Academy of Opto-Electronics,
Chinese Academy of Sciences

Recent Research progress of Cal&Val Comprehensive Site and payload performance Assessment

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IVOS-25

Infrared and Visible Optical Sensors Subgroup to WGCV, CEOS

March 19-21, 2013 at ESA ESRIN

Outlines

- Brief Introduction to AOE
- Overview of ETA
- Current work and achievements in quality assurance group
- Preparation work of WGCV-36

Brief Introduction to AOE

- Academy of Opto-Electronics (AOE), established in 2003, is a high-tech research institution of the Chinese Academy of Sciences (CAS), which is dedicated to coordinate CAS's institutes to work together and carry out some prospective or omitted research on the the development of space and opto-electronic science and technology.
- AOE, with its headquarter based in Beijing, involves 5 independent research institutes of CAS located in 4 other cities of China.

Changchun Institute of Optics, Fine Mechanics Physics

Academy of Opto-Electronics

Xi' an Institute of Optics & Precision Mechanics

Shanghai Institute of Technical Physics

Shanghai Institute of Optics & Fine Mechanics

Chengdu Institute of Optics & Electronics

Charg'e-1
CCD/Imaging spectrometer
/Laser altimeter

Brief Introduction to AOE

The research activities of AOE focus on optical engineering, aeronautical and aerospace engineering and the application technology.

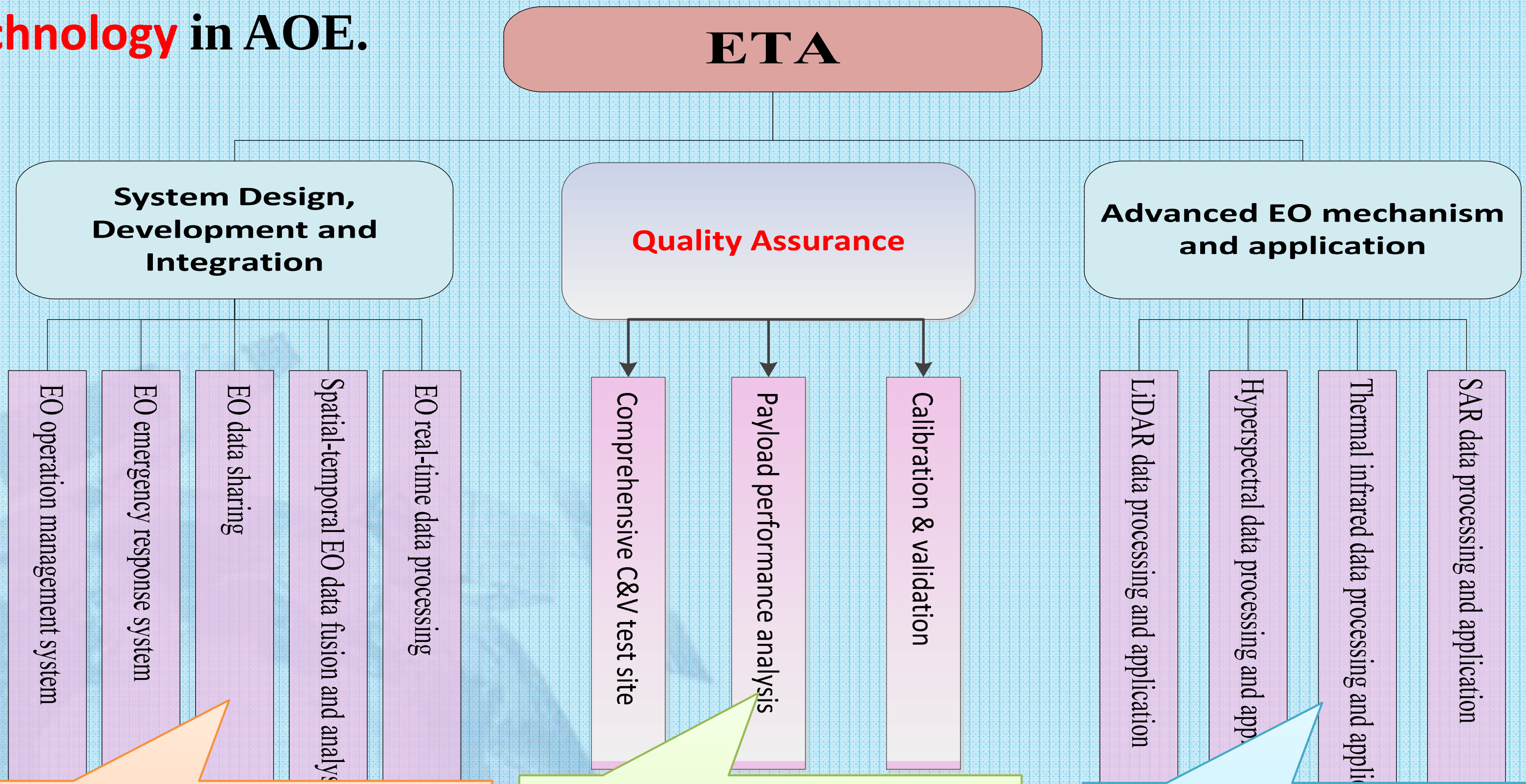
The application technology consists of opto-electric payload imaging mechanism and method, the opto-electric payload performance evaluation and data quality monitoring technology. ***The research activities in this field include prospective research and system solution design and implementation.***

The aeronautical and aerospace engineering consists of space systems engineering, satellite navigation and aerostat technology. ***The research activities in this field include the research of development strategy, the prospective research, the System solution design and implementation, key technology and system integration.***

The optoelectronic engineering consists of computational optical imaging technology, projection optical system technology and large complex laser technology. ***The research activities in this field include prospective research, system solution design and implementation, key technology and system integration.***

Overview of ETA

The Earth Observation Technology Application Department (ETA) was established in 2005, responsible for the research area of The application technology in AOE.



Engineering development of the data processing, operational management and emergency response system.

Calibration and validation test sites construction, the methodology research on Cal&Val and payload performance analysis.

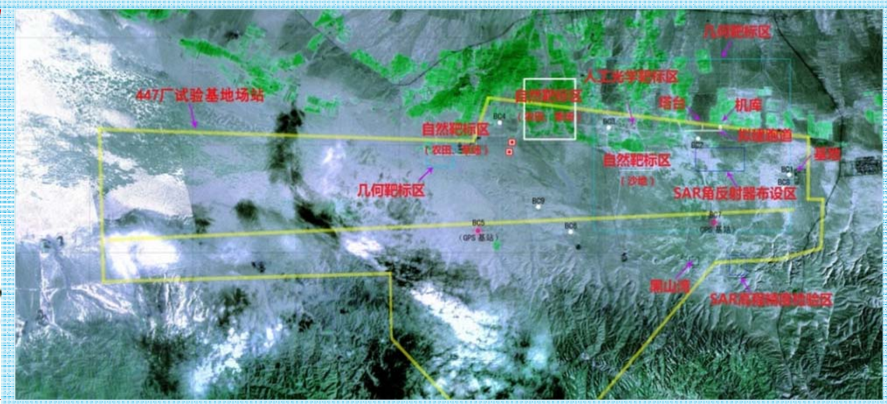
Mechanism and application research on quantitative remote sensing, including hyperspectral, thermal infrared, LiDAR and SAR.

