



Progress on Chinese Space-based Radiometric Benchmark Project



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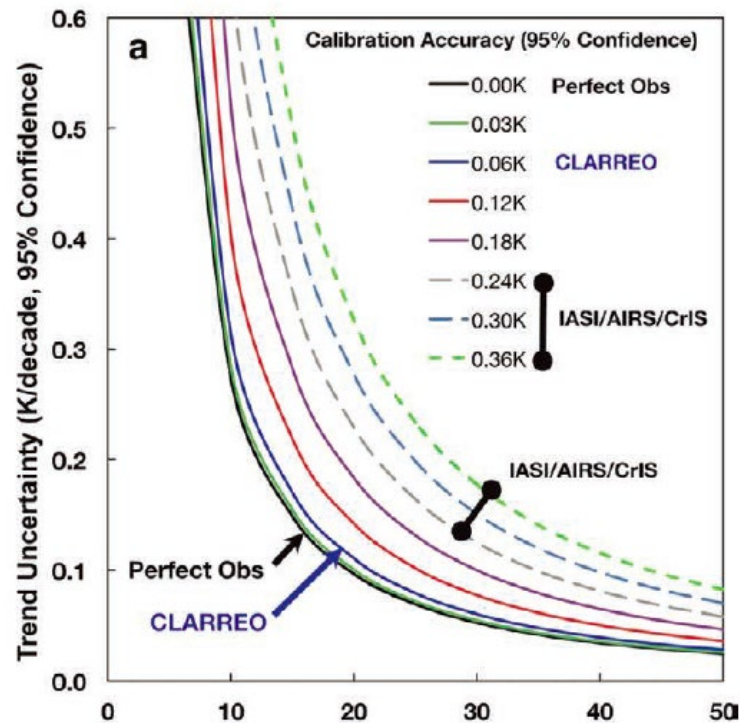
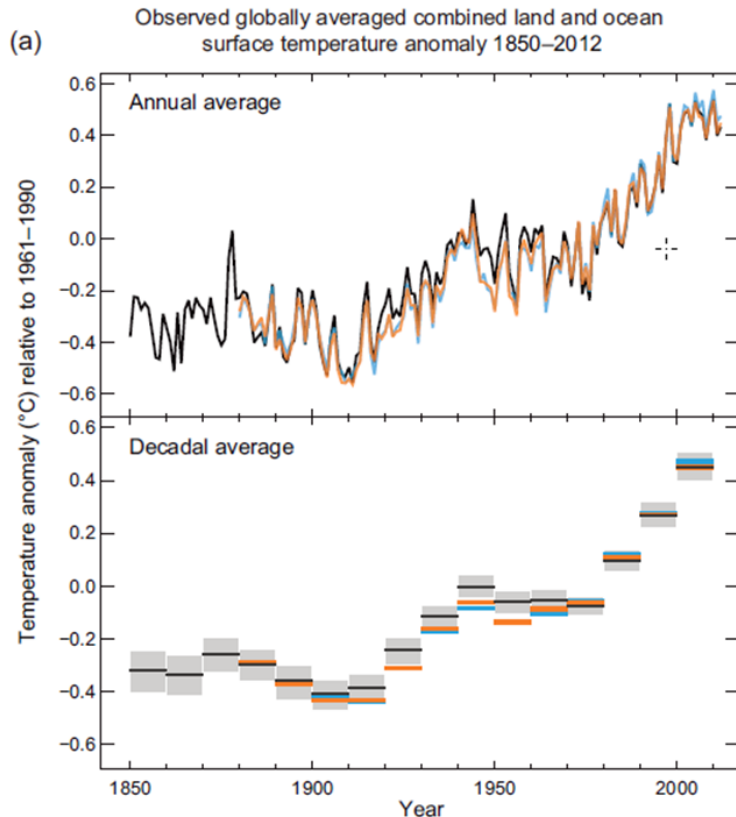
Outline

- Background
- Project Introduction
- Prototype Model Progress
- On-orbit Mode to Support Intercalibration
- Issues to be discussed

1. Background

IPCC Assessment Report 5, 2013

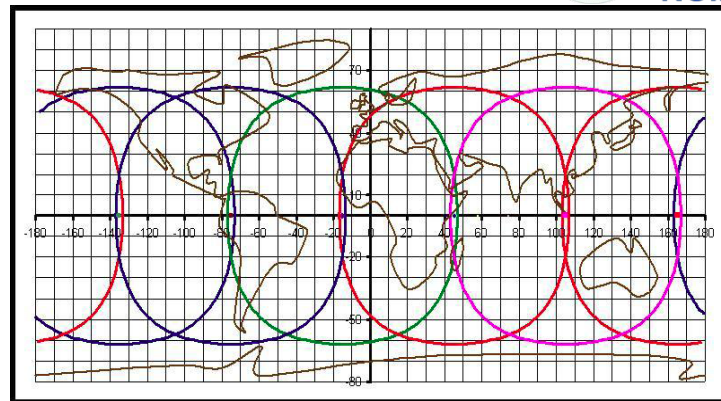
Bruce A. Wielicki, et al, 2013: Achieving Climate Change Absolute Accuracy in Orbit. BAMS



Vision for WMO Integrated Global Observing System in 2040



To harmonize the radiometric measurement from the all kinds of platform in operation



Tier 1 Backbone system with specified orbital configuration and measurement approaches

- Basis for Members' commitments, should respond to the vital data needs;
- Building on the current CGMS baseline, but with fully deployed (global) coverage, and with addition of newly maturing capabilities.

Tier 2 Backbone system with open orbit configuration and flexibility to optimize the implementation

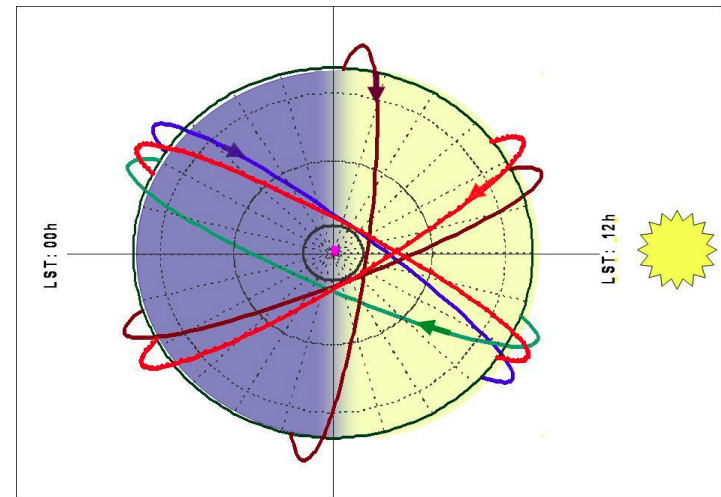
- Basis for open contributions of WMO Members, responding to target data goals.

Tier 3 Operational pathfinders, and technology and science demonstrators

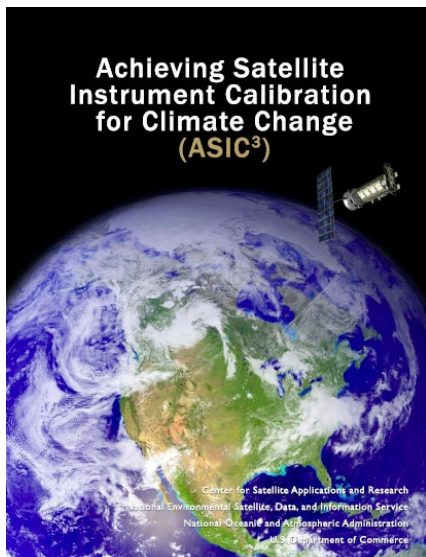
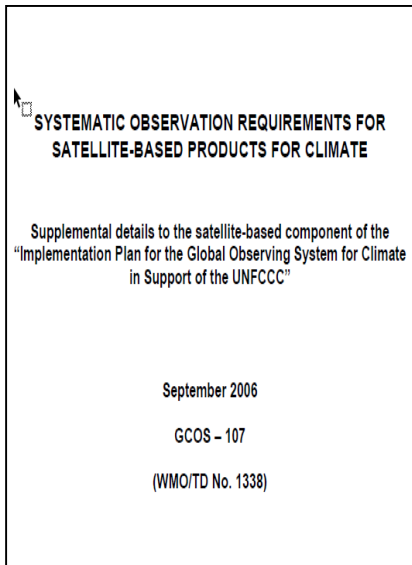
- Responding to R&D needs.

Tier 4 Additional capabilities

- Contributed by WMO Members and third parties including governmental and non-governmental actors (including from the academic and commercial sectors).



