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Communications

KOMPSAT Data Processing System: An Overview and Preliminary Acceptance Test Results

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Abstract : The optical sensors of Electro-Optical Camera (EOC) and Ocean Scanning Multi-spectral Imager (OSMI) aboard the KOrea Multi-Purpose SATellite (KOMPSAT) will be placed in a sun synchronous orbit in late 1999. The EOC and OSMI sensors are expected to produce the land mapping imagery of Korean territory and the ocean color imagery of world oceans, respectively. Utilization of the EOC and OSMI data would encompass the various fields of science and technology such as land mapping, land use and development, flood monitoring, biological oceanography, fishery, and environmental monitoring. Readiness of data support for user community is thus essential to the success of the KOMPSAT program. As a part of testing such readiness prior to the KOMPSAT launch, we have performed the preliminary acceptance test for the KOMPSAT data processing system using the simulated EOC and OSMI data sets. The purpose of this paper is to demonstrate the readiness of the KOMPSAT data processing system, and to help data users understand how the KOMPSAT EOC and OSMI data are processed, archived, and provided. Test results demonstrate that all requirements described in the data processing specification have been met, and that the image integrity is maintained for all products. It is however noted that since the product accuracy is limited by the simulated sensor data, any quantitative assessment of image products can not be made until actual KOMPSAT images will be acquired.

Key Words : KOMPSAT, EOC, OSMI, Data Processing, Simulated Sensor Data, Preliminary Acceptance Test

1. Introduction

As a part of the KOrea Multi-Purpose SATellite (KOMPSAT) program, the Korea Aerospace Research Institute (KARI) has undertaken the development, installation and operation of the KOMPSAT receiving and processing system (KRPS) since 1995. The main mission of the KRPS is to acquire, process, store, and distribute the data from KOMPSAT payload instruments: an Electro-Optical Camera (EOC), an Ocean Scanning Multi-spectral Imager(OSMI), an Ionosphere Measurement Sensor (IMS), and a High Energy Particle Detector (HEPD).

The KRPS major subsystems as shown in Fig. 2 are the Data Acquisition Facility (DAF), the Direct Ingest System (DIS), the Data Processing Facility (DPF), and the Value-Added Subsystem (VAS). The DAF subsystem tracks the KOMPSAT satellite and captures the X-band downlinked telemetry stream. The DIS ingests these real-time data stream, formats the data, and stores the data

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on a Redundant Array of Inexpensive Disks (RAID). The data can then be archived or processed immediately by the DPF that generates standard image products. The VAS using PCI software completes the processing through the generation of end-user products (Level-4). All subsystems are connected by a 100Mbps Ethernet.

In this paper, we are primarily concerned with testing the ability of the KRPS to process the EOC and OSMI data and thus focus on the functional test. Since the actual EOC and OSMI data are not available for this test, we have used the simulated EOC and OSMI data as will be discussed in the next section.

2. Simulated Sensor Data

The timely provision of the reliable simulated EOC and OSMI data has been considered important for the KRPS project in terms of validating the KRPS development software, and hence these tasks have been procured by the experienced organizations. In principle, the usefulness of the simulated sensor data depends upon the thoroughness with which the data are prepared, the adherence to format/content specifications, and the realism of the data (Gregg *et al.* 1997). The efforts to adhere such a principle have been made in the development of the simulated EOC and OSMI data. The KOMPSAT specific parameters of spacecraft, orbit, sensor, and data format were incorporated in the simulated EOC and OSMI data. Along with these simulated sensor data, we have generated the corresponding ancillary data necessary for generating standard image products.

The Colorado Front orthorectified imagery (1 meter resolution) and its associated Digital Elevation Model (DEM) map (20 meter posting) were used to generate stereo pairs of the simulated EOC image. The process consists of the DEM data processing, the platform ephemeris and line-of-sight (LOS) generation, the surface back projection and processing of the detector array for a single time sample, and the EOC sensor modeling. The radiation model code MODTRAN was used to calculate the transmittance of the atmosphere and path radiance in the EOC sensor model. The process involved in the simulated EOC image is displayed in Fig. 1.

