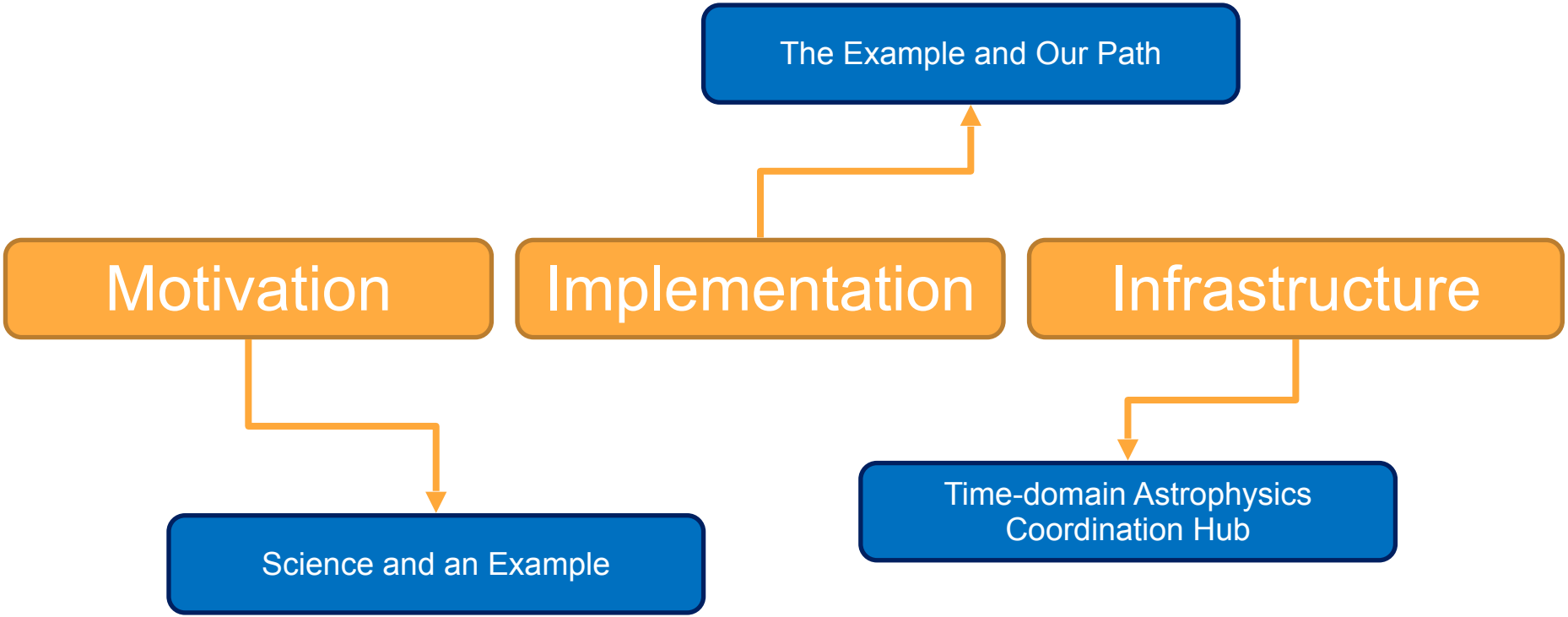
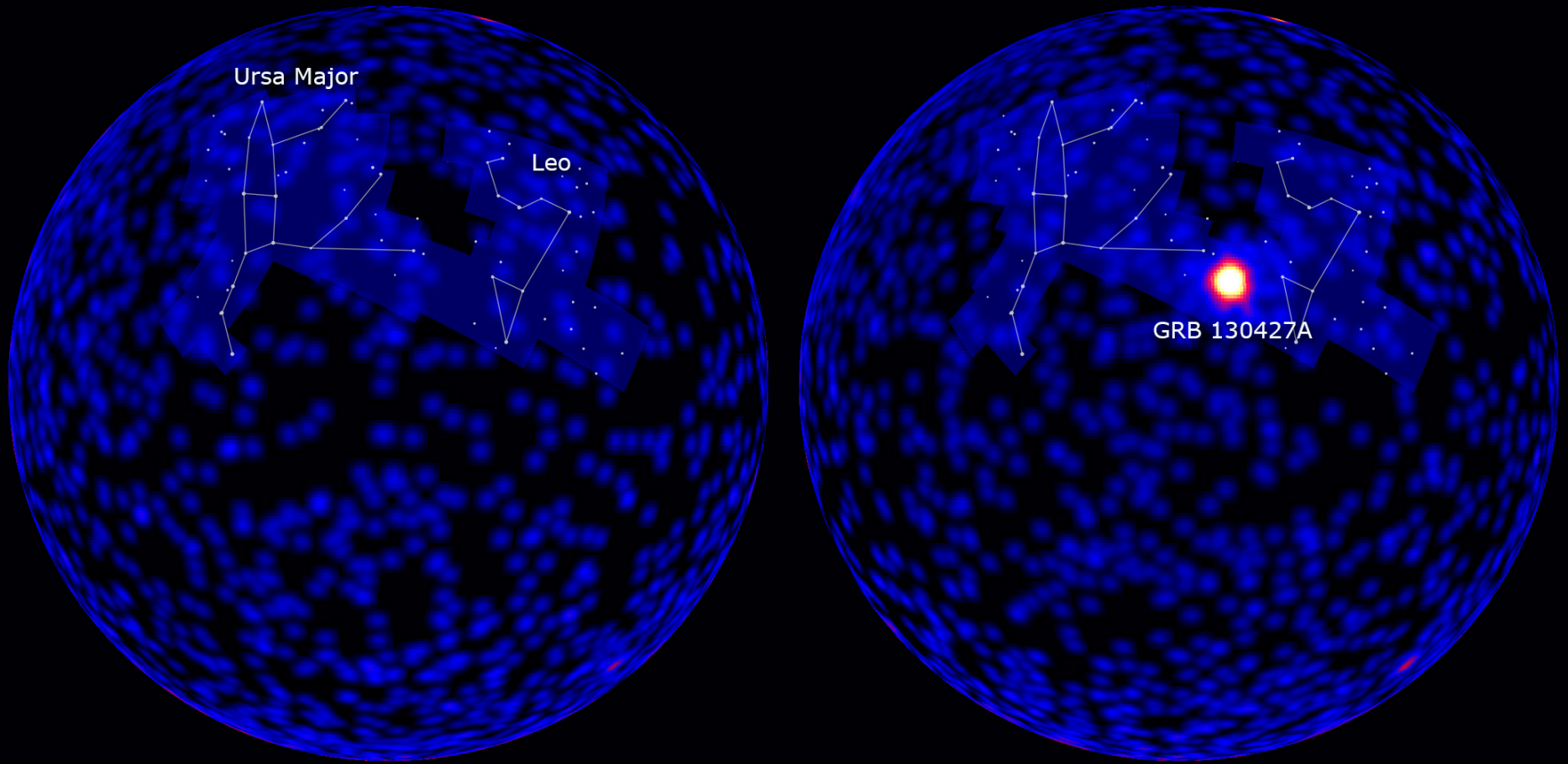
Towards a Network of GRB Detecting Nanosatellites

