StarBurst Multimessenger Pioneer

Mission Overview

Daniel Kocevski

NASA Marshall Space Flight Center

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Marshall Space Flight Center

U.S. NAVAL RESEARCH LABORATORY

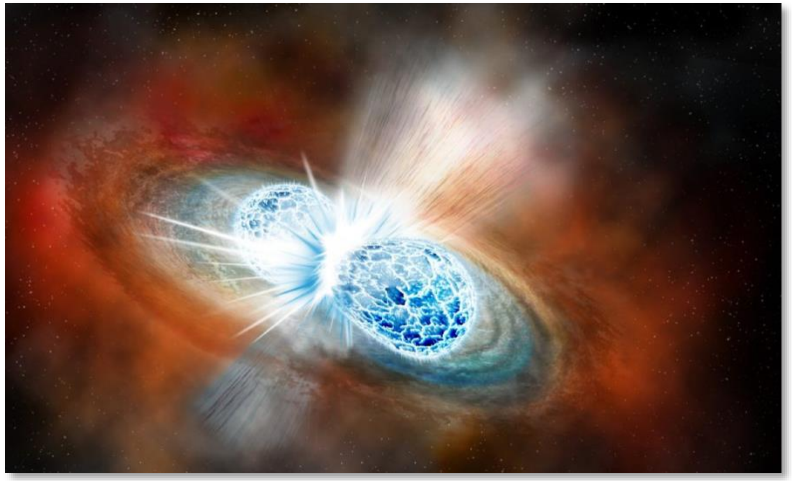
THE UNIVERSITY OF ALABAMA IN HUNTSVILLE

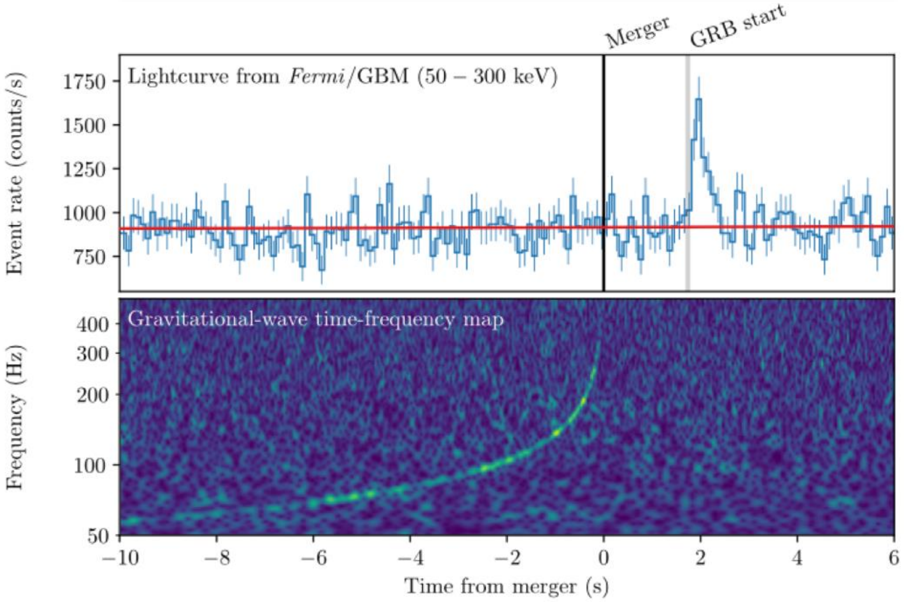
USRA Universities Space Research Association

UTIAS SFL

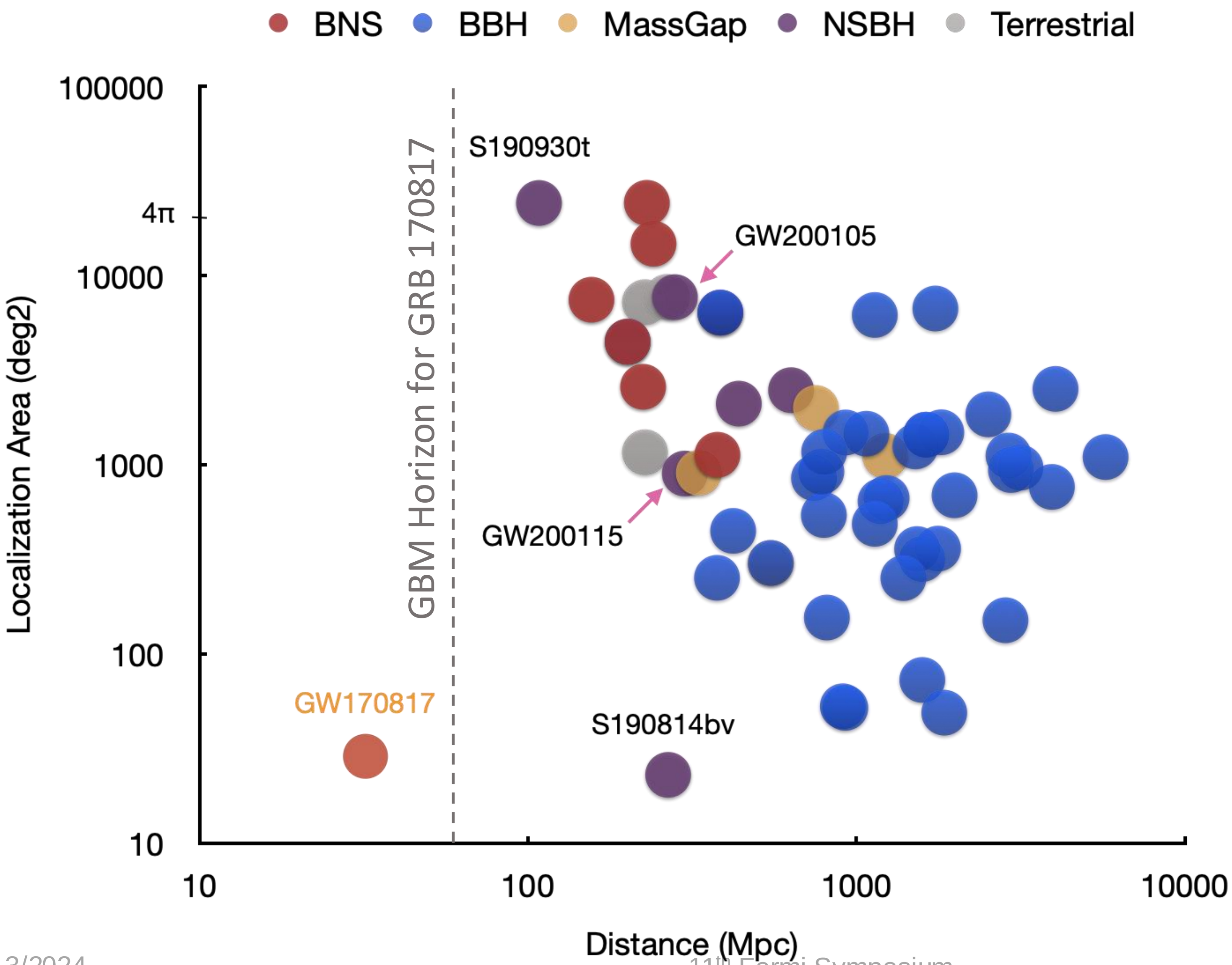
StarBurst Multimessenger Pioneer

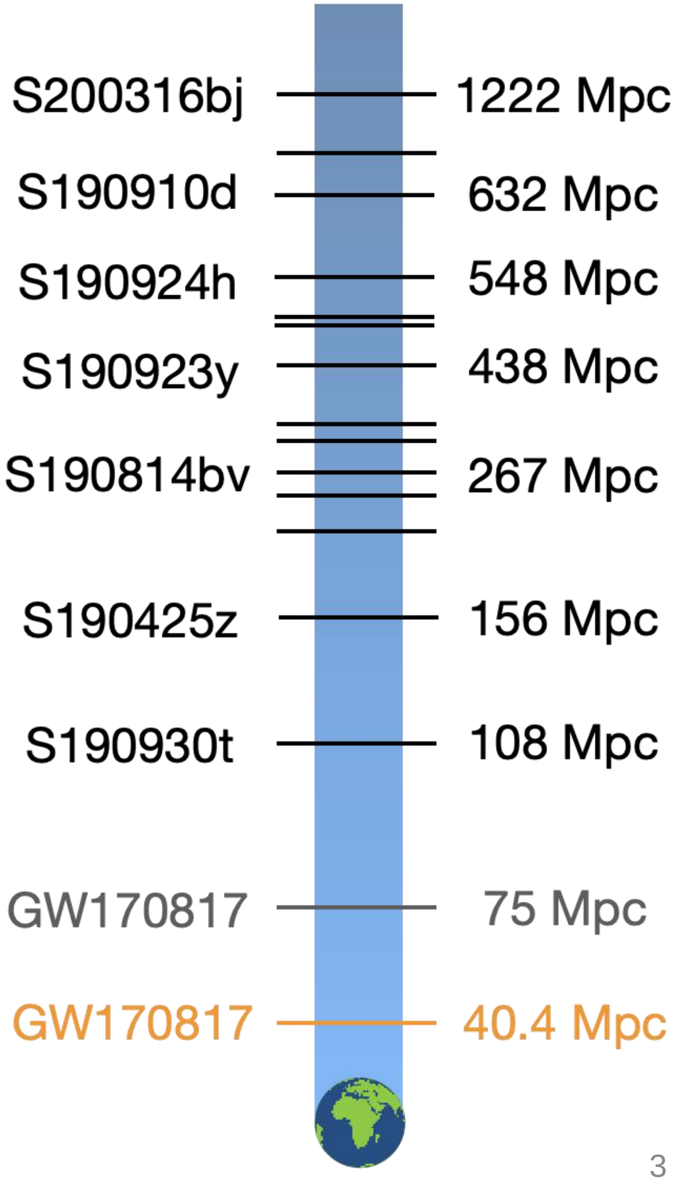
- StarBurst is one of NASA's new Pioneer class missions designed to detect a large sample of SGRBs coincident with GW detections
- StarBurst achieves this through large area scintillation-based detectors read out by SiPMs and low-cost COTS electronics
- Science objectives focus on what can be learned from the temporal and spectral properties of the gamma-ray signal
- Science Objectives:
  - 1) Constrain the progenitors of SGRBs
  - 2) Probe the remnants of NS mergers
  - 3) Constrain the neutron star equation of state
  - 4) Probe the structure of relativistic outflows produced in neutron star mergers
- Launch readiness in mid-2026 for a 1-2 year mission





