

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

Space Payload Team



Agenda

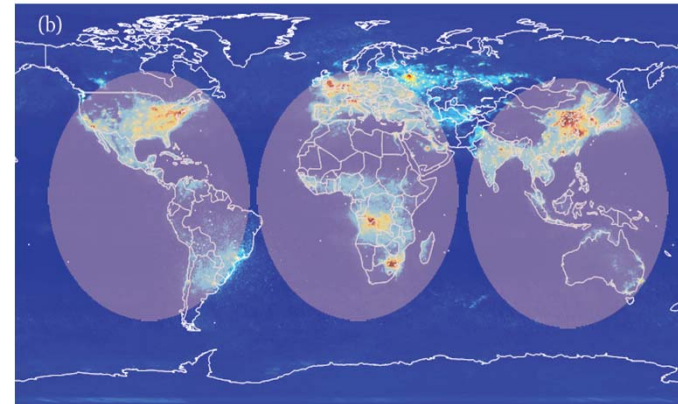
- Introduction
- GEMS Requirements
 - ◆ Operational Requirements
 - ◆ Performance Requirements
 - ◆ Interface Requirements
- Issues in the instrument design
 - ◆ Observation Time Slot
 - ◆ Ground Coverage
 - ◆ Expansion of Spectral Coverage
- Summary

Introduction

GEMS is a scanning UV-Visible imaging spectrometer to monitor trans-boundary pollution events in Asia-Pacific region.

◆ Science Objectives of GEMS

- ✓ To monitor O_3 , NO_2 , SO_2 , HCHO and Aerosol
- ✓ To provide measurements of atmospheric chemistry, precursors of aerosols and ozone in particular, in high temporal and spatial resolution over Asia
- ✓ To monitor regional transport events: transboundary pollution and Asian dust
- ✓ To improve our understanding on interactions between atmospheric chemistry and meteorology
- ✓ To better understand the globalization of tropospheric pollution
- ✓ To improve air quality forecast by:
 - Constraining emission rates
 - Data assimilation of chemical observations





