AGILE WebMon: monitoring the AGILE Payload through the WEB

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***Abstract*—AGILE AGILE is a Scientific Mission dedicated to high-energy astrophysics supported by the Italian Space Agency (ASI) with scientific participation of INAF and INFN. The AGILE Payload (P/L) is designed to detect and image photons in the 30MeV-50GeV and 15-45 keV energy bands. It was successfully launched on 23 April 2007. AGILE `WebMon` is a set of software tools developed by the AGILE team in order to access at any time and worldwide the sensible data related to the P/L instrument health and science monitoring. Moreover, the system is used as test bed for some of the software modules developed and maintained by the AGILE Team for the standard and scientific analysis system running at the ASI Science Data Centre in Frascati, which hosts the AGILE Data Center.**

I. Introduction

AGILE is the Scientific Mission dedicated to high-energy astrophysics supported by ASI with scientific participation of INAF and INFN. The AGILE Payload (P/L) [1] is composed of three detectors: a Tungsten-Silicon Tracker (ST) [2], [3], with a large field of view ($\sim$ 2.5 sr), optimal time resolution and angular resolution, and good sensitivity; a Silicon-based X-ray detector, Super-AGILE (SA) [4] for imaging in the energy range 18 keV - 60 keV and a CsI(Tl) Mini-Calorimeter (MCAL) [5] that detects gamma-rays or particle energy depositions between 300 keV and 100 MeV. The ST and MCAL form the AGILE Gamma-Ray Imaging Detector (GRID) for observations in the gamma-ray energy range 30 MeV - 50 GeV. The instrument is completed by an anti-coincidence (AC) system [6], made with plastic scintillator layers, for the rejection of charged particles, and by an efficient trigger logic for gamma-ray and X-ray data acquisition [1].

II. Input Data Flow

The AGILE TM is complaint with the ESA/CCSDS standard[1]. It foresees two dozens of different Source Packet layouts, that are identified by the APID/Type/SubType fields. One half of them is devoted to command receipt status information, housekeeping and diagnostic data reporting (Engineering TM). The remaining layouts are mainly devoted to the science data (Science TM).

Due to the low equatorial orbit, the AGILE TM is downlinked every 100 minutes to the ASI ground station at Malindi, Kenya. Within few minutes from the satellite pass, all the TM packets collected on-board during the last orbit are relayed in raw format (LV0) to the Mission Operations Centre at Fucino, and then to the ASI Science Data Center[2] (ASDC) in Frascati (Roma). Here the LV0 data are automatically ingested by the Telemetry Pre-Processing Subsystem (TMPPS) [7] in order to sort the TM packets by APID/Type/SubType and to generate one Level-1 (LV1) file for each different TM layout.

Each LV1 file contains all information present in the related TM packets. All the bits composing each individual data are simply extracted from the packets ([8]) and written into the LV1 file using the appropriate FITS NASA OGIP Standard[3] data type, without applying any conversion. The FITS format is particularly suitable to the scientific and monitoring tasks to be run at ASDC. All files are FITS Binary Tables, composed of a FITS Primary Array, followed by a maximum of three FITS Extensions. Each column may consists of either a single value or a FITS fixed length vector which hosts a set of homogeneous data contained in the TM packet.

All the LV1 files are available to the scientific pipelines and to the monitoring tasks within 25 min. after the end of the contact.

In order to keep track of all the LV0 and LV1 data files, the TMPPS makes use of a MySQL Relational Database (TMPPS DB) which identifies and associates the LV0 and the LV1 files archived for each contact. Suitable fields in the DB carry for each file the ancillary information required for data retrieval, such as for example the contact number, the date and time boundaries, and the processing status.

The LV1 files and the TMPPS DB, together with some auxiliary files (AUX) provided by AGILE Satellite Control Centre (e.g.: the Sequence of Events (SOE) and the Contact Table (COT)) represent the main data input to the AGILE WebMon system.

III. Software description

The AGILE `WebMon` overall architecture is sketched in Figure 1. The system runs on Linux Suse 9.2 platforms, and consists of three main tasks which process on orbit by orbit basis the LV1 files and the AUX files related to the last orbit received at ASDC.

As first step, some of the LV1 files are rewritten by the `Corrector` tasks into the COR files, with all data times aligned to Terrestrial Time (TT) and corrected for satellite attitude information.

