MSG's GERB Instrument

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The Geostationary Earth Radiation Budget experiment (GERB), selected as an Announcement of Opportunity instrument for MSG, will make accurate Earth-radiation-budget measurements from geostationary orbit. The GERB instrument (and its recurrent models) has been designed, developed and manufactured by an International Consortium* led by the Rutherford Appleton Laboratory (RAL).

* Consortium members: Imperial College of Science, Technology and Medicine (ICSTM), London; Leicester University, UK; AEA Technology, UK; Galileo Avionica, Italy; Amos, Belgium and the Royal Meteorological Office (RMIB), Belgium.

Introduction

The GERB instrument is a highly accurate visible-infrared radiometer, which will provide unique measurements of the outgoing short-wave and long-wave components of the Earth's radiation budget from geostationary orbit, which have not been achieved previously (Fig. 1). To date, all such measurements have been made from satellites in low Earth orbit (LEO). The data obtained from single satellites must be used with caution, as they cannot provide proper temporal sampling. In response to the diurnal variation in the solar heating, there are strong diurnal variations in the radiation budget observed, particularly over land. In order to provide coverage of the diurnal cycle with a temporal resolution of 3 h, four LEO satellites would be needed. However, at least hourly measurements are needed to resolve the diurnal cycle of tropical convection properly, and no practical system of polar orbiting or other LEO satellites can deliver this. The GERB instrument will provide a full Earth-disc image every 15 min, which will allow excellent temporal sampling.

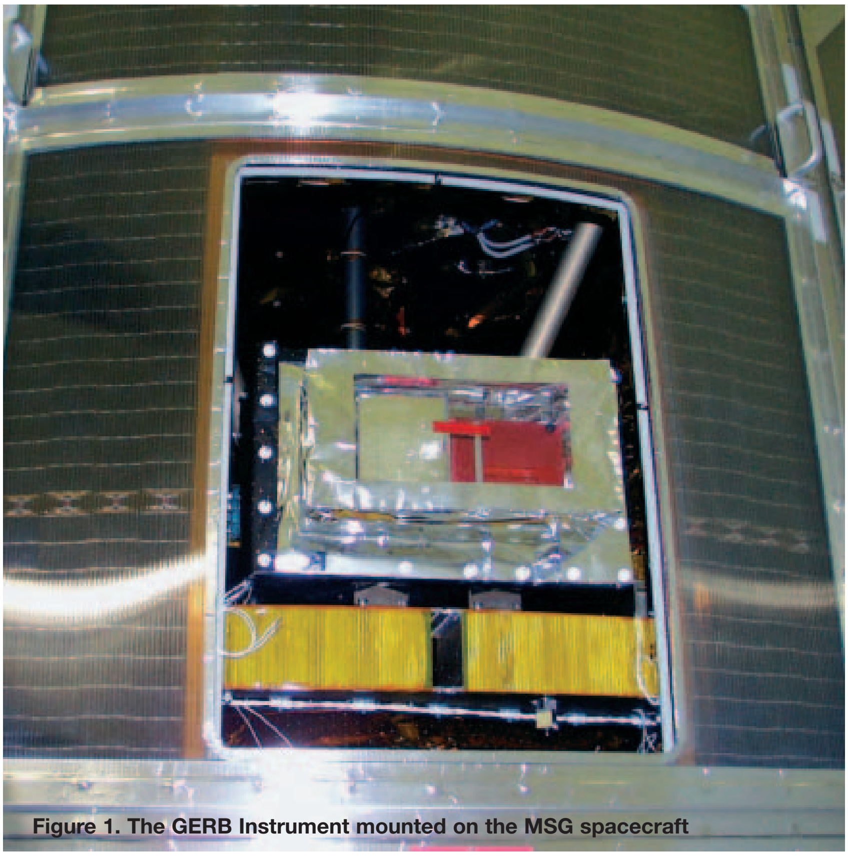

Figure 1. The GERB Instrument mounted on the MSG spacecraft

Scientific goals

The overall GERB scientific aims can be summarised as:

