Development of TSUBAME Observing System

A satellite for X-ray polarimetry of Gamma-Ray Bursts

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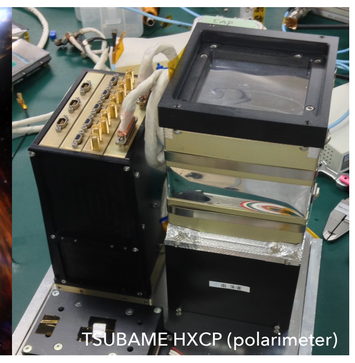
Hard X-ray polarimetry of Gamma-Ray Bursts (GRBs) is believed to be one of the promising methods to reveal the nature of the central engine of GRBs. TSUBAME is a micro-satellite developed by Tokyo Institute of Technology and ISAS for measuring polarization of hard X-rays from GRBs. It has two science instruments: Wide-field Burst Monitor (WBM) and Hard X-ray Compton Polarimeter (HXCP). WBM detects GRBs and determines their positions. Then, TSUBAME changes its attitude using Control Moment Gyroscope and starts polarimetry using HXCP within 15 seconds after detections. In 2013, calibration of instruments was finished, and they passed the vibration test at the AT level ensuring that they withstand the launch. We also developed software for autonomous GRB observation and instruments' protection. TSUBAME is now scheduled to be launched on the first half of 2014. In this paper, we review the design of the instruments and the software.

1. Polarimetry of GRBs


The images of GRB ©NASA


TSUBAME HXCP (polarimeter)

Scientific motivation: GRBs are still misterious:
-How to drive the fireball jets?
-How to radiate gamma-rays?

X-ray polarimetry at prompt emission is believed to provide crucial information of magnetic fields in the emission region.

Detector design:

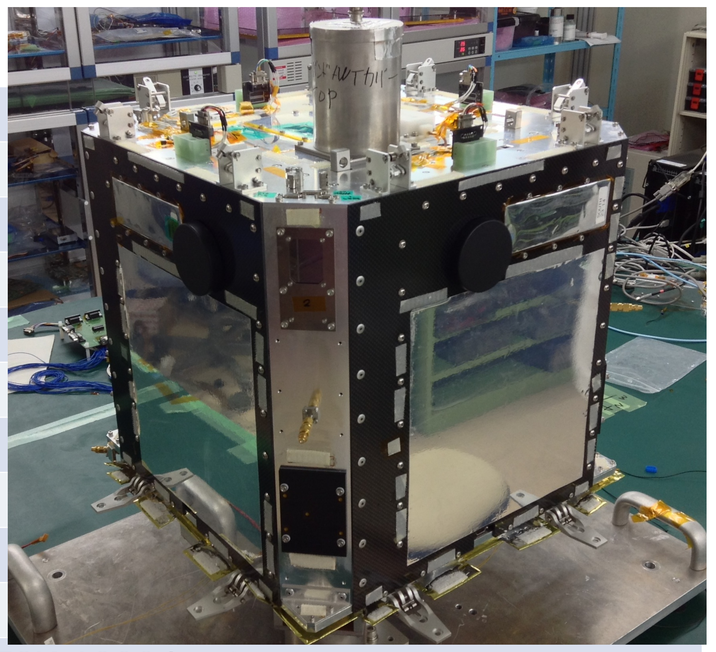
TSUBAME has two science instruments:

1) Hard X-ray Compton Polarimeter (HXCP) for high precision polarimetry, and
2) Wide-field Burst Monitor (WBM) for GRBs detection & localization.

Because HXCP has uni-directional sensitivity, WBM detects & localizes GRBs and then TSUBAME starts attitude maneuver to align the HXCP axis in the GRB's direction.

2. BUS System Specification

Size	500x500x430 mm^3	
Mass	50 kg	
Mission life	1 year ~	
Orbit	600 km (Sun synchronous)	
Launch	the first half of 2014	
Structure	Solar array panel deployment	
EPS	Cell	InGaP/InGaAs/Ge
	Power	134 W (EOL)
	Battery	Li-Polymar
Comm.	Tx	S-band (BSPK-100 kbps)
		UHF (CW/GMSK-9600bps AFSK-1200 bps)
	Rx	VHF AFSK-1200 bps
ADCS	3-axis zero momentum control	
	Actuator	Control Moment Gyroscope / Magnetic Torquers
	Sensor	Gyro (MEMS/FOG), Sun Sensor, Magnetometer, Star Tracker, GPS