Jeremy S. Perkins[1], Michelle Hui[2], Andras Pal[3], Judy Racusin[1], and Norbert Werner[2]

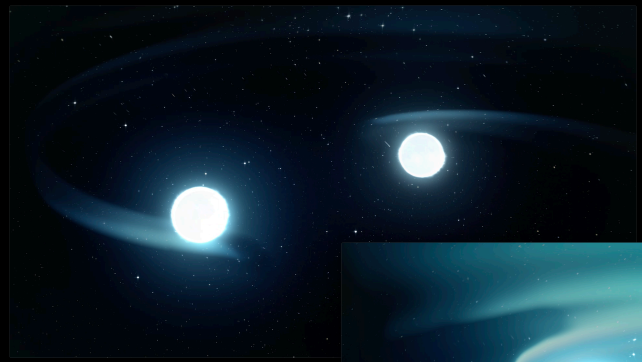
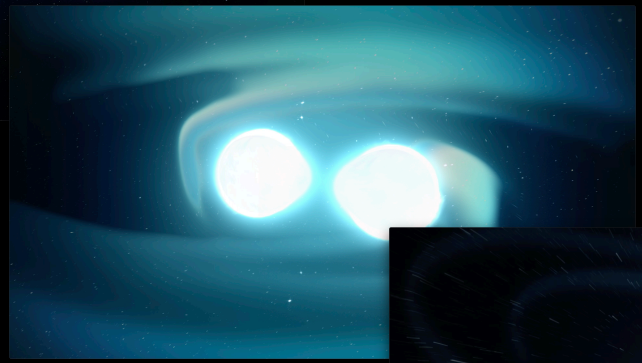
Three Parts

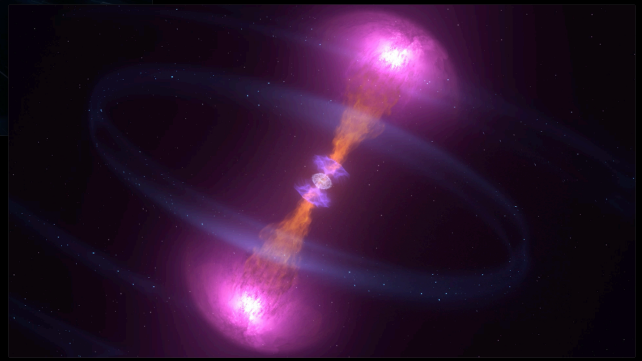

The Example and Our Path
Motivation
Implementation
Infrastructure
Science and an Example
Time-domain Astrophysics Coordination Hub

Start with the Science: Why do we Care

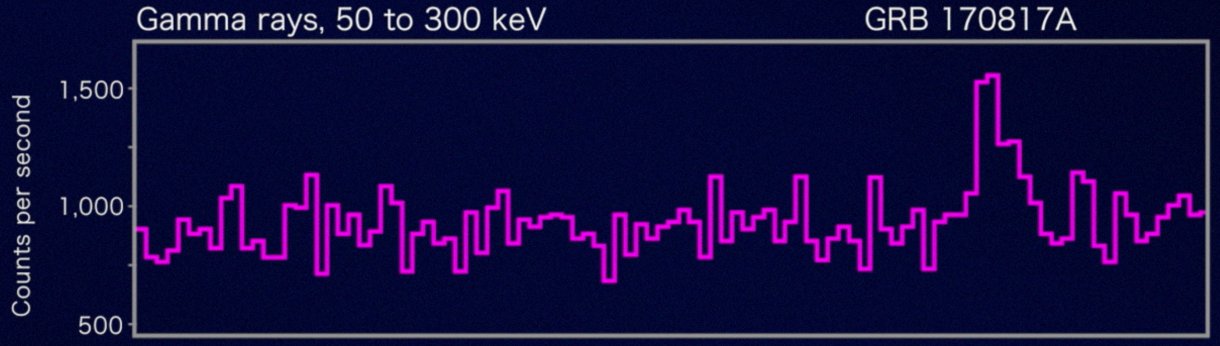


Before and after Fermi LAT views of GRB 130427A, centered on the north galactic pole

