CGMS-36, JAXA-WP-02
Prepared by JAXA
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Discussed in Plenary

Status of Greenhouse Gases Observing Satellite (GOSAT)

The status of JAXA's Greenhouse Gases Observing Satellite (GOSAT) is updated. Preparing for launch in early 2009, proto-flight test is on-going.

1. Introduction

The Greenhouse gases Observing Satellite (GOSAT) is a satellite to monitor the carbon dioxide (CO_2) and the methane (CH_4) globally from orbit, and it aims to contribute to the international efforts to prevent global warming, such as the Kyoto Protocol. It is a joint project of Japan Aerospace Exploration Agency (JAXA), Ministry of the Environment (MOE) and National Institute for Environmental Studies (NIES). JAXA is responsible for satellite development, launch, and satellite operation. JAXA and MOE are in charge of the sensor development. MOE and NIES are responsible for satellite data utilization. It is scheduled to be launched inearly 2009.

2. GOSAT Mission Objectives

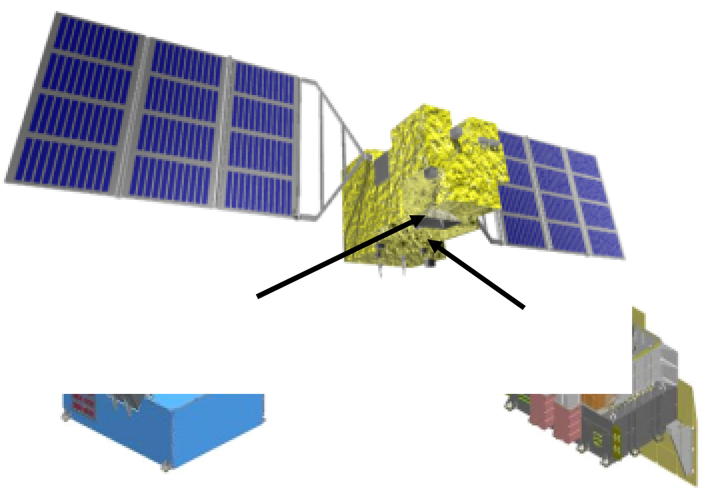
The objectives of the GOSAT mission ar e to contribute to environmental administration by estimating the Green House Gases (GHGs) source and sink in Sub-continental scale and to advance earth observation technologies for future missions.

The targets of the mission are to observe CO_2 density with 0.3 -1% (1 -4ppmv) relative accuracy in 3-month average in 1000km spatial resolution, and to observe CH_4 density with 0.6 -2% relative accuracy under the same conditions as CO_2 during the first commitment period (2008 to 2012) of the Kyoto Protocol and reducing errors by half in identifying the GHGs net absorption in sub-continental scale with the data obtained by GOSAT in conjunction with the data gathered by the ground instruments.

Other applications of GOSAT are to provide earth radiation data with high spectral resolution, to monitor the CH_4 gas leak distribution from the natural gas pipeline etc..

3. Satellite

GOSAT is a medium-size satellite which weighs 1750 kg. It will be launched by H-IIA rocket in early 2009. Fig. 1 illustrates the GOSAT spacecraft and sensors. Table 1 shows the summary of the GOSAT satellite. GOSAT will be placed in a 666 km sun-synchronous orbit of 13:00 local time, with an inclination angle of 98 deg.



TANSO-FTS:
Thermal And Near infrared Sensor for carbon Observation – Fourier Transform Spectrometer

TANSO-CAI:
Thermal And Near infrared Sensor for carbon Observation – Cloud and Aerosol Imager

Fig. 1. The GOSAT satellite and sensors.

Table 1. The GOSAT satellite characteristics.