Documents to Support the SI-Traceable Space-based Climate Observing System / Radiometric Benchmark System

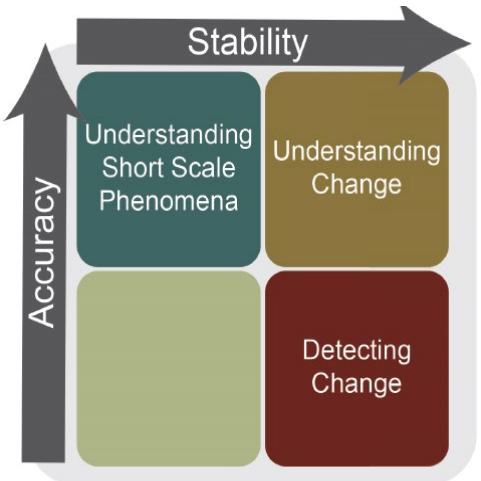


Strategy Towards an Architecture for Climate Monitoring from Space

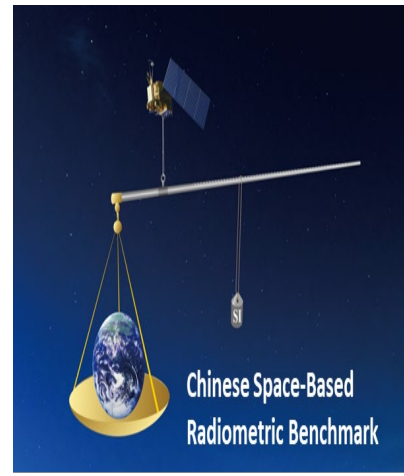
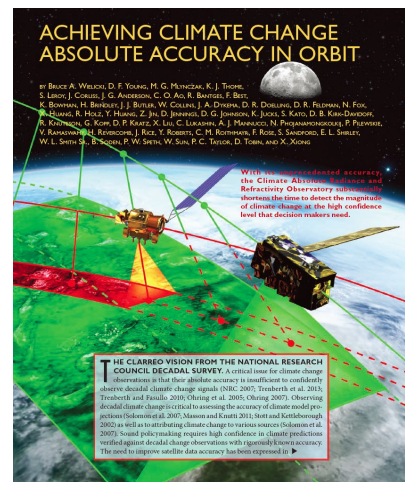
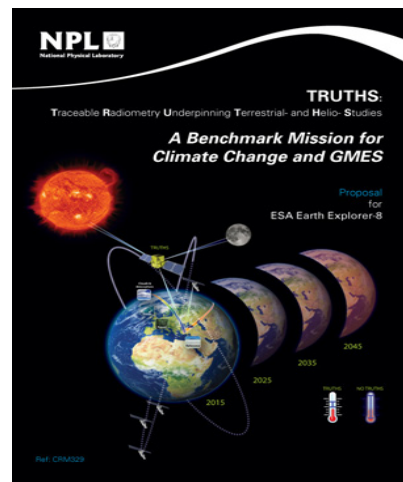


- WMO GCOS, 2006: Systematic observation requirements for satellite-based products for climate
- G. Ohringj, et al, 2007: Achieving satellite instrument calibration for climate change
- M. Dowell, et al, 2013: Strategy towards an architecture for climate monitoring from space
- CEOS/CGMS WGClimate, 2018: Space agency response to GCOS implementation plan

SI-Traceable Space-based Climate Observing System / Radiometric Benchmark System

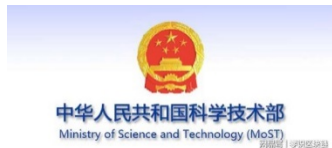


Accuracy vs. stability diagram following Ohring et al. (2004)



- Weather Satellite to Climate Satellite
- CEOS, CGMS response to GCOS
- Multiple On-orbit Instruments
- Historical Satellite Data Records

Projects on Space-based Radiometric Benchmark

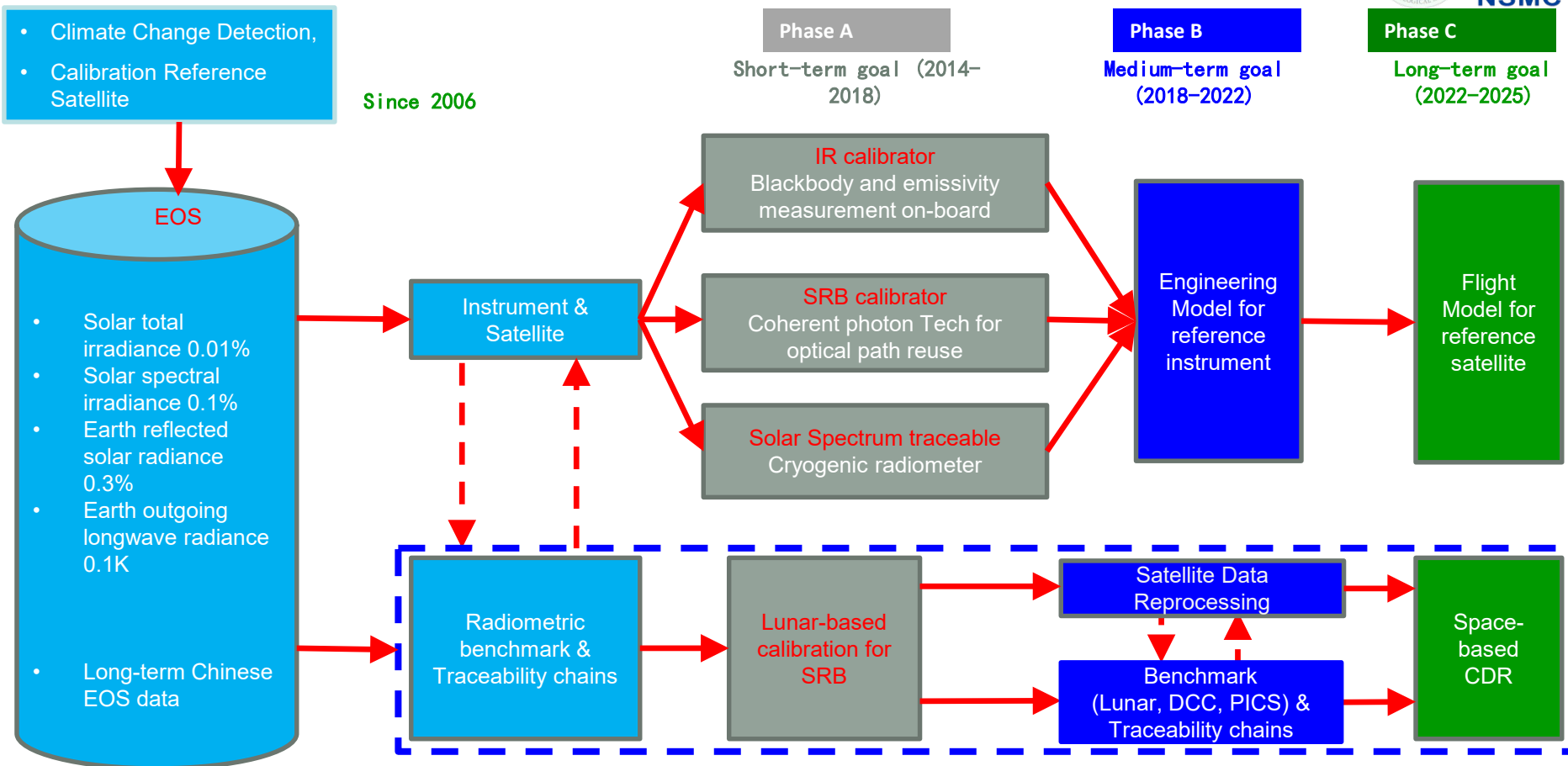


Realizing the importance of reference-type missions for improving climate science and for harmonizing global satellite observations, an expert team on Earth observation and navigation of Ministry of Science and Technology (MOST) proposed the concept of the Chinese Space-based Radiometric Benchmark (CSRB) in 2006. The CSRB project was approved and initially funded by MOST in 2014.

Founded by

- **National High Technology R&D Program of China** before 2018
- **National Key R&D Program of China** after 2018

Road Map of Chinese Space-based Benchmark Project



Phase A for SI-Traceable Standard (20 million RMB)

■ National High Technology Research & Development Program of China (863 program)

Standard for
Emitted Earth Spectrum
Blackbody and emissivity
measurement on-board



Shanghai Institute of Technical Physics (SITP), CAS

Standard for
Incident Solar Spectrum
Coherent photon Tech for
optical path reuse



Anhui Institute of Optics and Fine Mechanics
(AIOFM), CAS

Standard for
Reflected Solar Spectrum
Cryogenic radiometer



Changchun Institute of Optics, Fine Mechanics
and Physics (CIOMP), CAS

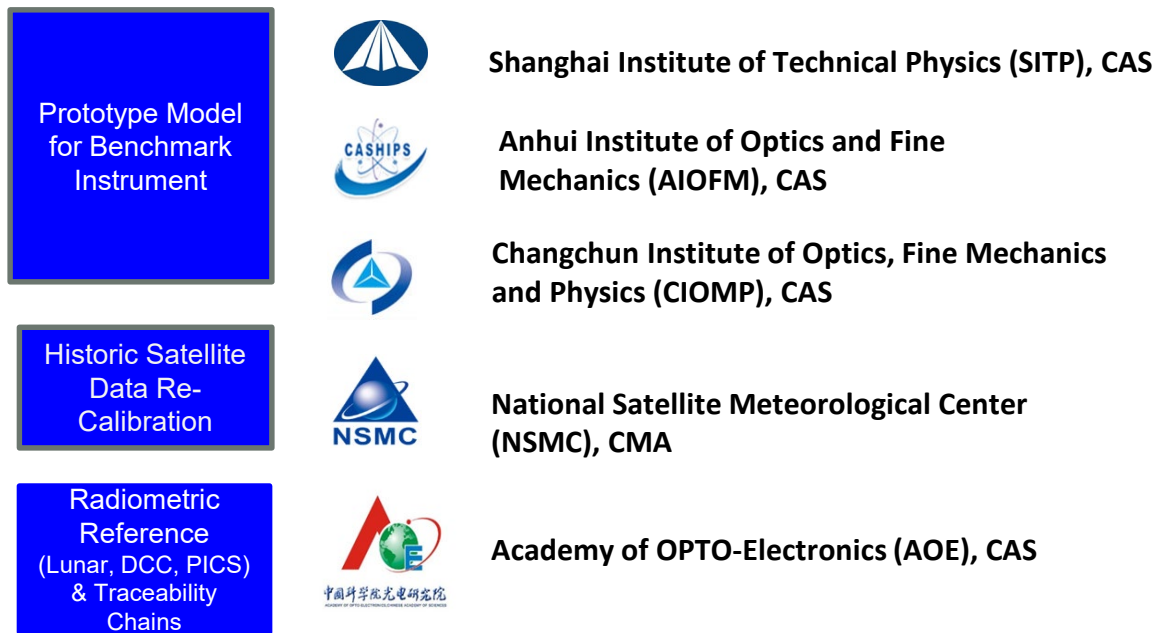
Lunar Radiometric
Model and Lunar-
based Calibration



