

# Geographic data needed in the interpretation of Indian satellite-based remote sensing data: Opportunities and realities

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**Information on the nature, extent, spatial distribution, potentials and limitations of natural resources is a pre-requisite for various developmental activities. Though topographical maps provide some spatial information about natural and cultural features of the terrain, apart from geographical location, it is not adequate enough for developmental planning. Aerial photographs and satellite data have, therefore, been used to generate such information. While geo-coordinates are available in satellite data though not accurate to the extent required, aerial photographs do not contain any geographic location. Topographic maps are, therefore, required for geo-referencing aerial and satellite data, field verification and for transfer of thematic boundaries. In addition, data integration in a Geographic Information System (GIS) environment also requires a sound map base which is met by the information available in the topographical maps. The article provides an overview of geographical data needs for deriving information from satellite data, availability of such data including Government's data security policy and suggestions for further improvement.**

## Introduction

Timely and reliable information on natural resources with respect to their potentials and limitations is a pre-requisite for sustainable development. Satellite remote sensing data by virtue of synoptic coverage of a fairly large area at a regular interval hold a great promise in providing such information in a timely and cost-effective manner. Generally, two approaches, namely, standard monoscopic/stereoscopic visual interpretation, and computer-aided digital analysis are employed to derive the above mentioned information from satellite remote sensing data. Satellite remote sensing data comprise essentially a faithful record of the reflected and/or emitted electromagnetic radiation from a given segment of the earth's surface. In order to relate such measurements with the features or phenomenon on the earth's

surface which reflect and/emit the electromagnetic radiation, their precise location on the ground in terms of geo-coordinates is a pre-requisite. Provision is, therefore, made right at the time of making spectral measurements aboard remote sensing satellites to incorporate the geographic location in terms of geo-coordinates of the segment of the earth's surface being imaged, by using precise orbit and attitude parameters of the platform and sensor system.

While processing remote sensing data on the ground, the image/scene co-ordinates are computed with the help of satellite attitude sensors' data and orbit parameters. For subsequent geometric correction and generation of standard data products too, geographic data in the form of topographical maps are required. Generation of geo-coded product which is in conformity with the topographical maps with respect to true north and image scale also requires geographic database. Furthermore, precision satellite data products are generated using ground control points (GCPs) taken from topographical maps. Since topographical maps are generated through conventional methods using aerial photographs or ground surveys, and are not updated regularly, satellite data form an ideal database for updating such maps. High spatial resolution satellite data with stereo coverage coupled with the ground measurements made with the Global Positioning System (GPS) enable generating orthoimage products which can be used as geographic database. This article provides an overview of the need of geographic database in the interpretation of remote sensing satellite data, role of satellite remote sensing as a geographic database, existing Government policy on dissemination of geographic data, relevant issues, and identifies future course of action.

## Role of geographic database

As mentioned earlier, geographic database is required right from identification of the area being imaged by an earth observation mission to generation of thematic maps on natural resources and environment. The following sections provide a brief account of the need of geographic database for various purposes: Until the 1920s topographical and cadastral maps were the only data-

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base available for both field check as well as preparation of final map on various natural resources and environment. With the subsequent availability of aerial photographs, thematic mapping began through their systematic visual interpretation. Topographical maps were still required for field check or ground truth collection and as a basemap for transferring thematic boundaries. With the development of photogrammetric analytical tools, topographical mapping at 1:50,000 and 1:25,000 scale began using aerial photographs. Launch of the Earth Resources Technology Satellite (ERTS-1), later renamed as Landsat-1, in 1972 marked the beginning of the usage of spaceborne multispectral data for mapping natural resources. Here too, like aerial photographs, topographical maps have been used both for field check as well as base maps for transferring final thematic boundaries. With the development of digital photogrammetric tools, satellite data are now being used on an experimental level for updating topographical maps.

### *Generation of geo-coded products*

The geo-coded products from satellite data are used to derive information on natural resources and environment, hence require very high geometric fidelity. On-board satellite, information on the location of the piece of land being imaged on the earth's surface is determined by its ground trace and from the measurements made by attitude sensors, namely earth-based sensors and star-sensors. While processing satellite data, the attitude information is utilized in geo-referencing the satellite data. Geo-coded products which are in conformity with the topographical maps with respect to ground location, orientation and coverage are routinely generated. Apart from geo-coded products, precision products from satellite data are generated by using ground control points (GCPs). Location error of precision product is  $\pm 50$  m while it is  $\pm 2$  km for geo-coded products. Swath modelling approach has been found to be an ideal approach for estimating geometric accuracy of satellite data products.

