Comm. in Asteroseismology
Vol. 152, 2008

BRITE-Constellation: Science Operations Concept

R. Kuschnig[1],[2]

[1] Univ. of British Columbia, 6224 Agricultural Road, Vancouver V6T 1Z1, Canada
[2] Institut für Astronomie, Türkenschanzstrasse 17, A-1180 Wien, Austria

Abstract

The BRITE-Constellation currently consists of two nano-satellites: BRITE-AUSTRIA and Uni-BRITE. Both are in principle of identical build with one exception, the respective telescopes will be designed for two different band-passes one constrained to RED (555-690nm) and the other to BLUE (400-450nm) wavelengths. In general both satellites will collect data from the same stars during any particular observing run. A proposal to build and launch an additional pair of spacecrafts to complement the constellation is currently under review. This article describes the organization structure, the main operations tasks and the software tools to conduct the mission.

BRITE-Constellation Management

The BRITE-Constellation mission will be governed by essentially three main entities working in concert. The Science Consortium is the deciding body for the instalment of observing plans by proposals from local Science Teams. Mission Control is responsible for evaluating the Observing Plan, detailed scheduling, instruments setups, daily data quality assessment, data reformatting, first-look science analysis, internal data release and data archiving. Satellite Control will aid the verification process of the observing plan, operate the satellites, control the ground stations, asses the health of the spacecrafts and their subsystems. Figure 1 depicts the organizational chart.

In baseline configuration the BRITE-Constellation will operate two satellites: BRITE-AUSTRIA and Uni-BRITE. Both shall, simultaneously, be in low earth orbit (in the same or different orbits is yet to be decided) for the main mission phase. It is possible that two more satellites will join the mission funded in Canada. In such a scenario it is planned that the BRITE-Constellation management will still rely on a single Science Consortium with full program authority but will have likely establish two collaborating Mission Control and Satellite Control teams located in the respective countries.

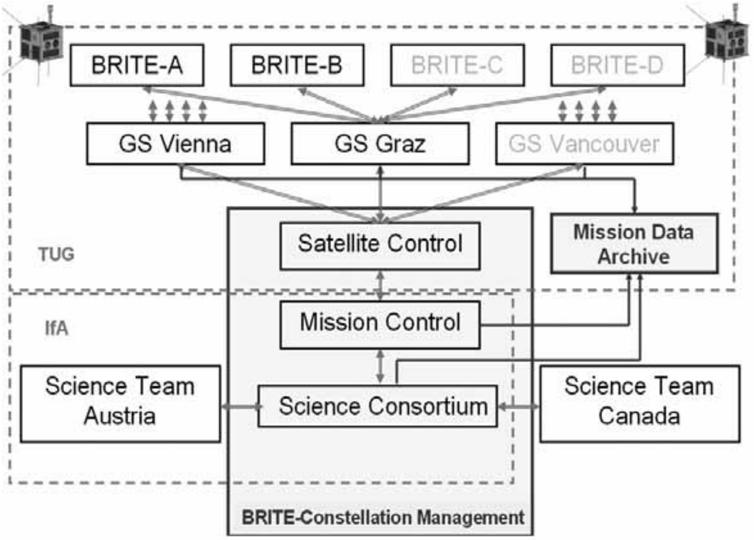

Figure 1: BRITE-Constellation Management Scheme.

BRITE Operations Overview

The primary input for the BRITE-Constellation operations will be an actual observing plan, to be released in bi-annual intervals by the Science Consortium. It will contain lists of primary targets with start and end observing dates. This plan will be subject to verification and optimization by Mission Control and Satellite Control personal prior to enactment. For each observing run the field orientation and camera setup parameters will be defined and submitted to the Satellite Control team for subsequent transmission satellites contributing to a specific observing run. Science data will be gathered during the specified observing period. During each ground station contact a satellites health diagnostic shall be performed and recorded. After data transmission the downloaded raw science data files (a.k.a. whole orbit data files or WOD) will be uncompressed and dissected into individual science records. Their contents will be displayed graphically as time series plots with automated checks for data quality and integrity. Then all valid data records from a finished observing run will be transformed into astronomy standard FITS files. Finally, data products like: setup parameters, the originally transmitted files, individual Science Data Records, satellite telemetry files, all log files, diagnostic information and finally the FITS files are moved to the Mission Data Archive.

