THE CONCEPTUAL, PLAN AND APPROACH OF RAZAKSAT™ : PRE-FLIGHT RADIOMETRIC CALIBRATION

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Abstract

RazakSAT™ is the second remote sensing satellite of Malaysia which has been developed by Astronautic Technology (M) Sdn. Bhd. (ATSB). Medium-sized Aperture Camera (MAC), the high resolution imaging payload of the RazakSAT™ is designed to provide one panchromatic band and four multi-spectral bands in the visible to near infra red (VNIR) spectrum: Red, Green, Blue and Near Infra Red (NIR) band. The RazakSAT™ pre-flight radiometric characterization of MAC consists of the laboratory observation of the integrating sphere that generates uniform radiance field to all multi-spectral and panchromatic channels. The Pre-flight Calibration data derived from the measurements shall be used as correction multipliers in the processing of the acquired MAC images. This paper attempts to give an overview of MAC System, describes the Pre-flight Radiometric Calibration methodology and approach as well as the calibration equipment derivation & identification.

Keywords: *Radiometric Calibration, RazakSAT™, Medium-sized Aperture Camera (MAC), Pre-flight Calibration, Calibration Equipment.*

1. INTRODUCTION

The mission of the second remote sensing satellite of Malaysia, RazakSAT™ by Astronautic Technology (M) Sdn. Bhd is to provide an Earth Observation System in the visible and near infra-red spectrum with high temporal revisit over the equatorial region. The mission lifespan is catered for three years. In supporting the mission, the spacecraft is designed for a Low Earth Orbit with an orbit inclination of 9 degrees and at a nominal altitude of 685km above sea level covering 20km of swath width. The intended applications for the RazakSAT™ mission lie within the reflected visible and near infra-red range, providing studies for vegetation, water body, soil, as well as map generation to the scale of 1:25,000.

2. PERFORMANCE SPECIFICATIONS

The imaging payload of the RazakSAT™ is the Medium-sized Aperture Camera (MAC), a pushbroom optical instrument consisting of four multi-spectral (MS) channels and one panchromatic (PAN) channel for operations. The data is linearly quantized to 8-bit for 256 radiometric levels. Ground Sampling Distances (GSD) is 2.5m and 5.0m for the panchromatic band and multi-spectral bands, respectively at the nominal altitude. Table 1 below shows a characteristic of the MAC spectral bands.

Spectral Bands	Wavelength	Pixels
Panchromatic	510 – 730 nm	8192
Blue	450 – 520 nm	4096
Green	520 – 600 nm	
Red	630 – 690 nm	
Near Infra-Red (NIR)	760 – 890 nm	

Table 1: Characteristics of Spectral Channels in MAC.

3. CALIBRATION REQUIREMENT

The calibration activities involve characterizing the radiometric performance of the complete RazakSAT™ MAC across all multi-spectral channels as well as the panchromatic channel. Therefore it is required to have uniform radiance across the MAC sensing field of view to characterise the response linearity and to obtain radiance responsivity for all sensing elements across all spectral channels. The calibration accuracy of the radiometric responsivity for the multi-spectral channels is required to be better than ± 10%. The calibrated sources hence become the fundamental requirement for this exercise, where the sources should be stable and reproducible. The radiance responsivity is required to be traceable to the National Institute of Standards and Technology (NIST).

These requirements impose the selection criteria for all characterisation instruments to be employed. As the integrating sphere is employed for spatial uniformity source, the sphere shall be driven by lamps as working standards referenced to diffusely reflected FEL type tungsten-halogen lamp as standard traceable to NIST. Similar requirements are expected for the spectral radiance measurements through the spectroradiometer.

4. PRE-FLIGHT RADIOMETRIC CALIBRATION

The pre-flight radiometric characterisation of MAC consists of the laboratory observation of the integrating sphere that generates uniform radiance field. Concurrent spectral radiance measurement shall also be measured by the spectroradiometer. The MAC shall capture the uniform radiance from the integrating sphere across its aperture, and with incremental radiance to characterise response linearity to full well capacity. With a uniform source across the whole field of view, the pixel-to-pixel response uniformity shall be characterised for all sensing channels. Interpolation of the MAC spectral band response digital counts to the corresponding in-band integrated spectral response from the spectroradiometer shall provide the MAC band radiance responsivity as conversion factor and offset for the four multi-spectral channels.

The uniformity characterization data produced for all pixels across all sensing channels shall be used as the correction data to be injected to the product generation subsystem of the Image Receiving & Processing System (IRPS) for Level-0 imagery. The multi-spectral band radiance conversion factor and offset data shall be distributed separately via product description or publication through the internet, for end-user correction and conversion.

Radiometric characteristics

The dark response measurement shall be carried out in the laboratory with absence of illumination and the MAC entrance baffle completely covered. The importance of capturing dark response is to define the baseline that needs to be subtracted from signal obtained during illumination so that the user-interest signal can be obtained.

