# Micro Sun Sensor with CMOS Imager for Small Satellite Attitude Control

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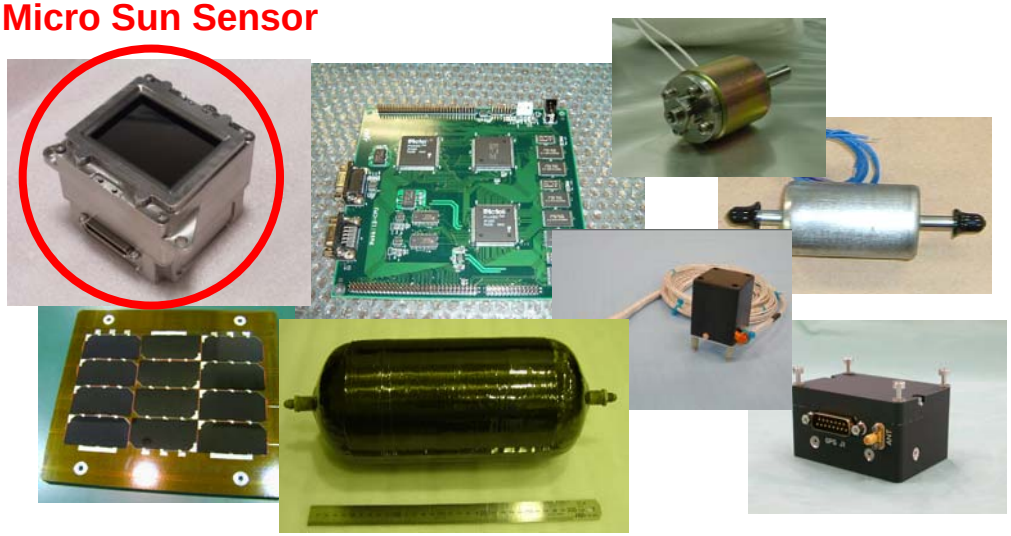
Japan Aerospace Exploration Agency

# Contents

# Introduction

- **JAXA's research and development program for next generation small satellite bus technology**
  - On-board computer, attitude sensor, reaction control system etc…
  - Newly-developed components and subsystems are planed to be installed in the **MicroLabSat-II** for on-orbit demonstration.

**Micro Sun Sensor**



**MicroLabSat-II**

# Concept of the MSS

The general concept of the MSS is to achieve **good balance** of size, mass, power consumption and performance.