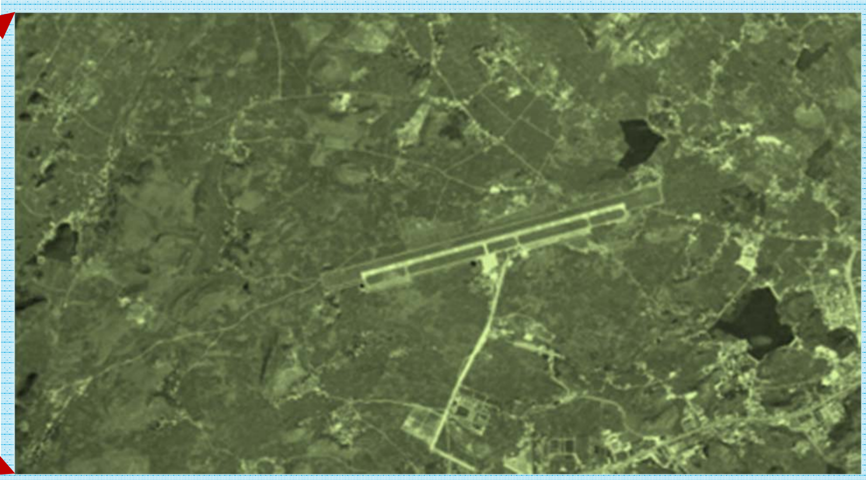
Current work and achievement in quality assurance group

- **Comprehensive Cal&Val test sites**

➢ Two comprehensive Cal&Val test sites were preliminarily established, which have different climate characteristics, various land cover types and topographic features.

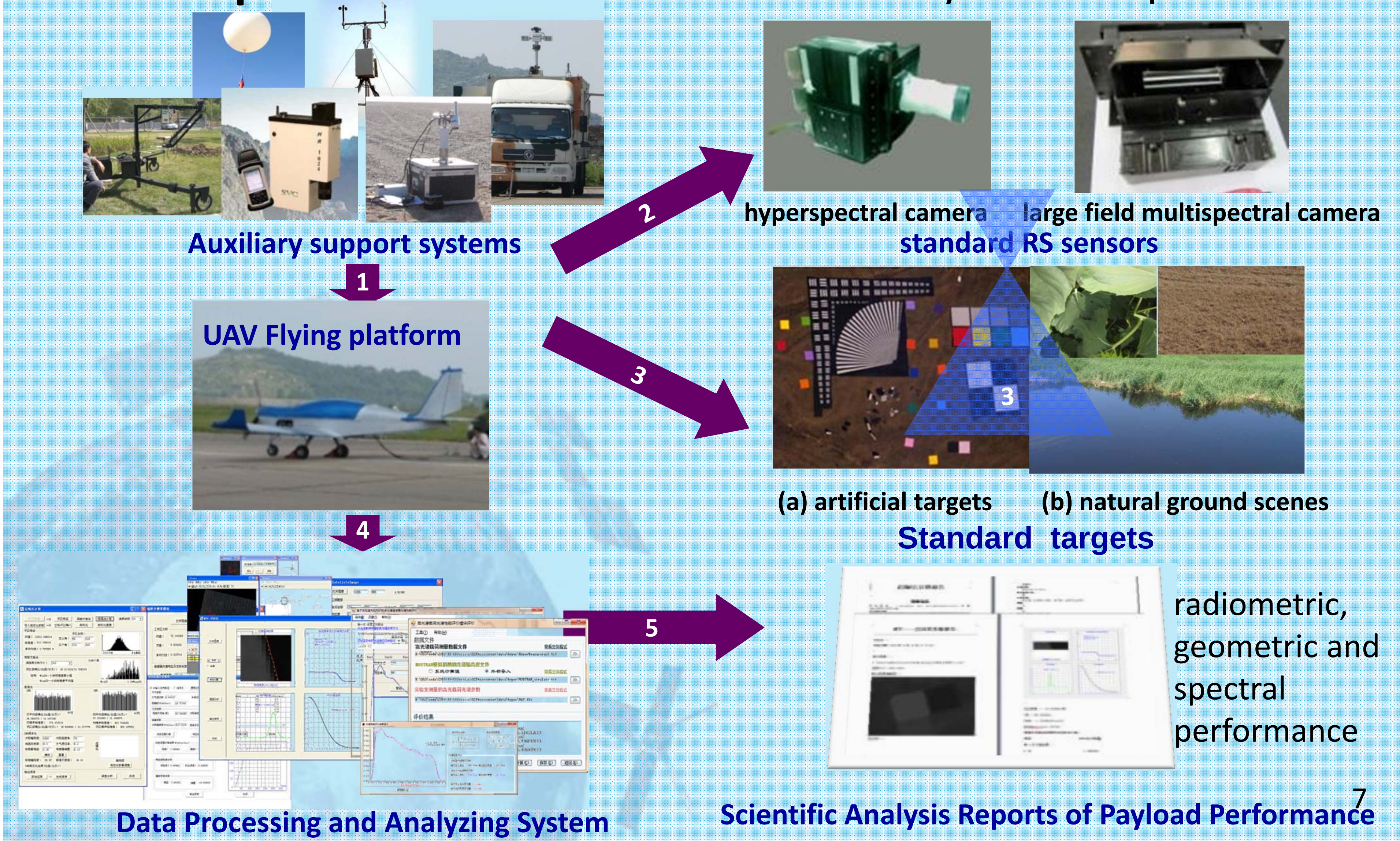
➢ Now they are being continuously established so as to support multi-grade validation of airborne and spaceborne sensors for stable and long-term operation





Current work and achievement in quality assurance group

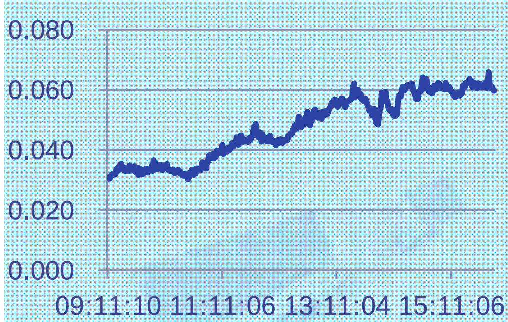
- **Comprehensive Cal&Val test sites -**System components



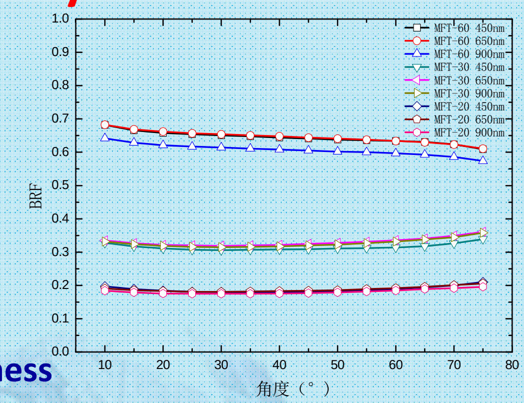
Current work and achievements in quality assurance group

- Atmospheric and field measurements

Spectral reflectance of targets were measured. The aerosol optical thickness data and meteorological profile *(including atmospheric temperature, atmospheric pressure, humidity, wind speed, wind direction, etc.)* above the test site were synchronously collected.

