WGCV Infrared and Visible Optical Sensors(IVOS) meeting

China Space-borne Radiometric Calibration Benchmark System Project, MOST

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Project Design

Under the guidance of long-term goals, MOST had arranged "Space-borne radiometric primary standard" project during 12th Five-Year. Currently, new projects on space-borne radiometric measurement benchmark payloads and transfer calibration are carrying out.

863 Plan

- Space-borne radiometric primary standard (2015-2017) — Finished

National Key R&D Plan of China

- **Space-borne radiometric benchmark system and transfer calibration**
  - Space-borne radiometric benchmark system in solar refection spectrum
  - Space-borne radiometric benchmark system in infrared spectrum
  - Space-borne radiometric benchmark transfer calibration and field validation → AOE
  - China remote sensing historical data recalibration → CMA

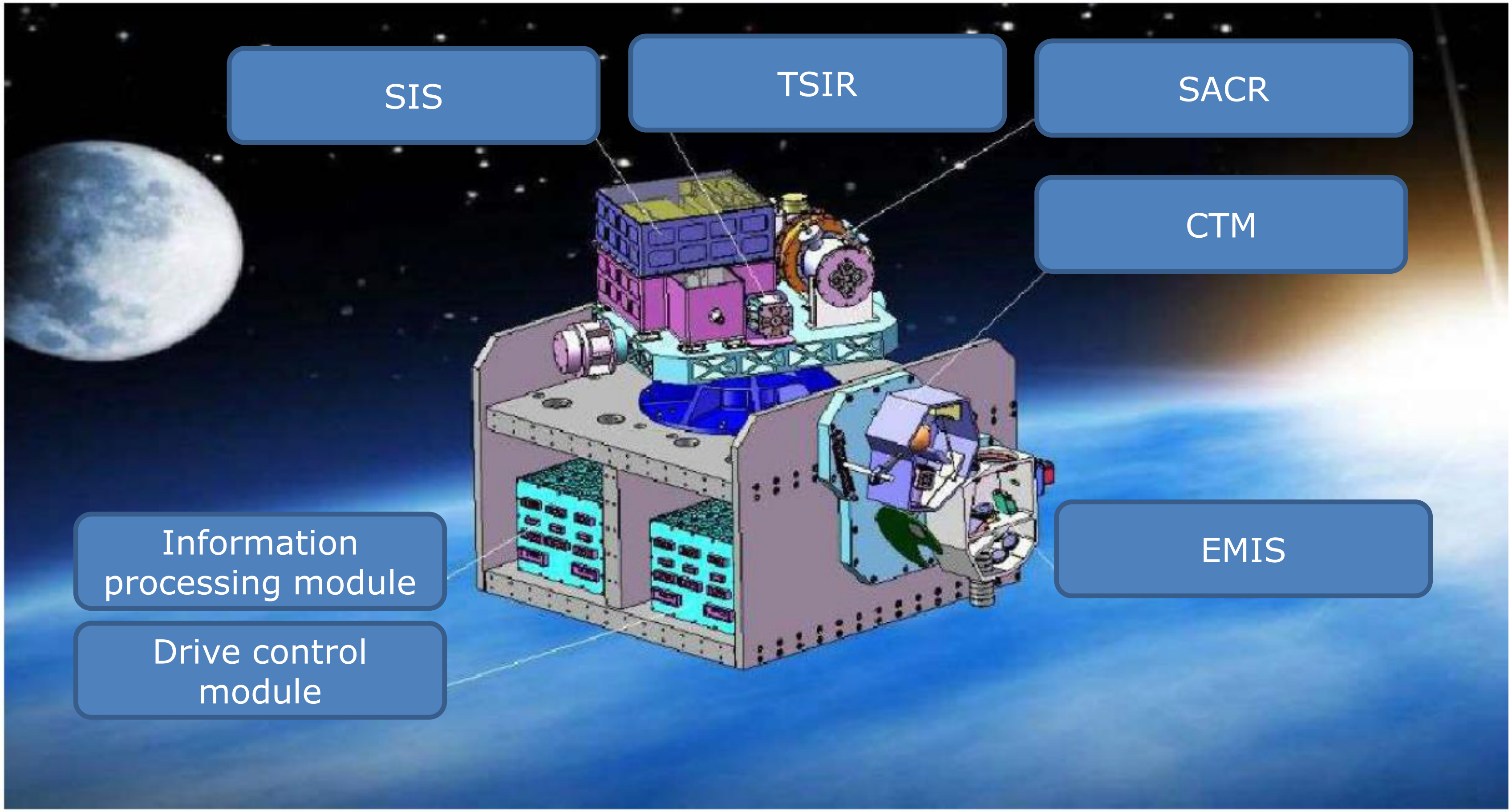
2018.7 - 2022.6

More than 30 participations:

Payloads design institutions: AIOFM, CIOMP, SITP, CAST, …
Cal&Val institutions: AOE, RADI, NIM, WHU, …
Application organizations: CMA, CRESDA, NSOAS, SASMAC, CAAS, …

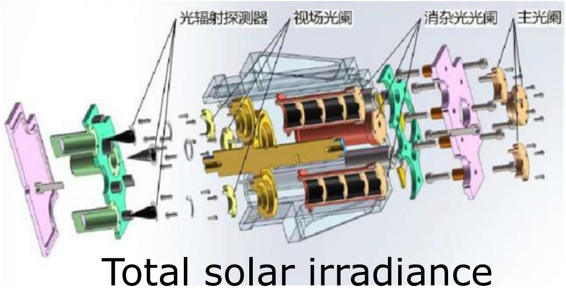
1. Space-borne benchmark system in solar refection spectrum

This system consists of 7 components: Earth/moon imaging spectrometer (EMIS), Solar irradiance spectroradiometer (SIS), Total solar irradiance radiometer (TSIR), Space-borne absolute cryogenic radiometer (SACR), Comparison transfer module (CTM), information processing module, and drive control module.



