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NEXT GENERATION HYPER RESOLUTION WIDE SWATH AND MULTI_CHANNEL OPTICAL PAYLOAD FOR CBERS SERIES

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I. INTRODUCTION

The China-Brazilian Earth Resources Satellite (CBERS) program, (also called ZY-1) the result of a space technology agreement between China and Brazil, was officially signed in 1988 after the first joint work report produced by National Institute for Space Research (INPE) and the Chinese Academy of Space Technology (CAST). During the 26 years of its existence, the program of cooperation between China and Brazil in space has achieved the successful launch of three satellites. It has become a unique example of cooperation in cutting edge technology between emerging nations. CBERS satellite is the first generation data-transferring remote sensing satellite developed by China. CBERS satellite data are widely applied to crop yield estimation, exploration of land and resources, urban planning, environmental protection and monitoring, disaster reduction, and other fields. CBERS series is just like Landsat series of USA and SPOT series of France.

CBERS 01/02 satellites are the first two satellites of the program. The two satellites are the same status. The CBERS 01 and CBERS 02 satellites were successfully launched on October 14, 1999, and on Oct.21, 2003 aboard the Long March 4B rocket. The instruments aboard the first two CBERS satellites are the CCD Camera, the Wide Field Imager (WFI) and the Infrared Multi-spectral Scanner (IRMSS). The CCD Camera is a charge coupled device instrument with 20 meters ground resolution and 5 spectral bands ranging from blue to near infrared. The WFI is an array detector device with 250 meters ground resolution and 2 bands centred in the red and the infrared channels. The IRMSS is a traditional scanner with 80 meters resolution in the PAN and the SWIR bands and 160 meters in the thermal band. Fig. 1 gives the modal of CBERS 01/02 and the image of CCD camera. Table 1 gives main payload parameters of CBERS 01/02 satellite.

Owing to the success of CBERS 01/02, the two governments decided, in November 2002, to give continuity the CBERS program by signing a new agreement for the development and launch of two more satellites, CBERS 03/04. The two countries agreed on the need to cover the gap that would be left between the end of 02 and the entry into operation of 03. It was necessary to guarantee the supply of data from the satellites. For this reason, CBERS 02B is to construct. CBERS 02B, still belonging to the first CBERS satellite generation is therefore almost identical to CBERS 01/02. The main improvement concerns the payload, with the replacement of the IRMSS imager by a High-Resolution Panchromatic Camera (HRC). The CBERS (02B) was successfully launched on September 19, 2007. Fig. 2 gives the modal and the image of CBERS 02B. Table 1 gives main payload parameters of CBERS 01/02 satellite.

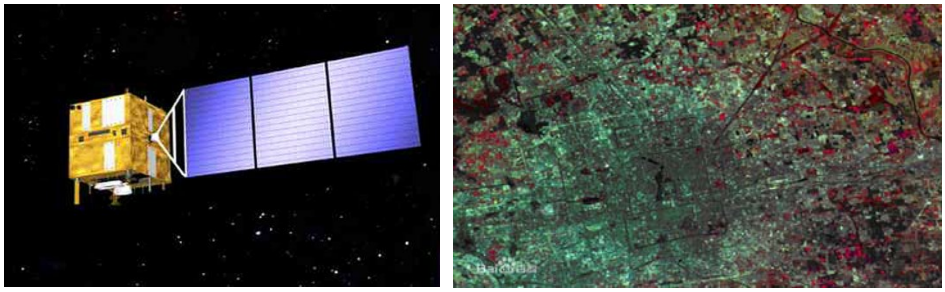

Fig. 1. CBERS 01/02satellite and The Beijing image of CCD camera

Table 1. Main Parameters of CBERS 01/02 Satellites

Payload	Band	Band /um	GSD/meter	Swath/Kilometre
CCD camera	B01	0.45-0.52	20	113
	B02	0.52-0.59		
	B03	0.63-0.69		
	B04	0.77-0.89		
	B05	0.51-0.73		
IRSMSS	B06	0.5-0.9	80	119.5
	B07	1.55-1.75		
	B08	2.08-2.35		
	B09	10.4-12.5	160	
WFI	B07	0.63-0.69	258	890
	B08	0.77-0.89		