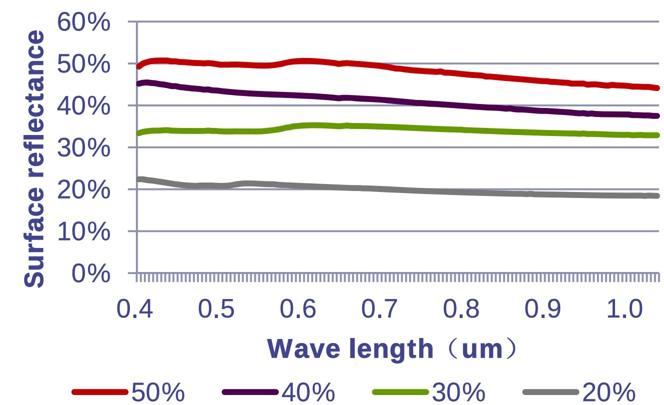


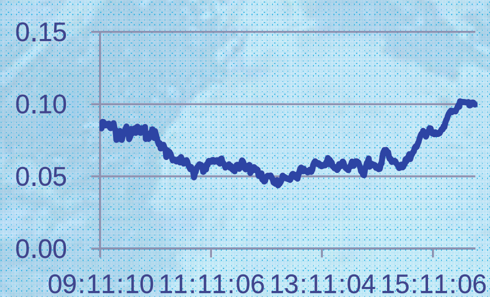
550nm aerosol optical thickness



BRF properties of targets

Spectral reflectance of gray-scale targets



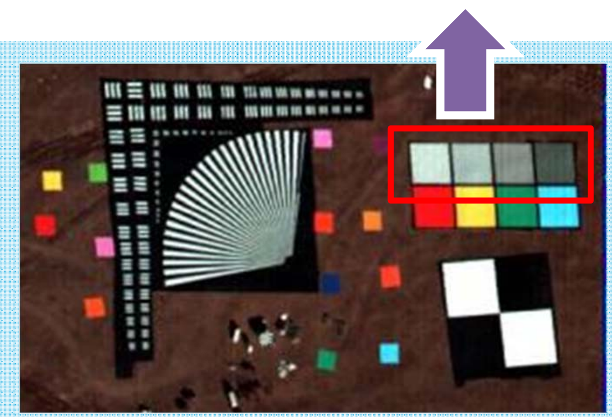


Moisture content

Radiosounding balloon

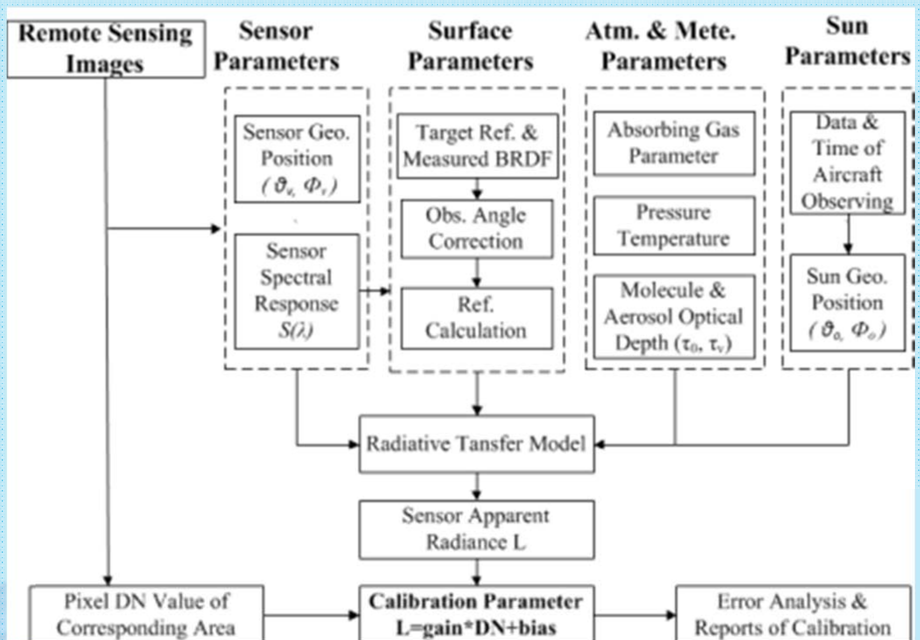
Automatic sun tracking photometer, CE318

Automatic weather station

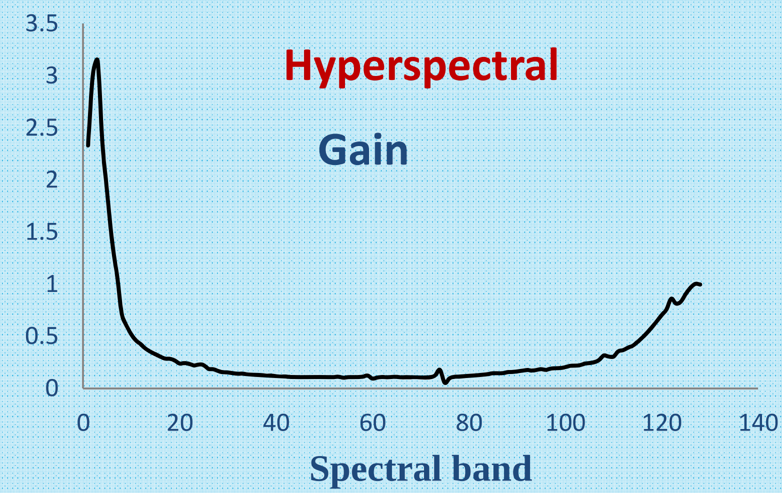


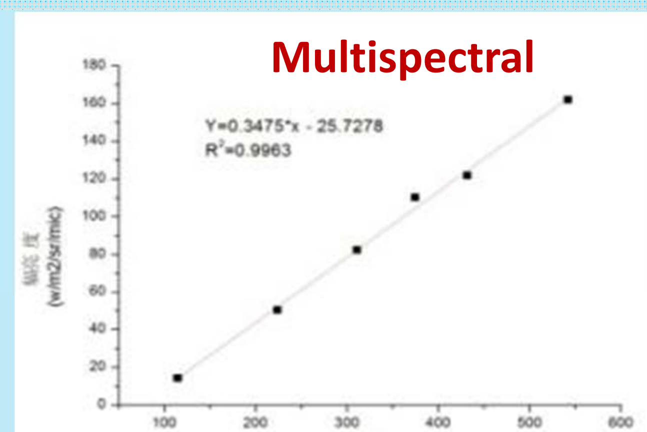
Inflight Calibration & Performance Assessment

Absolute radiometric calibration



Flow chart of optical sensor radiometric calibration



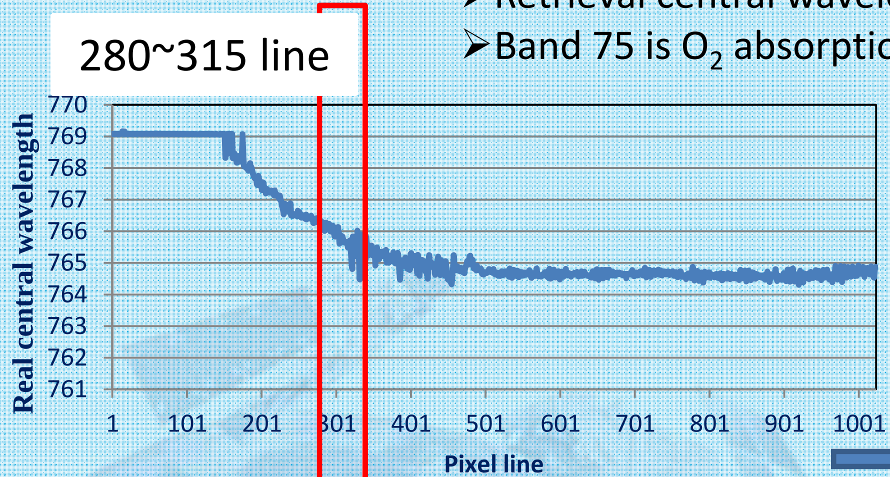


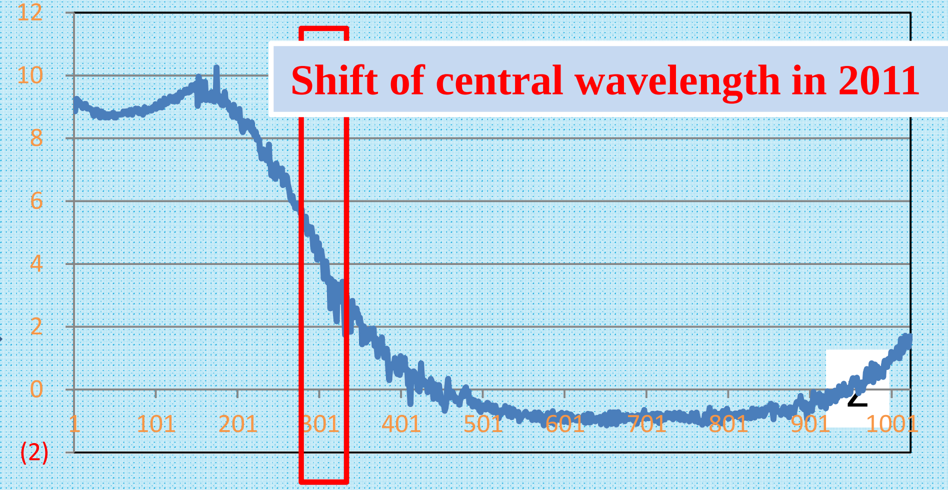
Radiometric calibration coefficients have very good linearity and the correlation coefficient reaches above 99%.