Instrument Requirements

Operational Requirements

■ Lifetime and Reliability

- Lifetime : 7 years (option > 10 years)
- Reliability : > 0.85 @ EOL

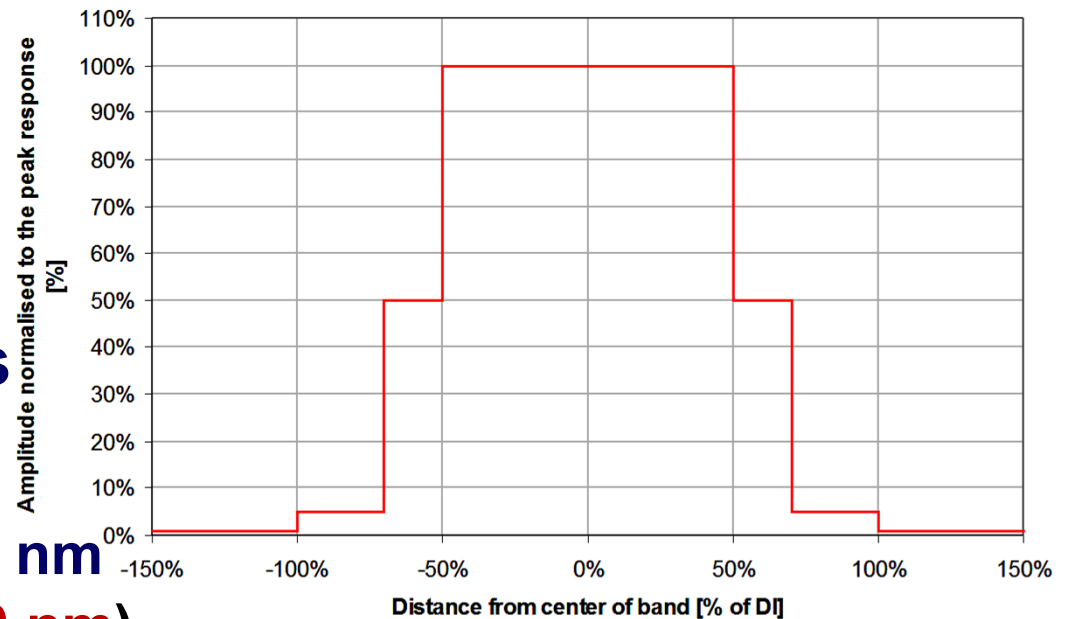
■ Mission Scenario

- GEMS orbital position : between 116°E & 138°E (TBC)
- Target area : 5000 km (N/S) × 5000 km (E/W) by the imaging instrument at nadir view
 - * Region of interest suggested
 - N/S region : from 55°N to 5°S
 - E/W region : from 75°E to 145°E
- Duty cycle : 8 images during daytime
- Imaging time : 1 hour

Performance Requirements

■ Geometric requirements

- GSD : 5 km (N/S) × 5 km (E/W) at Nadir
(option : 2.5 km (N/S) × 7.5 km (E/W) at Nadir)



■ Spectral requirements

- Continuous spectral channels from 300 to 500 nm
(option : expansion to 630 nm)
- Spectral resolution : $\Delta\lambda < \underline{0.6 \text{ nm}}$
- Spectral sampling : $\Delta\lambda < \underline{0.2 \text{ nm}}$

Performance Requirements (cont'd)

■ Radiometric requirements

- Input radiance level ($\text{W}/\text{m}^2/\mu\text{m}/\text{sr}$)

Spectral range [nm]	Nominal Radiance (L_{nom})	Minimum Radiance (L_{min})	Maximum Radiance (L_{max}) - COD ₁₀ /COD ₂₀
300-315	7.98	0.09	25.64/30.17
315-325	43.36	0.29	108.32/130.46
325-335	86.63	1.01	198.09/241.18
335-357	91.39	1.69	209.95/259.71
357-423	108.66	2.01	277.96/354.23
423-451	130.75	2.36	358.52/466.31
451-500	145.49	2.34	418.84/549.86

- SNR : 720 over the range of nominal radiance at 320 nm and 1500 over the range of nominal radiance at 430 nm
- Image data quantization : > 12 bits

Performance Requirements (cont'd)

■ MTF requirements

- MTF at GEMS level : > 0.3 (both N/S and E/W at nyquist)

■ Calibration requirements

- Radiometric Calibration Accuracy : < 4 %
- Spectral Calibration Accuracy : < 0.02 nm

■ Polarization requirements

- Polarization Factor : < 4 %

$$PF = (I_{max} - I_{min}) / (I_{max} + I_{min})$$

- Polarization Factor Variance : < 1 %

(relative polarization factor difference in the wavelength range)

Interface Requirements

■ Mechanical interfaces

- GEMS accommodation on +Zs face of satellite
- Volume ≤ 800mm (Xs), 1200mm (Ys), 700mm (Zs)
- Mass ≤ 110 kg

■ Thermal interfaces

- Satellite interface heat flux : TBD W
- Satellite interface temperature range : TBD

■ Electrical interfaces

- Satellite input regulated voltage : TBD V
- Max power demand : 100 W peak (TBC)
- Data rate : 10 Mbps (TBC)



