**
  - 375m x 375m per pix
    - Goal of 250m x 250 m per pix
- **Coverage area**
  - 300 km
    - Goal of 500 km
- **Spectral Range**
  - Hyperspectral UV-VIS-NIR; Multispectral SWIR
  - 345-900 nm; SWIR bands: 1245, 1640 & 2135 nm
    - Goal of 340-1100 nm; SWIR bands: 1245, 1640 & 2135 nm
- **Calibration**
  - Onboard Lunar and Solar Calibration
  - No internal wavelength sources
  - Each camera head includes several LEDs for flood lamp calibration

Coastal Ecosystem Dynamics Imager (CEDI) Block Diagram

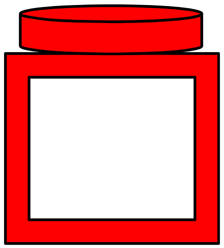
Integrated Design Capability / Instrument Design Laboratory



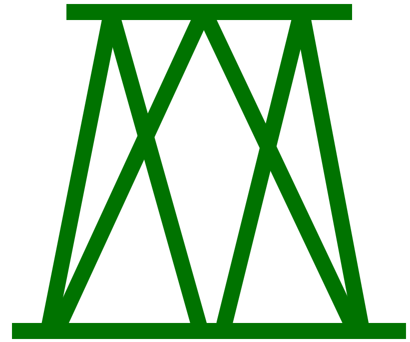
Coastal Ecosystem Dynamics Imager (CEDI) Block Diagram - Part 2



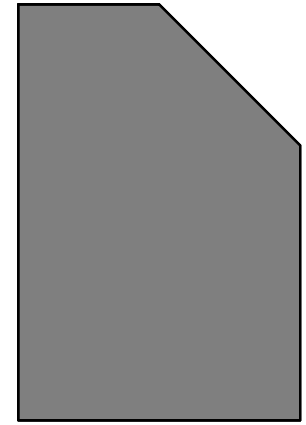
Coastal Ecosystem Dynamics Imager
(Other Assemblies For CEDI "Only" Configuration)



Calibration Assembly (on instrument enclosure)



Stewart Platform

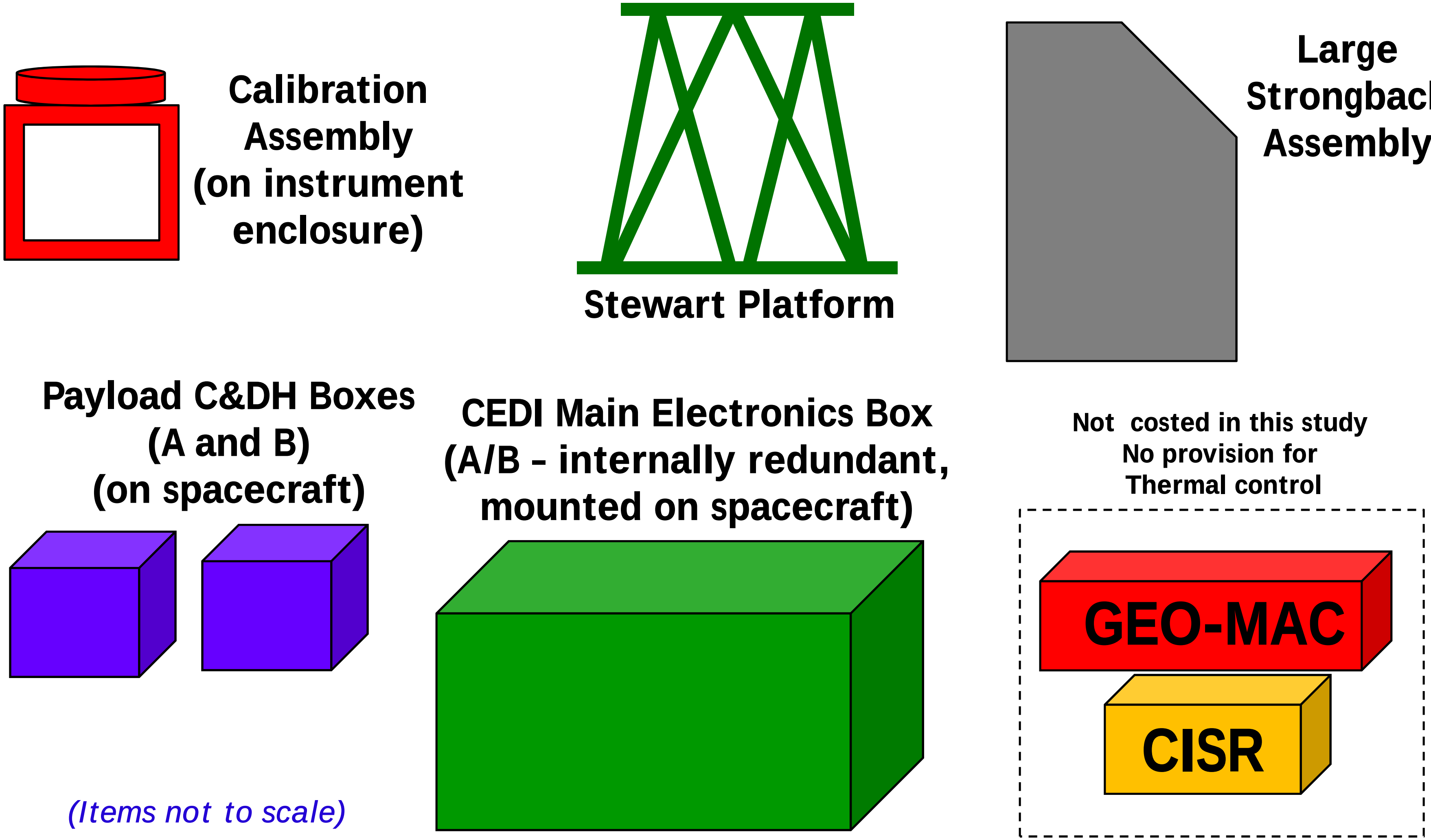


Small Strongback Assembly

CEDI Main Electronics Box (A/B - internally redundant, mounted on spacecraft)

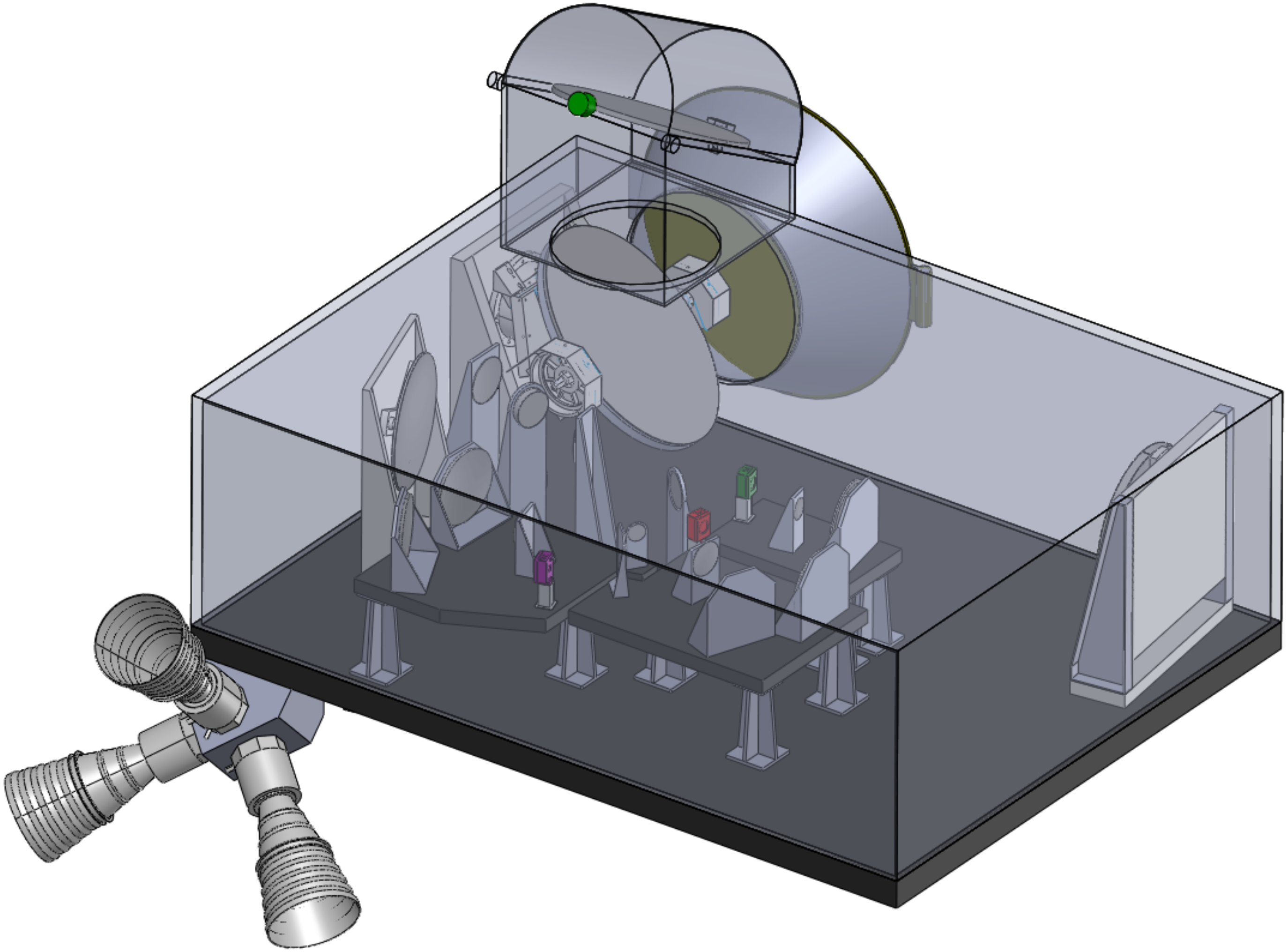
(Items not to scale)

Coastal Ecosystem Dynamics Imager
(Other Assemblies For GEO CAPE "Suite" Configuration)



(Items not to scale)

GEO-CAPE Mechanical Configuration



Total Instrument Rack-up

(no contingency included)

GEO-CAPE (CEDI) Instrument Assemblies	Total Mass	Total Power	Total Data Rate
CEDI Aperture Cover Mechanism Scan Mirror Assembly Telescope Assembly Slit Band 1 (340-600nm) Assembly Band 2 (600-900nm) Assembly SWIR Assembly Calibration Assembly Enclosure External Baffle Optical Bench Star Trackers (3) SIRU CEDI Main Electronics Box Strongback (small) Stewart Platform Additional GEO-CAPE Suite Assemblies Payload C&DH CISR GEO-MAC Thermal Subsystem	**CEDI Only** **621.4 kg** Details on page 15, 16 **GEO-CAPE Suite** **852.6 kg** Details on page 15	**CEDI Only** **392 W** Details on page 19	**CEDI Only** **88.4 Mbps** Details on page 18

Design Discussions / Design Evolution

- **Detectors**
  - Essentially no change in detector performance specs from last study
  - Adopting MCT H2RG 2Kx2K simply because that form factor is "off-the-shelf"
  - Assuming UV-VIS-NIR detector is custom 1Kx2K form factor of the TCM8050A
  - Assuming read out rates of 2.62 MHz and 1.25 MHz respectively

- **Optics**
  - Design developed assuming 375m spatial resolution per pixel which allowed implementation of a 0.5 m Primary and shrinking of optical the layout reducing the volume of the MDI (now CEDI) instrument
    - Was 15.3 m^3 (including calibration assembly)
    - Is 7.5 m^3 (including calibration assembly)
  - UV-VIS-NIR split into 2 bands
    - 345 nm to 600 nm
    - 600 nm to 900 nm (up to 1100 nm achievable optically but the QE of the detector is very low after 1 micron)
    - Optics presentation will provide commentary on implications of achieving a 300m spatial resolution

Design Discussions / Design Evolution

- **Solar Calibration Assembly**
  - Previous study inserted calibration source into optics train beyond the scan mirror and primary mirror and therefore was relatively small compared to current implementation
  - Current calibration system incorporates a reflective diffuser plate (spectralon) in a "pop-up" configuration that illuminates the entire scan mirror and primary mirror
    - "Lazy-Susan" approach abandoned in favor of smaller "pop-up" configuration
  - Note: The spectralon diffuser plate is larger than 15 cm and thus requires a trade study as precision hardware of that size has little heritage.

- **GEO-CEDI Mechanisms**
  - Reusable Aperture Door / launch lock
  - Scan Mirror (2DOF)/ launch lock(2)
  - Calibration Assembly Cover / launch lock
  - Diffuser Plate Select Mechanism / launch lock

- **GEO-CAPE Suite Mechanical**
  - Mounting is similar to GEO-MDI configuration
  - Strongback size has been scaled back in keeping with reduction in size of CEDI; updated mass to be provided

Design Discussions / Design Evolution

- **ACS**
  - Increased the number of Star Trackers from 2 to 3
    - Note: We are assuming the same Star Trackers from GEO-MDI study (BALL CT-602)
    - Other smaller and cheaper options are available (e.g. DTU micro-Astro Stellar Camera)
  - Provides redundancy and ability to maintain pointing requirements in the event of a Star Tracker Failure
  - Assuming a Stewart platform is required for GEO-CEDI standalone and GEO-CAPE Suite configurations
    - We did not reevaluate or resize the platform from the GEO MDI study
    - Passive, 6 DOF Stewart platform was recommended for the GEO-CEDI standalone configuration

- **Electronics**
  - Assuming internally redundant CEDI Main Electronics Box
  - Assuming redundant Payload C&DH boxes (GEO-CAPE Suite configuration only)

Design Discussions / Design Evolution

- **GEO-CEDI Solo Mechanical**
  - Current design would also require a strongback (assuming top mounting to spacecraft)
  - Orientation of slit must be maintained w/r/t earth
  - Rotation of instrument would necessitate reorientation of optics

- **Instrument Processing Capability**
  - Driven by ACS System / Scan Mirror control loop interface
    - 100 Hz scan mirror control is the maximum capacity of the 133MHz BAE Rad750, given other nominal 1Hz processing responsibilities
  - Assuming 750RAD Processor as current "line-in-the-sand"
    - Expect new technology available before instrument design/development starts

SCS-2 SYSTEMS PRESENTATION PART II

CEDI
Mass Summary by Subsystem

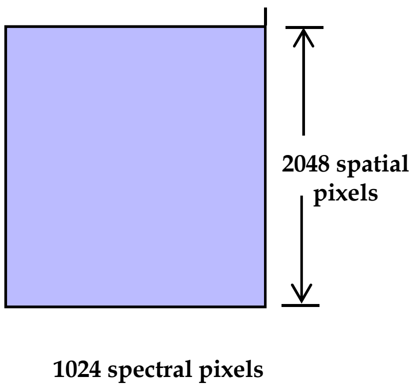
IDL provides cost estimates based on Current Best Estimate (CBE) of mass; mass margin and contingency is accounted for in the Integrated Design Center's Mission Design Lab (MDL), otherwise the customer must account for this additional mass

Subsystem*	CEDI Mass CBE (kg)	% of Total Mass	MDI Mass CBE (kg)	% of Total Mass
Optical	36.1	5.8%	81.8	8.7%
Detector	0.2	0.0%	0.141	0.0%
Mechanism	38.5	6.2%	74.6	7.9%
Mechanical	378	60.8%	598.1	63.3%
Electrical	15.4	2.5%	10.0	2.6%
Harness	9.9	1.6%		0.0%
ACS	22.5	3.6%	25.2	2.7%
Thermal	71.6	11.5%	140.9	14.9%
Contamination	10	1.6%	0.0	0.0%
5% misc Hardware	39.2	6.3%	0.0	0.0%
Total (+ 5% hardware and no margin):	621.4	100%	930.7	100%

*this listing does not include all subassemblies, please refer to the final mass model (MEL) for a full summary

UV/VIS & VIS/NIR Detector Assumptions & Data Rate

Array (1Kx2K)pix



Detector Assumptions

- 2 (1Kx2K) Custom Detector Arrays, 8 outputs each (ie. 0.25Mpix each output)

- Readout [1K (spectral) x 2K (spatial)] pix.

- Frame transfer readout capability.

Readout Assumptions

- 4 frames @ 200mSec integration period

-14 bits/pix resolution

Data Rate Calculations

⇒ ADC Sample rate = 0.25Mpix/0.2sec = 1.25Mpix/sec (ie. 1.25MHz sample rate)

⇒ Readout Rate ~ (1.25Mpix/sec)x14bits/pix ~ 17.5Mbps each output

⇒ 140Mbps total for all 8 outputs

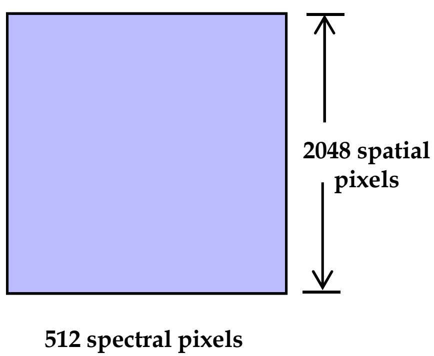
Co-Add 4 frames

⇒ Data Rate ~ 140Mbps/4 ~ 35Mpbs each detector

⇒70Mbps total for both detectors

SWIR Detector Assumptions & Data Rate

Array (512x2K)pix



Detector Assumptions

- 1 (2Kx2K) Detector Array, 32 outputs (ie. 0.125Mpix each output)
- Readout [512 (spectral) x 2K (spatial)] pix.
- Frame transfer readout capability.

Readout Assumptions

- 64 frames @ 12.5mSec integration period
- (64 x 512)pixels each of 32 outputs (ie. 0.0328Mpix each output)
- 14 bits/pix resolution

Data Rate Calculations

⇒ ADC Sample rate = 0.0328Mpix/0.0125sec = 2.62Mpix/sec (ie. 2.62MHz sample rate)

⇒ Readout Rate ~ (2.62Mpix/sec)x14bits/pix ~ 36.7Mbps each output

⇒ 1.17Gbps total for all 32 outputs

Co-Add 64frames

⇒Data Rate ~ 1.17Gbps/64 ~ 18.4Mpbs for downlink

⇒ CEDI Instrument Total: ~ (70+18.4)Mbps ~ 88.4Mbps

CEDI Main Electronics Box Summary

Circuit Boards (8"x6"), 0.5Kg each	QTY	Avg. PWR (Watts)	Mass (Kg)	Description	% Analog/ Digital
Instrument Processor Board	1A/1B	8.5	1.0	PowerPC750	5/90
Thermal Control	1A/1B	4.0	1.0	3 circuits each	70/25
Scan Motor Control (2DOF)	2A/2B	5.0	2.0		70/25
Aperture Motor Control	1A/1B	5.0	1.0		70/25
Cal. Assembly Motor Control	1A/1B	5.0	1.0	Output switched between 2 motors	70/25
Housekeeping	1A/1B	5.0	1.0	Temp, Voltages, Currents	70/25
* Power Converter (Assume 75% efficiency)	1A/1B	23.3	1.0		90/5
Backplane	1A/1B	-	1.4		0/0
Housing	1	-	2.9		
Total	**-**	**55.8**	**12.3**		

Box Estimate: (23 x 18 x 43)cm, ~ 55.8Watts, 12.3Kg (ie. 9.4Kg board total + 2.9Kg Housing)

Note: This box is internally redundant (ie. 8 prime boards with backplane plus 8 redundant cold standby boards)

GEO-CEDI Power Requirement Summary

Spacecraft Power Bus Requirement

Load	Avg. Power (Watts)
~~Payload C&DH Box~~	~~25.0~~
CEDI Main Electronics Box	55.8
Detectors, FET Drivers & Digitizer Boards (3)	21.0
Scan Mirror Motors (1 of 2 ON at a time)	13.0
Heaters (actively controlled)	3.0
Heaters (thermost controlled)	300.0
CEDI Only Instrument Total:	**392.0**

Note:

- Total does not include ACS components or Payload C&DH Box, which are powered by the Spacecraft
- Total does not include survival heater power (222 to 317W) to the CEDI instrument which is also powered directly by the spacecraft
- The CEDI detector heater control power (actively controlled) is shown here as 3W, and is estimated in the thermal model to be between 4.5W (orbit average) and 6.4W (peak)
- The CEDI operating heater power (thermostat controlled) is shown here as 300W, and is estimated in the thermal model to be between 250W (orbit average) and 375W (peak)
- The CEDI instrument will require the X-band downlink interface in the Payload C&DH box; this interface could be placed in either the CEDI MEB or the Spacecraft if the Payload C&DH box is not flown.

Changes to GEO MDI 2006 Configuration & Rationale
(1 of 3)

DESIGN CHANGES from GEO MDI to CEDI

- **Implemented customer's degraded spatial and spectral resolution requirements to realize a significant volume savings in the entire optical assembly, as well as the 3 channels**
- **Implemented a calibration housing that includes all optics in the lunar and solar calibration, and provides full aperture illumination from a frequent and an infrequent diffuser surface**
  - The previous diffuser housing did not illuminate the primary mirror and was injected downstream in the instrument to minimize volume
  - Eliminated the flip mirror in the GEO MDI design that initiated the calibration mode
- **Implemented a detector readout scheme that meets SNR goals and eliminates saturation in critical channels in the SWIR channel**
  - This increased the number of readout boards in the SWIR digitizer box, but they are identical, so there is an NRE savings
- **Considered the CEDI MEB and Payload C&DH electrical boxes in the thermal budget for survival heater power; previously these were not addressed as it was assumed they were mounted directly to the S/C**
- **Costed the redundant electronics for the CEDI MEB and Payload C&DH; previously it was intended that these electronics were redundant, but they were not costed**
- **Added a 3rd star tracker for redundancy (only 2 operate simultaneously)**
  - Confirmed the mass of the CT-602 star tracker, but allocated the additional 1.1kg as baffle mass where it was previously designated as electronics associated with the tracker

Changes to GEO MDI 2006 Configuration & Rationale
(2 of 3)

DESIGN CHANGES from GEO MDI to CEDI *continued*

- **Scaled the strong back for both CEDI-alone (small strongback) and GEO CAPE Suite (large strongback) configurations**
  - Confirmed that the preliminary structural assessment of the strongback indicated that the scale was appropriate in the original design
  - Confirmed that the CEDI-alone configuration would also need to be edge-mounted and require a similar strongback
- **Eliminated calibration lamp sources from previous mass model and replaced them with camera-mounted LEDs as flood lamp calibrators**
- **Implemented lightweight structural materials (M55J graphic/epoxy and honeycomb) to save mass over Al, wherever possible, as proposed in the MDI design**
- **Incorporated updated volume/mass estimates for CISR, as provided by the customer team, in our mass and mechanical models (GEO MAC remained the same as it was shown in 2006)**
- **Confirmed that the instrument-mounted ACS components are necessary for the closed-loop operation of the scan mirror and have accounted for that flight software control in our grassroots cost estimate**
  - Maintained a Rad750 PowerPC processor within the CEDI MEB as was proposed for MDI in 2006
- **Eliminated a filter wheel mechanism from the 2006 version and replaced it with a dispersive element in the SWIR channel and detector mounted filters (3)**
- **Have assumed Class S electronic parts for CEDI to be consistent with the high reliability parts recommended for a Class B mission (or the labor to upscreen lower quality parts when necessary); Class B parts were modeled for MDI in 2006**

Changes to GEO MDI 2006 Configuration & Rationale
(3 of 3)

DESIGN CHANGES from GEO MDI to CEDI *continued*

- Have shown the detector digitizer boxes mounted to the instrument enclosure (as they were intended for MDI in 2006, but time did not permit adding those details to the mechanical model)
- Assumed the same instrument lifecycle (development) schedule, but moved it forward to 2013
- Accounted for thermal blankets to cover the strong back, but have not provided active temperature control (although it is anticipated that the GEO MAC & CISR instruments would benefit from the CEDI-mounted ACS hardware)

DESIGN CONSIDERATIONS that may need to be revisited in the future, but were not undertaken in the CEDI study

- Did not (re)evaluate the specific star tracker or SIRU chosen for GEO MDI
- Did not (re)evaluate the specific Stewart platform recommended for GEO MDI
- Did not (re)evaluate the Payload C&DH function or capability proposed for GEO MDI as we did not discuss the GEO MAC or CISR processing or interface needs

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Optics

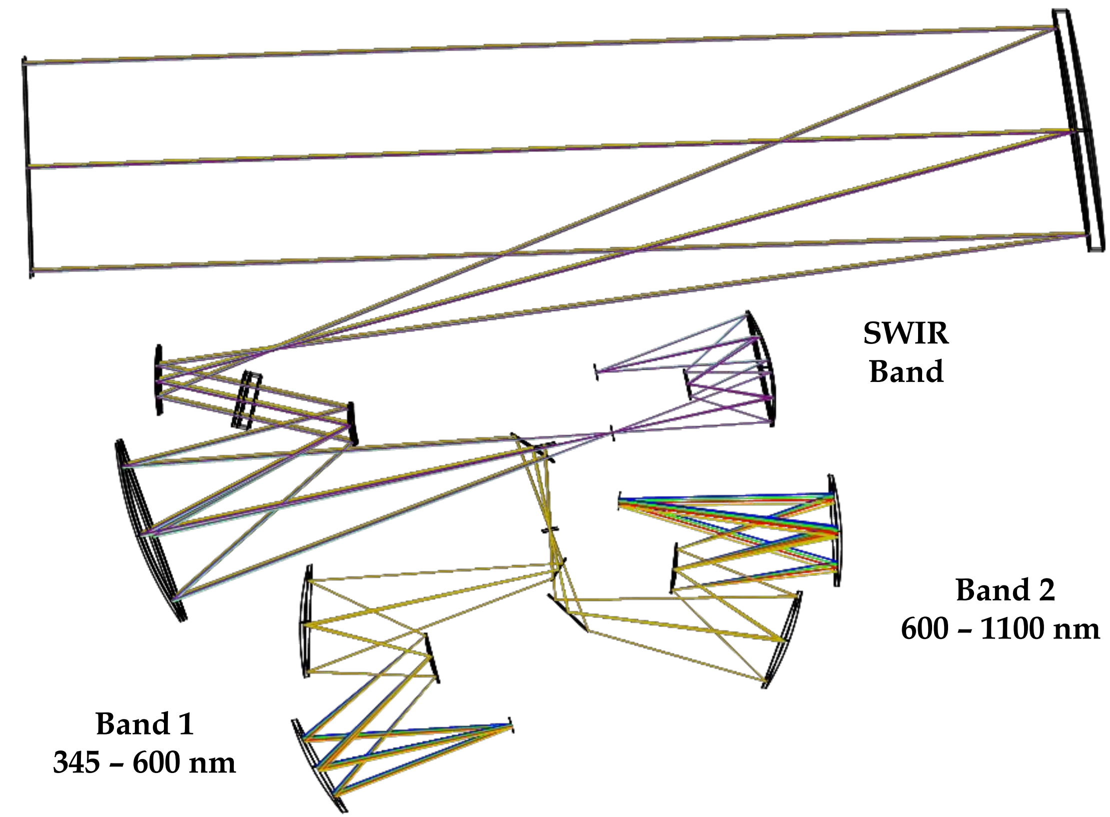
January 29, 2010

Optical Specifications/Requirements

- **Telescope Aperture: 0.5m**
- **Band 1 UVIS Spectrograph**
  - 350 – 600 nm; 0.5nm/pixel
- **Band 2 VNIR Spectrograph**
  - 600 – 1100 nm; 0.5 nm/pixel
- **Bands 1 and 2 share a common 18 µm x 3600 µm slit**
- **Band 3 - SWIR**
  - Camera with strip filters on detector
  - Filters at 1245, 1640, 2135 nm
- **Spatial Resolution for all channels: 375m/pixel; 2k pixels in spatial direction**
- **All detectors have 18 µm pixels**
- **Telescope focal length set for 1:1 Offner Spectrograph designs**
  - 0.375 km / 35786 km orbit = 1 pixel
  - Effective focal length = 1717.728 m, F/3.44 focal ratio
  - Field of view corresponding to the slit length: 1.2 degrees
- **This design is a modification of the previous IDL design of the MDI instrument in 2006.**

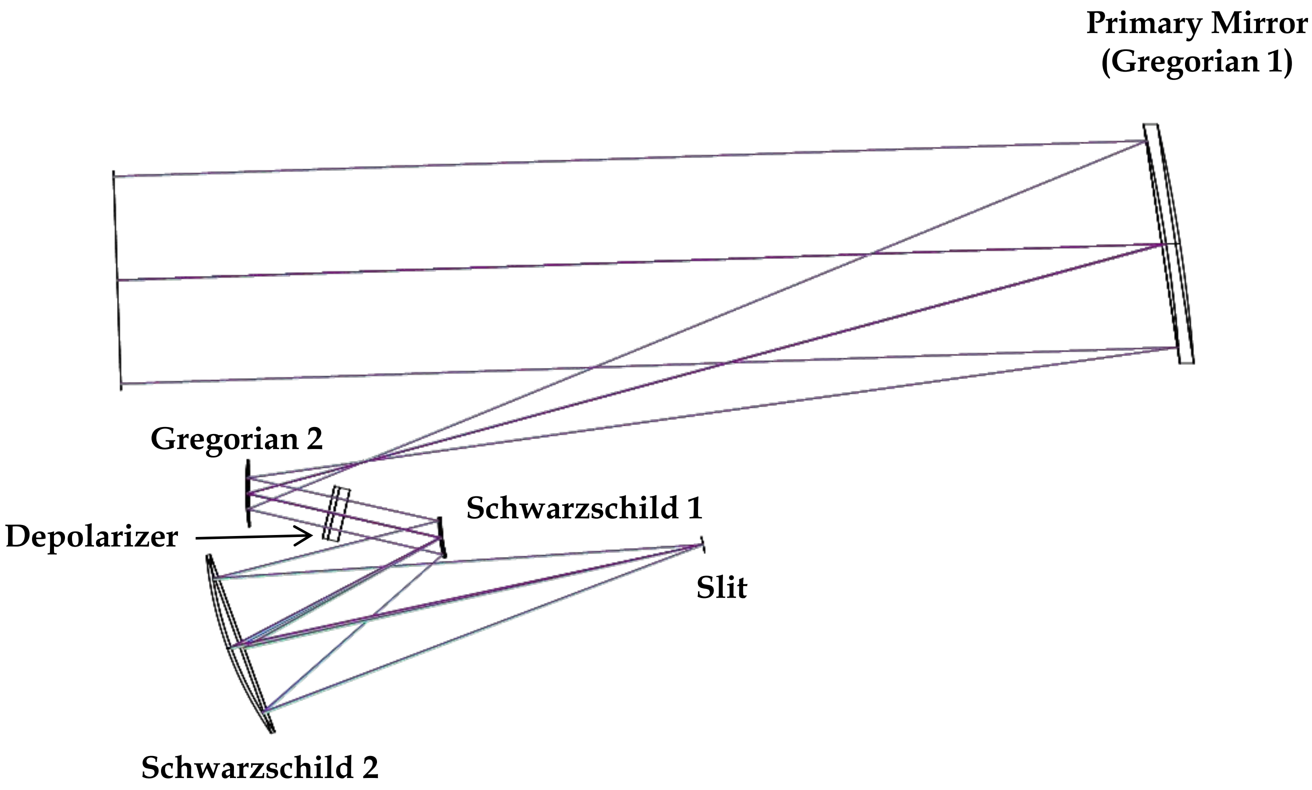
Optical System

Integrated Design Capability / Instrument Design Laboratory



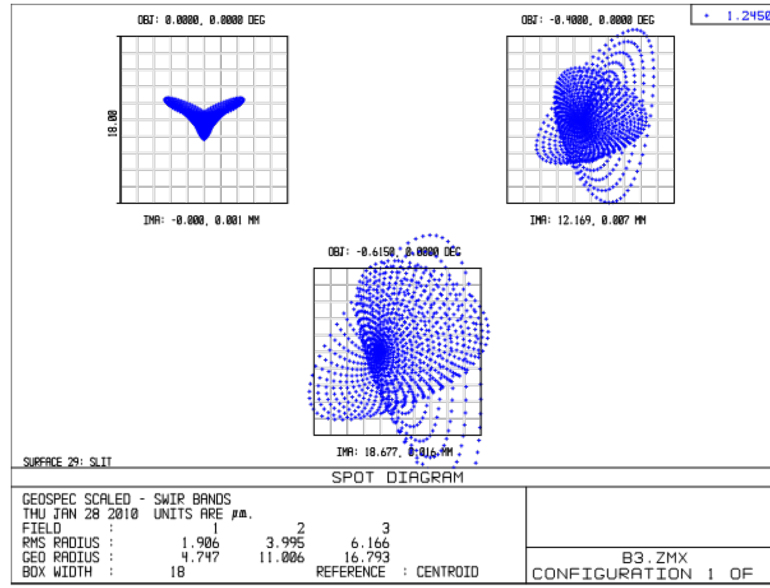
Telescope Design

Integrated Design Capability / Instrument Design Laboratory

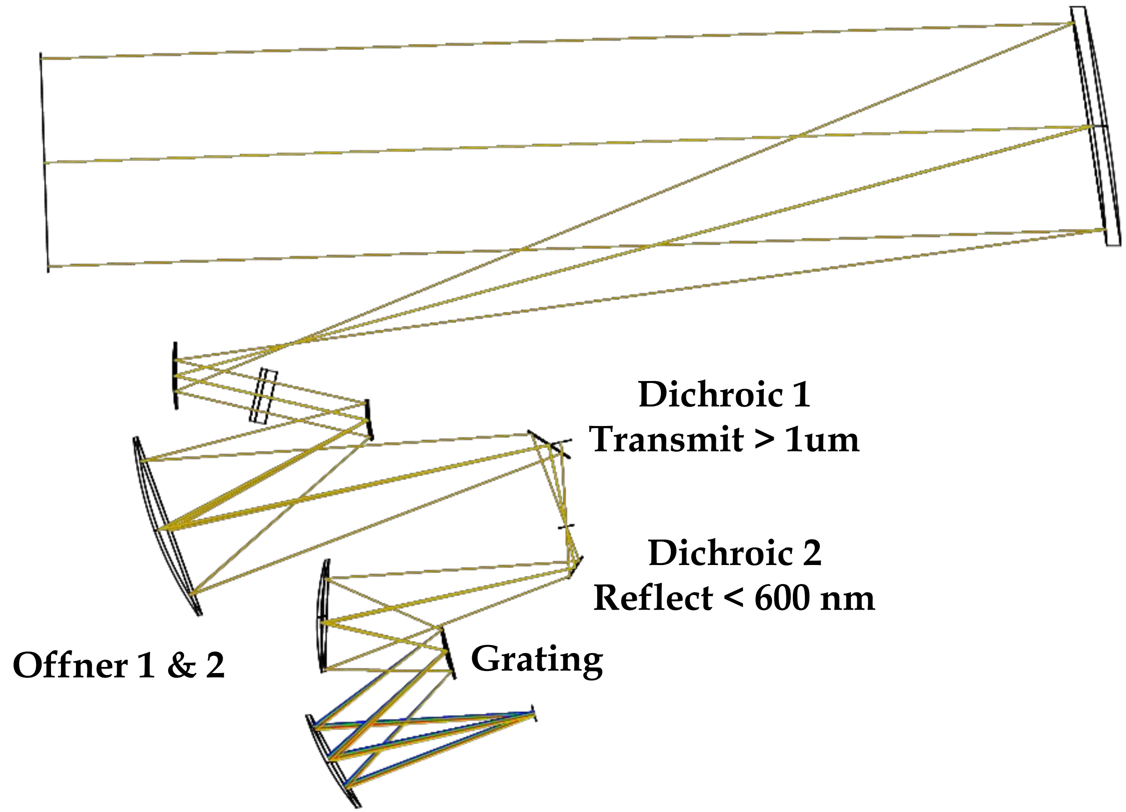


Telescope Details

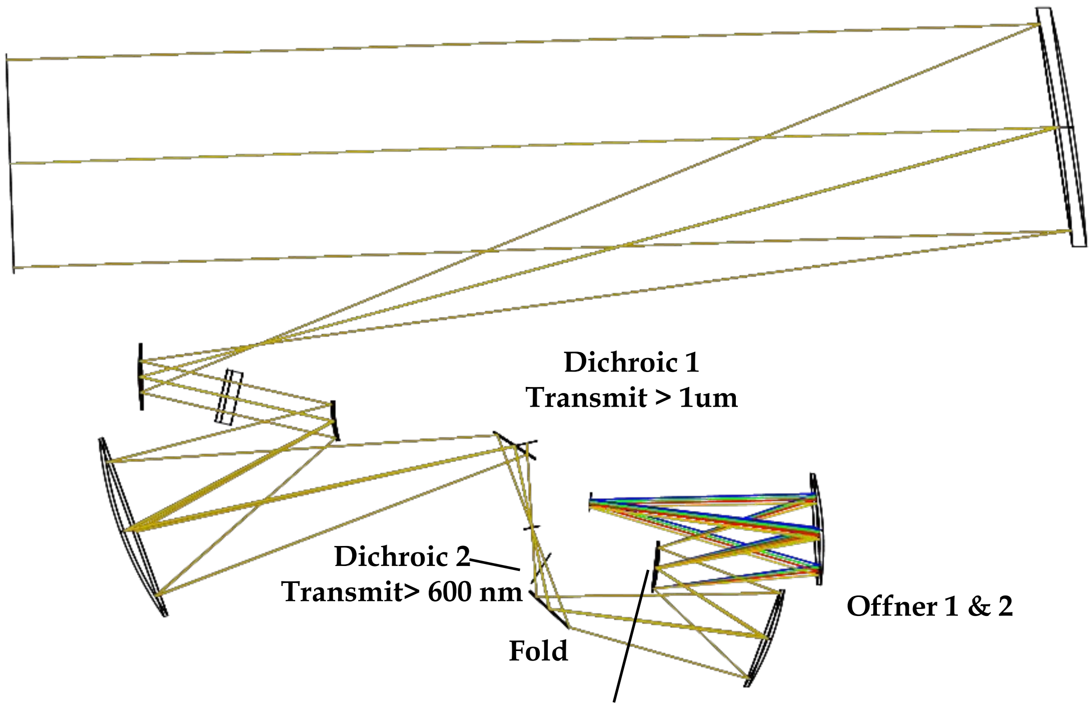
- **Near diffraction limited at long wavelengths**
  - Airy disk diameter = 3 um at 350 nm and 18 um at 2135 nm
- **Changed the primary mirror to be a “super conic” to reduce rms spot diameters.**
- **Secondary changed to off-axis hyperbola.**
- **Two Schwarzschild mirrors remain spherical.**
- **Depolarizer required to be in collimated beam.**
  - Two calcite wave plates with their fast axes 45 degrees apart