National Satellite Meteorological Center (NSMC),
CMA

Phase B for Prototype Instrument

- National Key R&D Program of China (300 million RMB)
- Chinese FY Satellite Program
- Chinese HY Satellite Program
- Chinese ZY Satellite Program



Specification of the Prototype Instrument



Table 1. Detailed payloads specifications of the LIBRA prototype model.

Instrument Name	Payload Requirements	Key Technology
IRS	Spectral range: 600–2700 cm^{-1} Spectral resolution: 0.5 cm^{-1} IFOV: 24 mrad Sensitivity: 0.1 K@270 K Emissivity of BB: ≥ 0.999 Measurement uncertainty: 0.15 K ($k = 2$)	Miniature fixed-temperature phase-change cells
EMIS	Spectral range: 380–2350 nm, Spectral resolution: 10 nm, Spectral precision: 0.5 nm, Spatial resolution: 100 m, Coverage: 50 km, Measurement uncertainty: 1% ($k = 2$)	Space Cryogenic Absolute Radiometer
TSI	Spectral range: 0.2–35 μm , Measurement uncertainty: 0.05% ($k = 2$) Long-term stability: 0.005%	Space Cryogenic Absolute Radiometer
SITQ	Spectral range: 380–2500 nm, Spectral resolution: 3 nm (380–1000 nm), 8 nm (1000–2500 nm) Spectral precision: 0.1–0.3 nm, Self-calibration uncertainty: 0.2%, Measurement uncertainty: 0.35% ($k = 2$)	Spontaneous Parametric Down-Conversion

Infrared Spectrometer (IRS)

Earth-Moon Imaging Spectrometer (EMIS)

Total Solar Irradiance (TSI)

Solar spectral Irradiance monitoring instrument Traceable to Quantum benchmark (SITQ)

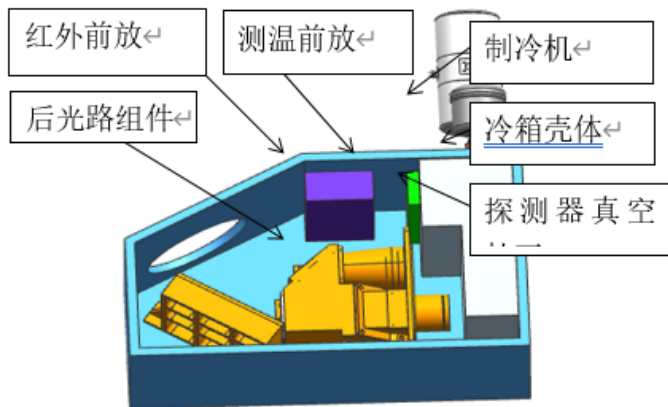
P. Zhang et al., 2020: Development of the Chinese Space-Based Radiometric Benchmark Mission LIBRA. Remote Sensing

3. Prototype Model Progress

IRS: System Scheme and performance

➤ Infrared interferometer

- Response spectrum: $600\text{ cm}^{-1}\sim 2700\text{ cm}^{-1}$
- Spectral resolution: 0.5 cm^{-1}



Broadband, large field of view infrared interferometer

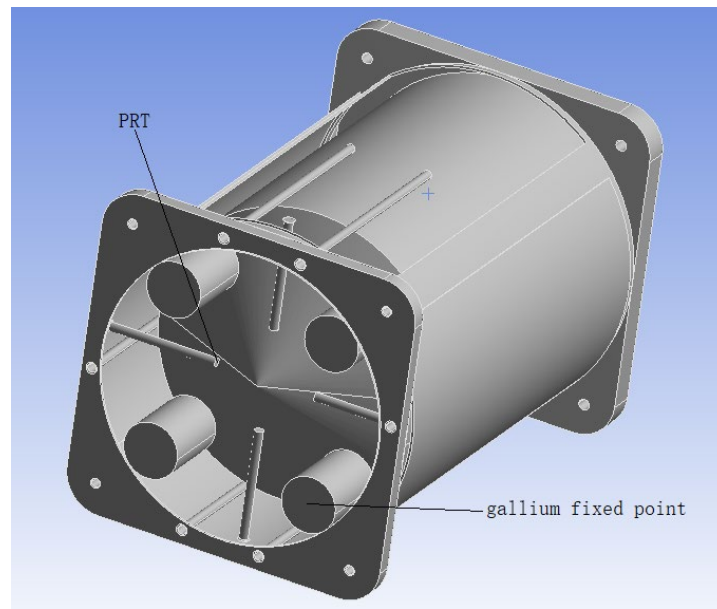
Broadband, large size & small array infrared sensors

Multi-temperature zone infrared cryogenic optics technology

Efficient refrigeration for 50K temperature technology

on-orbit accurate temperature scale established by using fixed-point-cells (miniature phase change cells)

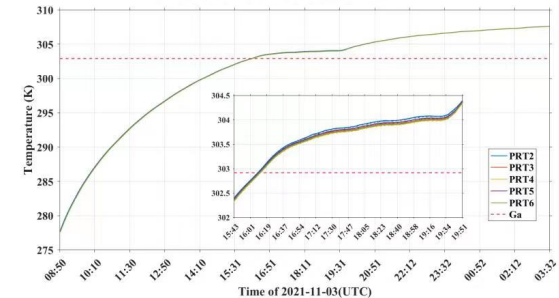
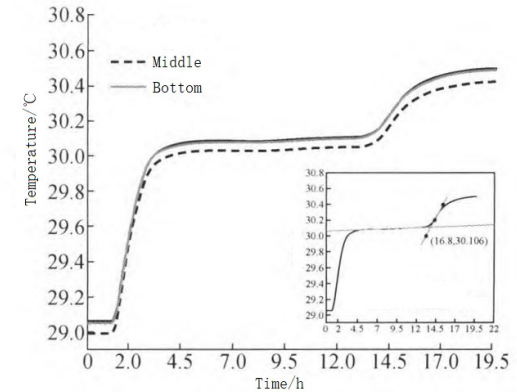
- System of miniature gallium fixed point onboard blackbody radiation source was added on HIRAS of FY-3E satellite as the prototype
- 4 crucibles filled with gallium and fixed on the bottom of the blackbody
- Heating circuit used to provide stable heat flow into the blackbody
- The temperature of gallium is very stable during the phase change process



Fixed point cells: Data collected in experiment and on FY-3E



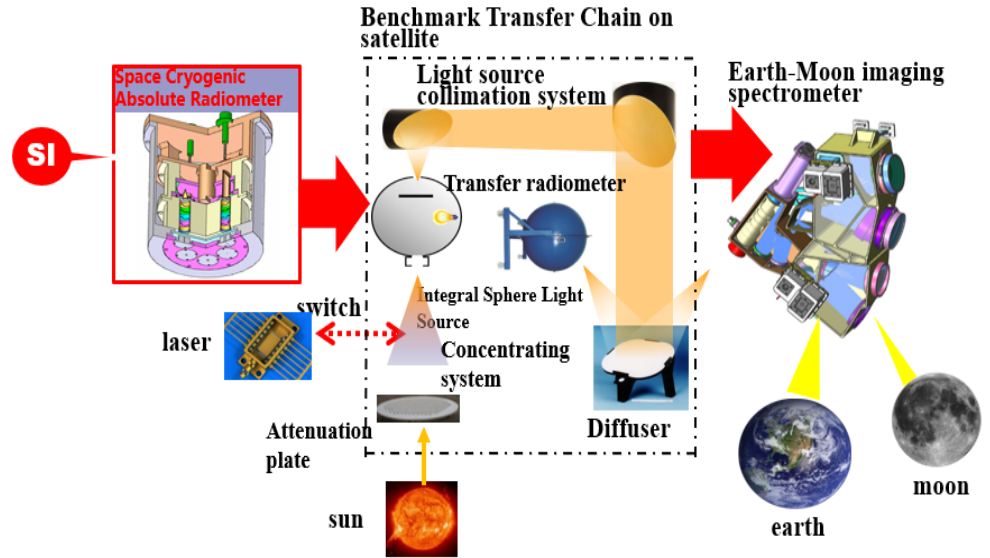
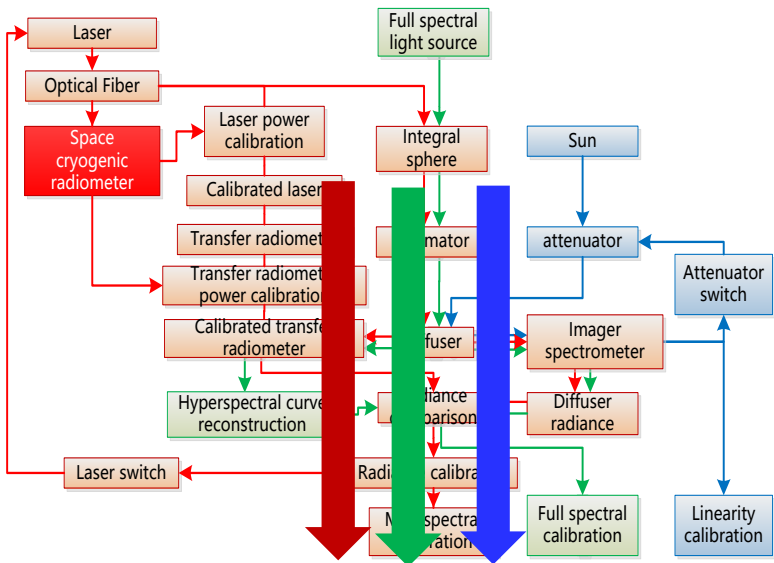
- Inflection point : the momentary temperature when the phase change is finished
- Inflection point has a relationship with the heating power
- In the experiment with the blackbody only, the reproducibility of the inflection point is better than 0.03K.
- In the on-orbit measurement, inflection point can be observed clearly. When the heating power is 4.11W, the inflection point is 304.1K.
- The relationship between the heating power and the inflection point is being analyzed with modeling.



