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GREENHOUSE GASES OBSERVSTION FROM SPACE
– Overview of TANSO and GOSAT –

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ABSTRACT

Japan Aerospace Exploration Agency (JAXA) is developing Greenhouse gases Observing Satellite (GOSAT). GOSAT is the first satellite to monitor the columnar density of carbon dioxide and methane operationally from space. The GOSAT is the joint endeavor with JAXA, National Institute for Environmental Studies and Ministry of the Environment. The GOSAT will be launched with the H-IIA launch vehicle in early 2009. This paper shows the overview of GOSAT and its mission instrument, TANSO. Mission objectives, sensor and satellite design, its performance and summary of ground test results are also provided.

1. INTRODUCTION

Currently, surface greenhouse gas density is regularly observed with ground observation network. One of the networks is World Data Center for Greenhouse Gasses (WDCGG). WDCGG consists of 258 ground stations and data is distributed worldwide via internet. WDCGG is operated by Japan Meteorological Agency (JMA) and World Meteorological Organization (WMO). However, the ground stations are not uniformly located. There are less observation stations in developing countries and over oceans. Frequency of data update is limited to around once a month and, in some cases, it takes two years for data release. The GOSAT is designed to observe columnar density distribution of CO2 and CH_4. GOSAT will conduct 56,000 observations in every three days and planned to distribute data within three days (Level-l one data) after observation. GOSAT data is expected to improve the accuracy improvement for global warming studies.

Fig. 1 Illustration of GOSAT in Orbit

2. MISSION OBJECTIVES

The mission objective of the GOSAT is to observe the global columnar density distribution of CO_2 and CH_4. The accuracy of CO_2 and CH_4 columnar density is expected between 1-4ppm and 10-34ppb respectively. The estimation of net absorption-emission rate in sub-continental scale is also planned and accuracy is expected to improve at least by half compared with current ground observation based estimation.

3. GOSAT SPACECRAFT

GOSAT is a medium-sized and single mission satellite. Its mass is 1,750kg and wing span is 13.7m. Fig. 1 illustrates the on orbit configuration of the GOSAT and Table 1 shows the satellite specifications. The satellite orbit is 666km altitude, 3 days recursive sun-synchronous orbit. In order to reduce development risks and to achieve high reliability, the GOSAT fully utilizes the flight-proven parts and components for its bus systems. GOSAT project team was established in April 2003. After the preliminary design review in 2005 and critical design review in 2007, assembly of Proto-Flight Model (PFM) was initiated. Currently, Proto-Flight Test (PFT) is under conducted. Entire PFT will be concluded in Oct.2008 and will be launched with Japanese H-IIA launch vehicle in early 2009.

Table 1. GOSAT Specifications

Size	3.7mx1.8mx 2.0m Wing Span 13.7m
Mass	1,750kg
Power	3.8 kW (EOL)
Mission life	5 years
Orbit	Sun synchronous orbit
	Local time: 13:00+/-0:15
	Altitude: 666km
	Inclination: 98deg
	Re-visit: 3 days
Launch	H-IIA in early 2009

Fig. 2 shows the picture of GOSAT PFM.

Fig. 2 GOSAT PFM under vibration test

4. MISSION SENSORS

4.1 TANSO-FTS

GOSAT has two mission sensors on-board. One is the Thermal ANd short wave infra-red Sensor for Observing greenhouse gases (TANSO-FTS). Fig. 3 and Table 2 show the overview and specifications of the TANSO-FTS respectively. The TANSO-FTS is a Fourier transform spectrometer and covers between 0.76um (micron) and 14um in 0.2cm^{-1} spectrum resolution. Fig. 4 shows spectral coverage and observed gases. The 0.76um band is used to observe O_2 density and determines the exact path length. The 1.6 and 2.0um bands in short wave infrared (SWIR) region are used to observe CO_2 density.