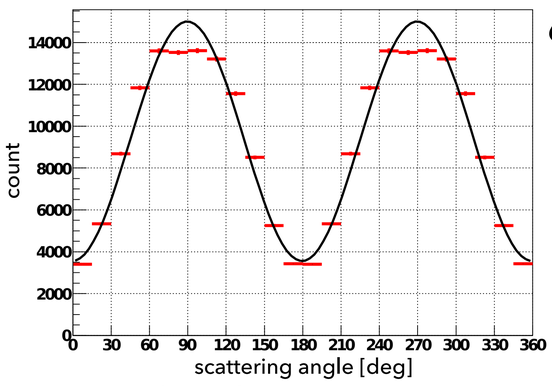
TSUBAME is the 4th satellite of Tokyo Tech. For the science missions, the satellite bus has

1) 6 deg/s high speed attitude control system,
2) 100kbps S-band RF transmitter for mission data downlink,
3) 134W large area deployable solar array panels.

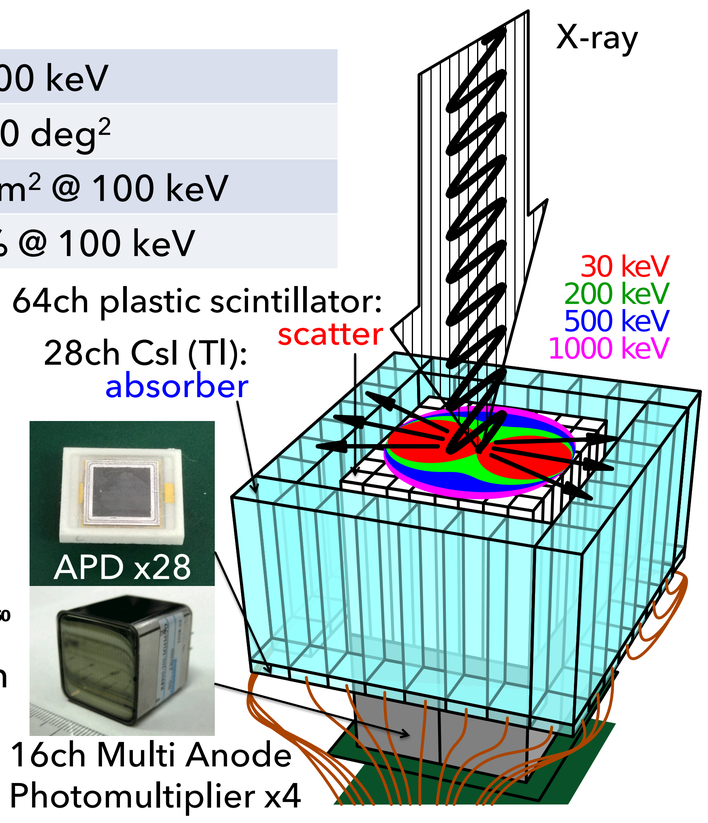
3. Hard X-ray Compton Polarimeter

Linearly polarized photons are scattered preferentially perpendicularly to the incident polarization vector. The HXCP measures polarization from this angular dependency.

Energy Band	30-200 keV
Field of View	30x30 deg^2
Effective Area	7.1 cm^2 @ 100 keV
Detectable Polarization	3.9 % @ 100 keV



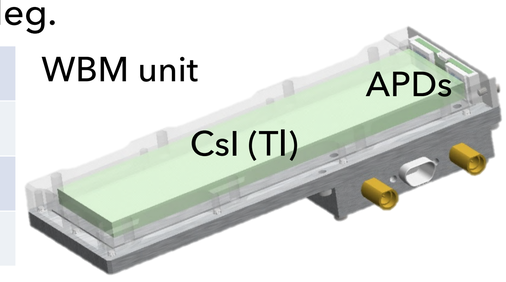
Result of Performance test with 80 keV on-axis polarized X-ray.
MF = 68.5 ± 0.3 %

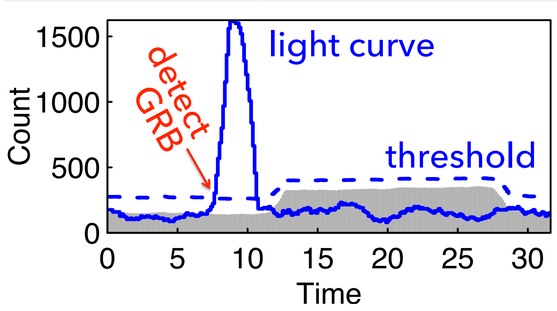


4. Wide Burst Monitor

The WBM consists of five scintillation counters mounted on the surface of the satellite. By comparing the count rates, it determines the positions of GRBs with an accuracy of ~5 deg.