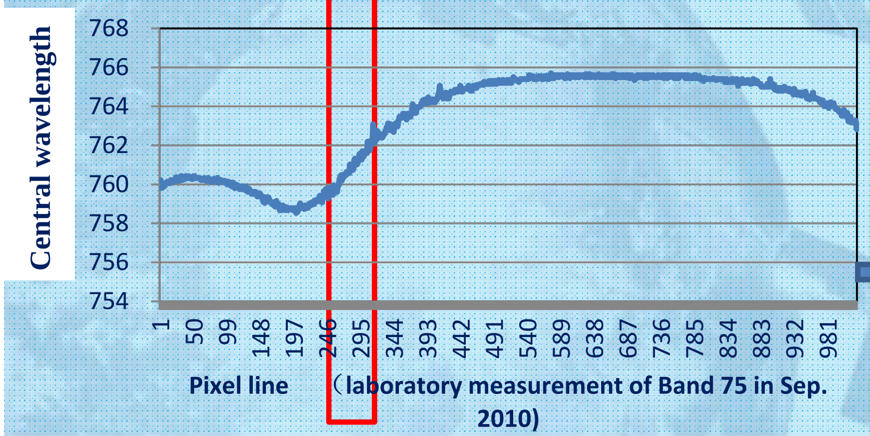
Current work and achievements in quality assurance group

– **Spectral calibration for hyperspectral sensor** with atmospheric absorption line

- Retrieval central wavelength based on flight data in 2011.
- Band 75 is O_2 absorption band.





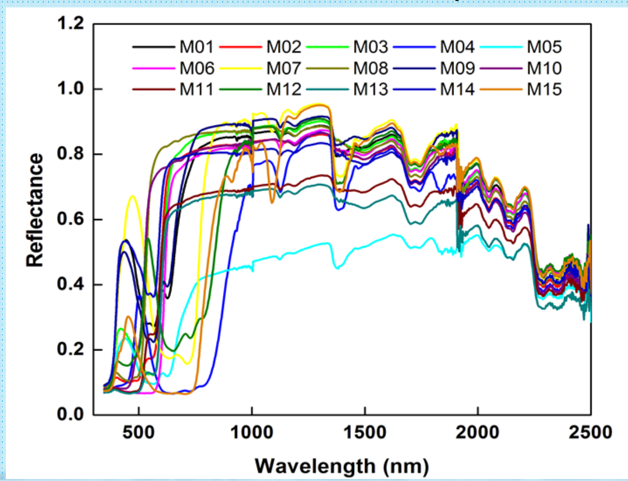


The shift of central wavelength is approximately 4~6nm compared to laboratory measurement.

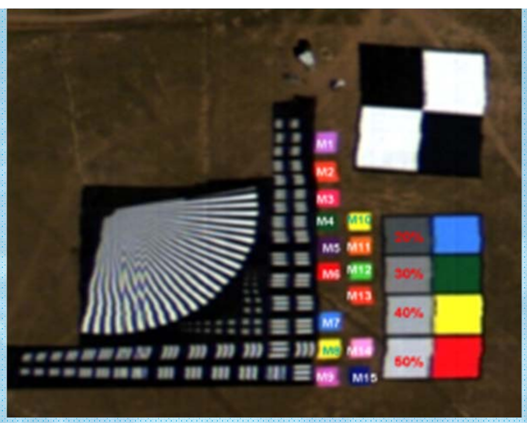
Current work and achievements in quality assurance group

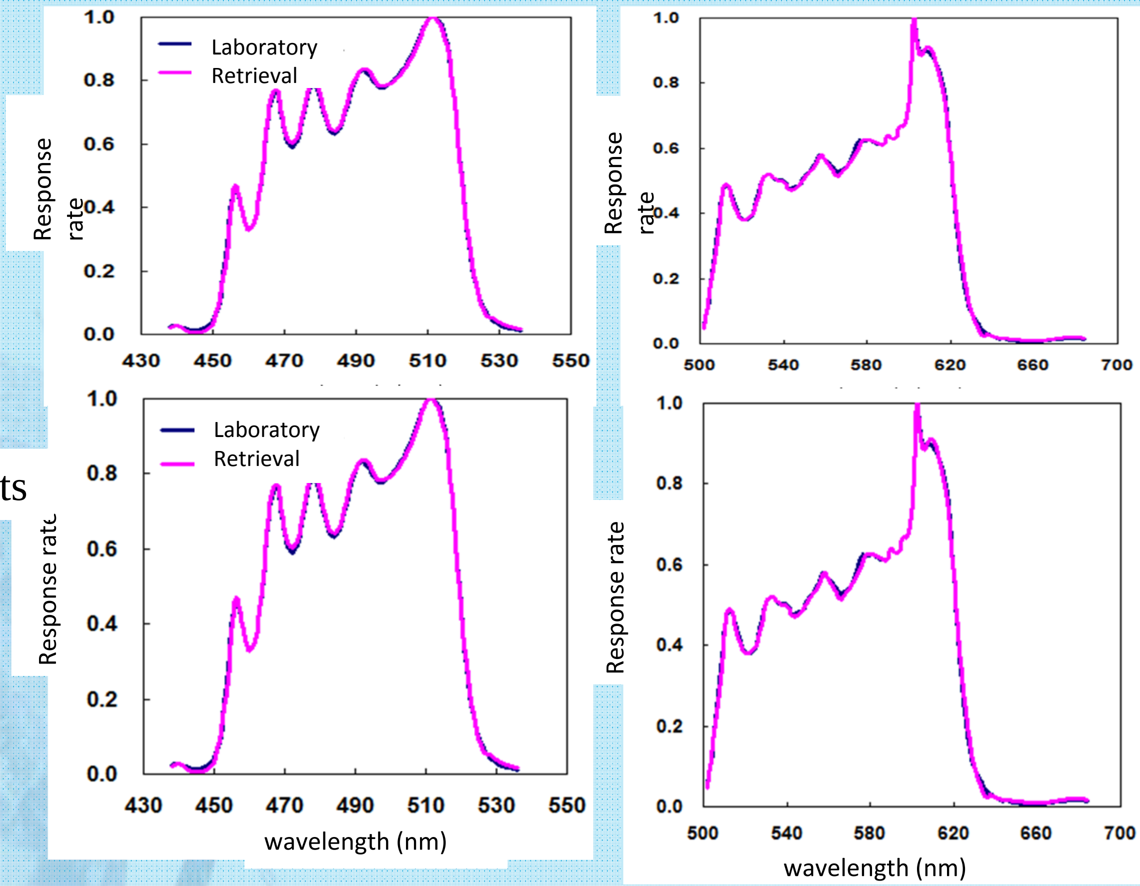
– Spectral calibration for multispectral sensor with colored targets

- Difficulty: Solving of spectral response function faces ill-condition matrix
- Solutions: The spectral reflectance of 15 multispectral targets were measured to add the number of equations; Piecewise fitting SRF according to laboratory measurements



Spectral reflectance of colored targets



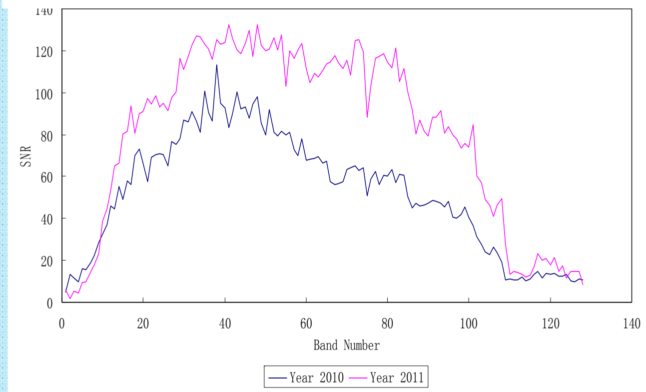


Current work and achievements in quality assurance group

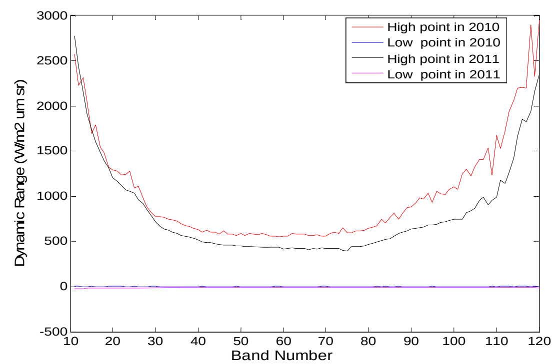
- Payload performance analysis

The payload performances were analyzed through several flight campaigns.

