A Simple Method for Correcting the Geometric Distortion of Airborn Multispectral Data

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ABSTRACT

An experimental study has been made to correct the geometric distortion of airborn multispectral imagery. Distorted images were corrected using measured attitude angles (Pitch & Yaw) by means of the newly developed program which was established by numerical simulations. Comparing the corrected images with the corresponding photographs clearly proves the advantage of this simple method for correction.

1. Introduction

The aerial multispectral imagery is required for remoto sensing in Japan, where the land is so narrow and so undulated that its utilizations are finely separated. The weather condition is such that less than 100 days a year will be suitable for remoto sensing. Fine weather accompanies gust, therefore most of surveying aircrafts can hardly keep steady flight.

Disturbed motions of surveying aircraft (6 degrees of freedom) incur considerable geometric distortions of the aerial multispectral imagery. Especially high rate of angular variation makes it impossible to discern ground informations.

If the motions of surveying aircraft were measured accurately, the geometric distortions would be corrected by mosaic techniques. In practice, standard aerial MSS has 2.5 m rad. (0.142°, or about 6 meter in diameter viewing from 2,400 meter hight) in IFOV angle. The position of surveying aircraft, which has been collecting a pixel, can not be measured within an accuracy which is consistent with the IFOV angle, unless the most sophisticated Inertial Navigation System is utilized. On the contrary, it is posible to measure the attitude angles with reasonable accuracy at the time of collecting each pixels. Conventional INS including strap-down type has errors of less than 0.05° and vertical or directional gyro has errors of about 0.2° [1].

So we investigated to correct the geometric distortions of aerial multispectral imagery by means of measured attitude angles which correspond to each scanning lines.

2. Attitude Measurement System

A conventional multi-purpose Inertial Sensing System was modified to measure the attitude angles of surveying aircraft. The ISS consists of following two parts; Inertial Measurment Unit which senses the 3 axes components of linear acceleration and the angular velocity components about 3 axes, and Digital Unit for coordinate transformations, integrations and for improving accuracy or data update.

In order to eliminate the drift of measured pitch and roll angles, the original system had the loop to feedback the difference between computed velocities and reference velocities given as outer signals. However when a surveying aircraft is fliying in strong wind, and if air speed data is utilized as a outer velocity signal, the feedback loop introduces another arror in angle measurements because of the difference between air and ground speed. In this program, Du was modified so as to increase the system flexibility. these are ;

(1) a constant reference speed is able to be set, (2) the feedback loop is able to open and (3) the bearing is able to be updated. Furthermore (4) Pulse-Code-Modulation was selected for the output signals of this system, because it is convenient to put the attitude data of the surveying aircraft into a blank channel of MSS data recorder. (see Fig. 1)

3. Principles of the Correction

In this method it was assumed that the surveying aircraft flew along the straight scheduled course with constant speed. The ground's or image viewer's coordinates (X,Y) corresponding to the center of a pixel which was collected at time (t) are obtained from Eq. (1), as functions of roll angle (Φ), pitch angle (Θ), yaw angle (Ψ) and of view angle (λ) = $2\pi\omega t$, where ω is scanning rate (scans/sec.),

$$\left.\begin{aligned} X &= H\cdot\tan\Theta\cdot\cos\Psi + H\cdot\tan(\Phi+\lambda)\sin\Psi/\cos\Theta + Vt \\ Y &= H\cdot\tan\Theta\cdot\sin\Psi - H\cdot\tan(\Phi+\lambda)\cos\Psi/\cos\Theta \end{aligned}\right\} \quad (1)$$

where H is hight above the ground and V is ground speed. The relationship between body and ground is shown in Fig.2. If MSS has a self correcting mechanism with rolling, thus Φ will be resolved into 0. Typical time constant for rapid motion of aircraft is longer than 1 second [2] and the scanning time for one scanning line is usually between 0.03 and 0.005 seconds. Accordingly it is reasonable to assume that the MSS attitude does not change during scanning one line.

For the pourpose of mapping imagery, it is usually convenient to divide the ground area into regular square blocks for drawing a frame of MSS image, side length of wich is the same as the correspoding diameter of the smallest pixel (or scanning line center's width), as illustrated in Fig.3. When the optimal pixel's data are inserted in these blocks, the geometric correction will be finished.

