

The GOSAT satellite is shown in orbit against a black background. It features a central gold-colored body with various instruments and a large array of blue solar panels extending outwards. The Earth's blue and white horizon is visible at the bottom of the frame.

Workshop on the Data Utilization of Greenhouse Gases Observing Satellite (GOSAT) “IBUKI”

Outline of GOSAT Spacecraft and TANSO Sensor

November 5, 2008

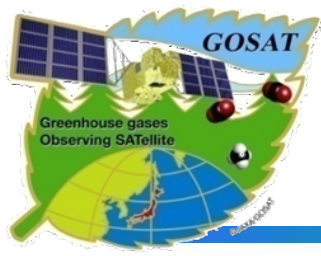
Takashi Hamazaki

Project Manager

GOSAT Project Team

Japan Aerospace Exploration Agency





1. GOSAT OVERVIEW



GOSAT is;

✿ **The Greenhouse gases Observing SATellite.**

✿ **A satellite to monitor global distribution of Greenhouse Gases (GHG);**

✿ **Carbon dioxide and Methane at 100-1000km spatial scale**

✿ **with relative accuracy of 0.3-1% (1-4ppm) for CO₂ and 0.6-2% (10-34ppb) for CH₄**

✿ **A joint project of**

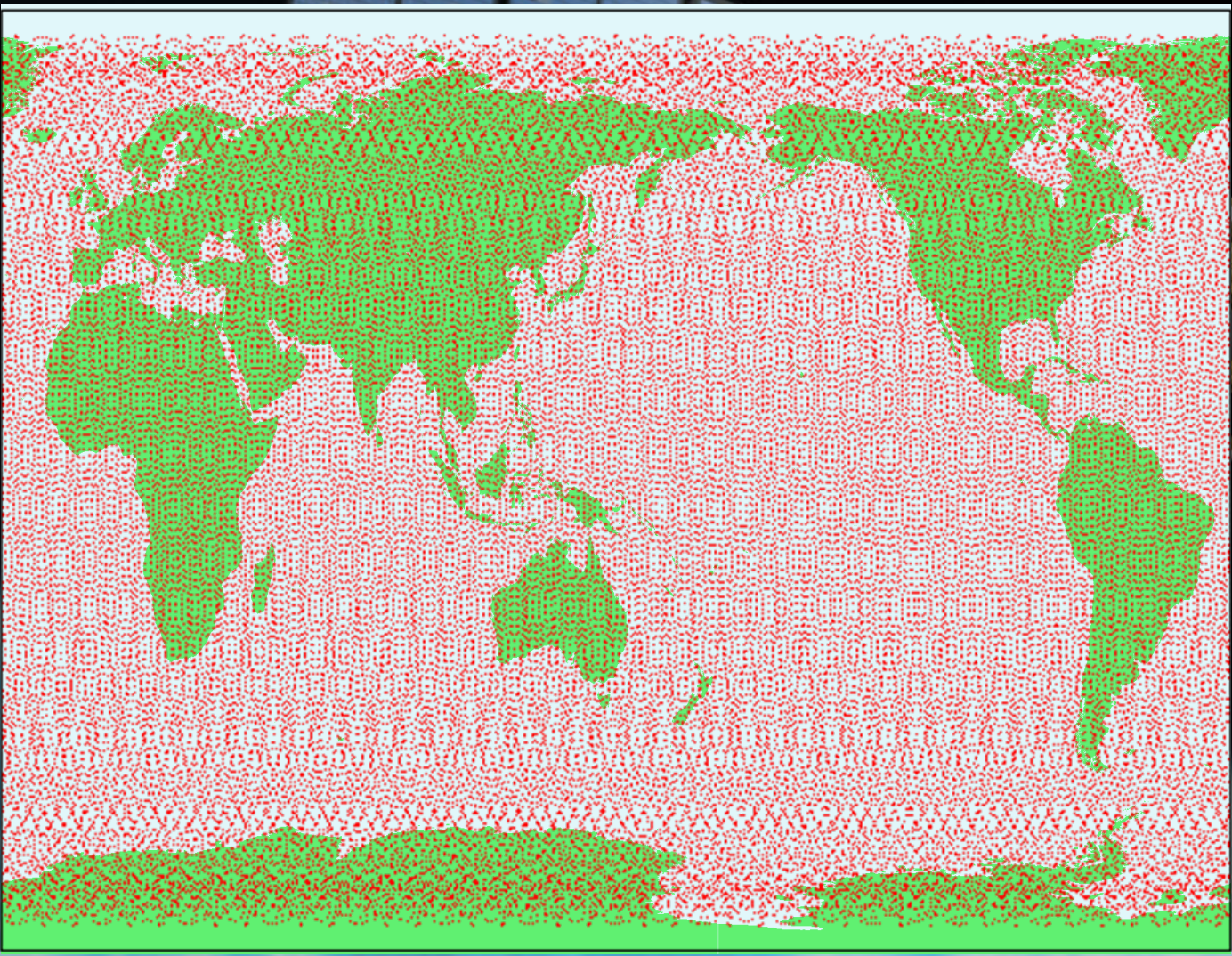
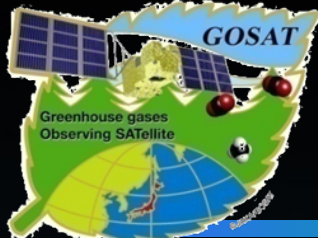
✿ **JAXA (Japan Aerospace Exploration Agency),**

✿ **MOE (Ministry of the Environment) and**

✿ **NIES (National Institute for Environmental Studies).**

✿ **Scheduled to be launched by Japan's H-IIA launch vehicle in early 2009 from Tanegashima Space Center**

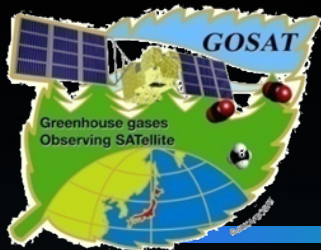
✿ **Recently named as "IBUKI"**



GOSAT



Global
frequent
observation
single
instrument



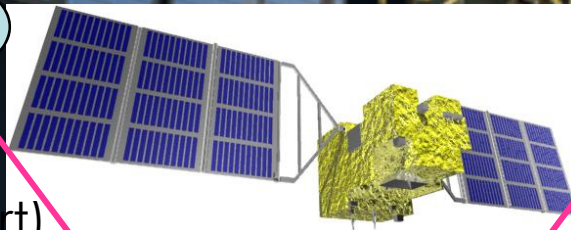
GOSAT Organization



GOSAT is the joint project of JAXA, Ministry of Environment and NIES (National Institute of Environmental Studies).



