

# PROCESSING OF IRS-1C PAN IMAGE BLOCKS

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## ABSTRACT

This paper describes a method for processing the images acquired by the 3 CCD arrays of the PAN camera of IRS-1C together. A PAN full scene which consists of 9 subscenes each is of dimension 23.5 km x 23.5 km can be adjusted simultaneously with a single GCP to establish relationship with the ground co-ordinate system. This block extension of individual strip formations is practical because the bias angles and the internal geometry of the three detectors are known. The model describes the orbit in terms of orbital parameters with constraints and attitude in terms of higher order polynomials and relate object space to image space with collinearity equations. Two tests were conducted to verify the accuracy and consistency of the model. An average rms error of 10.5m in latitude direction and 11.3m in longitude direction was obtained with a single surveyed GCP used for modelling. The results of the tests show that the triangulation of IRS-1C PAN full scenes is an effective means of reducing the number of ground control points required to permit the precise determination of ground co-ordinates.

## 1. INTRODUCTION

High resolution and off-nadir viewing capability are the most innovative features of IRS-1C PAN camera. Details of the IRS-1C space craft and its camera systems are given by Kasturirangan et al. (1996) and George Joseph et al. (1996). PAN camera has a spatial resolution of 5.8m and it consists of 3 CCD arrays each having 4096 active sensor elements. This camera can be steered up to  $\pm 26$  deg. which in turn increases the revisit capability to 5 days. The nominal inter-pixel distance in the image plane is  $7\mu\text{m}$ . Each LISS-III scene can accommodate four PAN full scenes designated as A,B,C and D. An overlap of approximately 1 km. will be there between A & C and B & D. During a single pass, either A & C or B & D will be acquired. We have developed a method for processing the quadrants A & C ( or B& D) together with a single ground control point for orienting the images. A PAN full scene consists of 9 subscenes each is of dimension 23.5 km x 23 km. IRS-1C imagery is acquired in a continuous strip mode and any subscene segment represents an artificial window which is extracted from a long digital image and defined in a uniform co-ordinate system. The fact that IRS-1C PAN camera has 3 CCD arrays offer a possibility to adjust the images taken by them together by exploiting the knowledge of inter CCD alignment angles.

Now, including IRS-1C/1D PAN, there are many practical remote sensing systems available for space cartography. Successful exploitation of the high accuracy potential of these systems depends on good mathematical models for the viewing geometry. A number of papers have been published on different

approaches for the orbit and attitude determination of these satellites. (Dowman, 1991, Heinrich Ebner et al. 1995). The approaches differ in the use of constraints and in the method of determining the initial values of the unknowns. These methods demand multiple controls for correction. The requirement of highly accurate control is a major problem in remote areas where IRS-1C PAN image is most useful for topographic mapping.

Therefore, with the aim of reducing the control requirements to a minimum, a model for the orientation of IRS-1C PAN full scenes has been developed.

The approach, initially developed for a single image and strip has been extended to a block of images. Satellite position is derived using the collinearity condition equations. Initial orbit is obtained from the given ephemeris data and refinement is carried out using an iterative least squares solution. This can be done directly, as long as the digital image data is given in a fully continuous stream of scan lines in a uniform time frame. The method described represents a rigorous geometric reconstruction of ground from IRS-1C PAN images. This method of processing is ideal where the following conditions exist.

- multiple monoscopic coverage from different detectors during the same pass is available.
- either minimal control is available or cost considerations require minimizing the use of available control (In this model, we require a minimum of 1 GCP for processing.)

- the desirable geometric accuracy is to be comparable with the input GCP accuracy (or the resolution of the sensor).