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[1] http://public.ccsds.org/publications/archive/100x0g1.pdf

[2] http://AGILE.asdc.asi.it

[3] http://heasarc.gsfc.nasa.gov/docs/heasarc/fits.html

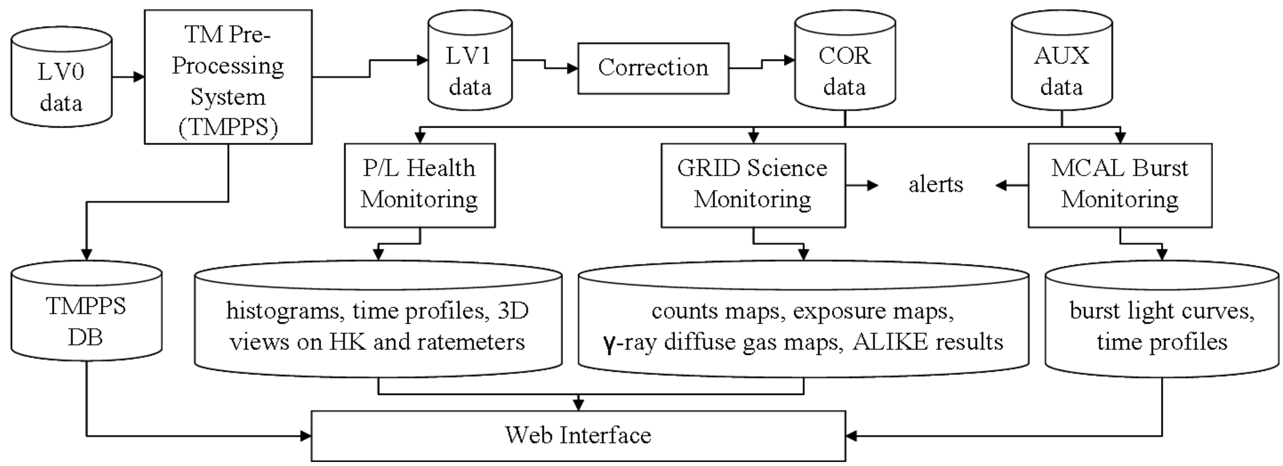

Fig. 1. WebMon overall architecture.

Hence, the input data are ingested by three pipelines running in parallel:

- P/L Health Monitoring (PHM): to process the P/L Housekeeping (HK) and the P/L Scientific Ratemeters in order to produce time profiles of the parameters that summarize the status of all the P/L Subsystems;
- GRID Science Monitoring (GSM): to process the GRID Science TM in order to build the counts, exposure and gamma-ray diffuse gas maps and perform on them the Maximum Likelihood ratio test statistic method (MALIKE) to check for the presence of Galactic and extra-Galactic sources in the Field of View (FoV) of the AGILE GRID instrument.
- MCAL Burst Monitoring (MBM): to search for gamma-ray bursts detected by MCAL in order to generate the related light curves, time profiles, and alerts.

All the data products of the three pipelines are available to the user through the AGILE `WebMon` Web interface.

A. The P/L Health Monitoring pipeline

The P/L Health Monitoring (PHM) pipeline enables the AGILE Team for a fast check of the overall status of all the P/L subsystems. The PHM pipeline software is based on the Quick Look (QL) framework that we developed for the AGILE assembly, integration and verification (AIV) activities. This QL framework was extensively used in the MCAL Test Equipment (TE). Further improvements have been implemented for the QL version exploited in the Electrical Ground Support Equipment (EGSE) to support all the AGILE AIV activities carried out at payload and satellite levels, included the launch campaign, and during the in-orbit commissioning, as reported in [9]. Details on the QL framework architecture are given in [10].

We developed the P/L Health Monitoring pipeline by reusing the same C++ classes of the QL framework (Data Manager, Data provider, Chain Managers, Chain manager Coordinator, View manager), and by introducing a new specialized C++ View class for the generation of PNG images instead of root canvases.

The QL version provided the interactive graphical display of the data, such as for example histograms and time profiles (the so-called `view`). In the new version, the View class creates automatically a snapshot of the graphical display using the Portable Network Graphics (PNG)[4] format.

We integrated the QL C++ modules into PHM pipeline by developing Ruby[5] scripts that sequence and control the pipeline operations. The CERN ROOT library[6] and the `CFITSIO` library [11] are used for the graphics and the data filing, respectively.