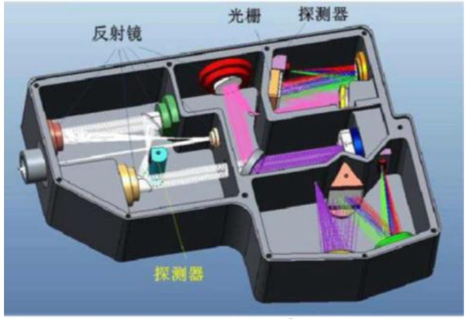
Research Contents

1. Space-borne benchmark system in solar refection spectrum



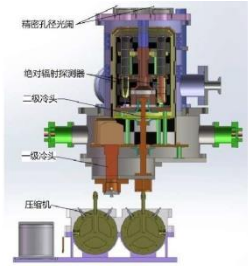
Total solar irradiance radiometer (TSIR)

Spectral range: 0.2μm-35μm
Detection SNR: > 3000
Uncertainty of radiometric measurement: < 0.05%

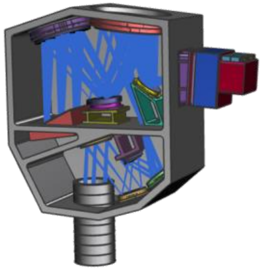


Solar irradiance spectroradiometer (SIS)

Spectral range: 380nm-2500nm
Spectral resolution: < 3nm (380nm-1000nm); <8nm (1000nm-2500nm)
Spectral calibration accuracy: 0.2nm~0.5nm
Detection SNR: > 500
Uncertainty of radiometric measurement: < 0.3%



Space-borne absolute cryogenic radiometer(SAR)



Earth/moon imaging spectrometer (EMIS)

Spectral range: 380nm~2350nm
Spectral resolution < 10nm
Spectral calibration accuracy: 0.2nm~0.5nm
Detection SNR > 300
At-nadir spatial resolution < 100m
Swath: ≥ 50km
Uncertainty of spectral radiance: < 1%

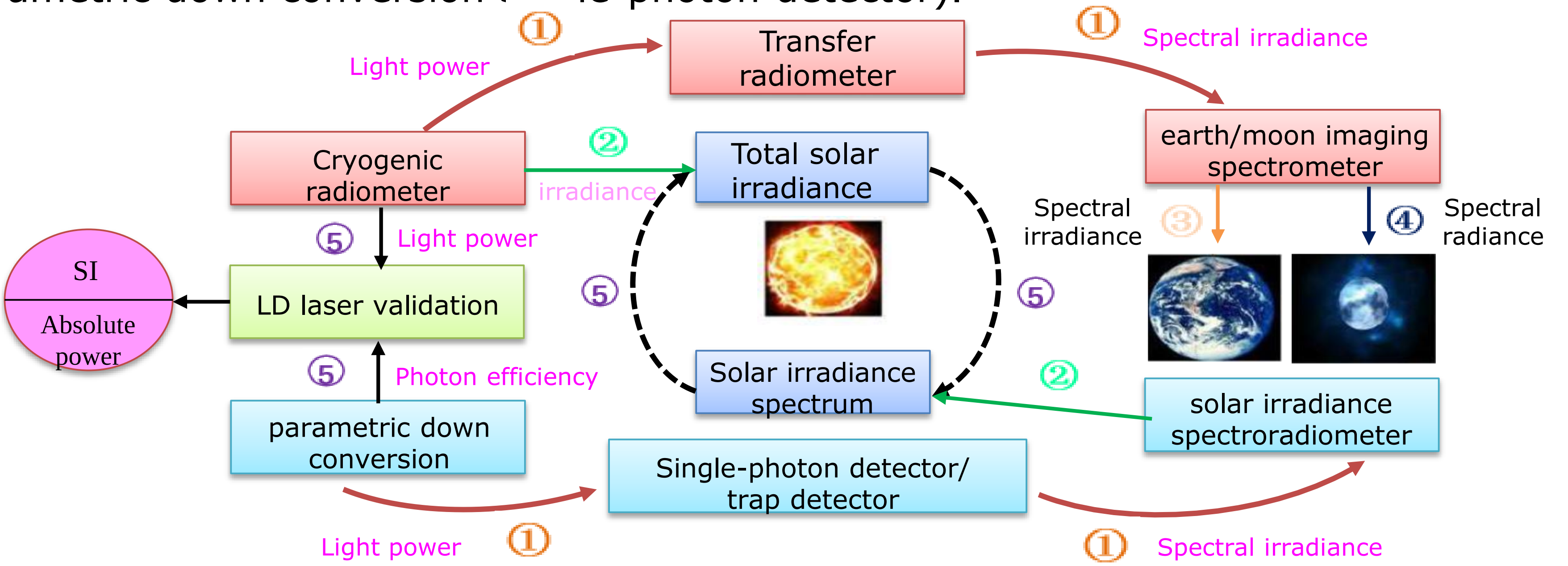
● 1. Space-borne benchmark system in solar refection spectrum

Five operation modes:

➢ Self-calibration mode. Using cryogenic radiometer as primary standard, to calibrate the total solar irradiance radiometer, multi-band transfer radiometer and the Earth-lunar imaging spectrometer. Using parametric down conversion single-photon detector as standard reference source, to calibrate the solar irradiance spectroradiometer.

➢ Sun-viewing mode / Earth-viewing / Moon-viewing mode. Pointing to the sun, observing the total solar irradiance and the irradiance spectrum; Using earth/moon imaging spectrometer to measure the earth-reflected radiance/the full moon disc irradiance spectrum.

➢ Benchmark comparison mod. Comparison of sources (cryogenic radiometer vs. parametric down conversion single-photon detector).



