

# Night-Time Color Imaging with High Resolution from a 35 kg Microsatellite

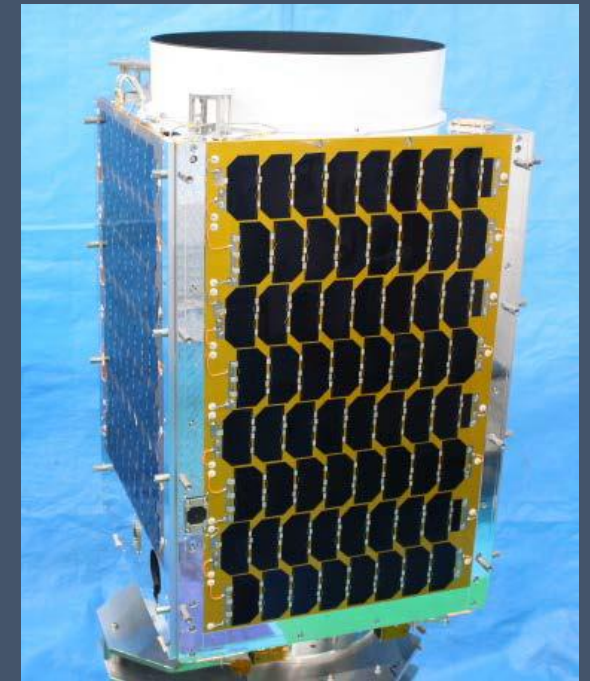
10<sup>th</sup> August 2021

Canon Electronics Inc.

Shinji Matsuzawa, Takuma Shibata, Tomoya Inakawa,  
Yoshito Niwa, Nobutada Sako

# Background

- Canon Electronics Inc. (CEI) launched its first satellite in 2017.
  - CE-SAT-I, a 65 kg microsatellite with 40 cm Cassegrain telescope, has been taking high resolution pictures for four years.
- CEI has been developing new products based on its key technique to expand space business.
  - Precision machining
  - Image process
  - Mass production
- CE-SAT-IIB was launched in October 2020 by Rocket Labs Electron.



CE-SAT-I FM

# CE-SAT-IIB Missions

- Demonstration of three types of optical systems
  - Two sizes of Cassegrain telescopes
  - COTS compact digital camera
- Validation of in-house developed components
  - GAS, SAS, STT, IRU, MTQ, and RW

# General Specifications



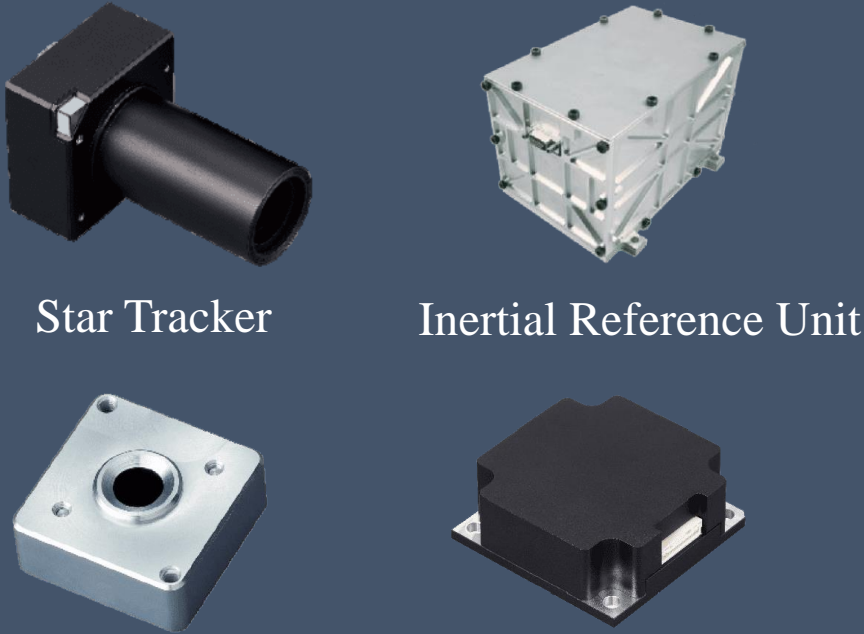
CE-SAT-IIB FM

Dimension	292 × 392 × 673[mm]
Mass	35.5 [kg]
Power	Average generation: 40 [W]
Communication	Up : 32 [kbps] in S band Down : 0.5/8.7 [Mbps] in X band
Attitude Control	Pointing : 0.19 [deg] Stability : $2.8 \times 10^{-5}$ [deg]/0.01 [sec]
Orbit	Sun synchronous orbit Height: 525 [km] LTDN 9:30

