# Post-launch Calibration and Date Quality Assessment of Chinese High Resolution Satellites

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# Outline

1. China HR satellites and sensors overview
2. Post-launch calibration requirements and status
3. Exploration of Inter-calibration of HR satellite sensors based on RadCalNet sites
4. Summary

# China HR satellites and sensors overview

## China HR satellites

Currently more than 20 HR satellites are on orbit.

2011.12~now ZY-1 02C/ 04a

5m Pan/10m MUX

2019.9~now ZY02D

30m HSI (166 bands)

Land resources satellite series

2013.4~now GF-series

2013.4~now GF-1 01/02/03/04 2m Pan/8m Mux

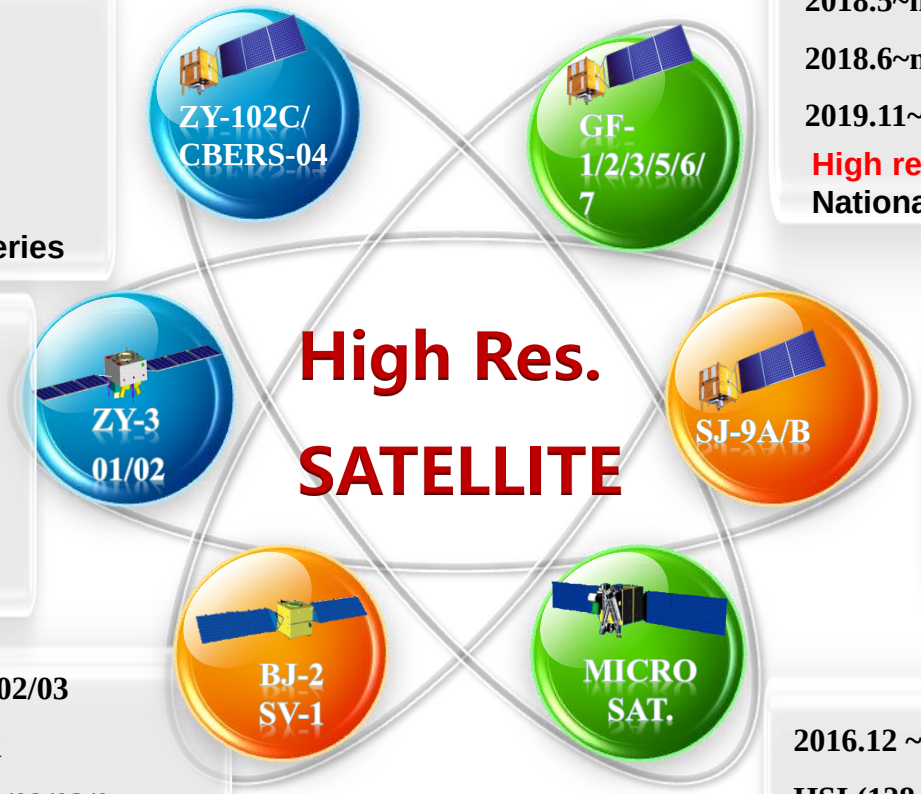
2014.8~now GF-2 1m Pan/4m Mux

2018.5~now GF-5 HSI (330 bands) 30m

2018.6~now GF-6 2m Pan/8m Mux

2019.11~now GF-7 0.8m pan/3.2 m MUX

High resolution EO system from National major project




2012.01~now ZY-3 01/02

2.1m Pan/5.8m MUX

Mapping satellite DEM production

