Research on Technologies of Three-linear Tridimensional Mapping Camera

Beijing Institute of Space Mechanics & Electricity

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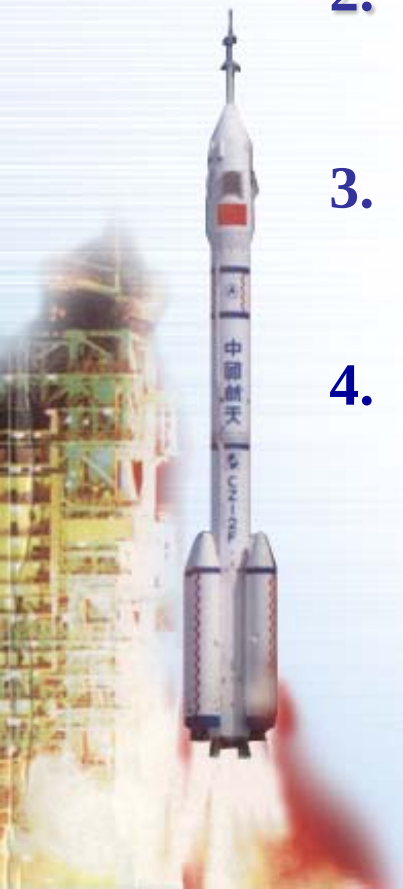

1. Project introduction
2. The influencing factor for mapping precision
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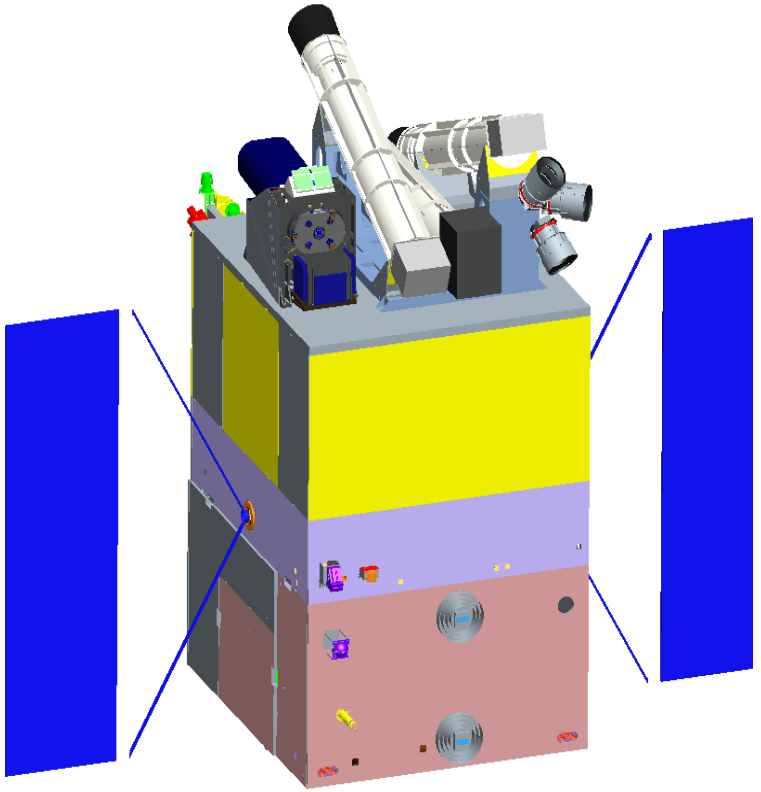
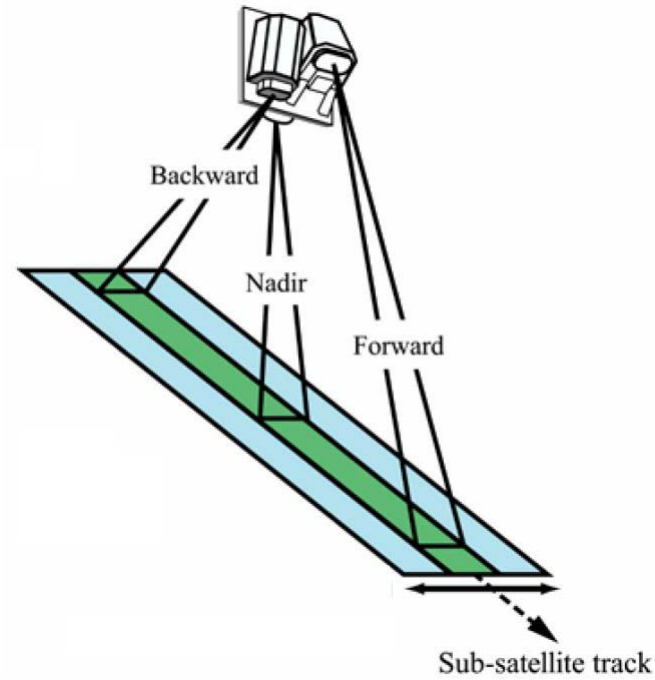
1. Project Introduction

- In China’s economic construction, lots of fields have shown their strongly demand for mapping. So China is developing our space mapping camera’s technology lately years, there will be our first transfer mapping satellite to be launched this year, with our own three-line stereo scan imagery system inside.

