GEMS (Geostationary Environment Monitoring Spectrometer) Instrument Requirements and Issues in the Instrument Design

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Agenda

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  - Performance Requirements
  - Interface Requirements
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  - Radiation Effect
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Introduction

- **Overall Scientific Requirements**
  - **Monitoring of Environmental Gases**
    - **O_3, NO_2, SO_2, HCHO, Aerosol**
  - **Around Korean peninsula in Eastern Asia**

- **Instrument Requirements**
  - **Based on the User Requirement Discussion meeting on April 16 2009**
  - **Inquired for the possibility of GSD enhancement and Higher spectral resolution in early 2010**

Instrument Requirements

Operational Requirements

- **Lifetime and Reliability**
  - [R-010] lifetime : 7 years (TBC)
  - [R-020] reliability : 0.85 (TBC)
- **Mission Scenario**
  - [R-050] GEMS orbital position : between 116°E & 138°E (TBC)
  - [R-060] Target area : 5000 km (N/S) × 5000 km (E/W) by the imaging instrument at nadir view

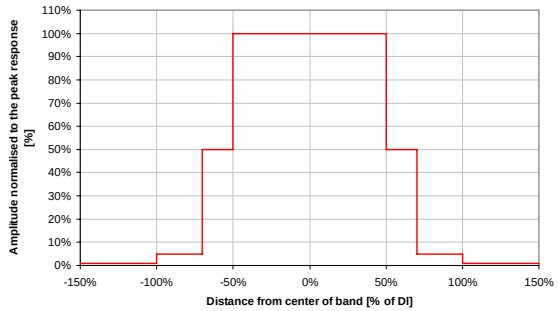
    ∗ Region of interest suggested

    – NS region : from 55°N to 5°S

    – EW region : from 75°E to 145°E
  - [R-070] duty cycle : 8 images during daytime
  - [R-080] imaging time : 1 hour (TBC)

Performance Requirements

- Geometric requirements
  - **[R-100] GSD : 2.5 km (N/S) × 7.5 km (E/W) at nadir**
- Spectral requirements
  - **[R-200] continuous spectral channels from 300 to 500 nm**
  - **[R-210] spectral resolution : $\Delta\lambda$ = 0.8 nm (TBC)**
  - **[R-220] spectral template (FWHM) ≈ 3 pixels**
  - **[R-230] new req. item of the spectral sampling distance should be added**



Performance Requirements (cont'd)

- Radiometric requirements
  - [R-300] input radiance level

Spectral range [nm]	Nominal Radiance (Lnom)	Maximum Radiance (Lmax)	Saturation Radiance (Lsat)
300-315 (TBC)	16.2 (TBC)	41.4 (TBC)	43.5 (TBC)
315-325 (TBC)	22.2 (TBC)	91.3 (TBC)	95.9 (TBC)
325-335 (TBC)	33.9 (TBC)	132.4 (TBC)	139.0 (TBC)
335-357 (TBC)	32.5 (TBC)	120.6 (TBC)	126.7 (TBC)
357-423 (TBC)	28.8 (TBC)	123.1 (TBC)	129.2 (TBC)
423-451 (TBC)	28.4 (TBC)	105.1 (TBC)	110.3 (TBC)
451-500 (TBC)	20.9 (TBC)	92.2 (TBC)	96.8 (TBC)

