

JAPANESE SPACEBORNE THREE-LINE-SENSOR AND ITS MAPPING CAPABILITY

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ABSTRACT

This paper describes Japanese spaceborne three-line sensor, Panchromatic Remote-sensing Instrument for Stereo Mapping (PRISM), and its capability for mapping. Result of investigation of several data compression techniques applied to PRISM data is also provided.

1 INTRODUCTION

The PRISM is a Japanese solution to high-resolution and stereo (or triplet) imaging. It is boarded on the Advanced Land Observing Satellite (ALOS) which will be launched in August 2002 by Japanese H-IIA rocket. The ALOS (Hamazaki et al, 2000) is given five mission: technology development, mapping, regional observation, disaster observation and Earth resources surveying (Osawa et al, 1995). To achieve the requirement mainly from mapping, the PRISM consists of three sets of telescopes for forward, nadir and backward view and is given 2.5 m spatial resolution.

2 PRISM SYSTEM

The PRISM is a so-called “three-line scanner”, which provides images observed in three different angle simultaneously. As shown in Fig. 1, fore- and aft- looking telescopes are attached on an optical bench. These two telescopes are inclined plus and minus 24 degrees from nadir direction each, in order to give them the base to height ratio of 1. These specifications are given to achieve the accuracy for 1/25,000 scale maps, which is e.g. height accuracy of 3 to 5 meters. The PRISM will also bring us wide swath image data. It is realized electronically using eight CCDs which aligned along a half mirror prism. The pixel size of CCD’s photo detector is 7 micron for cross-track direction and 5.5 micron for along-track direction. Regarding along-track direction, 2.5 m sampling requires high speed data rate of CCD sensors at 14 MHz. Its 70 km width data is convenient to detect the change of land cover not only in “local” but also in “regional” area. It is also useful for revising maps frequently.

In order to accomplish the 1/25,000 scale “quality”, the position of each pixel should be determined precisely, and image data itself should be high quality. To realize the first requirement, the PRISM and an optical bench have the ultra low distortion structure, which is made by specially fabricated Carbon Fiber Reinforced Plastics (CFRP) and their