# Components

We are developing sensors and actuators for small satellites. Some of the sensors and actuators are used for ADCS of CE-SAT-IIB.

Sensors



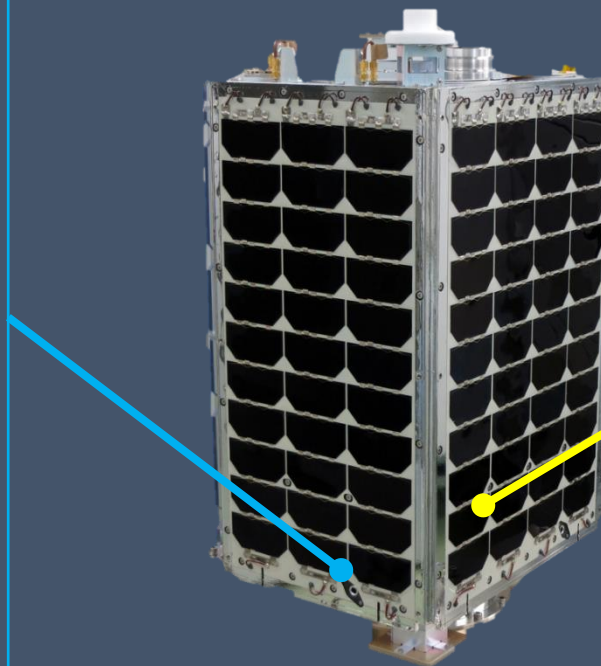
Star Tracker

Inertial Reference Unit

Sun sensor

Magnetometer

This block contains four sensor components arranged in a 2x2 grid. The top-left component is a black Star Tracker with a cylindrical lens. The top-right component is a silver, boxy Inertial Reference Unit. The bottom-left component is a silver, square Sun sensor. The bottom-right component is a black, square Magnetometer. A blue line connects the bottom-right corner of this block to the bottom-left corner of the central satellite image.



Actuators



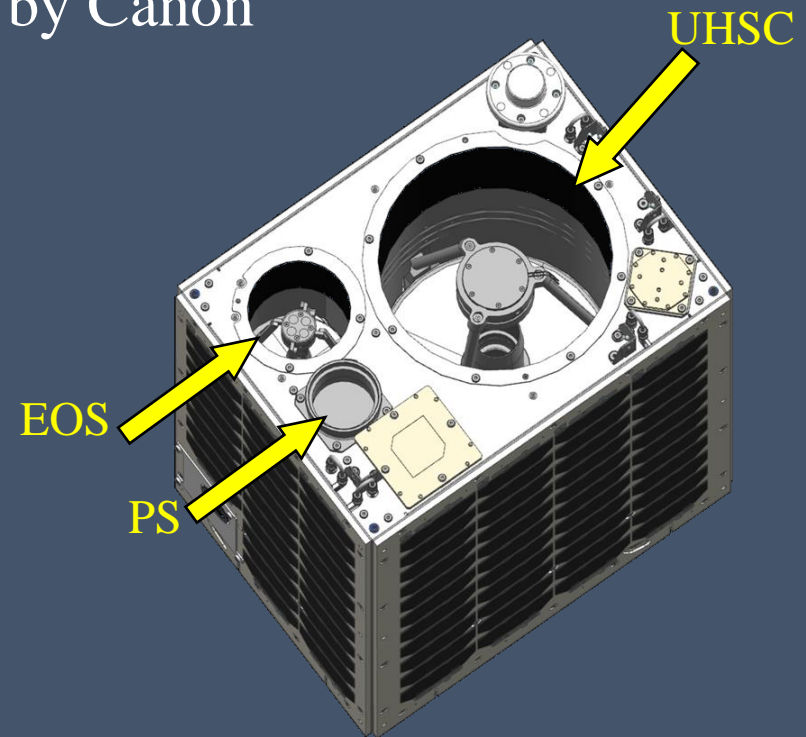
Magnetic torquer

Reaction wheel

This block contains two actuator components. The top component is a long, black, cylindrical Magnetic torquer. The bottom component is a black and silver Reaction wheel. A yellow line connects the bottom-right corner of this block to the bottom-right corner of the central satellite image.