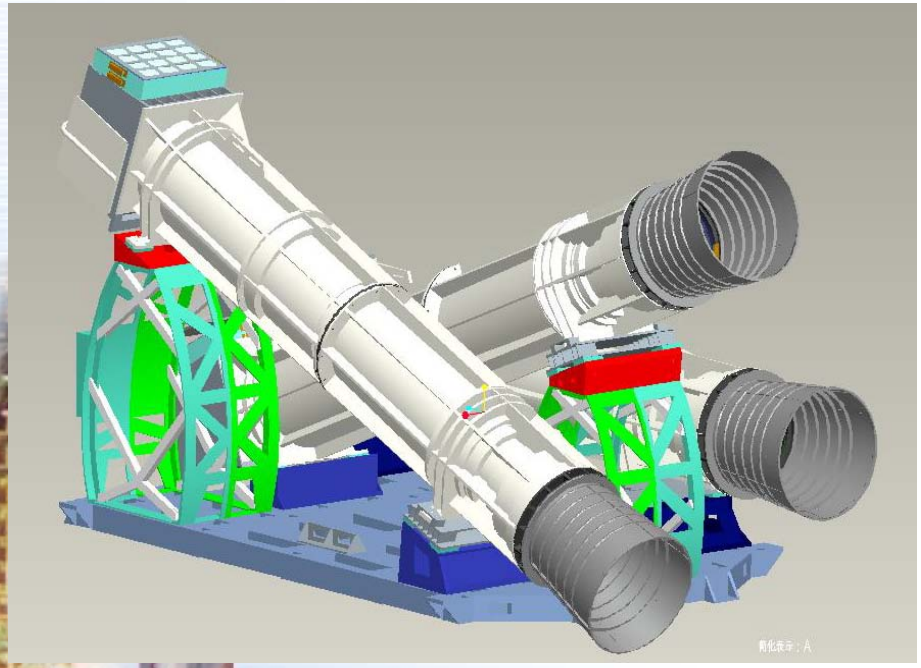


1. Project Introduction

- The three-line scanner imagery use linear CCD as imaging device. The whole system is made up by three linear CCD cameras with individual lens, the three cameras are in the fixed position, which could obtain three overlapped pictures with certain angle by scanning the ground. Each image line is obtained by linear CCD, and this image line is corresponding to the inner-position and outer-position elements at the imaging moment. According to the imaging measurement theory, with known coordinate of the imaging point, and outer-position element from neighboring moment of the image, the ground coordinate could be calculated by using intersection.



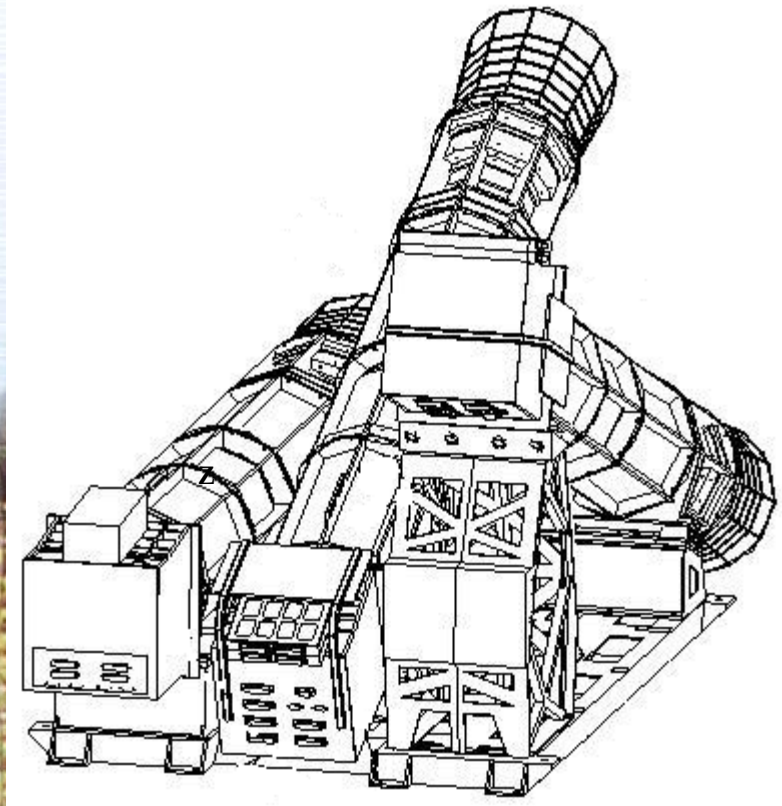
1. Project Introduction



Resource 3 satellite is the first-generation tridimensional mapping satellite in China. Its optical payload subsystem adopts transmission cameras with a format of “3+1”, Which means ， three line panchromatic TDICCD camera plus 1 multispectral camera. The camera is used to photograph vertically and obtain orthographic images. The convergence angle between forward, backward camera and nadir camera is 22°, which is used to obtain the stereo images in order to meet the requirements of 1:50000 scale drawing and 1:25000 scale map correction and measurement.

1. Project Introduction

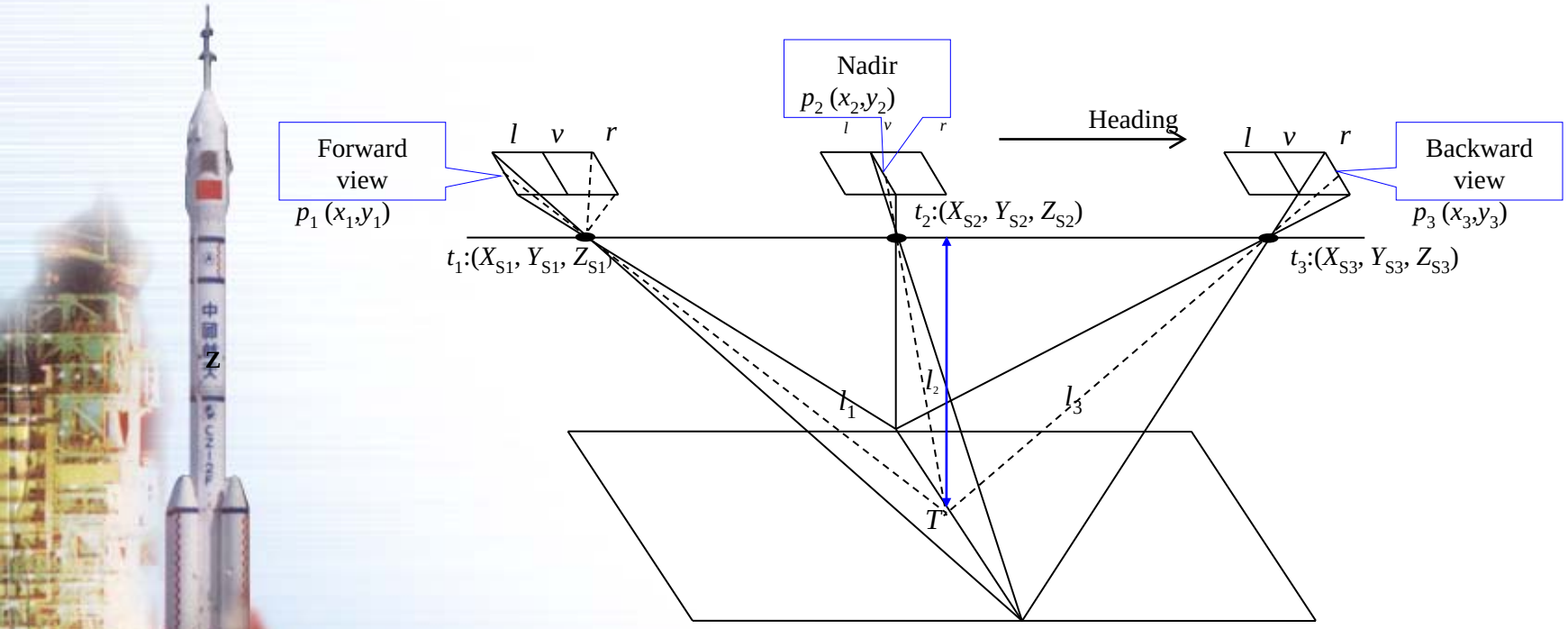
Major performance parameters of the three-linear tridimensional mapping camera



