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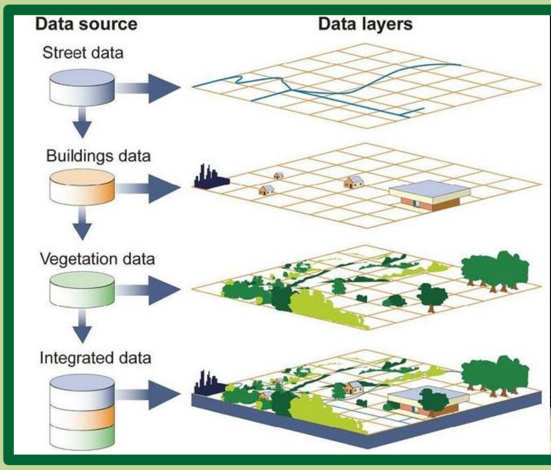
# NATIONAL TECHNICAL DOCUMENT FOR ESTABLISHING CARTOGRAPHIC BASE IN INDIA

## Generation of Large Scale (1:10,000; 1:2,000 & Lesser) Maps for Disaster Management and Planning




**March 2016**

**National Disaster Management Authority**
**Government of India**

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**Member**
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**Government of India**

# FOREWORD

The National Disaster Management Authority (NDMA) has the mandate for laying down policies, plans and guidelines as an apex institution for Disaster Management. An efficient mechanism involving deployment of scientific tools for identification, assessment and monitoring of hazards, risks and associated vulnerabilities is vital for effective disaster mitigation, preparedness and response.

Non-availability of Digital Cartographic base at appropriate scales for the Indian landmass has been a serious impediment for holistic management of disaster, natural or man-made, in the country. The need for higher resolution Geo-spatial Data for Disaster Management has been inviting attention of several departments / agencies involved in the domain of Disaster Management work.

The topographical maps presently available in the country at the present scales and contour intervals are not adequate for risk assessment purpose. It is also known that availability of digital cartographic base for Indian landmass at right scales and contour intervals is an essential technological tool required for the Geographic Information System (GIS), which will serve as a very useful tool in all stages of disaster management cycle, such as disaster preparedness, mitigation, response, relief and rehabilitation. Though Survey of India is already in possession of 1:50,000 scale maps, these maps cannot support the requirements in the areas of Disaster Management.

A Working Committee of Experts under the Chairmanship of Dr. Prithvish Nag, Former Director, National Atlas & Thematic Mapping Organization (NATMO), a specialized institution of the Department of Science & Technology was entrusted with the task of preparation of the said document with specification for mapping of 1:10,000, 1:2,000 and lesser scales with 1m and 0.5m contour intervals respectively. The formulation of 1:10,000 and 1:2,000 National Topographical Data Base are major initiatives for Geo-spatial Decision Support System at local, State and national levels. Web-enabled Geo-spatial information integrated in space and time will facilitate better decision making, learning and research in the disaster management field.

The technical document that has been prepared includes the various technological options for establishment of the cartographic base at a given scale and contour intervals along with the merits and limitations of each technology or combination of technologies. I am sure that this National Technical Document will assist the stakeholders in the country at various administrative levels for preparation of hazard / risk maps which are need based. It is worth noting that opinion of the S&T cartographic base should be vetted by the Survey of India, being the national mapping institution in the country, before utilization of the map for Disaster Management related work.

In conclusion, I must place on record my sincere thanks to Dr. Prithvish Nag for his technical guidance and involvement in preparation of the technical document. I also thank the experts and officials of the NDMA who worked tirelessly towards successful completion of this document.

March, 2016
New Delhi

**(R. K. Jain)**

**Dr. D. N. Sharma**
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**Government of India**

# PREFACE

Remote Sensing and Geographical Information System (GIS) techniques play a very vital role in effective and efficient assessment and holistic management of natural disasters as well as man-made disasters / emergencies like cyclone, flood, earthquake, CBRN etc on digital platform. These tools are equally important for other development activities. The generations of cartographic maps of various themes are necessary even for disaster risk reduction programme.

Many of the Government Departments / Institutes, Private Institutions etc are carrying out hazards mapping for various aspects of disasters management at different scales i.e., 1:1,25,000; 1:1,00,000; 1:50,000 and so on. Since, small scale maps are not useful for disaster risk reduction programmes and micro level development planning, a need of technical document was felt by NDMA to provide guidance to all stakeholders for generation of maps at large scale for disaster management related projects for qualitative utilization of resource available in the country.

NDMA therefore, took a proactive step in preparation of technical document on development of Cartographic Base in India for generation of large scale (1:10,000; 1:2,000 and lesser) maps for Disaster Management and other planning purposes. This is a technical document intended for providing guidance to the Government Departments, Universities and various other Stakeholders in formulation of Remote Sensing and GIS projects with aspect of disaster management.

March, 2016
New Delhi

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# ACKNOWLEDGEMENT

The digital cartographic base at appropriate scale helps in holistic management of disasters. However, the current topographical maps available in India required to be upgraded to serve the purpose of disaster risk assessment. To achieve this objective, NDMA took an initiative for preparation of technical document for establishing cartographic base in India at large scale i.e. 1:10,000; 1:2,000 and lesser. It has been a challenging process for more than five years to prepare this technical document.

I am extremely grateful to the specialists & technical experts Dr. Prithvish Nag, Former Director, National Atlas & Thematic Mapping Organization (NATMO); Dr. V. C. Jha, Former Director, NATMO and Dr. S. K. Srivastva, President, eOa Natural Disaster Management Initiatives (NDMI) Pvt Ltd for initiating the task of preparation of national technical document under the guidance of Shri B. Bhattacharya, Former Member, NDMA. The committee of experts provided valuable technical inputs for preparing this document.