The first step of correction is to use Eq.(1) to calculate which block is really pointed by the center of each collected pixels. If a block is pointed by nothing, or by two or more pixels, the way branches off into two, the one is famous Nearest Neighbor method, i.e. the selection of the pixel datum for a certain block is baced on the nearest linear distance between the centers of block and pixel. The other is the Average method, i.e. the average data value of the pixels which are pointing the block or the circumambient block is used as the key datum of certain block.

In this paper we have chosen the later method by reason of reducing the required computer's working area. In practice, the necessary working area of 2N scanning lines was prepared in the computer to store both the image data and corresponding indices (k) which is the number of inserted data pointing a certain block. N is a integer exceeding the value of maximum attitude angle, which is obtained at the time of collecting the image, divided by IFOV angle. The pixel data are sequentially inserted into these memories, using Eq.(1). If the block, which has been already occupied by a datum (a), is pointed by a newly appeared another datum (b), the average value $(a+b)/2$ is given to this block. In the same way, the value $(k\cdot a+b)/(k+1)$ would be given to the block after $(k+1)$ data has been pointed. When the pixel pointing the (2N+1)th scanning line firstly appears, the vacant blocks (memories), if we have any in the scanning line up to Nth, should be sorted out by meanes of $k=0$. The average data value of its circumambient block is given to each vacant block. Then the data up to Nth scanning line have been corrected and are transmitted to the buffer memory. Then the vacant working area is allocated to scanning lines from the (2N+1)th to the 3Nth. Repeating these operations will complete the necessary geometric correction.

4. Example of the Correction

A digital MSS image was intentionally made distorted by rudder kicks, and the measured motions of the surveying aircraft (YS-11) are shown in Fig. 4, that is air-speed, air-altitude, roll rate, roll angle, pitch rate, pitch angle, yaw rate and yaw angle. The MSS image thus obtained results in a geometricl distortion as shown in Fig. 5 a, if no correction is applied after corrections for overlaps and for tangent, the image is as shown in Fig. 5 b. An aerial photograph of the training area taken at same time is also shown in Fig. 6.

The parameters of this correcting method such as scanning rate, ground speed, hight above the ground and track angle determine basically the accuracy of mapped image. Consequently, on the occasion with either the map or the aerial photograph is prepared for correcting a frame of image, these parameters should be corrected reasonably by means of the geometric relationship with known ground points.
After such parameter adjustments the corrected image was finally made and shown in Fig. 7.

CONCLUSION RIMARKS

This correcting method will give images a relief from damage due to aircraft lateral oscillations which cange some part of image into a certain pattern.

If sufficient scanning line overlaps were attaind, the Average method is superior to the Nearest Neighbor method in that the former uses all collected pixels and has filtering effect.

The semi-on-time correction for one channel of MSS image is possible a micro-computer which has suitable size of random acces memory, by use of few seconds delay time.