EMIS: System Scheme and performance



The radiometric benchmark is established by space cryogenic absolute radiometer, and transferred to the Earth-Moon imaging spectrometer by benchmark transfer chain, in order to improve the long-term accuracy.



A Multispectral Calibration

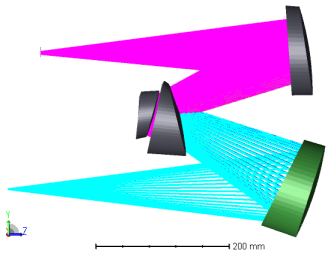
B Full spectrum Calibration

C Linearity Calibration

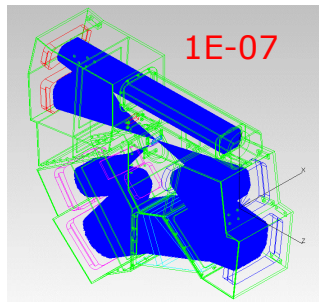
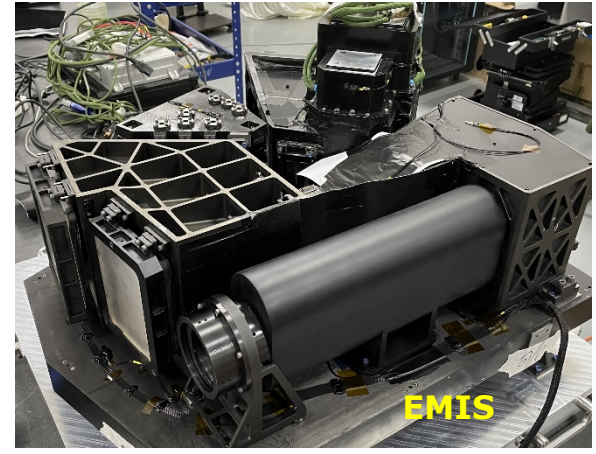
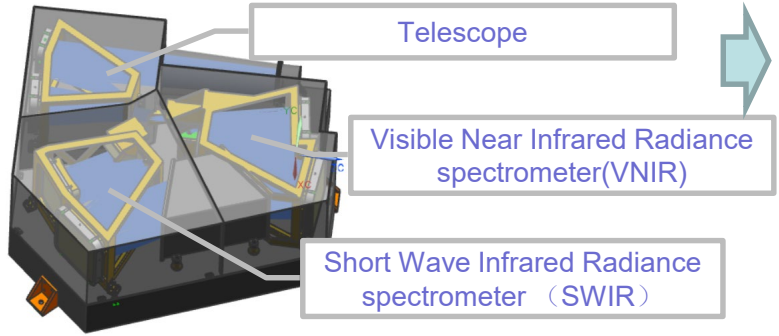
Earth-Moon Imaging Spectrometer (EMIS)



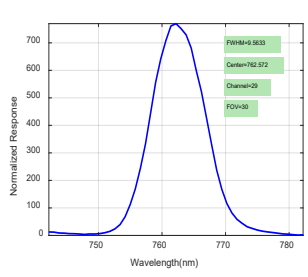
EMIS has completed the whole machine integration, detected the spectral radiation characteristics, and carried out the **flight calibration experiment**



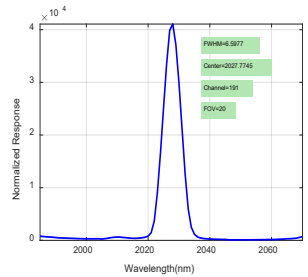
EMIS adopts off axis three mirror optical design



Stray light analysis



9.56nm



6.59nm

The average spectral resolution is better than 10nm

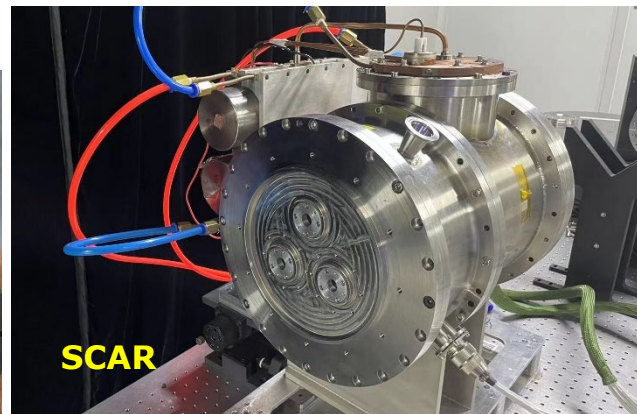
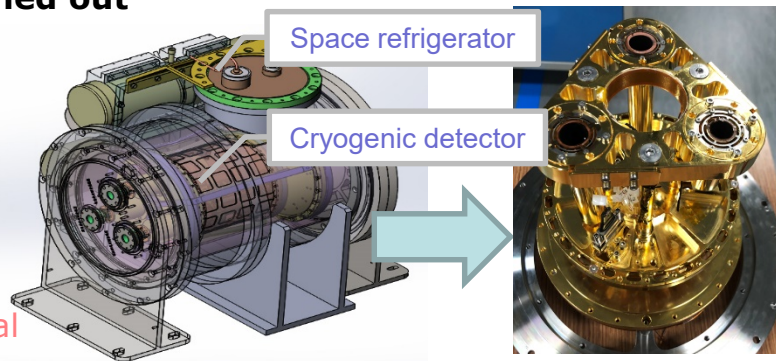
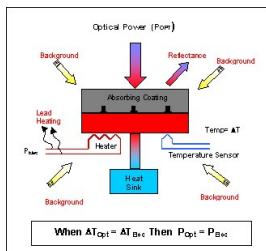


Local images of ground objects taken in flight calibration experiment

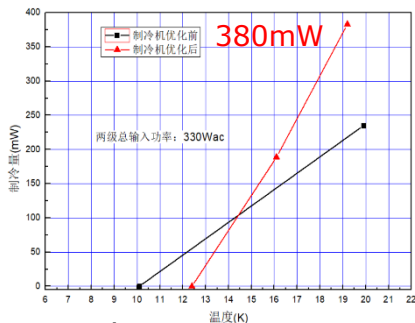
Space Cryogenic Absolute Radiometer (SCAR)



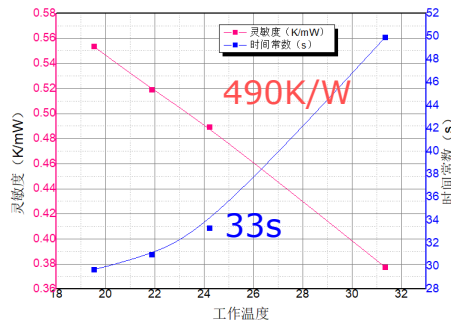
The cryogenic detector and space refrigerator of the SCAR are integrated, and relevant tests and optimization are carried out



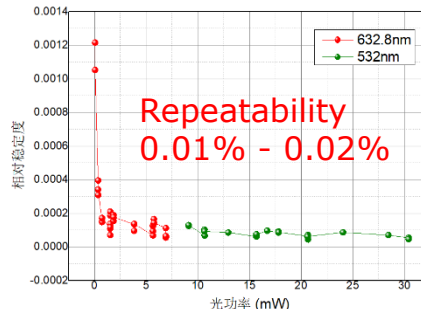
SCAR is based on electrical substitution principle



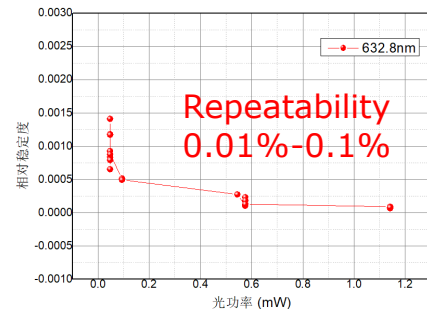
Cooling capacity was optimized to 380mW



Sensitivity is 490K/W@25K
Time constant is 33s@25K



High power channel (1-30mW)