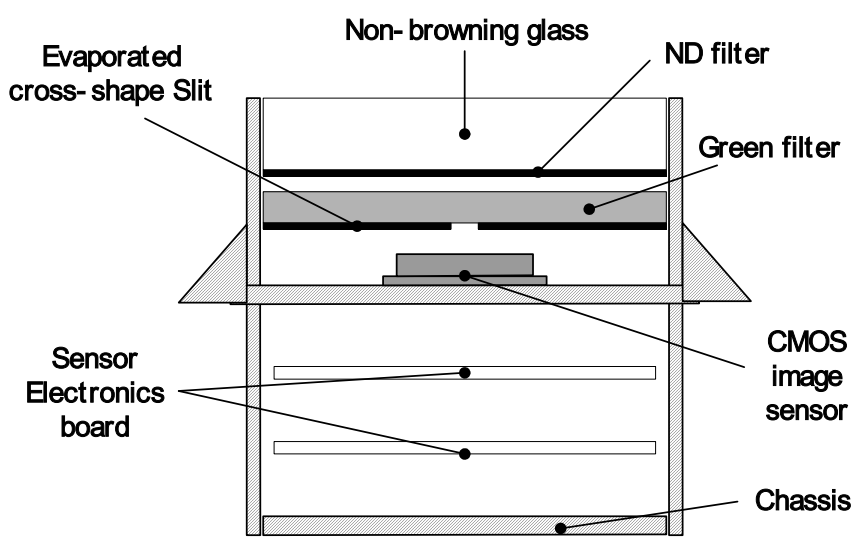
## Design concept of the MSS

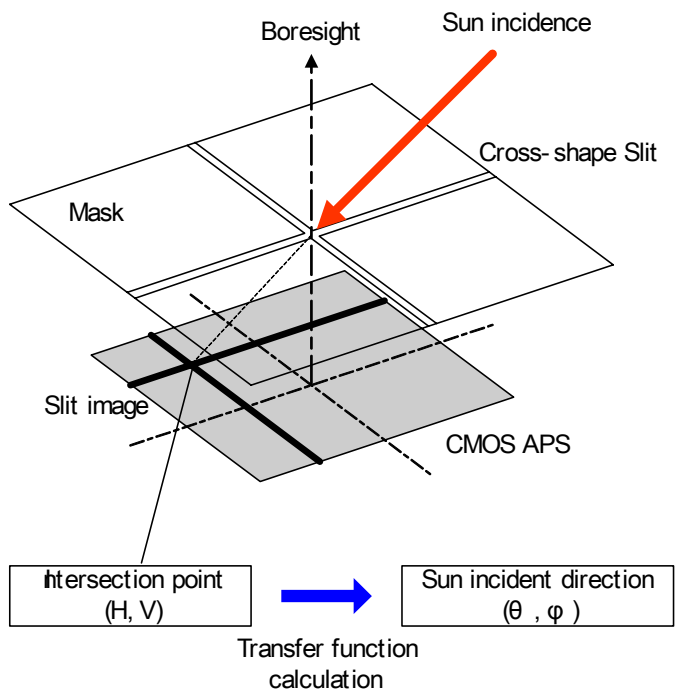
- **Adoption of the CMOS APS as detector**
  - MSS's simplicity and lower power consumption.
- **FPGA based signal processing**
  - Simplicity and compactness of the digital electronics.
  - Flexibility in the implementation of the signal processing.
- **Using COTS APS, optical filter and EEPROM**
  - The state-of-the-art commercial parts are high performance and lower cost.
  - Radiation hardness is not guaranteed is verified by radiation test.

# Concept of the MSS

## Measurement principle

- Sunlight incident on the APS through a **cross-shaped slit**.
- The **coordinates of the intersection** of sun image are computed.
  (Centroid calculation acquires sub-pixel resolution and accuracy)
- **Two axis solar aspect angle** is derived from the intersection coordinates.



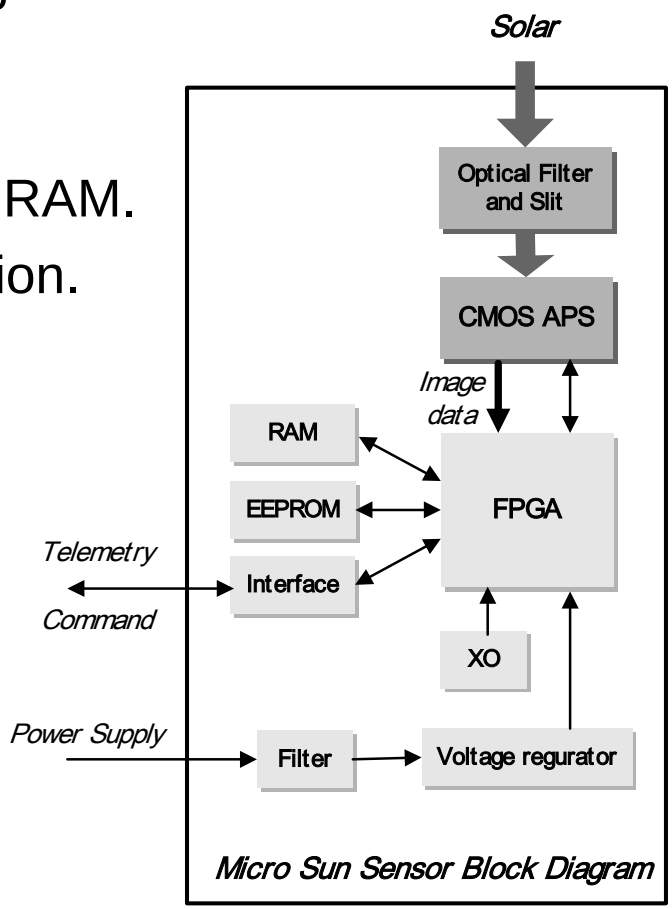
# Functionality and Architecture

## Function and technology

- Output of pixel coordinates of sunlight intersection for solar angle calculation in OBC.
- Raw pixel data output for APS test.
- Direct access (read/write) to ROM and RAM.
- Overcurrent detection and reconfiguration.

## Electronics architecture

- Signal processing and command /telemetry handling functions are implemented in a single FPGA.
- CMOS/TTL serial data interface.
  (RS-422 is also available)



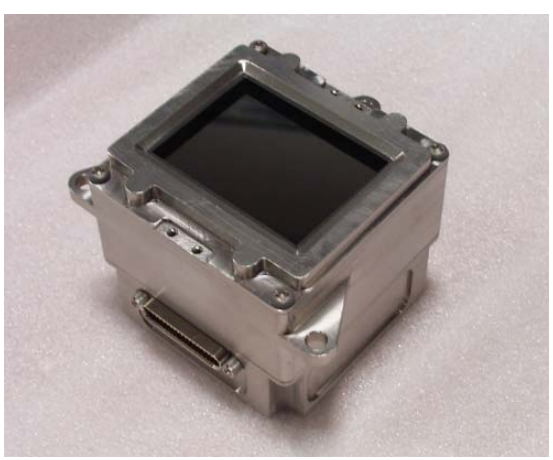
# Design Target and Current Status

## Design Target

| Item | Specifications |
|---|---|
| Dimension | 60mm(W) * 60mm(D) * 60mm(H) |
| Mass | 330g |
| Power | 5VDC, < 1.5W (nominal) |
| FOV | 90×90deg |
| Performance | <0.1deg (bias error, 3sigma)<br><0.01deg (random error, 3sigma) |