- investigation of the role of clouds in the Earth's radiation budget and cloud radiative feedback
- investigation of the role of water vapour in radiative feedback
- observational studies of specific processes, such as tropical convection and marine strato-cumulus formation, and their diurnal and synoptic variability
- identification of additional constraints on numerical weather-prediction models
- improvement of LEO diurnal-variation simulation models and surface bi-directional reflectance functions
- validation of climate models for the MSG-observed regions
- contribution to a global Earth-radiation-budget measuring system by combining GERB data with that from other sensors (e.g. LEO satellites, CERES and ScaRaB), and
- synergy with SEVIRI short-wave visible calibration.

The GERB measurements will provide substantial contributions in each of these areas, leading to improved operational weather

Perfomancecharacteristics of the GERB instrument

Wavebands	Total Short wave (SW) Long wave (LW)	0.32 – 30 µm 0.32 – 4 µm 4 – 30 µm
Radiometry	**SW**	**LW**
Absolute Accuracy Signal/Noise Ratio Dynamic Range	<1% 1250 0 – 380 $W.m^{-2}ster^{-1}$	<0.5% 400 0 – 90 $W.m^{-2}ster^{-1}$
Spatial Sampling	45 x 40 km^2 (NS x EW) at nadir	
Temporal Sampling	15 min SW and LW fluxes	
Cycle Time	Full Earth disc, both channels in 5 min	
Co-Registration	Spatial: 3 km w.r.t. SEVIRI at satellite subpoint Temporal: within 15 min of SEVIRI at each pixel	
Instrument Mass	25 kg	
Power	35 W	

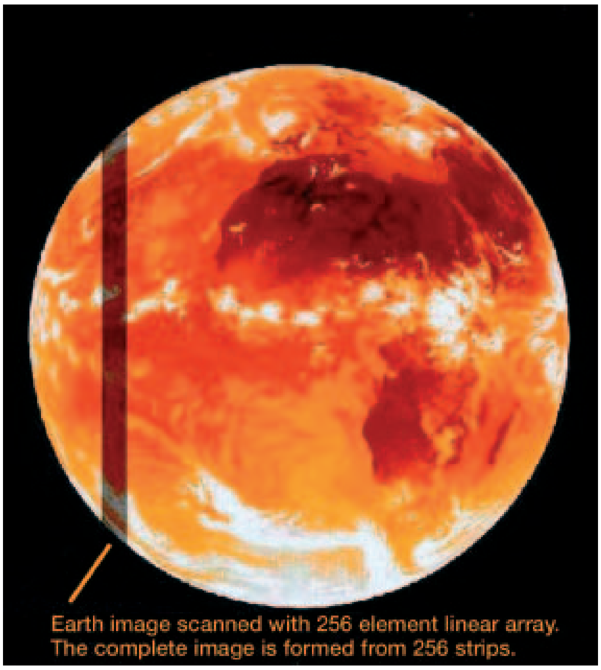

Figure 2. The Earth as observed by GERB (18º x 18º).

monitoring and permitting further important progress in climate-change research. Both short-wave (0.32 - 4 micron) and total (0.32 - 30 micron) radiance measurements will be made, with long-wave (4 - 30 micron) data obtained by subtraction. The accuracy requirements (1% short wave and 0.5% long wave) are an improvement over previous radiation-budget measurements. The Earth's radiation is detected by a thermoelastic detector array (bolometer) of 1 x 256 pixels, designed to image the full Earth's disc (18° field-of-view) in a north-south direction (Fig. 2). The exposure time to the Earth's radiation is limited to 40 ms within an MSG rotation. Full coverage of the Earth is achieved by scanning the detector' field of view continuously from west to east and back again, thereby building an image from a series of consecutive strips in the north-south direction. Three raw measurement samples covering the same scene (full Earth's disc) will be taken within a 15 min interval and averaged to bring the radiometric noise of the corresponding processed radiance within limits.