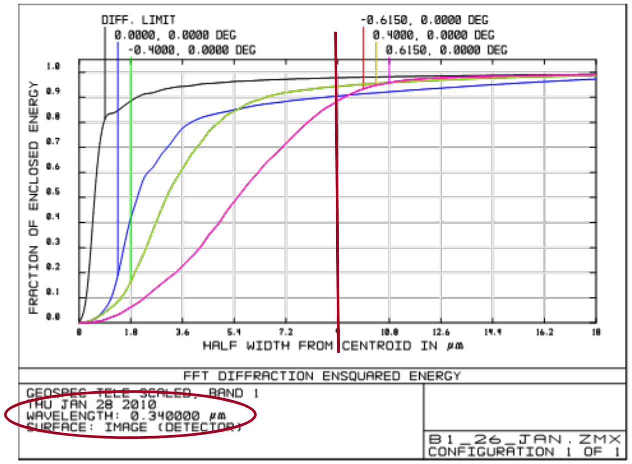
Band 1 Layout

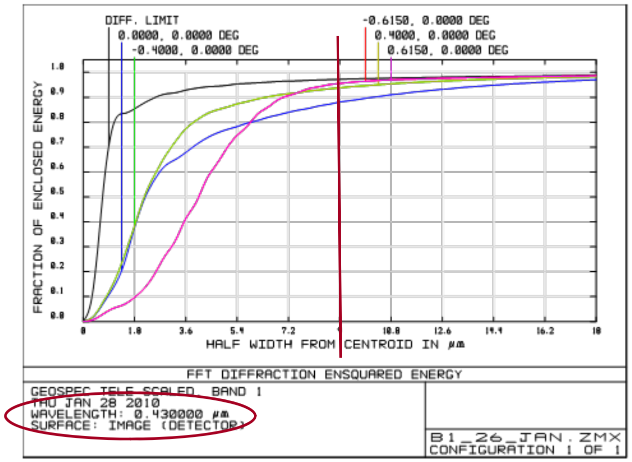


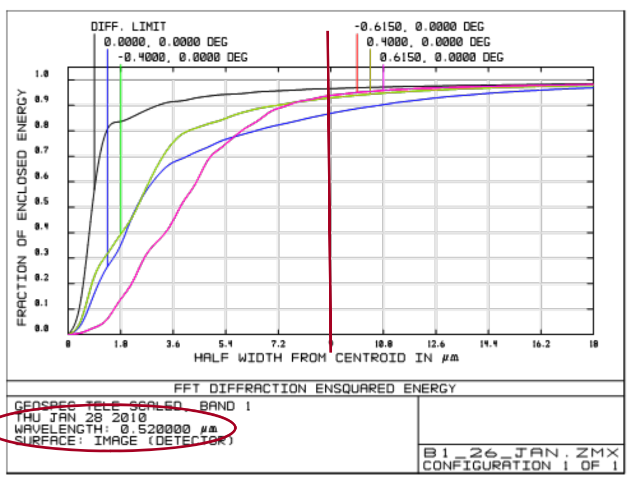
Band 2 Layout

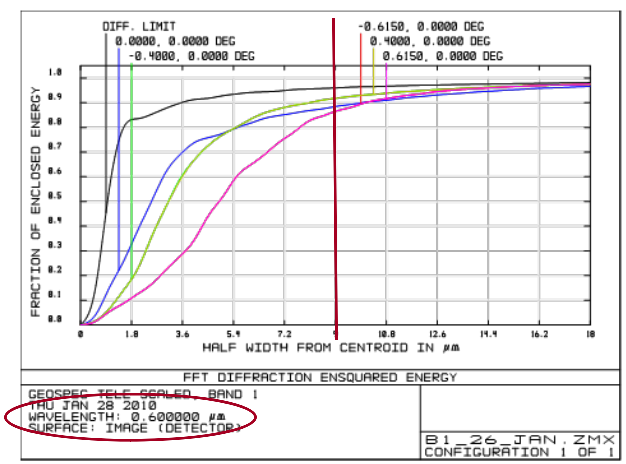


Performance of Band 1

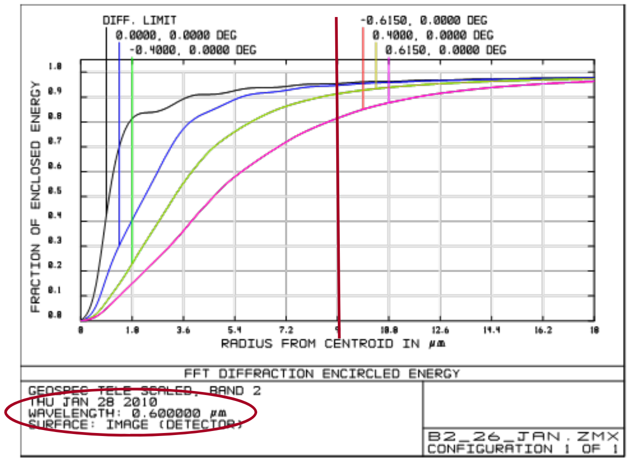


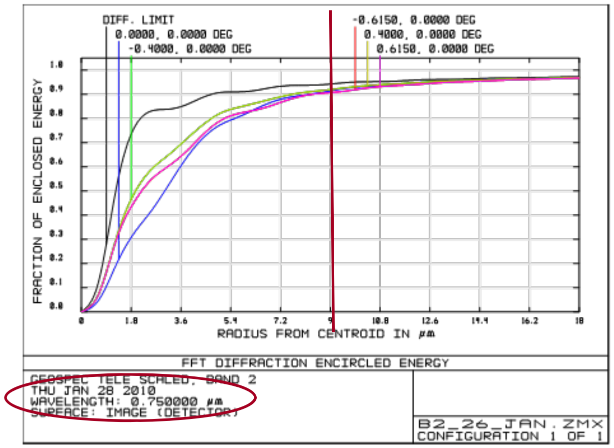


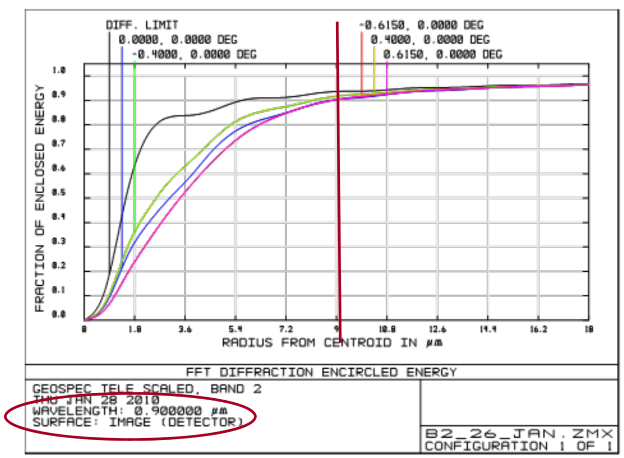


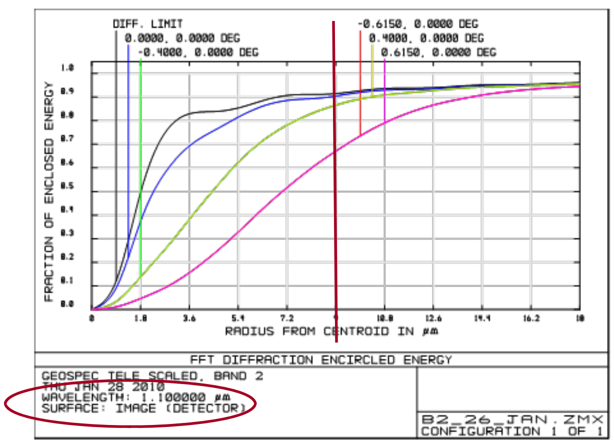


Performance of Band 2







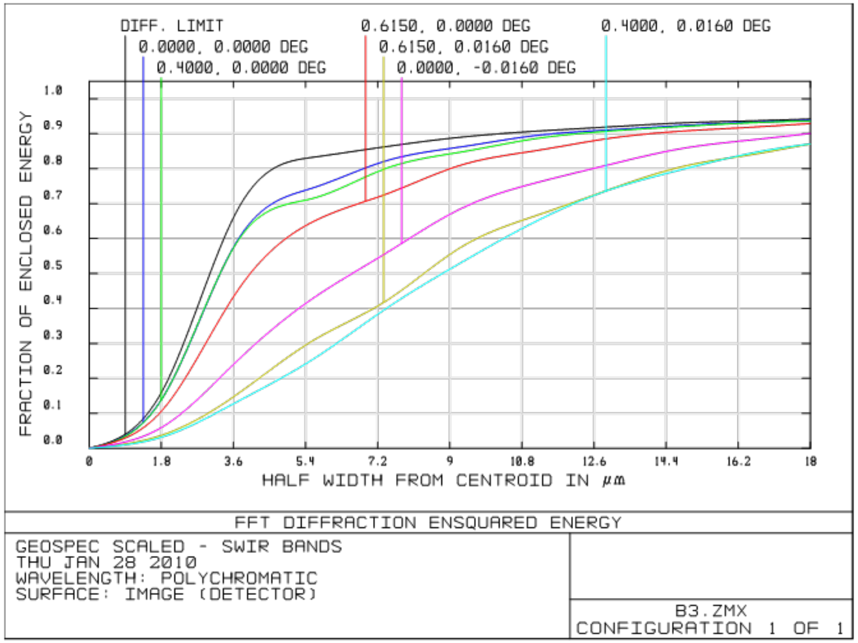


Band 1 and 2 Optics

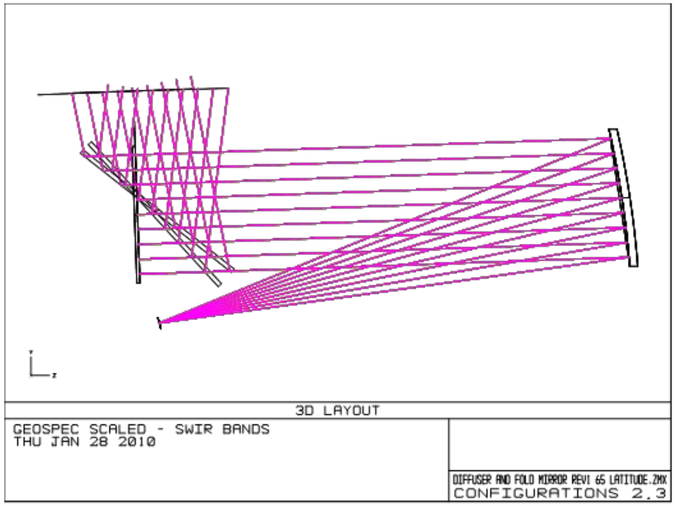
- **Offner mirrors changed to conics to improve image quality.**
- **Convex gratings have low groove density - 108 and 112 grooves / mm.**

Band 3

- **Assumed that this would be a camera with bandpass filters on the detector.**
  - 16 pixels required for each band and several pixels needed between bands.
- **Image quality needs to be improved.**

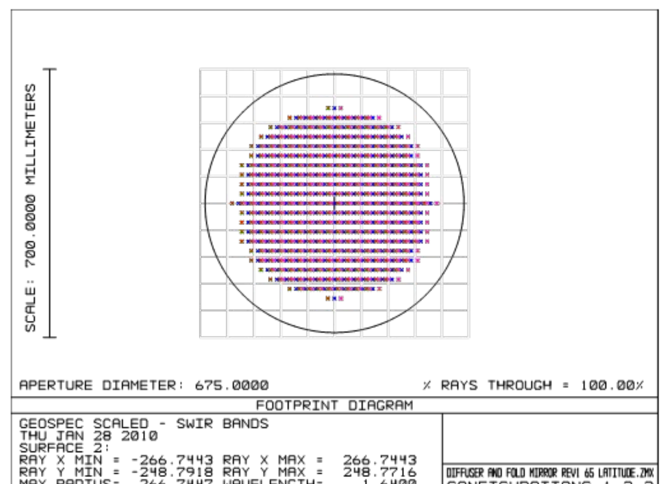


Port Size



North 50 degrees-South 45 degrees Lattitude
East-West +/- 65 degree Longitude scan
Max 9.26 degree optical angle
Science Port (5% oversize) at 675mm diameter

Instantaneous footprint on science port (534x498mm)



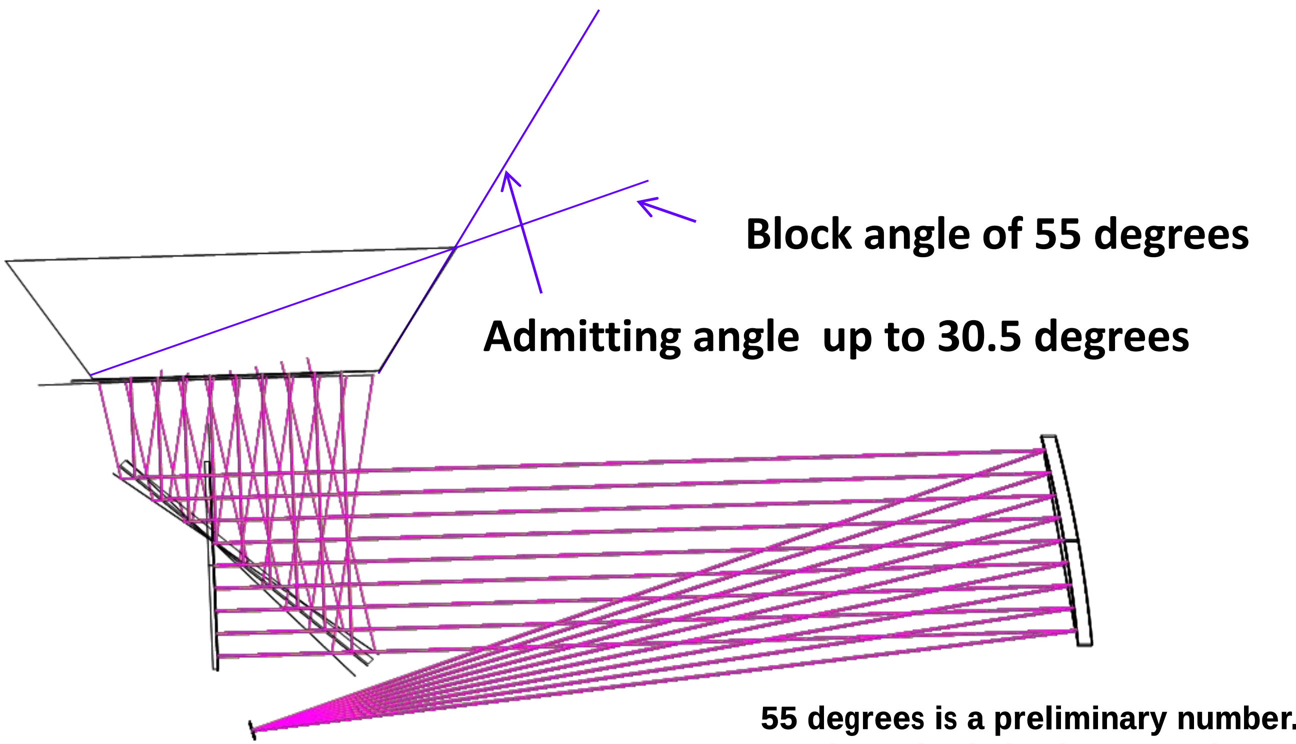
Baffle Details

Moon diameter 0.44 -0.51 degrees
Moon declination : +/- 18 degrees and +/- 29 degrees
min inclusion angle = 29+0.51 degrees = 29.51 degrees

Conical Baffle

outer diameter	**1066mm**
inner diameter	**675mm (science port diameter)**
height	**332mm**
block angle	**55 degrees**
admittance angle	**30.5 degrees**

Baffle Optical Model



55 degrees is a preliminary number.
Need required viewing scenario.

Diffuser Discussions

- **We considered a transmissive diffuser but decided it was not at a high enough TRL level.**
  - The diffuser would have to be at least 0.5 m in diameter and this is hard to build.
  - No technology required to scale it up, it just hasn't been done.
  - Presumably this would yield a smaller volume impact.

Band 1 Throughput Estimates

Band 1	340 - 600 nm	Wavelength (nm)											
	Coating	350	360	385	412	425	443	460	475	490	510	532	555	583
Primary	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Collimator	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Relay Mirror 1	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Relay Mirror 2	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Depolarizer	Calcium Flouride	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
Dichroic 1	Reflection	0.900	0.920	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
Dichroic 2	Reflection	0.900	0.920	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
Offner Mirror 1	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Grating		0.500	0.600	0.600	0.700	0.700	0.700	0.700	0.700	0.700	0.600	0.550	0.550	0.500
Offner Mirror 3	Quantum Silver	0.938	0.939	0.932	0.958	0.952	0.943	0.936	0.941	0.950	0.961	0.967	0.971	0.971
Degrading 5% over time		0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
Total		0.24	0.31	0.31	0.43	0.42	0.39	0.38	0.39	0.41	0.38	0.36	0.37	0.33

Quantum Silver Reflectivities based on measured data.
Depolarizer transmission based on transmission curves.
Grating efficiencies based on measured curves. However these covered slightly different wavelength regions and groove densities.

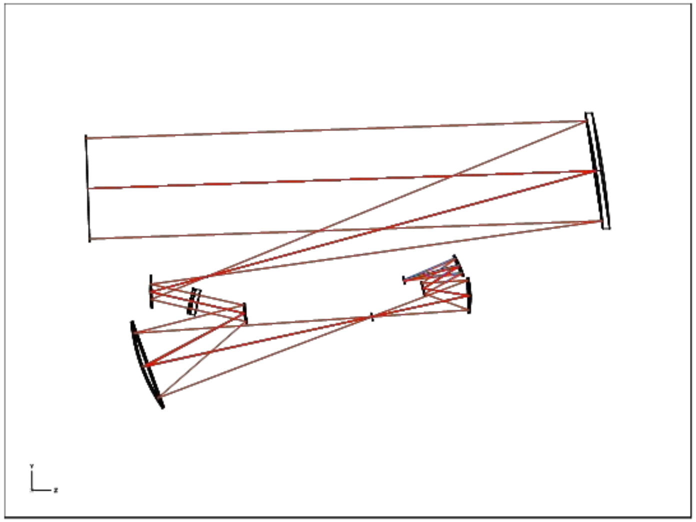
Band 2 & 3 Throughput Estimates

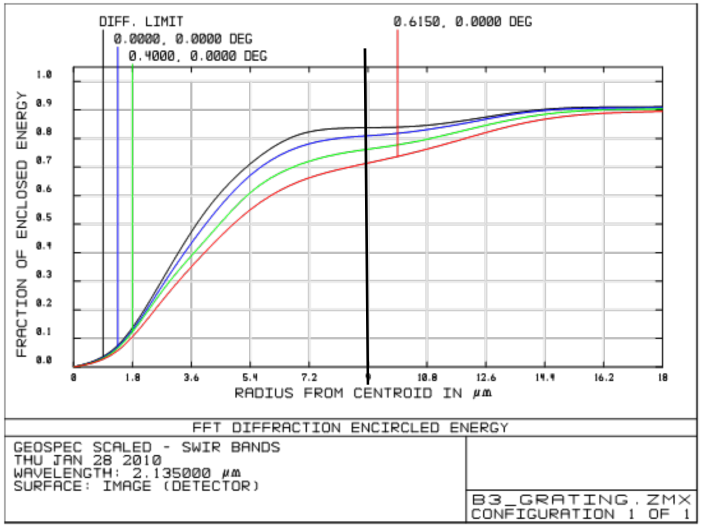
Band 2	600 - 1100 nm										
	Coating	**617**	**640**	**655**	**665**	**678**	**710**	**748**	**765**	**820**	**865**
Primary	Quantum Silver	0.967	0.965	0.964	0.964	0.963	0.965	0.971	0.973	0.980	0.983
Collimator	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Relay Mirror 1	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Relay Mirror 2	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Depolarizer	Calcium Flouride	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930	0.930
Dichroic 1	Reflection	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
Dichroic 2	Transmittance	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850	0.850
Fold Mirror	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Offner Mirror 1	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Grating		0.600	0.600	0.650	0.700	0.700	0.700	0.700	0.650	0.650	0.650
Offner Mirror 3	Quantum Silver	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961	0.961
Degrading 5% over time		0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950	0.950
Total		**0.33**	**0.33**	**0.35**	**0.38**	**0.38**	**0.38**	**0.38**	**0.36**	**0.36**	**0.36**

		Wavelenth (nm)		
Band 3	**Coating**	**1245**	**1640**	**2135**
Primary	Quantum Silver	0.988	0.988	0.988
Collimator	Quantum Silver	0.961	0.961	0.961
Relay Mirror 1	Quantum Silver	0.961	0.961	0.961
Relay Mirror 2	Quantum Silver	0.961	0.961	0.961
Depolarizer	Calcium Flouride	0.930	0.930	0.930
Dichroic 1	Transmittance	0.850	0.850	0.850
Offner Mirror 1	Quantum Silver	0.961	0.961	0.961
Offner Mirror 2	Quantum Silver	0.961	0.961	0.961
Offner Mirror 3	Quantum Silver	0.961	0.961	0.961
filter on detector		0.950	0.950	0.950
Degrading 5% over time		0.950	0.950	0.950
Total		**0.56**	**0.56**	**0.56**

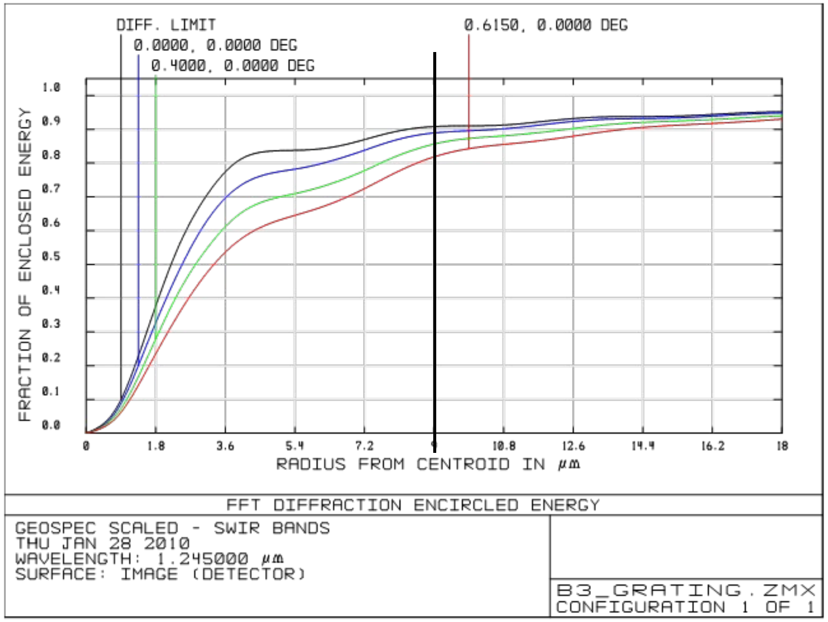
SWIR bands changed to Spectrograph

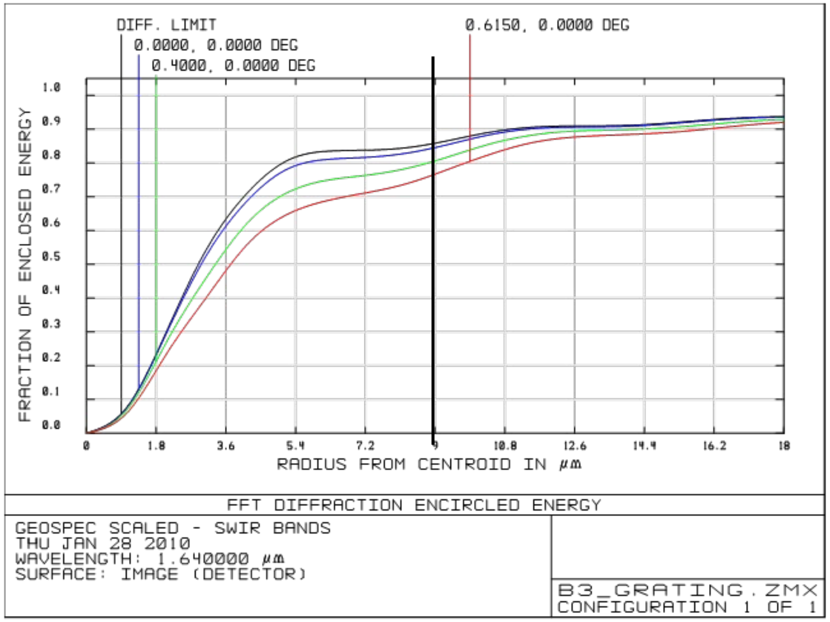
- **Required change to generalized aspheres for two Offner mirrors.**
- **Would fit in the same general volume.**
- **Image quality requirements need to be determined.**
- **Assumed 2.5 nm/pixel sampling**
  - From 1225 – 2160 covers 374 pixels.





"New" SWIR Band Performance





Impact to Changing to 300 m Spatial Resolution

- **Assuming keep the 500 mm aperture stop diameter**
  - Less signal because of smaller footprint.
  - Length of slit on the ground becomes smaller (600km vs. 750km)
    - Field of view is smaller
    - Takes longer to scan the same area on the ground
  - Effective focal length becomes longer (2147mm vs. 1717mm)
  - System wants to be longer.
  - Quick look at keeping telescope the same and modifying Offner designs:
    - Telescope slit would have to be 14.4 um width
      - Airy disk diameter is 14.4 um and larger for 1.75 um and longer
      - Do not want a slit smaller than Airy disk diameter.
    - Offner mirrors want to be larger and the second leg wants to be much longer.
  - Keeping Gregorian primary and secondary constant and modifying two Schwarzschild mirrors.
    - This looks very promising!
    - Distance from second Schwarzchild mirror to slit grows but because spectrograph designs are 1:1 magnification, they can remain nearly the same.
    - Slight degradation at the ends of the slit – more design work needed.
    - It looks as if all spectrographs could be packaged in the same volume!
- **What happens if you have 300 m spatial resolution and 585 mm entrance aperture?**
  - Modified the telescope model for above requirements, image quality was degraded.
  - Need more time to evaluate.
  - Worst case is to scale system by 585/500.

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Detectors

January 29, 2010

Geo-CAPE Detector Requirements

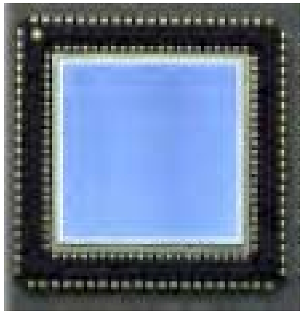
- **Near UV-Visible Channel 1:**
  - 340nm-600nm
  - 1k x 2k array format
  - 1Me- well capacity
  - <100e- read noise
  - QE>60%
- **Visible-Near Infrared Channel 2:**
  - 600nm-900nm
  - 1k x 2k array format
  - 1Me- well capacity
  - <100e- read noise
  - QE>60%
- **Short Wave IR:**
  - (3) Bands at 1245nm, 1640nm, 2135nm
  - 512 x 2k array format
  - 100ke- well capacity
  - 20e- read noise
  - QE>60%

Geo-CAPE Detector Choices

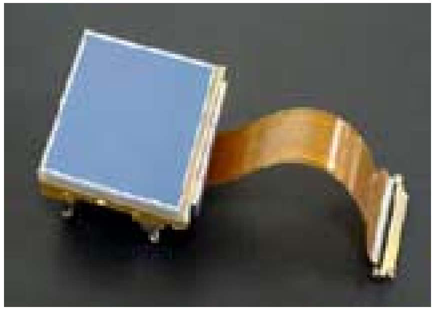
- Channels 1& 2: Silicon material of choice for the required wavelengths
  - High quantum efficiency, low dark current and noise
  - Well known and understood technologies, high TRL level
    - CCDs:
      - Pros
        - 100% fill factor
        - Very low read noise
      - Cons
        - Slow readout speed: would require a frame transfer device and multiple read taps
        - Small full well capacity (~150-200ke- for 18um pixels)
        - 2kX1k non-standard format
    - PIN diode array hybridized with a Si ROIC (Read Out Integrated Circuit)
      - TCM 8050A
        - 100% fill factor
        - medium read noise
        - Limited readout speed/number of outputs
        - Large full well capacity 3Me- lowest gain setting
        - 2kX1k non-standard format
      - HAWAII-2RG
        - 100% fill factor
        - low read noise
        - Limited readout speed/number of outputs
        - Small full well capacity 100ke-

Channels 1&2 Detector Choice

- **Custom 2k X 1k Teledyne TCM 8050A**
  - TCM 8050A not designed to be buttable like HAWAII ROICs
  - Use higher gain setting with 1Me- well capacity
  - ~100e- read noise
    - No CDS built in. Would have to be performed in software using a minimum integration time frame. Pseudo CDS can be performed in software by subtracting a common dark frame obtained each day
  - (8) outputs, 256 rows each, maximum read rate of 5M pixels/sec
  - Silicon thickness and anti-reflection coating optimized for each wave band
    - UV-A Coating for channel 1
    - Near IR coating for channel 2
  - Set operating temperature to maintain dark current and noise below all other noise sources $\leq$220K
    - Radiation damage not an issue: slight increase in dark current and noise due to displacement damage
      - (No need to keep the traps full like in a CCD)

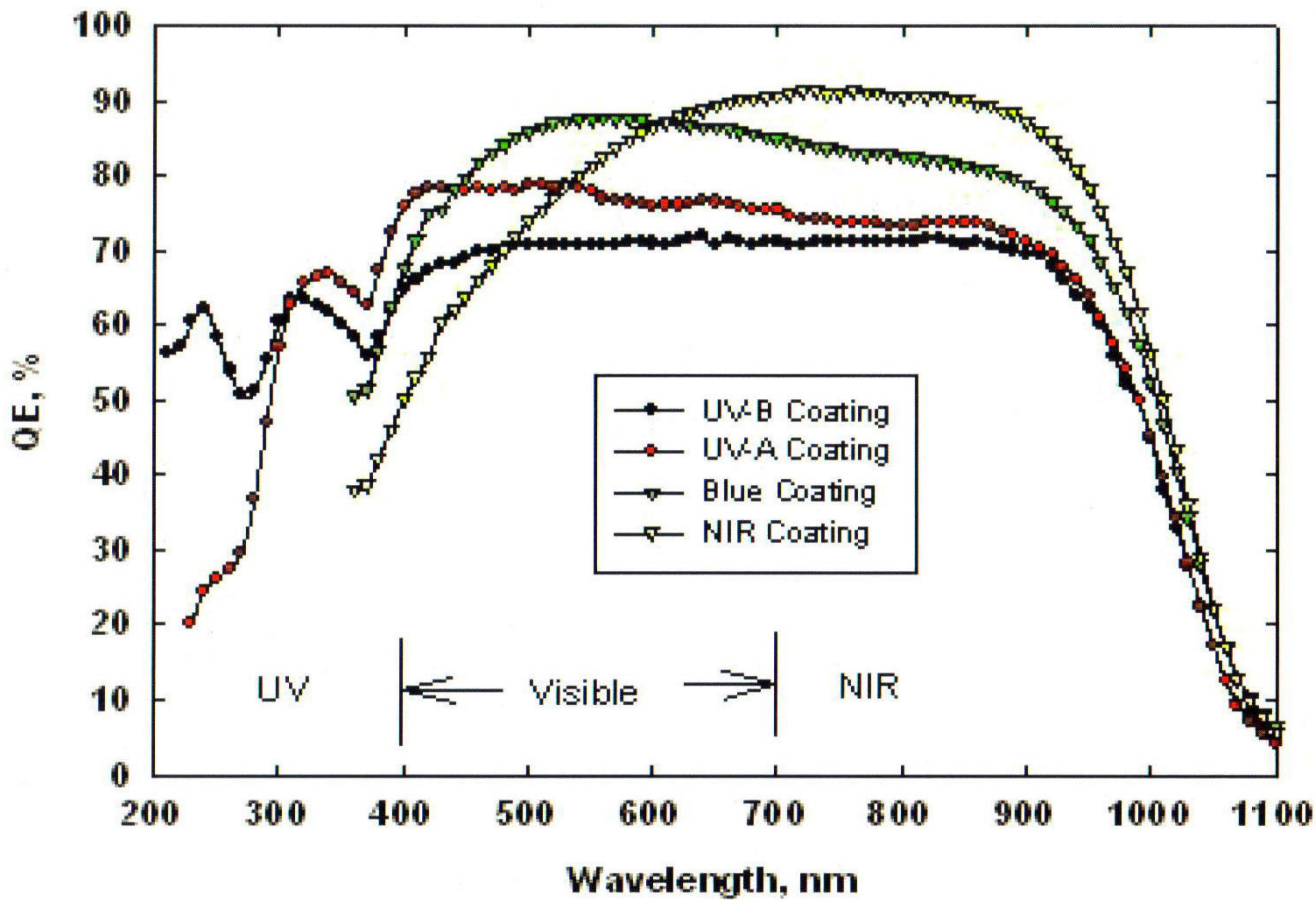


TCM 8050A



HAWAII-2RG

Teledyne HyViSI Quantum Efficiency



Teledyne HyViSI Dark Current

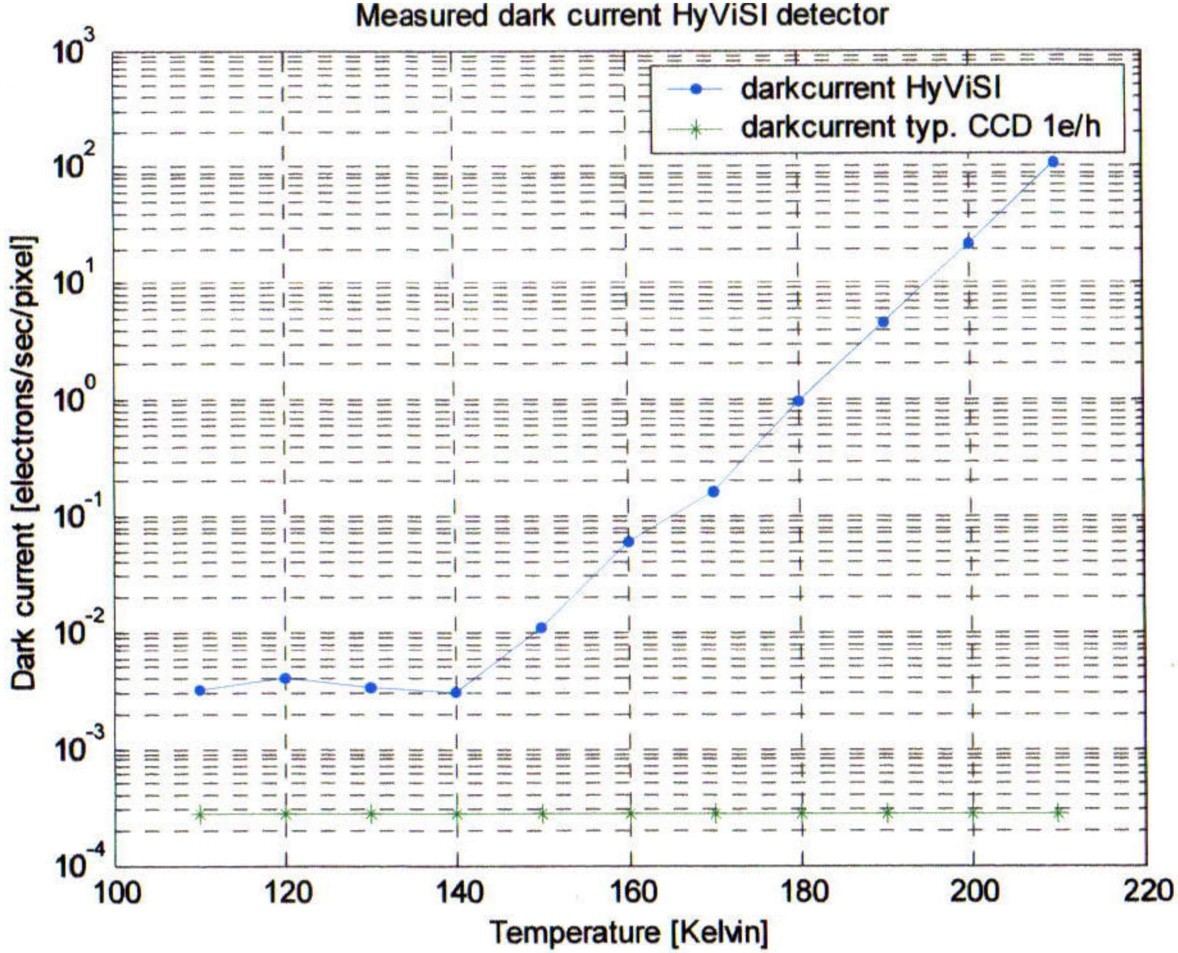
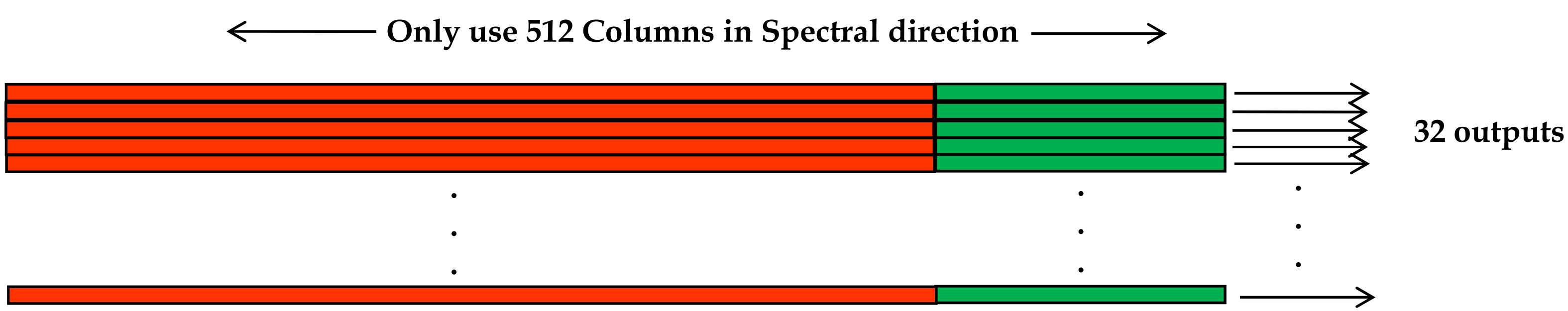


Figure 8 Darkcurrent as a function of temperature.

