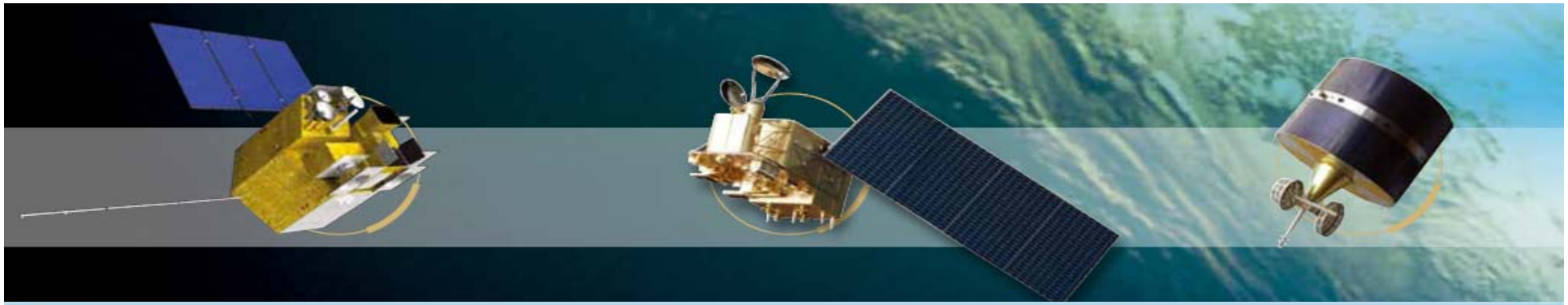


The status and future plan of Yengyun(FY) meteorological Satelltes

Peng ZHANG

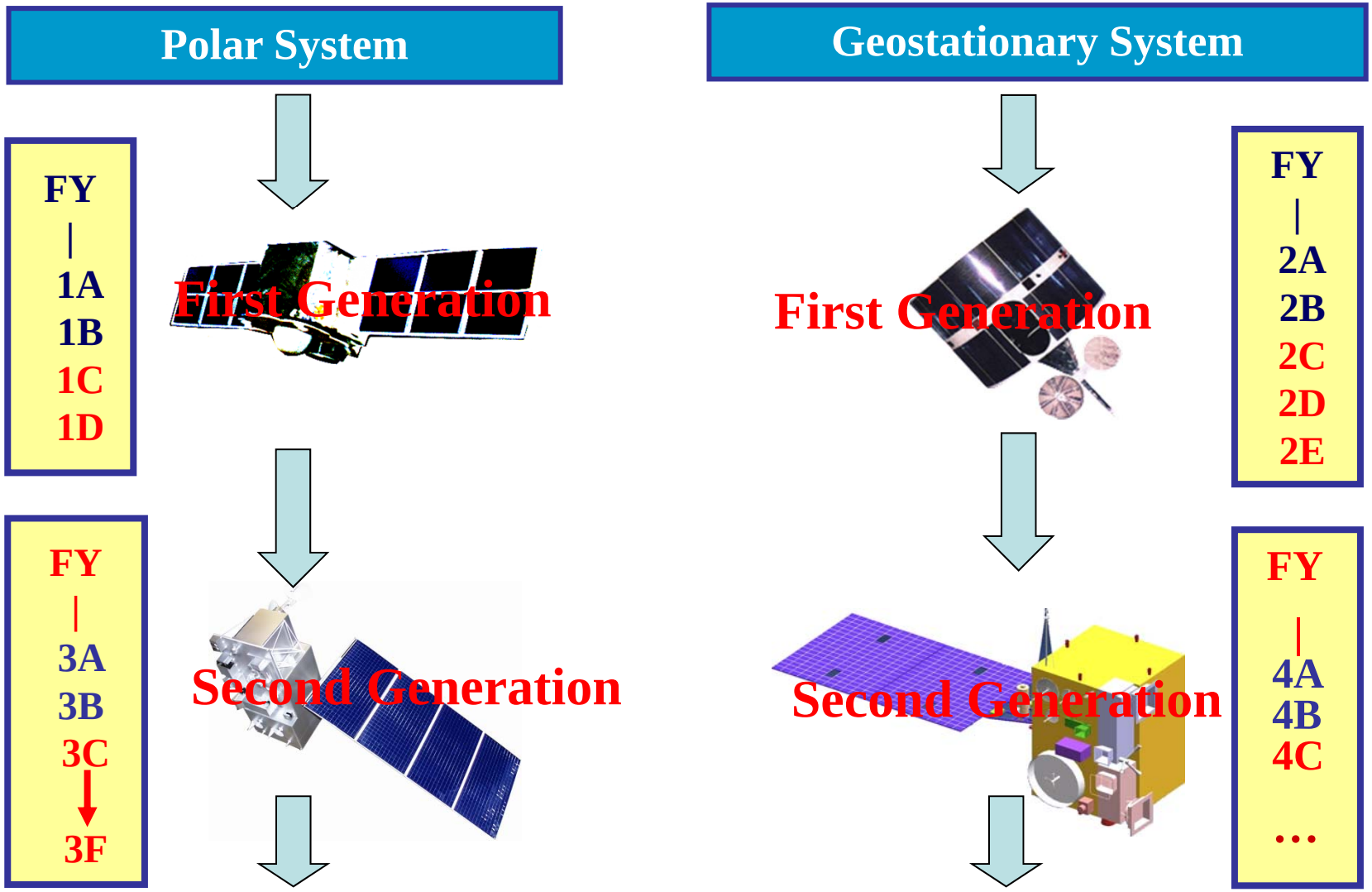
National Satellite Meteorological Center ,CMA