Instrument design

The highly autonomous GERB instrument consists of two main units:

The Instrument Optical Unit (IOU) which is very compact (56 x 35 x 33 cm^3), and includes essentially (Figs. 3 and 4):

– a telescope (three-mirror anastigmatic system)
– a de-scanning mirror for staring at appropriate targets, continuously rotating at 50 rpm in the opposite direction to the satellite's rotation (100 rpm), freezing the view of the Earth for a period of 40 ms

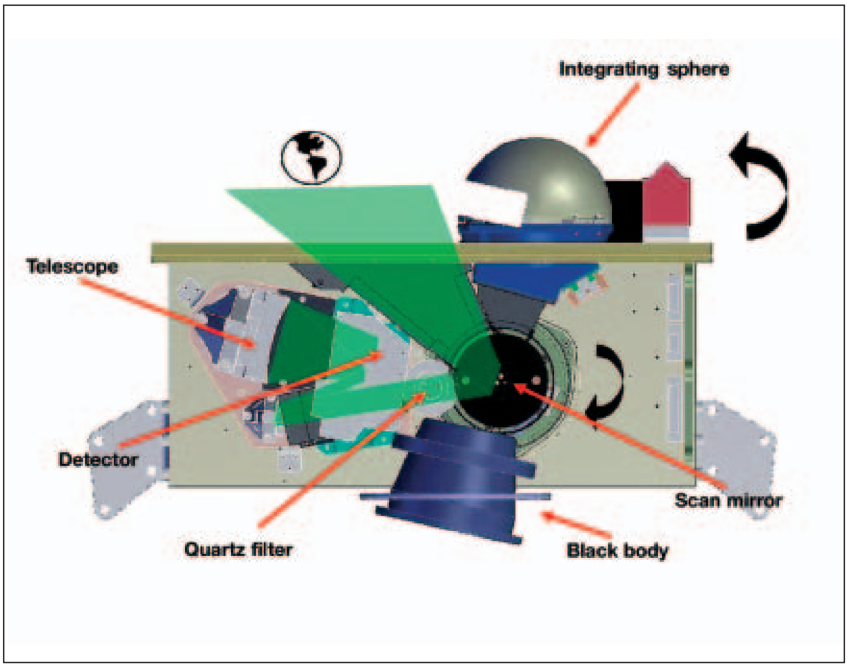

Figure 3. Schematic of the GERB Instrument Optical Unit (IOU)

