# Improvement of Expected Performance of MONSTER onboard HiZ-GUNDAM satellite

*The third annual conference of Transformative Research Areas (A), "Multimessenger Astrophysics"*
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## *ABSTRACT*

- Current development status of MONSTER, a visible & near-IR telescope onboard HiZ-GUNDAM
- Possible improvement of expected scientific performance of MONSTER, namely the detector system



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# List of my talk

1. Introduction - purpose of MONSTER onboard the GRB search satellite
2. Current Design Specifications of MONSTER
3. Key technical challenges in MONSTER development
4. Status of on-going works
   (1) BBM development of MONSTER Telescope
   (2) Imaging sensors
5. Possible improvement of scientific performances

Summary

# HiZ-GUNDAM satellite

## Wide field X-ray Monitor

**EAGLE** Exploration of Ancient GRBs with Lobster Eye

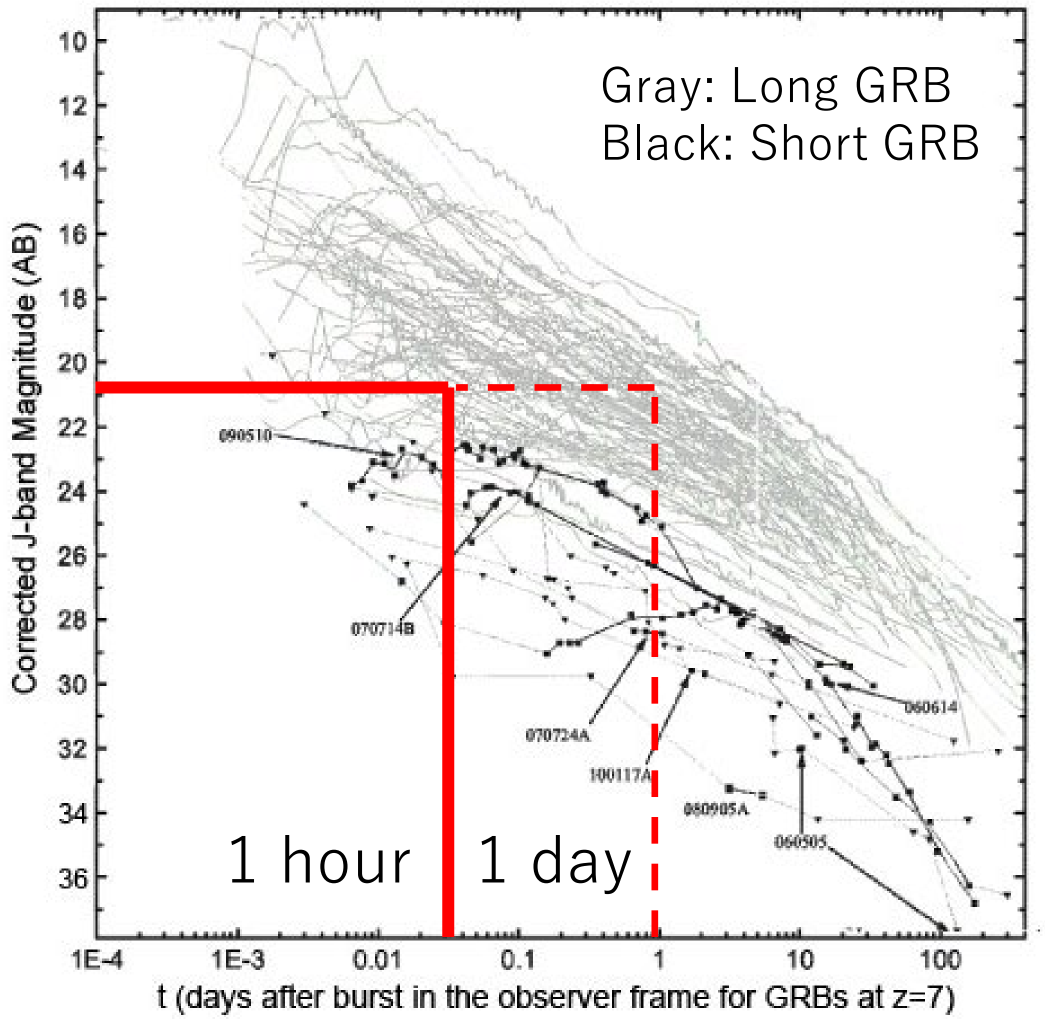
Satellite Bus (Attitude control. Data Handling, telecom. etc.)