Research Contents

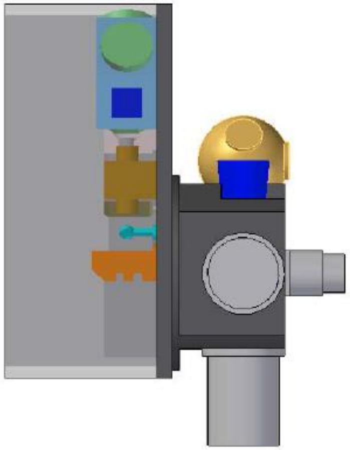
2. Space-borne benchmark system in infrared spectrum

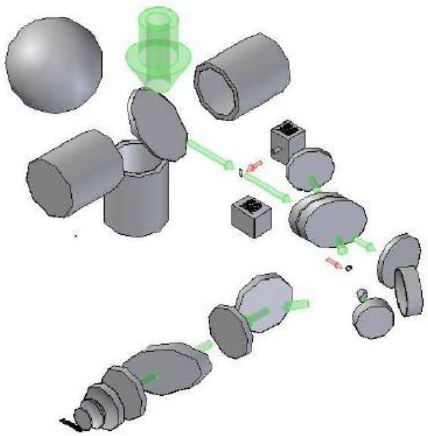
Primary ideas:

- Adopting the fixed point method to realize on-orbit calibration of the built-in blackbody.
- Measuring spectral emissivity of space environment radiation, and monochrome emissivity of the laser, to realize on-orbit measurement of the blackbody emissivity.
- Using hyperspectral infrared sensor to realize the radiometric quantity transfer.

System composition:

phase transition fixed-point blackbody; multiple sets of on-orbit blackbody; Translational Fourier interferometer; on-orbit laser





Layout of the space-borne radiometric standard reference sensor in thermal infrared band

2. Space-borne benchmark system in infrared spectrum

Quantity tracing system: fixed-point blackbody <- variable temperature blackbody <- infrared sensor

Fixed-point blackbody

Variable temperature blackbody

User blackbody

phase transition fixed-point reference source

Temper: ITS-90 reference value   Cavity emissivity: 0.9999

Mercury fixed-point blackbody 234.3210K	Gallium fixed-point blackbody 302.9146K	Gallium fixed-point blackbody 302.9146K
Aperture Φ=30mm	Aperture Φ=30mm	Aperture Φ=30mm

Fourier spectrometer 3um-1000um

Vacuum radiation thermometer 8um-14um

Variable temperature blackbody reference source

Temper: contact thermometer   Cavity emissivity: 0.9999

Vacuum low-temperature BB 125K-200K	Alcohol bath blackbody 190K-340K	Vacuum high-temperature BB 335K-700K
Aperture Φ=30mm	Aperture Φ=30mm	Aperture Φ=30mm

Fourier spectrometer 3um-1000um

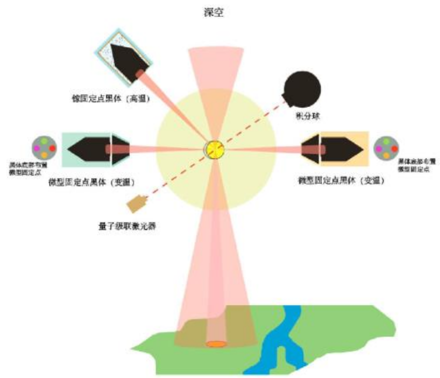
Vacuum radiation thermometer 8um-14um

Vacuum low background test site

Blackbody to be calibrated

Research Contents

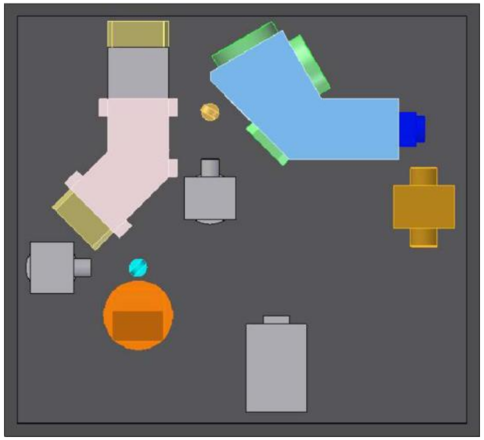
2. Space-borne benchmark system in infrared spectrum



Space-borne infrared standard reference sources

- 1 Gallium fixed-point on-orbit blackbody (standard reference source)
- 3 micron phase transition fixed-point variable temperature on-orbit blackbody (transfer reference source)

Temperature range: 250K-330K
Emissivity: ＞0.999
Blackbody stability: 10mk
Uncertainty of brightness temperature: < 0.1K