MOE



JAXA



- Sensor Development (Partial Funding Support)
- Data use for Policy Development

- Algorithms development
- Data use for science
- Data processing (L2-4)
- Validation

NIES



- Sensor development
- Satellite development
- H-IIA launch
- Satellite operation
- Data acquisition
- Calibration

GOSAT
Science
Team

- Scientific Advisory



Satellite



Size	Main body	1.8m x 2.0m x 3.7m (Wing Span 13.7m)
Mass	Total	1,750kg
Power	Total	3.8KW
Life Span	5 years	
Orbit	sun synchronous orbit	
	Local time	13:00+/-0:15(Descending)
	Altitude	666km
	Inclination	98deg
	Re-visit	3 days
Launch	Vehicle	H-IIA
	Schedule	Jan. 21 st , 2009



H-IIA Launch Vehicle

GOSAT on orbit



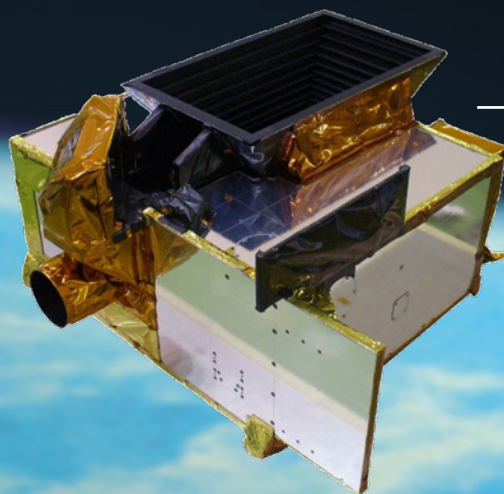


2. MISSION(TANSO) OVERVIEW

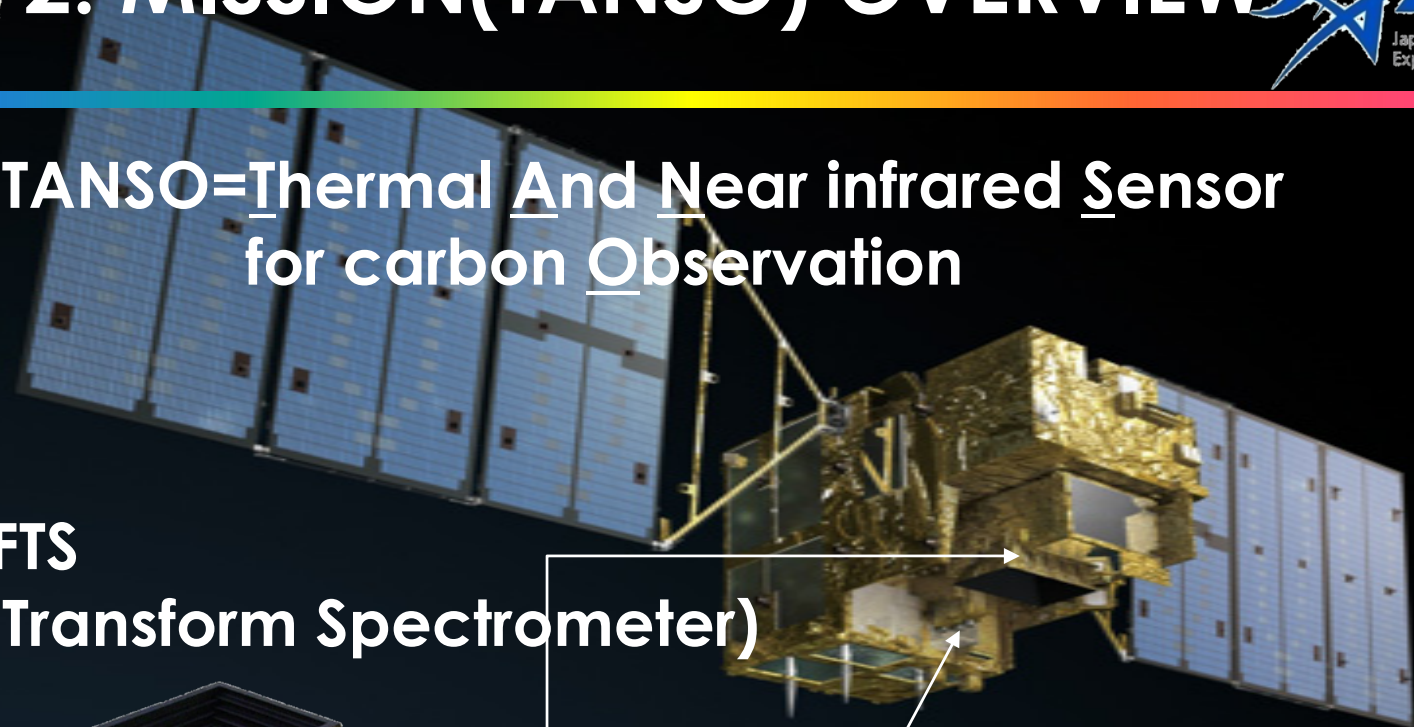
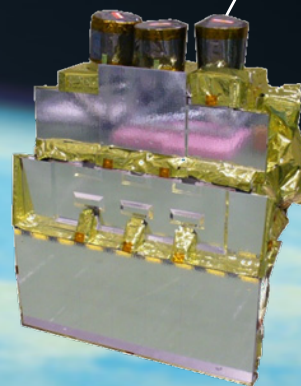


TANSO=Thermal And Near infrared Sensor
for carbon Observation

TANSO-FTS
(Fourier Transform Spectrometer)



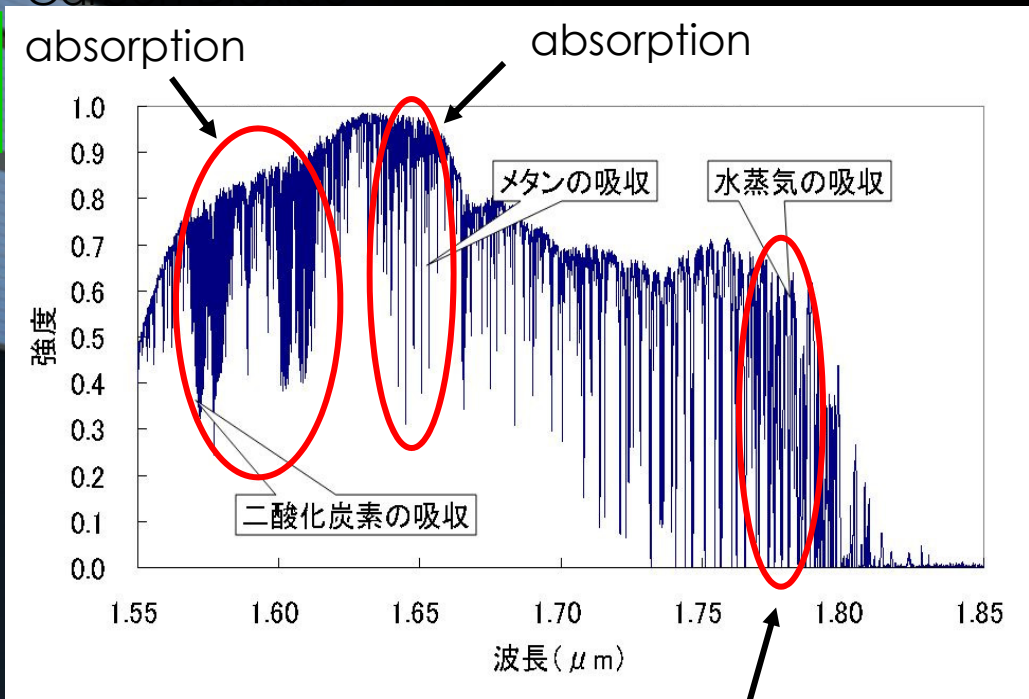
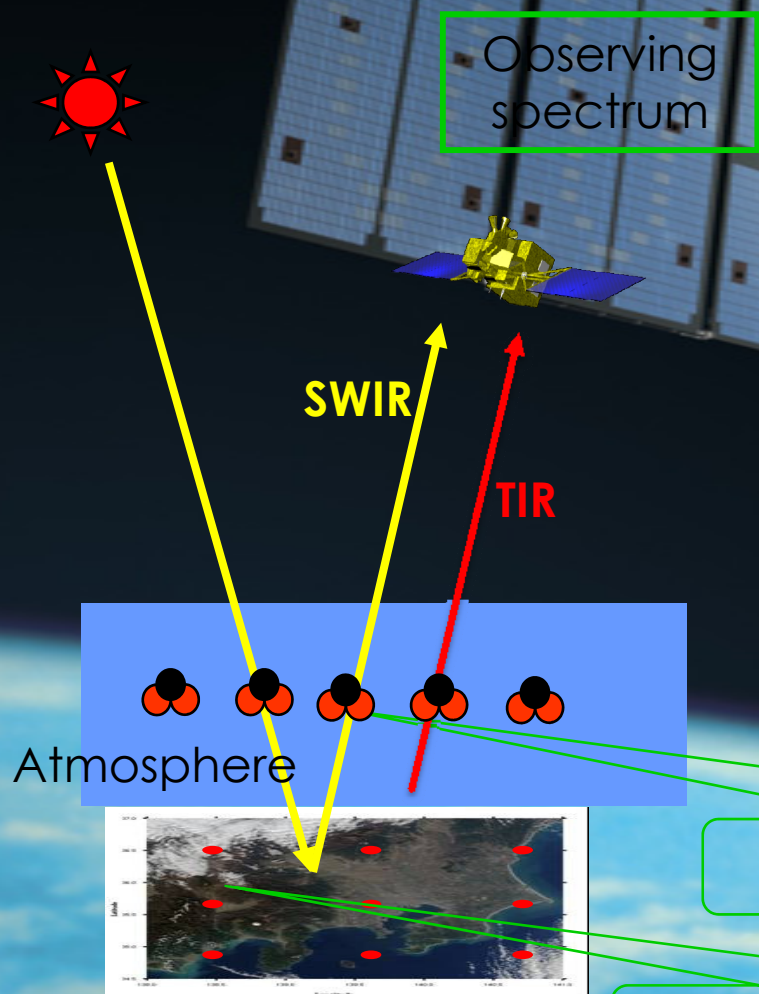
TANSO-CAI
(Cloud and Aerosol Imager)





