THE GOCI INSTRUMENT ON COMS MISSION – THE FIRST GEOSTATIONARY OCEAN COLOR IMAGER

Topic 1 - Optical instruments for Earth / Planets surface and atmosphere study

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ABSTRACT:

Geostationary Ocean Color Imager (GOCI) is completing development to provide a monitoring of Ocean Color around the Korean Peninsula from geostationary platforms. Manufactured by ASTRIUM SAS, it is planned to be launched onboard Communication, Ocean, and Meteorological Satellite (COMS) of Korea in 2009.

GOCI will be the first ocean color imager to operate from geostationary orbit. The instrument is developed for use in South Korea under a KARI contract. The GOCI instrument completes its production and delivery to Korea for integration end 2008 onto the COMS satellite aside the COMS Meteo Imager (MI).

The mission is designed to significantly improve ocean observation from low orbit service by providing a high frequency coverage. The GOCI is designed to provide multi-spectral data to detect, monitor, quantify, and predict short-term changes of coastal ocean environment for marine science research and application purpose. Target area for the GOCI observation in the COMS satellite will cover a large 2500 x 2500 km2 sea area around the Korean Peninsula, with a local resolution of 500m.

This paper gives an overview of the mission objectives and major system requirements and an overall description of the instrument design and main characteristics. Several innovative features include the use of a dedicated advanced CMOS detector matrix coupled with a specifically designed pointing mechanism and of the use of solar calibration to provide an accurate absolute radiance

1. INTRODUCTION

Ocean color sensors such as MODIS, SeaWiFS, and MERIS have been developed to obtain the multi-spectral visible and near infra-red images of oceans. These ocean color sensors on low Earth orbiting satellites are capable of supplying highly accurate water-leaving spectral radiance with high spectral and spatial resolution at a global revisit period of approximately two to three days [1]. The relatively low frequency coverage of these sensors, further reduced in the presence of clouds or sun glint, is inadequate to resolve processes operating at a shorter time scales. In addition, the current sun-synchronous polar orbiter observations along coasts are aliased with the tidal frequency. High frequency observations are required in order to remove the effects of tidal aliasing and to validate tidal mixing terms in coastal ecosystem models [1] [2].

Geostationary Ocean Color Imager (GOCI) is completing development to provide a monitoring of ocean color at the Korean Peninsula from a geostationary platform. GOCI will be carried by the Communication, Ocean, and Meteorological Satellite (COMS) of Korea. The mission of GOCI and the corresponding requirement specification have been defined according to the requirement from the oceanography user community.

2. THE COMS MISSION

COMS is being developed by Korea Aerospace Research Institute (KARl) to provide to South-Korea three services from geostationary orbit :

- A meteo mission
- An ocean imager mission
- An experimental Ka band telecommunication mission

The meteo mission, provided by the Meteo Imager (MI), will allow continuous monitoring of imagery and extracting of meteorological products with high resolution (1kmx1km) and multi-spectral imager (1 visible and 4 IR). It will be used for early detection of special weather such as storm, flood, yellow sand, etc. Extraction of data on long-term will monitor change of sea surface temperature and cloud

The ocean color imaging mission is relying on the GOCI to provide classical ocean color information: chlorophyll, alga blooming, etc. for monitoring of long-term and short-term change of marine ecosystem.

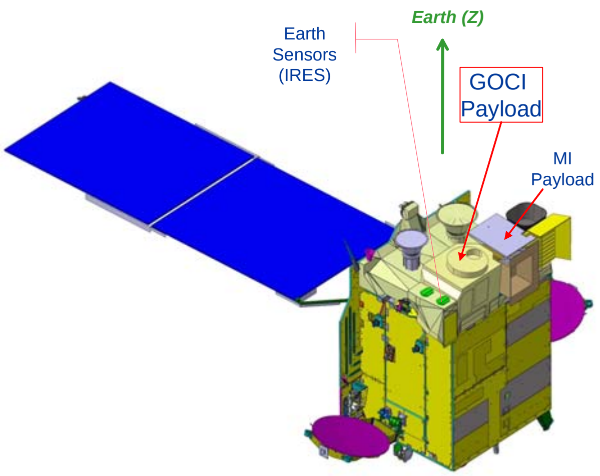

Fig 1 : COMS geostationary satellite

3. GOCI MISSION OVERVIEW

The GOCI is designed to provide multi-spectral data to detect, monitor, quantify, and predict short-term changes of coastal ocean environment for marine science research and application purpose.