# Optical Systems

- First camera is a newly-designed ultra-high sensitivity camera (UHSC).
  - 20 cm Cassegrain telescope
  - Ultra-high sensitivity image sensor developed by Canon
- Second camera is an 8.7 cm Cassegrain telescope with EOS M100 as a detector.
- Third camera is PowerShot G9X Mark II.



# UHSC Specifications

Main mirror diameter	200 [mm]
Focal length	1,860 [mm]
Telescope type	Cassegrain + correction lens
Detector + Image processor	Ultra-high sensitivity image sensor developed by Canon Detachable ND filters
Resolution	5.1 [mGSD]
Foot print	3.5 x 2.3 [km]

# EOS Specifications

Main mirror diameter	87 [mm]
Focal length	809 [mm]
Telescope type	Cassegrain + correction lens
Detector + Image processor	EOS M100 base
Resolution	2.3 [mGSD]
Foot print	5.6 x 3.7 [km]



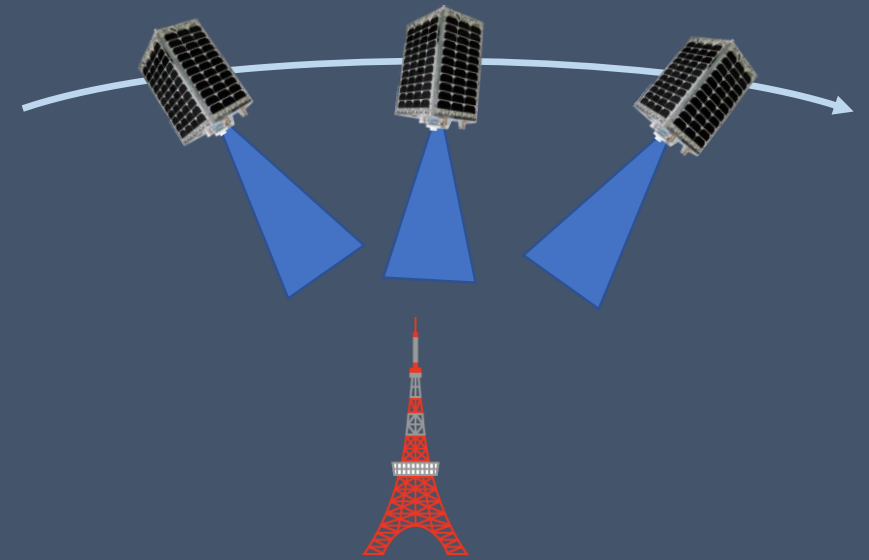
# PS Specifications

F number	2-11
Focal length	84-28 [mm] (35mm equivalent)
Telescope type	Refracting telescope
Detector + Image processor	PowerShot G9X Mark II base
Resolution	40-120 [mGSD]
Foot print	215 x 145 – 645 x 435 [km]