2012.10~now SJ-9 A/B

2.5m PAN/10m MUX

New technology experiment satellites

2015.7~now BJ-2 01/02/03

0.8m Pan/3.2m MUX

2016.12~now SV-1 01/02/03/04

0.5m Pan/2m MUX

Commercial HR satellite constellation

2016.12 ~ now CX-6 02

HSI (128 bands) 30m

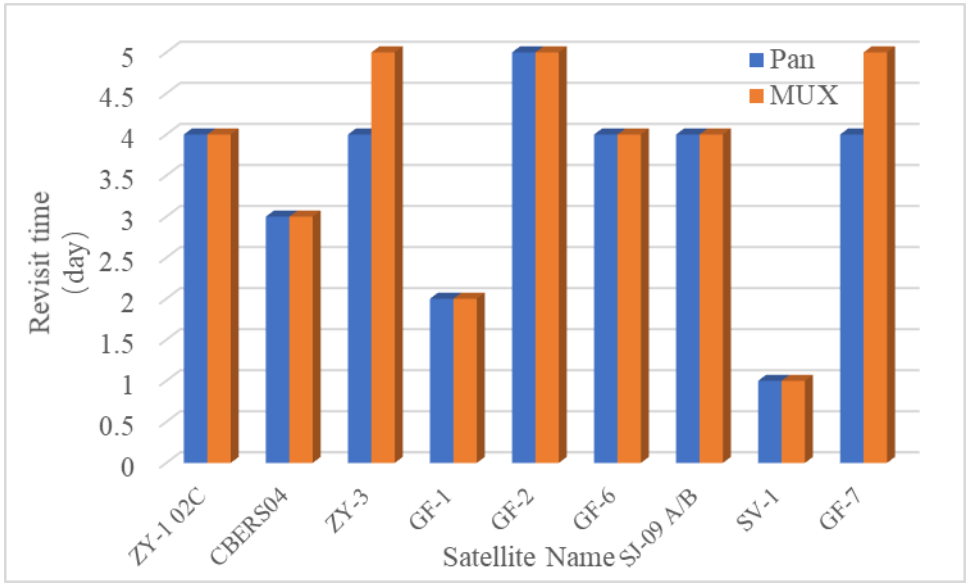
2017.6 ~ now OHS-series

MSI (32 bands) 10m

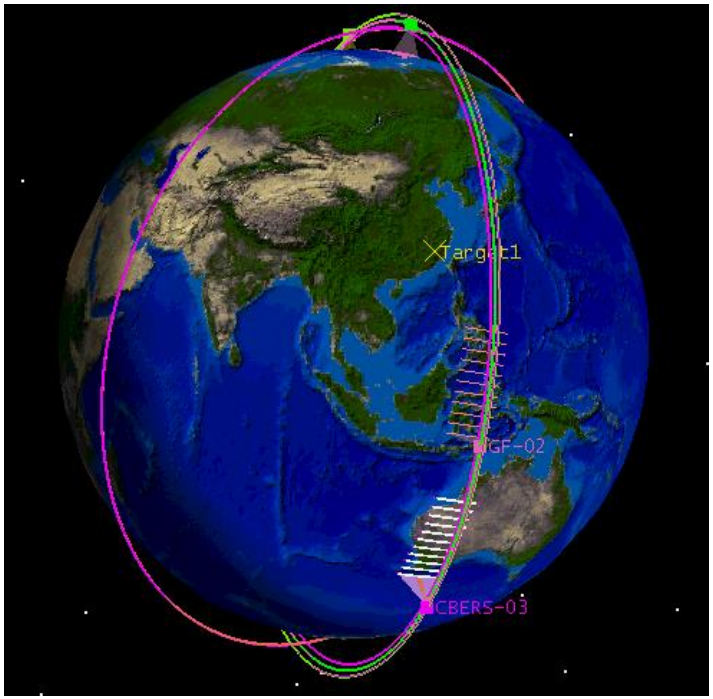
MICRO satellites

# Chinese HR satellites and sensors overview

## Temporal characteristics




Revisit time of satellite @ 30° sidelooking

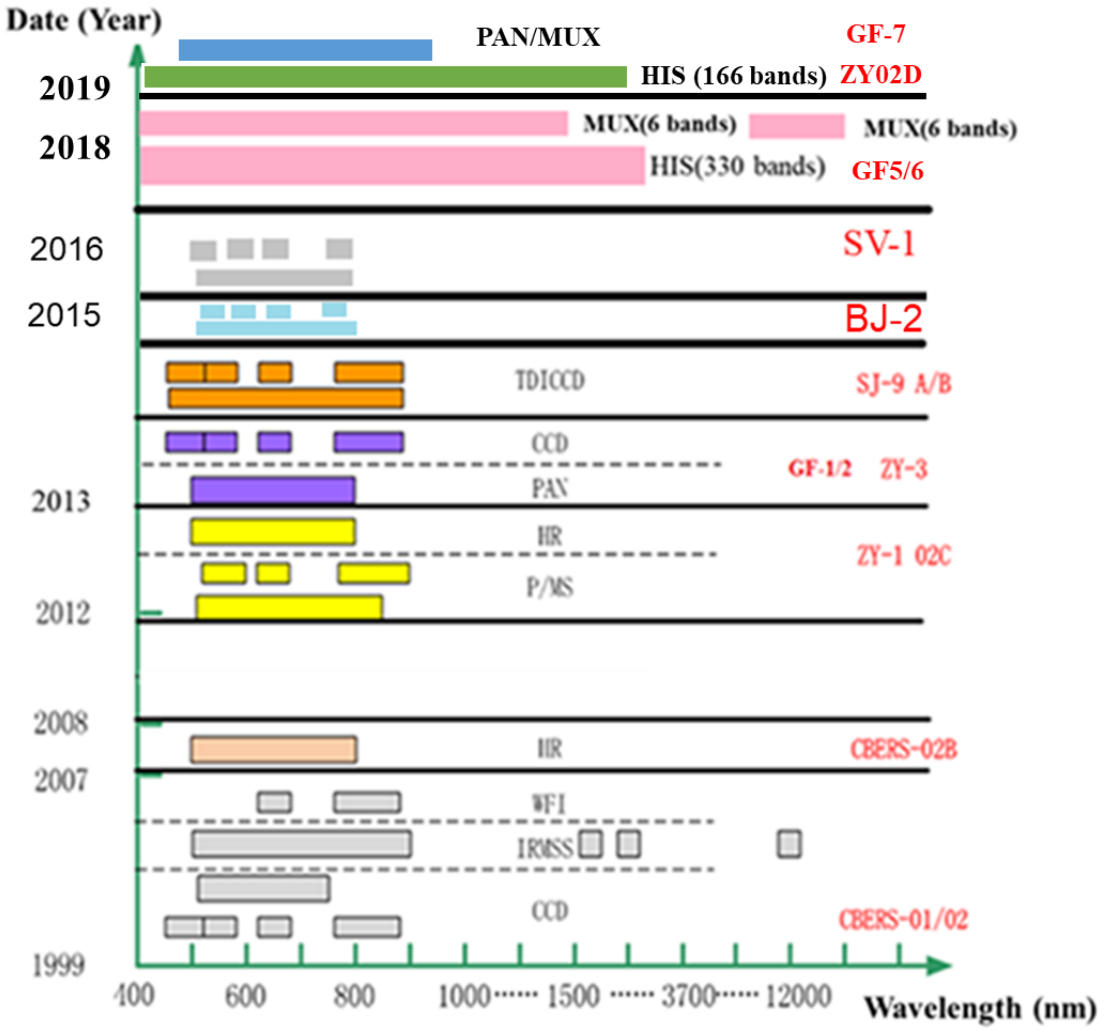



The shortest revisit time of single satellite series is 1 days (e.g. SV-1).

# Chinese HR satellites and sensors overview

## Spectral characteristics

- Pan spectrum range is 0.45μm-0.89μm.
- Multispectral spectrum range is visible, near-infrared, middle-infrared and thermal infrared bands.
- Hyperspectral range is 0.4μm-2.5μm, and the highest spectral resolution is 5 nm.