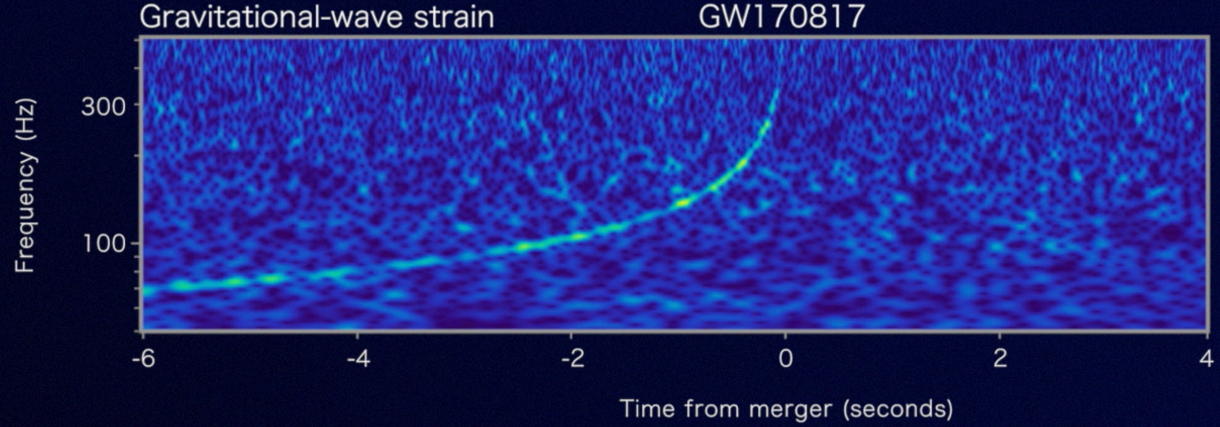





Fermi

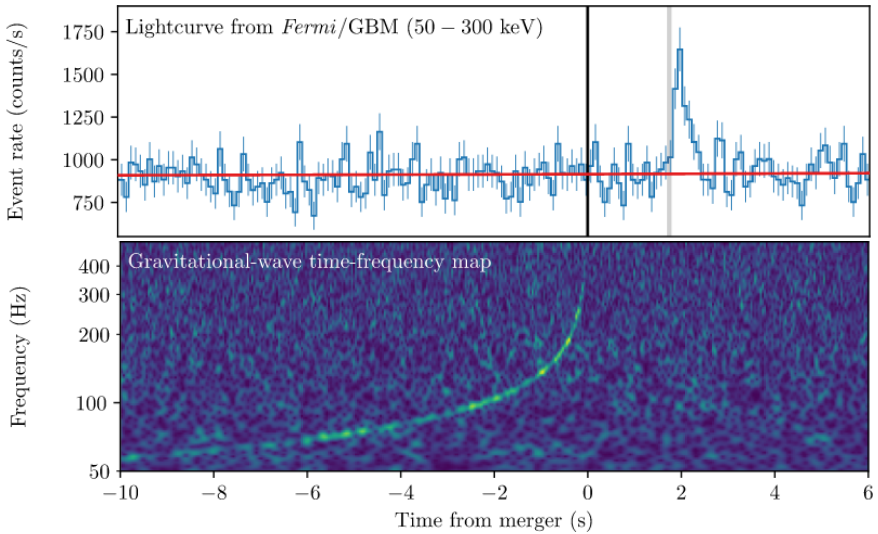

Gamma rays, 50 to 300 keV
GRB 170817A
Counts per second
1,500
1,000
500

LIGO


Gravitational-wave strain
GW170817
Frequency (Hz)
300
100
-6
-4
-2
0
2
4
Time from merger (seconds)