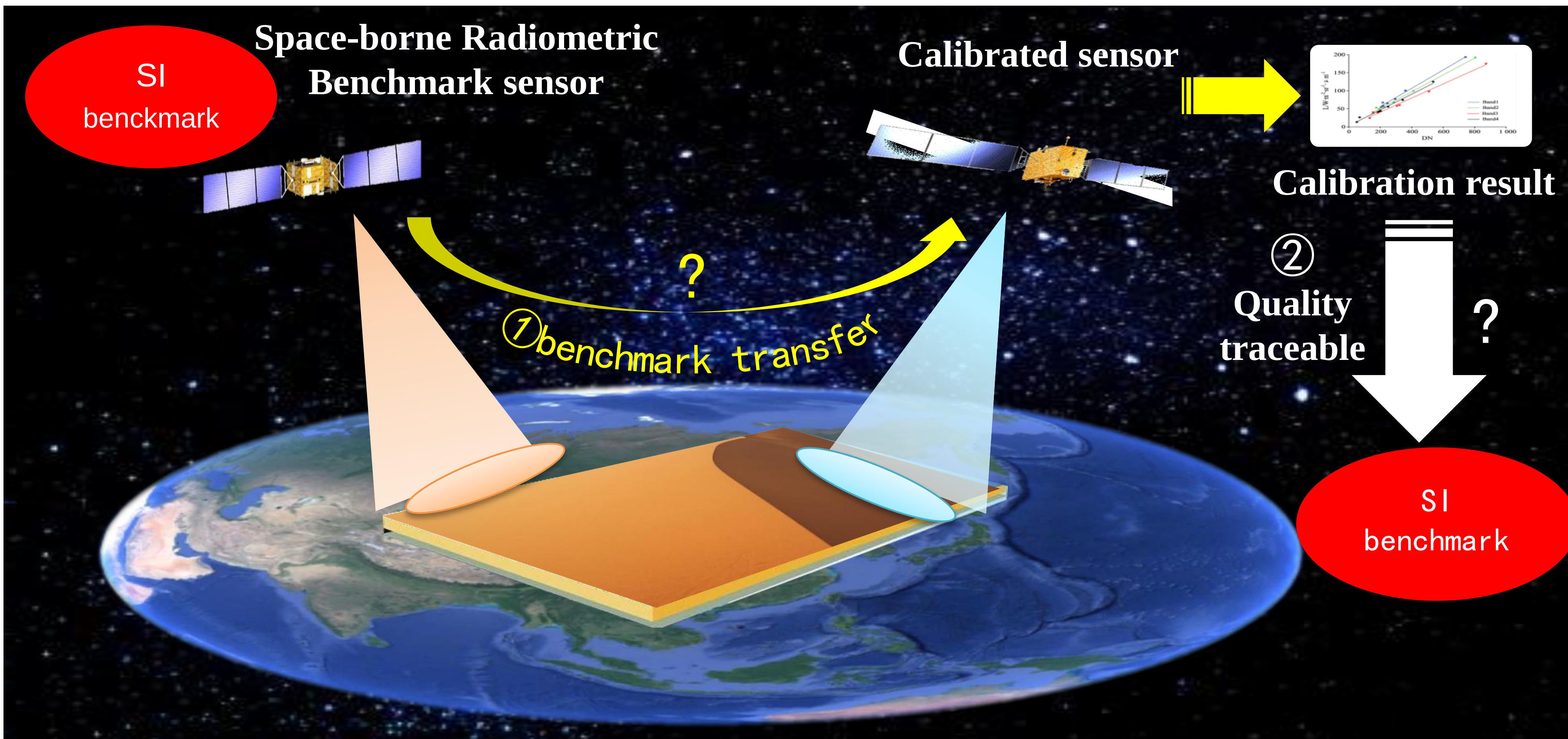


Broad spectum hyperspectral infrared sensor

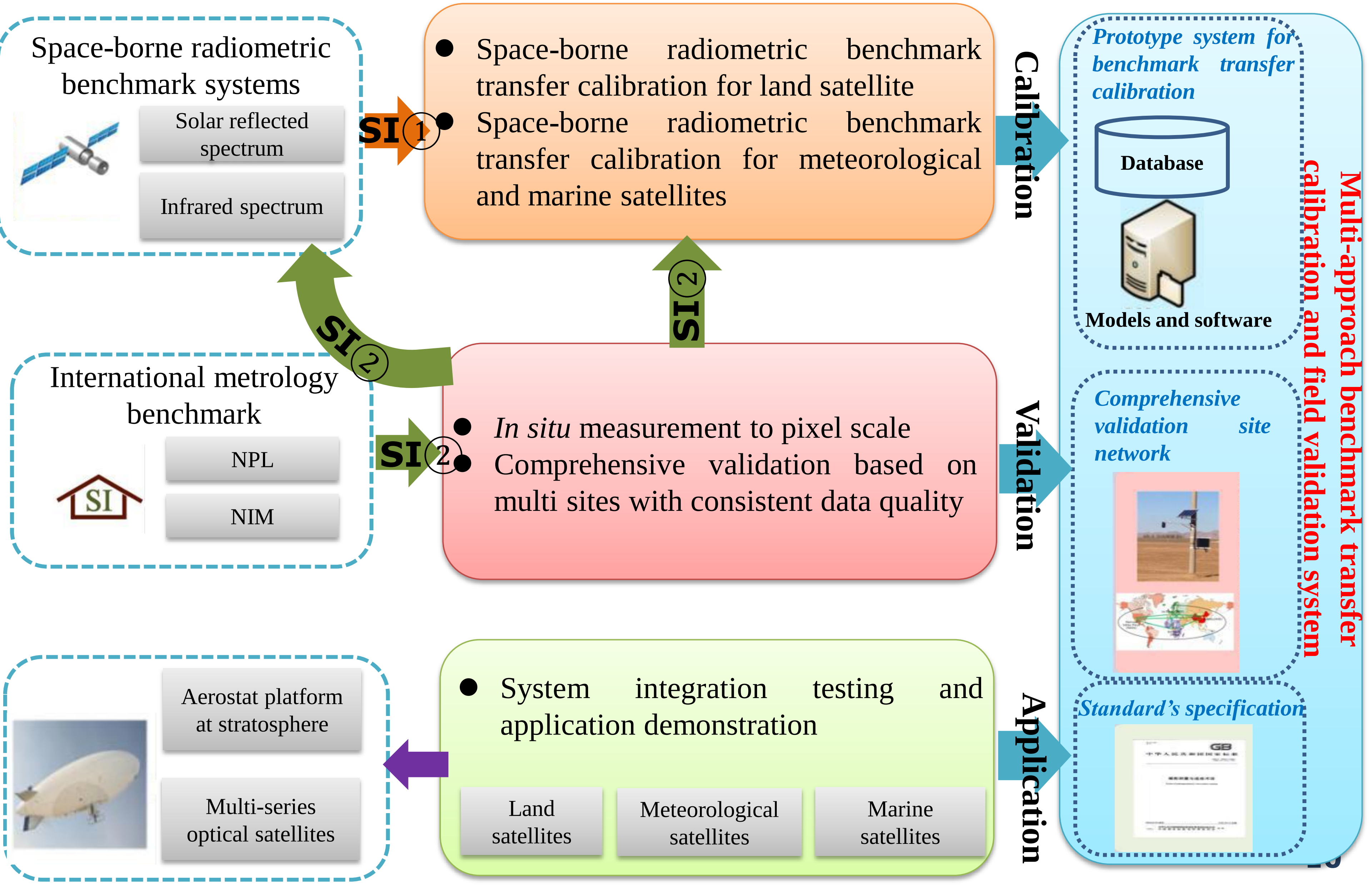
Spectral range: 600 cm^{-1}~2700cm^{-1}
Spectral resolution: < 0.5cm^{-1}
IFOV: 17km
Radiometric sensitivity: 0.1K@270K
Uncertainty of absolute calibration: < 0.2K

• 3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation

Scientific objectives: accurately transferring of spaceborne radiometric benchmark , and consistently tracing of the data radiometric quality, achieving the **transfer uncertainty** from the space-borne radiometric benchmark sensor to the calibrated sensor of **2%** in solar reflected spectrum, and **0.2K** in the infrared spectrum.