Linearity tests shall be carried out to determine if the system behaves linearly within a defined range of operating conditions. This will allow MAC to be characterised for all five sensing channels to determine the saturation level of detectors.

The MAC detector module consists of five linear elements with odd and even pixel readouts to the amplification module. The response uniformity of MAC can be affected by dark response uniformity as well as possible vignetting effects that may originate from the optical components. Therefore, response uniformity across all pixels for all channels at full system level will be tested via the uniform radiance field from the integrating sphere.

Determination of the radiance responsivity shall be carried out by exposing MAC to illumination from the integrating sphere which acts as a stable source, and spectral radiance characteristics of the given illumination are measured simultaneously by the spectroradiometer. The radiance responsivity of the respective channel is calculated as the quotient of the integrated radiance and the digital count.

Measurements shall be carried out to determine several gain level for Signal Processing Unit (SPU). Also, appropriate gain setting shall be determined to match the approximate earth leaving radiance to the approximate full dynamic range of the five spectral channels.

5. GROUND SUPPORT EQUIPMENT

The primary illumination source will be obtained from the 40-inch diameter integrating sphere equipped with a combination of Tungsten-Halogen and Xenon arc lamps, providing uniform radiance field across its selectable 14-inch or 16-inch exit port. The integrating sphere is custom designed that produces stable and uniform light sources with known spectral radiance from 300nm to 2400nm. The detectors are radiometrically calibrated for band-width radiance measurement with traceability to the NIST. Figure 1 shows the equipment involve in the preflight calibration activities.

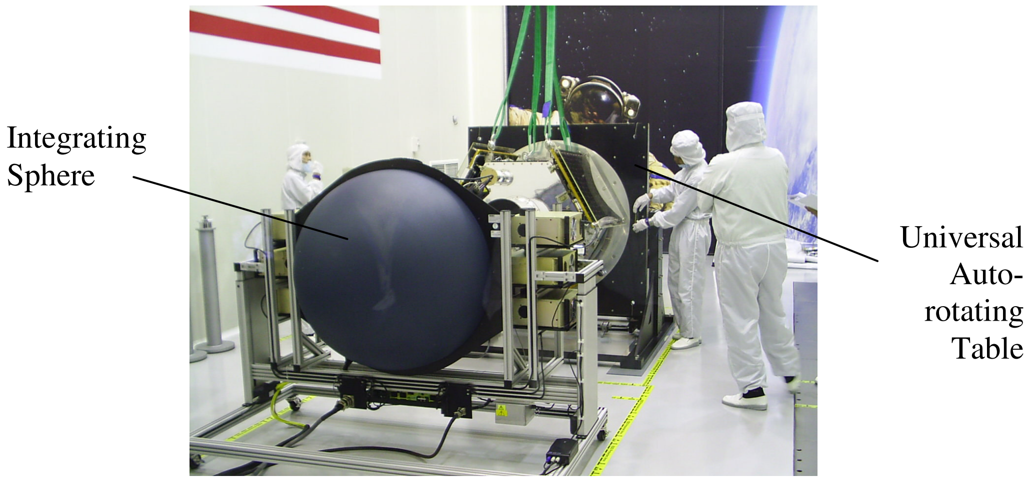

Figure 1: Ground Support Equipments consist of Integrating Sphere and Universal Auto-rotating Table

The integrating sphere is measured and cross-referenced by the spectroradiometer, whereby the spectroradiometer spectral range of operation covers VNIR spectrum, 325nm to 1075nm. Radiance calibrations of all foreoptics are performed by the manufacturer, using verifiable NIST-traceable irradiance, reflectance and wavelength standards.

The spectral range of this instrument covers spectral range of all MAC detection channels. This instrument shall be used to measure the spectral radiance of the integrating sphere. The resultant spectral radiances shall be integrated with the ranges correlating to Red, Green, Blue, NIR and PAN channels of MAC.

The RazakSAT™ alignment to integrating sphere was made possible by using the specially designed and developed Universal Auto-rotating Table which was used to mount and rotate RazakSAT™ satellite to horizontal configuration as depicted in Figure 2.

6. MEASUREMENT SETUP

The RazakSAT™ shall be mounted and secured on the Universal Auto-rotating Table. With the tilt of 90 ± 0.2 degrees, MAC pointing vector shall be at the horizon. The vertical adjustability and wheel mobility of the integrating sphere shall provide alignment that approximates coverage of MAC aperture within the size of the sphere exit port. Alignment of the integrating sphere exit port to MAC entrance baffle does not require high precision as the radiance source is uniformly distributed across the sphere exit port. The spectroradiometer shall be mounted on its tripod and placed next to the integrating sphere, where the fiber optic jumper shall be connected to the wedge adapter on the sphere wall under the exit port. The side view of the equipment arrangement is graphically presented in Figure 2.