Images are provided in eight spectral bands selected for ocean color monitoring in a 2500x2500 km2 area centered around the Korean peninsula.

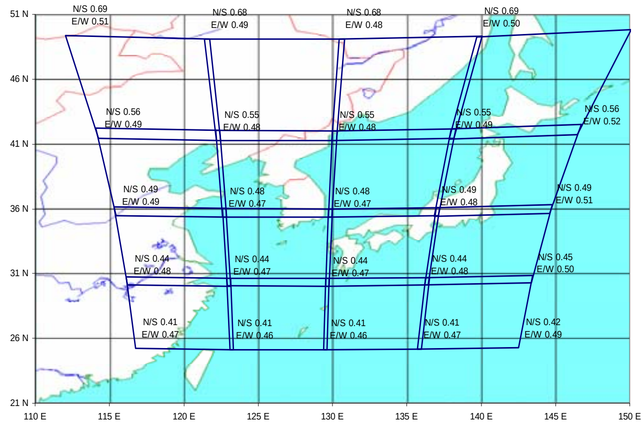

Fig 2 : GOCI target area around Korea

The GOCI spectral bands have been selected for their adequacy to the ocean color observation, as shown in Table 1.

Table 1 : GOCI spectral bands

Band	Center	Band-width	Main Purpose
1	412 nm	20 nm	Yellow substance and turbidity extraction
2	443 nm	20 nm	Chlorophyll absorption maximum
3	490 nm	20 nm	Chlorophyll and other pigments
4	555 nm	20 nm	Turbidity, suspended sediment
5	660 nm	20 nm	Baseline of fluorescence signal, chlorophyll, suspended sediment
6	680 nm	10 nm	Atmospheric correction and fluorescence signal
7	745 nm	20 nm	Atmospheric correction and baseline of fluorescence signal
8	865 nm	40 nm	Aerosol optical thickness, vegetation, water vapor reference over the ocean

Fig.2 shows the eight GOCI narrow bands spread over the visible spectrum from 0.4 to 0.9 µm.

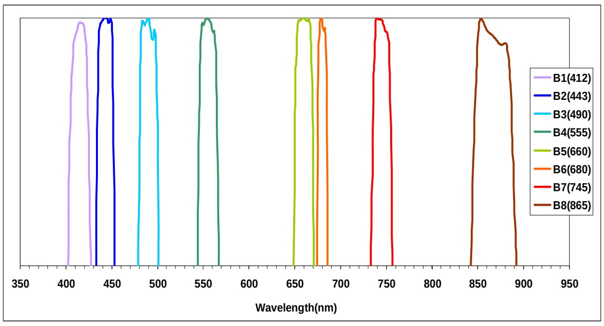

Fig 2 : GOCI global spectral response

4. GOCI MAIN REQUIREMENTS

GOCI imaging main requirement is to cover a 2500x2500 km2 area around South Korea as shown in Fig 2. Ground pixel size is 500x500 m2 at centre of field, defined at (130°E - 36°N). Such resolution is equivalent to a Ground Sampling Distance (GSD) of 360 m in NADIR direction, on the equator.

The GSD is varied over the target area because of the imaging geometry including the projection on Earth and the orbital position of the satellite.

Imaging principle on GOCI is step-and-stare based on a dedicated 2Mpixels CMOS detector (1400x1400 pixels) passively cooled and regulated around 10°C. The GOCI matrix is a custom CMOS imaging sensor featuring rectangular pixel size to compensate for the Earth projection over Korea, and electro-optical characteristics matched to the specified instrument operations. The detector comes from the COBRA family, developed and qualified by ASTRIUM in cooperation with ISAE/CIMI for circuit design and with E2V for back-end manufacturing.

