

# Use of Remote Sensing for Earthquake Damage Assessment

(August 2004)

## Overview

Remote sensing and Geographical Information System (GIS) data have become an increasingly important resource for the disaster management community. GIS technology provides the ability to gather, organize, manipulate, display and analyze complex collection of geographic data and information. Earthquake disasters are inevitable and it is almost impossible to fully recoup the damage caused by the disasters. But it is possible to minimize the potential risk by developing disaster early warning strategies, prepare and implement developmental plans to provide resilience to such disasters and to help in rehabilitation and post disaster reduction. Space technology plays a crucial role in efficient mitigation and management of disasters. Remote sensing and Geographical Information System (GIS) plays a major role in evolving a suitable strategy for disaster management and occupational framework for their monitoring, assessment and mitigation, identifies gap areas and recommends appropriate strategies for disaster management using these technologies.

## 6<sup>th</sup> April 2004 – Another Earthquake strikes Afghanistan

### International reports

#### *From USGS Earthquake Hazards program. ([www.earthquake.usgs.gov](http://www.earthquake.usgs.gov))*

A strong earthquake occurred at 21:24:04 (UTC) on Monday, April 5, 2004- local time Tuesday, April 6, 2004 at 1:54:04 AM. The magnitude 6.6 event has been located in the HINDU KUSH REGION, AFGHANISTAN  
location: 36.527°N, 71.028°E  
depth: 191.4 km (118.9 miles) set by location program

Reports: At least one person killed in the Shahr-e Bozorg area. Felt strongly at Kabul. Also felt at Delhi and Guragon, India; Srinigar, Kashmir; Islamabad and Lahore, Pakistan; Dushanbe, Tajikistan; Tashkent, Uzbekistan.

#### *From Relief Web (WFP - Afghanistan Weekly Situation Report 15 - 21 Apr 2004)*

On 15 - 16 April, a WFP mission team assessed recent earthquake damage to Sari Qul and Yaftal villages in Badakhshan province. It was found from the assessment, among others, that ten out of 22 households were evacuated to adjacent villages, and that the remaining villagers were drinking water from a muddy river nearby. WFP is providing food aid to the victims, one of the emergency items needed together with tents, blankets, water containers, utensils and medicine.

[http://www.usaid.gov/our\\_work/humanitarian\\_assistance/disaster\\_assistance](http://www.usaid.gov/our_work/humanitarian_assistance/disaster_assistance) -

### **AFGHANISTAN – Complex Emergency**

Situation Report #2, Fiscal Year (FY) 2004 April 26, 2004

**Earthquake in Badakhshan Province.** On April 6, 2004, an earthquake with a magnitude of 6.6 struck Badakhshan Province along Afghanistan's northeast border with Pakistan at 1:54 a.m. local time. The epicenter of the earthquake was in Jurm District, 50 miles south-southeast of Faizabad. According to the Afghan Red Crescent Society (ARCS), the earthquake resulted in at least one death. ARCS also reported that several buildings in Faizabad collapsed, and minor structural damage occurred across the region.

## Availability and Accessibility of Remote Sensing Data following a major disaster

*The Charter:* Satellite imagery is very expensive and not affordable by most developing nations without their own space programs. In the event of a natural or man-made disaster, space technology data should be readily available, for nations like Afghanistan, which do not have or cannot afford their own space programs. Since November 2000 the 'Charter On Cooperation To Achieve The Coordinated Use Of Space Facilities In The Event Of Natural Or Technological Disasters' ([www.disasterscharter.org](http://www.disasterscharter.org)) was launched by several space agencies. The International Charter aims at providing a unified system of space data acquisition and delivery to those affected by natural or man-made disasters through authorized users.

Immediately following the 6th April 2004 earthquake of Jurm District, Badakhshan Province in Afghanistan, AIMS contacted the United Nations Office for Outer Space Affairs in order to request satellite imagery from the Charter to enable the following:

- a) Damage assessments;
- b) Map the extent and impact of the earthquake on the lives and properties of Afghans
- c) Provide a decision support system for Government Authorities and the Humanitarian Agencies in addressing rescue, relief, rehabilitation, reconstruction and mitigation.

Through UNOSAT which is an Authorized User of the Charter, AIMS received a set of satellite imagery covering both pre and post disaster periods.

## Satellite Imagery received from UNOSAT

SAC – Argentinean Satellite.

