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REPORT FOR MISSION SELECTION OF HYPER RESOLUTION CAMERA FOR CHINESE MARS MISSION

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I. INTRODUCTION

Mars is the most similar planet as the Earth in the solar system. So it is the most studied planets in the solar system. U.S.A., Russia and E.U. have launched more than 43 satellites or spacecraft. China has realized to surround and land on the Moon, but has never been to explore Mars. In the 2020, China will launch the first spacecraft to Mars independently. Though it is later, but China has started on the high level. In this exploration, it will realize three activities, which are to surround, land and rover on Mars.

The scientific objectives and tasks of China Mars Exploration:

(1) To study morphology and geological structure characteristics and their changes of Mars;
(2) To study the Martian surface soil characteristics and the distribution of water ice;
(3) To study the Martian surface composition;
(4) To study the Martian atmospheric ionized layer and surface climate and environmental characteristics;
(5) To study the Martian physical field and internal structure.

II. MISSION REQUIREMENTS OF HYPER RESOLUTION CAMERA

The shortest distance is 55,000,000 kilometers between Mars and the Earth. The longest distance is 400,000,000 kilometers. It will take 3 minutes for data to transfer from Mars to the Earth. Data rate is one of main engineer constraints because of the long distance. So it is important to get more information in the limited data rate to explore Mars.

This mission will have three activities, which are to surround, land and rover on Mars. The spacecraft has surrounding segment, landing segment and rover. Mass is greatly limited to realize so many activities because of the limit of lunch rocket. The Hyper Resolution Camera (HRC) is mounted in the surrounding segment and to get the image of Mars. The tasks of HRC are:

(1) To get hyper resolution image of Mars;
(2) To help to choose the landing site;
(3) To study morphology and geological structure characteristics and their changes of Mars.

A. The image characteristic of Mars

Mars and the Earth are planets of the solar system. They are quite different, as figure 1.

Fig. 1. The Earth and Mars

The soil of Martian surface includes ferric oxide. The ferric oxide transfers into red and yellow oxide because of long term exposure to ultraviolet rays. So Mars is like a word full of rust. The reflectivity of Martian surface is 0.08-0.40 and the average reflectivity is about 0.25. On the surface there is a thin atmosphere, the pressure is no more than 0.01atm. The heat flux from sun to Mars is about 595 w/m^2, which is about 1/2.3 of the heat flux from sun to earth, that is 1353 w/m^2.

B. The orbit anslysis of surrounding segment

The surrounding orbit is elliptical orbit. The perigee of the orbit is about 265km and the apogee of the orbit about 15341.8km. The orbit inclination angle is 93.1 degree. The requirement of observation arc is from perigee to 1000km.

Figure 2 gives a full orbit period analysis. From the figure, we can get the solar elevation angles of full orbit period and the distance variation between the surrounding segment and surface of Mars.

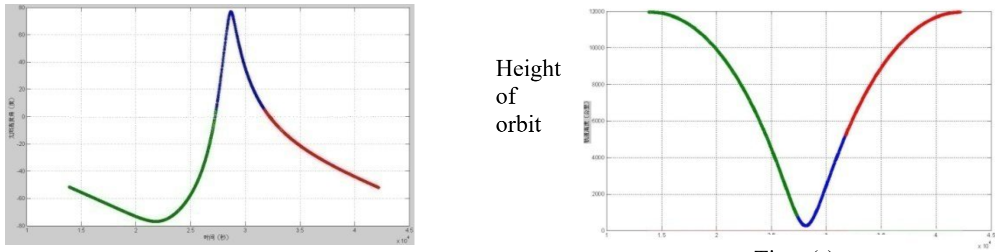


Fig. 2. Full orbit analysis

C. Oribtal heat flux Analysis of surrounding segment

The distance between the spacecraft and sun increases, the solar irradiance decreases. The average solar irradiance near the Earth is 1353 w/m^2. The max is 1419 w/m^2 and the min is 1317 w/m^2. The average solar irradiance near Mars is 595w/m^2. The max is 717 w/m^2 and the min is 493 w/m^2. Figure 3 gives the solar irradiance with distance variation.

