

## Development of a Comprehensive Site for Remote Sensing Payload Performance and Data Quality Testing

### Basis and Prospects

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# Outline



**1 General View of the Comprehensive C&V Site**

**2 Inflight Calibration & Performance Assessment**

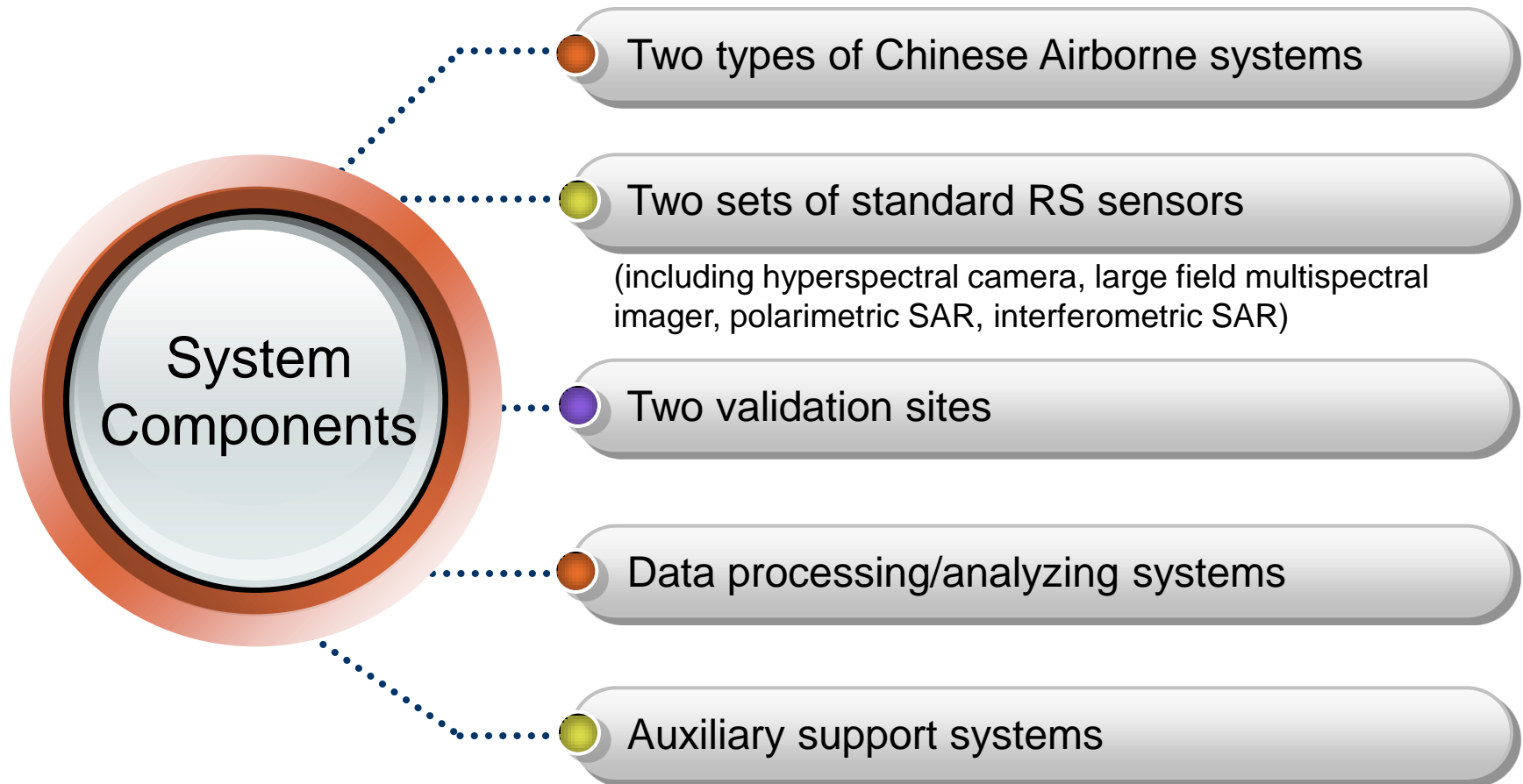
**3 Future Activities and Plans on Test Site Construction**



# 1. General View of the Comprehensive C&V Site



- System components



# 1. General View of the Comprehensive C&V Site

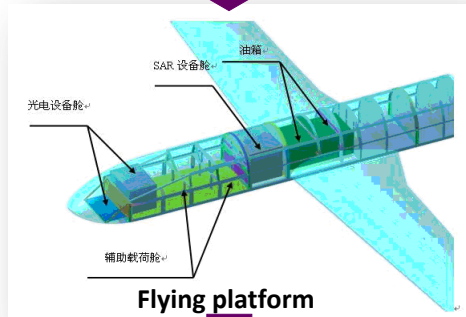


- System components



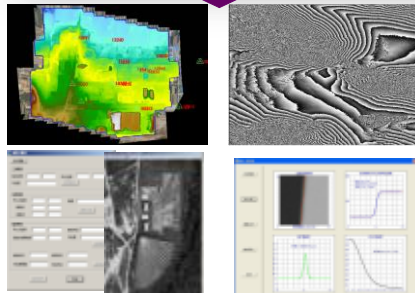
Campaign Planning and Management

1

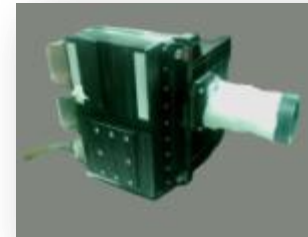
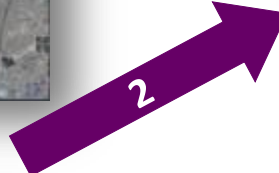


Flying platform

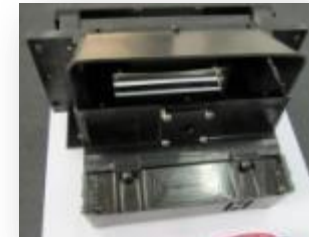
4



Data Processing and Analyzing System



hyperspectral camera

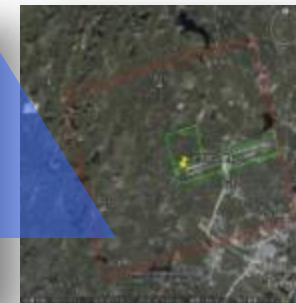


large field multispectral camera

High Accuracy Standard Sensors

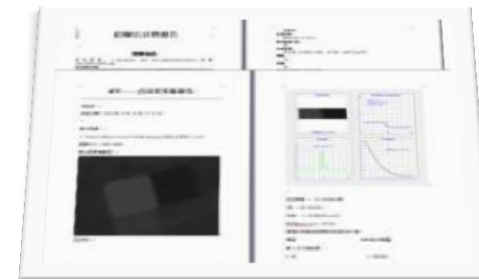


(a) North China site



(b) South China site

Validation Test Sites



Scientific Analysis Reports of Payload Performance

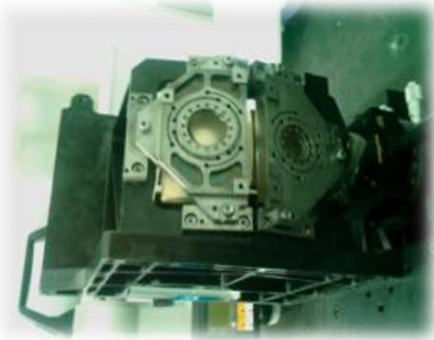
# 1. General View of the Comprehensive C&V Site



## • Standard optical sensors - developed by CAS

### ❑ Offner convex grating hyperspectral camera

- Spectral range: 400nm-1000nm
- Spectral resolution: 5nm
- IFOV: 0.2 mrad
- Band number: 128
- FOV: 11.5°
- Swath width: 1.6km@ Flight height 8km
- GSD: 1.6m @Flight height 8km



hyperspectral camera



Large field multispectral imager

### – Large field multispectral camera

#### – multispectral detector

- Spectral bands : Blue (420 ~ 520nm)  
Green (520 ~ 600nm)  
Red (630 ~ 690nm)  
NIR (760 ~ 900nm)
- Pixel Size: 13 $\mu$ m $\times$ 13 $\mu$ m
- GSD: 1.6m @8km Flight height
- Samples per scan line: 6000/line

#### – Panchromatic detector

- Pixel Size: 6.5 $\mu$ m $\times$ 6.5 $\mu$ m
- GSD: 0.8m @8km Flight height
- Samples per scan line: 12000/line



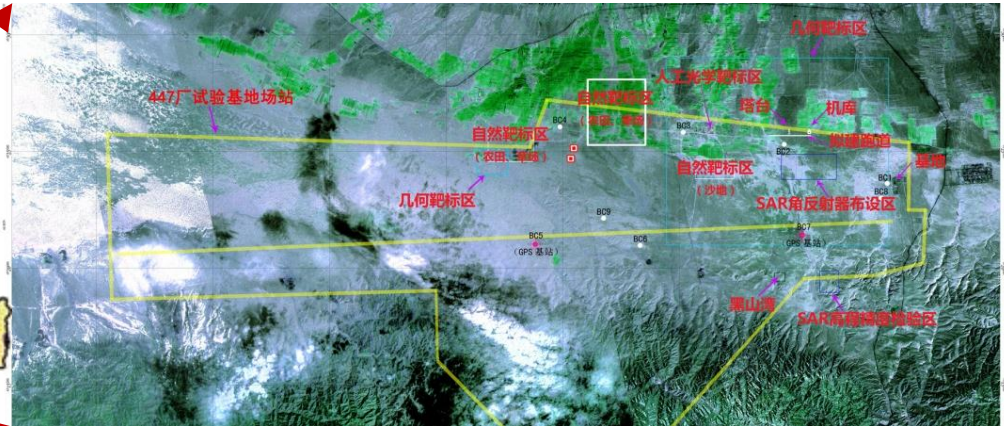


# 1. General View of the Comprehensive C&V Site



- Two validation sites

North China site



# 1. General View of the Comprehensive C&V Site



- **Validation site** - Standard artificial target for optical payload



**Knife-edge target**



**Fan-shaped target**



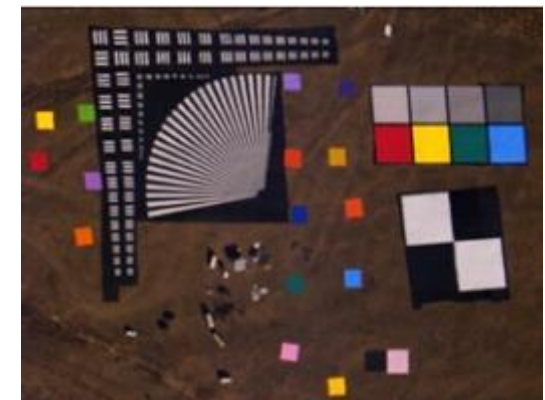
**Three-bar target**



**Gray-scale target**



**Colored target**



**Layout of targets**



# 1. General View of the Comprehensive C&V Site



## • Validation site - Natural ground targets

- The object types included: *maize, rice, potato, sunflower, soil, et al.*



(a) Rice



(b) Maize

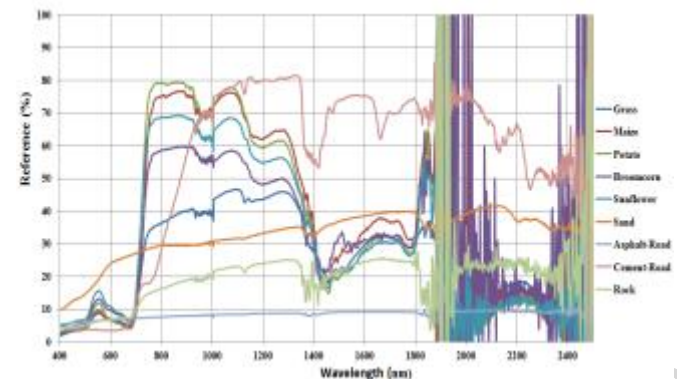


(c) Potato



(d) Sunflower

- The land surface parameters, such as reflectance, LAI, fPAR et al., were measured by instruments before and after flight day.