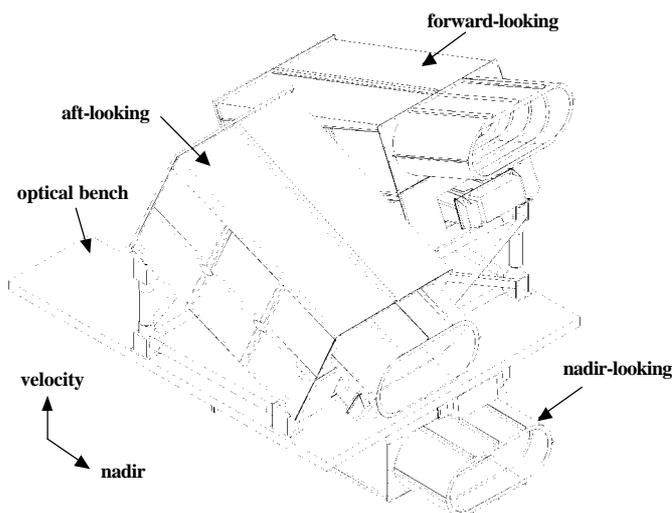


Fig. 1. PRISM's three independent telescopes

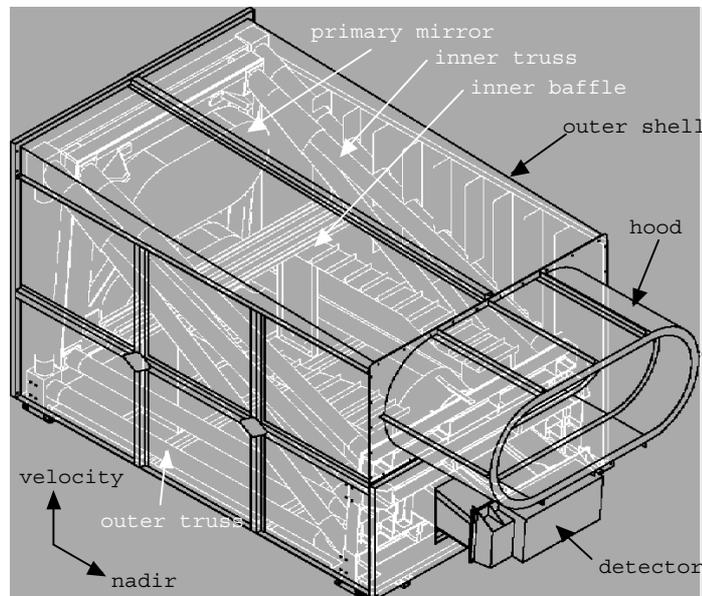


Fig. 2. Exterior (black lines) and interior (white lines) design of PRISM.

temperature are precisely maintained ($\pm 3^{\circ}\text{C}$). For better performance, PRISM structure consists of two parts; an inner truss and an outer truss as shown in Fig. 2. The Inner truss, which supports mirrors and a detector module, is maintained its temperature very precisely by passive thermal control from the heater attached on the outer shell. The outer truss supports the inner truss and is attached to the spacecraft's optical bench. In addition, high precision star trackers and inertial reference units are mounted on the bench to determine its attitude. To evaluate the PRISM's performance, Bread-Board Model (BBM) was manufactured by way of trial as shown in Fig. 3..

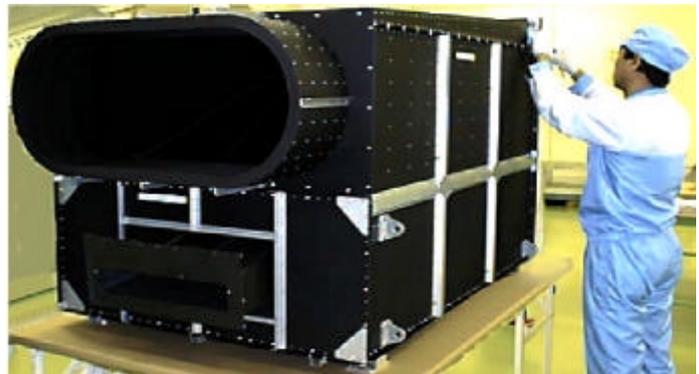


Fig. 3. PRISM Bread Board Model.

The model consisted of an optics, a detector module, which included a half prism and two CCD sensors, and PRISM's structure. Optical performance test, electrical performance test and structural performance test were conducted. We ascertained the PRISM performance through these tests.

To achieve the second requirement, the PRISM adopts three-mirror optics. The optics has no chromatic aberration over wide field of view, so its modulation transfer function (MTF) can be high.

We are currently in basic design phase and conducting subsystems' EM (engineering model) manufacture. The result of EM which includes key components for the data quality, such as a data compression circuit, a star tracker and a GPS receiver will convince us of their performance.

To achieve requirements of mapping and regional observation, the PRISM system provides along-track stereoscope images by three independent telescopes with high-resolution and wide swath width. To realize the resolution of 2.5m, one pixel size of Charge Coupled Device (CCD) sensor is $7\mu\text{m}$ for cross-track direction and $5.5\mu\text{m}$ for along-track direction. The detectors, 40,000 pixels total per one telescope, are aligned on 300mm-length half prism along the focus of three-mirror off-axis optical system. The optics characteristics is shown in Table 1 and PRISM nominal performance is shown in Table 2.

Table 1. PRISM's optical figures.

Focal Length:	about 2000 mm
Primary mirror size:	about 600 mm x 300 mm
MTF of the optics:	$\geq 50 \%$

Table 2. PRISM performance (nominal).