High Level Working Group on Satellite Matters

Outline

- Current Status
- Future Plan for LEO
- Future Plan for GEO
- Conclusions

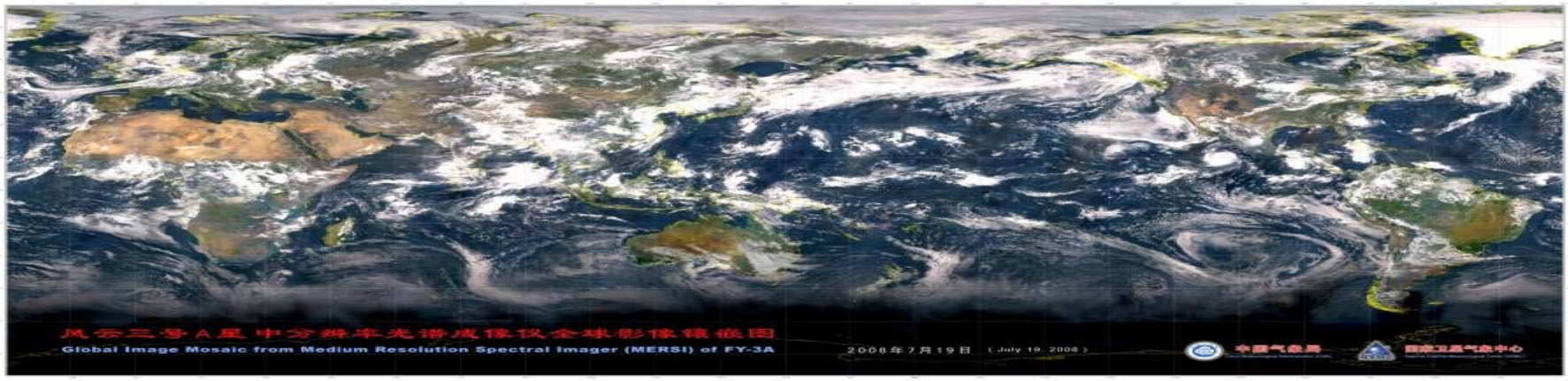
1. Current Status



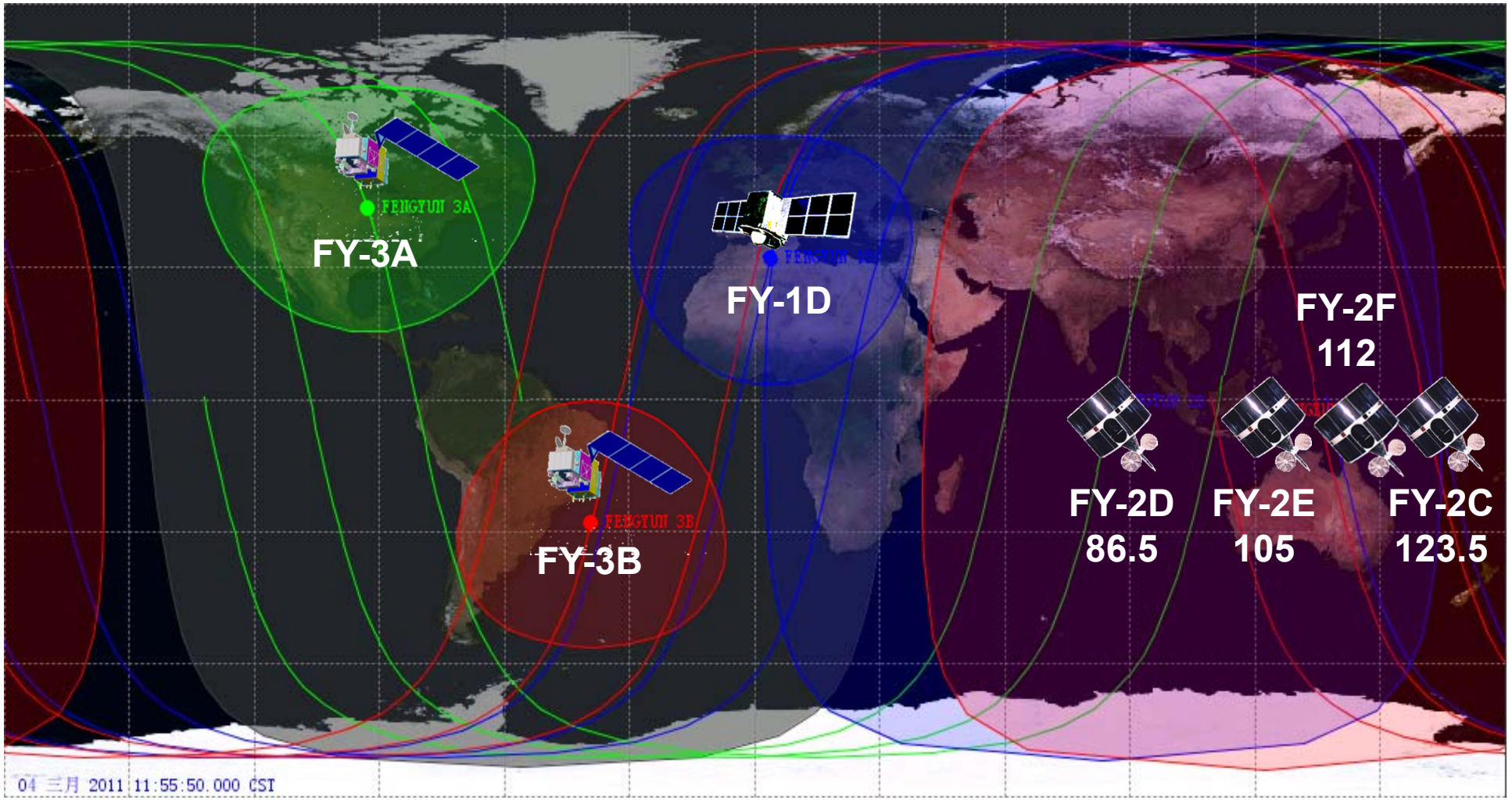
FengYun Meteorological Satellites

Launched Satellites

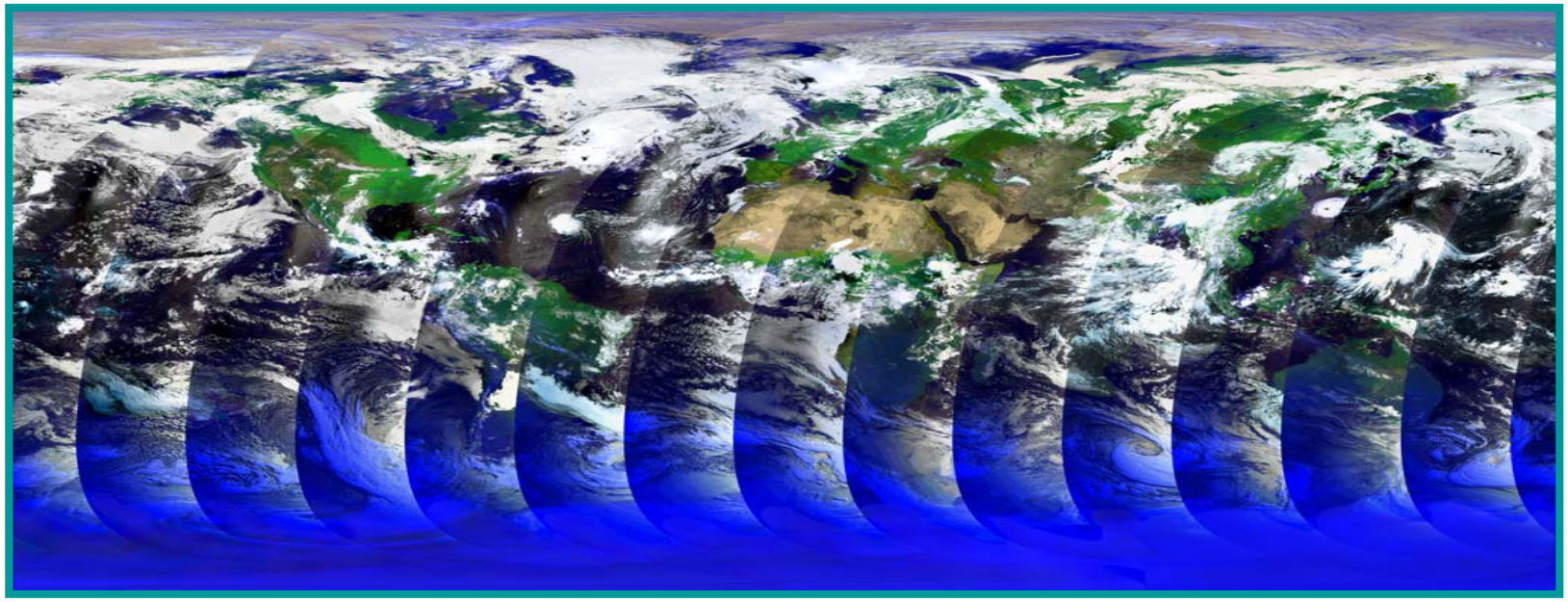
Since Jan. 1969, China began to develop his own meteorological Satellite				
Leo	Launch Data		Geo	Launch Data
FY-1A	Sept. 7, 1988		FY-2A	Jun. 10, 1997
FY-1B	Sept. 3, 1990		FY-2B	Jun. 25, 2000
FY-1C	May 10, 1999		FY-2C	Oct. 18, 2004
FY-1D	May 15, 2002		FY-2D	Dec. 8, 2006
FY-3A	May 27, 2008		FY-2E	Dec. 23, 2008
FY-3B	Nov 5, 2010		FY-2F	Jan. 13, 2012



On-orbit Satellites



FengYun LEO. Satellites: FY-1



Instruments:

✓10 chl. Visible and Infrared radiometer.