Spectral curves of different objects



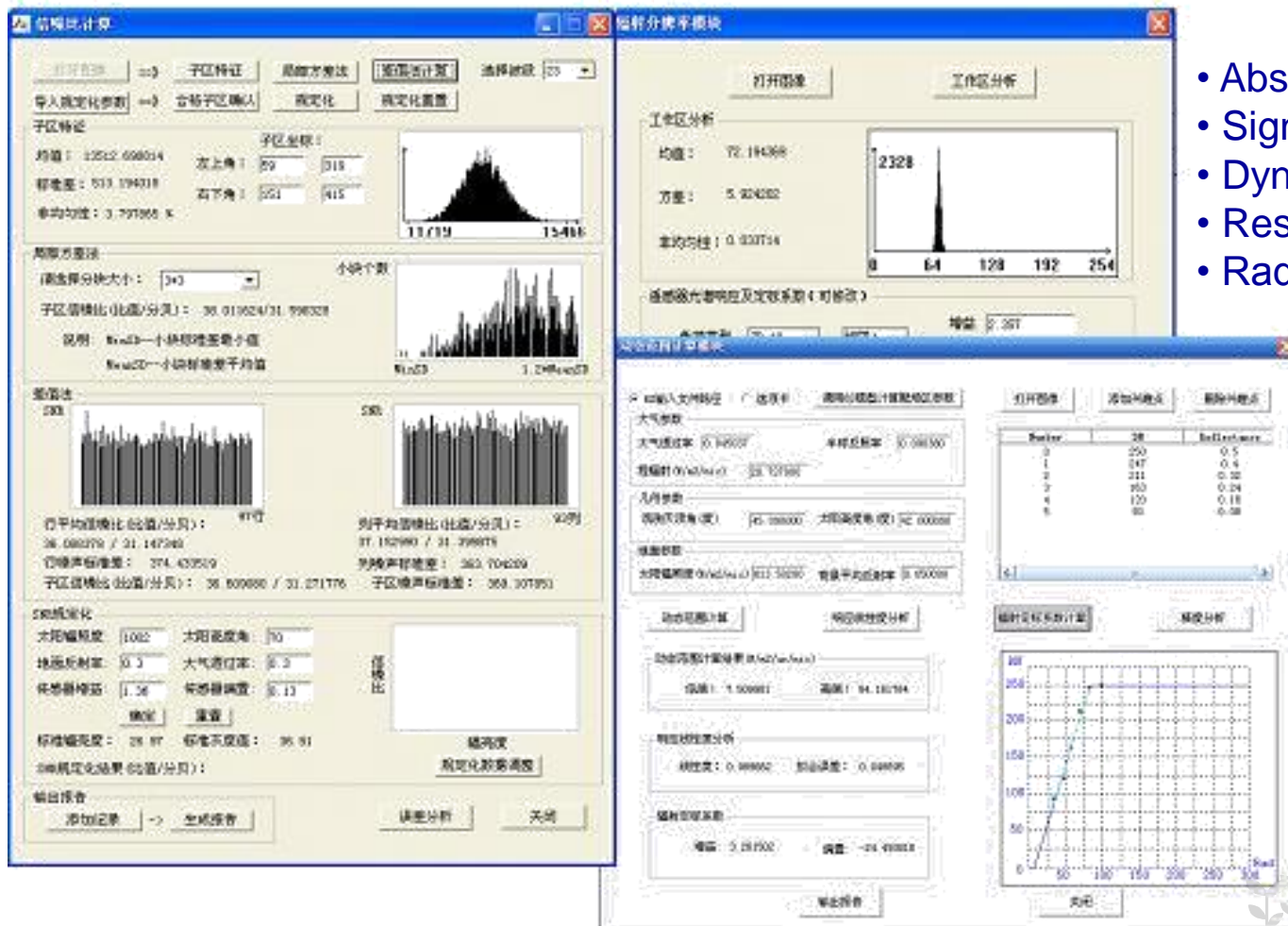
# 1. General View of the Comprehensive C&V Site



## • Data processing/analyzing system

### Radiometric Performance Assessment

- Absolute radiometric calibration
- Signal to Noise Ratio, SNR
- Dynamic range
- Response linear degree
- Radiometric resolution,  $NE\Delta\rho$



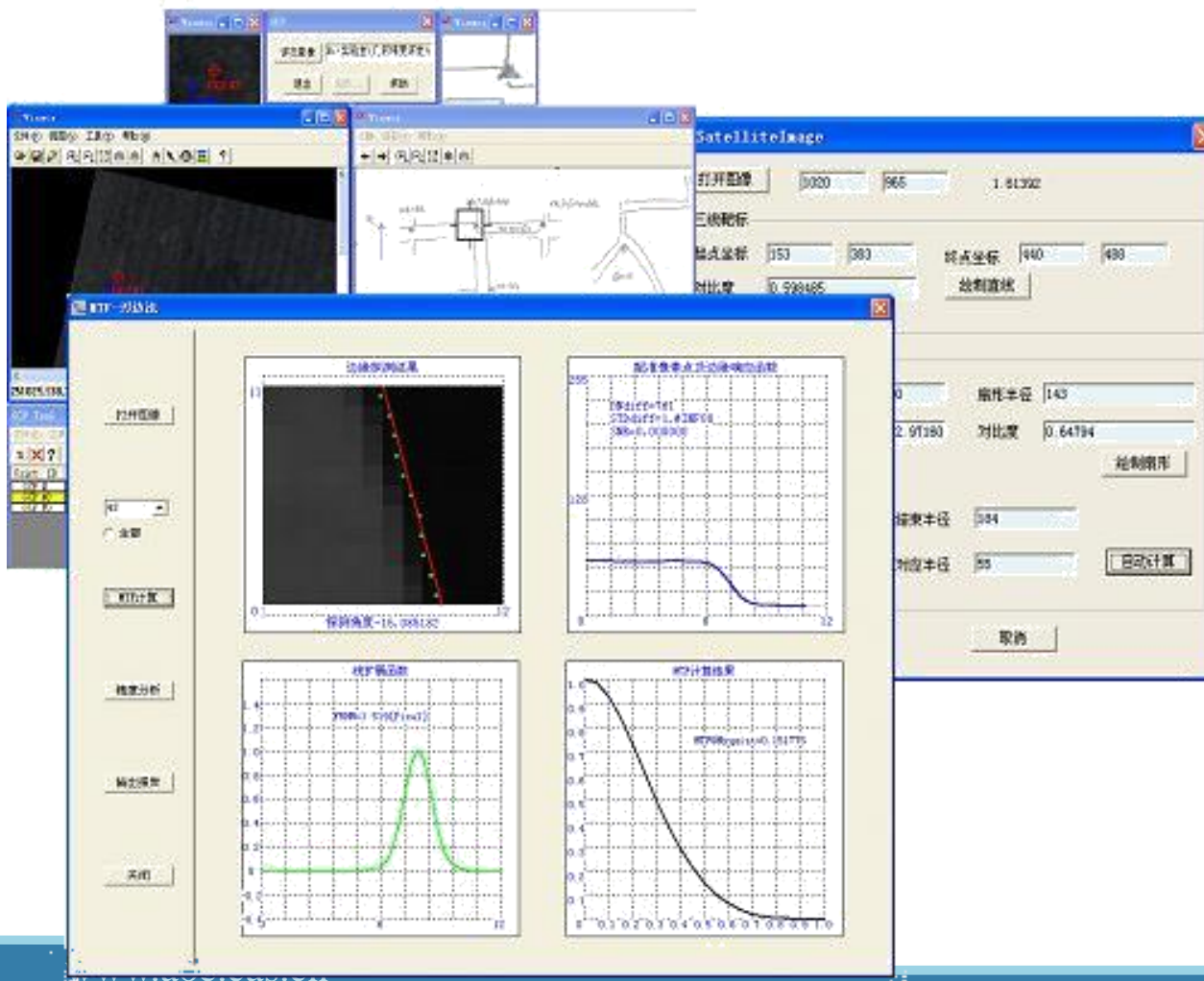
# 1. General View of the Comprehensive C&V Site



## • Data processing/analyzing system

### Geometric Performance Assessment

- Ground resolution
- MTF
- Band registration precision



# 1. General View of the Comprehensive C&V Site



## • Data processing/analyzing system

### Spectral Performance Assessment



- Hyperspectral camera: central bandwidth; FWHM
- Multispectral camera: spectral response function





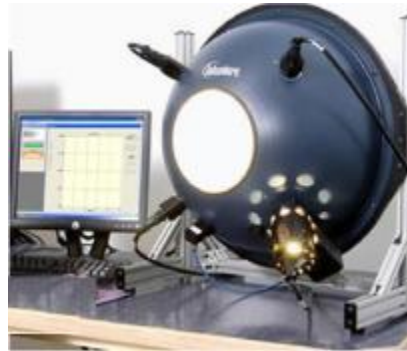
# 1. General View of the Comprehensive C&V Site



- Auxiliary support systems-** Ground-based standard test equipments



An omni-directional and multi-angle automatic observing systems



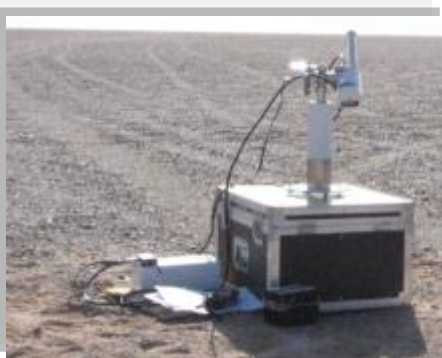
USS-200C Integrating sphere system



Leica TCR1202 Total Station



Three-dimensional turntable (Zolix PSAG 15 + RAK 3500)