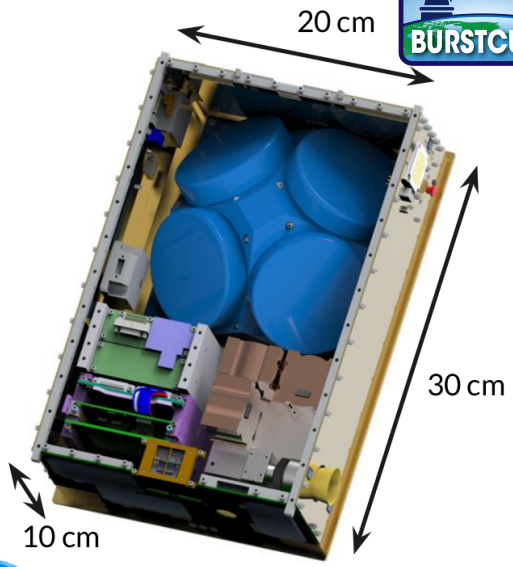
Start with the Science: Why do we Care

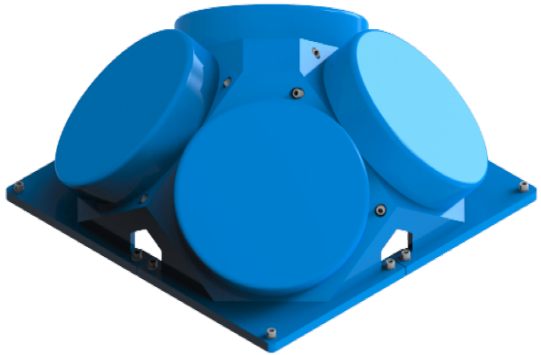
- Joint detection of GRB 170817A and GW170817
  - Proved that binary neutron star (BNS) mergers are progenitors of SGRBs
  - Difference between the speed of gravity and the speed of light: -3 x 10^{-15} and 7 x 10^{-16} c
- Questions remain:
  - Spectral properties observed in GRB 170817A a signature to these events?
  - What is the origin of gamma-ray emission?
- Need to provide electromagnetic context to gravitational wave events detected by **LIGO, Virgo**, and **KAGRA.**



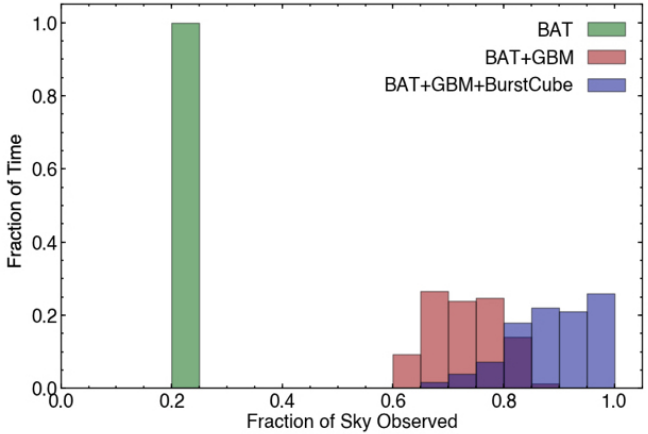
One Solution is BurstCube: A CubeSat for Gravitational Wa

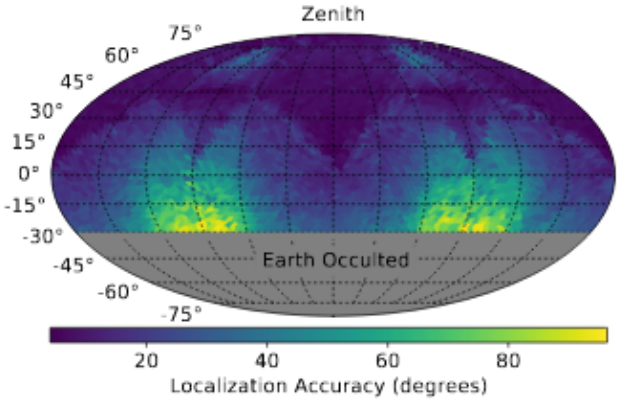
- 6U CubeSat with the primary goal to detect, localize, and characterize short Gamma-ray Bursts (sGRBs).
- Instrument:
    - Four CsI scintillators coupled with arrays of silicon photomultipliers (SiPMs)
    - Energy range: ~50 keV - 1 MeV
    - Field of view: 50% of the sky
- Rapid Communications via TDRS
- Launch Readiness in Q3 2021