Size	Main body	3.7 x 1.8 x 2.0 m
Mass	Total	1750kg
Power	Total	3.8 kW(End of Life)
Life Span		5 years
Orbit	Sun Synchronous	
	Altitude	666 km
	Inclination	98 deg
	Local time	13:00 +/- 0:15
	Revisit	3 days
Launch	Vehicle	H-IIA
	Schedule	Early 2009

Since March this year, GOSAT proto-flight model (PFM) has been subjected to initial electric performance test and environmental tests such as thermal vacuum tests, acoustic tests, vibration tests(Fig.2), Payload attach fitting(PAF) separation shock test and solar paddle deployment shock tests(Fig.3) at JAXA Tsukuba Space Center. These tests were completed successfully.
Currently, GOSAT PFM is being subjected to final electric performance tests, and it is scheduled to be transported to JAXA Tanegashima Space Center, the launch site at the beginning of November.

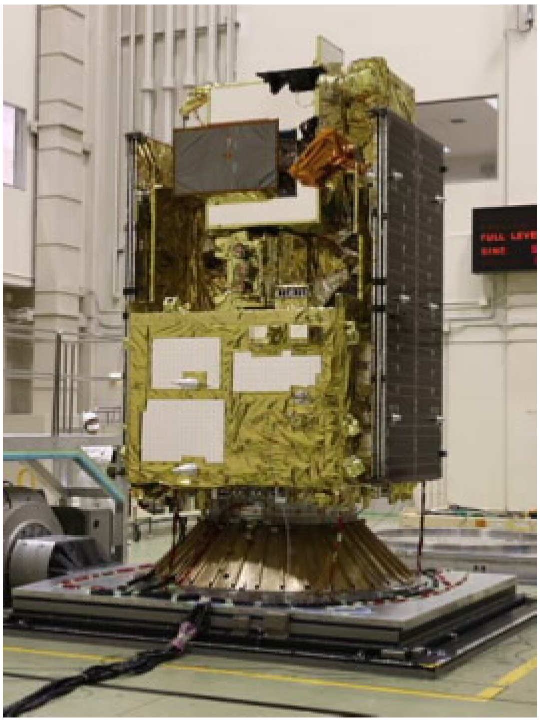


Fig. 2. Vibration test

Fig. 3. Solar paddle deployment shock test

4. GOSAT Onboard Sensors

4.1 TANSO-FTS

TANSO-FTS (Thermal And Near infrared Sensor for carbon Observations - Fourier Transform Spectrometer), which is to be accommodated on GOSAT, is a Fourier Transform Spectrometer (FTS) with high optical throughput and spectral resolution. Table 2 shows the specification of the TANSO-FTS and Fig. 4 shows the proto-flight model of the instrument. The optical layout consist of the pointing mechanism, relay optics, FTS, and detectors. The two axes redundant pointing mechanism can view the earth's surface, deep space, blackbody, and diffusers. The FTS optics and the optics of the band separation and detector are illustrated in Fig. 5 and Fig. 6, respectively. The FTS is a double pendulum type interferometer with two corner cube reflectors, and it covers from 0.76 to 15 micron with a ZnSe beam splitter and the fully redundant 1.31 micron DFB laser sampling system is applied. The modulated light by the FTS is divided into four spectral bands with diachronic filters. Then, the SWIR bands (Band1-3) lights are divided into two detectors with the polarization beam splitters. The InGaAs detectors are cooled with thermo-electric coolers. The TIR light is collected on the HgCdTe (MCT) detector, which is cooled with the pulse tube cooler. The small camera is also installed on the optical bench to register the TANSO-FTS instantaneous field of view.

Last year, proto-flight test of TANSO-FTS was finished successfully. The test result showed that TANSO-FTS (including SWIR and TIR) achieved an equipment SNR(Signal and Noise ratio) of ≧300 under specified observing conditions of wavelength and typical radiation intensity. Through this test result, we got the prospect of meeting the target of GOSAT to measure CO_2 with 0.3 -1% accuracy and to measure CH_4 with 0.6 - 2% accuracy.

Table 2. The specification of TANSO-FTS.