Spectral radiance values are $W.m^{-2}.sr^{-1}.\mu m^{-1}$

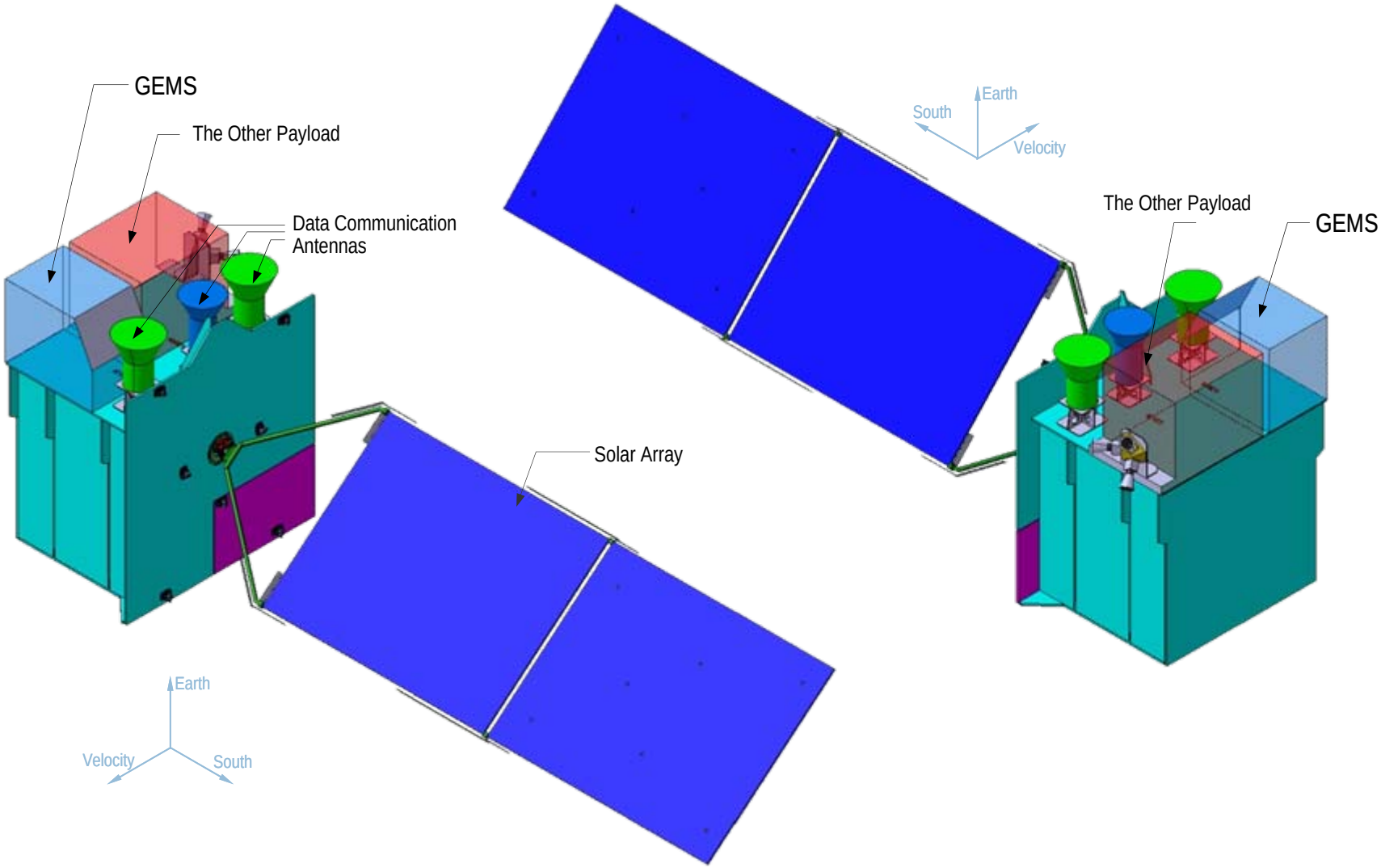
  - [R-350] SNR : 720 (TBC) over the range of nominal radiance at 320 nm (TBC) and 1500 (TBC) over the range of nominal radiance at 430 nm (TBC)
  - [R-370] absolute radiometric accuracy : 4 % (TBC)
  - [R-400] image data quantization : 12 bits (TBC)
- Spatial performance requirements
  - [R-450] MTF at GEMS level : 0.3 (TBC)