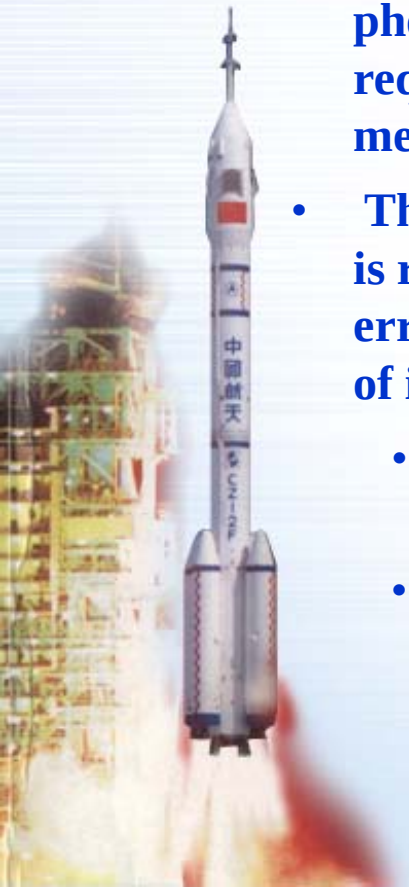
Item	Specification		
	Nadir	Forward	Backward
Observation Band	0.50μm ~ 0.80μm		
IFOV	4.15μrad	6.91μrad	6.91μrad
FOV	6 degrees	6 degrees	6 degrees
Focal Length	1700mm	1700mm	1700mm
MTF	≥0.2 （71.5lp/mm）	≥0.22 （50lp/mm）	≥0.22 （50lp/mm ）
SNR	≥48dB	≥48dB	≥48dB
Angle from nadir	nadir	+22 degrees	-22 degrees

2. The influencing factor for mapping precision

For the design and manufacture of a three-linear tridimensional mapping camera, how to accurately measure the linear camera interior orientation elements and the convergence angle between each camera is very important.



2. The influencing factor for mapping precision



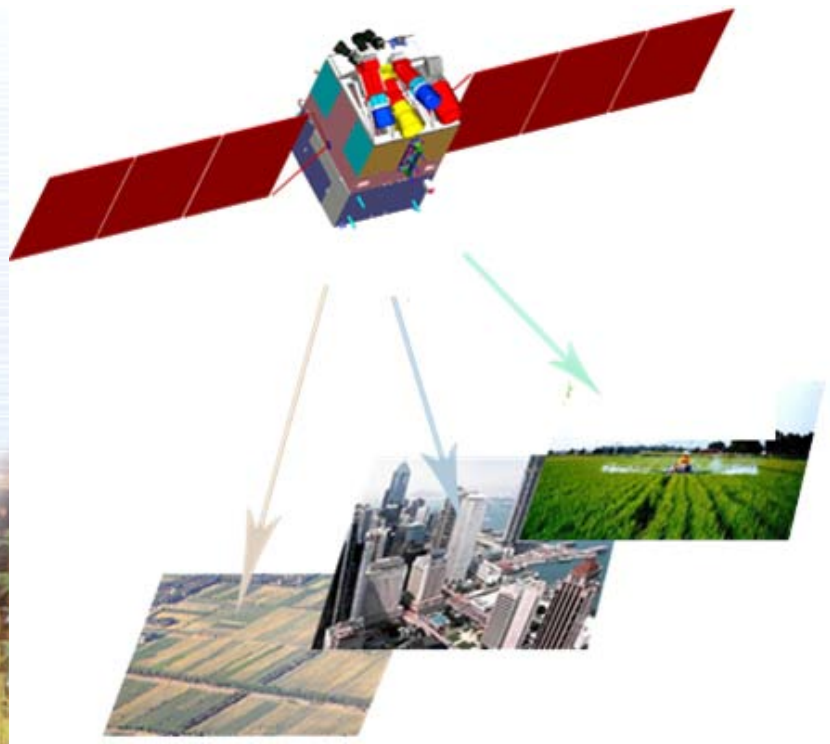
- **Measurement Precision**
  - **The measurement and plotting of 1:50000 scale geographical maps requires that the precision of photogrammetric images meet the requirement of relative elevation measurement precision ±3m**
  - **The elevation measurement precision is relative to the parallax observation error and the measurement precision of image point coordinates .**
    - **The parallax observation error: 8.5μm**
    - **The measurement precision of image point coordinates:6μm**