The PHM pipeline processes the COR files of the last orbit containing the Engineering and Science TM packets summarized in Table I. For each P/L subsystem it generates a set of specific views.

The COR files related to the Periodic TM and the Science Ratemeter TM are processed to generate:

- time profiles of all the housekeeping of each P/L Subsystem, such as for example: status, currents, temperatures and voltages;
- time profile of the SA Science Ratemeters, such as for example: *good event*, *single hit*, and *multi hit* counters for each SA SAFEE unit;
- time profile of all the MCAL Science Ratemeters.

The COR files related to the SS and GPS TM are ingested by the the pipeline to create, respectively, the time profile of the attitude quaternions and the time profile of the Satellite-Earth vector.

A special effort is devoted to the GRID subsystem. The pipeline exploits the COR file containing the (39,1), (39,2) and (39,3) data in order to provide detailed views for each GRID engineering aspect, such as for example:

- ST strip noisy level: a set of views related to ST ratemeters (a set of counter of the triggers of the ST when a photon or a particle interacts) and a set of counters related to each strip;
- ST pedestal noisy level: a view with the following values calculated for all the ST components: (i) mean value for

[4]http://www.libpng.org/pub/png/png.html
[5]http://www.rubycentral.org
[6]http://root.cern.ch

TABLE I
Engineering TM and Science TM for WebMon.

TM packet(Type/SubType)	Description
Periodic (32,1)	∼900 P/L housekeeping, sampled every 16 s.
GRID Event (39,1)	variable number of GRID events, the last sample of the SS attitude and the GPS Ephemeris acquired before the packet generation.
GRID Calibration (39,2)	variable number of single GRID Calibration events detected during the GRID Physical Calibration. The last sample of the SS attitude and the GPS Ephemeris acquired before the packet generation.
ST Pedestal (39,3)	noise values evaluated during the ST Pedestal Procedure for each ST channel. Each packet is related to a single ST chip.
MCAL Burst Event (39,8)	variable number of MCAL Burst data acquired by the Burst logic: MCAL events and rate meters. Plus fixed zone with orbital phase, time tag information and instrument scientific set-up.
Science Ratemeters (39,13)	five fixed structures which contain rate meters of each detector (AC, GRID, SA, MCAL). For each structure the rate meters are arranged on-board for several geometrical regions and wide energy bands. They are accumulated over 1024 ms time bin by a detector dependent simplified algorithm. The packet are generated every 8 s data along the whole orbit.
SS Data (39.14)	variable number of SS measurement and related time tags, sampled every 0.1 s.
GPS Data (39.16)	variable number of GPS measurement, the related time tags and the computed unit vector related to Satellite-Earth position.

each strip (36864 values), (ii) RMS value for each strip (36864 values), (iii) common mode for each chip (288 values).

- GRID event cluster[7] information: a view shows the total charge (the sum of all the charges of the cluster), the total width (the number of strips) of the cluster and the charge of the 5 central strips of the cluster; in Figure 2 we report the histograms of the charge of the central strip of a cluster for some plans of the ST;
- the pull (the ratio between the strip with the maximum and its RMS) and SNR of the ST;
- the energy deposited in the MCAL subsystem;
- the counts and ratemeters of the AC subsystem.

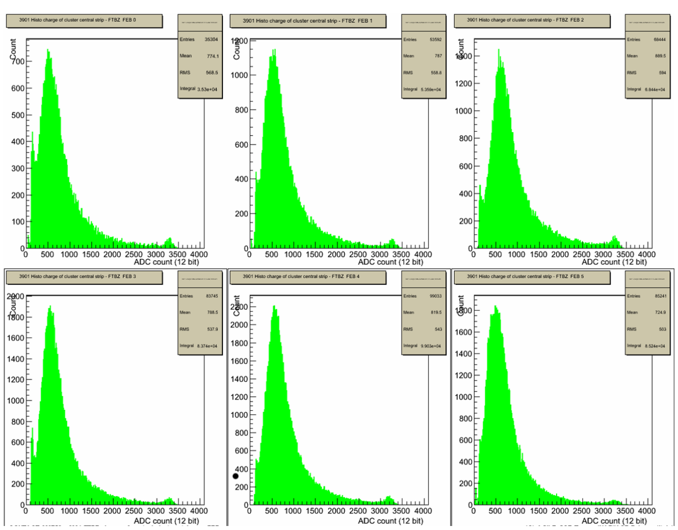

Fig. 2. *Histograms of the charge of the central strip of a cluster for some plans of the Silicon Tracker.*

[7]In the Grid TM, the ST data consist mainly of up to $48X + 48Z$ groups of contiguous strips identified as GRID cluster.