BRITE On-board Science Data Generation

Prior to the description of ground software packages the core BRITE science data contents, generated on-board the satellites, are described.

Image Data Generation

The BRITE telescopes (3cm aperture, 5 lens plus filter, system) will each feed a KODAK KA11002 interline transfer progressive scan CCD. The light sensitive area is a 4008x2672 pixels array and with its plate scale of about 30 arcsec/pixel a wide field ($\sim$ 33 x 22 deg) is covered in a full frame. Given a baseline time sampling of 1/min for a typical set of 7-15 target stars per field and the downlink bandwidth limits a sub-raster scheme with stacking of individual exposures are required to operate the camera. Figure 2 presents an example of how bright Orion stars could be exposed in the focal plane with 7 sub-rasters, each typically 32x32 pixels large (the FWHM of the image PSF is $\sim$ 6 pixels) covering the primary objects of interest.

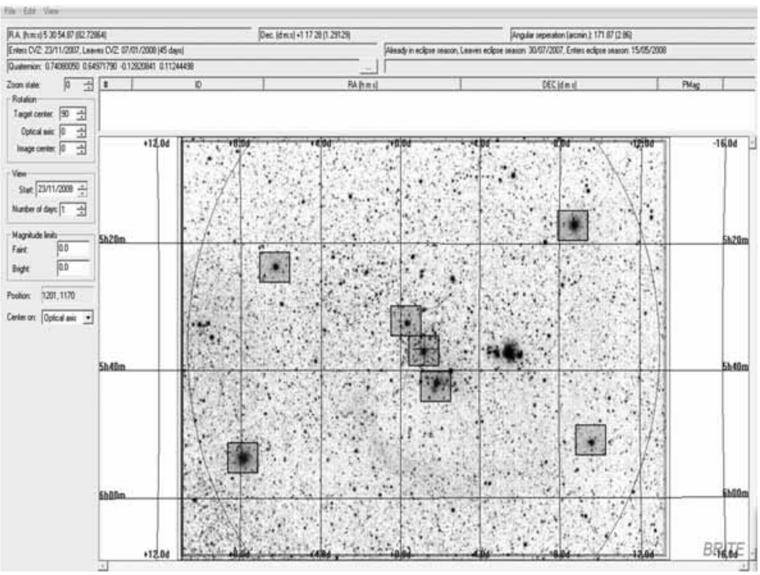

Figure 2: Virtual display of the BRITE FOV/CCD, placed to render the Orion field.

With exposures times of typically 1sec and even shorter depending on the brightness of the primary target star, image data from consecutive exposure with be co-added 'stacked' on-board. This scheme is illustrated in figure 2.

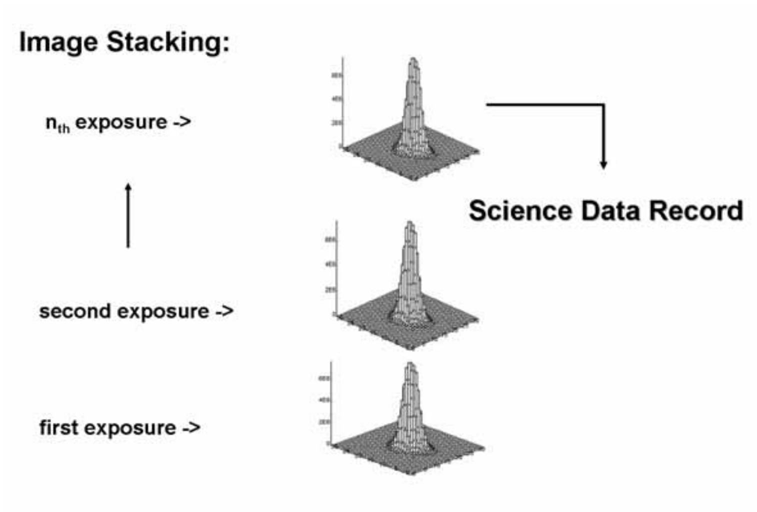

Figure 3: An illustrtion of on-board image stacking.

