INVESTIGATION FOR MAPPING ACCURACY OF THE AIRBORNE DIGITAL SENSOR-ADS40

Tohru Yotsumata
Masaomi Okagawa
Yumiko Fukuzawa
Kikuo Tachibana
Tadashi Sasagawa
PASCO Corporation
1-1-2 Higashiyama, Meguro-ku, Tokyo, Japan
tohru_yotsumata@pasco.co.jp
masaomi_okagawa@pasco.co.jp
yumiko_fukuzawa@pasco.co.jp
kikuo_tachibana@pasco.co.jp
tadashi_sasagawa@pasco.co.jp

ABSTRACT

ADS40 is an airborne digital sensor with 3 panchromatic and 4 multispectral (RGB and near infrared) CCD line sensors developed and supplied by the LH Systems, LLC. Each panchromatic sensor is set to collect forward, nadir and backward views, and it is able to acquire the same ground area 3 times at different angles. The exterior orientation parameters are calculated from the direct geocoordinate system that uses GPS, inertial measurement unit (IMU) and photogrammetric bundle adjustment. We conducted a study to estimate the mapping accuracy by utilizing the panchromatic images of ADS40 for the Tsukuba City in Ibaraki Prefecture, Japan. The control and check points, distributed throughout the study area, were used to evaluate the accuracy.

1. INTRODUCTION

Recently, it has become possible to collect the exterior orientation parameters of the various kinds of sensors by the technical development of Direct Geo-reference system. PASCO has introduced APPLANIX's POS/AV-DG 510 system and evaluated its performance combined with aerial camera RC-30, LH Systems. It is confirmed that the ability of POS system is accurate and stable enough to the Japanese accuracy standard for 1/2,500 scale mapping.

PASCO has also introduced a newly developed digital multispectral airborne sensor ADS40 (LH Systems). The ADS40 contains POS system as position and orientation sensor. This orientation data is used together with photogrammetric observations in the simultaneous bundle adjustment to improve block geometry.

In this study, the accuracy evaluation assuming 1/2,500 scale mapping was carried out and the result is presented in this article.

2. OUTLINE OF THE SYSTEM

ADS40 is an aerial multispectral sensor system that uses APPLANIX POS system as position and attitude sensor. It has panchromatic sensors of forward, nadir and backward direction, and also has multispectral sensors of RGB and NIR. Stereo model is obtained by the combination of the panchromatic images. Sensor head, SH40, contains digital optical device, DO40, and IMU device and it is designed to fix to gyrostabilizer camera mount (PAV30) used with aerial camera RC30. The operations are carried out by using touch panels of operator interface OI40, and all the data is recorded in Mass Memory (MM40). The components of ADS40 are shown in Figure 1 and Figure 2. The first (SP1) and second (SP2) models have different configurations as shown in Figure 3-1 and Figure 3-2, respectively.

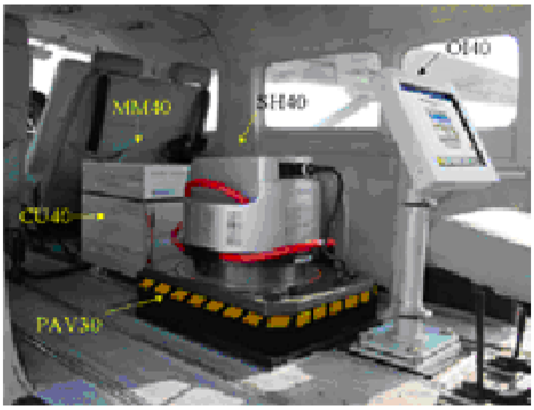
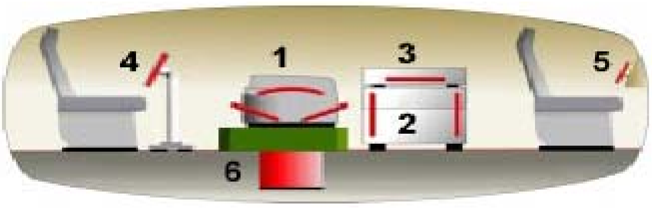
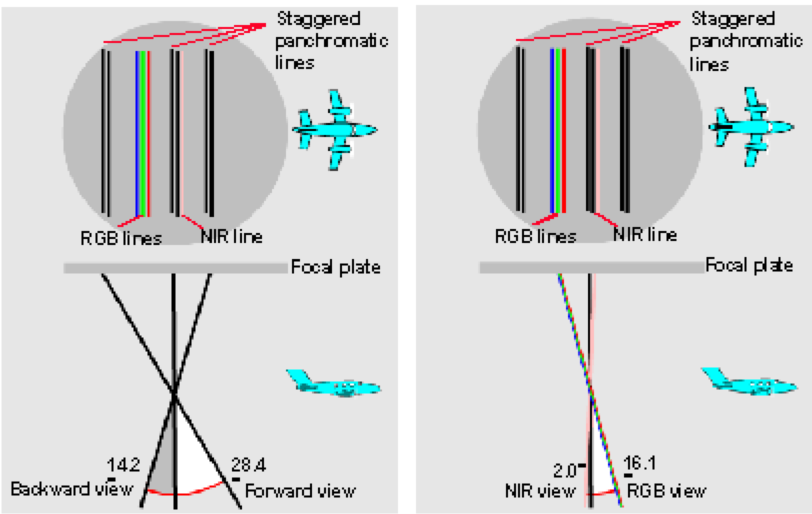


