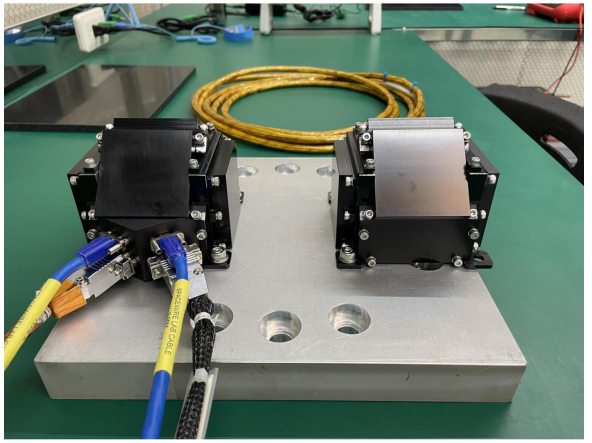
The Gamma-ray Transients Monitor (GTM) on board Formosat-8B

Hsiang-Kuang Chang
National Tsing Hua University (NTHU), Hsinchu, Taiwan
On behalf of the GTM team

1. Science goal:

To monitor Gamma Ray Bursts (GRBs), and bright gamma-ray transients from other sources in 30 keV – 2 MeV.

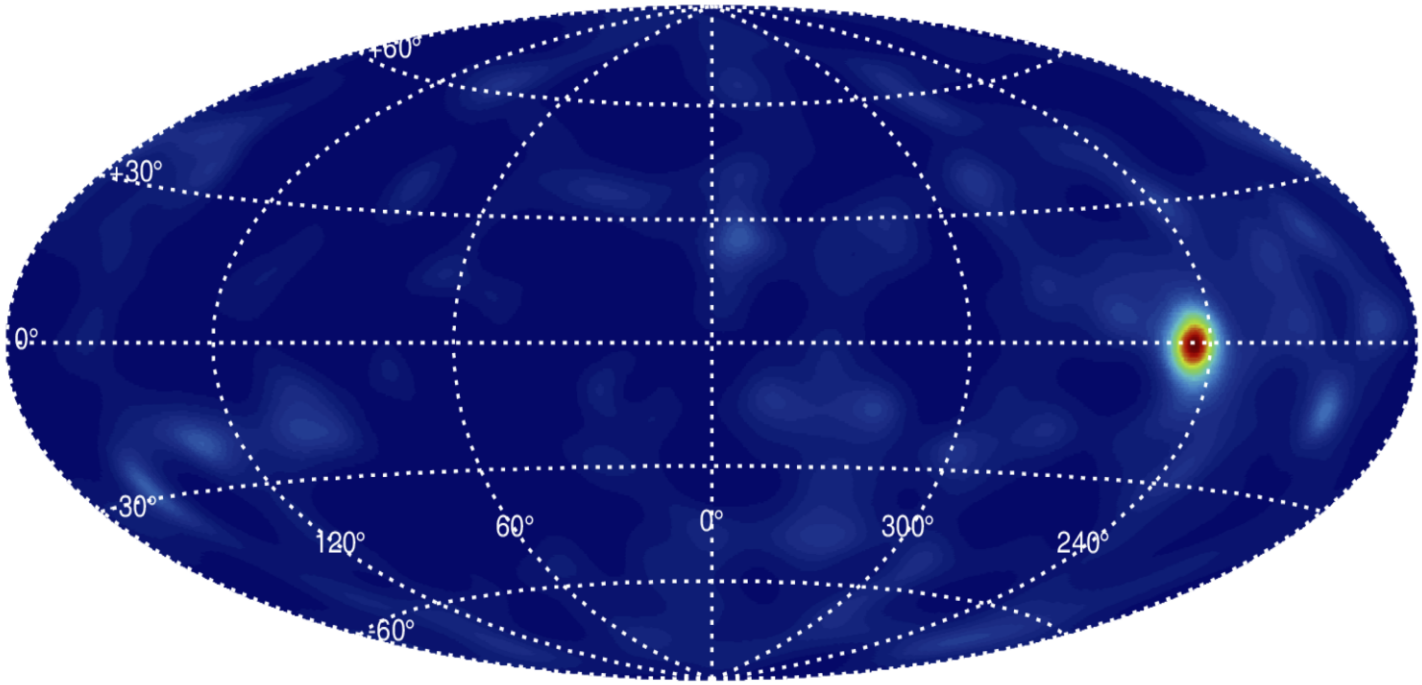
2. Instrument design

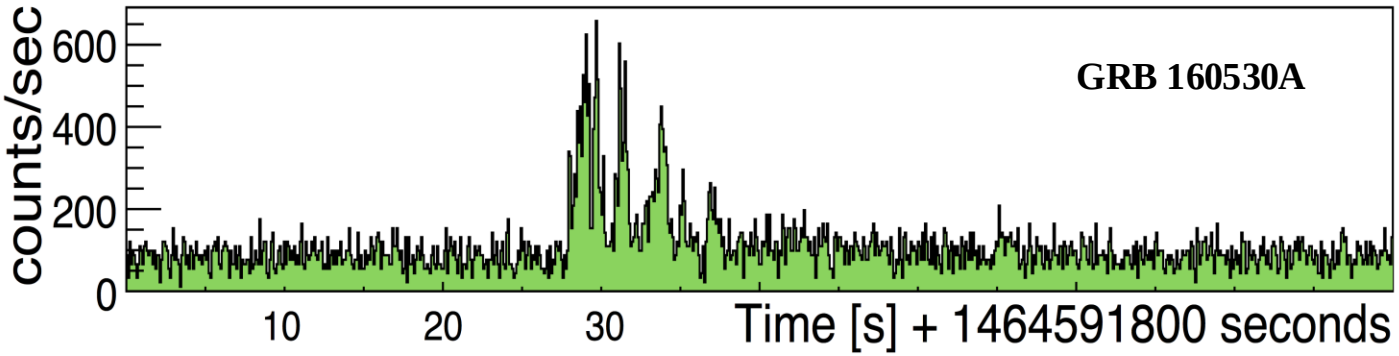


3. Current status

*** A quick summary:**

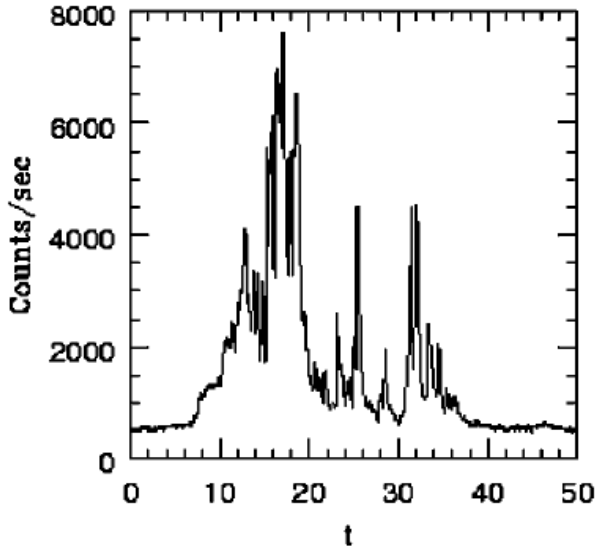
FS-8B will be launched into a sun-synchronous LEO in 2026.
GTM is expected to detect about 50 GRBs per year.
GTM can detect and localize GRBs, can perform spectral analysis, and, for very bright GRBs, can measure polarization states.

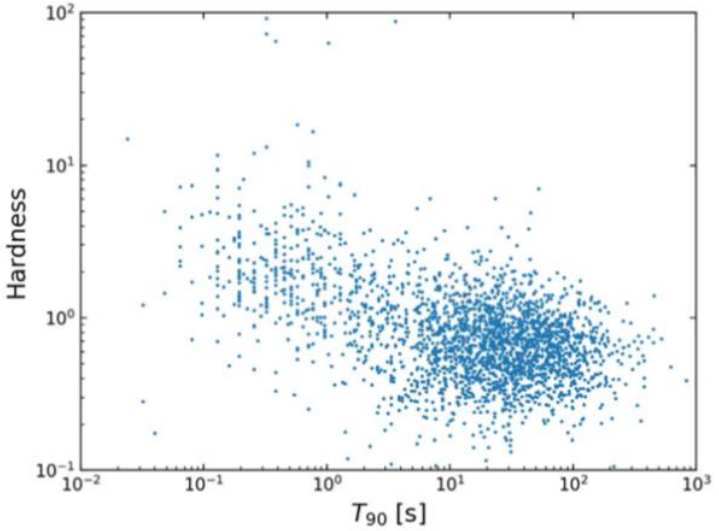


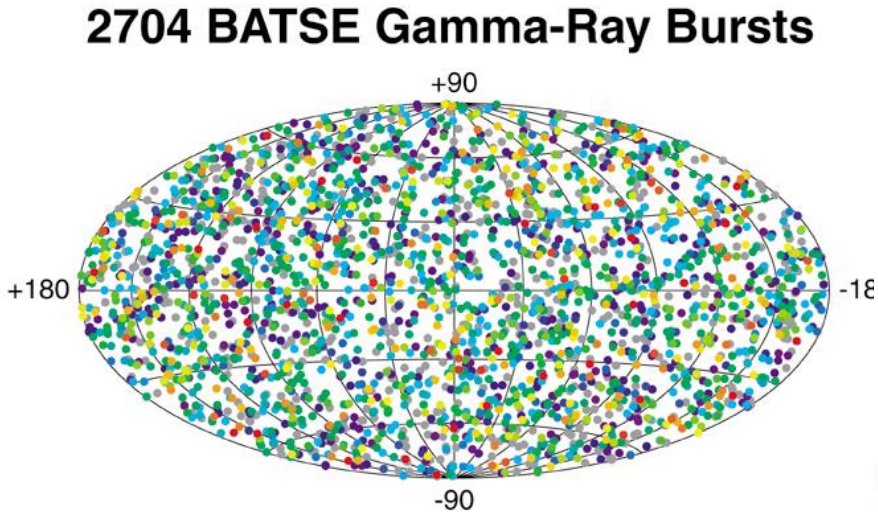


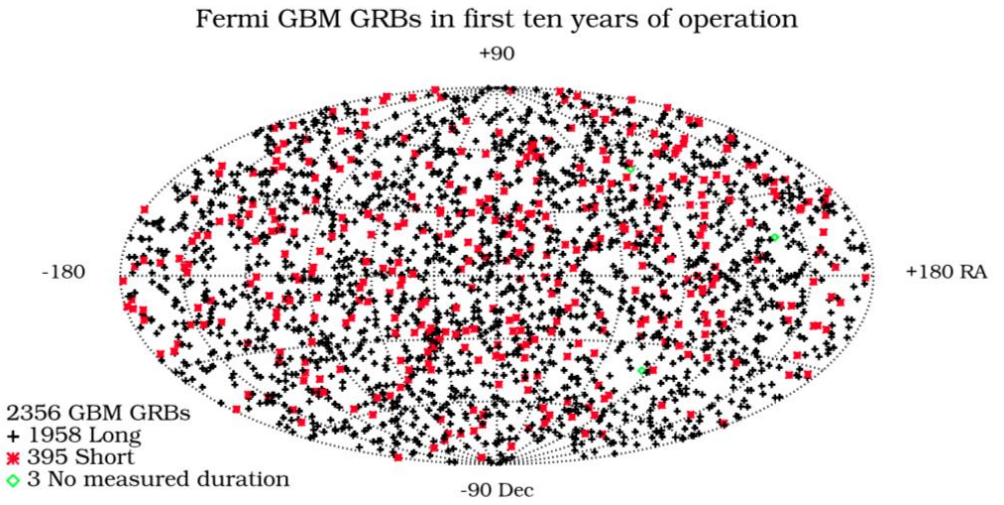
A GRB detected by COSI. What is its nature?

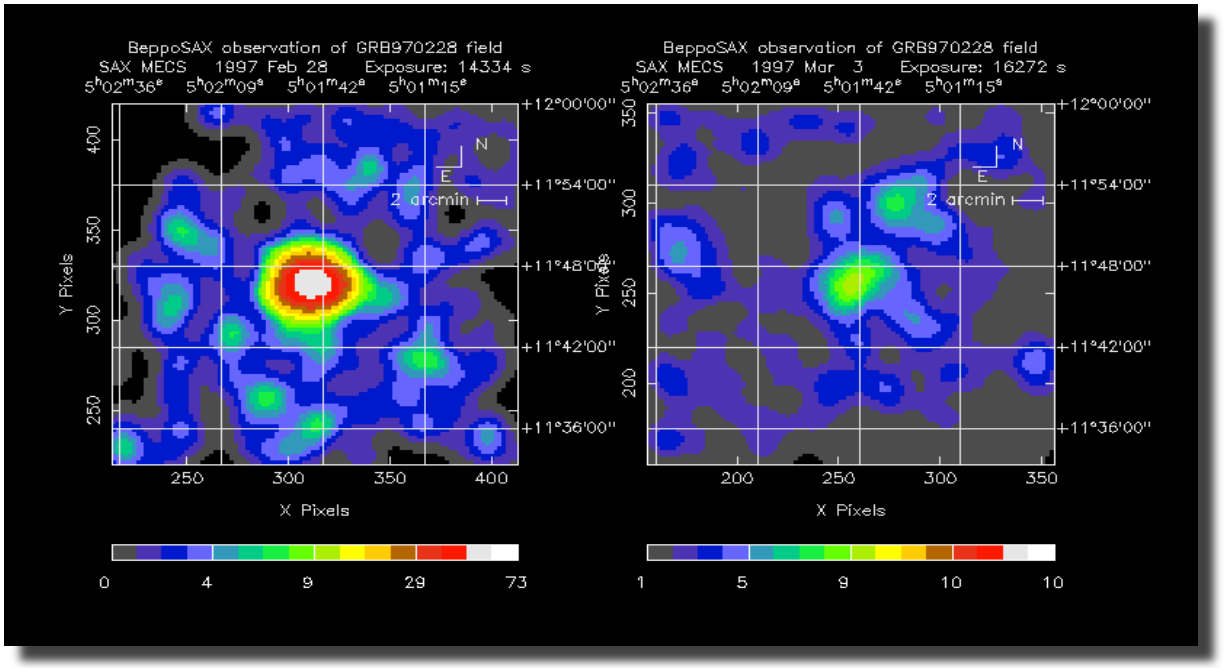
Gamma Ray Bursts (GRBs)





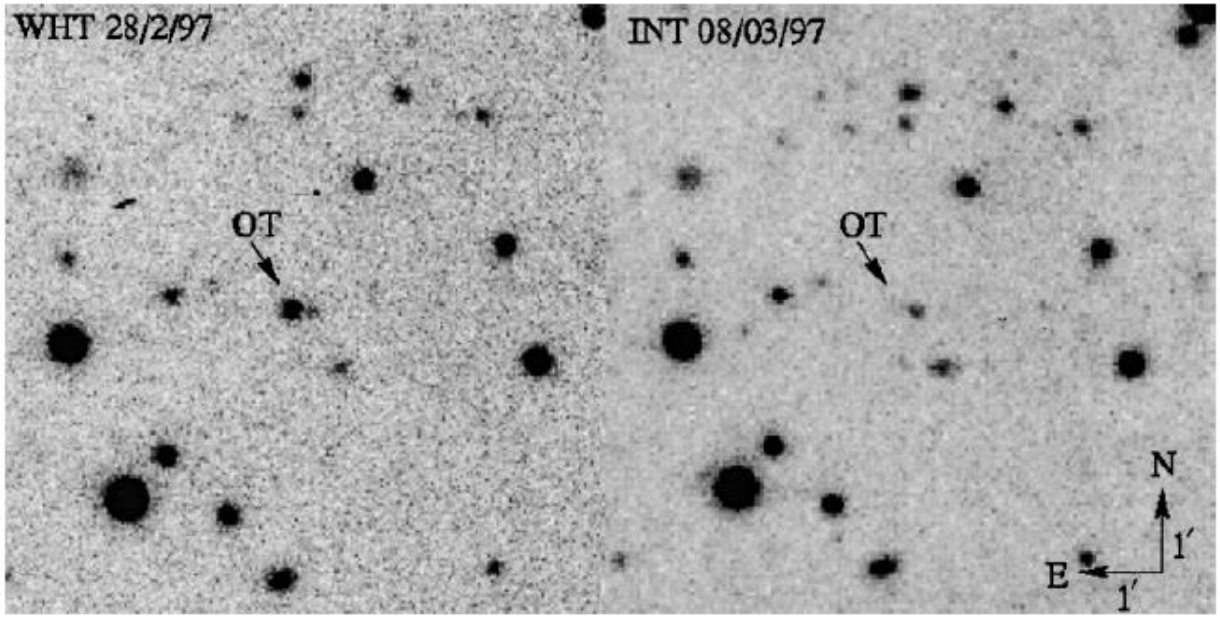




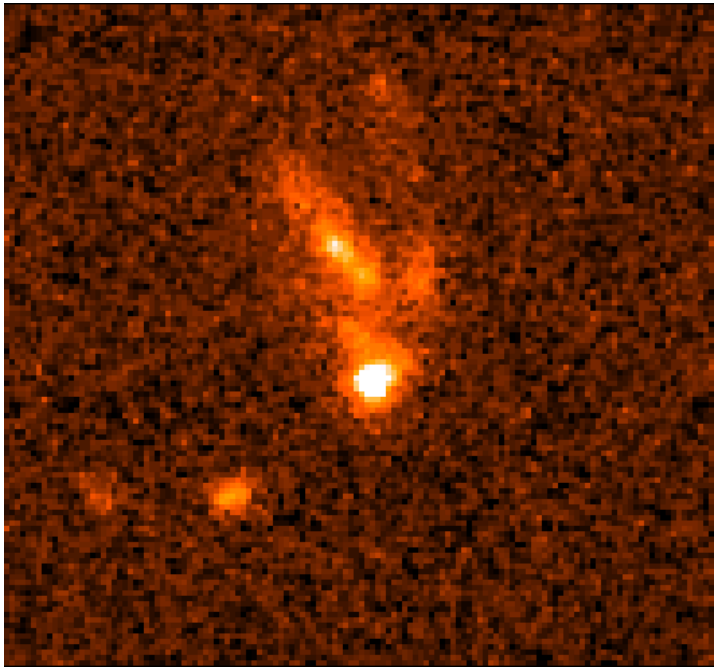


GRB 970228, the first GRB afterglow observations in X-ray and optical bands.