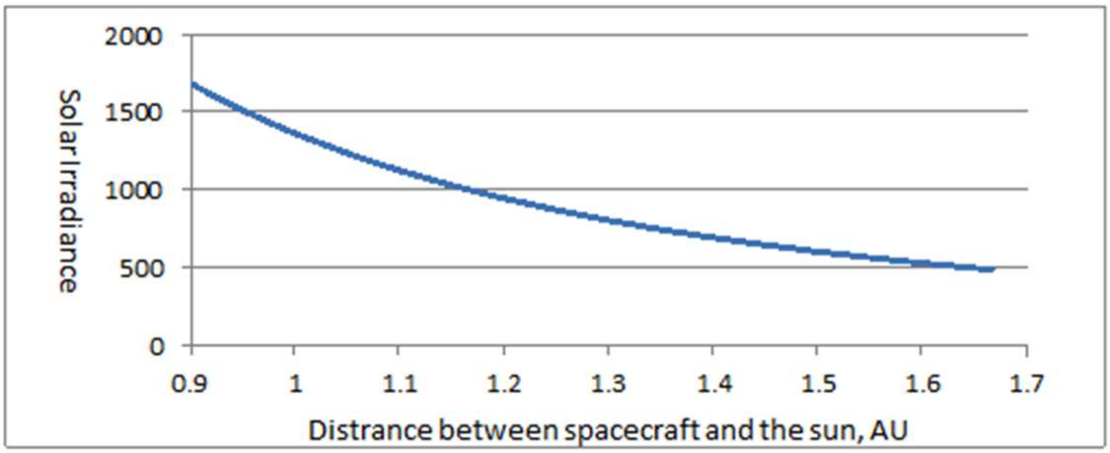


Fig. 3. Solar Irradiance with distance variation

The orbit of surrounding segment is elliptic. The perigee is about 265km. The radiation from Mars varies with the height of orbit. Figure 4 gives Mars radiation varies with height of the orbit.

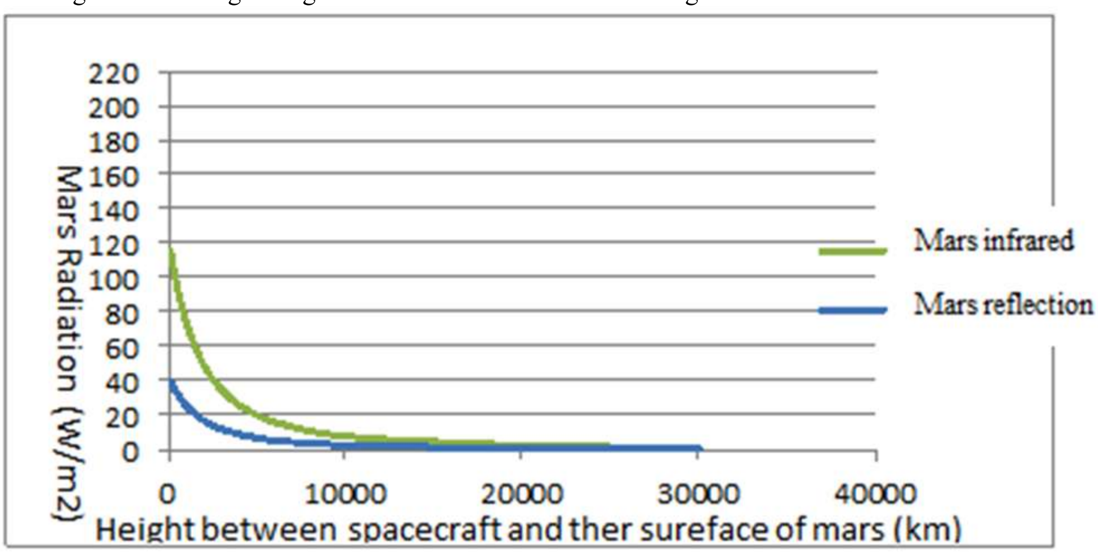


Fig. 4. Mars radiation varies with height of the orbit

III. DESIGN OF THE HYPER RESOLUTION CAMERA

The camera includes two equipment, one is Optical Main Body (OMB) and the other is Integrated Electronics. The OMB includes optical lens, focusing mechanism, and focal assembly and focal electronics. The Integrated Electronics includes image processing circuit, image compression circuit, management circuit, and second power circuit. Figure 5 gives the sketch of Hyper Resolution Camera.

