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Glowbug: a gamma-ray telescope for bursts and other transients

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Objective and status

Objective

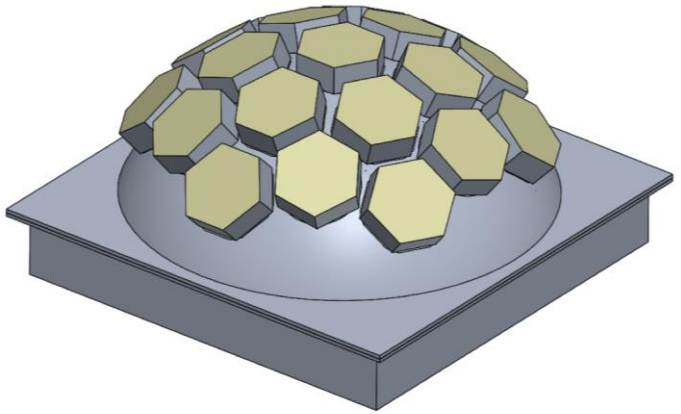
- From the proposal

> **The objective of the research program we propose here is to assemble, test, and deploy a low-cost GRB localizer with sensitivity quite similar to Fermi GBM. Glowbug will complement existing and future gamma-ray instruments by providing electromagnetic counterpart context and locations for GW transients to allow follow-up in other wavebands.**

- Instrument similar in concept to Fermi GBM
  - Large field-of-view (FOV > 2π sr) zenith-pointed "telescope"; array of scintillator panels
  - GRB localization estimated from differential response of detector panels
- Use DoD Space Test Program (STP) for launch and one-year of ops

Status

- Initial funding received Mar 2019
  - Funding profile re-phased relative to proposed profile
- Redesigned for increased sensitivity
  - Procurements underway; some flight components in house
- Successful DON and DoD Space Experiment Review Board (SERB) rankings



Glowbug instrument concept, as proposed

Instrument redesign

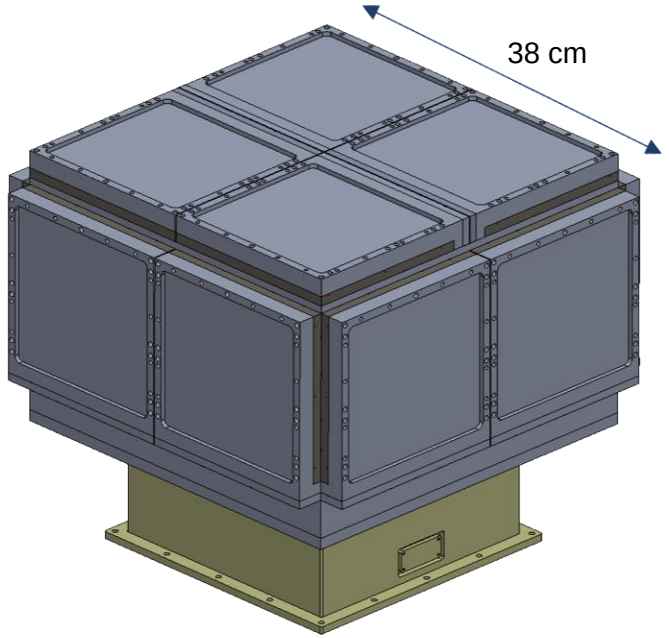
Opportunity to improve the sensitivity

Motivation

- Funding profile inverted by APRA program
- Gamma-ray sensitivity is highest priority
  - Gravitational Wave (GW) horizon is increasing quickly
  - Kilonovae are not gamma-ray bright (c.f. GRB 170817A)
- DoD STP launch opportunity to ISS
  - Huge downlink b/w
  - Generous mass limit, power limit