Geo-CAPE Detector Choices

- Channel 3: Mercury Cadmium Telluride (MCT) is the material of choice for the required wavelengths
  - High quantum efficiency, low dark current and noise (operate at 150K)
  - InSb or InGaAs would require cryogenic operating temperatures
    - Sterling cycle cooler cost, mass and power hit
  - Well known and understood technologies, high TRL level
  - PIN diode array hybridized with a Si ROIC (Read Out Integrated Circuit)
    - HAWAII-2RG
      - 100% fill factor
      - low read noise
      - High readout speed
        - 32 outputs, each reads out 64 rows at 5M pixels/sec
      - Small full well capacity, 100ke-, requires frame averaging to avoid saturation
      - 2k X 512 non-standard format: just use ¼ of a 2k X 2k array rather than a custom array



Note: Any section of 512 contiguous columns could be used

Conclusions

- **No technology issues or concerns**
- **Heritage on the HAWAII-2RG, Si-PINs and MCT-PINS**
- **Custom 2k X 1k TCM8085A required to avoid lost spatial pixels if (2) 1k x 1k arrays were butted**

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Mechanical Systems

January 29, 2010

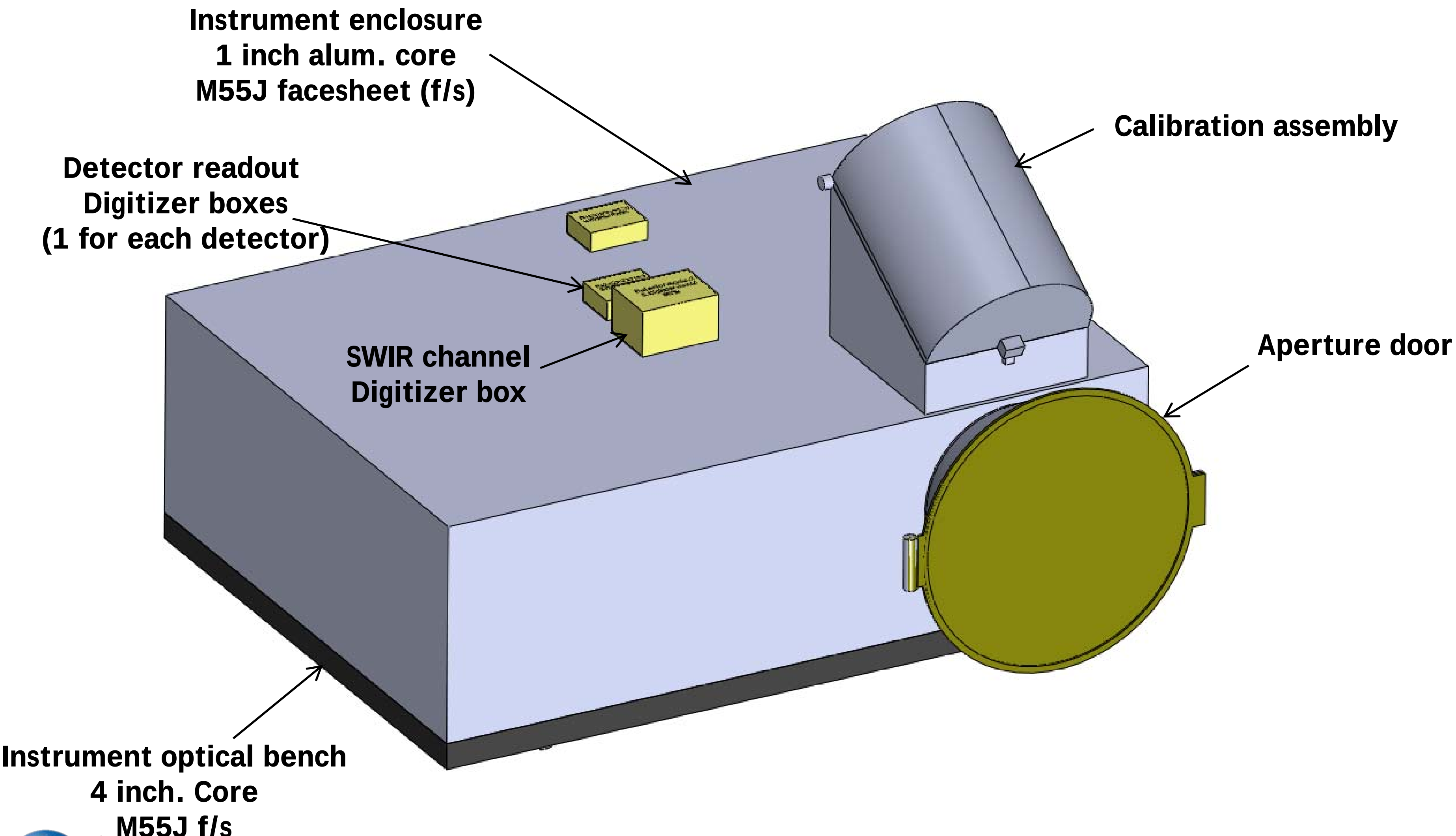
Study Requirements

- **Package CEDI components**
  - Optical – Telescope, Band 1, Band 2 and SWIR
  - Mechanisms – Aperture door, Scan Mirror, diffuser assembly
  - Star trackers, Gyro
- **Minimize mass and volume**
- **Represent S/C mounted boxes : Payload C&DH, CEDI MEB**
- **Re-evaluate the "Strong back" in light of reduced size and mass for the CEDI (vs. GEO-MDI), GEO-MAC and CISR.**
- **Develop two instrument/ spacecraft configurations:**
  - CEDI only
    - Develop an instrument/ spacecraft interface w/o strong back
  - CEDI, GEO-MAC, and CISR
    - GEO-MAC and CISR represented as volumes only
    - Instruments mount to the strong back; strong back interfaces to the spacecraft.

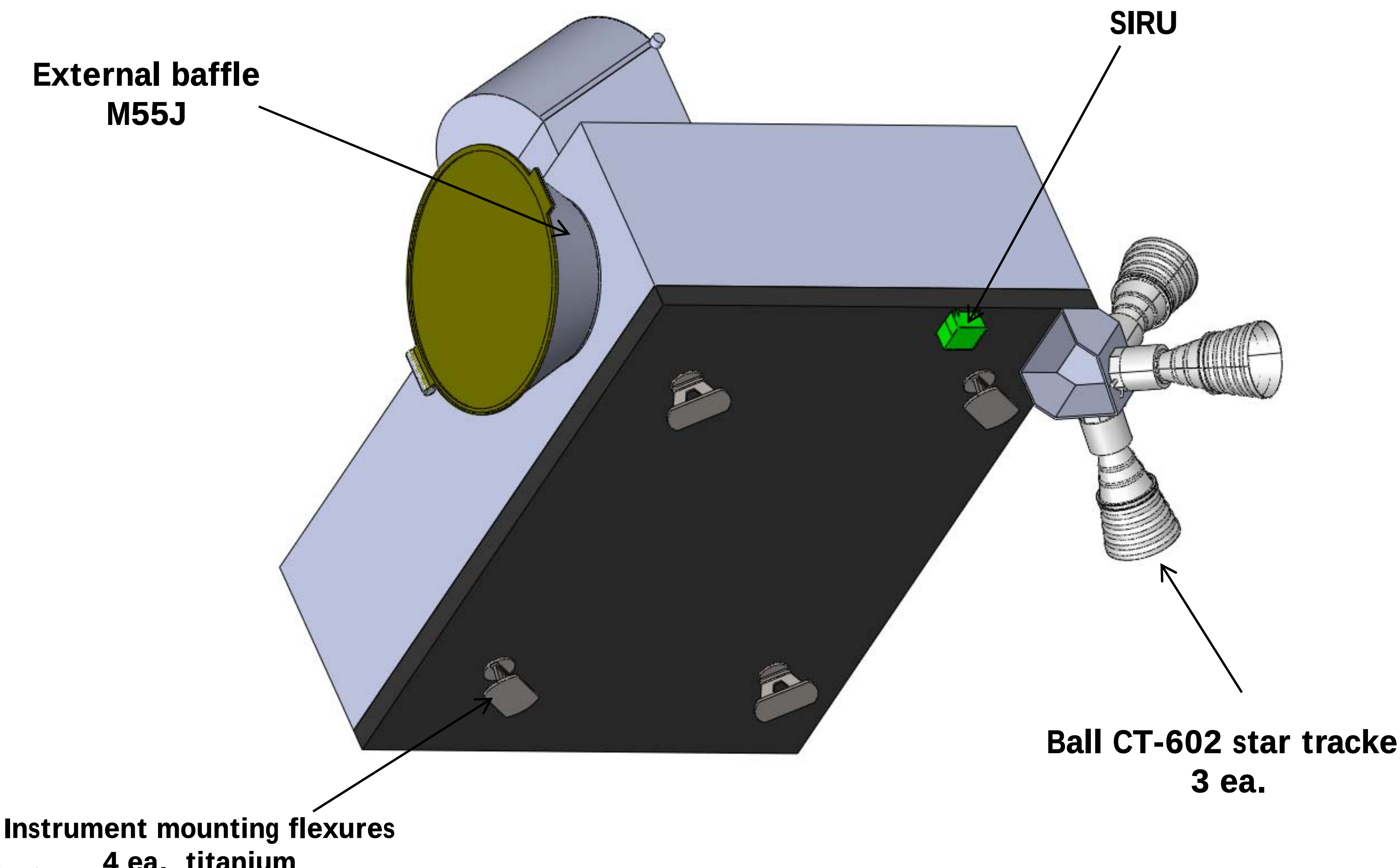
Study Design Drivers

- Minimize volume: package optics as tight as possible
- Minimize mass: material selection (aluminum, M55J graphite/epoxy), light weight structural components (honeycomb panels)
- Alignment/stability requirements: material selection (low Coefficient of Thermal Expansion (CTE) composites)
- I&T considerations
- Detector electronics located close to the detectors.

External Assembly

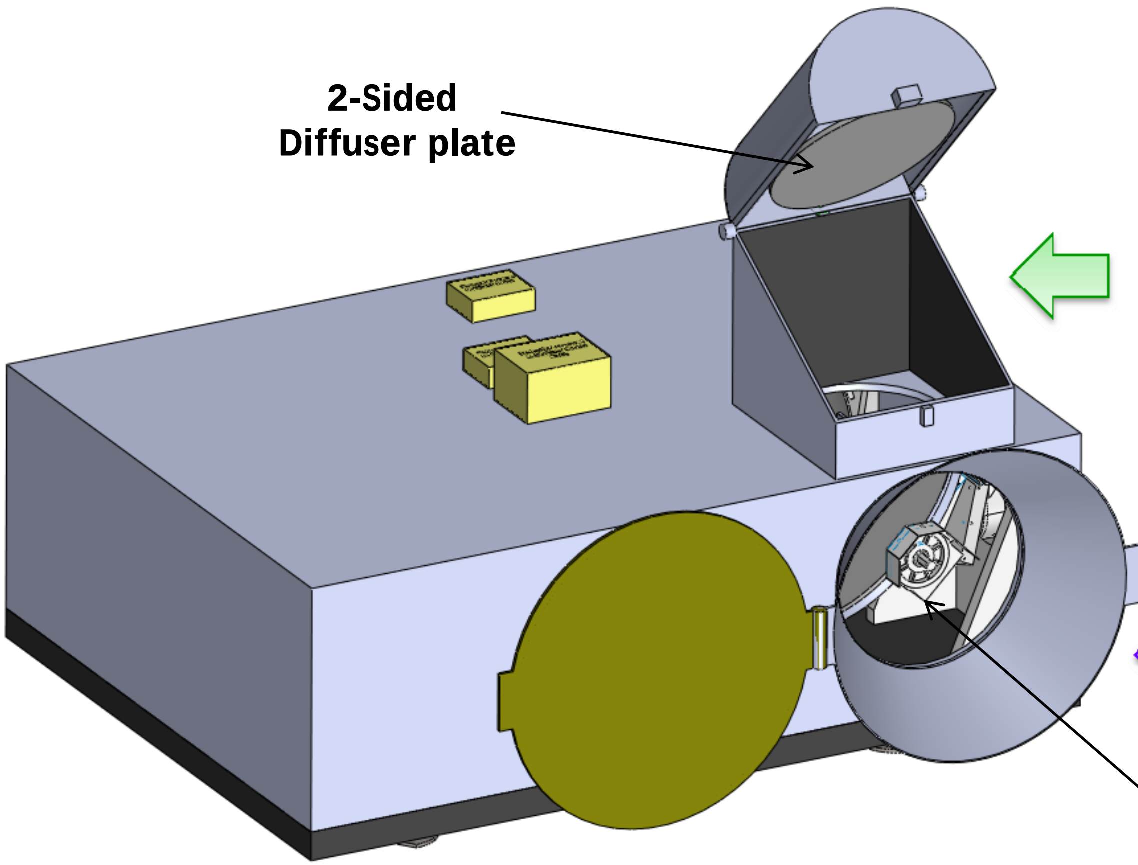


Mounting Interface

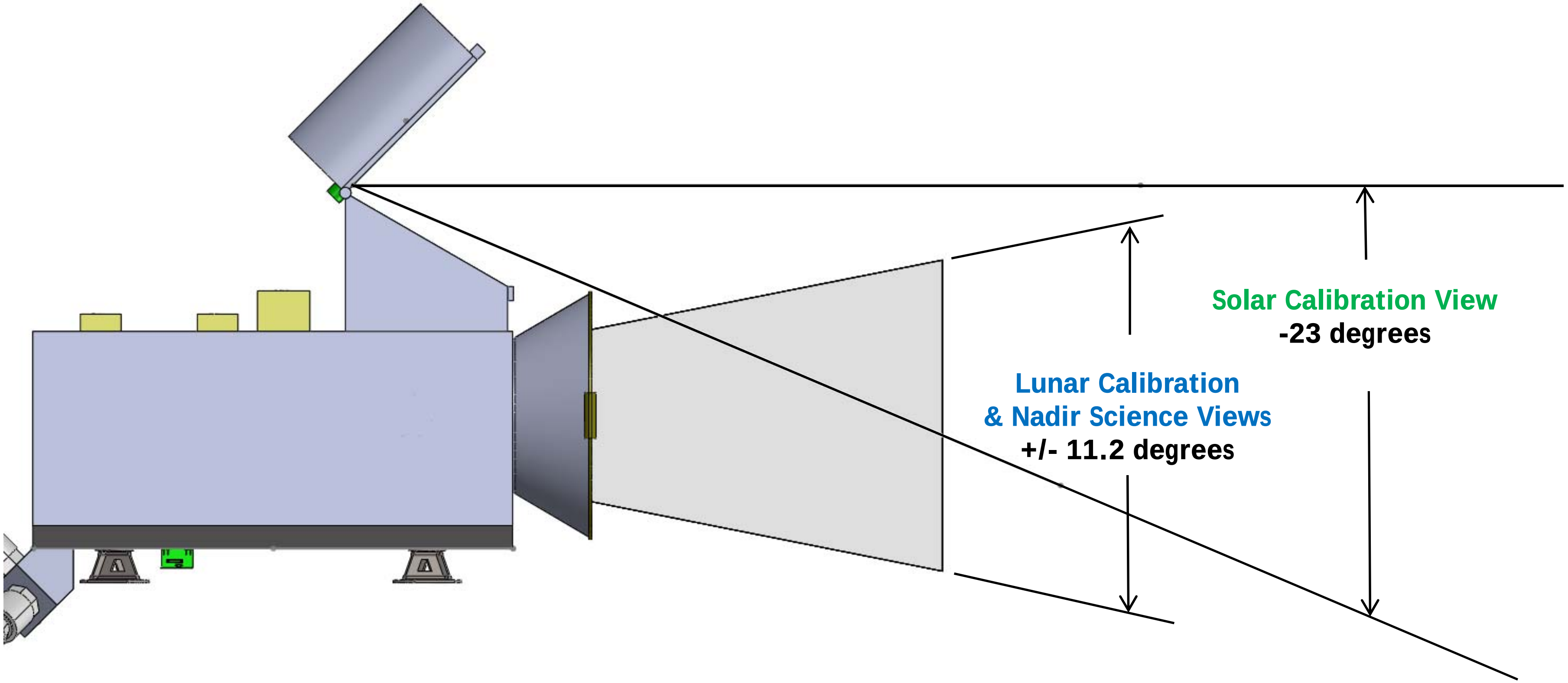


Aperture & Calibration Covers Opened

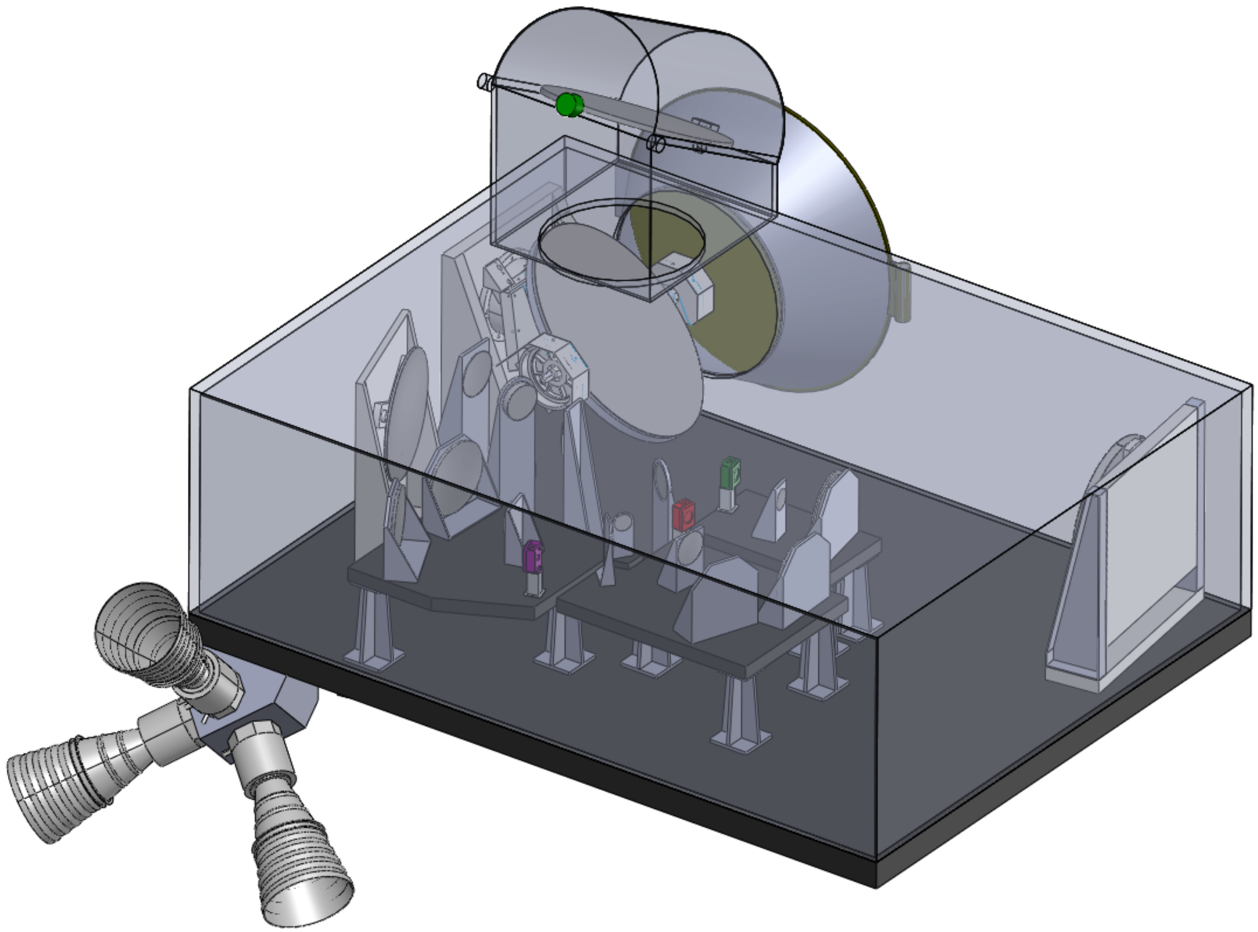
Integrated Design Capability / Instrument Design Laboratory



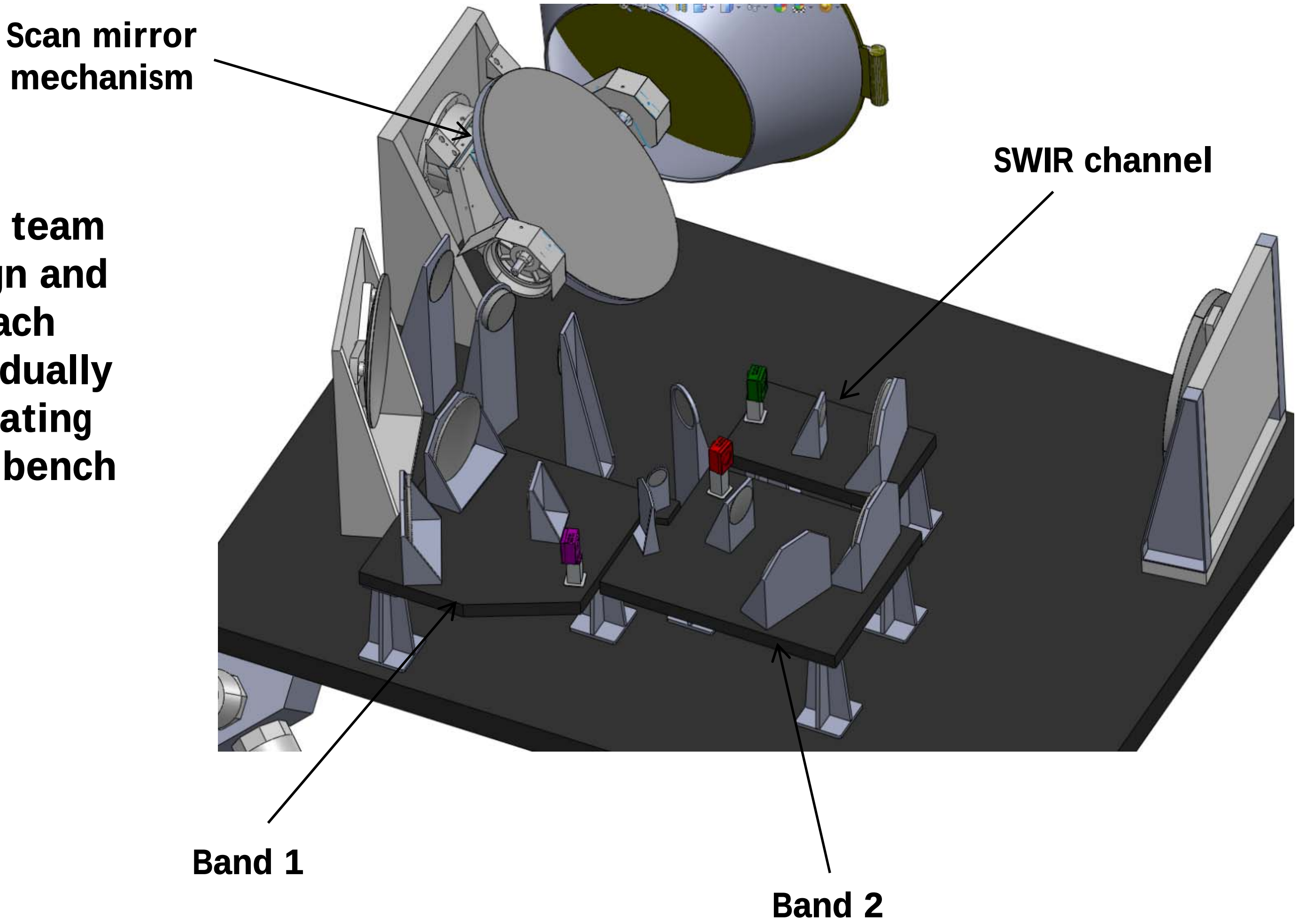
Calibration FOV Requirement



Internal Assembly

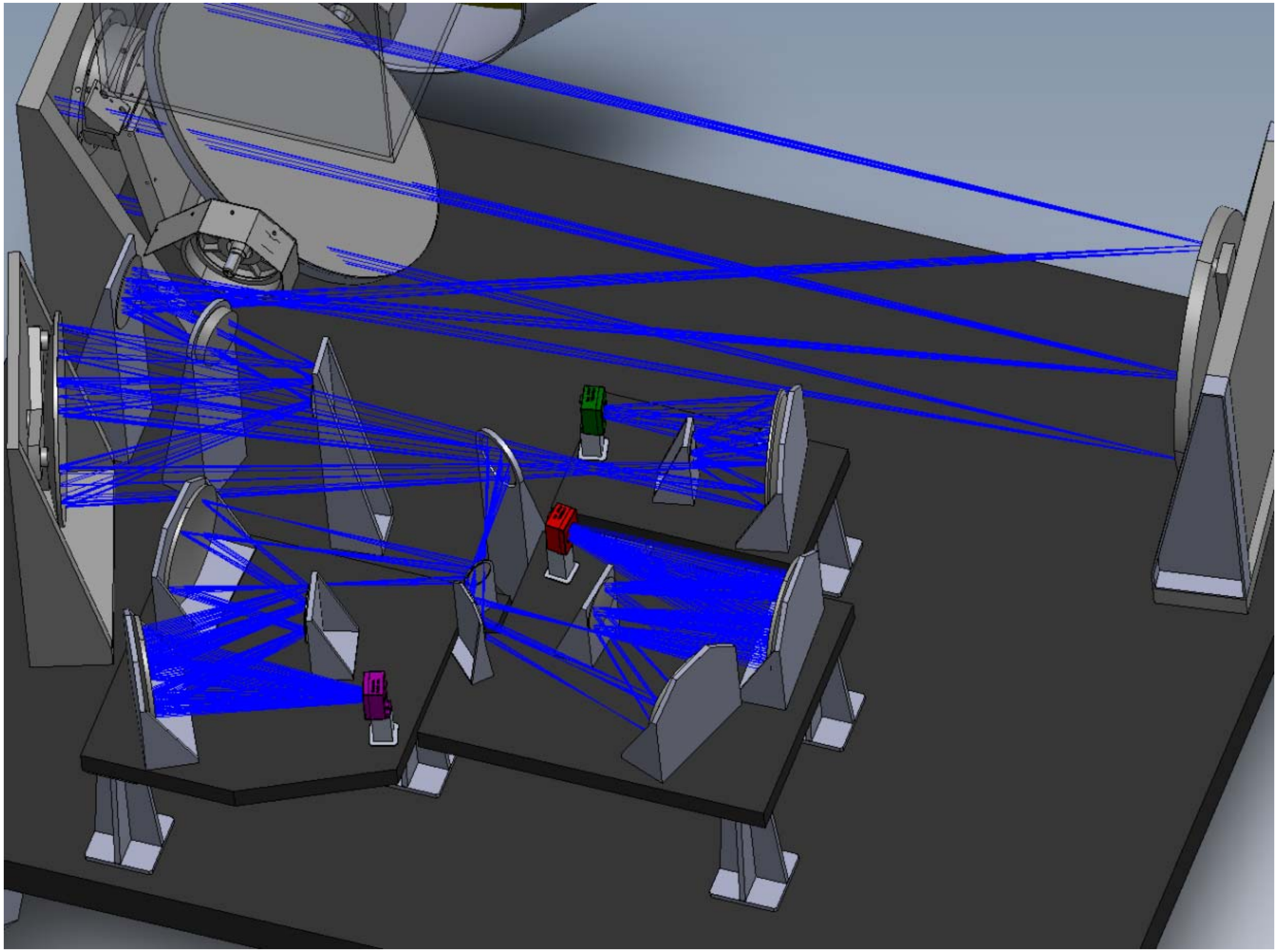


Individual Benches for Each Channel

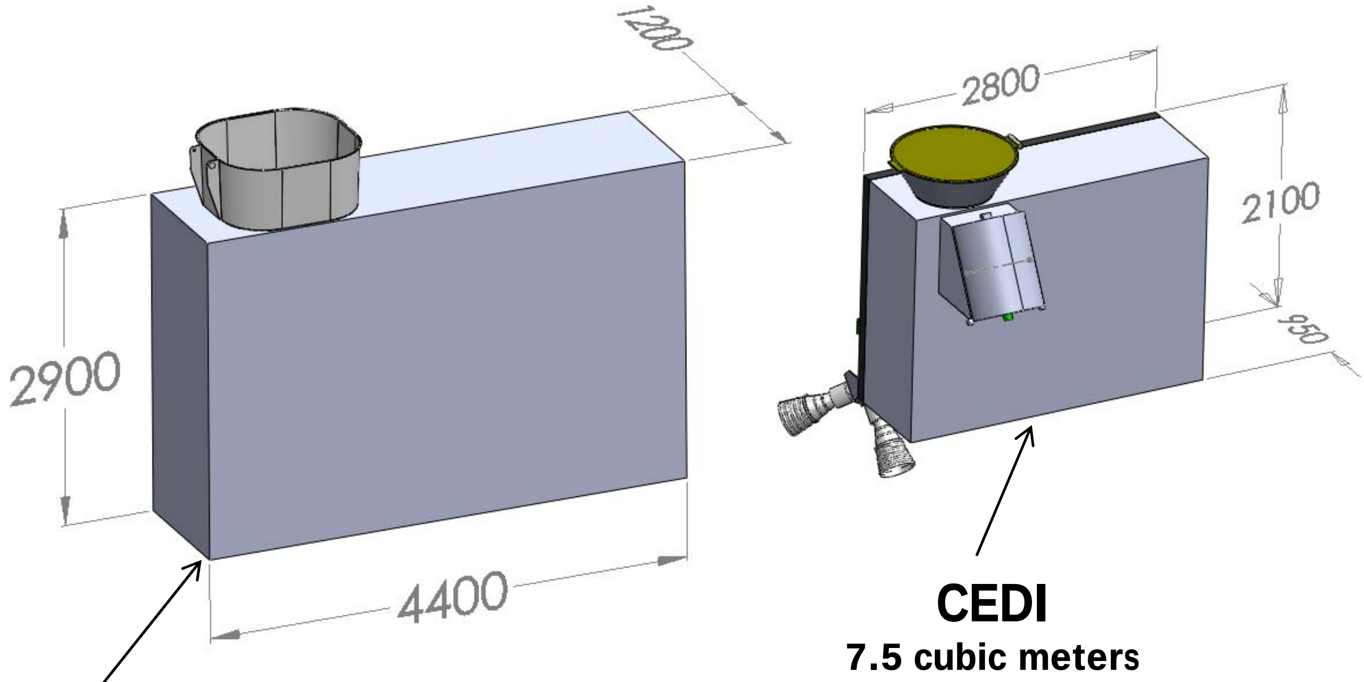


The customer team intends to align and calibrate each channel individually before integrating with the main bench