The Sea-viewing Wide Field-of-view Sensor

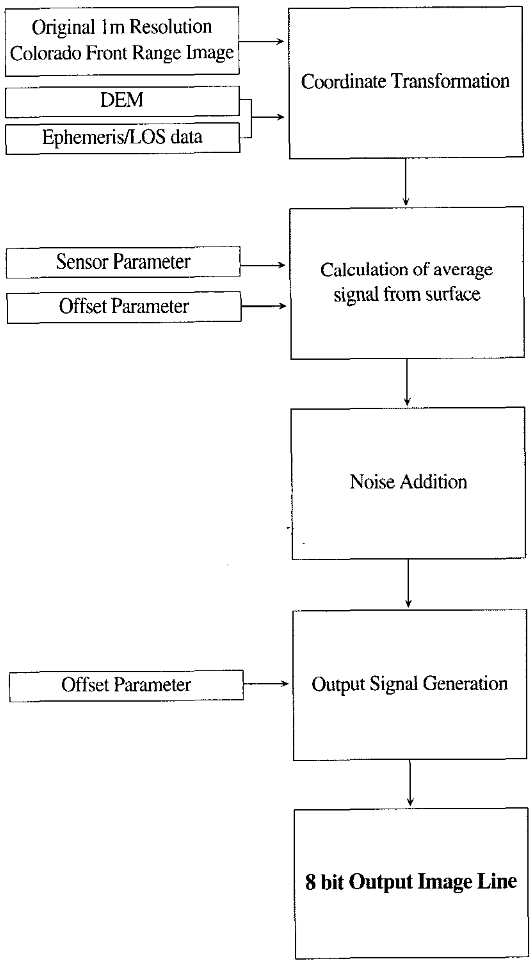


Fig. 1 Flow Chart of EOS Simulated Data

(SeaWiFS) data were used as source data to produce the simulated OSMI data. A total of 12 scenes including the coastal and open ocean environments were generated for the various sea states and cloud cover. The raw SeaWiFS data were radiometrically corrected using sensor gains and offsets, and converted into at-satellite spectral radiances. The resulting pixel values were projected onto the Earth's surface. A sensor-Earth viewing model incorporates the OSMI viewing geometry and was used to produce at-satellite radiance as a function of frame number, along-track pixel, and spectral band. These at-satellite radiances were then converted into digital counts and formatted into Science Data Format (SDF) for the KRPS test.

3. Product Processing

As shown in Fig. 2, the DPF retrieves the Level 0 telemetry from the DIS, combines with ancillary data, and produces the EOC and OSMI standard products. The EOC and OSMI data products will be archived in Hierarchical Data Format (HDF). The level definitions of the EOC and OSMI data products are given in Table 1. The radiometric calibration processing described in the Appendix converts the measured digital number to the physical quantity (at-satellite radiance) and produces Level 1R images for EOC and Level 1B images for OSMI.

The EOC product processing is performed by the OPEN2000 software that basically consists of the following six software modules: Catalog Browse Module (CBM), External Browse Module (EBM), Geometric Correction Module (GCM), Product Control Module (PCM), Product Tracking Module (PTM), and Satellite Programming Module (SPM). Fig. 3 illustrates the EOC product processing flow from the data collection planning to the generation of an orthoimage map. Radiometrically corrected Level 1R images are geometrically corrected by using either the position, velocity and attitude of spacecraft or ground control points (GCP) to

