RADI
Institute of Remote Sensing and Digital Earth
Chinese Academy of Sciences

Recent Advances in Chinese Spaceborne Hyperspectral Missions

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28-July-2015

OUTLINE

- Introduction
- Review of current sensors in China
- Ongoing and future missions in China
- Pre-measure for upcoming missions
- Conclusions

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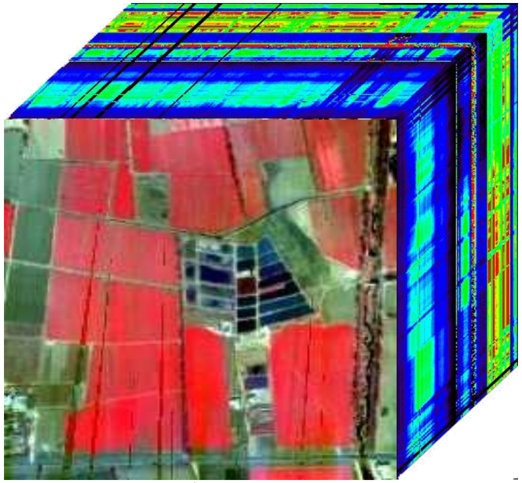
Introduction

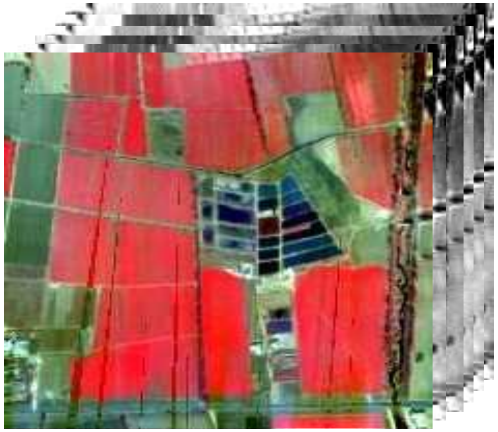
Conception of HRS

From Panchromatic to Hyperspectral—Increasing the Spectral Resolution

Hyperspectral



Multispectral



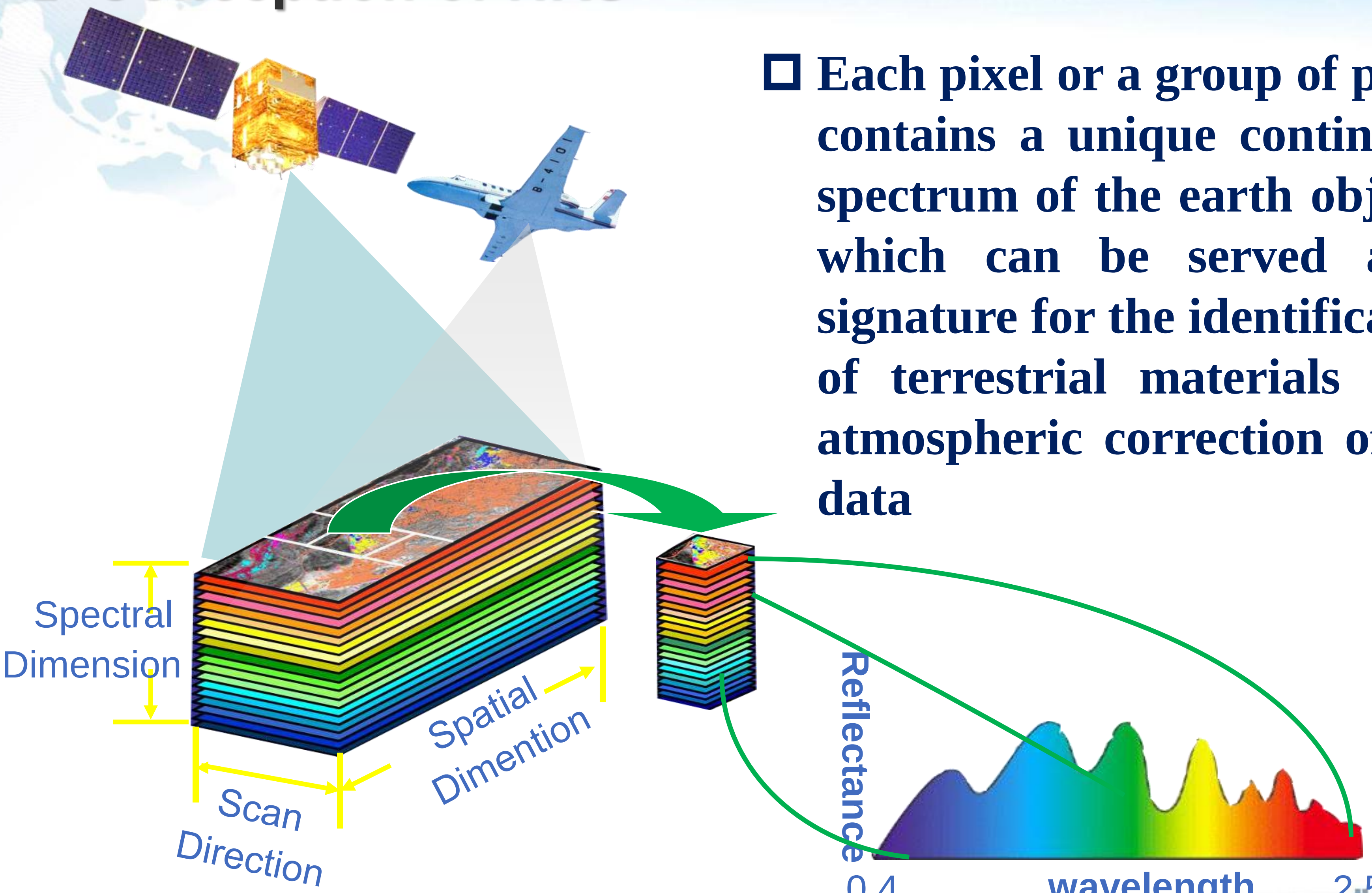
Color photography

When the spectral Resolution reached higher than λ/100 the Optical Remote Sensing can be Considered as **Hyperspectral Remote Sensing**

Introduction

Conception of HRS

- Each pixel or a group of pixels contains a unique continuous spectrum of the earth objects, which can be served as a signature for the identification of terrestrial materials after atmospheric correction of the data



Introduction

Progress of HRS

7 June 1985, Volume 228, Number 4704

SCIENCE

Imaging Spectrometry for Earth Remote Sensing

Alexander F. H. Goetz, Gregg Vane, Jerry E. Solomon, Barrett N. Rock

Alexander F. H. Goetz, et.al. *SCIENCE*, 1985

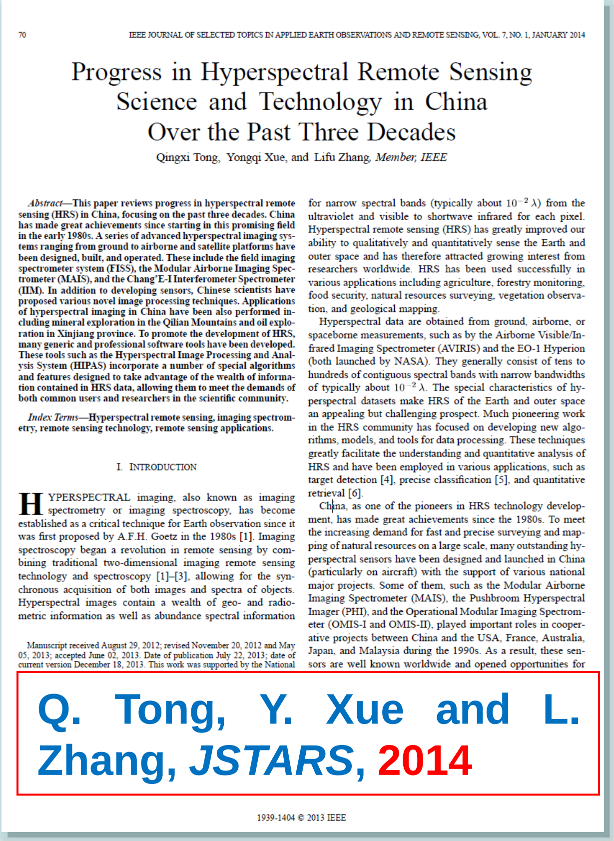
Remote Sensing of Environment 113 (2009) S5–S16

Remote Sensing of Environment

Three decades of hyperspectral remote sensing of the Earth: A personal view

Alexander F. H. Goetz

Alexander F. H. Goetz. *RSE*, 2009



IEEE JOURNAL OF SELECTED TOPICS IN APPLIED EARTH OBSERVATIONS AND REMOTE SENSING, VOL. 7, NO. 1, JANUARY 2014

Progress in Hyperspectral Remote Sensing Science and Technology in China Over the Past Three Decades

Qingxi Tong, Yongqi Xue, and Lifu Zhang, *Member, IEEE*

Q. Tong, Y. Xue and L. Zhang, *JSTARS*, 2014

First paper of HRS

Three decades of HRS

Three decades of HRS in China

OUTLINE

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Review of current sensors in China

Overview

Spaceborne Hyperspectral Imaging Sensor

Sensor	Spectral Coverage /μm	Spectral Res. /nm	No. of Bands	Available Date
CMODIS	0.4-12.5	20	34	2002
HJ-1A HSI	0.45–0.95	5	115	2008
FY-3 MERSI	0.44–0.89 0.39–1.04 1.62-2.15 10-12.5	50 20 50 2500	5 12 2 1	2008
Chang'E-1 IIM	0.48-0.96	15	32	2009
TG-1 HSI	0.40-1.0 1.0-2.5	10 23	128	2011