Optical Paths



Volume Comparison



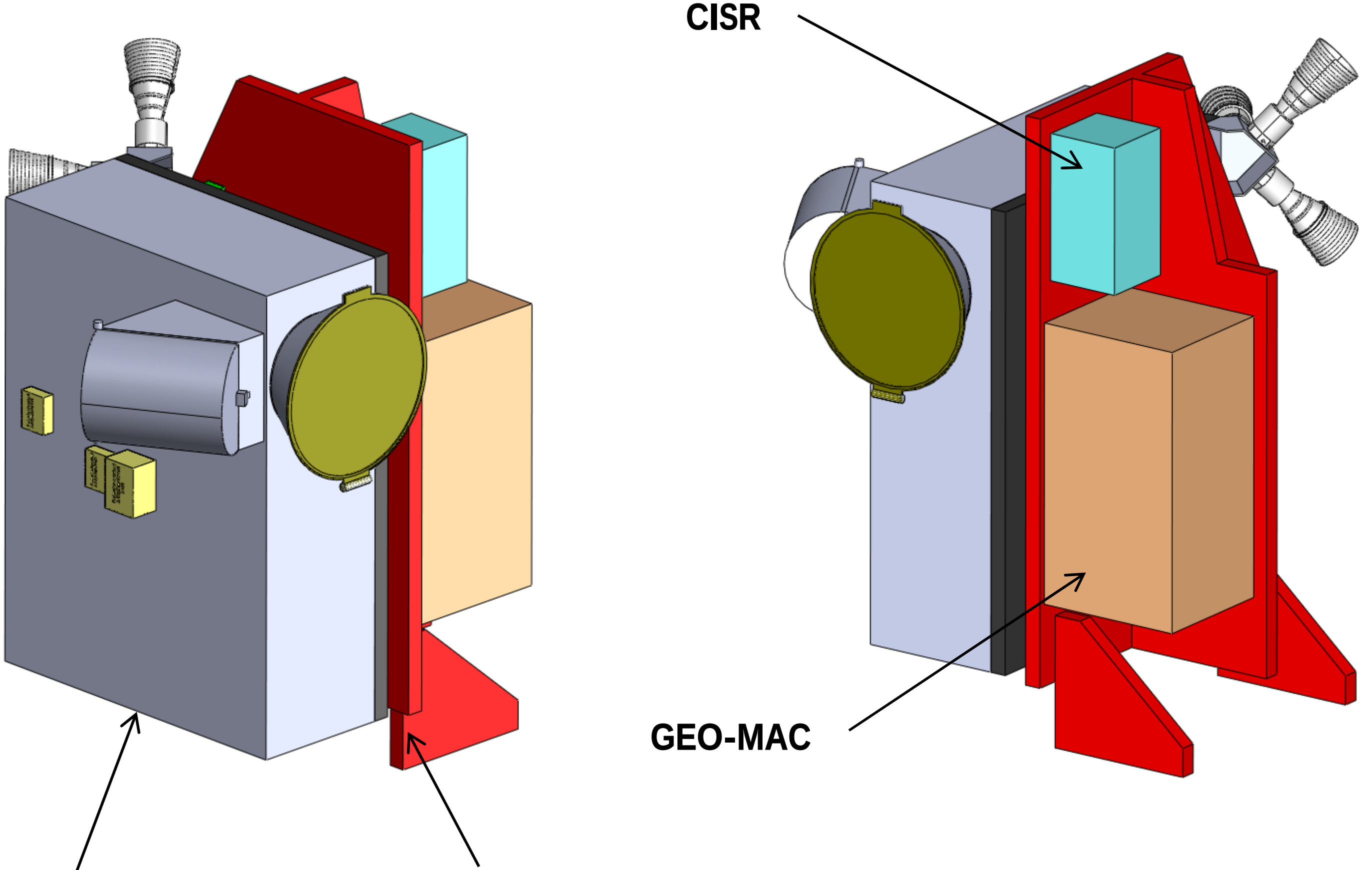
GEO-MDI
15.3 cubic meters
(includes calibration assy. Volume)

CEDI
7.5 cubic meters
(includes calibration assy. volume)

Note: dimensions in millimeters

GEO-CAPE Suite

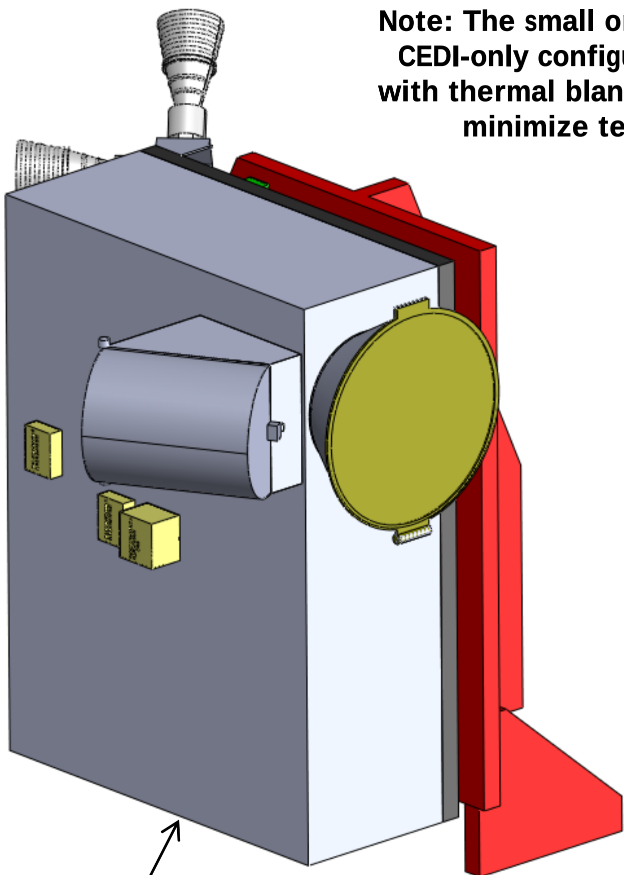
Note: The large or "tall" Strong Back for the GEO CAPE Suite was not costed



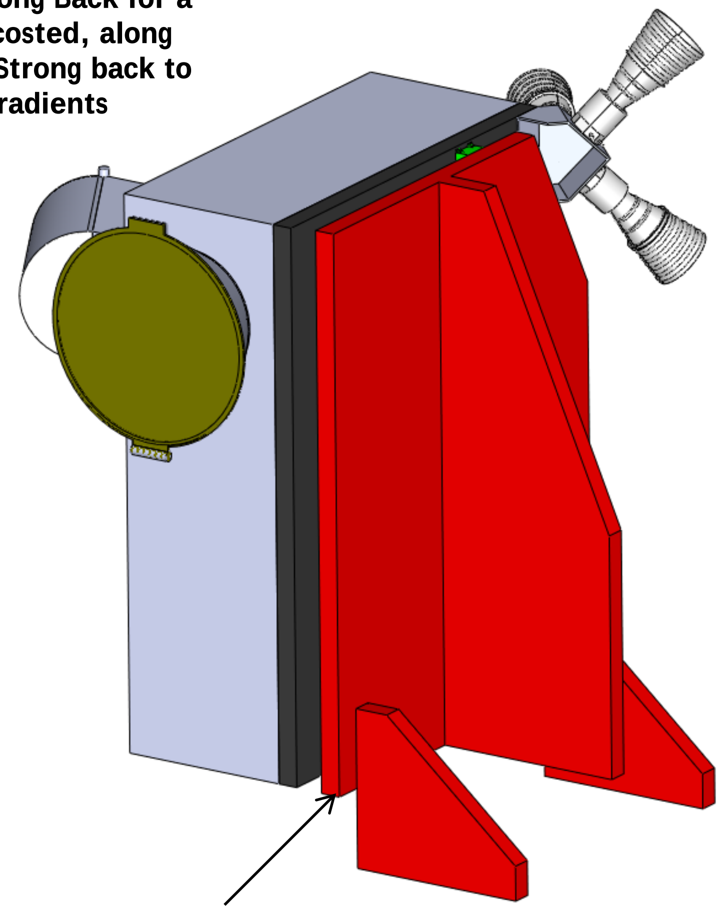
Note: CAD models of the current GEO-MAC and CISR instruments were not available. These instruments are represented by volume envelope only.

CEDI Mounting Configuration

Note: The small or "short" Strong Back for a CEDI-only configuration was costed, along with thermal blankets for the Strong back to minimize temperature gradients



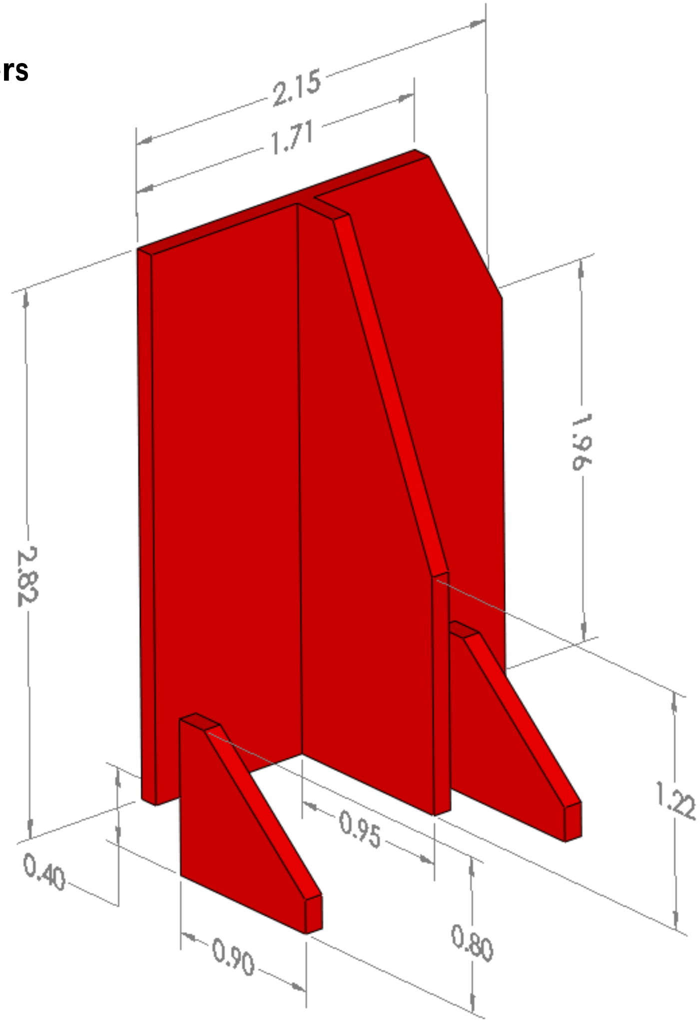
CEDI



Strong back
4 inch core
M55J facesheets

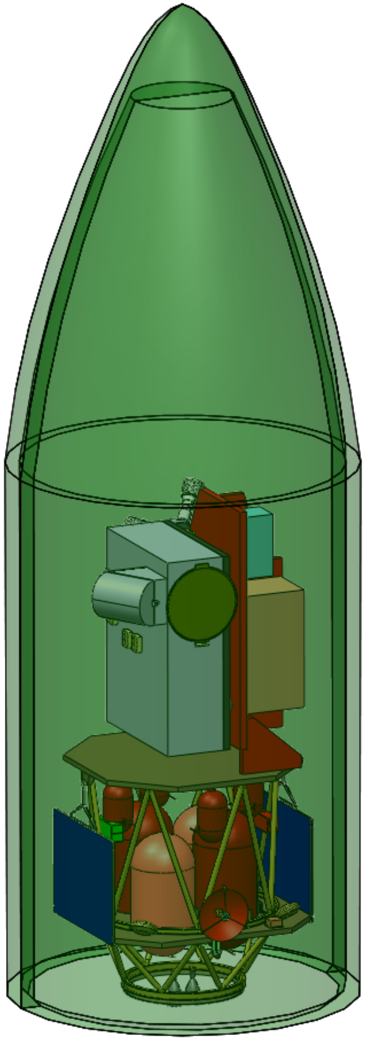
CEDI Only Strong Back

Note: dimension in meters

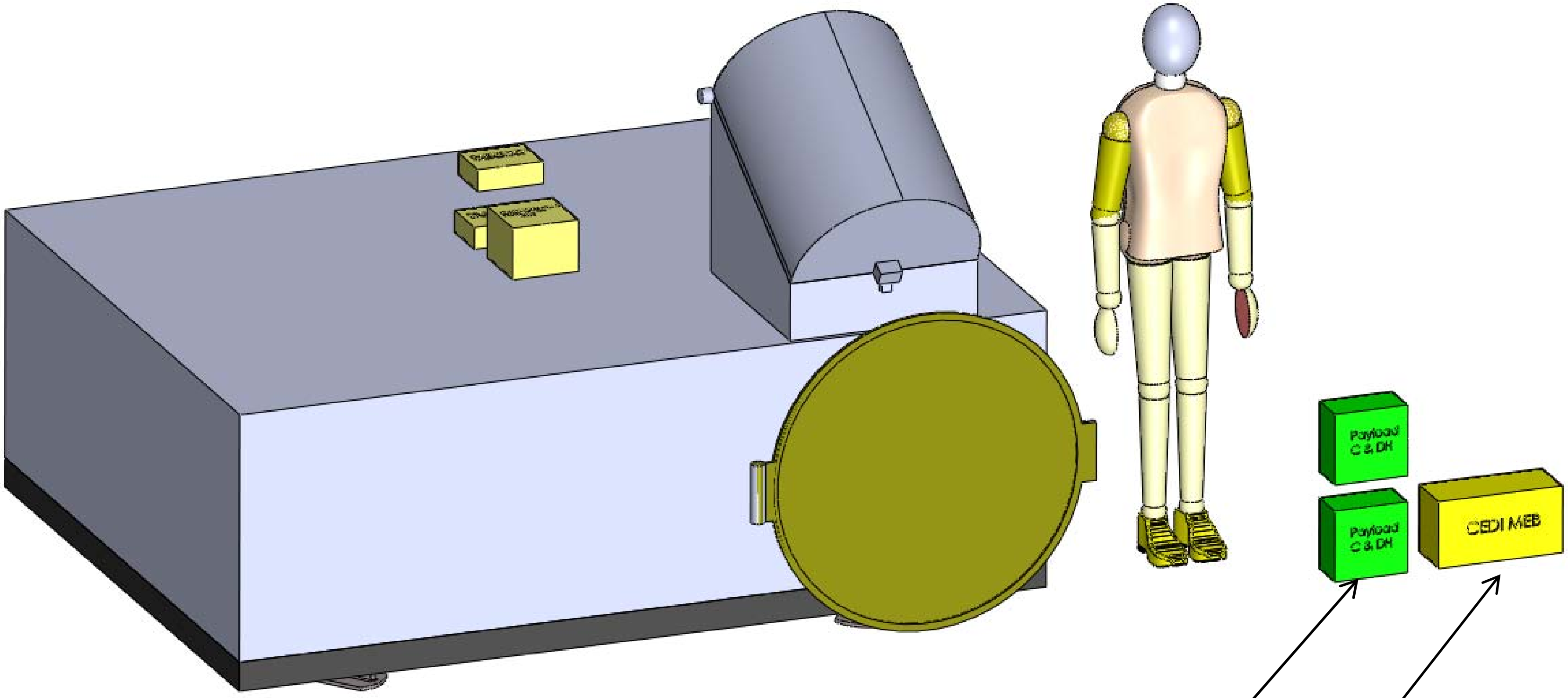


GEO-CAPE in Atlas 5 Fairing

Note: spacecraft configuration shown is from previous GEO-MDI study and has not been (re)evaluated for GEO-CAPE (recommended Stewart platform at the spacecraft interface is not shown)



Relative Size



Payload C&DH
2 ea.

CEDI MEB
(internally redundant)

Conclusions

- **The SWIR, Band1, and Band 2 optics are mounted to 3 individual "mini" optical benches which are in turn mounted to the instrument optical bench. This approach was driven by I&T considerations. An alternate approach would eliminate the "mini" benches and mount the SWIR, Band1 and Band2 optics directly to the instrument optical bench.**
- **There are no technology risks associated with the mechanical or structural design (i.e. standard materials as well as fabrication and assembly techniques for primary and secondary structure).**
- **The detector readout digitizer boxes are required to be in close proximity to the detectors. There are two options: mount the electronics to the optical benches or to the instrument enclosure. For optical bench thermal distortion considerations, these heat sources were located on the outside of the instrument.**
- **The CEDI instrument could be rotated 180 degrees so that the scan mirror assembly and calibration assembly are near the S/C mounting interface. This will lower the CG, but it is not clear how significant the change would be. FOV's will also need to be considered when positioning the CEDI on the S/C.**
- **A strong back approach to mounting CEDI is still required for the "CEDI only" configuration because the current optical design dictates the orientation of CEDI with respect to the S/C.**

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Electromechanical

January 29, 2010

Overview

- **Scan Mirror**
  - Used to direct sensor path to various ground POIs and to diffuser for calibration
- **Aperture Door**
  - Used to shield internal optics from stray light and contamination
- **Calibration Assembly**
  - Used to calibrate instrument optics
  - Composed of the Cover Mechanism and the Diffuser Plate Select Mechanism

Scan Mirror Mechanism
Design Assumptions

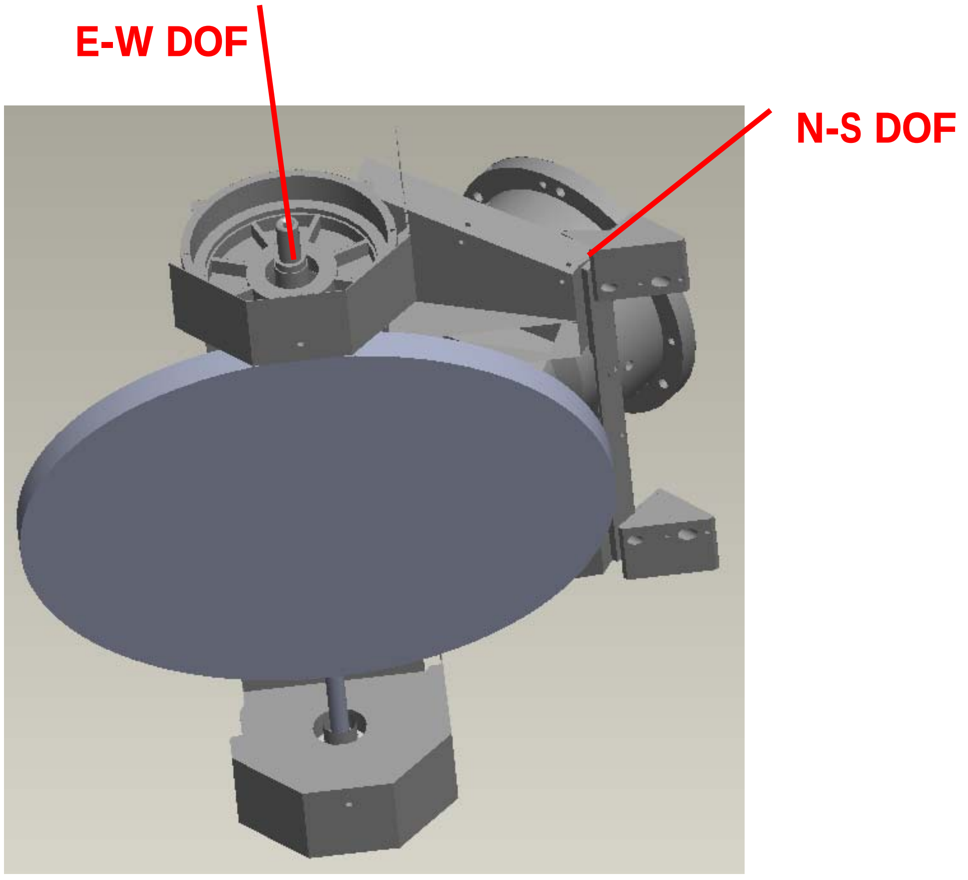
- **2 Degrees of Freedom (DOF)**

- **Range of motion**
  - Optical sensors need to see…
    - View of Earth from 50N – 45S, 30W – 160W during science operations
    - Direct view of diffuser during solar calibration
    - Moon at 1^0 off of Earth disk through science aperture (during lunar calibration)
  - The actuator requirements are therefore…
    - N-S DOF: -10.2^0 to $+90^0$
    - E-W DOF: -10.2^0 to $+10.2^0$

- **Motion**
  - E-W DOF: step over 1.1 arc-sec and settle in <250 ms, repeat once per second
  - N-S DOF: slew between scan boxes
    - No motion requirements defined

- **Image Stability**
  - Goal of 0.5 arc-sec (0.5 arc-sec on N-S DOF, 0.25 arc-sec on E-W DOF)

Scan Mirror Mechanism
Proposed Solution

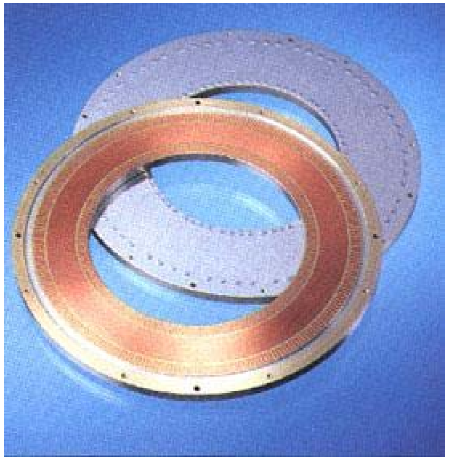


Scan Mirror Mechanism
Proposed Solution

- **Limited Angle Torque Motor**
  - No commutation
  - Very smooth torque curve (no torque ripple)
  - Low electrical time constant
  - Direct drive, no transmission issues
  - Redundant windings
  - Tend to be slightly larger than commutating equivalent
  - Flight heritage
  - Need linear amplifier and programmable motion controller

http://aeroflex.com/ams/motion/datasheets/motion-motors-lat.pdf

- **Inductosyn Transducer**
  - High accuracy (<±0.5 arc-sec)
    - Dependant on electronics accuracy
  - High resolution
  - Flight heritage



http://www.ruhle.com/absolute_rotary_transducer.htm

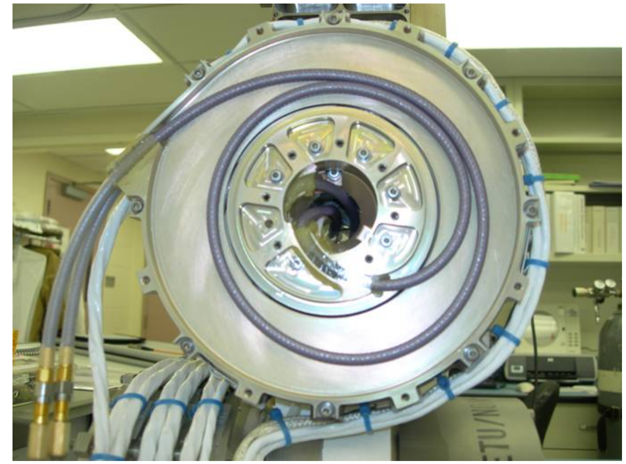
Scan Mirror Mechanism

Proposed Solution

- **Implementation based on GEO-MDI report written in 2008**
  - Controller requires input from accelerometer and angular rate gyro
  - Requires that dampers (passive stewart platform) are placed between S/C and instrument for vibration isolation
- **Control system corrects for various types of disturbances**
  - With no disturbances, settling time is <200 ms
  - Low frequency disturbances (~40rad/sec) are adequately attenuated by feed-forward controller
  - Higher frequency disturbances (~100/sec) are not significantly attenuated by feed-forward controller
- **Report uses system that is not identical to CEDI. The report uses…**
  - Larger mirror
  - Larger motor
  - Smaller step size (1.4 arc-sec, CEDI is 1.1 arc-sec)
- **More intensive and detailed study is needed to determine whether or not this control scheme can be successfully implemented for CEDI.**

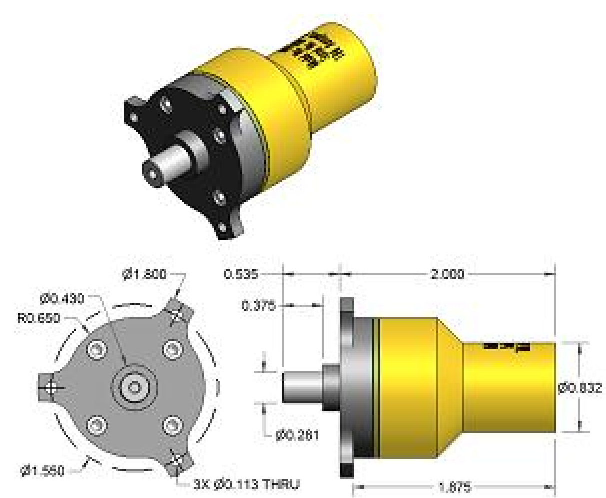
Scan Mirror Mechanism
Proposed Solution

- **Cable Wrap**
  - Protects E-W Actuator cables from fatigue



Example cable wrap assembly

- **Pin Puller**
  - SMA type actuator
  - Acts as launch lock
  - One for each DOF
  - Redundant activation circuit
  - Highly reliable mechanism
  - Much less power draw than fail-safe brakes



Pin Puller (http://www.tiniaerospace.com)

Scan Mirror Mechanism

Summary

- **Power**
  - 9.5W for 120ms; twice at beginning of mission for launch locks
  - 13W continuous during data scanning
- **Mass**
  - About 31kg total for mechanisms, structural elements, and mirror
- **Volume**
  - Envelope about 1.1m cube
- **TRL**
  - Individual hardware components are level 5
  - Implementation of control scheme may be level 3 or 4. More investigation is needed.
- **Other**
  - Actuator will need to be very stiff, smooth, well balanced, and well characterized in order to achieve intended accuracy and stability

Aperture Door Mechanism

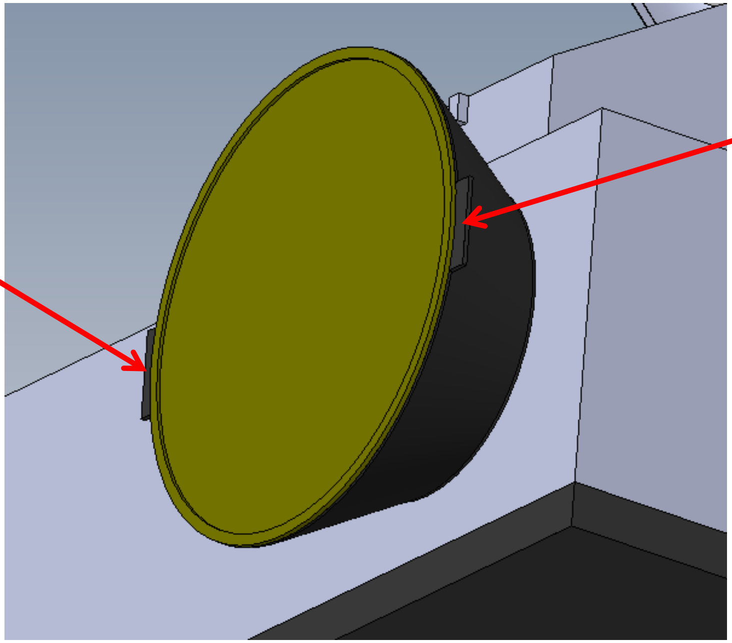
Design Assumptions

- Door must be rigid for launch
- Door must be opened to take science data
- Door must be closed during optical calibration and launch

Aperture Door Mechanism

Proposed Solution

Actuator

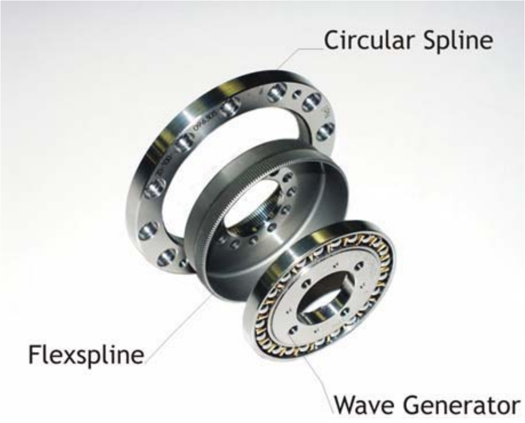


Launch Lock

Aperture Door Mechanism

Proposed Solution

- **Actuator**
  - Brushless DC motor
    - Smooth, precise motion
    - Redundant windings
  - Harmonic Drive
    - Provides transmission ratio so that motor can be smaller and less massive
    - Very reliable
  - Absolute Encoder
    - Provides knowledge of angle. Knowledge will not be affected by power failure.
    - 12-bit BEI sensor
    - Redundant read heads



BEI Absolute Encoder

- **Pin Puller**
  - Keeps aperture door locked closed (
  - TiNi Aerospace model P5-STD
  - Redundant activation circuit
  - Highly reliable mechanism

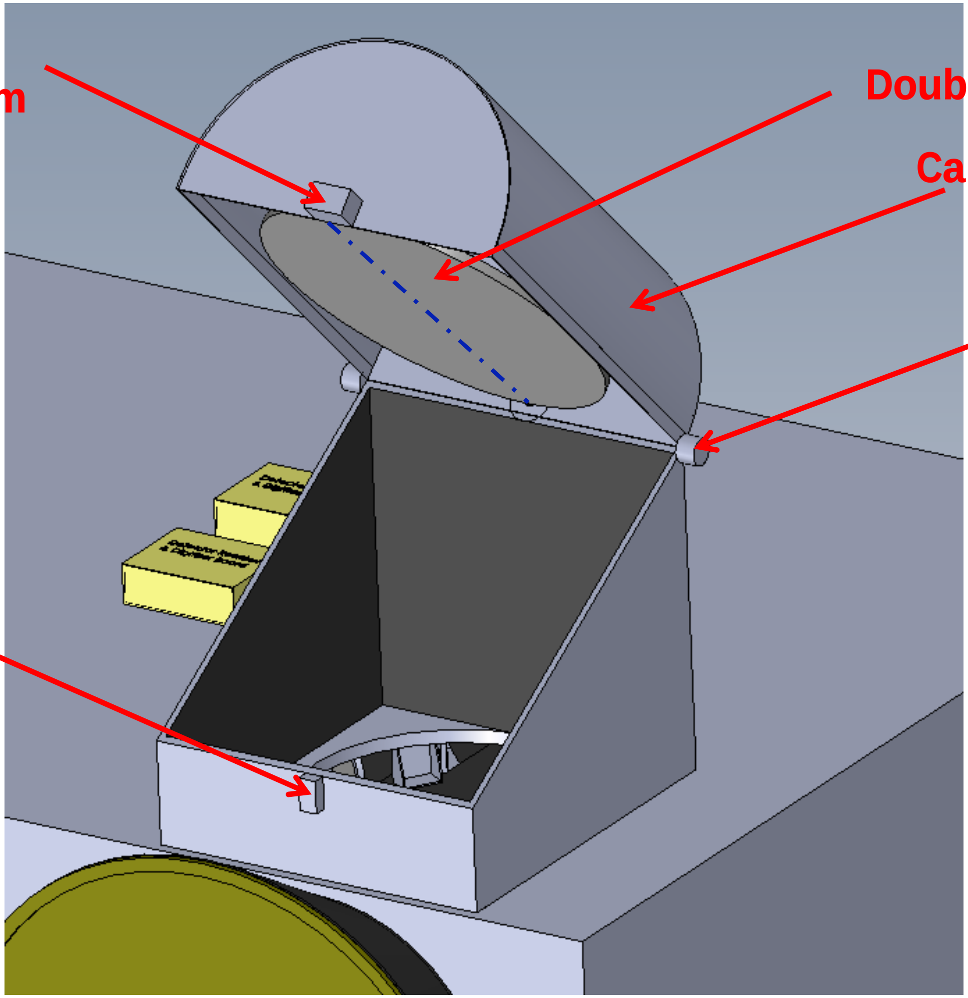
Aperture Door Mechanism
Summary

- **Power**
  - 9.5W for 120ms; once at beginning of mission for launch lock
  - 3W for opening and closing of door; once per week for calibration
- **Mass**
  - About 4kg, including aperture door
- **TRL 5**
- **Other**
  - Entire mechanism could easily incorporate ejection system so that aperture can ejected if it becomes stuck closed

Calibration Assembly Mechanism
Design Assumptions

- **Mechanism must switch between each side of a double-sided diffuser**
- **Mechanism must protect diffusers from sunlight when not in use, and must prevent stray light from entering instrument optics during science mode**
- **Diffuser orientation must be repeatable within ±3.4 arc-min**
  - Cosine of reflection angle must not deviate by more than 0.1%

Calibration Assembly Mechanism
Proposed Solution



Calibration Assembly Mechanism
Proposed Solution

- **Brushless DC Motor**
  - Provides smooth, precise motion
  - Redundant windings
- **Harmonic Drive**
  - Gears down motor to provide smoother operation, allow for smaller motor
  - Must use gear ratio larger than 50:1 and size larger than 20 in order to maintain positional accuracy
  - Very reliable
- **Absolute Encoder**
  - 13-bit BEI sensor needed to control positional accuracy
- **Pin Puller**
  - Used as launch lock; one time use
  - TiNi Aerospace model P5-STD
  - Redundant activation circuit
  - Highly reliable mechanism

Diffuser Assembly Mechanism
Summary

- **Power**
  - About 3W once a week for calibration
  - Motors will not be actuated simultaneously
- **Mass**
  - About 27 kg, including actuators, diffusers, and cover
- **Volume**
  - In closed configuration, protrudes about 0.9m out from instrument
- **TRL 5**
  - Low TRL is partially due to size of diffuser

Conclusions

- **Aperture Door mechanism is fairly straight forward**
- **Calibration Assembly mechanism is also fairly straight forward, but could be further optimized to reduce volume and/or mass**
- **Scan Mirror mechanism is on the edge of what is achievable. A separate, intensive study should be performed to determine feasability**

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

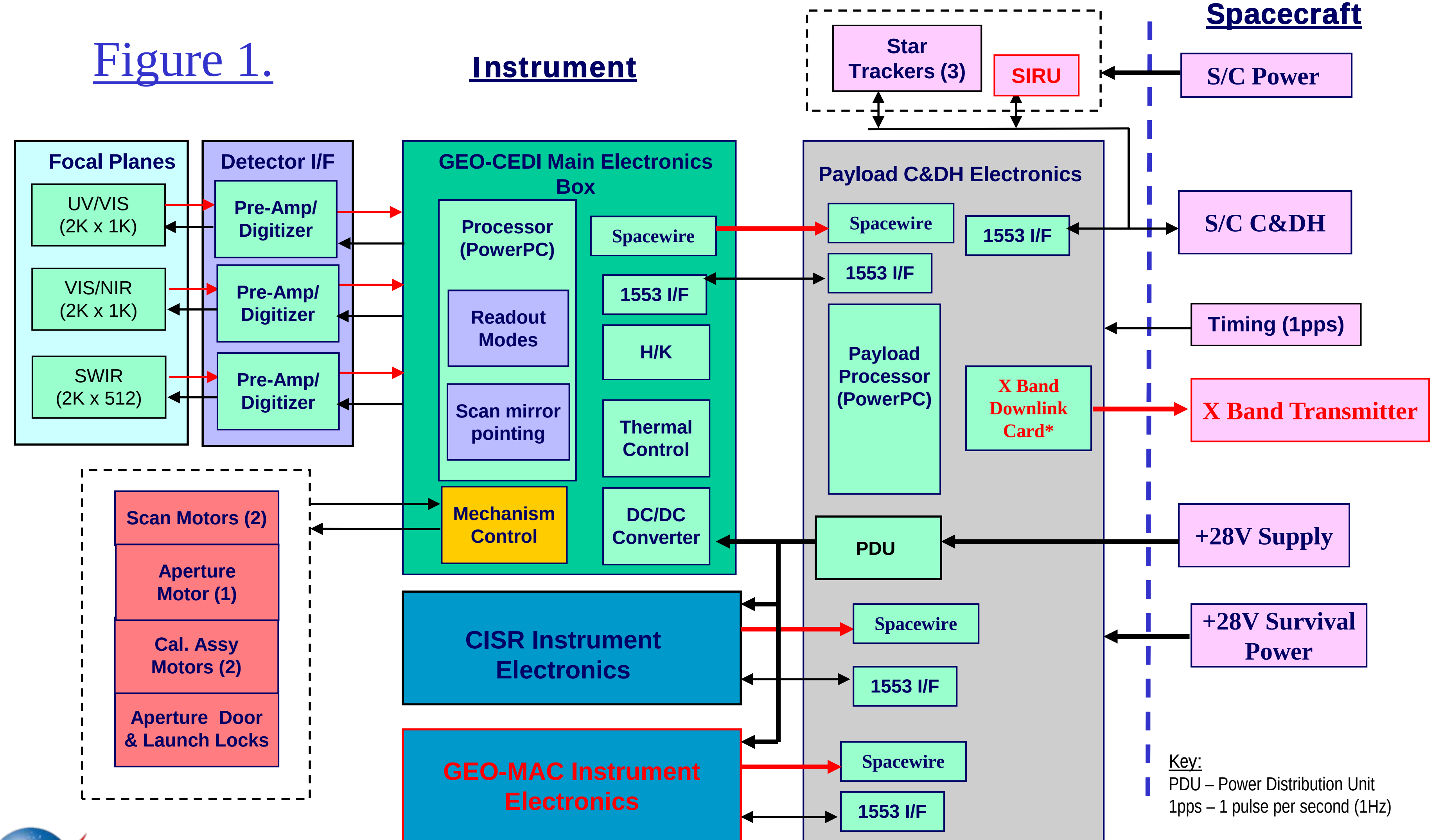
Electrical Design

29 January 2010

GEO CAPE Instrument Suite Block Diagram

Instrument Synthesis & Analysis Laboratory

Figure 1.