✓Space Environment Monitor

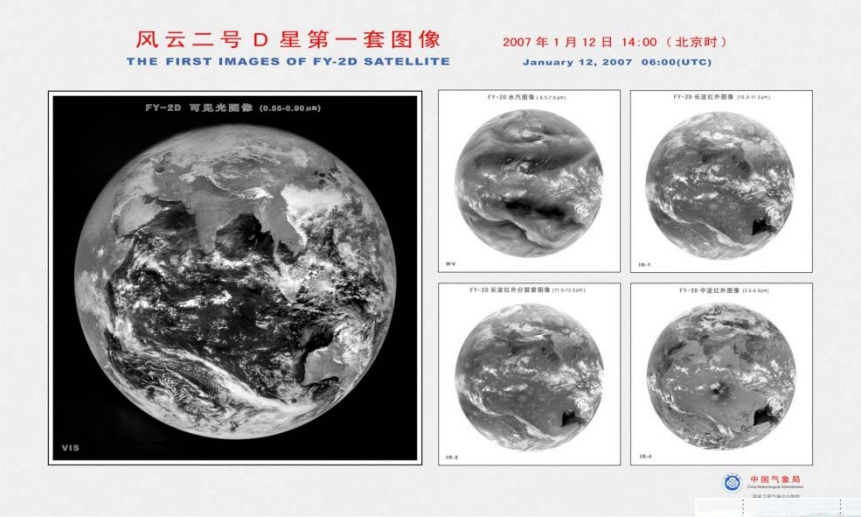
Transimission:

✓ HRPT: 1.3308Mbps (DB)

✓ GDPT: 1.3308Mbps

No.	Status	Launch	Druation
FY-1A	Exp. (dead)	Sept.7, 1988	6 months
FY-1B	Exp. (dead)	Sept.3, 1900	8 months
FY-1C	Op. (dead)	May 10, 1999	>7 years
FY-1D	Op. (working)	May 15, 2002	>7 years

FengYun GEO. Satellites: FY-2



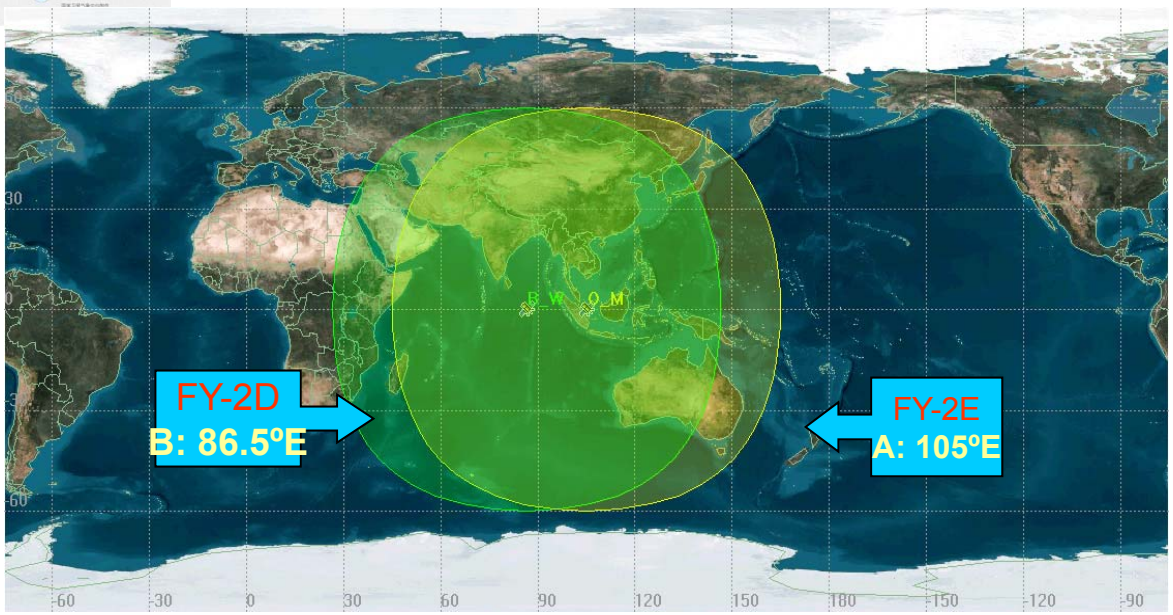
No.	Pos.	Status	Launch
FY-2A	105E	Exp. (dead)	Jun.10, 1997
FY-2B	105E	Exp. (dead)	Jun.20, 2000
FY-2C	105E	Op. (working)	Oct.18, 2004
FY-2D	86.5E	Op. (working)	Dec.8, 2006
FY-2E	105E	Op. (Stored)	Dec.23,2008

Platform: Spin stabilization

Payload: 5 chl. VISSR

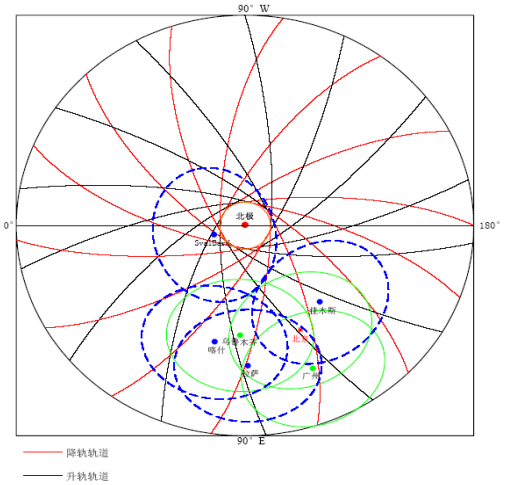
Full Disc: every 30 min. at most

- ✓ FY-2E & FY-2D are working together to implement 15 min. interval obs.
- ✓ FY-2E takes over FC-2C in DEC., 2009!