I am grateful to Brig. Girish Kumar, Survey of India (SoI); Shri M. Raju, Addl. Director General (Policy Support System), Geological Survey of India; Dr. P. S. Acharya, CEO, National Spatial Data Infrastructure (NSDI), DST; Dr. Anuradha Banerjee, Professor, JNU; Shri Diwakar Parsi, Dy. Director, NRSC, Hyderabad for their valuable contributions.

I am thankful to Shri R. K. Jain, Member, NDMA for continuous support and guidance in finalization of this document. I am also grateful to Dr. D. N. Sharma, Member, NDMA for his valuable guidance and suggestions at various stages.

I am also happy to acknowledge the support and cooperation extended by officers of Mitigation Division Shri S. N. Singh, Dr. Susanta Kumar Jena, Shri S. K. Mishra and Dr. Ravinder Singh for providing technical inputs and preparation of final version of document.

**(Anil Kumar Sanghi)**

March, 2016
New Delhi

# Table of Contents

# List of Figures and Tables

# Abbreviations

The following abbreviations and acronyms appear in the text and have following meaning:

| | |
|---|---|
| ACA | Additional Central Assistance |
| ACR | Annual Cyclone Review |
| AHP | Analytical Hierarchy Process |
| AICTE | All India Council for Technical Education |
| ALS | Airborne Laser Scanner |
| ALTM | Airborne Laser Terrain Mapper |
| ARMV | Accident Relief Medical Van |
| ASI | Archaeological Survey of India |
| ATCOR | Atmospheric and Topographic Correction |
| ATI | Administrative Training Institute |
| AWiFS | Advanced Wide Field Sensor |
| BFE | Base Flood Elevation |
| BIS | Bureau of Indian Standards |
| BMTPC | Building Materials and Technology Promotion Council |
| BPR | Business Process Re-engineering |
| BRO | Border Roads Organisation |
| CAD | Computer Aided Design |
| CBO | Community Based Organisation |
| CBSE | Central Board of Secondary Education |
| CBRI | Central Building Research Institute |
| CCD | Charge Coupled Device |
| CDMM | Centre for Disaster Management and Mitigation, Vellore |
| CFI | Construction Federation of India |
| CFM | Critical Facility Map |
| CI | Contour Interval |
| CIO | Conventional International Origin |
| CoA | Council of Architecture |
| CRF | Calamity Relief Fund |
| CRRI | Central Road Research Institute |
| CSC | Citizen Service Center |
| CSIO | Central Scientific Instrumentation Organisation |
| CSR | Corporate Social Responsibility |
| CTP | Conventional Terrestrial Pole |
| CWC | Central Water Commission |
| DCR | Development Control Regulation |
| DDMA | District Disaster Management Authority |
| DEM | Digital Elevation Model |
| DG | Direct Georeferencing |

| | |
|---|---|
| DGM | Directorate of Geology and Mining |
| DIT | Department of Information Technology, Government of India |
| DLTs | Digital Linear Tapes |
| DM | Disaster Management |
| DMA | Disaster Management Authority |
| DMP | Disaster Management Plan |
| DMS | Disaster Management Support |
| Do IT&C | Department of Information and Communication Technology, |
| DoM | Department of Mines |
| DORIS | Doppler Ranging Integrated on Satellite |
| DoS | Department of Space |
| DRISS | Doppler Radar and Infrared Satellite Sensing |
| DRM | Disaster Risk Management |
| DSHA | Deterministic Seismic Hazard Analysis |
| DST | Department of Science & Technology |
| DTRL | Defence Terrain Research Laboratory |
| FDS | Flight Data Storage |
| FMC | Forward Motion Compensation |
| FSI | Forest Survey of India |
| GCP | Ground Control Points |
| GoI | Government of India |
| GSD | Ground Sampling Distance |
| GSI | Geological Survey of India |
| IAKAR | Inertially-Aided Kinematic Ambiguity Resolution |
| ICT | Information & Communication Technology |
| IERS | International Earth Rotation and Reference Systems Service |
| IERS | Earth Rotation and Reference Systems Service |
| IMD | India Meteorological Department |
| IMU | Inertial Measurement Unit |
| INSAR | Interferometric Synthetic Aperture Radar |
| IT | Information Technology |
| ITES | Information Technology Enabled Services |
| ITRF | International Geocentric Reference Frame |
| ITRS | International Terrestrial Reference System |
| KAR | Kinematic Ambiguity Resolution |
| LIDRA | Light Detection and Ranging |
| LIS | Land Information System |
| LISS-III | Linear Imaging and Self Scanning Sensor |
| LLR | Lunar Laser Ranging |
| MDR | Mission Data Records |
| MMP | Mission Mode Project |

| | |
|---|---|
| MRI | Magnetic Resonance Imaging |
| NGRDS | National Geodetic Reference Database System |
| NIC's | National Informatics centers |
| NIR | Near Infrared |
| NISG | National Institute of Smart Governance |
| NOAA | National Oceanic and Atmospheric Administration |
| NPS | National portal Secretariat |
| NRSA | National Remote Sensing Agency |
| NTDB | National Topographic Database |
| OBIA | Object-Based Image Analysis |
| PET | Positron Emission Tomography |
| RGB | Transformation of Red, Green, Blue |
| RPCs | Rational Polynomial Coefficients |
| RS | Remote Sensing |
| RSMC | Regional Specialized Meteorological Center |
| RTK | Real-Time Kinematic |
| SBAS | Satellite Based Augmentation Service |
| SDC | State Data Center |
| SLR | Satellite Laser Ranging |
| SSL | Secure Socket Layer |
| SST | Stereo Strip Triangulation |
| SWAN | State Wide Area Network |
| TDI | Transfer Delay and Integration |
| TDI | Time Delayed Integration |
| TIN | Triangulated Irregular Network |
| TRF | Terrestrial Reference Frame |
| UOPS | User Order Processing System |
| UTM | Universal Transverse Mercator |
| VLBI | Very Long Baseline Interferometry |
| VRS | Virtual Reference Station |

# Glossary of Terms

**AERIAL PHOTOGRAPHY**

Photographing of terrain on the ground and objects in the air by cameras mounted in aircraft. It is utilized in satellites, multispectral scanning and intricate data handling systems. Also referred to as aerial photo or air photo

**BASE MAP**

A map showing certain fundamental information used as a base upon which additional data of specialised nature are compiled.