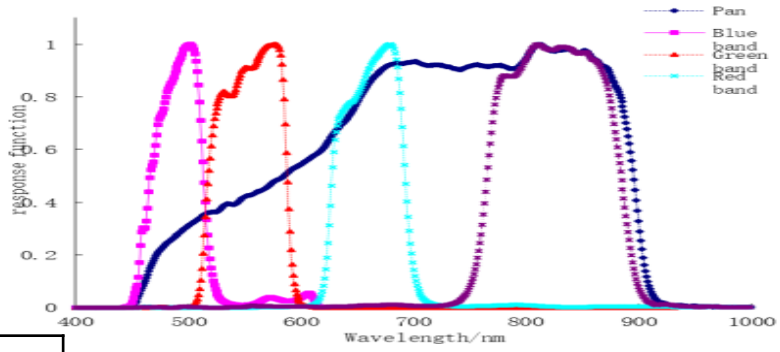


# Chinese HR satellites and sensors overview

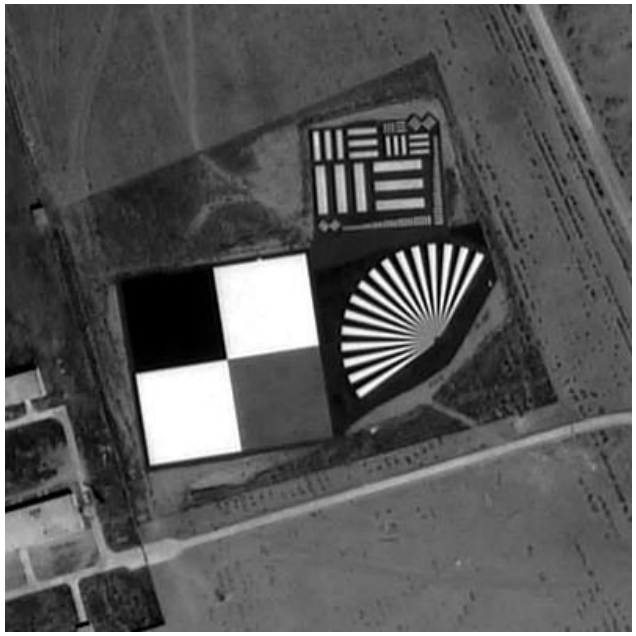
## HR satellites-Pan/Mux sensors

- Chinese HR multispectral satellites consist of: ZY-series (ZY02C、ZY3-01/02), GF-series (GF-1, GF-2, GF-4, GF-6, GF-7) ;
- Spatial resolution: 0.8m-5m (Pan), 3.2m-50m (MUX)
- Revisit periods: 20s(GEO), 2-5d(LEO) ;

| Sat. | Orbit altitude | Swath (km) | GSD (m) | Revisit periods (days) |
|---|---|---|---|---|
| ZY02C | 780 | 60 | Pan:5<br>MUX:10 | 3 |
| ZY3-01/02 | 505 | 51 | Pan:2.1<br>MUX:6 | 5 |
| GF-1 | 654 | 60/800(WFV) | Pan:2<br>MUX:8/16 | 4/2(WFV) |
| GF-2 | 631 | 45 | Pan:1<br>MUX:4 | 5 |
| GF-4 | 36000 | 400 | MUX:50 | 20 s |
| GF-6 | 505 | 90/800(WFV) | Pan:2<br>MUX:8/16 | 4/2(WFV) |
| GF-7 | 505 | 20 | Pan:0.8<br>MUX:3.2 | 5 |




GF-1 PMS SRF



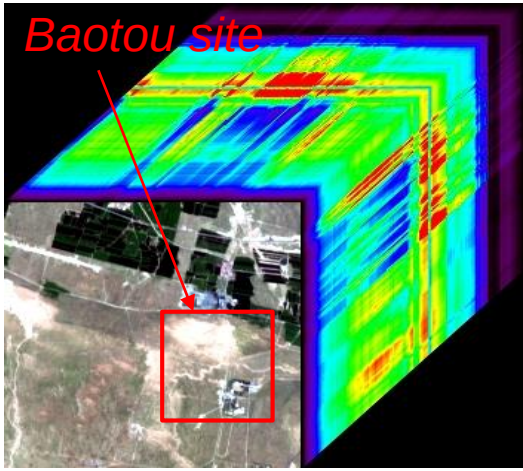
GF-2 Pan image over Baotou site 2018/6/6

# Chinese HR satellites and sensors overview

## HR satellites- Hyperspectral sensors

- GF-5 was launched on May 9 2018.
- ZY02D was launched on Sep. 12, 2019.

| | GF-5 | ZY02D |
|---|---|---|
| GSD | 30 m | 30 m |
| Spectral range | 0.4-2.5 μm | 0.4-2.5 μm |
| Spectral resolution | VNIR ≦ 5 nm; SWIR ≦ 10 nm | VNIR ≦ 10 nm; SWIR ≦ 20 nm |
| Spectral calibration accuracy (LED) | VNIR：≦0.5nm；SWIR：≦1.0nm | VNIR：≦0.5nm；SWIR：≦1.0nm |
| Swath | 60 km | 60 km |
| Bands | 330(VNIR:150, SWIR: 180) | 166 (VNIR and SWIR) |
| Revisit period | 51 days (no side-looking) | 55 days (no side-looking) |

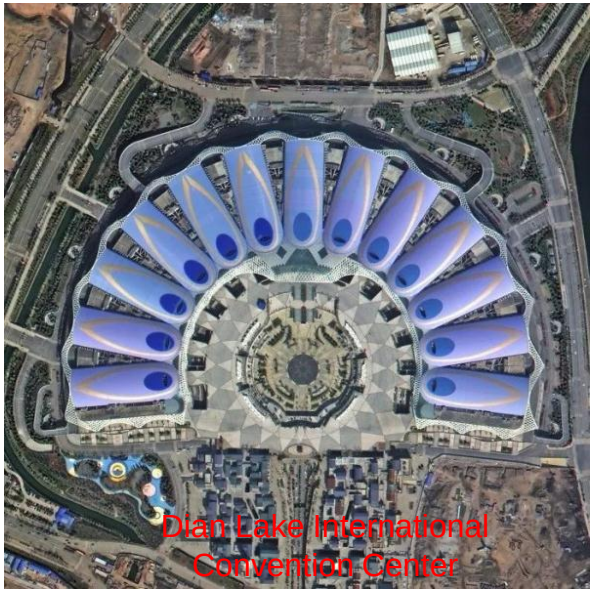


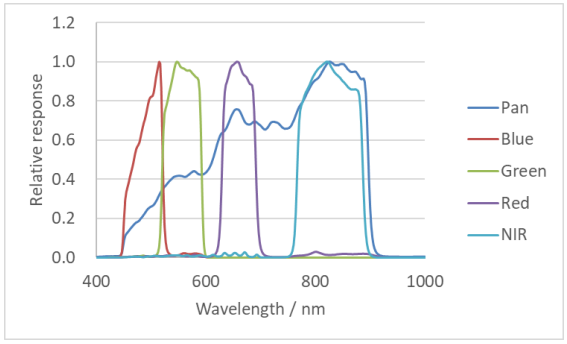

GF-5 AHSI image
(2018/8/8)

# Chinese HR satellites and sensors overview

## HR satellites- Commercial satellites

- SV(SuperView)-1 is Chinese first commercial high resolution satellite series. SV-1 01/02 were launched on Dec 28 2016, and SV-1 03/04 were launched on Jan 9 2018. Onboard sensor: Pan band 0.5m, MUX bands 2m. By networking scheme of these four satellites, the revisit time can be shorten to 1 day.
- ZhuHai-01 commercial constellation (ZH-01/OHS2A, OHS2C, OHS2D) (Orbita Aerospace Ltd.) was launched on Apr 26 2018. The hyperspectral imagers aboard: 10m GSD, spectral range 400nm~1000nm, 32 bands, mean spectral resolution 2.5nm. the revisit period is 2 days (with 35° side-looking).