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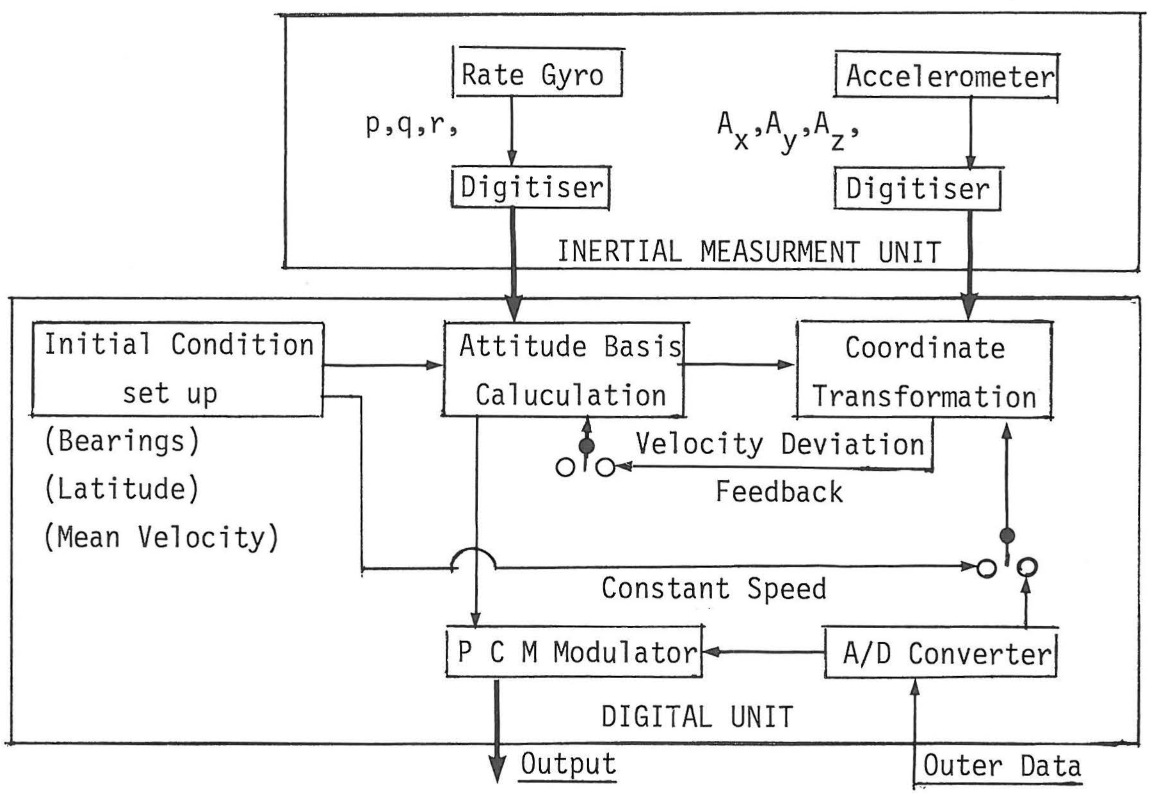
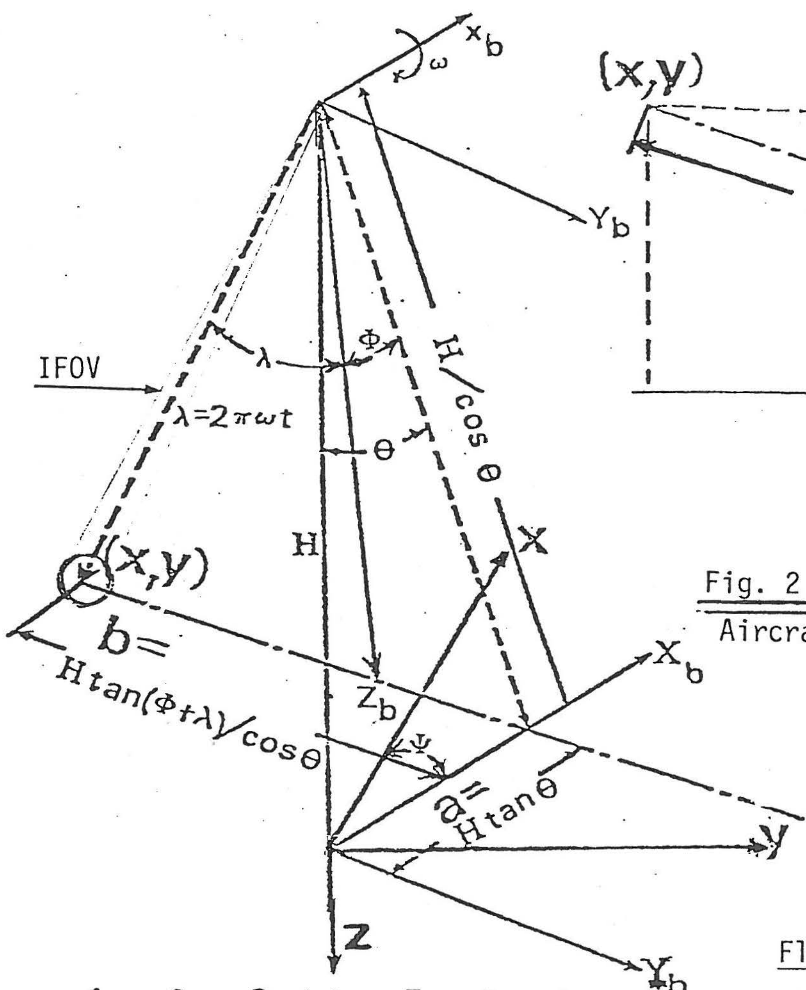