FengYun LEO. Satellites: FY-3

11 instruments on board FY-3A/B, including:
VIRR: Visible and Infra-Red Radiometer
MERSI： Medium Resolution Spectral Imager
IRAS： Infrared Atmospheric Sounder
MWTS：MicroWave Temperature Sounder
MWHS: MicroWave Humidity Sounder
MWRI: MicroWave Radiation Imager
SBUS: Solar Backscatter Ultraviolet Sounder
TOU: Total Ozone mapping Unit
SIM: Solar Irritation Monitor
ERM: Earth Radiation Monitor
SEM: Space Environment Monitor



Station Name	Longitude	Latitude
Beijing Station	116° 16′ 36″ E	40° 03′ 06″ N
Guangzhou Station	113° 20′ 20″ E	23° 09′ 52″ N
Wulumuqi Station	87° 34′ 08″ E	43° 52′ 17″ N
Jiamusi Station	130° 22′ 48″ E	46° 45′ 20″ N
Kiruna Station	21° 02′ E	67° 32′ N

2. Future Plan for LEO

FY-3 OPERATIONAL SATELLITE INSTRUMENTS	FY-3C	FY-3D	FY-3E	FY-3F
MERSI – Medium Resolution Spectral Imager (I, II)	√(I)	√(II)	√(II)	√(II)
MWTS – Microwave Temperature Sounder (II)	√	√	√	√
MWHS – Microwave Humidity Sounder (II)	√	√	√	√
MWRI – Microwave Radiation Imager	√	√		√
WindRAD - Wind Radar			√	
GAS - Greenhouse Gases Absorption Spectromete		√		√
HIRAS – Hyperspectral Infrared Atmospheric Sounder		√	√	√
OMS – Ozone Mapping Spectrometer			√	
GNOS – GNSS Occultation Sounder	√	√	√	√
ERM – Earth Radiation Measurement (I, II)	√(I)		√(II)	
SIM – Solar irritation Monitor (I, II)	√(I)		√(II)	
SES – Space Environment Suite	√	√	√	√
IRAS – Infrared Atmospheric Sounder	√			
VIRR – visible and Infrared Radiometer	√			
SBUS – Solar Backscattered Ultraviolet Sounder	√			
TOU – Total Ozone Unit	√			

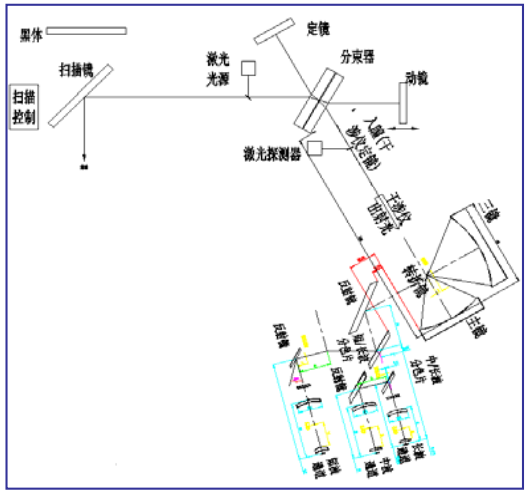
FY-3 series is expected to last its measurements at least 15 years with additional four satellites. There are 16 improved or new instruments will be configured from FY-3C to FY-3F in the schedule.

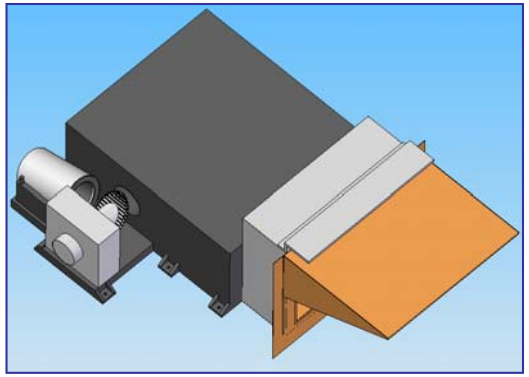
Improved Instruments

- **MERSI Ⅱ** will increase the channels from 20 to 25 after merging the VIRR channels
- **MWTS Ⅱ** will increase the channels from 4 to 13
- **MWHS Ⅱ** will increase the channels from 5 to 15
- **SIM Ⅱ** can track the Solar disk automatically to improve the accuracy of the measured Solar constant
- **ERM Ⅱ** will increase one broad channel to measure the outgoing longwave radiance directly

New Instruments

- **HIRAS** (Hyperspectral Infrared Atmospheric Sounder) is an IASI/Metop-like instrument to improve the measured temperature and moisture profile instead of the IRAS
- **OMS** (Ozone Mapping Spectrometer) is a SCIAMACHY/Envisat-like instrument to detect the ozone and the other atmospheric chemical species as well instead of the suite of TOU and SBUS. The total column content and the profile of trace gases can be retrieved from the nadir view and limb view separatively.
- **WindRAD** (Wind Radar) will measure the sea wind
- **GAS** (Greenhouse Gases Absorption Spectrometer) will measure the CO2 and CH4 globally
- **GNOS** (GNSS Occultation Sounder) will improve the measured temperature and moisture profile at the upper atmosphere





HIRAS Specification

Specification	LWIR Band	MWIR Band	SWIR Band
Spectral Range	650 – 1136 cm-1	1210 – 1750 cm-1	2155-2550 cm-1
Spectral Res	0.625 cm-1	1.25 cm-1	2.5 cm-1
NEΔT @250K	0.15~0.4K	0.1~0.7K	0.3~1.2K
pixes per scan line	58		
Scan Angle	±50.4° around nadir		
Spatial Res	1.1 degrees (16.0km) IFOV at arranged in 2×2 array		
Power/Mass	129watts/120kg		

HIRAS/FY-3: Michelson interferometer
Aims: global temperature and moisture sounding from the infrared spectrum from 650 to 2550 cm−1

1) **retrieving atmospheric temperature and humidity profiles with high accuracies for numerical weather prediction and climate research at high vertical resolution.**
2) **Trace gases to be derived from HIRAS include ozone columnar amounts in deep layers and columnar amounts of carbon monoxide, nitrous oxide, methane, and carbon dioxide.**
3) **Cloud parameters .**

OMS

OMS/FY-3:

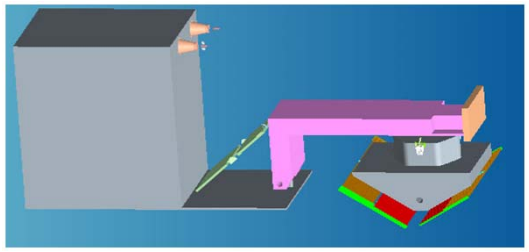
- **total column ozone mapping**
- **ozone profiler which includes nadir ozone profiler and limb ozone profiler**
- **the high spectral resolution OMS will replace the former UV ozone instruments TOU and SBUS flown on FY-3A/B/C**

Aims: global total column ozone and profile, global total amount of SO2, NO2 and aerosol optical properties such as aerosol index, optical depth

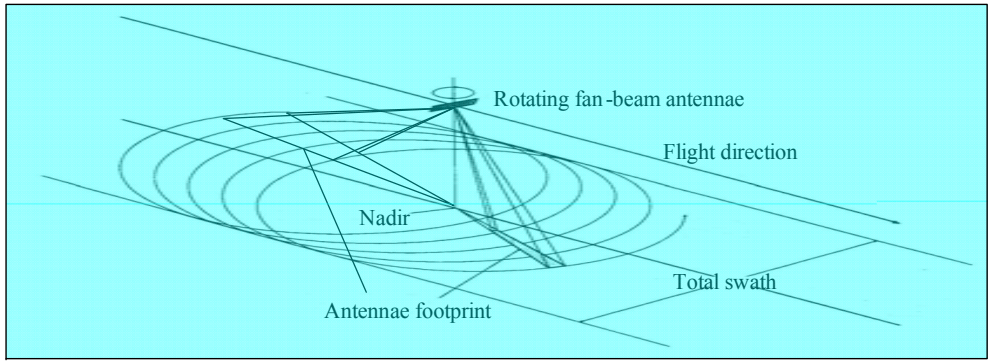
	Nadir detection		Limb detection
	Total column amount	**Vertical profile**	
Spectral range	300~500nm	250~310nm	290-500nm
Scientific purpose	O_3、NO_2、SO_2、HCHO、BrO、OClO、aerosol	O_3 profile	O_3、NO_2、SO_2、HCHO、BrO、OClO、stratospheric aerosol profiles
Spectral resolution	300~365nm×0.4nm 365~500nm×0.6nm	250~310nm×0.4nm	290-500nm×0.6nm
Spatial resolution	15（along track）×25（cross track）km	34（along track）×60（cross track）km	3km
Field of view	112°	2.3°（along track）×0.045°（cross track）	2.3°（along track）×0.045°（cross track）
Dynamic range	10^4	10^5	10^5