SV-1 MUX SRF

| | |
|---|---|
| Orbit altitude | 530 km |
| Swath | 12 km |
| GSD | Pan: 0.5 m |
| | MUX: 2 m |
| Maximum sidelooking angle | 45° |

ZH01/OHS2A (Baotou site)

# Post-launch calibration requirements and Status

- More HR satellites are planned to be continuously launched in the near future.
- It is necessary to carry out post-launch calibration and data assessment, so as to improve data quality consistency among Chinese HR satellites, and especially between Chinese satellites and international satellites.

Space Infrastructure Plan (2019 - 2025)

- X-SAR Sat. (0.5m)-2
- L-SAR Sat. (3m)—4
- High orbit SAR Sat. (20m)—2
- S-SAR Sat. (5m)—4
- C-SAR Sat. (1m)— 2

☆**39 satellites**



- Stereo mapping Sat. (0.8/2.1m)— 3
- Optical Sat. (1/4m) — 6
- High-res muti-mod Sat.— 2
- High-orbit sat (20/50m)-4
- Hyper-s sat (5-20m)-3

☆ **45 payloads**

**27 optical and atmospheric,**

**3 Lidars, 7 SARs, 8 electromagnetic**

- Electromagnetic Sat.—2
- Greenhouse gas monitor Sat.—1

- Atmospheric environment Sat—1
- Terrene carbon Sat—1
- High resolution multi-mode synthetical imaging Sat—1

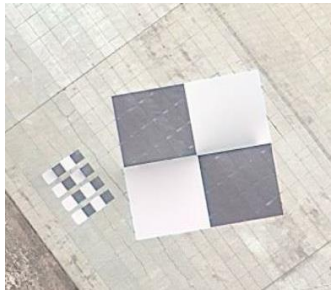
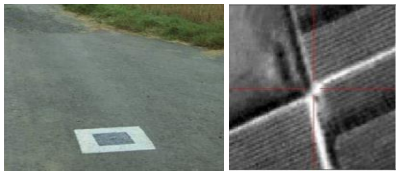
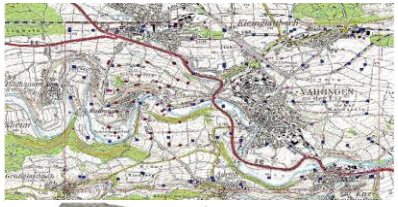
# Post-launch calibration requirements and Status

There are plenty of performance indexes to be evaluated:

| Calibration/monitoring task | Parameters to be determined | Main methods |
|---|---|---|
| Radiometric calibration | Relative radiometric calibration coefficients;<br>Absolute radiometric calibration coefficients | Vicarious calibration based on field site is still served as the main calibration method for HR satellites, especially for commercial and micro-satellites. |
| Spectral calibration | Central wavelength;<br>… | Onboard calibration instrument + atmospheric absorption feature analysis |
| Geometric calibration | Internal geometric distortion;<br>Positioning accuracy;<br>Band registration accuracy;<br>… | Internal geometric distortion: based on geometric calibration site<br>Positioning accuracy: using GCPs network throughout China to eliminate system errors |
| Imaging performance assessment | MTF;<br>SNR;<br>Dynamic range;<br>Response linearity;<br>… | MTF: knife-edge target<br>SNR, dynamic range, response linearity: measured in lab; validation through uniform field area |

# Post-launch calibration requirements and Status

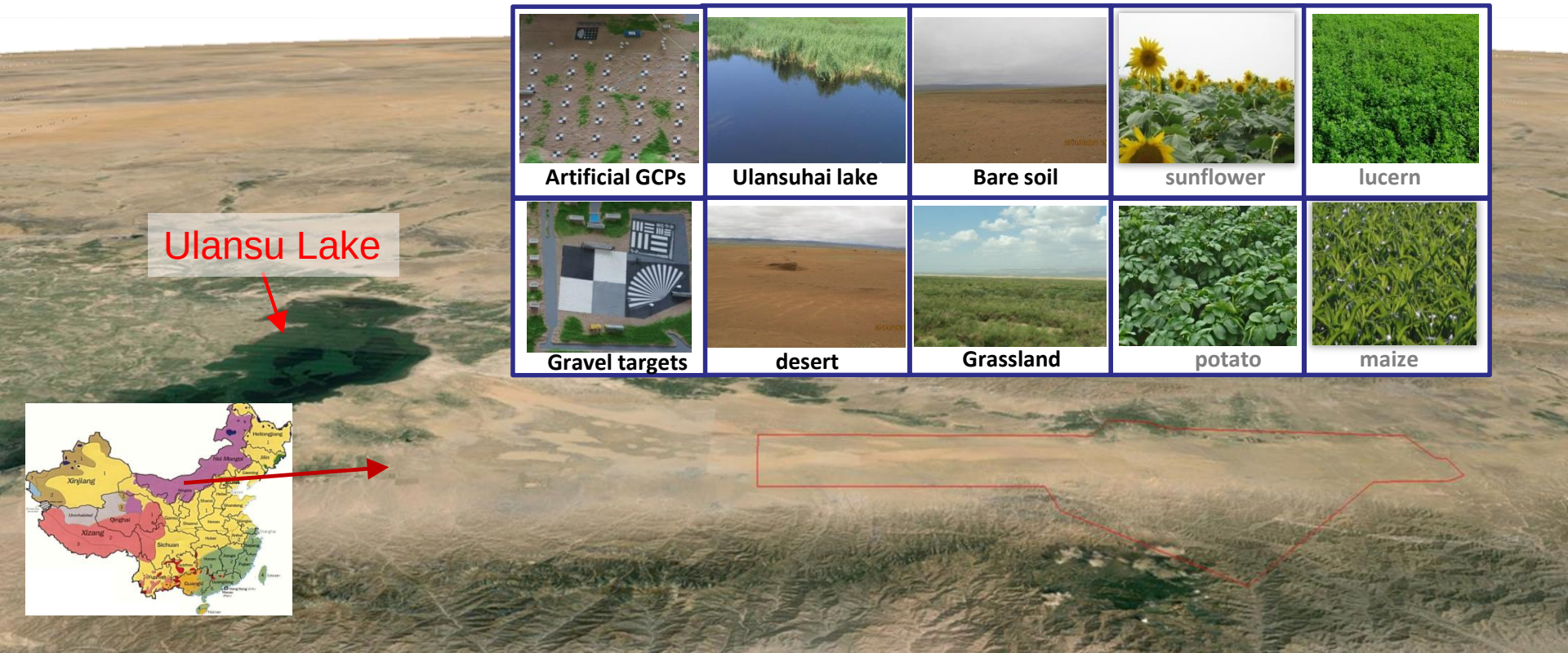
Different performance assessment will use different ground targets, which is a challenge and painful work.
Fortunately, the high resolution feature of the sensor makes it possible to put so many targets in one place. This will make the calibration activities more efficient.