## Visible and near-IR telescope

**MONSTER** Multiband Optical and Near-IR Simultaneous Telescope for Efficient Response

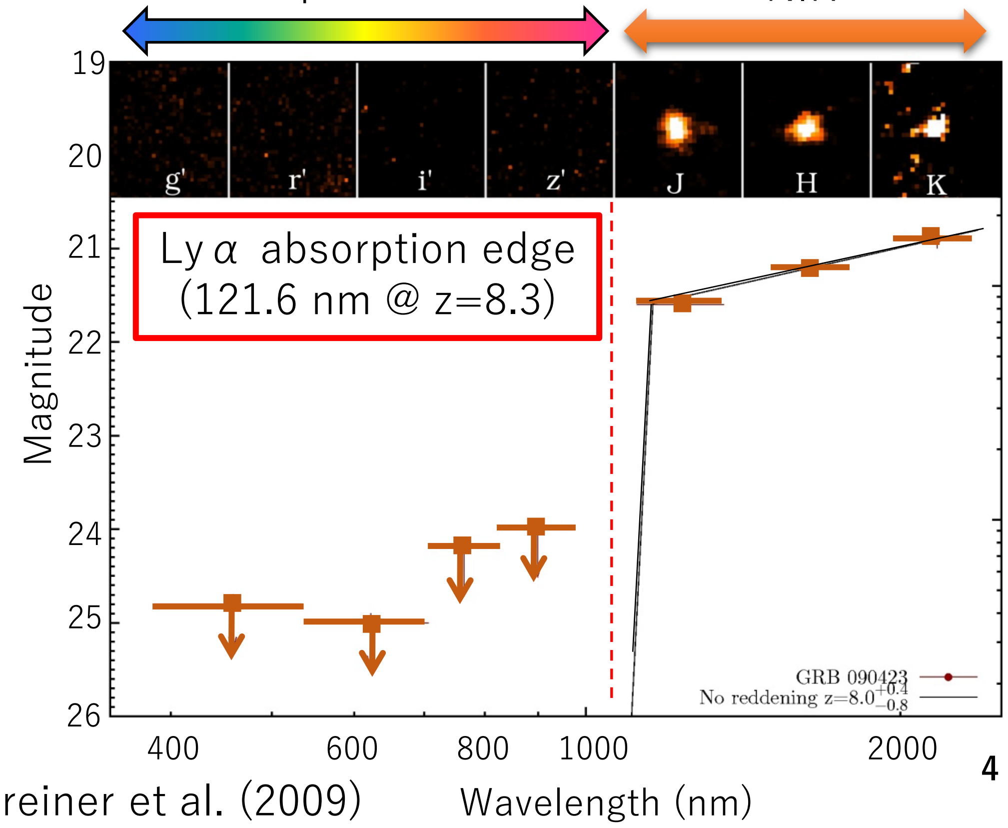
# 1. Introduction
# Quick follow-up is a Key to catch high-z GRB

Expected Light curve for GRBs @ z = 7




Based on Kann et al. (2010)

