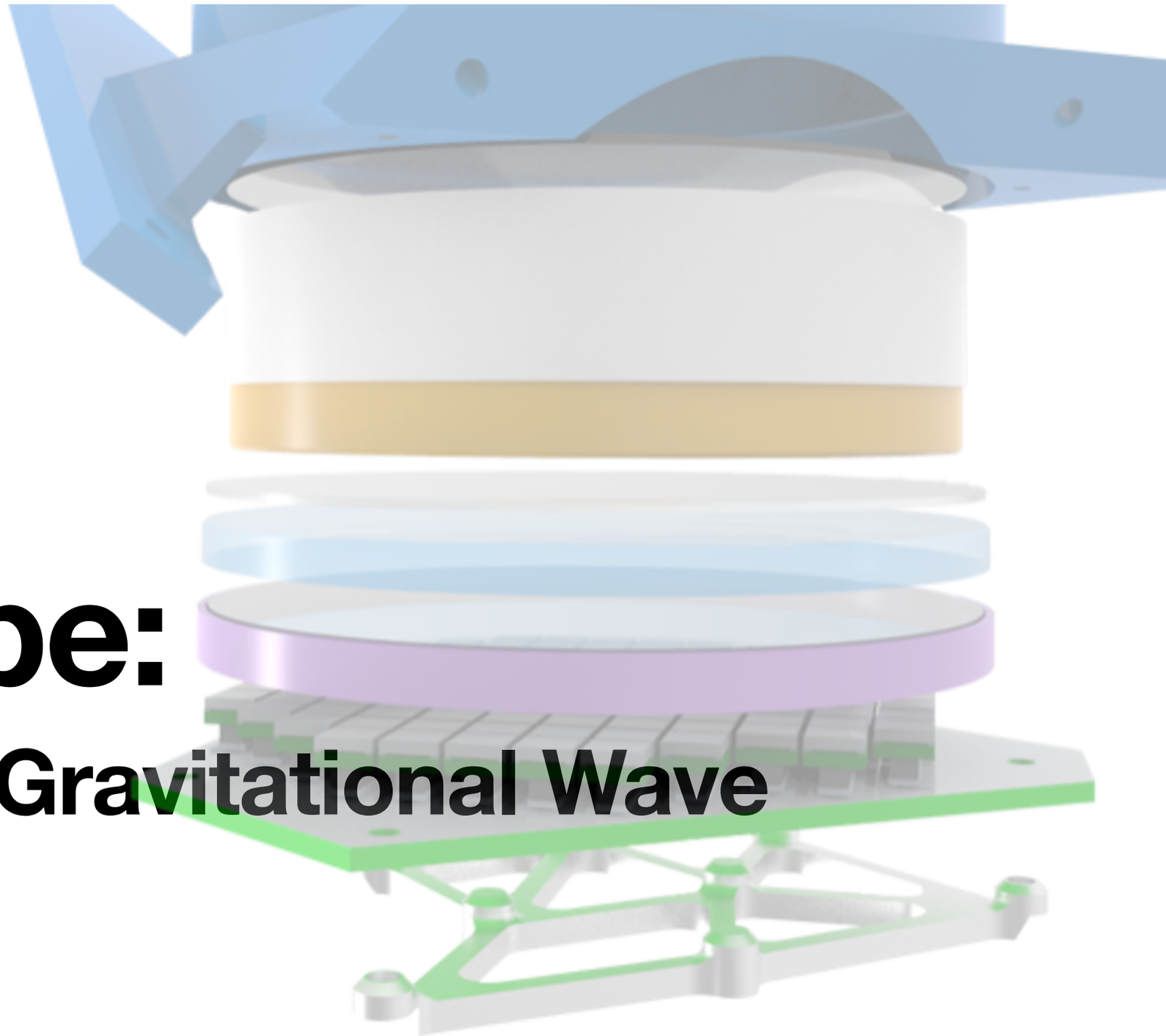

BurstCube:

A CubeSat for Gravitational Wave Counterparts

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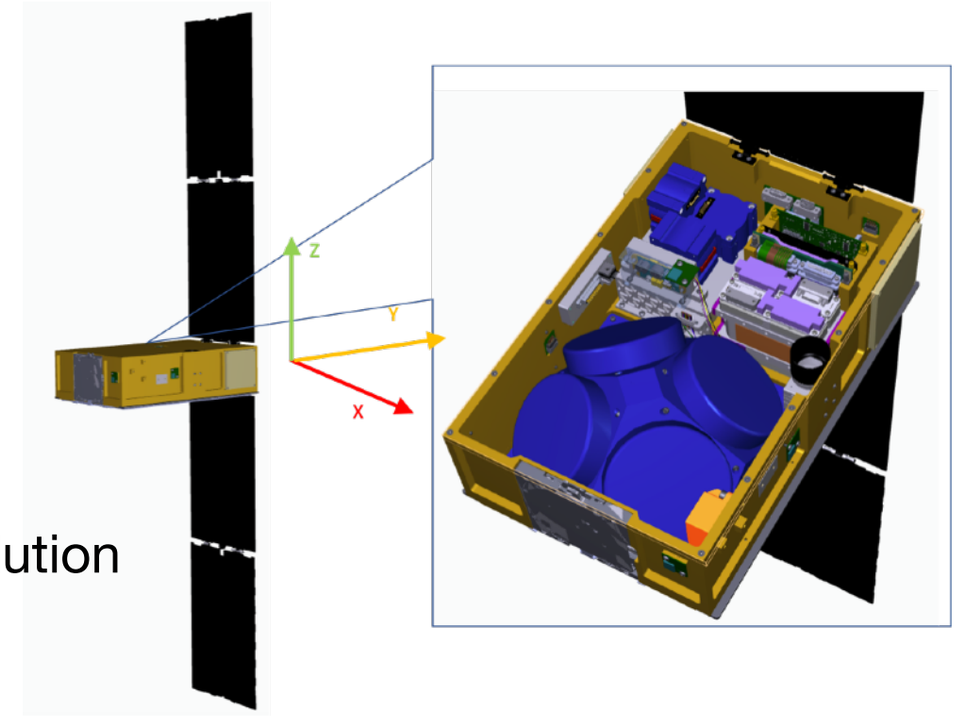
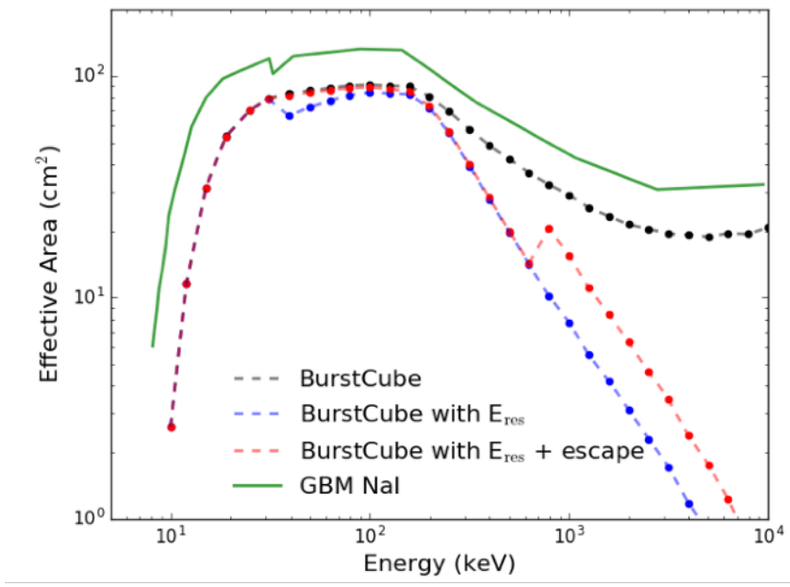
NASA GSFC

June 7, 2023

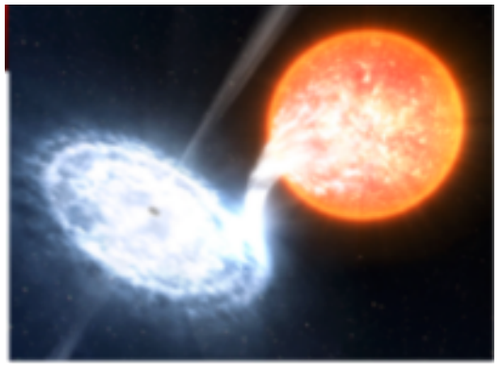
Overview



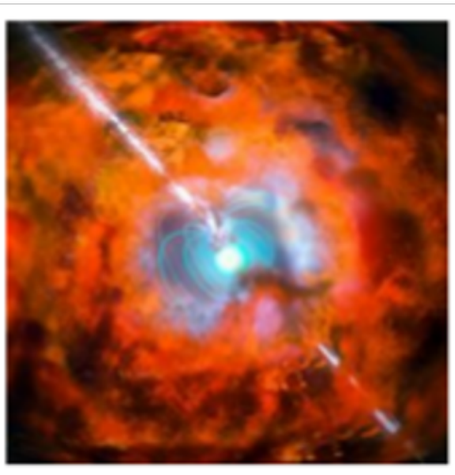
- 6U (10 x 20 x 30 cm) CubeSat
  - **Energy range:** ~50 keV - 1 MeV (with 10% energy resolution at 662 keV)
  - **Field of View:** ~50% of the sky (instantaneous)
  - Low Earth orbit
- Designed to increase sky coverage for GRB detection
- Complement current and future missions:
  - **Current:** Fermi GBM, Swift BAT
  - **Future:** Glowbug, Starburst, BlackCat, MoonBEAM (and many more)
  - Effective area is 70% that of GBM NaI detectors at 100 keV and 15º incidence