Payload C&DH Box Diagram

Instrument Synthesis & Analysis Laboratory

Note: The payload C&DH function/capability recommended for GEO MDI in 2006 was not evaluated for the 2010 CEDI design, as we did not evaluate the processing or control of the other 2 GEO CAPE instruments (CISR & GEO MAC). If CEDI is manifested alone, the Payload C&DH box is not required as long as the S/C provides the X-Band downlink capability

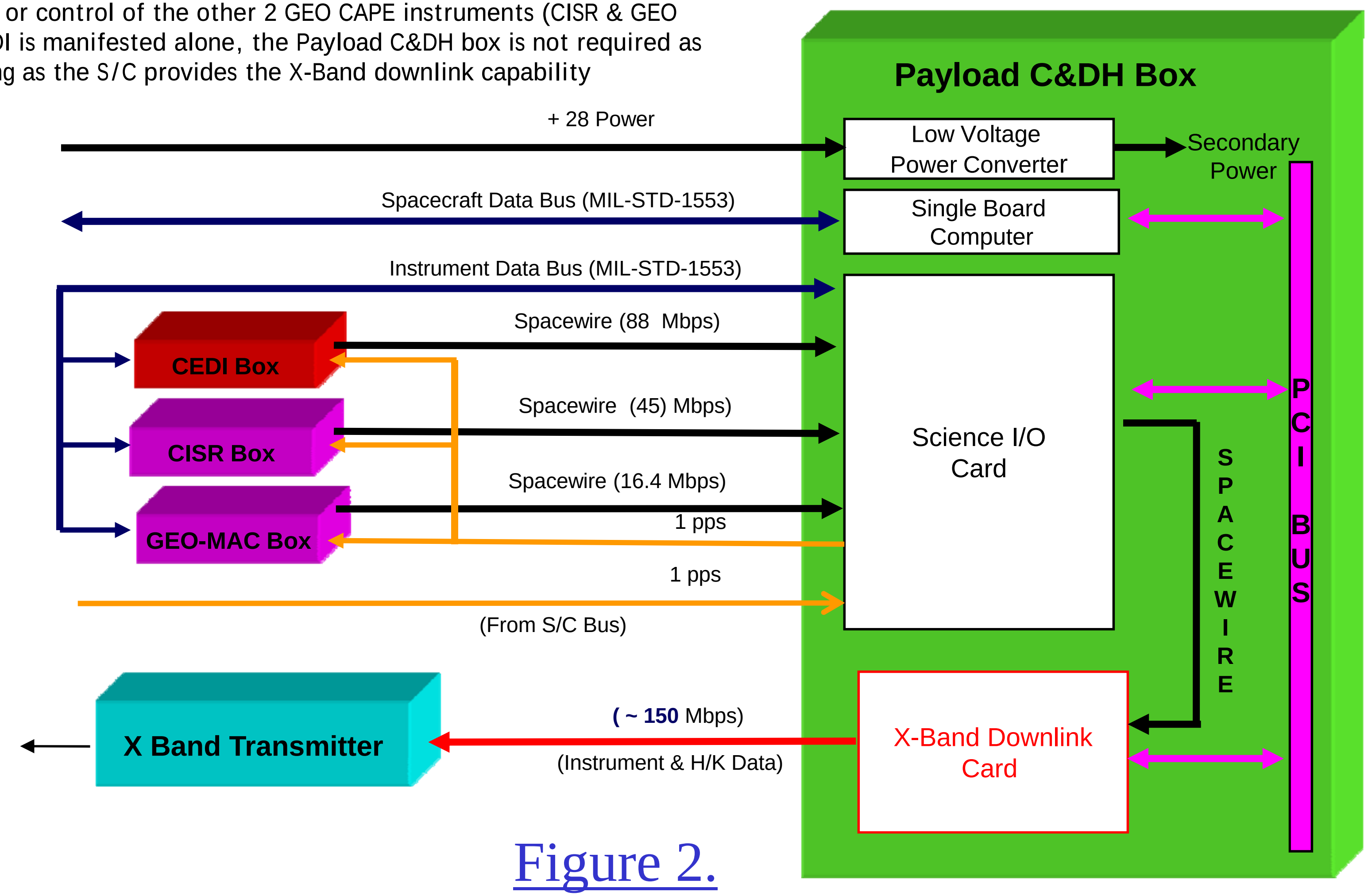
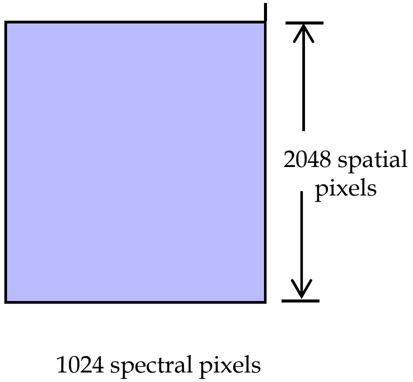


Figure 2.

UV/VIS & VIS/NIR Detector Assumptions & Data Rate

Array (1Kx2K)pix



Detector Assumptions

- 2 (1Kx2K) **Custom Detector Arrays**, **8 outputs each** (ie. 0.25Mpix each output)
- Readout [1K (spectral) x 2K (spatial)] pix.
- Frame transfer readout capability.

Readout Assumptions

- 4 frames @ 200mSec integration period
-14 bits/pix resolution

Data Rate Calculations

⇒ ADC Sample rate = 0.25Mpix/0.2sec = 1.25Mpix/sec (ie. 1.25MHz sample rate)
⇒ Readout Rate ~ (1.25Mpix/sec)x14bits/pix ~ **17.5Mbps** each output
⇒ **140Mbps** total for all 8 outputs

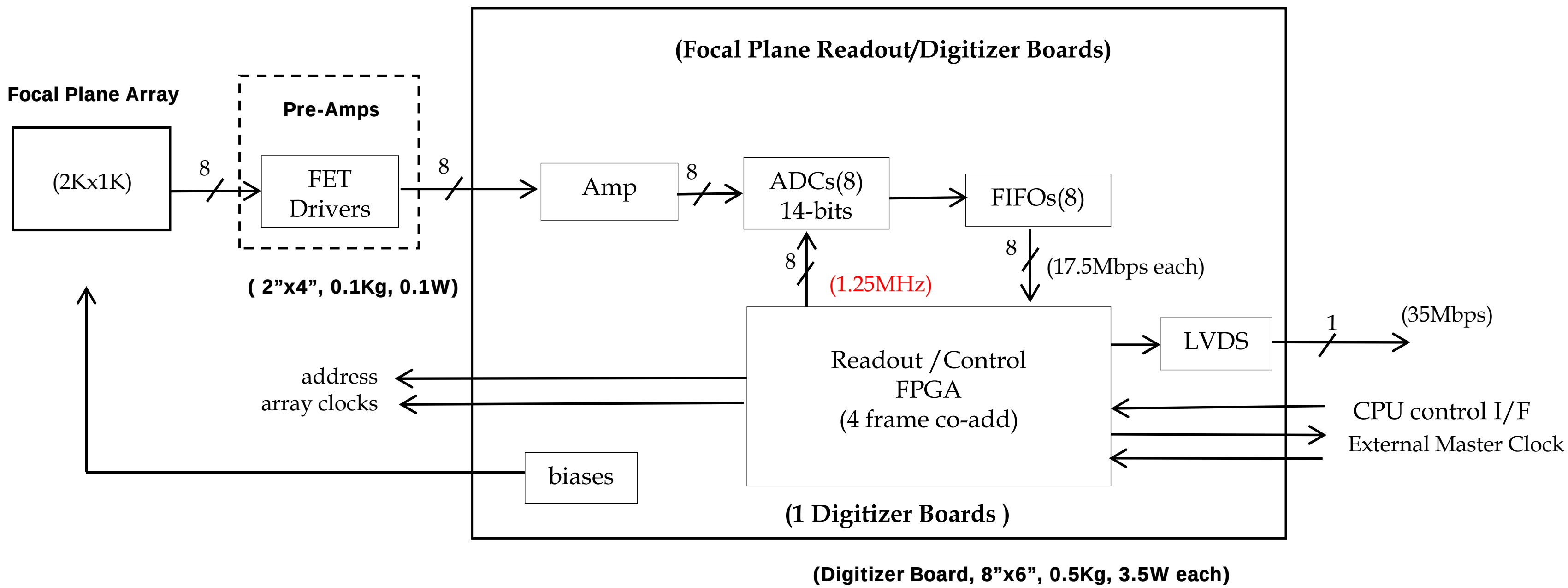
Co-Add 4 frames

⇒ Data Rate ~ 140Mbps/4 ~ **35Mpbs** each detector

⇒**70Mbps** total for both detectors

UV/VIS & VIS/NIR Focal Plane Readout

Detector Readout & Digitizer Board



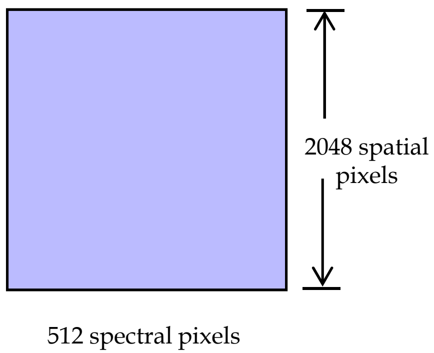
Box Estimate: (23 x 18 x 7.5)cm, 2Kg (ie. 1Kg board total + 1Kg Housing), 3.5W

Note:
This digitizer box is internally redundant (ie. Two boards for the UV/VIS box and Two boards for the VIS/NIR box).

Figure 3.

SWIR Detector Assumptions & Data Rate

Array (512x2K)pix



Detector Assumptions

- 1 (2Kx2K) Detector Array, **32 outputs** (ie. 0.125Mpix each output)
- Readout [512 (spectral) x 2K (spatial)] pix.
- Frame transfer readout capability.

Readout Assumptions

- 64 frames @ 12.5mSec integration period
- **(64 x 512)pixels each of 32 outputs** (ie. 0.0328Mpix each output)
- 14 bits/pix resolution

Data Rate Calculations

⇒ ADC Sample rate = 0.0328Mpix/0.0125sec = 2.62Mpix/sec (ie. 2.62MHz sample rate)

⇒ Readout Rate ~ (2.62Mpix/sec)x14bits/pix ~ **36.7Mbps** each output

⇒ **1.17Gbps** total **for all 32 outputs**

Co-Add 64frames

⇒Data Rate ~ 1.17Gbps/64 ~ **18.4Mpbs** for downlink

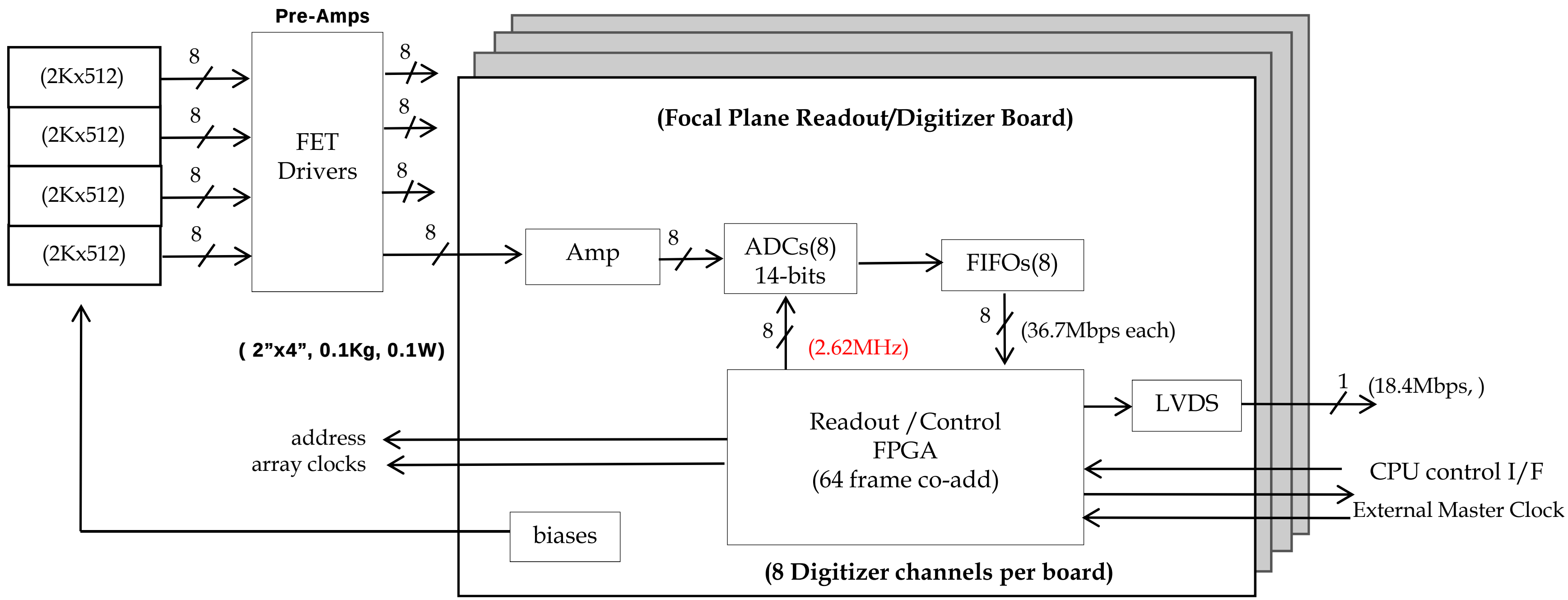
⇒ CEDI Instrument Total: ~ (70+18.4)Mbps ~ 88.4Mbps

SWIR Focal Plane Readout

Instrument Synthesis & Analysis Laboratory

Detector Readout & Digitizer Board

Focal Plane Array



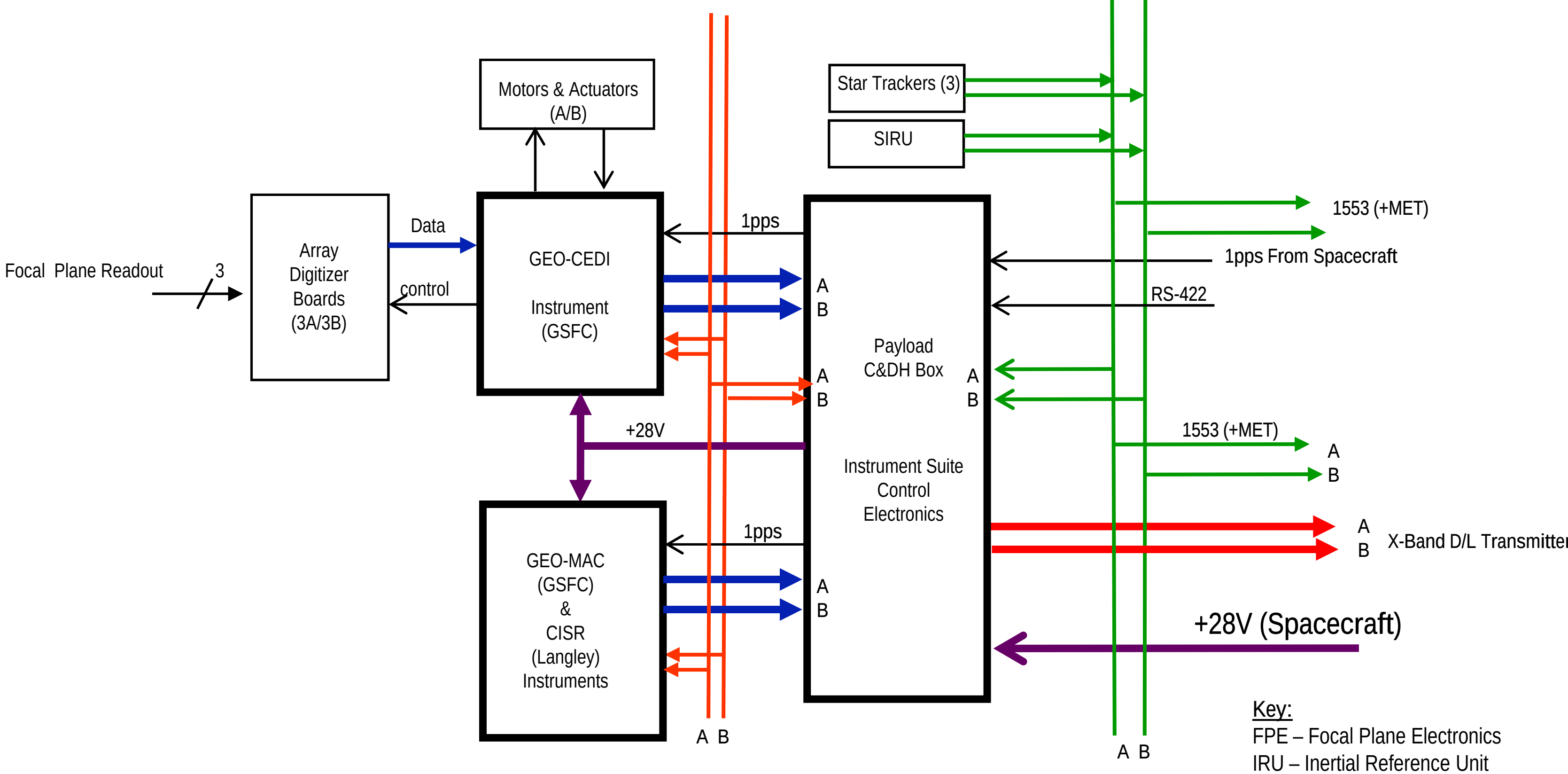
(4 Digitizer Boards, 8"x6", 0.5Kg, 3.5W each)

Box Estimate: (23 x 18 x 23)cm, 6.6Kg (ie. 4.8Kg board total with backplane + 1.8Kg Housing), 14.0W

Note:
This digitizer box is internally redundant (ie. 4 prime boards with 8 channels each plus 4 cold standby boards).

Figure 4.

Electrical Components & Redundancy



Key:
FPE – Focal Plane Electronics
IRU – Inertial Reference Unit
ST – Star Tracker
MET – Mission Elapsed Time (time tag)
1pps – 1 pulse per second (1Hz)
LVDS – Low Voltage Differential Signaling

Figure 5.

CEDI Main Electronics Box Power Dissipation

Power Supply Load

	Average	
E-Box External Load	**Power (W)**	
1 of 2 Scan Motors	13.0	
Detectors	0.4	
Digitizers	21.0	
Heaters	3.0	
E-Box External Dissipation:	**37.4**	
E-Box Boards (Internal Load)	**Power (W)**	
Control Board	**8.5**	
Thermal Control	**4.0**	
Scan Motor Drive Board -1	**5.0**	
Scan Motor Drive Board -2	**5.0**	
Cal Assembly Motor Drive Board	**5.0**	
Aperture Motor Drive Board	**5.0**	
LVPC (Power Supply) Board	**~**	
Circuit Boards Dissipation:	**32.5**	
E-Box Power Board Load	69.9	(ie. External + E-Box boards)
Converter % Efficiency	75	(%)
E-Box Power Converter Dissipation:	**23.3**	{ie. (load/eff) - load}
E-Box Dissipation:	**55.8**	(ie. E-Box boards + Converter)
Spacecraft Load	**Power (W)**	
Additional Load:	***0.0***	
EE Total:	**93.2**	S/C Power Bus Rerquirement

CEDI Main Electronics Box Summary

Circuit Boards (8"x6"), 0.5Kg each	QTY	Avg. PWR (Watts)	Mass (Kg)	Description	% Analog/ Digital
Instrument Processor Board	1A/1B	8.5	1.0	PowerPC750	5/90
Thermal Control	1A/1B	4.0	1.0	3 circuits each	70/25
Scan Motor Control (2DOF)	2A/2B	5.0	2.0		70/25
Aperture Motor Control	1A/1B	5.0	1.0		70/25
Cal. Assembly Motor Control	1A/1B	5.0	1.0	Output switched between 2 motors	70/25
Housekeeping	1A/1B	5.0	1.0	Temp, Voltages, Currents	70/25
* Power Converter (Assume 75% efficiency)	1A/1B	23.3	1.0		90/5
Backplane	1A/1B	-	1.4		0/0
Housing	1	-	2.9		
Total	**-**	**55.8**	**12.3**		

Box Estimate: (23 x 18 x 43)cm, ~ 55.8Watts, 12.3Kg (ie. 9.4Kg board total + 2.9Kg Housing)

Note:
This box is internally redundant (ie. 8 prime boards with backplane plus 8 redundant cold standby boards).

Payload C&DH Box Summary

Payload Interface Electronics Box Summary

Load (Assume 6U-220 Card size)	Avg. Power (Watts)	Mass (Kg)
Single Board Computer (SBC)	7	1.5
X-Band Downlink Card	5	0.9
C&DH Interface Card	3	0.9
Backplane + Stiffener	-	1.0
Power Distribution Unit (PDU)	10	1.8
Box Total:	**25**	**6.1**

Box Size: (10” X 9.6” x 5.5”) @ 8.1Kg (ie. 6.1Kg board & modules total + 2Kg Housing)

Note: The payload C&DH function/capability recommended for GEO MDI in 2006 was not evaluated for the 2010 CEDI design, as we did not evaluate the processing or control of the other 2 GEO CAPE instruments (CISR & GEO MAC). The power estimates shown here are the same as those presented in the GEO MDI 2006 study. Two C&DH boxes are recommended for reliability; previously only one box was costed.

GEO-CEDI Power Requirement Summary

Spacecraft Power Bus Requirement

Load	Avg. Power (Watts)
~~Payload C&DH Box~~	~~25.0~~
CEDI Main Electronics Box	55.8
Detectors, FET Drivers & Digitizer Boards (3)	21.0
Scan Mirror Motors (1 of 2 ON at a time)	13.0
Heaters (actively controlled)	3.0
Heaters (thermost controlled)	300.0
CEDI Only Instrument Total:	**392.0**

Note:

- Total does not include ACS components or Payload C&DH Box, which are powered by the Spacecraft
- Total does not include survival heater power (222 to 317W) to the CEDI instrument which is also powered directly by the spacecraft
- The CEDI detector heater control power (actively controlled) is shown here as 3W, and is estimated in the thermal model to be between 4.5W (orbit average) and 6.4W (peak)
- The CEDI operating heater power (thermostat controlled) is shown here as 300W, and is estimated in the thermal model to be between 250W (orbit average) and 375W (peak)
- The CEDI instrument will require the X-band downlink interface in the Payload C&DH box; this interface could be placed in either the CEDI MEB or the Spacecraft if the Payload C&DH box is not flown

Harness Mass Estimates

Harness Definition	Qty	Avg. Length Each (M)	Mass (Kg)	Description
CEDI MEB to Payload C&DH Box	1A/1B	1.0	1.0	LVDS, 1553, Power, bi-level (1pps)
CEDI MEB to detector Heaters	3A/3B	3.0	0.7	power
CEDI MEB to Operational Heaters	1A/1B	3.0	1.2	power
CEDI MEB to Motors	5A/5B	4.0	2.5	Analog Drive , Digital position
CEDI MEB to Launch Locks	5A/5B	4.0	1.3	Switched power
CEDI MEB to Digitizer Boxes	3A/3B	3.0	2.3	Spacewire (LVDS)
Digitizer Boxes to Detector Arrays/Drivers	3A/3B	0.3	0.2	Analog/Digital
MEB to TEC harness	3A/3B	3.0	0.7	
Total	**-**	**-**	**9.9**	

Issues / Conclusion

- No low TRL items or concerns. All TRLs are > 6.
- Baseline design assumed 200mSec integration period for the UV/VIS & VIS/NIR detectors and a pixel readout rate of 1.25Mhz (versus spec limit of 5MHz). Therefore, it is possible to reduce the integration period to 100mSec and increasue the pixel readout rate to 2.5MHz if desireable.
- Revised Baseline design now assumes 12.5mSec integration for the SWIR detector and a pixel readout rate of 2.6MHz which is allows 64 frame co-add, thereby improving the dynamic range. Initial baseline assumed 25mSec integration period and a 5MHz readout which is at the specification limit (not good design practice).
- Baseline design is best estimate of actual mass, power, and volume (ie. No margins or contingency were added).

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Final Presentation ~

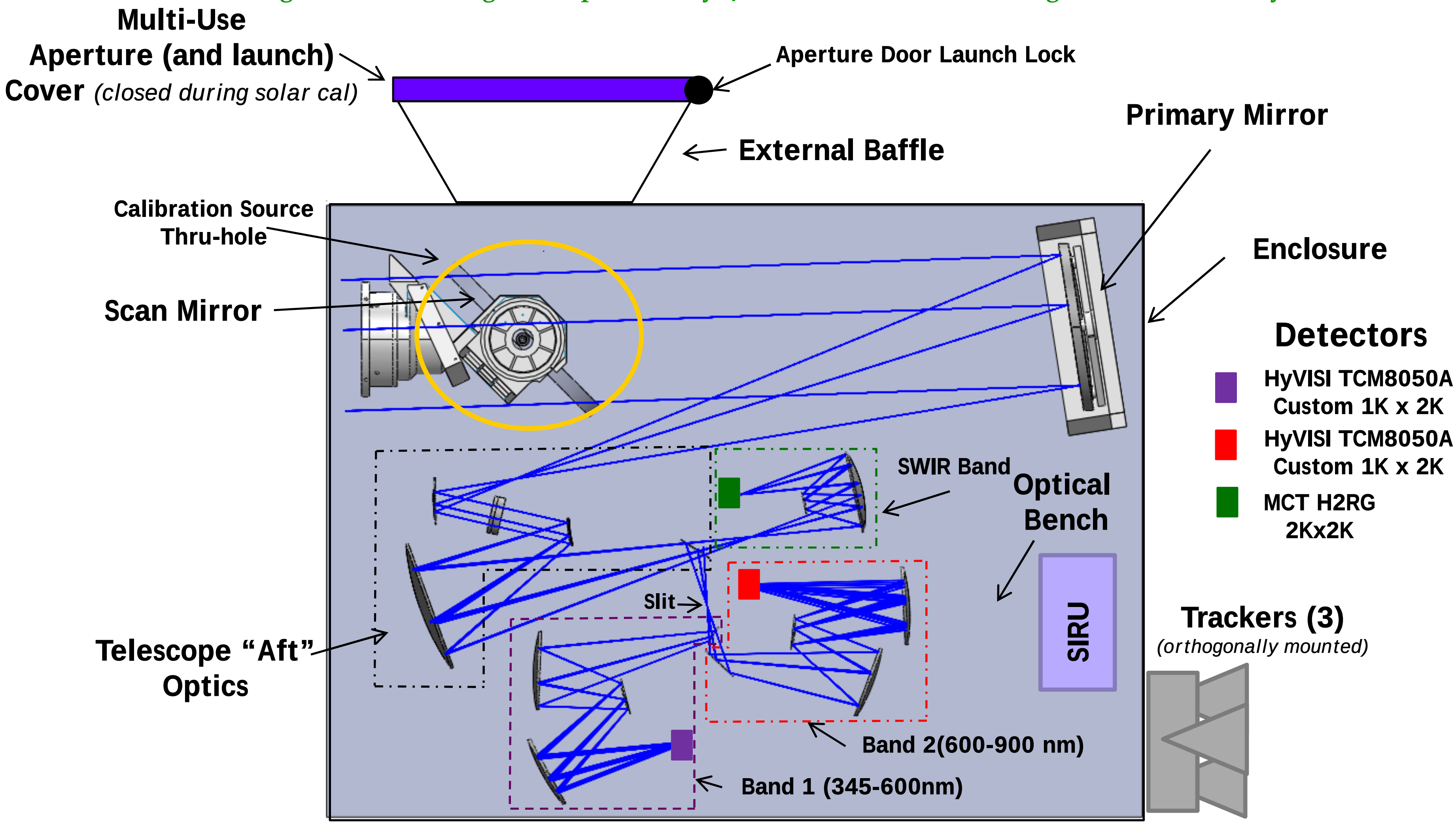
Flight Software

January29, 2010

Introduction

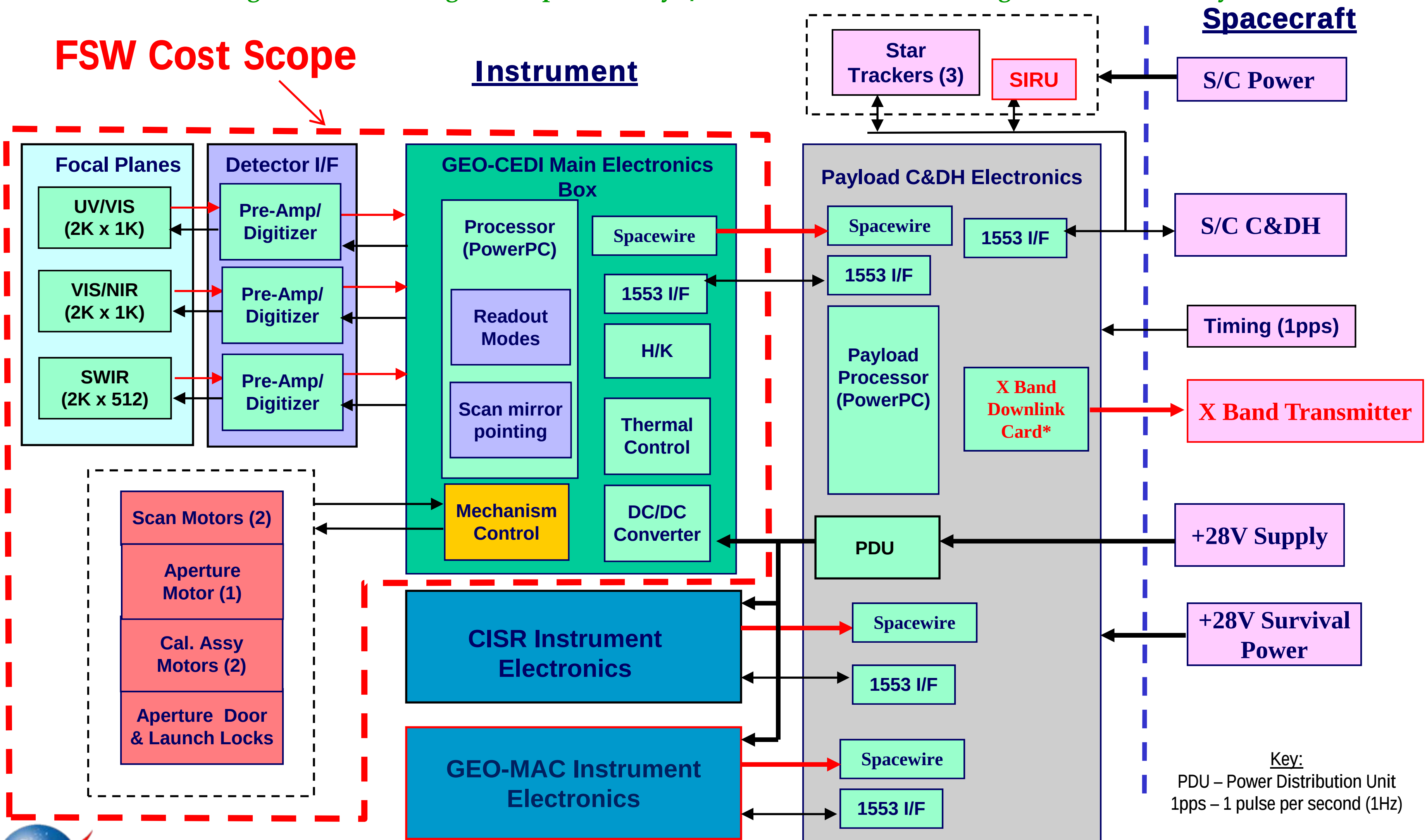
- **Functional Diagrams**
- **Block Diagrams**
- **Flight Software Requirements**
- **Conceptual Architecture**
- **Concerns and Future Investigation**

Coastal Ecosystem Dynamics Imager (CEDI) Block Diagram



GEO CAPE Electrical Block Diagram

Integrated Design Capability / Instrument Design Laboratory



CEDI Driving Computations

Computation	Responsible Component
Image Processing - Co-adding - Look-up Table Correction - Bias Subtraction - *Gain Table Correction* - *Band Averaging*	Pre-Amp Digitizer contains FGPA based control and processing of pixel data –see electrical presentation
Precision Instrument Attitude Determination - Read a suite of Gyros, Accelerometers, Star Trackers mounted on optical bench - 10Hz to 100Hz attitude determination	Main Computer
High Rate Scan Mirror Control - > 1KHz feedback control loop	Embedded Controller on Scan Motor Mechanism Boards

Flight Software Requirements

- **Requirements**
  - Mode Control: configuration of integration times and pixel/frame processing performed in digitizer
    - Earth View Mode
    - Solar Calibration Mode
    - Lunar Calibration Mode
    - Dark Space Calibration Mode
    - LED Flood Mode
    - Diagnostic Mode (raw data)
    - Manual Target Mode
  - Attitude Determination (< 100Hz)
  - Mechanism Control
    - Scan Motors (Scan Mirror)
    - Aperture Motor
    - Diffuser Motor
  - Packetization and Science Buffer Management
    - Certain modes may require data to be buffered and streamed to the spacecraft at a lower data rate
  - Instrument Command and Configuration
    - Pass through mechanism commands
    - Real-time command processing
  - Thermal Control
  - Housekeeping

- **Not Requirements**
  - Stored Command Processing
  - Compression

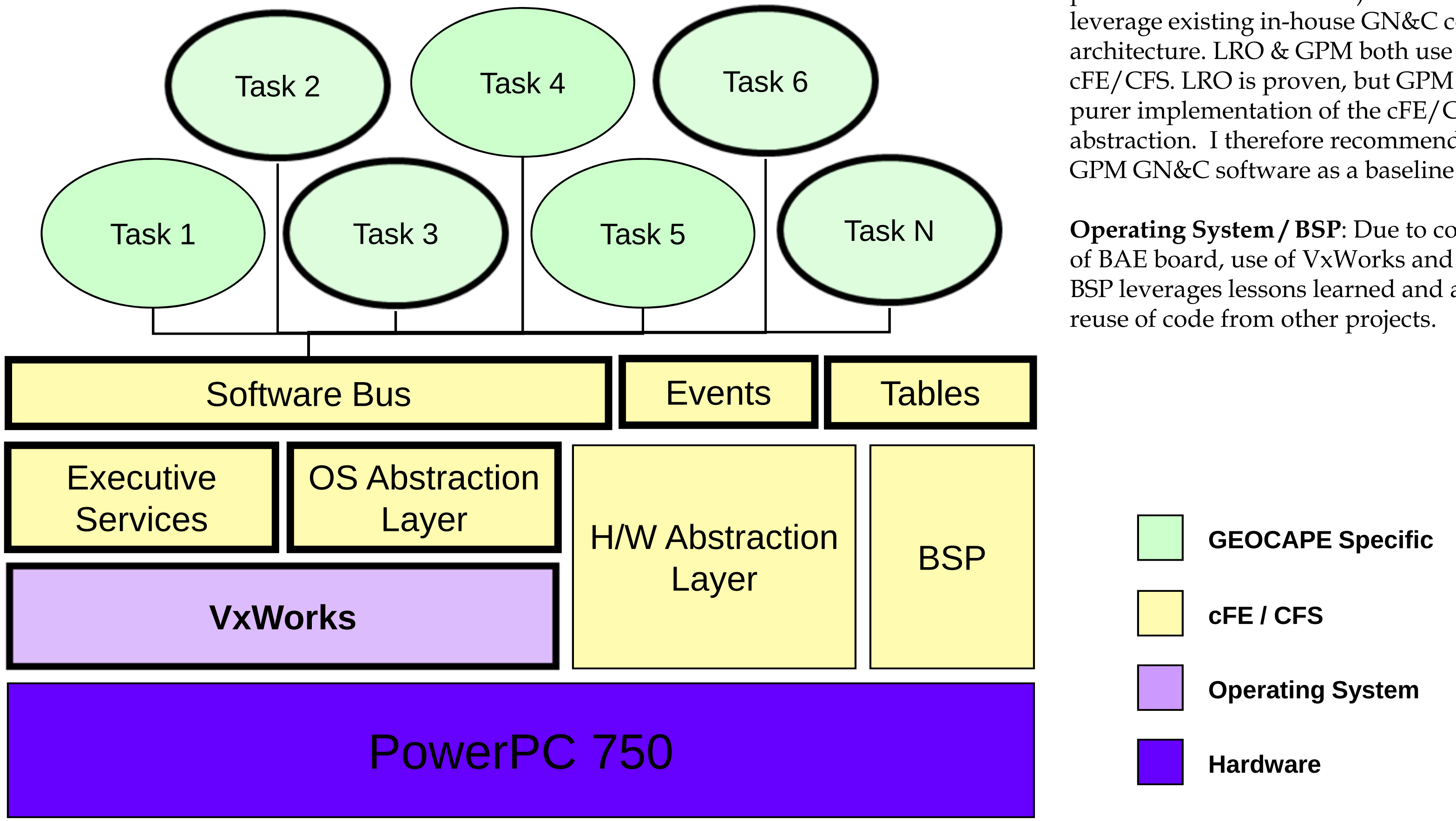
- **Interfaces**
  - 1553 command and housekeeping spacecraft interface
  - 1553 ACS interface
  - 1PPS from spacecraft
  - Spacewire science interface
  - TBD (cPCI?) interface to mechanism and housekeeping boards
  - LVDS (Spacewire?) pre-amp/digitizer science interface
  - Serial (422?) pre-amp/digitizer control interface

- **Derived**
  - Diagnostics
  - Bootstrap
  - Software Management

What These Requirements Mean

- **The attitude determination requirement, if near 100Hz is SIGNIFICANT.**
  - Assume typical S/C ACS is 1% of CPU per 1Hz of processing
  - If 100Hz is needed, it would consume 100% of 133MHz BAE Rad750 and other (future) alternatives would need to be explored
- **High bandwidth mechanism control loop**
  - In order to preserve determinism, processing should be handled in a dedicated embedded processor resident on mechanism board
- **There are no Fault Detection & Correction (FDC) requirements**
  - If you can keep it this way, the better you are!
  - Once you take on the responsibility of looking at the data you are collecting and making decisions based off of it you promote the class of your software and significantly increase cost
  - Try to hold off on this decision and see if the autonomous monitoring requirements can be handled by a Spacecraft TM system
- **Human in the Loop Control**
  - Your current system design has all important decisions going through a human – there are no autonomous decisions being made on-board
  - Keeping it this way will keep costs down. It is my experience that having the on-board processing make autonomous decisions based on the data it sees can increase costs by a factor of two.