## Status

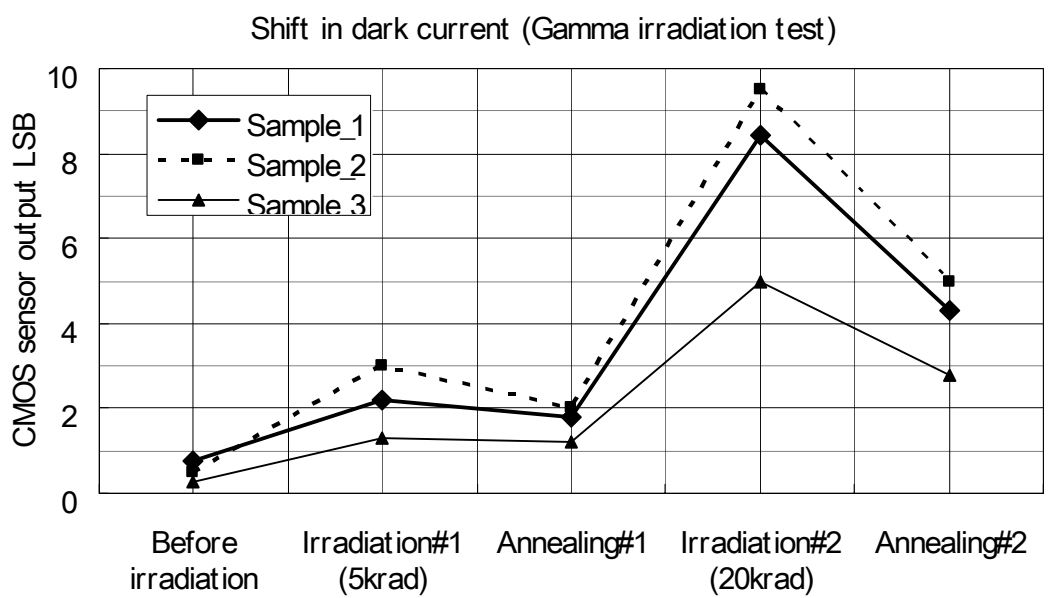
- Ground Test Model (GTM) was fabricated and tested.
- GTM satisfies all MSS's design target.



# Radiation Test for Commercial APS

## Gamma rays irradiation test with Co60

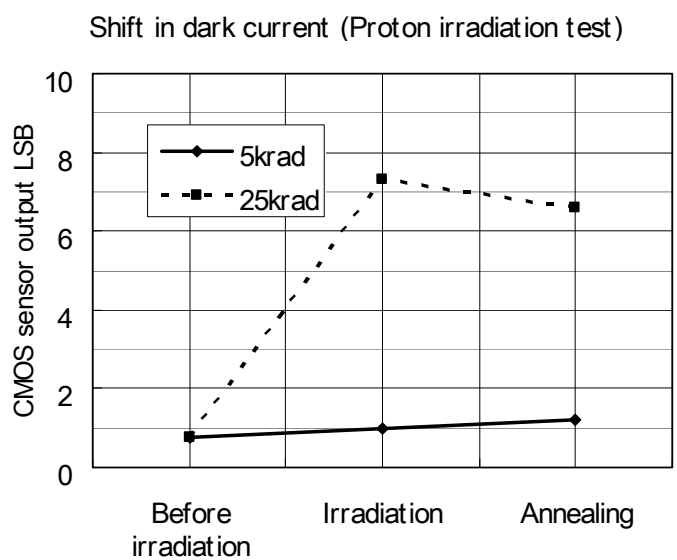
- The APS operated normally and did not lose any function in 25krad expose.
- The dark current level was increased after gamma irradiation and recuperated after annealing.
- The reduction of the sensitivity was not identified.



# Radiation Test for Commercial APS

## Proton irradiation test

- The APS operated normally and did not lose any function in 25krad expose.
- The increase of the dark current level and pixel-to-pixel variations of the dark current were identified.
- Some recoveries out of degradation were confirmed after annealing.
- The reduction of the sensitivity was not identified.