Automatic sun tracking photometer, CE318



SVC Spectroradiometer



LAI-2000 Plant Canopy Analyzer



Radiosounding balloon



Dynamet Weather Station



# 1. General View of the Comprehensive C&V Site



- Auxiliary support systems- Flying guarantee



Tower



Command vehicle



Maintenance equipment



Aircraft Hangar



## 2. Inflight Calibration & Performance Assessment



- **2.1 Flight campaigns**

- **Nov 2010 Campaign**

- Airborne optical sensors in North China test site*

- **Jul 2011 Campaign**

- Airborne optical and SAR sensors in South China test site*

- **Sep 2011 Campaign**

- Airborne optical and SAR sensors in North China test site*



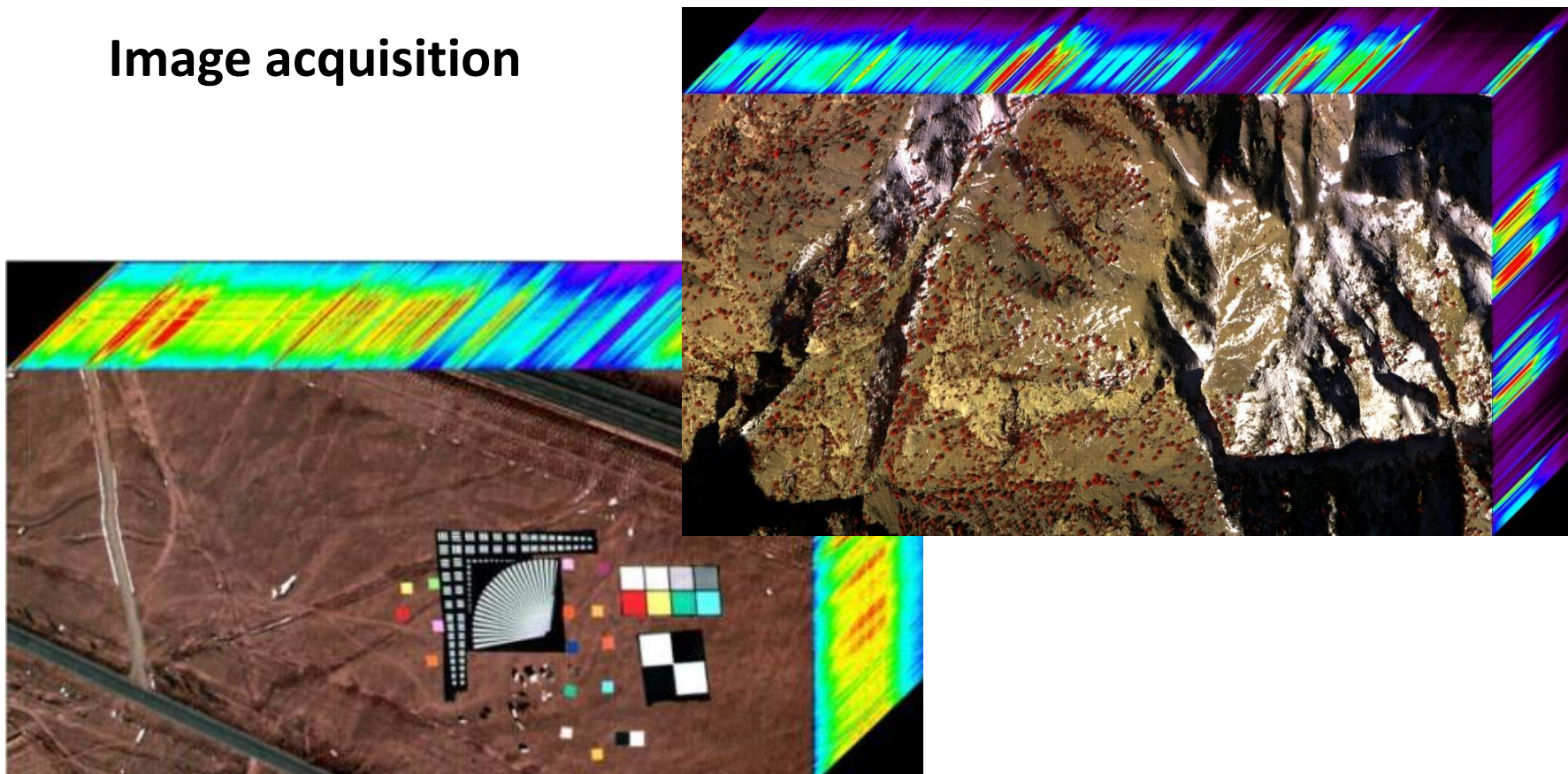


## 2. Inflight Calibration & Performance Assessment



- 2.1 Flight campaigns

### Image acquisition



### 3D Cube of Hyperspectral Image



## 2. Inflight Calibration & Performance Assessment



- 2.1 Flight campaigns



Panchromatic Image from North China validation Site

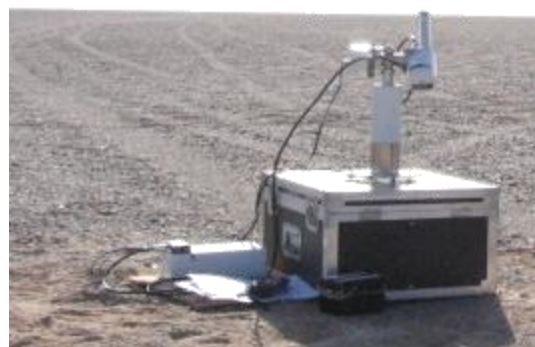


## 2. Inflight Calibration & Performance Assessment

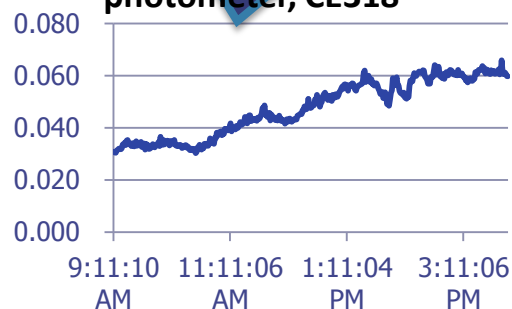


### • 2.2 Atmospheric and field measurements

- 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.



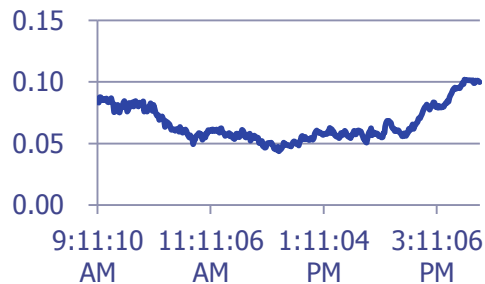
Automatic sun tracking  
photometer, CE318



550nm aerosol optical thickness

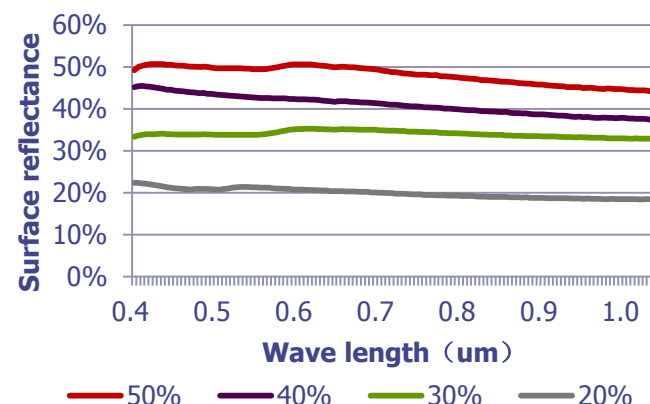


Radiosounding  
balloon Automatic  
weather station



Moisture content

Target reflectance by filed measurement



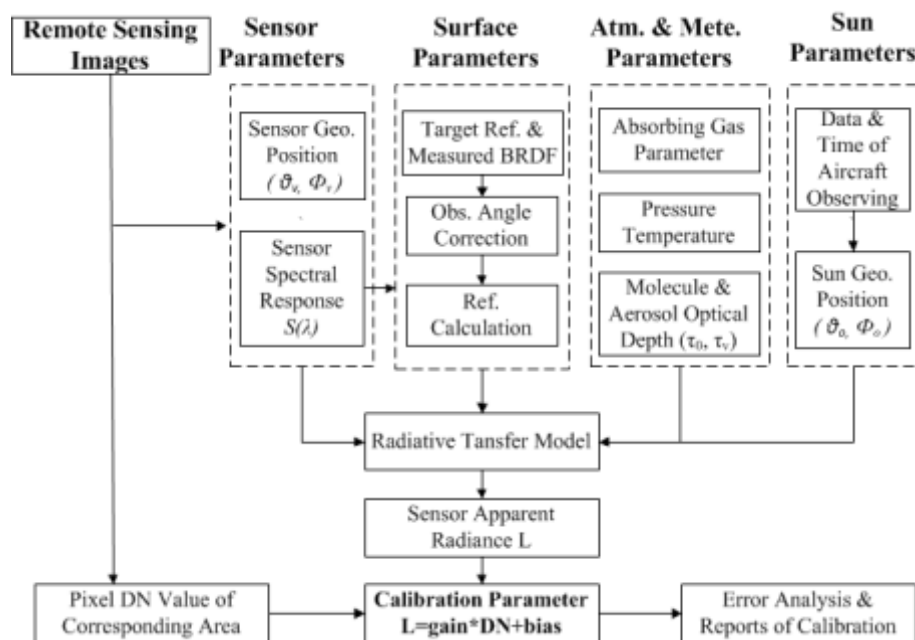
Radiometric target in red frame

## 2. Inflight Calibration & Performance Assessment

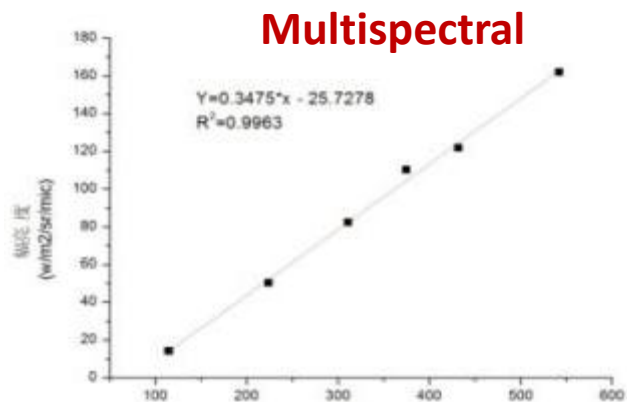
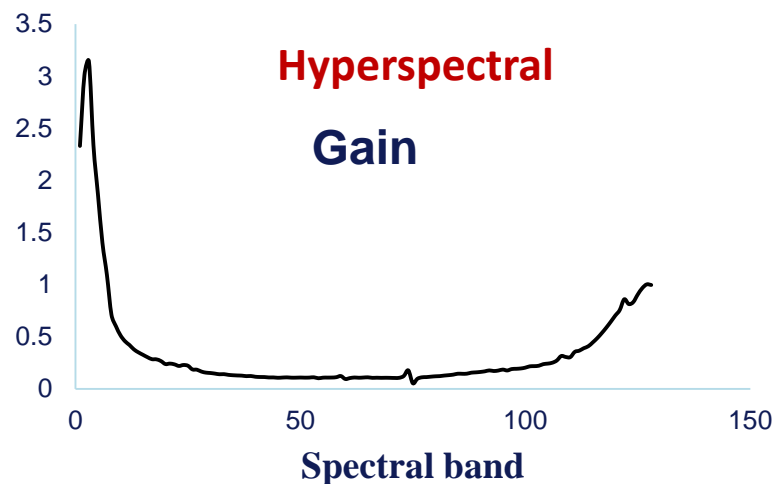