**BLUELINE**

A non-reproducible blue image printed on paper from vellum or mylar sheet

**BREAKLINE**

An elevation polyline, in which each vertex has its own X, Y, Z values.

**CADASTRAL MAP**

A map showing boundaries of subdivision of land for purposes of describing and recording ownership

**CONTACT PRINT**

An aerial photograph reproduced from an original negative to photographic paper.

**CONTOUR**

An imaginary line on a land surface connecting points of equal elevation

**DESIGN SCALE**

A scale for which data source has been designed or selected to ensure product accuracy in derived products the design scale is the smallest scale of individual features.

**DVP**

Digital Photogrammetric Mapping Software the City uses for maintaining the Enterprise Stereoscopic Model (ESM) topographic mapping.

**DMOG**

Formerly known as PUCC, the Digital Map Owners Group (DMOG) is a nine member sub-committee of the Toronto Public Utility Co-ordinating Committee (TPUCC), sharing in the cost of maintenance of the underground utilities of the former City of Toronto.

**DTM**

A Digital Terrain Model is a land surface represented in digital form by an elevation grid or lists of three-dimensional coordinates.

**ESM**

The City’s Enterprise Stereoscopic Model (ESM) delivers digital photogrammetry to the desktop as a fully oriented 3Dimage for the amalgamated City of Toronto. The ESM is the primary environment for maintaining 2D/3D topographic mapping, high-resolution orthoimagery and Toronto Mono Viewer(TMV). The City’s Digital Terrain Model (DTM) is collected and maintained in ESM environment.

**GEOGRAPHIC COORDINATE SYSTEM**

A system used to measure horizontal and vertical distances on a planimetric map. The City of Toronto's operational coordinate system is currently the Modified Transverse Mercator (MTM) projection, North American Datum 1927 (NAD27), with a truncated northing or y value (-4,000,000).

**GEOREFERENCING**

A process of assigning map co-ordinates to image data to conform to map projection grid.

**LARGE-SCALE**

A description used to represent a map or data file having a large ratio between the area on the map and the area that is represented. If the map the size of this page shows only a small area such as your house, it would be described as large scale mapping.

**MAP SCALE**

The ratio of a distance on a map to the true distance on the ground. For example, if the map scale is 1:1000, 1cm on the map represents 10 m on the ground. See also design scale.

**MAP PROJECTION**

A mathematical model that transforms the locations of features on the Earth's surface to locations on a two-dimensional surface. Because the Earth is three-dimensional, some method must be used to depict a map in two dimensions.

**ORTHORECTIFICATION**

A form of rectification that corrects for terrain displacement. See also Rectification

**PHOTOGRAMMETRY**

The art and science and technology of obtaining reliable information about physical objects and the environment through process of recording, measuring, and interpreting images and patterns ofelectromagnetic radiant energy and other phenomena.

**PLANIMETRIC MAP**

A map that represents only the horizontal positions for the features represented.

**PUCC**

Public Utilities Coordinating Committee. See DMOG

**RASTER DATA**

Data that are organised in a grid of columns and rows.

**RECTIFICATION**

A process of making image data conform to a map projection.

**RESOLUTION**

A level of detail in data. For example, ground pixel distance in aerial photography.

**SPOT ELEVATION**

A point on a map whose height above a specified reference datum is noted, usually by a dot and elevation. Also called spot height.

**STEREOSCOPY**

The science and art that deals with the use of binocular vision or observation of a pair of overlapping photographs.

**TIN**

A land surface model based on triangles. A specific representation of DTM in which elevation points an occur atirregular intervals.

**TMV**

The Toronto Mono Viewer (TMV) is an application that enables user to view aerial images of the entire City. User can also query images by municipal address and street intersection.

**TOPOGRAPHIC MAP**

Map that presents the horizontal and vertical positions of the features represented. It is distinguished from a planimetric map by the addition of relief in measurable form.

**VECTOR DATA**

Data that represent physical elements such as points, lines and polygons

# 1 Generation of National Topographic Database (NTDB) For 1:10,000; 1:2,000 & Lesser Scale

## Preamble

Map is a two dimensional representation of the three dimensional earth (globe) as a whole or a part of it on a paper. Hence, some adjustments are to be made for such transformation in a scientific way. These transformations depend on the use or application of the spatial information. Hence, the choice of datum, projection, plotting techniques and symbols become relevant. Apart from the scientific component, the artistic components are equally important. The way of presentation, design, choice of colours and symbols, visualization and the message or theme communicated or highlighted have also become integral part of map-making.

With the advent of digital technologies, the process of map-making has changed significantly. The scientific components have become more accurate while the artistic or design components have become more dependent on the options available with the software than on drawing skills. As a whole, maps, either in hard copy form or soft copy, have become more software driven. With such changes in the preparation of maps or spatial data, the applications have multiplied enormously. One of the important applications is in the field of disaster management.