On-board Data Processing

The main target stars of the BRITE mission will be between 0 and 4 mag and in general for all those objects in ant given field, image data will be obtained. However performance simulations reveal that even fainter objects down to 6 mag could provide useful signal levels respectively scientifically relevant photometry. Considering that the number of sub-rasters (the total amount of pixel resolved image data) is limited, photometric values from those stars have to be obtained by means of on-board data processing. This will reduce the bulky image data manageable amounts of background and star signal values. The details of on-board data treatment collected from fainter stars are still under investigation but are all based on customized aperture photometry schemes.

Complete Data Record

Beyond gathering image data and processed photometry a Science Data Record (SDR) will also contain auxiliary information acquired from the instrument and the other satellite sub-systems. Among those are: timing information, pointing errors, various temperatures, heather voltages and local magnetic field strength, all sampled with a typically a 1Hz rate. The Science Data Generation Code (SDGC) executed by the instrument on-board computer (a DSP type micro-processor) will handle those tasks and produce the SDRs. Individual SDRs will be compressed and bundled into larger files for on-board storage and subsequent ground transmission. Figure 4 shows the schematic processing and information collection by the SDGC.

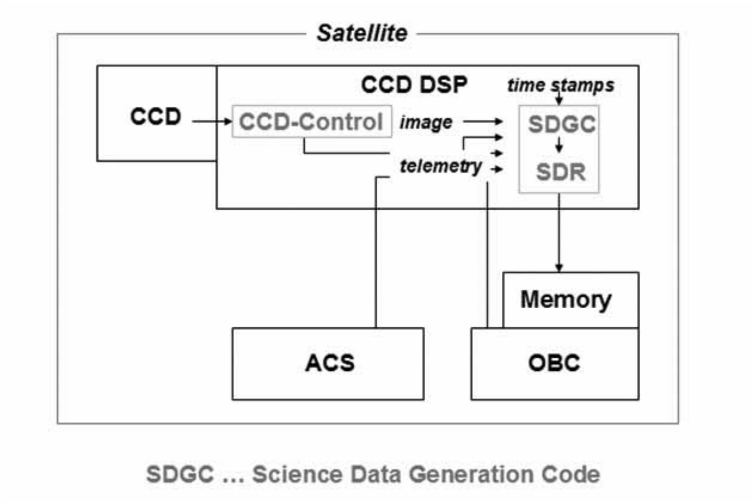

Figure 4: On-board Science Data Generation Scheme.

BRITE Ground Software Modules

In figure 5 the main software modules are schematically placed in relation to the operations teams, Mission Control and Satellite Control as well as the Science Consortium. On the left side (arrow up) utilities are listed that will help to: prepare the observing plan, setup the camera, control the spacecraft subsystems, operate the ground stations and regulate data transmission. On the right are programs that will diagnose the satellites health, separate individual data records from raw download files, check and display science data and related telemetry, reformat data and perform first cut science data analysis.

In the following part individual programs and software packages are described in abstract form. The reader shall be aware that currently working titles are used and that final names and definitions will emerge out of the ongoing design and specification phase.