### • 2.3 Radiometric performance

#### – Absolute radiometric calibration



Flow chart of optical sensor radiometric calibration



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

## 2. Inflight Calibration & Performance Assessment



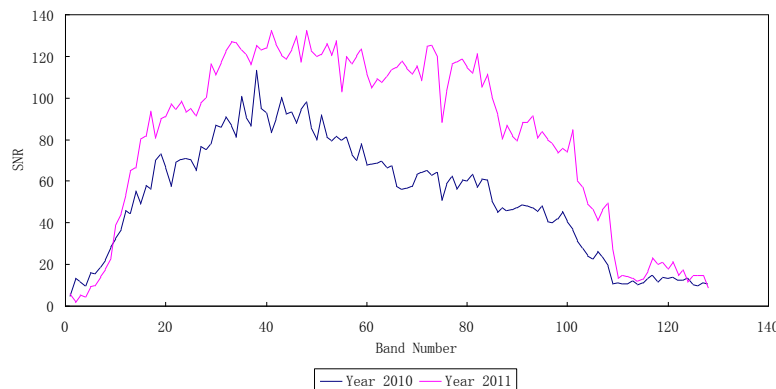
### • 2.3 Radiometric performance

- Radiometric resolution
- SNR
- Dynamic range/response linear degree

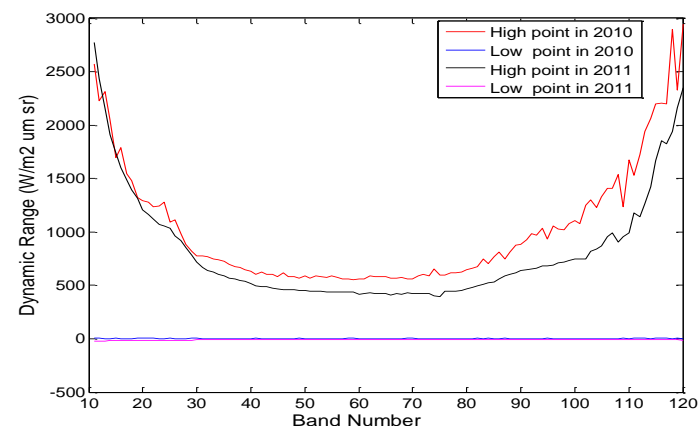
**SNR and radiometric resolution evaluation results of multispectral sensor in 2010/2011**

Data	Standard Radiance	NE $\Delta\rho$	SNR normalization
Panchromatic band in 2010	107.72	0.0037	59.89
Panchromatic band in 2011	107.72	0.0015	111.26
Blue in 2010	107.72	0.0047	88.60
Blue in 2011	107.72	0.0024	182.10
Green in 2010	107.72	0.0041	72.26
Green in 2011	107.72	0.0017	200.24
Red in 2010	107.72	0.0042	70.44
Red in 2011	107.72	0.0019	147.74
NIR in 2010	107.72	0.0020	63.41
NIR in 2011	107.72	0.00114	129.85

**SNR Normalization of hyperspectral sensor in 2010/2011**



**Dynamic range evaluation of hyperspectral sensor in 2010/2011**



## 2. Inflight Calibration & Performance Assessment



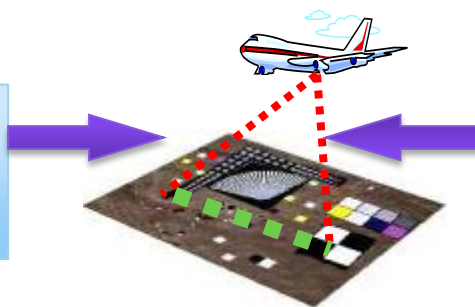
### • 2.4 Spectral performance

#### ➤ Multi-spectral sensor

- Multi-spectral data
- Target measurement data
- Atmospheric parameters

Extracting the Spectral Response Function

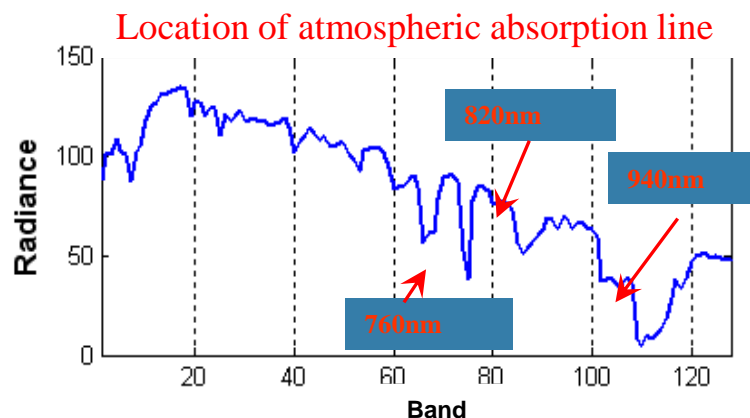
Effective Central Wavelength and FWHM



#### ➤ Hyperspectral sensor

Combination of atmospheric absorption features, the central wavelength and FWHM were retrieved according to the hyperspectral radiance and simulated radiance data.

Absorption gas	Wavelength ( $\mu\text{m}$ )	Number of HSI Band
Oxygen	0.76	75
water	0.82	87
water	0.94	111





## 2. Inflight Calibration & Performance Assessment

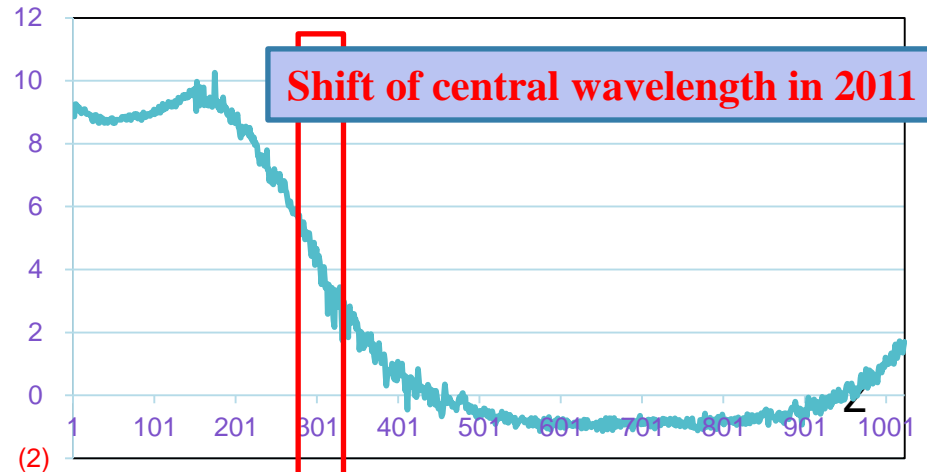
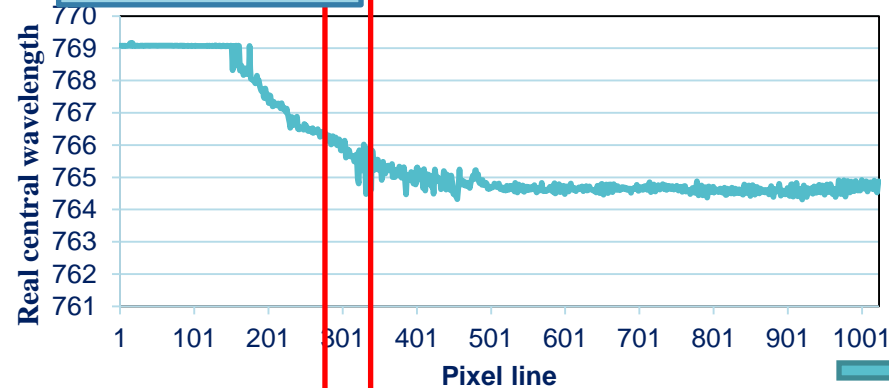


### • 2.4 Spectral performance

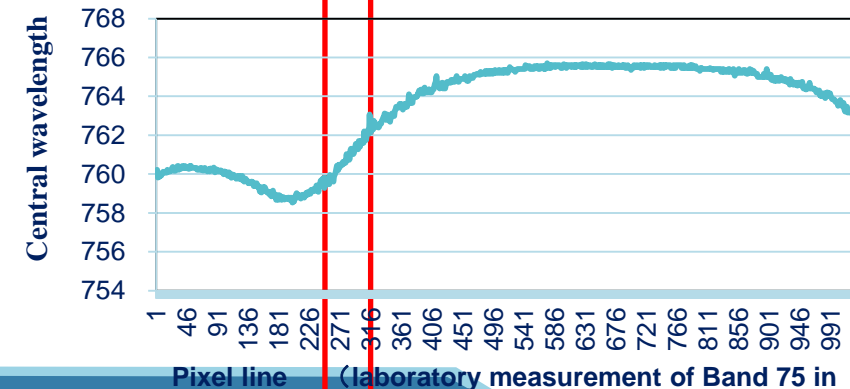
#### – Spectral calibration for hyperspectral sensor

- Retrieval central wavelength based on flight data in 2011.
- Band 75 is O<sub>2</sub> absorption band.