Principle of the Observation

Carbon Dioxide



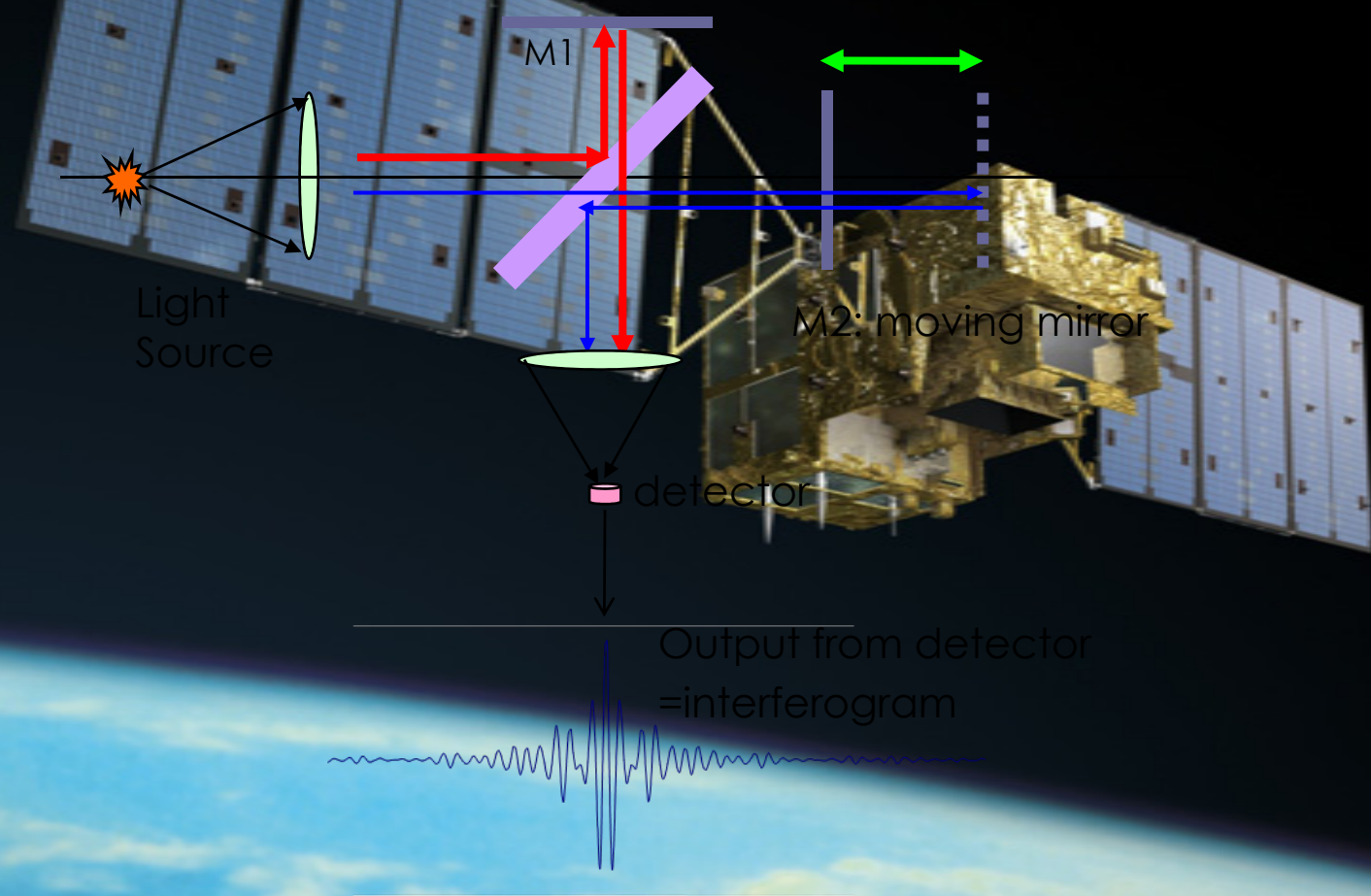
Water Vapor absorption

GHGs absorb specific infrared spectrum.

Reflection on the Earth Surface



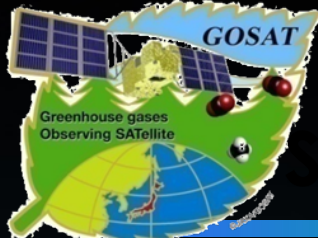
Principle of the Fourier Transform Interferometer