Figure 1. ADS40 installed at Sessna 208 aircraft.



1. Sensor Head SH40
   - Digital Optics DO64
   - IMU
2. Control Unit CU40
   - Position and Orientation Solution POS
3. Mass Memory MM40
4. Operator Interface OI40
5. Pilot Interface PI40
6. gyro-stabilized mount PAV30

Figure 2. ADS40 system components.



ADS40 Sensor (SP1)
1. 3 panchromatic view, each 2 * 12000 pixels, staggered by 3.25 µm
2. 4 multispectral bands, each 12000 pixels
3. Pixel size: 6.5 µm * 6.5 µm
4. Field of view: 64 °
5. Focal length: 62.77mm
6. Stereo angle: 14, 28, 42 °

Figure 3-1. Sensor configuration (SP1).

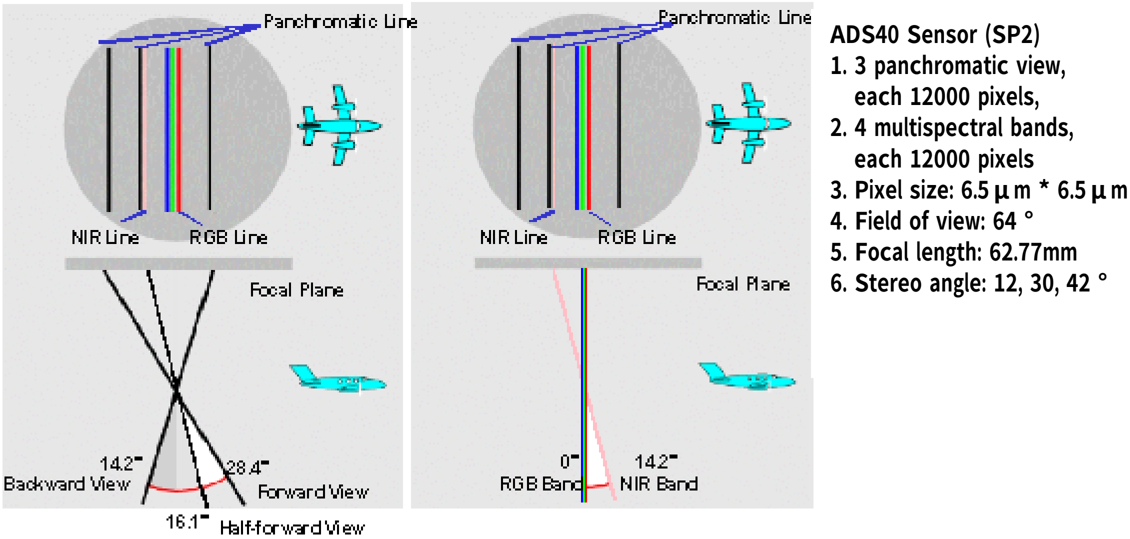


Figure 3-2. Sensor configuration (SP2).