# Radiation Test for Commercial APS

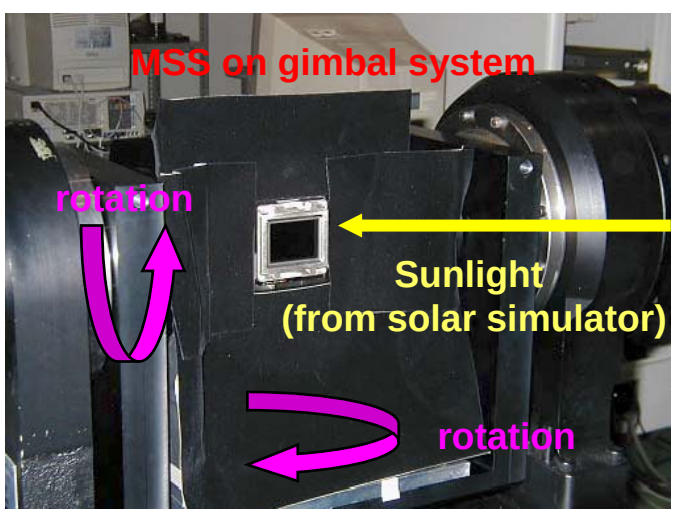
## Summary of the radiation tests

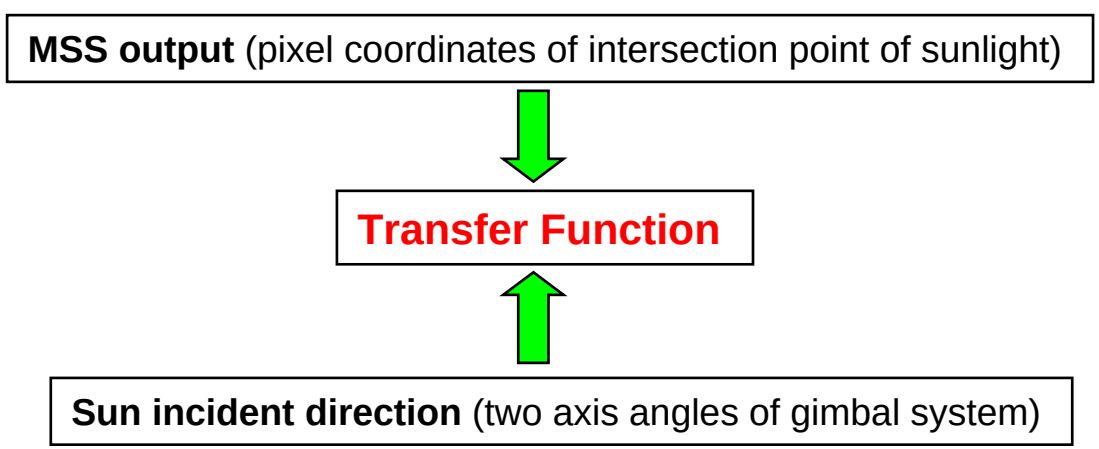
- Minor degradation of several optical characteristics of the APS was identified in gamma and proton irradiation test.
- However the MSS is expected to maintain all functions and necessary optical performance in 25krad irradiation.

# Optical Performance Test

## Objective

- To evaluate the accuracy (bias and random error) of the MSS over the whole FOV.
- To defined "**transfer function**".
- To evaluate the effect of spin rate on the performance of the MSS.