GEOCAPE Layer Architecture

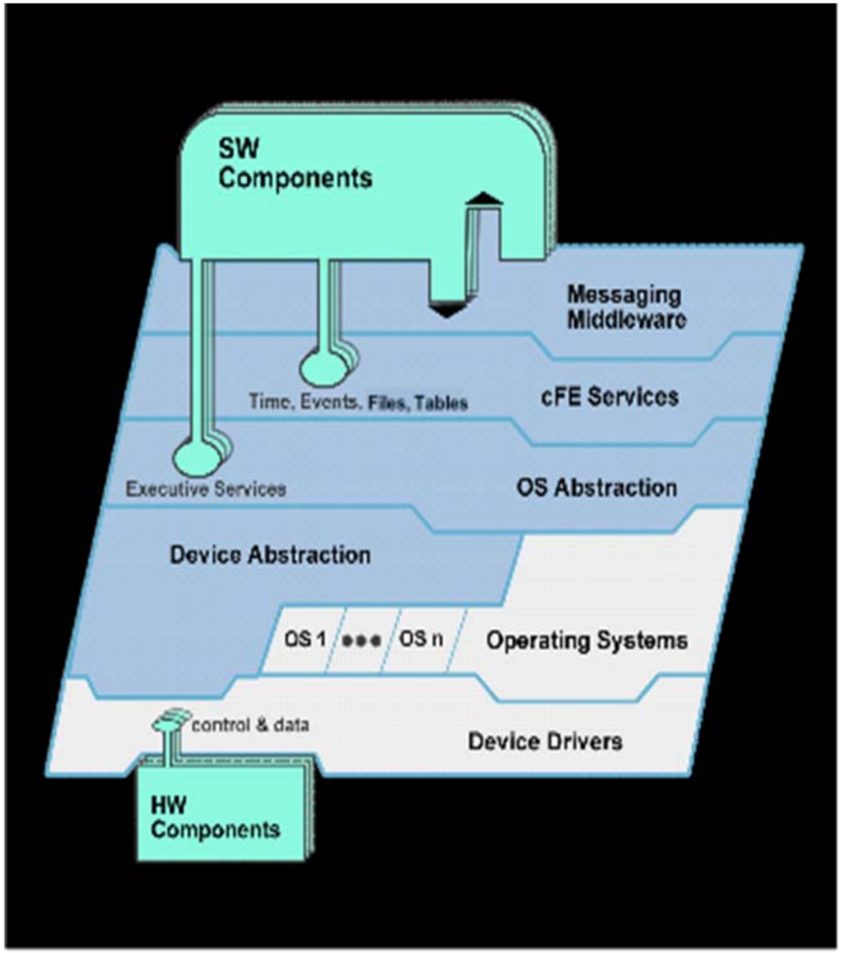


Software Base: Use cFE/CFS (GSFC 582 product: C&DH executive) in order to leverage existing in-house GN&C code and architecture. LRO & GPM both use the cFE/CFS. LRO is proven, but GPM uses a purer implementation of the cFE/CFS abstraction. I therefore recommend using the GPM GN&C software as a baseline.

Operating System / BSP: Due to complexity of BAE board, use of VxWorks and provided BSP leverages lessons learned and allows reuse of code from other projects.

cFE - Core Flight Executive

- **582 developed and maintained product.**
- **cFE Overview**
  - Provides component based architecture
  - Event notification
  - Publish/Subscribe messaging mechanism (software bus)
  - Time services
  - Operating system abstraction
  - Execution context (task creation, initialization)
- **Advantages**
  - True code reuse - verified and previously flown code that doesn't change
  - Plug 'n play applications available
- **Disadvantages**
  - Increased complexity
  - 3rd party dependency



Concerns & Future Investigation

- **100Hz Attitude Determination may exceed existing proven technologies**
  - The current trend for achieving higher processing power is fabricating devices in radiation tolerant but not hard devices. This works well for on-board science data processing when upsets can be handled by reprocessing the data. But it is much harder for computations that are a part of control systems. If an upset is not tolerable, voting may be required and complexity increases dramatically.
  - There are higher throughput commercial SBCs on the market
    - Maxwell SCS750 – disaster on GLORY
    - AiTech S950 – designed for LEO
    - BRE440
    - Maestro / Maestro-Lite – single chip data processing solution developed by NRO, tremendous processing power (x100 anything above), difficult logistical path

- **Compression**
  - If compression is needed you will need either dedicated hardware or a separate processing board.

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Electro-Optics

January 29, 2010

Changes from last MDI Study

- Ground scene IFOV resolution from (250m x 250m) to (375m x 375m)
- Instrument swath FOV was 500km and is now 750km
- FOR probably the same as before or larger to accommodate the solar and lunar observations.
- Most UV – NIR FWHM bandwidths went from 12nm to 15nm
- Entrance aperture reduced from 0.66m dia. to 0.5m dia.
- UV to NIR sampling $\Delta\lambda$ (FWHM) went from 0.8nm to 0.5nm
- SWIR sampling $\Delta\lambda$ (FWHM) went from fixed filters with full width to 2.5nm
  - Grating dispersion for all there bands
- Revised Ltyp and Lmax values
- Revised Dynamic range for unsaturated operation
- Maximum well capacities were 'refined' (as well as read noise, dark signal, …)
  - Silicon = 1 million pe's
  - MCT = 100k pe's
- Balanced SNR performance with saturation avoidance at full Dynamic range

Radiometry Model

- **Irradiance = W / m^2 - $\Delta\lambda_{um}$ (TOA = top of atmosphere)**
  - Used MODTRAN4 model output to compute Lunar performance
- **Radiance: L = W / m^2 - $\Delta\lambda_{um}$ - Ω_{ster}**
  - Ltyp and Lmax data provided by the CEDI science team
    - Lambertian surface scatter
    - Ltyp and Lmax surface reflectivity
    - Ltyp and Lmax Solar illumination angle (SZA = 70°)
- **Watts = Joules / sec**
- **Photon Energy = hc / λ = Joules / photon**
- **Watts / Photon Energy = photons / sec**
- **Radiance on detector (photons) = Ps**
- **$Ps = L * \tau_{sec} * A_m{}^2 * \Delta\lambda_{um} * \Omega_{ster} * eff$ - (eff = system Tx * det. QE)**
- **Noise = √ signal_pe's + dark_pe's + $read\_noise^2$ + $quant\_noise^2$**
- **$SNR_{pixel} = Ps_{pixel}$ / Noise**

$SNR_{final} = SNR_{pixel}$ * √ # of data points averaged

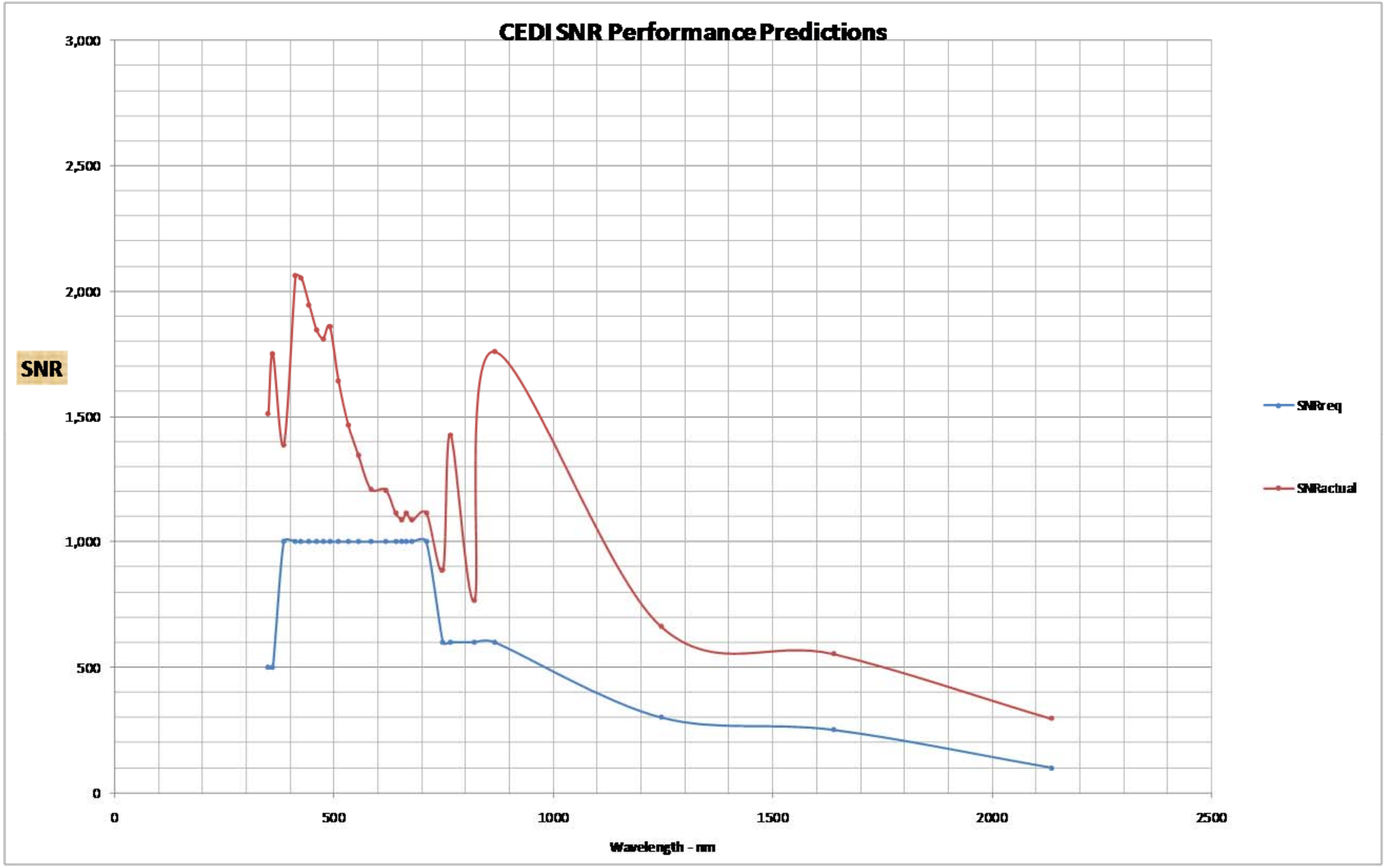
Radiometry Parameters

Lunar Distance - m	384,400,000		
Lunar radiius - m	3,476,000		
Orbit - m	35,786,000		
h*c - (J-m)	1.9864E-25		
Si – Δλ – um	0.00050		
SWIR – Δλ – um	0.00250		
Scene (sq) - m	375		
Pixel IFOV - rad	1.0479E-05	# lunar samples/dia.	
Lunar Scene (sq) - m	4,028	862.9	
Total Integ. τ - sec.	0.8		
UV/VIS Integ. τ - sec	0.4	2	2
VIS/NIR Integ. τ - sec	0.4	2	2
SWIR Integ. τ - sec	0.0173913	46	46
A/D Bits	14		
Si - Well Capacity	1.00E+06		
Dark Signal	1	1 e^-/sec @ 180K	
Quant. Noise	18		
Read Noise	100		
Si - $NOISE_{total}$	10,311		
MCT - Well Capacity	1.00E+05		
Dark Signal	100	100 e^-/sec @ 150K	
Quant. Noise	2		
Read Noise	20		
MCT - $Noise_{total}$	503		
Aperture (dia) - m	5.00E-01		
Aperture Area - m^2	1.96E-01		

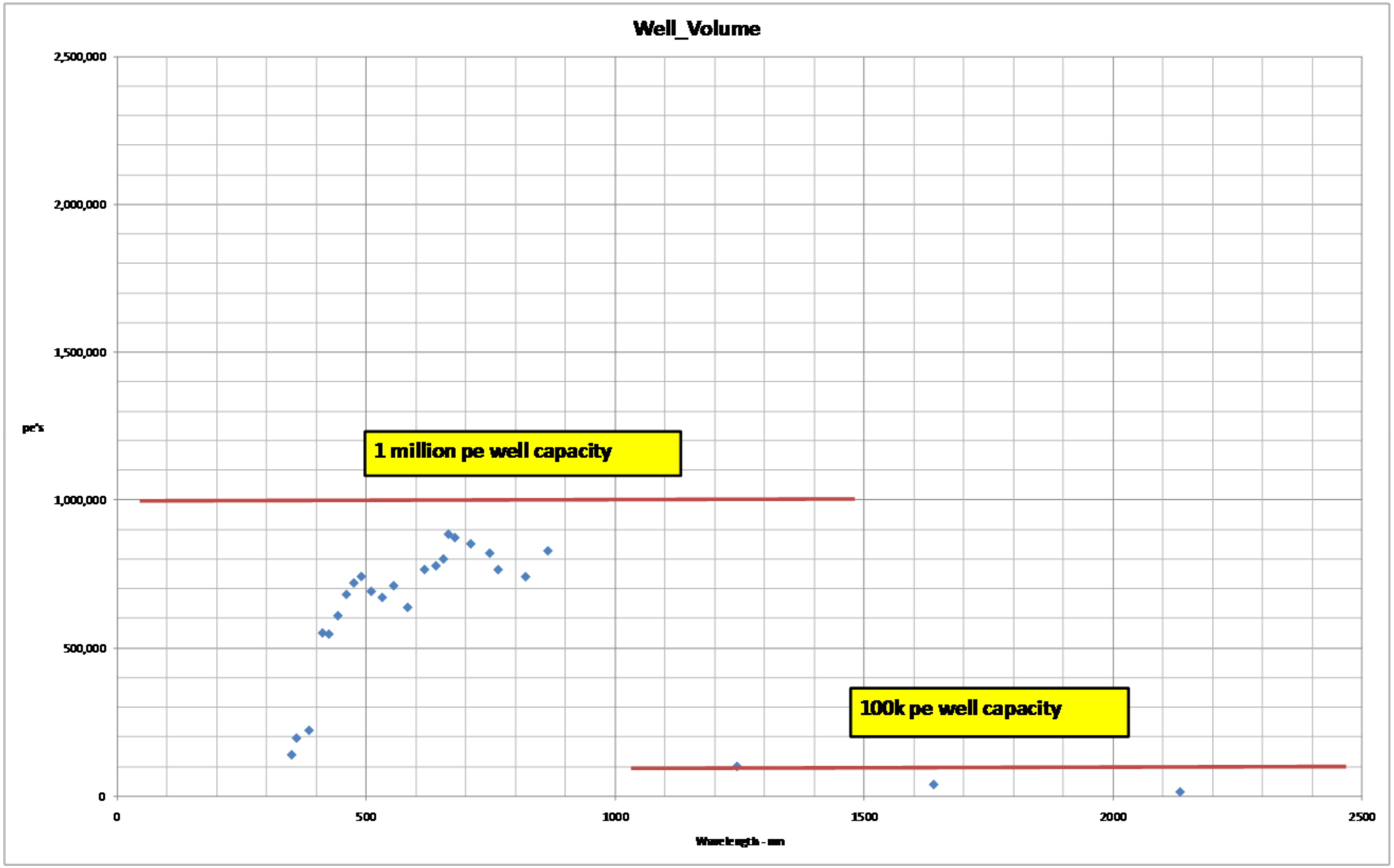
Radiometry Requirements & Results

λ_o - Bands	FWHM	W/m^2-Δλum-ster		Req'd	Well_Capacity	Averages	Ltyp	Lmax	eff		Req'd	Ltyp
nm	Δλ – nm	Ltyp	Lmax	Dynamic Range	Dynamic Range	Δλ	Well_Volume	Well_Volume	Opt. Tx	Det. QE	SNR_{req}	SNR_{actual}
350	15	39.26	117.5	2.99	21.49	60.00	46,538	139,247	0.24	0.65	500	1512
360	15	38.00	124.1	3.27	16.71	60.00	59,840	195,393	0.31	0.65	500	1750
385	10	32.16	125.7	3.91	17.65	40.00	56,656	221,513	0.31	0.68	1000	1385
412	10	41.77	198.7	4.76	8.65	40.00	115,662	550,095	0.43	0.72	1000	2061
425	10	40.63	193.1	4.75	8.70	40.00	114,935	546,085	0.42	0.73	1000	2054
443	10	37.51	219.1	5.84	9.61	40.00	104,106	608,151	0.39	0.74	1000	1947
460	10	33.14	238.9	7.21	10.60	40.00	94,319	679,962	0.38	0.75	1000	1844
475	10	30.25	238.3	7.88	10.96	40.00	91,250	718,621	0.39	0.75	1000	1811
490	10	29.25	226.4	7.74	10.45	40.00	95,675	740,472	0.41	0.75	1000	1859
510	10	24.23	218.8	9.03	13.08	40.00	76,441	690,354	0.38	0.75	1000	1641
532	10	20.09	214.8	10.69	15.96	40.00	62,645	669,884	0.36	0.75	1000	1467
555	10	16.11	212.2	13.17	18.57	40.00	53,862	709,431	0.37	0.75	1000	1345
583	10	14.56	205.9	14.14	22.22	40.00	45,007	636,418	0.33	0.74	1000	1210
617	10	11.25	192.1	17.07	22.34	40.00	44,758	764,026	0.33	0.9	1000	1206
640	10	9.39	186.1	19.82	25.53	40.00	39,177	776,529	0.33	0.91	1000	1114
655	10	8.33	176.6	21.20	26.51	40.00	37,718	799,554	0.35	0.91	1000	1088
665	10	7.83	176.9	22.59	25.58	40.00	39,087	882,988	0.38	0.91	1000	1112
678	10	7.37	171.3	23.24	26.66	40.00	37,510	871,697	0.38	0.91	1000	1085
710	15	5.36	161.4	30.10	35.39	60.00	28,256	850,622	0.38	0.9	1000	1114
748	10	4.89	147.5	30.17	36.82	40.00	27,156	819,179	0.38	0.9	600	887
765	40	3.62	141.9	39.18	51.32	160.00	19,486	763,516	0.36	0.9	600	1428
820	15	2.82	129.7	46.04	62.24	60.00	16,067	739,677	0.36	0.89	600	766
865	40	4.50	139.0	30.89	37.36	160.00	26,770	826,886	0.36	0.88	600	1758
1245	20	0.88	59.5	67.61	67.72	368.00	1,477	99,843	0.336	0.85	300	637
1640	40	0.29	17.6	60.69	156.00	736.00	641	38,903	0.336	0.85	250	514
2135	50	0.08	4.7	58.75	424.41	920.00	236	13,843	0.336	0.87	100	263

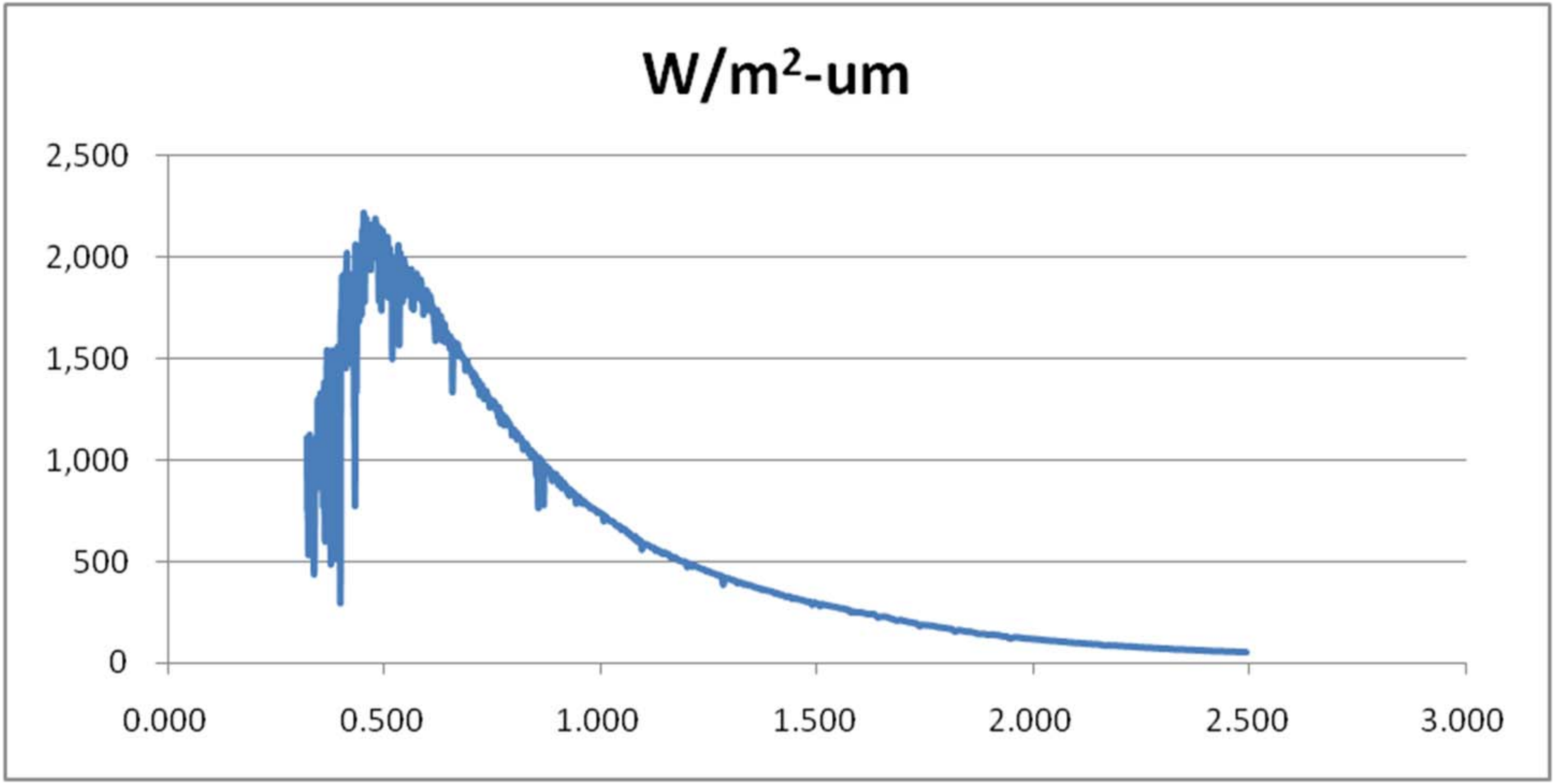
SNR Model Predictions



Detector Well Predicts



TOA Irradiance (MODTRAN4)



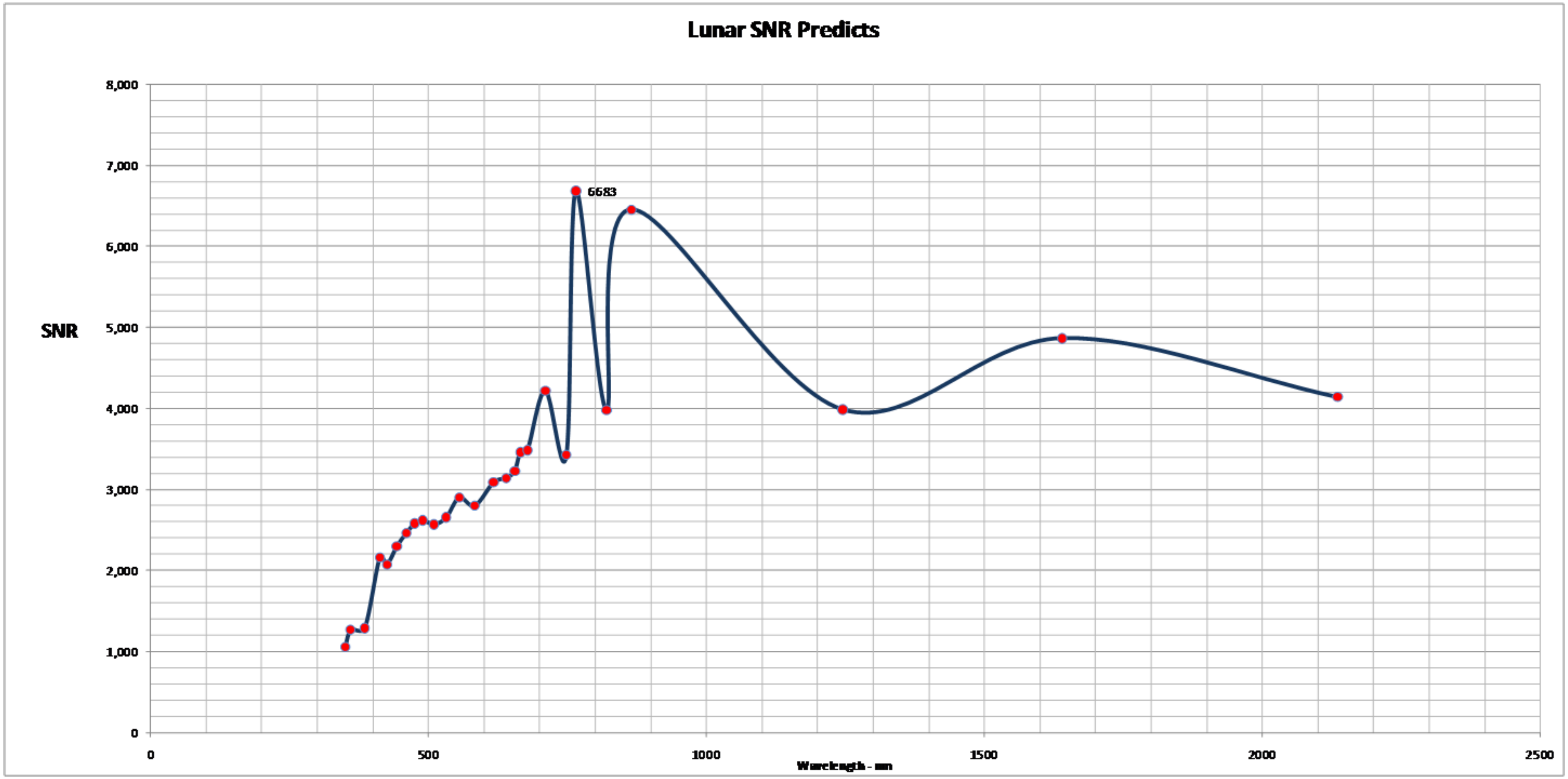
Wavelength - um

Lunar Radiometry and Performance

λ_o - Bands	FWHM	Lunar				
nm	$\Delta\lambda$ – nm	W/m^2-um		W/m2-$\Delta\lambda$um-ster		
		TOA – Irradiance	Lunar Reflectance	Lunar Radiance	Well Volume	SNR_{lunar}
350	15	1143	0.0600	21.84	25,884	1054
360	15	1038	0.0670	22.14	34,857	1270
385	10	1218	0.0730	28.30	49,859	1286
412	10	1786	0.0800	45.47	125,919	2158
425	10	1567	0.0830	41.40	117,103	2075
443	10	1887	0.0850	51.07	141,732	2299
460	10	2055	0.0865	56.59	161,043	2461
475	10	2085	0.0880	58.39	176,125	2580
490	10	1931	0.0900	55.30	180,898	2616
510	10	1929	0.0900	55.27	174,403	2566
532	10	1874	0.1000	59.66	186,017	2655
555	10	1876	0.1100	65.69	219,634	2897
583	10	1847	0.1130	66.43	205,322	2796
617	10	1688	0.1160	62.34	247,995	3086
640	10	1623	0.1190	61.46	256,428	3140
655	10	1539	0.1220	59.76	270,635	3229
665	10	1557	0.1250	61.95	309,248	3460
678	10	1512	0.1280	61.59	313,482	3484
710	15	1394	0.1310	58.11	306,327	4217
748	10	1280	0.1340	54.60	303,224	3425
765	40	1232	0.1370	53.72	289,059	6683
820	15	1077	0.1400	47.99	273,703	3978
865	40	952	0.1500	45.45	270,367	6455
1245	20	452	0.1800	25.92	62,532	3985
1640	40	231	0.2000	14.71	46,737	4866
2135	50	92	0.2200	6.44	27,257	4139

Lunar View SNR Predicts

Integrated Design Capability / Instrument Design Laboratory

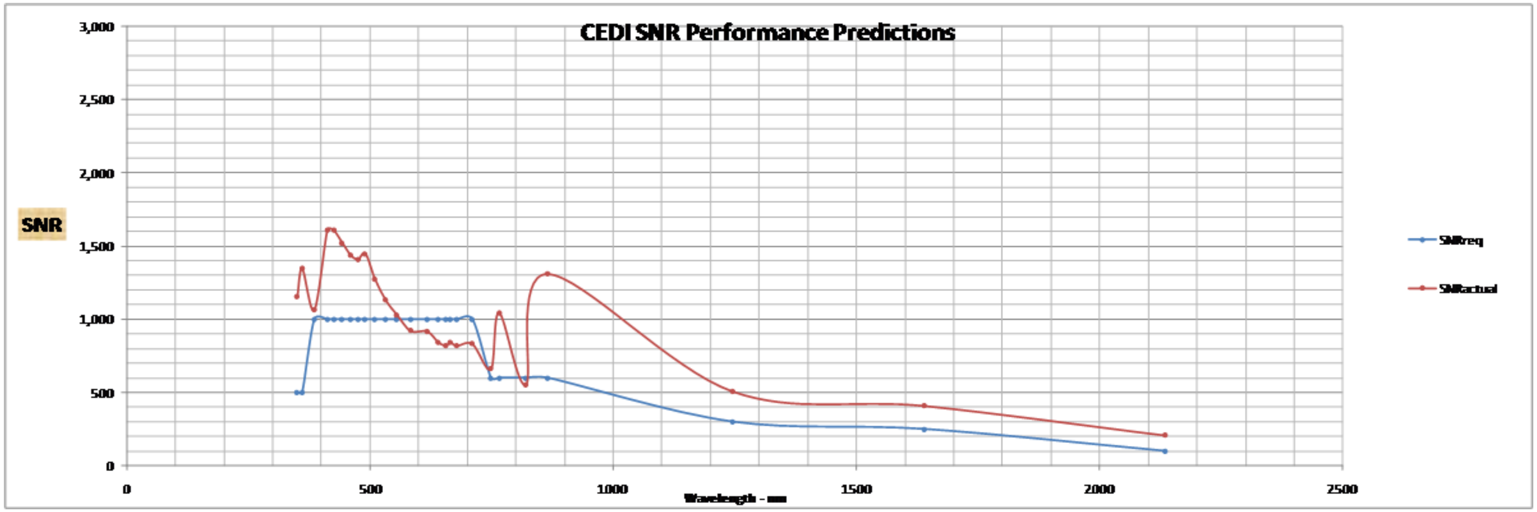


Design Drivers

- **Balancing Ltyp SNR performance while avoiding well saturation at Lmax.**
  - Spectral sampling interval
    - Silicon - 0.5nm
    - MCT – 2.5nm
  - Integration times
    - Multiple smaller integration period 'snapshots' to fill available integration window (0.8sec) allows for more dynamic radiance range with minimal impact on SNR performance
- **Balancing MCT well volume (100k pe's) with max. ROIC readout speed (5MHz)**
  - Solution = Rotate array 90° and read out 'column'(now rows) data along the spectral direction thus enabling the use of all available readout taps (32 vs. 8) to readout 2048 columns (now rows), but now you only need to readout the 256 spectral columns and 'dump' the rest of the elements.

Conclusions and Future Work

- **Current baseline requirements have been met with Aperture = 0.5m**
- **Minimum footprint - 350m**
  - Si - integration = 2 x 0.4 sec
  - MCT - integration ~ 46 x 17.4ms
  - SNR at 678nm = 997 vs. 1000 required
- **SNR performance with footprint = 300m with same spec's as above (chart below)**



- **With footprint = 300m, the aperture would need to increase to 0.585m to preserve SNR performance & radiance dynamic range (Ltyp to Lmax).**

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Thermal

January 29, 2008

Thermal Requirements

Component	Temperature (°C)	Temperature Stability (°C)	Survival Temperature (°C)
SWIR Detector	-123 (150 K)	±0.1	-243
Band 1 Detector	-60	±0.1	-243
Band 2 Detector	-60	±0.1	-243
Detector Electronics (Qty.: 3)†	-10 to 40	N/A	-20 to 50
Optics	23	±2	-30 to 50
Scan Mirror Assembly	23	±2	-30 to 50
Primary Mirror & Aft Optics	23	±2	-30 to 50
Diffuser Assembly	-40 to 50	N/A	-50 to 60
Star Tracker (Qty.: 3; 2 Op)‡	23	±0.2	-30 to 50
Gyro	-20 to 40	N/A	-30 to 50
Main Electronics Box†	-10 to 40	N/A	-20 to 50
Payload I/F Electronics†	-10 to 40	N/A	-20 to 50
Aperture Cover Mechanism†	-40 to 50	N/A	-50 to 60

†Not included in thermal control in 2006 study.