(BeppoSAX Science Data Center (SDC) and the Agenzia Spaziale Italiana (ASI))

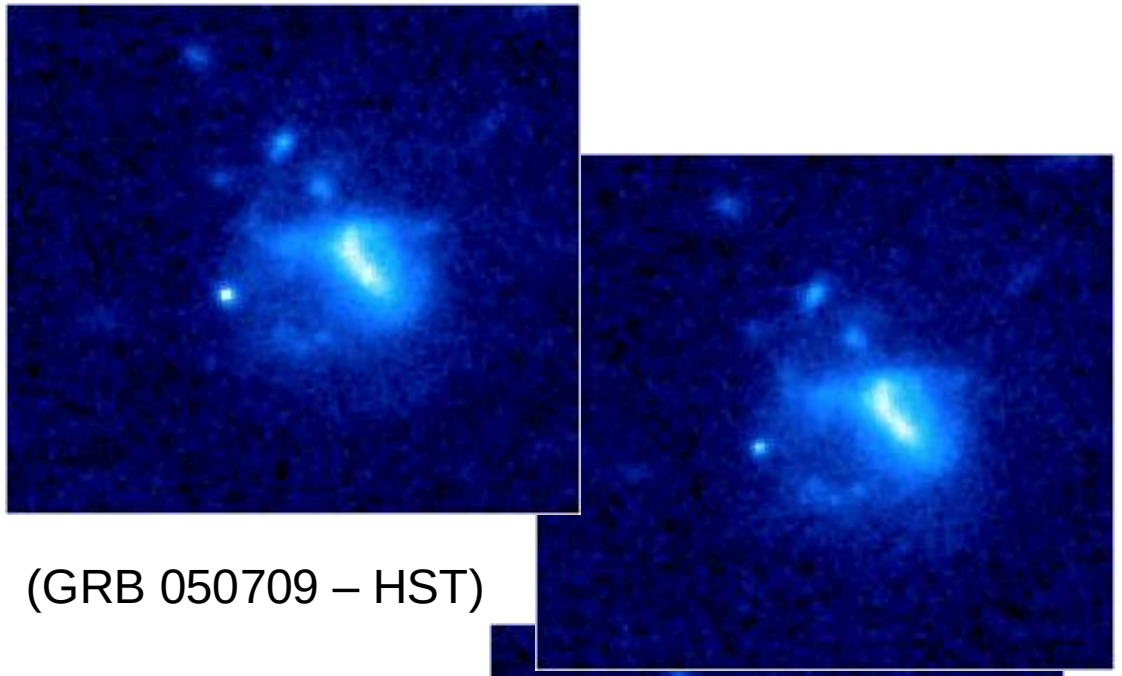


(P. J. Groot (U. Amsterdam) et al., WHT, INT)

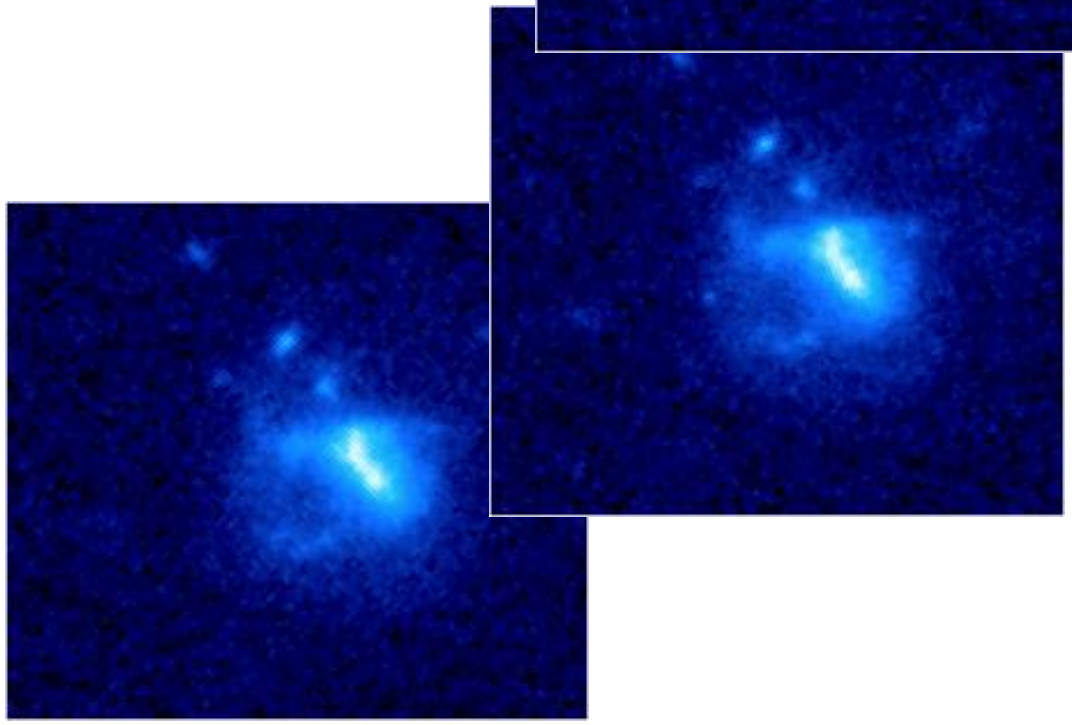


(GRB 990123 – HST)

(STScI)



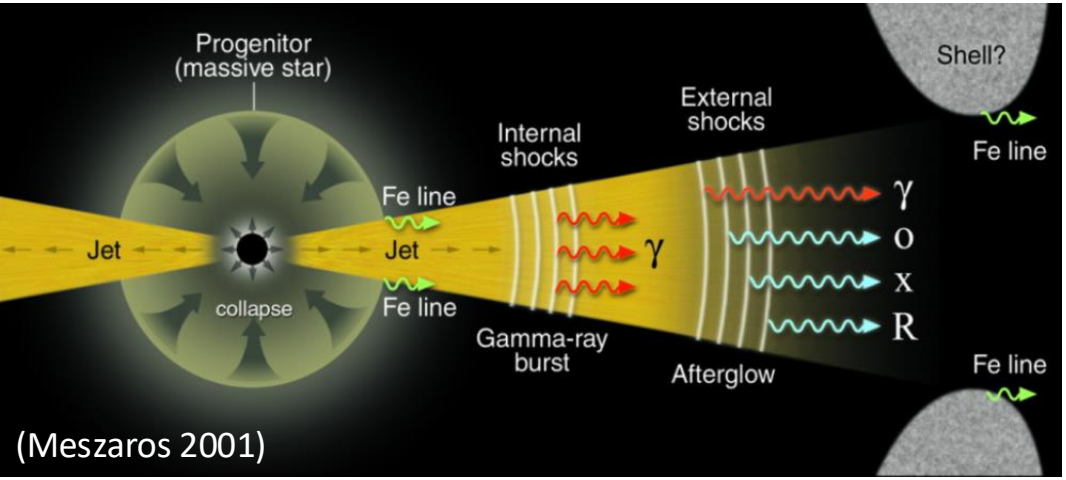
(GRB 050709 – HST)



(Derek Fox/Penn State University)

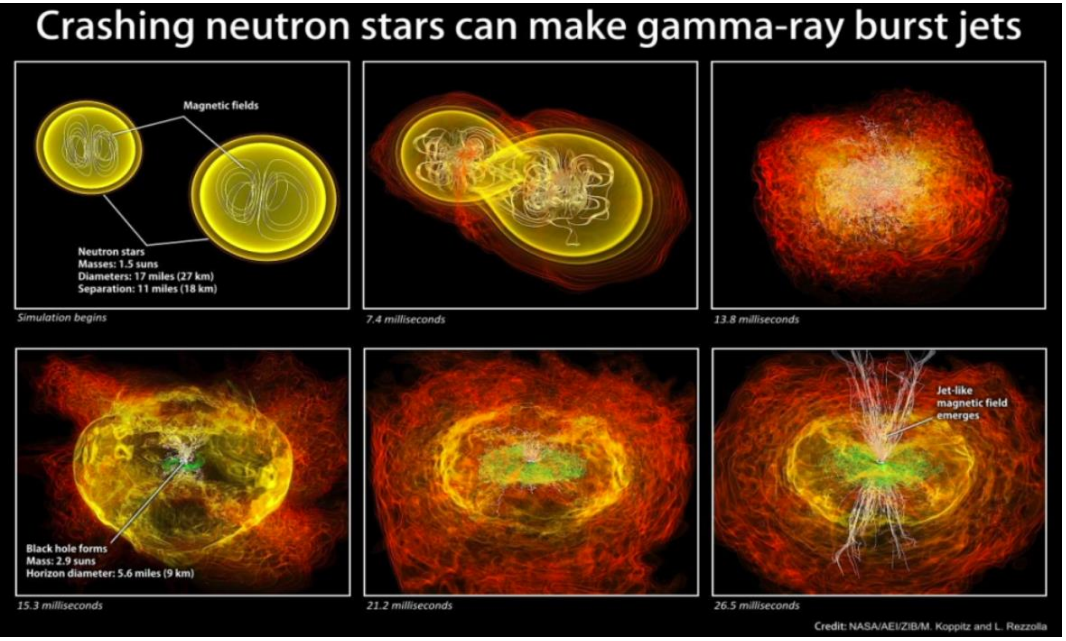
GRB host galaxies and afterglows all show large redshifts.

GRB models



(Meszaros 2001)

Long GRBs:
hypernova, collapsar,
high redshift,
the first star



Short GRBs:
kilonova, merger,
EM counterparts to
GW events

The birth of black holes!
Or?

(Credit: NASA/AEI/ZIB/M. Koppitz and L. Rezzolla)

- Key issues:

Observation of afterglows

Detection of host galaxies

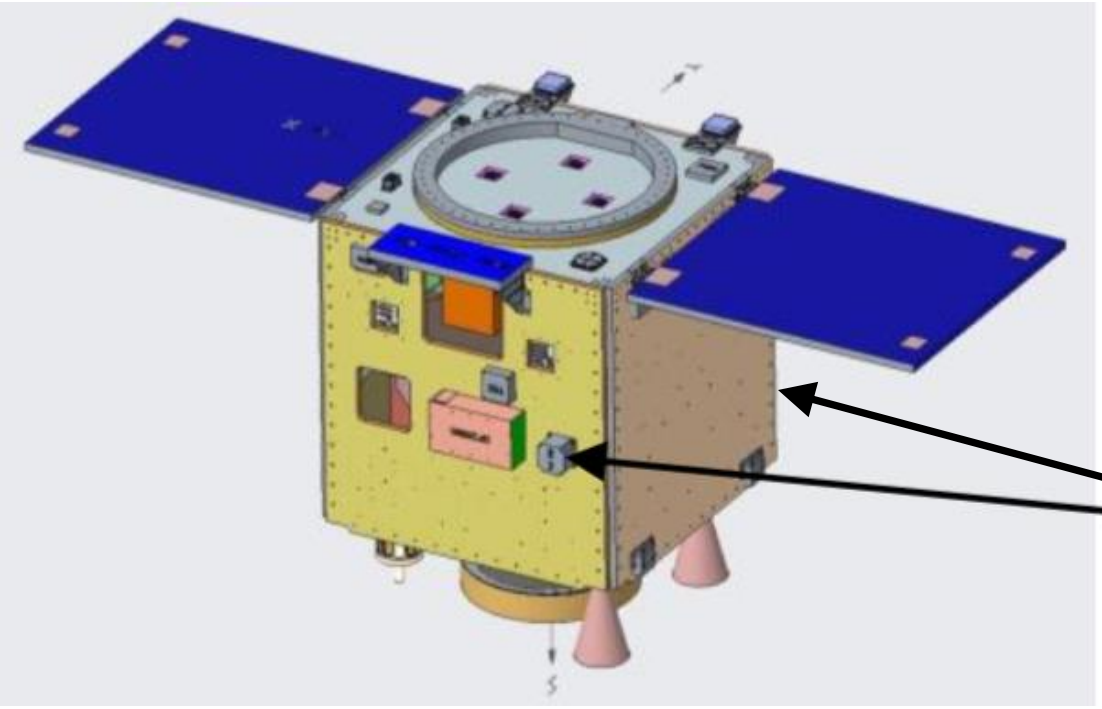
Sky coverage

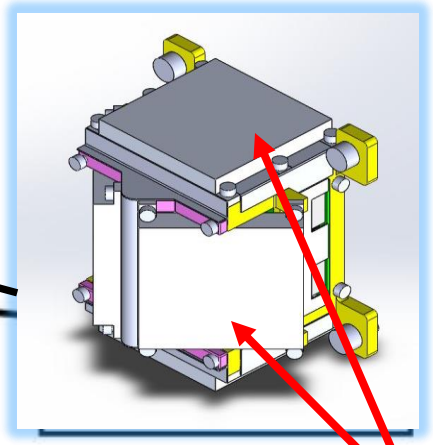
Localization capability

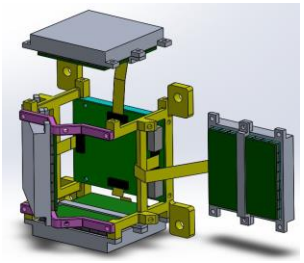
- More GRB monitors are desired to enhance sky coverage and provide better localization

Small instruments can do that.

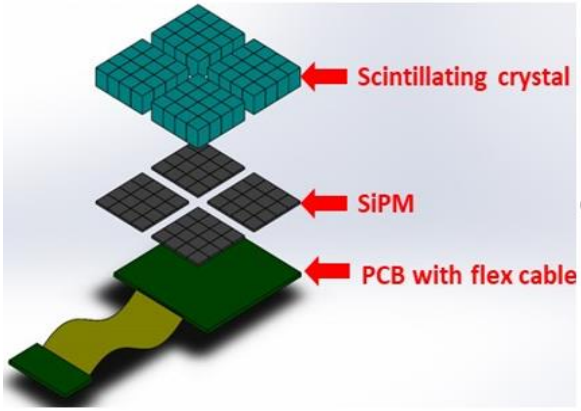
GTM on board Formosat-8B

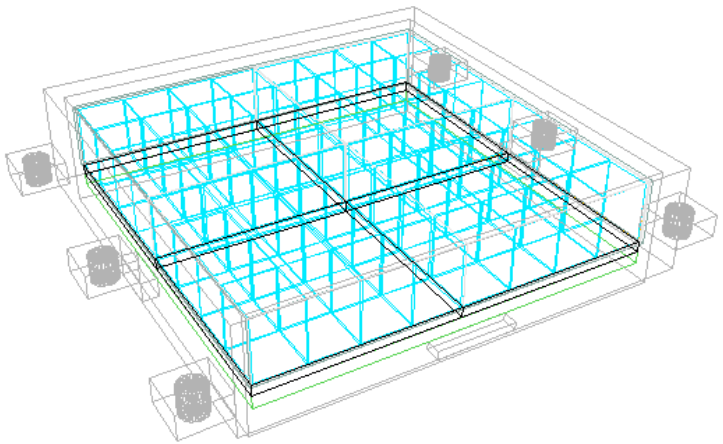


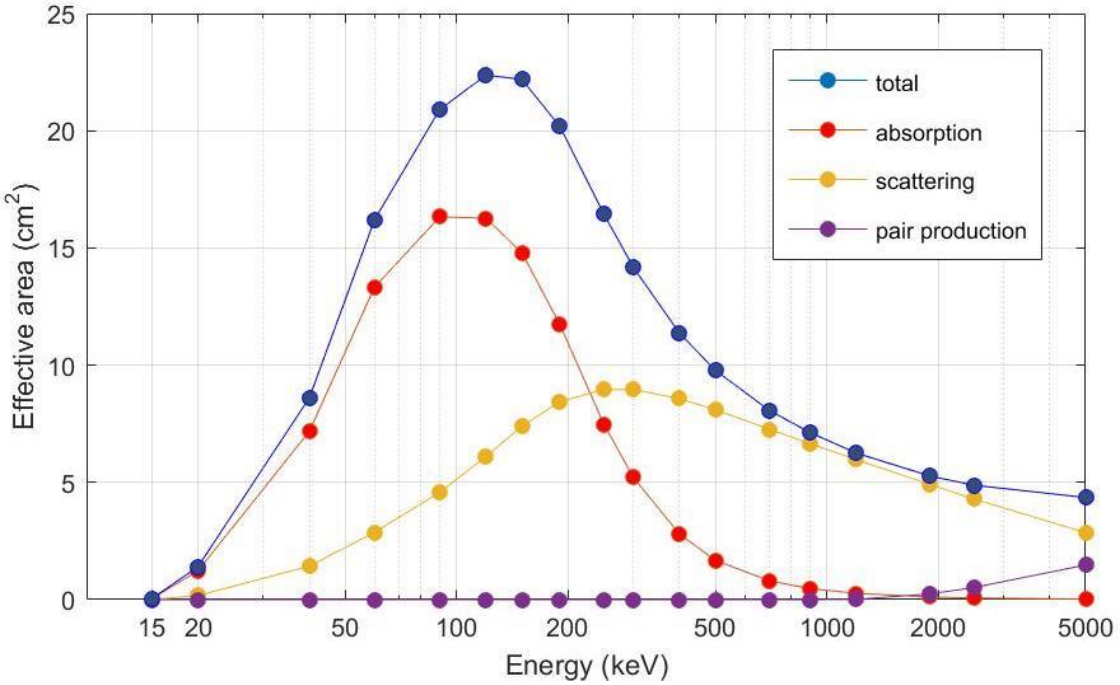




The Gamma-ray Transients Monitor (GTM) consists of two identical modules located on two opposite sides of FS-8B. Each module has four sensor units facing different directions to cover the whole sky. Each sensor unit is composed of a GAGG scintillator array (51 mm x 51 mm x 8 mm) and SiPM of corresponding pixel size for readout. (Chang et al. 2022, ASR, 69, 1249)

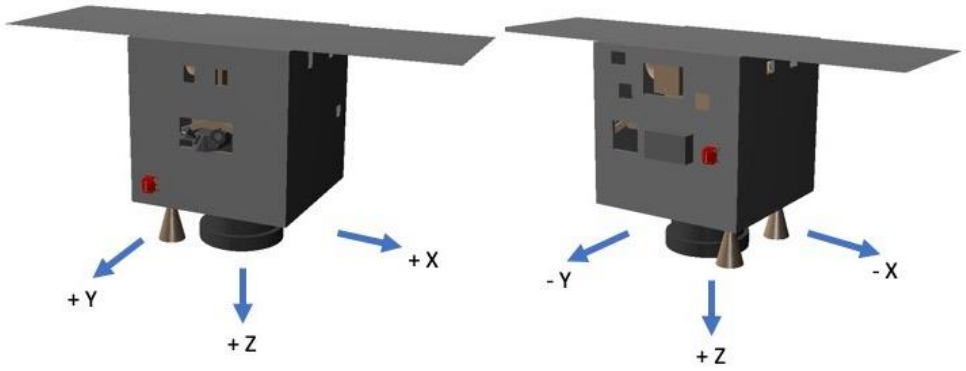






The effective area of one GTM GAGG (Gadolinium Aluminum Gallium Garnet) sensor unit.