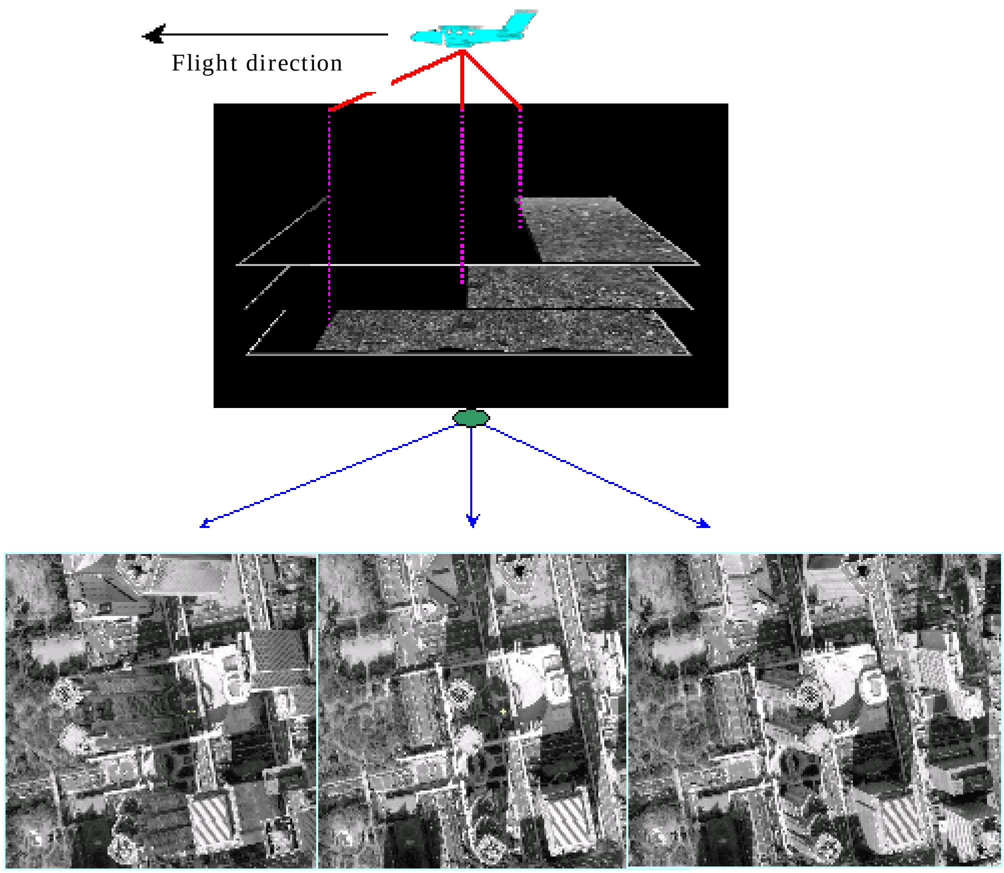


Figure 4. Panchromatic images.

The outline of the ADS40 data processing is shown in Figure 5. The processing is roughly divided into 2 stages, one is the analysis of GPS/IMU data, and the other is the block adjustment. In the former process, analysis of GPS/IMU, the exterior orientation parameters are calculated from the position and attitude of the airplane at the time of image capturing. This process is carried out with the POSProc software of APPLANIX Corporation. In the latter process, block adjustment, the accuracy of the block is improved by simultaneous bundle adjustment with the exterior orientation parameters from the former process and tie point by automatic point measurement. Furthermore, by the adjustment with self-calibration and/or ground control point, systematic error between GPS/IMU, sensors and systems are also adjusted simultaneously. Although it is already proved that the accuracy of the exterior orientation parameters obtained by APPLANIX POS system have certain degree of accuracy, e.g., small scale mapping, in the case of large scale mapping by ADS40's line images, block adjustment with ground control points is a standard procedure.