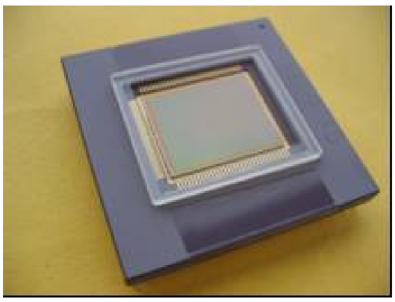

Fig 3 : GOCI 2 Mpixels CMOS Detector (shown with temporary window)

The step-and-staring method is used to build a slot for each band, with an adjustable integration time ranging typically between 3 and 8 seconds depending on spectral band. This acquisition time is needed to obtain the high Signal-to-Noise Ratio (SNR) requirement, above 1000, specified for all bands. For each image, two gains are acquired to build a non saturated image: high gain for sea with low radiance and low gain for clouds with high radiance. Low gain images are done with a short integration time of about 0.1second.

The onboard electronic digitalizes the signal in both gains on 12 bits. To reduce downloaded data, the electronic unit selects the pixels sent on ground: high gain if not saturated, low gain in the opposite case.

Radiometric accuracy is obtained using in-orbit calibration on sun light with a full pupil solar diffuser.

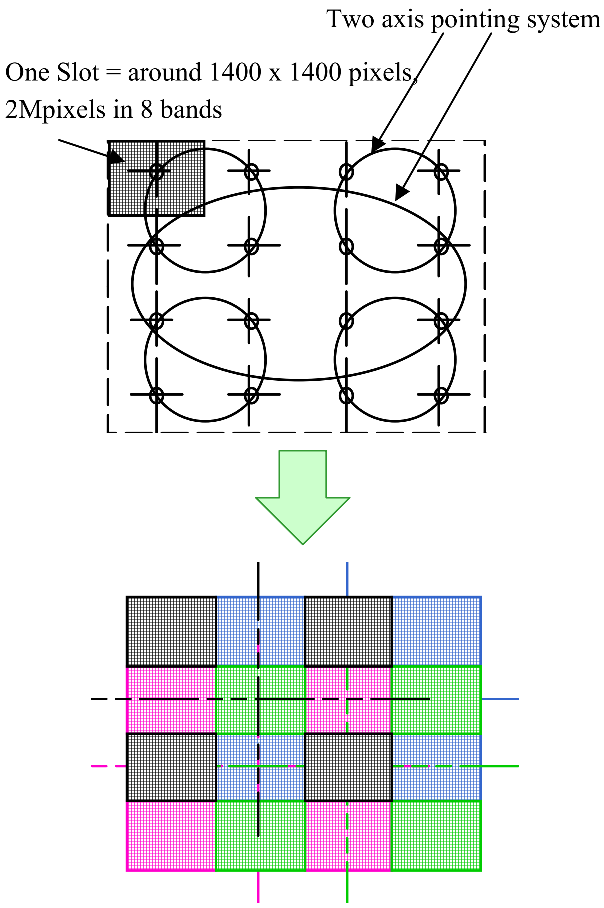

Fig 4 : Principle of GOCI image acquisition
Total field of view is 32 Mpixels acquired in 16 slots

A pointing mirror supported by a 2-axis scan mechanism allows choosing the centre of the slot. The image is built by successively positioning the Line of Sight (LOS) at the centre of the 16 slots resulting in a 32 Mpixel images, as shown on Fig. 4. A slot acquisition takes about 100 seconds for the 8 bands and dark signal acquisition. The complete image set in all bands is thus acquired and downloaded in less than 30 minutes.

The principle of the pointing mechanism is an assembly of two rotating actuators mounted together with a cant angle of about 1°, the top actuator carrying also the Pointing Mirror (PM) with the same cant angle. When rotating the lower actuator the LOS is moved on a circle and by rotating the second actuator, a second circle is drawn from the first one. It is thus possible to reach any LOS position inside the target area by choosing appropriate angle position on each circle. The mechanism pointing law provides the relation between rotation of both actuators and the LOS with a very high stability. This high accuracy pointing assembly used to select slots centers is able to position the instrument LOS anywhere within a 4° cone, with a pointing accuracy better than 0,03 ° (500 µrad). Position knowledge is better than 10 µrad (order of pixel size) thanks to the use of optical encoders. The pointing mechanism is shown on Fig 5.