‡Qty.=2 in 2006 study

Power Dissipation

	Nominal Dissipation (W)
SWIR Detector	0.2
Band 1 Detector	0.2
Band 2 Detector	0.2
Detector Electronics (FET Drivers & Digitizer Boards (Qty: 3; all Operating)	Bands 1 & 2 are 3.5 W each; SWIR is 14 W
Scan Mirror Assembly	18 (75% duty cycle)
Star Trackers (Qty: 3; 2 Operating)	8 Each
SIRU/Gyro	22
Main Electronics Box	55.8
Payload C&DH Electronics (Qty,: 2; 1 Operating)	25

Detector Thermal Design Summary

- **Temperature limitation of thermoelectric cooler (TEC)**
  - Current technology limits coldest temperature to 160 K, due to material properties
- **Disadvantages of TEC (for use in flight)**
  - Reliability
  - Electrical power required
  - Power supply/electronics required
  - Radiator required for cooling hot side heat sink
- **Advantage of TEC is ground testing in ambient air**
- **Use TEC in ground testing in ambient air but passive cooling in thermal vacuum test and in flight**
- **Detector temperatures are cold biased and temperature stability is maintained by trim heaters and precision heater controllers**
- **Constant conductance heat pipes (ethane) thermally coupled detector cold fingers to radiators**
- **Short K1100 heat straps provide flexible linkages between heat pipes and detectors**

Optics, Electronics and ACS Component Operating Mode Thermal Design Summary

- **Optical Bench thermally isolated from payload deck**
- **Thermal coating for interior of optics/mirrors enclosure and optical bench in enclosure is Aeroglaze Z307 black paint**
- **Operating mode heater circuits on optics/mirrors enclosure and optical bench controlled to 23ºC±2ºC by mechanical thermostats**
  - Constant conductance heat pipes (CCHPs) embedded in optical bench ensure uniform temperature and minimize number of heater circuits
- **Operating mode heater circuits on diffuser mechanism assembly controlled to -37ºC±2ºC by mechanical thermostats**

Optics, Electronics and ACS Component Operating Mode Thermal Design Summary

- **Detector electronics thermally isolated from optics/mirrors enclosure and cooled by patch radiators**
- **MEB and Payload C&DH Electronics (location TBD) thermally isolated from spacecraft and cooled by radiators**
- **Star Trackers thermally isolated from optical bench, cooled by a radiator, and controlled to 23ºC±0.2ºC by temperature controllers provided by Electrical System**
- **Gyro outside thermally isolated from optical bench, cooled by a North radiator**

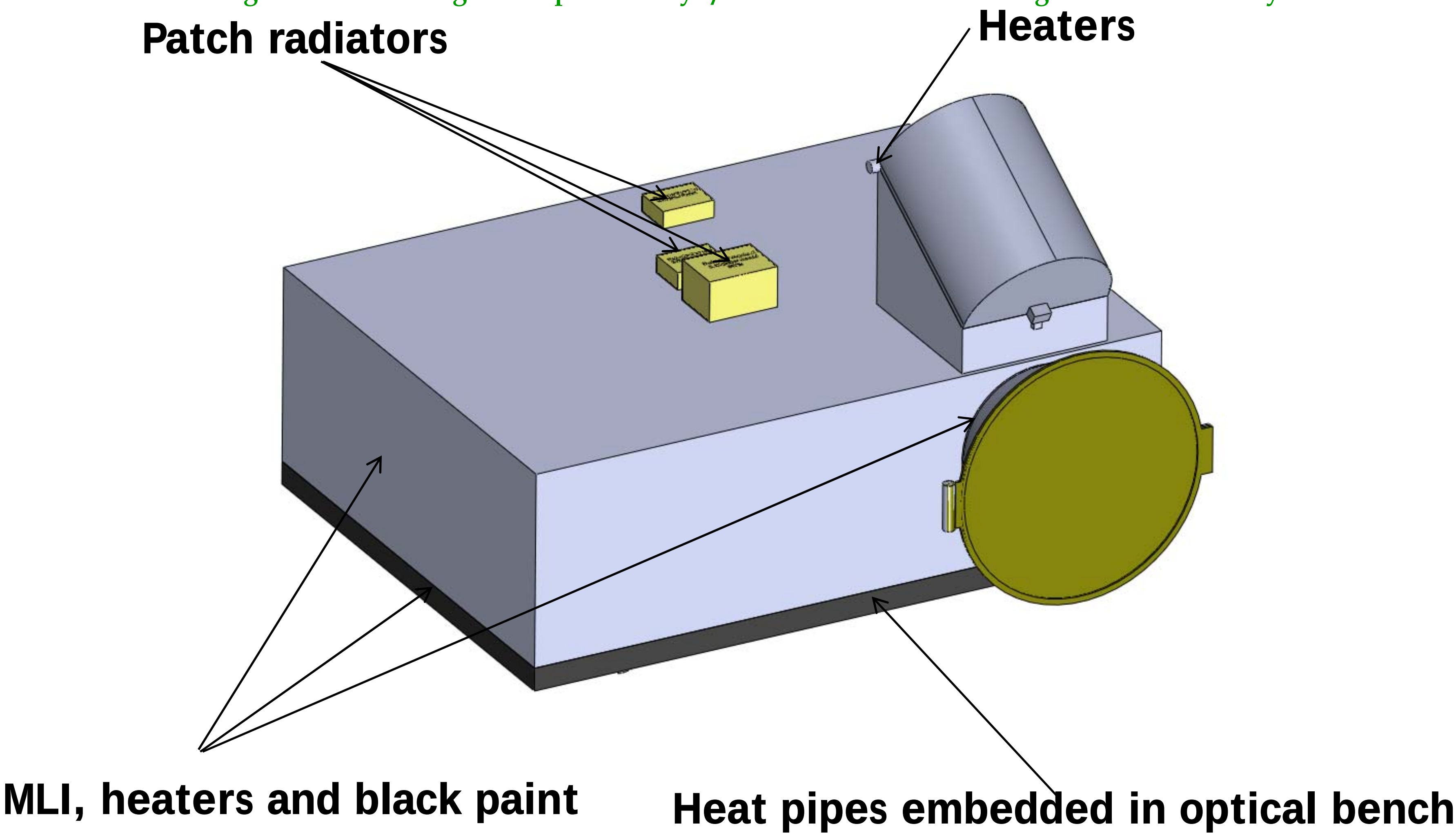
Survival Mode Thermal Design Summary

- **Survival heater circuits maintain**
  - Optics/mirrors enclosure and optical bench above -30ºC
  - Scan mirror assembly, diffusion mechanism assembly and aperture cover mechanism above -50ºC
  - Detector electronics, MEB and Payload C&DH Electronics above -20ºC
  - Star Trackers and gyro above -30ºC
  - Detectors above -243ºC

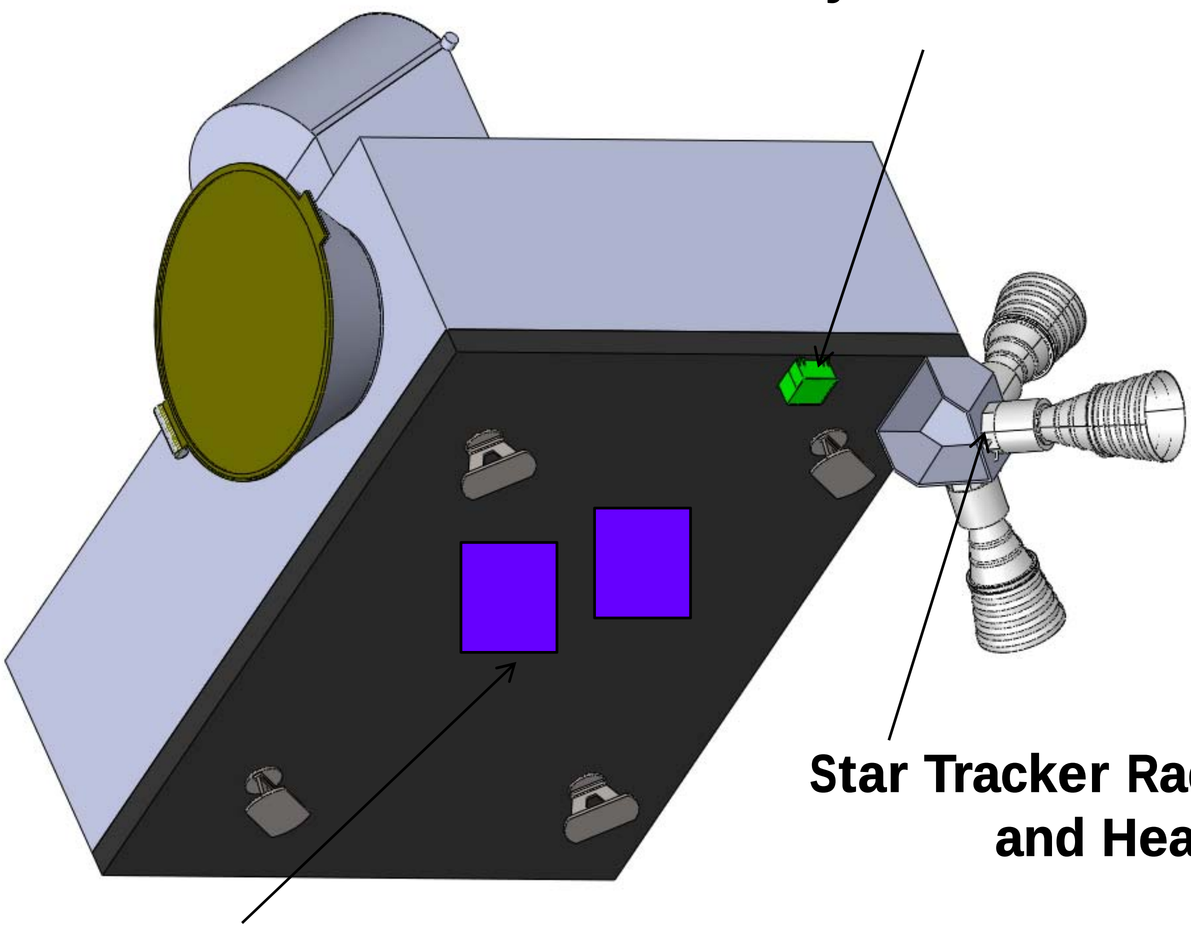
Scan Mirror Assembly Thermal Design Summary

- Scan mirror Vacuum Deposited Aluminum (VDA) is over-coated with Y_2O_3 to minimize degradation due to charged particle bombardment
- AZ93 white paint on scan mirror backside
- Scan mirror sunshield/baffle reduces solar flux entering scan mirror aperture (0.684 m diameter)
  - Sunshade is conductively isolated from optics/mirrors enclosure frame
  - Sunshield length is presently 0.332 m
    - An increase in sunshield length decreases solar flux entering scan mirror cavity, but won't eliminate the problem
      - Length may be constrained by fairing
  - GOES scan mirror peak temperature is close to 70ºC
  - Phase change material (paraffin) could resolve peak temperature issue

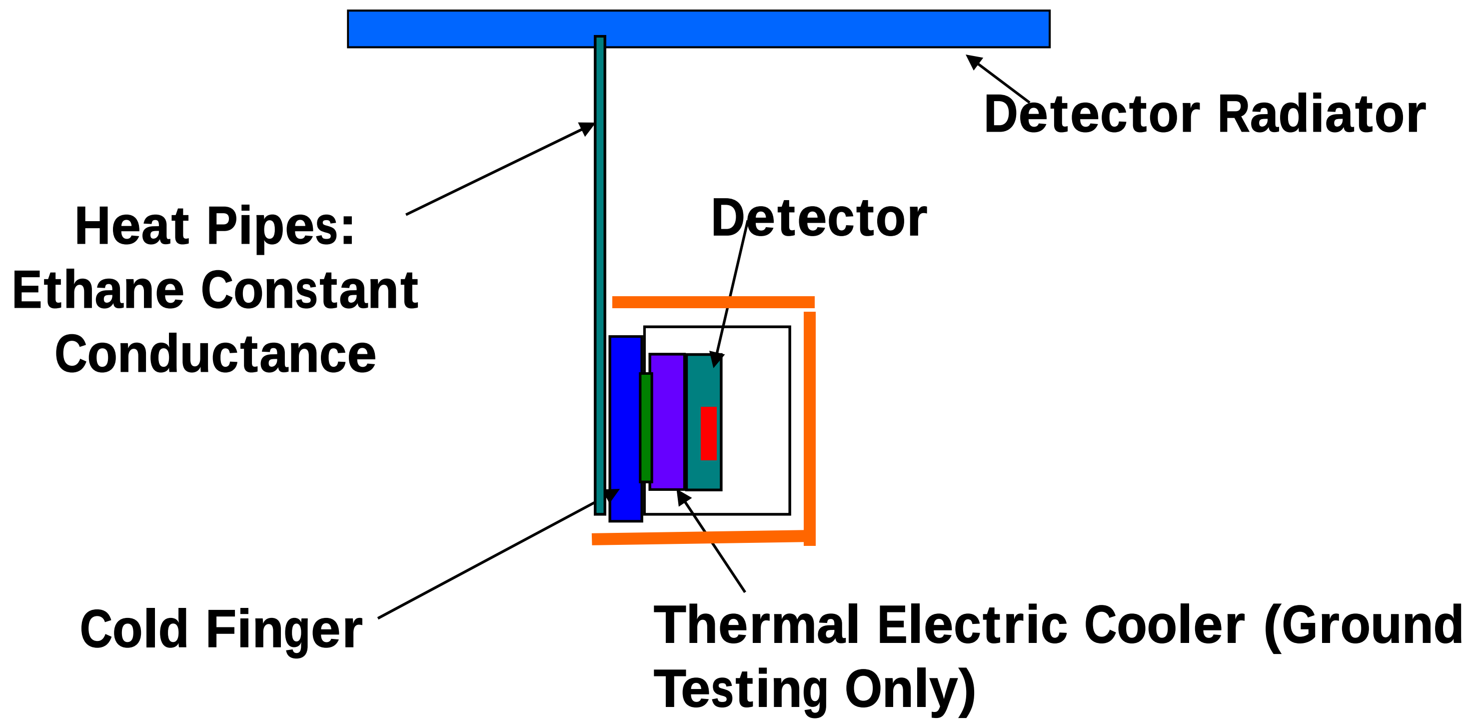
Thermal Design



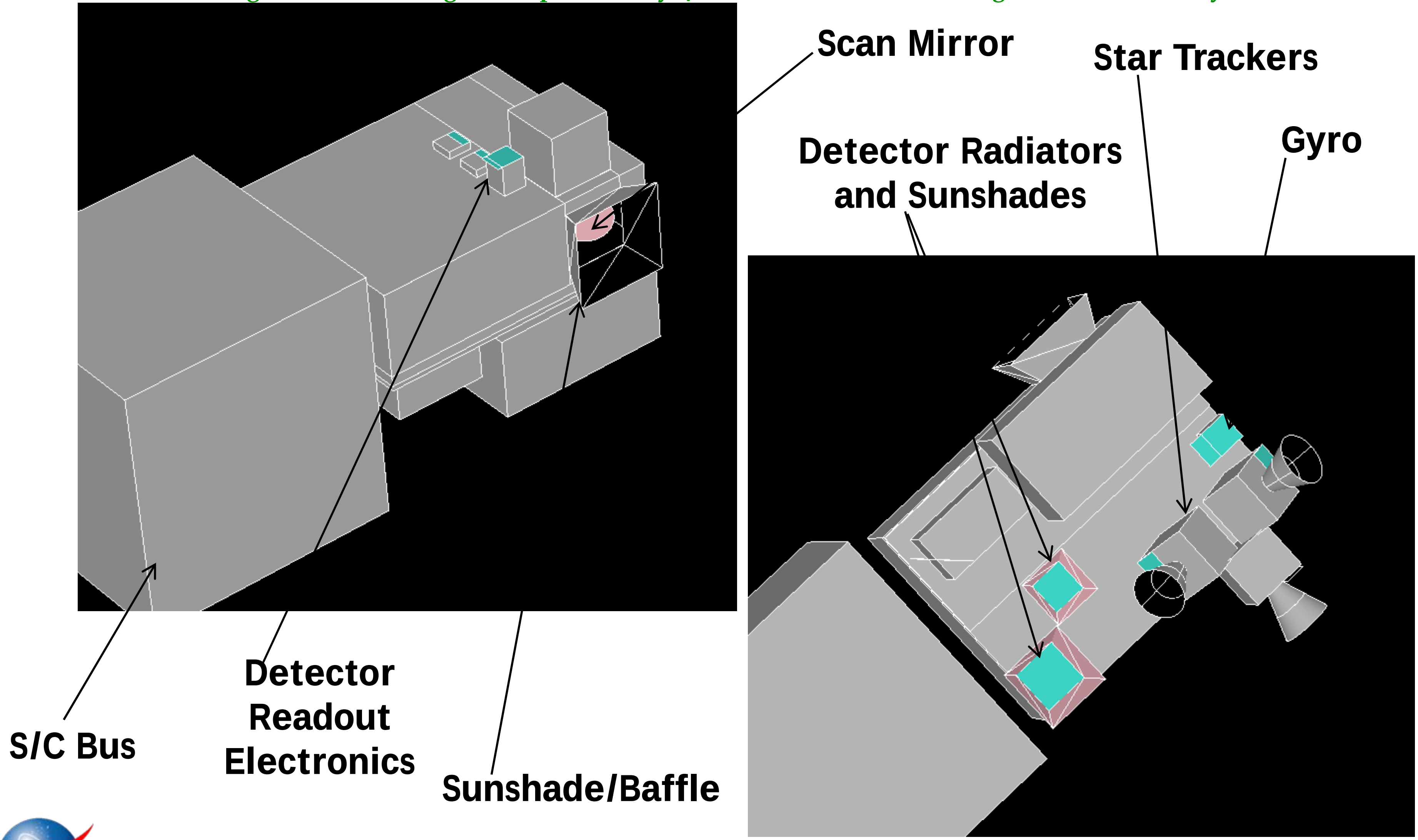
Detector and ACS Thermal



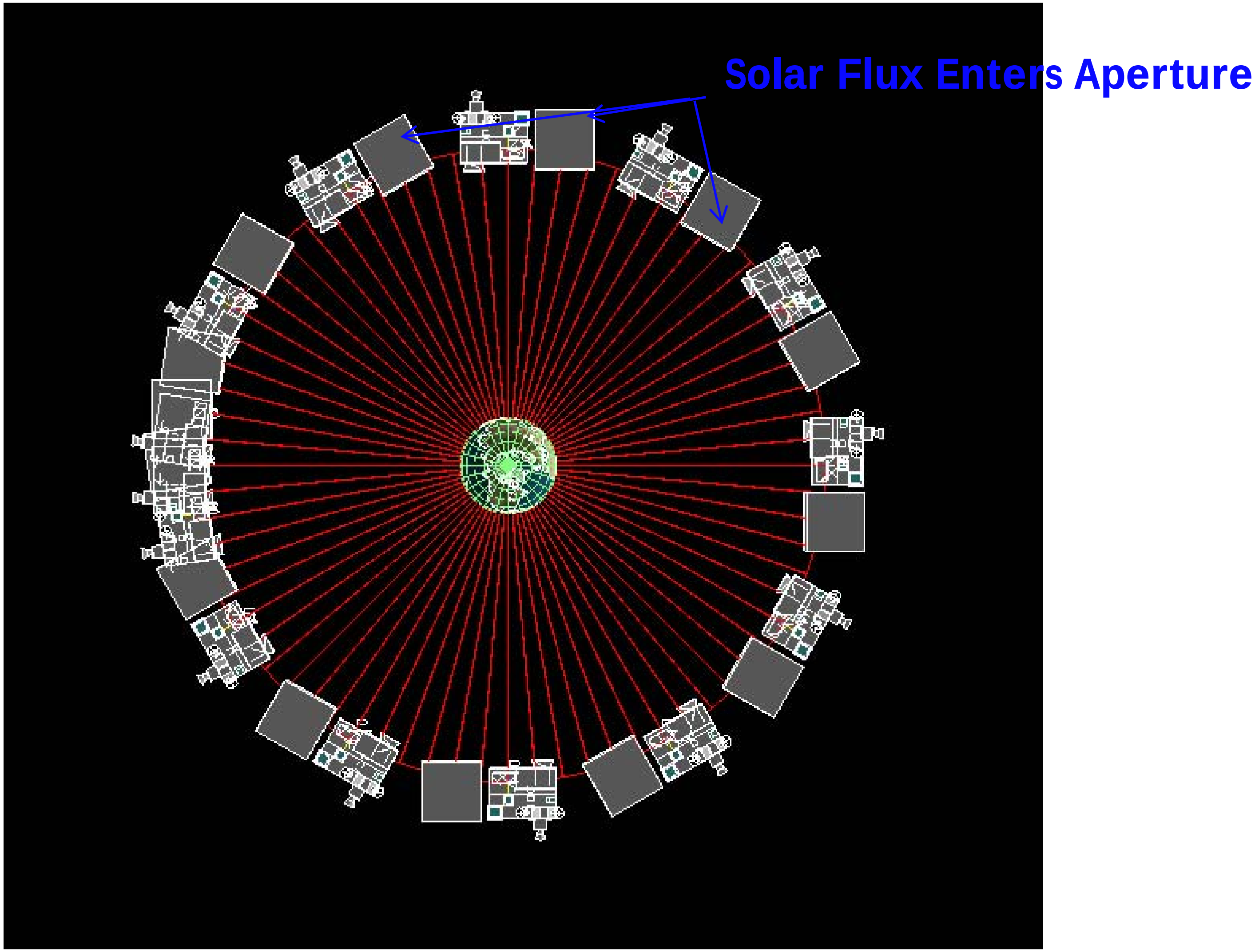
Detector Thermal



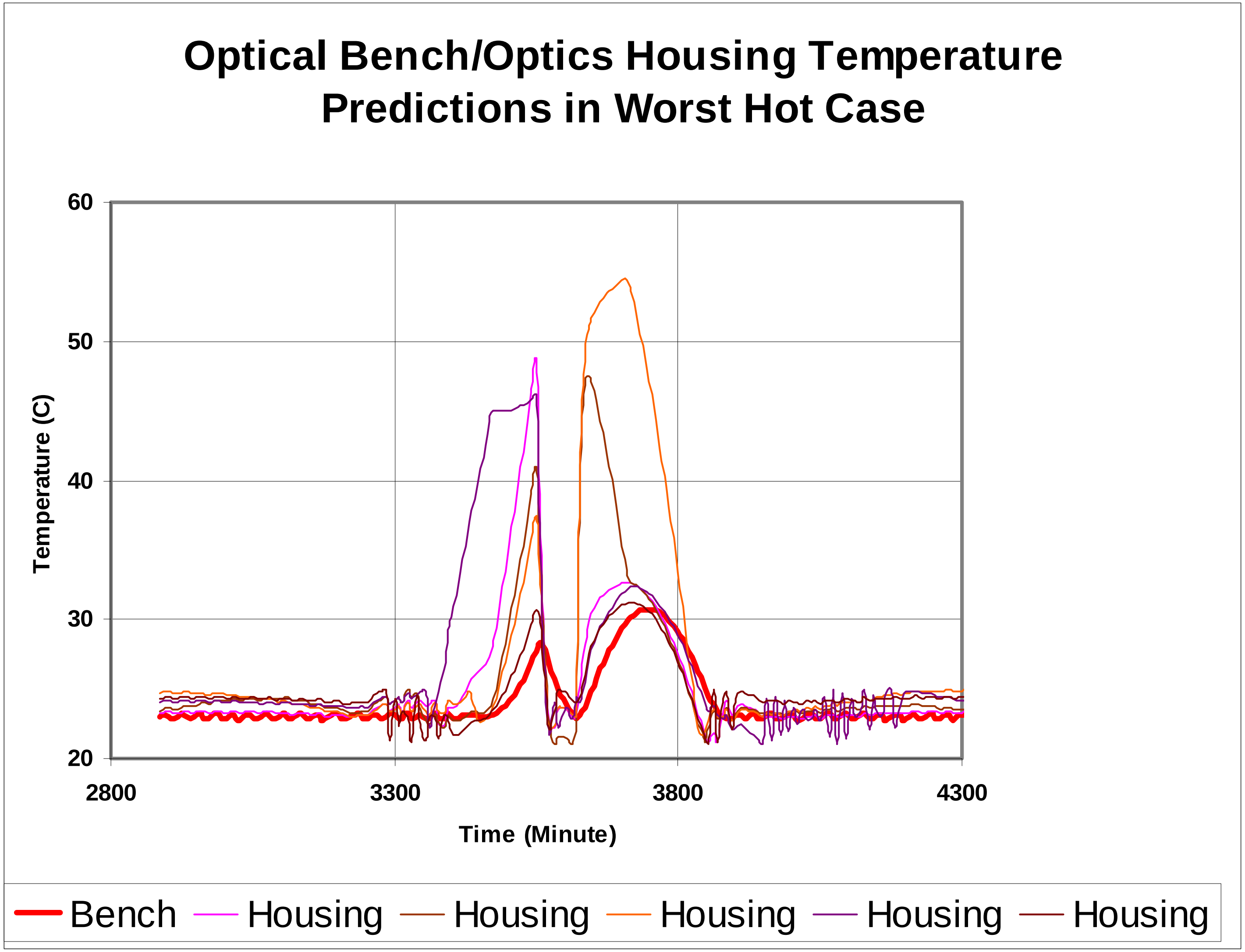
Thermal Model



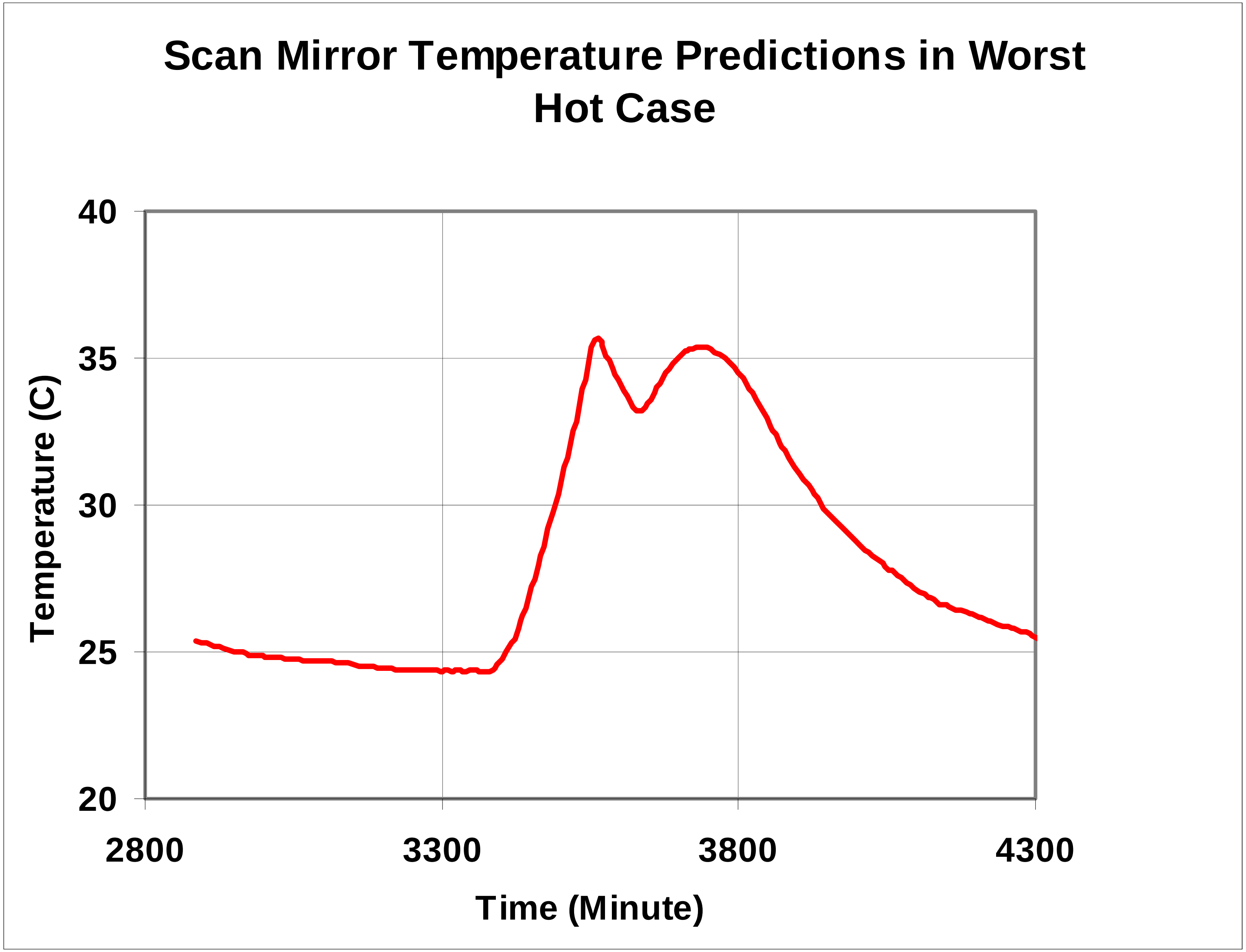
Thermal Model



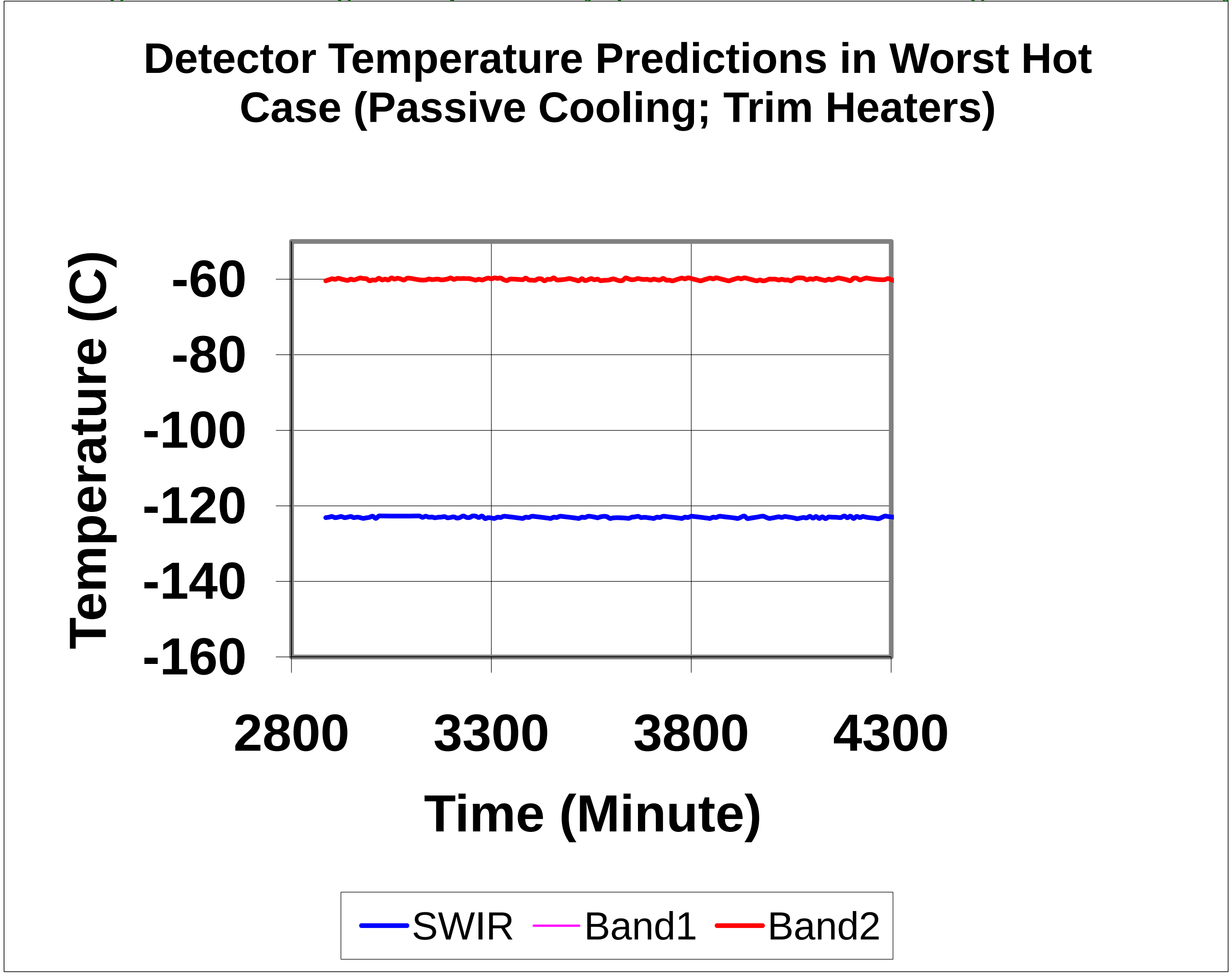
Hot Case Thermal Predictions



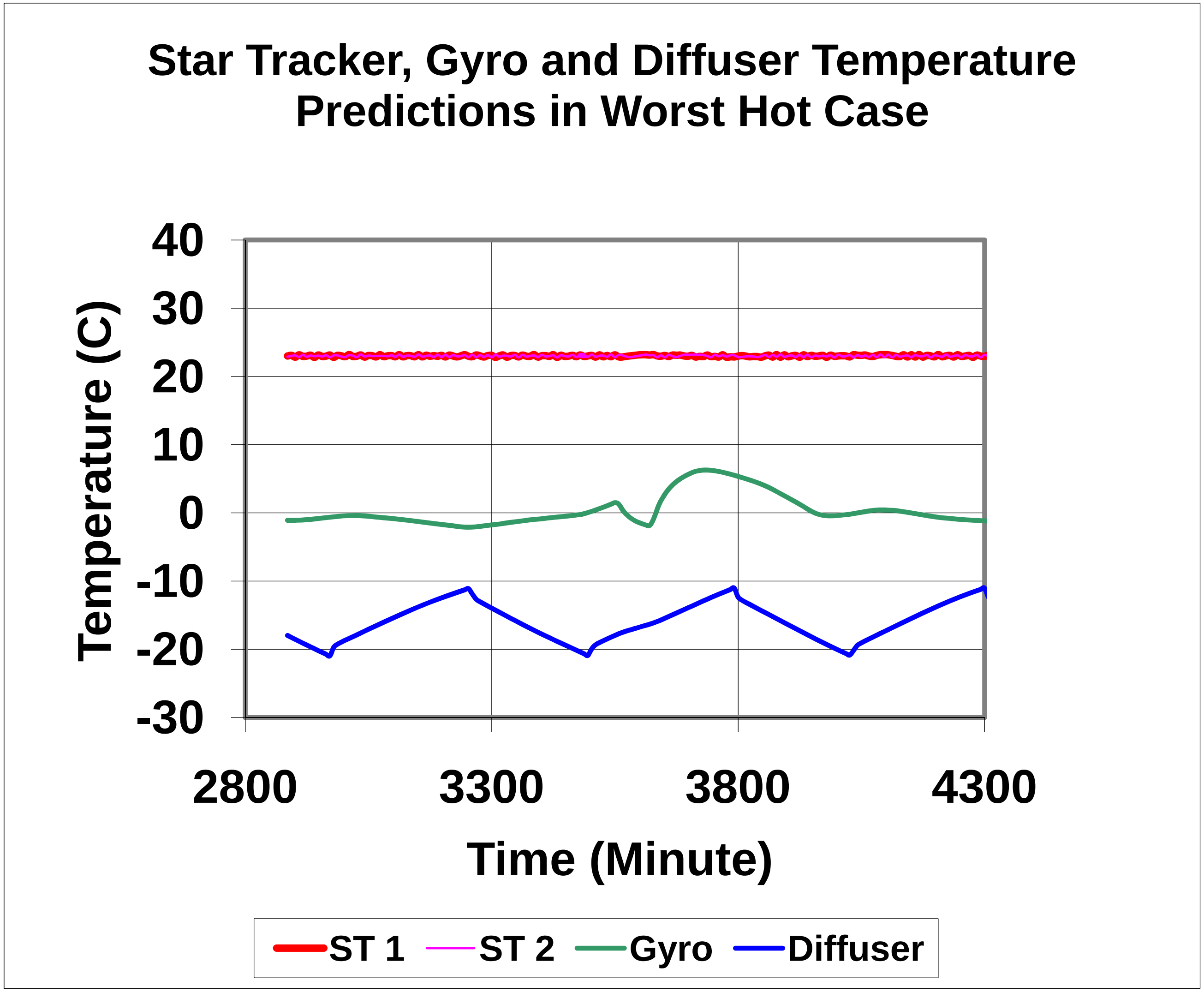
Hot Case Thermal Predictions for Scan Mirror