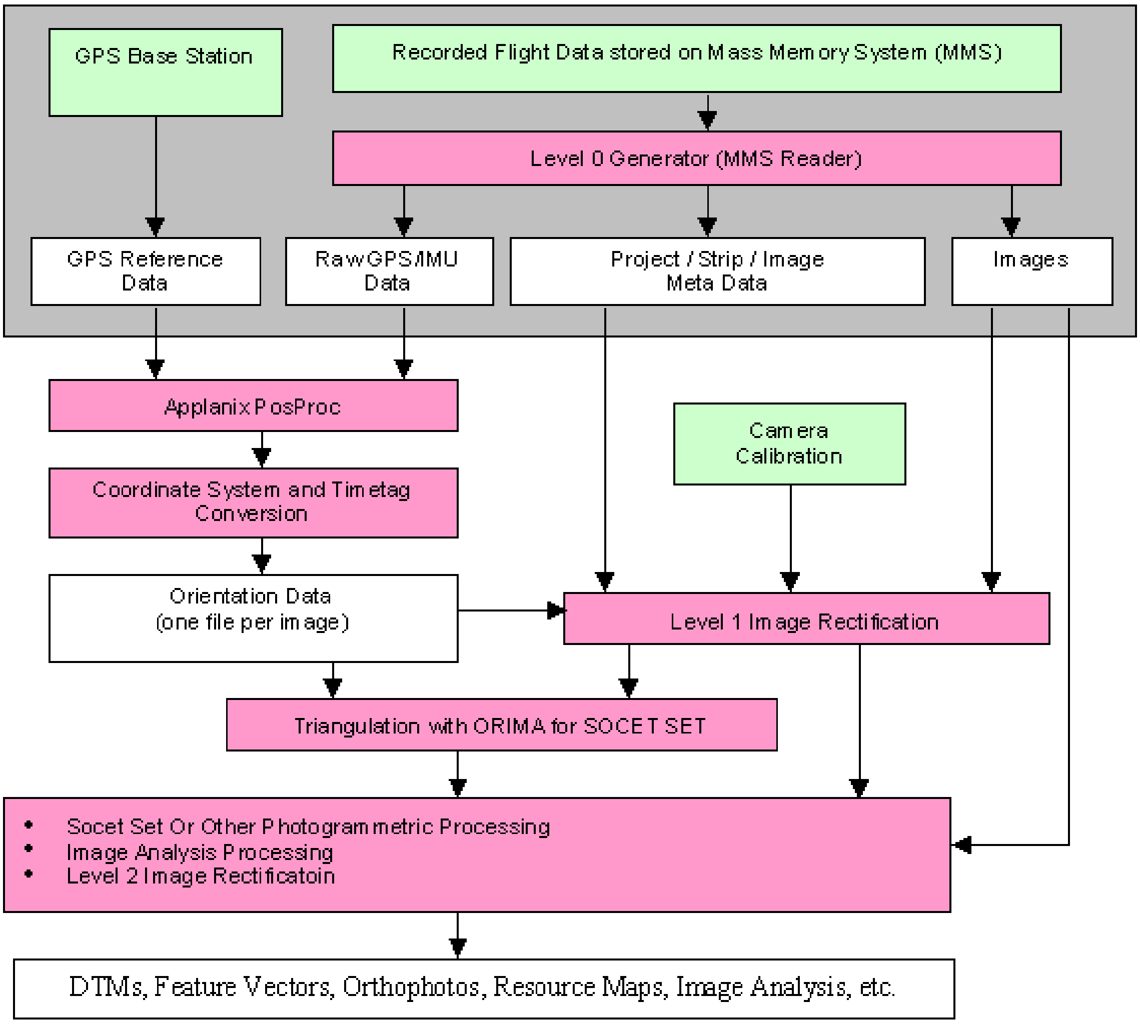


Figure 5. ADS ground processing workflow.

3. ACCURACY EVALUATION

In accuracy analysis, the coordinates of check points are observed on the images by ADS40 during block adjustment as unknown point using SOCET SET and ORIMA (LH System), then compared with coordinates obtained by the ground survey. The details are shown below.

3.1 Test block configuration

The test block description is shown in Table 1. SP1 data was acquired on February 1, 2002, and for SP2, April 24, 2002.

Table 1. The test block description

Item	Description	Remarks
Study area	Tsukuba area (about 10km × 20 km)	
Date	February 1, 2002 (SP1) April 24, 2002 (SP2)	
Ground sampling distance	0.2m	
Flying height	1956 m (6520 feet)	
Scale	1/31,000	
Course number	5 normal strip + 2 cross strip	
Data quantity	72.6GB	7 course * 3 = 21 images

3.2 Arrangements of ground control and check points

A total of 26 ground control and check points were distributed throughout the study area and observed by GPS surveying (Figure 7). The coordinate values are adjusted using Japanese permanent GPS network GEONET point Tsukuba-shi 1.

Figure 6. Images showing ground control point and check point (Left: No. 5, Right: No27).

