CONSIDERATIONS ON SOUNDING INSTRUMENTS OF FUTURE CHINESE SATELLITES

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1. INTRODUCTION

In China, meteorological satellites have become an irreplaceable weather and ocean observing tool. These satellites are monitoring major natural disasters and improving the efficiency of many sectors of our national economy. Therefore, the meteorological satellite has been regarded as a kind of applied satellite with notable social and economic benefit among man-made satellites in China. It is not feasible nowadays to ignore the space derived data in the field of meteorology, hydrology, agriculture as well as disaster monitoring in China, such a big agricultural country. For this reason, China is making her unremitting efforts on building up the meteorological satellite systems and data applications, based upon the policy "for the benefit of all mankind".

The developing strategy of meteorological satellites in China observes the following baseline: For carrying on China's space technology and remote sensing technology, keeping pace with the onward march of the meteorological satellite development and application over the world, China will establish her own, with combination of polar and geostationary orbits, operational satellite system as well as the ground monitoring and application data systems around the year 2000, in order to meet the needs on various aspects, and enhance the capacity of participating international collaboration.

In China, meteorological satellites are named simply as Fengyun series, abbreviated as FY-series. The Chinese words Fengyun in English standards for "Winds and Clouds". We use the FY- odd number ,i.e. FY-1, FY-3, etc. to name the polar orbiting satellite system, and FY-even number, i.e. FY-2, FY-4, etc. for geostationary system.

2. DEVELOPMENT OF CHINA'S POLAR METEOROLOGICAL SATELLITES

China's polar orbiting meteorological satellite system, according to present planning, will consist of four satellites for FY-1 series, as well as the corresponding ground data acquisition and data processing and application systems.

2.1 The China's first generation of polar orbiting meteorological satellites

2.1.1 The FY-1A and FY-1B

On September 7, 1988, China launched successfully her first self-developed experimental trial-type polar-orbiting meteorological "Fengyun-1"(FY-1A), marking a historical new phase entered by China in meteorology of probing the earth and atmosphere from space.

The FY-1A was designed and manufactured by the Ministry of Aeronautics and Astronautics of China according to the requirement specifications of China Meteorological Administration (CMA). The satellite is a hexahedron of 1.4 × 1.4 × 1.2(in height) and the weight is 750 kg. The main meteorological payloads are the Visible and Infrared Radiometers. There are no sounding instruments on FY-1 satellite series. Table 1 gives the main orbit parameters and table 2 gives the channel characteristics of the radiometers onboard FY-1A and FY-1B satellites

Table 1. Orbit parameters of FY-1 Meteorological satellites

Satellite	FY-1A	FY-1B
Launch date	September 9,1988	September 3, 1990
Orbit	Sun-synchronous	Sun-synchronous
Altitude (km)	901	901
Period (minutes)	102.86	102.86
Inclination (degrees)	99.0	98.9
Eccentricity	<0.005	<0.005
Descending Node(LST)	03:30	07:50
Attitude Control	Three-axis Stabilized	Three-axis Stabilized

Table 2. The channel characteristics of radiometers onboard FY-1A and FY-1B

Channel	Wavelength(μm)	Primary Use
1	0.58-0.68	Cloud and surface image, vegetation
2	0.725-1.1	Cloud and surface image, vegetation
3	0.48-0.53	Ocean color
4	0.53-0.58	Ocean color
5	10.5-12.5	Diurnal cloud and surface image, SST

The FY-1 data transmission format is very much similar to NOAA/HRPT format. In addition, there are Automatic Picture Transfer (APT) and Delayed Picture Transfer (DPT) formats as well.

The status of FY-1A

FY-1A was launched successfully on September 7, 1988 by launch Vehicle of Long March-4. The spacecraft went into the predicted orbit accurately and started to make observations at the same day. The pictures from the visible channels were quite good, and the signal to noise ratios was higher than the designed ones. Unfortunately, it worked only for 39 days and did not fulfill its expected lifetime because the satellite attitude was out of control. However, during the flight of FY-1A the performance and specifications of the payload and the satellite subsystems were examined. The results are: the overall consideration of the system and its subsystem designs were reasonable, all the requirements on orbit parameters were met. The satellite structure and most of the service subsystems are quite satisfied. The main problems are the attitude control subsystem. The main problem for the radiometer is that the observation of infrared channel was failed because of the possible water vapor pollution on infrared sensors.