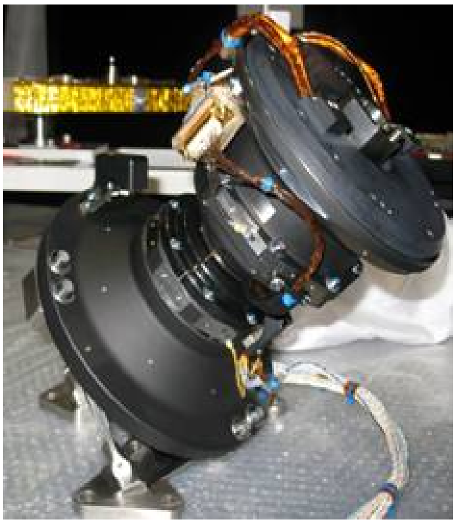

Fig 5 : GOCI Pointing Mechanism (w/o mirror)

System MTF is required better than 0.3 at Nyquist on all bands after ground processing. Ground processing is used to level the SNR and MTF at equivalent values on all bands and direction.

Instrument nominal life time is 8 years, including 10 images per day and a calibration every night.

5. GOCI DESIGN OVERVIEW

The GOCI instrument is split into a Main "optical" Unit and an Electronic Unit.

Total GOCI Mass is below 78 Kg. Power needed is about 40W for the electronics plus about 60W for Main Unit thermal control. A Payload Interface Plate (PIP) is part of the Main Unit. It supports a highly stable full Sic telescope, mechanisms and proximity electronics and it interfaces with the satellite structure. Fig. 6 shows the Main Unit layout which overall dimensions are 1.00 (PIP 1.4) x 0.80 x 0.80 m3. The PIP is larger than the instrument to carry the satellite Earth position sensor. The Electronic Unit is deported on a satellite wall about 1.5 m from the instrument and provides mechanisms control, video acquisition and digitalization, mass memory and power. It interfaces with the satellite power and control bus. Fig 7 shows the Electronic Unit.

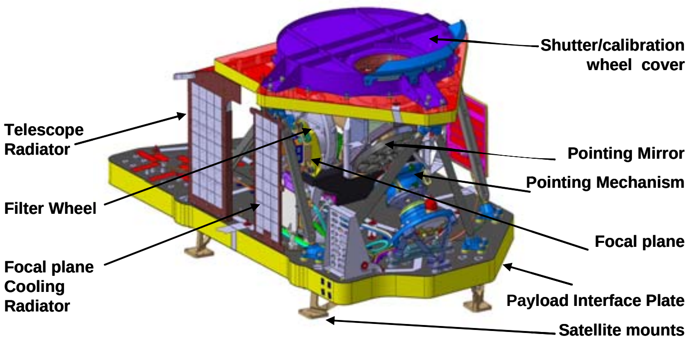

Fig 6 : GOCI Main Unit, without MLI protection

Fig 7 : GOCI Electrical Unit

The 8 spectral channels are obtained by a filter wheel which includes a dark plate in order to measure the system offset as well as 8 spectral filters. The filter wheel is shown on Fig. 8, with protective covers removed to show the 8 filters.

Fig 8: GOCI filter wheel

Calibration is achieved by sunlight at night through a full pupil diffuser, made of fused Silica insensitive to radiation aging. A second diffuser of smaller size is used to verify the main diffuser stability. The full pupil solar diffuser (Fig 9) and diffuser monitoring (Fig 10) are both carried by the shutter wheel which also provides open or closed position in front of the optical aperture.

The radiometric calibration of the GOCI will be performed for all pixels of detector matrix at ground segment by using the on-ground and in-orbit calibration data. The radiometric response of the GOCI has been characterized through on-ground calibration. The radiometric gain parameters will also be estimated through in-orbit calibration. The change of radiometric response will be corrected periodically through in-orbit calibration using the on-board calibration devices [3]. The GOCI operation concept is compatible with “every night” in-orbit calibration. The radiance provided by the Solar Diffuser (SD) over the whole field of view of the GOCI is calculated using the sun angle and the diffusion factor of solar diffuser which was characterized through ground tests.