Interface Requirements

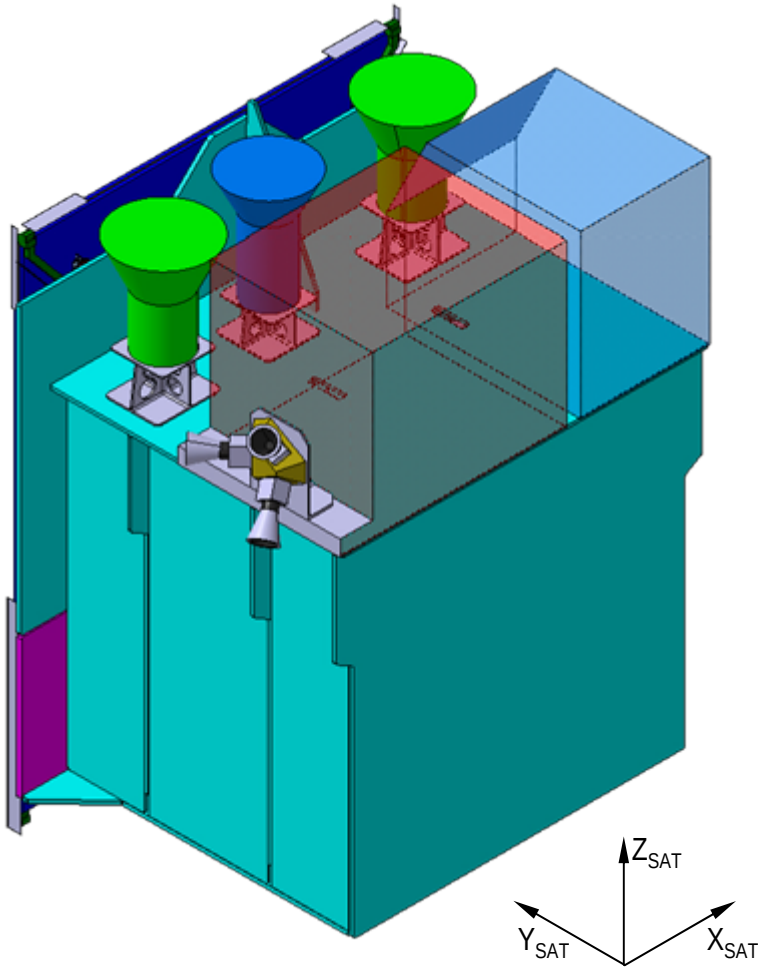
- Mechanical interfaces
  - [R-700] GEMS accommodation on +Zs face of satellite
  - [R-710] volume ≤ 800mm (Xs), 1200mm (Ys), 700mm (Zs)
  - [R-750] mass ≤ 110 kg
- Thermal interfaces
  - [R-800] satellite interface heat flux : TBD W
  - [R-810] satellite interface temperature range : TBD
- Electrical interfaces
  - [R-900] satellite input regulated voltage : TBD V
  - [R-910] max power demand : 100 W peak (TBC)
  - [R-920] data rate : 10 Mbps (TBC)