BNS/BHNS Events in O2 & O3





Mission Overview

Primary Institutions

Marshall Space Flight Center (MSFC)
- Principle Investigator (PI)
- Project Manager (PM)
- Chief (CE) & System Engineering (LSE, SE)
- Central Electronics Box (Instrument), Enclosure & Electronics
- Flight Software, development and testing
- Environmental testing (Instrument)
- Thermal Analysis

Naval Research Lab (NRL)
- Instrument design and fabrication
- Detector electronics

Space Flight Laboratory (SFL)
- Spacecraft bus
- Observatory: AI&T, Flight Analysis
- Mission Operations Center (MOC)
- Launch Site Support

University of Alabama (UAH)
- Instrument Flight Software lead
- Instrument calibration

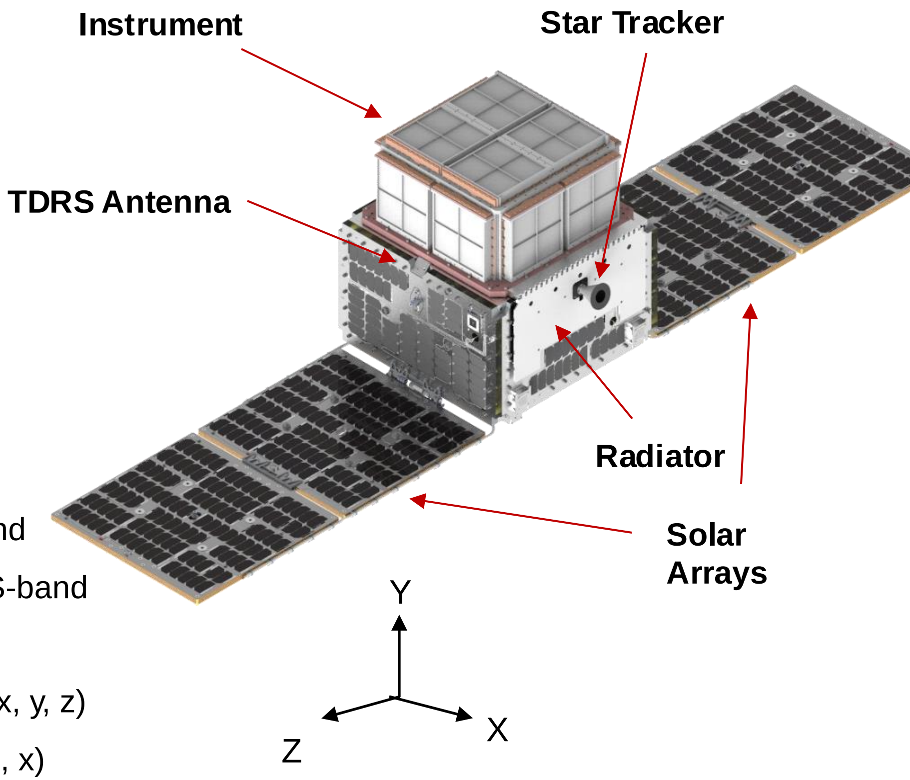
University Space Research Association (USRA)
- Science Operation Center (SOC)

Quick Facts

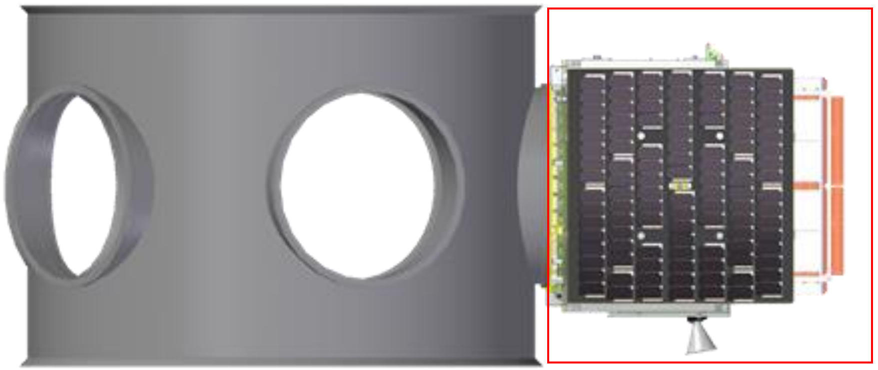
- Energy range: 30-000 keV
- Energy resolution: 25% at 662 keV
- Field-of-view: > 2π sr
- Pointing strategy: Fixed zenith
- Relative time resolution: 2 μs
- Absolute time accuracy: 8 ms
- GRB localization: 3° for GRB 170817
- Instrument mass (CBE): 143.7 kg
- Observatory mass (CBE): 304.5 kg
- Nominal & peak power (CBE): 82 W
- Launch readiness date: Mid 2026
- Mission duration: 1 year
- Orbit: Low inclination (0° - 50°) LEO
- Low-latency communications: TDRS via S-band
- High-latency communications: KSAT-Lite via S-band
- Ground stations: KSAT-Lite @ TBD and TBD
- Size (stowed): 971 mm x 957 mm x 917 mm (x, y, z)
- Deployed: 971 mm x 3689 mm x 917 mm (y, z, x)

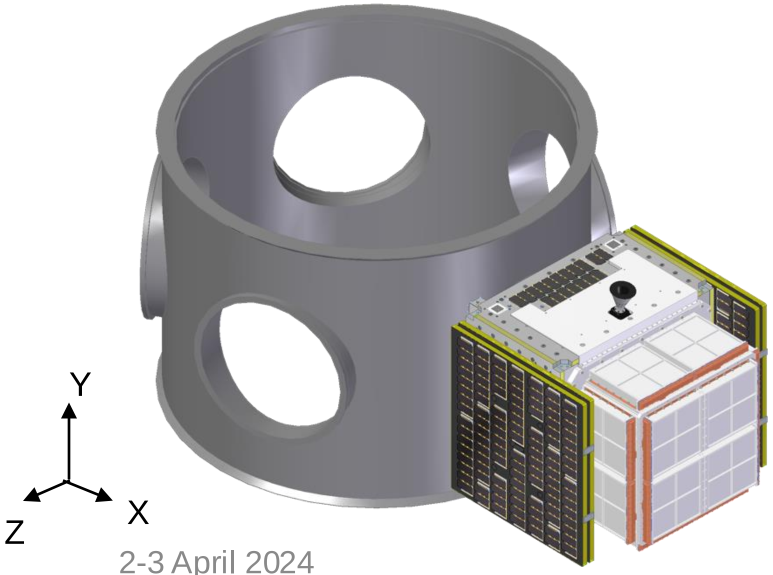
Observatory Description

StarBurst is a straightforward, low-risk, high-heritage, passive instrument that combines the strengths of MSFC, NRL, UAH, and USRA in developing, flying, operating, and managing gamma-ray missions



