Design and evaluation of a MeV gamma-ray camera aboard a 50-kg class small satellite

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Abstract: Waseda University and Tokyo Tech are developing a 50-kg class small satellite, tentatively named INSPIRE, scheduled for launch in FY2026. The satellite’s primary detector is a BOX-type Compton Camera (CC-BOX). This camera covers a dynamic range spanning two orders of magnitude: it observes low energy (30 keV – 200 keV) in Pinhole mode and high energy (200 keV – 3 MeV) in Compton mode. The CC-BOX comprises a pixelized Ce:GAGG scintillator array and an MPPC array operating at 40V. The absorber features a four-layer, 20mm thick depth-of-interaction (DOI) structure. Additionally, Ce:GAGG elements are positioned on the sides of the detector to enhance its sensitivity than traditional Compton Cameras. For the observation of low-energy gamma rays, the scatter has 5mm square holes to facilitate pinhole imaging. Furthermore, BGO shields are positioned on the side and bottom of the detector for efficient event rejection. In this poster, we begin by detailing the design of the CC-BOX, its data processing flow and power specifications. Next, we assessed the detector’s anticipated performance through simulations, focusing on detection sensitivity, imaging resolution, energy resolution, and anticipated spectra when observing the Crab Nebula. Finally, we share the findings from a series of environmental tests in preparation for the FY2026 launch.

Introduction

- MeV Gamma-ray Astronomy
  - Nuclear gamma-rays are abundant
  - The origin of rare metals (Pt, Au ++)
  - Blackhole, Gravity waves, kilonova...
  - But...
    - It is necessary to observe in space
  - Background (CXB, Albedo) > Signal

MeV Gamma-ray is difficult to detect

Our Motivation

- 50-kg class satellite: Low cost (~2M USD), Short-term development (~3yr)
- Performance comparable to COMPTEL

Detector - INSPIRE -

- BOX-type Compton Camera (CC-BOX)
  - Scintillator: Ce:GAGG array
  - veto shield: BGO plate
  - photon detector: MPPC array

Spatial Resolution
Scatterer: 1mm Rear: 2mm
Energy Resolution
Ce:GAGG: 9% (FWHM) @662keV
BGO: 16% (FWHM) @662keV

characteristic
- Active Pinhole: Low-Energy detection
- Rear DOI: Sensitive to high-Energy
- Absorber-side: Higher sensitivity
- BGO shield: BKG/escape event removal

Gamma-ray Detection Method

Pinhole-mode
Compton scattering

Data Processing & Power specifications

- Detector Part
- DAQ Part
- Electric Power: ~18W

Satellite BUS

Environmental tests for Launch

Performance - Geant4 simulation -

- Intrinsic Efficiency
- Continuum Sensitivity
- Line Sensitivity
- Angular Resolution Measure

Example Image

Crab Observation

Assumption
- Crab: Center
- CXB/Albedo: Isotropic radiation

10^5 s observation

Continuum Sensitivity

CXB: 55,866 evt
Albedo: 412,448 evt

Background removal
1D projection

Communication test

- High-rate data acquisition: ~20kHz
- MPPC signal readout using Raspberry Pi

Complete engineering model
- Vibration test, thermal vacuum test..