Fig. 1 Inertial Sensing System Block Diagram



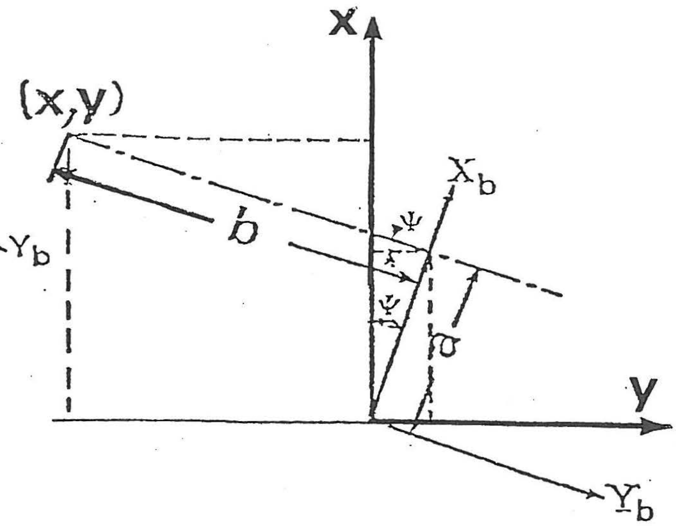


Fig. 2 Schematic Relationship
Aircraft body, ground and MSS

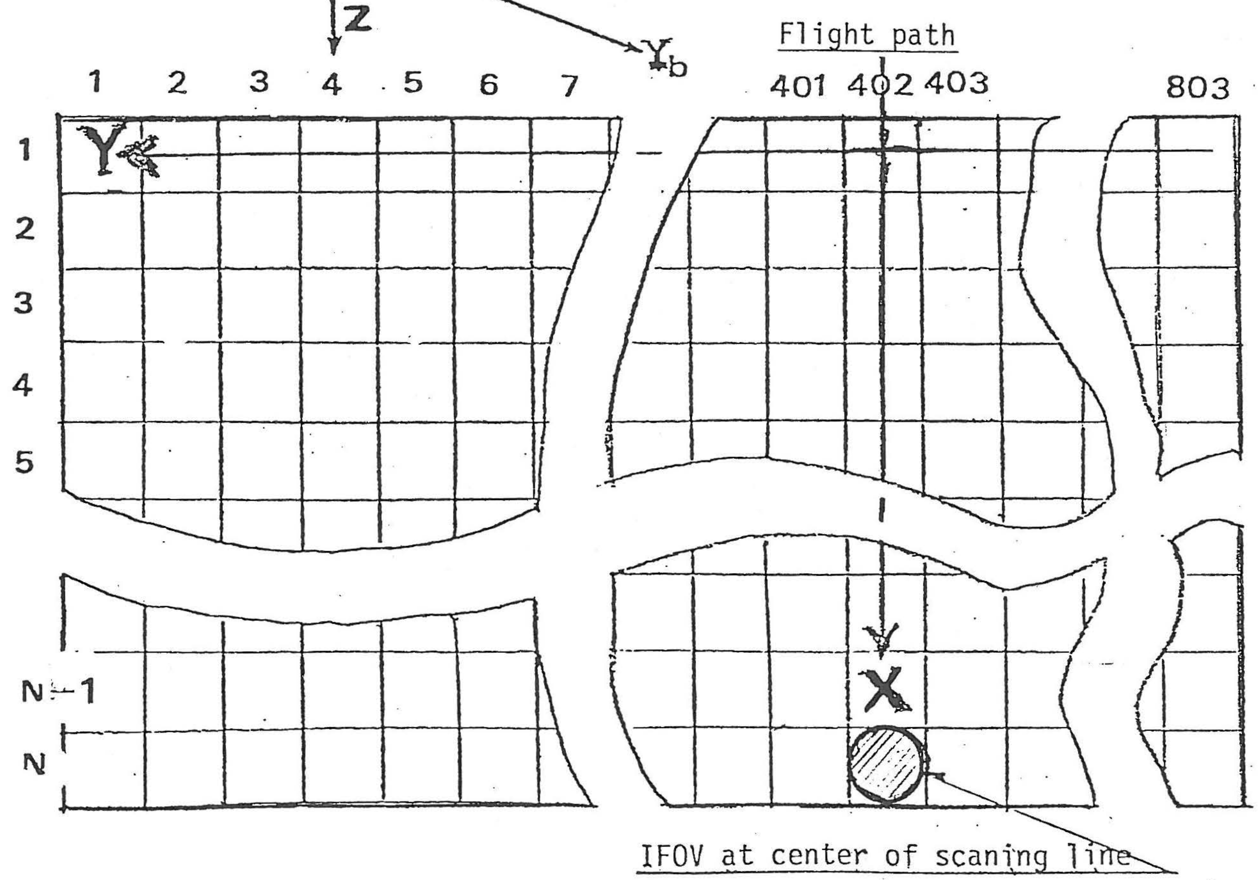