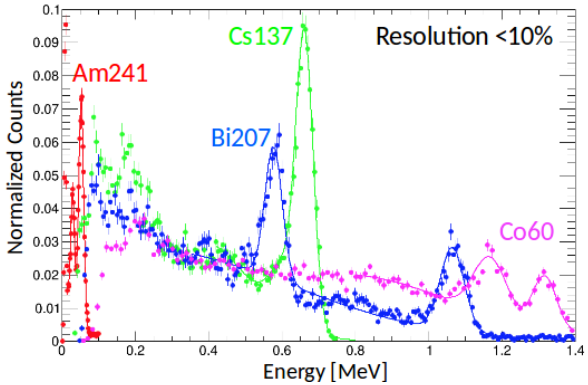


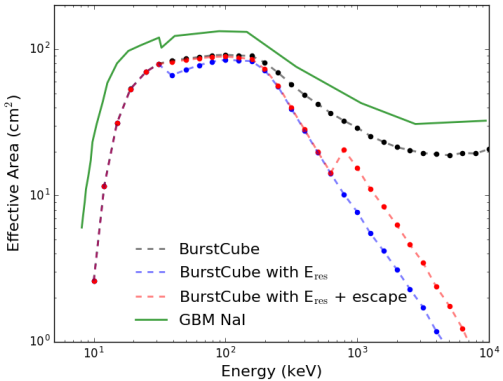


BurstCube Performance



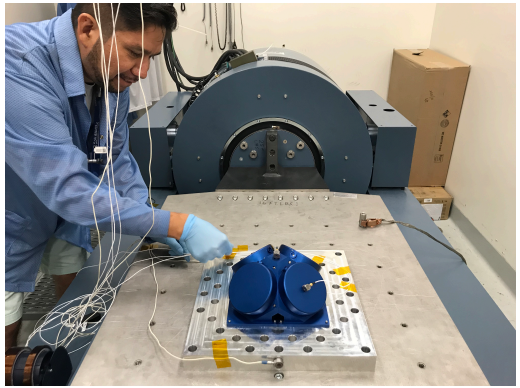


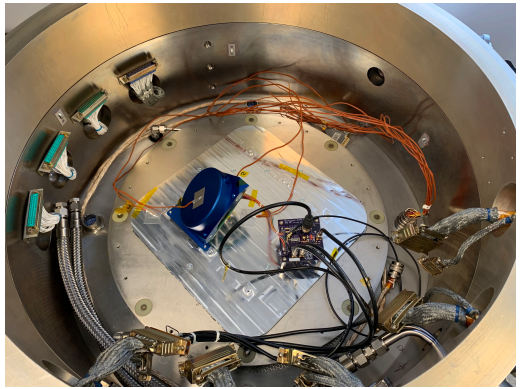




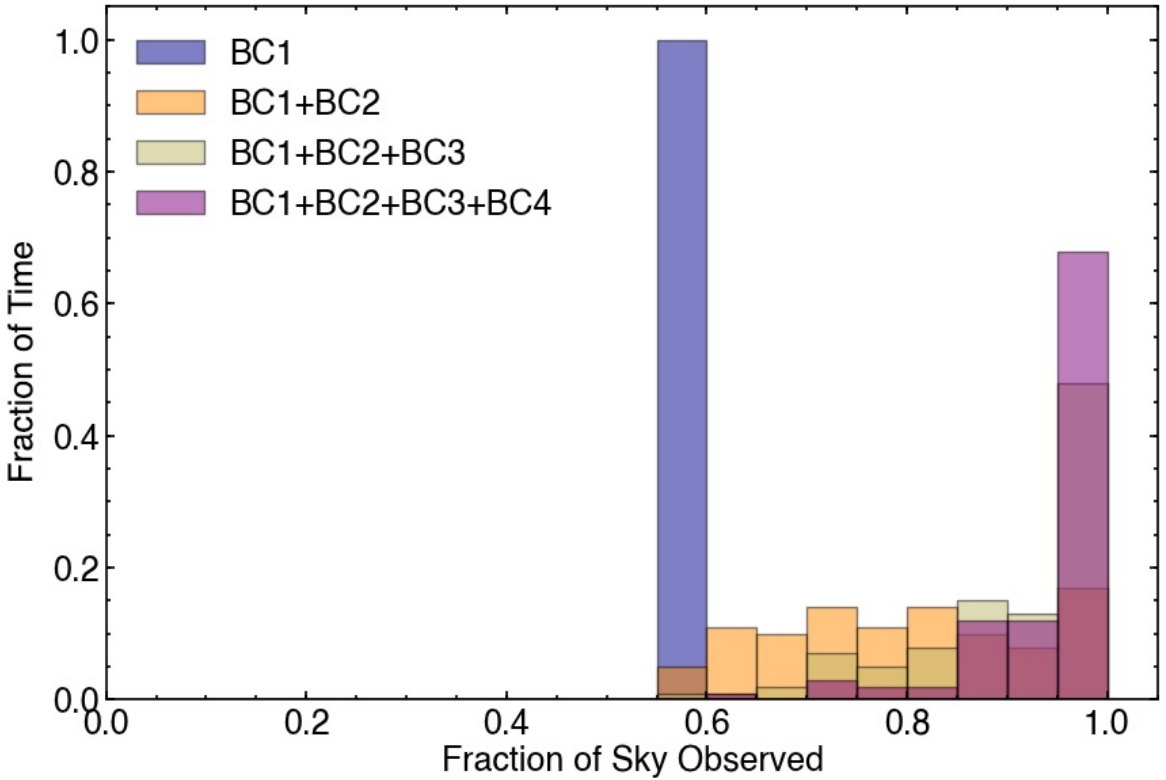
BurstCube Status

- Fully funded via NASA/APRA (Astrophysics R&D).
- Protoflight instrument passed environmental (Vibe and TVAC).
- Instrument CDR was in Nov 2019.
- Mission CDR was in May 2020.
- Software CDR was in March 2020.
- **Currently building the flight instrument.**
- Instrument delivery to spacecraft in 2021.
- Launch readiness in January of 2022.





But what about a network?



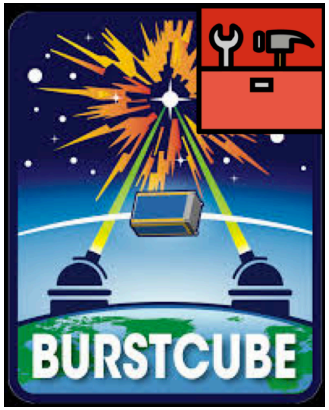
Many GRB CubeSat Missions

- Many groups around the world are developing CubeSats to detect GRBs:
    - **BlackCat** (PSU), **BurstCube** (NASA/GSFC), MoonBeam (NASA/MSFC), Nano-Gam (Technion), **GRID** (Tsinghua), **CAMELOT** (Hungary), **HERMES** (INAF), **Eirsat** (UCD), **Glowbug** (NRL), Sphinx (KTH), RadCube (), **UVI BurstCube** (UVI), GECAM (IHEP), probably many more…
    - These are in various stages of development (proposal phase, funded, launching soon). **Bold** are funded at some level.
- Bottom Line: a single institution/funding agency/nation **dose not need to develop** a global monitoring system of GRB nanosatellites as long as we can **work together** and **coordinate** our resources.