## 2. ORBIT ATTITUDE MODELLING APPROACH

The model is based on the one developed by the authors for SPOT satellite (Radhadevi et al. 1994). It was further extended for twinstrips of SPOT acquired with a twin-instrument configuration. (Krishnan et al. 1998). The ephemeris data-stream from both the instruments in a twin pair configuration can be appended and they can be used as images in the same strip. Orientation of IRS-1C PAN imagery poses different problems from that of SPOT because of the changes in the internal geometry of the sensors, payload steering mechanism, projection geometry of the optical instrument, co-ordinate system in which the ephemeris is given and the file configurations. Taking into account all these factors, we developed the rectification procedure for IRS-1C PAN subscenes. A detailed description of this model can be found in Radhadevi et al. (1998). A multiscene adjustment model for scenes in the same pass has been developed as an extension of this subscene adjustment method. The experience gained through twin strip adjustment of SPOT satellite helped us to visualize the possible alignment errors of IRS-1C PAN sensors and take care of them. The geometry of this extended image can be rectified with a single GCP as for a subscene. The requirement of only one GCP for orbit attitude modelling is made possible by the following approximations.

- Small arc of the orbit is approximated as a circular one.
- modelling the slowly varying orbital parameters as linear function of time.
- attitude parameters and the radius of the orbit are modelled as third order polynomials in time.
- using additional equations relating the correlated parameters.
- using the ephemeris data to derive the initial values of the parameters.
- using appropriate weight matrices for measurements and parameters.

With these approximations, the set of orbital parameters needed in the adjustment can be reduced to four.

- $i$  inclination;
- $\Omega$  longitude of ascending node;
- $t$  time at the ascending node; and
- $r_0$  orbital radius.

The attitude parameters to be modelled are

- $\omega$  roll;
- $\rho$  pitch; and
- $\kappa$  yaw.

For the PAN full scene adjustment, it is necessary to regard the four orbital parameters as corrections to the set of estimated values. Start values of the simplified orbital model parameters as estimated from the appended ephemeris of all the scenes. By using the same corrections to all the scenes, the extended image is kept rigid and the orbital parameters for the whole pass are kept to four. Similarly start values for attitudes are calculated from the ephemeris. This is possible because the overlap between successive scenes allows an uninterrupted sequence of attitude measurements to be constructed. With these start values, same corrections can be applied to all the scenes. The modelling approach for full scenes is to be modified from the single scene approach to take care of the following factors.

1. The CCD arrays cannot be placed edge-to-edge without doing an inflight calibration for each array. The focal lengths of each array will be slightly varying.
2. The attitude rate measurements given in the respective record in the leader file are not correct. Therefore, the weight matrices for attitude parameters in the adjustment model should be chosen properly to take care of any insignificant errors due to attitude variations within the full scene.
3. The overlap of imagery joins are to be internally computed without doing the common point identification manually.
4. Scene centre time, scene centre pixel, total number of lines, pixels, look direction of each pixel etc. should be computed from the overlaps considering all the scenes from the three detectors as a single very big image.

### 2.1 Determination of relative focal length of each CCD array

The focal length is the perpendicular distance between the perspective centre and the particular CCD array with which the image is taken. A small error in the focal length is of little importance in normal modelling of one scene, because it will be absorbed in the orbit position parameters. In the adjustment of multiple scenes from 3 CCD arrays from the same orbital position, different errors in focal length will cause different scales along a line in the three images. The values of focal lengths from the pre launch calibrations may have changed. The absolute values of these focal lengths can hardly be calculated from inflight measurements. But we can find the variations relatively. We assume that detector 1 is having an error-free focal length. The values of focal lengths for detector 2 and 3 will be treated as parameters in the

model so that the values can be determined in relation to detector 1. Thus the relative focal lengths of the each CCD array will be scaled so as to be compatible with the image measurements. Solving for this scale distortion, the CCD arrays can be placed edge to edge.

## 2.2 Determination of overlap of imagery joins

The overlaps between two images are determined using the image co-ordinates. As the images from a single detector are registered continuously, it is easy to determine the overlap between them in the alongtrack direction. The grey values of all the pixels in the last line of an image can be compared with grey values of all the pixels in each line of the successive image till they perfectly match. This will give the number of overlap lines which is to be calculated for time tagging. The pixel location of any point common to two images is the same.