B. The GRID science monitoring pipeline

The WebMon AGILE GRID Science Monitoring (GSM) provides a quick look on scientific data products, such as counts and exposure sky maps, aimed at monitoring gamma-ray variable sources in the AGILE GRID Field of View (FoV).

To this purpose, we developed in the Ruby language a pipeline which sequences and controls the s/w modules developed by the AGILE Team for:

1 the standard analysis[12], which processes the COR files to produce the events and log files ;
2 the scientific analysis [13], which produces a set of maps that allow the detection and identification of Galactic and extra-Galactic sources; these s/w modules are publicly available at the ASI Data Center web site (http://agile.asdc.asi.it/).

In the standard analysis, the direction of the GRID events is reconstructed by a Kalman filter technique. To reduce the particle background contamination, the event selection is performed with a background filter. At the time of writing we typically use two background filters called $F4$ and $FT3ab$. Other filters are under development and test. An event file for each orbit is produced which contains the corresponding RA and DEC Equatorial J2000 coordinates calculated for each event. In addition, a log file that contains the attitude of the S/C is produced.

In the scientific analysis, the events and the log files are processed to produce a set of maps to be used for the source detection analysis. Because of the low event rate and the extent of the AGILE GRID point-spread function (PSF), statistical techniques like the maximum likelihood ratio test method are required to analyze the AGILE point sources [14].

In the standard analysis step, the GSM pipeline builds orbit-by-orbit the event files, the log files and all the maps (counts map, exposure map and galactic diffuse emission map) required by the scientific analysis. All the maps are binned, with a bin dimension of $0.5°$, with an AGILE GRID FOV of $70°$. With the standard integration time of 1 day, at each new orbit we produce maps with the last 24 hours. These maps are centered in the current AGILE pointing direction, which is determined for each orbit using a mean of the current RA/DEC pointing direction calculated into the log file. In this way we take into account the drift of the AGILE satellite during an AGILE pointing. The list of all the pointings is available at the ASI Data Center web site.

In the scientific analysis step, the pipeline processes the above maps and the list of sources contained into the current FOV, and performs a search of the most significant sources. At the end of this procedure a file containing all the detected sources is generated an an e-mail alert for the most significant sources is sent to the AGILE Team. At the time of writing, this procedure uses three catalogs : (i) the Third EGRET catalog [15]; (ii) a list of Low and High mass X-ray binaries; (iii) a list of TeV sources.

C. The MCAL burst monitoring pipeline

The MCAL monitoring is performed automatically on orbital basis. The procedure produces plots of the instrument ratemeters and critical housekeepings. A discussion of the in-flight performance and on the burst detection of MCAL is reported in reference [16] and [17], respectively. If the 39.08 data package is present (i.e. if any burst trigger has been issued by the on-board trigger logic) an additional script processes every trigger and, for significant triggers passing all the validation steps, the following data products are generated:

- light curve in different energy bands, in graphic format for quick look analysis;
- light curve in ASCII format for GRB triangulation by means of the 3^{rd} Inter-Planetary Network (IPN)[8];
- satellite ephemeris at trigger time, to be used for triangulation too;
- short text report indicating a preliminary estimation of the main GRB quantities (duration, peak flux, fluence, hardness ratio);
- a template ready to be submitted as a GCN[9] time-only notice.

The script is also in charge of sending alert e-mails containing light curves and relevant GRB information, and performing automatic alert telephone calls. Figure 3 shows the light curve for a GRB triggered on 2008 May 28, at 18:27:50 UT, as prepared and e-mailed by the automatic GRB analysis script.

An additional automatic procedure scans scientific ratemeters data (39.13 data packet) in search for significant rate increase independently of the on-board trigger logic results. This procedure was used for GRB detection when the trigger logic was not enabled yet (prior to November 2007), but it is still active as a backup tool.