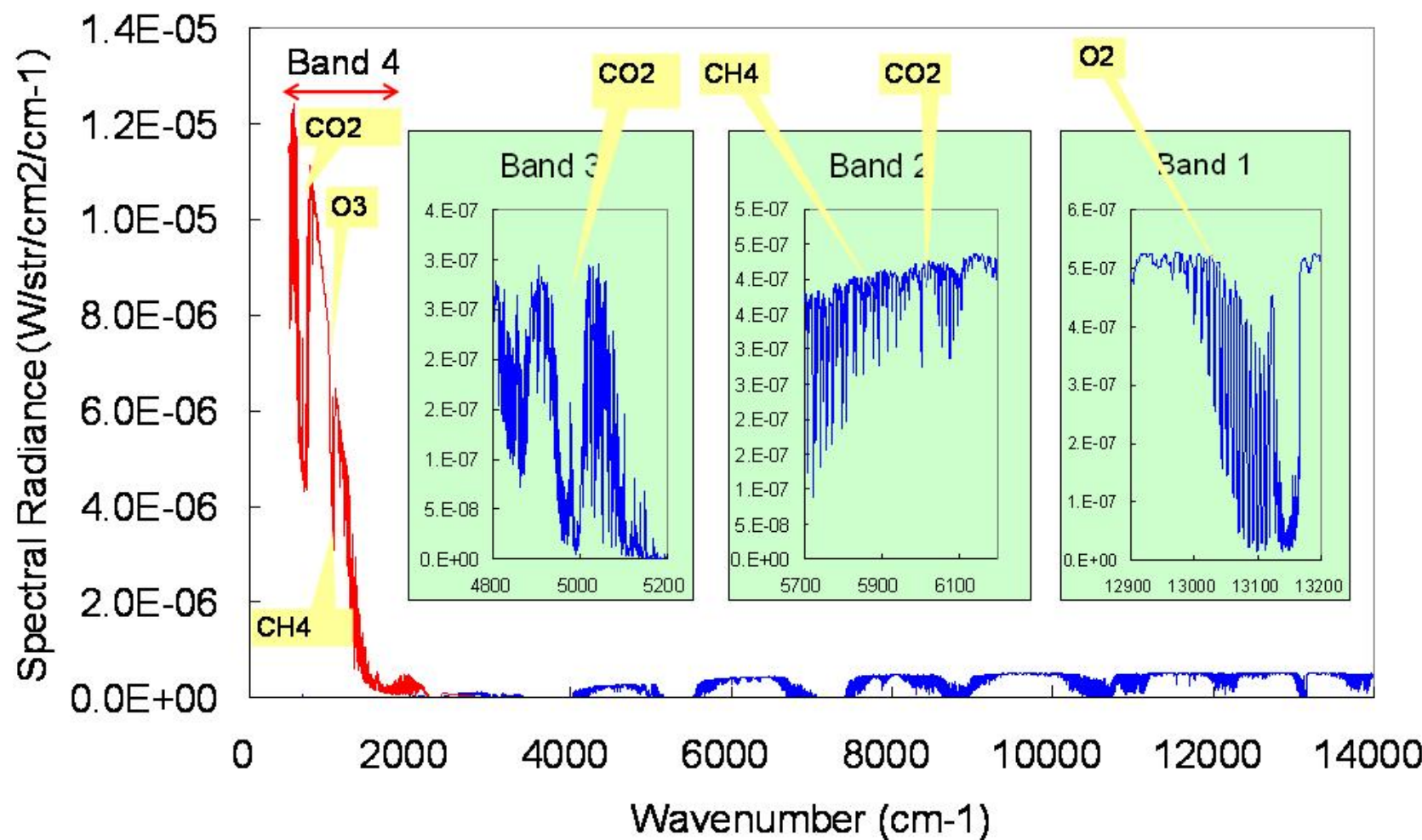


Specifications

Ground Pointing Mechanism and Fore optics	Configuration	2-axes pointing mirror, auto ground pointing, calibration			
	Pointing	Cross Track (+/-35 deg) Along Track (+/-20 deg)			
	Field of view	IFOV = 10.5 km FOV=790 km (scan width)			
Fourier Transform Spectrometer	Speed	4, 2, 1.1 sec/ 1 Interferogram			
	Spectral ch	1P, 1S	2P, 2S	3P, 3S	4P, 4S
	Obs. band (micron)	0.75-0.78	1.56-1.72	1.92-2.08	5.5-14.3
	Resolution (cm ⁻¹)	0.2	0.2	0.2	0.2
	Detector	Si	InGaAs	InGaAs	PC-MCT
	Calibration	Solar Irradiance, Deep Space, Moon, Diode Laser (1.55 μm, ILS)			Blackbody, Deep space