Fig. 3 Coordinated Blocks

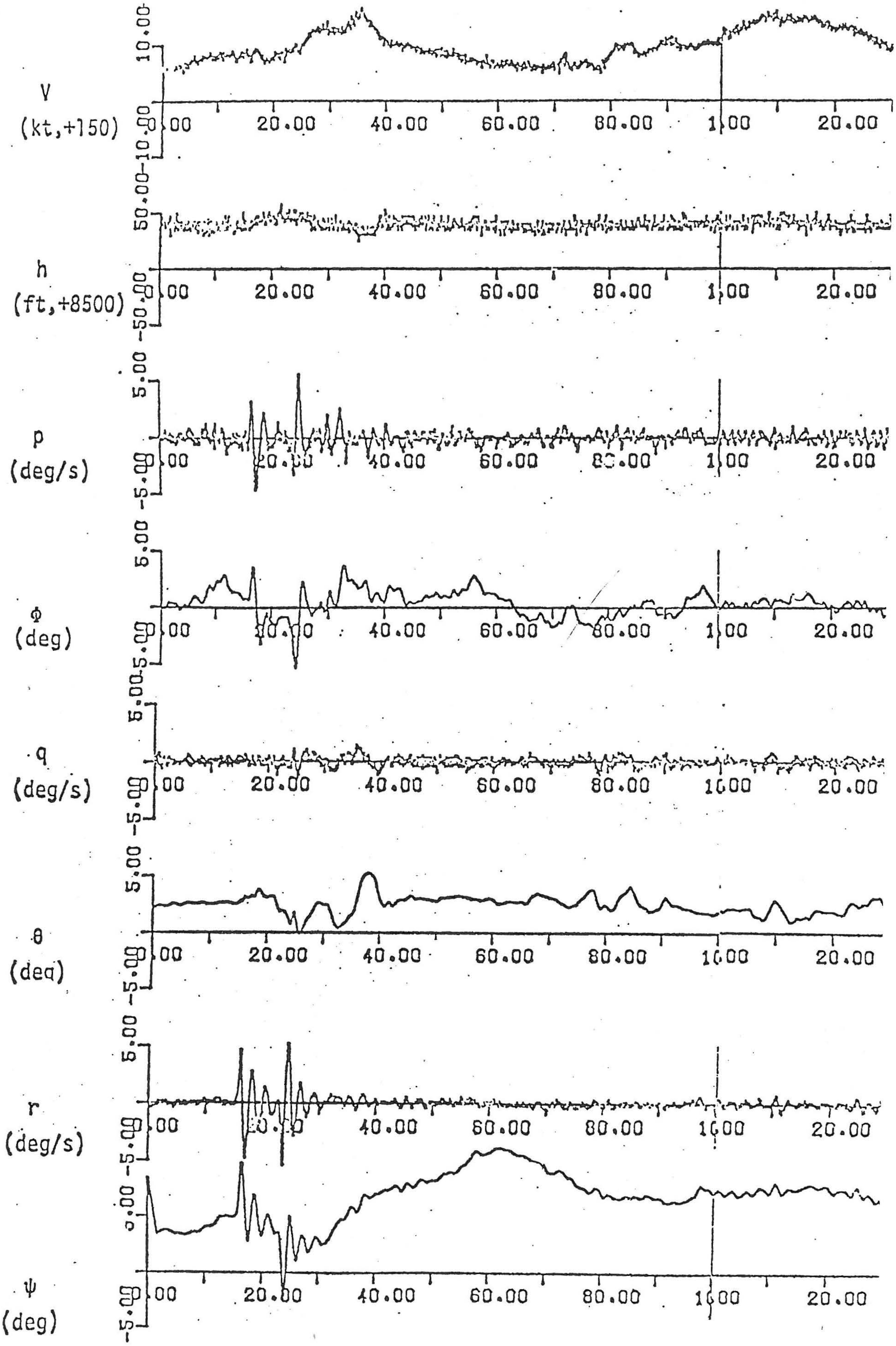


Fig. 4 The Motions of Aircraft collecting Fig. 5

Fig. (5,a)

Fig. (5,b)

Fig. 6,
Aerial Photograph

Fig. 7, Finally Corrected Image