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.

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, ...

863 Plan
Finished


Space-borne radiometric benchmark system and transfer calibration

- Space-borne radiometric benchmark system in solar reflection spectrum
- Space-borne radiometric benchmark system in infrared spectrum
- Space-borne radiometric benchmark transfer calibration and field validation
- China remote sensing historical data recalibration

National Key R&D Plan of China

2018.7 - 2022.6
AOE
CMA

2018.7 - 2022.6
AOE
CMA
1. Space-borne benchmark system in solar reflection 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.
1. Space-borne benchmark system in solar reflection spectrum

**Total solar irradiance radiometer (TSIR)**
- Spectral range: 0.2μm-35μm
- Detection SNR: > 3000
- Uncertainty of radiometric measurement: < 0.05%
- 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%
- At-nadir spatial resolution: < 100m
- Swath: ≥ 50km
- Uncertainty of spectral radiance: < 1%

**Solar irradiance spectroradiometer (SIS)**
- 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%

**Space-borne absolute cryogenic radiometer (SAR)**

**Earth/moon imaging spectrometer (EMIS)**
1. Space-borne benchmark system in solar reflection 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 mode.** Comparison of sources (cryogenic radiometer vs. parametric down conversion single-photon detector).
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

<table>
<thead>
<tr>
<th>Reference Source</th>
<th>Temperature Range</th>
<th>Cavity Emissivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury fixed-point blackbody</td>
<td>234.3210K</td>
<td>0.9999</td>
</tr>
<tr>
<td>Gallium fixed-point blackbody</td>
<td>302.9146K</td>
<td>0.9999</td>
</tr>
<tr>
<td>Gallium fixed-point blackbody</td>
<td>302.9146K</td>
<td>0.9999</td>
</tr>
</tbody>
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<tr>
<th>Aperture Φ</th>
<th>30mm</th>
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### Variable temperature blackbody reference source
- Temper: contact thermometer
- Cavity emissivity: 0.9999

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<th>Reference Source</th>
<th>Temperature Range</th>
<th>Cavity Emissivity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vacuum low-temperature BB</td>
<td>125K-200K</td>
<td>0.9999</td>
</tr>
<tr>
<td>Alcohol bath blackbody</td>
<td>190K-340K</td>
<td>0.9999</td>
</tr>
<tr>
<td>Vacuum high-temperature BB</td>
<td>335K-700K</td>
<td>0.9999</td>
</tr>
</tbody>
</table>

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**Vacuum low background test site**

**Vacuum radiation thermometer 8um-14um**

**Blackbody to be calibrated**
2. Space-borne benchmark system in infrared spectrum

- 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

Spectral range: 600 cm$^{-1}$~2700 cm$^{-1}$
Spectral resolution: < 0.5 cm$^{-1}$
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

- Space-borne radiometric benchmark systems
  - Solar reflected spectrum
  - Infrared spectrum

- International metrology benchmark
  - NPL
  - NIM

- Aerostat platform at stratosphere
  - Multi-series optical satellites

- In situ measurement to pixel scale
  - Comprehensive validation based on multi sites with consistent data quality

- System integration testing and application demonstration

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

Prototype system for benchmark transfer calibration
- Database
- Models and software
- Comprehensive validation site network

Multi-approach benchmark transfer calibration and field validation system
- Standard’s specification

Land satellites
Meteorological satellites
Marine satellites
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 cannot cover that of the calibrated sensor

Consideration of multi-energy level and large-FOV targets, enlarging the dynamic range of calibration samples
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 ≥ 3km²
- Spatial homogeneity ≤ 3%
- Uncertainty associated with surface reflectance ≤ 3%
3. Consistent transfer calibration based on Space-borne radiometric benchmark and field validation

3.3 *In situ* measurement at pixel scale

- 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

3.4 Comprehensive validation based on multi sites with unified data quality

- 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

Reducing the uncertainties in the SI transfer chain
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 18 km 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%

International reference satellite data
Field feature Measurement data
Moon observation data
Domestic sat. sensor para.

Optical common tech.
History data radiometric reference
History data re-calibration model
Life-time response degeneration model
Multi-sensor reference transfer model

Microwave common tech.
History data radiometric reference
History data re-calibration model
Life-time response degeneration model
Reference transfer model

Land satellite history data
Radiometric reference construction
Radiometric reference construction of multi-scale history data
Land sat. history data re-processing platform
Land sat. primitive climate dataset
Land sat. thematic product dataset

Ocean satellite history data
Radiometric calibration of weak signal
Microwave sensor data re-calibration
Ocean sat. history data re-processing platform
Ocean sat. primitive climate dataset
Ocean sat. thematic product dataset

Meteo. satellite history data
History data tracing & diagnosis
High accuracy positioning when lack of attitude info
Meteo. sat. history data re-calibrating
Meteo. sat. primitive climate dataset
Meteo. sat. thematic product dataset

Product quality evaluation & validation
Sharing & distribution of re-calibration dataset and thematic dataset
4. History data re-calibration for multiple series of Chinese remote sensing satellites

- History data tracing & diagnosis
- Optical radiometric reference & calibration model
- Microwave radiometric reference & calibration model

History data rapid re-processing platform

- High accuracy positioning when lack of attitude info
- Radiation info restoration when non-ideal calibration in life-time
- Meteo. sat. cross-generation radiometric reference transfer

- Re-located products (FY-1/3)
- Re-calibrated products (FY-1/2/3)
- Retrieval products (SST/LST/OLR/NDVI)

- High accuracy GCP database
- Multiple radiation reference sources
- Multiple product reference sources

Quality assessment

Normalized meteo. sat. primitive & thematic product dataset

Sharing platform for Chinese satellite climate datasets

Meteorological satellite
Ocean satellite
Land satellites
Research period & phased roadmap

- Research period: 10 year

**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

**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

**2016-2017**

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

**2021-2013**

**Phase 4:**
- Satellite-borne test
- Operational demonstration

**2024-2025**
- 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