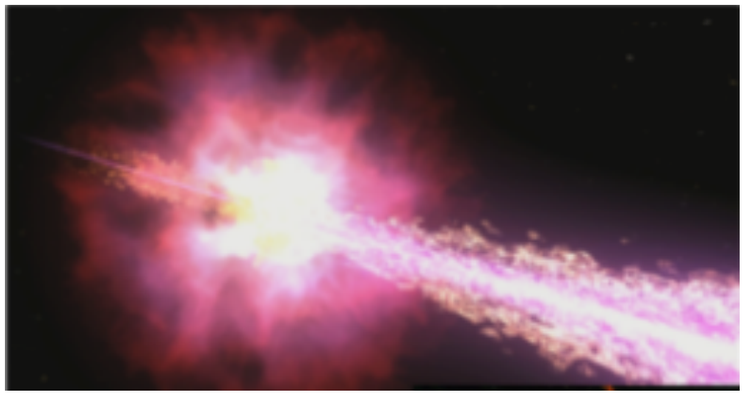


BurstCube Science

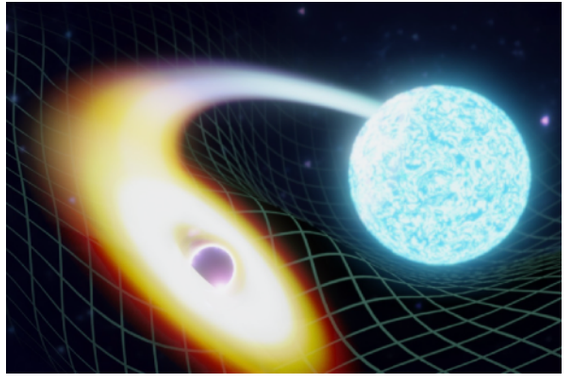


- **Primary science goal:** detect GRBs from the entire unocculted sky
  - Broadband spectra
  - Rough localizations
  - Accurately timed light curves
- Will also detect solar flares, magnetar flares, and other transients
- Combined with Fermi and Swift, BurstCube will provide all-sky coverage for a small fraction of an explorer mission