Research Contents



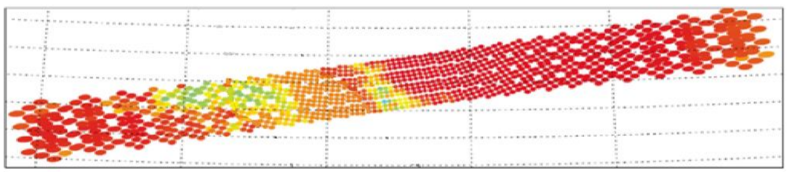
Research Contents

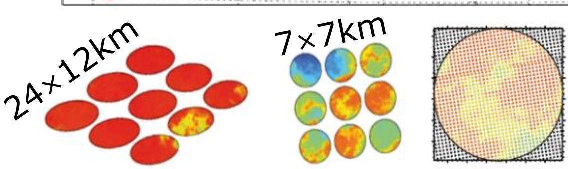
- **3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation**

3.1 Space-borne radiometric benchmark transfer calibration for meteorological and marine satellites

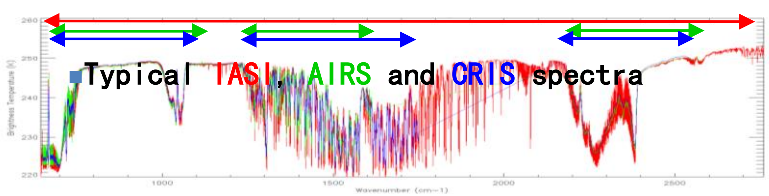
In consideration of the pixel spatial response, some methods related to pixel spatial matching and spectral compensation will be developed, so as to lower the uncertainty caused by the spatial and spectral differences.

Q1：Spatial deformation for large swath



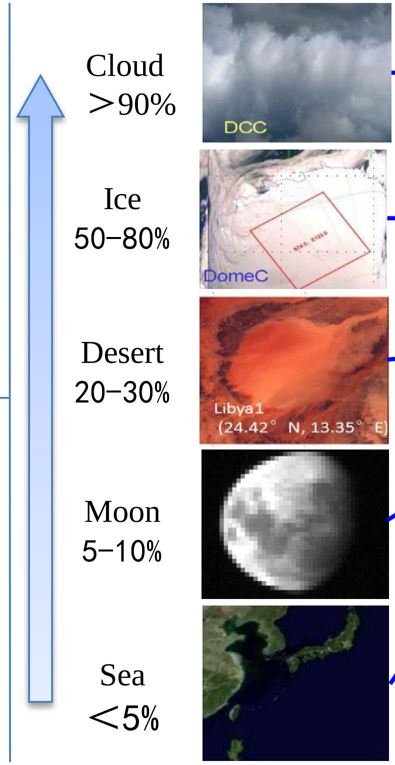


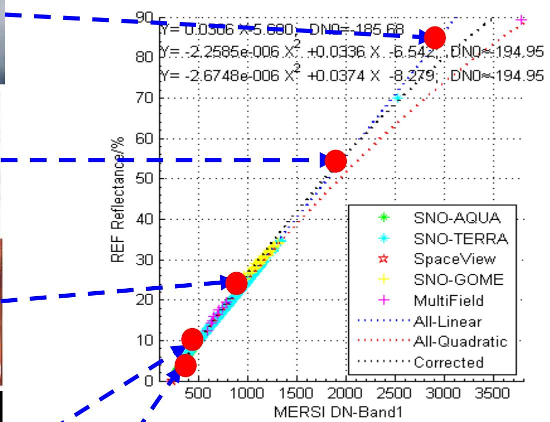
Q2：Inhomogeneity in low resolution pixel



Q1：Lower spectral resolution of the calibrated sensor

Q2：The spectrum range of the benchmark sensor can not cover that of the calibrated sensor





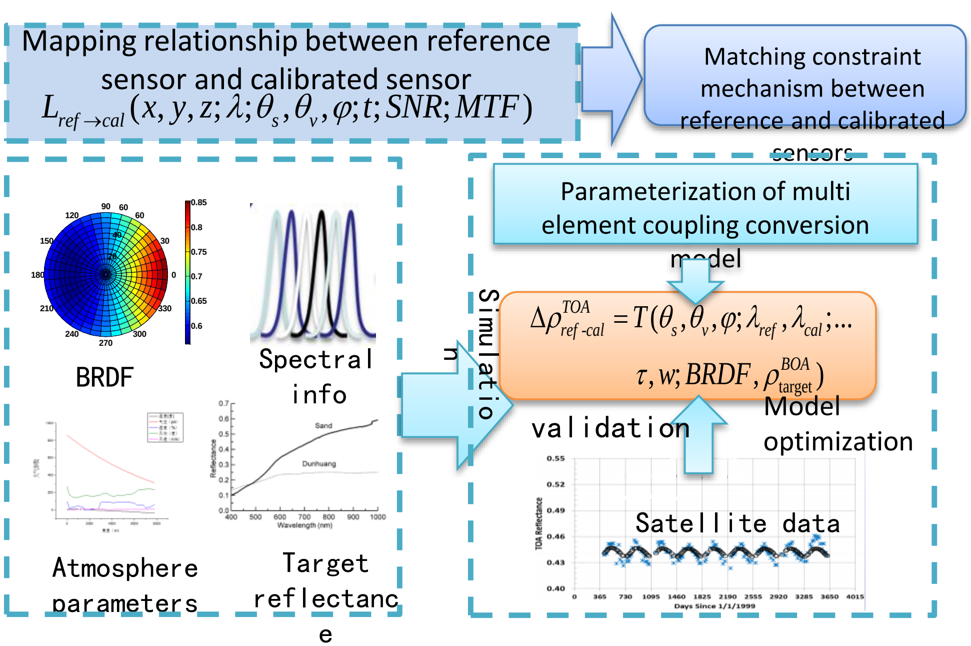
Consideration of multi-energy level and large-FOV targets, enlarging the dynamic range of calibration samples