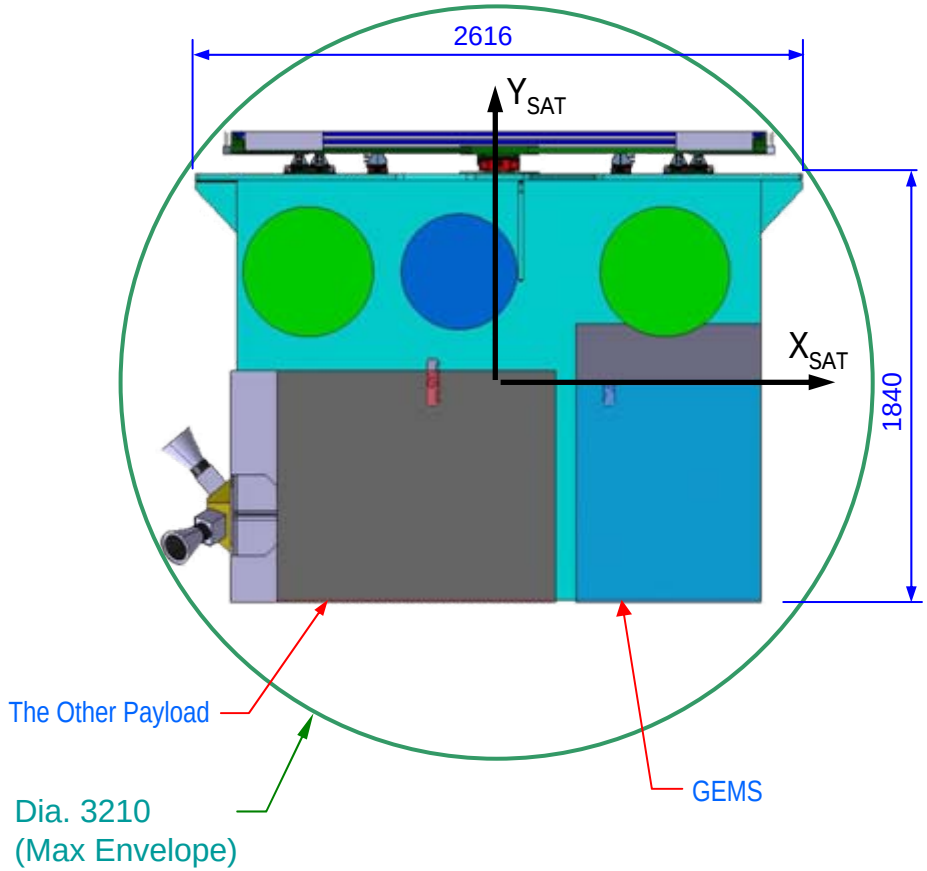
Issues in the Instrument Design

GEMS Interface Configuration (in-orbit)



GEMS Interface Configuration (Launch)