FS-8B/GTM, Source and Background Models



MEGAlib (Zoglauer et al. 2008)

Background:

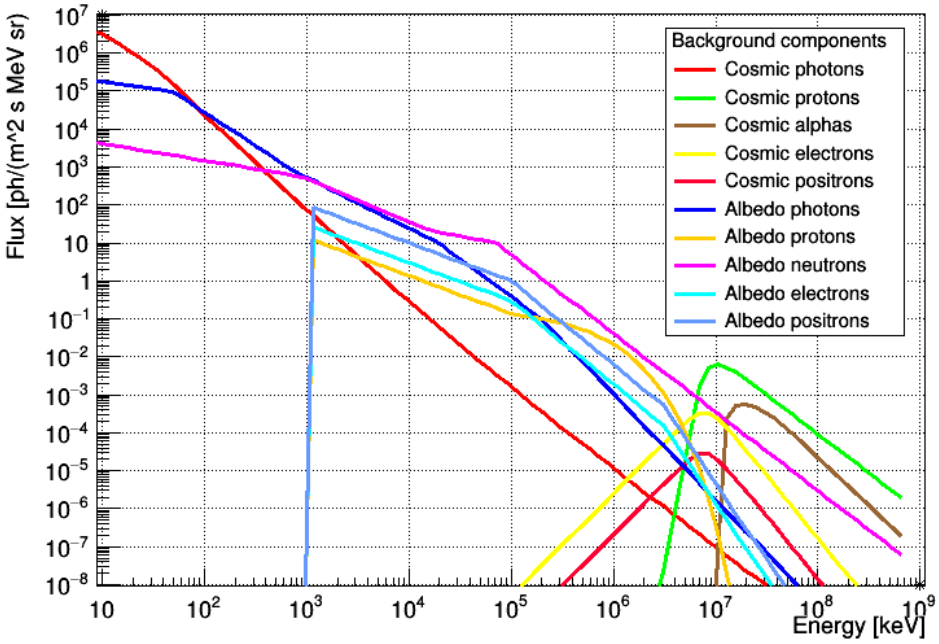
A polar (97°), low-altitude (560 km) Earth orbit; embedded in MEGAlib.

Source spectral model:

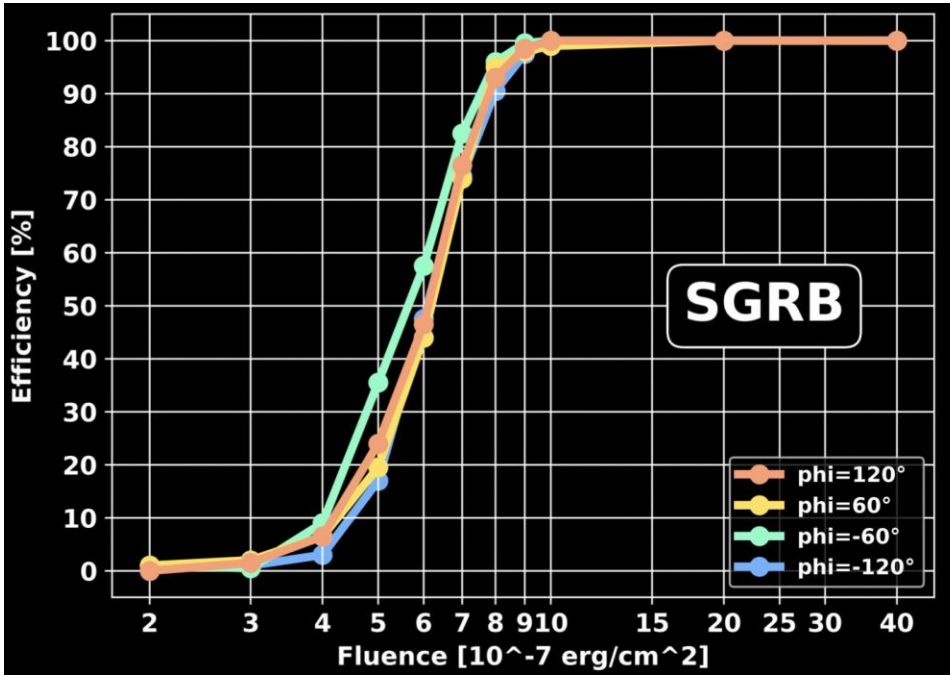
$$N_E \propto E^{\alpha}\, e^{(-E(2+\alpha)/Ep)}$$

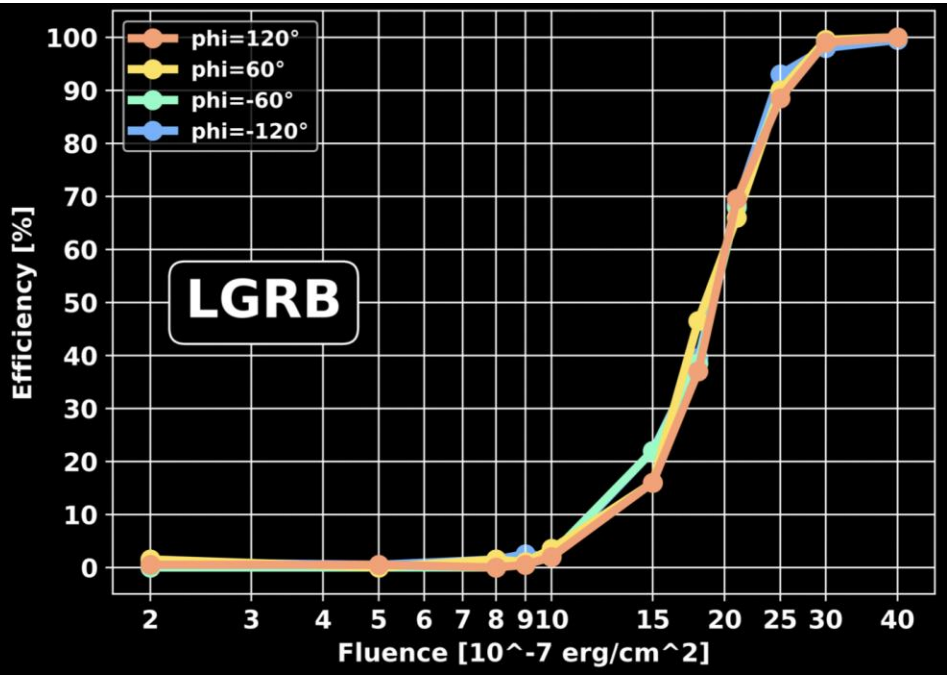
Long GRBs:
$\alpha = -1$, E_p = 300keV, duration 10 sec
Short GRBs:
$\alpha = -0.5$, E_p = 500keV, duration 0.5 sec

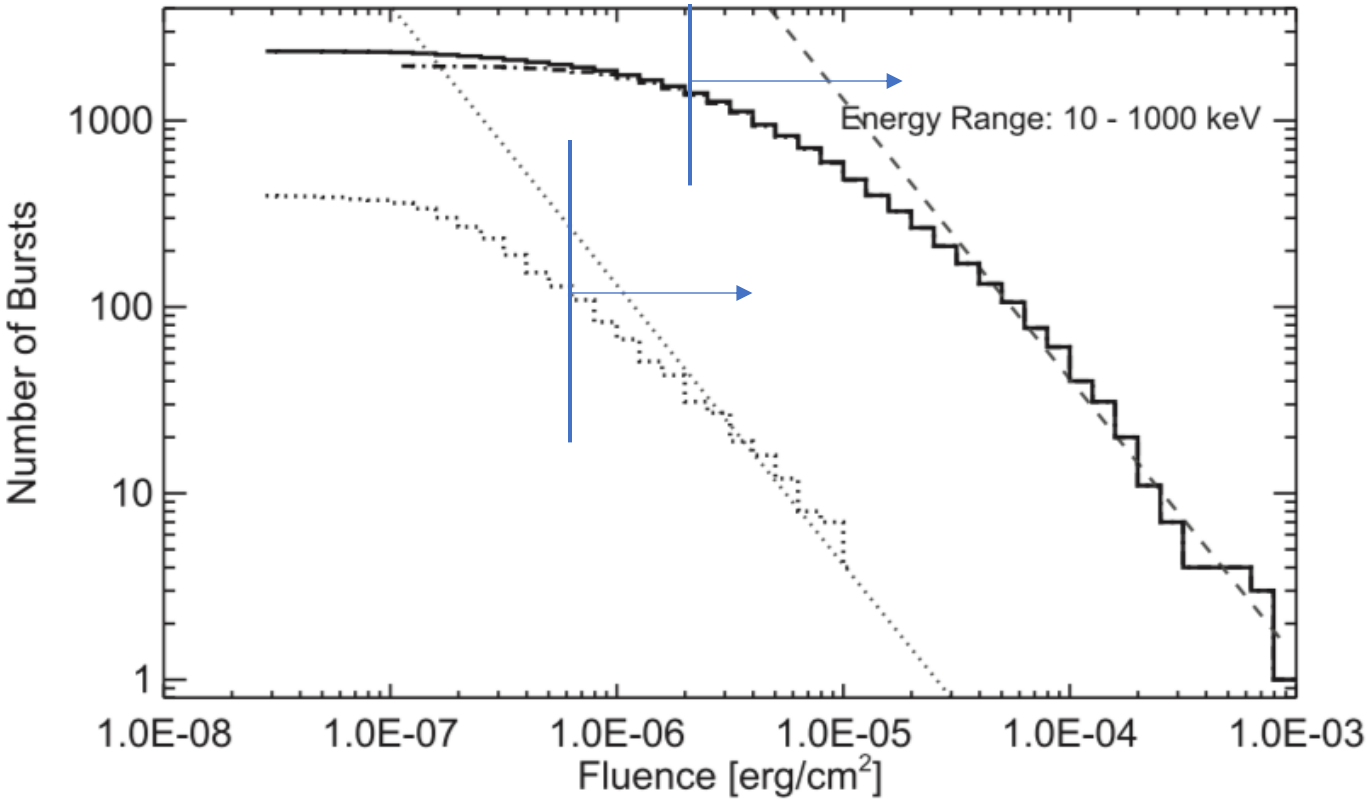
These numbers are the median of t_{50} and corresponding spectral parameters of Konus-WIND-detected GRBs (Svinkin et al., 2016; Tsvetkova et al., 2017).



GTM's GRB detection efficiency





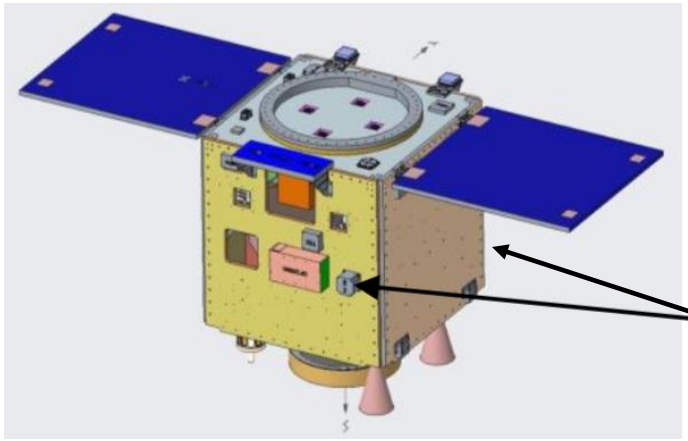


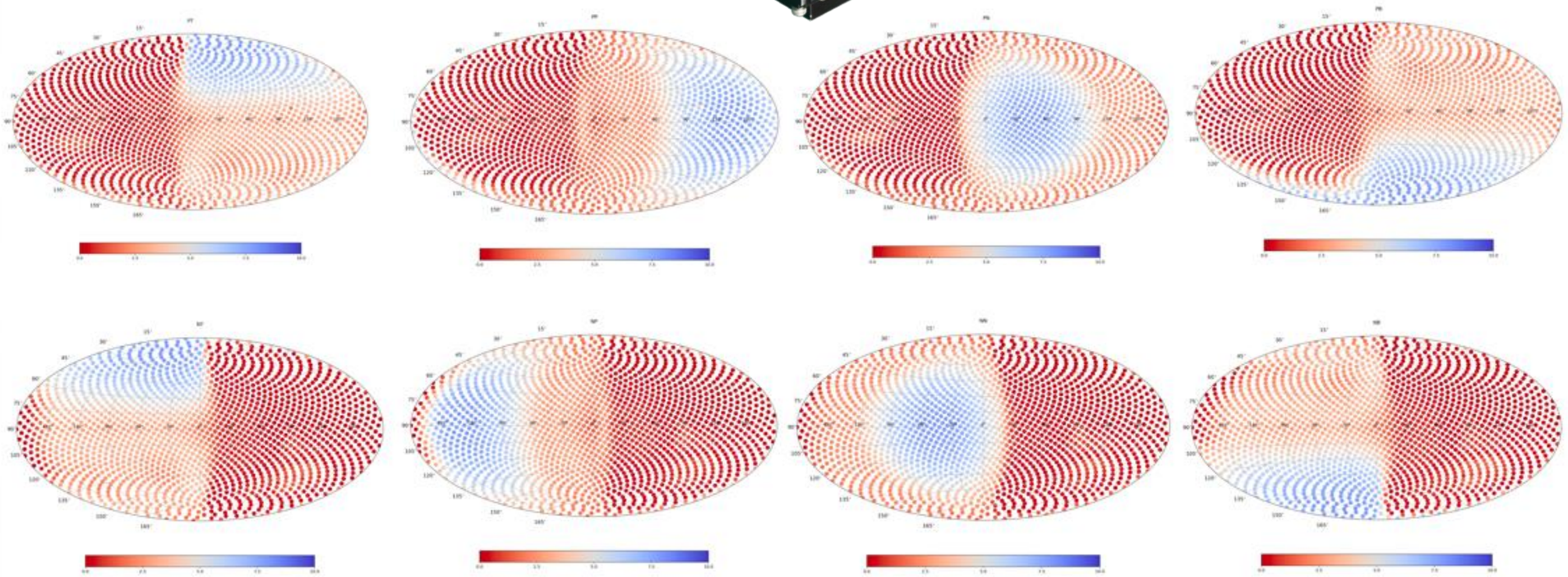
Fermi/GBM 10-year GRB fluence distribution (von Kienlin et al. 2020)

Assuming a 36% duty cycle,
FS8B/GTM will detect about 50 GRBs per year.