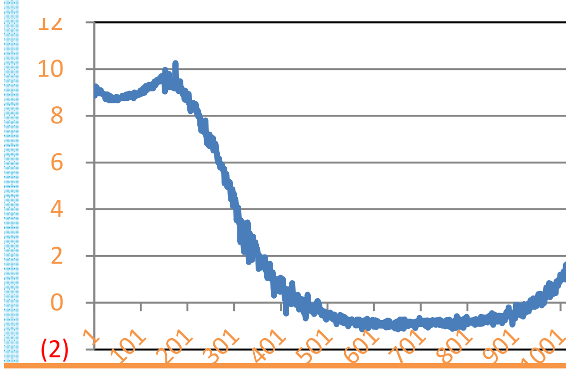
SNR Normalization of hyperspectral sensor in 2010/2011



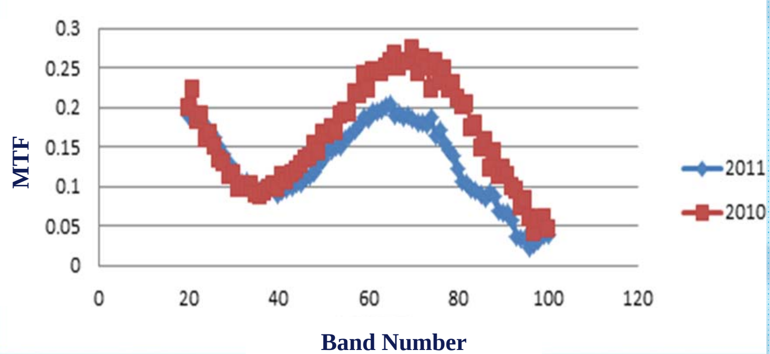
Dynamic range evaluation of hyperspectral sensor in 2010/2011

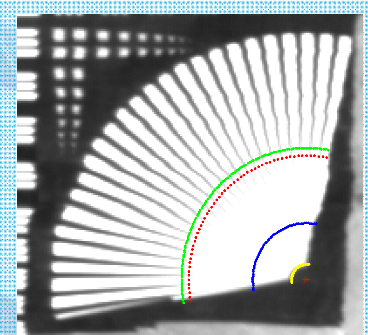


Shift of central wavelength of hyperspectral sensor in 2011



HSI MTF@Nyquist in 2010/2011





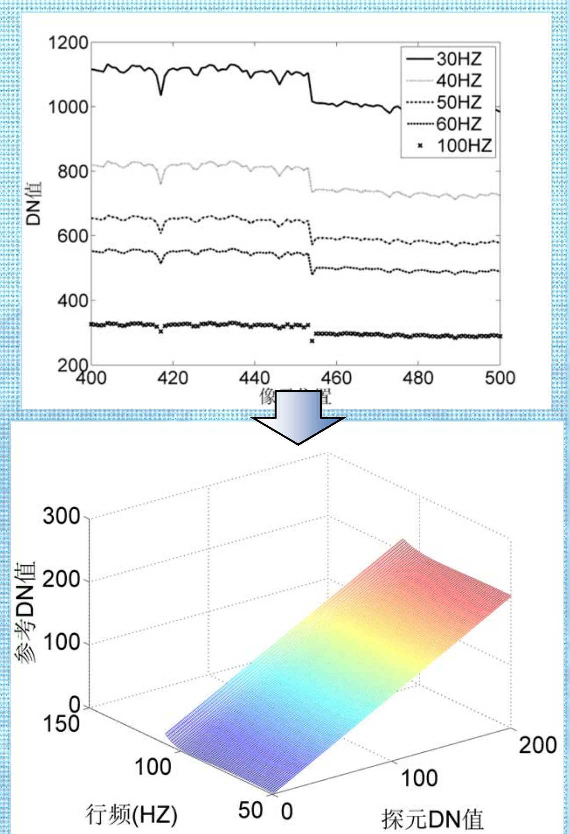
Panchromatic image in 2011

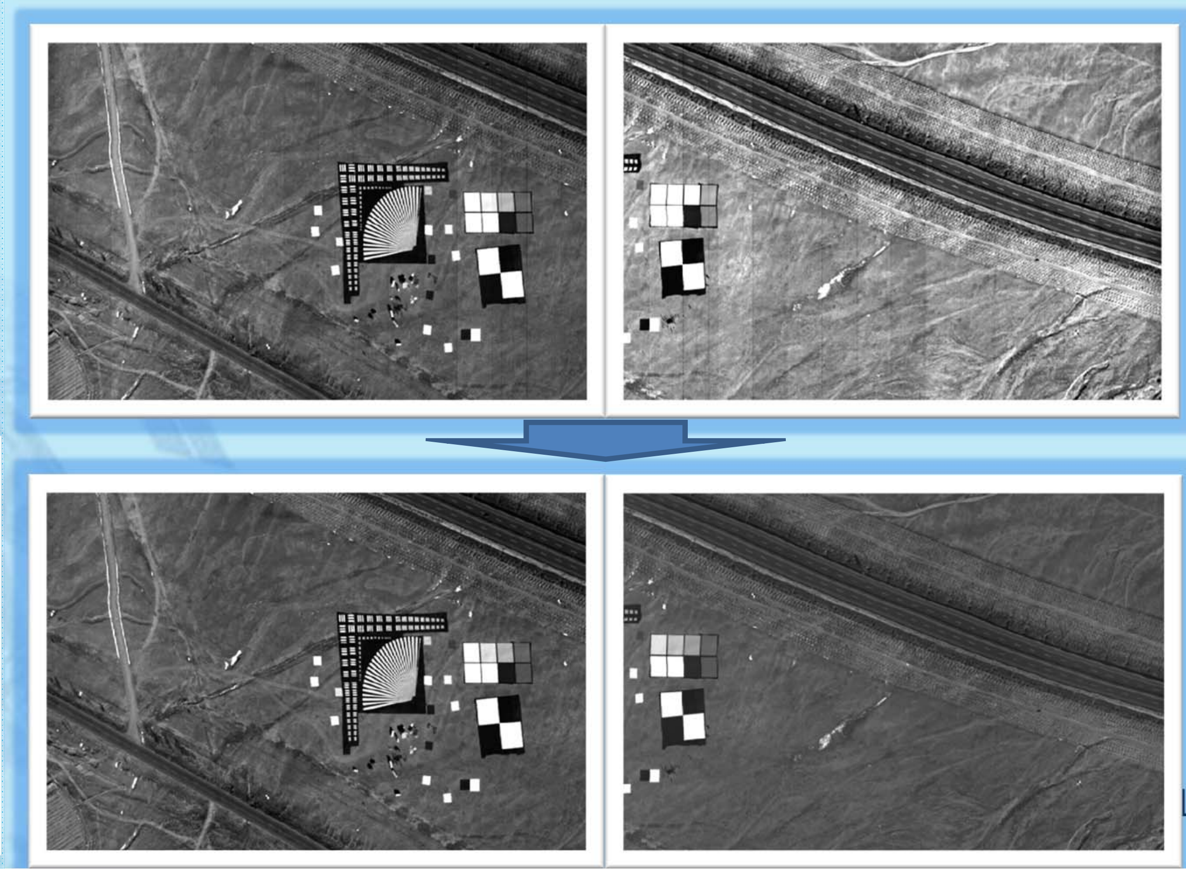
- Absolute radiometric calibration
- Signal to Noise Ratio, SNR
- Dynamic range
- Response linear degree
- Radiometric resolution, NEΔρ
- Ground resolution
- MTF
- Band registration precision
- central bandwidth; FWHM
- multispectral SRF
- Reflectance/LAI retrieval ……

Current work and achievements in quality assurance group

- Cal&Val method – relative radiometric calibration

Because of the variation in velocity height ratio, the images of hyperspectral imager between adjacent flight strips lack of comparability for different surfaces.
A 3-D relative radiometric calibration method based on line frequency difference is proposed to solve this problem.