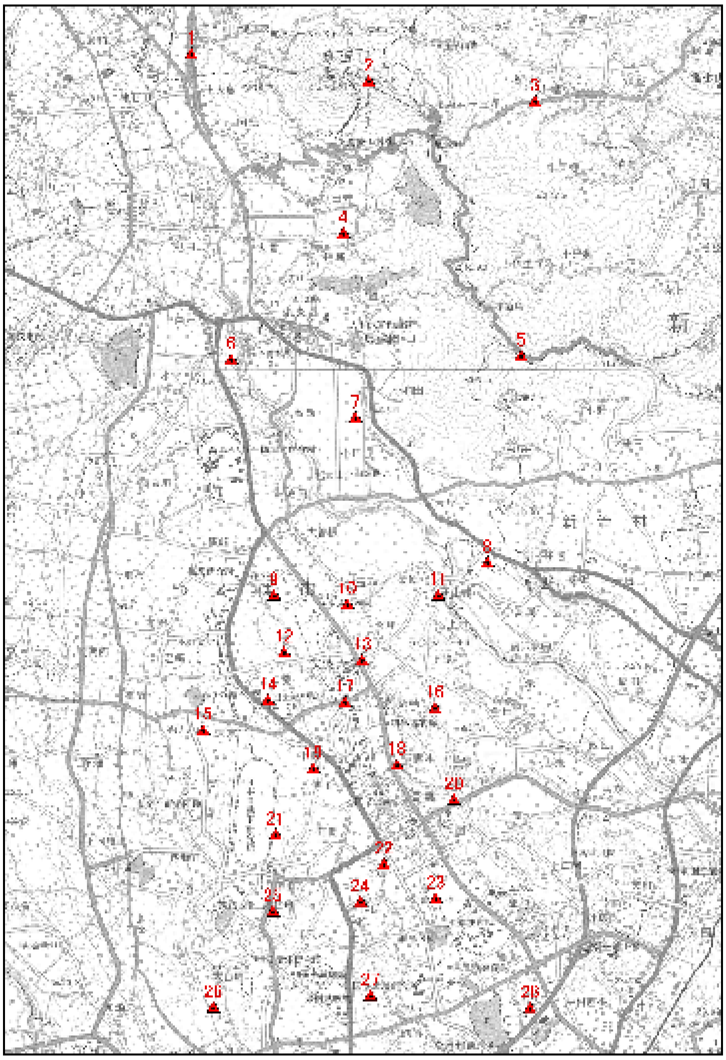


Figure 7. Distribution map of the ground control and check points.

3.3 ADS40 data processing

3.3.1. GPS/IMU analysis

GPS/IMU data is analyzed by APPLANIX POSPac software with same GPS station Tsukuba-shi 1 as a known point. Figure 8.1 and Figure 8.2 illustrate the flight trajectory of SP1 (February 1) and SP2 (April 24), respectively.

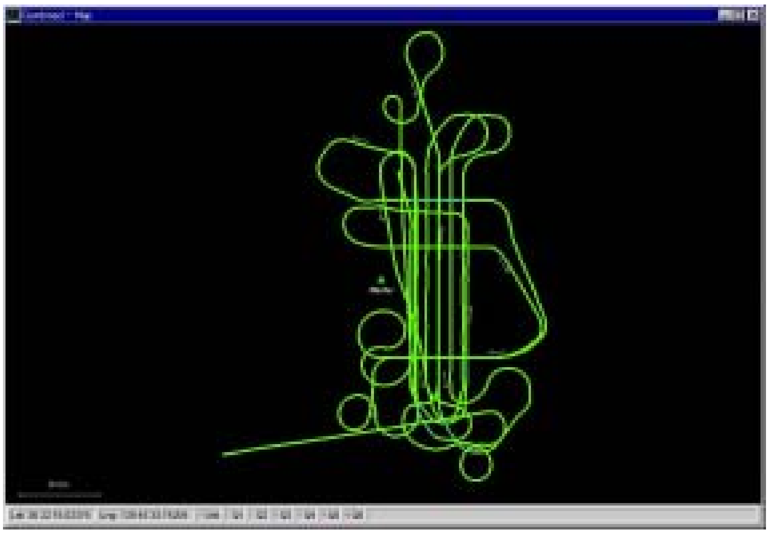


Figure 8-1. Flight trajectory and ground reference point (triangle mark) on February 4, SP1.

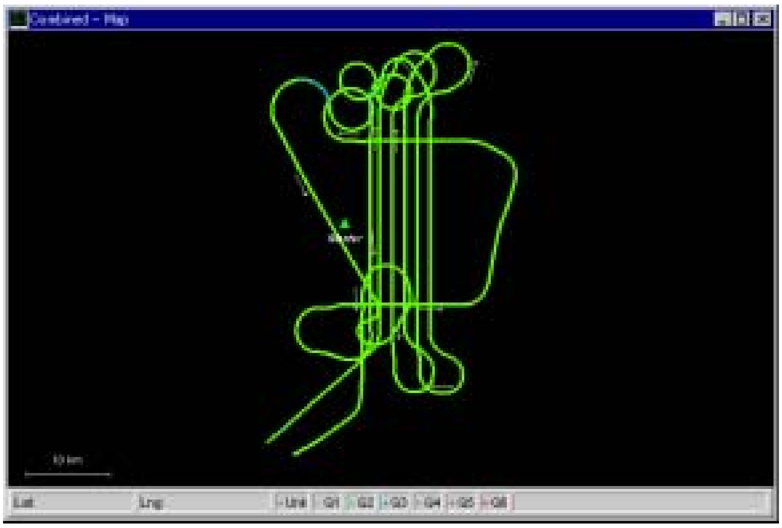


Figure 8-2. Flight trajectory and ground reference point (triangle mark) on April 24, SP2.

The color of the trajectory in the figure shows the quality of the GPS solution. Green shows that the FIX solution of GPS is obtained. Both of these two flights, the FIX solution is obtained in whole mission.