06-10-2001 – SAC Multi-spectral Image – 120 m Resolution

06-10-2001 – SAC Panchromatic Image – 35 m Resolution

See MAP 1 for locations

SPOT

18-10-2003 – HRG 2 (12000 by 12000) 5m level 1 A processing

17-04-2004 – HRG 1 PAN (24000 by 24000) 2.5m level 1 A processing

17-04-2004 – HRG 1 Multi-spectral (Image Corrupt – contact UNOOSAT for data)

IRS-P6

26-03-04 06:14 (LISS-3) Medium Resolution Multi Spectral 24m

14-04-04 06:19:09 (LISS-4) High Resolution – Panchromatic – 5m

14-04-04 06:19:19 (LISS-4) High Resolution – Panchromatic – 5m

See MAP 2 for locations

## Description of Imagery

### SPOT<sup>1</sup>

The information in a SPOT image gives an objective, reliable picture of the Earth's surface. Both accurate and all encompassing, a single SPOT image covers a surface area of 3,600 km<sup>2</sup>

SPOT is tailored for multiscale requirements, it covers a wide area of 60 KM by 60 KM with resolutions ranging fro 20m to 2.5m. It can be used for applications ranging from regional (1:500,000) to local scales (1:10,000).

3000 * 3000	20 m
6000 * 6000	10 m
12000* 12000	5 m
24000* 24000	2.5 m

#### SPOT product spectral modes

SPOT products	SPOT satellites	Spectral mode	Bands Nb	Pixel size
2.5 m colour	5	VHR+HX	3	2.5 m
2.5 m B&W	5	VHR	1	2.5 m
5 m colour	5	HM+HX	3	5 m
5 m B&W	5	HM	1	5 m
10 m colour	5	Hi	4	10 m
	4	M+Xi	4	10 m
10 m B&W	4	M	1	10 m
	1, 2, 3	P	1	10 m
20 m colour	4	Xi	4	20 m
	1, 2, 3	XS	3	20 m

#### SPOT satellite spectral bands and resolutions

Sensor	Electromagnetic spectrum	Pixel size	Spectral bands
SPOT 5	Panchromatic	2.5 m or 5 m	0.48 - 0.71 µm
	B1: green	10 m	0.50 - 0.59 µm
	B2: red	10 m	0.61 - 0.68 µm
	B3: near infrared	10 m	0.78 - 0.89 µm
	B4: mid infrared (MIR)	20 m	1.58 - 1.75 µm
SPOT 4	Mono-spectral	10 m	0.61 - 0.68 µm
	B1: green	20 m	0.50 - 0.59 µm
	B2: red	20 m	0.61 - 0.68 µm
	B3: near infrared	20 m	0.78 - 0.89 µm
	B4: mid infrared (MIR)	20 m	1.58 - 1.75 µm

<sup>1</sup> See [www.spotimage.com](http://www.spotimage.com)

SPOT 1	Panchromatic	10 m	0.50 - 0.73 $\mu\text{m}$
SPOT 2	B1: green	20 m	0.50 - 0.59 $\mu\text{m}$
SPOT 2	B2: red	20 m	0.61 - 0.68 $\mu\text{m}$
SPOT 3	B3: near infrared	20 m	0.78 - 0.89 $\mu\text{m}$

### SPOT Scene

Level 1A: Radiometric correction of distortions due to differences in sensitivity of the elementary detectors of the viewing instrument.

Intended for users who wish to do their own geometric image processing.

Level 1B: Radiometric correction identical to that of level 1A.

Geometric correction of systematic effects (panoramic effect, Earth curvature and rotation). Internal distortions of the image are corrected for measuring distances, angles and surface areas.

Specially designed product for photo-interpreting and thematic studies.

Level 2A: Radiometric correction identical to that of level 1A. Geometrical correction done in a standard cartographic projection (UTM WGS84 by default) not tied to ground control points. Allowing for possible differences in location, this product is used to combine the image with geographical information of various types (vectors, raster maps and other satellite images).

All images have been provided as level 1A products.

## IRS – P6 Data (RESOURCESAT-1)<sup>2</sup>

All the three cameras on board the Indian Space Research Organization's (ISRO) latest remote sensing satellite, RESOURCESAT-1, have been tested and the photographs received indicate excellent performance of the cameras. RESOURCESAT-1, was launched by ISRO's Polar Satellite Launch Vehicle, PSLV-C5, from Satish Dhawan Space Centre-SHAR on October 17,2003.