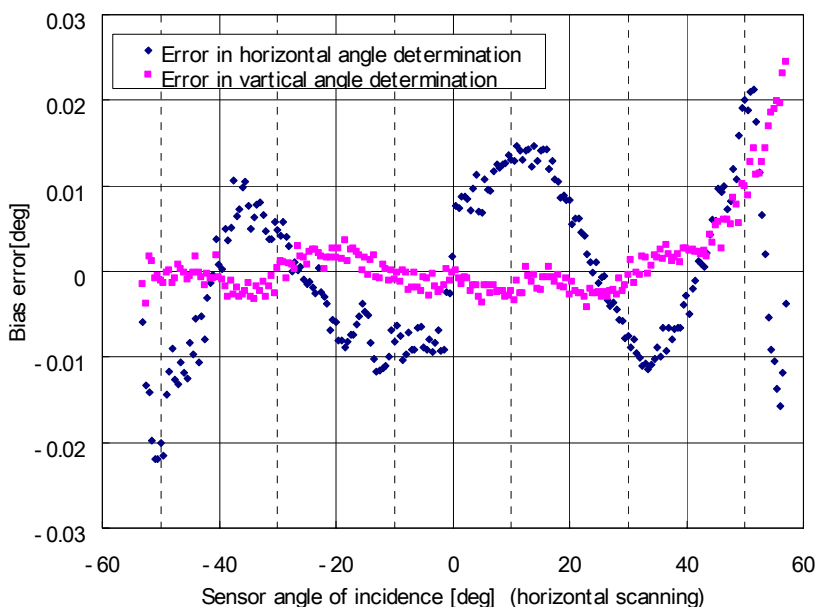


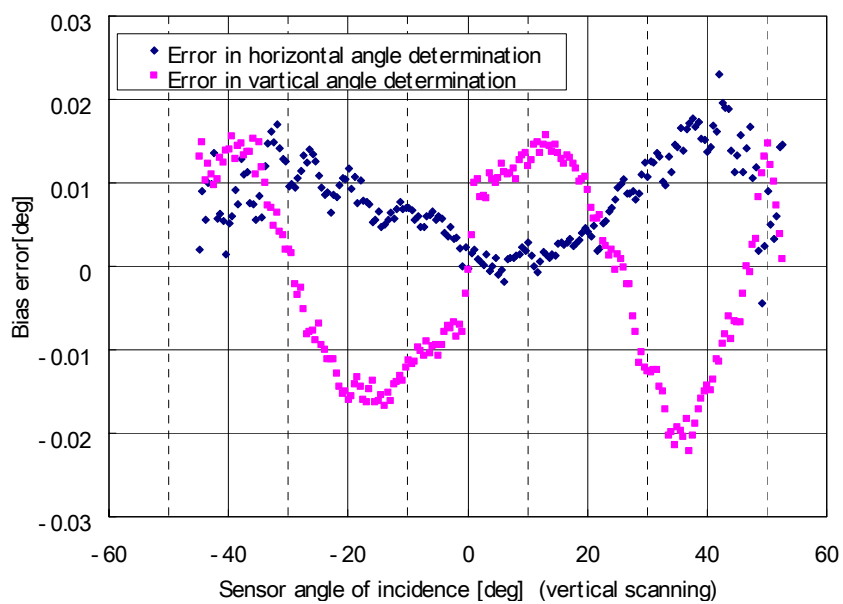



# Optical Performance Test

## Bias error evaluation

- Bias error satisfied the target specification (<0.1deg) over whole FOV.

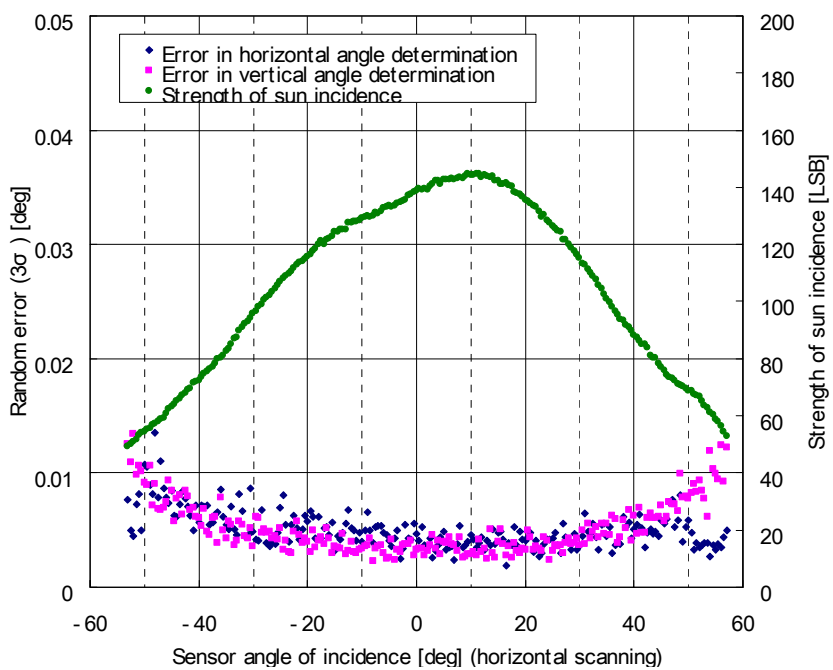


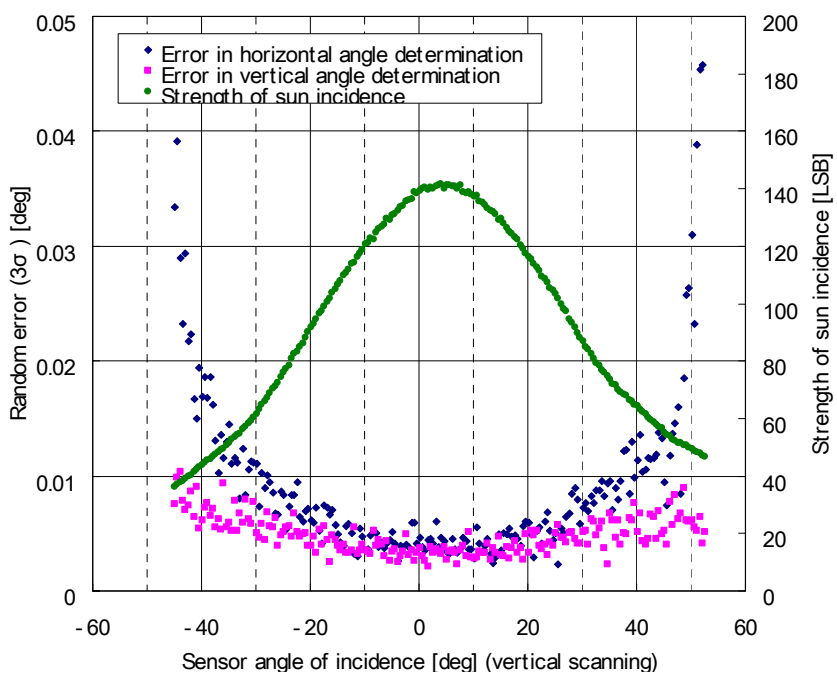



# Optical Performance Test

## Random error evaluation

- The random error is associated with the strength of the sun incidence.
- Random error satisfied the target specification.