Research Contents

3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation

3.2 Space-borne benchmark transfer technology for land satellites

- Because of the long revisit period and narrow width for land satellites, it's necessary to increase temporal and angular differences between reference and calibrated sensors, so as to increase cross over-passing opportunities.
- Considering the anisotropy and temporal difference of reference targets, temporal- spatial-spectral-angular coupling conversion method will be developed under the exploration characteristics of earth/moon stable targets.



Stable target/scene：

- ✓ Based on PICS, a global stable targets database with no less than 20 targets；
- ✓ RadCalNet sites network；
- ✓ Moon：

Ground target characteristic library:

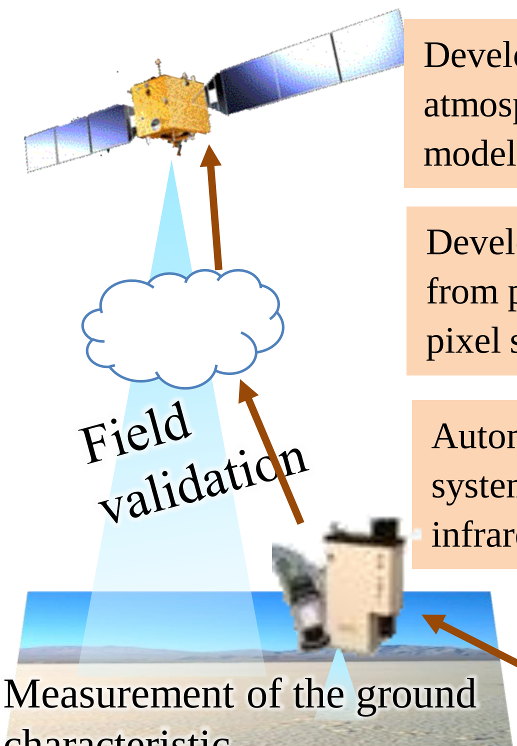
- ✓ Site area≥3km^2
- ✓ Spatial homogeneity≤3%
- ✓ Uncertainty associated with surface reflectance ≤3%

Research Contents

3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation

3.3 *In situ* measurement at pixel scale → 3.4 Comprehensive validation based on multi sites with unified data quality

Improve the accuracy of *ground-based* measurements



Develop accurate local atmospheric radiative transfer model

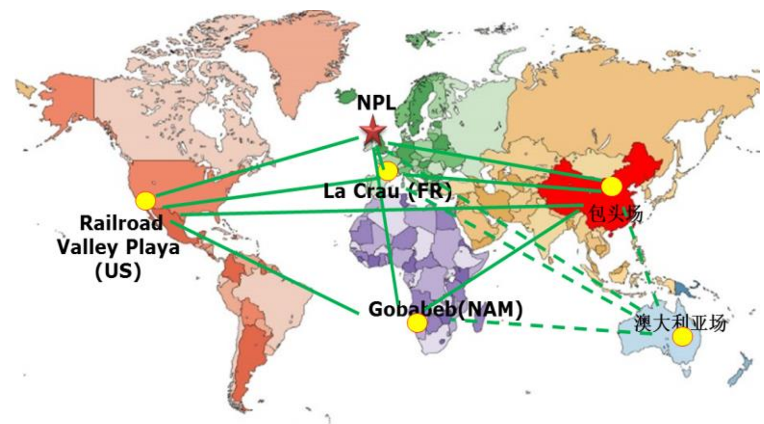
Develop upscaling method from point measurement to pixel size

Automated field measurement systems in solar reflected and infrared spectrum

SI benchmark

Reducing the uncertainties in the SI transfer chain

Guarantee the consistency of multi-site



Extend ground validation sites in China

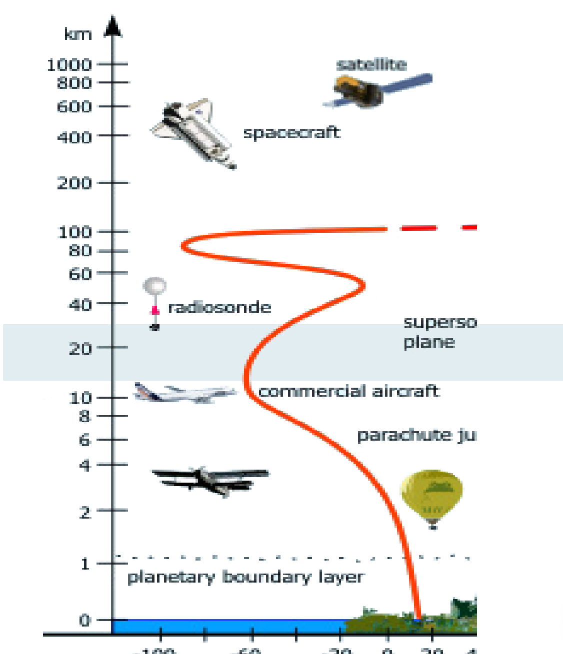
Comparison among multi validation sites based on field benchmark transfer radiometer