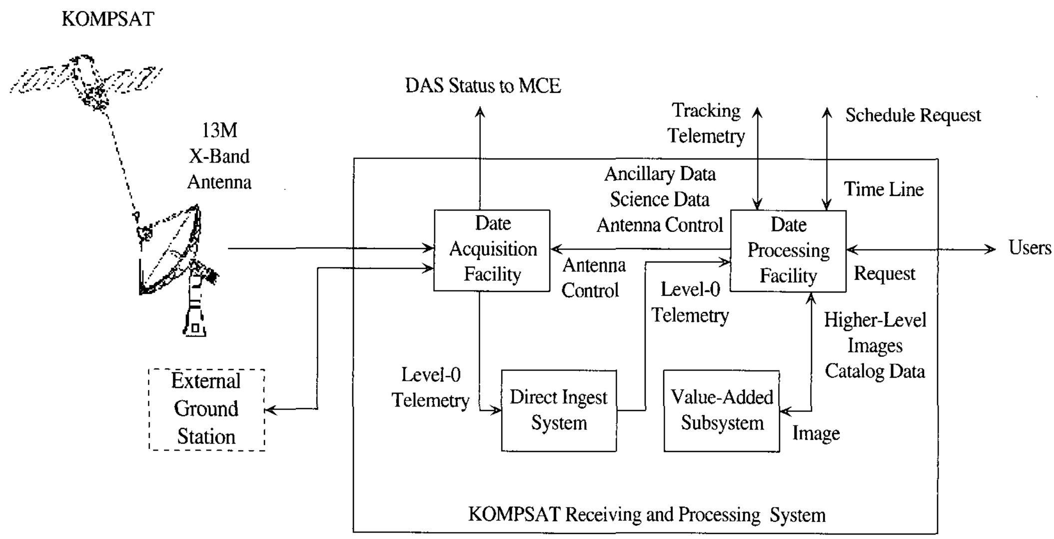


Fig. 2. KOMPSAT Receiving and Processing System

Table 1. Data product level definitions

	Product Level	Description
EOC	Leve l 0	Frame formatted, unprocessed instrument/payload data at full resolution; any and all communications artifacts (e.g., synchronization frames, communications headers) removed
	Level 1A	Unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (i.e., platform ephemeris) computed and appended, but not applied, to the Level 0 data
	Level 1R	Level 1A data that have been radiometrically corrected
	Level 1GR	Level 1R data that have been geometrically corrected and geo-referenced
	Level 1GC	Level 1R data that have been geometrically corrected and geo-coded Note: Level 1GC may be further processed with the following options: Level 1GC_P: Precise geometric correction with GCP Level 1GC_D: Geometric correction with DEM
	Level 4	Value added EOC products such as mosaic, DTM and maps
OSMI	Level 0	Frame formatted, unprocessed instrument/payload data at full resolution; any and all communications artifacts (e.g., synchronization frames, communications headers) removed
	Level 1A	Unprocessed instrument data at full resolution, time-referenced, and annotated with ancillary information, including radiometric and geometric calibration coefficients and georeferencing parameters (i.e., platform ephemeris) computed and appended, but not applied, to the Level 0 data
	Level 1B	Radiometrically corrected level 1A data that have been converted to at-satellite radiances
	Level 2	Derived geophysical variables at the same resolution and location as the Level 1A data
	Level 3	Geophysical variables mapped on uniform space/time grid scales
	Level 4	Value added OSMI products

produce the Level 1GC and Level 1GC_P images, respectively. Level 1GR products are intermediate in terms of geometric correction because only the effect of the Earth's rotation has been corrected. The DEM products are derived from a pair of Level 1R (left and right) images for a given area. If DEM is available for a given area, Level 1R images are subsequently processed for the generation of Level 1GC_D images and orthoimage maps.