| Image resolution | MTF assessment | Geometric assessment | Cal&Val |
|---|---|---|---|
|  Bar target |  Knife-edge target |  Artificial/natural control points |  Dunhuang site |
|  Fan-shaped target |  Point target |   Geometric calibration test field |  Qinghai Lake homogenous scenes |

# Post-launch calibration requirements and Status

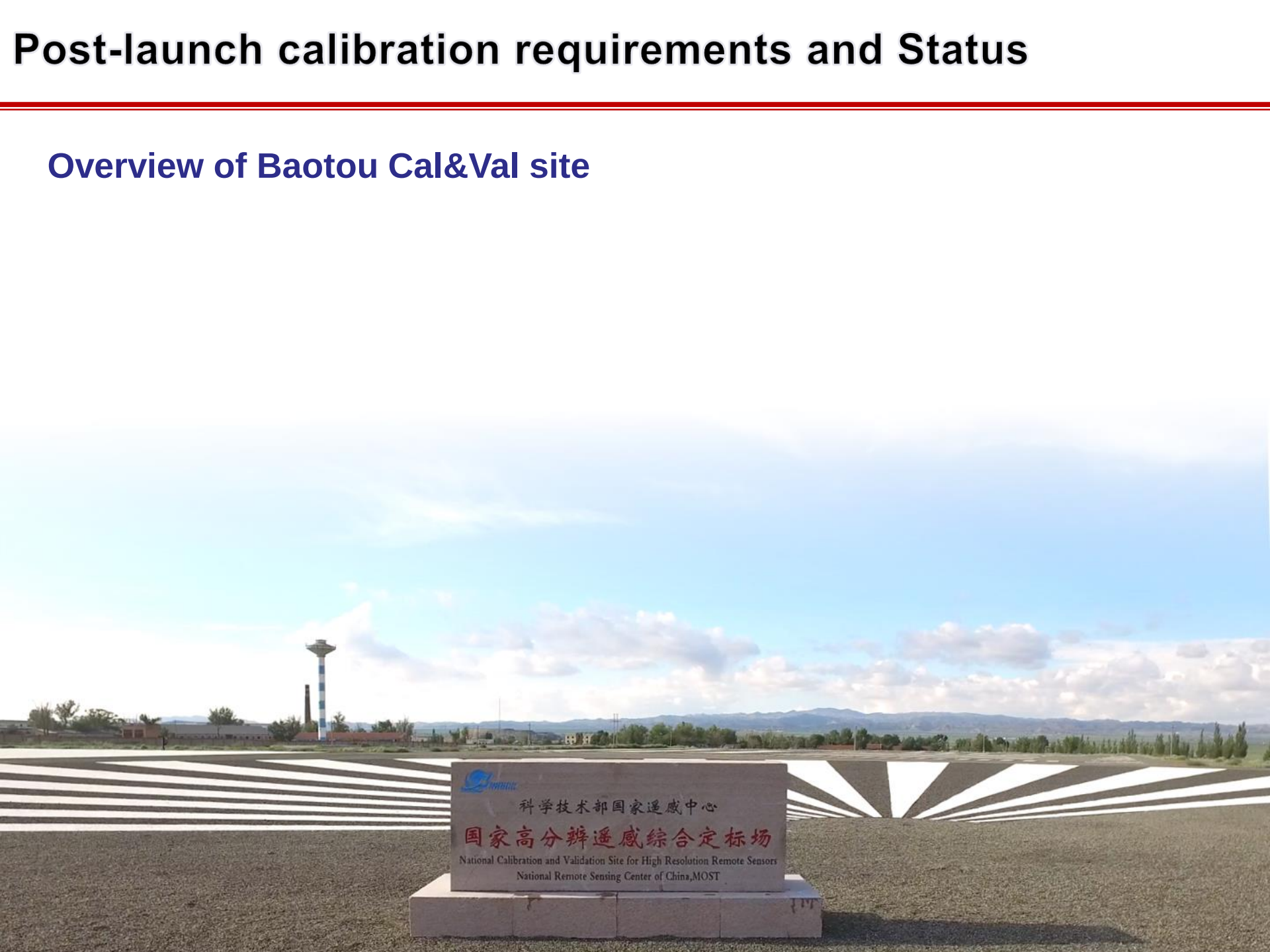
## Overview of Baotou Cal&Val site

- “National Cal&Val Site for High Resolution Remote Sensors" by the MOST, China
- Located in Inner Mongolia, China, 50km away from Baotou city.
- A flat area of approximately 300km$^2$, about 1270m above sea level.
- Integrate multi-type natural scenes and artificial targets in a single test site for HR sensor comprehensive calibration and data evaluation.



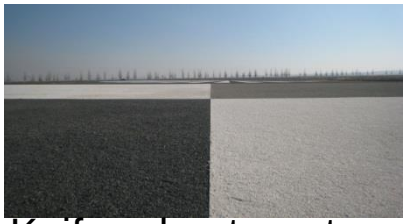
# Post-launch calibration requirements and Status

## Overview of Baotou Cal&Val site



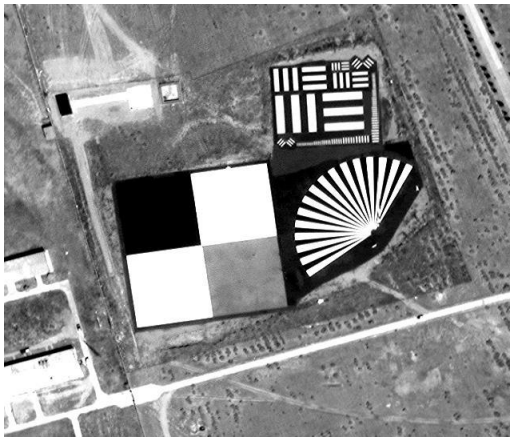
# Post-launch calibration requirements and Status