Concurrent measurements made by the Indian Remote Sensing Satellite (IRS-1C/1D) Linear Imaging Self-scanning Sensor (LISS-III) and PAN sensors have made it possible to exploit simultaneously the multispectral information from LISS-III data and high spatial resolution information from PAN data for mapping natural resources. Precision geo-coded products from LISS-III and PAN-merged data are generated by digitally registering and geo-referencing to topographical maps and merging them using several standard algorithms, namely intensity, hue and saturation (IHS) transformation, principal component analysis (PCA), wavelet transform, Brovey transform, etc. The areas for which topographical maps of desirable scale are not available

and it is possible to take any scene (image) in a particular pass (orbit) of the satellite for which GCPs are available, and estimate the location error. The location error, so obtained, could be applied to any scene within the pass. Such exercise greatly reduces the location error and it is generally within  $\pm 200$  m.

### *Generation of orthoimage*

Inputs for orthoimage generation include basic stereo pair, GCPs and/or map, and satellite ephemeris. The generation of orthoimage is accomplished in three steps, viz. generation of digital elevation model (DEM) using stereo pair and GCPs, geometric correction and grid generation in a given map projection using ground to image mapping, and re-sampling to generate a gray-level image in a required output (map) resolution<sup>1</sup>. Satellite stereo images have been used for generating DEM (ref. 2). Accuracy of the DEM and orthoimage depends, to a large extent, on the source of GCPs used for modelling. Heights of better than 15 m are achieved using 1:25,000 scale Survey of India map GCPs and better than 30 m from GCPs taken from 1:50,000 scale topographical maps. Planimetric accuracy of the order of 20 m and 35 m is achievable using 1:25,000 and 1:50,000 scale topographical maps, respectively<sup>1,3</sup>. For creating an orthoimage, the DEM is, initially, generated either from existing topographical maps or by photogrammetric methods using satellite stereo images with image correlation technique. Since digital image correlation is automatic, the digital orthoimages can be generated automatically with very little human intervention. For generating orthoimages from IRS-1C/1D PAN stereo data, among other softwares 'soft space' – a software developed by the Advanced Data Processing Research Institute (ADRIN), Department of Space, Government of India, is used. A minimum of one ground control point (GCP) is required for orbital modelling, and 3 to 4 GCPs for precise geometric correction of a PAN sub-scene. The height accuracy achievable by autocorrelation approach using above-mentioned package is  $\approx 12$  m, which is optimal for generation of orthoimage on 1:25,000 scale. For undulating and hilly terrain, the planimetric accuracy achievable by this approach is  $\approx 6$  m.

### *Generation of base maps*

Base maps are required, as pointed out earlier, both for geo-referencing of satellite data and for its interpretation or analysis to derive information on natural resources and environment. Satellite images have been used for topographical mapping<sup>4-8</sup>. Early results from Landsat-TM data with an IFOV of 30 m and B/H ratio of 0.1 have been quite encouraging though such maps could

not meet the desired accuracy. The SPOT-Panchromatic Linear Array (PLA) data with 10 m spatial resolution and stereo coverage (B/H ratio = 0.831) enabled generation of DEM with rms error of less than 7 m as against corresponding grided DEMs rms error of less than 10 m which meets NATO standards<sup>5</sup>. The NATO standards require that 90% of planimetric errors fall within 25 m for a 1:50,000 scale map and 12.5 m for a 1:25,000 if they are to be considered as accurate (class A)<sup>9</sup>. Using this criterion SPOT-PLA data could be used to produce positionally accurate planimetric maps at both these scales although line maps from these sources would contain only a limited amount of cultural information. However, none of the currently available sensors (Table 1) is able to produce sufficient resolution of quality to the revision of 1:50,000 scale maps without the need for a considerable amount of field work. Topographical maps, thus prepared, may cost about one-fifth to one third of the present cost or better. The use of spaceborne images holds promise for further cost reduction through automation of much of the planimetric feature extraction work involved in map making<sup>10</sup>.