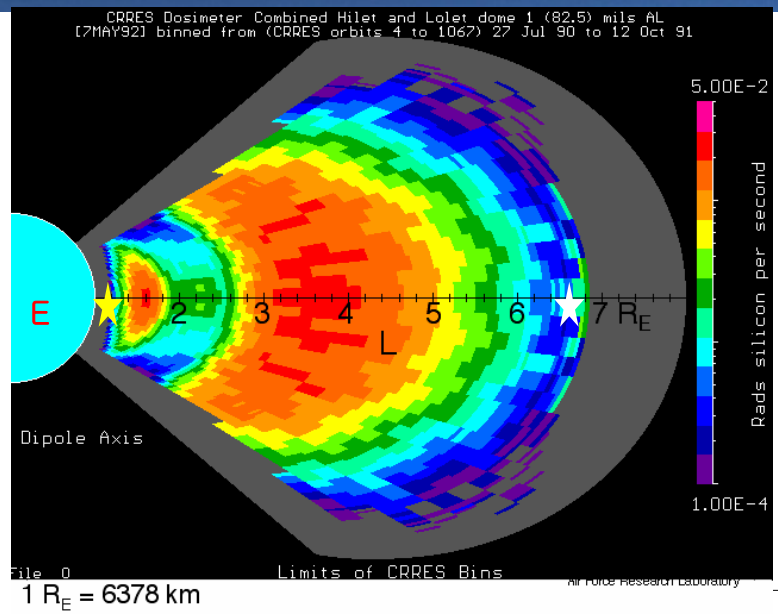




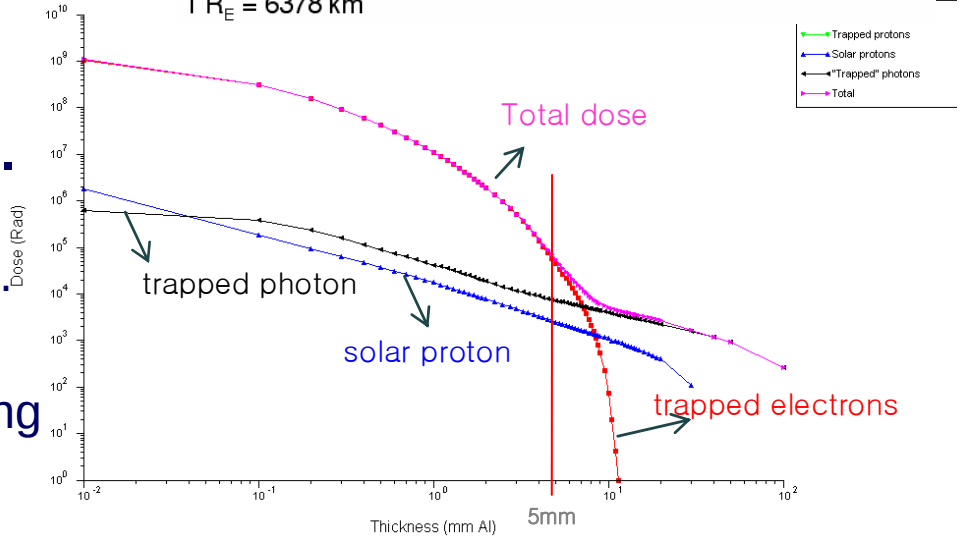
Radiation Effects

- **At GEO, outer radiation belt is the main source of trapped particles.**
  - Approximately 1 Grad(Si) of total dose is expected without the shielding (10 years analysis).

Al 5mm shielding	GEO (10yr)	LEO (5yr)
TID (Si)	56.6 krad	2.3 krad



- **Trapped electrons are more dominant than trapped protons.**
  - Low energy electrons are the cause of electrostatic discharging.
  - Unlike protons, the shielding is much more effective for attenuating electrons.



5mm

GSD Improvement

- **GSD req. was asked to be enhanced from 5Km (N/S) * 15Km (E/W) to 2.5 km (N/S) × 7.5 km (E/W) with same swath width and to check the implementation possibility**

  - **Possible solution and results**
    - ✓ **two axis scanning → longer imaging time**
    - ✓ **Applying two detectors → same imaging time**

  - ➔ **Use of two detectors in along direction (N-S) considering the imaging time**
  - ➔ **Possible to implement with some impact, but still has some difficulties: how to overcome the gap between detectors**
  - ➔ **The GSD of 2.5 km (N/S) × 7.5 km (E/W) is defined at nadir, while it should be worse at the edge of the field of view**

Higher Spectral Resolution

- **Higher spectral resolution req. was inquired for the possibility : from $\Delta\lambda$ = 0.8 nm to $\Delta\lambda$ = 0.4 nm**

  - **Possible solution and results**
    - ✓ **Applying two detectors in the spectral direction**
      - → **Drastic change in the design and budget violation**
    - ✓ **Applying totally new spectrometer with new grating of higher resolving power in a new optical design**
      - → **No proven technology**

➔ **Not possible for the implementation without major impact**

Integration Time req.

- The allocated imaging time is one hour at maximum, in which the integration and the data transmission should be completed.
- If GEMS images longer than 30 minutes, it may be a jitter disturbance source onto the other payload in a platform.