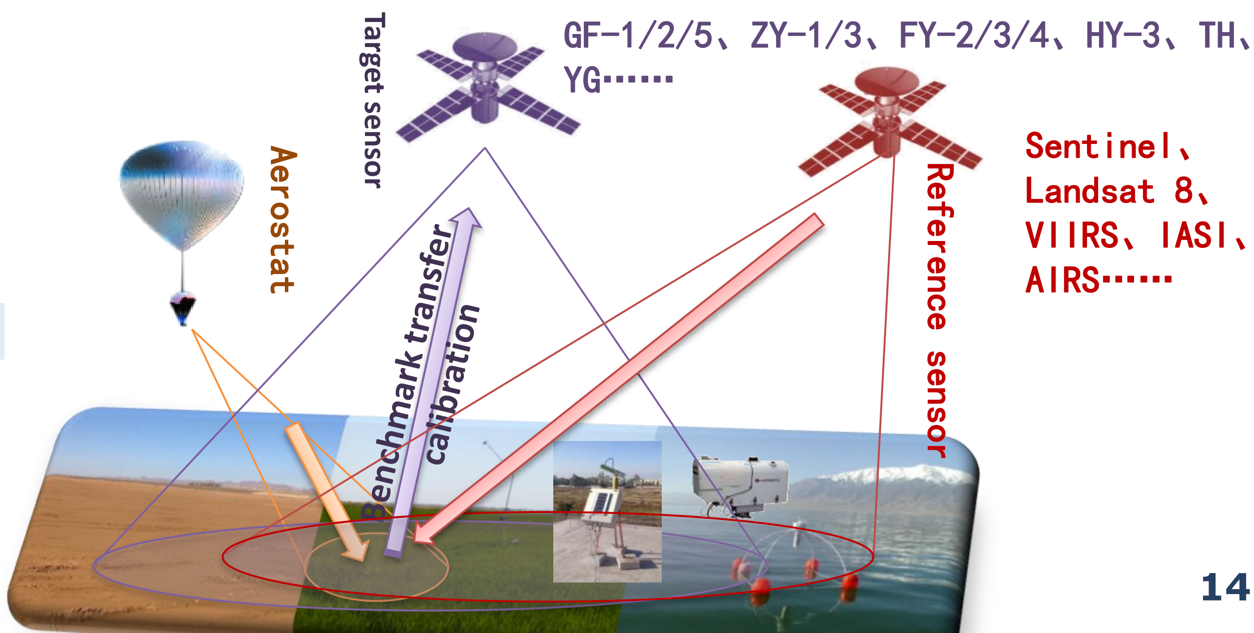
Weight allocation for multi validation sites

3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation

3.5 System integration & demonstration application

- Using high-altitude balloon as main platform, the aerostat-borne benchmark transfer calibration demonstration system will be developed. The key techniques on resistance of near-space physical environment, effective target observation control will be studied.
- The flight campaign with altitude above 18km will be carried out with demonstration system. Besides Chinese satellite, high-accuracy satellite such as Sentinel and Landsat will be involved as a reference.



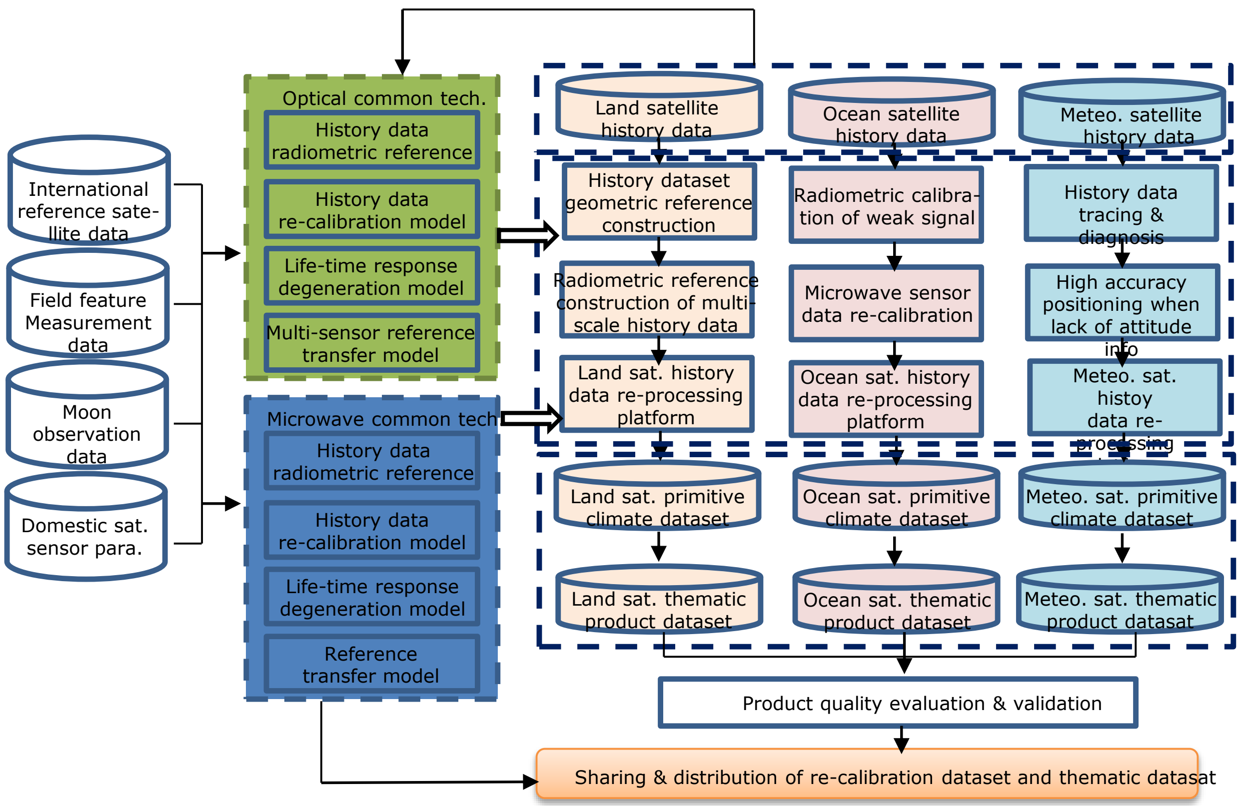


Research Contents

● 4. History data re-calibration for multiple series of Chinese remote sensing satellites