Review of current sensors in China

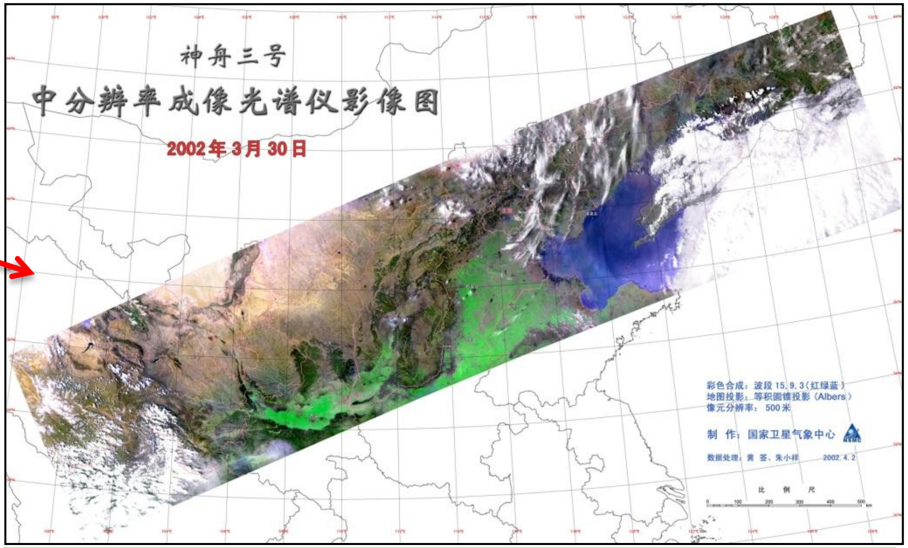
CMODIS: first satellite hyperspectral imager

"SHENZHOU-3"(SZ-3) – A China's Spaceship

Launched in 25th March,2002

- No. bands: 34, Include:
- Visible: 20 (20nm, from 412 nm)
- NIR: 10 (20nm, from 822 nm)
- SWIR: 1 (2.150-2.250 µm)
- TIR: 3

(8.40-8.90,10.30-11.30 µm,11.50-12.50 µm）

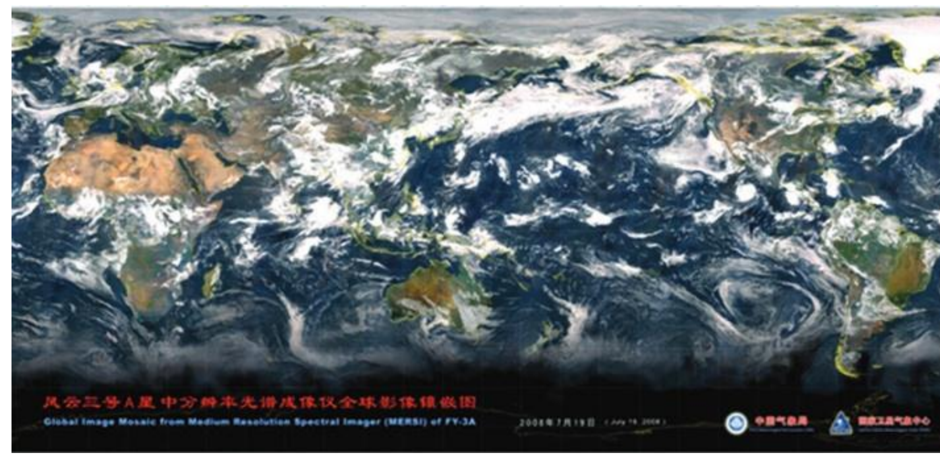


A typical CMODIS image

Review of current sensors in China

MERSI/ FY-3A

Launched in 2008



A global image mosaic from MERSI with natural color and resolution of 3 km

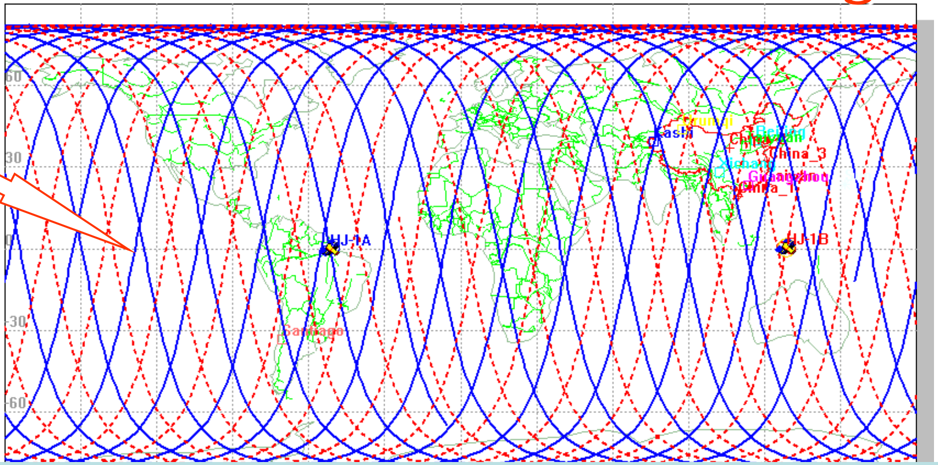
(Courtesy: Chaohua Dong *et al*.)

Spec.Range: 0.4-12.5um
Number of Bands: 20
Spatial Resolution: 0.25-1km
Scanning range: ±55.4°
Quantization: 12 bit
Radiometric calibration Accu. <7%
Assembling two onboard calibration systems

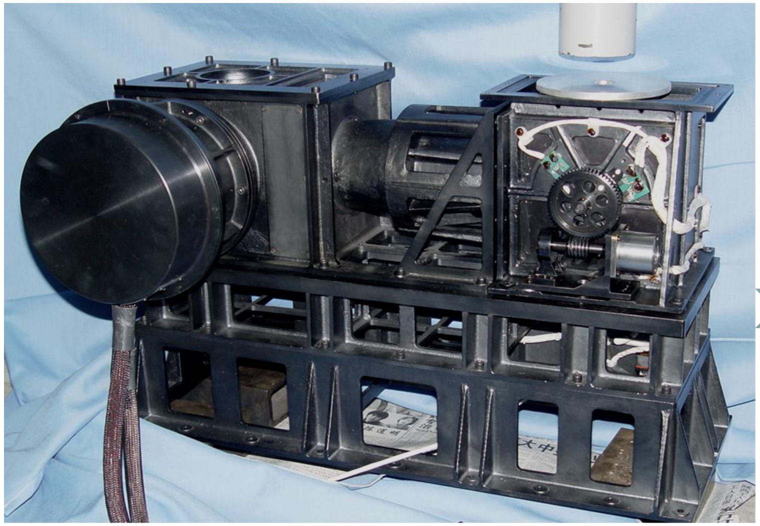
Review of current sensors in China

HJ-1A HSI

A Constellation of 2 Small Satellites (HJ-1) was launched in Sept. 6, 2008 for Environment and Disasters Monitoring



One of the Main Payloads on Board of the Satellite is a VIS-NIR Imaging Spectrometer (HSI)