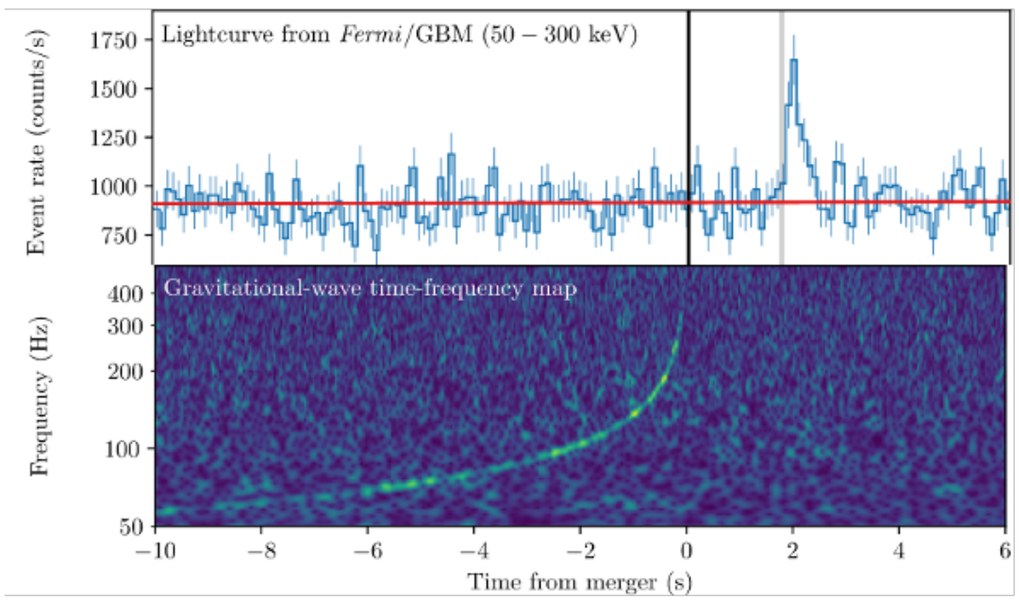




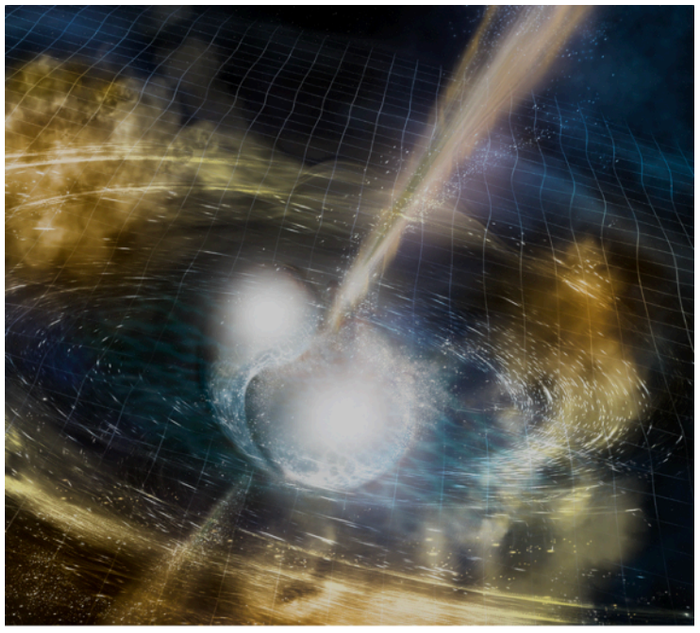
BurstCube Science



- Motivated by measurement of GRB 170817A/ GW 170817
- Designed to provide electromagnetic context to gravitational wave events from LIGO/Virgo/KAGRA (LVK)
  - Only 1 coincident event has been measured so far :(
- Increasing sky coverage with small, efficient satellites will increase the chances of coincident detection



Abbott, et. al. 2017 arXiv:1710.05834



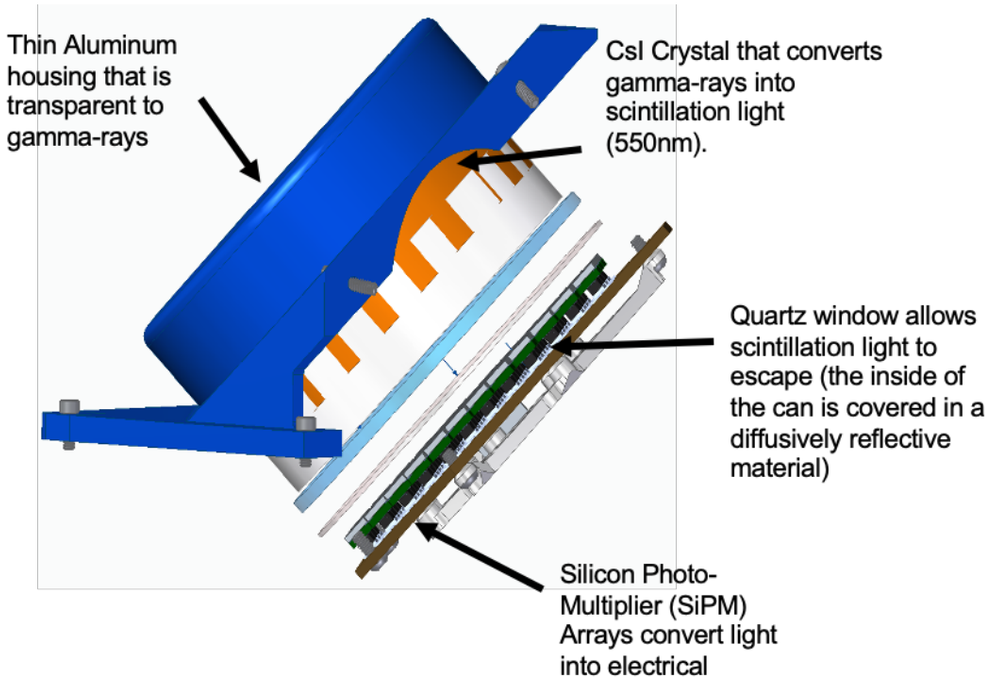
BurstCube Hardware

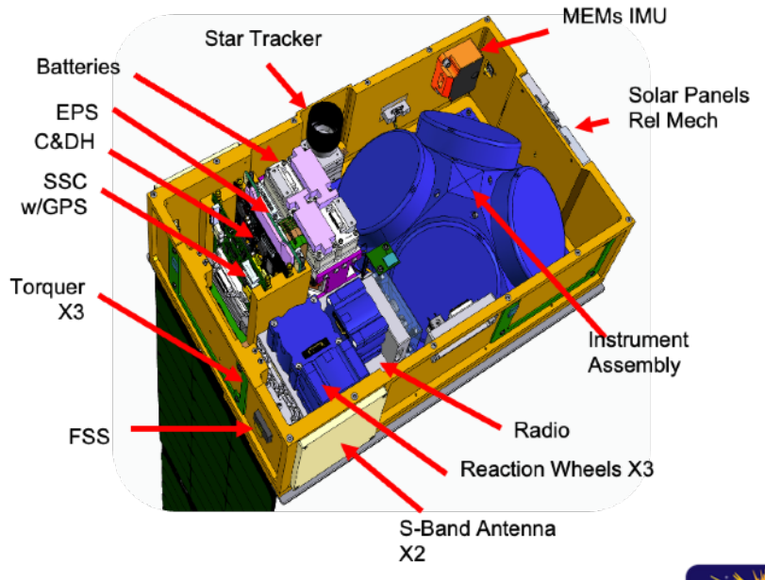
- 6U CubeSat with deployable solar panels and full ACS (Attitude Control System)