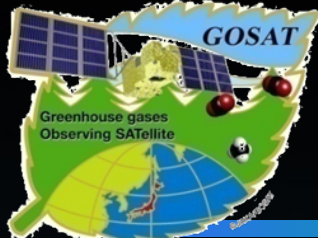
Spectral coverage



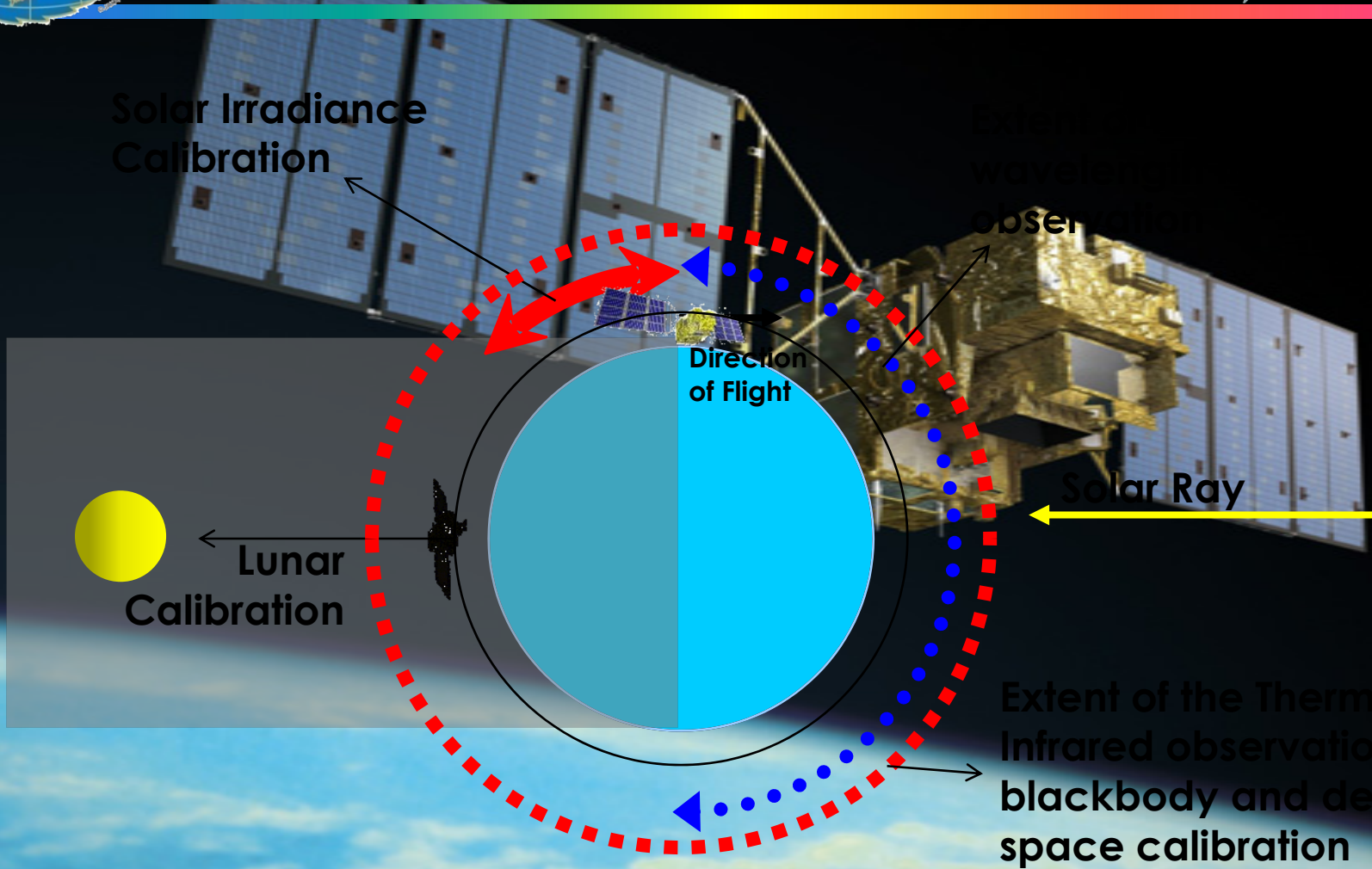


Operation

Operation mode		Description
Observation mode I	day time	Observation in the short wavelength infrared bands and the thermal infrared band.
	night time	Observation in the thermal infrared band. Performs blackbody and space calibration.
Observation mode II		The operation of thermal infrared observation is suspended and the pointing mechanism is locked and TANSO-CAI is assumed as set to the All off mode. (In case of a failure of one of the solar paddles or other similar events) * The observation time is limited to ten minutes per orbit, and the sensor is set to Standby II mode for the rest of the time.
Specific observ. mode	Sunglint observation	Observation of the sunglint points according to the commands.
	Specific points observation	Observation of the specified points according to the commands. "Specific points" include lakes, validation sites, ground-based CO2 observatories etc.
Calibration mode	Lunar calibration	Calibration using the moon in the SWIR bands once a year, as necessary. This calibration is performed by rotating GOSAT to point to the moon and orienting the sensor's FOV toward the moon using the pointing mechanism.
	Solar irradiance calibration	Calibration using the solar irradiance for every orbit when the satellite is in sunlight and the ground surface is in shade. This calibration takes place at rise of the sun.
	Instrument function calibration	Calibration of the instrument function by irradiating a 1.55 μm wavelength semiconductor laser light.
	Electrical calibration	Calibration of the signal processing in the analogue signal processor and beyond, by inputting a reference voltage signal.



In-Orbit



Blackbody and deep space calibration are performed at regular intervals.



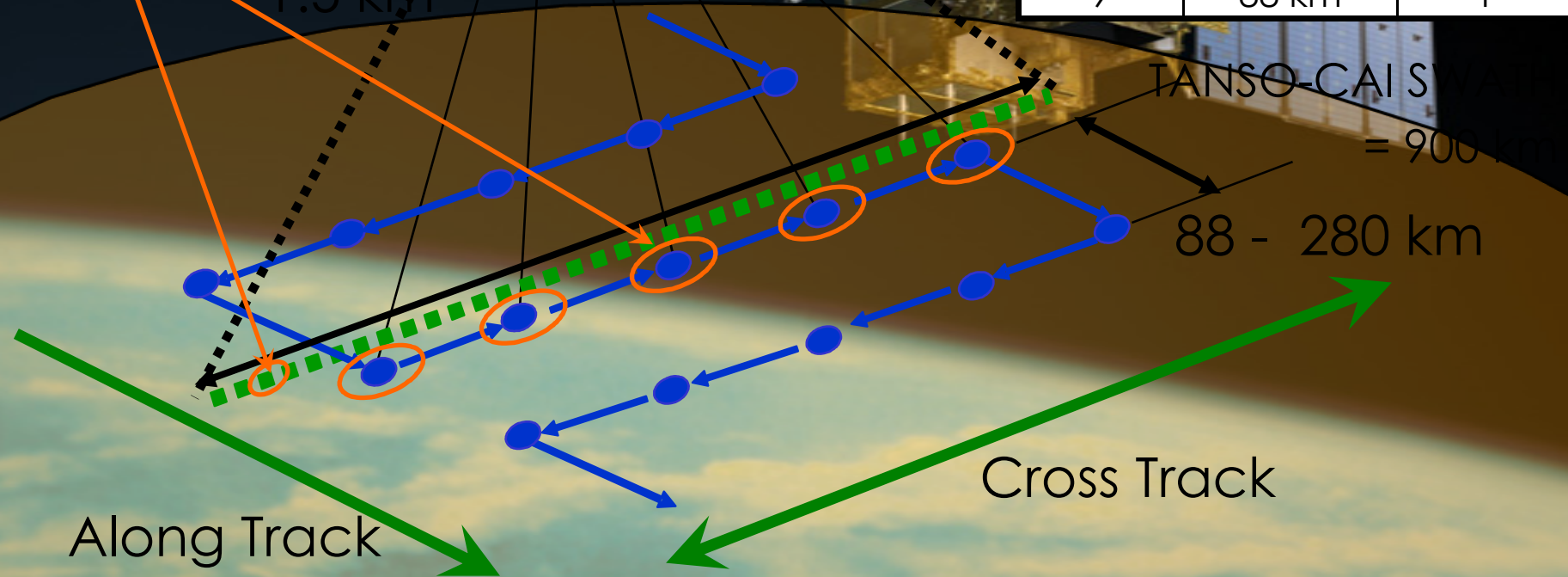
Operation

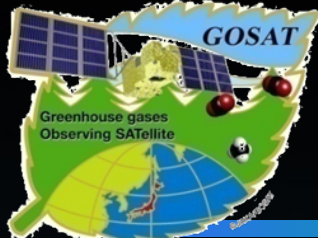


GOSAT

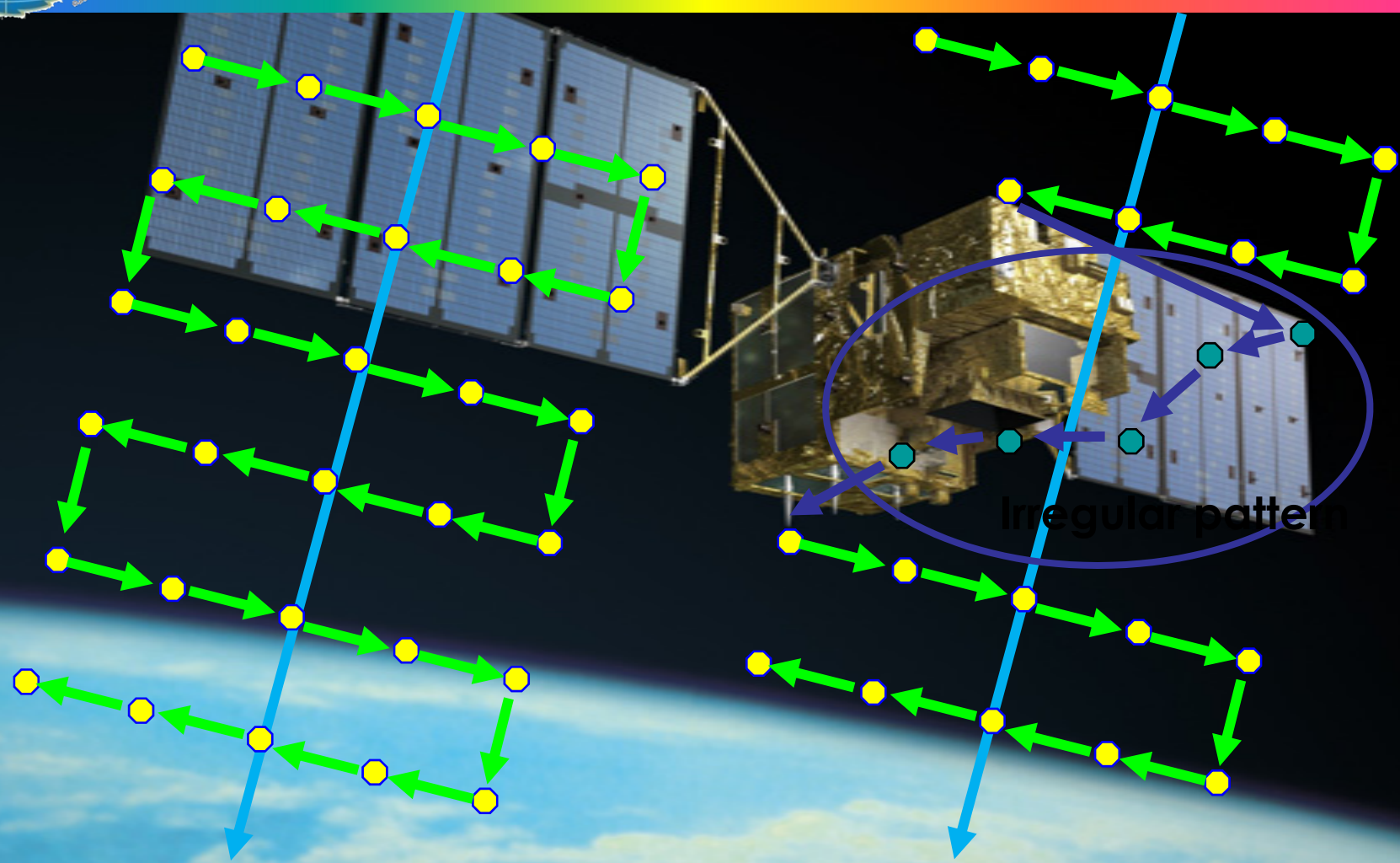
Footprint
FTS IFOV=10.5 km
CAI IFOV=0.5,
1.5 km