$$M_{dh} = \pm 3m$$

$$M_{dp} = \frac{f \cdot \frac{B}{H} \cdot M_{dh}}{H} = 8.5\mu m$$

$$M_{xy} = \frac{M_{dp}}{\sqrt{2}} = 6\mu m$$

2. The influencing factor for mapping precision

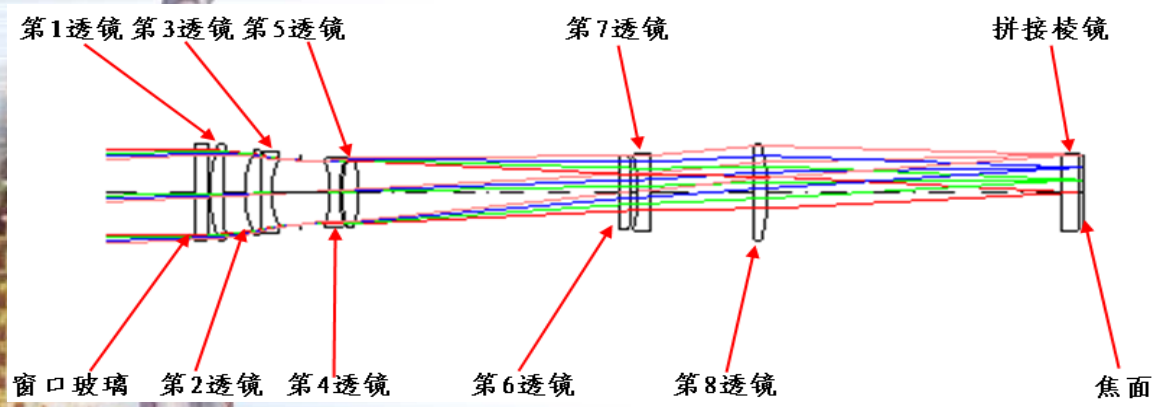


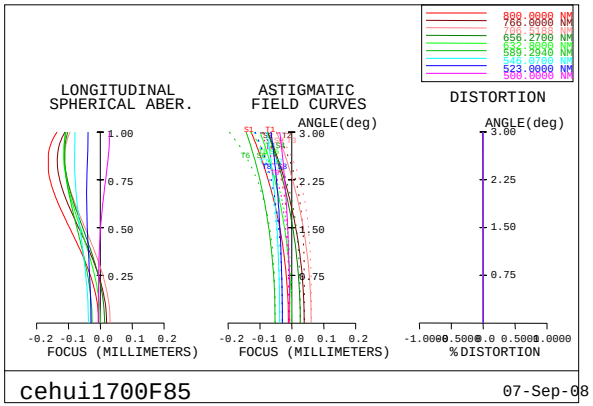
- The parallax observation error is a system error, it has similar influence on each image.
- In order to correct and eliminate the system error, it is necessary to reduce and measure error as soon as possible during the course of design and manufacture, which enables the corrected precision to meet the requirements much more.
- The measurement precision requirement
  - camera distortion measurement precision: 0.3 pixel.
  - the intersection angle measurement precision : 3''

3. Solution of Stability and Calibration Precision

The optic system design

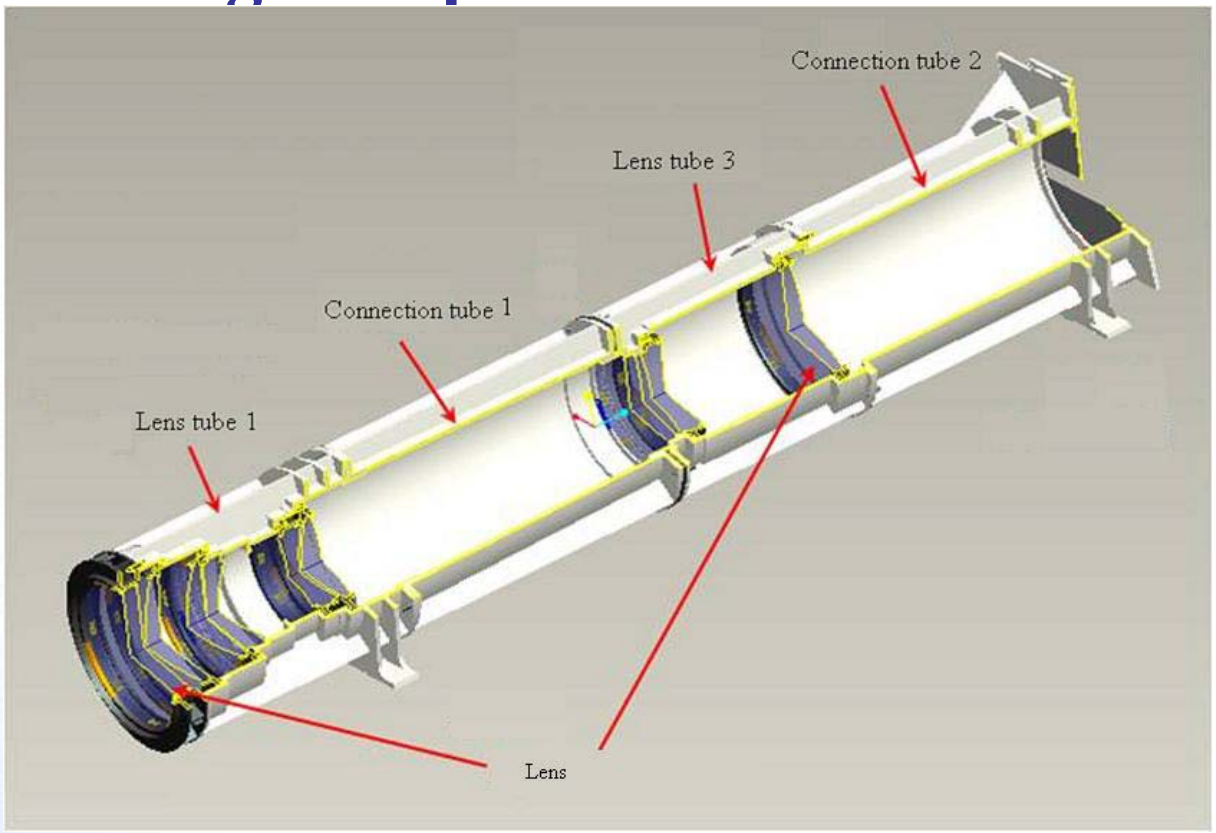
The optical system of the three-linear camera adopts the telecentric beam path in image space, the whole system is nearly zero aberration, the image height can be stable and the measurement error caused by system defocusing can be reduced.