Higher spatial resolution (5.8 m) data from IRS-1C/1D could be used to generate base maps at 1:50,000 scale with improved positional accuracy (better than 12.5 m) that is obtainable from the topographical maps of the same scale. However, in comparison to topographical maps of 1:50,000 scale, only 60 per cent of the terrain features could be detected and identified on IRS-1C/1D-derived basemaps. Our experience at the National Remote Sensing Agency has revealed that the positional accuracy of the order of  $\approx 10$  m is achievable. Theoretically, using digital mapping systems, the accuracy with respect to plan (positional location) and height that could be achieved, equals to 1.5 times of the spatial resolution of the sensor. The DEM generated from IRS-1C/1D PAN stereo images with well-distributed height controls has been found to be adequate enough to generate the contour maps with an accuracy of 10 to 15 m depending upon the terrain.

### *Mapping natural resources and environment*

For improved planimetric accuracy of thematic maps on natural resources and environment, geographic data in the form of topographical maps, as mentioned earlier, are required at three stages. Initially, for geo-referencing of satellite data, subsequently for location of sample areas/points on the ground during field check and lastly for transferring thematic details. In the last stage geographic data is required in the form of map base. Terrain features required for geo-referencing satellite data are basically linear cultural features, and include road network, railways, canal network, and occasionally bridges or culverts. During ground truth mission which aims at establishing the relationship between image elements like colour/tone, texture, shape, size, shadow, pattern, association, etc. and the objects/features/phenomenon on the ground, both natural as well as cultural features of the terrain are required for precise location of sample areas and/observation points. Included under natural features are: drainage network, relief (spot height and contour, and aspect) river morphology, water bodies, reserve forest/notified forest boundaries, salt pans/salt cultivation, swamps/marshes/lagoons, snow-bound areas, scrubs, sandy areas/sand dunes, gullied/ravinous land. Among cultural features other than those required for geo-referencing are: settlements, brick kilns, industrial units, etc.

For base map preparation, apart from above-mentioned natural and cultural features, administrative boundaries like village boundary, block/mandal boundaries, tehsil/taluka boundaries, district and state boundaries, and watershed/command area boundaries are required to define the limits of the test site or study area. While topographical maps at the scale ranging from 1:250,000 to 1:25,000 scale provide most of the desired information on terrain features, more detailed information at village level is available in cadastral maps. Cadastral maps are generated by Revenue Department of concerned States, and are available in dif-

**Table 1.** Currently available high resolution optical sensors

Platform	Sensor	Launch year	Spectral range	No. of channels	Resolution (m)	Image frame/swath width (km)
Priroda	MOMS-02		VIS, NIR	4	13.5	78
			PAN	1	4.5	37
			PAN (Stereo)	2	13.5	78
IRC-1C/1D	PAN LISS-III	1995/98	PAN (Stereo)	1	5.8	70.5
			VIS, NIR, MIR	4	23.5	141
					70.5	
KOSMOS	KVR-1000		PAN	1	10	40 × 40 km <sup>2</sup>
SPOT-4	PLA	1998	PAN (Stereo)	1	10	60
	MLA		VIS, NIR, MIR	4	20	
Landsat-7	ETM+	1999	PAN	1	15	185
			VIS, NIR	4	30	
			SWIR	2	30	
			TIR	1	60	

ferent scales ranging from 1:8046 to 1:4023. However, in hilly terrain of Punjab and Himachal Pradesh, cadastral maps at 1:2219 or 1:1109 scale are available.

### *Database needs for GIS applications*

The Geographic Information System (GIS) applications for decision making essentially involves integration of both spatial and attribute data on natural resources and environment. Such data need to be stored in a geo-referenced database portraying both natural and cultural features. While decision makers dealing with the management of natural resources and conservation of envi-

ronment need such map base at small, medium and large scale, urban planning activities require very large scale base maps for urban environment. The IRS-1C/-1D PAN stereo data has been used for generating 1:12,500 scale base maps for urban environment. Geographic database requirement for GIS application at different scale is given in Table 2.