In the across track direction, the overlaps in both pixel and line direction are to be computed. Because of the illumination differences, the images from three detectors may not have the same clarity. Also overlap between detector2 and detector3 is very less compared to detector1 and detector2. Therefore common point identification from split screen display is very difficult if not impossible. - A large number of high contrast, rectangular window subimages were extracted from the corners of each subscene and automatic correlation was used to find the conjugate point identification from the adjacent images.

## 3. TEST DETAILS

The accuracy of the model for simultaneous processing of images from 3 CCD arrays of IRS-1C PAN camera was investigated in two tests. The objectives of the tests were the following:

- to determine the accuracy which can be obtained for PAN full scenes corrected with the model
- to verify the consistency and robustness of the model
- to compare the accuracies obtained by using different types of control for modelling

The points, which can be used as check points as well as control points were gathered from three sources. A few surveyed controls were available where most of the points were from manual identification on 1:25,000 and 1:50,000 scale SOI maps. The surveyed controls can have an identification error which can reach 10 meters. A 1:50,000 map has approximately a plottable error of 12.5 m in-plan and 20m in height. In practice, while digitizing a specific feature for control, the error could be 25-35m in plan. The measurement errors of the image coordinates of GCPs as well as check points are inhomogenous (0.5 to 2 pixel) because of the manual pixel pointing of the image coordinates monoscopically. The image data and imaging geometry details used for the tests are given below:

Test	Path/ row	Sub-scenes adjusted	date of pass	Look angle
1	100/60	C1; C2; C3; C4; C5; C6; C7; C8; C9	11-4-96	-17.98°
2	100/60	D1; D4; D5; D6; D7; D8; D9	20-1-96	0.01°

## 4. RESULTS

Table 1 present the accuracies obtained for the two tests. An average rms error of 10.5 m in latitude direction and 11.3 m in longitude direction was obtained when a single surveyed ground control point was used for modelling. When a GCP from 1:25,000 map was used for modelling, an average error of 34.3m. in latitude direction and 39.2m. in longitude direction was obtained. When the GCP used for adjusting the block was from 1:50,000 map, the average error was 50.40m. in latitude and 43.27m. in longitude. Experiments with increased number of control points show that the errors are not much dependent on the number of control points but depends on the accuracy of the control/check points

Test	No. of GCPs	No. of check points	Source of control/ check points	Latitude error (m.)	Longitude error (m.)
1	1	10	Surveyed	12.60	10.36
	1	40	1:25,000 map	30.80	36.40
	1	26	1:50,000 map	45.64	45.36
2	1	7	Surveyed	8.40	12.38
	1	41	1:25,000	37.80	42.01
	1	31	1:50,000	55.16	41.18

**Table 1: RMS errors obtained for two tests with different sources of control**

The specified control accuracy figures of each source of control were just met with 1 GCP. Figures 1 and 2 show the error vectors for the two tests. The check points are uniformly distributed in the block. The position of the GCP used for adjusting is also indicated. In test 2 (we can see from Fig.2), subscenes 2 & 3 are not available. The number of overlap lines are approximate which will reflect as a latitude error. The model is not sensitive to the location of the used GCP. The geoidal height of the GCP is used in the adjustment without converting to the ellipsoidal height whereas the satellite position given in the ephemeris is with respect to the ellipsoid. This would have contributed some error. This method of processing will work for continuous PAN full scenes acquired during the same pass. But due to lack of images it is tested only for one full scene.