The topographical maps available in the country are at the scale of 1:250,000, 1:50,000 and for some areas at the scale of 1:25,000 scale as well. These maps have been prepared scientifically and of very high accuracy at the given scale. The contour intervals are of 5m or 20m. Neither the scale of the maps nor the contour intervals exactly meet the requirements of disaster management or mitigation. The requirements of maps for these purposes have been widely discussed in the National Disaster Management Authority. The Steering Committee and other committees have dealt this issue at a greater length and considering all types of disasters in the country, following types of maps have been suggested:

(a) Maps at 1: 10,000 scale with contour interval of 1m for the whole country giving priority to multiple disaster prone areas; and

(b) Maps at 1:2,000 scale with contour interval of 0.5m for selected areas.

The maps at the scale of 1:10,000 are not only required for disaster management but for other activities as well. The PC-NNRMS Committee on Cartography of the Planning Commission has supported mapping at this scale for resource management. Further, the Ministry of Defence also requires maps at this scale for defence and security purposes. Survey of India is also planning to introduce a new series of topographical maps at this scale.

The maps at 1:2,000 and lesser scale has been much in demand for urban management and planning, municipal taxation, JNNURM related activities; and for conducting elections and censuses. It is to provide a basis for urban flood management and microzonation. Hence, the maps at both the scales would not only be useful for disaster management but will also prove to be a national asset.

### Present Status

Survey of India is already in possession of 1: 50,000 scale maps. However, in these maps detailed features are not available due to scale limitation. It is not possible to represent details like utility buildings such as hospitals, schools, police stations, fire stations, government offices etc in 1:50,000 scale. But these features are imperative for risk assessment and disaster management. It is also essential to depict roads on these maps for microzonation and development of vulnerability and hazard maps. During any disaster scenario, it is essential to visualize the access roads and probability of their closure for relief and rescue planning. It is also essential to map various layers of utilities including population density for final planning of effects of any disaster and rehabilitation planning after the disaster.

The proposed 1:10,000; 1:2,000and lesser scale National Topographic Databases (NTDB) are a major initiative for heralding a geospatial decision support system at local, state and national levels. The primary objective is to provide geospatial data for advanced geospatial tools and applications that are required for improving the land, water, infrastructure and other essential resources. Moreover, mapping at these scales were considered necessary and some attempts were made as well.

## 1.1 Mapping at 1: 10,000; 1:2,000 and Lesser Scale

The methodology of mapping is based on job specification and deliverables given in the tender document. Mapping at 1:10,000; 1:2,000 scale and lesser with 1 meter and 0.5 meter contour interval (C.I) has to be done, considering the guideline provided in the new National Map Policy and confirming to the National Topographical Database (NTDB):

A. Mapping on the proposed scale based on the aerial photographs or high resolution remote sensing data, GPS, ground survey or in combination.

B. The details in the maps to be given like road/railways, rivers, administrative boundaries from villages to state, infrastructures like bridges, power stations, hospitals, shelters, helipads, dropping points, basic land use like water bodies, settlements, built up areas, arable lands, forests, communication lines etc.

C. The policy and identification of the multi-disaster prone or major disaster prone districts.

D. Estimate the cost of preparation of the multi-disaster prone or major disaster prone districts.

## 1.2 NTDB on 1:10,000; 1:2,000 and Lesser Scale - A National Need

As pointed out in Para 1 of this chapter, the SOI is in possession of the NTDB on 1:50,000 scale. Admittedly, scales donot have as much relevance in digital environment as for paper maps; but the NTDB of SOI has been made by digitization of analogue maps. Being in digital environment, it suffers from plotting error. Even assuming zero plotting error, the NTDB can't support the kind of details as required by the present map users. The detailed features call for higher scale maps even when available in digital form. For instance, on 1:50,000 scale, it is not possible to depict utility buildings like hospitals, schools, police stations, post offices etc., whereas these have become indispensable to be shown in village maps. On 1:10,000 scales, all these buildings can be comfortably depicted. In disaster management like microzonation, maps on 1:10,000, 1:2,000 and lesser scale are essential. In assessing natural resource endowments, agricultural practices, grazing lands, village forests, which are essential for rural development also can be shown.

The data requirement of various consumers mostly matches with the data structure of the 1: 10,000; 1:2,000 and lesser scale maps. It is therefore easy to be conclude that SOI has to endeavor to make the NTDB of 1:10,000 and 1:2,000scale with the latest data. This should be most expeditiously done to support the rapid pace of economic development of the country and has to be treated as a national mission. For more details, please refer to Appendix- I.

# 2 Geographical Information System for Disaster Management

Access to information, and its efficient assimilation and dissemination to a larger group of people, in a fast, easy and cost-effective manner is crucial for the effective management of disasters. Timely access to accurate, preplanned, historical and real-time information becomes inevitable for governments, authorities, task forces and common man, for disaster management. Also, the information should be processed and presented in an easily understandable manner, for timely actions to be taken.

Quite often, a considerable portion of the efforts and resources are spent on finding the relevant information because the information is stored redundantly in different places and in different formats. The use of GIS becomes relevant in the field of disaster management as well since it can effectively store and retrieve magnanimous amount of spatial and attribute data, analyze them and present the information in easily comprehensible formats. Most of the data requirements for emergency management are of a spatial nature and hence GIS becomes an extremely handy tool.

Mitigation of natural disasters can be successful only when detailed knowledge is obtained about expected frequency, character and magnitude of hazardous events in the area. Maps, aerial photography, satellite imagery, GPS data, rainfall data have spatial components. Many of these data have different project and coordinate systems and need to be brought in to common map base in order to be superimposed. GIS provides a historical database from which hazard maps indicating potentially dangerous areas can be generated. For more details, please refer to Appendix- I.