- **Case 1. SV-1 image quality assessment using integrated targets**

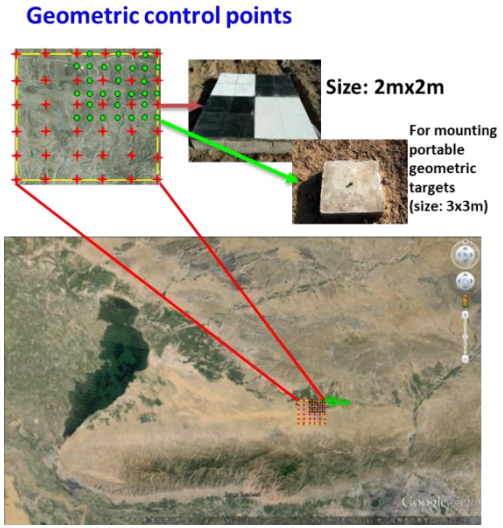


Knife-edge target

Fan-shaped target



SV-1 PAN



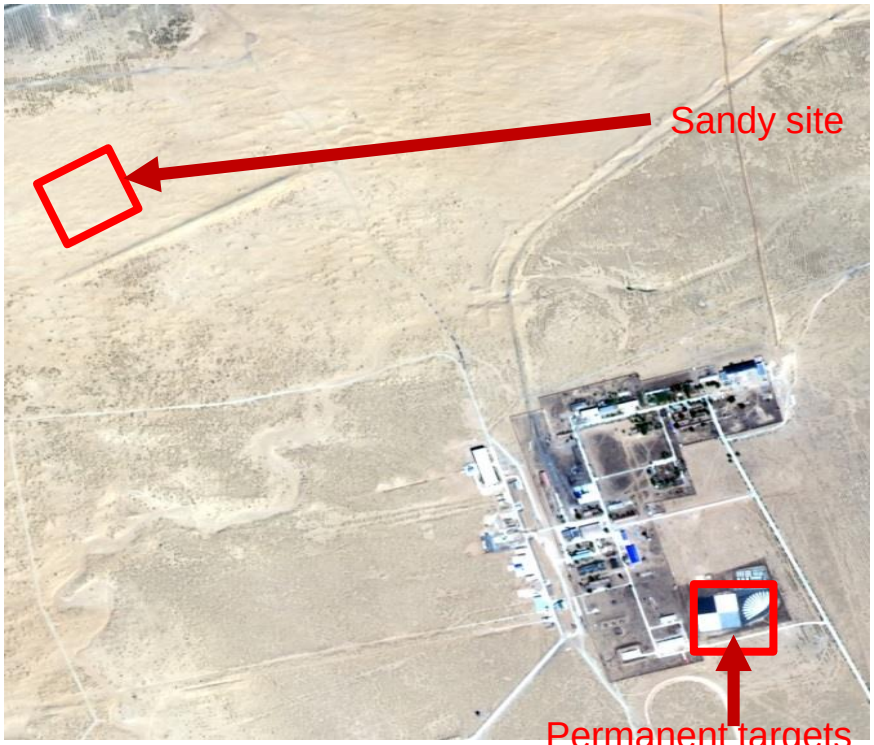

| Image quality evaluation index | On-orbit test results | |
|---|---|---|
| | Bands | Results |
| GSD | Pan | 0.58m |
| Positioning accuracy | Pan | 7.6 m |
| Internal geometric accuracy | Pan | 1.1m |
| Registration accuracy of Pan and MUX images | Pan/MUX | 0.15 pixel |
| Registration accuracy of MUX images | MUX | 0.14 pixel |
| MTF@Nyquist | X-axis | 0.105 |
| | Y-axis | 0 .093 |

# Post-launch calibration requirements and Status

## Case 2. Automatic calibration for various Chinese HR satellites

- In Baotou site, there are complete instrument system for surface spectral feature measurement and atmospheric parameter automatic measurement.
- As one of the RadCalNet sites, automated radiometric calibration in Baotou site can capture opportunities at each time when satellite overpasses, if only the weather condition is good enough.

Equipments: Automatic spectral radiance measurement system, channel radiometer, automatic sunphotometer (CE318), automatic weather station, all-sky imager



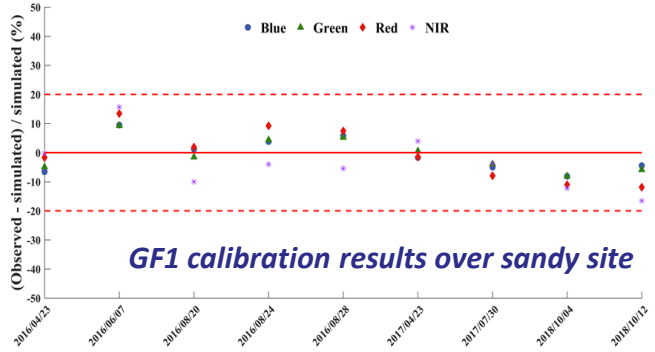

SV-01 MUX
(2018/5/2 12:03:54)

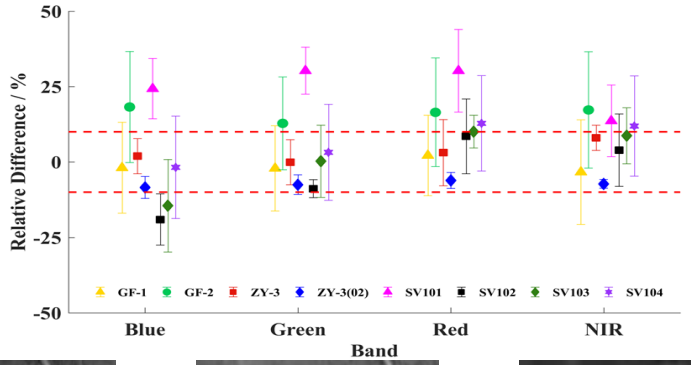
# Post-launch calibration requirements and Status

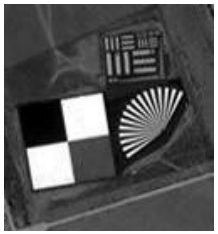
## Case 2. Automatic calibration for various Chinese HR satellites

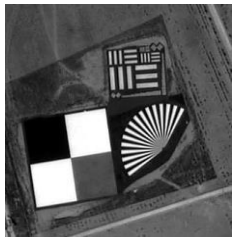
- Several management agencies of Chinese HR satellites are increasingly trying to use Baotou site to automatically calibrate their satellites. Totally 65 matchups have been acquired, including GF-1, GF-2, ZY3-01, ZY3-02, SV-1 01/02/03/04.