Cross-track pattern	Distance bet. points	Exposure (sec)
1	790 km	4x3
3	260 km	4x3
5	160 km	4
7	110 km	2
9	88 km	1





Operation

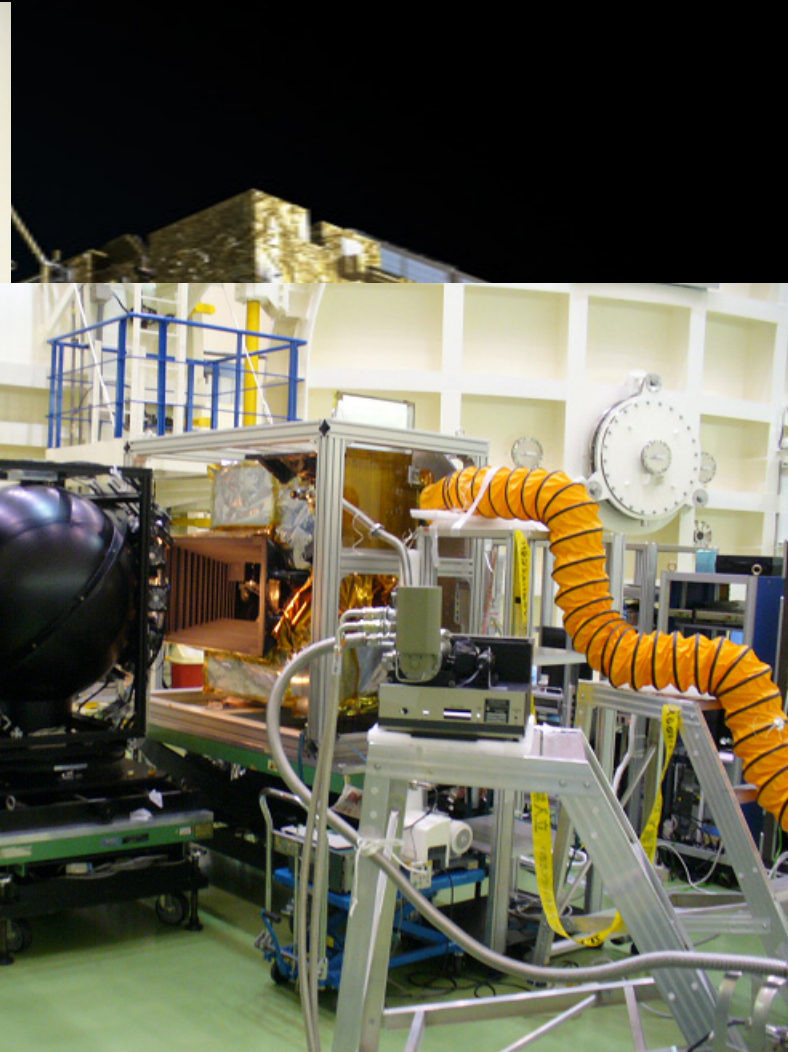
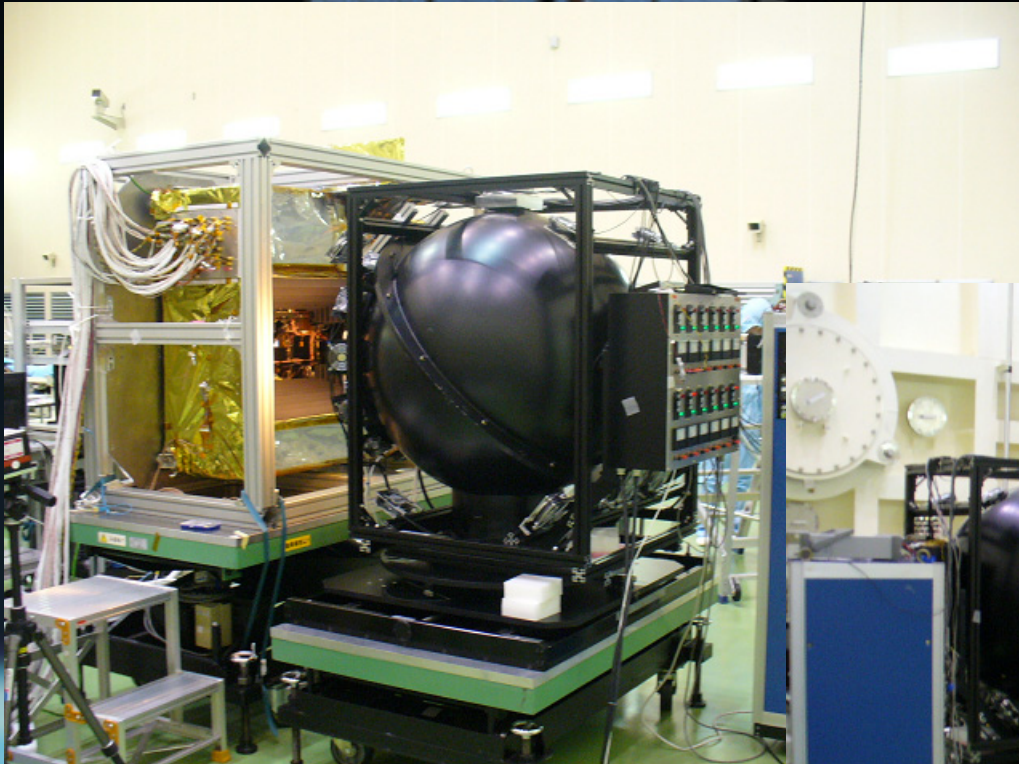