The comparison of time series forward and reverse solution is shown in Figure 9-1 and Figure 9-2, and the standard deviation of GPS solution is shown in Figure 10-1 and Figure 10-2. The conditions of satellite and cycle slip during mission flight are checked, then, available satellites, available period and cut off angle are selected. The priory estimated standard deviation of L1 phase and C/A code are assigned.

As in Figure 9-1 and Figure 9-2, the difference between forward and reverse solution is about 15 to 20 cm, and that standard deviation of 3 dimensions position is about 5 cm all the time. It shows that good results are obtained from both data.

Figure 9-1. Comparison between forward and reverse solutions (February 1, 2002, SP1).

Figure 9-2. Comparison between forward and reverse solutions (April 24, 2002, SP2).

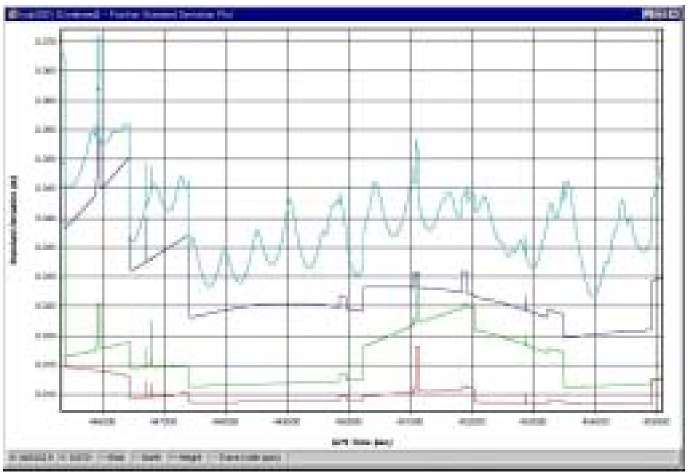


Figure 10-1. Standard deviation after GPS analysis (February 1, 2002, SP1).

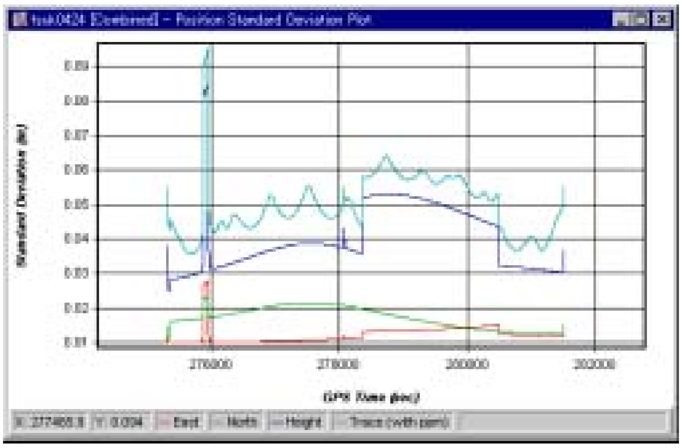


Figure 10-2. Standard deviation after GPS calculation (April 24, 2002, SP2).

The standard deviations of final GPS solution are shown in Figure 11, Figure 12 and Figure 13. As for IMU data, quality is evaluated by checking abnormal value and drift value. Furthermore, standard deviation value of GPS solution is used during combined processing of GPS and IMU data. The final position standard deviation after combining with IMU data was about 5 cm for each. The GPS and IMU solution meet the requirements for the accuracy analysis.

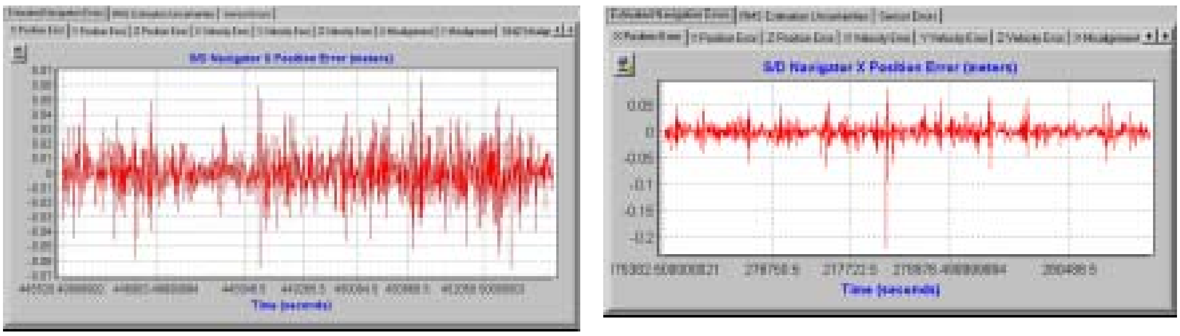


Figure 11. Standard deviation after GPS/IMU analysis (X-coordinate).
(Left: February 1, 2002, SP1; Right: April 24, 2002, SP2)