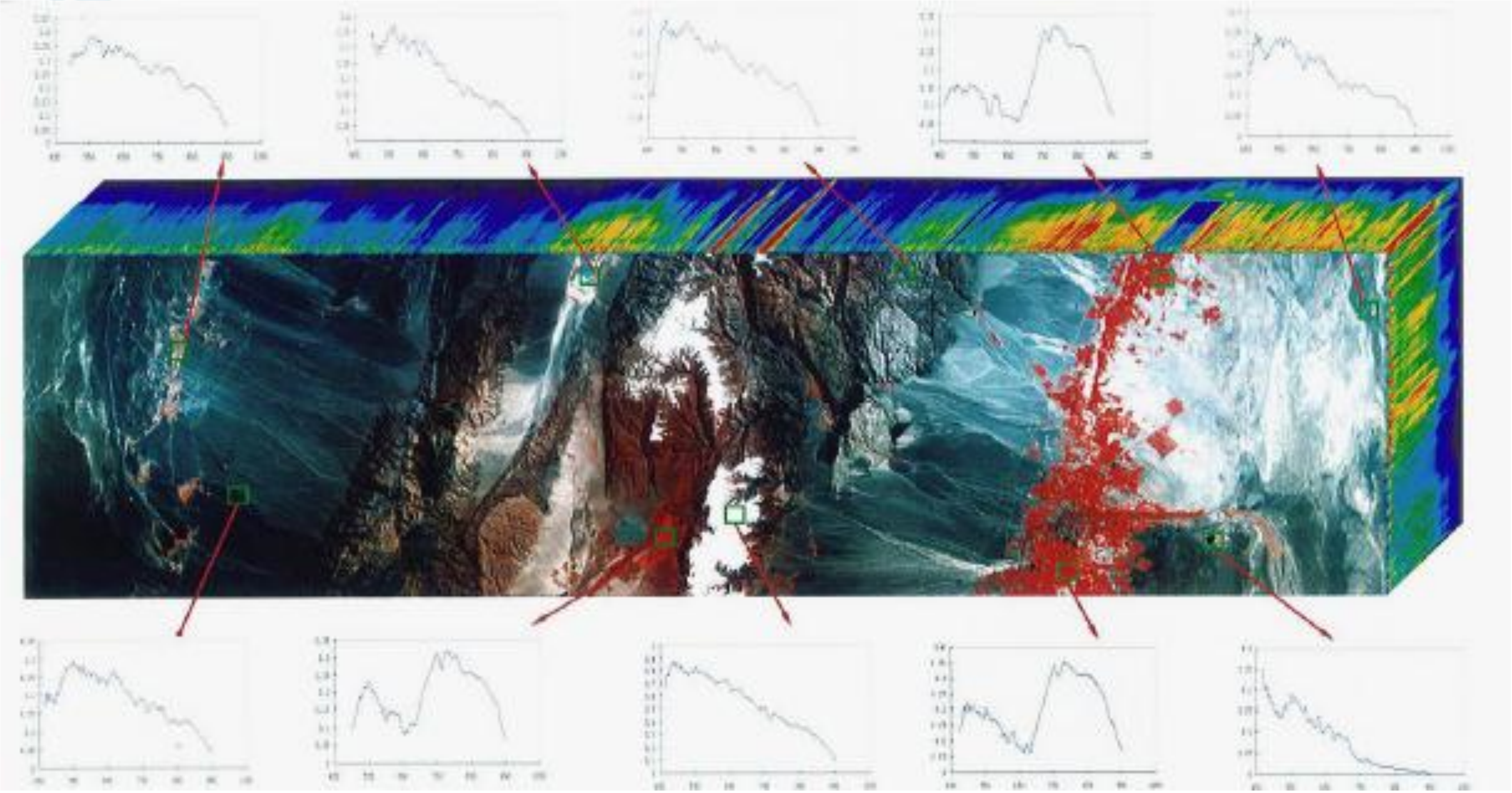


Spec.Range: 450nm-900nm
Number of Bands: 115
Spatial Resolution: 100m
Ground Coverage: 50km
Side Looking： ±30°
Revisit： 4-31days

Review of current sensors in China

HJ-1A HSI

A typical Image Cube from HJ-1 Satellite



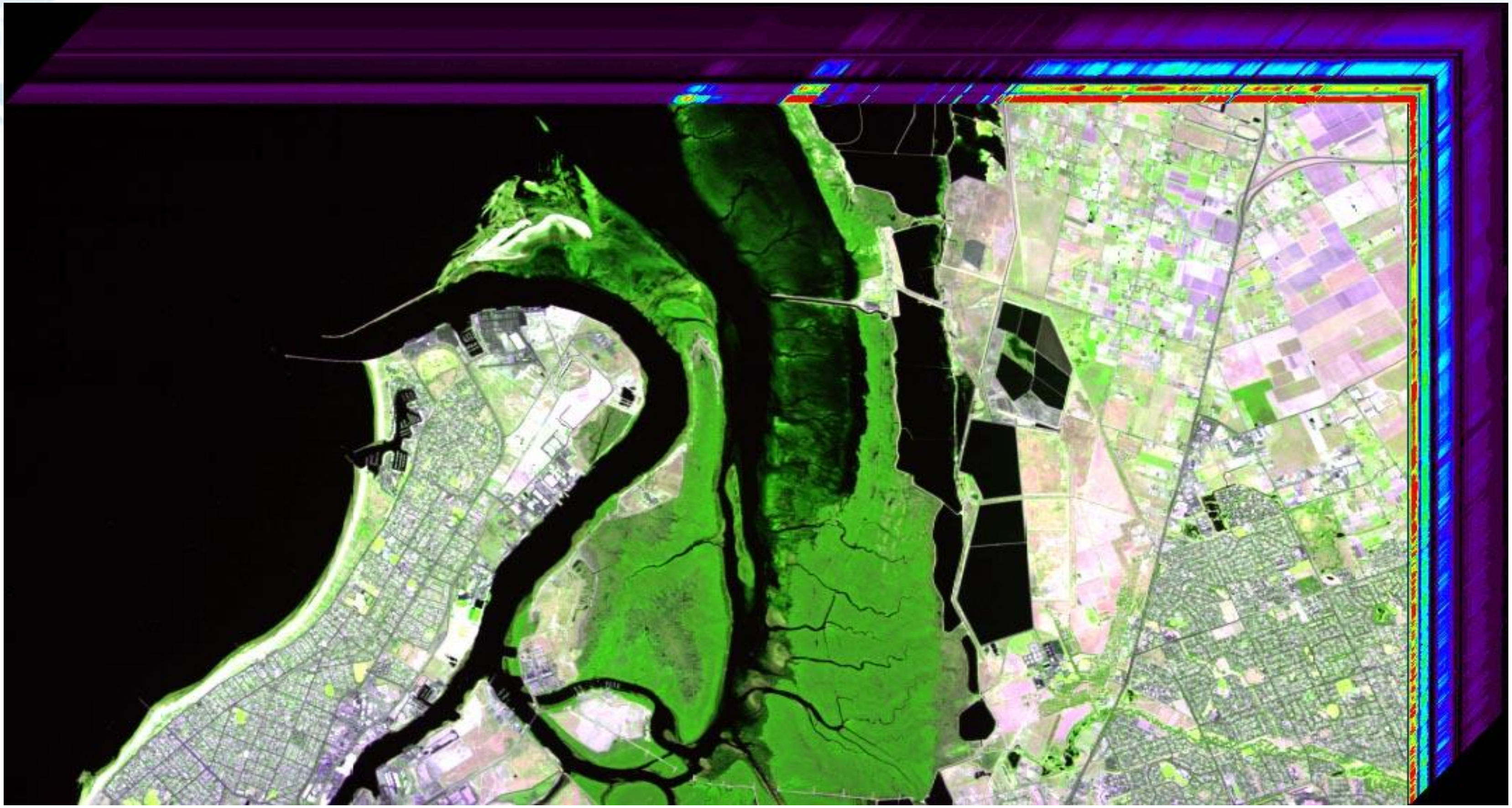
Review of current sensors in China

TG-1 HSI: China's first target vehicle

Hyperspectral sensor

Spectral Coverage /nm	**400-2500**
Spectral Res. /nm	10/23
No. of Bands	128
MTF	0.34
Swath/km	10
SNR	180@1600nm

Review of current sensors in China



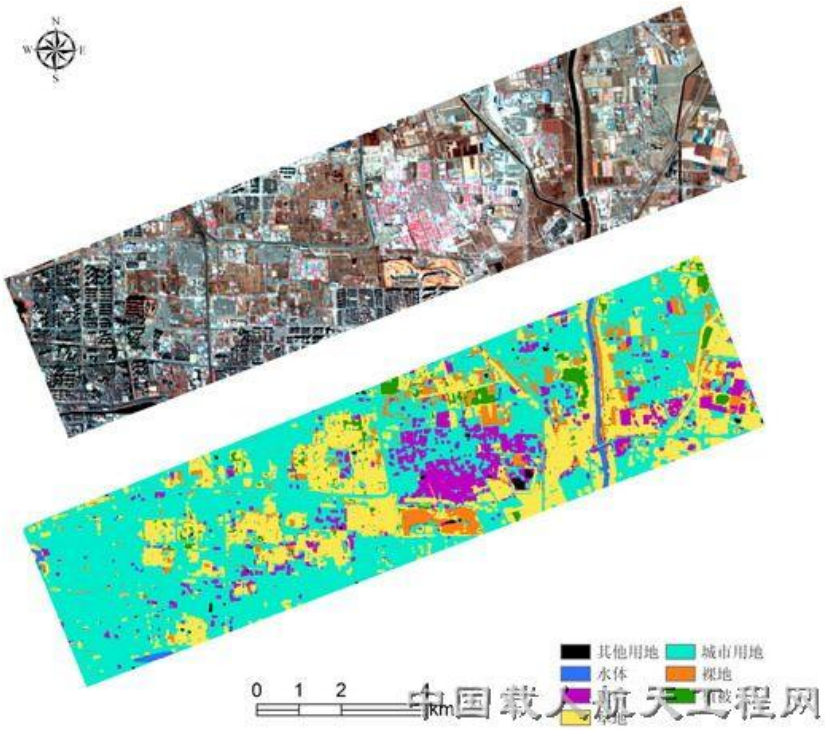
TG-1 Image, South Australia

Review of current sensors in China

TG-1 HSI: China’s first target vehicle

Qinghai, China

- Numerous applications have indicated that the TG-1 HSI has achieved high performance levels in spatial, spectral, and SNR (Signal to Noise Ratio).