The OSMI product processing is however done through the OSMI data analysis system (OSMIDAS) with a product search function embedded in the PTM. The OSMIDAS is developed based upon the NASA SeaWiFS data analysis system (SeaDAS) and capable of processing, display, and analysis of all OSMI data products from Level 0 to standard map images (Lee *et al.*, 1999). Figure 4 shows the OSMI product processing flow with the relevant input specification. Level 3 processing not shown in Fig. 4 is identical to the SeaWiFS algorithms. The module l1bgen in the OSMIDAS performs the radiometric calibration processing with an appropriate calibration file, yielding Level 1B products. The module l2gen reads Level 1A products and performs the radiometric correction and the atmospheric correction with the use of weather data such as ozone, wind, precipitable water, and pressure. Weather data are obtained from NASA/GSFC via ftp. The results of l2gen processing include the following geophysical outputs: normalized water leaving radiance (at 412nm, 443nm, 490nm, and 555nm), CZCS-like

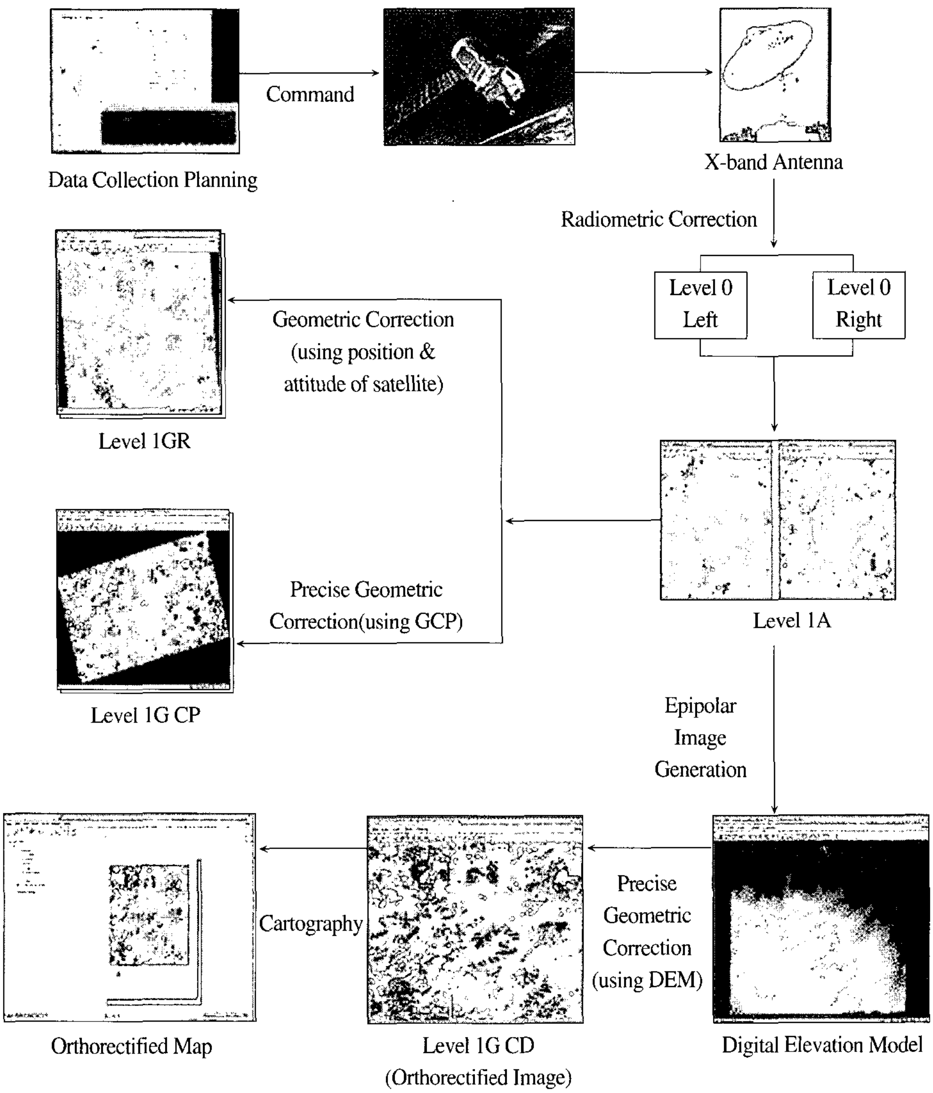


Fig. 3. EOC product processing flow

pigment concentration, chlorophyll a concentration, diffuse attenuation coefficient (K_490), a ratio of chlorophyll a to K_490, epsilon of aerosol correction (at 765nm and 865nm), and aerosol optical thickness (at 865nm). The bl1map and bl2map modules provide a geometric correction function for Level 1A, 1B, and 2 products to improve the individual map projection. Level 3 products are generated from Level 2 products taking spatial averages over a 9km × 9km bin and temporal averages over a period of a day, 8 day, 1 month, and 1 year.

4. Test Procedures and Results

The preliminary acceptance test for the KRPS has been conducted at KARI to qualify the DIS,

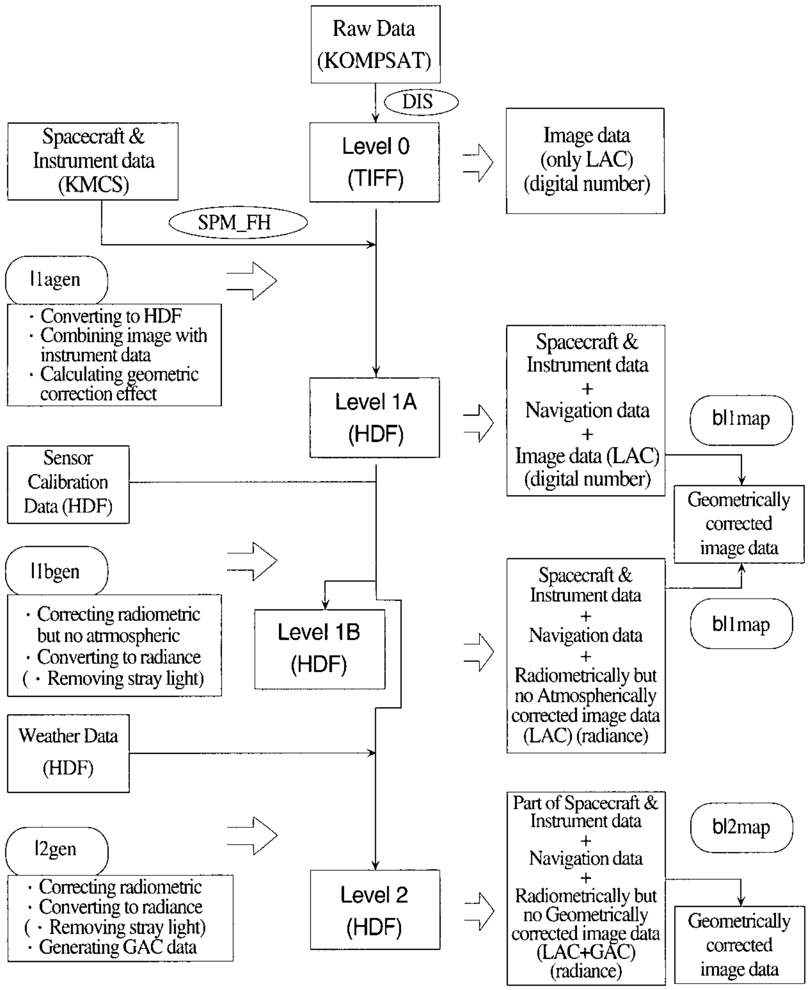
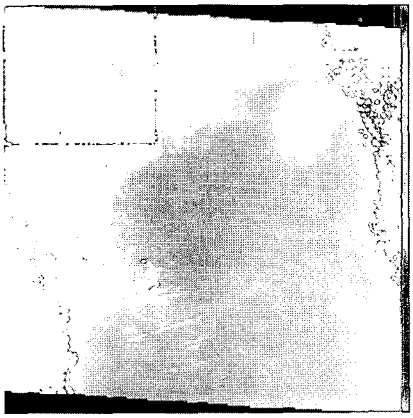
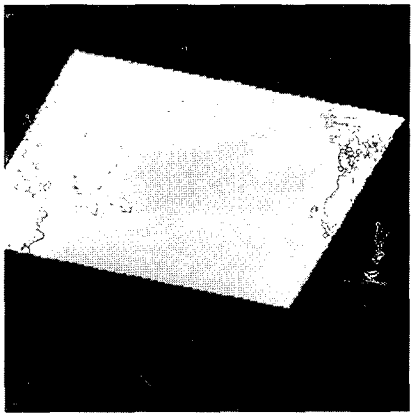