The Inspiration: BRITE

- We’re not the first to do this and we looked to the BRITE Constellation for inspiration (https://brite-constellation.at).
    - (These aren’t the only folks that are doing something like this)
- Main Difference:
    - We want to use the disparate hardware that already exists and leverage it to maximize our science output.
    - Very loose collaboration (but this might change)
    - We don’t have a single design (celebrate the different ways of doing the same thing)

An Example: bc-tools (gitlab.com/burstcube/bc-tools)



- bc-tools is BurstCube's main software package
  - Simulations
  - Analysis
- Written in Python
- Built around and compatible with gbm-data-tools
- bc-tools is detector-agnostic
  - No hardcoded values
  - Easily adapted for other detectors through a configuration file

The challenge.

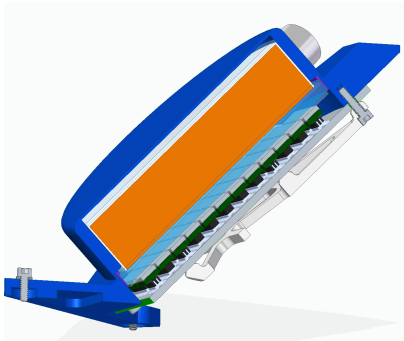
Not one way to build something. Funding agencies have different goals.

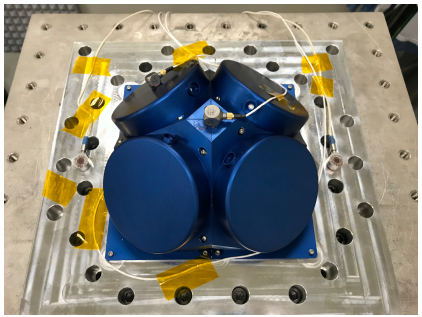
Step 0: Talk

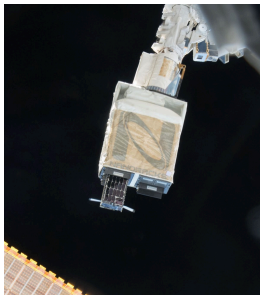
- Secured funding (thanks Norbert!) to host a meeting at the Hungarian Academy of Sciences in Budapest in Sept. 2018. Over 40 people attended.
    - Over 40 people attended representing over 20 missions.
    - https://asd.gsfc.nasa.gov/conferences/grb_nanosats/
- This was a working meeting.
    - 3 sessions with quick 10 minute overviews of the missions.
    - Broke into four groups and discussed Data Sharing, Hardware Development, Communications, and Software Development
    - Each group produced a google document that they presented to the whole group and we jointly worked on a final document.

Producing a GRB Detecting NanoSat Network

Design the Thing → Build the Thing → Launch the Thing







Producin Detecting Na etwork

What about the what abouts?

What about data rapid comms?

What about localization?

What about data analysis?

What about localization?

Des the T

What about instrument response?

B

What about activation?

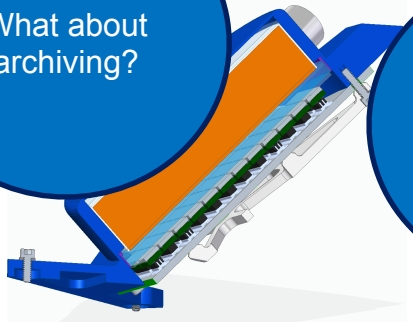
Launch the Thing

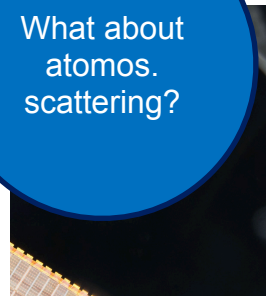
What about archiving?

What about pipelines?

What about alerting the community?

What about atomos. scattering?





Results

- Decided that we want to collaborate and move forward.
  - Decided we cannot collaborate on somethings:
    - Like designing and building the hardware (of course there are exceptions).
    - We run into restrictions really quickly here.
  - Decided we have to collaborate on other things:
    - Like developing software, reusing pipelines, testing algorithms, figuring out atmospheric scattering and more.
  - Decided it would be difficult to collaborate on some things
    - Like publications, detections, and so on. We can make it easy to opt in and opt out.

Logistics, Moving Forward, and Challenges

- Registered a domain (https://www.grbnanosats.net) to host a wiki, mailing list and handle other logistics.
- We have a git repo to share code and other things.
- Received EU funding to host at least two more meetings. There is a need to push forward and finalize how we are working together.
    - Now that we have a baseline, we want to push on actually doing things.
- The challenge is that we are all working on multiple things and have to carve out time to make this successful.
- During COVID we are having ~monthly telecons to share ideas.