Low power channel (0.01-2mW)

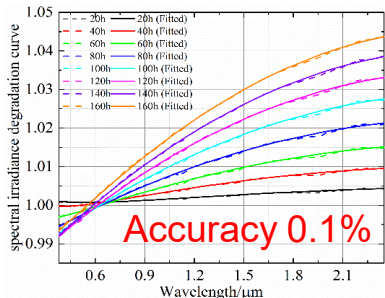
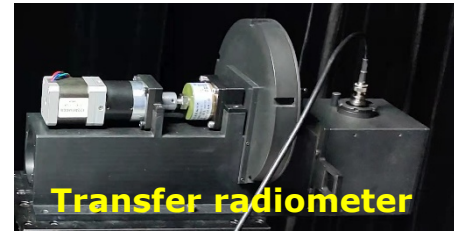
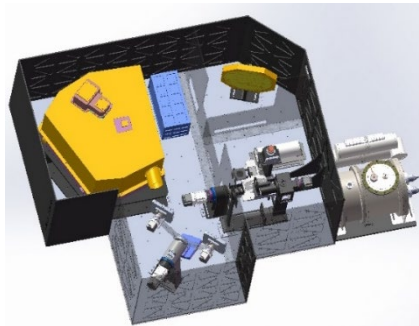
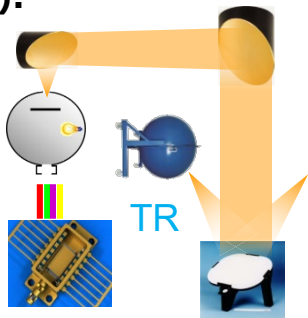
Optical power measurement

Benchmark Transfer Chain(BTC)

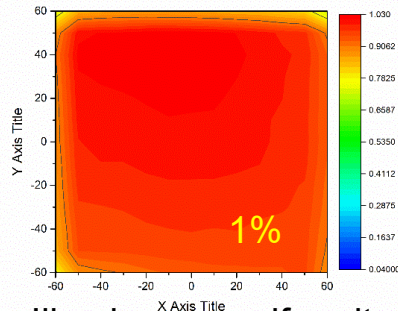


The BTC has completed layout, and researched the full spectrum light source, multi-spectrum monochromatic light source, free-form surface reflector and Transfer Radiometer (TR).

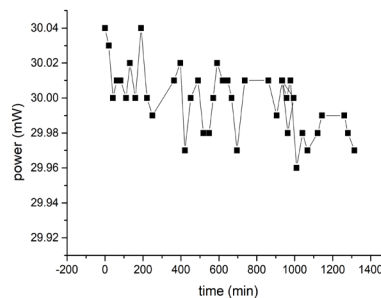
Benchmark is transferred by the calibrated TR



Full spectrum light source reconstruction



Illuminance uniformity of free-form surface reflector is 1%

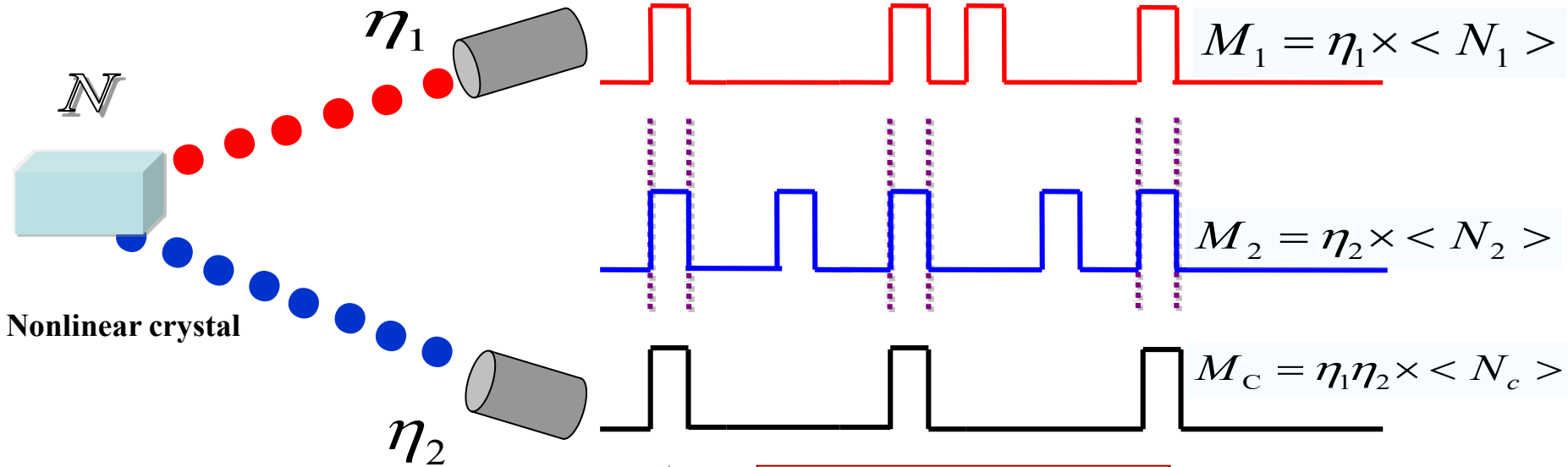


Monochromatic light source stability is 0.1% (P-P) @781nm



Radiance comparison with National Institute of Metrology

Spontaneous Parametric Down-Conversion with Correlated Photos



Twin photons of strict correlation in crystal

Absolute quantum efficiency of detectors

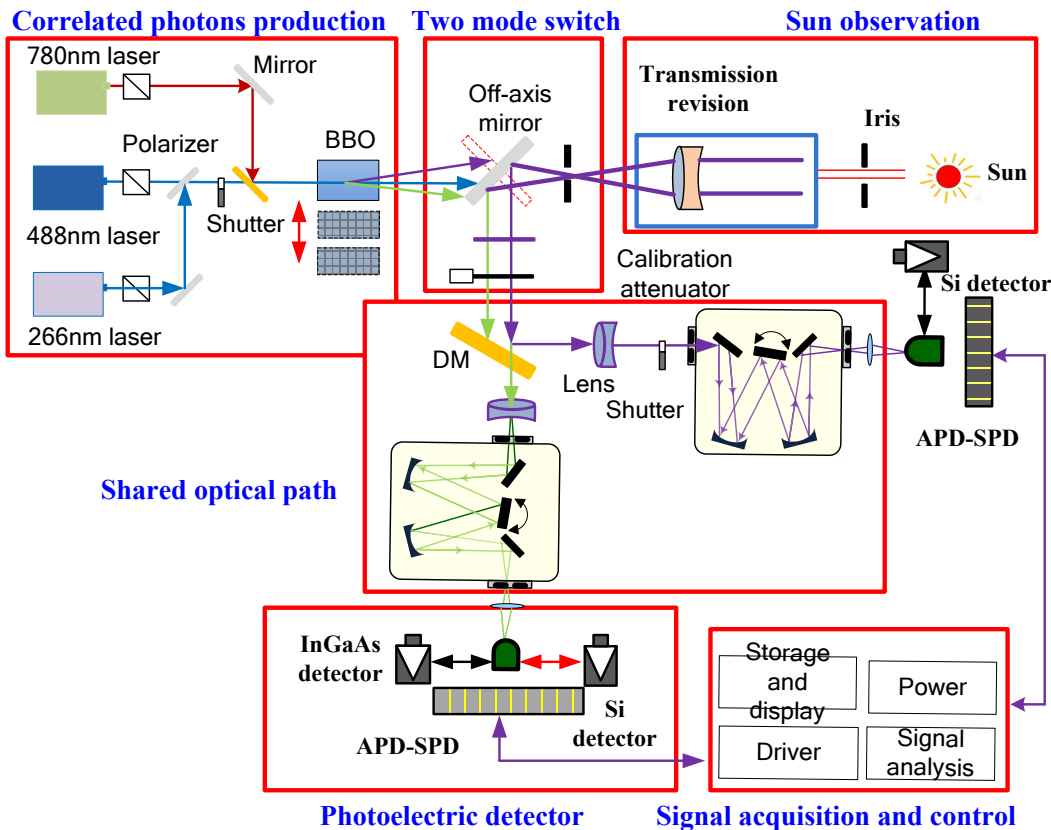
$$\langle N_1 \rangle = \langle N_2 \rangle = \langle N_c \rangle$$

$$\eta_1 = M_c / M_2$$
$$\eta_2 = M_c / M_1$$

Independent on primary standard and standard transfer train, the method is intrinsically absolute