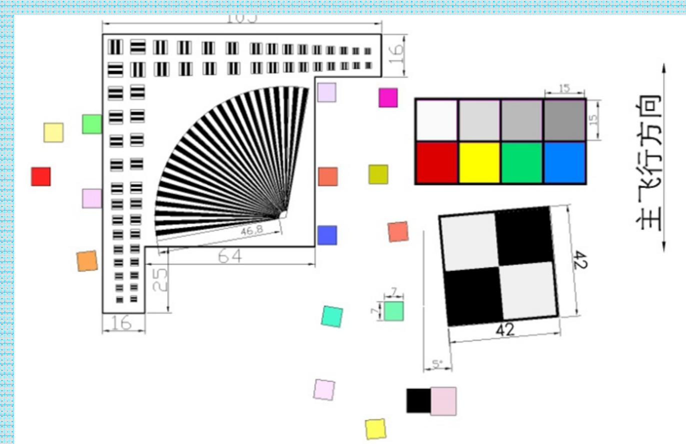


Current work and achievements in quality assurance group

- Cal&Val method– Color calibration for hyperspectral image
  - **Why color calibration?**
    - **True-color composition image from arbitrarily selected hyperspectral channels located in the red, green and blue range will cause significant difference with comparison to the human visual.**
    - **The degradation of the sensor performance will also have great impacts on the color composition.**
    - **It's attractive to robustly and efficiently obtain the true color image from hyperspectral data.**

- Spectral range: 400nm-1000nm
- Spectral resolution: 5nm

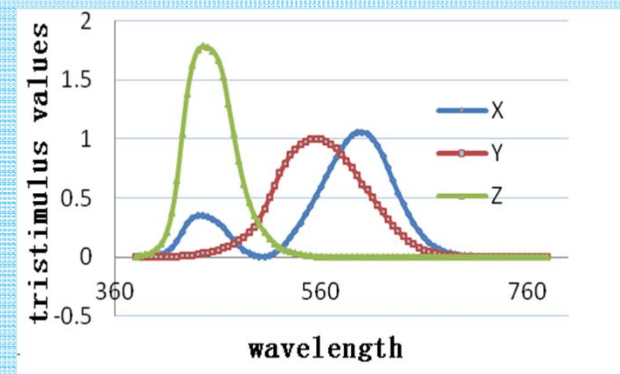
635 nm/545 nm/465nm



Current work and achievements in quality assurance group

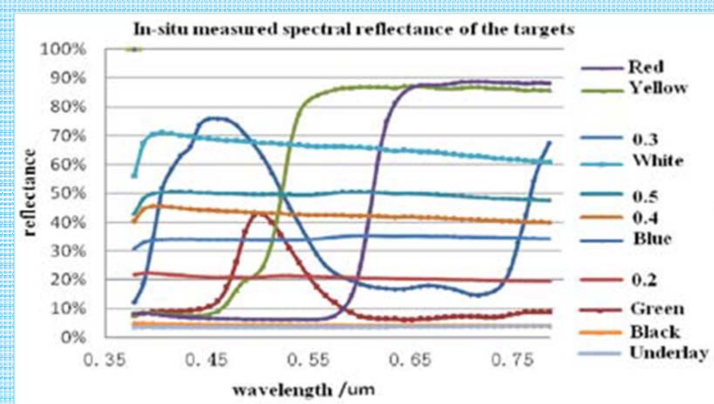
- Cal&Val – Color calibration for hyperspectral image

  - **True color image composition based on the spectral luminosity colorimetric theory**
    - ✓ The RGB values of the at-sensor true color image is calculated with the hyperspectral images in the CIE-XYZ space.



The standard color-space CIE-XYZ by CIE

  - **TOA theoretical color acquisition based on radiative transfer simulation from field measurement**
    - ✓ With the in-situ measurements of spectral reflectance, we can obtain the theoretical color according to the radiative transfer equation.



In-situ measured spectral reflectance of the targets

Current work and achievements in quality assurance group

- Cal&Val method– Color calibration for hyperspectral image
  - **Color calibration model establishment**

    A relationship between the theoretical colors and reconstructed colors is established and used to correct the image

Theoretical color

Reconstructed color with hyperspectral image

$$M_{RGB \to R'G'B'} = \begin{bmatrix} 2.5635 & -0.3903 & -0.2178 \\ -0.1077 & 3.7997 & 0.5655 \\ 0.0416 & 0.2628 & 12.4262 \end{bmatrix}$$

True–color correction coefficient matrix

The corrected true-colored image

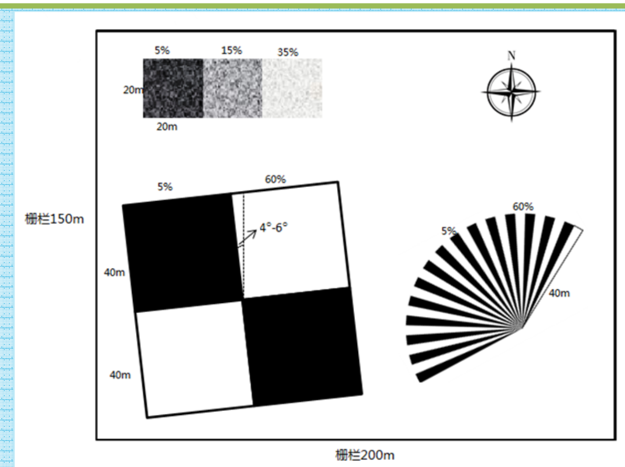
Composition Image before calibration

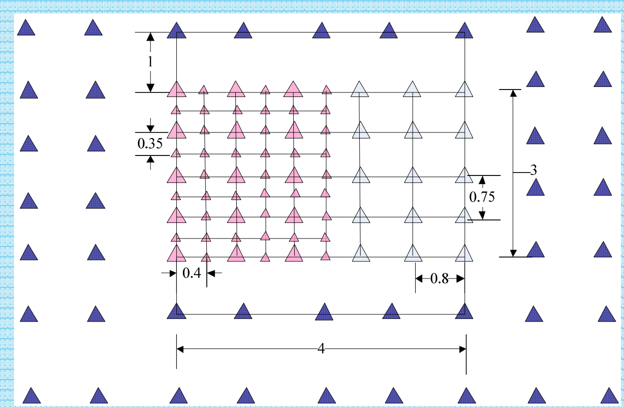
Current work and achievements in quality assurance group

- The extension of the Cal&Val test sites – permanent targets

> ➢ **In order to support in-flight/orbit calibration and long-term monitoring of payloads, we carried out wide investigations and now are establishing permanent targets for geometric and image quality test.**

Sjökulla (FGI, Finnish Geodetic Institute)



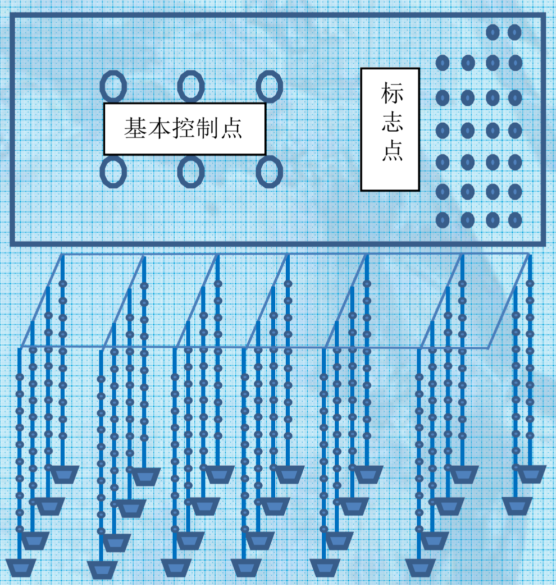


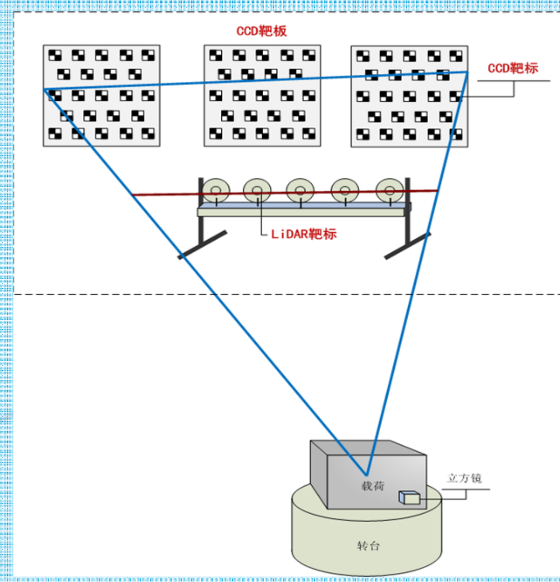
Current work and achievements in quality assurance group