Conclusion

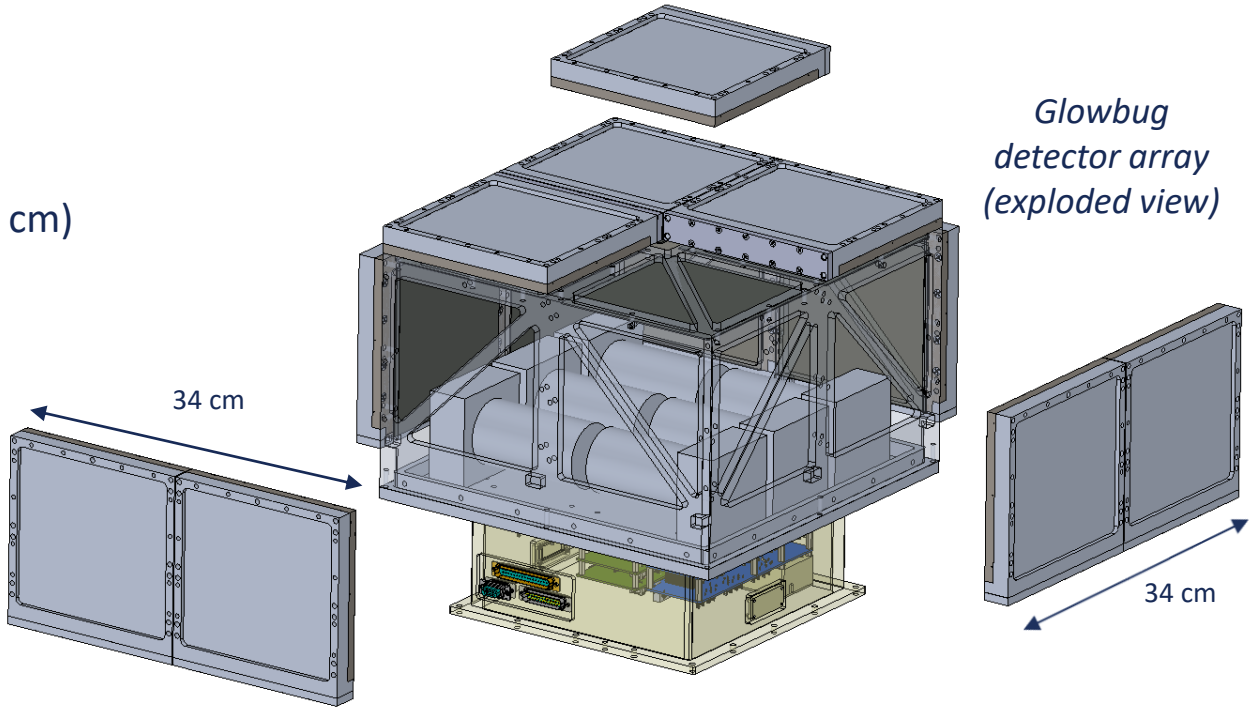
- Increase the detector area, sensitivity
  - Cube has highest surface area per volume
  - Trade some localization ability for more sensitivity
- Add high-energy detector



Glowbug instrument

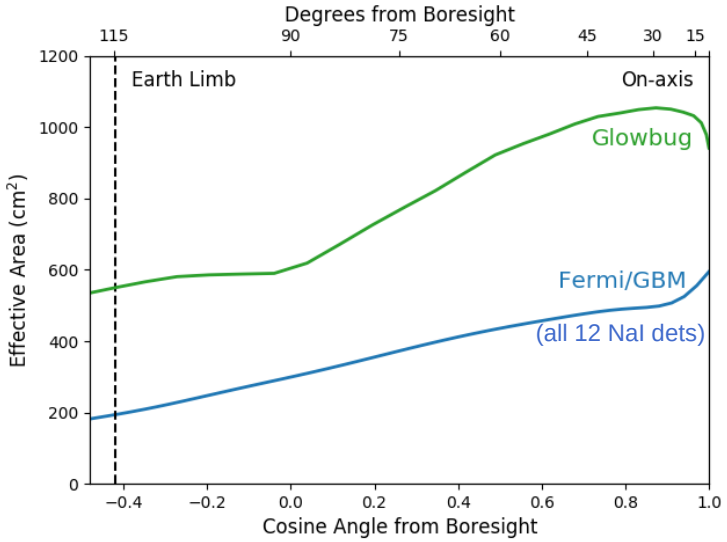
Revised instrument design

- Large scintillator array: Below 300 keV, **effective area more than double the proposed design**
  - CsI(Tl) + SiPM readout (12 detectors, each 15x15x1 cm^3)
    - Good stopping power; not hygroscopic
    - Low size, weight, and power readout
- High-energy detector added
  - CLLB + SiPM readout (6 detectors, each 5 cm diam x 10 cm)
    - Additional effective area above 1 MeV
    - Space-qualify new $Cs_2LiLaBr_6(Ce)$ scintillator
      - » Neutron and gamma sensitivity; excellent dE resolution
- Front end and DAQ from NRL's SIRI-2
  - Low power, space qualified