### **Geographic data security policy**

Topographical maps in the range of 1:250,000, 1:50,000 and 1:25,000 are important for planning and management of natural resources. Globally, only 42% of

**Table 2.** Database needs for GIS applications

Scale	Information required
Small scale (1:1 M to 1:250,000)	<ul style="list-style-type: none"> <li>• All national and state highways</li> <li>• Major railways</li> <li>• DEM with 100 meters interval</li> <li>• Major drainage and waterbodies</li> <li>• Administrative boundaries up to district level</li> <li>• Thematic maps such as               <ul style="list-style-type: none"> <li>– Soils</li> <li>– Land use/cover</li> <li>– Water resources</li> <li>– Geology/geomorphology</li> <li>– Forests, etc.</li> </ul> </li> <li>• District-level socio-economic and meteorological data</li> </ul>
Medium scale (1:100,000–1:25,000)	<ul style="list-style-type: none"> <li>• All road network including cart track, footpath, etc.</li> <li>• All rail lines</li> <li>• DEM at 10 meters interval</li> <li>• All drainage and water bodies</li> <li>• Administrative boundaries up to village level and forest boundaries</li> <li>• Watershed boundaries up to micro watershed level</li> <li>• Level-II/-III class thematic maps, such as               <ul style="list-style-type: none"> <li>– Soils</li> <li>– Land use/cover</li> <li>– Geology/geomorphology</li> <li>– Water resources</li> <li>– Forests</li> <li>– Crops, etc.</li> </ul> </li> <li>• Village-level socio-economic and meteorological data</li> </ul>
Large scale (1:10,000–1:1,00)	<ul style="list-style-type: none"> <li>• All roads with their categories and width</li> <li>• Rail lines</li> <li>• All buildings with their categories and annotation</li> <li>• All waterbodies</li> <li>• All streams (perennial/ephemeral)</li> <li>• Overhead tanks, surface tanks, wells, etc.</li> <li>• Avenue trees and vegetation cover with categories</li> <li>• Property boundaries, walls, etc.</li> <li>• Power supply systems</li> <li>• Telecommunication network</li> <li>• Archeological, heritage and religious areas</li> <li>• Post offices, hospitals, police stations, fire stations, petrol bunks, educational institutions, recreation areas, etc.</li> <li>• Water supply systems</li> <li>• Sewerage systems</li> <li>• Administrative and political boundaries</li> </ul>

**Table 3.** Details of the information permitted for digitization from topographical maps

Information	Permissible content
Administrative boundaries	International, state, district, taluk, development block boundaries that are depicted on the topographic maps
Road network	Road features of different types – NH, SH, district roads, cart/foot tracks
Drainage	Drainage system, not connected with any dam may be shown. Clearance from MOD may be taken for supply of drainage pattern in areas where dam appears
Water bodies	All water bodies – reservoirs, lakes, ponds, etc. except dams and hydroelectric stations symbols and their descriptions
Relief and spot heights (slopes)	Relief in form of layers/slopes/a few heights as appearing on unrestricted maps be given
Settlements	Cities, towns, villages – in terms of their extent (boundaries)
Man-made features	Man-made features not restricted under the existing policy may be given. Details of areas falling under existing MOD restriction policy may be given only after obtaining the clearance of MOD
Area and point features	All users need not be given all encompassing information. It should be ‘development-specific’. The details that can be given to various agencies should be worked out by Survey of India
Co-ordinate/locational	Co-ordinate/locational information on national grid should not be supplied. The designated agencies may supply data on an arbitrary grid covering only the ‘development-specific’ areas

1:50,000 scale maps are available. In addition, the map revision is very often poor<sup>6</sup>. The main problem of topographical mapping from satellite images is the object identification. For mapping at 1:50,000 scale a ground resolution of 12.5 m is necessary<sup>4</sup>. Further, ground resolution better than 5 m causes a loss of some information which has to be mapped independent of scale. Survey of India – the national survey and mapping organization under the Department of Science and Technology, Government of India – generates topographical maps, collects geomagnetic, gravity and tidal data for various users in the country. Topographical maps at 1:1 M, 1:250,000 and 1:50,000 scale are available for entire country with the Survey of India. In addition, Survey of India has generated 1:25,000 scale topographical maps for selected priority areas. The Survey of India has grouped these maps broadly into two categories, namely restricted and un-restricted for supply to governmental and non-governmental organizations keeping in view national security, although there are higher level of classified maps which are not available to anyone. Topographical maps at 1:1 M scale except for maps of the outlying islands, viz. Andaman and Nicobar, and Lakshadweep islands<sup>11</sup> are not restricted, hence are freely available to the public. As per security policy of the Ministry of Defence, Government of India, all grided (Lambert grid) maps, and those covering 50 miles belt along the coast line of our country and international borders have been categorized as restricted. Over the years, Government of India has evolved ‘restriction policy’ for supply of topographical maps at scales 1:250,000 and larger to various Government Departments. The non-Governmental Organizations (NGOs) and other private agencies do not have access to topographical maps and aerial photos. Realizing the need for digital geographic database for various developmental