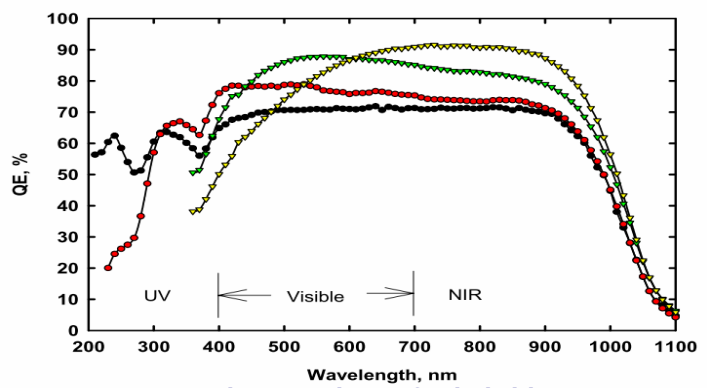
→

- The idea of two axis scanning by 1K×1K detector case is hard to be a solution
- Possible in case of using two 1K×1K detectors or one 2K×1K detector in along direction (N-S)
- If the imaging time lasts a little longer (37 min. e.g.) then the jitter condition should be revisited for the accommodation

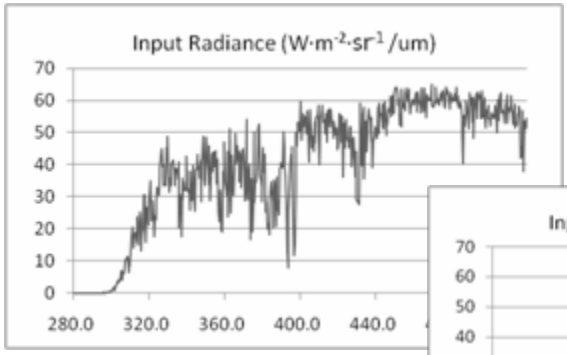
SNR Analysis Results (1/2)

- **SNR was analyzed using provided input radiance with the assumption of hybrid detector design**

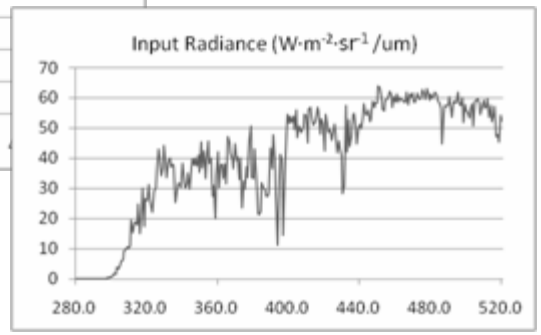
Parameter	Value
Orbit altitude	Geostationary
Ground sampling	2.5 X 7.5 Km
Spectral Band	280nm - 520nm
Optical sys. Transmission	0.3
Detector Qntm efficiency	See the graph
Pixel size	18 μm
F#	2.5
Detector RMS noise	No consideration
Channel noise	No consideration
Quantization noise	No consideration
Shot noise	Sqrt(signal)