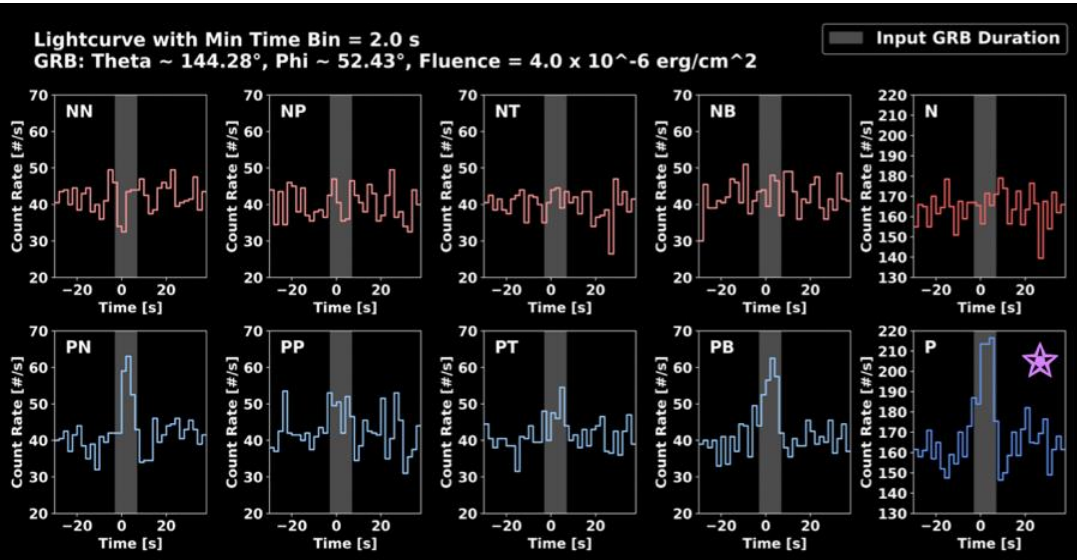
Detector response (50-300 keV) of the 8 sensors in different directions in the sky

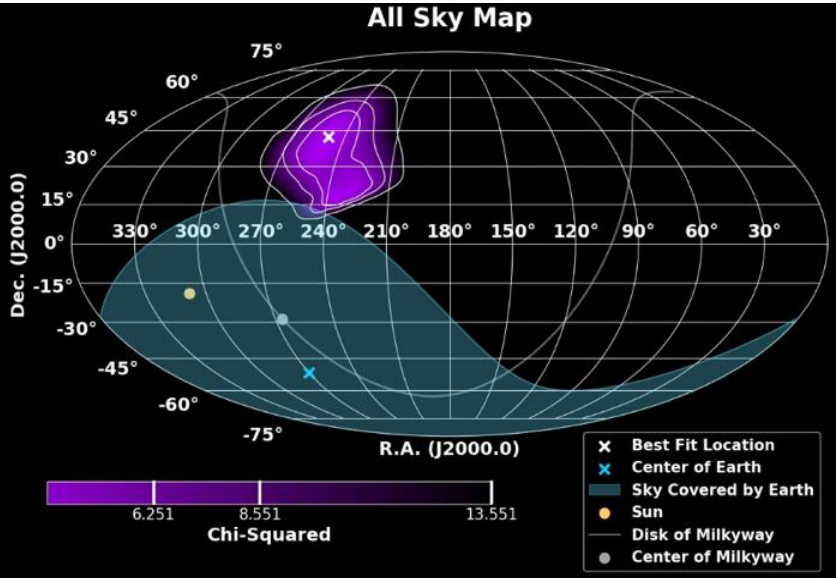
($\alpha = -1$, $E_p = 300$keV)