RESOURCESAT-1 carries three cameras on board:

- A multi-spectral high spatial resolution camera, namely, Linear Imaging Self Scanner-4 (LISS-4) providing a spatial resolution of 5.8 m and a swath of 23 km. It operates in the Visible and Near Infra Red spectral bands. LISS-4 can also be operated in mono-chromatic (black and white) mode providing a spatial resolution of 5.8 m and a swath of 70 km. In addition, , the camera can be steered across track to take stereoscopic imagery.
- A multi-spectral Linear Imaging Self Scanner-3 (LISS-3), which has a spatial resolution of 23 m and a swath of 141 km. It operates in the Visible, Near Infra Red and Short Wave Infra Red spectral bands.
- A multi-spectral Advanced Wide Field Sensor (AWiFS) with a spatial resolution of 56 m providing a swath of 740 km. The camera operates in the Visible, Near Infra Red and Short Wave Infra Red spectral bands. AWiFS is a unique camera having the capability to take the imagery of the world repeatedly every 5 days with a very high radiometric resolution.

## Methodological Approach

- Clarification of what needs to be assessed.
- Collation of Remotely Sensed and Ancillary/Supporting Data Sets (Infrastructure, Topographic Maps, DEM, Settlement, population).
- Collection of Incident Reports

<sup>2</sup> From [http://www.isro.org/pressrelease/Nov10\\_2003.htm](http://www.isro.org/pressrelease/Nov10_2003.htm)

- d) Creation of Multi layer GIS to provide assessment of location of Earthquake – and initial assessment of location of areas likely to be affected – consider timeliness of data and resolution.
- e) Visual Inspection and selection of useful imagery
- f) Simple Rectification of Imagery
- g) Rectification Pre-post event imagery (same sensor)
- h) Provide Simple Visual Assessment of Damage/ No damage

### ***Mapping the Earthquake (applying the methodology)***

- 1 Overview of All RS - done
- 2 High resolution – frames and GIS layers
  - 2.1 description of/example of RS data -
    - 3.1 Satellite Images + GIS -24m
    - 3.2 Satellite Images + GIS -5m
    - 3.3 Satellite Images + GIS -2.5m4 Reported Incidents? Damages one map with “pins”
    - 4.1 Imagery (imagettes – small subsets of images) – showing pre and post event – any damages – small text description.

#### **Importing and viewing IRS P6 data within ERDAS IMAGINE (8.4) using Import Generic Binary data**

IRS-P6 is the most advanced remote sensing satellite built by ISRO. Presently there are no standard import filters in ERDAS Imagine 8.4 to handle this new format. In order to view and work with the imagery it must be imported as “generic binary data”

Imagines import filter needs to know certain things about the data, the file and the image, see Figure 1, before being able to read and reconstruct the image as an \*.img file. Assuming that the image is available as digital data on file or cd-rom – the following information is required.

#### ***Data Description***

**Data format:** Specifies how the image data is stored within the data file. Typical formats are BIL, Band Interleaved by Line, BSQ, Band Sequential, BIP, Band Interleaved by pixel.

**Data Type:** Specifies how the image data has been written in the file – for optical, or most processed data it is normally Unsigned 8 bit.

#### ***Tape/File Options***

**File header bytes:** At the beginning of the image data file some space is normally used in which to store information about the file – this is known as the files header information. A set number of bytes are used to store this data.