Glowbug detector array (exploded view)

Glowbug summary

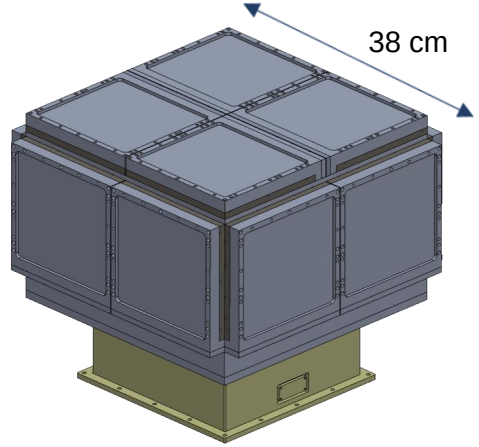


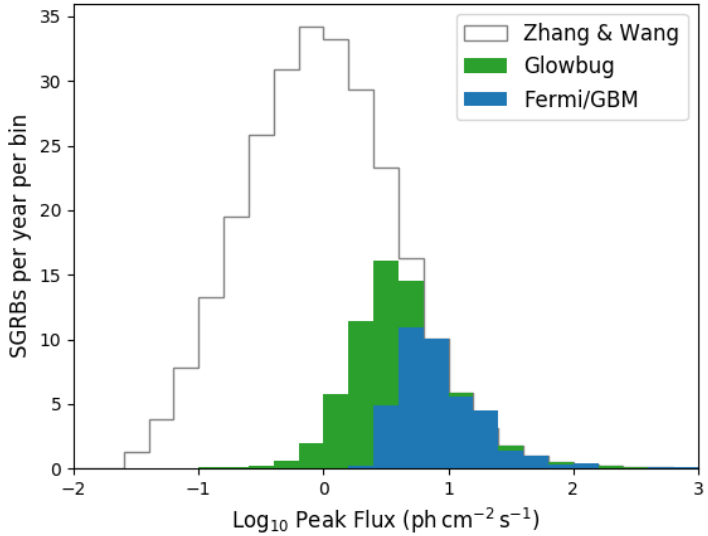
Good sensitivity at low cost

Effective area ~2 x Fermi GBM

Large area scintillators with SiPM readout

Attached payload Instrument ~65 kg



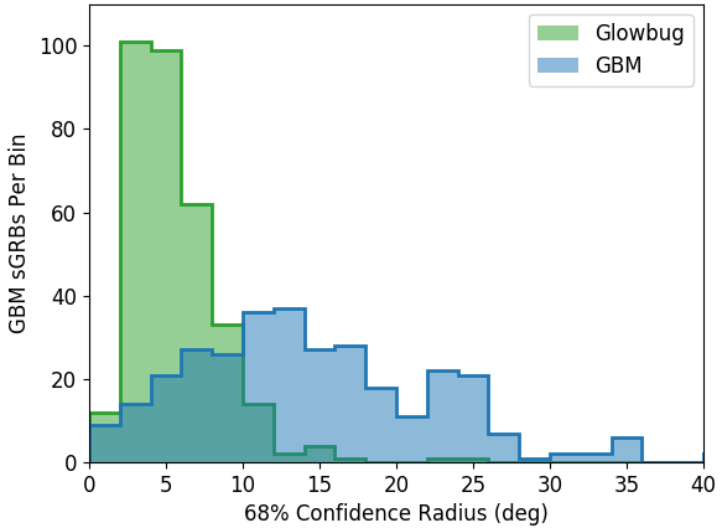


High rate of GRB detections

Rate ~ 70 short GRBs / year

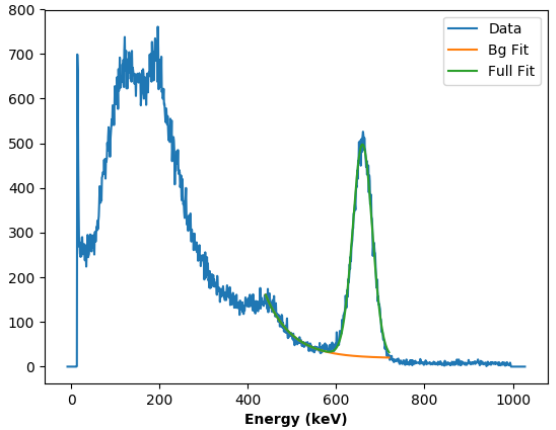
Modest localization ability

Comparable to Fermi GBM

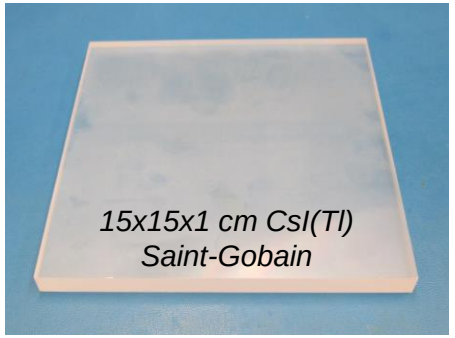


Detector testing

Bench tests of prototype detectors



Flood illumination with ^{137}Cs

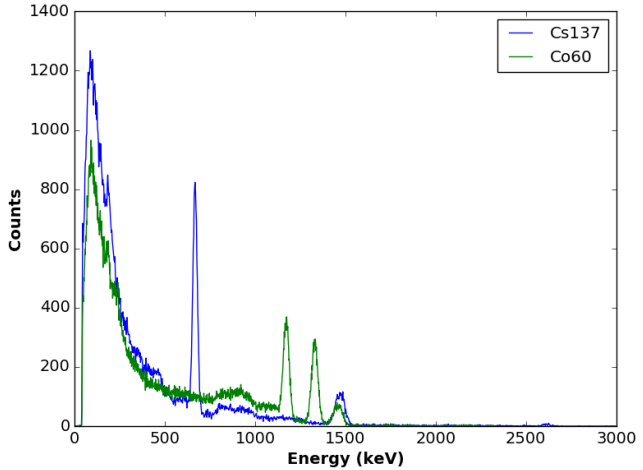


CsI(Tl) + SiPM array

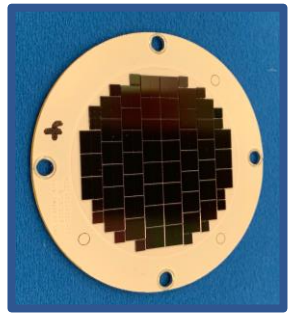
- Xtal wrap is VM2000 specular reflector
- Flood illumination: 7.9% FWHM at 662 keV (^{137}Cs)
- Response map through pinhole array: 1% rms variation

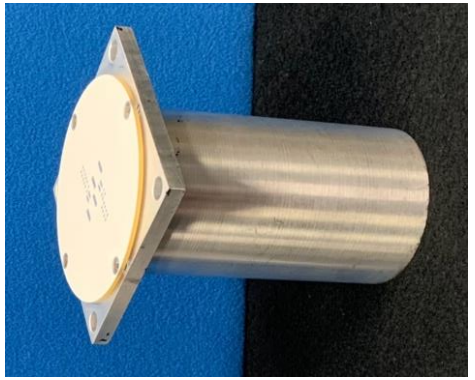
CLLB + SiPM array

- Proto-flight detectors and SiPM array
- Flood illumination: 4.5% FWHM at 662 keV (^{137}Cs)



Proto-flight CLLB and SiPM array. CLLB is 5x10 cm





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Space Test Program

Launch via DoD Space Test Program (STP)

- STP provides integration, launch, and 1 year mission operations costs
- Does not support instrument development costs in any way

Payload selection process

- Briefed Dept of Navy Space Experiment Review Board (SERB) June 2019
  - DON SERB ranked Glowbug in top 40% of payloads
    - Extensive discussion with Houston STP team for potential hosting on ISS
- Briefed Dept of Defense Space Experiment Review Board Nov 2019
  - DoD SERB ranked Glowbug in top 66% of payloads

Potential ride

- Proposed for STP-H9 to International Space Station (ISS) in Jan 2023
  - Express pallet; possible location Columbus Exposed Facility SOZ
  - Zenith-viewing, with reasonably clear sky access
  - Payload manifesting likely Summer 2020
- STP-H7 and H8 are nadir-viewing