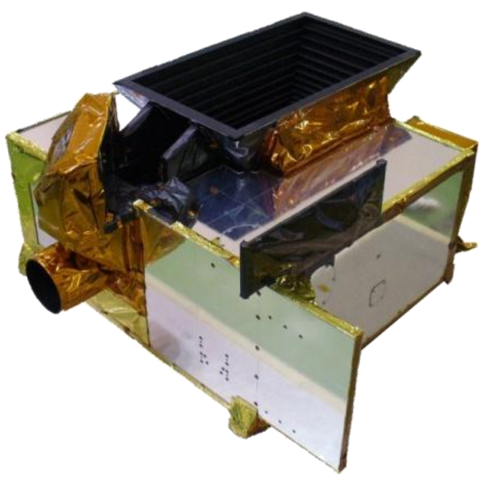

Fig.3 TANSO-FTS

The 1.6um band is also used to observe CH_4 density. The 5.5-14um band in thermal infrared (TIR) region is used to observe CO_2, CH_4, water vapor, atmospheric temperature and pressure. Altitude distribution profile for CO_2 and CH_4 is also available with this band. The number of total observation channel reaches up to 18,500. Fig. 5 shows the optical schematics of TANSO-FTS. Sensor has fully redundant pointing mechanisms on-board. Two axes pointing mechanism allows GOSAT to observe any selected observation points on the earth surface. In the normal operations mode, one observation takes four seconds to keep enough integration time. Five observation points are allocated in one single row and then proceeds to the next column (See Table 3 and Fig.6). With this zigzag sequence, 180km mesh world-wide observation becomes possible. Over the ocean in day-time, operation mode is switched to the sun-glint points tracking mode. Sun-glint points tracking mode gives brighter sun reflection and consequently higher accuracy observation is expected. Through the performance tests, TANSO-FTS has been verified to meet all of the specifications.

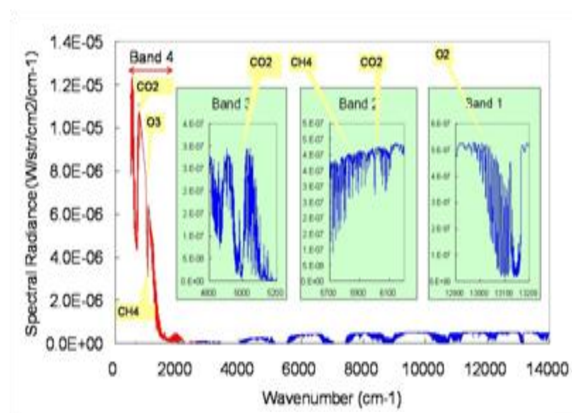

Fig. 4 TANSO-FTS Spectral Coverage and observed gases

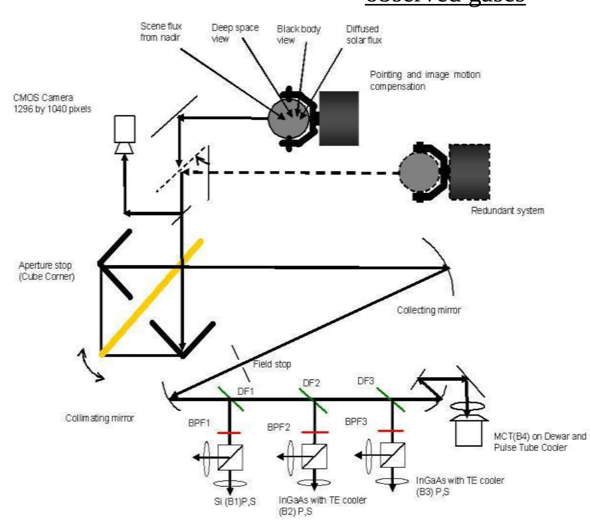

Fig.5 TANSO-FTS Optical Schematics

Table 2. TANSO-FTS Specifications

Ground Pointing Mechanism and Fore optics	Configuration	2-axes scanner (fully redundant) for ground pointing and calibration			
	Scanning angle	Cross Track (+/-35 deg), Along Track (+/-20 deg)			
	Field of view	IFOV =10.5 km FOV=790 km (scan width) (at latitude of 30 deg)			
Fourier Transform Spectrometer	Speed	0.25, 0.5, or 1 (Interferogram)/sec selectable			
	Spectral band number	1P, 1S	2P, 2S	3P, 3S	4
	Wave length(um)	0.75-0.78	1.56-1.72	1.92-2.08	5.5-14.3
	Wave number(cm^{-1})	12900-13200	5200-6400	4800-5200	700-1800
	Resolution (cm^{-1})	0.5	0.2	0.2	0.2
	Detector	Si	InGaAs	InGaAs	PC-MCT
	Calibration	Solar Irradiance(Spectralon), Deep Space, Moon, Diode Laser (1.55 micron, ILS)			Blackbody, Deep space