System Architecture & Design Concept

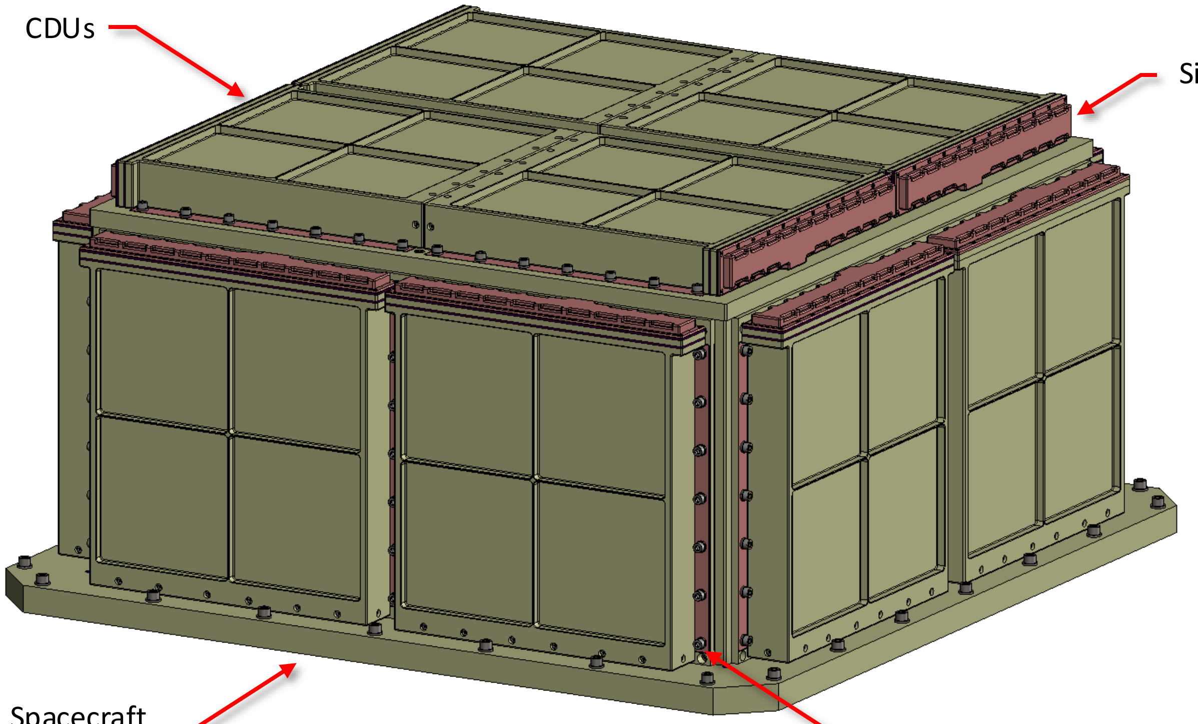




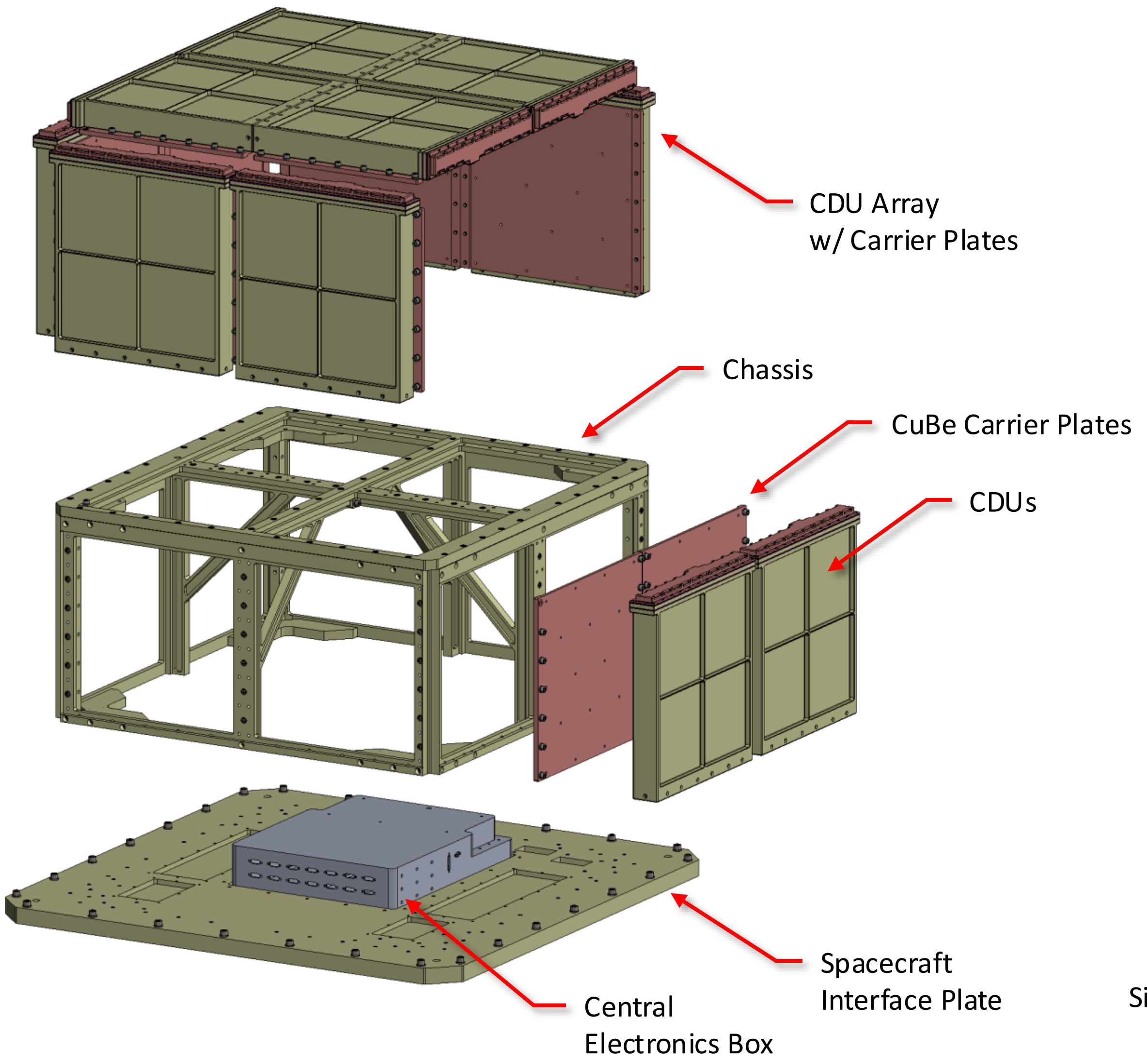
- StarBurst Observatory designed to attach to the ESPA Grande Ring
  - Port mass capacity 465 kg
  - Volume available 42” x 46” x 38” (y, z, x)
  - Spacecraft interface 24” circular
- Mass is 304.5 kg (CBE), 335 kg (with contingency)
  - Instrument 143.7 (CBE), 160 kg (with contingency)
  - Spacecraft bus 160.8 (CBE) ,160 kg (with contingency)
- Size
  - Stowed: 971 mm x 957 mm x 917 mm (y, z, x)
  - Deployed: 971 mm x 3689 mm x 917 mm (y, z, x)
- Orbit: LEO
  - Altitude: 365 km to 545 km
  - Inclination: 0 - 60°

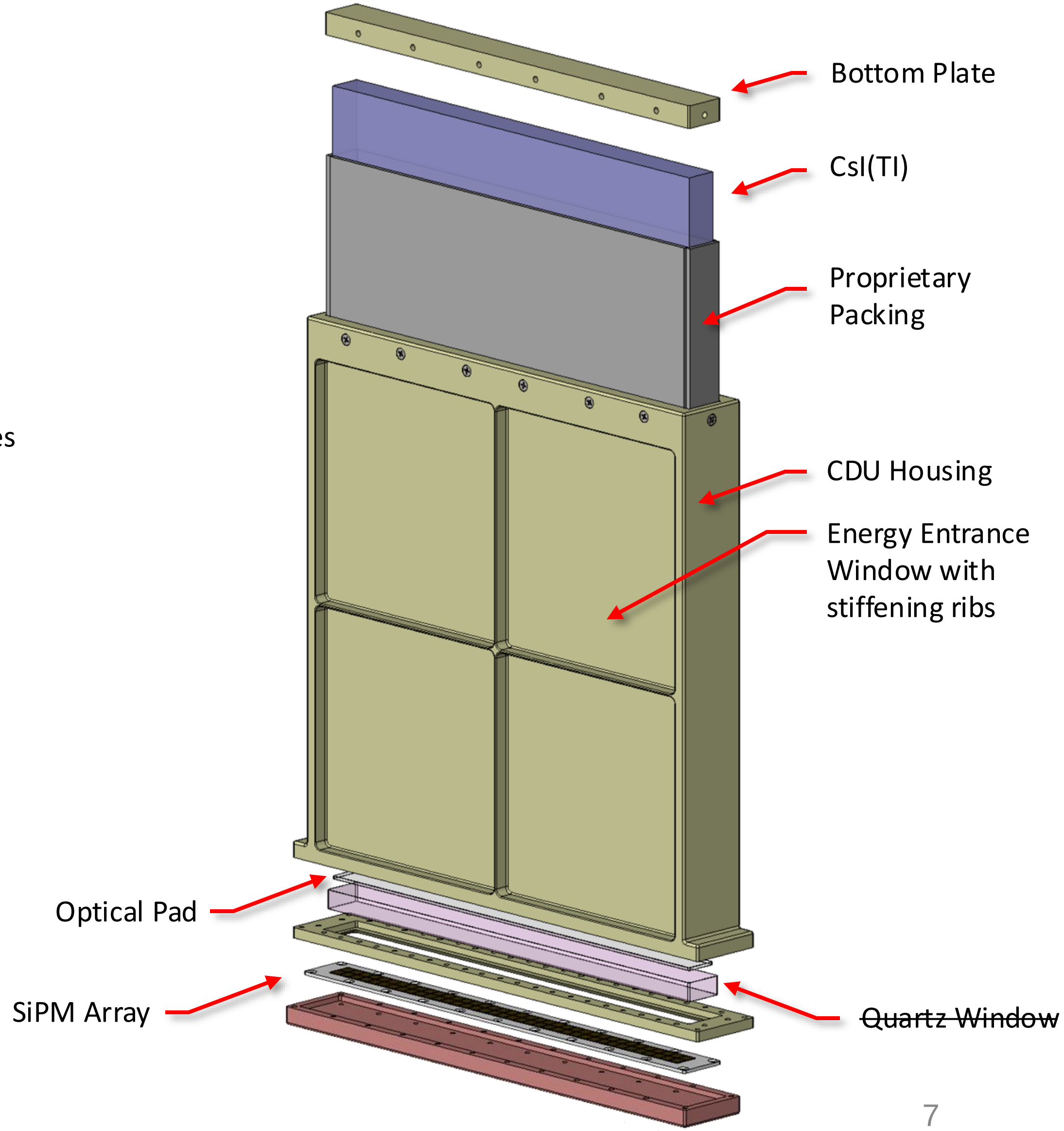
StarBurst Instrument Design Overview

- Crystal Detector Units (CDUs)
  - 12 large CsI(Tl) panels
    - 240 mm x 240 mm x 13 mm
  - Mounted to CuBe carrier plate
- Silicon Photomultiplier (SiPM) readout
  - Edge readout
  - Active summing circuit
- Copper-Beryllium (CuBe) SiPM trays
- Copper-Beryllium (CuBe) carrier plate
- Central Electronics Box (CEB)
  - Housed within the detector array
  - Bridgeport Instruments SlimMorpho multichannel analyzers
- Spacecraft Interface Plate (SIP)