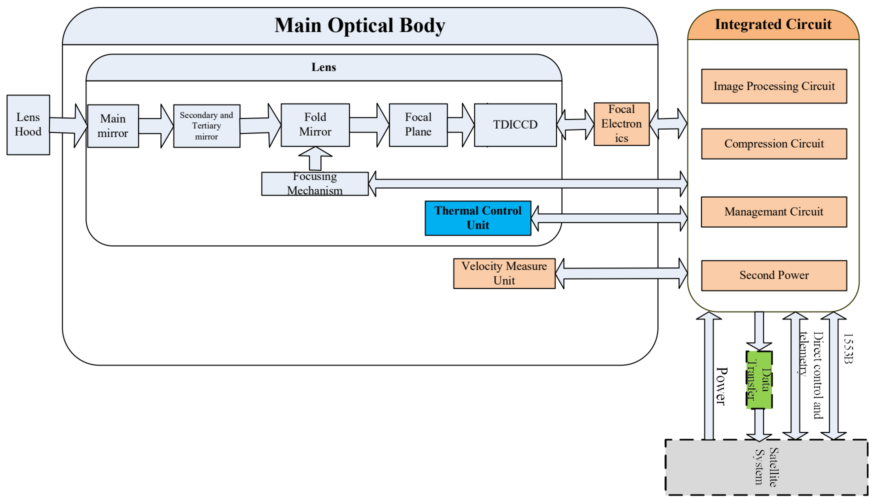


Fig. 5. The sketch of Hyper Resolution Camera

A. Compact design of camera

The mass is one of the most important engineering constraints. The less mass is the better. Several ways are taken to get the lest mass.

1) THE OPTICAL SYSTEM SELECTION

According to the investigation report of compact optical camera, Korch optical system is the most compact optical system. It can realize a long focal length and get a compact volume. HiRISE is one of the typical applications.

2) BIG F NUMBER DESIGN

F number decides the aperture of the optical system when its focal length is fixed. Big F number decreases the aperture, so it will decrease the volume and the mass. For TDI CCD detection system, F number is not the key factor for energy collection. But F number decides the diffraction limit of optical system.

Trade-off between the mass and the performance, we get an optical system. Focal length is 3750mm. F number is 10.5 and the Field of View is 2.64 degree. Figure 6 gives the optical layout.

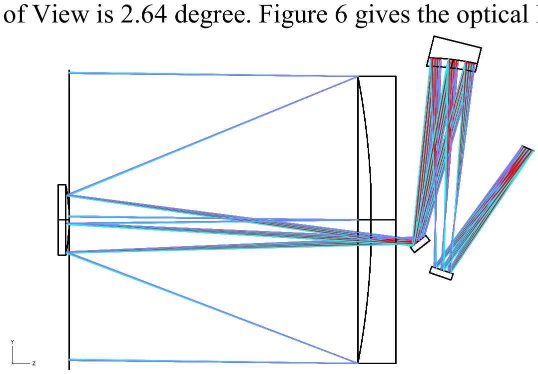


Fig. 6. Optical system layout of HRC

3) MATERIAL SELECTION

Material selection is very important to decrease the mass. Good material will ensure the image quality, improve the rigidity, decrease the mass and enhance the thermal stability.

The material of reflective mirrors is SiC. SiC has high elasticity modulus and high thermal conductivity. The material of main structure is carbon fiber. The structure of the main body is totally composite material.

4) MIRROR LIGHT WEIGHT AND SUPPORT

The topology of mirror light weight is double-arched structure to get the most mass decrease. Bipod support is used to realize the mirror fixation.