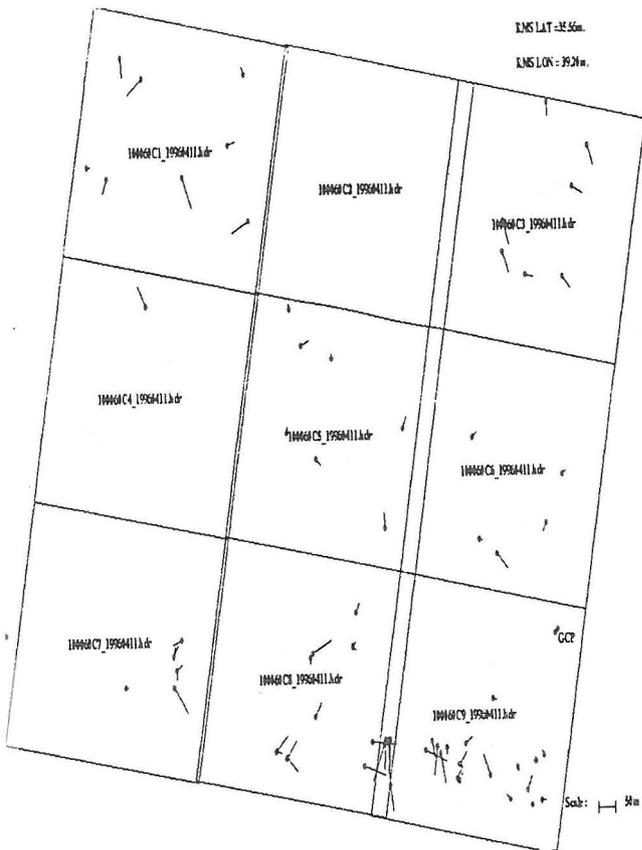


Fig.1 - Positional RMS error vectors of Test 1 (check points from 3 different sources)

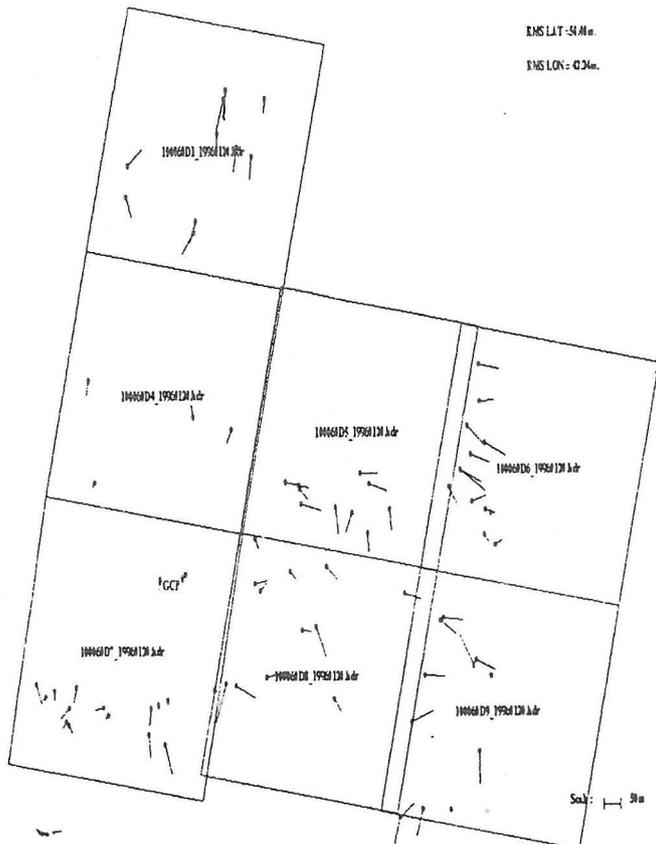


Fig.2 - Positional RMS error vectors of Test 2 (check points from 3 different sources)

## 5. CONCLUSIONS

The major conclusions drawn from the results are the following:

- The method of processing of PAN image blocks described in this paper will allow for the generation of mapping products over large areas (approximately 140km x 70km).
- Using a fully weighted adjustment, keeping the adjustment parameters to a minimum, by orbital and attitude constraints, and by using the internal geometry of the detectors, the need for ground control points can be kept very low. A single GCP is enough for rectification of PAN full scene.

This is very important because ground control acquisition costs are high. This not only lowers the cost for ground control acquisition, but also enables the correction of scenes in remote areas taken by one detector, where control point acquisition is impossible, by extrapolation from scenes in nearby accessible areas taken by the other detectors.

- The model is not sensitive to the location of the used GCP.
- Errors are not much dependent on the number of control points but depends more on the quality of the control points.
- Automatic computation of overlap of imagery joins and relative focal lengths of each of the detectors make the triangulation very userfriendly avoiding the tie points and pass points in the adjustment. The user can rectify the full block as a single scene with a single GCP.

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