3. Solution of Stability and Calibration Precision

- The design of optic-mechanic structure

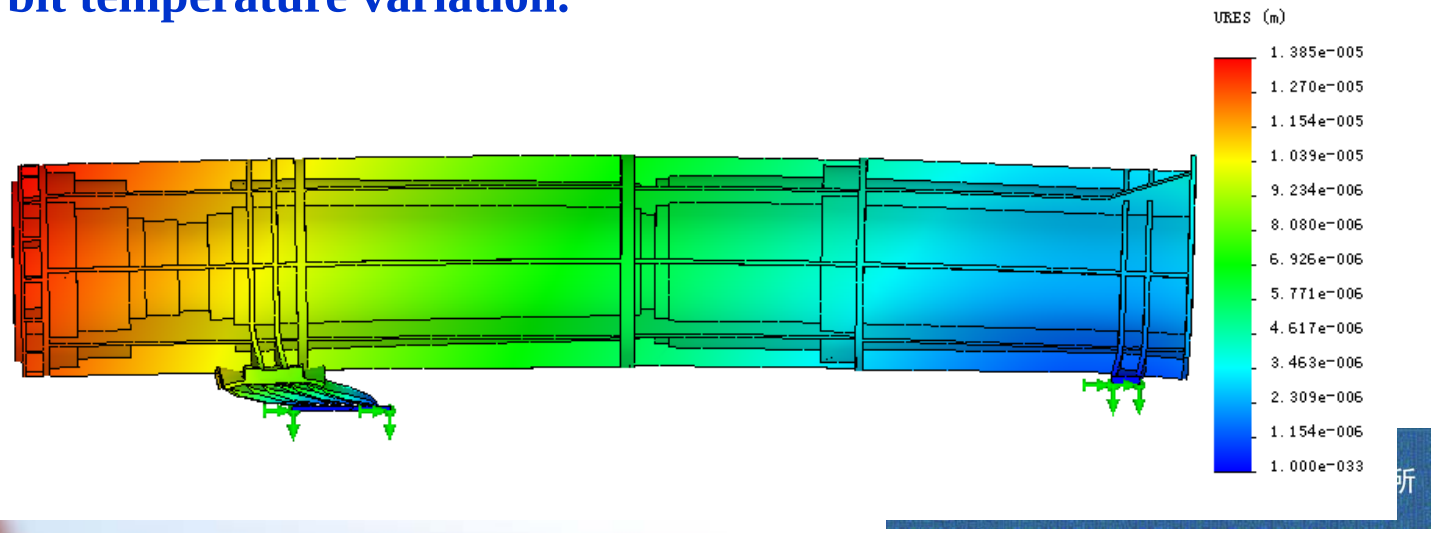


The optical lens of the three-linear camera adopts a proposal of titanium alloy optical-mechanical structure.

3. Solution of Stability and Calibration Precision

- **The design of optic-mechanic structure**

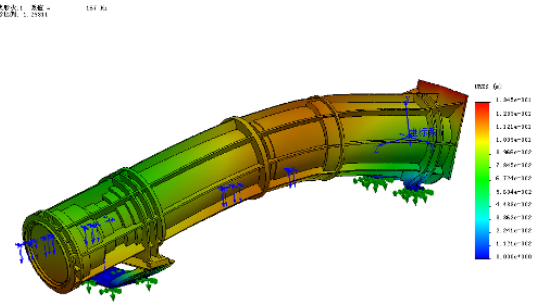
The selection of titanium alloy accomplishes the axial and radial thermal matching design of the lens optical-mechanical structure, which enables the camera body to have good mechanical property and thermal stability, therefore, the accurate position of each optical element and stable image surface can be assured even under the condition of gravity unloading and on-orbit temperature variation.



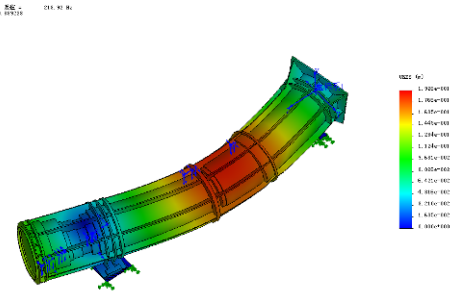
3. Solution of Stability and Calibration Precision