- Silicon Photomultiplier (SiPM) arrays mounted on an analog board which sums the signals

- A single analog signal comes out of a detector, indicating a single photon interaction

- Fully integrated into spacecraft bus, being tested at GSFC



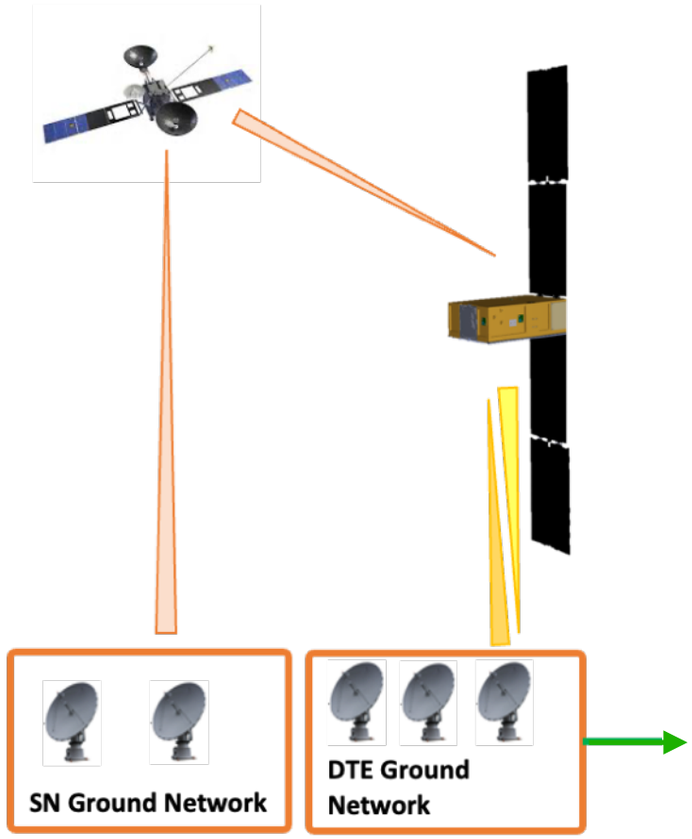


Consequences of a Small Mission

- CubeSats are quick and efficient instruments to build, establish a network
- Having a smaller mission means a smaller team —> more hands-on experience for team members
- Having a smaller mission **also** means limited resources, bandwidth