activities, the Ministry of Defence, Government of India has permitted nine central Government organizations, namely, Department of Space, Survey of India, National Informatics Centre, Geological Survey of India, National Bureau of Soil Survey and Land Use Planning, Ministry of Environment and Forests, Ministry of Rural Areas and Employment, Department of Ocean Development and Ministry of Water Resources to digitize nine features up to 1:50,000 scale for unrestricted areas. Included in the nine topographic map features are administrative boundaries, road network, drainage, water bodies, relief and spot heights (slopes), settlements, man-made features, area and point features, and coordinates/locational information (Table 3). There is a need to look at the requirements of topomaps by a common man and a mechanism to be evolved to generate the maps, the contents of which will not have any vital information.

## Conclusions

Geographical data play a key role in deriving information on natural resources and environment from aerial photographs and satellite data, and in the interpretation of spatial and attribute data in a GIS environment for decision making. The development of photogrammetric techniques and availability of high spatial resolution satellite data with stereo coverage hold great potential for updating topographical maps at 1:50,000 scale. Such capability is likely to further improve with the availability of high spatial resolution data from future Indian and foreign earth observation missions, viz. IRS-P5 (Cartosat-1), Orbview-4, Resource-21, etc. (Table 4).

Various developmental activities, namely urban planning, water supply, port development, highways and express ways, telecommunication network, etc. which require accurate and dependable large scale maps, and



**Table 4.** Future available high-resolution optical sensors

Platform	Sensor	Launch year	Spectral range	No. of channels	Resolution (m)	Image frame/swath width (km)
OrbView-3	OrbView	2000	VIS, NIR	4	4	8
OrbView-4	OrbView-4	2000	PAN	1	1	8
			PAN	1	1	
			VIS/NIR	4	4	
			VIS/NIR, SWIR	200	8	
IRS-P5 (Cartosat-1)	PAN	2000	PAN	1	2.5	30
IRS-P6 (Resourcesat)	LISS-IV	2001	VIS/NIR SIWR	4	6, 23.5	40
Cartosat-2	PAN	2002	VIS	1	1	30
SPOT-5	PLA	2002	VIS	1	2.5	30
	MLA		VIS/NIR MIR	4	10 20 (MIR)	60
HRST	PIC	2000	PAN	1	5	30
Resource-21	Hypersp.	2000	VIS, NIR	210	30	205
	M10		VIS, NIR MIR	5	10 20 MIR	
Quickbird	QB-P	2000	PAN	1	0.82	27
Resource-21	QB-M	2000	VIS, NIR	4	3.2	205
	M10		VIS, NIR	4	10	
			SWIR	2	2–100	

most of these projects are carried out with external assistance and expertise, denial of data accessibility to them will affect the national development. While policies of liberalization of economy for infrastructure development, and industrialization have been adopted, the restriction of base data accessibility slows down the anticipated progress in such areas. Effective utilization of available geographic data for developmental purposes, therefore, requires open dissemination of topographical maps including those covering restricted zones. Maps which are published on 1:50,000 and 1:25,000 scale area are security vetted and do not have vital areas or vital points and hence open dissemination maps for developmental projects by NGOs, private organization becomes a necessity. Since topographical maps contain vital information which is important from national security view point, need-based 'tailored maps' excluding vital areas/vital points need to be generated for NGOs and private organizations. Furthermore, making available digital vector data of topographical maps for free use for any developmental activities, removal of the restrictions of map keeping accountability, allowing the project team member including foreigners, private, NGOs and autonomous organizations to handle the maps are other issues requiring immediate attention. Lastly, the aerial photographs of un-restricted areas

need to be de-restricted as recommended by the National Committee on Restriction Policy.

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