280~315 line



Shift of central wavelength in 2011



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

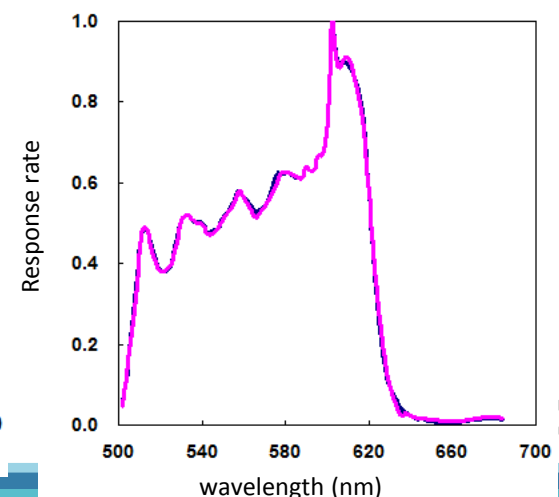
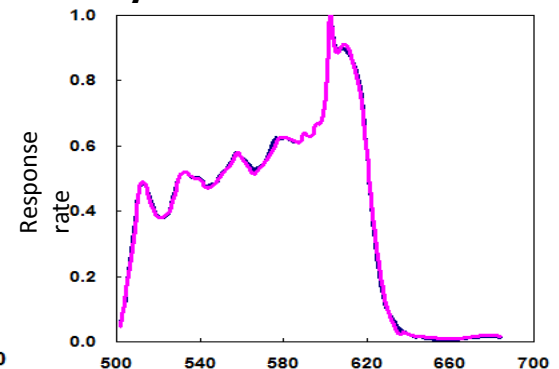
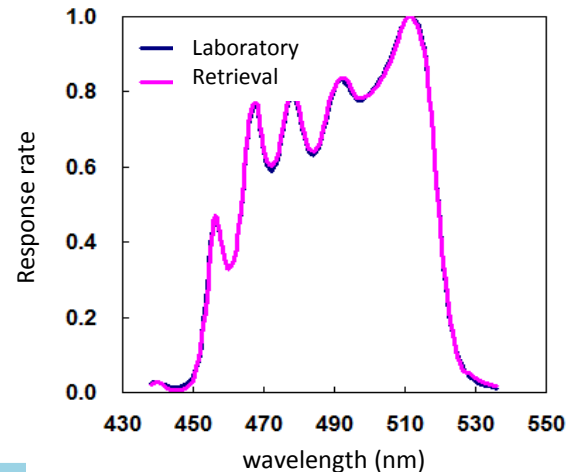
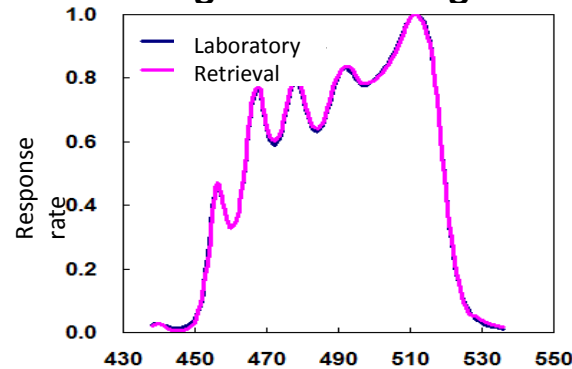
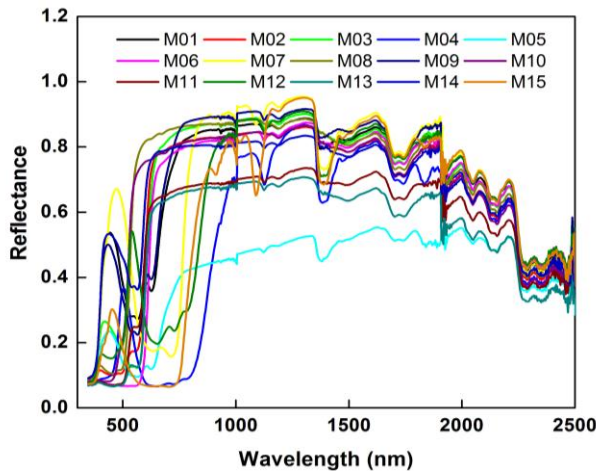
## 2. Inflight Calibration & Performance Assessment



### • 2.4 Spectral performance

#### – Spectral calibration for multispectral sensor

- **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



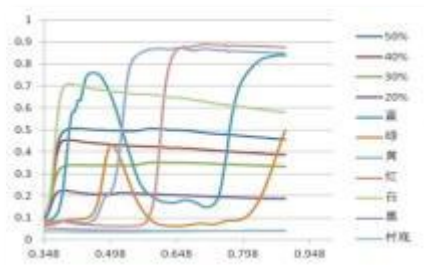
## 2. Inflight Calibration & Performance Assessment



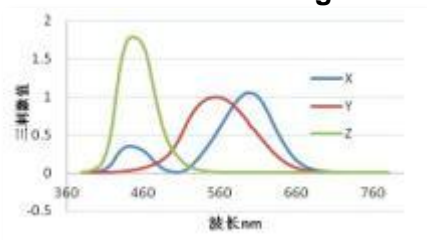
### • 2.4 Spectral performance

#### – True-color correction

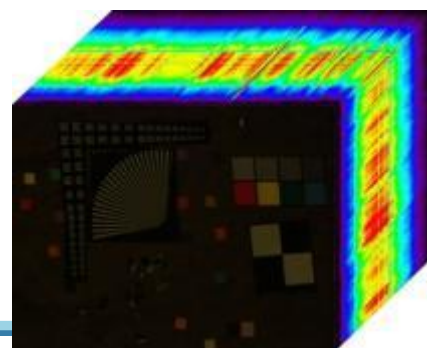
A general true color correction model is proposed based on the physical mechanism of color generation, which can fully employed all spectral information in VNIR reflection zones of hyperspectral images.



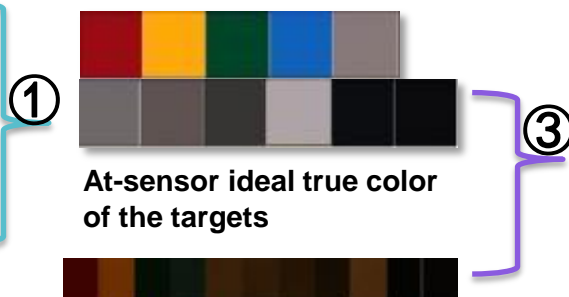
In-situ measured spectral reflectance of the targets



Human visual color matching function



At-sensor radiance HSI image



Reconstructed true color of the targets & Images before true color correction

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

True-color correction coefficient matrix

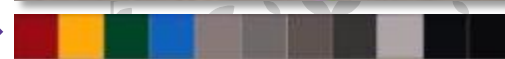
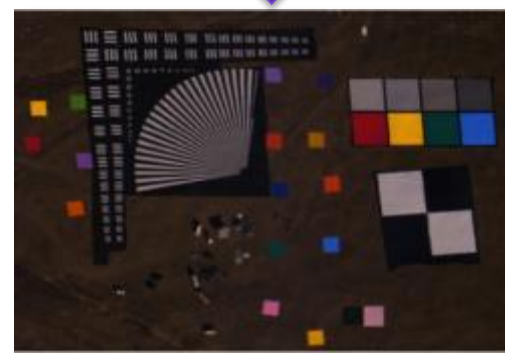


Image after true color correction



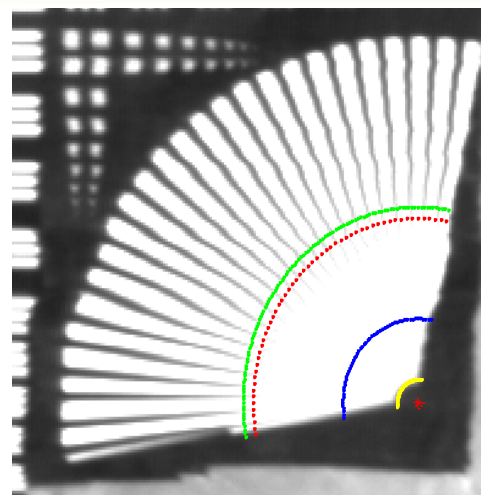
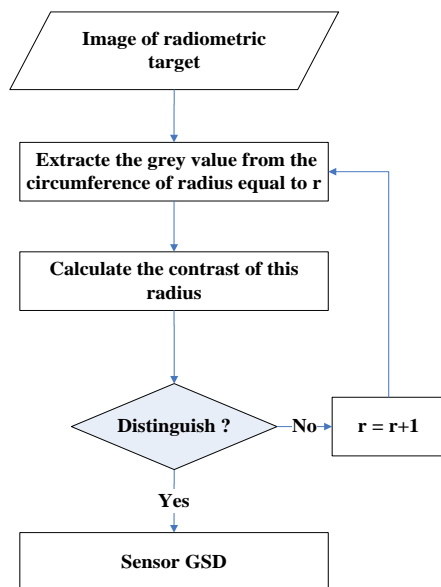
True-color correction

## 2. Inflight Calibration & Performance Assessment

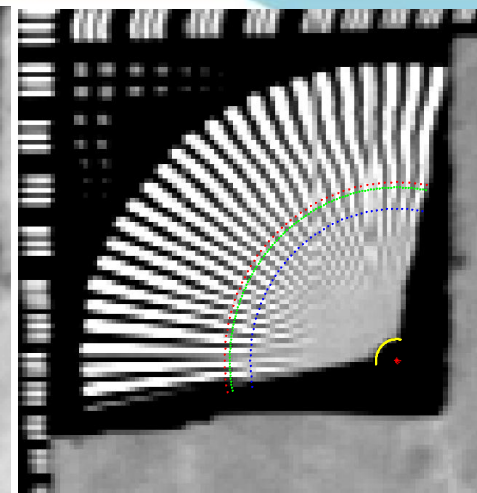


### • 2.5 Geometric performance

- **Ground resolution:** Defined as the least ground distance or the least size of object that can be distinguished.



Panchromatic image in 2011



Hyperspectral image in 2011

Camera		Calculated Resolution (m)	Visual resolution (m)	GSD (m)
Panchromatic		0.7941	0.8153	0.35
Multispectral	B1	0.8889	0.8178	0.70
	B2	0.7800	0.8083	0.70
	B3	0.8875	0.8428	0.70
	B4	0.7500	0.7750	0.70