- The mode analysis of camera's optical lens

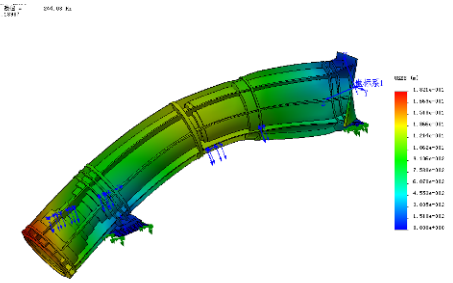
Nadir



167Hz

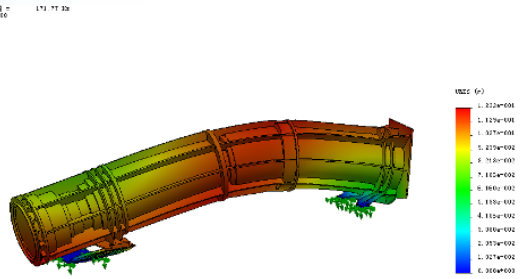


218.92Hz

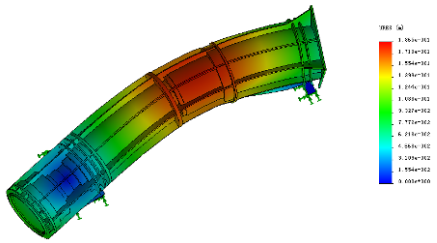


244.08Hz

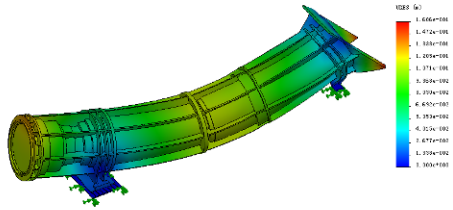
Forward& Backward view



177.77Hz



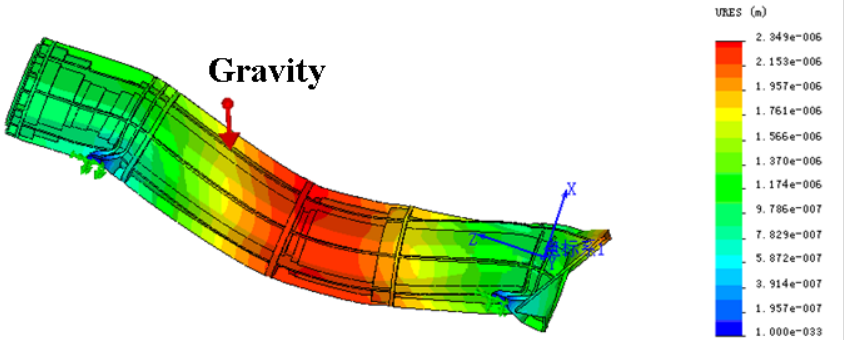
205.59Hz



227.26Hz

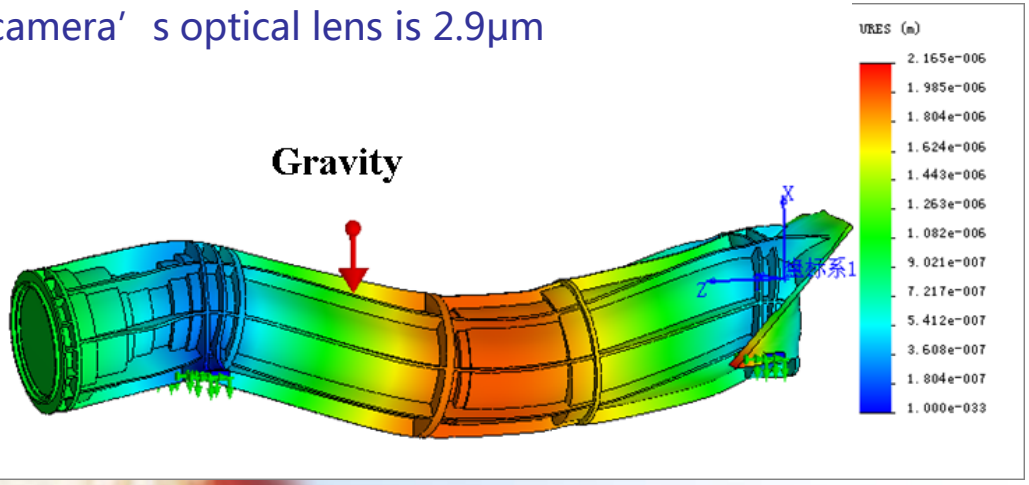
3. Solution of Stability and Calibration Precision

The gravity influence analysis of the camera's optical lens

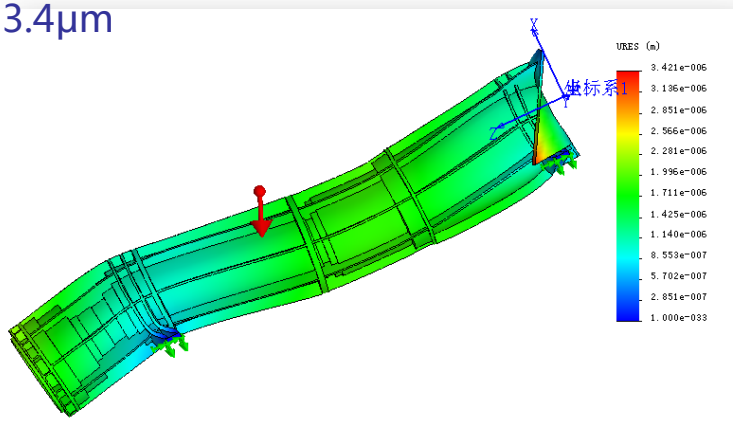


The maximum distortion of the forward camera' optical lens is 3.4μm

The maximum distortion of the nadir camera' s optical lens is 2.9μm



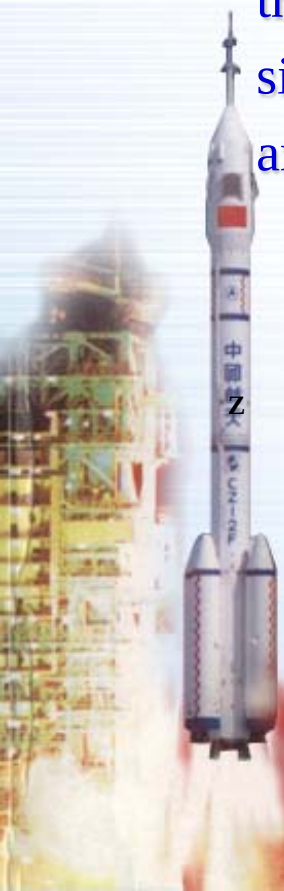
The maximum distortion of the backward camera' s optical lens is 3.4μm

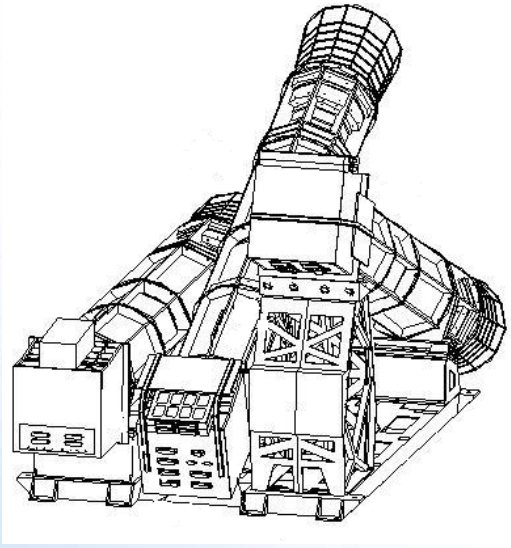


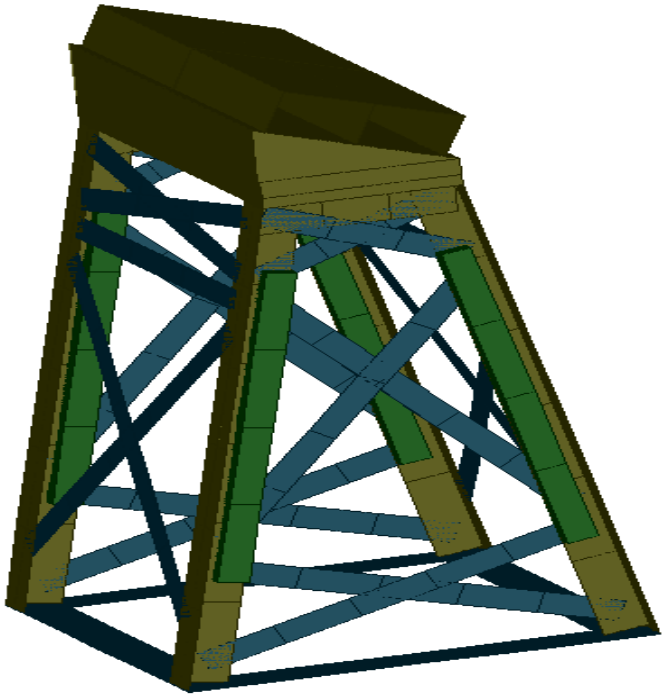
3. Solution of Stability and Calibration Precision

- **The integrative bracket design plan**

For the design and development of the integrated supporting frame, the zero- expansion composite supporting component is used to control the thermal deformation of the integrated supporting frame along X axis. The simulation and testing prove that the requirement of the intersection angle stability can be satisfied.







