Simulating BurstCube Operations and Performance

Pi Nuessle[1,2,3] on behalf of the BurstCube team

[1]NASA Goddard Space Flight Center, Greenbelt, Maryland, USA
[2]The George Washington University, Washington, D.C., USA
[3]nnuessle@ndc.nasa.gov

INTRODUCTION

ABSTRACT

Fermi's observations of gamma-ray bursts (GRBs) allow us to model the next generation of GRB instruments, including CubeSats such as the soon-to-be launched BurstCube. Over the first 14 years of its operation, GBM has studied nearly 3500 GRBs, many in stunning detail, which is a significant sample for simulating aspects of BurstCube's observations when combined with detailed simulations of the orbit and pointing profile. In this poster, we describe how we have used these observations of the prompt emission to seed a bootstrap analysis of BurstCube's predicted on-orbit performance. During operation, BurstCube will primarily point zenith, scanning the entire unocculted sky for gamma-ray transients, with some deviations to minimize drag and maximize power to the solar panels. The four CsI scintillator detectors will take data continuously except for tracks through the South Atlantic Anomaly. Onboard triggers will be downlinked as quick binned data via TDRSS and automatically add the time-tagged event data to the next ground station pass. We will describe how this simulation predicts the on-orbit performance.

BURSTCUBE OVERVIEW

- Instrument (4U):
  - Four CsI (Tl) scintillators, 4.5 cm rad., 1.9 cm thickness (0.6 Aeff GBM)
  - Readout by arrays of 116 SiPM
  - Sensitive from 50 keV to 1 MeV
- Spacecraft (2U):
  - In-house design from GSFC
  - Primarily CoTS components
  - Communications through NASA space network (TDRSS) and Direct-to-Earth network (DTE)

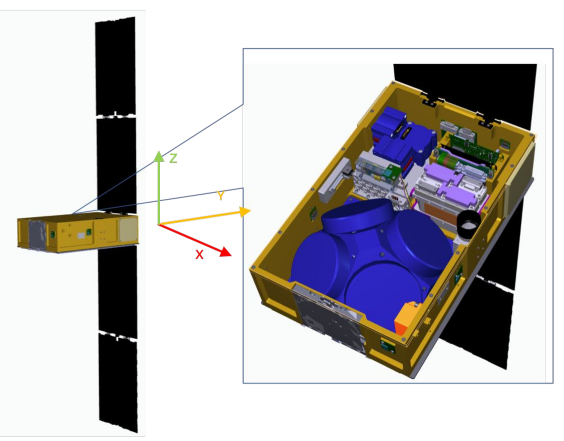


Fig. 1: BurstCube instrument and Spacecraft components

- Concept of Operations:
  - Observes entire entire unocculted sky
  - Points zenith except during day passes at low beta to optimize power and drag (Fig. 2)
    - Beta–angle between sun and orbital plane
  - Daily DTE pass for science data and demand access TDRSS contacts for transient alerts.
  - Suspend data collection in SAA
  - 1+ year mission (orbital lifetime limited)

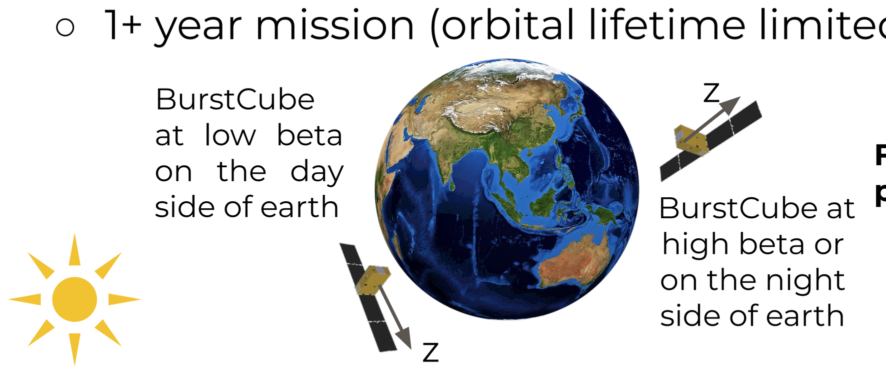


Fig. 2: BurstCube's pointing strategy

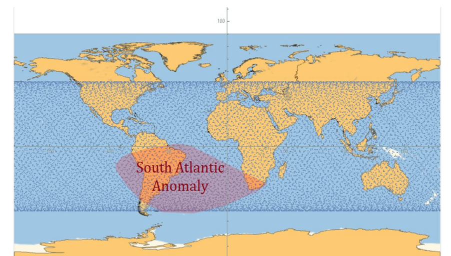
SCIENCE OPERATIONS

ORBIT AND ATTITUDE MODELING

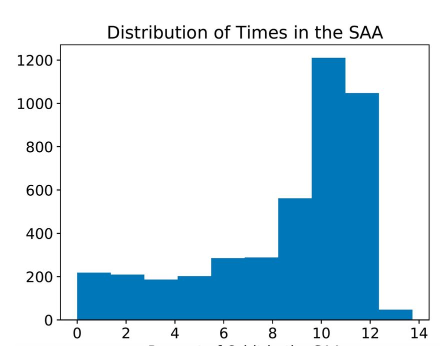
- Manifested to launch to and be deployed from the International Space Station in early 2023
  - Goal: operate during LIGO-Virgo-KAGRA O4 observing run
- Primary orbit modelling software has been the General Mission Analysis Tool, or GMAT [1]
- 42 [2] is used to model instrument's pointing and drag