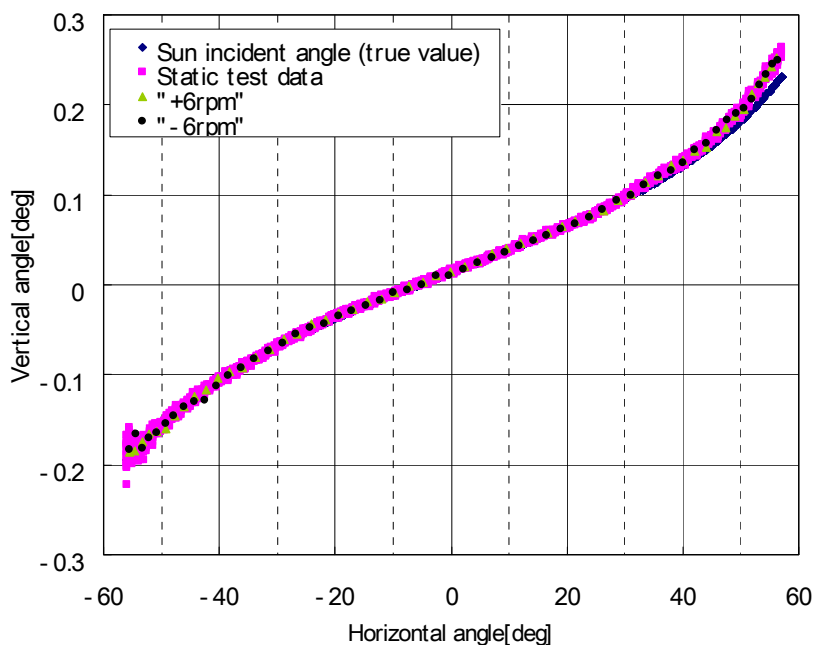


# Optical Performance Test

## Dynamic performance evaluation

- MSS data was acquired in the situation that the gimbal was rotating.
- Remarkable increase of the performance error was not identified in 6RPM.



# Optical Performance Test

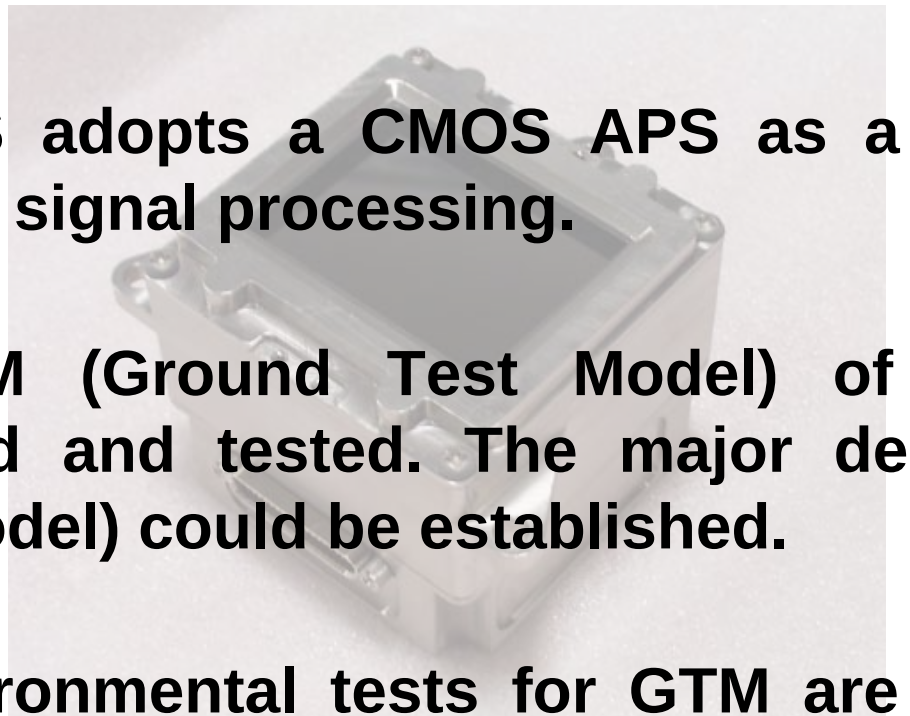
## Summary of the optical performance tests

- Both the bias error and the random error of the MSS satisfied the target specification.
- It was confirmed that the MSS can maintain its optical performance in the rate of 6RPM.