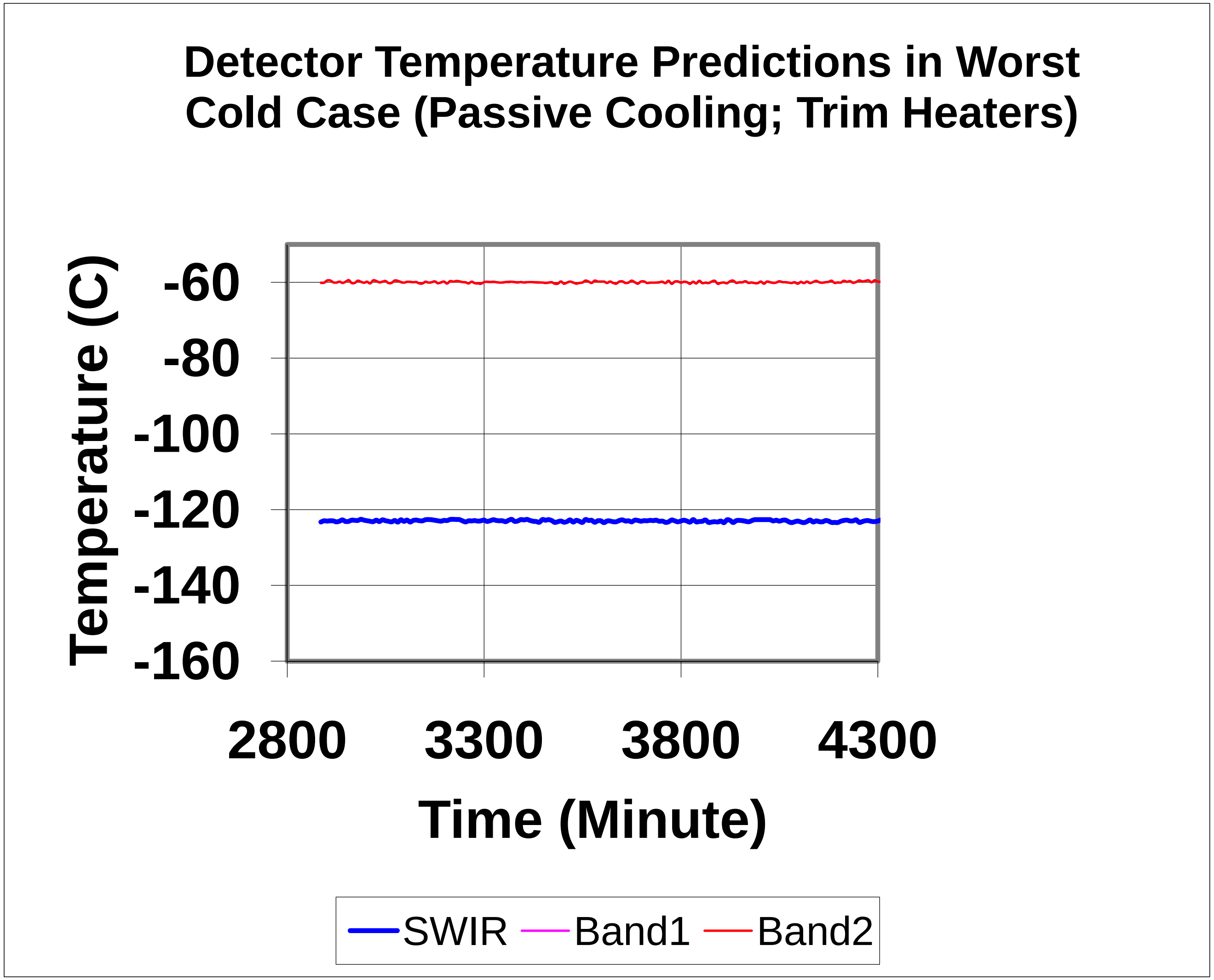
Hot Case Thermal Predictions for Detectors



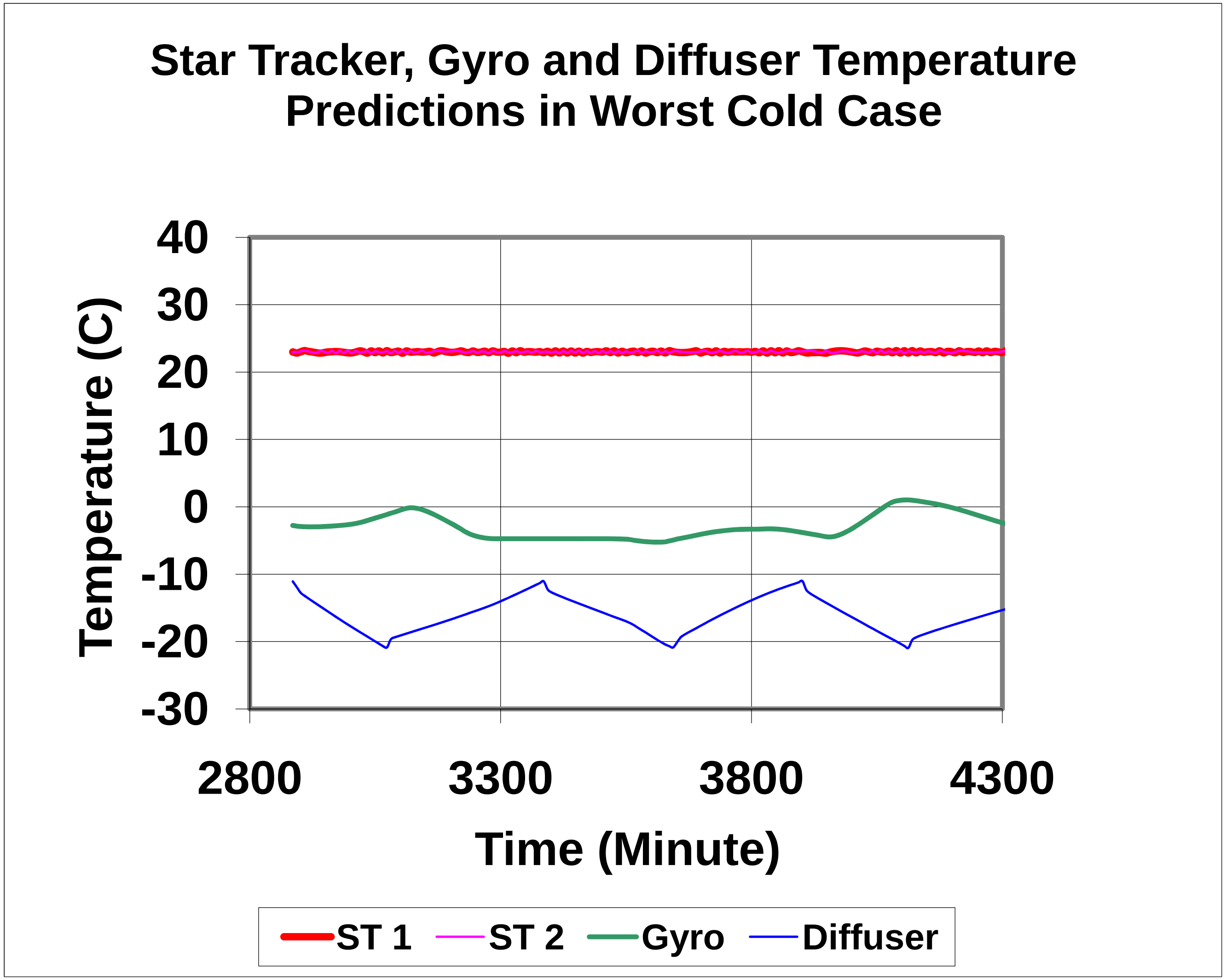
Hot Case Thermal Predictions for ST, Gyro and Diffuser



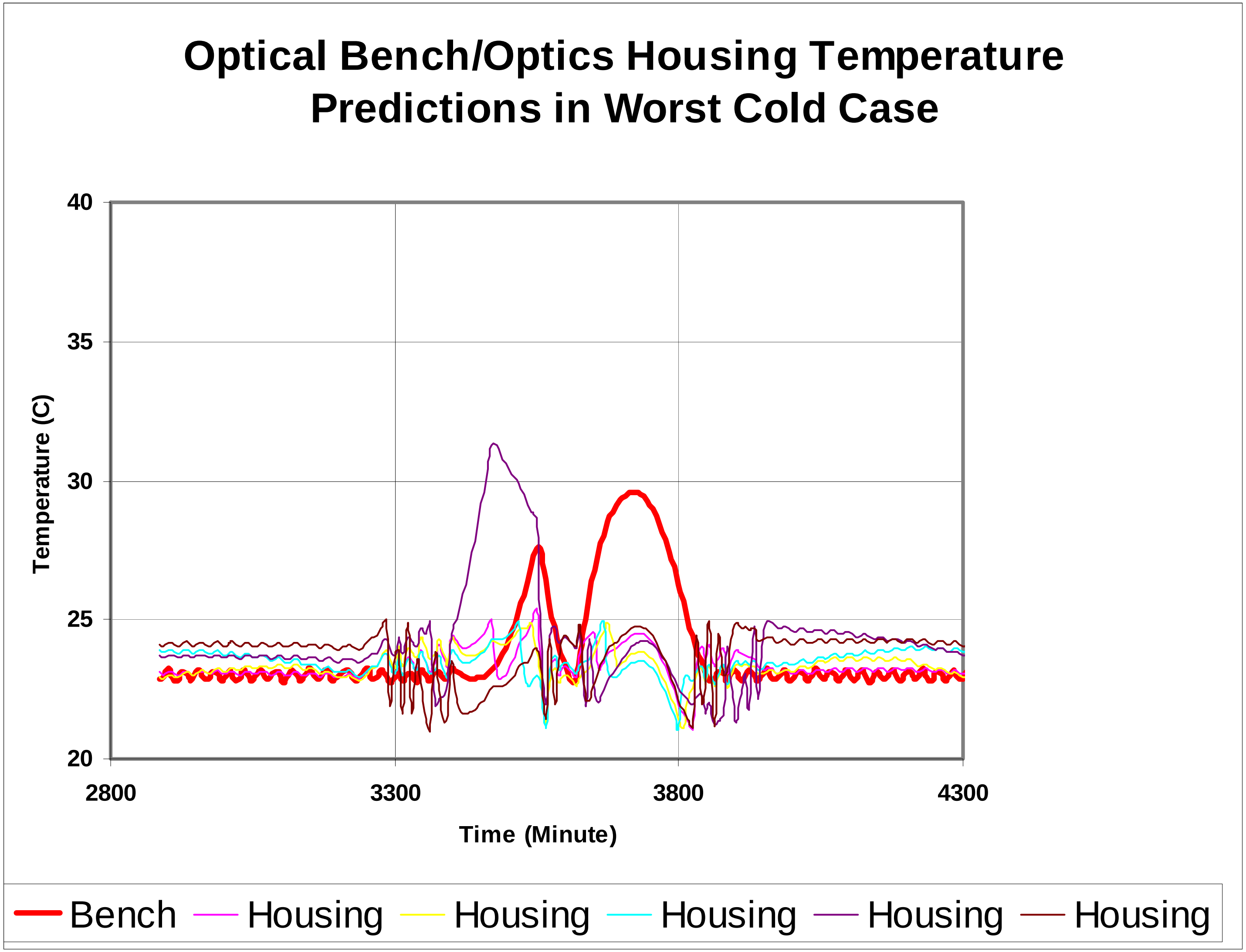
Cold Case Thermal Predictions for Detectors



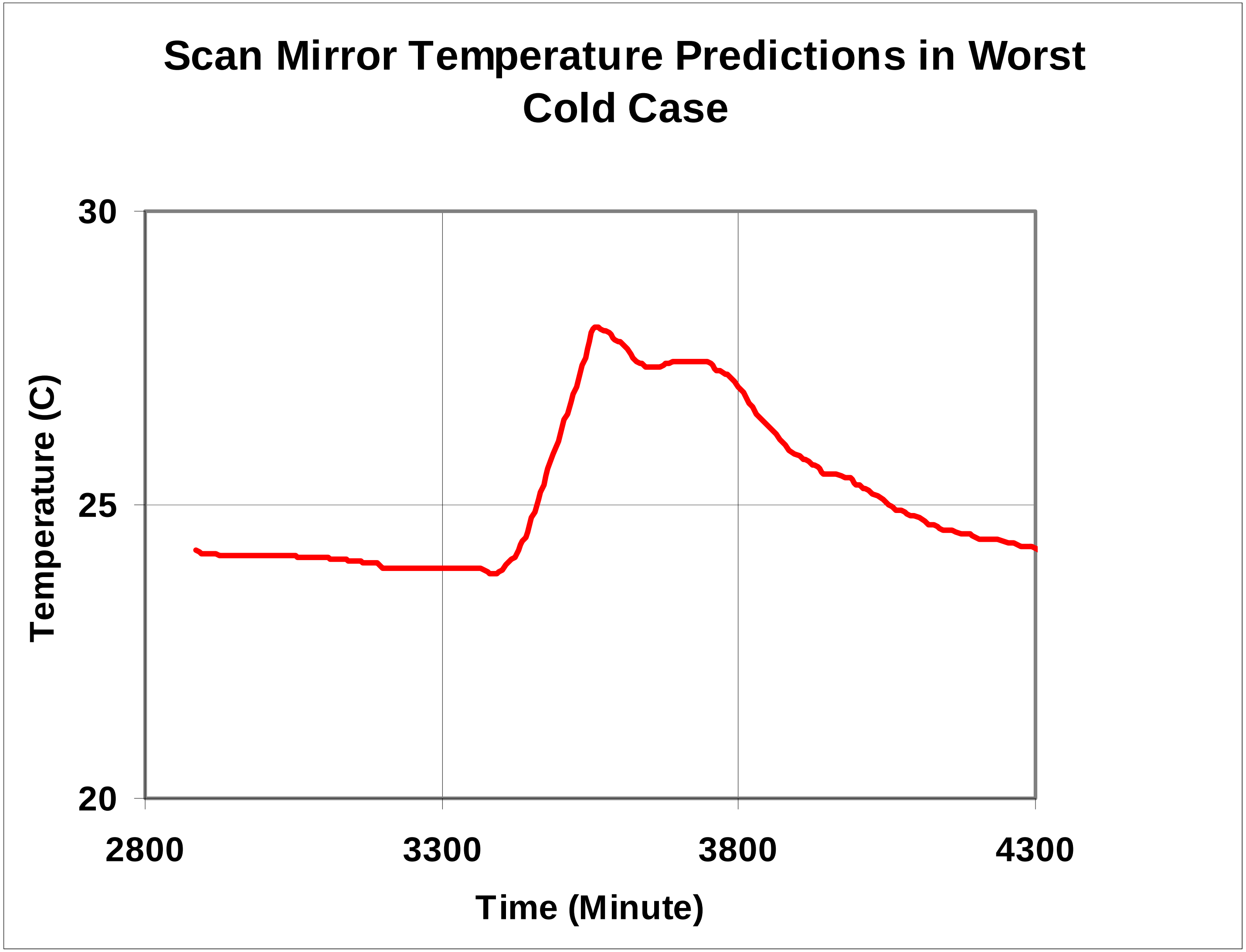
Cold Case Thermal Predictions for ST, Gyro and Diffuser



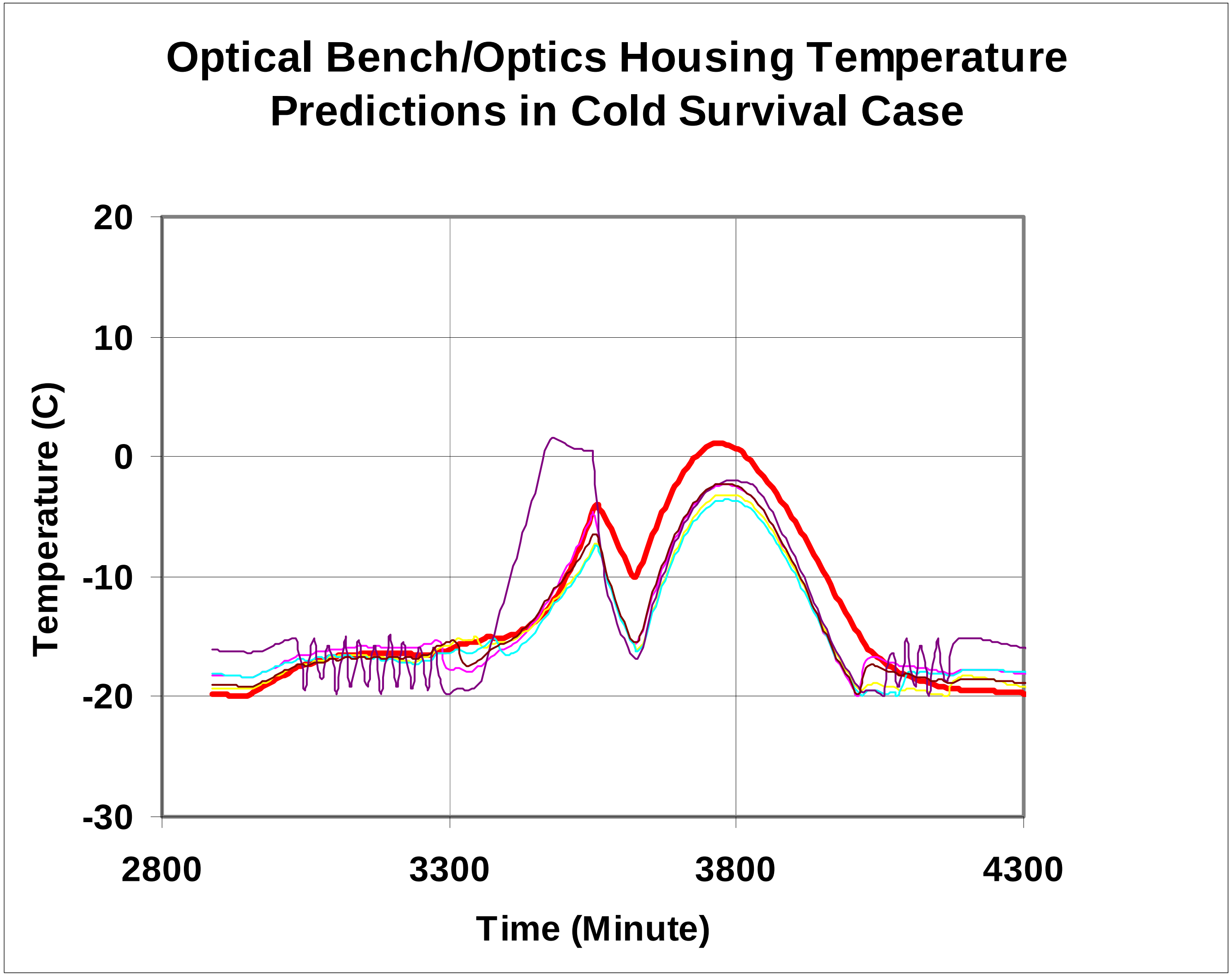
Cold Case Thermal Predictions for Optical Bench/Optics Enclosure



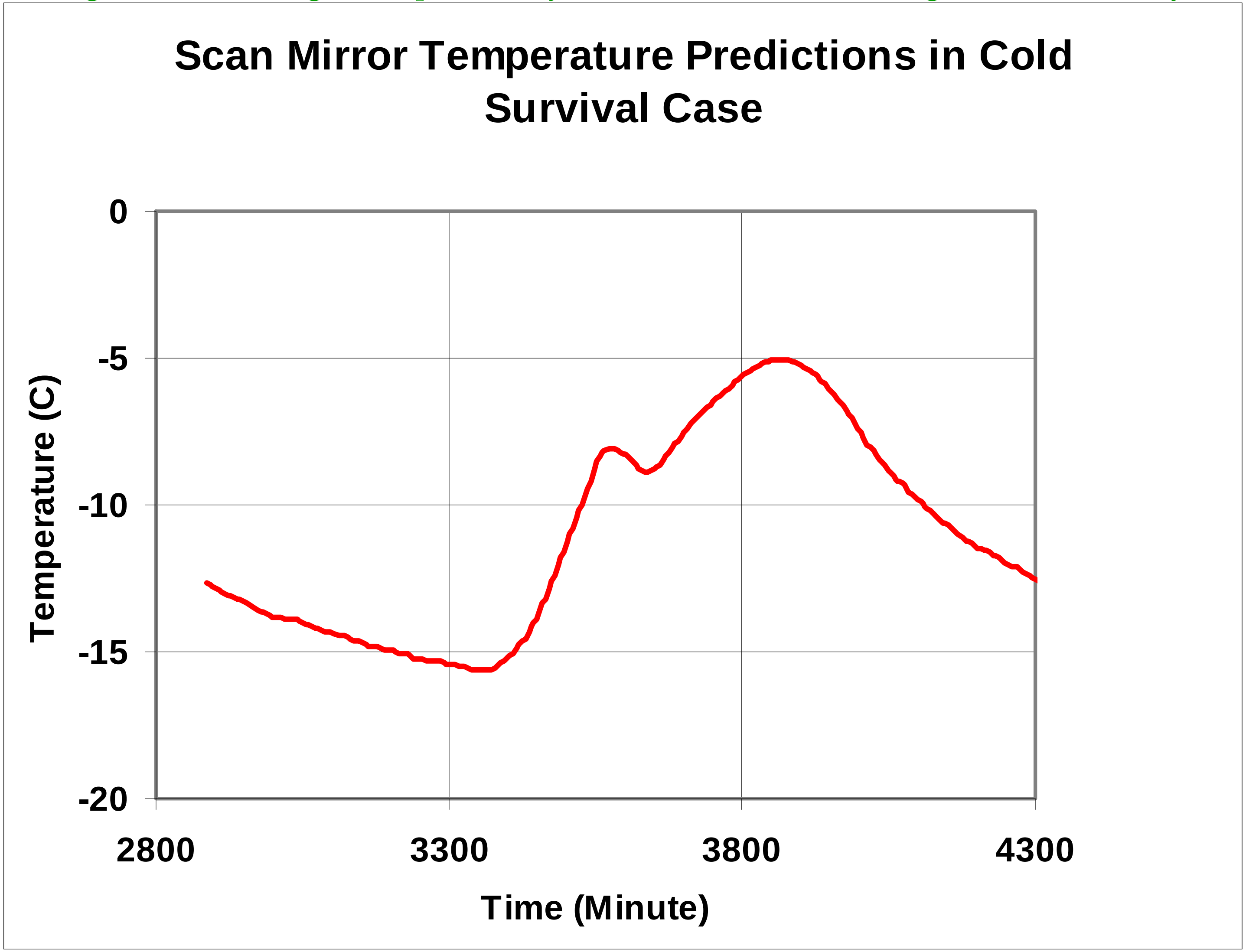
Cold Case Thermal Predictions for Scan Mirror



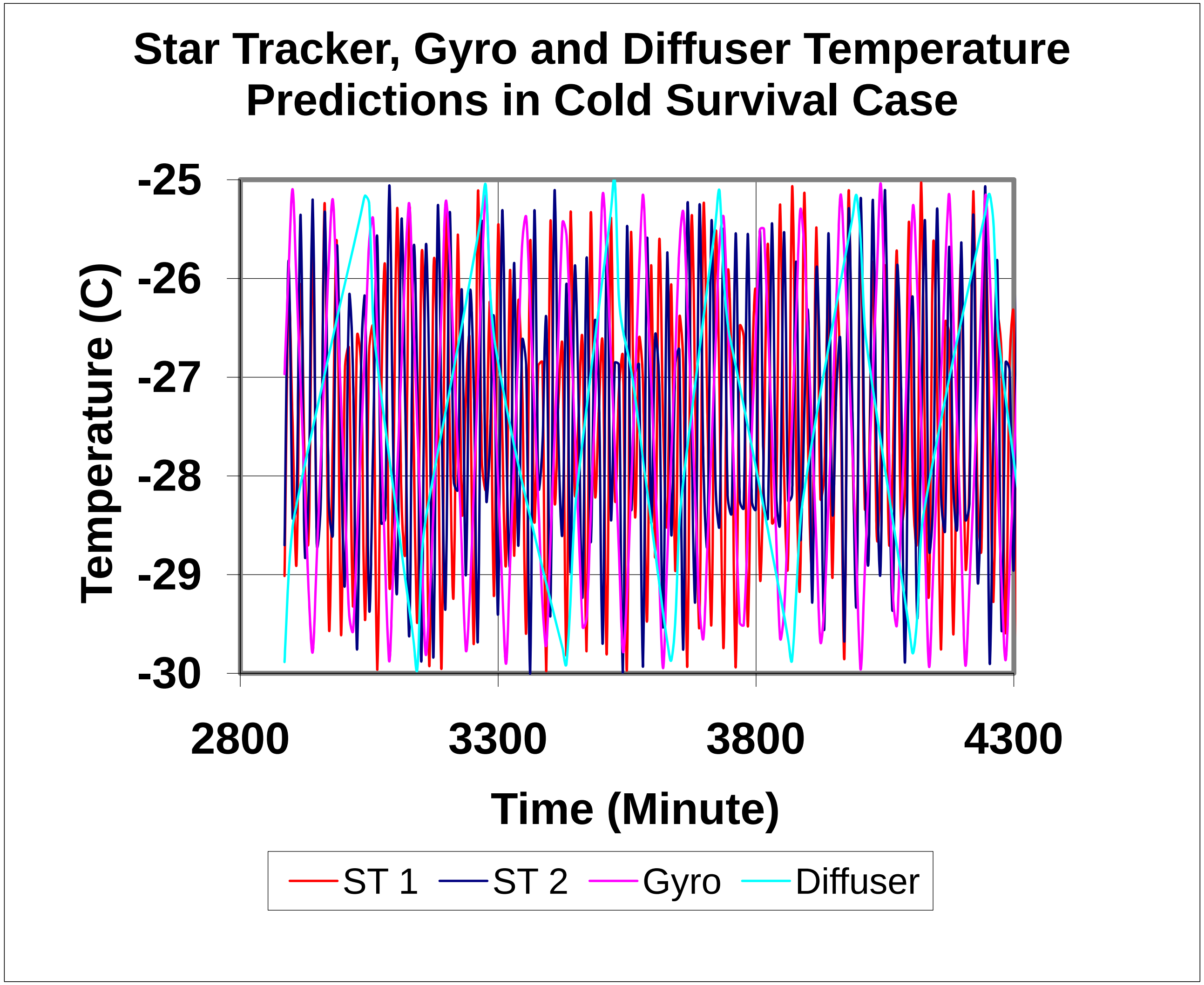
Cold Survival Thermal Predictions



Cold Survival Thermal Predictions



Cold Survival Thermal Predictions



Operating Mode Heater Power

	Peak Heater Power (W)	Orbital Average Heater Power (W)*
Optical Bench/Optics Enclosure	321†	225‡
Detectors	6.4	4.5
Star Trackers	16.5	11.5
Diffuser	12.6	8.8
Total	357	250

70% duty cycle per GSFC Gold Rules.
†819 W in 2006 study.
‡573 W in 2006 study.

Survival Heater Power

	Peak Heater Power (W)	Orbital Average Heater Power (W)
Optical Bench/Optics Enclosure	154†	108‡
Star Trackers	16.6	11.7
Gyro	22.9	16.1
Diffuser	11.3	7.9
Detector Electronics*	22.0	15.4
MEB*	58.4	40.9
Payload I/F Electronics*	26.1	18.3
Aperture Cover Mechanism*	6.0	4.2
Total	**317**	**222**

†295 W in 2006 study.

‡207 W in 2006 study.

*Not included in 2006 study.

Radiator Areas

	Location	Coating	Area (m^2)
Radiator for SWIR Detector*	Outside Optical Bench/Enclosure	OSR	0.337
Radiator for Band 1 & Band 2 Detectors*	Outside Optical Bench/Enclosure	OSR	0.0748
Radiator for SWIR Detector Electronics	Patch on Electronics Box	OSR	0.0616
Radiator for Band 1 or Band 2 Detector Electronics	Patch on Electronics Box	OSR	0.0154 Each
Radiator MEB	Patch on MEB	OSR	0.241
Radiator for Payload C&DH	Patch on C&DH (thermal sharing)	OSR	0.11
Radiator for Star Trackers	Patch on Star Trackers	OSR	0.0835
Radiator for Gyro	Patch on Gyro	OSR	0.0968

*Also require baffle/sunshade

Thermal System Mass Estimate/TRL

Sub System Components		Mass Ea (kg)	Qty	Mass Total (kg)	TRL
MLI on optics enclosure and optical bench	15-layers; 20 m2	12	1	12	9
MLI on scan mirror aperture sunshade	15-layers; 0.9 m2	0.54	1	0.54	9
MLI on Diffuser	15-layers; 1.8 m2	1.08	1	1.08	9
MLI on Star Trackers	15-layers; 1.8 m2 each	1.08	3	3.24	9
MLI on Gyro	15-layers; 0.3 m2	0.18	3	0.54	9
MLI on Detector radiators and sunshields	15-layers; 1.634 m2	0.98	1	0.98	9
MLI on FPA assemblies, K1100 Heat Straps and CCHPs	0.45 m2	0.27	1	0.27	9
MLI on MEB, payload C&DH electronics and detector electronics	0.6 m2	0.36	1	0.36	9
MLI on CEDI strongback	15-layers; 15 m2	9	1	9	9
Velcro, buttons, adhesive etc. for MLI blankets		2.5	1	2.5	9
Aeroglaze Z307 black paint	20 m2	1.736	1	1.736	9
K1100 heat straps from FPAs to CCHPs 0.076 m long;		0.09	3	0.27	7
Ammonia CCHPs embedded in optical bench	2.8 m long	0.84	15	12.6	7
Ethane CCHPs from heat straps to FPA radiators	1.2 m long	0.292	4	1.168	7
SWIR FPA radiator	aluminum; 0.337 m2	2.887	1	2.887	7
SWIR FPA radiator OSR and adhesive	0.337 m2	0.438	1	0.438	7
SWIR FPA radiator sunshield shroud	Aluminum; 1.022 m2	4.379	1	4.379	7
Bands 1 and 2 FPA radiator	Aluminum; 0.0748 m2	0.642	1	0.642	7
Bands 1 and 2 radiator sunshield shroud	Aluminum; 0.200 m2	0.857	1	0.857	7

Thermal System Mass Estimate/TRL Cont'd

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Sub System Components		Mass Ea (kg)	Qty	Mass Total (kg)	TRL
Bands 1 and 2 radiator OSR and adhesive	0.0748 m2	0.097	1	0.097	7
Star Trackers radiator OSR and adhesive	0.0835 m2	0.109	1	0.109	7
Gyro radiator OSR and adhesive	0.0968 m2	0.126	1	0.126	7
MEB radiator OSR and adhesive	0.241 m2	0.314	1	0.314	7
Payload C&DH radiator OSR and adhesive	0.11 m2	0.143	1	0.143	7
SWIR Detector Electronics radiator OSR and adhesive	0.0616 m2	0.08	1	0.08	7
Bands 1 &2 Detector Electronics radiator OSR and adhesive	0.0308 m2	0.04	1	0.04	7
Heaters on optical bench/optics enclosure	15 cm x 30 cm each	0.0294	432	12.7008	9
Heaters on Star Trackers, Gyro & Diffuser	5.1 cm x 6.4 cm each	0.002	64	0.128	9
Heaters on FPAs	1.5 cm x 1.5 cm each	0.001	6	0.006	9
Heaters on MEB, Payload C&DH , Detector Electronics and aperture cover mechanism	5.1 cm x 6.4 cm each	0.0018	36	0.0648	9
Thermistors/Platinum RTDs		0.001	80	0.08	9
Thermostats		0.006	290	1.74	9
Adhesive for Thermostats & Thermistors		0.2	1	0.2	9
Total				71.3156	

***123 kg in 2006 study**

Conclusions

- **Passive cooling is thermally feasible for all 3 detectors**
- **Operating mode heater power for optics enclosure and optical bench is 348 W smaller than 2006 study due to smaller aperture and MLI areas**
  - Reduces spacecraft electrical power system size and cost
- **Mass of thermal system is about 50 kg smaller than 2006 study**
- **Even if MEB, payload C&DH and detector readout electronics are included, survival heater power is 20 W smaller than 2006 study**

Geostationary Coastal Ecosystem Dynamics Imager (GEO CEDI) for the GEO Coastal and Air Pollution Events (GEO CAPE) Mission

~ Concept Presentation ~

Contamination

January 29, 2010

Early Concerns

- **Large instrument**
  - Only largest clean room facility will do
  - Large optics that require special handling
  - Two large entrance apertures
  - Large internal spaces that can retain contaminates
- **Significant number of optics**
  - Number of optical surfaces
    - Band 1 – 11, Band 2 – 13, SWIR - 11
  - Scan Mirror is in an exposed position
    - Operational constraint is needed to prevent solar viewing
- **Solar Calibration System**
  - Requires a second aperture
  - Two large diffusers that are sensitive to molecular contamination
- **Lunar and Stellar Calibration Capability**
  - Requires a large primary aperture and light shield
- **Scan Mirror needs a safe position**
  - Facing away from sun
  - Position for launch

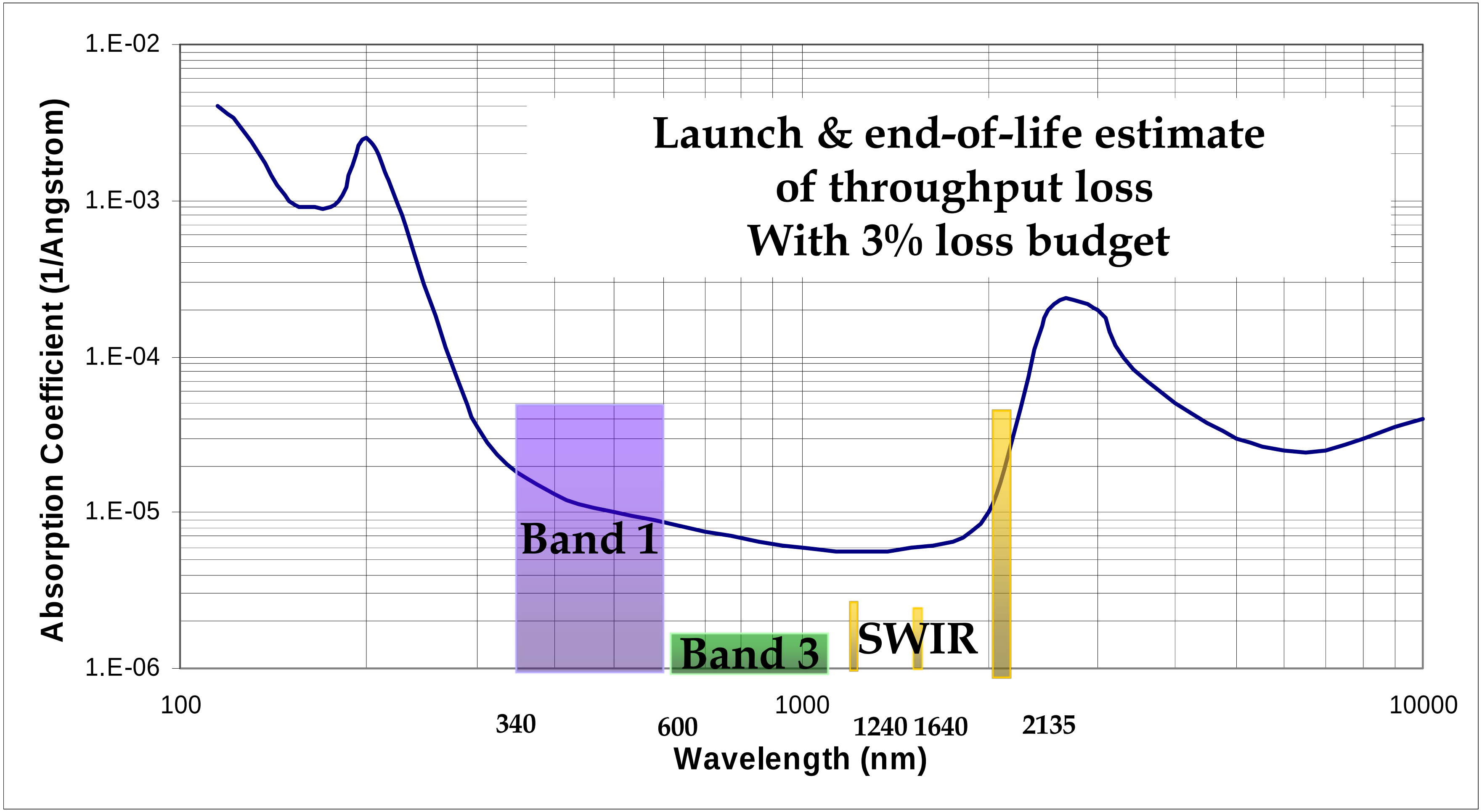
Solar Calibration Considerations

- **Two large Diffusers**
  - May be (white Teflon) or sandblasted quarts over aluminum
  - Elliptic in shape, 10% larger area than scan mirror.
  - May have to be a mosaic due to large size.
- **Two large doors**
  - Main aperture and solar calibration aperture
  - Both multi-use
  - Both can be closed on launch
- **Transmission Diffuser may save space**
  - Transmission differ would have a lower TRL number
  - Two technologies available:
    - Drilled plate – Less flight heritage, sensitive to particle contamination
    - Teflon – Long flight heritage, Teflon becomes brittle from radiation
  - Trade study required

GEO CAPE Wavelength Sensitivity

Integrated Design Capability / Instrument Design Laboratory

Line: 50 ang Molecular Contamination



Conclusions

- **No Show-stoppers**
  - Only commonly used materials and processes are required

- **Concerns**
  - Large instrument
    - Only largest cleanrooms and vacuum chambers can be used
      - Effects cost and schedule
    - Custom fixtures are required
  - Large diffusers
    - Larger than heritage examples
  - Launch vents requires
    - Large volume of gas inside the instrument on launch
    - Doors are closed on launch
    - Machined vents are needed