Regular Observation Pattern
(5 points in the cross-track direction)

Specific Points
Observation Pattern



Scene of the PMO





Test Results (Observed)



- The proportion of the minimum sensitivity to maximum sensitivity

band	1		2		3		4	
	P	S	P	S	P	S		
results (%)	93.0	92.2	92.8	85.9	86.8	91.9	46.3(700-1400nm)	28.6(1400-1800nm)

- The out of band characteristics

band	1		2		3		4	
out of band (μm)	<0.746	>0.787	<1.471	>2.000	<1.812	>2.222	<5.56	>14.29
results (%)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1



Test Results (S/N, Gain)

S/N

bands	Wave-length* (cm ⁻¹)	Spectral radiance* (W/cm ² /sr/cm ⁻¹)	result
1P	13050	5.5e-7	345
1S			246
2P	6200	5.2e-7	322
2S			257
3P	5000	3.8e-7	412
3S			287
4	700	280K	283

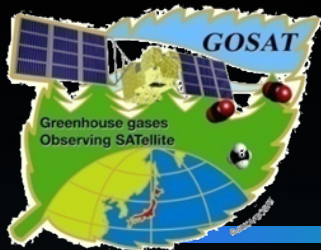
* The specification is defined at these value

Gain

gain	H	M	L
1P	6.97	7.50	7.85
1S	7.71	7.50	7.85
2P	9.62	8.77	7.85
2S	>10	>10	9.79
3P	8.98	9.02	7.85
3S	8.18	8.64	7.85
4	NA	9.49	NA

* The output voltage when the maximum radiance(below table) on each gain is observed.

Gain	Spectral radiance (W/cm ² /sr/cm ⁻¹)			
	Band 1	Band 2	Band 3	Band 4
H	5.5e-7	5.2e-7	3.8e-7	NA
M	1.8e-6	1.7e-6	1.3e-6	340K
L	5.5e-6	5.2e-6	3.8e-6	NA



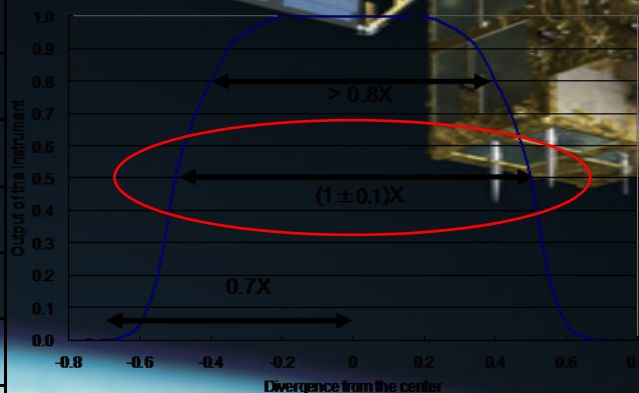
Test Results (FOV)

The proportion of the minimum output to maximum one in IFOV

FWHM in IFOV, i.e. angle where the relative peak is over 0.5

*definition of IFOV

band	AT/CT	result(%)
1P	AT	95.34
	CT	96.48
1S	AT	93.61
	CT	95.15
2P	AT	95.69
	CT	92.83
2S	AT	92.86
	CT	91.75
3P	AT	91.11
	CT	90.12
3S	AT	93.46
	CT	95.49
4	AT	84.75
	CT	80.81



optical axis

band	AT/CT	result(mrad)
1P	AT	15.4
	CT	15.4
1S	AT	15.4
	CT	15.4
2P	AT	14.70
	CT	15.66
2S	AT	14.82
	CT	14.61
3P	AT	14.67
	CT	15.58
3S	AT	14.57
	CT	15.54
4	AT	15.42
	CT	14.41



Test Results (Polarization)

Polarization sensitivity

Mode	bands	Specification	result
AT, CT= 0 degree	1	<34%	24.9%
	2	<38%	27.9%
	3	<38%	29.3%
CT= 35 degrees	1	<34%	19.9%
	2	<38%	25.3%
	3	<38%	27.0%
AT= 20 degrees	1	<34%	27.4%
	2	<38%	27.4%
	3	<38%	29.6%

$$\text{Polarization Sensitivity} = \left| \frac{P - S}{P + S} \right|$$

Polarization

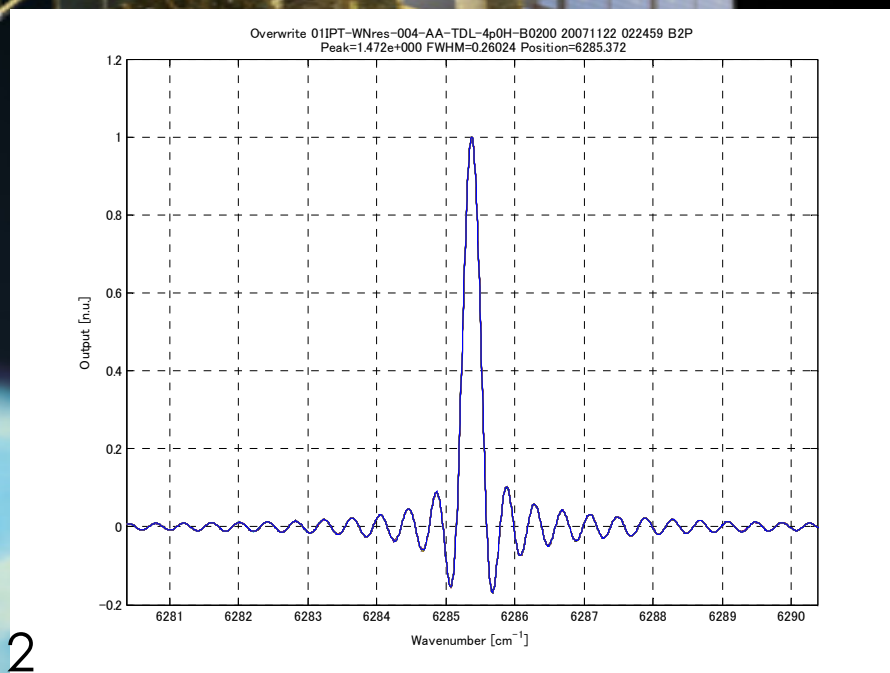
Mode	bands	Specification	result
AT, CT= 0 degree	1P		0.36%
	1S		0.37%
	2P		0.36%
	2S		0.37%
	3P		0.42%
	3S		0.53%
CT= 35 degrees	1P		1.04%
	1S		3.07%
	2P		4.11%
	2S		5.39%
	3P		4.17%
	3S		3.34%
AT= 20 degrees	1P		0.36%
	1S		0.37%
	2P		0.36%
	2S		0.37%
	3P		0.42%
	3S		0.53%



Test Results (Instrument)

Instrument function FWHM

band	Band 1		Band 2		Band 3		Band 4
polarization	P	S	P	S	P	S	0.246
FWHM(cm-1)	0.367	0.356	0.258	0.257	0.262	0.263	