As many types of disasters have certain precursors, satellite remote sensing may detect the early stages of these events as anomalies in a time series. When a disaster occurs GIS can be used to plan evacuation routes, design centers for emergency operations and integrate satellite data with other relevant data. In disaster relief phase, GIS is extremely useful in combination with GPS for search and rescue operations. And also damage assessment and aftermath monitoring for providing a quantitative base for relief operations. In disaster rehabilitation phase, GIS can provide damage information, census information and sites for reconstruction. Obviously, the volume of data required for disaster management is too much, particularly in context to integrated development planning. Thus, GIS platform may be used to model various hazard and risk scenarios for future development

## 2.1 GIS in Different Phases of Disaster Management

GIS as a tool is used for managing the large volumes of data needed for the identification of vulnerable regions and assessment of hazard and risks; and for planning the evacuation routes, design of centers for emergency operations, integration of satellite data with other relevant data in the designing of early warning system etc. further, in search and rescue operations, in combination with GPS (global positioning system), in areas that have been devastated and where it is difficult to orient. Furthermore, in order to organize the damage information, the post disaster information and for evaluation of sites for reconstruction or compensation GIS has been proved to be useful. The details are provided in Table2.1.For more details, please refer to Appendix- I.

| SN | PHASE | DESCRIPTION |
|---|---|---|
| **1.** | PLANNING | • Emergency management programs begin with identifying and locating potential risk elements / hazards.<br>• Using a GIS, hazards can be spatially identified and consequences evaluated to assess potential emergencies or disasters.<br>• Analyzing critical infrastructure that could be damaged or destroyed is necessary to restoring vital services and operations.<br>• Visualizing the hazards with the data of roads, pipelines, buildings, residential areas, power and communication infrastructure etc. helps officials to formulate mitigation, preparedness, response, and possible recovery plans as well as to spread awareness among the citizens.<br>• GIS facilitates an effective emergency management by providing a platform for thorough analysis and planning, and by allowing the agencies to view the various scenarios generated by combinations of spatial data. |
| **2.** | MITIGATION | • As potential disasters are identified, mitigation measures can be planned and prioritized.<br>• Utilizing existing socioeconomic and other databases linked to geographic features, help identifying the variations in vulnerability of the affected region and plan the mitigation accordingly. |
| **3.** | PREPAREDNESS | • GIS can help locating emergency infrastructure like firefighting stations, fire hydrants, hospitals etc in minimum response time.<br>• GIS can be used for integration of satellite data with other relevant data in the design of disaster warning systems and to display real-time monitoring of climatic and other conditions for early warning.<br>• GIS can also be used for the planning of evacuation routes, design of emergency operation centers etc. |
| **4.** | RELIEF | • GIS is extremely useful in combination with Global Positioning System in search and rescue operations in the devastated areas and where it is difficult to orient.<br>• GIS also supports planning for the relocating requirements and logistics for emergency supply chain management.<br>• GIS can also model the event in order to warn people and position public safety resources for immediate deployment.<br>• GIS is also used to analyze vulnerable populations for secondary health effects from a disaster, implementing preventive treatments, and positioning medical teams and medical supplies in locations to optimize preventive treatments. |

| | | |
|---|---|---|
| **5.** | REHABILITATION | • In the disaster rehabilitation phase, the damage caused can be assessed using satellite imageries.<br>• Customized applications can be developed on GIS to calculate the damage and issue damage certificates to the victims.<br>• GIS is also used to organize the damage information and the post-disaster information, and in the evaluation of sites for reconstruction, compensation etc. |

TABLE 2.1: PHASES OF DISASTER MANAGEMENT

Integration of the GIS and the internet technology can significantly increase the usage and accessibility of the spatial data, which is a necessity for disaster management. The planning and preparedness activities like identification and assessment of risk, awareness creation and early warning can be more effectively organized and implemented with the use of a web-enabled GIS.

An Internet GIS based emergency management network can help in ensuring effective public safety by providing a platform for continuous and cohesive exchange of data, ideas, knowledge and the latest update during the event of any disaster, at local, regional, city, state and national levels, which is of utmost importance. Also, workflows of the various agencies involved in the disaster management can be integrated with the web enabled GIS data and applications to manage situation more effectively; all of these eventually resulting in better management and control of resources. For more details, please refer to Appendix- I.