| Item | Test result | Target value |
|---|---|---|
| Bias Error [deg]<br>(3 sigma) | Horizontal < 0.045<br>Vertical < 0.045 | < 0.1 |
| Random Error [deg]<br>(3 sigma ave.) | Horizontal < 0.009<br>Vertical < 0.0065 | < 0.01 |

# Summary

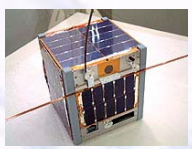
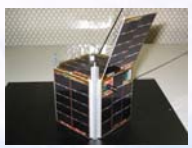
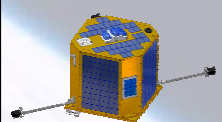
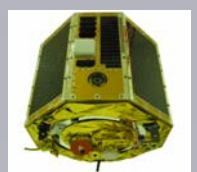
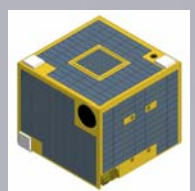
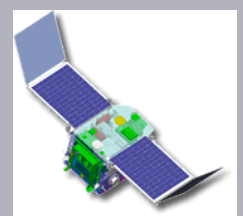
- **JAXA is developing the new type of Micro Sun Sensor.**



- **The MSS adopts a CMOS APS as a detector and a FPGA for signal processing.**
- **The GTM (Ground Test Model) of the MSS was fabricated and tested. The major design of the FM (flight model) could be established.**
- **The environmental tests for GTM are planned in this year. After the series of environmental test, the MSS FM will be stated to produce for the MicroLabSat-II.**

# Thank you for your attention !

# Small satellite activity in Japan

| Name | **Cubesat (XI)** | **Cubesat (CUTE-1)** | **WEOS** | **SOHLA-1** | **MicroLabSat** | **MicroLabSat 2** | **INDEX** |
|---|---|---|---|---|---|---|---|
| |  |  |  |  |  |  |  |
| Organization | Univ. of Tokyo | Tokyo Inst. of Tech. | Chiba Inst. of Tech. | SOHLA (SMEs union) | JAXA/ISTA/ STDRC | JAXA/ISTA/ STDRC | JAXA/ISAS |
| Mass | 1kg | 1kg | 50kg | 50kg | 54kg | 60kg | 70kg |
| Main mission | Education, technology demo. | Education, technology demo. | Whale ecology observation | Training, technology demo. | Microsat bus demo, precursor misson, training | Advanced microsat bus and space technology demo, training | Aurora observation, engineering experiment |
| Launch | 2003 | 2003 | 2002 | TBD | 2002 | TBD | 2005 |
| STATUS | In operation | In operation | In operation | Under development | In operation | Under development | Preparing for launch |

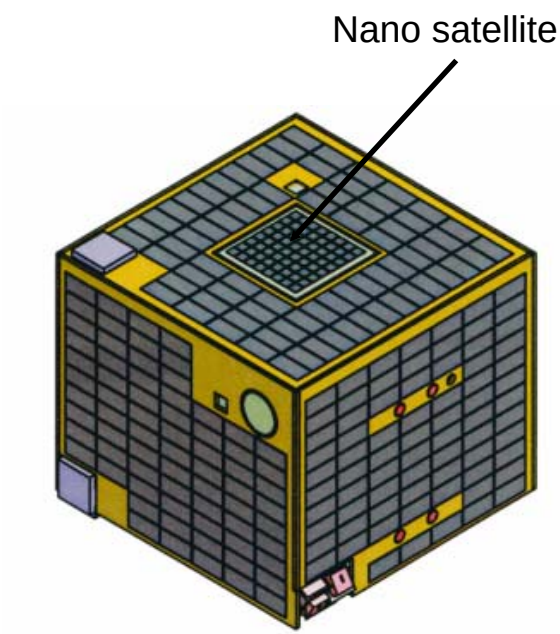
Furthermore, several small satellite projects are also being planned by other universities and organizations in Japan.