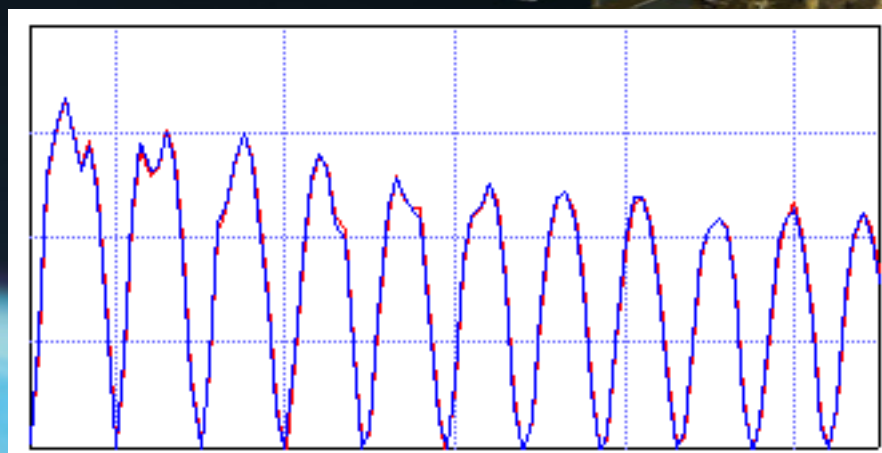
Example of the interferogram-Band 2



Test Results of

- (1) The light through the gas cell filled with only CO₂ was measured in the FOV of FTS.
- (2) The strong light source was set around the FOV of FTS.
- (3) It was compared that the cases where the strong light source was turned on and off.

The difference between two cases was under 0.1 %.



The test result of the stray light:

the red line shows the case that the light source was turned off,
the blue line shows the case that the light source was turned on.



Test Results (stability of the sensitivity)

- The stability of the sensitivity to the change in the temperature of the optical bench is measured in the thermal and vacuum test.
The output under the high temperature mode was compared with the output under the nominal temperature mode and the change per one degree C of the sensitivity was calculated.
- The maximum change of the sensitivity per degree C is 0.365 % and the change of the temperature of the optical bench where the optics are placed is estimated under 0.5 degree C per one revolution.
Therefore the change of the sensitivity is under 0.18 %.

the stability of the sensitivity (%) per degree C

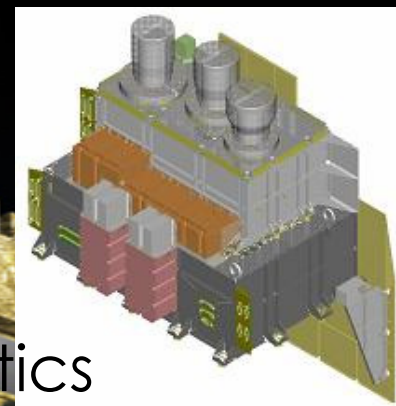
band	1		2		3	
	primary	redundant	primary	redundant	primary	redundant
P	0.365	0.364	-0.315	-0.310	-0.003	-0.023
S	0.189	0.196	-0.325	-0.326	-0.101	-0.111



Specifications

TANSO-CAI is operated together with TANSO-FTS to

- detect aerosol spatial distribution and cloud coverage
- retrieve scattering spectral characteristics of aerosol



Band No.	Observation Band (nm)	Center Wavelength (nm)	IFOV (km)	FOV (km)	No. of Pixels (cross track)
1	372-387	380	0.5	1000	2000
2	667-680	678	0.5	1000	2000
3	866-877	870	0.5	1000	2000
4	1560-1640	1620	1.5	750	500



Operation Mode



Operation mode		Description
Observation mode		Observation of all bands
Calibration mode	Lunar calibration	Calibration using the moon and performed once a year, as necessary. This calibration is performed by rotating GOSAT to point to the moon and orienting the sensor's FOV toward the moon simultaneously with FTS
	Electrical calibration	Calibration of the signal processing in the analogue signal processor and beyond, by inputting a reference voltage signal
	Night time calibration	Calibration of the offset level in the night time



2.2.2 Test Result

OBSERVATION WAVELENGTH

band	1	2	3	4
center wavelength(μm)	0.3783 (0.380 ± 0.005)	0.6734 (0.674 ± 0.005)	0.8720 (0.870 ± 0.005)	1.64 (1.65 ± 0.01)
wavelength width(μm)	0.018 (<0.02)	0.015 (<0.02)	0.014 (<0.02)	0.086 (<0.1)
out of band characteristics (%)	0.02(<0.360) 0.07(>0.400) 0.01(>0.700)	0.27(<0.658) 0.05(>0.692)	0.05(<0.840) 0.03(>0.890)	0.23(<1.53) 0.07(>1.69)



Test Result

Band	FOV (deg)	IFOV (km)	S/N	Polarization sensitivity	MTF*:CT/AT	Sensitivity deviation between pixels**
1	72.27 (>72.2)	0.497 (0.5±0.01)	274.4	0.018 (<0.03)	0.6627/0.7505 (0.203/0.317)	93.8 (>70)
2	72.28 (>72.2)	0.497 (0.5±0.01)	223.3	0.017 (<0.03)	0.4394/0.7310 (0.203/0.317)	85.7 (>70)
3	72.23 (>72.2)	0.496 (0.5±0.01)	231.8	0.024 (<0.03)	0.2343/0.6957 (0.152/0.238)	86.1 (>70)
4	60.18 (>60.0)	1.494 (1.5±0.02)	449.1	0.019 (<0.03)	0.3257/0.4020 (0.203/0.317)	92.1 (>70)

The bracketed value are specification.

*MTF is the value at the nadir

** the output of the minimum output pixel when the output of the maximum output pixel is normalized to 100.



Test Results

Dynamic Range

gain	Spectral radiance (W/m ² /sr/μm)			
	band 1	band 2	band 3	band 4
H	155	212	129	35
M	208	445	291	68
L	900	1254	777	201

MTF

band	1		2		3		4	
	CT	AT	CT	AT	CT	AT	CT	AT
edge	0.619	0.755	0.295	0.623	0.194	0.511	0.294	0.407
center	0.663	0.751	0.439	0.731	0.234	0.696	0.326	0.402
edge	0.661	0.763	0.313	0.641	0.194	0.333	0.257	0.399



Test Result

Registration between bands

Band	CT			AT		
	edge (-side)	center	Edge (+side)	edge (-side)	center	Edge (+side)
1	-0.365	0.168	0.516	0.046	-0.028	-0.028
2	-0.144	0.559	0.982	-0.376	-0.219	-0.098
3	0	0	0	0	0	0
4	0.095	0.125	-0.122	-0.006	-0.096	-0.120

*relative value to the band 3



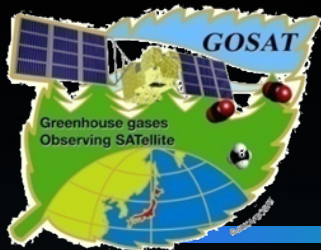
3. PRE-LAUNCH



The pre-launch calibration of TANSO was carried out to determine radiance, geometry and spectral characteristics.

The following items were evaluated as the pre-launch calibration.

	items	equipment used for the evaluation
FTS	instrument function	-integrated sphere (Ar lamp) -tunable laser
	sensitivity	-fixed point blackbody and integrating sphere -blackbody cavity
	IFOV (flatness of the sensitivity in the pixel)	-collimator
CAI	sensitivity	-fixed point blackbody
	bandwidth	-monochromator and collimator
	Registration between bands	-collimator



Pre-launch



TANSO-FTS

band	1	2	3	4
pre-launch	0.92 %	1.65 %	1.64 %	0.92 %
on orbit	3.01 %	3.01 %	3.01 %	3.01 %
total	3.15 %	3.44 %	3.43 %	3.15 %