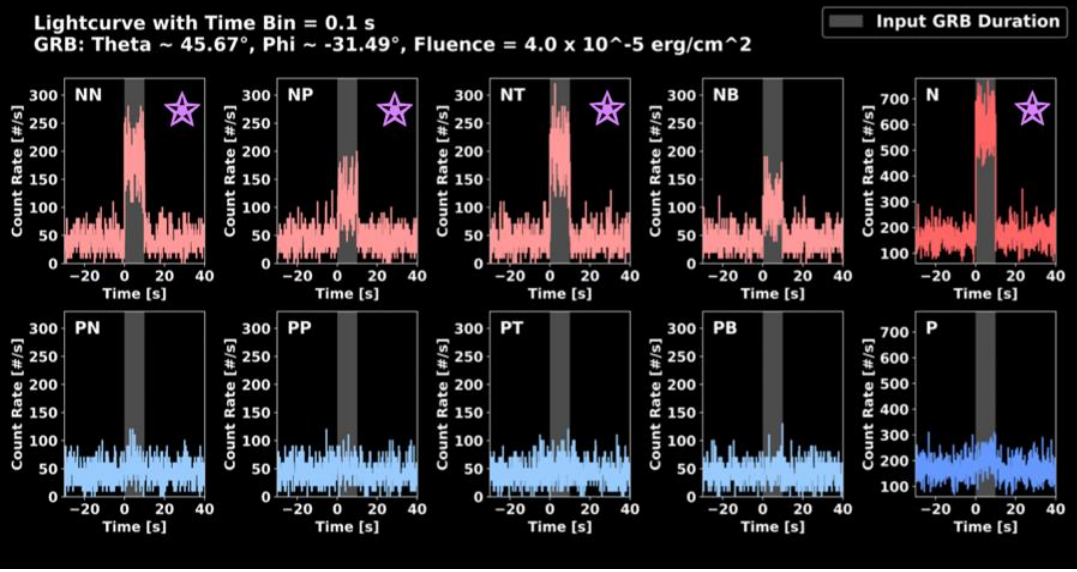


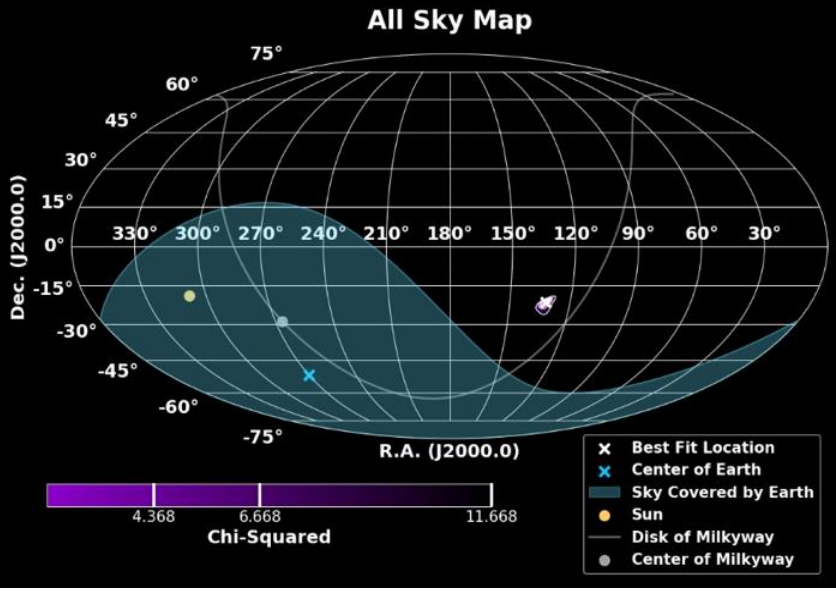


Examples of GRB detection and localization from GTM simulation

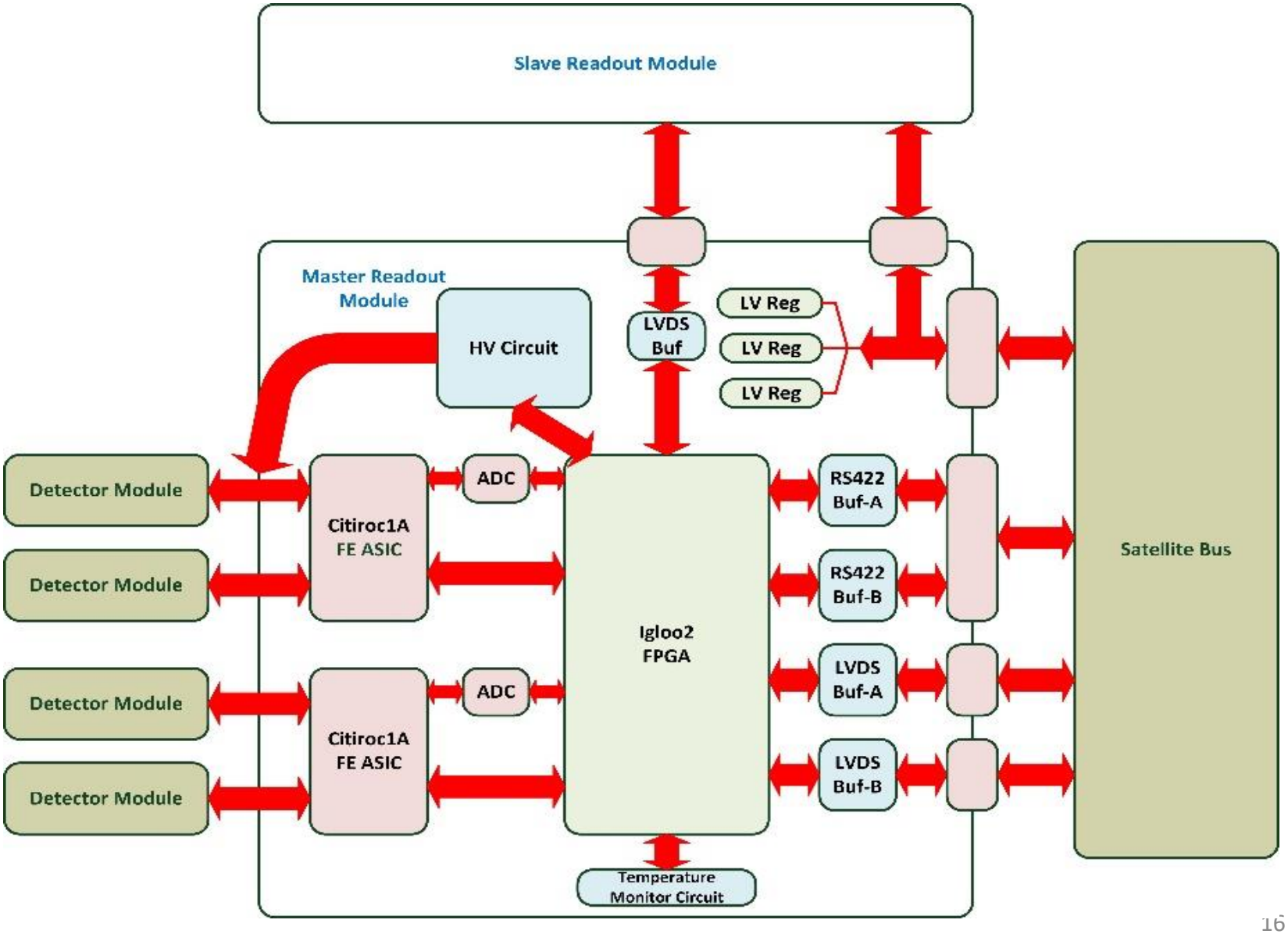




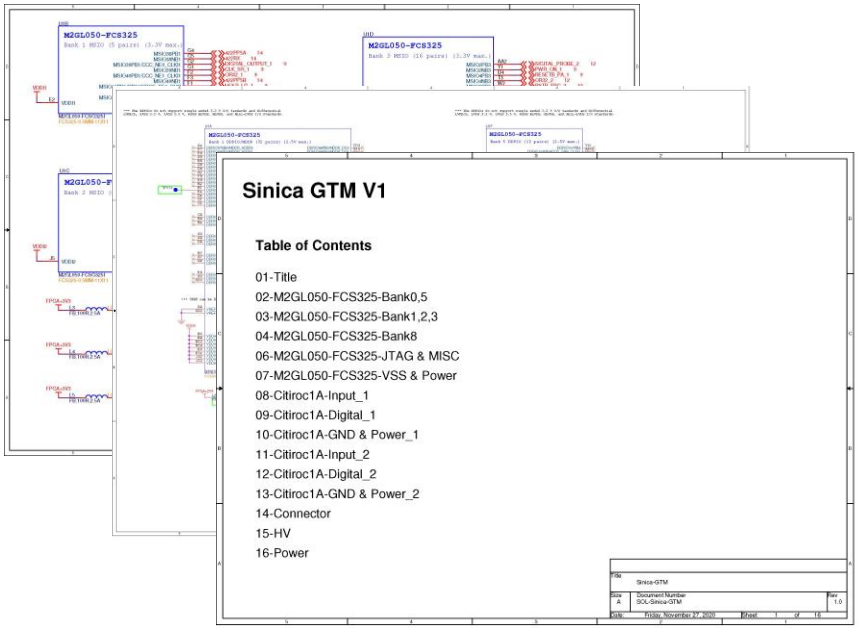


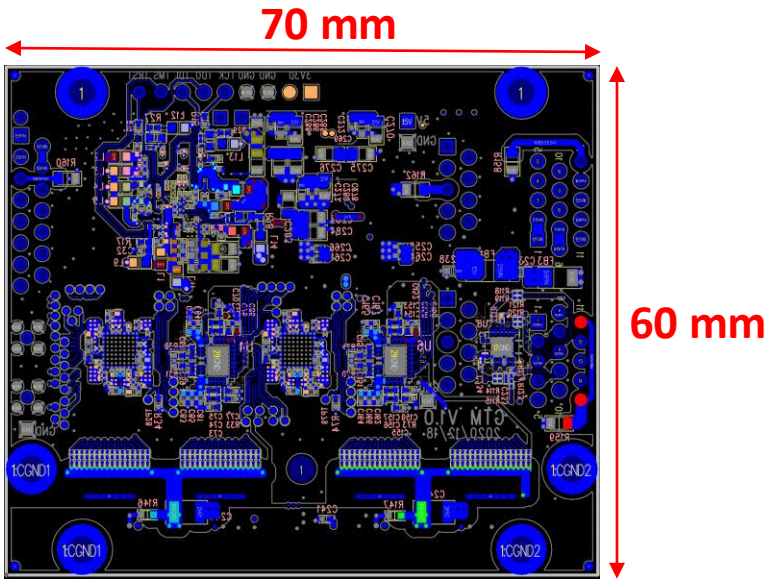


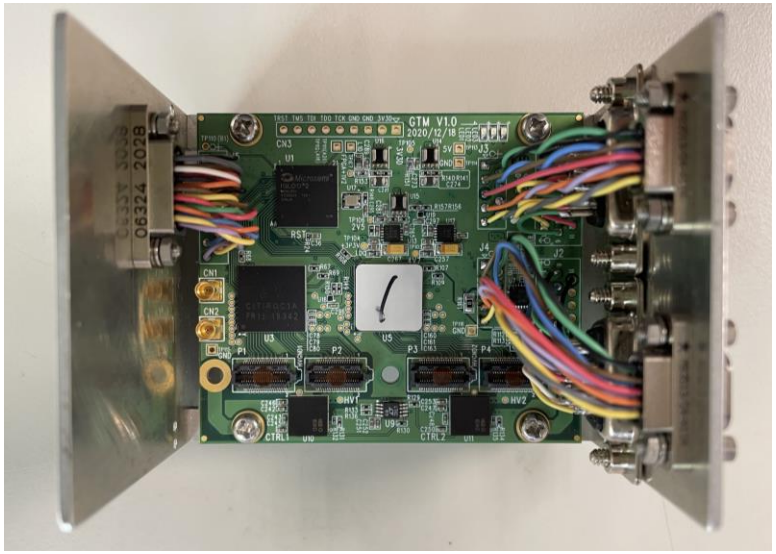
Readout system

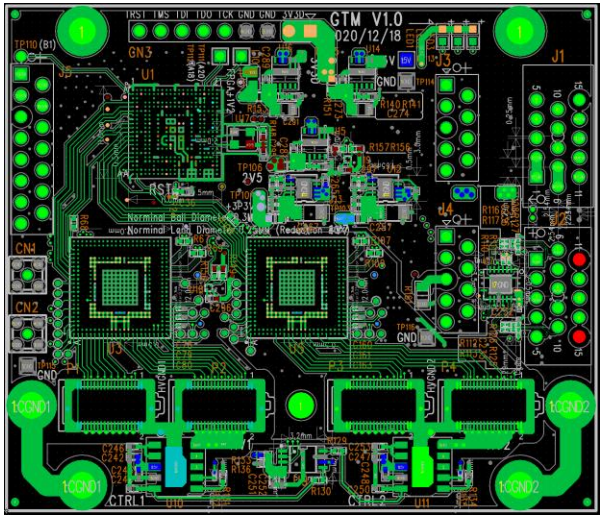


Readout system

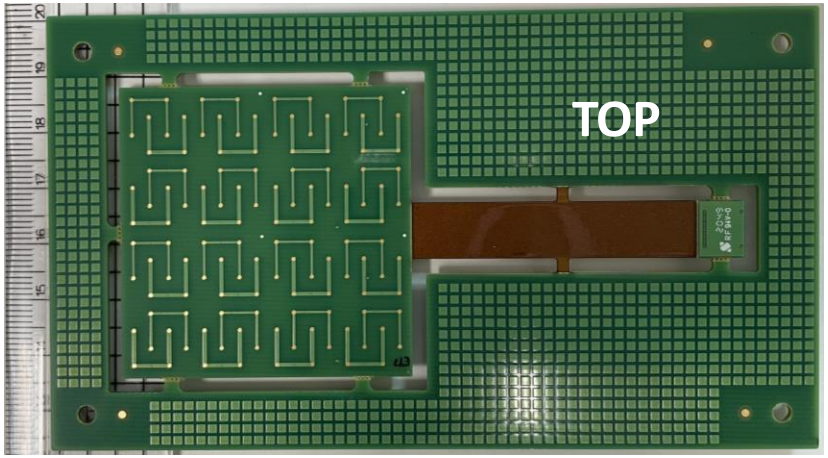


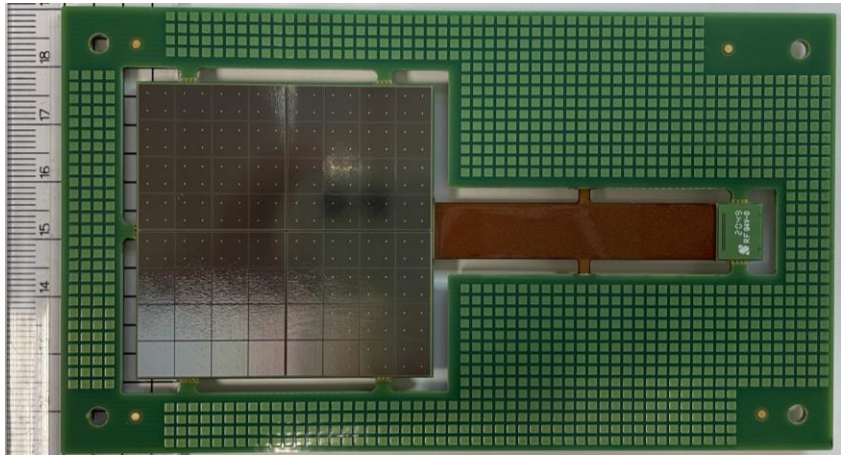


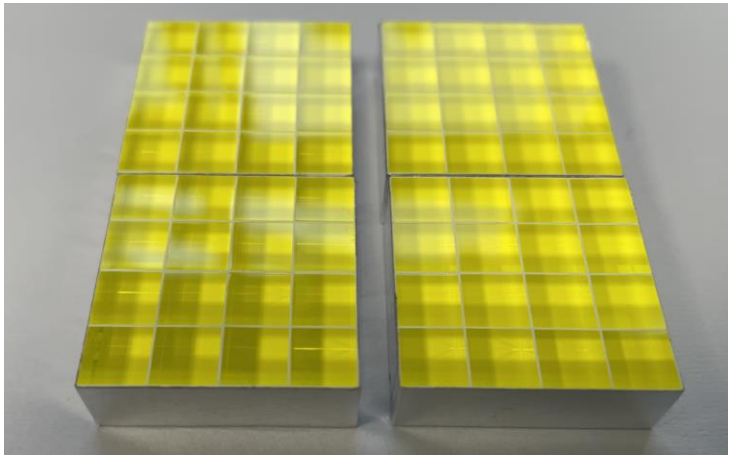


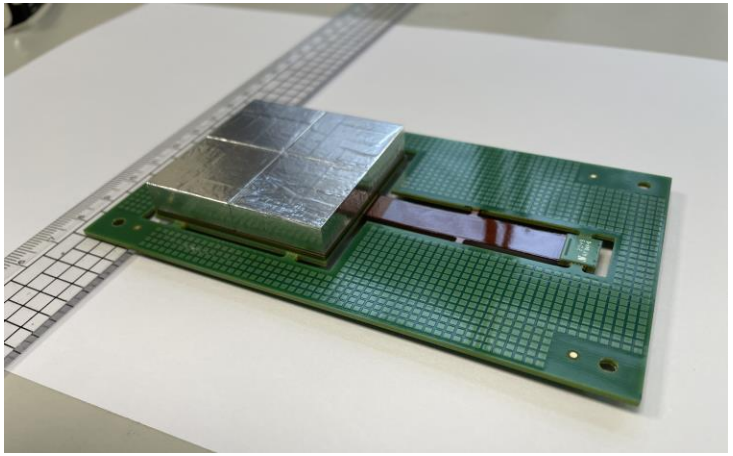


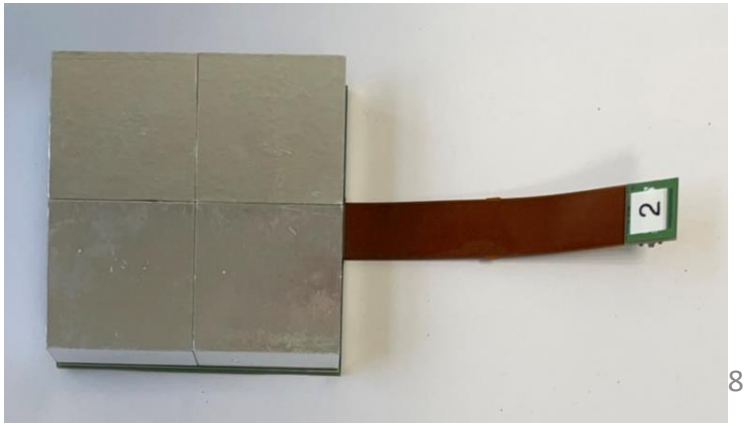
Sensor module



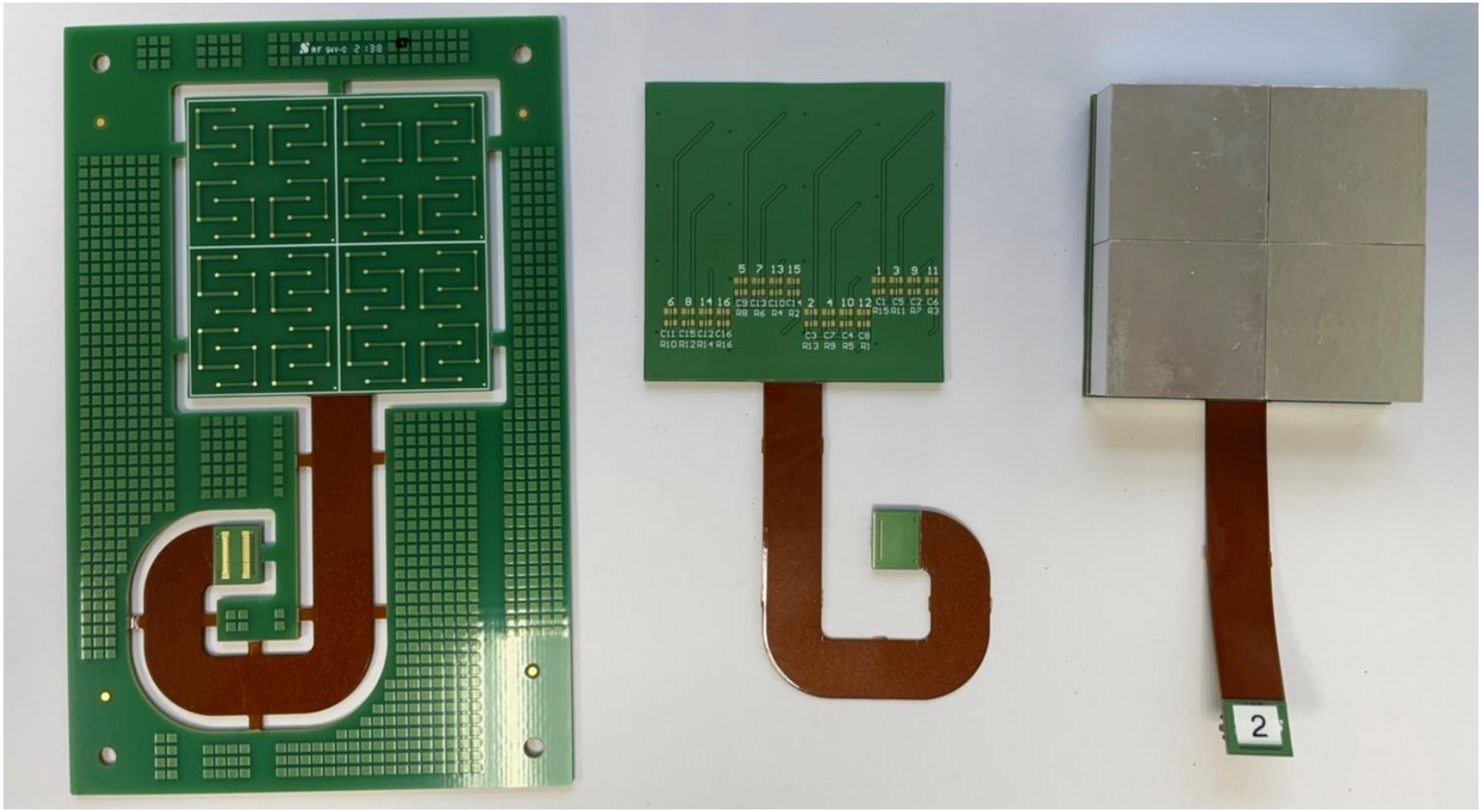




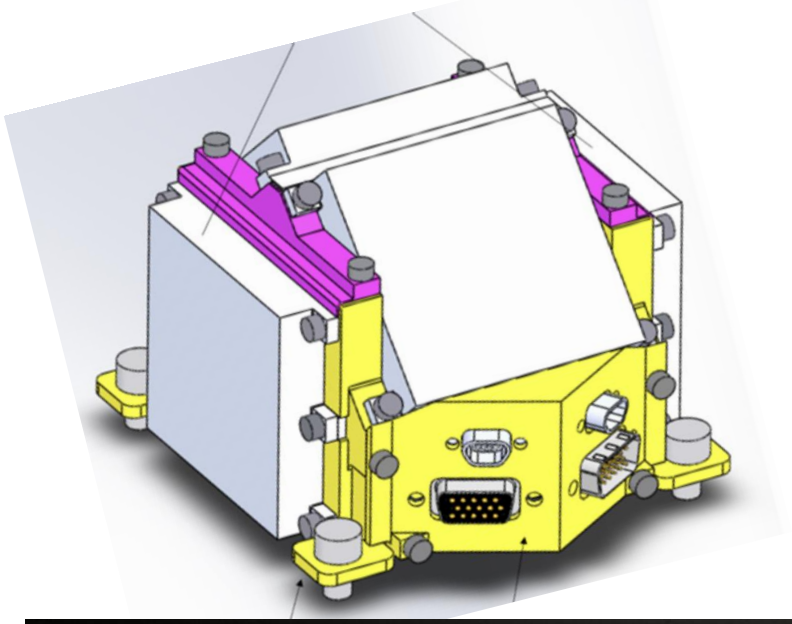