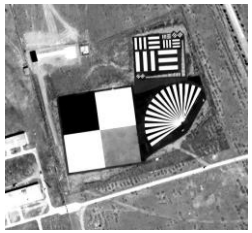
| Satellite | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| GF-1 | 04-23,06-07,08-20, 08-24,08-28,11-14, 11-30 | 04-23,07-30, 09-22 | 03-29, 04-23, 04-27, 10-04,10-12 | 05-09,05-13 |
| GF-2 | 04-22 | 03-28, 07-10, 09-07, 09-22 | 05-27,06-06,07-25 | 05-06,07-14 |
| ZY3 | 04-20,08-21,08-26 | 06-07, 06-12, 10-03, 12-01, 12-06 | 05-27,06-01, 06-06,,09-22 | 07-14 |
| ZY3-02 | 07-20 | 05-06,05-11,05-16 | | 07-20 |
| SV-101 | | | 05-15,08-15,09-22,09-29 | |
| SV-102 | | | 05-02, 05-17,08-09,09-23 | 06-11 |
| SV-103 | | | 04-28,09-20 | 06-09 |
| SV-104 | | | 05-02,08-09,09-23 | 06-05 |





GF-1 Pan
2018/4/23


GF-2 Pan
2018/5/27


SV-1 Pan
2018/5/2


SV-1 Pan
2018/5/2


ZY-3 Pan
2018/5/27


ZY-02C Pan
2017/4/13

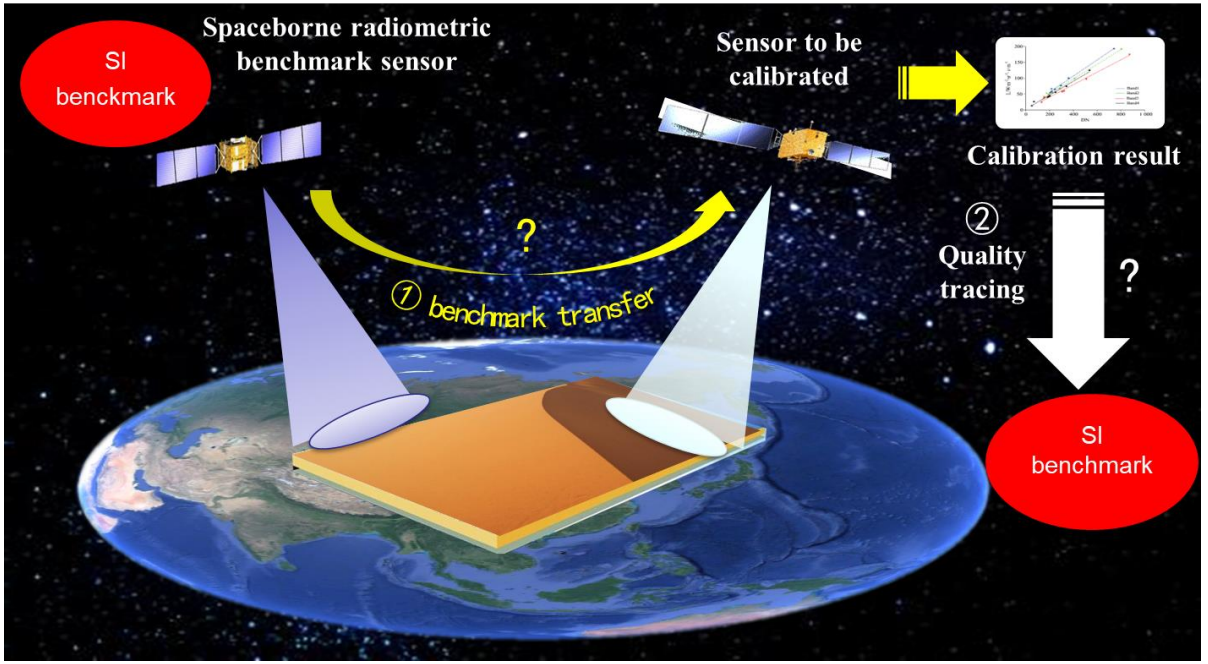
# Exploration of Inter-calibration of HR satellite sensors based on RadCalNet sites

## General ideas

- The high resolution satellite has long revisit period and narrow swath. So, it's very hard to get enough inter-calibration opportunities with the strict matching constraints of the SNO method.
- The RadCalNet sites provides user with SI-traceable BOA and TOA spectrally-resolved reflectance product and atmospheric parameters. It may be proper to act as calibration transferrers for high-medium resolution satellite.

## Two main tasks:

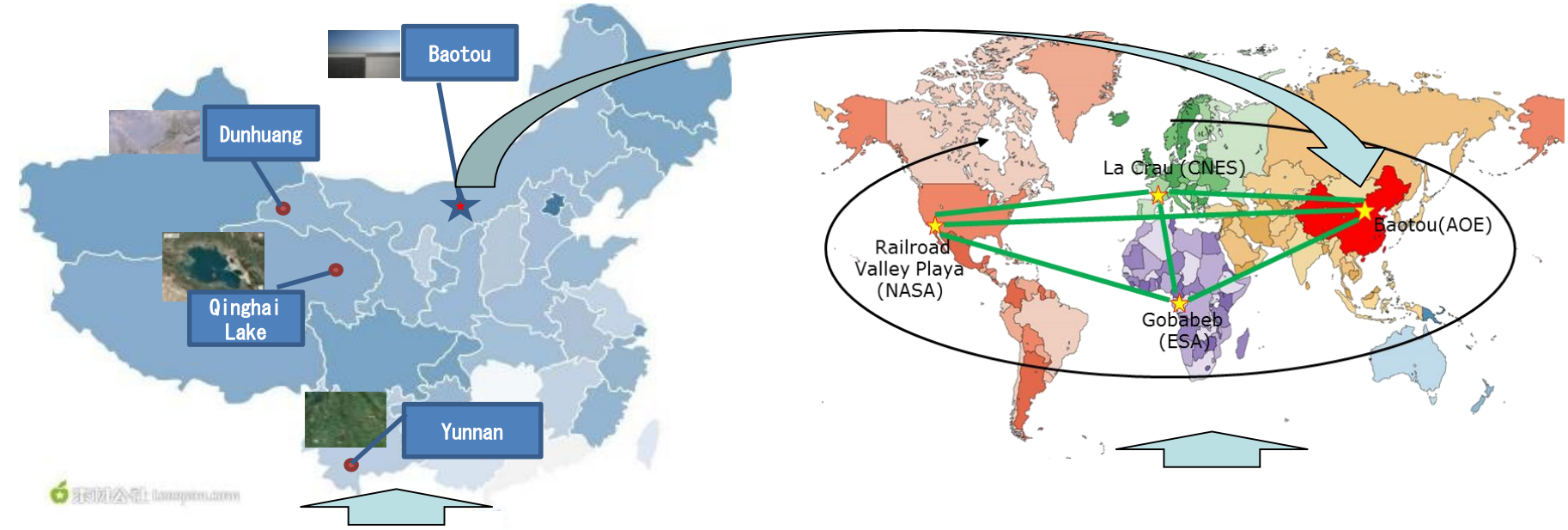
- ✓ Construct more automatic calibration sites to add more calibration transfer references.
- ✓ Develop a new inter-calibration algorithm based on RadCalNet sites.