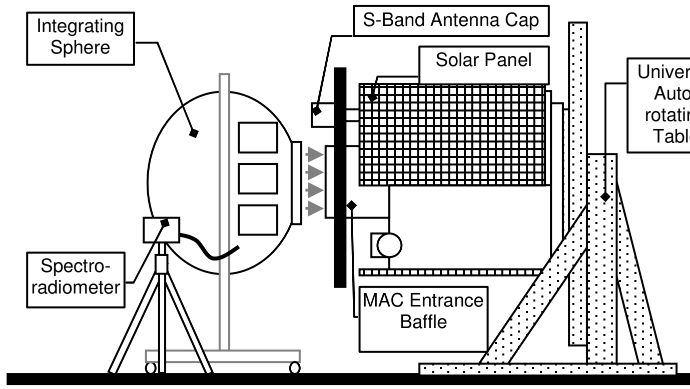

Figure 2: Side view of arrangement of RazakSAT™, Integrating Sphere and Spectroradiometer

7. MEASUREMENT PROCESS

Data Acquisition

The data acquisition could be divided into two groups: one on the measurement of dark response; another on measurements that involves illumination from the integrating sphere spectral radiance measurement from the spectroradiometer. The measurements of response linearity, response uniformity and radiance responsivity shall be grouped together and taken as per gain step, for primary & secondary SPU and per illumination level. The acquisition process flow that involves illumination from the integrating sphere is presented in the following Figure 3.

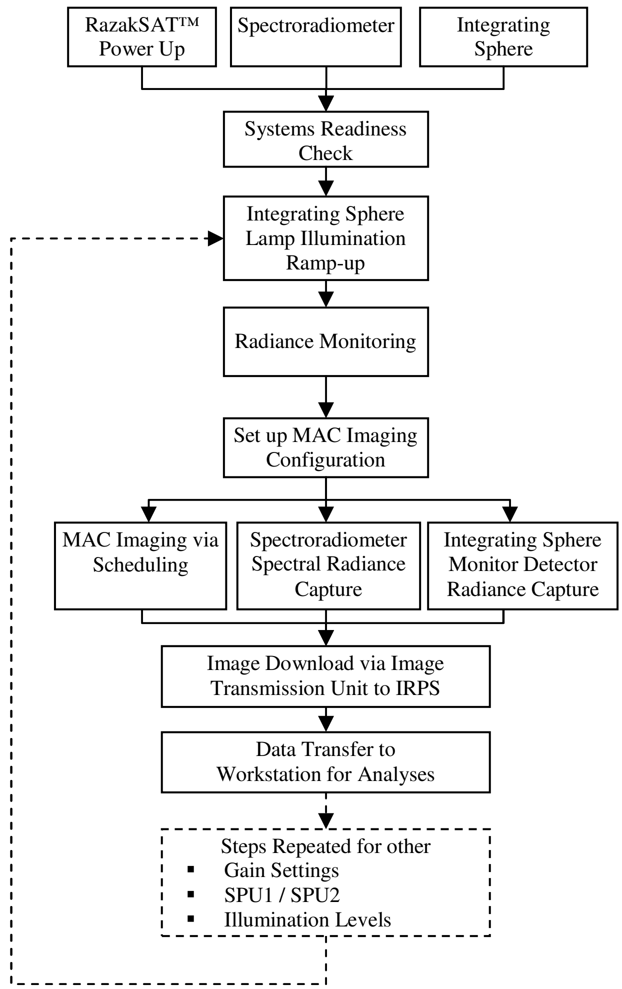

Figure 3: Flow Diagram for Response Linearity, Response Uniformity and Radiance Responsivity Measurements

Data Conditioning

The general approach to the characterisation is on a specific pixel basis. Since the image captured by MAC on a scene is made up of 8192 pixels by 8192 rows for PAN channel and 4096 pixels by 4096 rows of MS channels, data conditioning should be carried out prior to pixel-based analyses. For every scene that is captured according to the specific imaging configurations, 1000 PAN and 1000 MS rows will be extracted and averaged to produce single row pixels for the channels, which represents the response of the detectors. The averaged single-row data can then be used for the defined four characteristics analyses and the calibration data generation.

Data Analyses

The averaged dark response measurements shall be used as baseline that will be subtracted from signal for the later analyses of the response linearity, uniformity and radiance responsivity. The intended measurements shall generate system level radiometric performance characteristics via direct measurements as well as derivation from analyses.

8. SUMMARY

The calibration data shall be used for correction process of MAC images. It involves a combination of dark and uniform measurements to derive the gain and offset of each pixel, for each channel, and for the two signal processing units.

The offset calibration value shall be derived from the dark signal offset and uniformity characteristics; where as gain calibration value will be derived from the response linearity as well as the radiance responsivity. The pixel-based calibration gain and offset shall be compiled and stored as calibration file.

The result derived from the measurement of the MAC sensor will be used as a multiplier in the IRPS system during image processing and acquisition.

9. REFERENCES

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