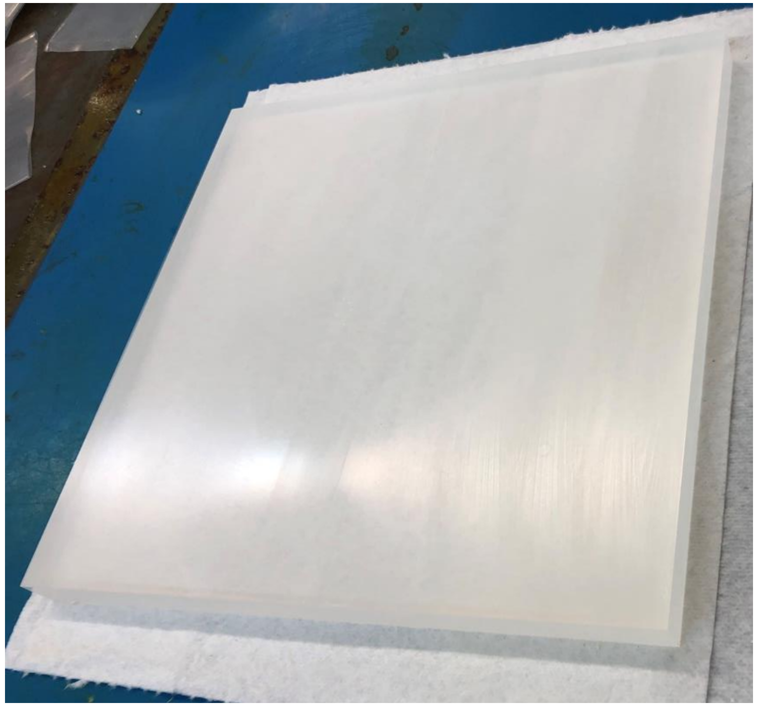


StarBurst Instrument Design Overview

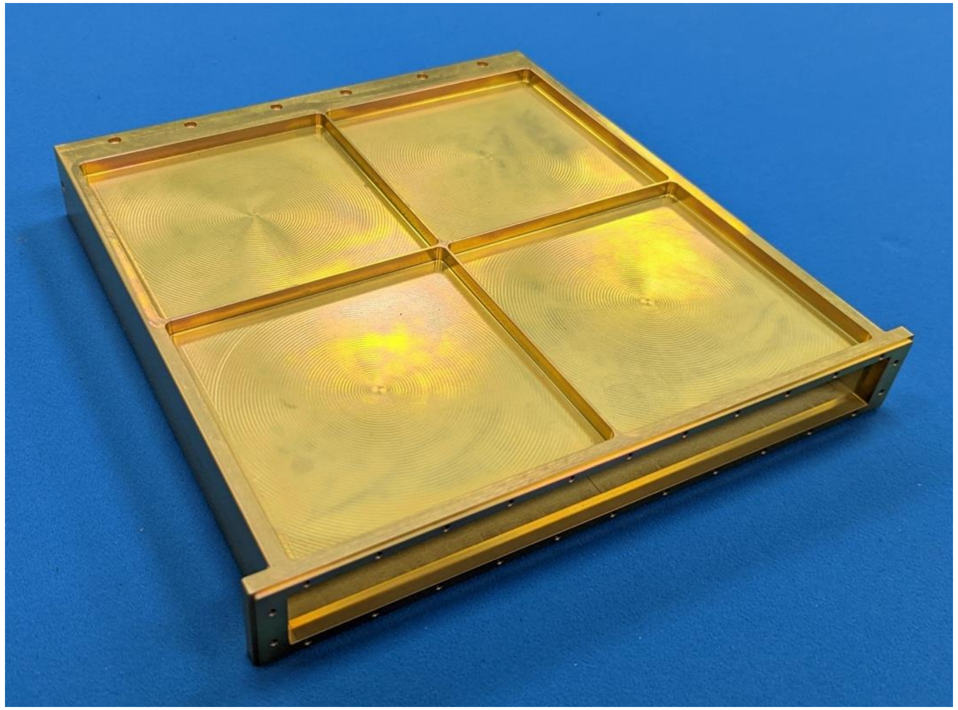




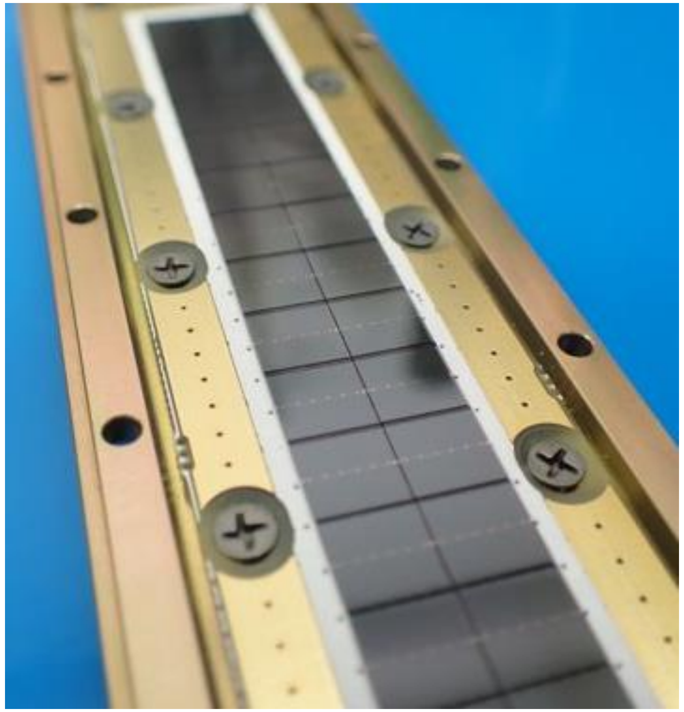
CDU Hardware



Bare CsI(Tl) crystal



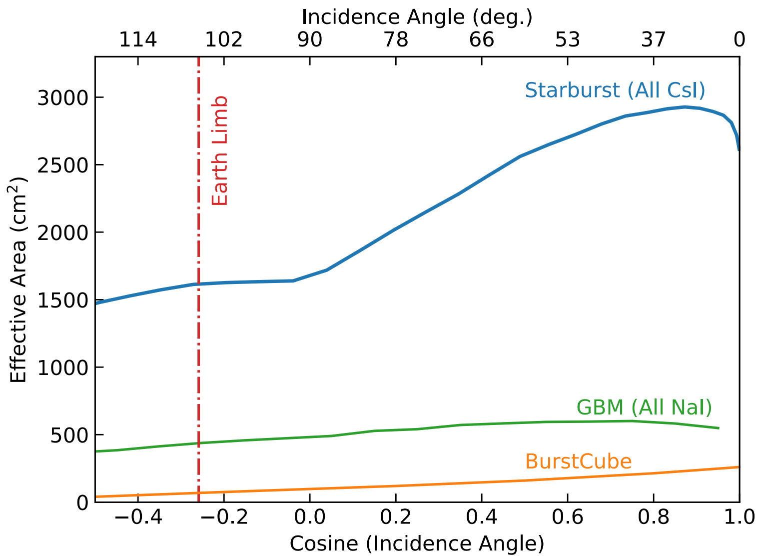
CDU housing

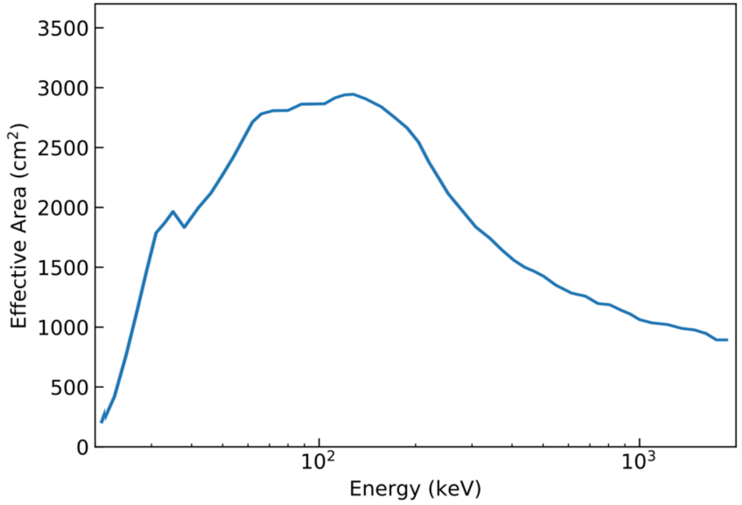


SiPM array in closeout tray

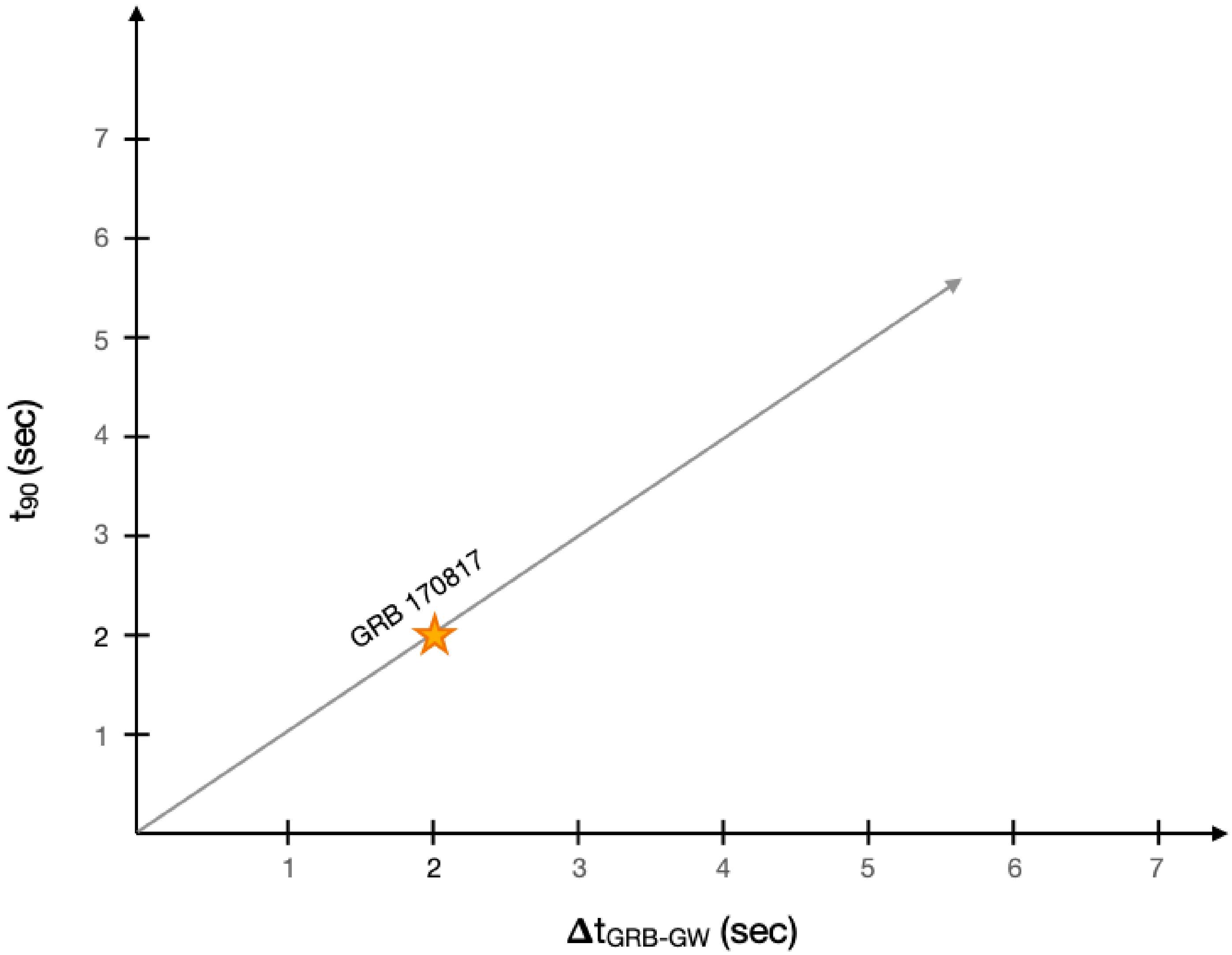
Instrument Performance

- Effective Area
  - Azimuth average effective area peak of ~3000 cm^2
  - StarBurst effective area ~ 500% of GBM
- GRB Detection Rate
  - StarBurst: 158 SGRBs/yr (790 LGRBs)
  - Swift: 8.6 SGRBs/yr, GBM: 40 SGRBs/yr
- Joint detection rates
  - Based on E. Howell et al (2018) and Abbott et al. (2020)
  - Roughly 3.7% of the median A+ BNS detection rate
  - Median rate of 7 GW-SGRBs/yr (2.6—25.2 @ 90% CL)