# MicroabSat-II Satellite

## Main characteristics

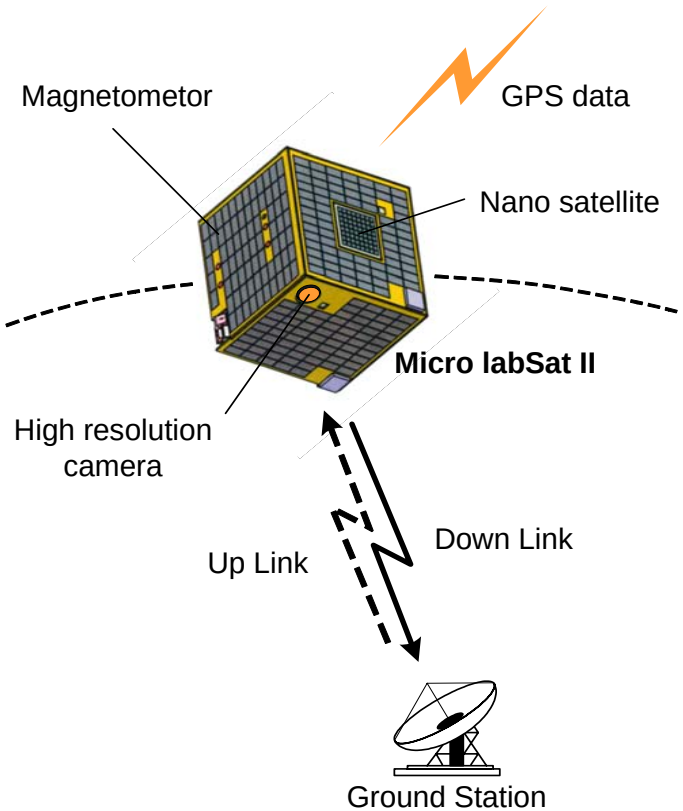
- 50kg-class micro-satellite
- Earth oriented 3-axis attitude control
- Carry and release a nano-satellite on orbit

| Item | Characteristics |
|---|---|
| Size | 600(W)×600(D)×500(H)mm<br>200(W)×200(D)×150(H)mm(NanoSat) |
| Mass | 60kg(Total), 5kg(NanoSat) |
| Power | 100W |
| Attitude | Earth oriented 3-Axis control |
| Comm. | Micro LabSat II ⇔ Ground Station:<br>S-band, 4kbps(Up), 1.6Mbps(Down)<br>NanoSat ⇔ Ground Station: S-band<br>Micro LabSat II ⇔ NanoSat: TBD |
| Orbit | LEO, Sun synchronous |
| Launch | TBD (The completion of development < 2008) |

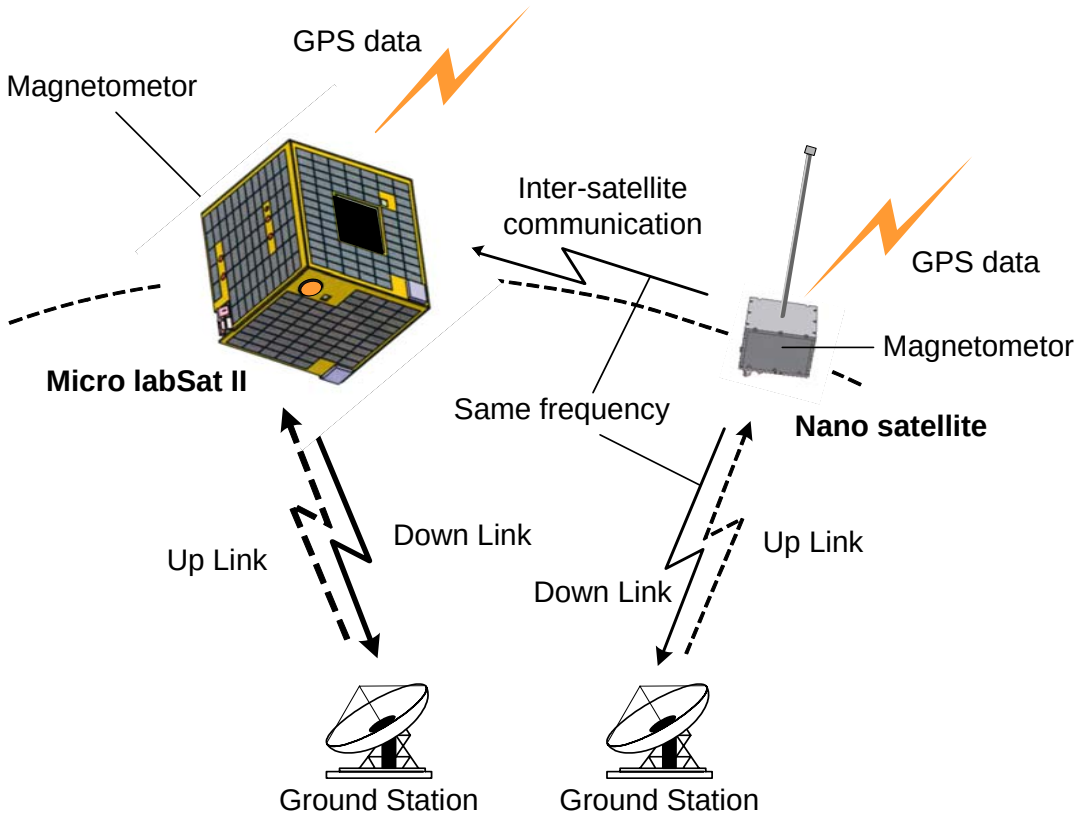



MicroLabSat-II image

# Experiment in collaboration with NanoSat




Before release nano satellite




Experiment image in collaboration with nano-satellite