BRITE-MAP: This is the main tool to investigate the observing constraints of star fields in a global perspective. This program has a rich graphics user interface as well as analytical routines to support the Science Teams and the

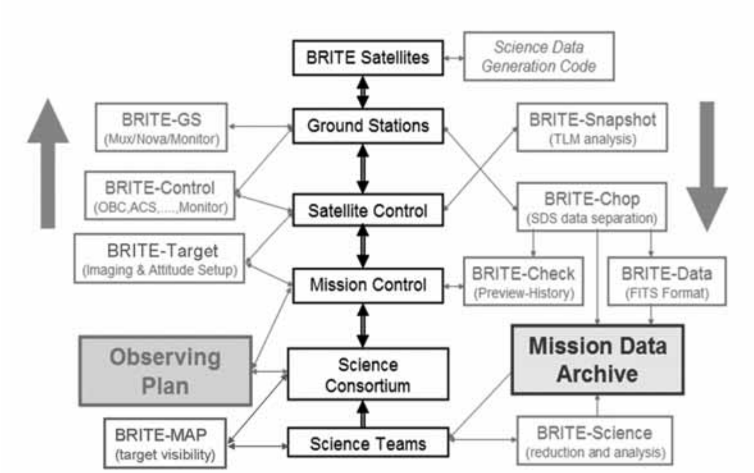

Figure 5: BRITE-Constellation software modules overview in context with operation teams

Science Consortium to contemplate observing scenarios and finally to assemble observing plans. Applications examples are found in this volume ('Observing Strategies' Kaiser, A.).

BRITE-Target: Displays selected target fields as a virtual projection on the instrument FOV/CCD (see Figure 2). It allows the precise placement a reference star onto any pixel on the detector and the selection of an instrument bore sight roll angle. This program enables the definition of sub-rasters covering target stars, sky areas as well as dark and bias regions. To each sub-raster a processing code can be assigned which specifies what kind of on-board procedures shall be applied. The output is a unique set of setup and processing parameters.

BRITE-Control: This is group of programs will allow Satellite Control teams to instruct and operate all spacecraft subsystems most notably the Camera Control System to conduct science data collection and the Attitude Control System responsible for pointing the instrument precise and stable in a specified direction.

BRITE-GS: Software modules to operate a ground station like satellite tracking, pass scheduling, rotor/antennae control, data transfer and emergency shutdown.

BRITE-Snapshot: A routine that automatically investigates the most vital spacecraft telemetry information during contact times (ground station passes). It will send instantaneous feedback (via e-mail) information to Satellite Control and Mission Control team members. Alarm conditions can be specified and

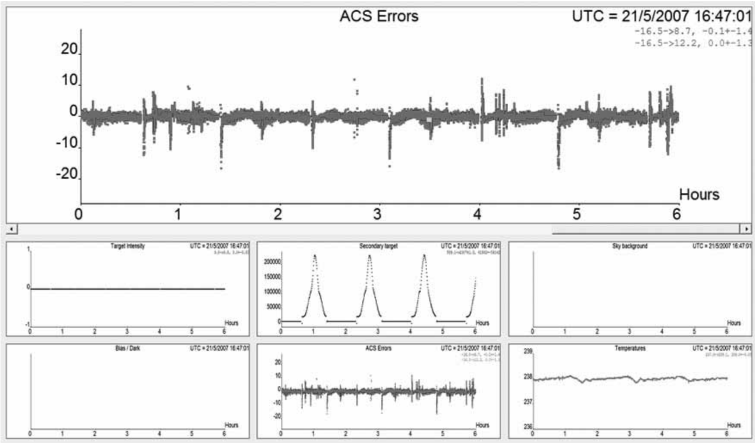

Figure 6: Time series display of science data records and spacecraft telemetry. Top panel: pointing errors.