WindRAD

The Wind Radar monitors Global ocean surface wind field (OSWF) from space. The wind radar will measure the radar backscattering of sea surface from different azimuth and then retrieve wind vector with the geophysical model function (GMF). The OSWF data will significantly contribute to improve weather forecast, especially numerical model prediction of typhoon tracks and landfalls.



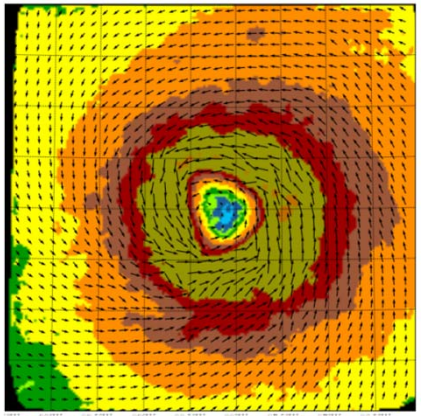
Wind Radar



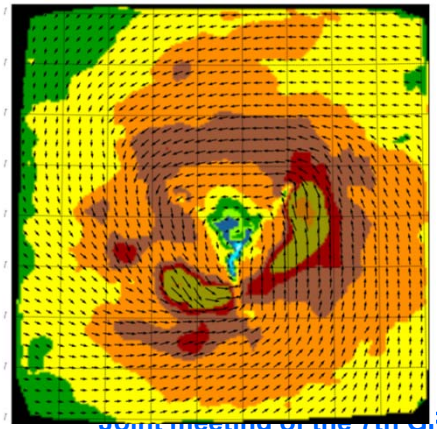
Measurement geometry of Wind Radar

The four antennae (two polarization of each frequency) of Wind Radar rotate slowly around the vertical axis of spin platform, and each pixel within the swath will be illuminated from more azimuth directions than the existing spaceborne sactterometers due to the low rotation rate .

Wave band		C	Ku
Centre frequency		5.3GHz	13.256GHz
Polarization		HH,VV	HH,VV
Spatial resolution	azimuth direction	≈25 km	≈10 km
	range direction	≤ 10 km	≤ 5 km
Swath width		> 1200 km	
Incidence angle		36° ~ 45°	37° ~ 43°
Peak Gain		31 dBi	37.5 dBi
Transmitted power		124 W	141 W
Rotation rate		0.4 ~ 0.7 rad/s	
Radiometric accuracy		1dB（≤ 5m/s）; 0.5dB（others）	
Wind speed range		3 ~ 50 m/s	
Wind speed accuracy		1.5 m/s（≤ 20m/s）; 10%（others）	
Wind speed range		0 ~ 360°	
Wind direction accuracy		< 20°	



Wind Radar

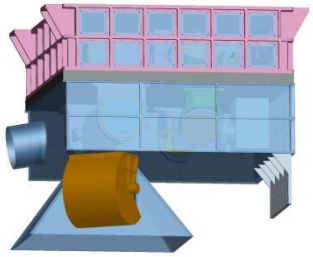


SeaWinds

Expected performance of the Wind Radar

- Better spatial resolution than the current spaceborne scatterometers;
- High wind retrieval capability ;
- Nearly all-weather capability .

GAS



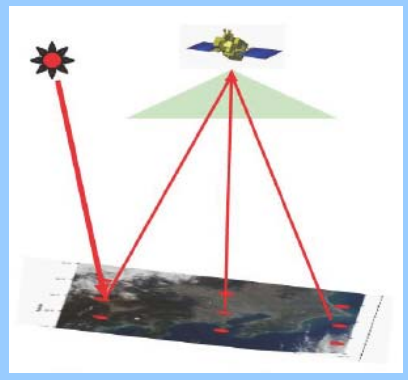
Aims

- Improve our understanding on the Spatial & temporal distribution of global CO_2
- Monitoring the CO_2 variation on seasonal scales

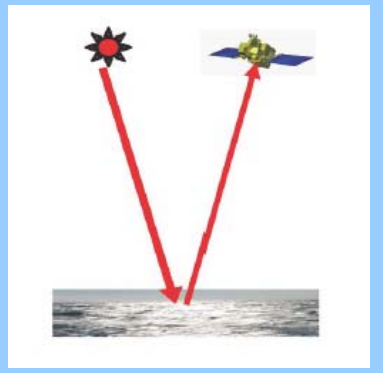
Expected Performance

CO2 retrieval precision: 1~4 ppm

Nadir Mode



Glint Mode



Greenhouse gases Absorption Spectrometer				
Band	1	2	3	4
Spectrum	0.75-0.77μm	1.56-1.72μm	1.92-2.08μm	2.20-2.38μm
target	O_2-A	CO_2 CH_4 （H_2O）	CO_2 （H_2O）	CH_4、CO 、N_2O
Spectrum res.	0.6 cm^{-1}	0.27 cm^{-1}	0.27 cm^{-1}	0.27 cm^{-1}
S/N	＞300:1			
Cal. Error	<2%			
IFOV	0.685°			

GNOS

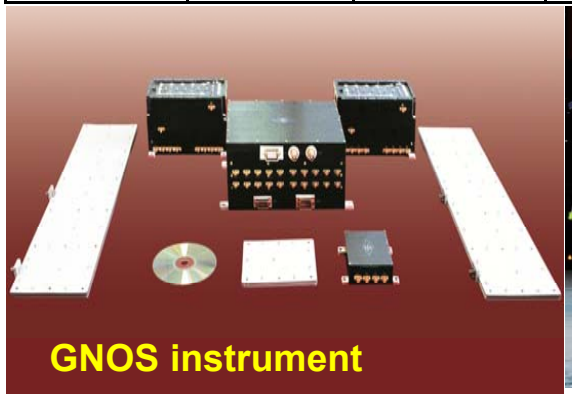
GNOS will receive two types of signal from GPS and China BeiDou-2. GNOS will observe over 1000 occultations per day with GPS and BD satellites,

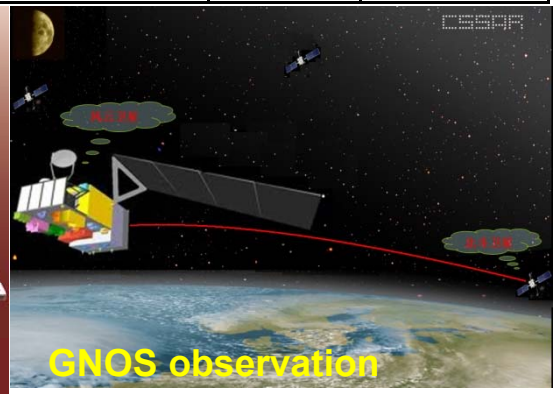
Expected Products

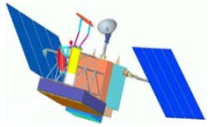
- Temperature profiles
- Humidity profiles
- Refractivity profiles
- Electronic content profiles

