How do GRB NanoSats fit into the Future of TDAMM Plans at NASA and Other Agencies?

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+ Discussion with all of you

https://www.grbnanosats.net/wiki/Internal:Monthly_Calls

Why are we here?

- GRB NanoSats provide
  - testbed for maturing new technologies
  - spaceflight experience for emerging space programs
  - training early career engineers and scientists
- GRB NanoSat Science
  - Collectively an all-sky monitor for GRBs and other short transients
  - Complementary spectral coverage to instruments with narrower or lower-energy bandpass
- GRB NanoSats can do more in cooperation than independently
  - requires significant infrastructure efforts
- How do GRB NanoSats fit into the future GRB mission/instrument landscape?

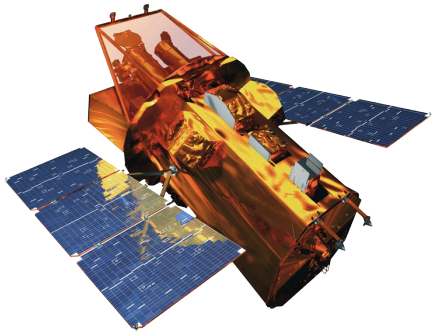
Current Large GRB Missions

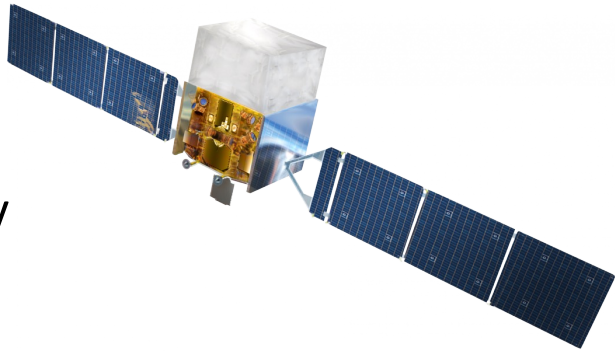
Mission	Year Launched	GRB Detection	Light Curves	Locali-zation	Spectra	Polarization	Afterglow	GRB Rate (yr^{-1}) (long/short)
KONUS	**1994**	✓	✓		✓			~130
INTEGRAL (SPI-ACS)	**2002**	✓	✓					~170
Swift	**2004**	✓	✓	✓	✓		✓	90/10 (BAT)
Fermi	**2008**	✓	✓	✓	✓		✓ (LAT)	200/40 (GBM) 20/2 (LAT)
CALET (CGBM)	**2015**	✓	✓		✓			30-40
AstroSAT	**2016**	✓	✓	✓	✓	✓	✓	~50
Insight-HXMT	**2017**	✓	✓			✓		~90
GECAM	**2020**	✓	✓	✓	✓			~70

Apologies if I missed something!

ASTRO2020: Current Missions

- “In addition, NASA’s workhorse hard X-ray and gamma ray transient facilities (Swift and Fermi, respectively) are aging and their longevity is uncertain.” (2-33)
- “In addition to the threats of lost capabilities resulting from the aging of Swift and Fermi, there are also potential new international opportunities to meet the scientific needs, such as the Space Variable Objects Monitor (SVOM). Contribution of instruments to international efforts is another possibility for achieving some elements of the program. The specific needs to sustain and enhance the optimum suite of space capabilities will change over the upcoming decade, and it is likely that these capabilities will be most effectively achieved by a complement of missions on different scales, including contributions to international efforts.” (7-18)
- “For rapid follow-up and correlation studies, continued support of *Swift* and *Fermi* spacecraft operations will be crucial until newer missions replace them.” (B-10)





Upcoming Medium/Large GRB Missions

Mission	Year Launched	GRB Detection	Light Curves	Localization	Spectra	Polarization	Afterglow	GRB Rate (yr^{-1}) (long/short)
Glowbug	**2023**	✓	✓	✓	✓			?/70
SVOM	**2023**	✓	✓	✓	✓		✓	70-80
StarBurst	**2025**	✓	✓	✓	✓			1200/200
COSI	**2025**	✓	✓	✓	✓	✓		20
Lots of CubeSats/SmallSats (e.g. EIRSAT-1, GALI, BurstCube, HERMES, CAMELOT, Formosat-8B, GRID, Light-1, SpIRIT, …)								
Many proposed missions (e.g. AMEGO-X, GAMOW, MoonBEAM, LEAP, THESEUS, …)								

Apologies if I missed something!