Fig 9 : Full pupil Solar Diffuser (external side)

Fig 10 : Diffuser monitoring (internal side)

A dedicated actuator was developed to rotate the filter wheel and shutter wheel.

6. MAIN TECHNICAL CHALLENGES

Advantages of geostationary orbit are numerous from a mission point of view. Continuous observation of the scene of interest is possible with images provided every hour, which maximizes chance of clear observation of the whole field even in cloudy season. No sun glint occurs thanks to the angular position of the field of view during daytime, while it discards many observations in low orbit. Possible short-term operational monitoring and long term analysis are both possible. Finally, the geostationary position allows benefiting from a full pupil calibration with sun light, every night as needed.

However such advantages mean also some technical challenges. The main challenges are radiometry and environment constraints.

Radiometry is obviously critical: geostationary orbit is much further from target than low orbit, reducing available signal more than 500 times. Narrow filter bands are used and low water radiance coupled with high SNR call for long integration times which would be incompatible with a scanner concept. This has been overcome thanks to the use of the CMOS matrix, thermally regulated for high stability, allowing integration times of few seconds per pixel while keeping a total field acquisition below 30 minutes.

Challenging mass and volume targets were coupled with strong mechanical and thermal environment constraints due to compatibility with all launchers and an instrument position outside satellite structure. This was met with a compact and stable full Sic telescope not requiring fine thermal control.

7. PROJECT DEVELOPMENT STATUS

GOCI development started mid 2005 along with COMS satellite.

The Flight Model (FM) is now ready and completing its test sequence for shipment and integration onto COMS satellite by end 2008. Fig. 12 and Fig 13 show the unit during integration and alignment test phases. Fig. 11 shows the Main Unit during vibration tests before summer 2008

Launch is foreseen in 2009 and operational mission will start after a half-year commissioning.

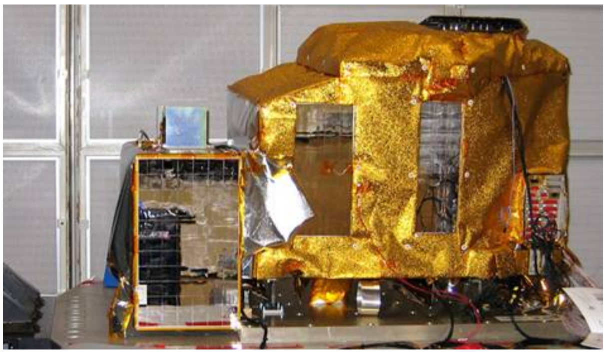

Fig 11: GOCI Flight Main Unit during Vibration Test

Fig 12: GOCI Flight Main Unit during Integration without MLI protection

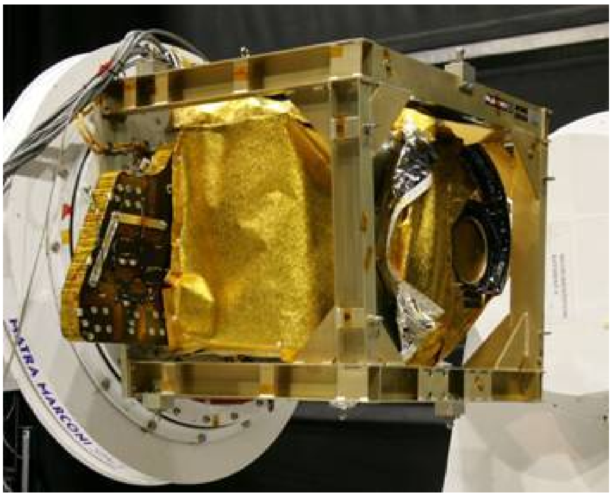

Fig 13 : GOCI Flight Main Unit during alignment tests

8. REFERENCES

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[3] SPIE (2006) *Radiometric Calibration Method for the GOCI (Geostationary Ocean Color Imager)*, Gmsil Kang, Heong Sik Youn, and Seong Bong Choi, Korea Aerospace Research Institute (South Korea) Pierre Coste, Astrium (France), Proc. SPIE, Vol. 6361, 636112