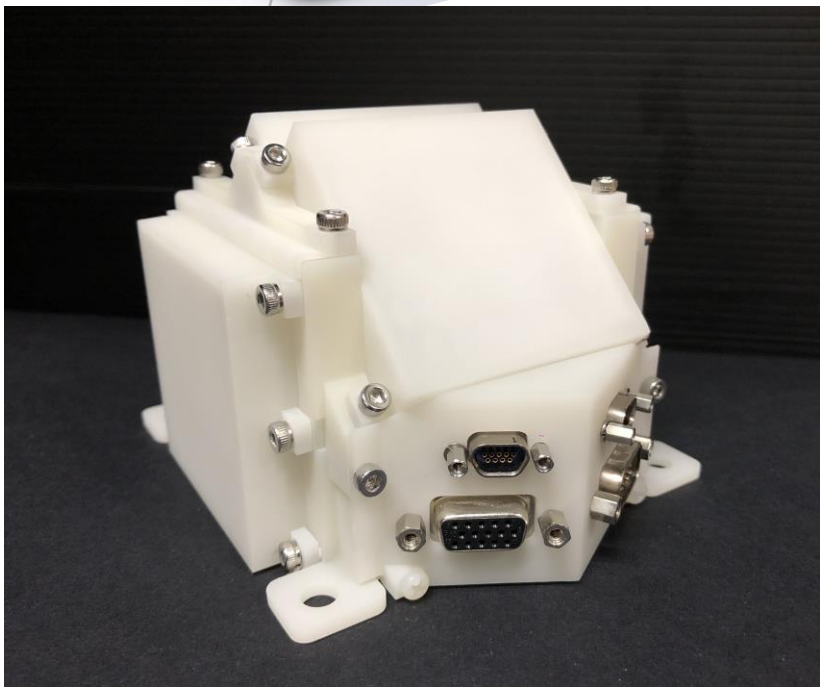


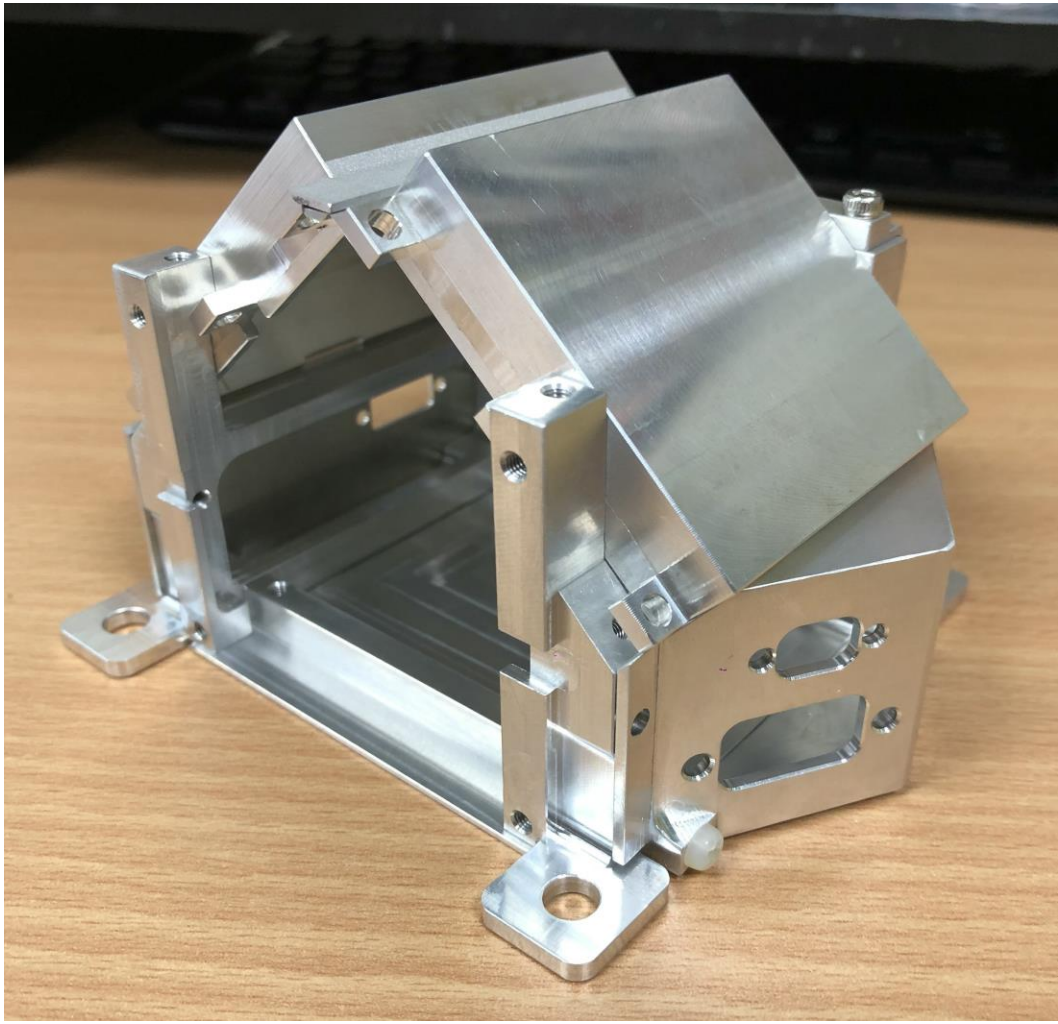
Sensor module



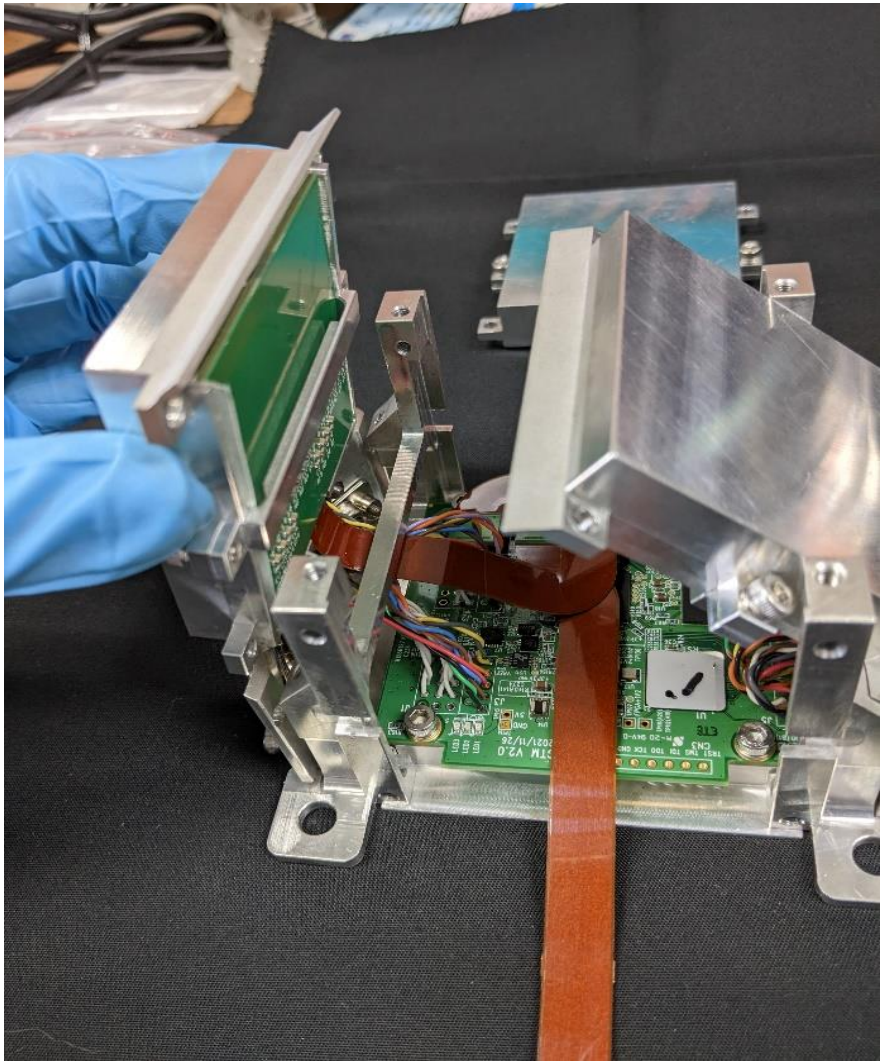
Mechanical structure

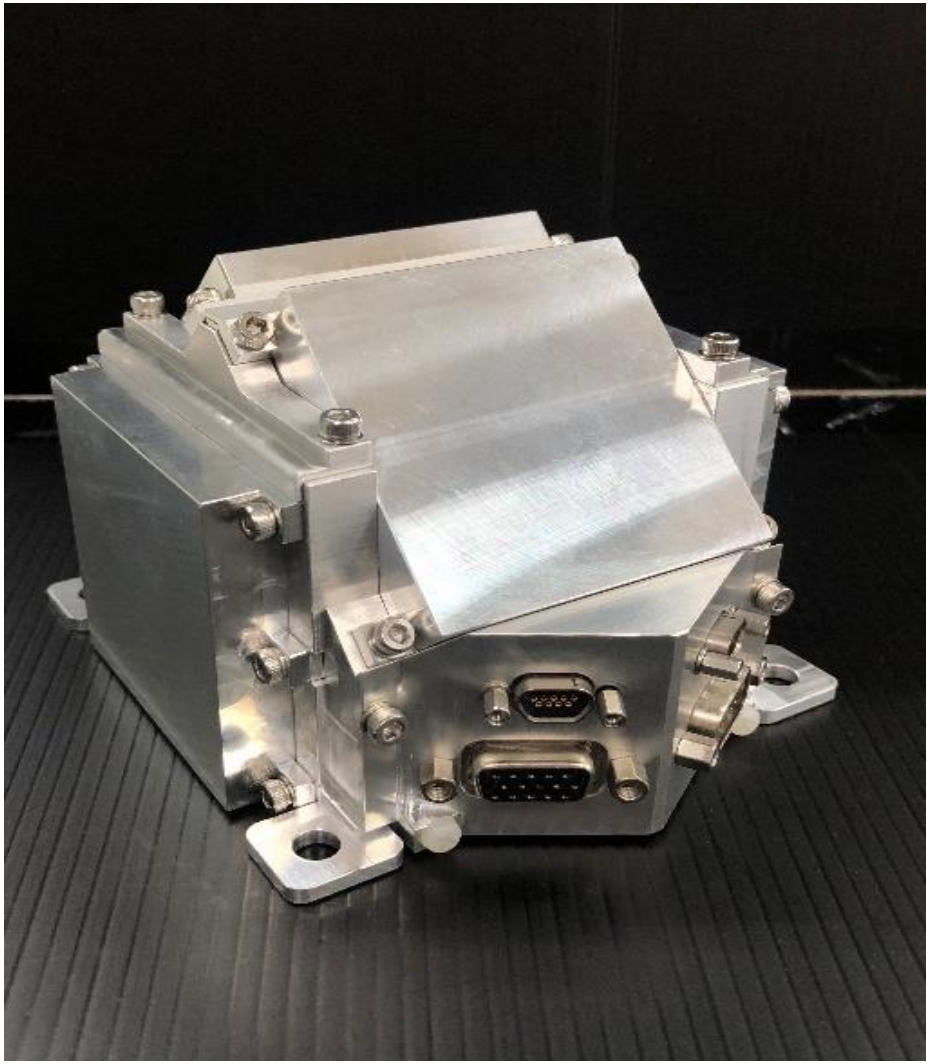




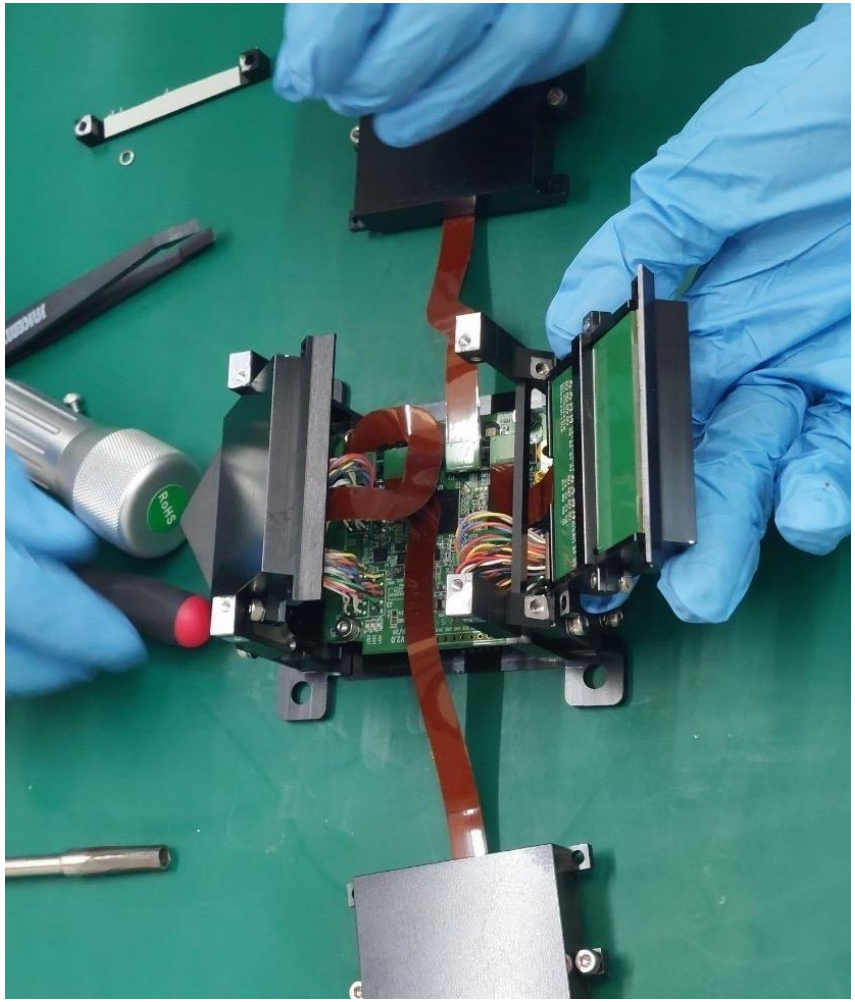


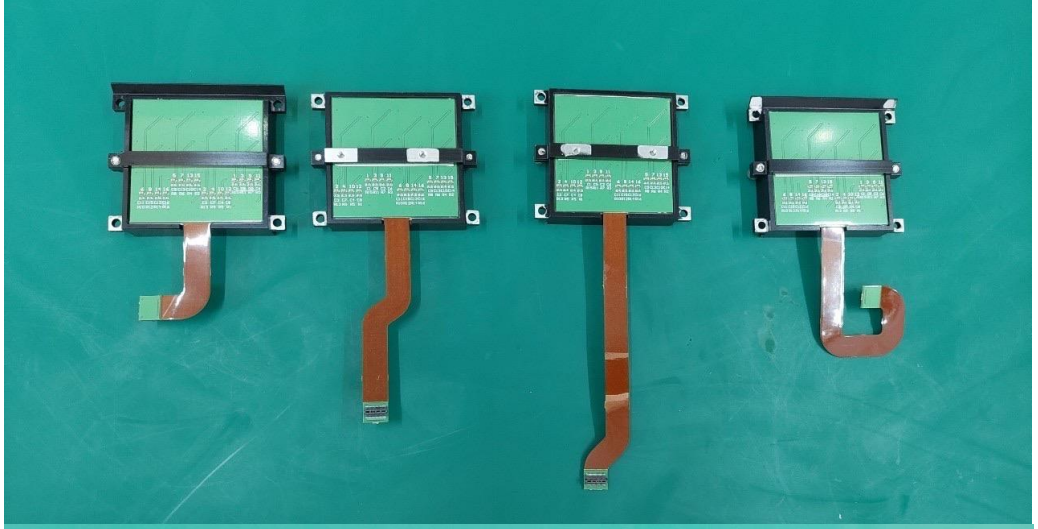
EM assembly

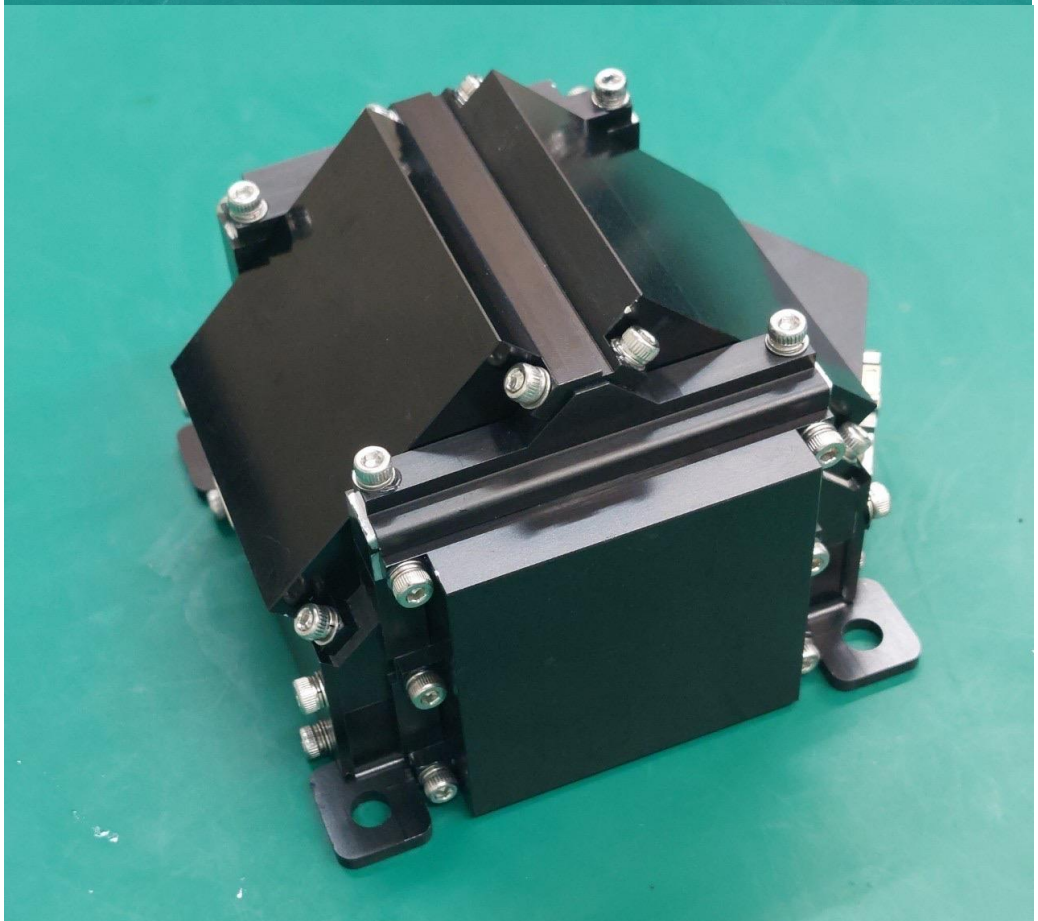


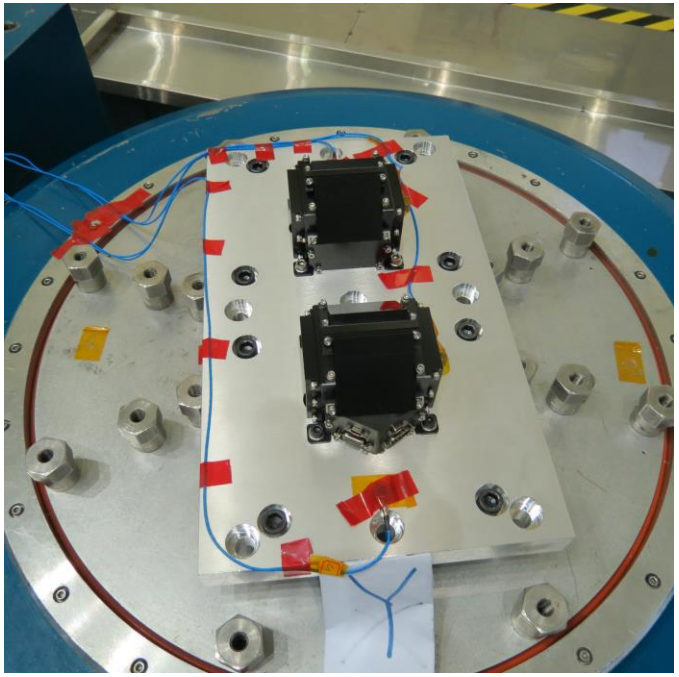


EQM assembly

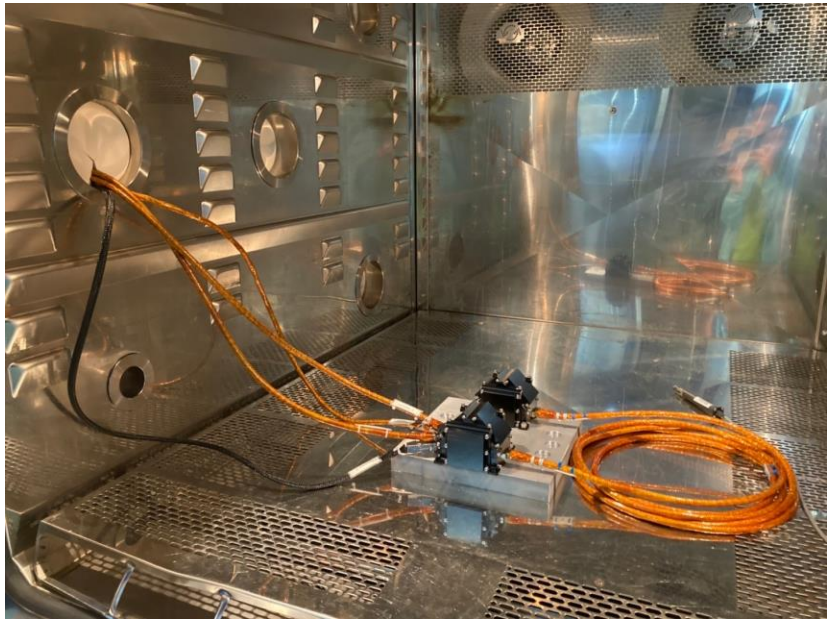


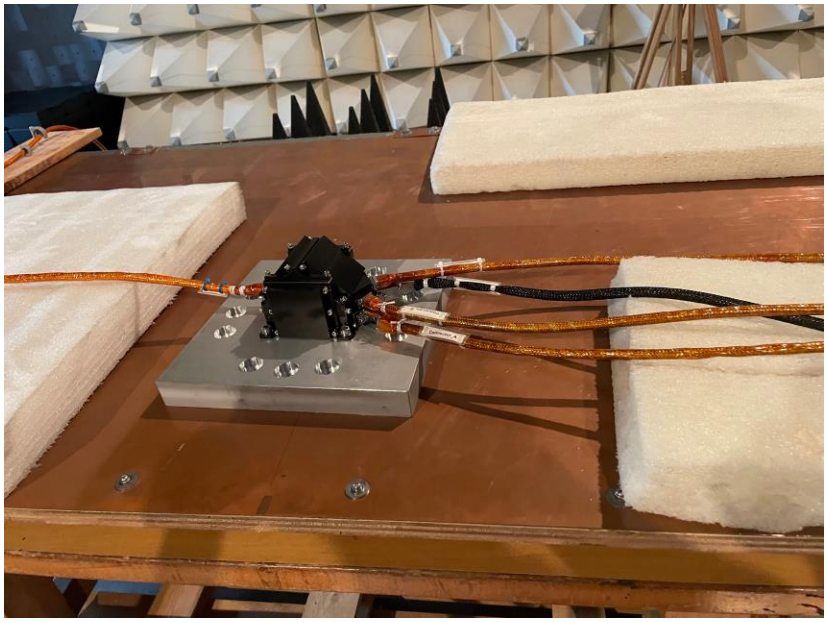


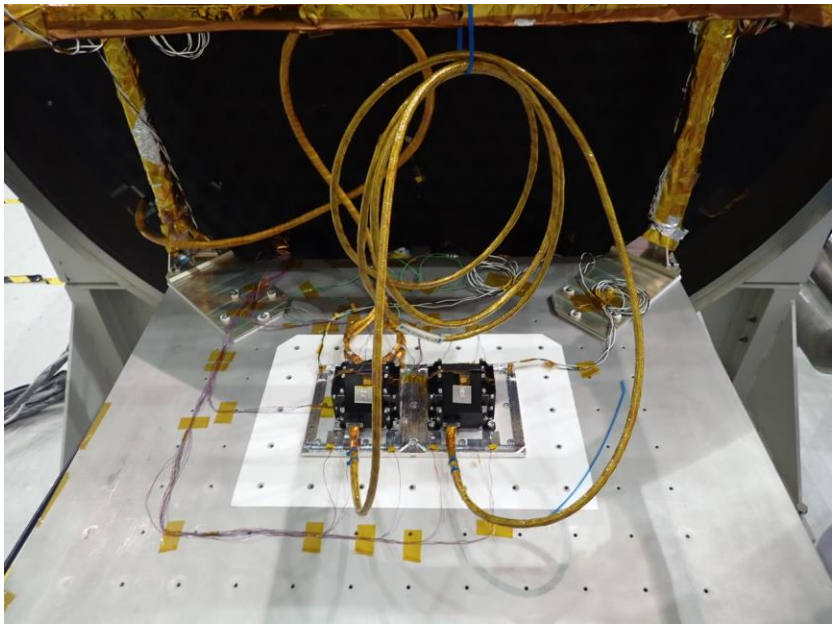


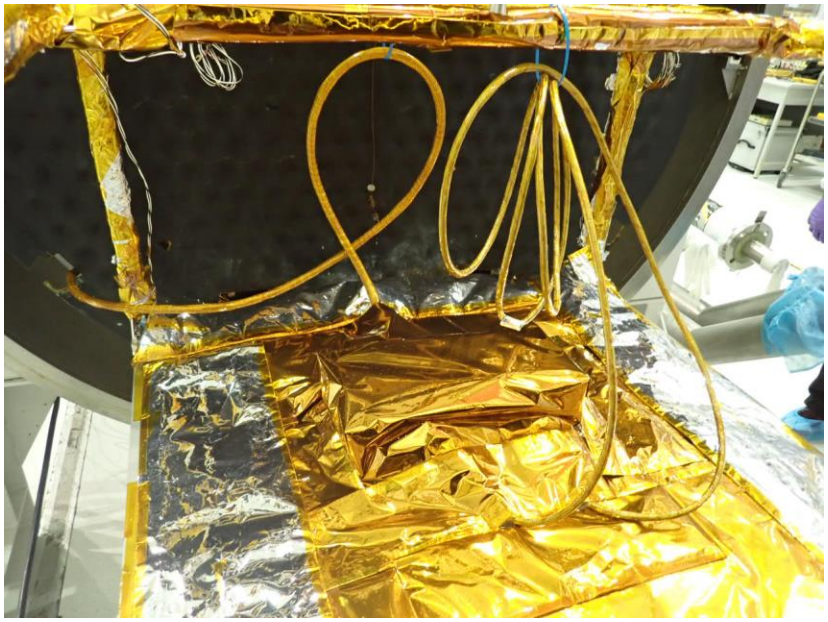


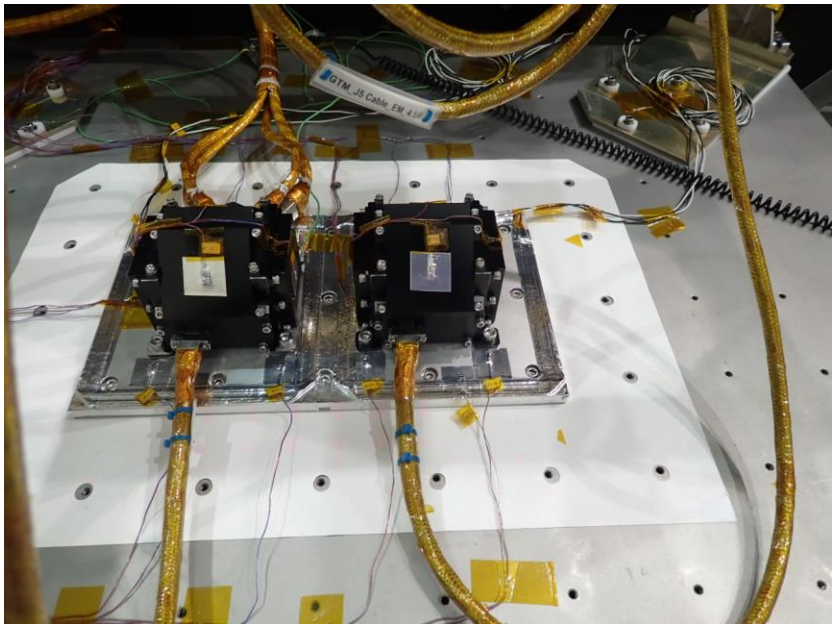
GTM EQM functional, vibration, thermal cycle and EMC/EMI tests (Sep-Oct, 2022).