Item	Performance
Wavelength	0.52 - 0.77 μm
FOV	7.6°
IFOV	3.61 μrad
Swath width	70 km (nadir-looking) 35 km (triplet mode)
Spatial resolution	2.5 m (nadir)
System MTF at Nyquist freq.	0.27 for cross-track direction 0.21 for along-track direction
Stereo imaging	Base-to-Height ratio = 1.0
Pointing angle	$\pm 1.5^\circ$ (triplet mode)
S/N	80
Quantization	8 bits
Data rate	960 Mbps (total)

3 DATA COMPRESSION

High resolution and wide swath image produces huge data. In the case of the PRISM, each telescope generates the data of 320 Mbit per second, therefore 960 Mbps data need to be transmitted to a ground station. The satellite data link to the station, however, is limited to 240 Mbps, so we decided to equip data compression equipment on-board. At the time of conceptual study, we investigated the effect of data compression using the PRISM simulation images. The analysis includes the comparison of several compression techniques, e.g. DCT (Discrete Cosine Transform), Vector Quantization, with their horizontal and height extraction errors, which is shown in Fig. 4. According to the figure, every compression methods are satisfied with the requirement (5 m vertical error), we chose DCT as the ALOS compression method because there is a fast transform algorithm, and the image quality is better. In the Fig. 4, it should be noted that the result of “not compressed” is the worst. It is considered that the data compression reduces some high spatial frequency from original one, and it affects the result better. If we change matching method, the result would be different. Further study of matching method which adequate to each compression technique would be desired.

We also examined the effect of compression rate (how much data is remained after the compression) on the stereo matching. The result, shown in Fig. 5, shows us that compression rate of 1/4 (the size of compressed data is 25 % of its original) is quite acceptable, and 1/10 is still adequate to many applications. We

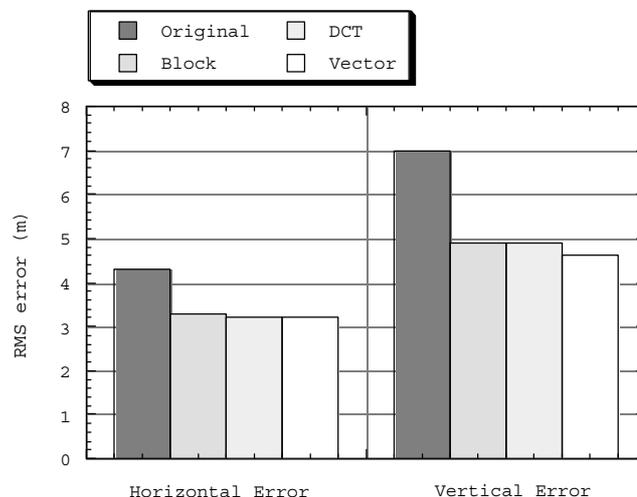


Fig. 4. RMS errors after stereo matching due to various compression methods. (Original: no compression, Block: block coding, DCT: discrete cosine transform, Vector: vector quantization.)

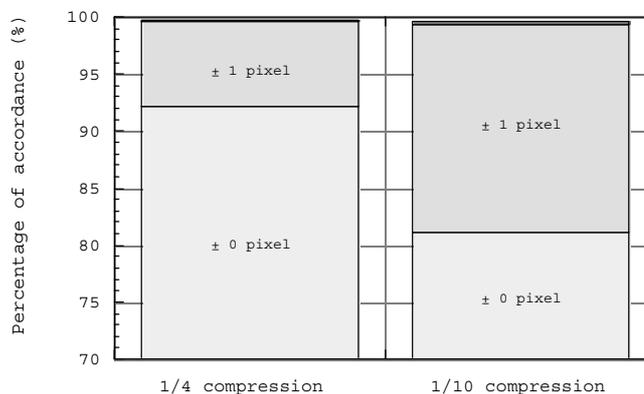


Fig. 5. Matching errors due to compression rate.

therefore chose the data compression ratio to 1/4 and 1/8 for the ALOS compression equipment. These values correspond to the data rate of 240 Mbps and 120 Mbps, respectively, those are the ALOS's downlink data rate. An example image of compressed data is shown in Fig. 6.

4 CONCLUSIONS

The PRISM and the data compression performance are examined from the standpoint of mission requirements. After the ALOS launch, the way of gathering land data globally would be changed and the ALOS data could be used for many applications.

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Fig. 6. Example of 1/4 compressed data.
(2.5 m forward looking simulation image.)