- **The extension of the Cal&Val test sites** -Pre-flight calibration and performance

➢ **Considering the disassemble characteristic of airborne sensors, in-situ high-precision calibration and performance test system is being developed on the test site.**

Visible- SWIR： MTF、SNR、resolution、MRC、uniformity…
MIR-TIR： MDT、MRDT、MTF、NETD、SNR、uniformity…



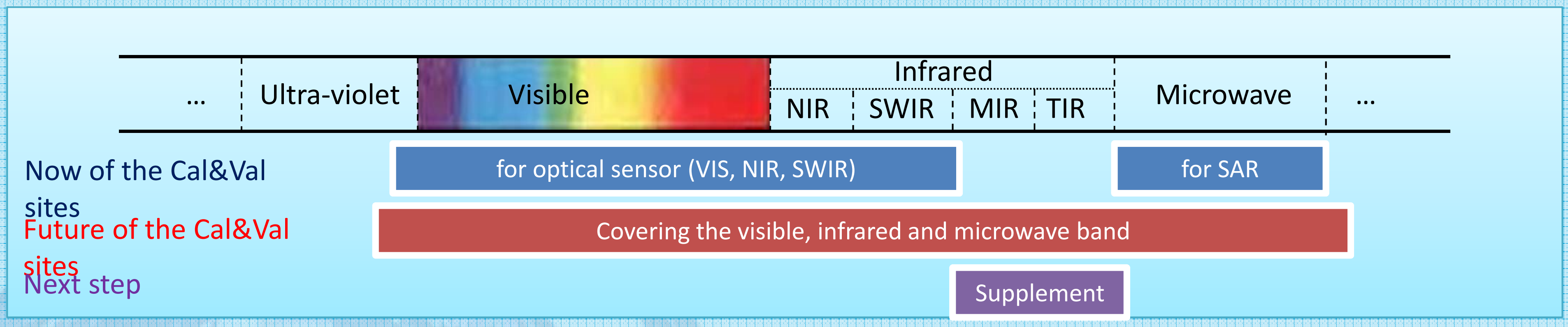


Preflight geometric calibration

Current work and achievements in quality assurance group

- **The extension of the Cal&Val test sites-** **Spectrum extension to MIR and TIR**

> ➢ **Till now, the Cal&Val test sites can meet the requirements in radiometric, geometric and spectral Cal&Val of VIS, NIR, SWIR sensors**
>
> ➢ **The Cal&Val for MIR and TIR payload will be addressed next step.**



The Cal&Val for MIR and TIR calls for a simultaneous measurement of surface temperature distribution, emissivity spectrum of surface materials, atmospheric temperature and moisture profiles.

Current work and achievements in quality assurance group

- **The extension of the Cal&Val test sites-** Spectrum extension to MIR and TIR

Standard spectrometer imager

It can be used in the field to simultaneously capture the **temperature variations** and **emissivity and reflectivity spectrum** for a large area rapidly.

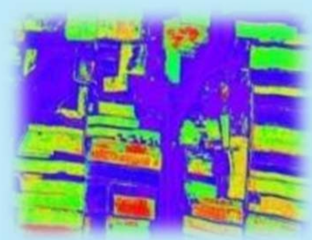
Standard spectrometer imager：
Covering VIS, NIR, SWIR and TIR (to 12.5 μm) ;
Spectral resolution: 1nm, 5nm, 30nm;
Radiometric accuracy: 2%, 2%, 0.3K;
GSD: 0.002m, 0.002m, 0.05m @1m.

Standard airborne spectrometer

To assure the accuracy in the multi-level validation.

Standard airborne spectrometer：
Covering VIS, NIR, SWIR and TIR (to 12.5 μm) ;
Spectral resolution: 5nm，10nm，60nm;
Radiometric accuracy: 3%, 3%, 0.5K;
The FOV is larger than 60 ° ;
GSD: 0.5m, 0.5m, 0.5m @~1km.




Anticipated traceable absolute radiometric calibration accuracy：
5.0%(0.4-2.5μm); 1.0K(@300K)(8-12.5μm)

Current work and achievements in quality assurance group

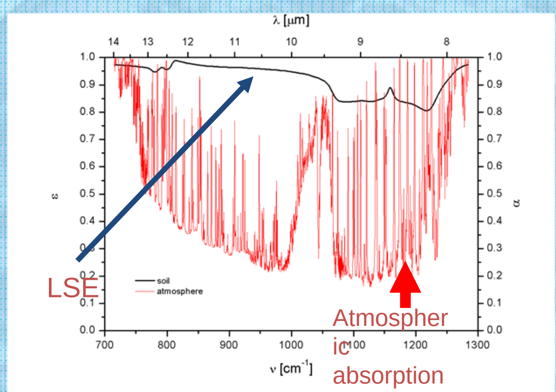
- **Hyperspectral thermal infrared data processing and retrieval**

Thermal infrared remotely sensed radiance, which is a measurement of emitted signals from both the surface and atmosphere, consists synthetic effects of land surface temperature, emissivity, atmospheric profiles of temperature and water vapor, and other gas contents.
A key issue in the retrieval is the ILL-POSED problem (unknowns > equations).

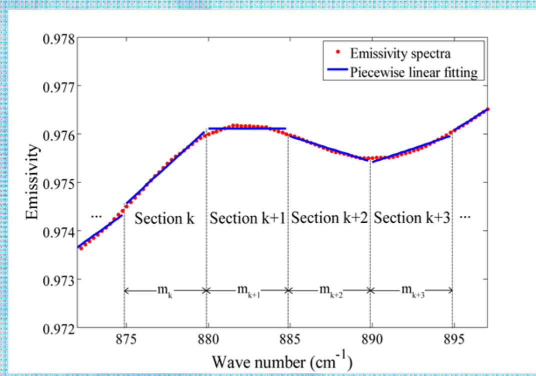
Radiative transfer equation $$L_{ag}(\lambda) = \varepsilon(\lambda)B(\lambda,T) + (1-\varepsilon(\lambda))R_{at\downarrow}(\lambda)$$

Unknowns > Equations， an ill-posed problem

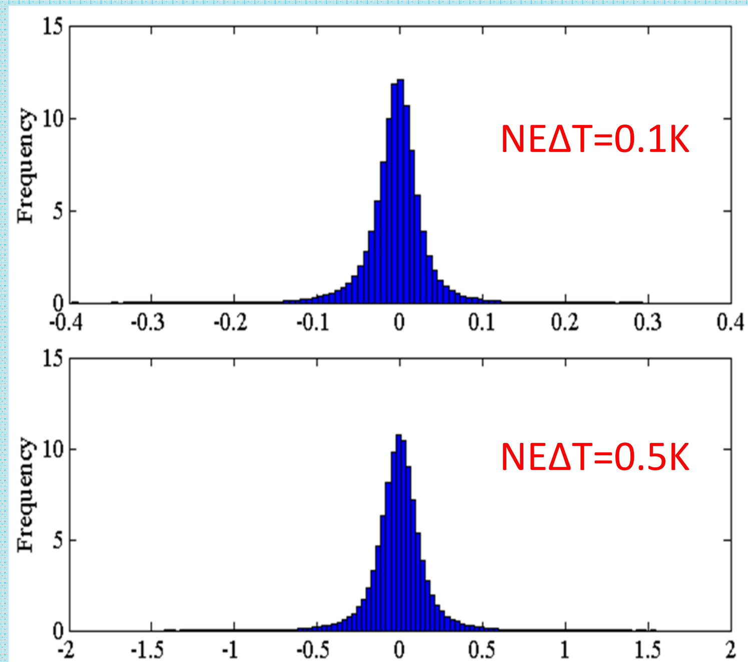
New method development
Because the surface emissivity spectrum is generally smooth enough, it can be represented as a piecewise linear function. The number of unknowns will be efficiently decreased.



surface emissivity is smooth



piecewise linear function can capture the feature of LSE



Current work and achievements in quality assurance group

- **Hyperspectral thermal infrared data processing and retrieval**

The performances of TES methods for hyperspectral TIR data are also influenced by the radiometric, spectral and other properties of the hyperspectral sensors. The influence is necessary to be analyzed!