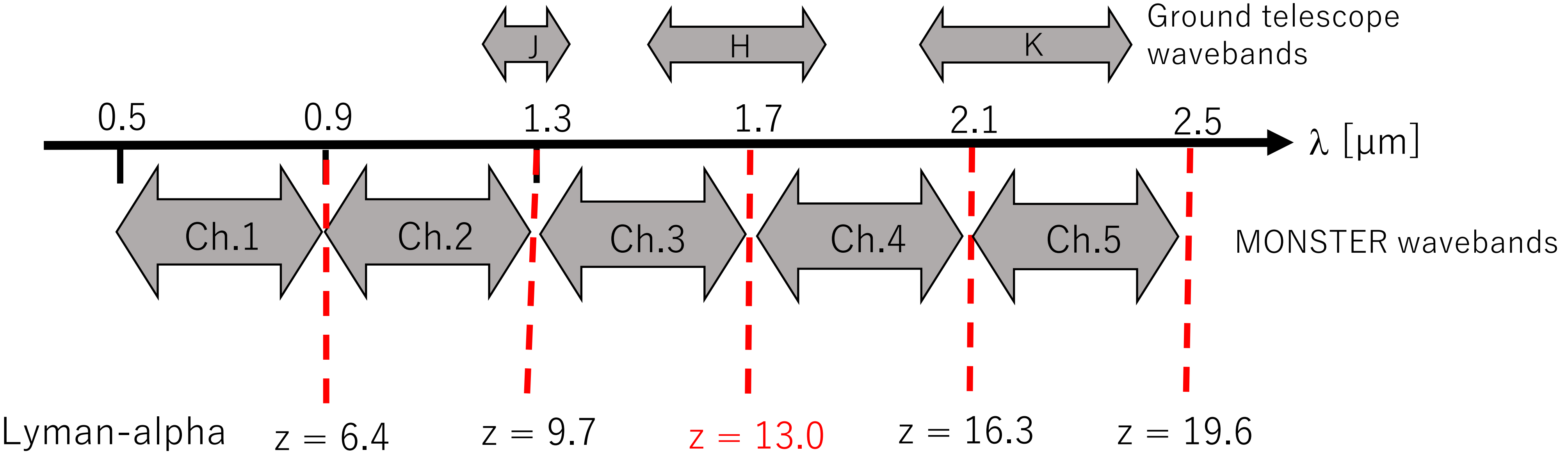
The afterglow is expected to be brighter than 21mag at 1 hour after the burst (in >90% probability)




Greiner et al. (2009)

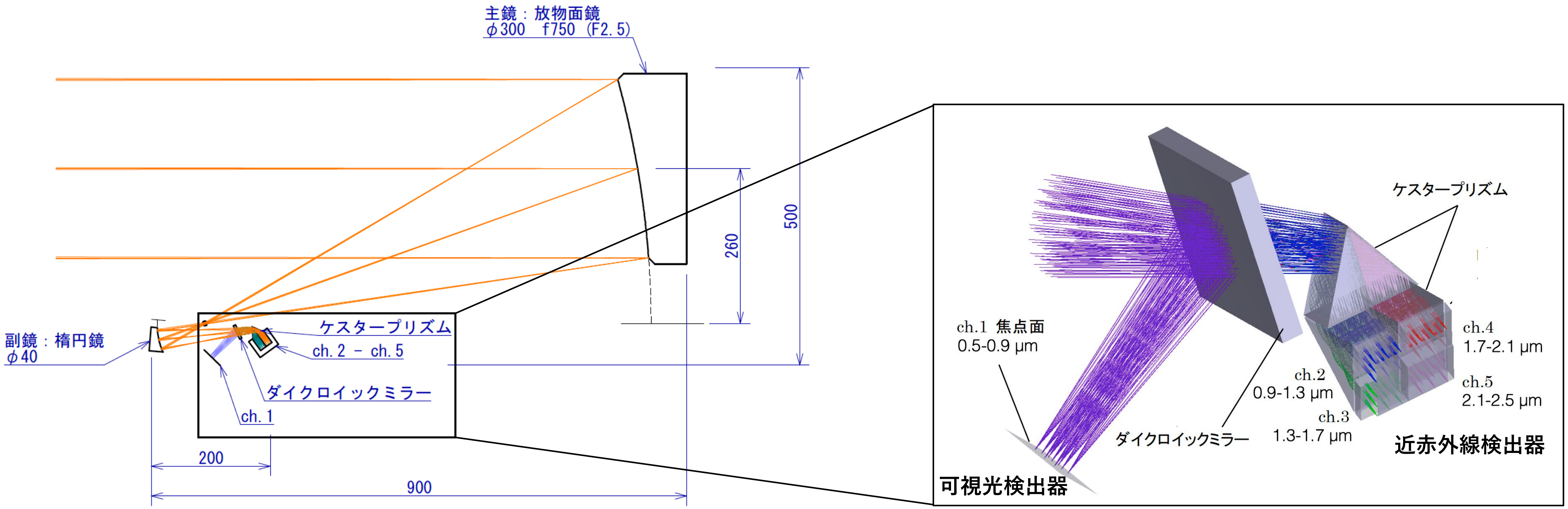
# 1. Introduction
# Purpose of MONSTER onboard the GRB search satellite