Land use monitoring, Beijing, China

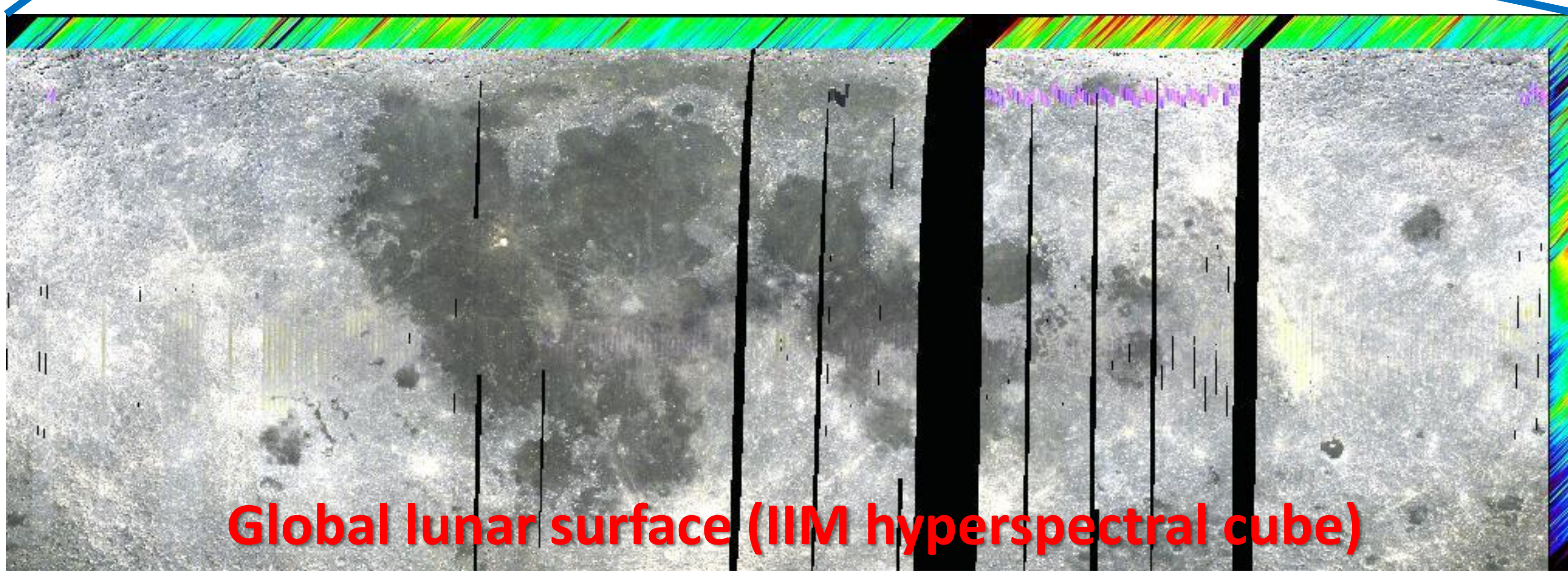
(China Manned Space Engineering)

Review of current sensors in China

Chang'E-1 IIM: for Lunar exploration

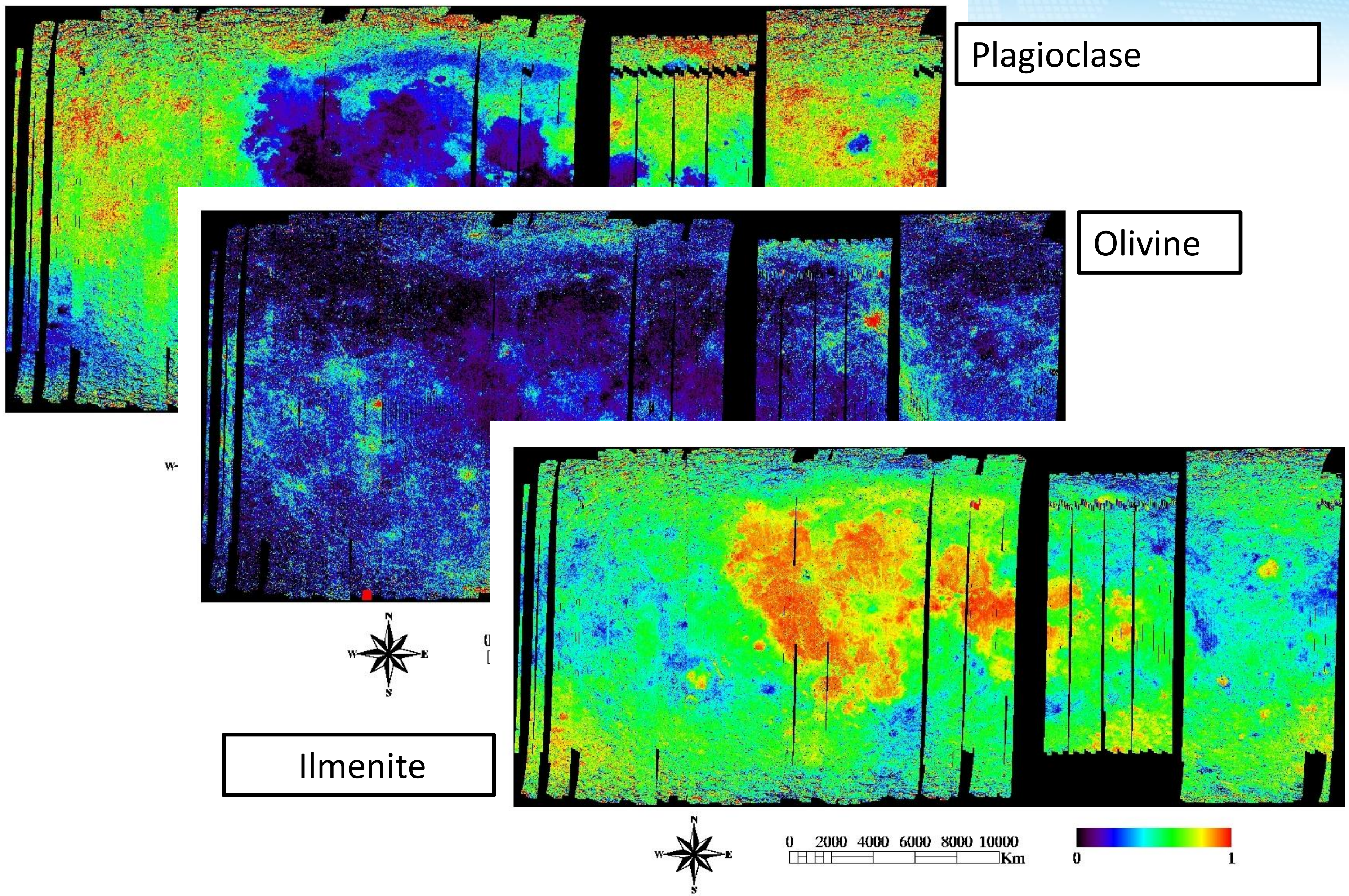
Width of Swath	25.6km
Spatial Resolution	200m
Imaging Region	75° N~75° S
Spectral Range	480~960nm
Spectral Bands	32
Digitazation	12bit
MTF	≥0.2

24-Oct-2007



Global lunar surface (IIM hyperspectral cube)

Abundance Analyses Map of Some Lunar Minerals



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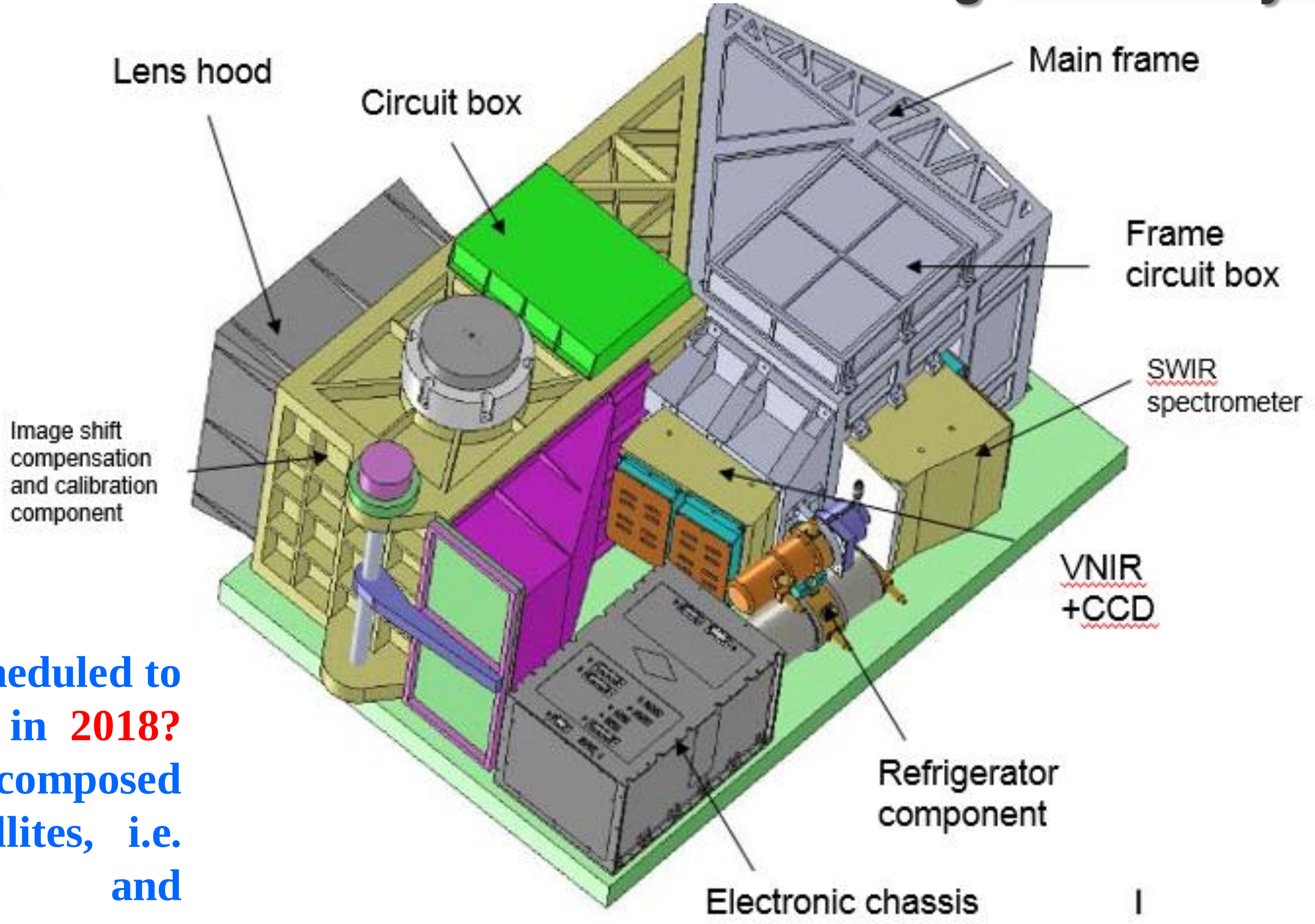
Ongoing & future missions in China