**Red line** denotes the location of ground resolution estimated by our method.

**Blue line** denotes the location of GSD.

**Green line** denotes the location of ground resolution estimated by visual method.



## 2. Inflight Calibration & Performance Assessment

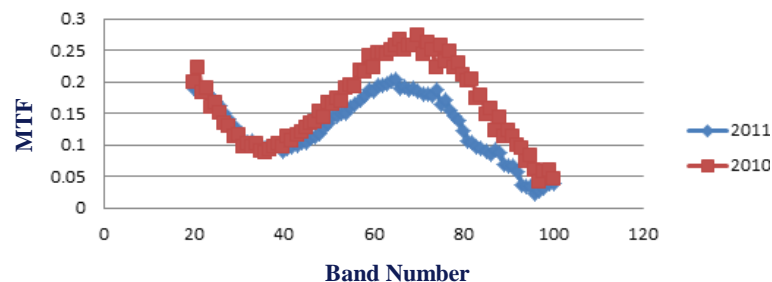


### • 2.5 Geometric performance

### • Evaluation method

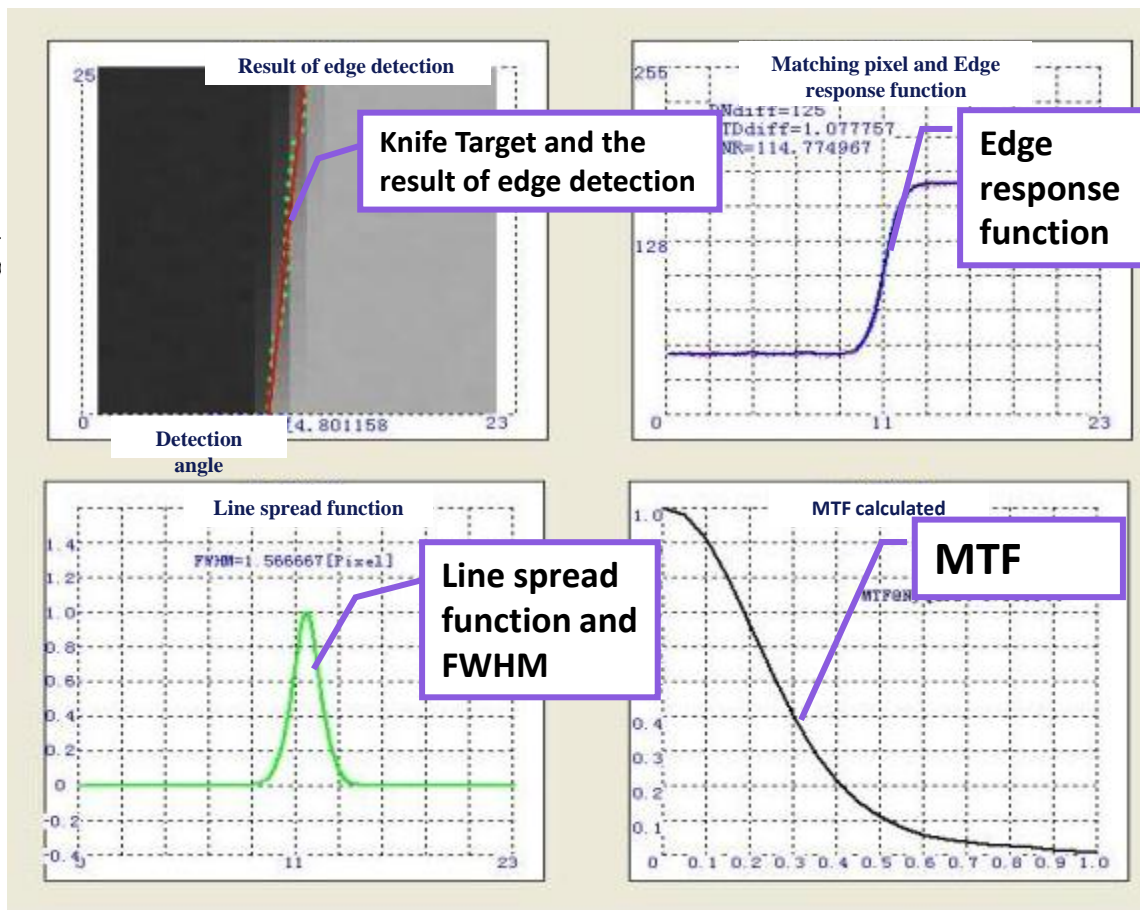
#### – MTF

HSI MTF@Nyquist in 2010/2011



Multispectral camera MTF@Nyquist in 2010/2011

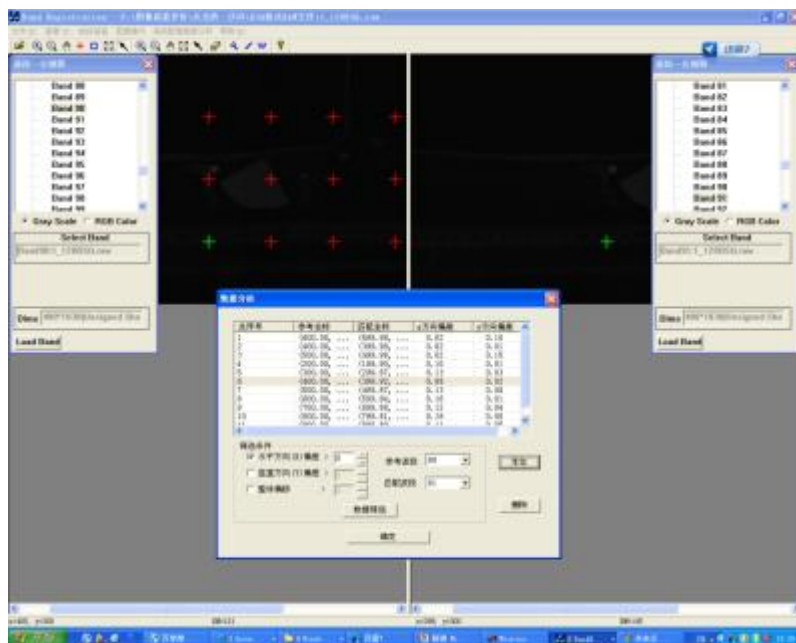
	2010	2011
Linear panchromatic camera	0.064	0.071
Area-array panchromatic camera	-----	0.368
Linear Multispectral:B1	0.353	0.357
Linear Multispectral:B2	0.349	0.380
Linear Multispectral:B3	0.353	0.376
Linear Multispectral:B4	0.242	0.312



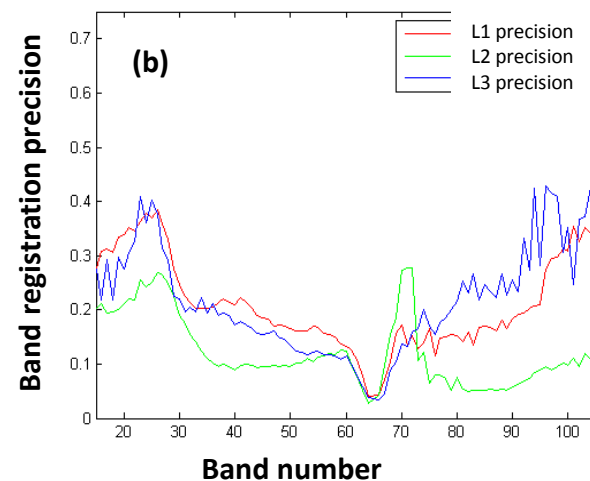
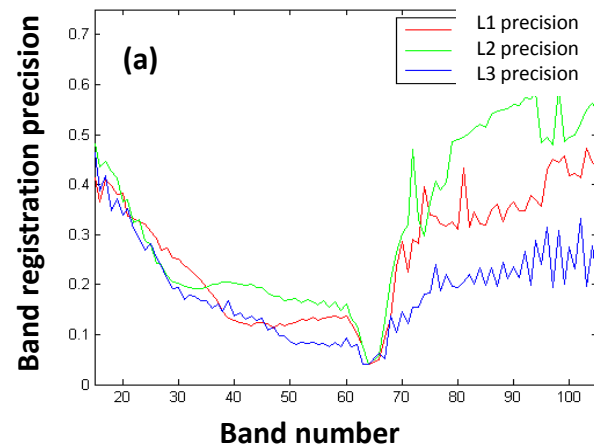
## 2. Inflight Calibration & Performance Assessment



- 2.5 Geometric performance
  - Band registration precision



Band-to-band registration precision of hyperspectral sensor is high, and the registration error is less than 0.7 pixel.



Hyperspectral sensor band registration precision for three-flight routes (L1, L2, L3) in **along-track** (a) and **cross-track** (b) direction in Sep. 2011

## 2. Inflight Calibration & Performance Assessment



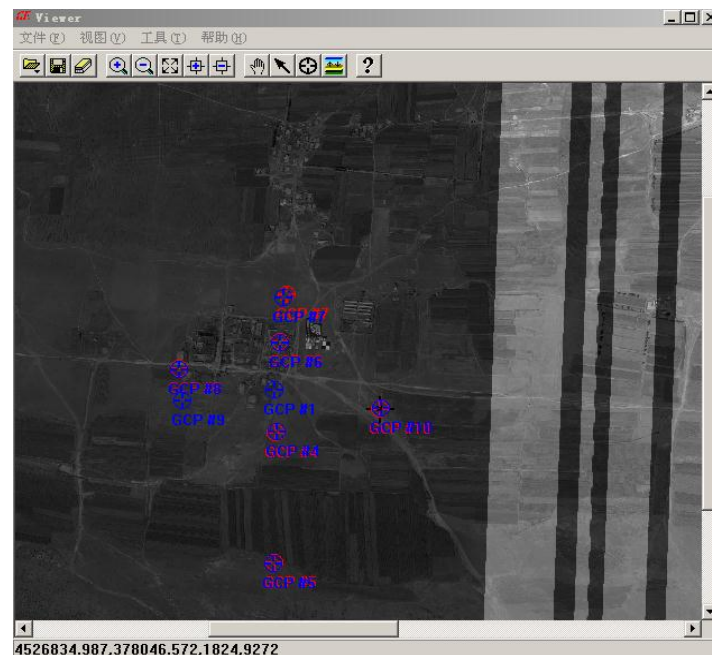
### • 2.5 Geometric performance

#### – Geometric distortion

**Geometric distortion evaluation result of panchromatic image in Sep. 2011 in Baotou city, China.**

Data Type	External distortion Positioning error		Internal distortion	
	X-direction ( m )	Y-direction ( m )	Distance distortion ( m )	Angle distortion ( ° )
Geometric coarse correction	22.106	155.295	14.859	167.16
Geometric precision correction	0.568	1.012	0.866	0.085

**Geometric distortion evaluation module**



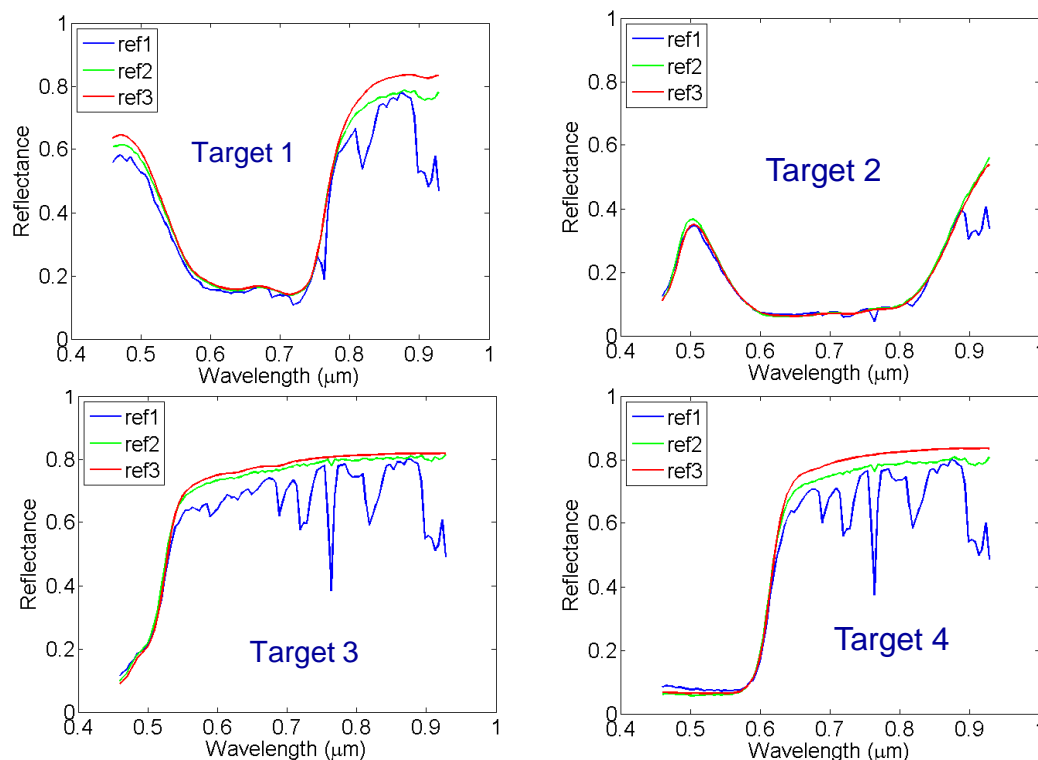
**After geometric precision correction, the positioning accuracy can reach a meter-scale and the image distortion has also been corrected well.**

## 2. Inflight Calibration & Performance Assessment



### • 2.6 Application performance - reflectance retrieval and validation

- **Surface reflectance** was retrieved by LUT model from hyperspectral data at four hyperspectral man-made targets.