3. Solution of Stability and Calibration Precision

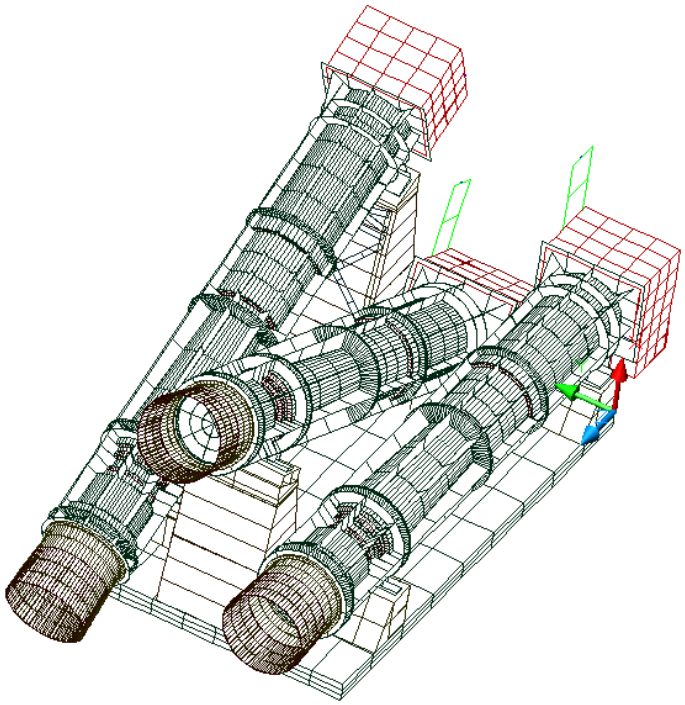
- Base on the certain solution on optic and structural design, the inner-position element and intersection angle for the mapping camera is steady. Under the work condition that the horizontal axis has 2℃ difference, and vertical axis has 0.2℃ difference, the camera's MTF has no change; focal distance has 25μm change; the image height has 3.5μm change.

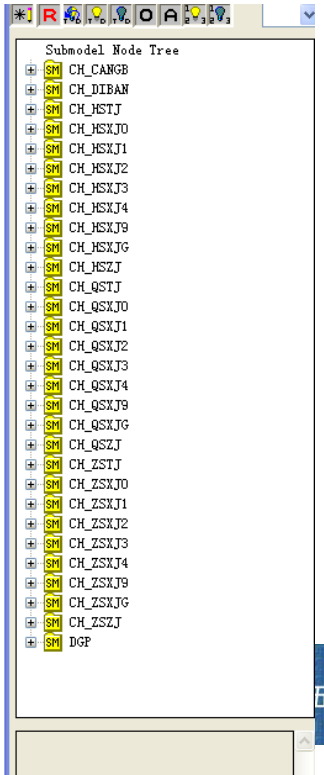
	20 ℃ No slope	Vertical slope 0.1 ℃ Horizontal slope 2 ℃	Vertical slope 0.2 ℃ Horizontal slope 2 ℃	Vertical slope 0.3 ℃ Horizontal slope 2 ℃	Vertical slope 0.4 ℃ Horizontal slope 2 ℃
Focal distance (f)	1700	1700.0130	1700.0247	1700.0539	1700.0740
Image height (Y)	89.0918	89.0935	89.0953	89.0972	89.0991
Δf′	——	0.0130	0.0247	0.0539	0.0740
ΔY′	——	0.0017	0.0035	0.0054	0.0073

3. Solution of Stability and Calibration Precision

- **High-precision camera thermal control technology**

To keep the stable inner-position element and intersection angle for the mapping camera, except the certain solution on optic and structural design, the accurate thermal control are necessary as well. The precision of thermal control achieve 0.3 ℃ in whole camera system.





3. Solution of Stability and Calibration Precision

The analysis and testing for angle stabilization

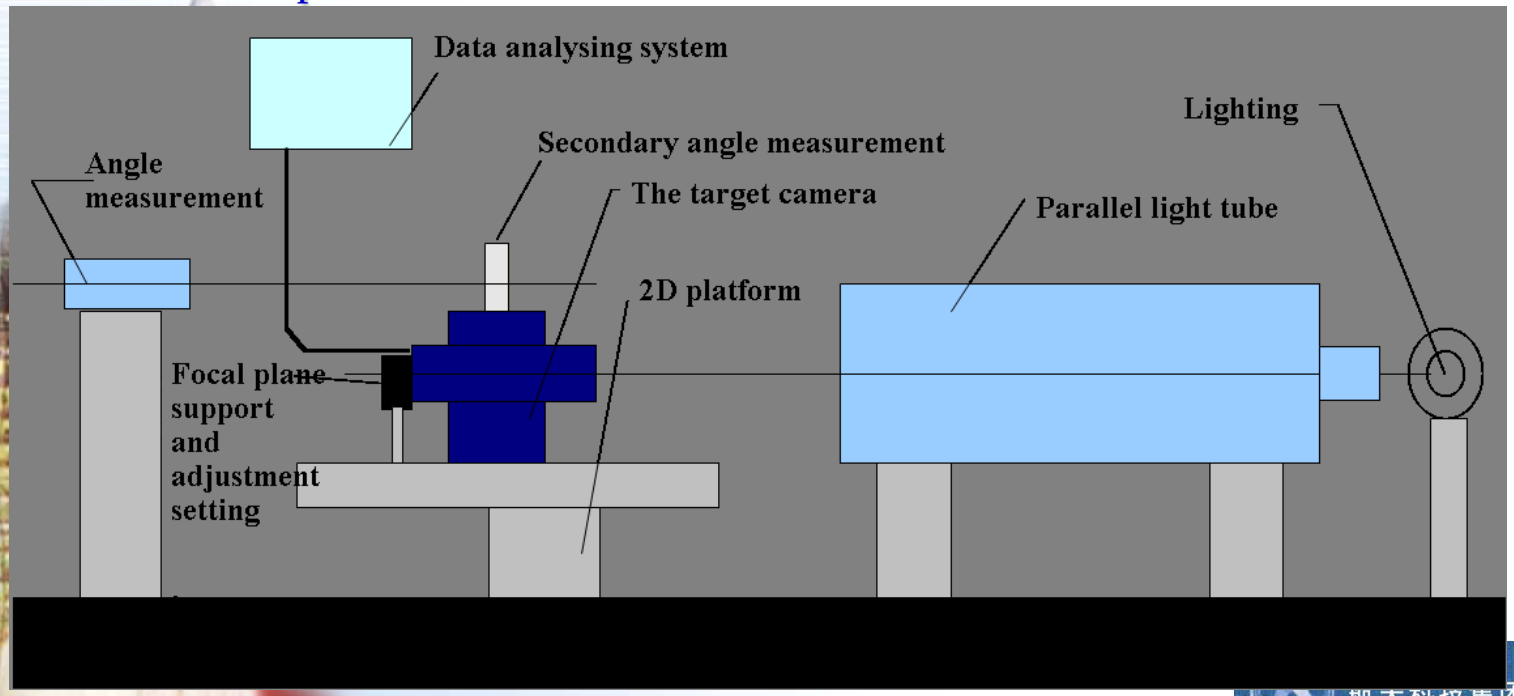
The thermal deformation of the three-linear camera shall be analyzed in the status of complete satellite. Under several different working condition, the maximum pointing change is 0.4″, the maximum intersection angle change is 0.6″, the intersection angle stabilization is very high.