Measured spectral QEs for hybrid CMOS



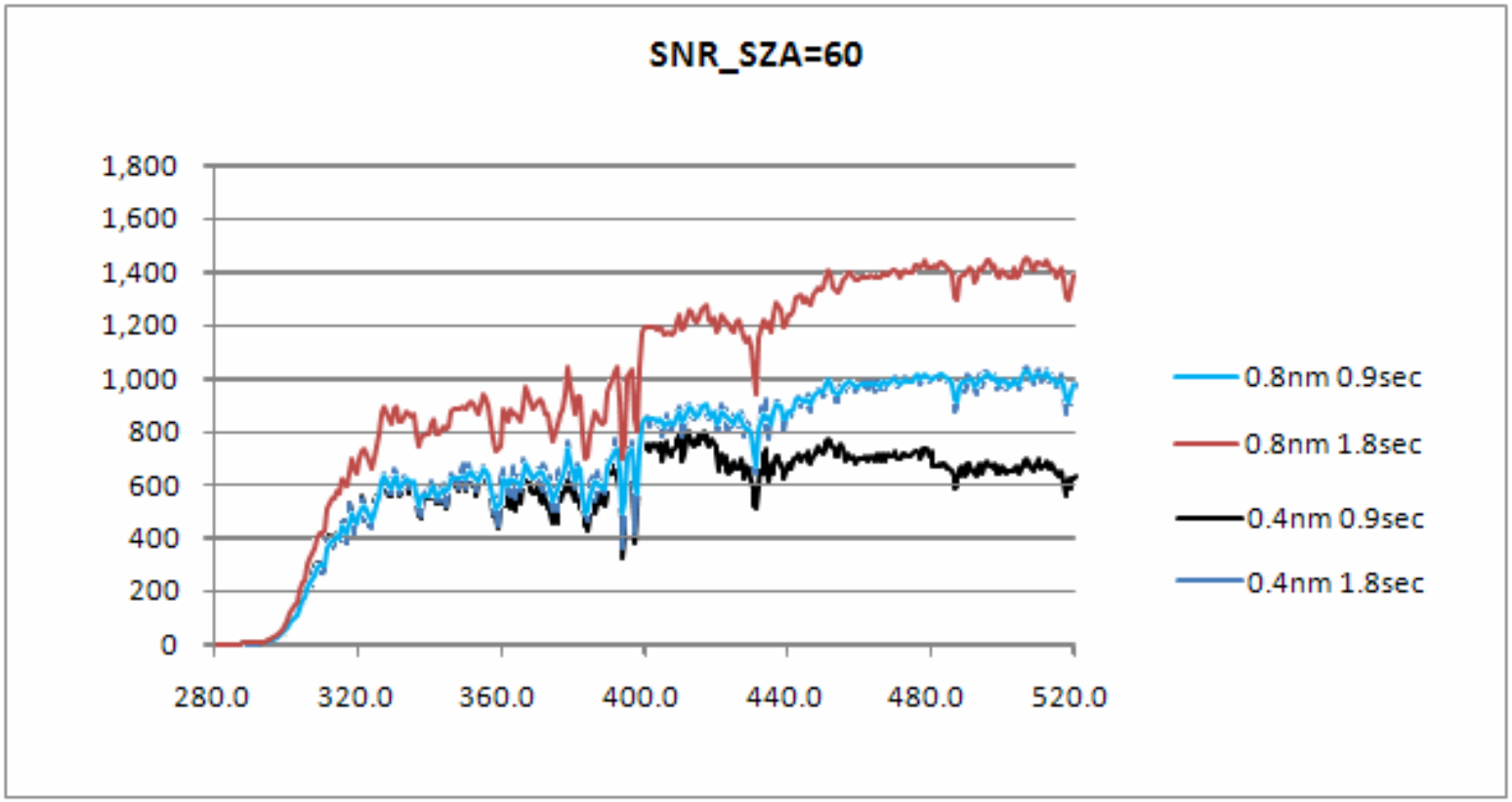
Uza00_Razi00_ray+gas
(Sza=60˚, Δλ= 0.4 nm)



Uza00_Razi00_ray+gas
(Sza=60˚, Δλ= 0.8 nm)

SNR Analysis Results (2/2)

- **Four(4) cases are under analysis**
  - **Integration time : 0.9 & 1.8 sec**
  - **Spectral resolution: 0.4 & 0.8 nm**



Summary

- **Key requirement items for the instrument H/W fixed with GSD improved**
  - **Target area : 5000 km (N/S) × 5000 km (E/W) at nadir view**
  - **Duty cycle : 8 images during daytime**
  - **GSD : 2.5 km (N/S) × 7.5 km (E/W) at nadir**
  - **continuous spectral channels from 300 to 500 nm**
  - **Spectral resolution remains as $\Delta\lambda$ = 0.8 nm due to H/W limitation**
- **Radiation effect and SNR analysis leads to the refinement of H/W**
- **Imaging operation concept should be finalized after the analysis on the jitter disturbance of H/W**
- **Requirement items with TBC or TBD attached should be finalized in order to distribute RFP document (preferred before RFI ready)**