# Imaging Modes

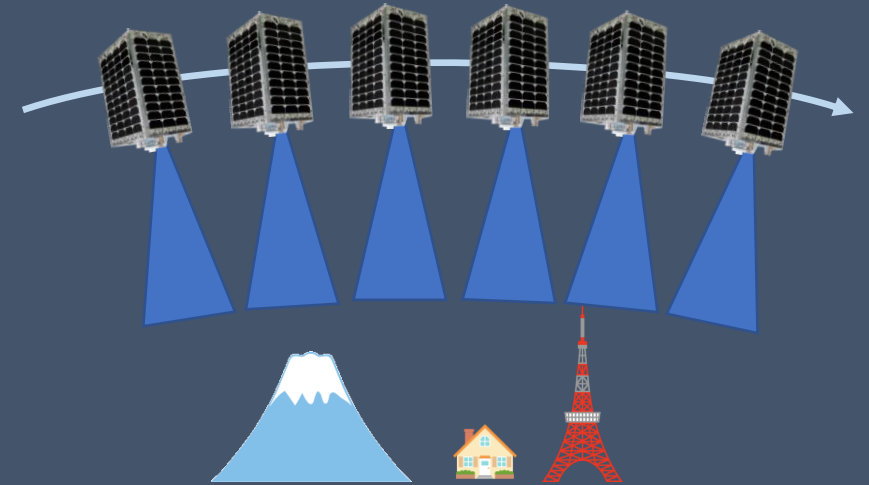
- Tracking

- Day and Night-time imaging
- Longer exposure time for night-time imaging without artificial light
- Images for super-resolution process can be acquired