Hyperspectral targets in red frame

- ref1:** at-sensor reflectance  
without atmospheric correction
- ref2:** surface reflectance after atmospheric correction
- ref3:** field measured reflectance

It can be seen that the proposed method can eliminate the atmospheric effect well.

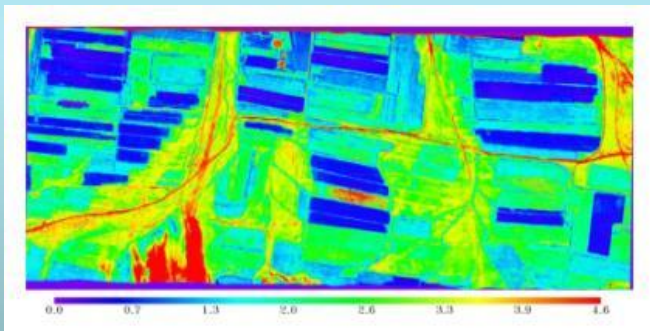


## 2. Inflight Calibration & Performance Assessment

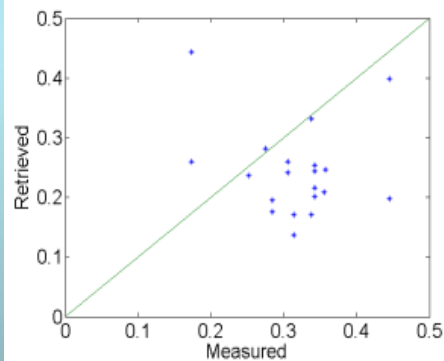


### • 2.6 Application performance - SVIs retrieval and validation

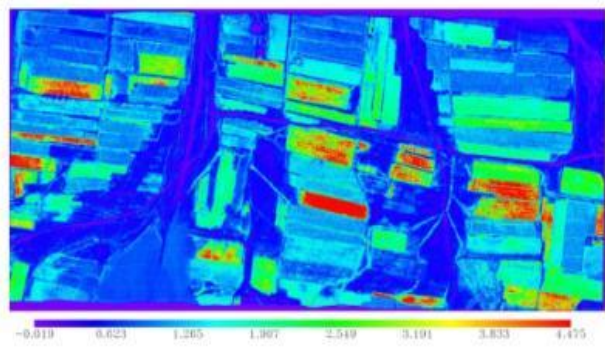
- **Spectral Vegetation Index (SVI)** was retrieved using hyperspectral land surface reflectance estimated by LUT model.



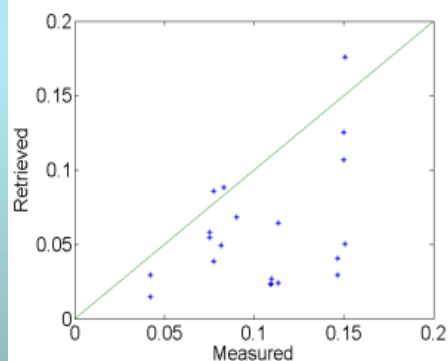
Chlorophyll Absorption Ratio Index, **CARI**



retrieved vs. measured



Modified chlorophyll Absorption Ratio Index, **MCARI**



retrieved vs. measured

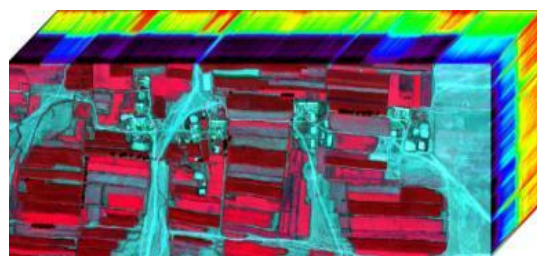
Compared to the measured data, the validation accuracies of CARI and MCARI are slightly lower. It might be due to that

- (1) **acquiring time** was different with **ground measuring time**, so as the atmospheric and solar illumination condition were different
- (2) Scaling bias between field measurements and RS retrievals
- (3) The trend of saturation for NIR band which is obvious high to vegetation

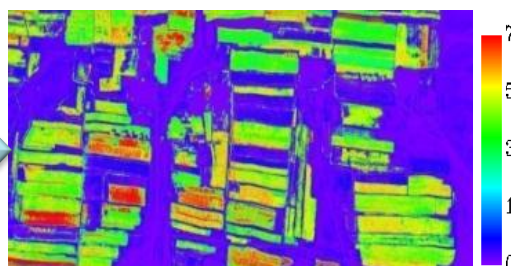
## 2. Inflight Calibration & Performance Assessment



- 2.6 Application performance - LAI retrieval and validation
  - **LAI** was retrieved from hyperspectral data according to the image classification.

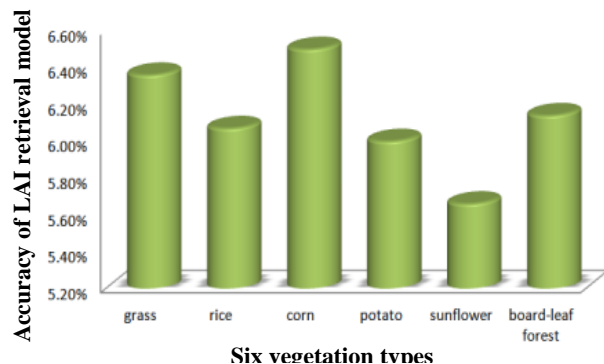


Retrieve



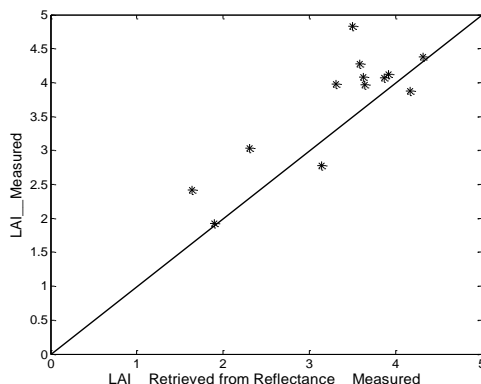
Airborne hyperspectral reflectance three-dimensional cube

Result of LAI retrieved



Six vegetation types

Accuracy of LAI retrieval model for six vegetation types



Accuracy assessment using field measurements on Sep 3, 2011.

(1) Accuracy of LAI retrieval model is less than 7%.

(2) Validation results show that the retrieval error of LAI is approximately 21.7% with field measurement data.

(3) It might due to the retrieval error of reflectance, the saturation of NIR band with the increasing of LAI, the error of instruments.



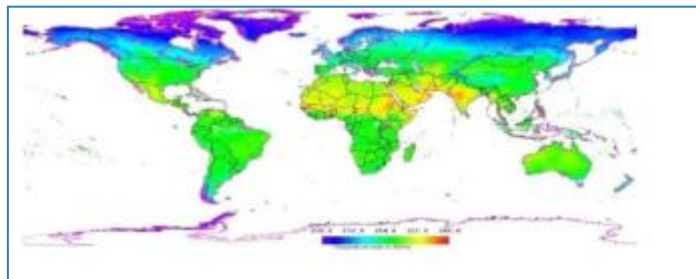
### 3. Future Activities and Plans on Test Site Construction



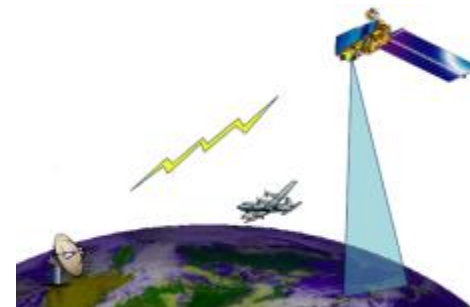
#### • Prospects



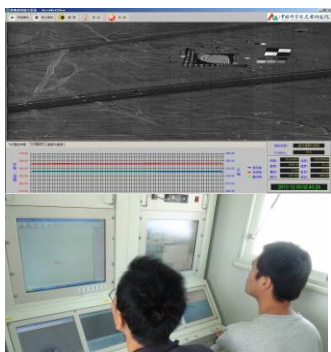
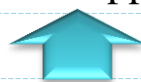
Sensors design  
and development



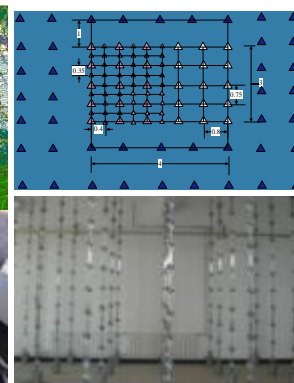
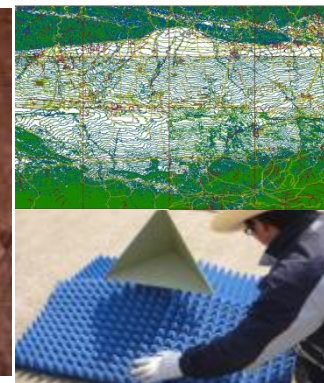
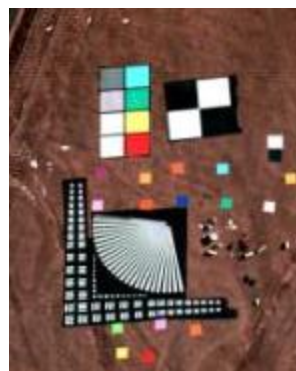
Remote sensing  
quantitative application



Emergency response system



Remote sensing data acquisition platform



Comprehensive validation site of remote sensing

### 3. Future Activities and Plans on Test Site Construction



#### • Goals

##### Comprehensive test site, for stable and long-term operation

- Support pre-launch calibration and testing for payload (visible and near infrared, hyper-spectral, infrared, SAR, LiDAR, etc.)
- Support in-flight/orbit calibration and long-term monitoring of payloads

##### Multi-grade validation system for payload on airborne and satellite platforms

- Support payload performance and data quality test, with analysis and evaluation functions through full band
- Support the validation of quantitative RS parameters retrieval

##### A set of evaluation indicators and test specification according to international standards

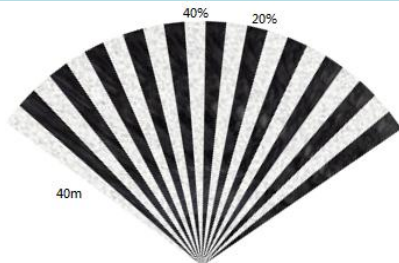
- Support reliable/trusted payload quality evaluation and C&V
- Form a set of test specifications covering test methods, test procedures, test objectives, test results evaluation.