Caveats

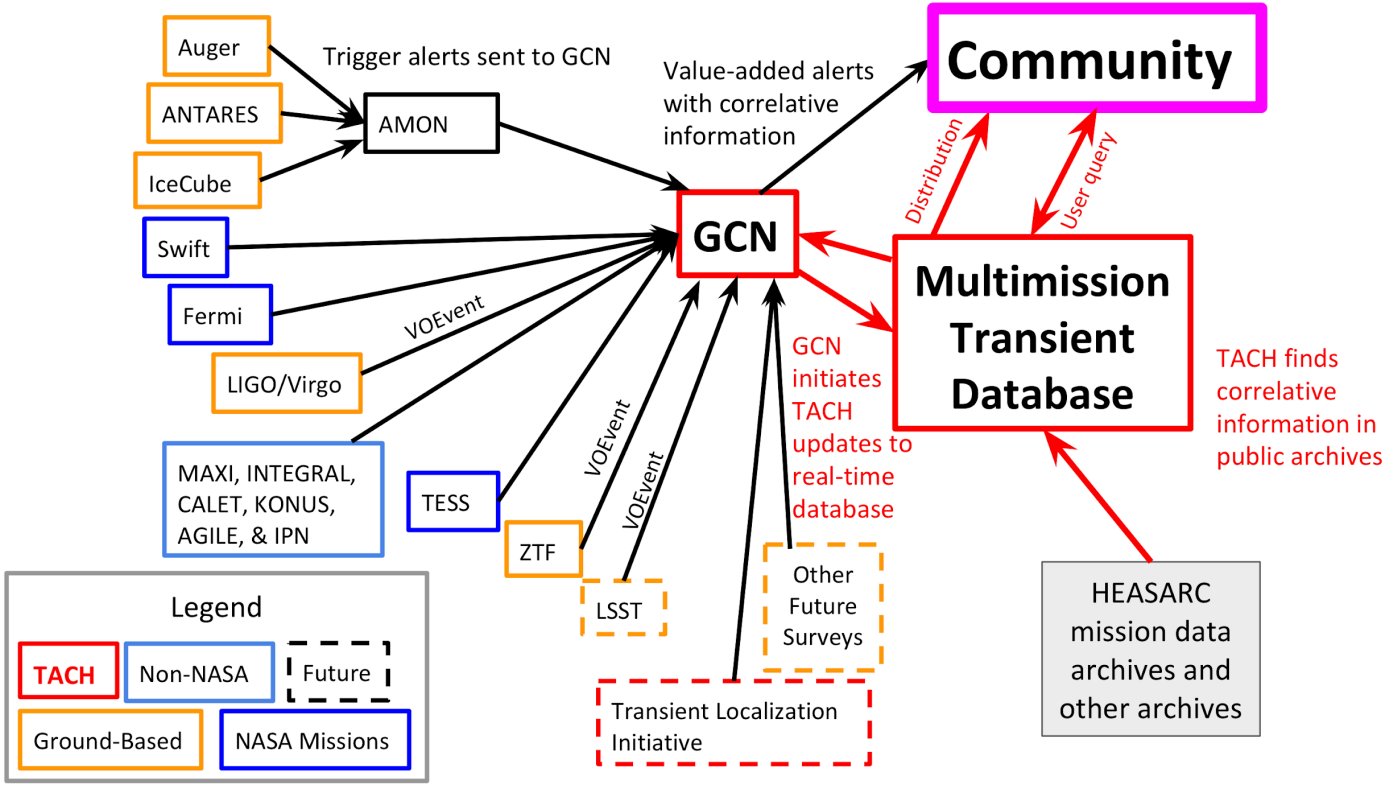
- This is not a replacement for a larger GRB mission:
    - If you want more sensitivity (and with the GW networks being upgraded, there is definitely a need), nanosats are probably not the solution.
    - If you want to measure other GRB features (polarization, wide energy coverage, multiple wavebands, precision localization) then nanosats are probably not the solution.
- It could all fall apart; we depend on funding, good will, and the missions actually working.
- We need help making sure that open data is supported by the community.
- This is a work-in-progress and the most important thing that we are doing is communicating and respecting each other’s work.

Infrastructure: Time-domain Astronomy Coordination Hub (TACH)