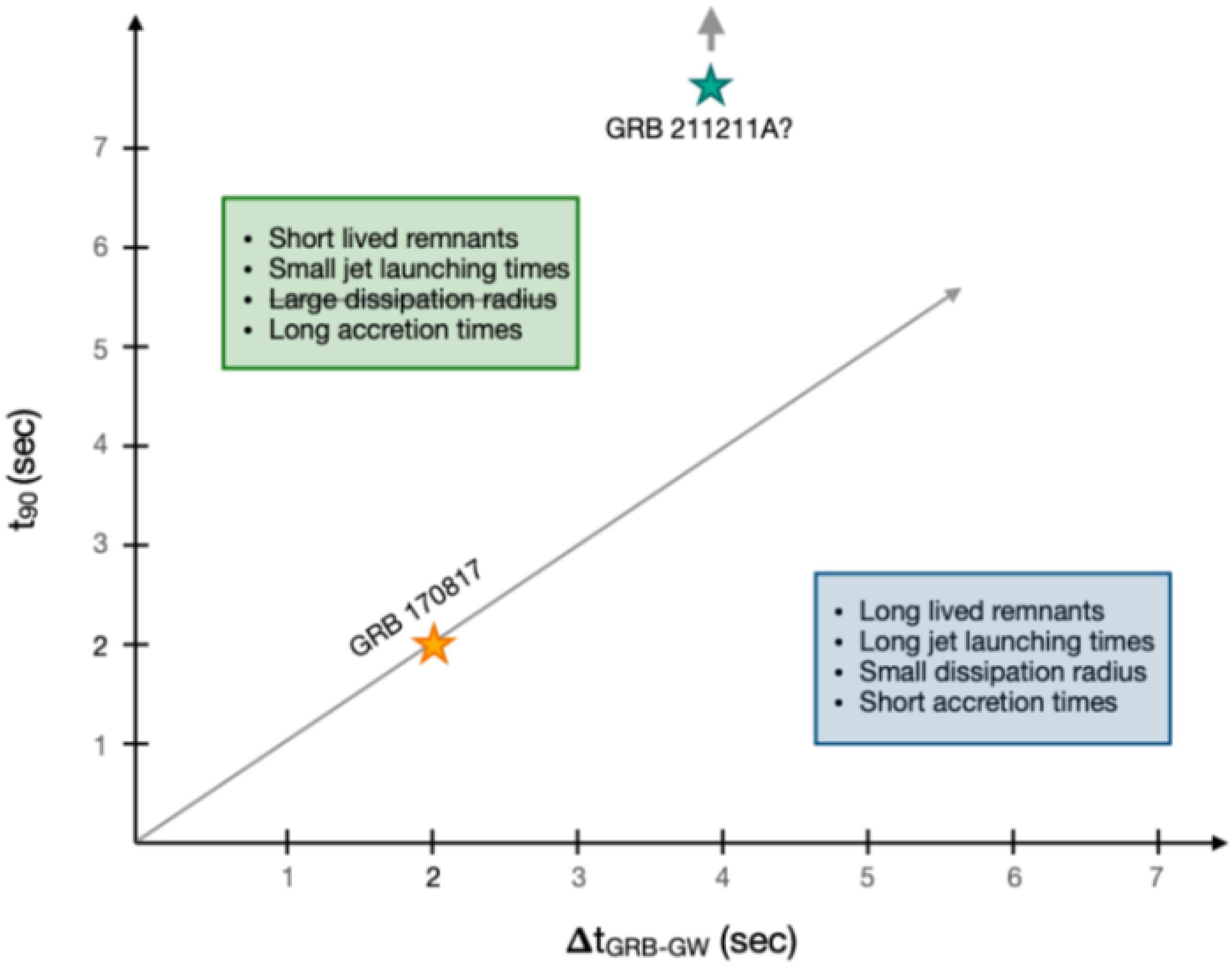




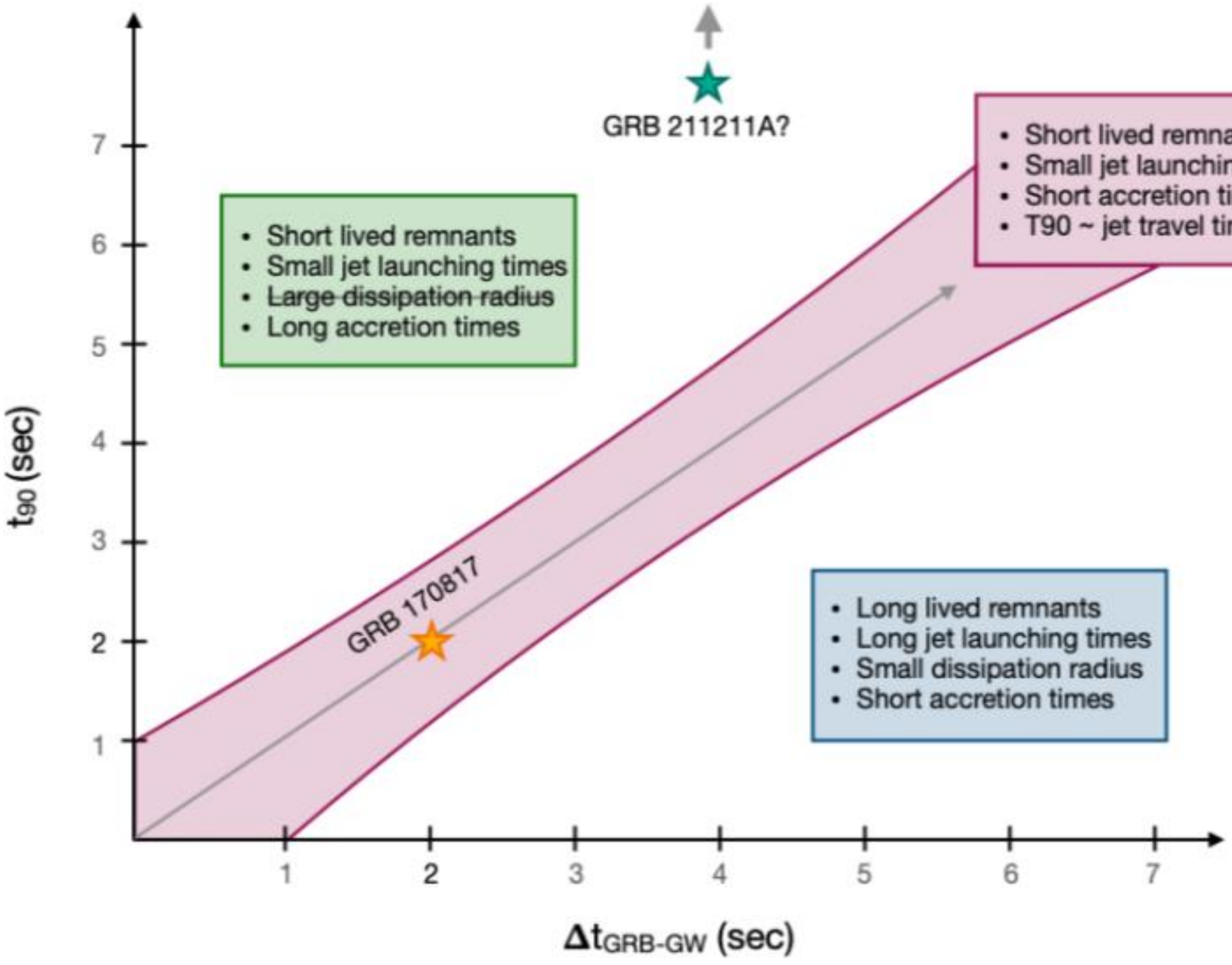
Future Science – GRB-GW Time Delays



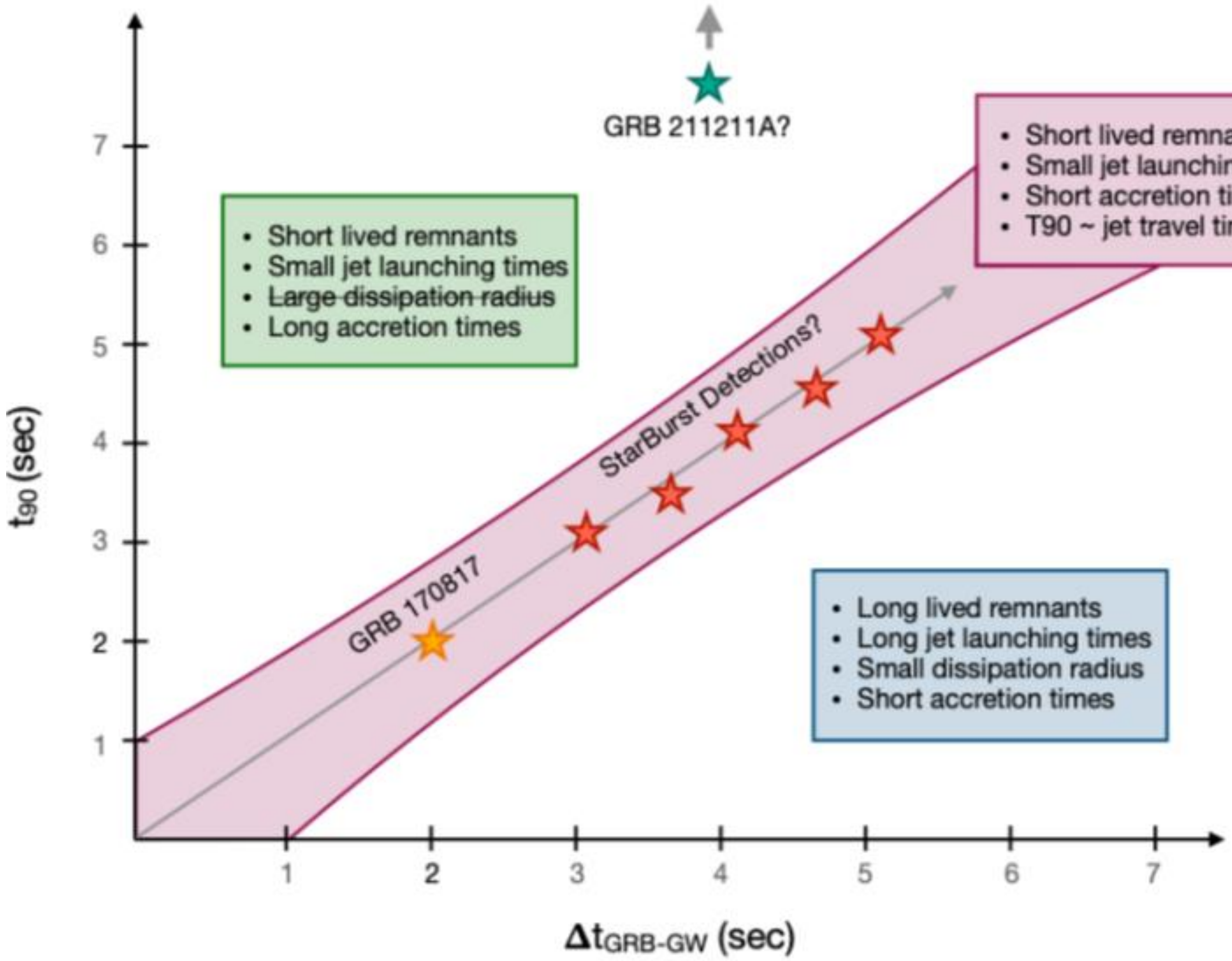
Future Science



Future Science



Future Science



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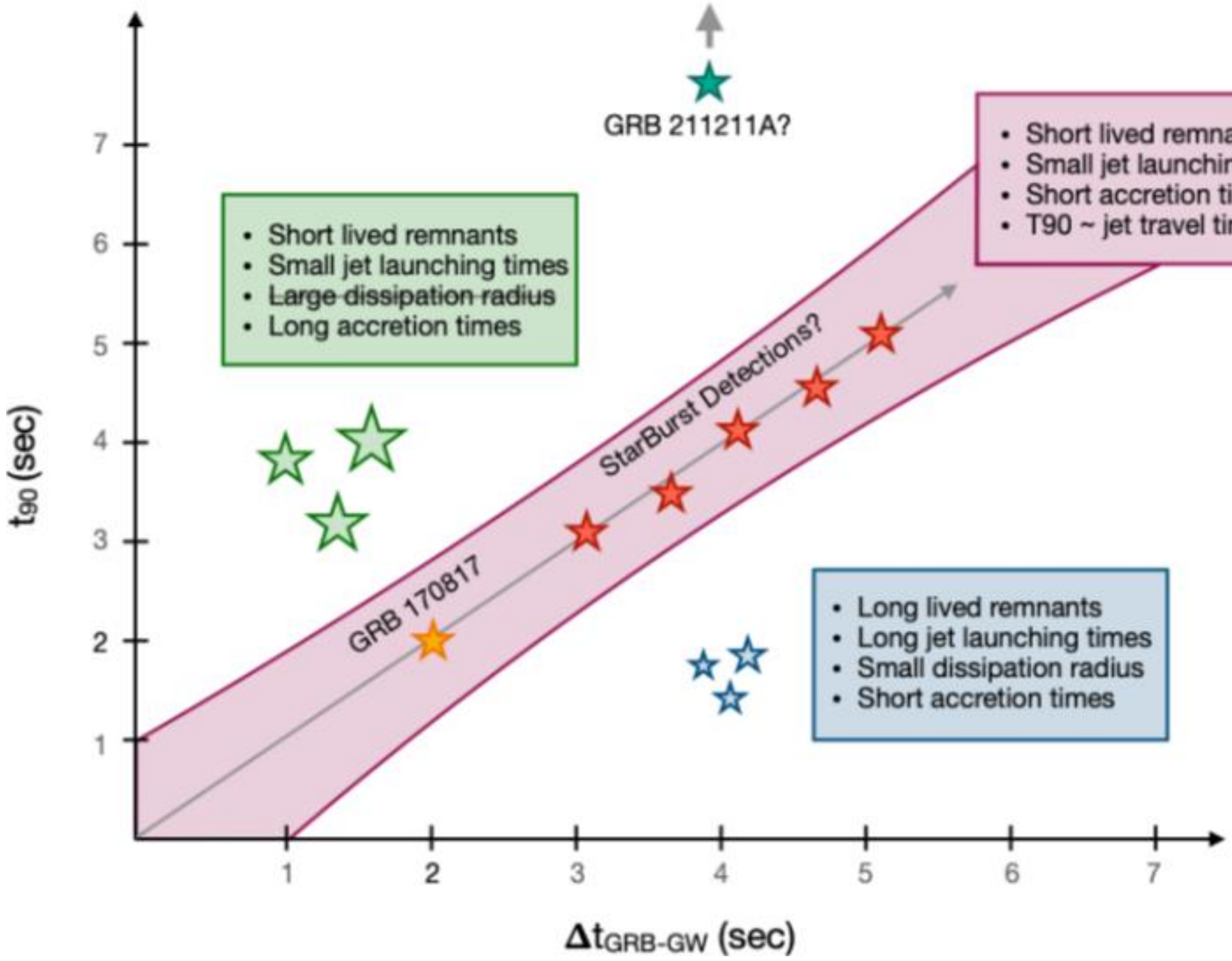


Current Status and Schedule

- StarBurst is starting Phase D
  - Preliminary Design Review was held on on 11/16/2022
  - Critical Design Review was held on for 04/03/2024
- Flight unit fabrication and assembly beginning
  - Instrument delivery in Nov 2024 and observatory AI&T to being in Dec 2024
- Launch readiness date in mid 2026
  - Storage option allows us to wait to time the mission operations to coincide with LIGO O5 run
- Awaiting launch opportunity identification by NASA’s Rideshare Office
- SpaceX announced they will begin offering mid-inclination (45 deg) orbits, which may be our ticket to LEO