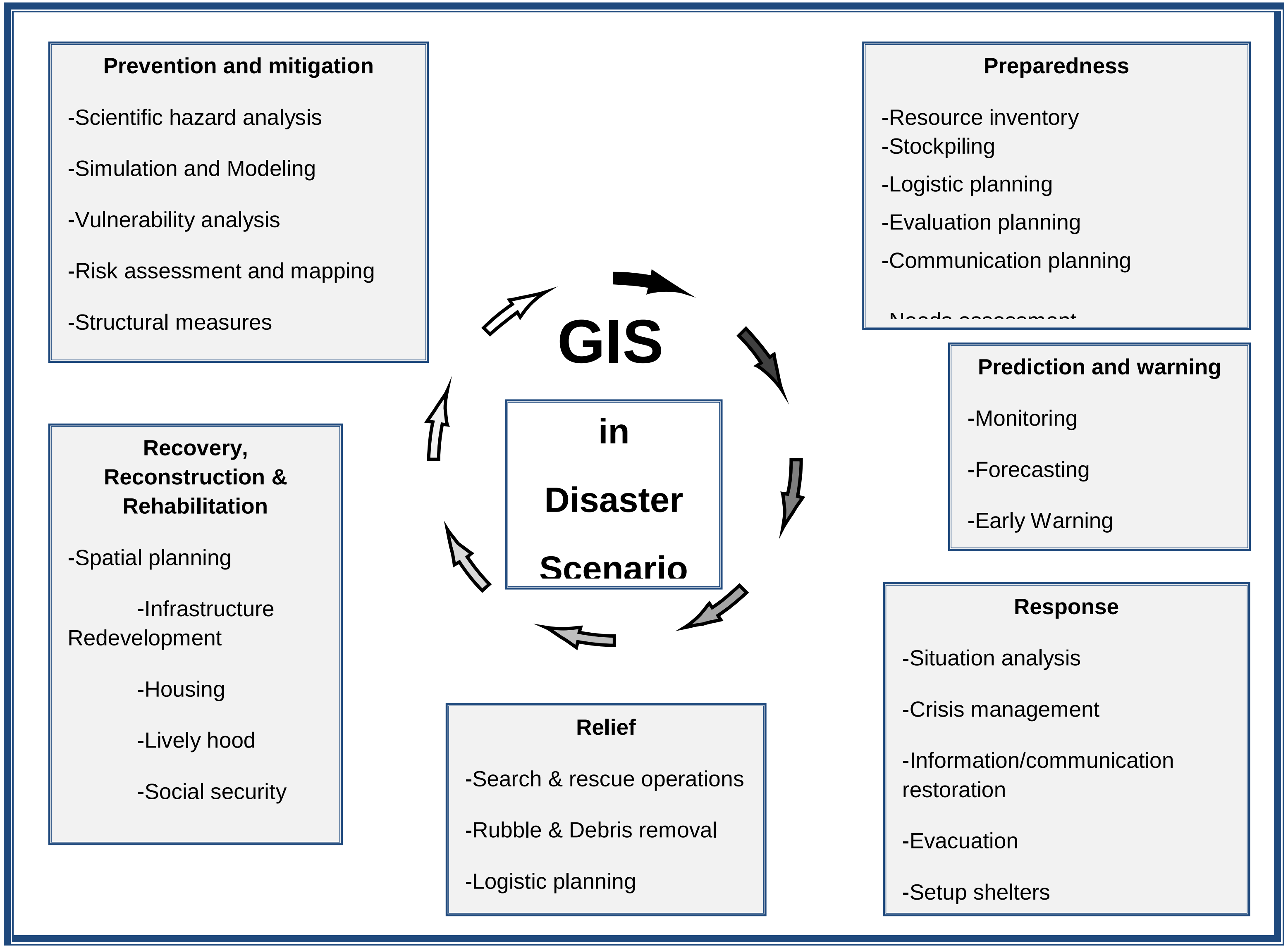



FIGURE 2.1: GIS IN DISASTER SCENARIO

## 2.2 GIS Database for Disaster Management

The data from different disciplines and agencies, as listed below, is required for disaster management process to obtain satisfactory results.

1. Spatial and temporal data on the disastrous phenomena like landslides, floods, earthquakes their location, frequency, magnitude, etc.
2. Data on the environment of the region like topography, geology, geomorphology, soils, hydrology, land use, vegetation etc.
3. For more details, please refer to Appendices. Data on elements in the region that might be affected by the disaster like infrastructure, settlements, population etc. and the socioeconomic condition of the region.

It can be seen that most of these data are of spatial nature, hence a GIS would not only be the most appropriate way to compile the data, but also the best platform to analyze them. A GIS database for disaster management would consist of several sets of information, as given below (Table 2.2).

| | |
|---|---|
| **1.** | Base maps |
| **2.** | Remotely sensed imageries like Quickbird, IRS LISS III |
| **3.** | Thematic maps like, geology maps, geomorphology maps, Soil maps, Flood maps and digital terrain model |
| **4.** | Temporal data on disasters and their details, connectivity and communication infrastructure like roads, railways, ports, airports, helipads etc. |
| **5.** | Hospitals and medical facilities |
| **6.** | Other emergency Infrastructure like fire stations, police control rooms etc. |
| **7.** | Urban and town distributions, land use and facilities |
| **8.** | Demographic data |
| **9.** | Socioeconomic data etc. |

TABLE 2.2: INFORMATION REQUIRED FOR GIS DATABASE FOR DISASTER MANAGEMENT

Databases at various scales and accuracy will be required for the various activities related to disaster management. A three-tier database is envisaged for India.

| | |
|---|---|
| **TIER 1** | A regional level database at 1:50,000 scale developed from IRS LISS images and 1:50,000 scale Survey of India toposheets |
| **TIER 2** | A district level database at 1:10,000 scale developed from Quick bird imagery (0.6m accuracy) |
| **TIER 3** | A site-level investigation or micro level database of 1:2,000 scale and lesser for all the towns/cities falling under the major disaster prone/multi disaster prone districts developed from aerial photography and ground survey. |

TABLE 2.3: THREE TIER GIS DATABASE FOR DISASTER MANAGEMENT

For Tier 1, the Survey of India topographical sheets are useful. However, a few additional features would be required for NDMA purposes. Regarding Tier 2 and Tier 3, this document on 1:10,000 and 1:2,000 & lesser scales are being prepared.

The site investigation scale GIS is used in the planning and designing of engineering structures such as building, bridges, roads etc. It is also used on detailed engineering measures to mitigate natural hazards. Nearly all the data is quantitative in nature and GIS is used for data management instead of data analysis. Deterministic models and 3D GIS can be of great advantage at this stage. The selection of scale of analysis is usually determined by the intended application of the mapping results; however, the choice of analysis technique remains open. This choice is dependent upon the type of problem, availability of data, availability of financial resources, time available for investigation and finally, the professional experience of the experts involved in the survey. For more details, please refer to Appendix 2.

## 2.3 Scope for Developing a GIS Database for Disaster Management

The draft scope of work of the project includes (but not limited to) the following:

- Data model definition for all the three tiers of the database. The National Map Policy guidelines and National Topographical Data Base (NTDB) must be referred to.
- Source procurement guidelines formulation.
- Firming up and detailing the database creation methodology, solution architecture, the technology and platform, compliance criteria, resource model and products.
- Documentation and approval of the project blue print.
- Project estimation, structuring, planning and scheduling.
- Detail project report finalization and approval.
- 1:10,000; 1:2,000 & lesser scale mapping and database creation: secondary data collection, mapping, attribution, and database structuring.
- Analysis and Products.
- Quality assurance and project handover.