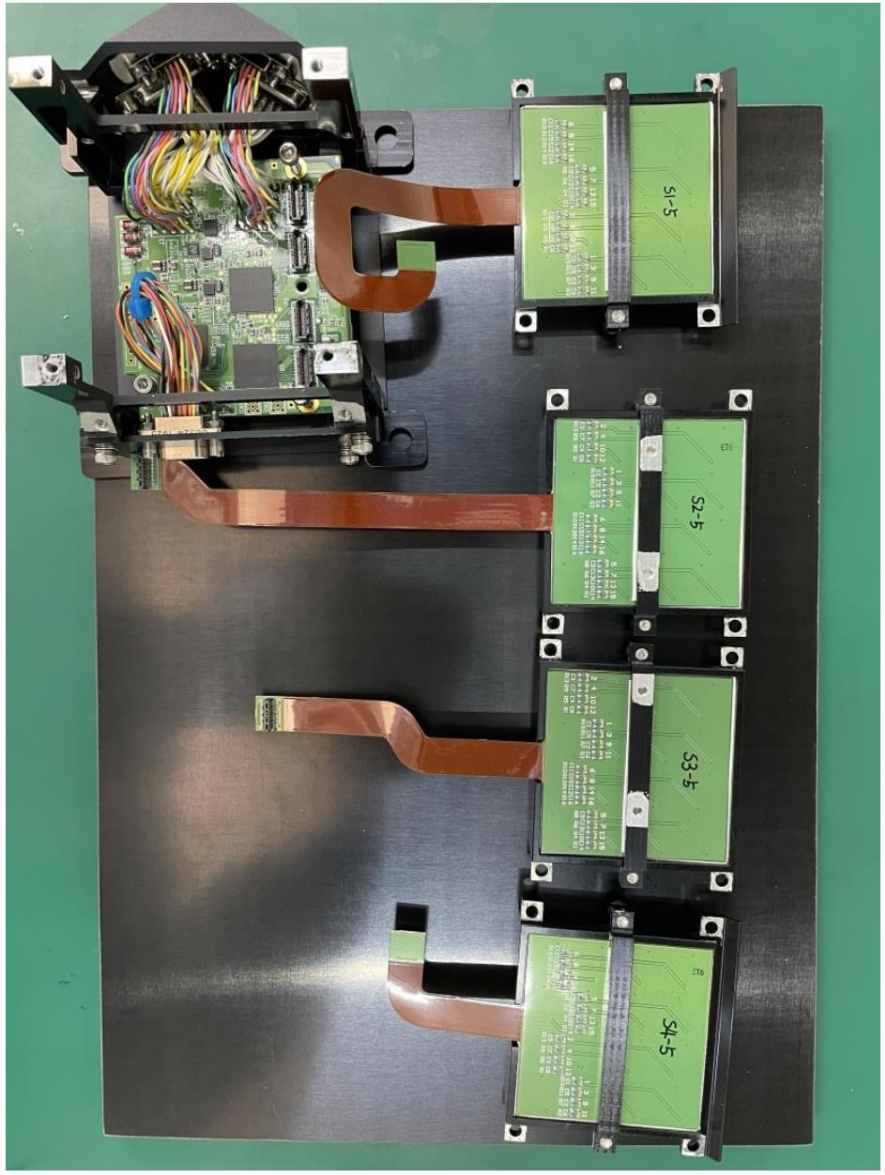


GTM EQM thermal vacuum test in January 9-13, 2023

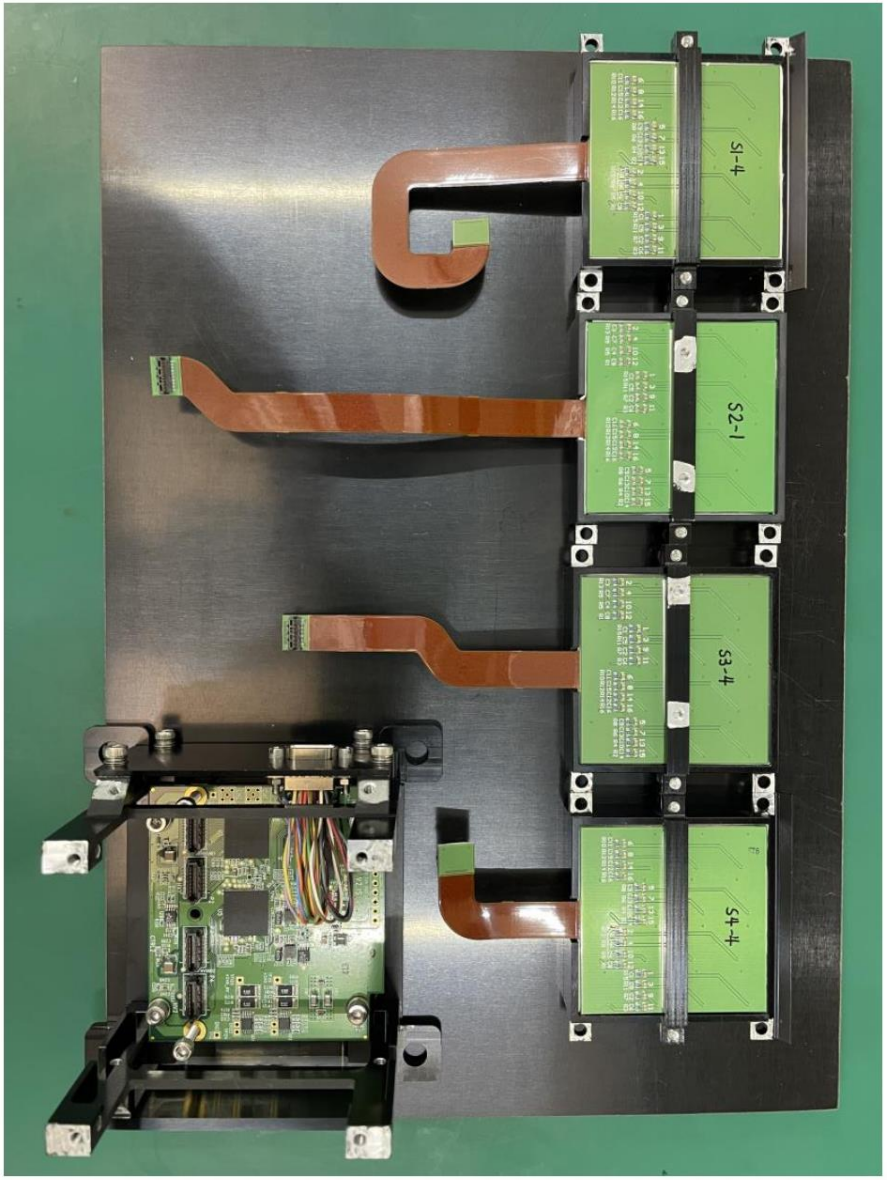
GTM Flight Model (FM) assembly (March 6-7, 2023)