- **Rapid (goal: within 15 min) automatic follow-up** toward target detected by EAGLE
- **Identify GRB afterglow & estimate its (crude) photometric redshift**
  - Redshift can be determined with good accuracy up to z < 13.0.
  - In principle, detection is possible up to z < 19.6



# 2. Current Design Specifications of MONSTER

- A reflective (offset Gregorian) telescope with 30 cm aperture
- Simultaneous 5-band (visible + 4 NIR) imaging via dichroic mirror and a **Kösters prism**
- Field of View: 15 x 15 arcmin$^2$ (12 x 12 un-vignetted) : sufficiently larger than EAGLE error circle (3 arcmin radius)　two image sensors(visible and NIR) with 3 arcsec image quality
- Cooled Telescope : shall be below 200 K, while the NIR sensor is below 120 K by only passive, radiative cooling system
- Telescope structure: all aluminum, athermal design (similarly contraction by cooling)

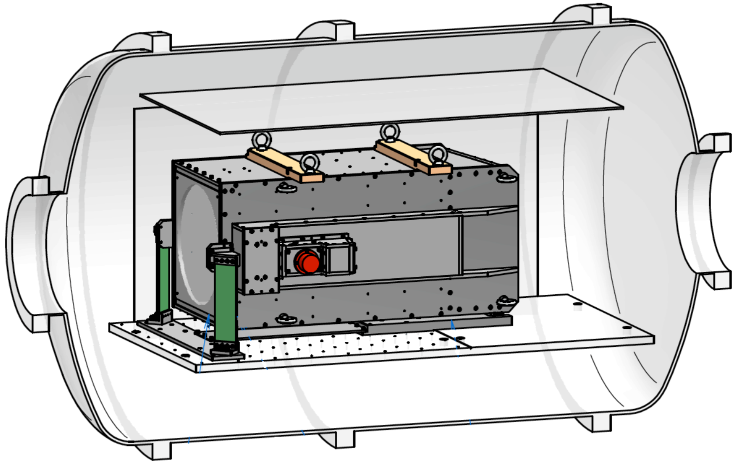


# 3. Key technical challenges in MONSTER development

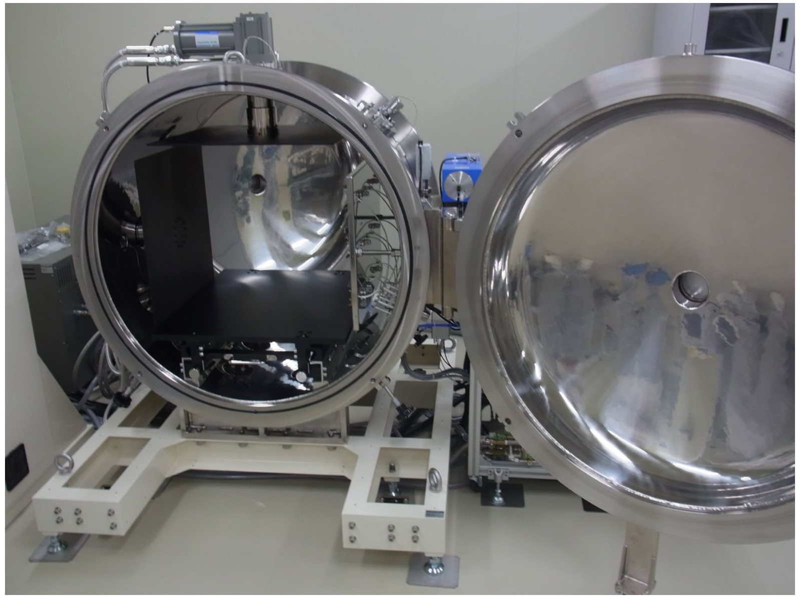
- Thermal design, with only passive cooling to cool and maintain telescope below 200 K, detectors below 120 K
  - industrial and inhouse study (see R. Kageyama's poster #62 for in-house study)
- Optical: god image quality shall be maintained at cold
  - Verification by BBM with "athermal design"
- Kösters prism development (see Hori's talk next)
  - a noble beam-splitter splitting incident light into multiple wavelengths on a single image sensor
- Image sensors (detectors) with electronics
- Onboard image data processing (see H. Niinuma's poster #57)