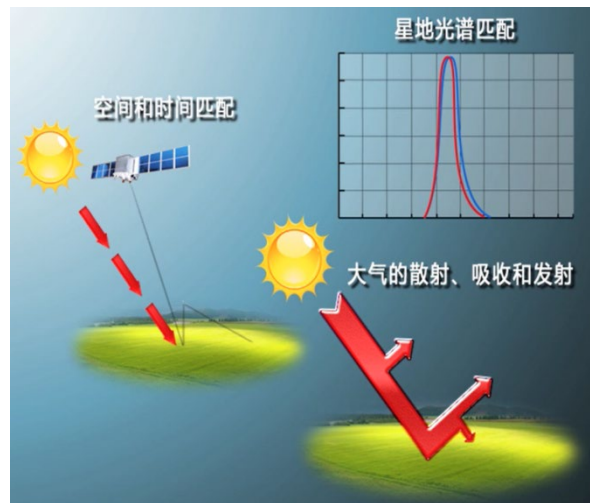
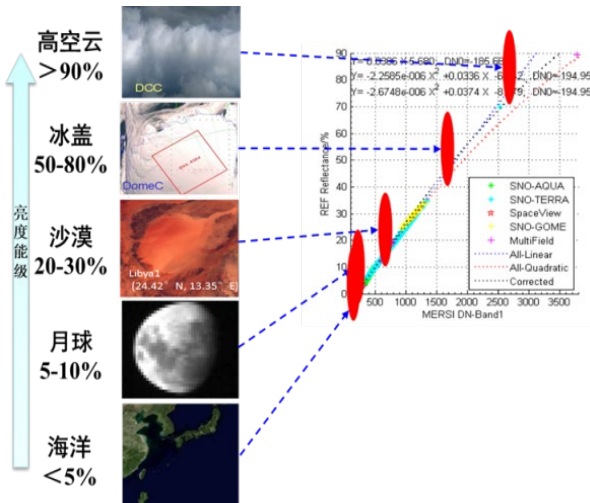
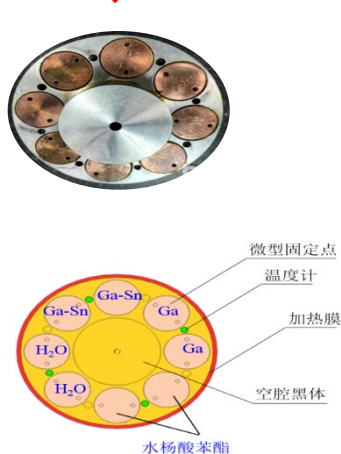
Space-borne solar spectral irradiance radiometry with absolute calibration by correlated photons



- Spectral range: 380 nm - 1000 nm
- Spectral resolution: 3 nm
- Absolute solar spectral irradiance accuracy: 0.3%
- Spectral expanded to 2500 nm by 2022.

4. On-orbit Mode to Support Intercalibration

The integration of space and ground

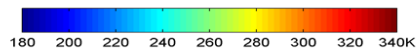
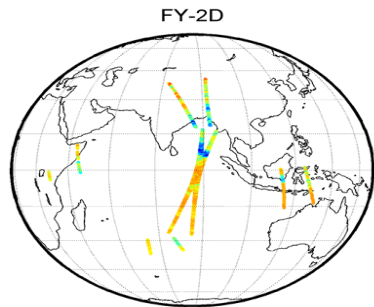


1. Making benchmark

2. Finding benchmark

3. Radiometric transfer & SI traceability

Inter-calibration with reference sensors



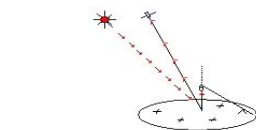
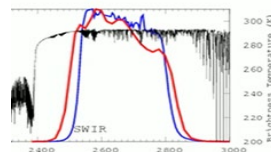
Geo-Leo