GTM Flight Model (FM) assembly

Master

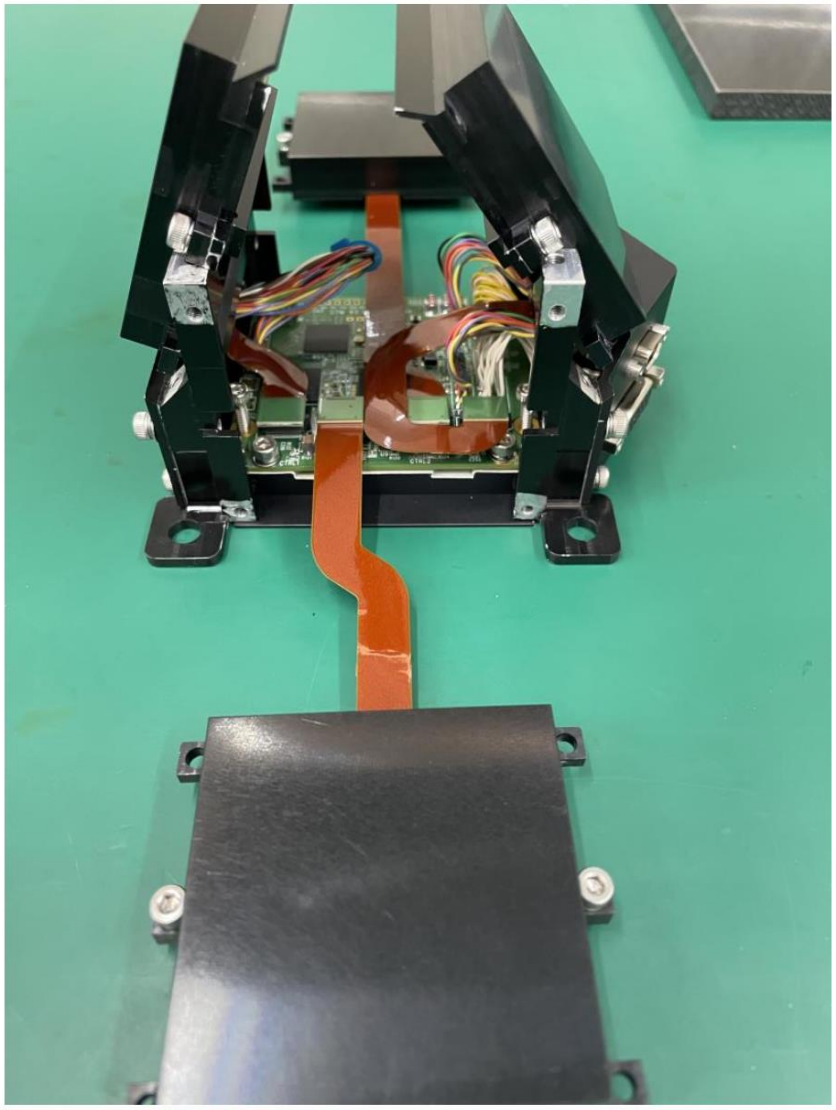


Slave

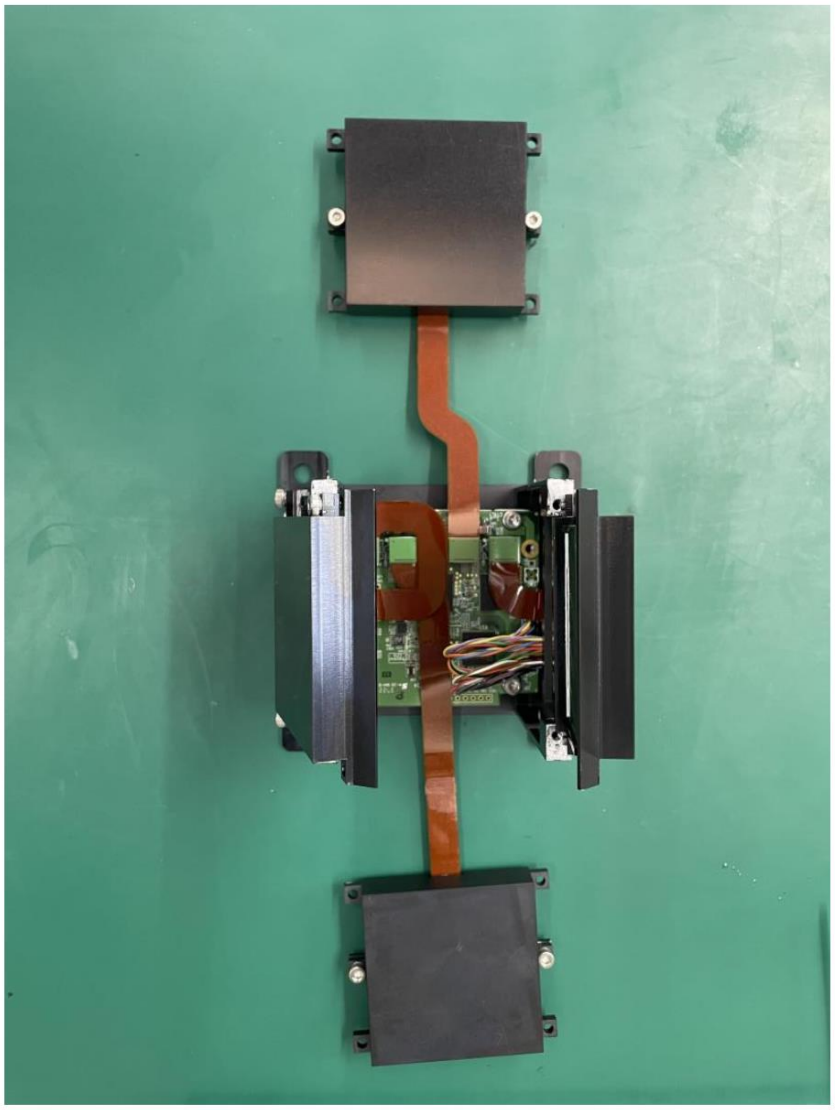


GTM Flight Model (FM) assembly

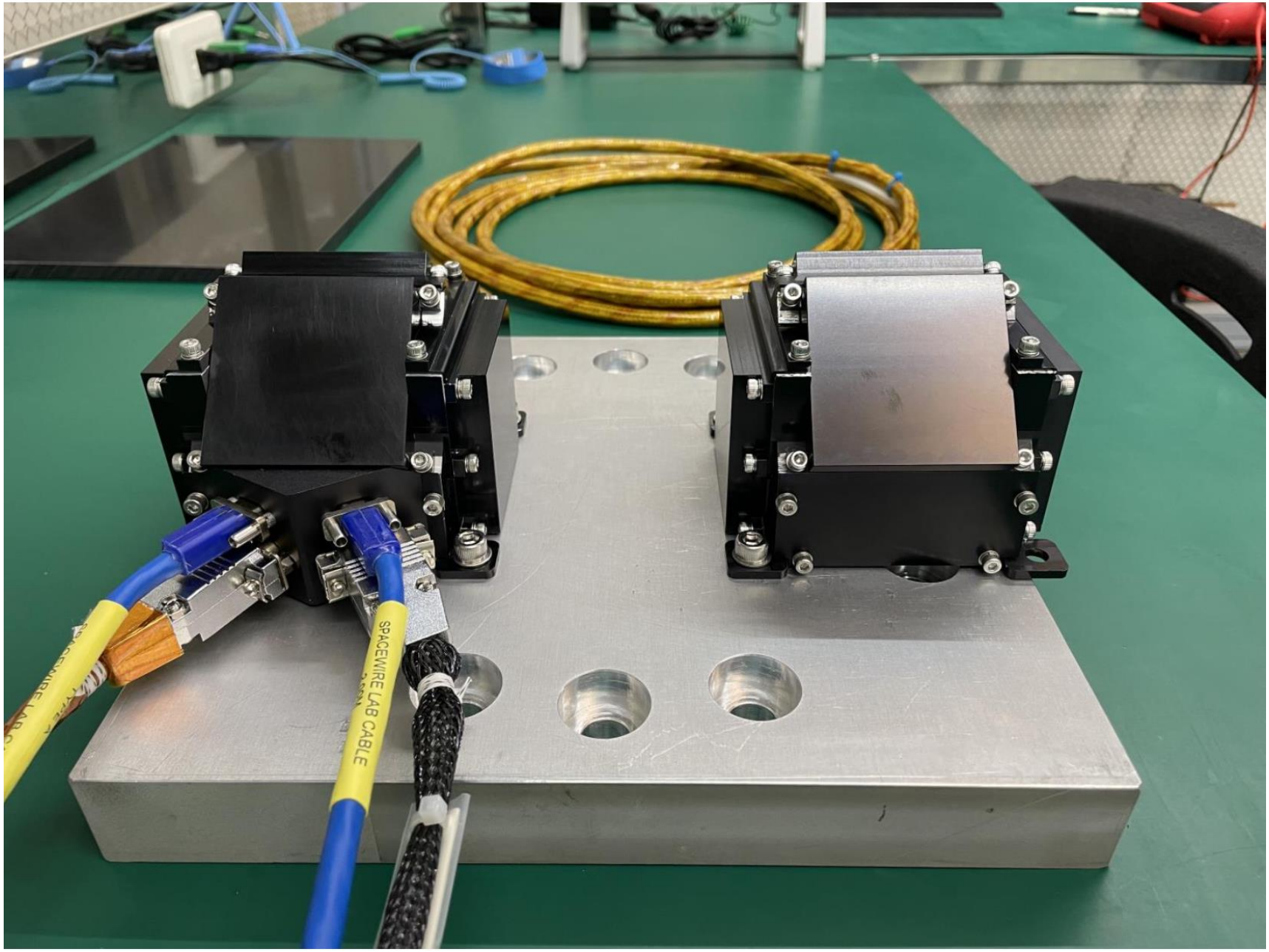
Master



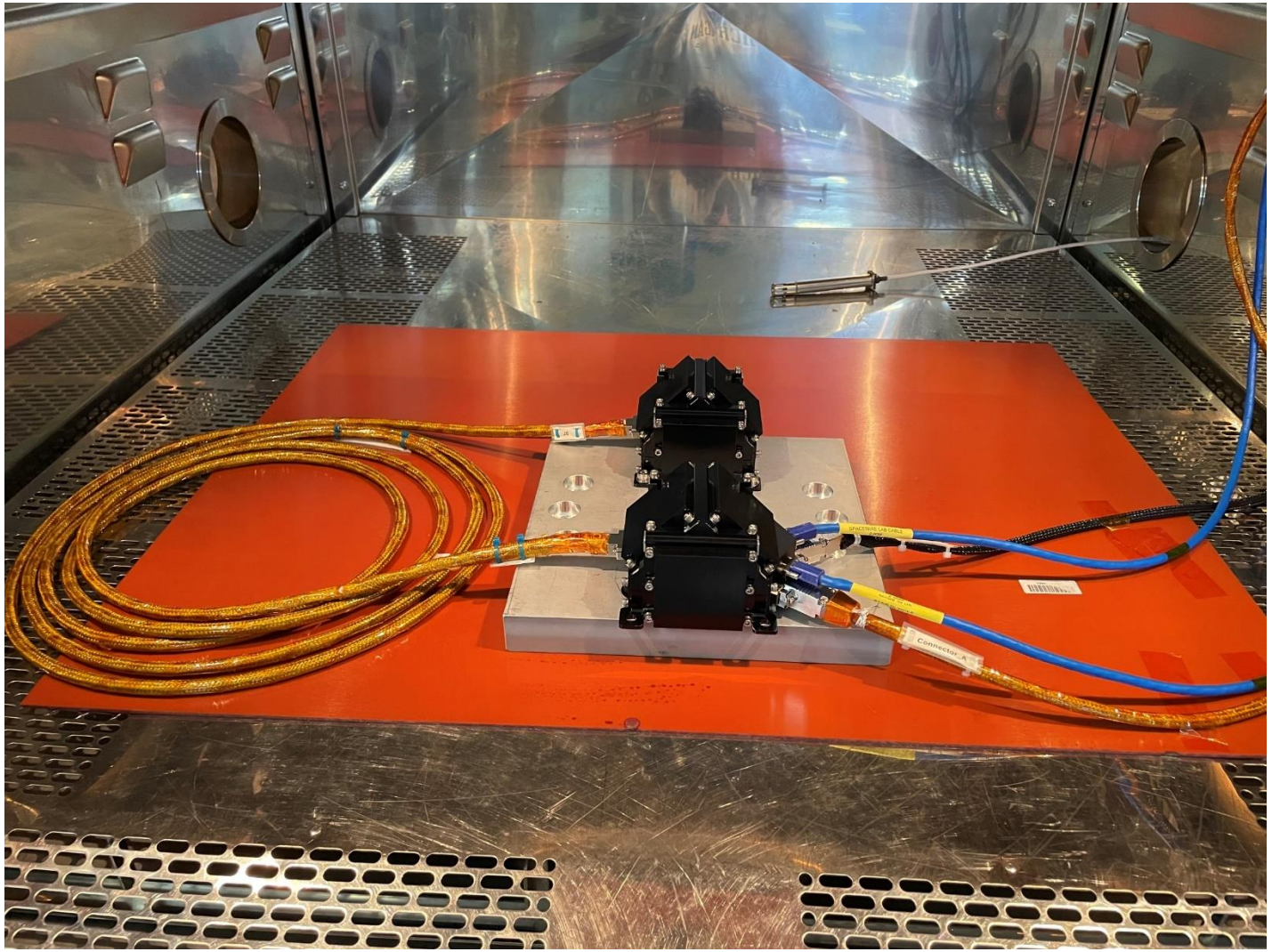
Slave



GTM Flight Model (FM) assembly



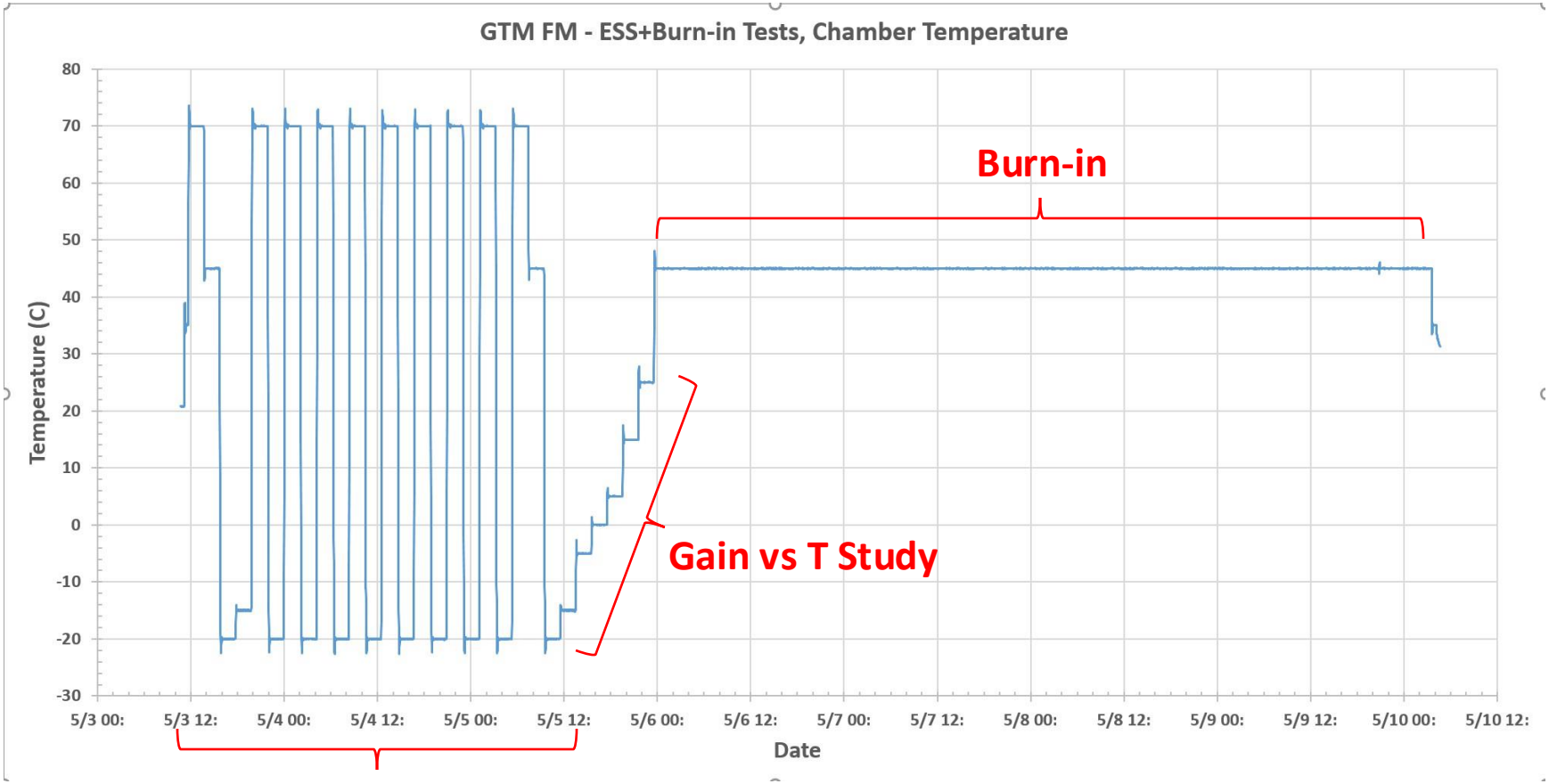
GTM FM ESS+Burn-in Tests - Setup



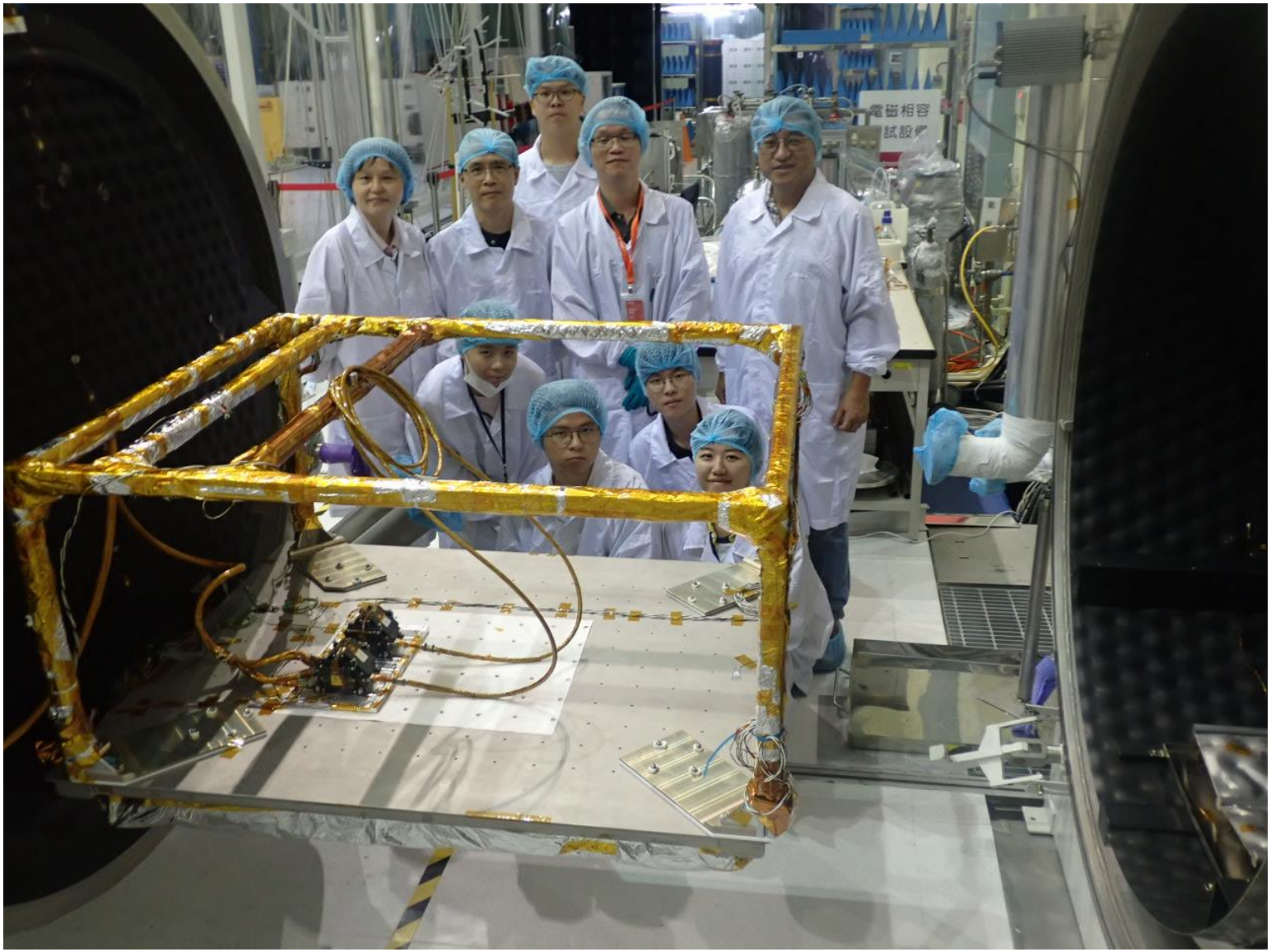
(May 3-10, 2023)

GTM FM ESS+Burn-in Tests – Chamber Temperature Log

- **Non-operation: -20°C to 70°C**
- **Operation: -15°C to 45°C**

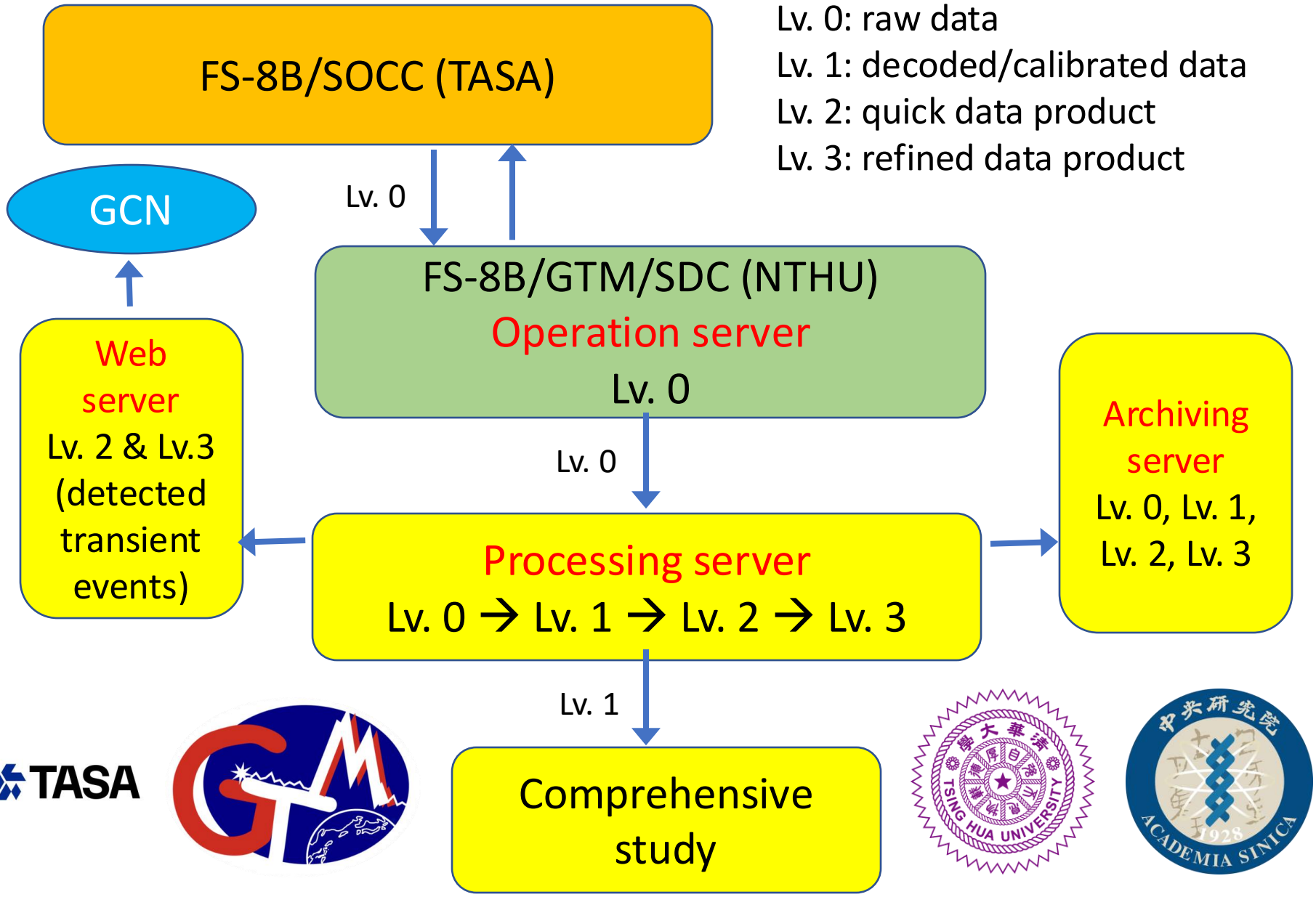


GTM FM TVT successfully completed

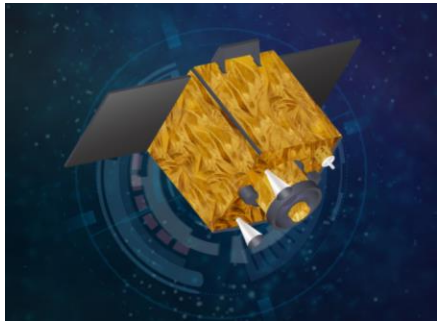


(Aug. 28, 2023)

FS-8B/GTM data flow



Current status (February 2025)



(TASA.org.tw)

- FM was delivered to TASA on September 8, 2023.
- SMRR was completed on October 23, 2023.
- Calibration measurements on ground are been conducted.

  (A paper submitted to NIMA is under review.)
- Integration with FS-8B bus will be in 2025.
- Waiting for the launch in 2026.
- We are also working on a GTM successor, which is more optimized for polarization measurement.

The GTM Team