Working condition	Forward(″)	Backward(″)	Nadir(″)	F/N angle(″)	B/N angle (″)	F/B angle(″)
Temperature difference between camera and the satellite is 1℃	0.0572	0.094	0.034	-0.218	0.02	-0.151
Partly temperature of the bracket arise 1℃	0.0152	0.38	0.072	-0.80	-0.013	-0.021
The temperature of the load car arise 1℃	0.3912	0.1095	0.23	0.608	-0.327	0.281

3. Solution of Stability and Calibration Precision

Accurate Measurement of Interior Orientation Elements

The interior orientation elements reflect the position relationship between camera projective center and image plane, which mainly includes the principal point coordinates, the principal distance and distortion. For a mapping camera, the interior orientation elements shall be measured accurately to facilitate the final image processing. The special instrument had been developed for the interior orientation elements measurement.

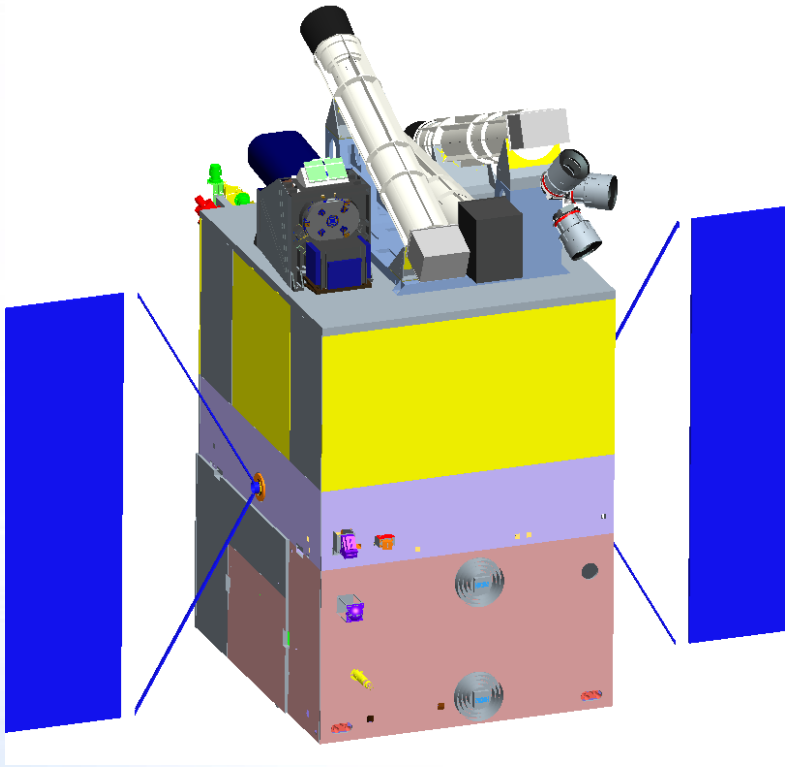


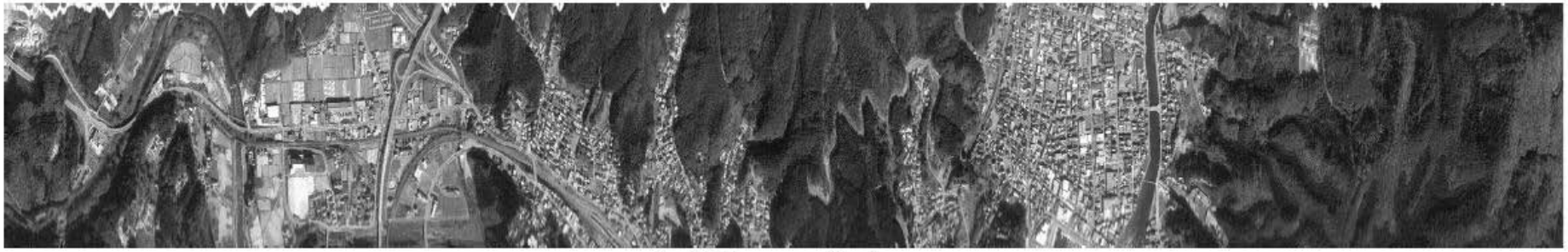
The accuracy of the main-point testing is better than 5μm.

The measurement error of focal distance is 16μm.

4. The progress of the project

The three-line scanner imagery has been in the AIT stage, will be launched this year.

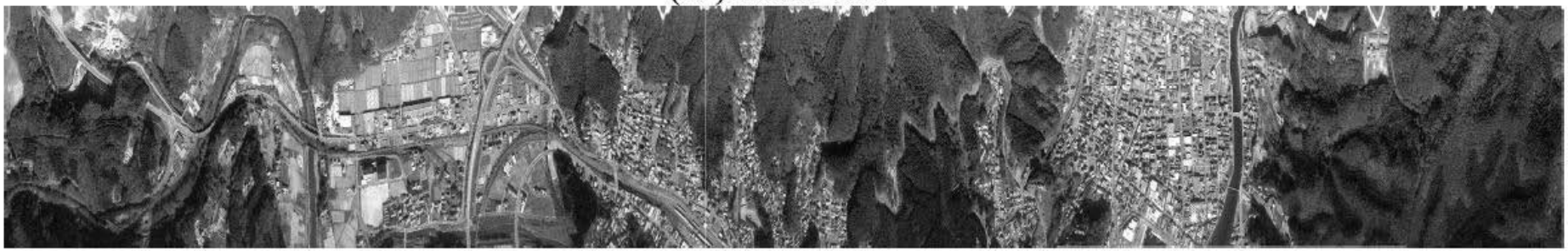




(a) Forward view

Thank you !

(b) Nadir view



(c) Backward view