CCRSS: China Commercial Remote-sensing Satellite System

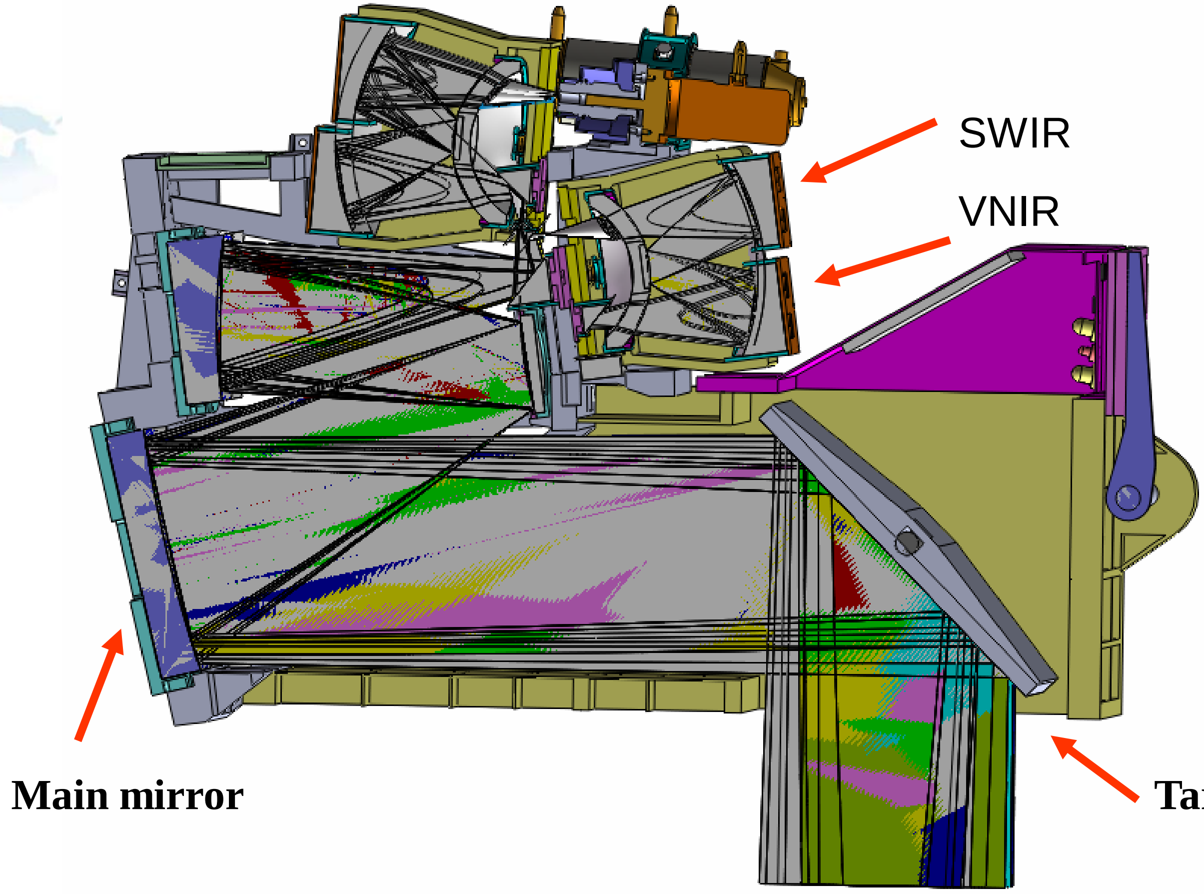


- CCRSS is scheduled to be launched in **2018? (TBD)**. It is composed of two satellites, i.e. **CCRSS-A** and CCRSS-B.

Framework of CCRSS-A

Ongoing & future missions in China

- **CCRSS:** China Commercial Remote-sensing Satellite System



Optic figure of CCRSS-A

- CCRSS-A will provide commercially panchromatic/ multispectral imagery and hyperspectral imagery from visual to shortwave infrared.

Ongoing & future missions in China

CCRSS: China Commercial Remote-sensing Satellite System

Scheme & Para.	Scheme I	Scheme II	Scheme III	Scheme IV
	HRS	HRS+ Thermal infrared	HRS	HRS+ Thermal infrared
Spec. range	0.4-2.5μm	0.4-2.5μm 8.0-12.5μm	0.4-2.5μm	0.4-2.5μm 8.0-12.5μm
No. bands	328	328+2~5	328	328+2~5
Swath	40km	30 km	30 km	30 km
Spatial Res.	30m	30/60m	15m	15/30
Aperture	180mm	135mm	300mm	300mm
Volume	1020*980*550mm	1150*1000*500mm	1600*1100*800mm	1600*1200*700mm
Weight	147kg	187 kg	260 kg	300 kg
Power	260W	360 W	300 W	400 W
Budget	170 million	220 million	180 million	230 million
Period	2.5 years	3.5 years	2.5 years	3.5 years

Ongoing & future missions in China

- GF-series: high-resolution satellite program

GF-1 (2013)
- 2m/8m/16m

GF-2 (2014)
- 1m/4m

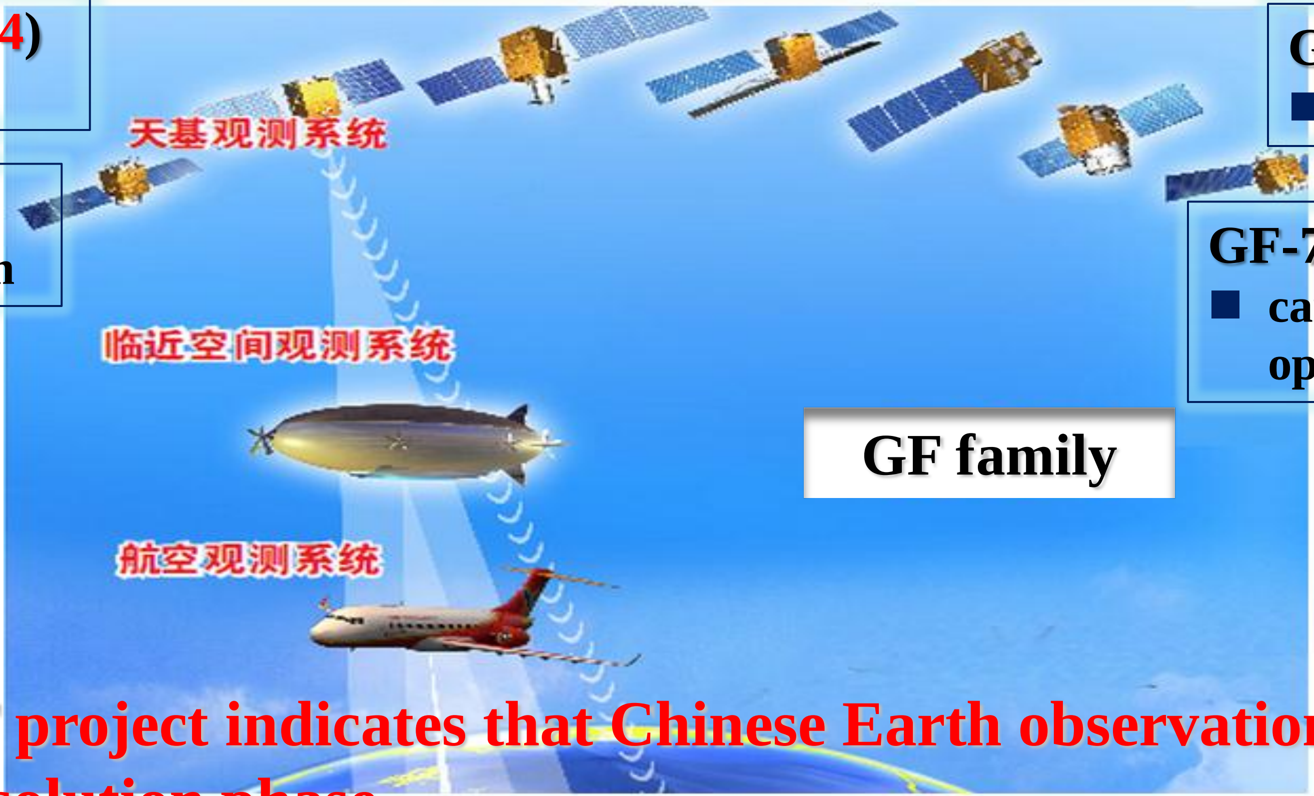
GF-3 (2016)
- CSAR

GF-4 (2015)
- 50m-geostationary

GF-5 (2016)
- HRS

GF-6 (2017)
- Like GF-1

GF-7 (2018)
- cartographic optical satellite



GF family

The GF project indicates that Chinese Earth observation enters high-resolution phase