Frequency	GPS L1/L2; BD2
Receiver Channels	8 (Navigation) 4 (Occultation)
Sampling rate	1 ~ 50 Hz
Crystal oscillator	1e-11 (100s)
Real-time position	10m（RMS）
Real-time velocity	0.1m/s(RMS)
Phase center accuracy	2 mm (RMS)
Antenna number	1 (Navigation) 2 (Occultation)

		Temperature	**Humidity**	**Refractivity**	**Electronic Content**
RMS Accuracy	Low Tropos.	0.5-3 k	0.25-1.0 g/kg	0.1-0.5%	(100-600 km) < 20%
	High Tropos.	0.5-3 k	0.05-0.2 g/kg	0.1-0.2%	
	Low Stratos.	0.5-3 k	--------	0.1-0.2%	
	High Stratos.	0.5-5 k	--------	0.2-2.0%	

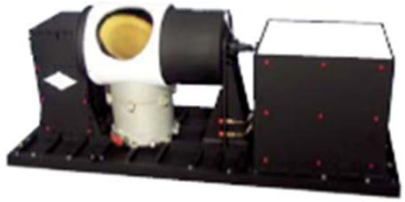

GNOS instrument


GNOS observation



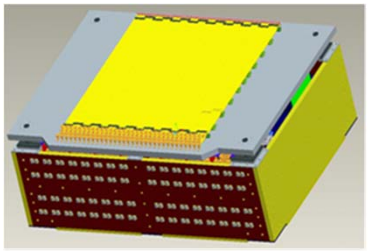
The main objectives of RM satellite

- Consist a Global observation constellation system with FY3-2 AM and PM satellites, as well as GPM satellite
- Improve the severe convective system monitoring ability in china together with GPM satellite
- Provide 3D precipitation structure over both ocean and land
- Improve the sensitivity and accuracy of precipitation measurement over china and surrounding area



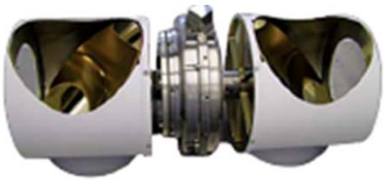
MWTS

MWRI



KaPR

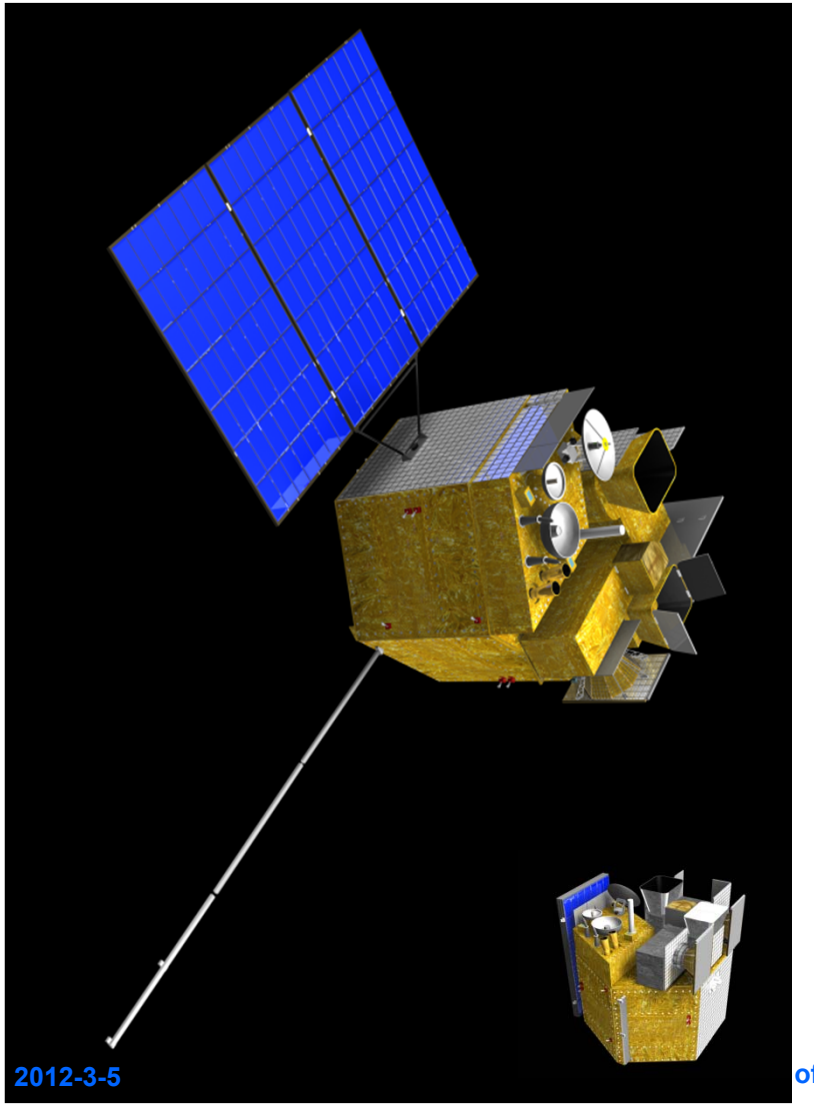
KuPR



MWHS

3. Future Plan for GEO

FY-4A



Main Instruments

1)GIIRS: Geo. Interferometric Infrared Sounder
2) AGRI: Advanced Geosynchronous Radiation Imager
3) LMI: Lightning Mapping Imager
4) SEP: Space Environment Package

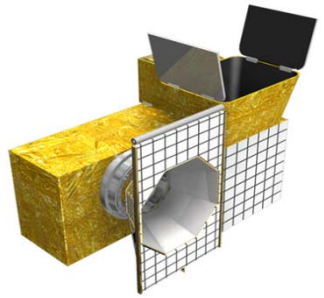
Spacecraft:

1. Launch Weight: approx 5300kg
2. Stabilization: Three-axis
3. Attitude accuracy: 3″
4. Bus: 1553B+Spacewire
5. Raw data transmission : X band
6. Output power: >= 3200W

Comparison between FY-2 & FY-4

	FY-4A	FY-2 Op series
Stabilization	**Three-axis**	**Spin**
Design Life	**7 Year, Operation 5 Year**	**3 Year**
Observation Efficiency	**85%**	**5%**
Observation Mode	**Imaging +Sounding + Lightning Mapping**	**Imaging Only**
Main Instruments	**AGRI :14 channels** SSP Resolution：0.5~4Km Global imaging：15min Flexible imaging ： 2D	**VISSR: 5 channels** SSP Resolution：1.25~5Km Global imaging：30min Flexible imaging ： 1D
	GIIRS:913 channels Spectral Resolution: 0.8,1.6cm-1 SSP Resolution:16Km	**N/A**
	LMI SSP Resolution:7.8Km	**N/A**
	SEU High energy particles Magnetic field	**SEU** High energy particles Solar X ray fluxes