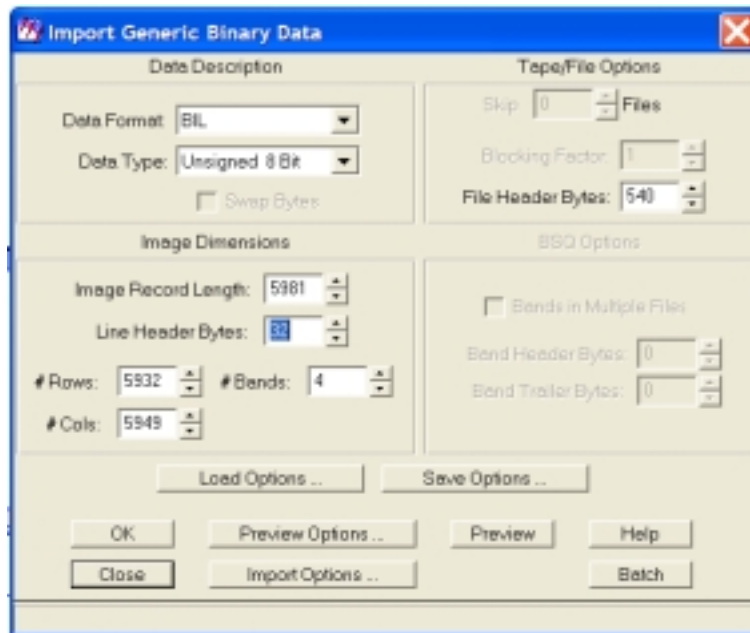


Figure 1: import dialogue for MS IRS P6 data

## ***Image Dimensions***

**Image Record Length:** The image record length depends upon the Data Format the image stored in – for BIL (Band Interleaved by line) the image record length should be the same size as number of columns + line header bytes.

**Line Header Bytes:** Each line of image data may also be preceded by ancillary information – this information is not image data and needs to be ignored or skipped over by Imagine.

**Number of Bands:** Number of Image Bands stored within the file

**Number of Rows:** Number of Rows (lines) in the image

**Number of Columns:** Number of Columns (pixels per line) within the image

## ***Obtaining Values.***

The required information for IRS-P6 images will be located in one of two places:

**CDINFO file:** Depending upon the method of processing of the image a file call CDINFO may be present with the data. In this case the required information can be found within this text file.

**Within Data file:** if the CDINFO file is not present then it is necessary to open and read the actual binary data stored within the image files. All binary data files can be read in Erdas Imagine using the tool “View Binary Data”, see

Figure 2, under the “Tools” menu – it is most convenient to view the data as “ASCII”.

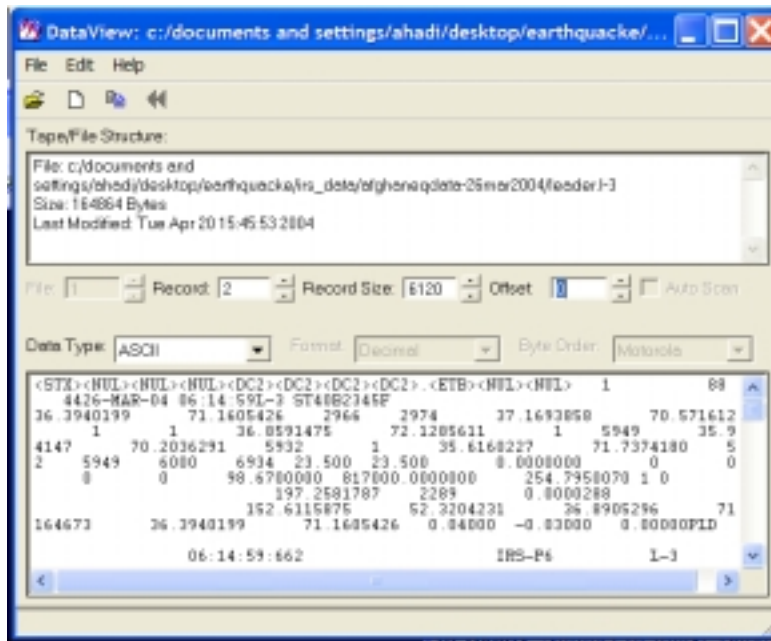


Figure 2: Erdas Imagine's Data Viewer to read data in binary files.

## Understanding the IRS-P6 File Structure

The LGSOWG (Landsat Ground Station Operators Working Group) format contains basically five files as described below.

### Logical Volume

A logical volume is a logical collection of one or more files recorded consecutively. All logical volumes have a volume directory as the first file and null volume directory as the last file. When a logical volume is split between physical volumes the volume directory is repeated at the start of the next physical tape with some updated information.

#### Volume Directory File

The volume directory file is the first file of every logical volume. It is composed of volume descriptor record, a number of file pointer records and a text record. The volume descriptor record identifies the logical volume and the number of files it contains.

There is a file pointer record for each type of file in the logical volume, which indicates each file's class, format and attributes.