Table 3 Cross-track Pointing

Cross-track pattern	Distance b/w obs. points (at 30deg in latitude)	Observation time (Integration time)
1	790 km	4sec x 3times
3	260 km	4sec x 3times
5	160 km	4sec
7	110 km	2sec
9	88 km	1sec

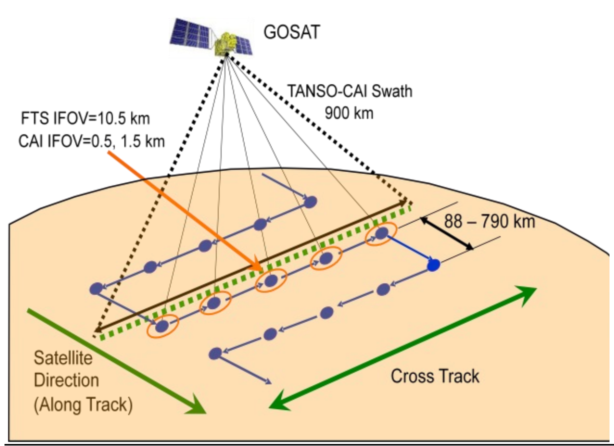

Fig.6 Observation Geometry

4.2 TANSO-CAI

The second sensor is the Cloud and Aerosol Imager (TANSO-CAI) and it is used to compensate errors which are caused by cloud and aerosol. TANSO-CAI configuration and specifications are shown in Fig.7 and Table 4 respectively.

Fig.7 TANSO-CAI

Table 4. TANSO-CAI Specifications

ch	Observation Band (nm)	Spatial Resolution (km)	FOV (km)	No. of Pixels
1	372-387	0.5	1000	2000
2	667-680	0.5	1000	2000
3	866-877	0.5	1000	2000
4	1560-1640	1.5	750	500

5. GROUND TEST MODELS AND CAMPAIGNS

Two kinds of ground test models were developed. The first "TOKYO" was developed in 2004 and used to demonstrate the TANSO-FTS hardware concept prior to its engineering model fabrication and test. TOKYO is capable of collecting data over 3 spectral bands (0.76 micron, 1.6 micron band, and 2.0 micron band). Aperture diameter of TOKYO is slightly smaller than TANSO-FTS because of the component availability of that time. The laboratory test results showed that TOKYO accurately detected the CO_2 and CH_4 spectra with 0.2 cm^{-1} spectral resolution. The performance demonstrations aboard an aircraft and airship were carried out between 2004-2007 as the joint research between NIES and JAXA (See Fig.8). The demonstration results show that the effect of vibration was relatively small and negligible.

The second "TSUKUBA" was developed in 2006 under the contract from MOE. The hardware of TSUKUBA was very close to TANSO-FTS. This model was provided to NIES for the aircraft campaign in Australia and Siberia and used to verify the accuracy of NIES's data processing algorithm

Fig. 8 TOKYO and Its Campaign
(Aircraft and Airship)

6. DATA DISTRIBUTION

JAXA is responsible for GOSAT sensor and satellite development, launch and operation. JAXA is also responsible for Level-1 (Spectra) data processing while NIES is responsible for Level-2 (CO_2 and CH_4 columnar density) and higher level data processing. Standard products are exchanged between JAXA and NIES and will be distributed worldwide. GOSAT data distribution via ESA and/or NASA is under coordination. General distribution for Level-1 data and Level-2 data are planned to start nine months and twelve months after launch respectively.

7. CONCLUSION

GOSAT is at the final phase of proto-flight testing and will be launched in early 2009. TANSO-FTS and TANSO-CAI has been verified to meet its specifications. GOSAT data will be processed by JAXA and NIES and distributed worldwide.