Ongoing & future missions in China

- **GF-series: high-resolution satellite program**

http://www.sastind.gov.cn/n25770/

Heicheng, Hebei by GF-1, 2013

Ongoing & future missions in China

- **GF-series: high-resolution satellite program**

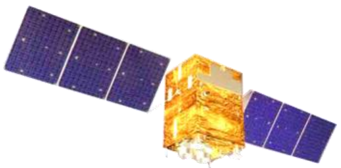
Beijing by GF-2, 2014

Shanghai by GF-2, 2014

Ongoing & future missions in China

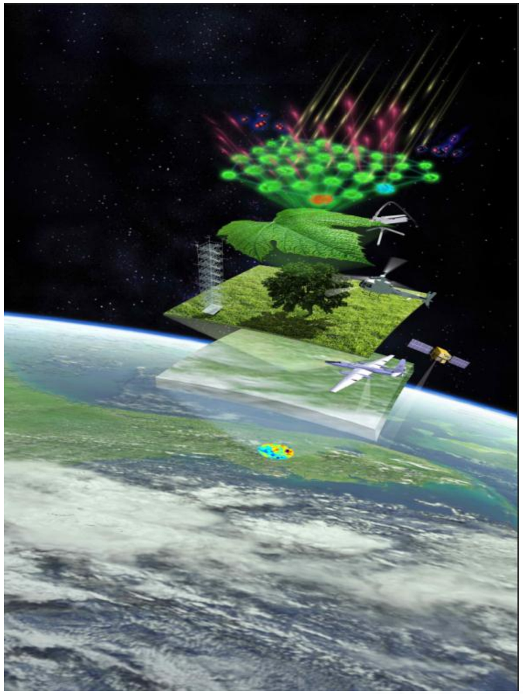
CarbonSat: Super-spectral spectrometer

Objective: Global carbon cycle monitoring by integrating vegetation reflectance and sun-induced fluorescence emission flux.



- **Launch date: 2018 (TBD)**
- **Spectral range: 670-780 nm**
- **FWHM: less than 0.3 nm**
- **SNR: 200-600**

Similar to ESA FLEX-FLORIS



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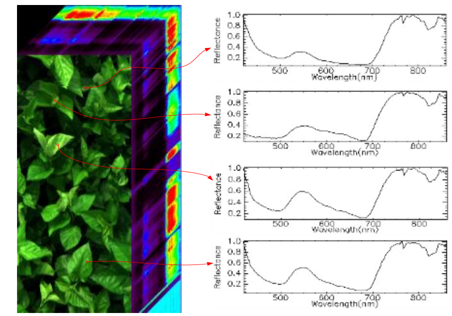
Pre-measure for upcoming missions

New instrument: Field Imaging Spectrometer System (FISS)

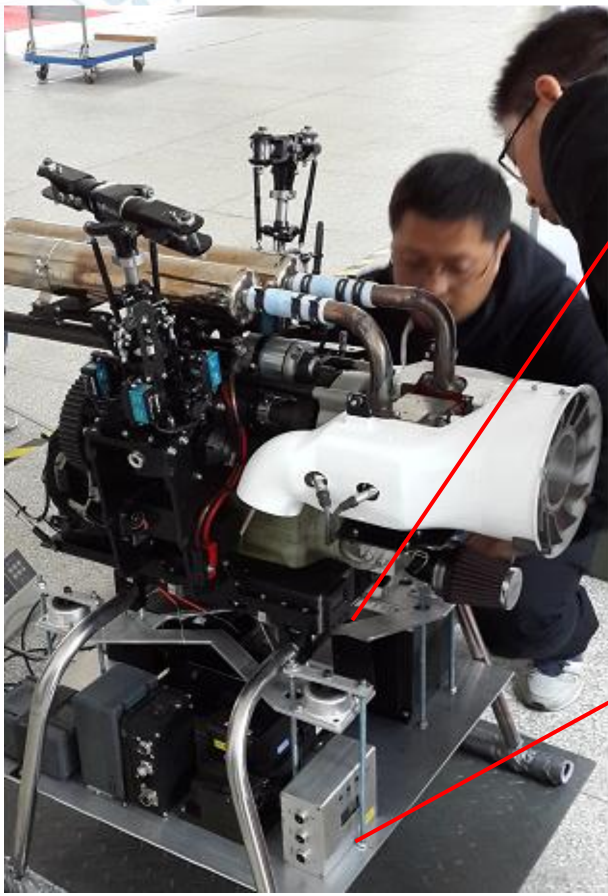


Number of bands	344	Imaging rate	Maximum 20 frames/s
Spectral range	437–902 nm	Scan field	–20° to +20°
Spectral resolution	Better than 5 nm	Quantitative value	12 bit
Spatial resolution	Maximum < 2 mm	Signal to noise ratio	>500 (60% bands)
Radiance calibration precision in laboratory	Better than 5%	Spectral sampling interval	About 1.4 nm

- **Field Imaging Spectrometer System was developed by IRSA (CAS) which is considered the first field imaging spectrometer in China.**

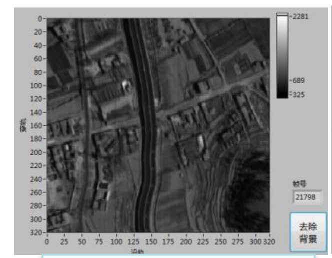
Pre-measure for upcoming missions

- **New instrument**: Light Weight airborne Imaging spectrometer remote sensing system

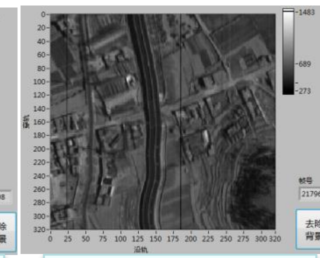


Spectral Interval	400–2500nm
weight	25kg
Visible - Near Infrared Imaging Spectrometer Shortwave Infrared Imaging Spectrometer PHASE ONE high resolution camera High accuracy IMU	