Fig. 4. OSMI product processing flow

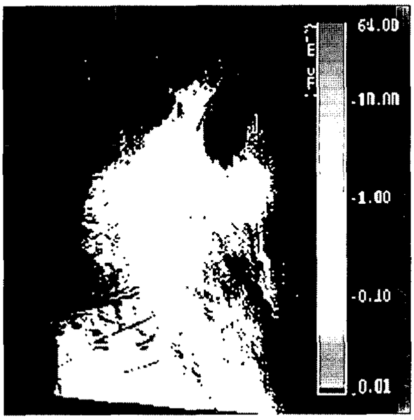
DPF, and VAS hardware and software, with emphases on the image processing for the EOC and OSMI sensors. The test procedure for image processing consists of the following: data ingestion, data retrieval, inventory/catalog order, product search, product order, product generation, and product archival (Frost, 1999; Ringwald, 1999). The EOC product generation was tested for Level 1R, Level 1GR, Level 1GC_P, DEM, DEM mosaic, Level 1GC_D, and EOC orthoimage maps. The OSMI product generation includes the Level 1A, Level 1B, Level 2, Level 3, and standard map images. Fig. 3 and Fig. 5 show some product images of the EOC and OSMI data processing, respectively, for which the corresponding simulated data are used. It is apparent that image integrity remains in each product image. Test results also demonstrated that some quantitative requirements for the EOC data processing (e.g., 1:25,000 scale orthoimage map generation and DEM with 20m vertical accuracy when adequate GCPs are available) have been met using the 1m resolution geocoded image and DEM map. Nevertheless, it is cautioned that



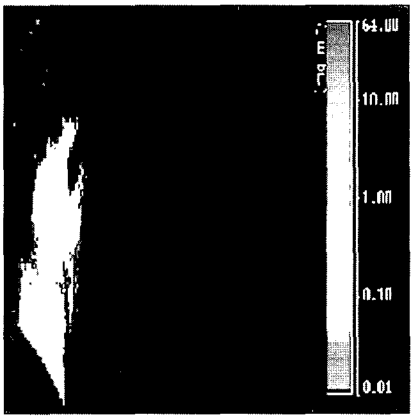
Level 1A (555 nm)



bl1map (555 nm)



Level 2 (Chlorophyll a)



Level 3 (Chlorophyll a)

Fig. 5. OSMI image products derived from the simulated data over the eastern coast of Canada

because of the limitations of the simulated sensor data, the detailed quantitative assessment with respect to image fidelity must be deferred until after the KOMPSAT launch.

5. Online Data Services

Anyone in the user community can have access to the online catalog database of the EOC and OSMI imagery via the World Wide Web (WWW). The URL of the KRPS web site is http://krps.kari.re.kr. The catalog database maintained by the EBM(External Browse Module) server includes the EOC and OSMI browse image and the related information such as date, time, geographical location, cloud cover, and so forth. The user can log in to the EBM server either as a registrant or as a guest. Once the user logs in successfully, a graphical map query will be displayed to allow selection of a specific sensor (EOC or OSMI) and a geographical search area. After the user has entered the search criteria, the scene list with identification data will be presented to the user. The user may then choose any of the items on the list for viewing and click on the add button to order images.