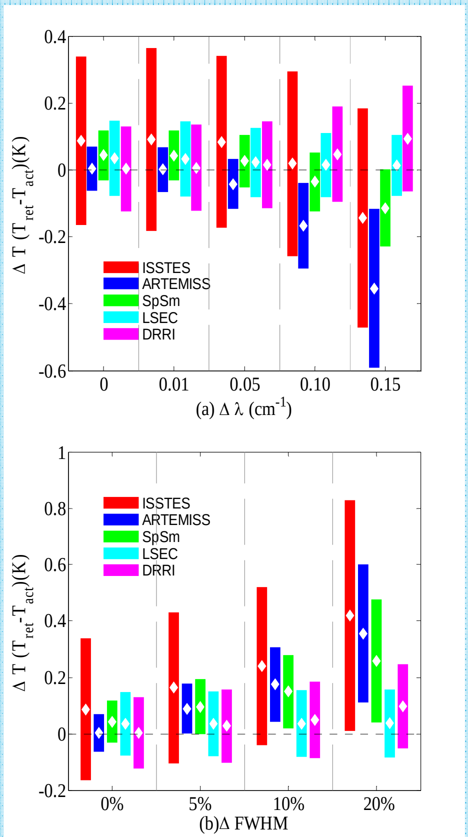
Five published TES method:

- Iterative spectrally smooth temperature-emissivity separation method (ISSTES) (Borel, 1997)
- Automatic retrieval of temperature and emissivity using spectral smoothness method (ARTEMISS) (Borel, 2008)
- Spectral smoothness method (SpSm) (Kanani et. al, 2007)
- Downwelling radiance residual index method (DRRI) (Wang et. al, 2008)
- linear spectral emissivity constraint method (LSEC) (Wang et. al, 2011)

Test data: Simulated hyperspectral TIR data

Test aim: Influence of spectral shifting or FWHM broadening on the TES accuracy.

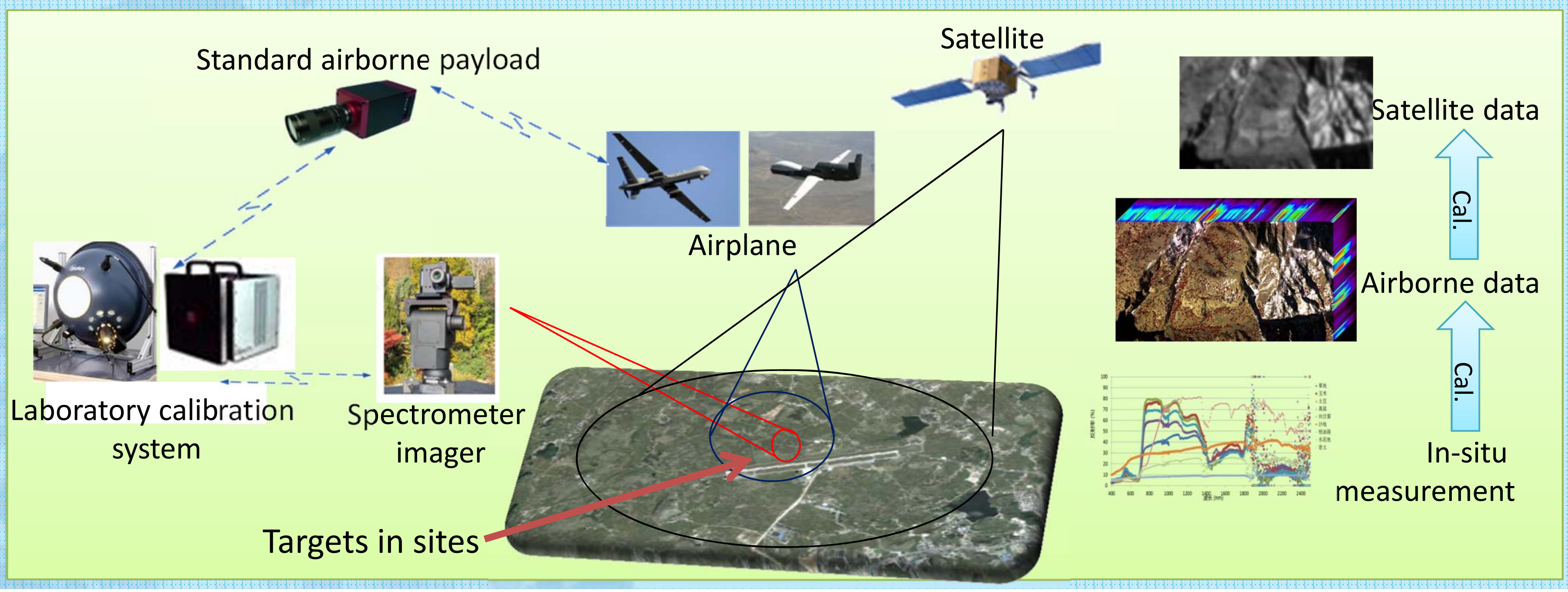
- All methods are affected by spectral shifting and FWHM broadening but in different magnitude.
- LSEC (wang et. al, 2011) was the most insensitive method to the spectral shifting and FWHM broadening of the sensor. So, it may be the best choice among the published method. **But, much more analysis are needed!**



The cyan bar is for LSEC

Prospect

- **The extension of the Cal&Val test site**
  - New equipment developing and distribution
  - A complete target system for performance assessment
  - Supporting the calibration and validation for VIS, NIR, SWIR, TIR and LiDAR payloads
- **Technology and method research**
  - Test site basis data collection and database construction
  - A multi-level and multi-scale calibration and validation system building
  - Accurate vicarious calibration methods research



WGCV-36

The 36th CEOS Working Group on Calibration and Validation Plenary (WGCV-36)

Hosted by the Academy of Opto-Electronics (AOE) and, the Shanghai Engineering Centre for Microsatellites (SECM), Chinese Academy of Sciences (CAS)

Shanghai, China, May 13-17, 2013

中国科学院光电研究院
ACADEMY OF OPTO-ELECTRONICS,CHINESE ACADEMY OF SCIENCES

microsat

- There is 34 registrations to date (not including AOE, SECM, etc.)
- Conference and hotel Location:

The Okura Garden Hotel Shanghai
Address: 58 Maoming Road (S.), Shanghai, China
www.gardenhotelshanghai.com

WGCV-36

- If you require transportation from the airport or train station to the hotel when you arrive in Shanghai, please send your travel information by e-mail to the WGCV Secretariat (Eric.Arsenault@asc-csa.gc.ca) by April 30th or sooner if possible.
- We will arrange for someone to greet you at the arrival gate with a sign indicating “WGCV”. We will also be providing transportation from the hotel to the airport or train station for your departure from Shanghai. Please also make sure to tell us if you travelling with family or other individuals to make sure that we have enough room to accommodate everyone in the vehicle.
- Preliminary plan of social events in the evening
  - ✓ banquet by AOE, SECM
  - ✓ Shanghai acrobatics
  - ✓ boat tour

Thank you!