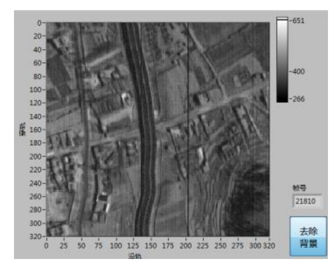
Spectral curve



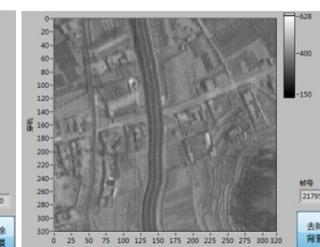
λ=2100nm



λ=2200nm



λ=2300nm

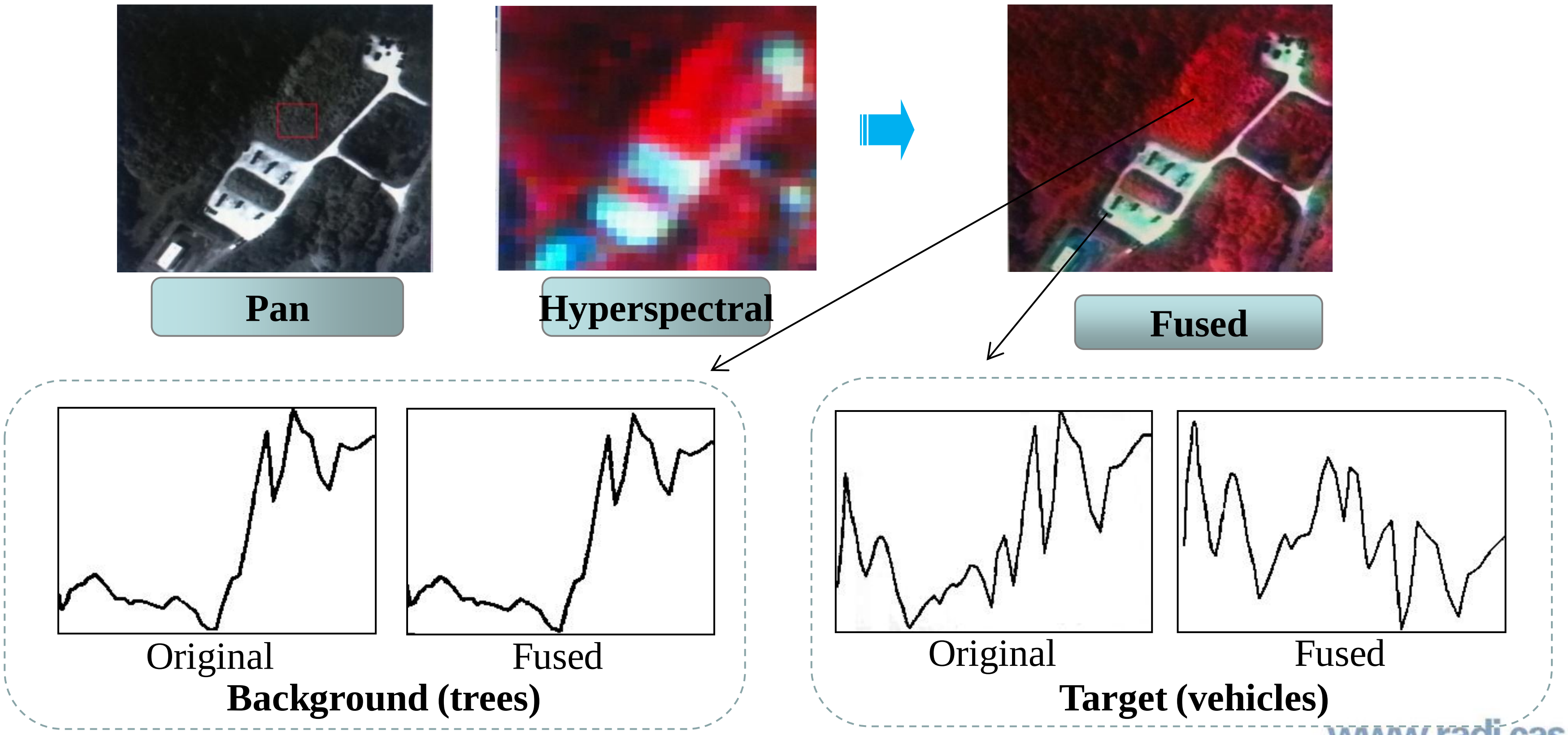


λ=2400nm

Pre-measure for upcoming missions

New techniques: Spatial and spectral information fusion

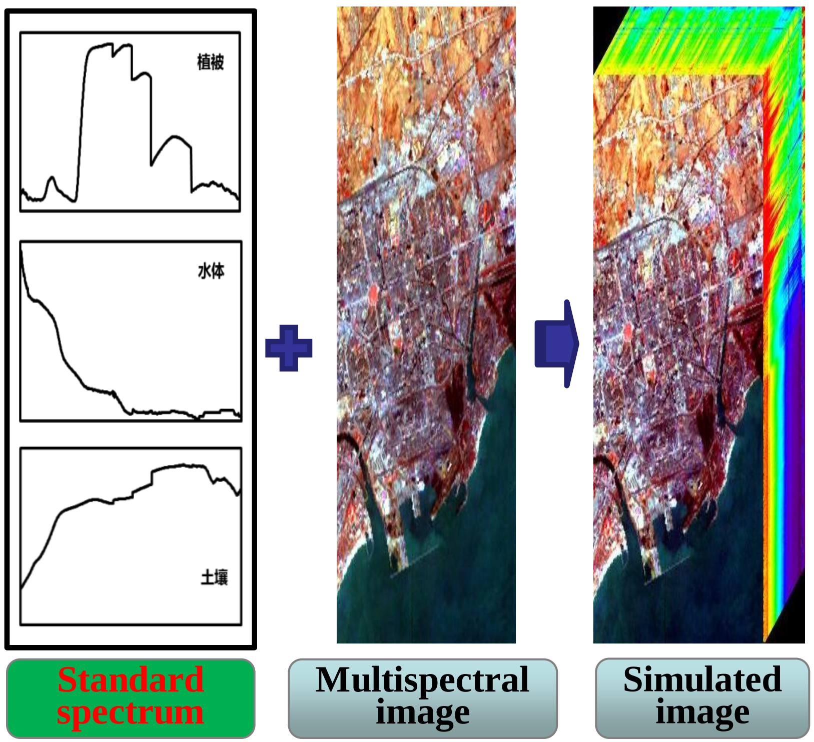
- Application of hyperspectral data fusion technology on TG-1 data for target detection and classification.
- Separability between target and background is enhanced.

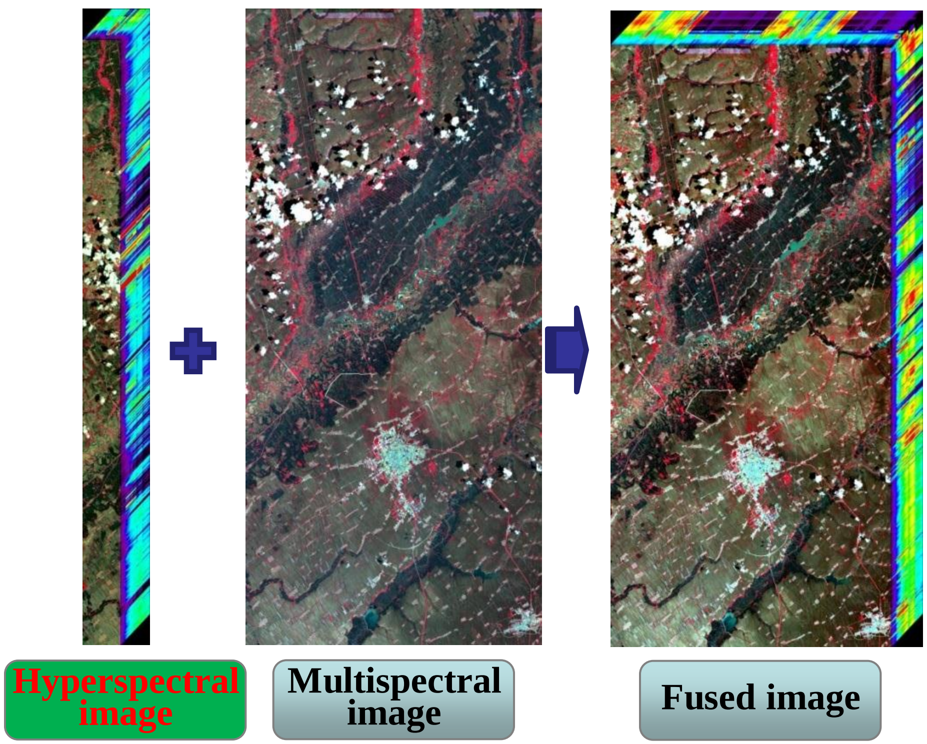


Pre-measure for upcoming missions

New techniques: Coverage area extending

- Research on hyperspectral image simulation based on standard spectrum
- Research on hyperspectral information extending on spatial dimension



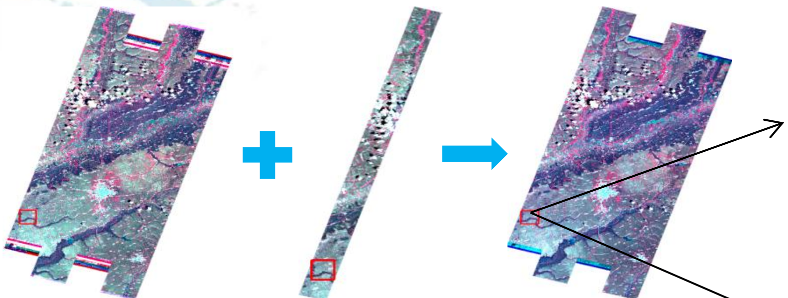


Liu, B., Zhang, L.F., Zhang, X., Zhang, B., & Tong, Q.X. (2009). Simulation of EO-1 Hyperion Data from ALI Multispectral Data Based on the Spectral Reconstruction Approach. ***Sensors***, *9*, 3090-3108