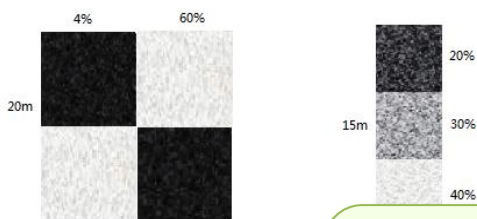
### 3. Future Activities and Plans on Test Site Construction



Fan-shaped target



Knife-edge target



Gray-scale target

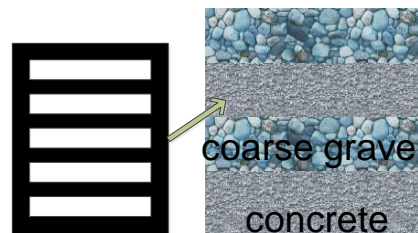
Optical permanent artificial target

SAR permanent artificial target

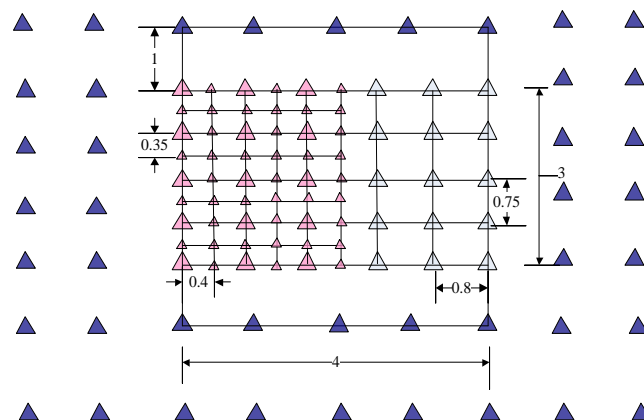
Corner reflector base



Microwave bar target



Long-term  
stable  
operation



Geometric calibration field

Natural ground scenes

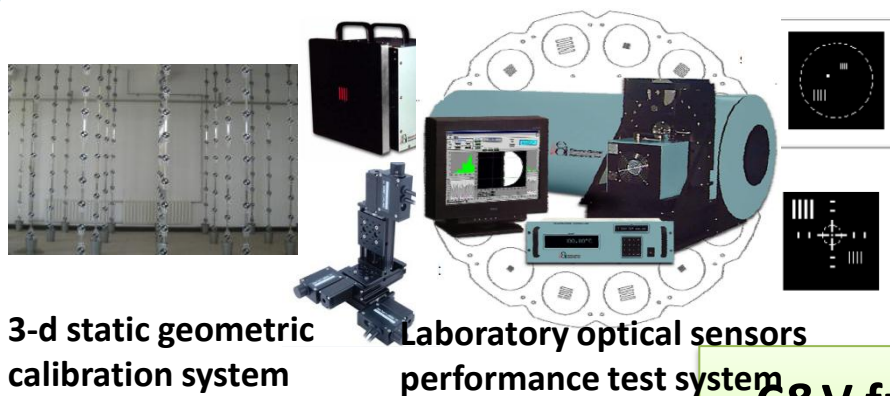


Wuliangsu Lake

### 3. Future Activities and Plans on Test Site Construction



#### Pre-flight calibration and performance test

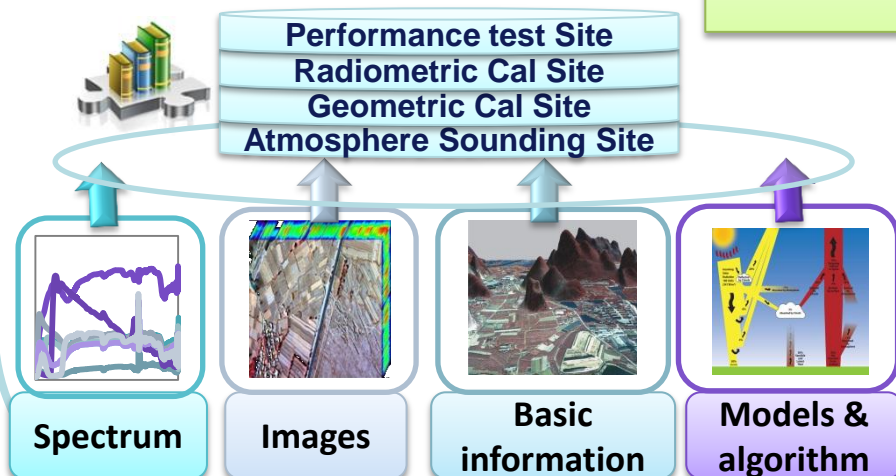


#### New verification method by means of array point source target

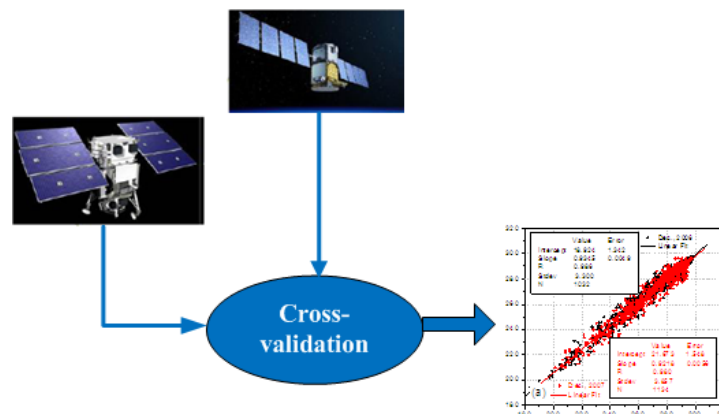


#### C&V function extension

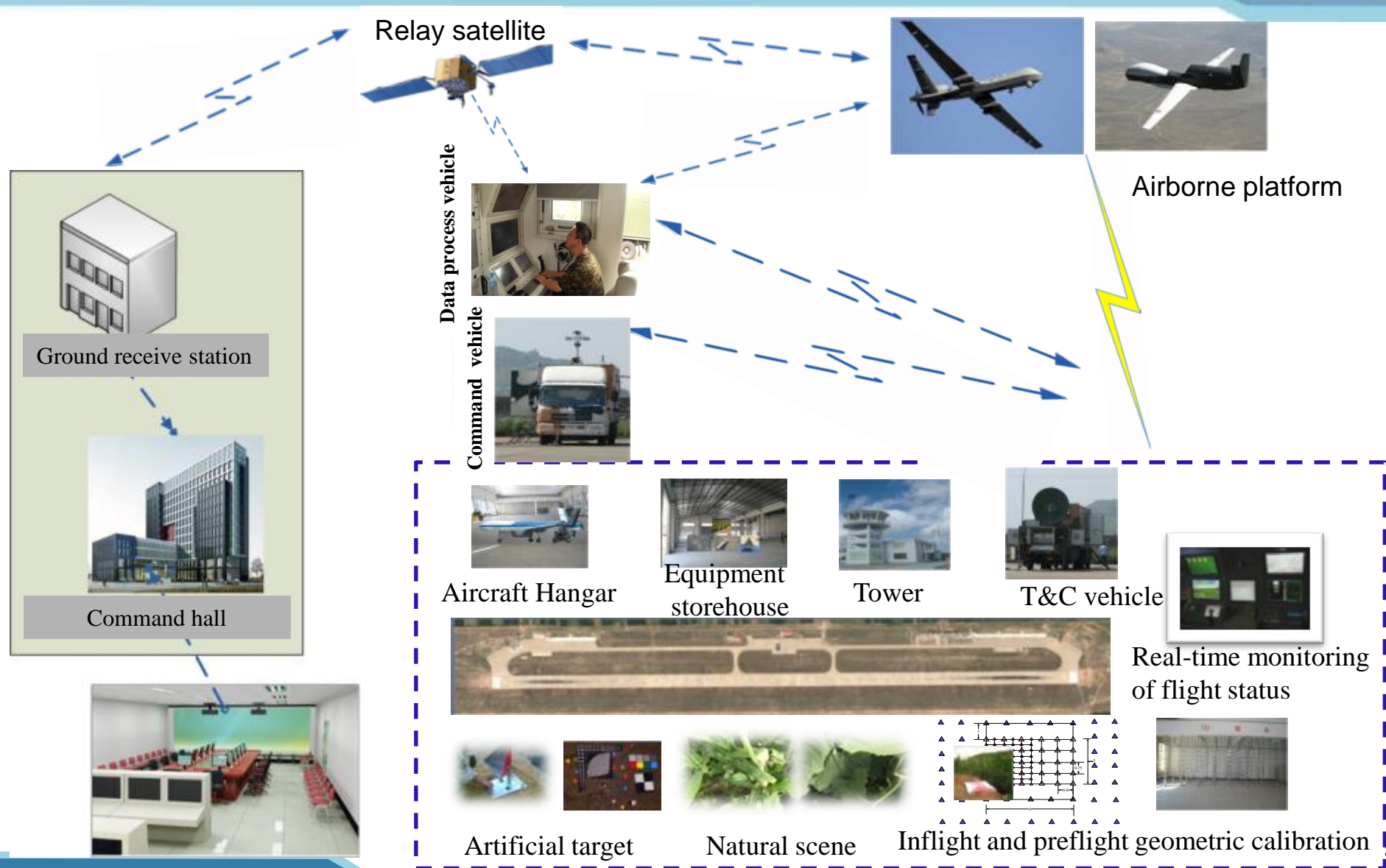
#### Knowledge Library



#### Multi-sensors cross validation



### 3. Future Activities and Plans on Test Site Construction





A scenic landscape photograph featuring a calm body of water in the middle ground. In the foreground, several dark branches of cherry blossom trees are heavily laden with vibrant pink flowers, some in full bloom and others as buds. The background consists of lush green hills or mountains under a clear, light blue sky. A small boat is visible on the water in the distance. The overall atmosphere is peaceful and beautiful, typical of a spring day.

*Thank you !*