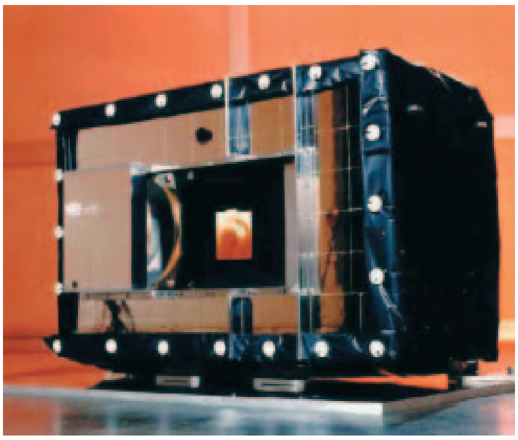

Figure 4. The GERB IOU flight unit

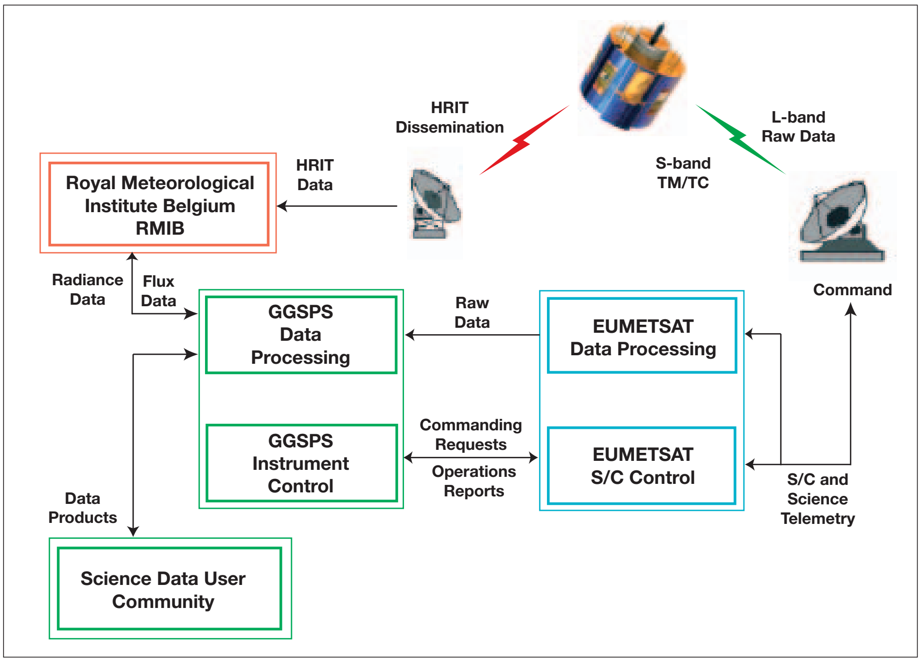

Figure 5. GERB data-processing scheme

– a wideband detector array (a linear, blackened, 256-element thermo-electric array) with its own signal-amplification and processing circuitry (including ASICs and a DSP)
– a quartz-filter mechanism used to switch the measurement into alternative wavebands (total and short-wave)
– calibration devices: a black-body for thermal calibration and a solar diffuser for monitoring the degradation of the short-wave reflectance of the mirrors, quartz-filter transmittance and detector absorption
– a passive thermal design, and
– a structure based on a solid-optical-bench design.

The Instrument Electronic Unit (22 x 27 x 25 cm^3) is designed to receive detector data, format them and pass them on to the spacecraft's data-handling system. It also provides regulated power to all of the subsystems, the thermal control of the IOU, and the command and data interfaces and the instrument monitoring and control functions.

Instrument calibration

GERB-1 has been exhaustively tested in a purpose-built calibration facility consisting of a vacuum chamber with a black body at about 300 K, which represents an Earth-like source (Warm Black Body, WBB), a black body at liquid-nitrogen temperatures as an approximation of the cold space (Cold Black Body, CBB), and an integrating sphere for calibration in the solar spectral domain. Radiometric data (gain, filter transmission, linearity, etc.), spectral responses at several discrete wavelengths, Point Spread Functions (PSF), and on-board black body performance have been measured. Checks for stray light and for gain drift as a function of temperature have also been made.

Data analysis and its comparison with unit-level measurements and instrument-level predictions has demonstrated the validity of the GERB concept.

Apart from the on-ground calibration, extensive in-orbit calibration campaigns will be carried out throughout instrument's in-orbit lifetime. A variety of targets such as the Moon and reference sites on the Earth will be used to derive proper instrument performances.

In-orbit operation and data processing

Once in orbit, the GERB instrument's operation will be monitored by a team at RAL and ICSTM. In addition, a number of satellite parameters will be monitored at Eumetsat to provide a basic check on the safety of the instrument. The processing of the GERB data will be divided between two locations (Fig. 5). The conversion of raw GERB data to calibrated geo-located radiances will be done at RAL using software of the GERB Ground Segment Processing System (GGSPS). The processed data will then be passed to RMIB for conversion to fluxes. RMIB will make certain flux products available via the World Wide Web for short-term usage, but the main GERB data and product archive for long-term usage will be at RAL.

Several of the planned scientific studies are expected to take advantage of the synergy between the GERB and SEVIRI (see companion article in this Bulletin) instruments and their data. From the merging of the two data streams, near-real-time estimates of the Earth's radiation budget with the high spatial resolution of SEVIRI (3 km at nadir) can be anticipated. It is expected that once the scientific community realises the full potential of GERB as a result of the GERB-1 flight, there will be a growing demand for its measurements and processed data.

Acknowledgement

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