## 2.4 Projection System

The Universal Transverse Mercator (UTM) coordinate system must be used. The datum must be WGS 84. Such datum is compatible to GPS, remote sensing data and the Open Map Series now under preparation by Survey of India.

## 2.5 Positional Accuracy

The regional level database must have a minimum accuracy of 5 m. The district level database should have sub-meter accuracy and micro level database should have accuracy up to millimeters.

## 2.6 Technology

1. Survey: Survey must be conducted using highly calibrated DGPS, electronic total station etc.
2. Image Processing: Image processing involves image engineering, image classification, and image interpretation. ERDAS Imagine is widely used software.
3. GIS Technologies: ESRI, Autodesk, Bentley, MapInfo etc. are the technologies that can be used for GIS mapping and analyses.
4. Source Procurement: passive and active sensor based technologies must be explored for image procurement. Quick bird, Landsat, IRS LISS III, LISS IV, Cartosat I and II etc can be used appropriately.

## 2.7 Functional Requirements for Database Management

1. Seamless integration of 1:10,000 and 1:2,000 database with 1:50,000 database and its regular updation and maintenance. National Spatial Data Infrastructure (NSDI) / Survey of India (SOI) have developed a Standard Operating Procedure (SOP) for storage of geospatial data on Relational Database Management System (RDBMS) with web based feature services.

2. Seamless integration of enterprise services and data. The solution will be able to serve the data in heterogeneous formats as a consolidated view to the end users.

3. The solution must support popular geospatial data sources from ESRI, TNT Mips, Intergraph, Autodesk MapInfo, Post GIS, Oracle Spatial, Bentley, OGC web maps, etc.

4. Ingestion of high resolution satellite imagery from Cartosat, Google Maps, Virtual Earth, Pictometry and OGC compliant providers.

5. Easy (web-based) ability to integrate multiple applications meant for various agencies / decision making purposes.

6. The solution will act as a single-window portal hosting applications and serving data pertaining to different agencies.

7. The end user would need only a standard web browser to avail of desired functionalities.

8. Authorized user(s) must be able to browse through available metadata and the request specified geospatial data of interest.
9. The solution will be designed on open standards with wide support for various emerging industry standards.

10. Visitors may be able to contribute information for collaboration and sharing using Web services and there would be intuitive user friendly, user interfaces.

11. Multi-lingual support should be provided.

12. User identity and access management.

13. User may be able to edit spatial data (geometry and attributes) using editing tools.

14. Advanced map layer / MIS database column searches.

15. Configurable search wizards.

16. Flexibility to print only the map or with attributes definition of new print templates.

17. Users should be able to place points, line, polygons and text and save Redlining for future retrieval.

18. Support for custom tools and commands and toolbars.

19. Users should be able to create charts based on selected data layer e.g. pie, bar, line, charts etc.

20. Enable user to display attribute table based on selected map views.

21. Provision to sort attributes in descending / ascending order for both OGC and standard data sets.

22. Accessibility to Multi Hazard Maps (MHMs) and Critical Facilities Maps (CFMs) by all stakeholders in shapefiles etc. at common Web Service platform of Data Managing Government Department like NSDI with data-sharing policy.

# 3 Critical Facilities Mapping (CFM)

The definition used is an expanded version of that proposed by the U.S. Office of Science and Technology Policy. In terms of the development planning process, it is important to ensure that the key elements described in the box below are included when considering critical facilities within project planning.

The term "Critical Facilities" is used to include all man-made structures or other improvements which because of their function, size, service area, or uniqueness have the potential to cause serious bodily harm, extensive property damage, or disruption of vital socioeconomic activities if they are destroyed, damaged, or if their services are repeatedly interrupted.

Terms such as "lifelines," "urban lifelines," and "emergency infrastructure" are used in post disaster damage studies, emergency preparedness planning, and socioeconomic impact evaluations. They usually refer to two particular categories: transportation and utilities. These two categories are of particular importance for

- Locating and serving new economic activities,
- Supporting existing economic activities,
- Providing the connections to, and support of, emergency facilities,
- Contributing to any disaster preparedness, response, recovery, and reconstruction activity, and
- Receiving a high priority for strengthening before a disaster, for emergency operations, and for rerouting or rapid repair after damage or interruption

The term "lifelines" has been variously defined as:

- Systems vital to the support of any community
- Facilities which are required to transport people, things, energy, and information, necessary "for a community in a modern industrial society to survive and prosper," and "indispensable to other facilities and services that are critical in a disaster setting such as hospitals, fire, fighting and emergency operation centers"
- Water,sewage,transportation,andcommunicationsnecessaryforthesurvival of community,
- Systems that provide essential services to a community,
- Servicesthatareimportantinourdailylivesandthat,ifinterrupted,couldcause widespread social and economic inconvenience or loss, and
- Geographically spread networks on which society is dependent
- Critical segments or components (for production facilities, infrastructure networks, and support systems to settlements) which should be recognized as priority elements for rehabilitation following a disaster

## 3.1 Defining Critical Facilities for Mapping

When a natural or man-made event affects a critical facility, the impacts are dramatically multiplied when compared to the effects that a similar event may have on non-critical systems.

**Primary effects** of an event on the built environment as dependent on the characteristics of the structures (location, design, materials used, and maintenance) and characteristics of the occupants (density, freedom of movement, and health during the event) must be considered. The effects of hazardous events on critical facilities depend not only on such characteristics, but also on a number of other characteristics unique to a critical facility.

The **secondary hazards** created from critical facilities (collapse or failure of dams, toxic-chemical storage facilities, etc.), the disruption of certain services (medical, fire, police, etc.), and infrastructure disruption (electricity, damage to roads and highways, etc.) can all bring increased negative impact to the community above the importance of the critical facility itself.