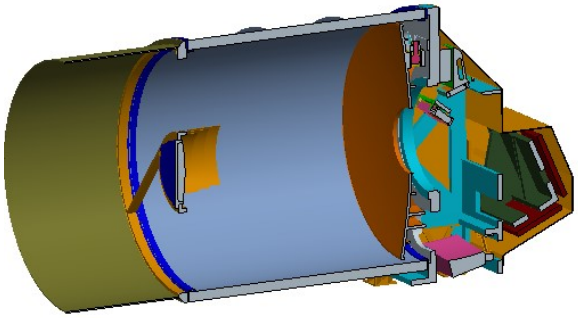
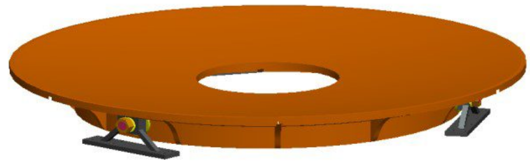



Fig. 7. Main Optical Body **Fig. 8.** Main mirror and support

B. Integrated Circuits

The circuits include ADC unit, image processing unit, image compression unit, management unit, thermal control unit, power unit, and velocity measurement unit. All the circuits are all integrated into one equipment. Figure 9 gives the sketch of integrated circuits.

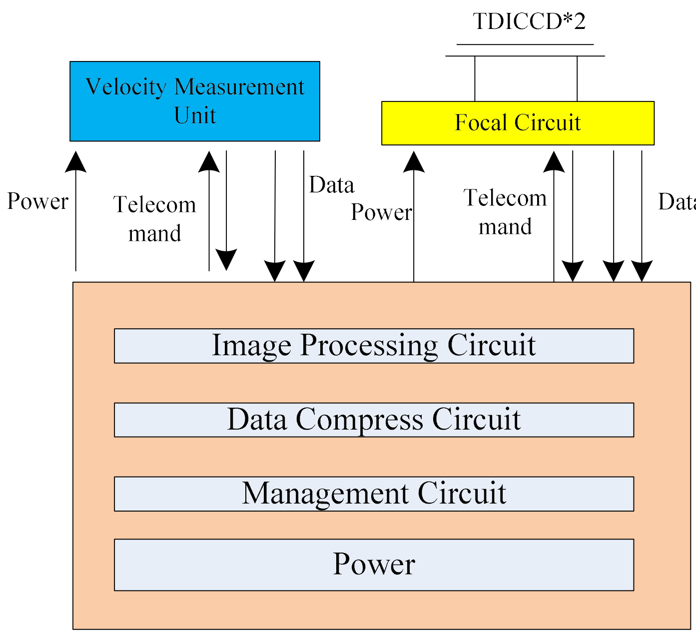


Fig. 9. The sketch of Integrated Circuits

Focal plane circuits include two same set of circuits, each of which include one multi-band TDI CCD, sequence circuit, drive signal circuit, analog filter circuit, and analog to digital circuit. All these functions are realized in one ASIC chip. ASIC chip reduces the dimension and power of circuits.

1) HIGH SNR TECHNOLOGY AT LOW ILLUMINATION

As analysis above, the radiance from Mars is much less than the radiance from the earth. In order to get good image quality, the requirement of SNR is 100 at the conditions of 0.2 reflectivity and 70°solar elevation angle. Several technologies are adopted to increase the SNR, which are TDI technology, pixel digital binning, 14bit ADC and automatic parameters adjusting. There is no cloud and the surface covers with ferric oxide. According to the feature of Martian scenery, the reflectivity varies slowly. So the TDI stages are automatic real-time adjusting.

2) DECREASE THE DATA RATE

As analysis above, date rate is one of the most important engineering constraints. In order to take full advantage of data transfer rate, several data transfer models are used.

Model 1: Normal model

Data are transferred at the design rate.

Model 2: Selection model

The width of the image can vary, and the band needed to be selected to be transferred.

Model 3: Degrade GSD model

The pixels can be binned to reduce the size of image for example 2x2, 4x4 and so on. But the GSD also is degraded.

Model 4: Different compression ratio

There are five kinds of compression ratio, which are raw data, 4:1, 8:1, 16:1 and 32:1. This model can be used with other models.

Model 5: Preview model

In this model, it will give the preview of the image and transfer the interesting zone.

Model 6: Automatic sand storm detection model

This is an intelligent model. Sand storm is very common on Mars. Once sand storm starts, we can get little useful information by the HRC. Sand storm can be detected intelligently on the orbit and to be removed in the image.

Model 7: Automatic Extraction base on characteristic

We can define the feature of the interesting scene. The camera automatically processes the image on the orbit and transfers the useful part. This is another intelligent model.