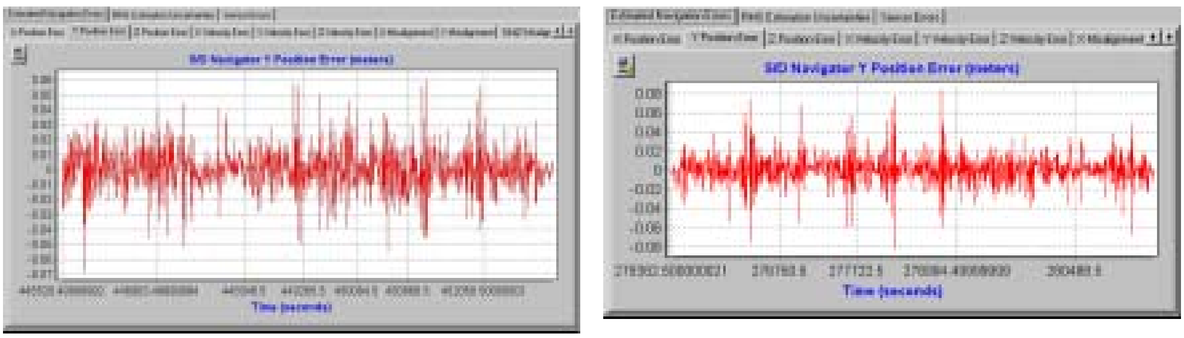


Figure 12. Standard deviation after GPS/IMU analysis (Y-coordinate).
(Left: February 1, 2002, SP1; Right: April 24, 2002, SP2)

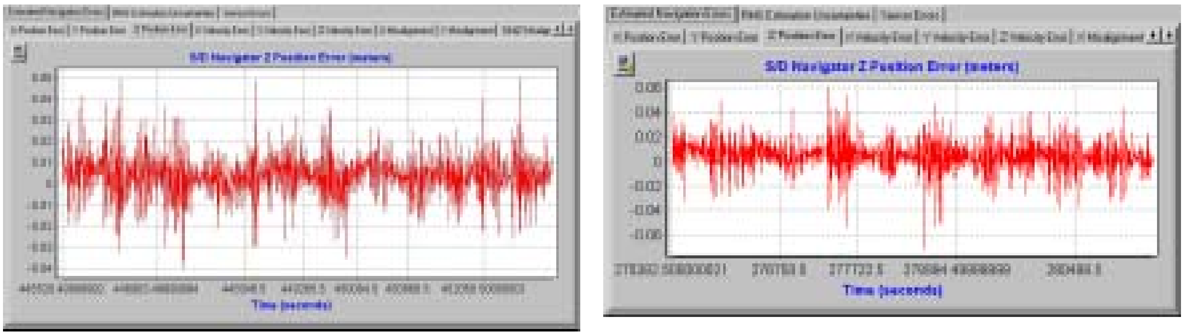


Figure 12. Standard deviation after GPS/IMU analysis (Z-coordinate).
(Left: February 1, 2002, SP1; Right: April 24, 2002, SP2)

3.3.2 Adjustment of blocks

In order to adjust the block, tie points were generated by automatic matching processing using exterior orientation parameters obtained by the POS and image data, then ground control points and check points were observed manually. As for automatic matching processing, APM (Automatic Point Measurement) function of SOCET SET was used.

Tie point distribution is in 5 lines for 1 strip, with 400 pixels intervals in the flight direction. It is equivalent to 80m on the ground. As for the data on February 1, the success rate of automatic matching processing was 80%. Afterwards, blunders were eliminated automatically by 30 micron meter threshold. Eliminated observations were equivalent to 15%. Final adjustment was carried out after confirming whether the points were dense enough throughout the object area. The red points in Figure 14 are the used tie points in the block on February 1.

4. RESULTS AND DISCUSSION

At the final evaluation, block adjustment was carried out using 4 corner points as ground control point. This is the standard procedure of mapping work by ADS40. 0.05m estimated priory standard deviation value is assigned to the control point. The residuals and the maximums of the 22 check points are evaluated. Sigma a priori and Sigma naught are both 5.4 micron meter as SP1, 4.4 micron meter as SP2. They are balanced before and after the adjustment. One pixel of original image is equivalent to 6.5 micron meters and both values are within 1 pixel. It shows that the block adjustment was done successfully.