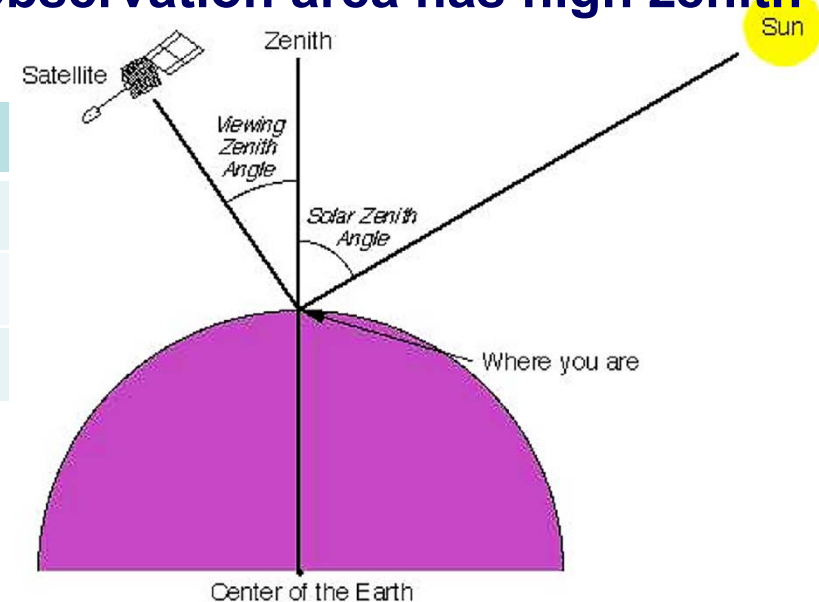
Issues in the Instrument Design

Observation Area & Time Slot

- Due to the geometry between the observation target and the satellite (from GEO), viewing zenith angle and solar zenith angle are changed at each time and season.
- The Region of Interest is slightly tilted from satellite Nadir-equator, the geological position of edge of observation area has high zenith angle.

Location	Seoul	Beijing	NewDelhi	Tokyo
VZA (Fixed)	43	47.5	64	43
SZA (ESZA < 58.67)	50	46.1	NA	50
SZA (ESZA < 72.31)	70	69.2	60.2	70

- For that reason, some area cannot meet adequate SZA requirement under difficult conditions.



Schematic illustration of the Solar Zenith Angle (SZA) and Viewing Zenith Angle (VZA) for observations from satellite-based instrument.
 [image taken from a NASA page with definitions
 (<http://asd-www.larc.nasa.gov/SCOOOL/definition.html>)]

Observation Area & Time Slot (cont'd)

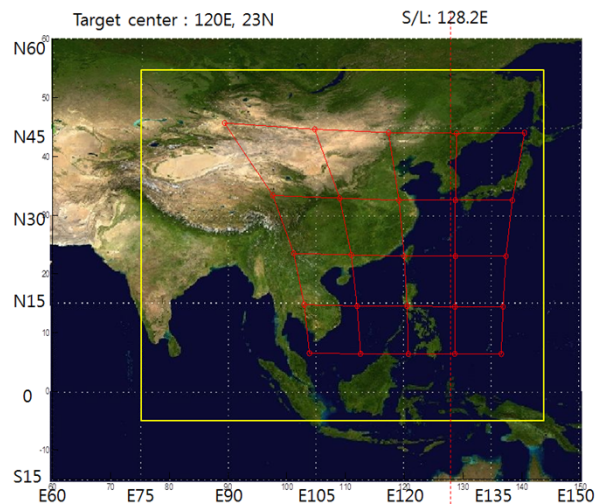
- This is the worst case (winter solstice) scenario for each location.

Time	Winter Solstice : ESZA < 58.67						Winter Solstice : ESZA < 72.31					
	Seoul	TopLeft	NewDelhi	Beijing	Russia	Tokyo	Seoul	TopLeft	NewDelhi	Beijing	Russia	Tokyo
9:00	0	0	0	0	0	0	0	0	0	0	0	0
10:00	0	0	0	0	0	0	0	0	0	0	0	1
11:00	0	0	0	0	0	0	1	0	0	0	0	1
12:00	0	0	0	0	0	0	1	0	0	1	0	1
13:00	0	0	0	0	0	0	1	0	0	1	0	1
14:00	0	0	0	0	0	0	1	0	1	1	0	1
15:00	0	0	0	0	0	0	1	0	1	1	0	0
16:00	0	0	0	0	0	0	0	0	1	0	0	0
Total	0	0	0	0	0	0	5	0	3	4	0	5