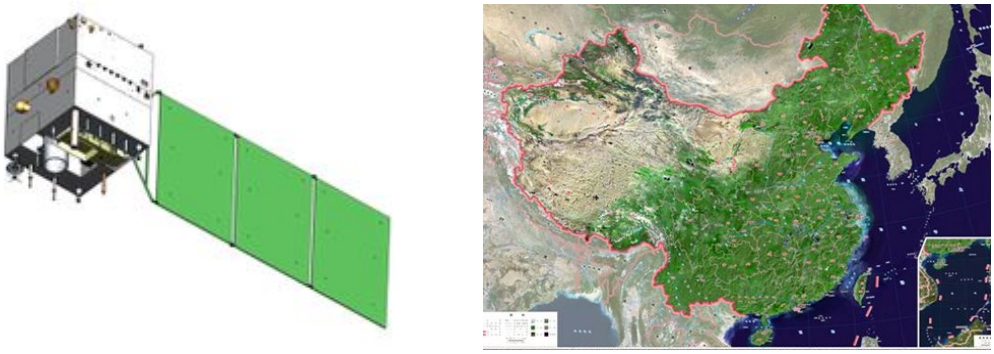

Fig. 2. CBERS 02B satellite and the China Map image of fusion of HRC and CCD camera

Table 2. Main Payload Parameters of CBERS 02B Satellite

Payload	Band	Band /um	GSD/meter	Swath/Kilometre
CCD Camera	B01	0.45-0.52	20	113
	B02	0.52-0.59		
	B03	0.63-0.69		
	B04	0.77-0.89		
	B05	0.51-0.73		
HR Camera	B06	0.5-0.8	2.36	27
WFI	B07	0.63-0.69	258	890

CBERS 03/04 was the next generation of CBERS program. The payloads have great improvements as to CBERS 01/02. CBERS 03 failed to enter the orbit in 2013 because of the rocket. CBERS 04 will be launched in 2014. Fig. 3 gives the modal of CBERS (03/04). Table 3 gives main payload parameters of CBERS 03/04 satellite.

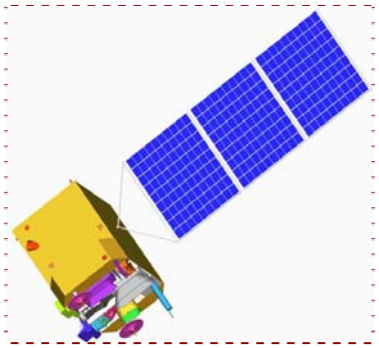

Fig. 3. CBERS 03/04 satellite

Table 3. Main Payload Parameters of CBERS 03/04 Satellite

Payload	Band	Band /um	GSD/meter	Swath/Kilometre
PAN Camera	B01	0.51-0.85	5	60
	B02	0.52-0.59	10	
	B03	0.63-0.69		
	B04	0.77-0.89		
IRS Camera	B09	0.43-1.05	40	120
	B10	1.5-1.8		
	B11	2.0-2.45		
	B12	9.8-13	80	
MUX Camera	B05	0.45-0.52	20	120
	B06	0.52-0.59		
	B07	0.63-0.69		
	B08	0.77-0.89		
WFI	B13	0.45-0.52	64	866
	B14	0.52-0.59		
	B15	0.63-0.69		
	B16	0.77-0.89		

After the launch of the CBERS 04, CBERS 05/06 is undergoing to plan. In order to improve the performance of the CBERS series satellite, a next generation hyper resolution wide swath and multi-channel optical payload is developed to overcome key technology.

II. DESIGN OVERVIEW OF THE HYPER RESOLUTION PAYLOAD

Table 4 gives the main parameters of the hyper resolution payload. The payload has two main improvements: more multi-spectral bands and wide swath. There are 1 panchromatic band and 8 multi-spectral bands and 1 short wave band. The swath is 118 km. As to the 2.5m GSD, it is the widest optical payload until now.