NASA

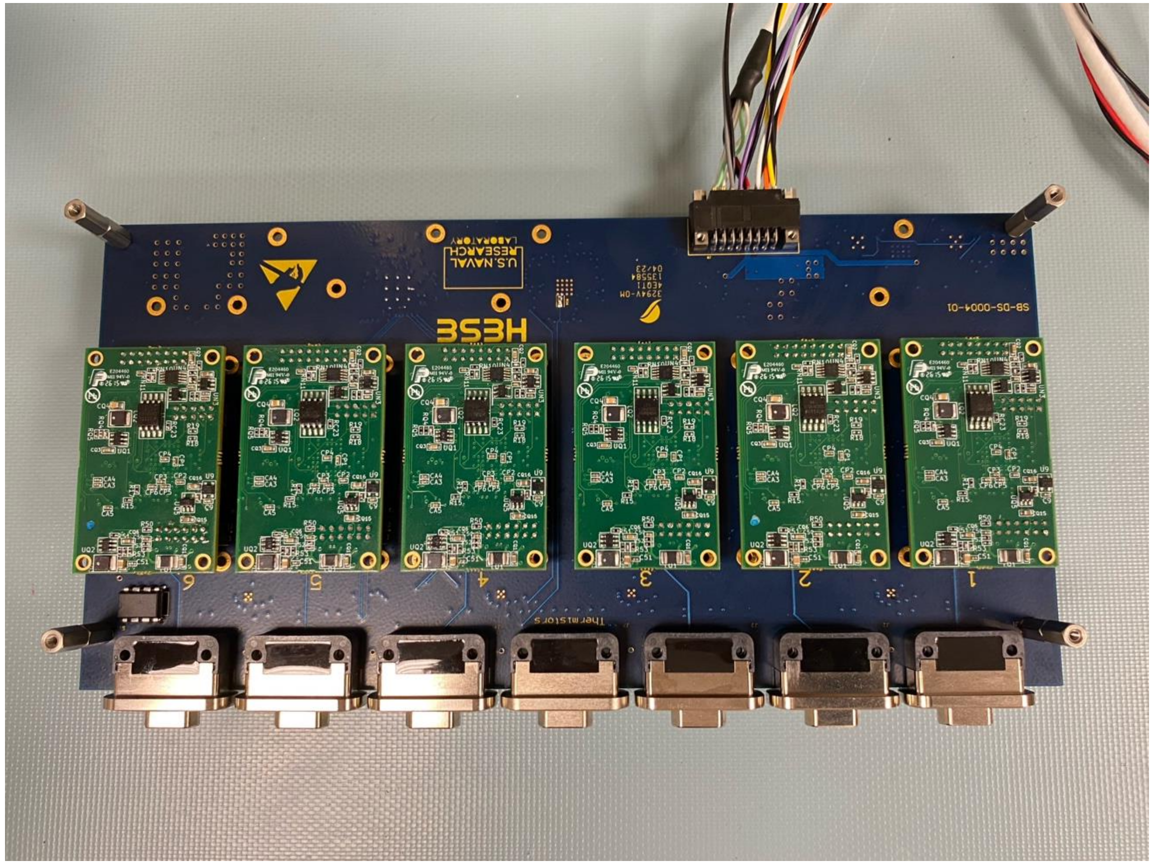
STARBURST MULTIMESSENGER PIONEER

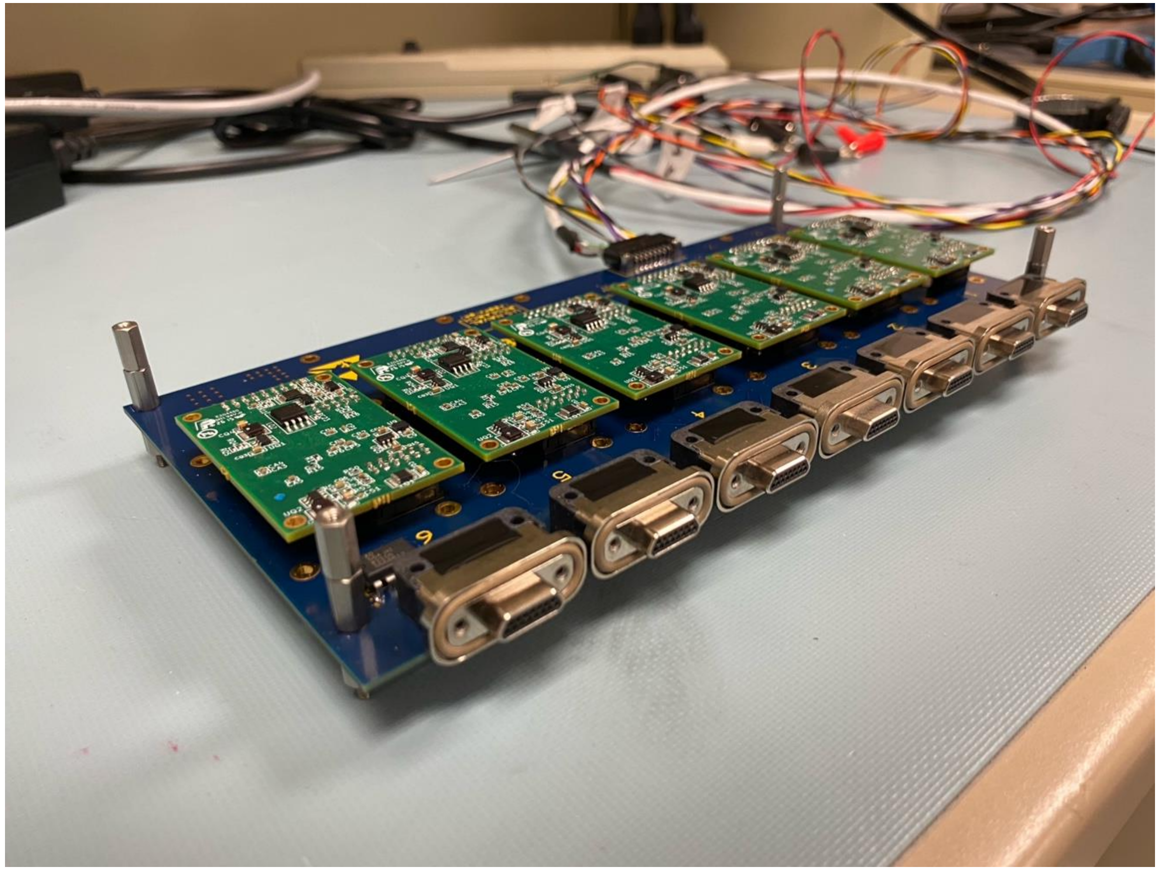
MSFC NRL SFL UAH USRA

Backup Slides

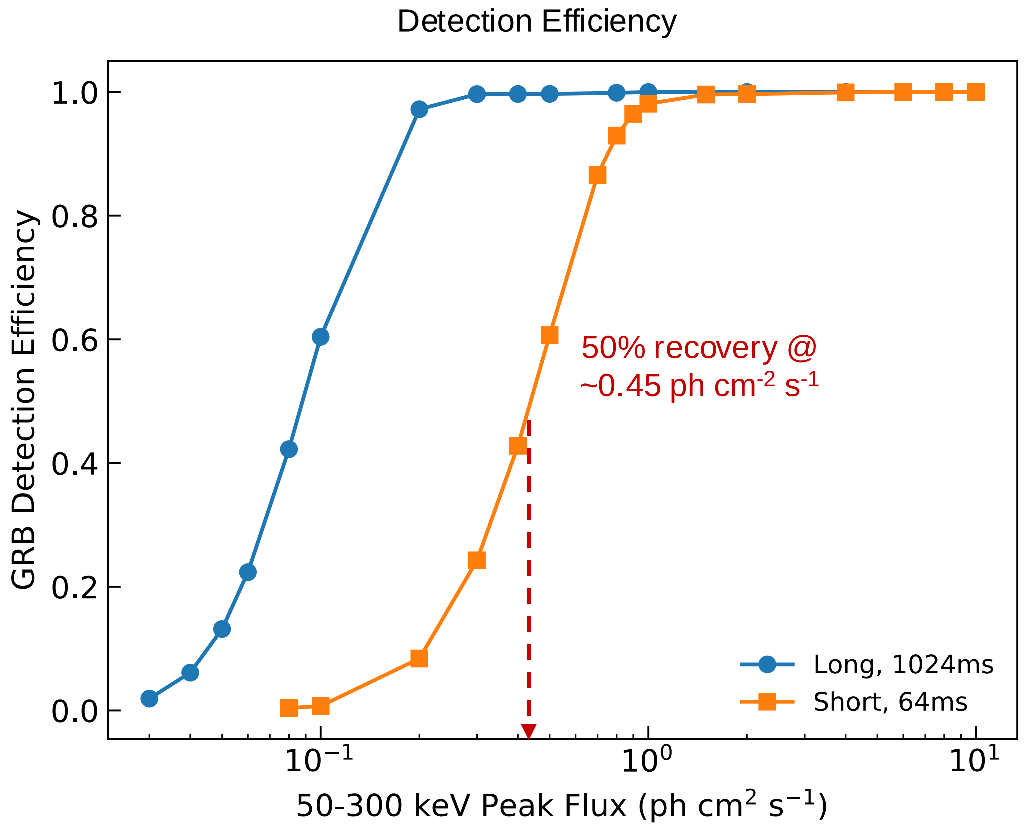
Detector Readout Electronics

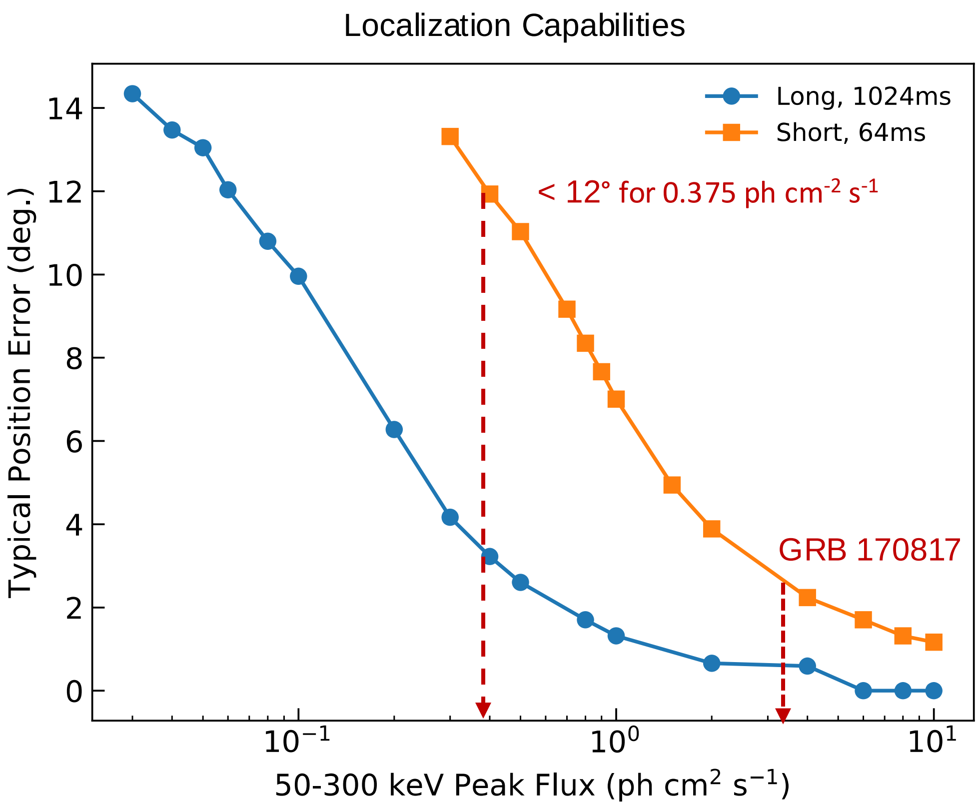
First EM Detector Electronics (HexMorpho with 6 slimMorphos) is now complete and tested