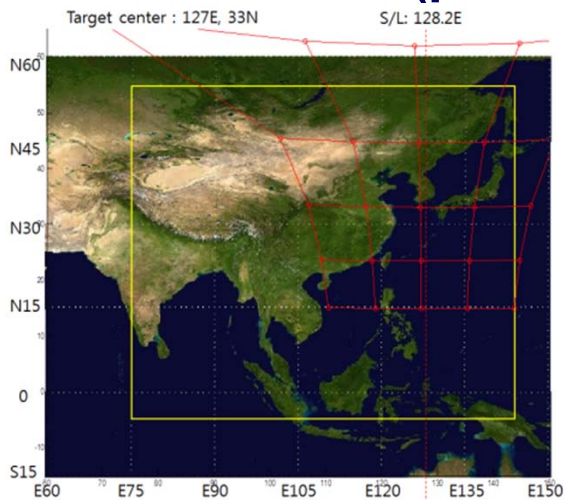
- Due to the large VZAs of NewDelhi, Russia, and TopLeft, there are still less chances for the GEMS to observe those area.
- It is better to observe the equatorial area rather than Northern area.
- FOR and ROI requirements need to be revisited practically.

Projected FOV, GSD and ROI

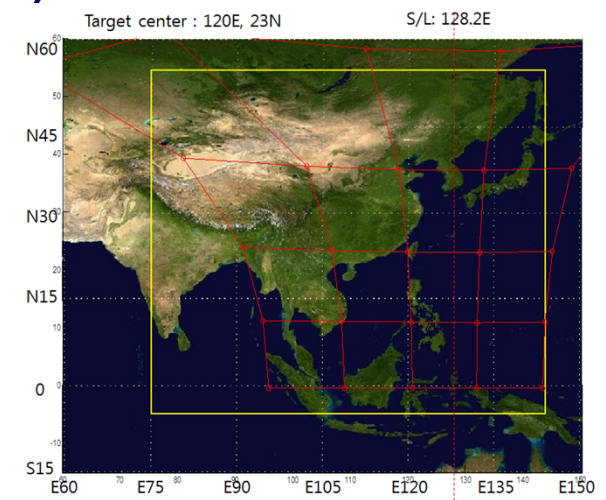
- From GEO SAT., the projected Earth surface with 1000 samplings and 5 km IFOV (current design concept) cannot cover full ROI (region of interest: 75°E~145°E and 5°S~55°N).
- There are some methods to cover the region, depending on the definition of payload nadir direction (position) and GSD reference.



Case A



Case B



Case C

- Trade-off between ROI, FOV & GSD requirements has to be performed.

Spectral Range Expansion

- **For the accuracy improvement of ozone detection, the measurement of Chappuis band (around 602 nm) is requested by End-user Group.**
- **Impacts on the GEMS design (in case of expansion to 630 nm)**
 - SNR decreases drastically → spectrometer must be redesigned
 - Overlapping diffraction order → order sorting filter must be added
 - MTF decreases → optical design must be changed
 - Data rate increases 1.65 times → higher compression ratio needed
 - Focal plane is enlarged → two 1k detectors or one 2k detector needed
- **It is need to define the requirements of SNR/MTF/Radiometric performance due to the expansion of the wavelength range.**

Summary

- **Key requirement items for the instrument H/W fixed.**
 - Target area : 5000 km (N/S) × 5000 km (E/W) at nadir view
 - Duty cycle : 8 images during daytime
 - GSD : 5 km (N/S) × 5 km (E/W) at Seoul (option 2.5 km × 7.5 km)
- **Spectral resolution improved and fixed as $\Delta\lambda = 0.6$ nm**
- **FOR and ROI requirements need to be revisited critically**
- **Expansion of the spectral range up to 630 nm is a big impact shaking most to its very foundation**
- **Requirement items with TBC or TBD attached should be finalized prior to the documentation of GEMS RFP**
- **Tasks ahead :**
 - Finalization the requirement spec and current issues**
 - RFP documentation and completion of formalities for its release**