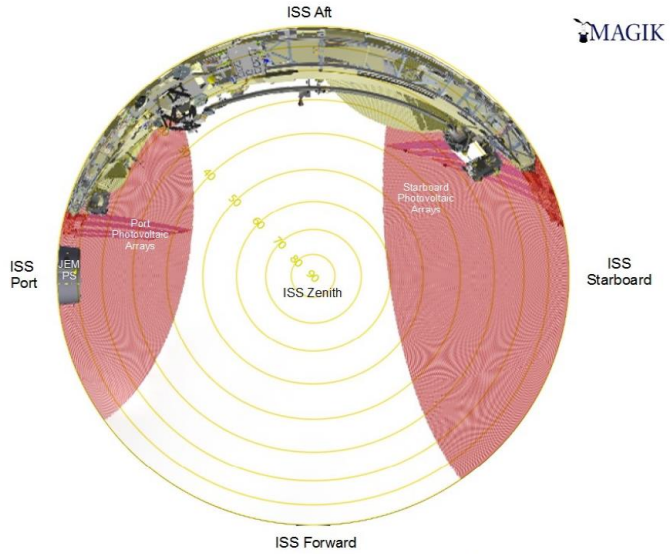


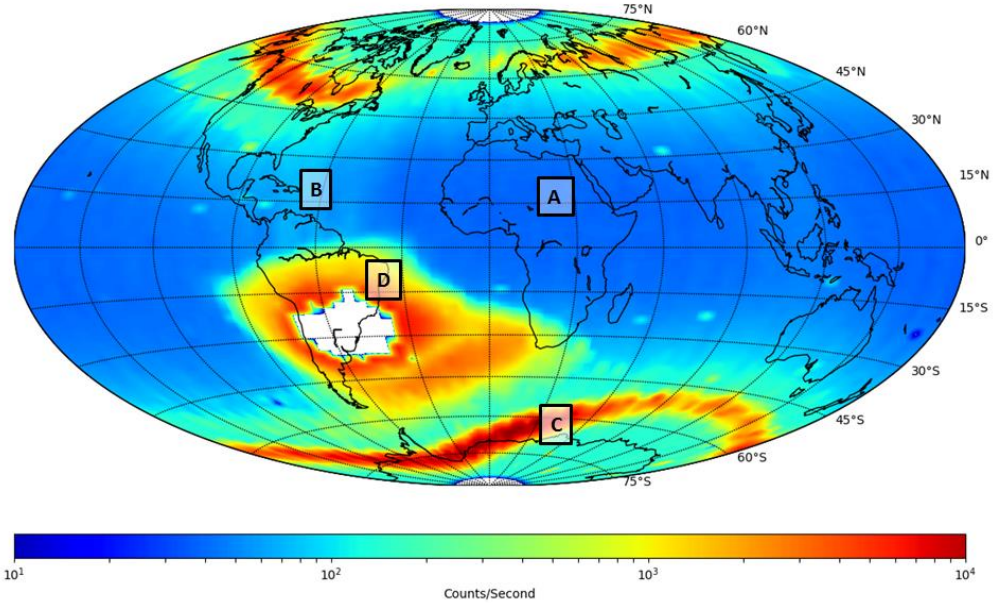
Figure 93: Columbus SOZ Zenith-Facing Fish-eye FOV

Aside: SIRI-1 space-qualifies SiPMs, SrI_2

SiPMs operating successfully on orbit since Dec 2018

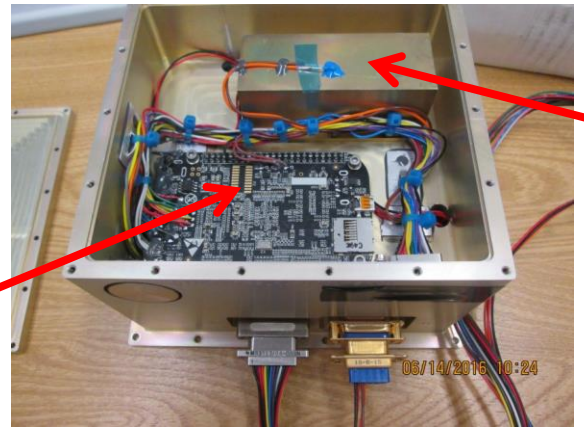
Strontium Iodide Radiation Instrumentation

- Purpose: Space-qualify high-resolution scintillator SrI_2, SensL SiPMs, with BeagleBone Black Single-Board Computer
- SIRI-1 launched 3 December 2018 on STPSat-5
  - STPSat-5 mission ended December 2019
  - S/C is powered off and decommissioned
- SensL J-series SiPMs operated on orbit through 1-year mission