3) DATA RATE ANALYSIS

The data is quantified by 14 bits, but is truncated to 8 bits to be transferred. Figure 10 gives the data rate in one period. Table 1 gives the data rate of panchromatic band. From the figure and band we can get that the data rate varies greatly at different time and different models.

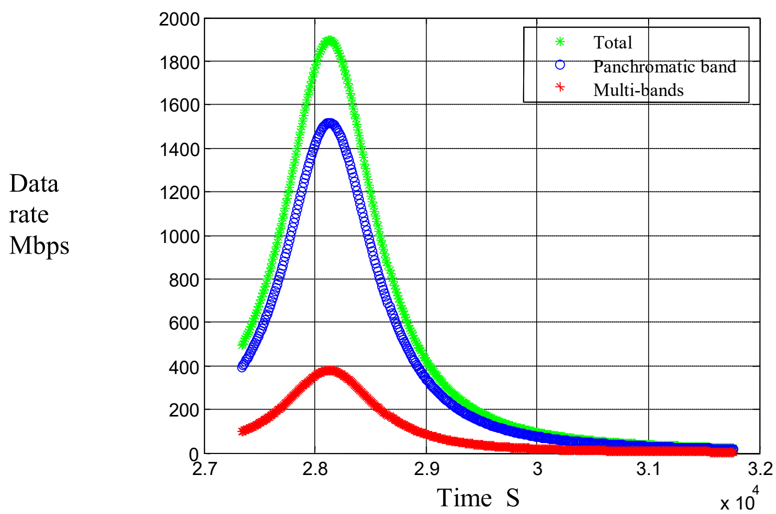


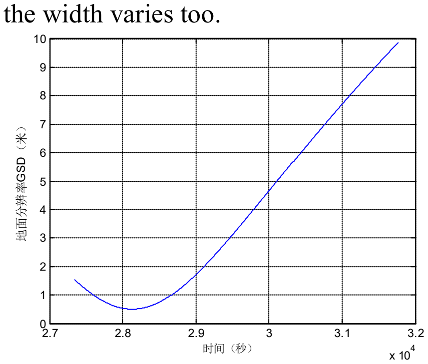
Fig. 10. Data rate in one period

Table 1. Data rate of panchromatic（Mbits）

Imaging Time	Raw Data	4:1 Compress	8:1 Compress	16:1 Compress	32:1 Compress	Preview
Perigee	90623.94	22655.99	11327.99	5664.00	2832.00	22.12
Perigee +1	88222.46	22055.62	11027.81	5513.90	2756.95	21.54
Perigee +2	83760.16	20940.04	10470.02	5235.01	2617.51	20.45
Perigee +3	77850.45	19462.61	9731.31	4865.65	2432.83	19.01
…						
1000km	1222.83	305.71	152.85	76.43	38.21	0.30

4) GSD VARIATION ANALYSIS

The orbiter moves on the elliptic orbit. GSD varies at the different height because of the characteristic of the orbit. The camera should image from perigee to 1000km. At the perigee, the GSD is 0.5m. With GSD variation, the width varies too.



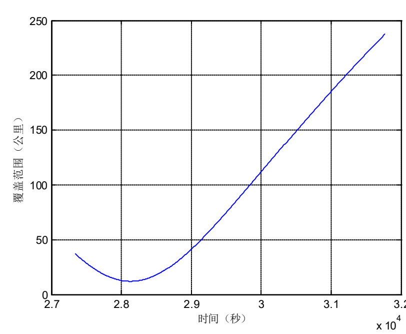


Fig. 11. GSD and width Vary with time in one period

IV. CONCLUSIONS

Hyper Resolution Camera is the main payload of orbiter. The main objective of the Camera is to get hyper resolution image of key region of Martian surface. The image will provide the base data and scientific basis for the selection of land site and will give the formation and change process of Martian surface.

Data rate and mass are the main engineer constraints to realize the scientific objective. Based on the two constraints and the characteristics of Martian surface, a candidate mission is provided, which has adopted high integrated design and intelligentialize. The Korch optical system, all composite structure and ASIC electronics are used to get the least mass. Image automatic identification based on feature extraction and image preview are used to take full advantage of data rate to get more valid data for scientific purpose.

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