The camera concept is a push broom. According to the swath, the FOV should be ≥8.8° in the 778km orbit.

There are three kinds of detectors to get the 10 bands. One is called five-band TDI CCD for panchromatic band and four traditional multi-spectral bands, which are B01-B05. One is called four-band TDI CCD for the other four new multi-spectral bands, which are B06-B09. The other is short wave band, which is B10. The first two detectors are TDI CCD. Five-band TDI CCD has 7um pixels for panchromatic band and 28um pixels for multi-spectral bands. Four-band TDI CCD has only 28um pixels for multi-spectral band. The third detector is InGaAs detector. It needs three image channels to set each kind of detector.

With pixel size and orbit height, the focal length should be more than 2184 to get 2.5m GSD of panchromatic band.

There is no such long detector array to cover the whole field of view. It needs to but the detectors of each band. There are two main butting methods: optical butting and field butting. Optical butting is chosen in the payload.

From the analysis above, the optical system should be a long focal length, wide field of view, and three image channels. According to these features, three-mirror anastigmatic optical system is chosen. Aspherical surface is used to correct the optical errors. Plat mirror is used to divide the field into three image channels. The design results reach the diffraction limit. The distortion is less than 0.04%. Fig. 3 gives the optical layout. Fig. 5~7 give the MTF curve of representative bands (B01/B02/B10).

Table 4. Main Parameters of Next Generation Payload

Band	Band /um	GSD/meter	Swath/Kilometre
B01	0.45-0.90	2.5	118
B02	0.45-0.52	10	
B03	0.52-0.59		
B04	0.63-0.69		
B05	0.77-0.89		
B06	0.40-0.45		
B07	0.59-0.625		
B08	0.705-0.745		
B09	0.86-1.04		
B10	1.5-1.7	25	60

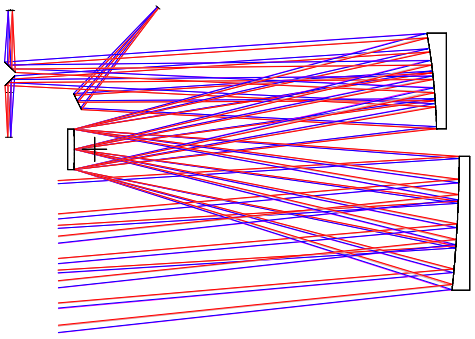

Fig. 4. Optical System Layout

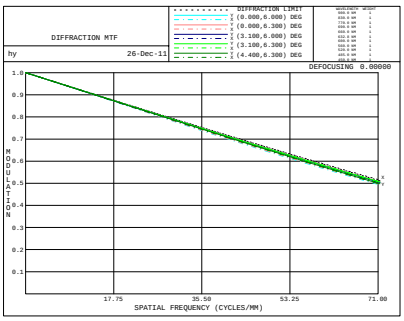

Fig. 5. MTF of Panchromatic Band (B01)

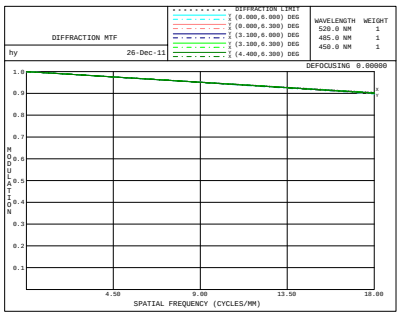

Fig. 6. MTF of Multi-Spectral Band (B02)

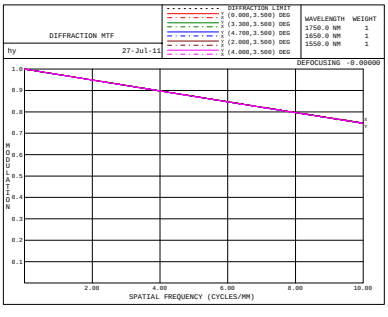

Fig. 7. MTF of Band (B10)

III. TEST AND VERIFICATION OF THE HYPER RESOLUTION PAYLOAD

From the design result of the optical system, the opti-mechanical body is designed and manufactured. The total lens is assembled with computer-aided alignment. After the assembly of the payload, a series tests and experiments are conducted to verify the design.