# Exploration of Inter-calibration of HR satellite sensors based on RadCalNet sites

## 1. Construct China calibration network with Baotou site as a core node

- China is constructing a radiometric calibration network.
- The Baotou site will play a role as its core node, since it is already an RadCalNet site. Other sites in the China network will reference the measurement standards and data processing standards used in Baotou site.




NIM SI (China) ⟷ NPL SI (U.K.)

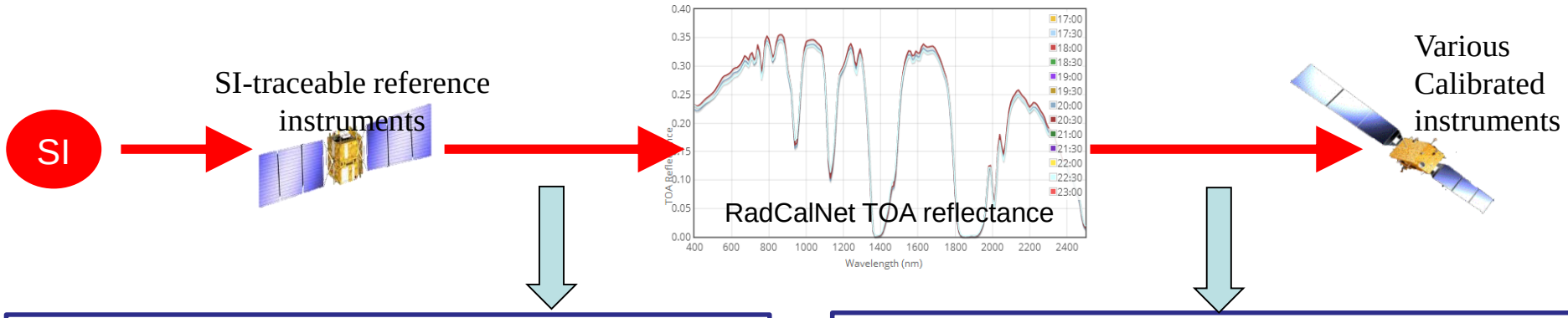
National Space Infrastructure Project
“Chinese radiometric calibration network”

WGCV automated radiometric calibration network（RadCalNet）

# Exploration of Inter-calibration of HR satellite sensors based on RadCalNet sites

## 2. Inter-calibration based on RadCalNet sites as calibration transfer targets

Benchmark transfer chain: SI-traceable reference instrument->RadCalNet TOA reflectance->Calibrated instruments




Step1: The SI-traceable spaceborne reference instruments are used to calibrate the RadCalNet TOA reflectance.

- ✓ The correction relationship between the reference satellite observation and the RadCalNet TOA reflectance is established by using a large number of observation data of the reference satellite

$$\rho_{RadCalNet}^{TOA} = f(\rho_{ref}^{TOA}, \theta_s, AOT, WVC...)$$

Step2: The calibrated RadCalNet TOA reflectance will be used to calibrate the sensors onboard other satellites.

- ✓ The RadCalNet TOA reflectance at the calibrated satellite overpass time is corrected based on the established relationship.
- ✓ Then, the sensors onboard other satellites are calibrated by corrected RadCalNet TOA reflectance.

$$gain = T(\rho'^{TOA}_{RadCalNet}, DN_{obs}^{cal})$$

# Exploration of Inter-calibration of HR satellite sensors based on RadCalNet sites

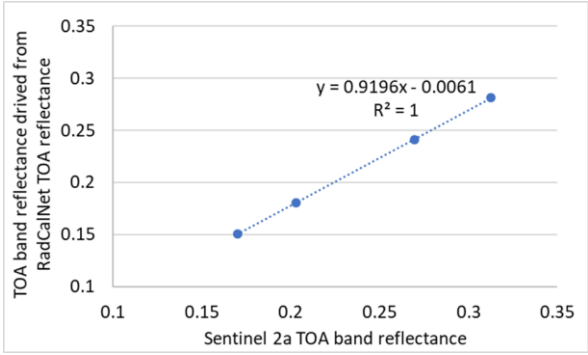
## 2. Inter-calibration based on RadCalNet sites as calibration transfer targets

### Preliminary results

Sentinel-2a/MSI was used as reference sensor, and the SV1-01/MUX sensor was calibrated based on the above method and the RadCalNet TOA reflectance of the Baotou sandy site.

SV1-01/MUX
2018/9/29 11:50:30

✓ The correction equation was established using Sentinel-2a TOA reflectance of B2, B3, B4, B8a, and the corresponding band TOA reflectance simulated by RadCalNet TOA reflectance product on 2018/9/29.




The correction equation

Sentinel-2a/MSI
2018/9/29 11:19:47

✓ The equation was used to correct the RadCalNet TOA reflectance of SV1-01 satellite at overpass time. The corrected TOA reflectance was used to calibrate the SV1-01/MUX sensor.

| | Official gains | Cross-calibration gains | Relative difference |
|---|---|---|---|
| Blue | 0.1435 | 0.1435 | -0.01% |
| Green | 0.1138 | 0.1295 | 13.75% |
| Red | 0.1082 | 0.1235 | 14.13% |
| NIR | 0.0807 | 0.0790 | -2.05% |

The Inter-calibration gains

# Summary

(1) China had more than 20 HR satellites in orbit, and more than 40 HR satellite payloads are planned to be launched in the future. At present, China's HR satellite calibration mainly depends on vicarious calibration.

(2) Baotou site, which has been included in RadCalNet, not only provides on-orbit performance assessment for China's multiple series of HR satellites, but also helps to ensure the consistency between Chinese and international satellites. China is establishing several other automatic radiometric calibration sites using Baotou site as reference.

(3) Considering the characteristics of high-resolution satellite, the method of spaceborne benchmark transfer calibration based on RadCalNet sites was explored. It is hoped that through further international cooperation, the accuracy consistency and calibration frequency of China's high-resolution satellite radiometric calibration can be improved.


Thank you !