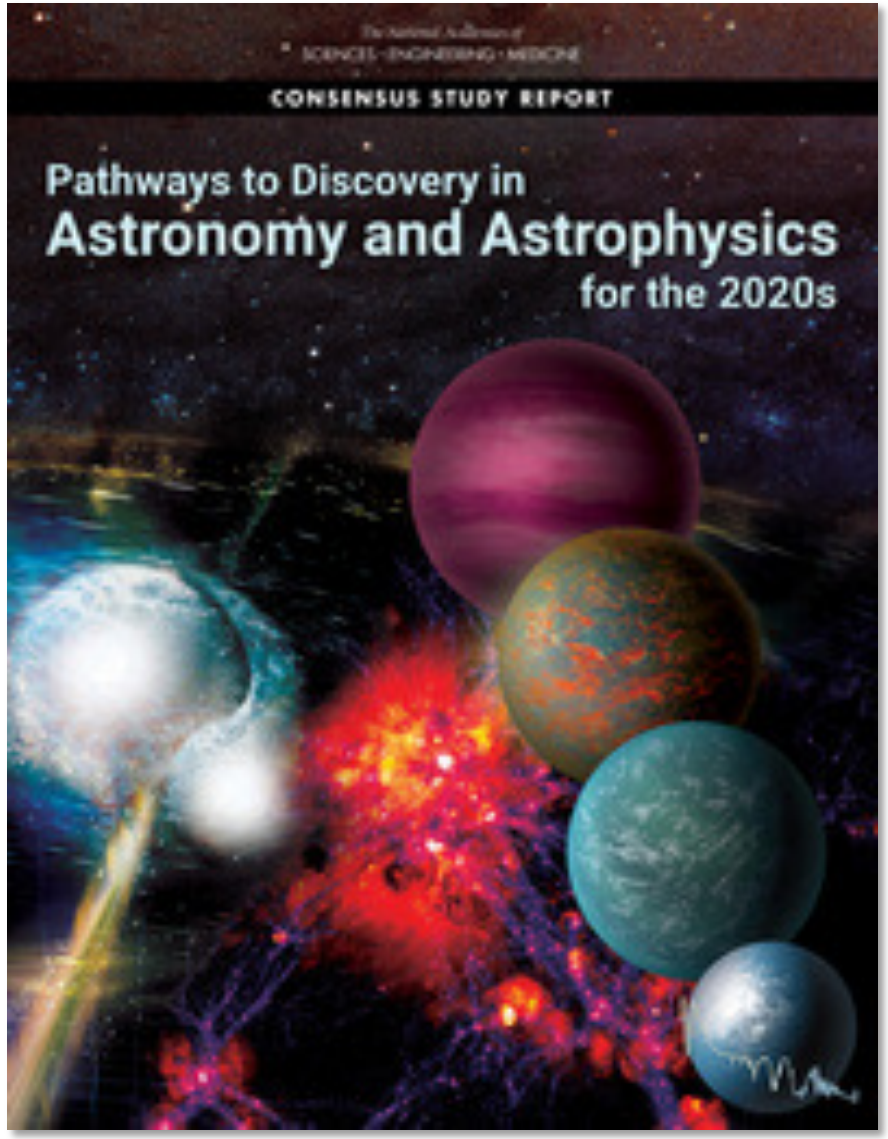
ASTRO2020: SmallSats and CubeSats

The emerging areas of SmallSats and CubeSats are gaining the attention of astronomers. SmallSats are being proposed to fill several key gaps in astrophysical research—namely, the **monitoring of sources for weeks or months at time**—and at wavelengths not accessible from the ground … Other science cases for SmallSats being developed now include a wide variety of astrophysical experiments, including exoplanets, stars, black holes and radio transients, galaxies, and **multi-messenger astronomy**. Achieving high-impact research with SmallSats is becoming increasingly feasible with advances in technologies such as precision pointing, compact sensitive detectors, and the miniaturization of propulsion systems. (I-25)