Ground Pointing Mechanism and Fore optics	Configuration	2-axes scanner (fully redundant)			
	Scanning	Cross Track (+/- 35 deg) Along Track (+/- 20 deg)			
	Field of view	IFOV <10.5 km 790 km (scan width) (latitude of 30 deg)			
Fourier Transform Spectrometer	Speed	0.25, 0.5, 1 (Interferogram)/sec			
	Spectral band	1	2	3	4
	Coverage (cm-1)	12900-13200 (0.76-0.78µm)	5800-6400 (1.6-1.7µm)	4800-5200 (1.9-2.1µm)	700-1800 (5.5-14.3µm)
	Resolution (cm-1)	0.2 cm^{-1} (both sides) (MOPD +/-2.5 cm)			
	Detector	Si	InGaAs	InGaAs	PC-MCT
	Observation Target	O_2	CO_2, CH_4	CO_2	CO_2, CH_4, O_3
	Calibration	Solar Irradiance, Deep Space, Moon, Diode laser			Blackbody, Deep space

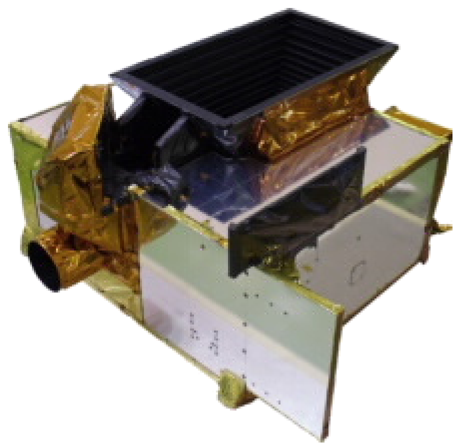
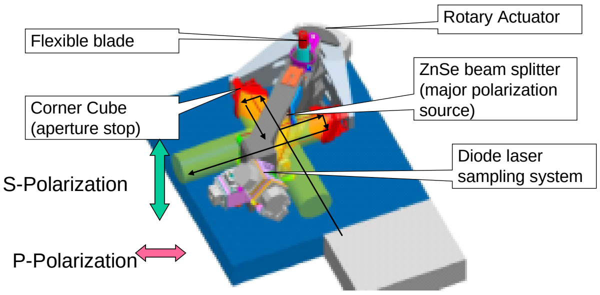


Fig. 4. The proto-flight model of TANSO-FTS



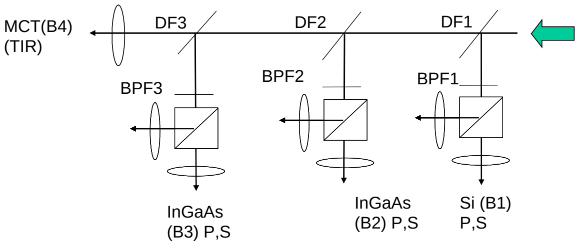


Fig. 5. The FTS optics. **Fig. 6. The band separation optics and the detectors.**

4.2 TANSO-CAI (Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager)

TANSO-CAI (Thermal And Near infrared Sensor for carbon Observations - Cloud and Aerosol Imager) to detect and correct the cloud and aerosol interference is also aboard together with the TANSO-FTS. Table 3 shows the specification of the TANSO-CAI and Fig. 7 shows the proto-flight model of the TANSO-CAI. The TANSO-CAI has continuous spatial coverage, wider field of view, and higher spatial resolution than the TANSO-FTS in order to detect the aerosol spatial distribution and cloud coverage. Using the multi spectral bands, the spectral characteristics of the aerosol scattering can be retrieved together with optical thickness. In addition, the UV band data will provide the aerosol data over the land. With the TANSO-FTS spectra, TANSO-CAI data, and the retrieval algorithm to remove cloud and aerosol contamination, the column density of the gases can be retrieved with 1 % accuracy.

Table 3. The specification of TANSO-CAI.