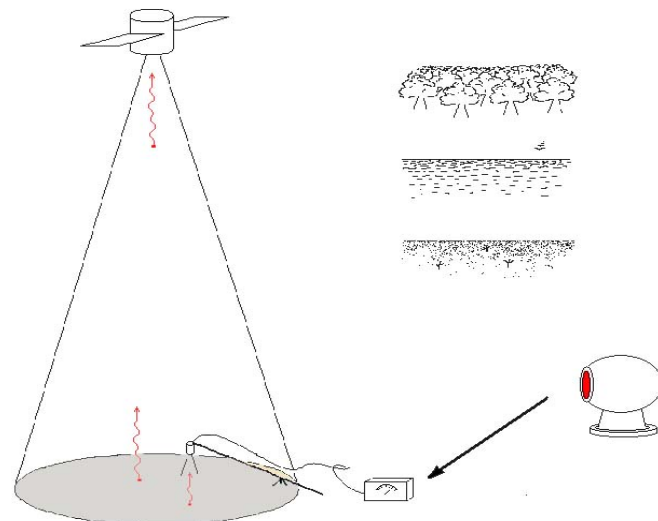
Leo-Leo

Direct Inter-calibration with global data matching

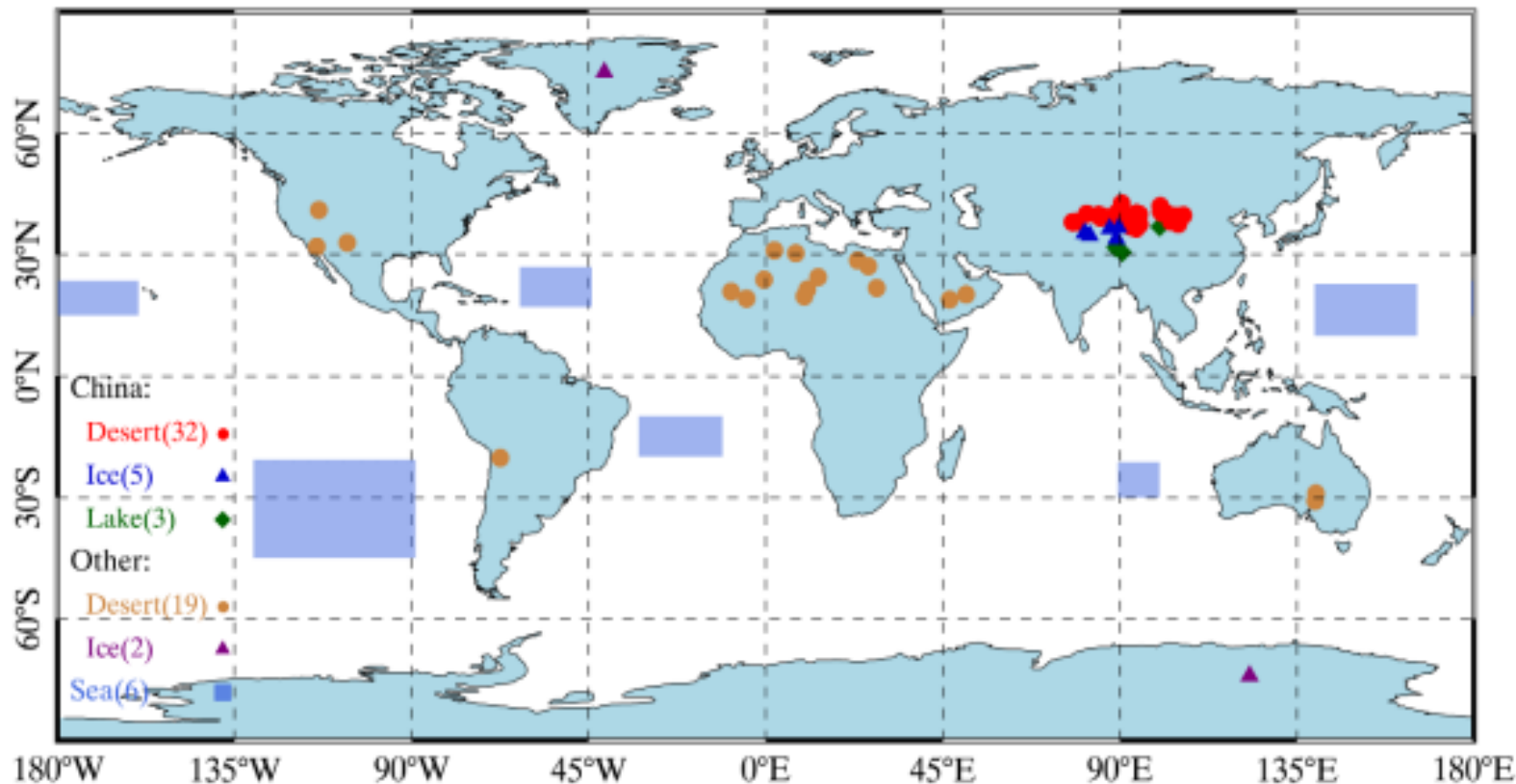
- Space
- Time
- Geometry
- Spectral



Indirect Inter-calibration with PICS

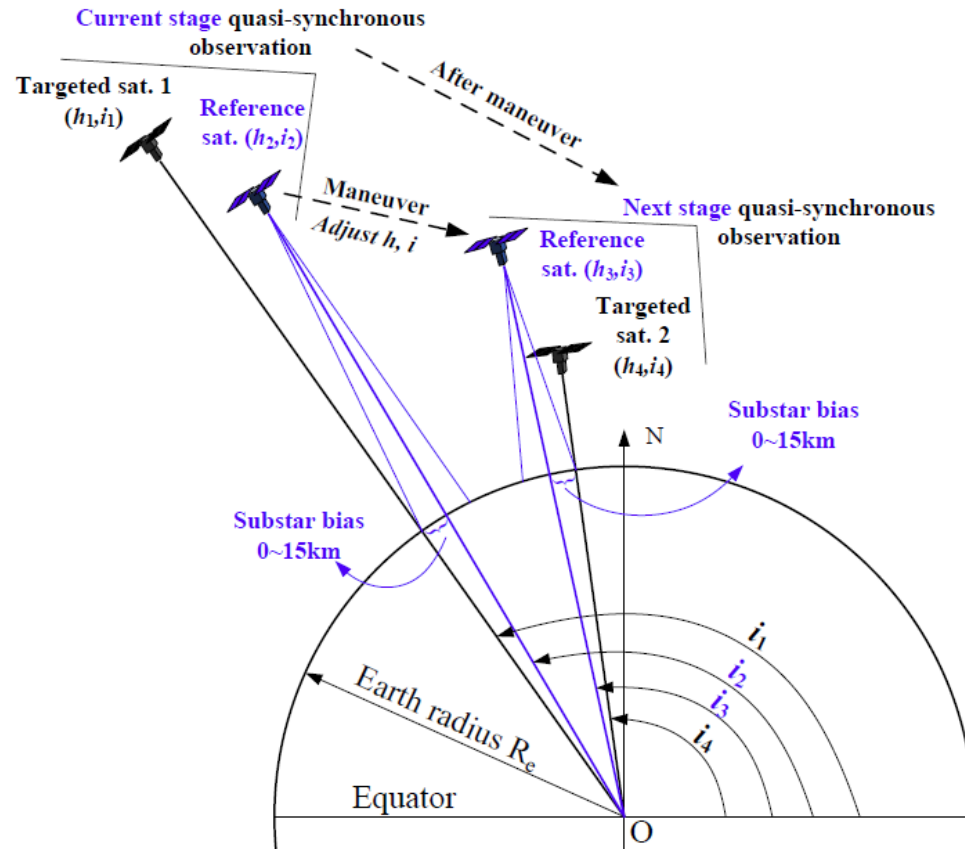


Pseudo-invariant sites (PICs)

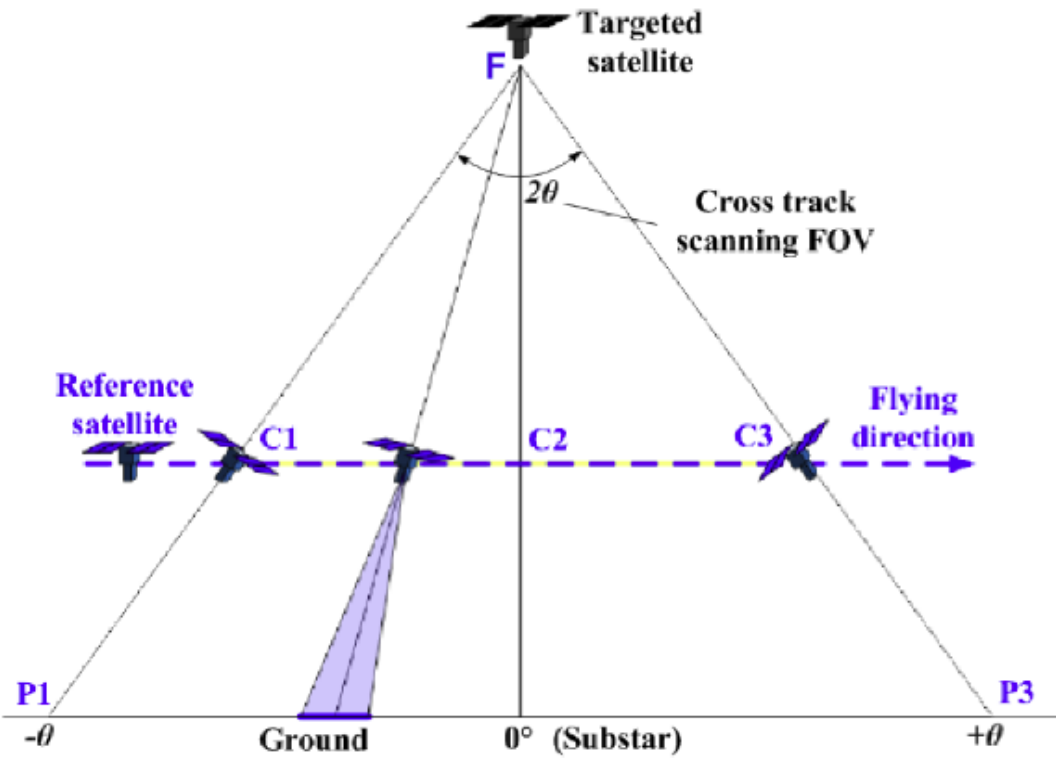


Xiuqing Hu, Ling Wang*, et al, Preliminary Selection and Characterization of Pseudo-Invariant Calibration Sites in Northwest China, *Remote Sens.* 2020, 12, 2517; doi:10.3390/rs12162517.

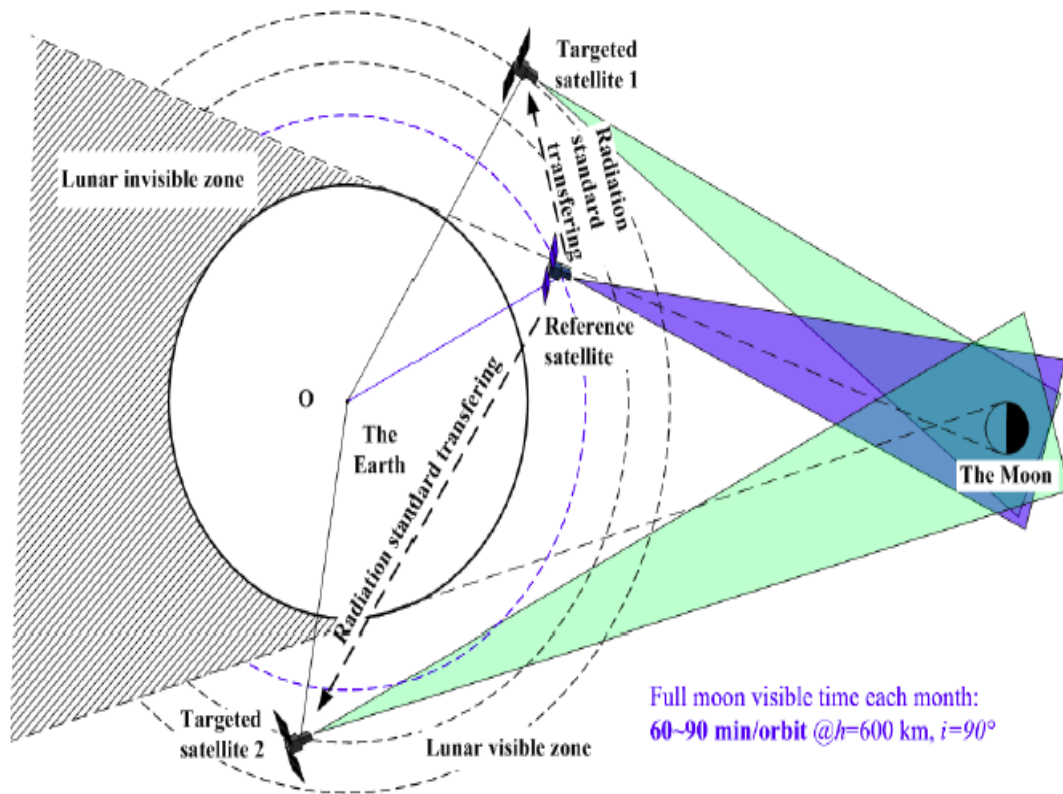
Quasi-Synchronous Intercalibration Transfer Mode by Orbital Maneuver



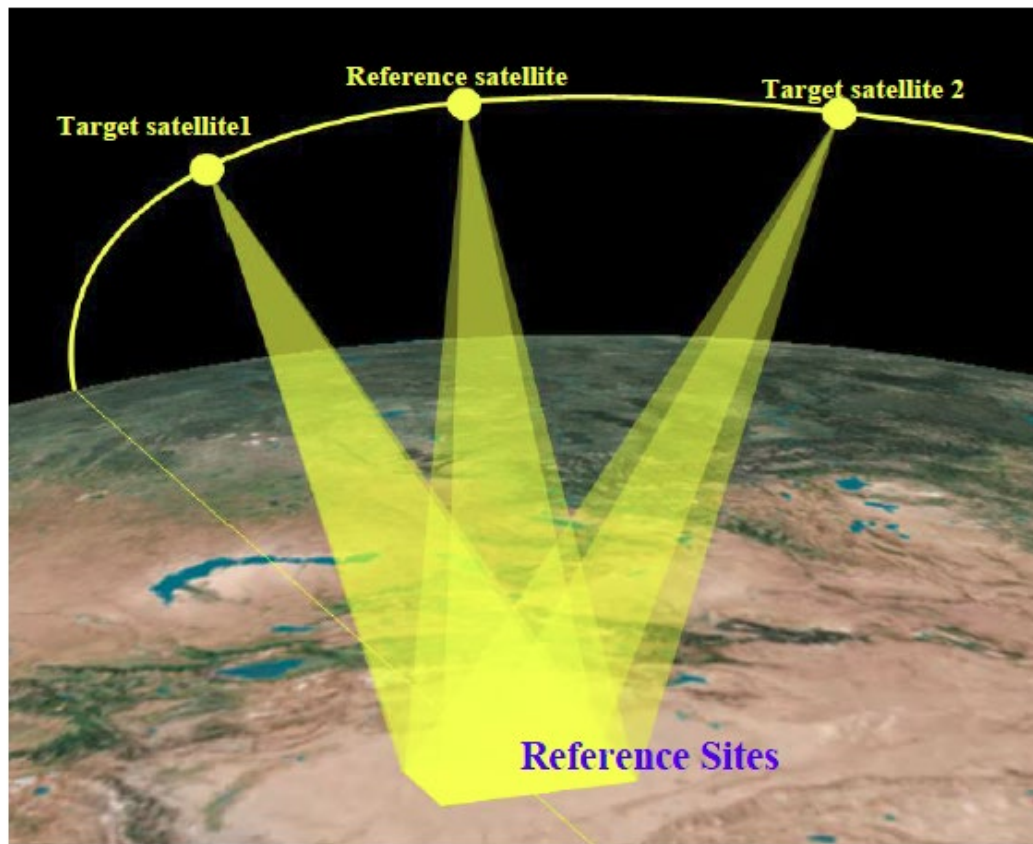
Simultaneous Nadir Overpass (SNO) Cross Intercalibration Transfer Mode (GEO-LEO or LEO-LEO)