The Status of FY-1B

The second spacecraft of FY-1 series, very similar to the FY-1A, was launched successfully into predicted orbit on September 3, 1990. Although the overall design of FY-1B is almost the same as FY-1A, the quality of FY-1B was really an improvement on FY-1A's, both on satellite attitude control and on scan radiometers. This satellite made successive observations for half a year. However, after half a year the same problem, the attitude out of control appeared again. After rescuing by ground commanding, the satellite was brought back and made observations again until the late 1992 when the rescuing was give up. This indicated that there are some problems on reliability remained to improve further.

2.1.2 The FY-1C and FY-1D

China decided to continue the FY-1 series and to launch FY-1C and FY-1D in the year of 1998 and 2000 respectively. Now the satellites are developed on the basis of FY-1A and FY-1B. Besides the efforts to improve the reliability and extend the life time of satellites there are some changes on imaging instruments and data transmission.

The main payload on FY-1C and FY-1D are ten-channel visible and infrared radiometers. The instantaneous field of view of the radiometer is 1.2 mrad and the resolution at the satellite subpoint is 1.1 km. The scan rate is still 6 lines/sec and the total pixels of each scan line are 2048. The channel features are indicated in table 3.

The FY-1C and FY-1D High Resolution Picture Transmission will be also very similar to NOAA/HRPT. It is considered that the system that receives and process NOAA/HRPT nowadays can receive and process the FY-1 data with updating as few as possible.

The transmission rate will be increased to 1.3308 Mbps, just twice as many as the bit rate of the current

NOAA/HRPT. The transmission modulation is PSK and bit format is split phase. There is no APT in FY-1C and FY-1D.

Table 3. The channel characteristics of radiometers onboard FY-1C and FY-1D

Channel	Wavelength(μm)	Primary Use
1	0.58-0.68	Daytime cloud, ice and snow, vegetation
2	0.84-0.89	Daytime cloud, vegetation
3	3.55-3.95	Heat source, night cloud
4	103.-11.3	SST, day/night cloud
5	11.5-12.5	SST, day/night cloud
6	1.58-1.64	Soil moisture, ice/snow distinguishing
7	0.43-0.48	Ocean color
8	0.48-0.53	Ocean color
9	0.53-0.58	Ocean color
10	0.90-0.985	Water vapor

2.2 China's second generation of polar orbiting meteorological satellites

Fengyun-3 series, the second generation of China's polar orbiting satellites, will be launched from 2000-2015 according to present plan. The main mission objectives for FY-3 are

- global sounding of 3-dimensional thermal and moisture structures of the atmosphere, cloud and precipitation parameters to support global numerical weather prediction
- global imaging to monitor large scale meteorological and/or hydrological disasters and biosphere environment anomaly
- provide important geophysical parameters to support researches on global change and climate monitoring.
- data collection

The development of FY-3 series will include two stages, i.e., Stage-I during 2000-2007 involving 3 satellites. To achieve above-mentioned objectives, nine instruments are planned in stage-I and two of them are main sounding instruments. In section 4 some details of the sounding instruments will be given.

3. CHINA'S GEOSTATIONARY METEOROLOGICAL SATELLITES

China will launch her first generation of geostationary meteorological satellite named FY-2A sometime this year. It will be located at 105°E over equator, facing the middle China so as to provide better upstream cloud pictures for China and most of Asian region.

The FY-2 system consists of the satellite and the ground system. The FY-2 satellite is a cylinder of 2.1m by 1.6m. The attitude of the satellite is spin stabilized with a speed of 100±111 rotation/min. The main remote sensing instrument is the Visible and Infrared Spin Scan Radiometer (VISSR). There will be no sounding instruments on FY-2 series of satellites. Table 4 gives the FY-2 satellite specifications and table 5 gives the VISSR characteristics.