D. The Web Interface

The Web Interface (WI) module allows the AGILE Team to access and display at any time and worldwide all the data products of the three WebMon pipelines described above. We developed this tool in Perl[10] language, through the use of:

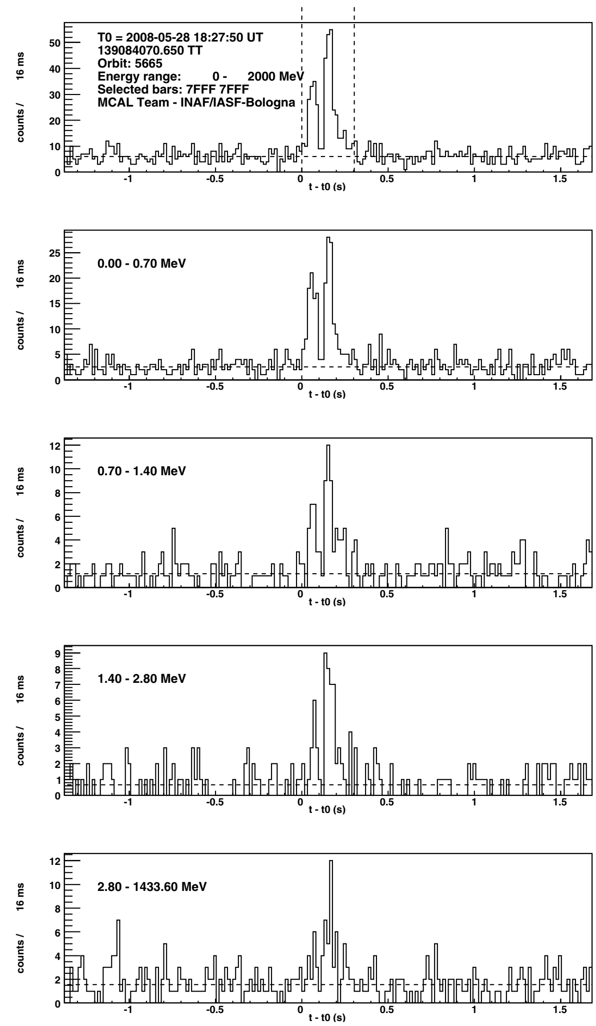

Fig. 3. MCAL light curve for a GRB triggered on 2008 May 28 at 18:27:50 UT, as produced by the automatic analysis script.

- the Perl CGI library to create the Web fill-out forms on the fly and to parse their contents;
- the Perl DBI module to interface to the MySQL TMPPS DB mentioned in Section II.

The WI module foresees one main section for each pipeline. Each section exploits the TMPPS DB to gather the information that allow the user to browse and select the period of interest. The PHM pipeline section displays by default a summary on the last 15 orbits, and allows the user to browse and display the data products of any selected orbit (see Figure 4).

The GSM pipeline section includes a *radio-button* with all the available filters, and another for the integration time selection. As shown in Figure 5, the main page provides the direct link to each data product available in the selected period for the selected filter and integration time.

Finally, the MBM pipeline section shows a summary (in short and log format) of all the burst alerts, and the direct links to the related data products of the MBM pipeline.

[8]IPN web page: http://www.ssl.berkeley.edu/ipn3/
[9]GCN web page: http://gcn.gsfc.nasa.gov/
[10]http://www.perl.com