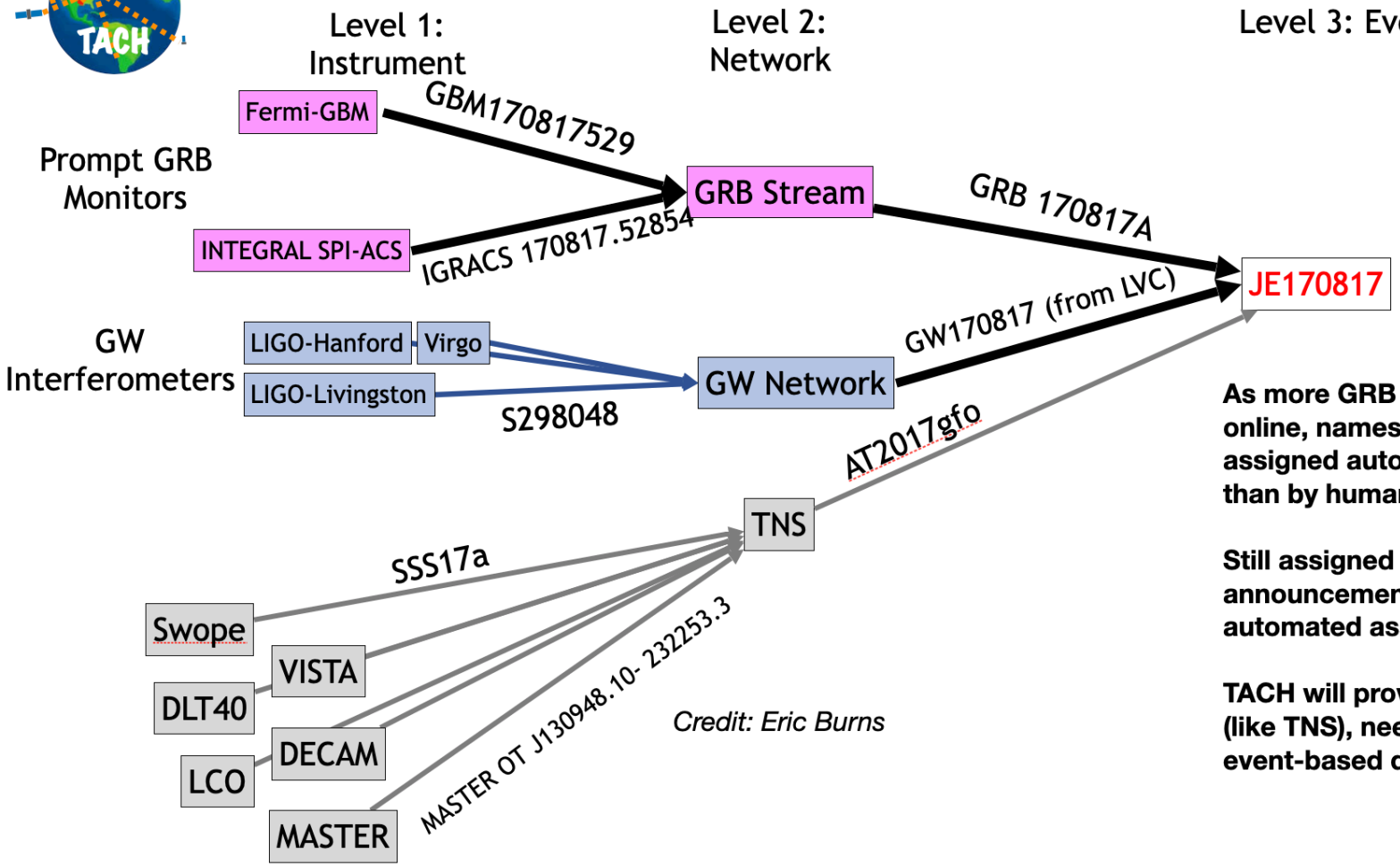
TACH is a project at NASA Goddard to build upon existing community resources to address the needs of the multi-messenger/multi-wavelength transient community

- Improvements to the Gamma-ray Coordinates Network (GCN)
  - Add reliability with mirror sites
  - Improved coincident source searches
  - Improve user interface
  - Provide new formats and protocols
- Realtime HEASARC database that ingests GCN & other public data streams to easily cross-correlate
  - Queryable by community
  - Historical and new data easily accessed
  - Superevent classifications for transients detected by multiple missions
- Provide infrastructure to do joint localizations with multiple transient detecting satellites

Infrastructure: Time-domain Astronomy Coordination Hub (TACH)



GCN GRB Name Server



As more GRB detectors come online, names need to be assigned automatically, rather than by humans.

Still assigned in order of announcement, requires automated associations.

TACH will provide a Name Server (like TNS), need for the MTD event-based database.

Towards a network...

Need to leverage existing and future resources.

Need to respect the needs and desires of individual members.

Need to embrace the spirits of open source, open science, and open data.

Need to understand that we will produce better results together and not alone.

BurstCube Team

PI: Jeremy Perkins (NASA/GSFC)

Website: https://asd.gsfc.nasa.gov/burstcube/

NASA/GSFC
Alessandro Bruno
Eric Burns
Regina Caputo
Brad Cenko
Georgia de Nolfo
Carolyn Kierans
Julie McEnery
Judith Racusin
Teresa Tatoli

CRESST/GSFC
Sean Griffin
John Krizmanic
Amy Y. Lien
Jacob R. Smith

NASA/MSFC
Michelle Hui
Daniel Kocevski
Colleen Wilson-Hodge

UCD
Lorraine Hanlon
Sheila McBreen
David Murphy
Alexey Uliyanov
Sarah Walsh

UAH
Michael Briggs
Oliver Roberts

GWU
Alyson Joens

NRL
Lee Mitchell

Clemson
Dieter Hartmann

UVI
Antonino Cucchiara
David Morris

UMD
Isabella Brewer
Peter Shawhan

Marshall Space Flight Center

GRBNanoSat Contributors

Hua Feng
Mark Pearce
Balazs Zabori
Fabrizio Fiore
Bin-Bin Zhang
Michele Trenti
Judith Racusin
Iyudin Anatoly
Nicolas Produit
Robert Laszlo
Jakub Ripa
Merlin Kole
Yasushi Fukazawa
Jakub Kapus

Kazutaka Yamaoka
Sheila McBreen
Varun Bhalerao
Felix Ryde
Magnus Axelsson
Michael Briggs
Andras Pal
Norbert Werner
Mathias Nowak
Jeremy S Perkins
Masanori Ohno
Antonino Cucchiara
Riccardo Rando
Martin JelÃnek

Ernst Paunzen
Luciano Burderi
Abe Falcone
Kento Torigoe
Yoichi Yatsu
Joseph Mangan
Michelle Hui
Nobuyuki Kawai
Shaolin Xiong
Lee Yakobi
Stéphane Schanne
Eric Grove
Marco Feroci
David Murphy

TACH Team

- PI: **Judy Racusin**
- Sub-package Leads: Scott Barthelmy, Alan Smale, Judy Racusin
- Rest of team: John Baker, Eric Burns, Brad Cenko, Tito dal Canton, Tom McGlynn, Jeremy Perkins, Jeremy Schnittman, Leo Singer