On-Orbit Performance of the GLAST Burst Monitor

Curran D. Muhlberger
University of Maryland & Cornell University
(Dated: August 8, 2008)

With the Gamma-ray Large Area Space Telescope now in orbit, it is necessary to evaluate the performance of the GLAST Burst Monitor in order to tune calibration parameters, flight software, data pipelines, and operational procedures prior to the onset of normal operations and the publication of science data. To support this effort, we developed a collection of software to assist both the scientific and operational components of the mission during on-orbit checkout. New capabilities provided by our tools include real-time orbit visualization, consistency checks for science data products, parsing of diagnostic files related to automatic gain control and observatory timelines, and web access to pipeline databases. Additionally, we have authored programs for generating high-resolution lightcurves with optimal signal-to-noise ratios to support the InterPlanetary Network and for computing coincidence rates for burst trigger algorithms to inform decisions concerning their thresholds. Our development work has enabled the GBM team to make steady progress in preparing NASA's newest cosmic observatory to study the universe's most energetic phenomena.

I. BACKGROUND

The Gamma-Ray Large Area Space Telescope (GLAST) was successfully launched on Wednesday, June 11, 2008, and the mission has been in the orbital checkout phase until now. The satellite is the successor to the Compton Gamma Ray Observatory (CGRO) and consists of two complementary instruments: the Large Area Telescope (LAT), managed by Stanford, and the GLAST Burst Monitor (GBM), managed by NASA's Marshall Space Flight Center. GBM is the successor to CGRO's Burst and Transient Source Experiment (BATSE) and consists of fourteen detectors able to observe nearly the entire unocculted sky. Twelve of these detectors are Sodium Iodide scintillators pointed in various directions in space. The remaining two are omnidirectional and made of bismuth germanate, enabling them to observe gamma rays with energies overlapping those detectable by the LAT.

Taken together, these detectors enable the satellite to detect and locate gamma-ray bursts using on-board software. Notices of these bursts are immediately sent to scientists around the world, enabling robotic ground telescopes to observe any optical afterglow and possibly identify the source of the burst. The instrument also informs the LAT of these bursts, and the satellite is capable of repointing the LAT for particularly strong events. Gamma-ray bursts are the most energetic phenomena in the universe, and by understanding them and other high-energy astrophysical systems scientists gain insight into fundamental laws of physics.

After launch, the two instrument teams have 60 days to evaluate the on-orbit performance of the observatory and to prepare both the instruments and the ground systems for normal science operations. Our work therefore revolved around writing new software supporting both scientific evaluations and mission operations. Over the course of the NASA Academy's 10-week program we developed over a dozen new tools and successfully used them to discover and diagnose bugs in data processing, tune flight software parameters, and streamline routine operations.

II. COLLABORATION SUPPORT

Essential to a successful mission is effective communication and collaboration both within the team and with the broader scientific community. To support real-time decision making, we configured AGI's Satellite Toolkit to display a live map of the earth featuring GLAST's current position and ground track, relevant ground sites and communications satellites, and other orbiting gamma-ray observatories. With the inclusion of a South Atlantic Anomaly (SAA) contour, this map informed the GBM team of the satellite's status when triggers were activated or commands were executed. Shading of regions in night provided a visual indication of time differences between Marshall and our international collaborators at Germany's Max Planck Institute for Extraterrestrial Physics (MPE). Furthermore, the attractive presentation makes the map the focal point of the GBM Instrument Operations Center (GIOC) when conducting tours or holding conferences.

Additional graphical support was provided by the GlastCam software at Goddard Space Flight Center, and with considerable effort we were able to successfully compile and deploy that same software at Marshall to provide 3D interactivity when examining the satellite's view of outer space. Its visual representation of the various instruments' and sensors' fields of view will support future trigger analysis.

We also wrote a tool in C to provide burst data to the InterPlanetary Network (IPN), which uses the relative timings of bursts observed by multiple spacecraft to pinpoint the burst's location. The reports we generated conformed to a strict format and facilitated the custom energy range selection and histogram binning required by the IPN. Furthermore, we developed an algorithm to identify the detectors required in order to maximize the signal-to-noise ratio of the summed lightcurve in the specified energy range.

III. PERFORMANCE EVALUATION

Since the data processing on GBM is digital, its various data products should be consistent with each other with regard to total counts in each energy band. To verify this, we developed a tool to compare the contents of CSPEC, CTIME, and optionally TTE files and to report any inconsistencies. The tool will also report errors in timing and channel alignment. Fortunately, the only inconsistencies discovered were pairs of ± 1 differences due to events lying precisely on a bin boundary.

Early on in the mission, we needed to adjust the Automatic Gain Control (AGC) to ensure that the energy channels in all of the detectors were aligned. However, the formatting of AGC diagnostic packets made evaluating the system a tedious, labor-intensive task. By writing a parser for these diagnostic files, we accelerated the process of evaluating the controller and freed up man-hours for other essential tasks.

The most significant tool we developed examined raw ground-initiated Time-Tagged Event (TTE) data in order to measure the statistics of the gamma-ray background. Additionally, it could simulate the on-board trigger algorithms and calculate the expected rate of coincidental triggers due to large background fluctuations in two or more detectors in the same time bin. When evaluating the initial set of algorithms, we found that two would yield an unacceptably high number of coincidental triggers each year. We then used the software to identify new thresholds in both cases that would keep the coincidence rate to less than one trigger per year.

Once we had accumulated a small collection of bursts, we implemented a quick tool to compute the hardness ratios for each burst, streamlining their evaluation. Additionally, during the development of all of these tools we produced a portable library providing high-level access to Level 1 data products in C. Furthermore, we discovered and diagnosed several minor bugs regarding the timing of events.

IV. OPERATIONS SUPPORT

In addition to supporting the scientists evaluating the instrument's performance, we also developed software tools to assist with ground operations. By exposing several pipeline databases in interactive web form, we greatly reduced the work needed to evaluate the receipt and generation of data files. These websites easily plug into an existing web framework and are portable, extensible, and modern in design.

We also designed a parsing framework for Integrated Observatory TimeLine (IOTL) files and related ATS summaries. The tools based on this framework can summarize the GBM-related contents of IOTL files containing tens of thousands of lines and can identify when commands are not being issued when the spacecraft is safely within SAA. They can also compare the contents of IOTL and ATS files automatically and notify the user of discrepancies. These tools have already saved large amounts of time for mission operators and have caught at least two errors made by the Mission Operations Center when generating final timelines.

V. RESULTS

Our collection of software tools has supported and streamlined the performance evaluation process in several areas during this critical checkout phase. In addition to catching software bugs and operations errors, they have greatly reduced several labor-intensive tasks and provide a framework for future software development. Our work has directly impacted decisions regarding trigger thresholds and timeline approval, and it will continue to inform decisions and facilitate collaboration upon the start of normal science operations.