- With the financial support of *Transformative Research Areas (A), we expect to perform all of the above activities. Hereafter I'll introduce on:*
  - **BBM telescope development and test**
  - **Image Sensor development (commercial CMOS sensor for visible band)**

# 4. Status of on-going works
# (1) BBM development of MONSTER Telescope

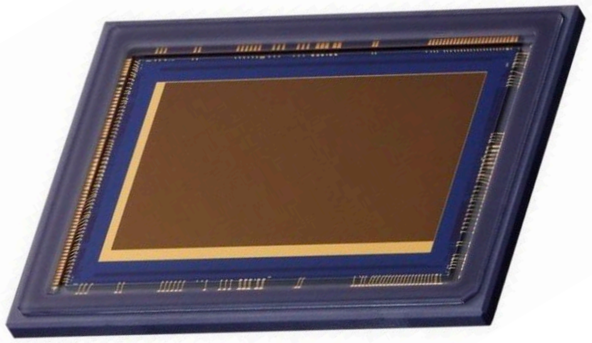


- Purpose
  - Verify the cryogenic optical performance is within the requirement
    - demonstration of athermal design (all major structure components are  made of Aluminum)

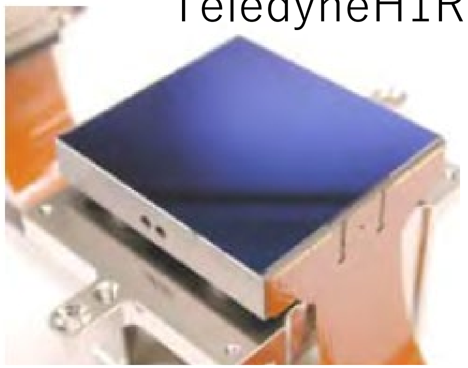


- Method
  - Modify the existing cryo-vacuum chamber at Kanazawa University
  - Image quality at cold is to be measured by introducing a ~30 cm $\phi$  collimated beam
- Planned Schedule
  - FY24: mechanical and thermal design of test configuration
  - FY25: design and fabrication of BBM mirrors and structures
  - FY26: BBM test in the cryo-vacuum chamber at Kanazawa University

# 4. Status of on-going works
# (2) Imaging sensors



Canon LI3030SAM



TeledyneH1RG

SIDECAR ASIC Focal Plane Electronics

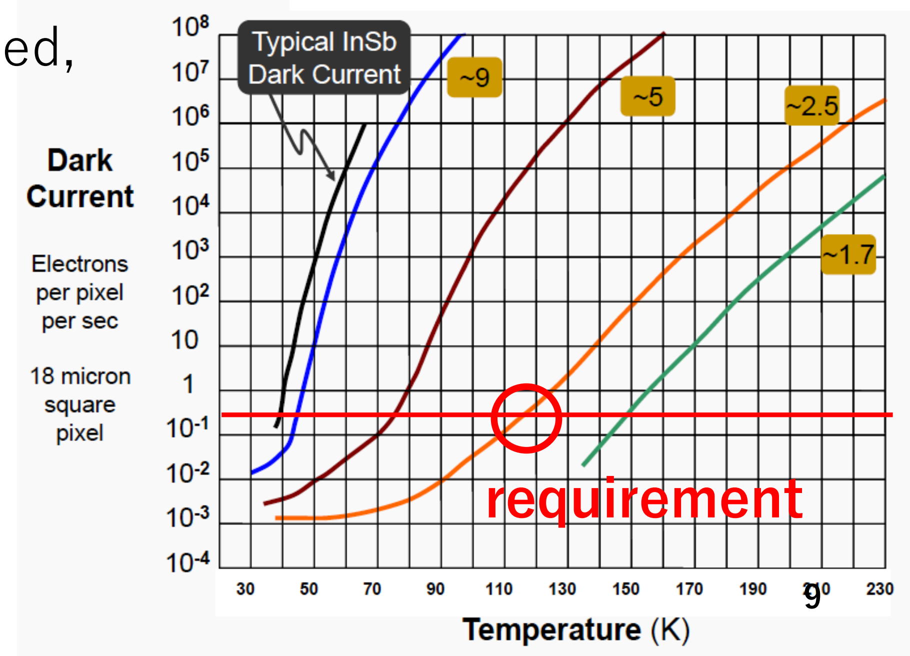
[ Visible-band detector ]