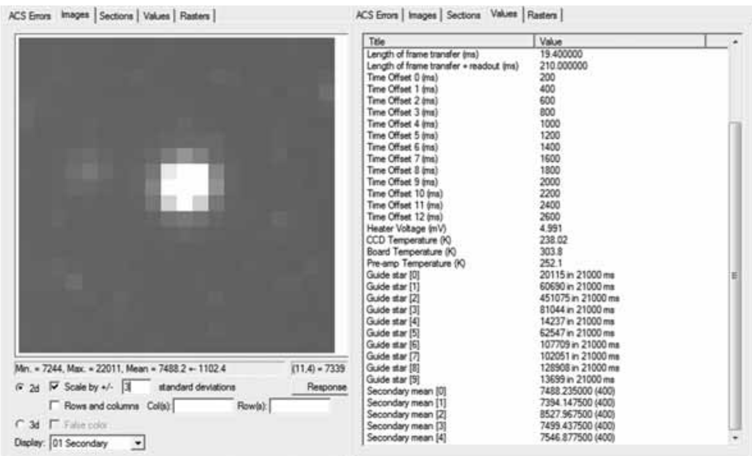

Figure 7: Preview display of a particular Science Data Record. Left: sub-raster image. Right: time offsets and processed photometry values

violations are listed at the top of the reports.

BRITE-Chop: Is a program that dissects 'chops' whole orbit data files that are originally transmitted to ground into individual science records/files which are subsequently sent to data repositories of the instrument monitoring system (BRITE-Check) and also forwarded to the Mission Data Archive.

BRITE-Check: This software package displays the contents of selected sets of Science Data Records as time series (history) and provides access to individual records (preview). This enables Mission Control to get a comprehensive and quick look at the instrument performance. Figure 6 and 7 are screenshots from development versions of history and preview displays.

BRITE-Data: A program to transform Science Data Records into FITS files. BRITE FITS files will contain not only information generated on-board the satellites. This software also calculates auxiliary values such as positions of the instrument with respect to Sun, Earth and Moon, ground corrected times and more. Essentially everything possibly needed to reduce and analyze the obtained photometry. FITS files will be the sole source for the BRITE Science Analysis.

BRITE-Science: This program package will comprise all optimized science data reduction and time series analysis routines. The core shall be a properly developed and tested data reduction pipeline. Ideally this software suite will be distributed among all science teams as an application to derive scientific results.

BRITE Mission Data Archive

All collected data and information will be sent to and organized within the Mission Data Archive.

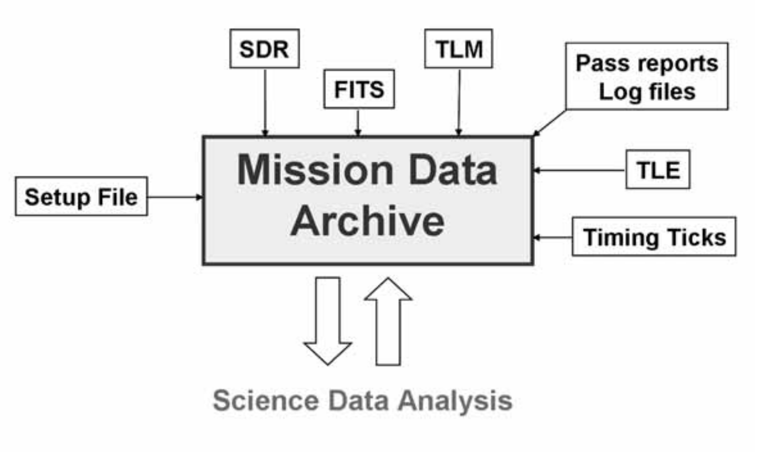

Figure 8: Mission Data Archive input: setup information, SDR Science Data Record, FITS files, TLM Telemetry files, Pass reports and log files, TLE Two Line Elements, Timing Ticks, Science analysis results.

Figure 8 lists the main input data products to the archive. Observing plans, setup information, science data files, telemetry data form all satellites, operations logs from all ground stations including pass reports, time reference data, FITS files, reduced photometry data and finally analysis results will be included. While many data products are just stored the FITS files will be made available for mission internal use as soon as possible. Furthermore, it is planned to sequentially open the Mission Data Archive to the wider science community after the elapse of a proprietary period (length yet to be decides).

Acknowledgments. Financial support was received from the Austrian Research Promotion Agency (FFG)

A. Kaiser, M. Unterberger, K. Zwintz and R. Kuschnig in front of the BRITE nanosatellite model.