Table 4. The FY-2A satellite specifications

Dimension	Diameter Height	2.1 meter 1.6 meter
Mass	Beginning of Life End of Life	516.5 kg 467.5 kg
Life	Design Life	3 Years
Spin rate		100±1 rpm

Table 5. VISSR Characteristics onboard FY-2A satellite

Characteristics	Spectrum	Value
Number of sensors	Visible Infrared Water vapor	4(+4 Redundant) 1(+1 Redundant) 1(+1 Redundant)
Number of scan lines	Visible Infrared Water vapor	2500*4 2500*1 2500*1
IGFOV	Visible Infrared Water vapor	35*35 μr 140*140 μr 1408140 μr
Spectral bands and resolution at satellite subpoint (SSP)	Visible Infrared Water vapor	0.55-0.75μm (1.25 km) 10.5-12.5μm (5.0 km) 6.3-7.6μm (5.0 km)
Scan step angle		140 μr (N-S scanning)
Frame time		30 minutes
Precision	Visible Infrared	6 bits 8 bits

The FY-2 ground system, with the primary ground center located at National Satellite Meteorological

Center in Beijing, is a multifunctional real time trial-operational system. The system includes a Command and Data Acquisition Station (CDAS), the Data Process Center (DPC) and Satellite Operation Control Center (SOCC), the Turn Around Ranging Stations (the primary station in Beijing and three secondary stations in Guangzhou, Urumqi and Australia), a communication system, the Data Collection Platforms (DCP), the Medium-scale Data Utilization Stations (MDUS), the Small-scale Data Utilization Stations (SDUS), and Facsimile or cloud image receiving stations (S-WEFAX) etc.

4. MAIN SOUNDING INSTRUMENTS ONBOARD FY-3 SATELLITES

China started design and development of atmospheric sounder as early as 1979. In 1984 the first prototype sounder with 9 channels has been made. To insure FY-3 mission has the capacity of obtaining global sounding to meet the need of global numerical weather prediction, now the designing and development of two main sounding instruments onboard FY-3 satellites, i.e. the Infrared Atmospheric Sounder and Microwave Atmospheric Sounder have been initiated.

4.1 Sounding instruments planned onboard stage-I FY-3 satellites

Infrared Atmospheric Sounder (IRAS)

The IRAS receives infrared and visible spectrum radiation through a telescope and selects 26 narrow

Table 6. IRAS system characteristics

Characteristics	Value
Calibration	Stable warm blackbody (290K) Space background (4K)
Calibration period	256 seconds
Cross-track scan	±49.5 degrees
Scan time	6.4 seconds
Number of steps	56
Optical FOV	0.97 degrees
Step angle	1.80 degrees
Step time	100 ms
Ground IFOV	14 km in diameter
Diameter of primary mirror	15 cm
No. of longwave IR detectors	13, HgCdTe
No. of shortwave IR detectors	7 HgCdTe
No. of visible and near-IR detectors	6 , Silicon, HgCdTe
Precision	13 bits
Size	755*320*350 (in height)
Total weight	45 kg
Power	45 watts (average)

radiation channels by means of a rotating filter wheel. It can measure incident radiation in 24 IR spectrum, include longwave IR, shortwave IR, near IR and 2 visible wavelengths. A passive radiant cooler provides an operating temperature of about 100K for the HgCdTe detectors. Low noise amplifiers and digital processing provide 13 bit data for satellite data multiplexing and transmission. Table 6 gives the IRAS system characteristics and table 7 shows the IRAS channels characteristics.