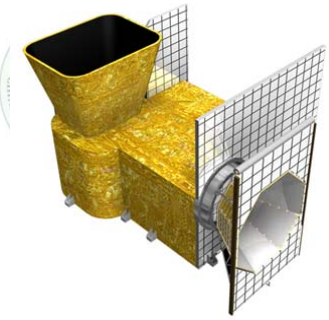
AGRI: Advanced Geo. Radiation Imager



14 Channels within 0.55~13.8μm for first satellite FY-4A

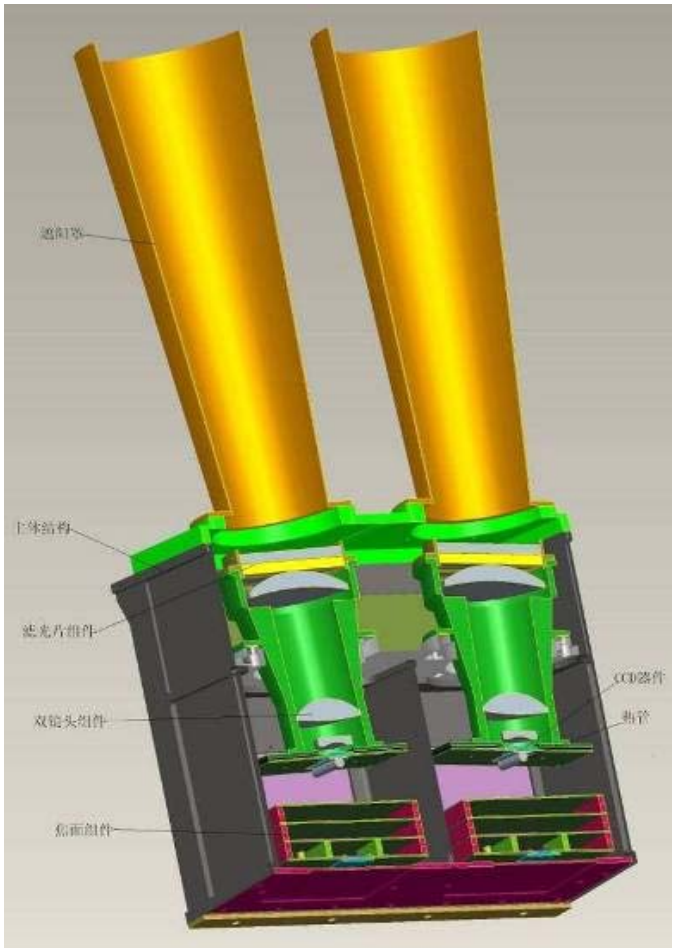
Channel	Band (*μm*)	Spatial Resolution (Km)	Detection Sensitivity		Main Application
Visible & Near-Infrared	0.45～0.49	1	S/N≥	70(ρ=100%)	Aerosol
	0.55～0.75	0.5～1		200(ρ=100%),5(ρ=1%)@0.5Km	Fog,Clound
	0.75～0.90	1			Vegetation
Short-wave Infrared	1.36～1.39	2	S/N≥	200 (ρ=100%) 5 (ρ=1%)	Cirrus
	1.58～1.64	2			Cloud,Snow
	2.1～2.35	2～4			Cirrus,Aerosol
Mid-wave Infrared	3.5～4.0(high)	2	NEΔT≤0.7K(300K)		Fire
	3.5～4.0(low)	4	NEΔT≤0.2K(300K)		Land surface
Water Vapor	5.8～6.7	4	NEΔT≤0.3K(260K)		WV
	6.9～7.3	4	NEΔT≤0.3K(260K)		WV
Long-wave Infrared	8.0～9.0	4	NEΔT=0.2K(300K)		WV,Cloud
	10.3～11.3	4	NEΔT=0.2K(300K)		SST
	11.5～12.5	4	NEΔT=0.2K(300K)		SST
	13.2～13.8	4	NEΔT=0.5K(300K)		Cloud,WV

GIIRS: Geo. Interferometric Infrared Sounder



	FY-4A (R&D)	FY-4B (Operational)
Spectral Parameters	Range / Resolution / Channels LWIR: 700-1130 / 0.8 / 538 S/MIR:1 650-2250 / 1.6 / 375	Range / Resolution / Channels LWIR: 700-1130 / 0.625 / 688 S/MIR:1 650-2250 / 1.2 / 500
Spatial Resolution	At Nadir: 16Km IFOV: 448μrad	At Nadir: 8Km IFOV: 224μrad
Operational Mode	China area 5000 × 5000 Km^2 Mesoscale area 1000 × 1000 Km^2	China area 5000 × 5000 Km^2 Mesoscale area 1000 × 1000 Km^2
Temporal Resolution	China area 1 hr Mesoscale area ½ hr	China area 1 hr Mesoscale area ½ hr
Sensitivity (mW/m2sr cm-1)	LWIR: 0.5 S/MIR: 0.1	LWIR: 0.3 S/MIR: 0.06
Calibration accuracy	1.5k (3σ) radiation	1.0k (3σ)
Calibration accuracy	10 ppm (3σ) spectrum	5 ppm (3σ)
Quantization Bits	13 bits	13 bits