The MTF is of high importance on the evaluation of the spatial frequencies transferred from object to the image of an imaging optical system. Table5 gives the test results of globe MTF of the payload. Fig. 8 gives the test layout and test result image.

Calibration test is to verify the radiometric quality of the camera. We can get the absolute calibration coefficients, relative calibration coefficients, linearity and S/N of the camera by the calibration test. A high steady and precision integral sphere is used to conduct the test. Fig.9 gives the test setup.

To check the whole system quality, the camera takes the images outside of the laboratory. Fig. 10-12 give the images.

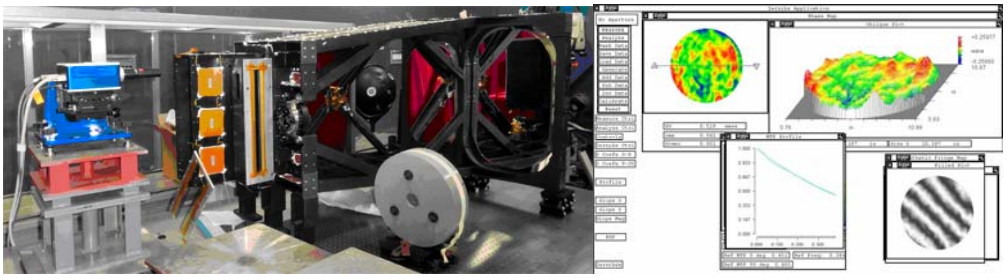

Fig. 8. Lens test in the laboratory

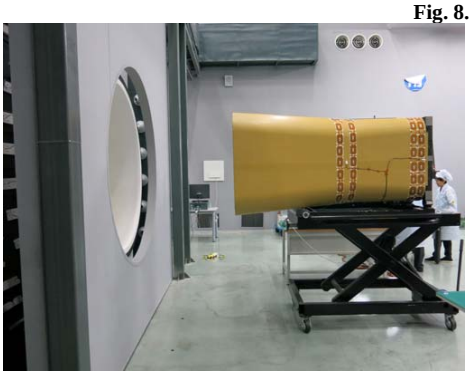

Fig. 9. Calibration Test setup in the laboratory

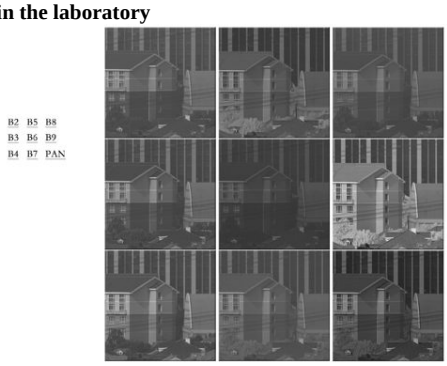

Fig. 10. Image of B01-B09

Fig. 11. Image of B10

Fig. 12. Image of fusion of B02/B03/B04 (true colour)

Table 5. MTF of Next Generation Payload

Band	MTF of Lens	MTF of System
B01	0.4	0.21
B02	0.73	0.41
B03		
B04		
B05		
B06		
B07		
B08		
B09		
B10	0.62	0.3

V. CONCLUSIONS

CBERS is the well known and stable development land observing satellite series of China. CBERS 01/02/02B satellites have been successfully launched in the past 15 years.

A next generation hyper resolution wide swath and multi-channel optical payload is developed and verified. The payload has 10 bands, which are 1 panchromatic band, eight multi-spectral bands and 1 short wave band. The 10 bands are laid up in three channels. GSD is 2.5m for panchromatic band and 10m for multi-spectral bands and 25m for short wave band with the swath 118km in the 778km orbit.

The payload should greatly promote the efficiency of land observing of CBERS series satellite. The key technology is overcome.

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