Table 7. IRAS channel characteristics

Channel	Central wavelength (μ)	Half-power bandwidth ($^{-1}$)	Main absorber	Max.Scene temperature (K)	Contribution Peak(Hpa)	Δ Specification	Main Purpose
1	14.95	3	CO_2	280	30	3.0	T(p)
2	14.71	10	CO_2	265	60	0.67	T(p)
3	14.49	12	CO_2	240	100	0.50	T(p)
4	14.22	16	CO_2	250	400	0.31	T(p)
5	13.97	16	CO_2	265	600	0.21	T(p)
6	13.64	16	CO_2/H_2O	280	800	0.24	T(p)
7	13.35	16	CO_2/H_2O	290	900	0.20	T(p)
8	11.11	35	Window	330	surface	0.10	Surface
9	9.71	25	O_3	270	25	0.15	Total ozone
10	8.16		H_2O	290	900	0.15	Water vapor
11	7.33	40	H_2O	275	700	0.20	Water vapor
12	6.52	80	H_2O	265	500	0.20	Water vapor
13	4.57	23	N_2O	300	1000	0.006	T(p)
14	4.52	23	N_2O	290	950	0.003	T(p)
15	4.47	23	CO_2/N_2O	280	700	0.004	T(p)
16	4.40	23	CO_2/N_2O	265	400	0.004	T(p)
17	4.20	23	N_2O	280	15	0.002	T(p)
18	4.00	35	window	340	surface	0.002	Surface T
19	3.76	100	window	340	surface	0.001	Surface T
20	0.69	1000	window	100%	surface	0.10%A	Cloud Detect
21	14.8	3	CO_2	280	5	3.00	High Level T
22	0.659	TBD	window	VIS	surface	0.003	CO_2
23	0.885	TBD	window	NIR	surface	TBD	Aerosol
24	0.94	TBD	H_2O	NIR	surface	TBD	Cirrus
25	1.24	TBD	window	NIR	surface	TBD	Cirrus
26	1.64	TBD	window	NIR	surface	TBD	Cirrus

From table 7 one can see that the first 20 channels of IRAS are almost the same as HIRS/3. The six more channels compared with HIRS/3 will enable IRAS to have the capacity of measuring aerosols, stratosphere temperature, carbon dioxide content and cirrus.

Microwave Atmospheric Sounder (MWAS)

The MWAS is a passive scanning microwave spectrometer with 8 channels, including 4 channels around 50 GHz similar to MSU and 4 channels in 19.35, 23.9,31.0 and 89.0 GHz respectively. The purpose of developing MWAS, at the first stage of FY-3, is using it as an auxiliary instrument to IRAS to improve sounding capacity in cloudy region. At the second stage of FY-3, the MWAS with 15 channels will become the primary sounding instrument to carry on all-weather sounding. The instrument and channel characteristics are shown in tables 8 and 9 respectively.

Table 8. The MWAS instrument characteristics

Characteristics	*Value*
Cross-track scan angle	±47.31 degrees
Scan time	25.6 seconds
Number of steps	11
Step angle	9.47 degrees
Step time	1.84 seconds
Ground IFOV at nadir	100 km
Calibration	Stable warm blackbody Space background each scan line
Date rate	640 bps

Table 9. Channel Characteristics of the MWAS

Ch.	Frequency (GHz)	Absorber	Band width (MHz)	NEDT (K)	Calibration Accuracy(K)	Resolution (Nadir, km)
1	19.35	window	220	0.3	1.5	100
2	23.90	H_2O	250	0.3	1.5	100
3	31.00	window	600	0.25	1.5	100
4	50.31	window	220	0.3	1.0	100
5	53.74	O_2	220	0.3	1.0	100
6	54.96	O_2	220	0.3	1.0	100
7	57.95	O_2	220	0.3	1.0	100
8	89.00	window	6000	0.8	1.5	50

4.2 Sounding instruments planned onboard FY-3 stage-II

In FY-3 stage-II the MWAS will be improved according to the present plan. The main improvement is: adding 7 or more channels around 60 GHz, to enable MWAS to have the improved sounding capacity. In addition, two new instruments related to sounding will be added. The two new instruments will probably be Microwave Humidity Sounder (MWHS) and Multichannel Infrared Atmospheric Sounder (MIRAS) with more than thousands of channels.

5. SUMMARY

China has been receiving cloud images from foreign satellites since 1960's and has gain great benefit by utilizing satellite data from foreign satellites since then. The above presented Chinese Fengyun series, with the combination of polar orbiting and geostationary meteorological satellites, consider the China contribution to the global environmental satellite system. China wishes, by the year 2000 with the operational Fengyun series, to have her own place among the world's operational system, and to let other countries to share the Chinese satellite data and to make benefit to the people world over.

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