#### Leader File

The leader file is composed of a file descriptor record and three types of data records. The record types are header, ancillary and annotation. Header contains information related to mission; sensor and processing parameters. Ancillary records contain information related to ephemeris, attitude and Ground Control Points (GCPs) for image correction.

#### Image File

Image file consists of file descriptor record and image data records. Image data records contain the video data in Band Interleaved by Line (BIL) format or Band Sequential Format (BSQ), and in addition, it also contains prefix and suffix information.

#### Trailer File

The trailer file follows the image data file. This is composed of a file descriptor record and one trailer record for each band.

#### Null Volume Directory File

The file, which ends a logical volume, is the null volume directory file. The file is referred to as 'null' because it defines a non-existent (empty) logical volume. This file contains a volume descriptor record.

## **Files and records in IRS-1C/1D/P3/P6/DAT**

<b>File No.</b>	<b>Seq.</b>	<b>Record Type and length</b>	<b>Description of file contents</b>
File 0		Variable No. of Records each of 360 bytes.	Volume Directory file (Volume descriptor, File Pointers and text record).
File 1		* Variable No. of Records each of 6120 bytes	Leader file (Descriptor, Header, ancillary, Calibration, Histogram, Map Projection, GCP, Annotation, Boundary, and Boundary annotation Record.
File2		* Variable No. of records * Variable record length	Image Data file
File 3		Variable No. of Records each of 360 bytes	Trailer file (Description and trailer records)
NULL		One Record of 360 bytes	Null file (End of logical volume will be overwritten to add another logical volume.)

Table 1: Files and Records in Indian Remote Sensing Satellite P6 data.

## **Digital Data File Structure**

	<b>File</b>	<b>Record</b>	<b>Description</b>
Volume Directory	Volume Directory file	i) Volume Descriptor ii) File Pointer for file-1 iii) File Pointer for file-2 iv) File pointer for file-3 v) Text Record	Identification of logical Volume and file pointer record corresponding to each file of logical volume. Specific file format record length, number of records etc The text record gives information about physical tape, environment in which the tape has been created.

\* Number. of records and record length will vary as per the product type or number. of bands or sensor

1.	Leader file	i) Leader file Descriptor  ii) Header Record  iii) Ancillary Records  iv) Annotation Record  v) Boundary Records and Boundary annotation record	Gives the mode of reading file and contains key data field location.  Information related to mission, sensor, processing parameters.  Contains information about ephemeris, attitude, calibration histogram, map projection and GCP's  Contains information about annotation and tick marks.  These records are dummy.
2.	Image data file	i) Image file descriptor  ii) Image data Records	Gives the mode of reading the file and contains key data field locations.  Contains RAW/PROCESSED/RADIOMETRIC Corrected Data
3.	Trailer file	i) Trailer file descriptor  ii) Trailer records	Gives the mode of reading the file and contains key data field locations.  These contain information about cloud coverage and parity errors.
NULL VOLUME	Null Volume file	i) NULL VOLUME Descriptor Record	Last file of the logical volume. The purpose of this is to mark the end of logical volume.

Table 2 Digital File Structure – Highlighted texts indicate the files/records that will contain key information required by to complete Erdas Imagines Generic Binary import filter.

## Locating Image and Data information

From

Table 2 it is clear that image and data information are likely to be located within the record number 2 of the leader file and record number 1 of the image data file. The most convenient way to find the location of the required data is to look at the technical description of the P6 data structure. This document is provided with the image data, see P6SUPER.doc. The description of the contents of record number 2 (header file) of the leader file is given in Table 2.4.3.2 (in technical description document) and the description of the content of the record number 1 (image descriptor file) of the imagery file is given in Table 2.4.4.1

## Information from images

**Image Date: 26-MAR-04 06:14 (LISS-3) Medium Resolution Multi Spectral**

Data from Leader File, Record 2, – Header Record (file leader.I-3)

Byte 100 onwards	Centre	Upper Left	Upper Right	Lower Right	Lower Left
Latitude	36.3940199	37.1693858	36.8591475	35.6160227	35.9214147
Longitude	71.1605426	70.5716124	72.1285611	71.7374180	70.2036291

Processed Pixel Spacing: 24.00 (bytes 1313-1320)

Processed Line Spacing: 24.00 (bytes 1321-1328)  
Band Interleaving Indicator: BIL (bytes 1329-1344)