Acknowledgments

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Appendix: EOC and OSMI Radiometric Calibration Processing

In this appendix we introduce the EOC and OSMI radiometric calibration processing which the measured digital numbers are converted to the physical quantities (at-satellite radiance). Each sensor calibration model described below formulates such conversion. Sensor calibration models are similar to the SeaWiFS calibration model (Barnes *et al.*, 1994) and can incorporate the selection of the electronic gains, the scan modulation factor, the long-term sensor degradation factor, and so on.

1) EOC calibration model

The basic equation to be applied for the EOC Level 1A data is as follows:

$$L_{EOC}(p,t,gs,os,T) = K_1(t)\cdot\{\frac{K_2(p)}{EG(gs)}\}\cdot\{1+K_3\cdot(T-T_{ref})\}\cdot\{C(p)-DC(p)-EO(os)\}$$

where

L_{EOC} is the measured radiance in units of $\frac{W}{(m^2\cdot sr\cdot\mu m)}$;

$K_1(t)$ is the unit-less long-term sensor degradation factor, modeled as a quadratic equation as a function of days since launch;

$K_2(p)$ is the Calibration Gain Factor in units of $\frac{W}{(m^2\cdot sr\cdot\mu m\cdot count)}$ for each sensor pixel p=0..2591;

EG(GS) is the unit-less electronic gain factor for each commanded gain setting gs=0..7;

K_3 is the temperature dependence factor in units of (°C)-1 to be multiplied by the difference between the sensor temperature T and a reference temperature T_{ref};

C(p) is the input pixel count in units of counts for each pixel p=0..2591;

DC(p) is the dark current in units of counts for each pixel p=0..2591;

EO(os) is the sensor electronics offset in units of counts based upon the commanded offset setting os=0..15.

2) OSMI calibration model

The basic equation to be applied for the OSMI Level 1A data is as follows:

$$L_{OSMI}(b,p,t,gs,os,fp,T)=R(b)\cdot(K_1(b,t)\cdot\{\frac{K_2(b,fp)}{EG(gs)}\}\cdot\{1+K_3(b)\cdot(T-T_{ref})\}\cdot K_4(p)\cdot\{C(b,p)-DC(b,fp)-K_5\cdot os\}$$

where

L_{OSMI} is the measured radiance in units of $\frac{mW}{(cm^2\cdot sr\cdot\mu m)}$;

R(b) is the unit-less mirror reflectance factor for each band b=0..5;

$K_1(b,t)$ is the unit-less long-term sensor degradation factor, modeled as a quadratic equation for each band b=0..5 as a function of days since launch;

$K_2(b,fp)$ is the Calibration Gain Factor in units of $(\frac{mW}{cm^2\cdot sr\cdot\mu m\cdot count})$ for each band b=0..5, and sensor frame pixel fp=0..95;

EG(gs) is the unit-less electronic gain factor for each commanded gain setting gs=0..7;

$K_3(b)$ is the temperature dependence factor in units of $(^{\circ}C)^{-1}$ for each band b=0..5, to be multiplied by the difference between the sensor temperature T and a reference tem-perature T_{ref};

$K_4(p)$ is the unit-less scan modulation factor (relative detector sensitivity changes along a scan) for each pixel p=0..1043;

C(b,p) is the input pixel count in units of counts for each band b=0..5, and each pixel p=0..1043;

DC(b,fp) is the dark current in units of counts for each band b=0..5, and sensor frame pixel fp=0..95;

K_5 is the sensor electronics offset in units of (counts/unit offset) to be multiplied by the commanded offset setting os=0..255.

The EOC and OSMI calibration files are formatted in HDF, which provides the capability to retain calibration history for the KOMPSAT mission lifetime. Each of the model factors described above is stored within HDF objects. For example, the EOC HDF objects are CalTimes, Electronics, Longterm, TempCorr, Slopes, and DCs, and the OSMI HDF objects include CalTimes, Electronics, Mirror, Longterm, TempCorr, Slopes, DCs, and ScanMod.