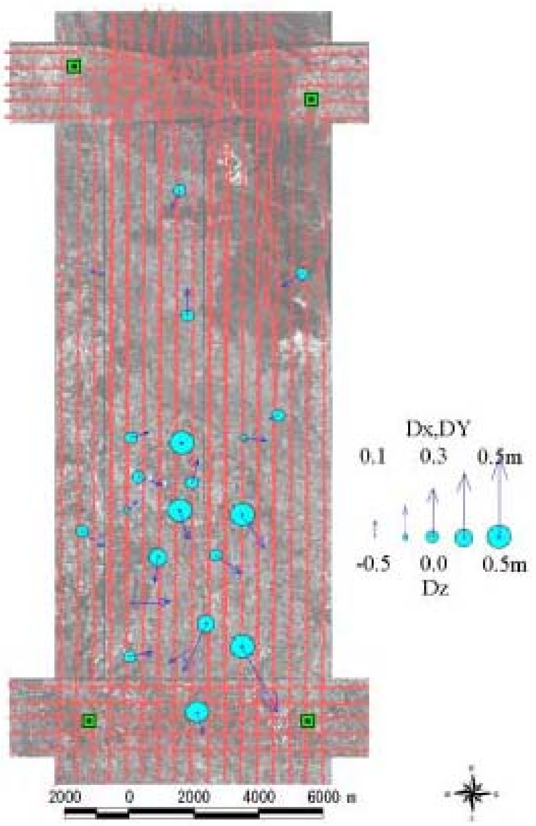
The results of SP1 and SP2 are shown in Table 2 and Table 3, respectively. Distribution of residuals are shown in Figure 14 where four corner points represented in square are the fixed ground control points. The vectors are the horizontal residuals and circles are the verticals ones.

Table 2. Result of SP1 (22 check points)

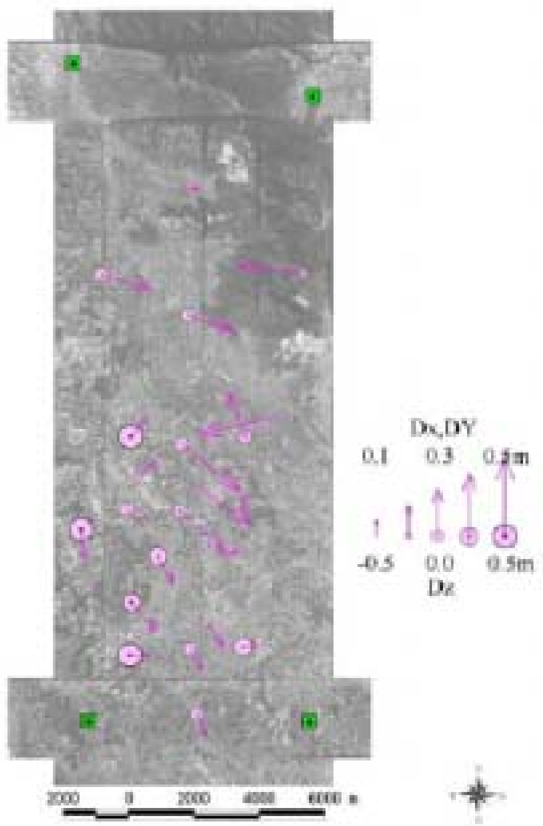
	X (E)	Y (N)	Orthometric Height
RMS (m)	0.12	0.15	0.28
Maximum (m)	-0.22	0.41	-0.50

Table 3. Result of SP2 (22 check points)

	X (E)	Y (N)	Orthometric Height
RMS (m)	0.22	0.15	0.28
Maximum (m)	0.49	0.28	-0.50



(a)



(b)

Figure 14. Residuals of ground control points on February 1, 2002, SP1 (a);
Residuals of ground control points on April 24 2002, SP2 (b)

It can be noted from Table 2 and Table 3 that the results are within the mapping standard of Japan for 1/2,500 scale mapping the final position accuracy of 1.75m in horizontal and 0.66m in vertical direction. At the same time, residuals of ground control points after adjustment are limited to 0.02% for RMS and 0.04% for maximum of flying height. In case of 150mm focal length and 1/10,000 photo scale, the values are equivalent to 0.3m and 0.6m. The results are even within the threshold.

5. CONCLUSION

In this study, it is demonstrated that the block of ADS40 has a great potential for 1/2,500 scale mapping according to the mapping standard of Japan. We also noticed that the processing for map preparation was faster and more economical with ADS40 data as compared to traditional photogrammetry. As a future work, we will employ ADS40 to larger scale mapping at 1/1,000. ADS40 is also providing high resolution RGB, and near-infrared images and we will explore the capabilities for its utilization in the remote sensing field as well.

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