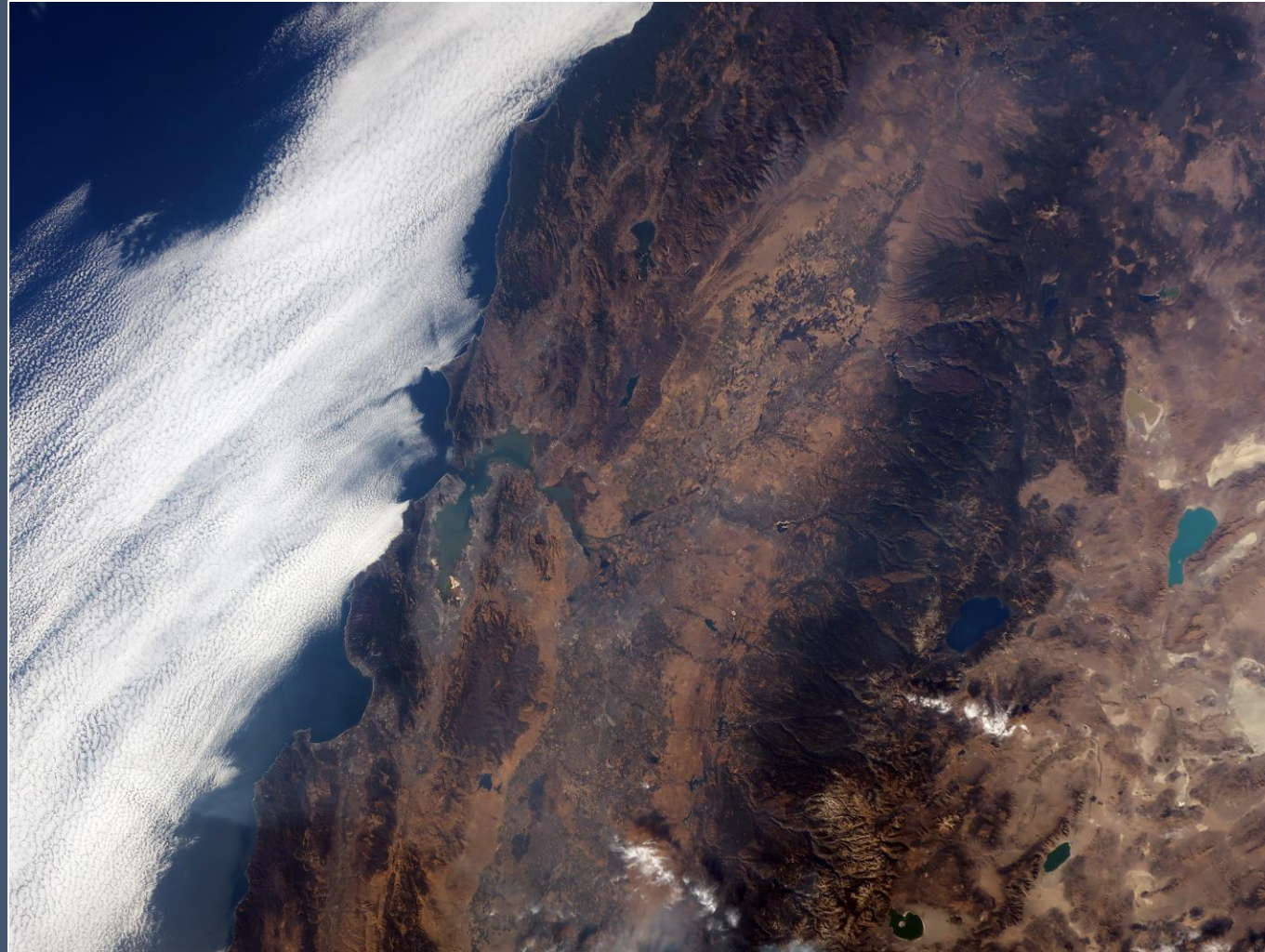


- Pseudo push broom

- Day-time imaging
- Proper exposure images can be acquired in short exposure time with high sensitivity
- Shooting time is almost same in an image as opposed to push broom using line-scan camera
- up to 1,700 km length (along-track)



# PS Image (First Light)



Nov. 3<sup>rd</sup>, 2020, California (pseudo push broom)

# EOS Image



Feb. 22<sup>nd</sup>, 2021, Ben Gurion Airport (tracking)

# UHSC Image [1]



Dec. 30<sup>th</sup>, 2020, North Pole, Alaska (tracking)

# UHSC Image [2]

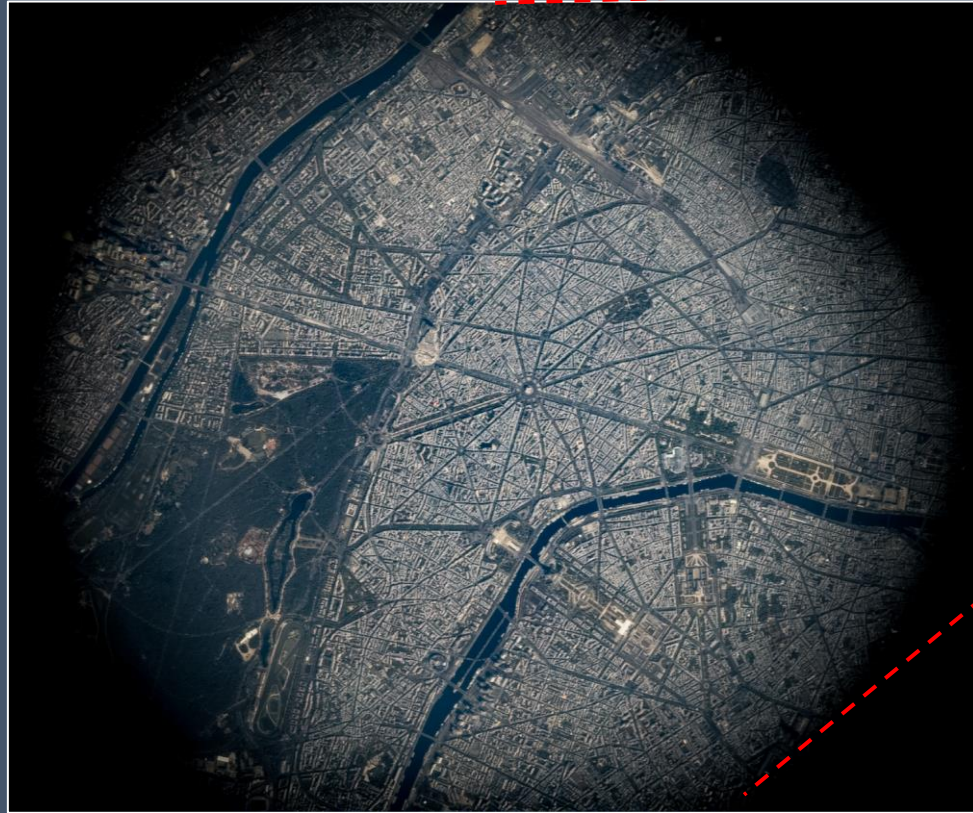


Mar. 28<sup>th</sup>, 2021, Matterhorn (tracking)

# UHSC Image [3]



Apr. 2<sup>nd</sup>, 2021, Paris (tracking)