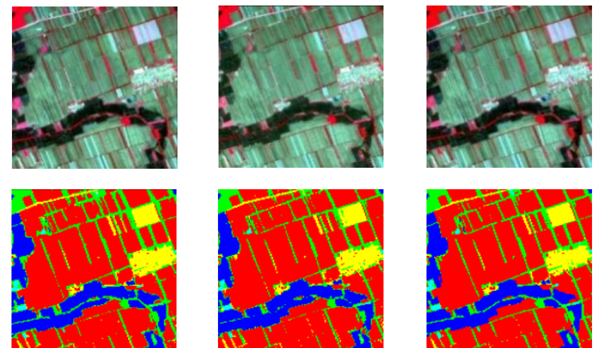
Pre-measure for upcoming missions

New techniques: Coverage area extending--results

Fusion results for visual interpretation and classification



Multispectral | Original hyperspectral | Fused hyperspectral

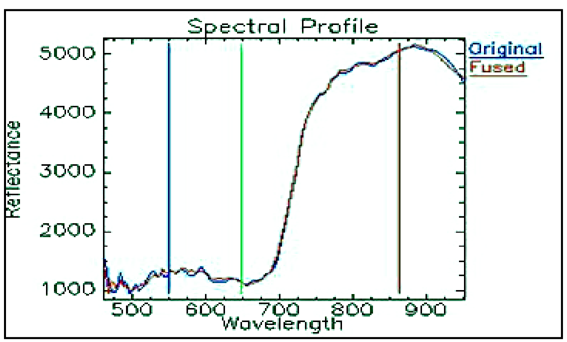


Visual interpretation

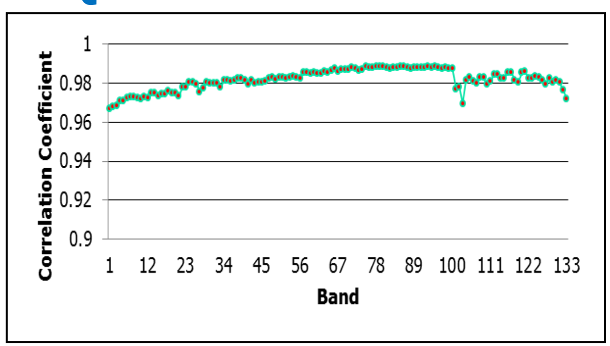
Classification

Multispectral | Original hyperspectral | Fused hyperspectral

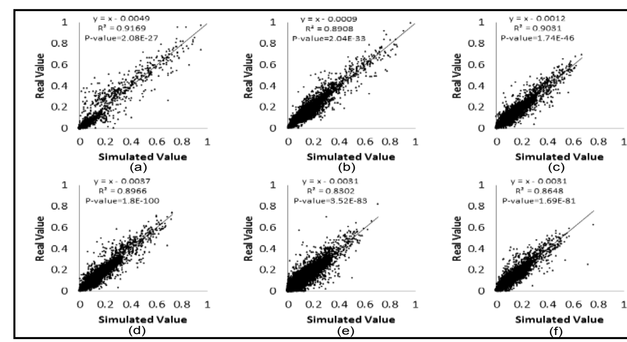
Quantitative assessment



Comparison of spectral curve



Correlation coefficients of each band



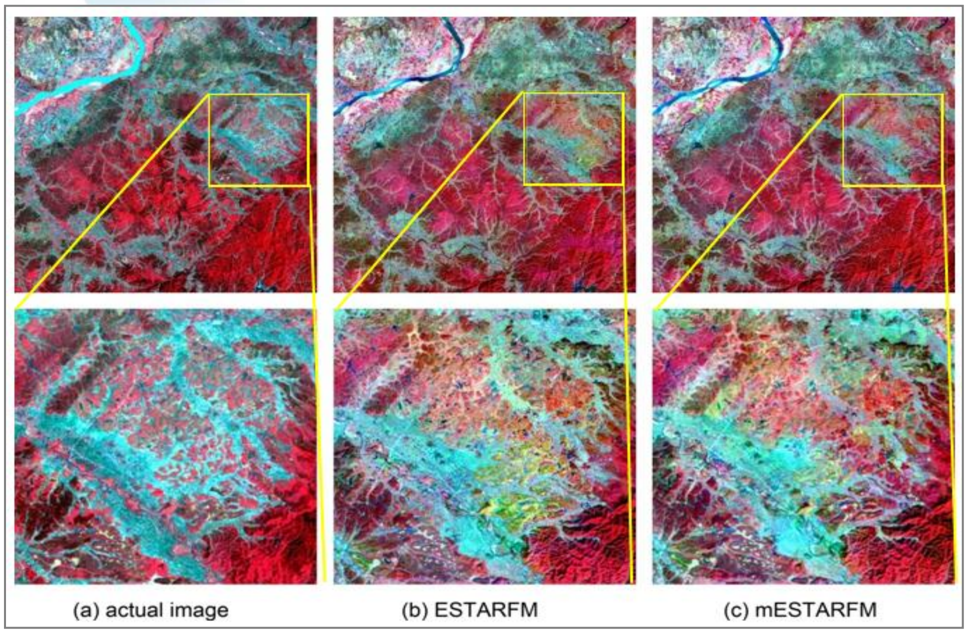
regression analysis

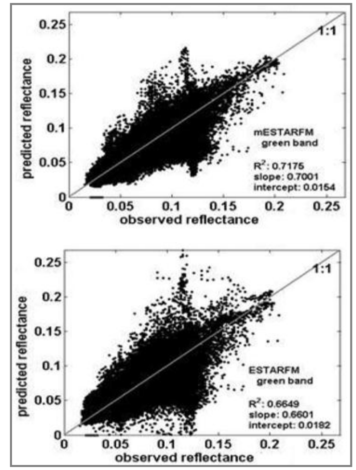
Sun X, Zhang L, Yang H, et al. Enhancement of Spectral Resolution for Remotely Sensed Multispectral Image[J]. ***IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing***, PP (99), 2014

Pre-measure for upcoming missions

New techniques: Spatial and temporal fusion

mESTARFM





Blending algorithms have been developed to enhance the temporal frequency of high spatial resolution data using high temporal medium resolution data (Emelyanova, McVicar, Van Niel, Li, & van Dijk, 2013; Fu, Chen, Wang, Zhu, & Hilker, 2013; Gao, Masek, Schwaller, & Hall, 2006; Gumma, Thenkabail, Hideto, et al., 2011; Zhu, Chen, Gao, Chen, & Masek, 2010). Emelyanova et al. (2013) tested these approaches in areas corresponding to IA1 (during a flooding episode) and IA 10 (during the peak irrigation-season) with good results (see Emelyanova et al.,

Fu, D., Chen, B., Wang, J., Zhu, X., & Hilker, T. (2013). An Impr oved Image Fusion Approach Based on Enhanced Spatial and Temporal the Adaptive Reflectance Fusion Model. ***Remote Sensing***, 5, 6346-6360

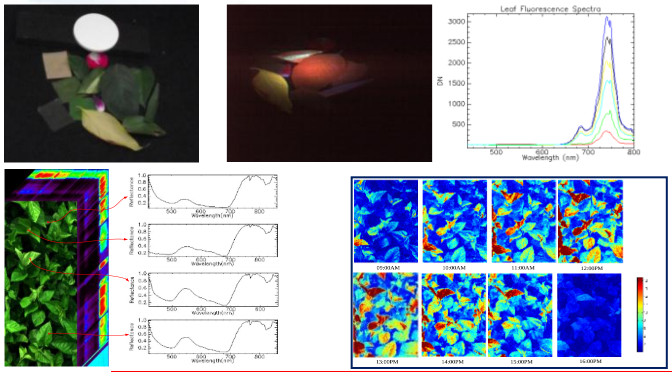
Pre-measure for upcoming missions

New techniques: Solar induced vegetation fluorescence remote sensing

(1) Fluorescence emission mechanism by FISS

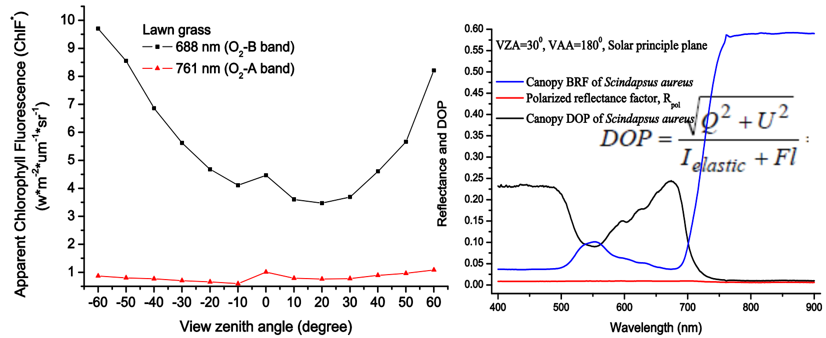
UV excited

Sun induced



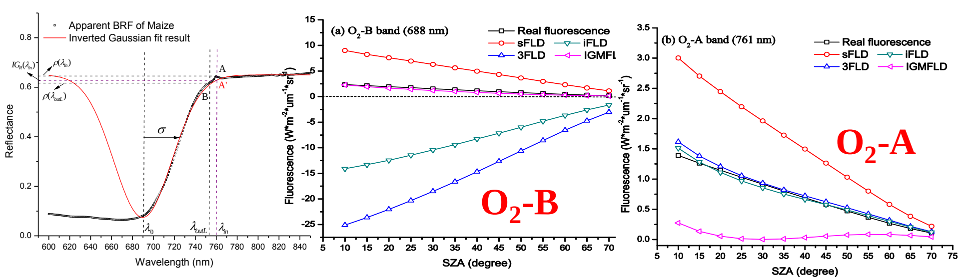
Huang C., Zhang L., et al., 2014

(2) Fluorescence characteristics investigation



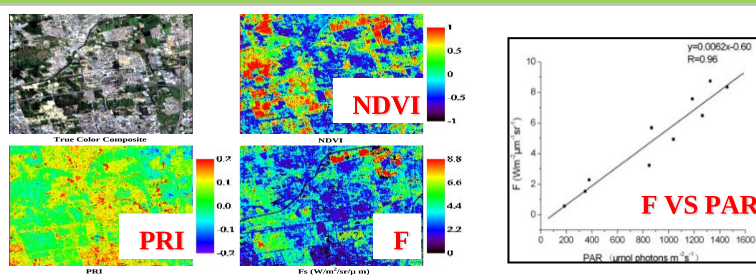
Huang C., Zhang L., et al. IGARSS, 2013

(3) SIF retrieval methods development



Huang C., Zhang L., et al. WHISPERS, 2015

(4) SIF retrieval from Hyperion satellite



Hu S. PhD thesis, 2013

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Conclusions

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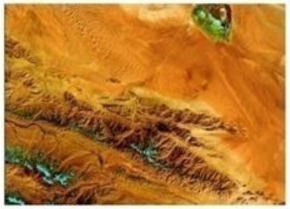
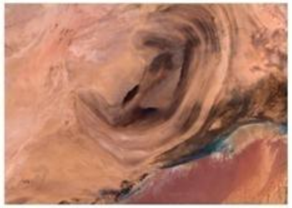
- We update recent advances and future plans in Chinese satellite hyperspectral missions, including
  - ✓ CCRSS: China Commercial Remote-sensing Satellite System
  - ✓ GF-serie satellites: high-resolution satellites (GF-1 to GF7)
  - ✓ CarbonSat: to detect sun induced vegetation fluorescence
- We introduce pre-measure for upcoming advanced missions, as
  - ✓ New instrument development: from field to UAV platforms
  - ✓ New techniques development: novel methods & algorithms
  - ✓ New software development: HyLab1.0 for HRS data

These pre-measure may improve data use efficiency of Chinese hyperspectral satellites, once they are launched and available.

Thanks!



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