- Teledyne HyViSI or Canon LI3030SAM
- HyViSI is current baseline, but we also seek for the possibility to use commercially available C-MOS detectors
  - Canon LI3030SAM : Cryogenic and radiation tests completed, now onboard control/readout electronics is under study

[ Near-IR detector ]

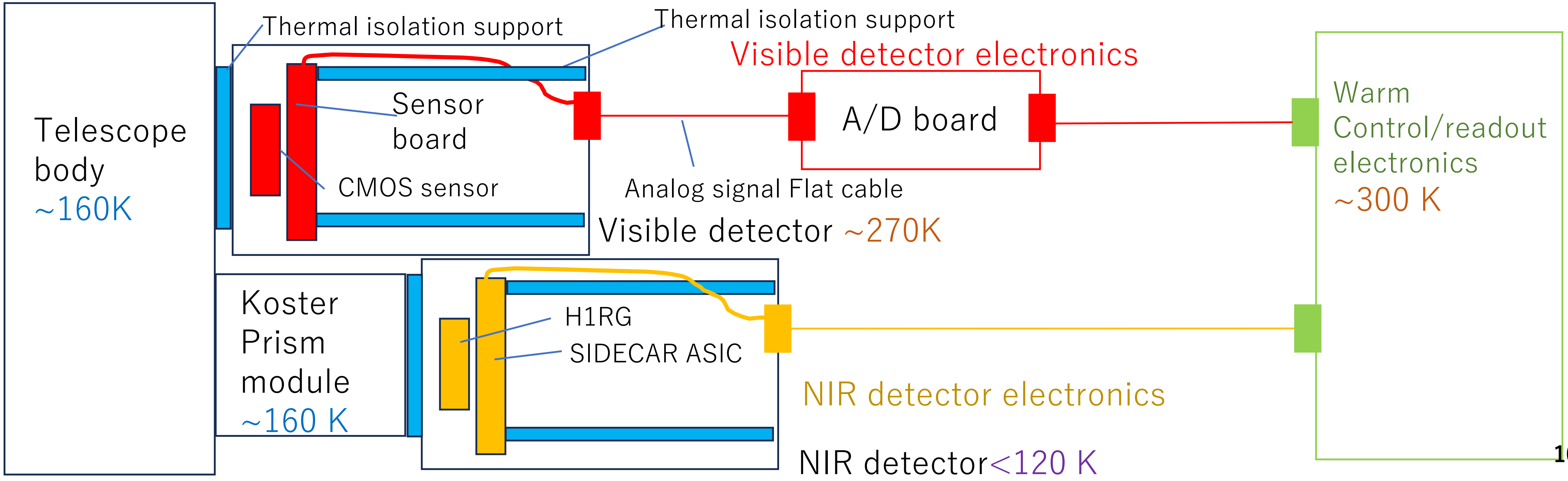
- Teledyne H1RG + SIDCAR (or ACADIA) ASIC
- Dark current must be <0.3 $e^{-}$/s from sensitivity requirement

  → temperature < 120 K



# 4. Status of on-going works
# (2) Imaging sensors： thermal/electrical architecture

- Challenges on commercial CMOS sensor onboard
  - Commercially used sensor normally provides us with fast (10~50 fps) readout but with large heat dissipation
  - but we only need relatively slow (0.1 – a few fps) readout but low heat dissipation → challenge in the readout/thermal design
  - In-house study (with help by two young JAXA members by a scheme of “intra-JAXA internship” )



# 5. Possible improvement of scientific performances

*Through our current activities we hope to obtain:*

- By BBM telescope development

  After verifying athermal design, we will also get how the image quality changes with temperature gradient

  → how much can we accept the earthshine illumination to telescope

  → improvement of GRB follow-up capability

- By Visible band detector development
  - Challenges: slow readout/low heat dissipation, thermal isolation
  - Once successful, this is the first visible sensor readout system onboard JAXA astronomical satellite!