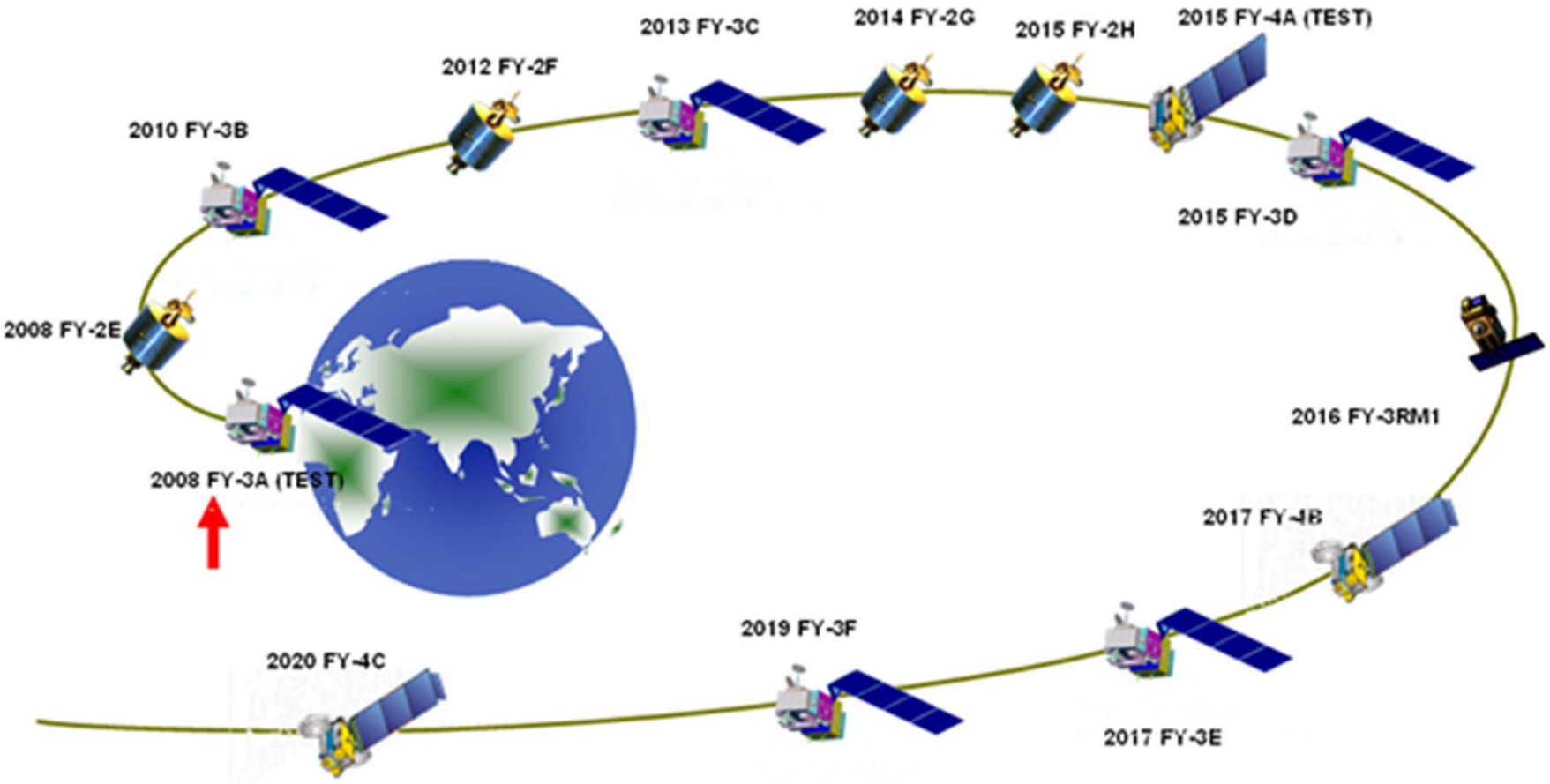
LMI: Lighting Mapping Imager



Spatial resolution	about 6 km at SSP
Sensor size	400×300 ×2
Wave-length at center	777.4nm
Band-width	1nm±0.1nm
Detection efficiency	>90%
False-alarm ratio	<10%
Dynamic range	>100
SNR	>6
Frequency of frames	2ms (500 Frames per sec.)
Quantization	12 bits
Measurement Error	10%

Prototype structure for LMI

4. Conclusion



Current: FY-3 Operational Products (42)

Cloud & Radiation Atmosphere Land Ocean Space

Instrument	Cloud and Radiation (10)	Atmosphere (12)	Land (13)	Ocean (4)	Space (3)
VIRR	• Cloud Mask • Cloud Classification • Cloud Properties • OLR	• Precipitable Water Amount • Aerosol Properties • Dust Storm Monitoring • Fog Monitoring	• Snow Cover • Surface Reflectance • LST • NDVI • Hot Spot Monitoring	• Ocean Color • Sea Ice Monitoring • SST	
MERSI	• Cloud Mask	• Precipitable Water Amount • Aerosol Properties	• Snow Cover • Surface Reflectance • NDVI		
IRAS/MWTS/MWHS	• OLR • Clear-sky Radiance Equivalent • Rain Cloud Mask	• Atmospheric Temperature/Moisture Profile			
MWRI		• Precipitation • Water Cloud Content • Precipitable Water Amount	• Drought/Flood Index • Snow Depth • Snow Water Equivalent • Soil Moisture, • LST	• Sea Ice Monitoring	
TOU/SBUS		• Total Ozone Amount • Ozone Profile			
ERM/SIM	• Solar Constant • Earth Outgoing Radiance				
SEM					• Proton • Electron • Heavy Ion

Future: FY-3 follow-on Operational Products (38)

Cloud & Radiation **Atmosphere** **Land** **Ocean** **Space**

Instrument	Cloud and Radiation (7)	Atmosphere (18)	Land (7)	Ocean (2)	Space (4)
MERSI Ⅱ	● Cloud Mask ● Cloud Classification ● Cloud Properties ● OLR	● Polar Wind	● Leaf Area Index ● Surface Albedo ● Photosynthesis Effective Radiation Coefficient ● NPP ● Land Cover ● LST ● Snow Cover	● Ocean Color ● SST	
IRAS/MWTS Ⅱ/MWHS Ⅱ		● Atmospheric Temperature/Moisture Profile			
HIRAS/MWTS Ⅱ/MWHS Ⅱ	● OLR ● Clear-sky Radiance Equivalent ● Ice Cloud Content Index	● Atmospheric Temperature/Moisture Profile Total Ozone Amount ● CO_2 Amount ● CH_4 Amount ● Atmospheric Unstability ● Tropical Cyclone Intensity			
MWRI		● Sea Surface Wind			
OMS		● Total Ozone Amount ● SO_2 Amount ● NO_2 Amount ● Aerosol Index ● Ozone Profile			
GNOS		● Upper Atmospheric Temperature/Moisture Profile			● TEC
WindRAD		● Sea Surface Wind			
GAS		● CO_2 Amount ● CH_4 Amount, ● CO Amount			
SEM Ⅱ Suite (SEM/WAI/IPM)					● Radiation Dosage ● Ionosphere Measurement ● Vertical TEC

Current: FY-2 Operational Products

Imaging Atmosphere Weather Radiation Land Water Cliamte

No.	Products	No.	Products	No.	Products
1	Raw image	10	Rainfall estimation	19	SST
2	Normalized image	11	Precipitable water	20	Snow cover
3	Projected image	12	AMV	21	Sea ice monitor
4	Mosaic image	13	Typhoon location	22	Fire spots
5	Cloud classification	14	Upper troposphere Humidity	23	Water bodies
6	Total cloud amount	15	Cloud water profile	24	Soil humidity
7	Sand storm detection	16	OLR	25	ISCCP dataset
8	Heavy fog monitor	17	TBB		
9	Precipitation index	18	Solar irradiance		

Future: FY-4 Operational Products

Atmosphere **Weather** **Radiation** **Land** **Water** **Space**

No .	Products	No.	Products	No.	Products
1	Clear Sky Masks	10	Downward Longwave Radiation: Surface	19	Rainfall Rate/QPE
2	Cloud Top Height	11	Upward Longwave Radiation: TOA	20	Convective Initiation
3	Cloud Top Temperature	12	Upward Longwave Radiation: Surface	21	Tropopause Folding Turbulence Prediction
4	Cloud Top Pressure	13	Reflected Shortwave Radiation: TOA	22	Sea Surface Temperature (skin)
5	Cloud Optical Depth	14	Downward Shortwave Radiation: Surface	23	Fire/Hot Spot Characterization
6	Cloud Liquid Water	15	Legacy Vertical Moisture Profile	24	Land Surface (Skin) Temperature
7	Cloud Particle Size Distribution	16	Ozone Profile & Total	25	Land Surface Emissivity
8	Aerosol Detection (including Smoke and Dust)	17	Derived Motion Winds	26	Snow Cover
9	Aerosol Optical Depth	18	Lightning Detection	27	SPACE AND SOLAR products

Conclusion

- FY series have been utilized in weather analysis, numerical weather forecasting, climate prognosticating, and environment and disaster monitoring broadly.
- FY-2D and FY-2E have constituted the Geo constellation to provide the regional observation in 15 minutes maximum.
- FY-3A and FY-3B have constituted the Leo constellation to provide the global observation of the Earth 4 times per day.
- The innovation analysis between observation and the simulation from the ECMWF Integrated Forecasting System has shown the FY-3 data to be of good quality overall.