Data from Imagery File – Imagery.I-3. Imagery File, Record 1

Number of image records: 23728 (bytes 181-186)  
Image record length: 5981 (bytes 187-192)  
Number of image (Bands): 4 (bytes 233-236)  
Number of lines per image: 5932 (Exc. top and bottom border lines) (bytes 237-244)  
Number of left border pixels per line: 0 (bytes 245-248)  
Number of image pixels per line: 5949 (bytes 249-256)  
Number of right border pixels per line: 0 (bytes 257-260)  
Number of top border lines: 0 (bytes 261-264)  
Number of bottom border lines: 0 (bytes 265-268)  
Interleaving indicator: BIL (bytes 269-272)

**Image Date: 14-APR-04 06:19:09 (LISS-4) High Resolution – Panchromatic – 70km**

Data from Leader File, Record 2, – Header Record (file leader.I-3)

Byte 100 onwards	Centre	Upper Left	Upper Right	Lower Right	Lower Left
Latitude	36.6650809	37.0534683	36.8890942	36.2760870	36.4391779
Longitude	71.0595333	70.7710613	71.5479219	71.3450394	70.5738997

From CDINFO file –

Product number :040101100101  
Satellite ID :P6  
Sensor :L-4  
Path-Row :088-044  
Date, Time and Scene Id. :14-APR-04 06:19:09L4MCST00B4 F  
Product Code :STPC0027J  
Orbit Number :0  
Image Layout :BSQ  
Number Of Bands :1  
Bands Present in Product :4  
Bands in this volume :4  
File Header :540  
Line Header (Prefix Bytes):32  
Line Trailer(Suffix Bytes):0  
Scan Lines :14081  
Pixels :14307  
Bytes Per Pixel :1  
Image Record Length(Bytes):14339  
No of Volume :1/1

**Image Date: 14-APR-04 06:19:19 (LISS-4) High Resolution – Panchromatic – 70km**

	Centre	Upper Left	Upper Right	Lower Right	Lower Left
Latitude	36.0753939	36.4635216	36.2999403	35.6866171	35.8489483
Longitude	70.8714577	70.5847094	71.3557551	71.1553600	70.3898782

From CDINFO file –

Product number :040101100201  
Satellite ID :P6  
Sensor :L-4  
Path-Row :088-045

Date, Time and Scene Id. :14-APR-04 06:19:19L4MAST00B4 F  
Product Code :STPC0027J  
Orbit Number :0  
Image Layout :BSQ  
Number Of Bands :1  
Bands Present in Product :4  
Bands in this volume :4  
File Header :540  
Line Header (Prefix Bytes):32  
Line Trailer(Suffix Bytes):0  
Scan Lines :14082  
Pixels :14304  
Bytes Per Pixel :1  
Image Record Length(Bytes):14336  
No of Volume :1/1

## Assessment Results

This image illustrates that the affected area is a mountainous area, with an altitude of over 3200 meters, with less population, and with most of the area permanent covered with snow. Due to the rugged terrain ground surveys by UN and Government authorities were limited only to surrounding settlements that were accessible by vehicles.

Image processing's done to both Pre and Post imagery of the available imagery from SPOT<sup>1</sup> and IRS P6 shows very little change detection. Due to the lack of detailed ground survey, the processed satellite image did not show any significant structural damage.

This exercise further shows that remote sensing data alone cannot provide all the answers to a problem, it has to be integrated with other ancillary data obtained through ground surveys.

## Conclusion

Remote Sensing and GIS in Disaster Management Mitigation of earthquake disaster management can be successful only when detailed knowledge is obtained about the expected frequency, character, and magnitude of hazard events in an area. Although, natural disaster have shown in the last decades a drastic increase in magnitude and frequency, it can as be observed that there is a dramatic increase in technical capabilities to mitigate them.

Availability and access to space technology in addressing natural disasters has been the main obstacles facing developing countries particularly those poor countries without their own space programs. This problem has been solved through the introduction of the Charter. Knowledge of the Charter is not common knowledge in most developing countries; there is need for a massive awareness campaign to educate decision makers about the Charter and the potentials of using space technology in addressing problems relating to disaster management. The skills to process satellite imagery and integrate it with GIS are lacking in most developing countries; there is need to embark on a massive capacity building exercise to ensure optimization of the benefits of the technology. AIMS has the expertise in GIS and Remote Sensing and is embarking on building the information management capacity of Government Departments.