Objective:

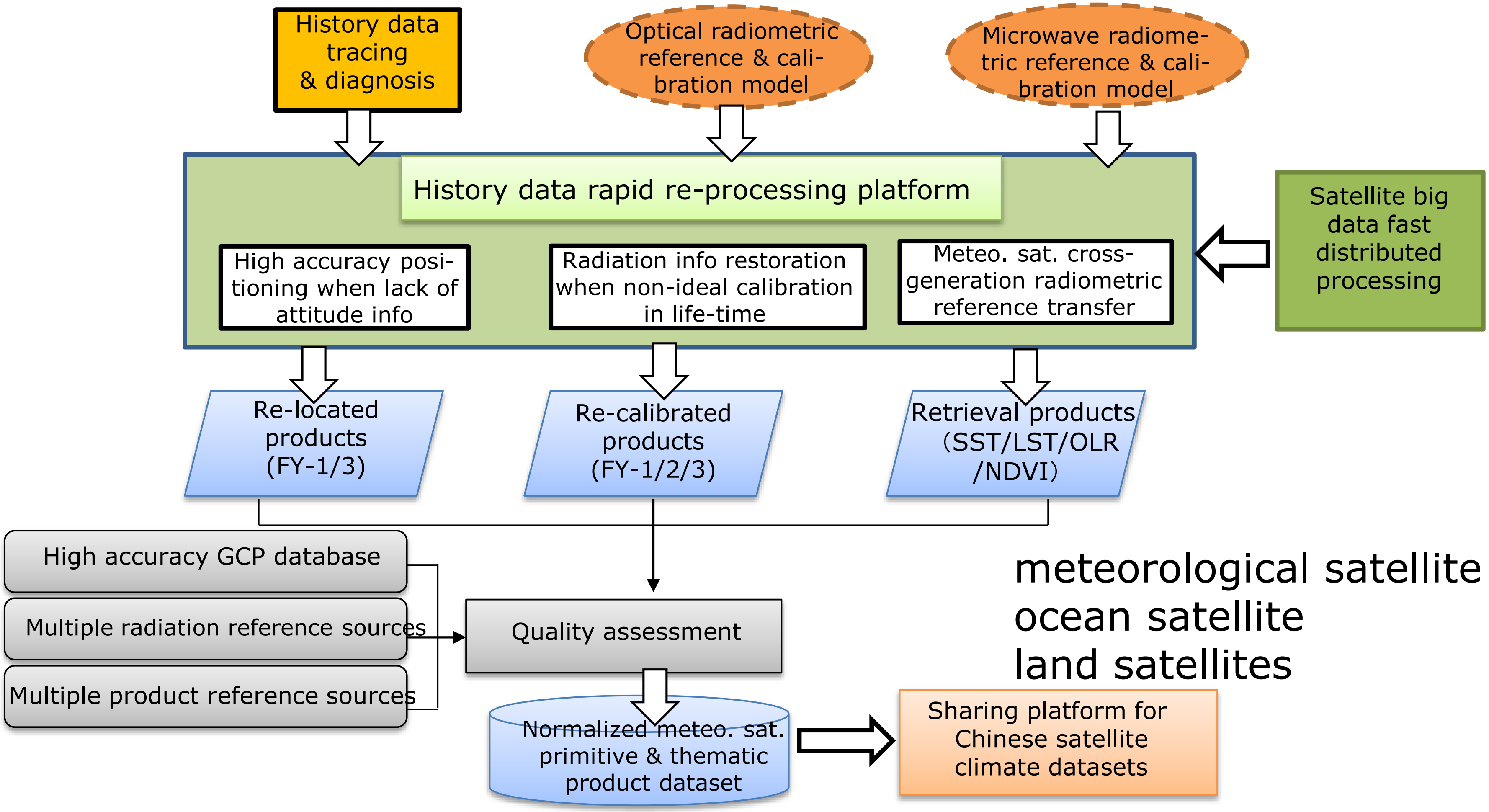
- ➢ building re-calibration technical system
- ➢ yielding long time-series (10~30 years) primitive climate data set based on consistently calibrated satellite data (including FY, HY, ZY series satellites).



- ✓ Radiometric calibration accuracy on reflective solar band: 5% (operational satellite); 8% (experimental satellite)
- ✓ Radiometric calibration accuracy on thermal band: 0.5K (operational satellite); 1K (experimental satellite)
- ✓ Radiometric calibration accuracy on microwave band: 1K
- ✓ Long-time stability of radiometric calibration: 2%

Research Contents

- **4. History data re-calibration for multiple series of Chinese remote sensing satellites**



meteorological satellite
ocean satellite
land satellites

Research period & phased roadmap

- Research period： 10 year

Phased roadmap

2016-2017

Phase 1:
- Design of technical implementation plan
- Technical development on solar-refection/infrared spectrum space radiometric calibration benchmark, ground-base Cal&Val net and cross calibration

2018-2020

Phase 2:
- Prototype of solar-refection/infrared spectrum space radiometric calibration benchmark system;
- Integrating ground-base Cal&Val network, and demonstration application of cross calibration

2021-2013

Phase 3:
- Manufacture of solar-refection/infrared spectrum space radiometric calibration benchmark system
- Aerostat-borne benchmark transfer calibration demonstration

2024-2025

Phase 4:
- Satellite-borne test
- Operational demonstration

Summary

- With Prof. Li's promotion, "Space-borne radiometric benchmark system and transfer calibration", a project funded by National Key R&D Plan of China by MOST, will be kicked-off in this year. The achievement of this project will benefit the whole remote sensing application society around the world.
- Since good technologies and experiences have been accumulated in IVOS, e.g. TRUTHS, CLARREO, RadCalNet, PICS, etc, we hope to carry out extensive international cooperation, introduce advanced ideas and technical support, optimize the technical plan, and ensure the implement of this project in both engineering and scientific aspects.

Thanks