Gamma-ray count rate (E > 30 keV) in SIRI-1

Early on-orbit results paper:
Mitchell et al. 2019, arXiv:1907.11364



Instrument paper:
Mitchell et al. 2017 Proc. of SPIE Vol. 10397, 103970B

Aside: SIRI-2 solar gamma-ray spectrometer

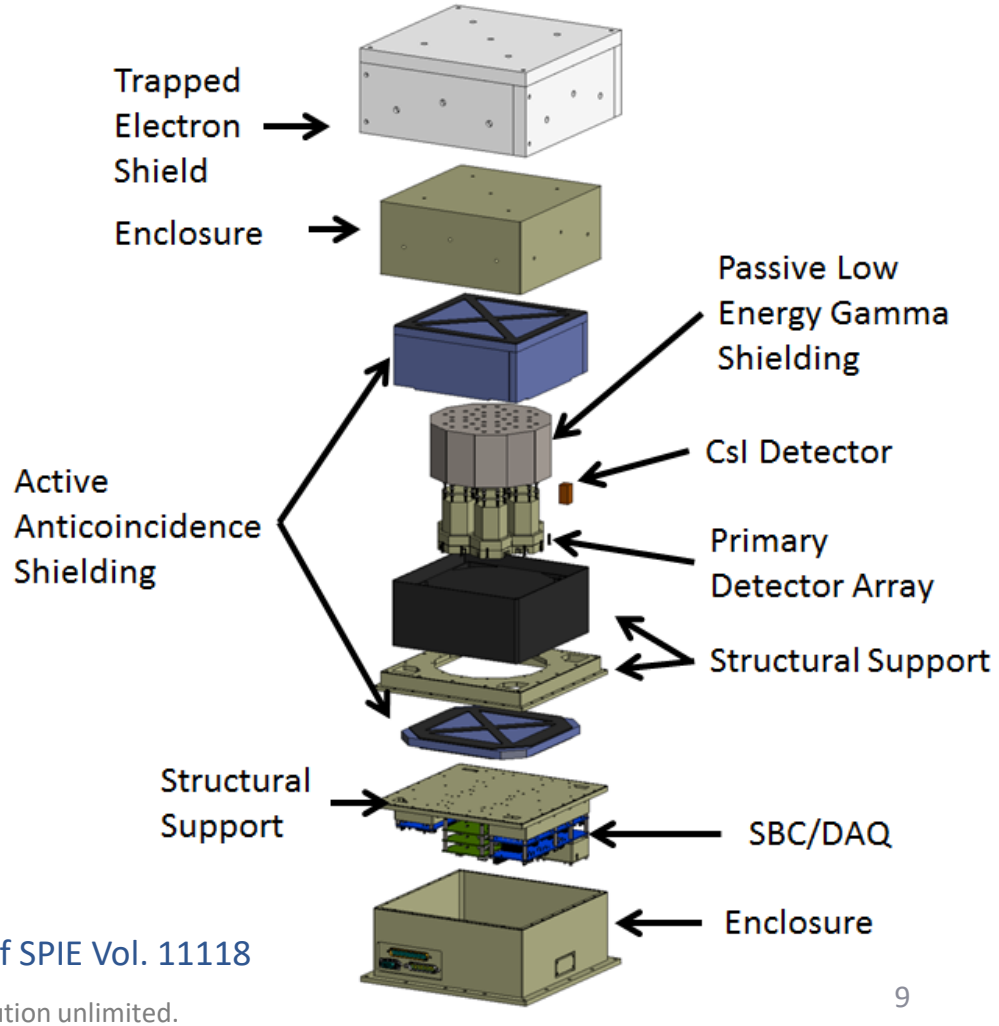
- *Instrument delivered to spacecraft vendor*
- *Awaiting launch Aug 2020 on STPSat-6 to GEO*

Design Overview

- Primary detectors
  - Seven $SrI_2(Eu)$ in hexagonal close-pack design
  - SiPM readouts
    - 19 6-mm SensL J-series SiPMs in hexagonal array on PCB
- DAQ
  - Commercial analog/digital front-end electronics
    - Bridgeport Instruments
  - Commercial single-board computer (SBC)
    - BeagleBone Black
  - Power distribution, SiPM bias

Glowbug DAQ

- Reuses SIRI-2 DAQ design
  - Larger channel count



Instrument paper: Mitchell et al. 2019 Proc. of SPIE Vol. 11118