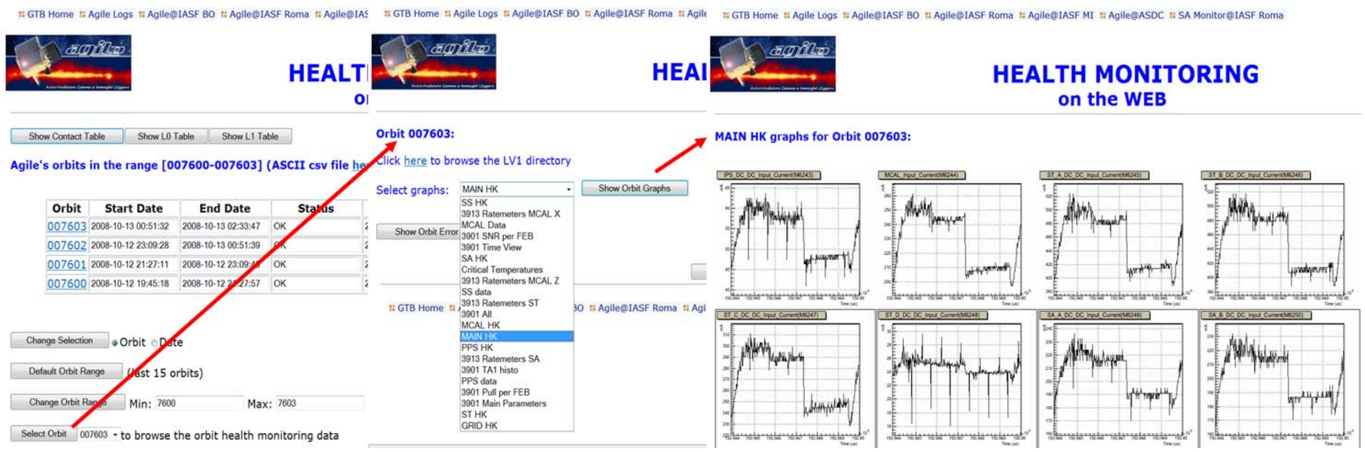

Fig. 4. *Screen-shots of the P/L Health Monitoring section of the AGILE WebMon user interface. From left to right: (i) the main page provides a summary of all the available data products on the orbit period selected by the user; (ii) a secondary page shows the data products, grouped by category, of the orbit selected by the user; (iii) display of the data products selected by the user.*

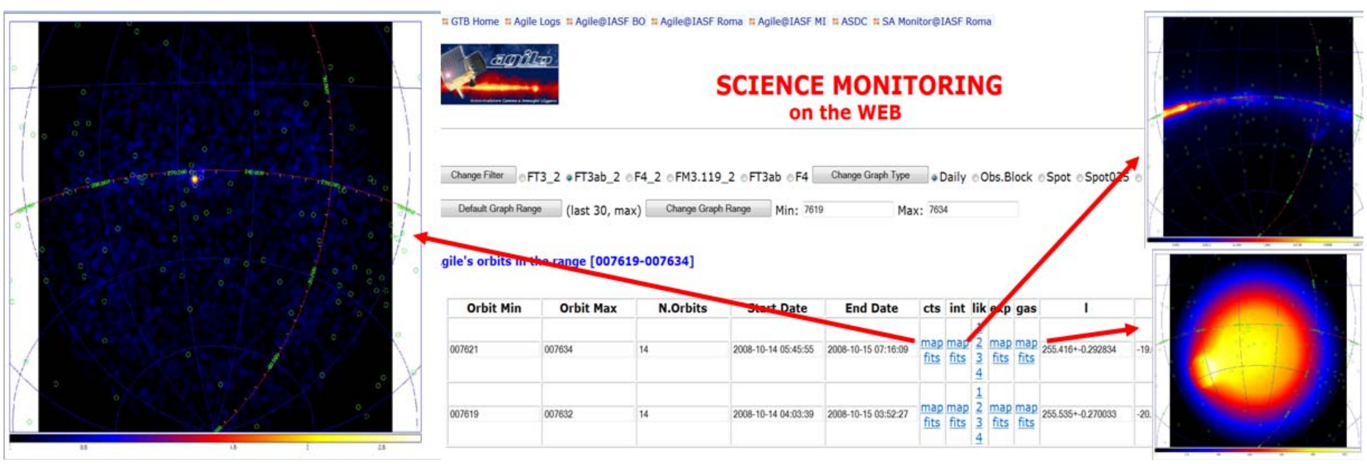

Fig. 5. *Screen-shots of the Grid Science Monitoring section of the WebMon user interface. The main page (in the middle) allows the user to select the filter, the integration time and the orbit period. The URL links shown in this page allow the direct retrieval and display of all the available data products (left and right pictures).*

IV. Conclusion

The AGILE `WebMon` system integrates various AGILE Team tools developed for the AGILE AIV and calibration activities carried out before the launch, and for the standard analysis and the scientific analysis which are being running at the ASI AGILE Science Data Centre. The aim of the AGILE WebMon system is twofold.

It provides a Web tool which allows the AGILE Team to monitor the AGILE P/L system, the Field Of View of the GRID instrument, and the gamma-ray bursts detected by MCAL. To this purpose, the AGILE `WebMon` system generates alerts and made easily accessible through the WEB all the required information, organized orbit-by-orbit.

Moreover it provides a development and test bed for the software modules procured by the AGILE Team to the ASI AGILE Science Data Centre.

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