	Band center wavelength (micron)	Band width (nm)	Spatial resolution (IFOV) (km)	No. of pixels (cross track)
1	0.380	20	0.5	2000
2	0.674	20	0.5	2000
3	0.870	20	0.5	2000
4	1.60	90	1.5	500

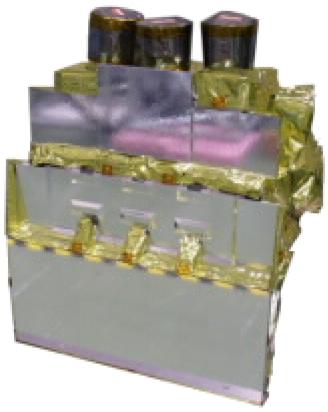


Fig. 7. The proto-flight model of TANSO-CAI

5. Sensor Operation

Fig. 8 shows the concept of the greenhouse gases observation. During the day, both the TANSO-FTS and the TANSO-CAI data are acquired, and at night only TANSO-FTS TIR (band 4) data is acquired. At the sunrise, the direct sun light is introduced into the TANSO-FTS through the Spectral on diffuser plates for SWIR radiance calibration. Two diffusers with different exposure time are introduced to correct the long term diffuser degradation. In addition, the 1.55 micron diode laser light is introduced through the diffuser plate into the TANSO-FTS to calibrate the instrument function onboard. The pointing mechanism views the deep space and inner blackbody periodically for the zero level and TIR radiance calibration.
By rotating the satellite, both the TANSO-FTS and the TANSO-CAI can view the moon surface, which provides the stable radiance source. This lunar calibration is scheduled once a year. Fig. 9 and Fig. 10 show the geometry of nadir-looking measurements and the concept of the GOSAT attitude control and pointing system, respectively. The pointing system and the FTS can point the same ground mesh footprint in every 3 days. Over the ocean in low latitude, the pointing mechanism point the sun glint point, where specular reflection occurs and reflectivity is high.

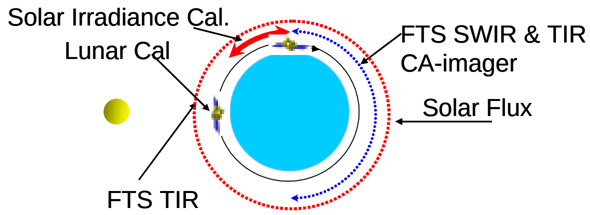


Fig. 8. The GOSAT operation.

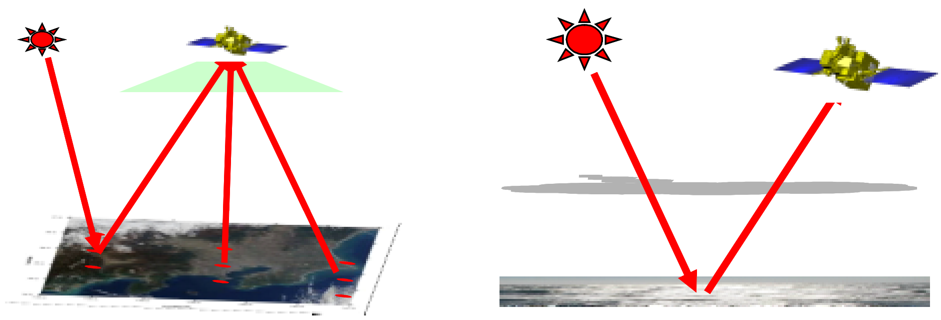


Fig. 9. The image of (a) nominal observation and (b) sun glint observation.