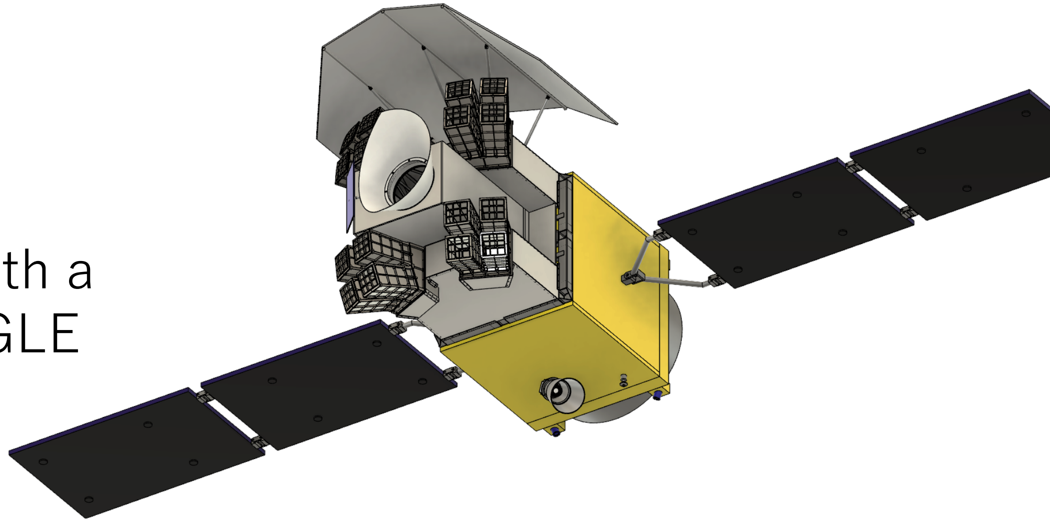
  ⇒Prospects to apply for future astronomy mission by JAXA
  - Obtain larger FoV for the visible channel:
    - LI3030SAM has 4-5 times larger format (with same pix size) than the HiViSI

# HyViSI vs Commercially available visible sensors

| | Teledyne HyViSI+SideCAR | Sony IMX533CLK | Gpixel GSENSE6060BSI | Cannon LI3030SAM |
|---|---|---|---|---|
| Pixel number (a) | 1024 × 1024 | 3015 × 3080 | 6144 × 6144 | 2160 × 1286 |
| Pixel size [μm] (b) | 18 | 3.76 | 10.0 | 19 |
| Size [mm] (a × b) | 18.4 ×18.4 | | 61.4 × 61.4 | 41.04 × 24.32 |
| A/D conversion | 16 bit | 14 bit | 14 bit | 14 bit |
| Efficiency | | | 95% @ 580 nm | 86% @ 550 nm |
| Readout Noise [e-] | 17 | | 2.3 (HDR mode) | 3.4 (rms, 40°C) |
| Dark current [e-/sec] | 0.3 | | 0.019 @ -55°C | 300 @ 60°C |
| Output | Digital | Digital | | Analog |
| Comment | Space Flight proven (e.g., JWST) | VERTEX (6U CubeSAT) | Operation guaranteed down to -55°C(218 K) | Space flight (nano-satellite) Tomo-e Gozen (@Kiso Obs.) |

**Baseline** **Option**

# Summary



- MONSTER onboard HiZ-GUNDAM will provide us with a rapid follow-up capability of targets detected by EAGLE

  (1) LARGE FoV (15 x 15 $\mathrm{arcmin}^2$)
  (2) simultaneous 5-band imaging at 0.5 – 2.5 μm
  (3) Passively cooled (radiatively) telescope (< 200 K), and a near-IR detector (<120 K)

- Possible improvement of science performances
  - BBM telescope ⇒ improvement of GRB follow-up capability
  - Visible detector ⇒ larger FoV for ch.1; application to future astronomy mission by JAXA
- Upcoming Plan (by FY2026)
  - Establish the thermal / mechanical design (in-house & industrial studies)
  - BBM optical performance test results will be available
  - Demonstration of CMOS visible sensor in space-use operation