NASA plans a cadence of 5 to 10 Pioneers and about 10 SmallSats (i.e., CubeSats <6 U) per decade. (H-19)

Astro2020: Space Priorities

- IR/O/UV Large Strategic Mission
  - Technology Maturation Program after which missions begin development mid-late decade
  - 5 years - $11B
- Time-Domain Program
  - A program of competed missions and missions of opportunity to realize and sustain the suite of capabilities required to study transient phenomena and follow-up multi-messenger events.
  - Over decade - $500M-$800M
- Probes
  - Far-IR and X-ray to complement Athena
  - Technology maturation in second half of decade
  - 1 per decade - $1.5B/mission



https://www.nationalacademies.org/our-work/decadal-survey-on-astronomy-and-astrophysics-2020-astro2020

Astro2020 Highest Priority in Space: TDA MMA (aka TDAMM)

- “Exploring the cosmos in the multi-messenger and time domains is a key scientific priority for the coming decade”
  - “maintain and expand space-based time-domain and follow up facilities in space”
  - “Explorer-scale platforms, or possibly somewhat larger”
  - “time-domain program is therefore recommended as an augmentation [to Explorer program] .. competed calls in broad, identified areas.”
  - (1-17)

NASA's Implementation of TDAMM?

Time Domain & Multi-Messenger Program

Actions are being developed to address Time Domain Astrophysics and Multi Messenger (TDAMM) recommendations of the 2020 Decadal Survey; NASA's current thinking is

- A panchromatic, multi-messenger program enabled by current and upcoming ground- and space-based facilities will require coordination and broad community involvement
- In addition to new flight missions, the program must involve multi-mission, interagency, and international coordination in the areas of data archives, data standards, transient alerts, and community research opportunities
- Existing and future (in development) NASA missions will continue to make valuable contributions to TDAMM, and upcoming NASA missions and partnerships promise to do likewise
- This will be a program with extensive international cooperation, shaped using broad community input
- NASA has invited its international partners and NSF to participate in the necessary cooperation

From Paul Hertz's Townhall talk Jan 2022:
https://science.nasa.gov/science-pink/s3fs-public/atoms/files/AstrophysicsDivTown%20Hall_Jan_11_2022_Q&A.pdf

- Does this mean new proposal opportunities?
- TDAMM science advisory group will be formed following broad community, interagency, and international input regarding the pressing science questions to be addressed in TDAMM over the next decade
- TDAMM workshop in August 2022
  https://pcos.gsfc.nasa.gov/TDAMM/

What role do GRB nanosats fill that can be complementary or supplementary to big GRB missions?

- GRB NanoSats add
  - More complete sky coverage for rare transients (e.g. GW BNS mergers)
  - Potentially wider energy coverage (e.g. relative to Swift-BAT)
  - joint localizations (requires significant coordination, e.g. IPN)
  - joint observing/follow-up triggers – e.g. Swift BAT GUANO
- If current missions end before replacements are flown
  - Small GRB detectors may be only source of GRB detections
  - Follow-up community is not used to chasing 10's-100's+ of square degree localizations

Notes from Discussion (1/2)

- TDAMM
  - an initiative, not a program
  - missions already in TDAMM portfolio (e.g. COSI, StarBurst)
  - new proposal opportunities – not clear yet
  - Workshop in August in Annapolis, MD, USA
- International partnerships
  - NASA HQ welcomes new partnerships – decided strategically, no longer as letters of interest
  - Also welcome via proposal teams
  - Rules of the road -> restricted data for teams no longer allowed
- Precursor science for future great observatories
  - workshop in April
  - UV/O/IR large mission, Far IR/X-ray Probes

Notes from Discussion (2/2)

- Standard data framework for joint localization/analysis
  - time and energy binning
  - discussion topic for Brno workshop?
- Coherent search algorithm for combined detections with multiple instruments
  - built from GBM targeted search algorithms
  - want to add new missions
  - limitations based on binned data phasing and response functions
  - Requested unbinned data around external triggers could help alleviate this, but requires coordination
- Infrastructure for GRB Network
  - another good topic for Brno workshop