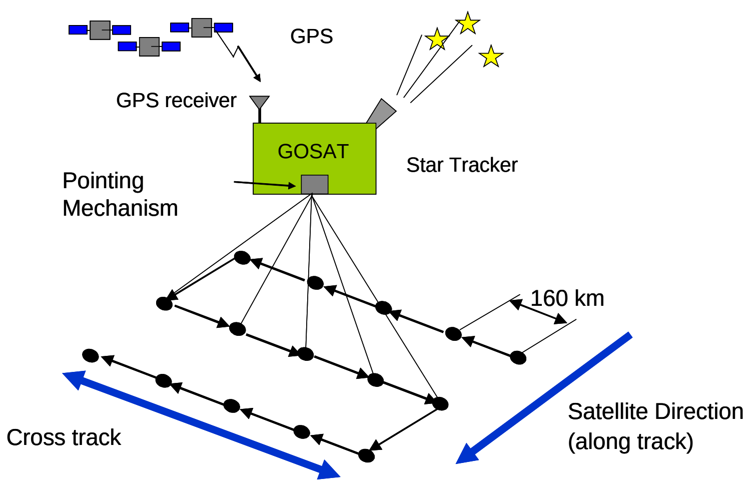


Fig. 10. The concept of attitude control and ground pointing.

6. Outline of the ground system

The obtained TANSO data accumulated on GOSAT data recorder are down linked to the ground stations in X-band at the data rate of 120 Mbps. Earth Observation Center (EOC) of JAXA and Svalbard ground station (Svalsat) of Kongsberg Satellite Services (KSAT) are assigned as the GOSAT ground stations. GOSAT data downlink is currently planned for every two satellite orbits (about every 200 minutes). All the down-linked data are decoded and divided to each APID (Application Process ID) data file and then transmitted to Earth Observation Research Center (EORC) of JAXA, in Tsukuba, where the level 1 processing for TANSO-FTS and CAI takes place. Production of level 1 products is one of the JAXA roles in GOSAT mission. Immediately after the creation, TANSO level 1 products are sent to NIES where higher level processing is applied to the TANSO data. With the higher level processing at NIES, not only column density products of GHGs including carbon dioxide and methane, also CO_2 source/sink information in sub-continental scale are retrieved. Level 1 ,2 and 3 data are planned as in HDF5, while higher products are to be in NetCDF.
The latency of level 1 product is 3 to 6 hours from the observation for global data with the current operation scenario basis (one downlink per two orbits). With downlink per every orbit, latency would be 0.5-3 hours. For higher level products, the latency is over a week since the higher level processing needs to wait the delivery of subsidiary data such as pressure, temperature and so on.

7. Data policy and data distribution

The outline of the GOSAT Data Policy is described as follows:

- GOSAT data will be available on Non-discriminatory basis.
- Charging dissemination fee for providing GOSAT data to scientific users (Free of charge via network).
- Minimum obligation to end-users; Indication of "GOSAT" credit on their publication, prohibiting re-distribution, etc.

NIES is responsible for the distribution of all GOSAT/TANSO products, while JAXA also has capability to distribute the TANSO products. Besides, JAXA is ready to accept organizational users that will use GOSAT data systematically for their operation under MOU. NIES and JAXA can distribute products shown in Table-4. Standard products will be distributed for general users. Research products will be distributed for specific users. (E.g. collaborating agency, research announcement users, and so on.)

As for the standard products, L1 products are planned to be released nine (9) months after the launch, and Levels 2 and 3 are planned 12 months after the launch, whereas Level 4 is expected to be ready in two (2) years (TBD) after the launch.

Currently, real-time data distribution is not planned; however, depending on the further requests from users, real-time service capability is possibly to be furnished. GOSAT TANSO data are open to the meteorological community utilization.