Using Lunar Observations for Intercalibration



Using Vicarious Reference Targets for Intercalibration



Products to support intercalibration with radiometric traceability



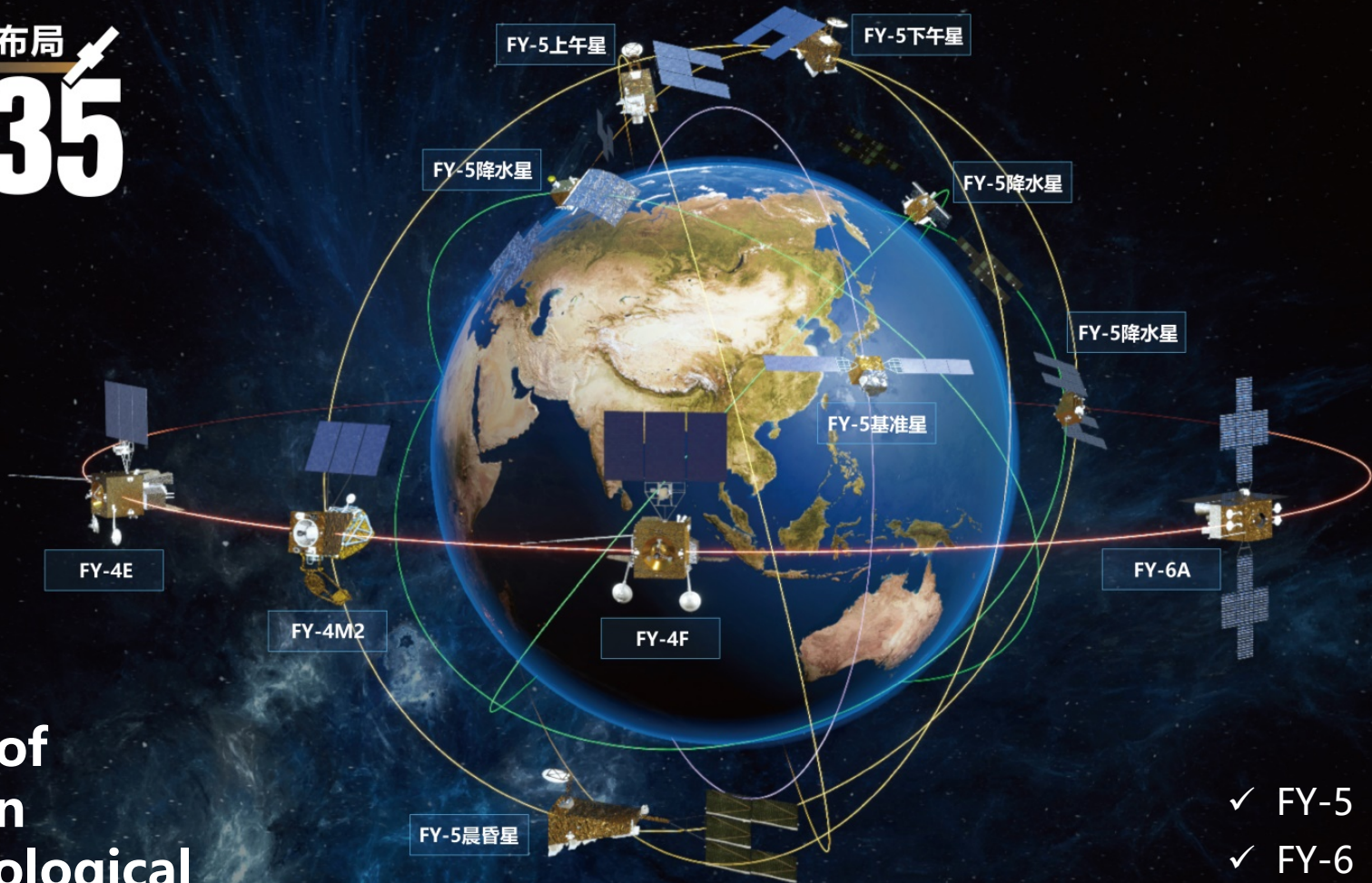
Table 3. Products to support intercalibration with radiometric traceability.

Instruments	Products	Intercalibration Method	Example
IRS	Spectrally-resolved infrared radiance	Quasi-synchronous intercalibration	[16]
		LEO-LEO SNO	[30,31]
		GEO-LEO SNO	[32,33]
EMIS	Spectrally-resolved reflectance of solar radiation	Quasi-synchronous intercalibration	[34]
		LEO-LEO SNO	[35,36]
		GEO-LEO SNO	[37]
	Selected DCC reflectance	DCC	[38,39]
	Selected PICS reflectance	PICS	[40]
Selected Lunar reflectance	Lunar	[41,42]	

P. Zhang et al., 2020: Development of the Chinese Space-Based Radiometric Benchmark Mission LIBRA. Remote Sensing

风云卫星布局

2035

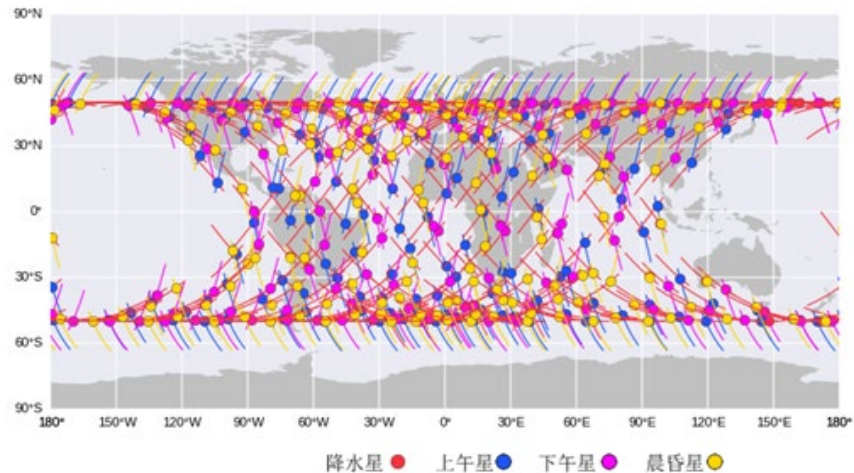
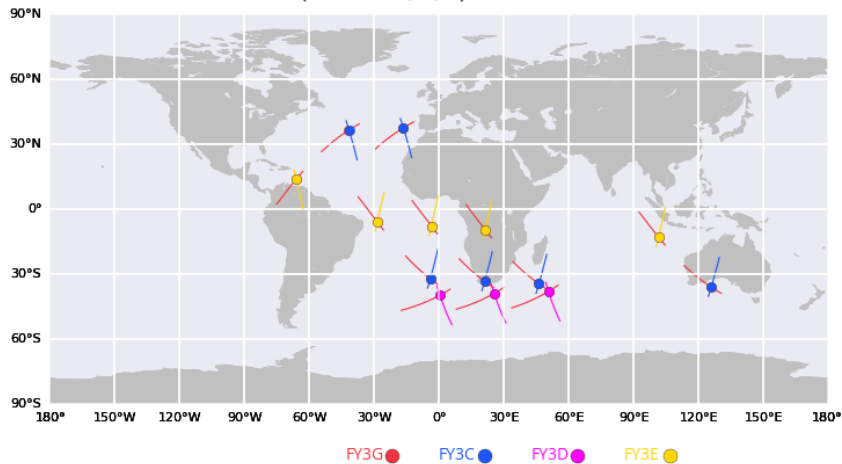


Layout of
FengYun
meteorological
satellites in 2035

- ✓ FY-5
- ✓ FY-6

FY-3G Rainfall Mission

FENGYUN(3G & 3C/D/E) SNO Distribution



5. Issues to be discussed



1. The Libra schedule
2. The Libra mission objectives, PICS characterization, the intercalibration of certain sensors, and climate benchmarking
3. What scan and amount of time where Libra perform for Earth target characterization, sites that have already been selected?
4. Could Libra intercalibrate individual concurrent GEOs while not intercalibrating selected sensors, most GSICS members are responsible for GEO calibration.
5. Lunar scanning and objectives.
6. Will Libra be in a precessionary orbit, what will Libra scanning do while in twilight conditions, are they going to be useful.
7. Will inter-calibration with CLARREO and TRUTHS be of the highest priority?

Together
For Better

谢

谢!

Make the data better and easier to use !