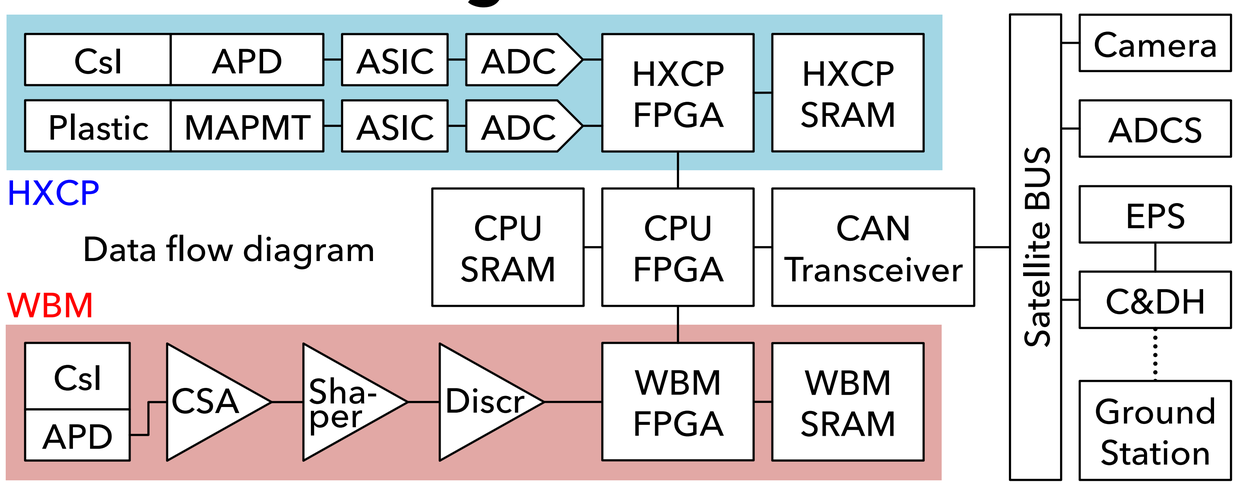
Energy Band	30-200 keV
Field of View	2π str
Effective Area	3560 mm^2/unit @ 100 keV
Accuracy	~5 deg (GRB021206)





The WBM checks the count rate every 0.125sec. if the count rate increases significantly comparing with the BG fluctuation, WBM judges GRB to be occured.

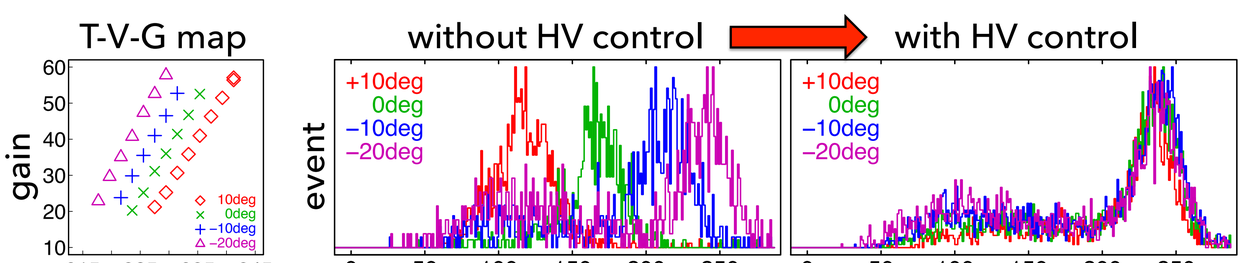
5. Data Handling



During observation, the data from the detectors is stored to SRAM respectively. After observation, the CPU send the data to C&DH flash memory from which we downlink the mission data. The current maximum size of data is ~5MB. Because Most of the data is from HXCP, we now trying to shrink it.

6. Detector Protection

Since the APDs' gain depends on its temperature, the CPU controls applied APD HV value to keep the gain stable, and to avoid HV breakdown.



In orbit, there are some regions that TSUBAME is exposed to high levels of radiation such as South Atrantic Anomaly. The CPU reduces applied photomultiplier HV value based on the orbit information and the WBM BG rate at there.