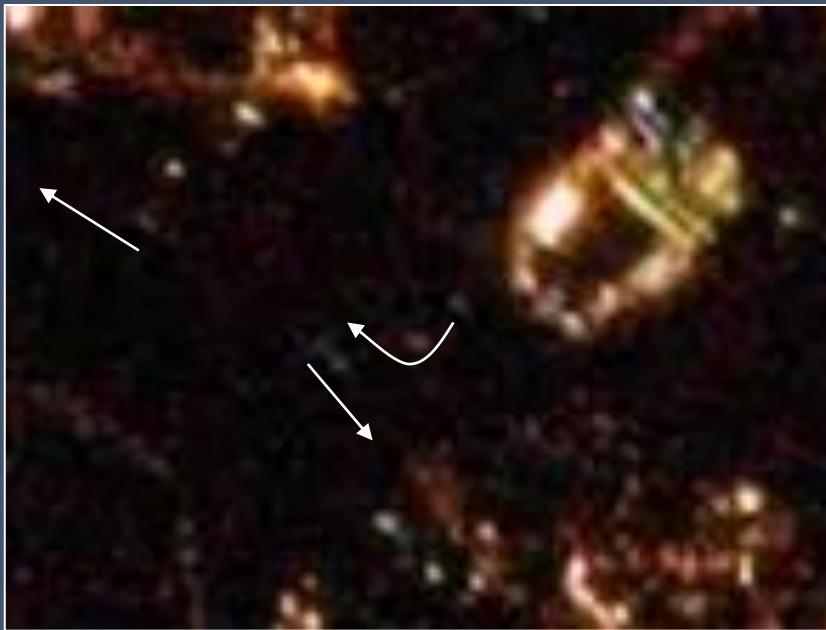


Apr. 22<sup>nd</sup>, 2021, Paris (pseudo push broom)



# UHSC Image [4]

- UHSC can take images up to 18 fps.
- We can find moving car lights from continuous images.



Feb. 12, 2020, Köln (tracking)

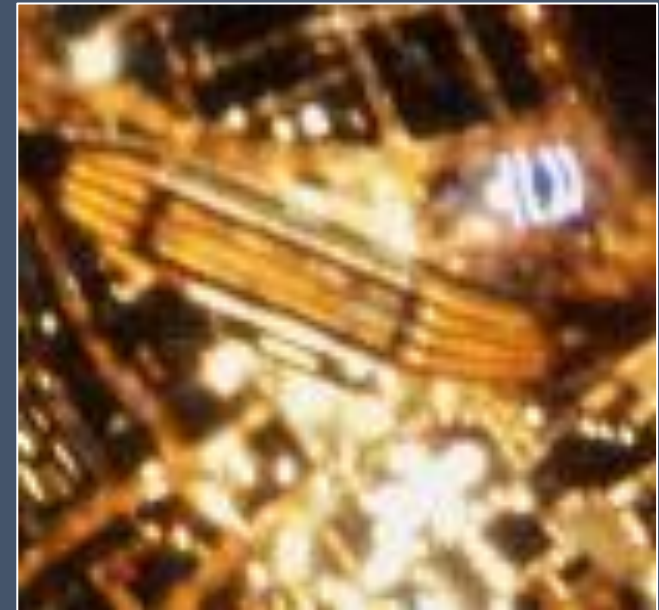


# Super-resolution

- Up-sampling and demosaicing with multiple frames
  - Higher resolution ( x 2)
  - Noise reduction
  - Suppression of false color and zippering artifacts (around edge region)



Original Image



Super-resolution Image (with 40 frames)

# Current and Future Tasks

- Image analysis
  - Basic investigation about night-time imaging and analysis by using UHSC
- HDR imaging
  - Taking moonlit ground and city lights simultaneously
- Further precise and agile attitude control

# Future Plans

- Project
  - More higher resolution with higher sensitivity
  - Other spectrum observation
- Business Domain
  - Whole satellite, satellite components, ground segment
    - We demonstrated two sizes of bus systems, three sizes of Cassegrain telescopes, and many ADCS components
  - Professional service from design to operation
  - Image and analysis data using own satellite constellation platform
  - Every options are examined now
  - Collaboration is welcome

Thank you