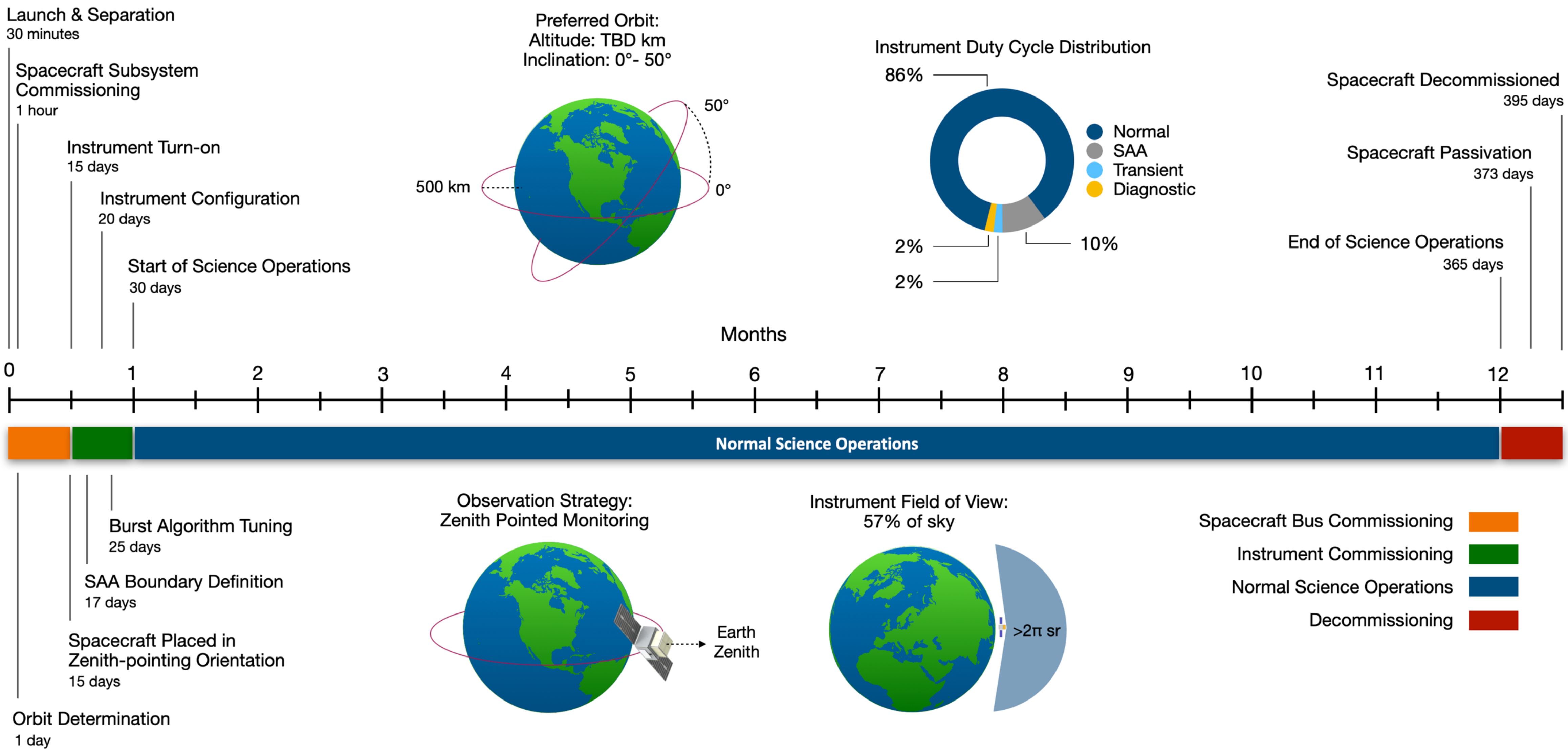
Instrument Sensitivity and Localization



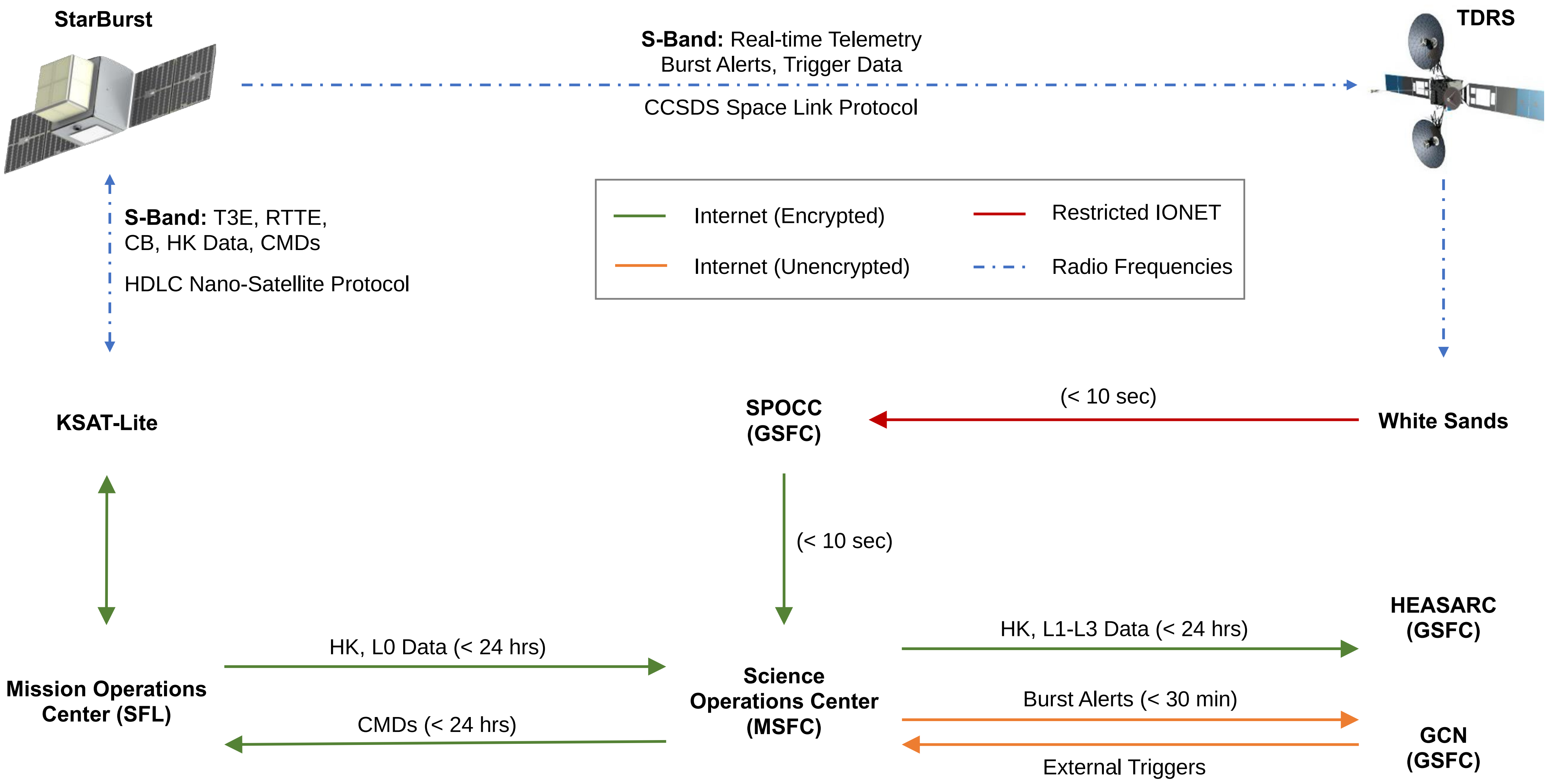


- GRB 170817A could be localized to within 3 deg, compared to ~10 deg with GBM
- Majority of bursts will always be near our detection threshold, so average will be same as GBM

Concept of Operations



Concept of Operations - Communications



Baseline and Threshold Mission

- Baseline Mission
  - A baseline science investigation requires detecting a sample of 140 Short Gamma-ray Bursts (SGRBs) during the A+ observing run would allow us to detect ≥ 5 joint GW-SGRB detections
- Threshold Mission
  - A threshold science investigation requires detecting a sample of 100 SGRBs during the A+ observing run would allow us to detect ≥ 4 joint GW-SGRB detections
  - Descope options are geared towards achieving the threshold mission
- Mission Success Criteria
  - A successful StarBurst mission detects at least 80 SGRB

StarBurst Organizations

- Marshall Space Flight Center
  - GRB astrophysics expertise
  - Science operations experience from BATSE and Fermi-GBM
  - Established connections with the GW community
  - Management and engineering support
- Naval Research Laboratory
  - Extensive space instrumentation expertise
  - Experience building & flying SiPM-based scintillation detectors
- University of Alabama Huntsville
  - Onboard science analysis (flight software) expertise
- University Space Research Association
  - Science operations experience from BATSE and Fermi-GBM
- Space Flight Laboratory
  - Small satellite expertise

Science Team

- The StarBurst science team leverages expertise from several lead institutions in the study of gamma-ray and multi-messenger astrophysics
- The team consists of a diverse group of researchers, including ten early career scientists, with a wide variety of backgrounds
  - Includes both observers and theorists with GRBs, GWs, and kilonova expertise
  - Early career scientists are mentored by team members with decades of experience in building and operating space-based gamma-ray telescopes
- Several science team members are also members of the LIGO collaboration and will facilitate collaboration between the two groups
- Several science team members are long-standing members of the multimessenger GW-GRB working group that led the joint work on GW170817