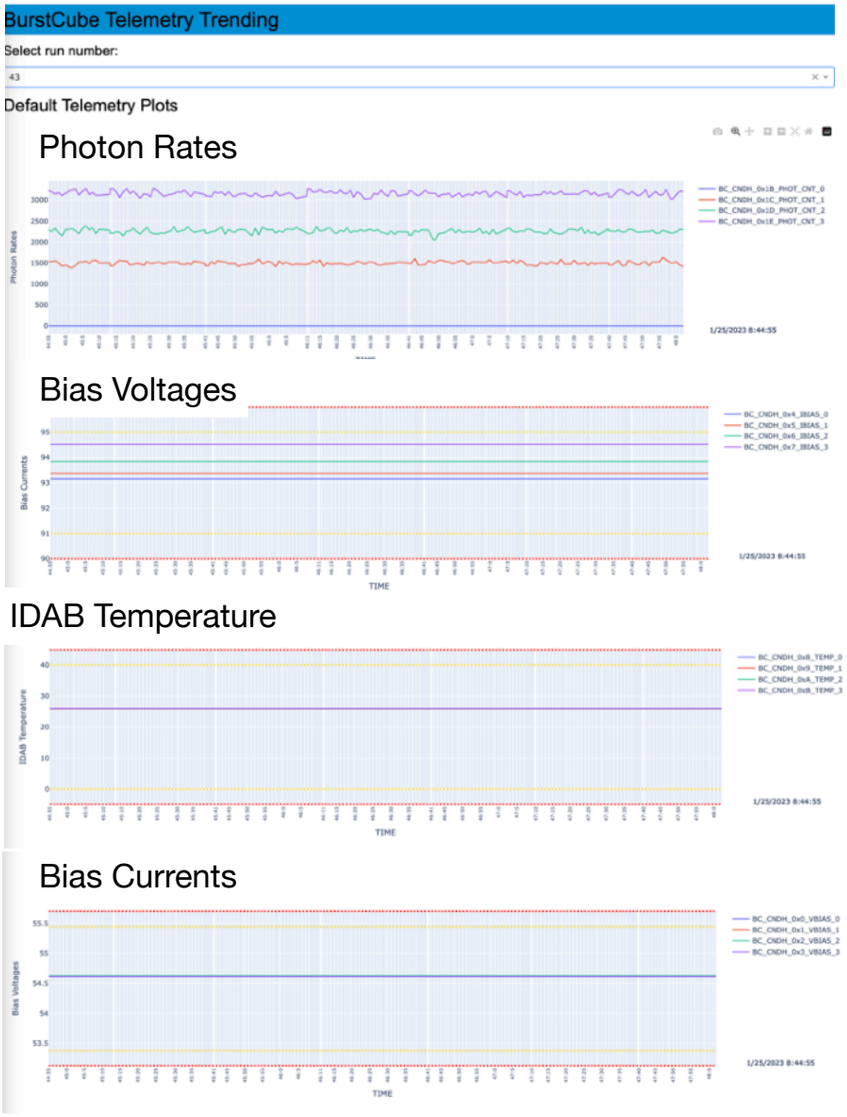
Comms & Planning

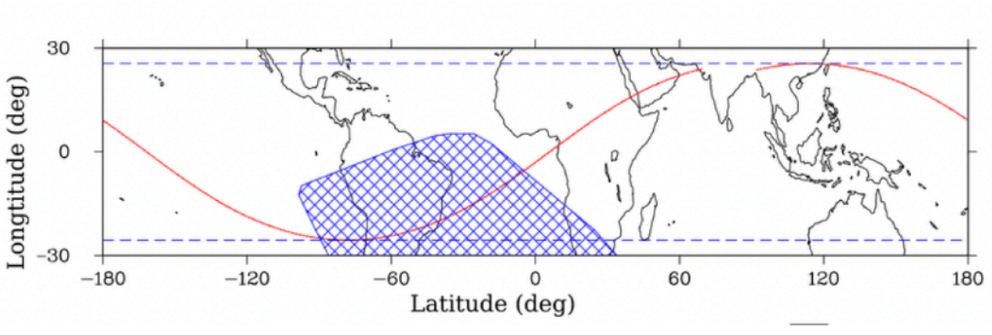
- Trigger data and localization sent through connection to SN - Space Network
  - Rapid downlinking through Tracking and Data Relay Satellite System (TDRSS) - available within ~15 min
- Restricted to **2 ground passes per day** (DTE - Direct to Earth)
- Ground passes require a lot of preparation to keep the process efficient
  - Much of what an instrument like GBM does on orbit has to be done on the ground



Operations Tools

- **Telemetry Trending Database**
  - Stores all spacecraft and instrument telemetry over the mission
  - Entries processed by lowest-level (L0) software pipeline
  - Displayed on internal website for Burst Advocates and Operators
  - Emphasize limit violations
- **SAA modes**
  - Define SAA polygons on the ground, determine entry/exit times
  - Different operating modes depending on whether BurstCube is in the SAA
- **Requested Time-Tagged Events (RTTE)**
  - 48-hour buffer of event data that might not have triggered
  - Important for GW (and other) follow-up
- **Command sequences**