Table 4 GOSAT Products Lists (Tentative)

Product Level	Sensor	Product definition	Type of Data	Data Format	Data Segment
Level 1A	FTS	FTS Interferogram	Internal	HDF5	60 files per 1 orbit
	CAI	CAI Uncalibrated Digital Number Data	Internal	HDF5	1 file per Daylight area
Level1 B	FTS	FTS Spectral Radiance	Standard	HDF5	60 files per 1 orbit
	CAI	CAI Calibrated Radiance data	Standard	HDF5	1 file per Daylight area
Level2	FTS SWIR	CO_2 Column Amount	Standard	HDF5	Each scanning point
		CH_4 Column Amount	Standard	HDF5	
		H_2O Column Amount	Research	HDF5	
	FTS TIR	CO_2 Column Amount	Research	HDF5	
		CH_4 Column Amount	Research	HDF5	
		CO_2 Vertical Profile	Standard	HDF5	
		CH_4 Vertical Profile	Standard	HDF5	
		Temperature Profile	Research	HDF5	
		H_2O Vertical Profile	Research	HDF5	
		H_2O Column Amount	Research	HDF5	
	CAI	Cloud flag	Standard	HDF5	
		Cloud Property	Research	HDF5	1 file per Daylight area
		Global Aerosol Property	Research	HDF5	
Level 3	FTS SWIR	Global CO_2 Distribution	Standard	HDF5	-
		Global CH_4 Distribution	Standard	HDF5	-
	FTS TIR	Global CO_2 Distribution	Standard	HDF5	-
		Global CH_4 Distribution	Standard	HDF5	-
	CAI	Global Radiance Distribution (all pixcels)	Standard	HDF5	-
		Global Radiance Distribution (clear sky)	Standard	HDF5	-
		Global Cloud Property	Research	HDF5	-
		Global Aerosol Property	Research	HDF5	-
		Global NDVI	Standard	HDF5	
Level 4A	FTS	Global CO_2 Flux	Standard	NetCDF	-
		Global CH_4 Flux	Research	NetCDF	-
Level 4B	FTS	Global CO_2 Distribution	Standard	NetCDF	-
		Global CH_4 Distribution	Research	NetCDF	

8. International cooperation with other organizations

Besides GOSAT, there is another greenhouse-gas observation satellite in plan, OCO, the Orbiting Carbon Observatory, from NASA/JPL, the United States. It is scheduled to be launched in early 2009, to simply monitor CO_2. OCO and GOSAT share similar technological issues, and as such, some cooperative projects are being planed. For example, OCO and GOSAT instrument data will be exchanged and calibrated for their accuracy prior to launch, to assign common observation standards. JAXA and NASA are also considering possibilities to compare post-launch data and conduct calibration experiments together as well as discussing shared data utilization.

JAXA is planning to provide European scientists with GOSAT data via the European Space Agency (ESA) and cooperate calibration for GOSAT with ESA.

JAXA is also promoting the cooperation with the European Center for Medium-range Weather Forecasts (EMCWF) in the field of data applications.

Recently, WMO responded to CGMS action 35.05; CGMS Members to indicate to JAXA their interest in having access to GOSAT data. WMO showed “The Global Atmosphere Watch (GAW) programme and its greenhouse gas research community wish to be added to the list of parties requiring access to GOSAT data.”
JAXA is willing to accept WMO’s request and is going to negotiate the method of delivering the GOSAT data with the Global Atmosphere Watch (GAW) programme and its greenhouse gas research community.
WMO also showed “The GOSAT instrument specifications anticipate an accuracy of <1% (1-4ppm; 3 months average) for CO_2 column retrievals, as well as 0.6-2% accuracy for CH4 - at a lower SNR - both would be in line with the GCOS accuracy requirements.”
As JAXA indicated in chapter 4.1, JAXA got the prospect of meeting the target of GOSAT to measure CO_2 with 0.3 -1% accuracy and to measure CH_4 with 0.6 – 2% accuracy, through the proto-flight test result which showed TANSO-FTS (including SWIR and TIR) achieved an equipment SNR(Signal and Noise ratio) of ≧300.
WMO also showed “Collaboration and cross-comparison with the data acquired by the OCO instrument (currently scheduled for launch around the same time as GOSAT - early 2009) is particularly encouraged.”
As JAXA described above, GOSAT and OCO is actively promoting the collaboration in the field of cross-calibration and data exchange.