SOUTH ATLANTIC ANOMALY MODELING

- Initial polygon convolution (Fig. 3) of Fermi-GBM/NICER
  - Planning procedure to refine on-orbit by comparing to data like Fig. 4
- Studying three-dimensional polygon to account for altitude variation



BurstCube's modelled orbit with its preliminary SAA polygon



Figs. 3 and 4: BurstCube's orbit and initial SAA, and a histogram of the first year of modelled SAA crossing durations

REQUESTING TIME TAGGED EVENT (TTE) DATA FROM THE ONBOARD BUFFER

- Insufficient bandwidth for continuous TTE (like GBM)
- 48 to 72 hour TTE buffer, pending solar activity
- Onboard trigger for transient alerts
  - Automatic downlink and distribution of alerts through GCN
- Requested Time-Tagged Event data (RTTE) added to daily DTE download timeline
- Public web portal and automated GCN notice listener for other instruments' triggers
- RTTE request prioritization (Table 1) generally follows:
  - Passes out of buffer sooner
  - Include more object or position information
  - GW events likely to involve neutron stars
  - Those requested by observers

Priority	Criteria
1	Automated triggers of simultaneous GW-GRB events
2	Automated triggers from LVK that likely contain a neutron star
3	Community-requested events that are well-localized
4	Community requested triggers that are poorly localized
5	Automated external triggers of GRBs
6	Community requests that only included a time
7	Automated requests of GRBs or NS GWs that were poorly localized
8	Automated requests of solar events
9	Automated requests of GW events that were likely to be binary black hole mergers

SIMULATED BEHAVIOR

CONCEPT MAP FOR SIMULATION

- Performing a simulation of the science operations of BurstCube (Fig. 5)
- Maximize use of orbit time while also being corrected by real data