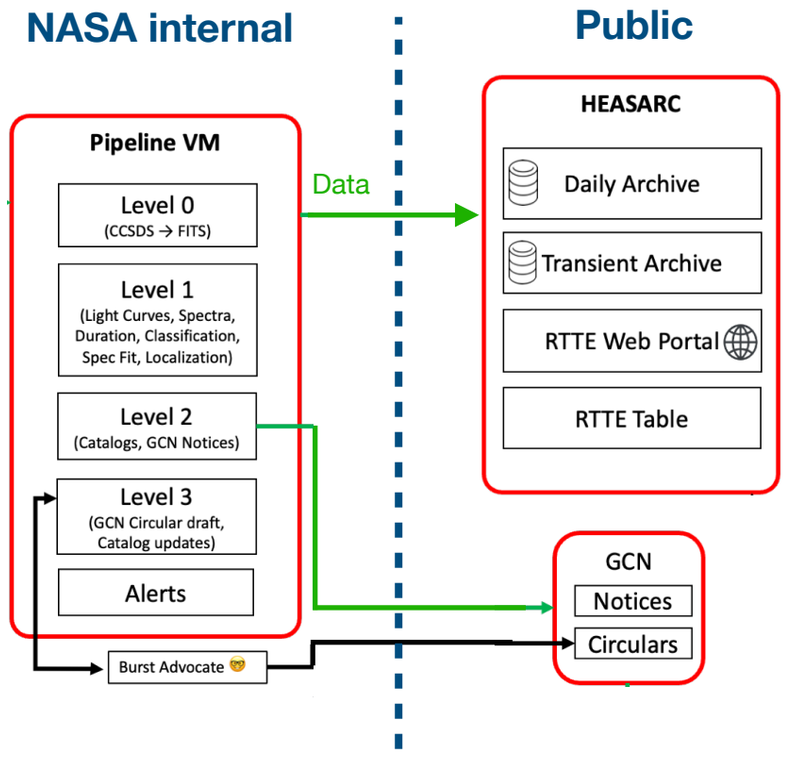


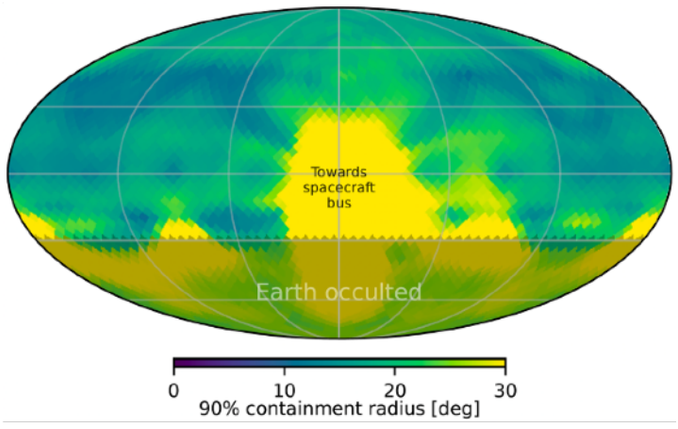


(SSA example from Fermi)

Software Pipeline

- **L0**: First level data processing
  - Deliver telemetry, “raw” data to HEASARC
- **L1**: Generate higher-level data products essential for BAs
  - Lightcurves, spectra, duration, classification, fitting, localization,…
- **L2, L3**: Add bursts to catalog, create GCN notices/circulars

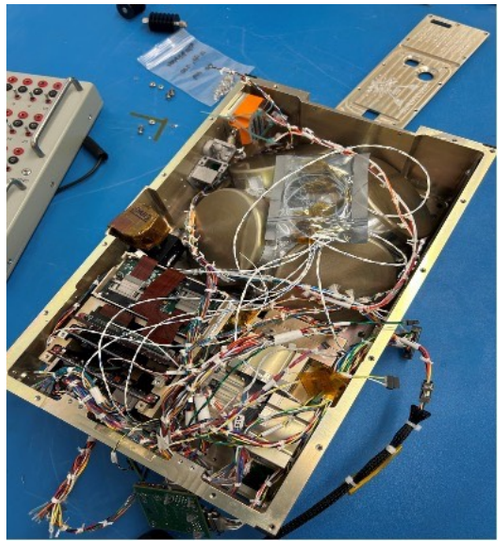




(Expected localization resolution)

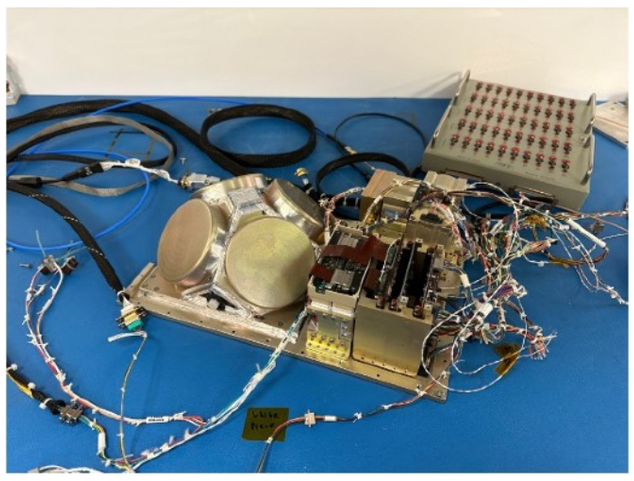
Current Status & Future Work

Current Status:



- Instrument and spacecraft fully integrated ✅
- Successful post-integration calibration ✅
- Conducting environmental tests, preparing for TVAC

Future work:



- Integrate operations tools into spacecraft/instrument testing
- Implement trigger classification, tie into L1 pipeline
  - Start with Bayesian method
  - Experiment with ML techniques
- Do Science!
  - Coherent, sub-threshold searches for GW counterparts
  - BA duty

So many CubeSats!