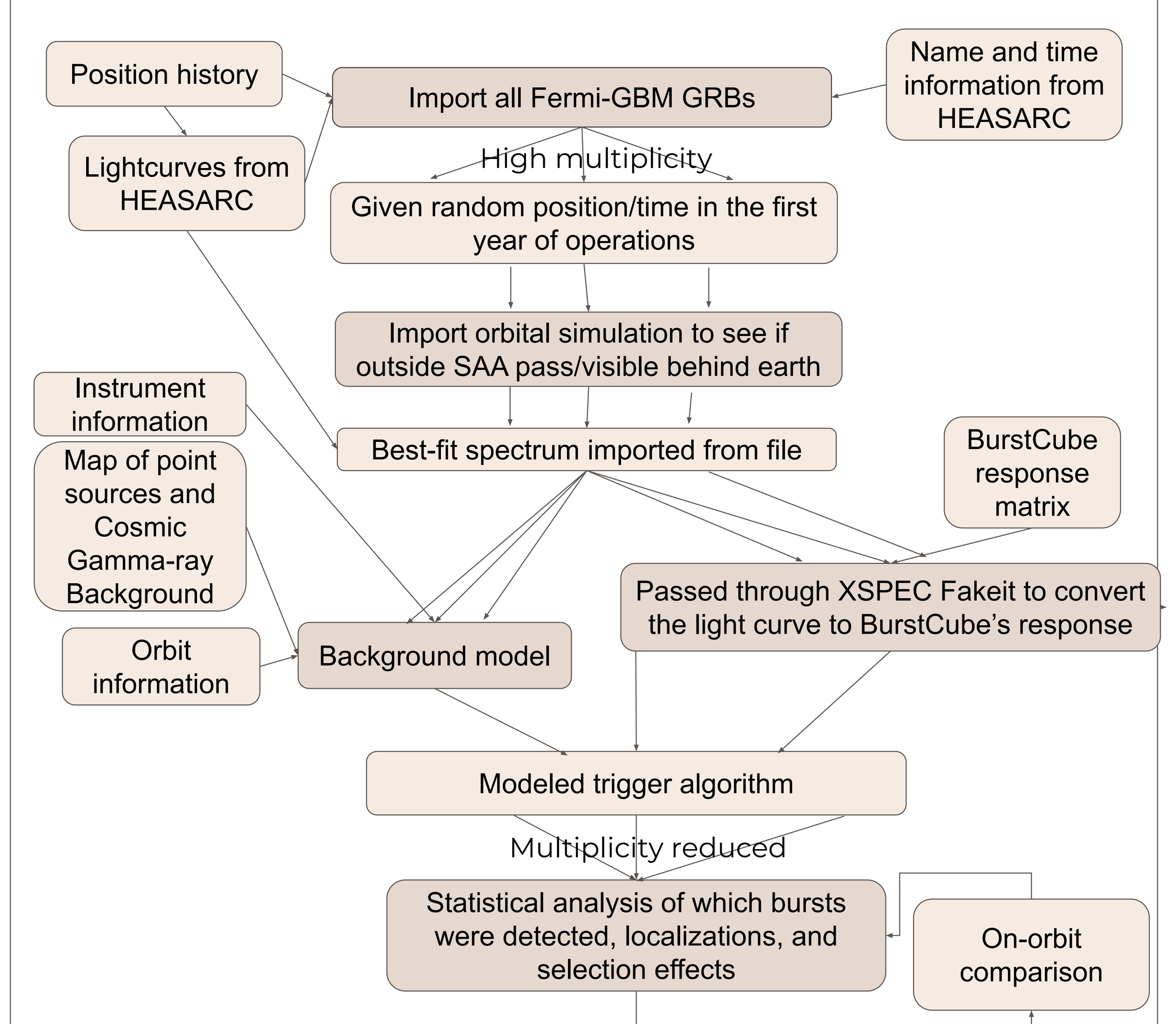


Fig. 5: A conceptual map stepping out the Monte Carlo simulation of the science operations of BurstCube that I am performing.

MODELING THE BACKGROUND

- Typically empirically fit post-hoc as a polynomial
- Biltzinger et al. [3] suggest a physically-motivated (cosmic gamma-ray background, SAA activation, point sources, cosmic rays, earth albedo, constant) model to fit GBM data (Fig. 6)
- Adapting this model to BurstCube
  - Taking advantage of GBM's large library of past data to create a Monte Carlo simulation of burst detections and downloads
  - Pass through orbit and response functions for BurstCube

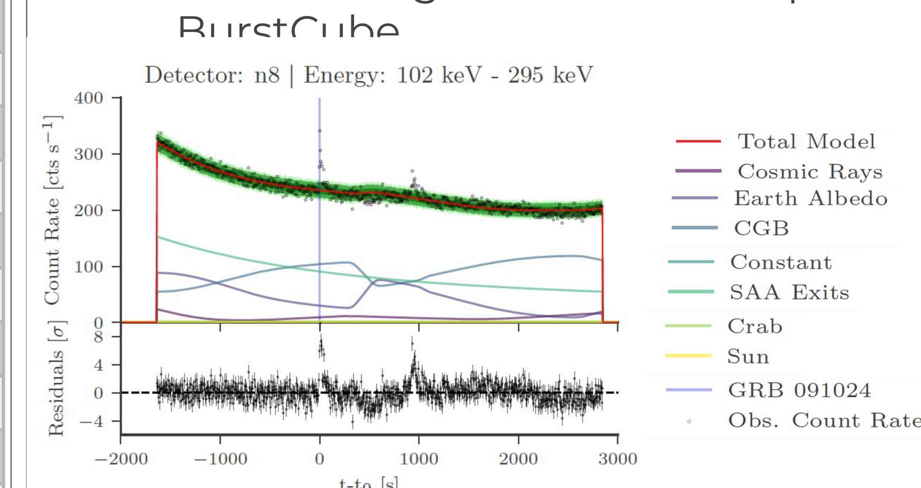


Fig. 6: Figure 18f of [3] showing each component of the background fit to ultra-long GRB 091024 as well at the data itself

STATUS AND GOALS

FINISHED

- Orbit modeling
- 2D SAA polygon modeling
- Initial RTTE request maker
- Initial RTTE prioritization code
- Importation of GBM GRBs and their trigger information
- Determining if bursts are visible to BurstCube

IN-PROGRESS

- The pointing modeling
- Adding the background models
- Determining if the bursts would be triggered on
- The statistical analyses of the trigger information
- Plan to release on public git repository

QUESTIONS WE WILL ADDRESS

- How many bursts will BurstCube observe?
  - Long, short, ultralong
- How many requests will the system receive?
  - What types of events will this allow the science team to download?
- What type of follow-up can be expected for BurstCube bursts?
- How many bursts will be concurrent with other instruments?
  - Swift-BAT, LVK, Fermi-GBM
- Urgency: BurstCube has a short mission. This pre-launch simulation prepares the team and the community for extracting the best science from the instrument.
- Simulations could later be adapted to other missions.

References

[1] "For Users - GMAT Wiki - Confluence," gmat.atlassian.net. https://gmat.atlassian.net/wiki/spaces/GW/pages/380273375/For+Users (accessed Aug. 30, 2022).
[2] "42," SourceForge. https://sourceforge.net/projects/fortytwospacecraftsimulation/ (accessed Aug. 30, 2022).
[3] B. Biltzinger, et al. 2020, Astronomy & Astrophysics, vol. 640, "A physical background model for the Fermi Gamma-ray Burst Monitor,"

ACKNOWLEDGEMENTS

BurstCube is funded via NASA/APRA (NNH16ZDA001N). For a full list of the BurstCube team, please see Proc. SPIE 11444 (https://doi.org/10.1117/12.2562796). The BurstCube team gratefully acknowledges the work by the engineering team within the engineering and technology directorate at NASA/GSFC as well as the guidance received from the SmallSat Project Office.