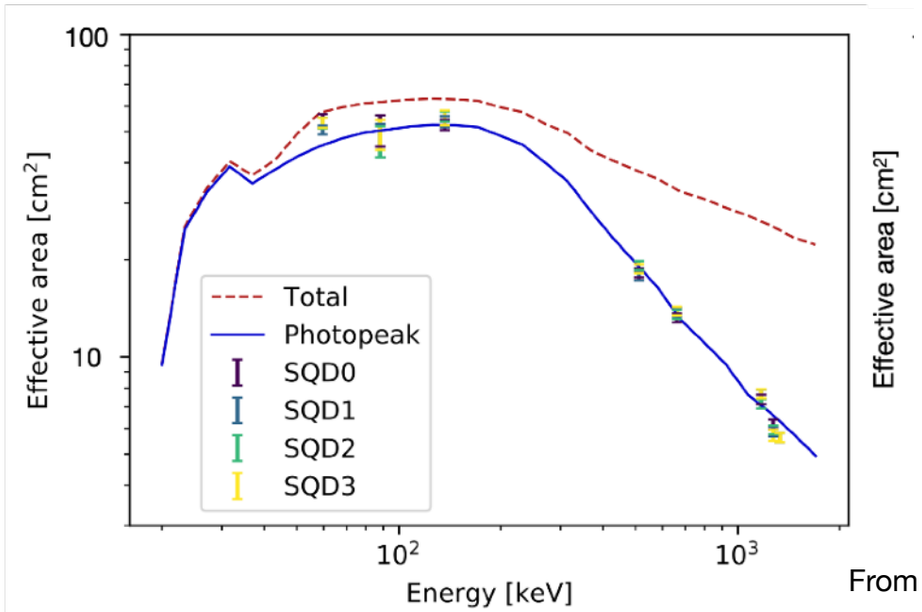
- Many groups around the world are developing CubeSats to detect GRBs:
  - **BlackCat** (PSU), **BurstCube** (NASA/GSFC), MoonBeam (NASA/MSFC), **Nan-Gam** (Technion), **GRID** (Tsinghua), **CAMELOT** (Hungary), **HERMES** (INAF), **Eirsat** (UCD), **Glowbug** (NRL), Sphinx (KTH), GECAM (IHEP), **StarBurst** (NASA/MSFC), …
  - In various stages of development
- We can (and should) work together to develop a global network of GRB nanosats

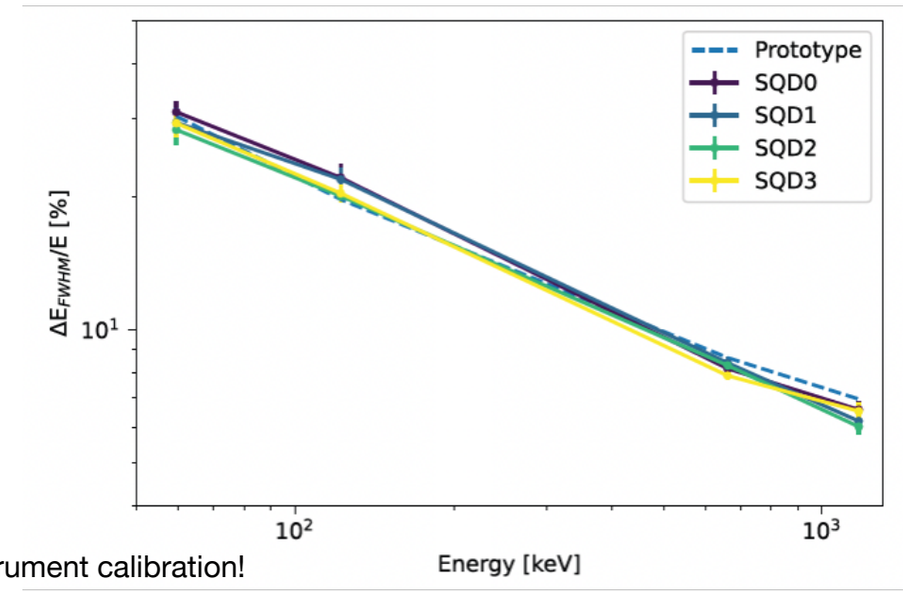
Thank you!

Back-up

Mission Performance

- Energy range: ~50 keV - 1 MeV (with 10% energy resolution at 662 keV)
- Field of View: ~50% of the sky (instantaneous)
- ~20 sGRBs/yr (GBM ~40)
- >100 lGRBS/yr (GBM ~200)





From instrument calibration!

Data Products

- BurstCube will provide various data products
  - Fine (TTE) and coarse (CBD) binning
  - Public immediately upon processing

Datatype	Latency	Type	Energy Channels	Time Resolution	Time Coverage
ATD (Alert Trigger Data)	~15 min	Trigger	16	50 ms to 2 s	-60 to +60 s
T³E (Triggered Time Tagged Events)	~1 day	Trigger	1024	10 μs	60 to 120 s around trigger
RTTE (Requested Time Tagged Events)	~1 day	Requested	1024	10 μs	requested
CBD (Continuous Binned Data)	~1 day	Continuous	16	256 ms	continuous

Ops Workflow