Other vital national or regional economic activities or facilities besides those defined above vary with each governmental jurisdiction, its resources, and its needs, and should be included in the preparation of a Critical Facility Map (CFM). For example:

| **PUBLIC SAFETY AND SECURITY** | **HIGH-DENSITY OCCUPANCY** | **TRANSPORTATION** |
|---|---|---|
| Civil defense installations, Communications centers, Emergency management centers, Fire stations, Hospitals and other medical facilities, Mass emergency shelters Police stations. | Auditoriums, theatres, Stadiums, Churches, Educational facilities, Hotels, Office buildings, Penal institutions. | Airways-airports, heliports Highways-bridges, tunnels, roadbeds, overpasses, transfer centers, Railways tracks, tunnels, bridges, yards, depots, Waterways-canals, locks, seaports, ferries, harbors, drydocks, piers. |
| **UTILITIES** | **INDUSTRIAL** | **AGRICULTURAL** |
| Communications-lines, Electric power-water impound-ments, Printing presses, Antenna complexes Fuel storage.<br><br>Generators, transmission lines, substations, switchyards.<br><br>Petrochemical installations-production, transmission, storage, terminals. | Corrosives-manufacture, transfer, storage, disposal.<br><br>Explosives-manufacture, transfer, storage, disposal.<br><br>Flammable materials-manufacture, transfer, storage, disposal Radioactive materials-manufacture, transfer, storage, disposal Toxins-manufacture, transfer, storage, disposal. | Food-storage, processing, transfer.<br><br>Irrigation systems.<br><br>Water containment-dams, Reservoirs, levees, dikes, other impoundments Potable water-collection, transmission, siphons, flumes, treatment, storage, Waste water-collection, treatment, discharge. |

TABLE 3.1: CRITICAL FACILITIES FOR MAPPING

# 4 Georeferencing of Satellite Imagery

Despite our best efforts, the natural development cycle of large scale emergency response is overwhelmingly a reactionary process -- crisis event, response, evaluation, innovation, preparation. Precious early moments are spent gathering situation knowledge as matters continue to destabilize.

In this regard, remote sensing is arguably a great equalizer, allowing for quicker analysis of larger affected areas and affording a means to “catch up” to a disaster using available reserves and incoming assistance. Quality geospatial information is among the most valuable and most sought resource in a modern situational crisis.

This places greater responsibility on the remote sensing community to continually develop improved methods and technology which will deliver data quickly and efficiently for the various applications namely from emergency response to urban planning to team preparation – all so that potential problems may be identified, visualized, countered, resolved, and in future, avoided.

Significant developments in digital technology, network capabilities and data storage have lent themselves well to the remote sensing (aerial and space borne) world, and extend beyond never before experienced processing speed and data-sharing potential.

Availability of fresh geographic information available in the critical early hours of a crisis remained a luxury as late as 2002. One critical time delay in getting this information in-hand was that ground control points (GCPs) were typically needed to produce accurate data for any purpose beyond ad hoc visualization. By definition, the horizontal datum is a rectangular plane coordinate system. All horizontal control shall begin and terminate on monuments that are in the National Geodetic Reference Database System (NGRDS). The vertical datum is normal to gravity. All vertical control shall begin and terminate on existing benchmarks that are in the National Geodetic Reference Database System (NGRDS).

Placing personnel on the ground to collect GCP data in order to properly orthorectify images is a time consuming affair. Moreover, images captured over inaccessible regions such as a heavily flooded or hostile area may be impossible or at least certainly not worth the risk. Under such conditions a relatively new method has to be explored – direct georeferencing.

Direct georeferencing produces an accurate relationship between the remotely sensed image data and the terrain it represents by accurately measuring the relative position and orientation of the sensor, removing the need for traditional ground-based GCP measurements. This approach employs a GPS-assisted inertial navigation system to determine the exact position and orientation of an airborne sensor at the exact moment of data capture.

As navigation sensors (GPS, IMU, etc.) continuously record sensor travel and rotation data before, during and after image capture, ranges and bearing measurements are produced to represent exact points on the ground via the sensor. It is then possible to calculate the exact position each image pixel represents on the ground through the corresponding points measured in the mapping frame; all without ever needing to collect a single GCP. This is true remote sensing in the sense that no work is required on the ground.

One current state-of–the-art namely, direct georeferencing system uses GPS measurements integrated with an Inertial Measurement Unit (IMU) and flight assistance technology to measure sensor position and orientation up to 300 times per second. Whereas, a GPS can refresh position and orientation data accurately approximately once every second only, given direct line of sight to a minimum of 5 GPS satellites, a quality IMU (supported by the GPS system) can fill in the GPS data gaps, performing even in the absence of a suitable number of GPS satellite connections, during long outages, and throughout tight turning maneuvers. (For more details please refer to appendices)

Software post-processing of collected data turns sub-meter accuracy into centimeter accuracy by comparing position and orientation information before and after data capture and filtering out anomalies. Integrating navigation data with airborne remote sensing data means that exterior orientation parameters can be produced in near real-time. Images are corrected without accepting the time cost, financial cost, or possible dangers of collecting GCPs.

Suddenly, the most significant delay in getting data to response teams becomes the wait for the plane to return.

Rapid response camera systems have benefited just as much from medium format airborne digital camera advances over the past five years as they have from overall system cost savings. Innovations in medium format lens quality, pixel sizes, CCD quantum efficiency, and radiometric performance have blurred long established divisions between medium and large format aerial camera systems.

# TECHNOLOGY FOR 1:10,000 SCALE MAPPING

# 5 Various Methodologies Available for Preparing Maps of Scale 1:10,000 from Images

The following methodologies may be considered for the generation of 1:10,000 database:

## 5.1 Satellite Imaging

Remote sensing makes it possible to collect data on dangerous or inaccessible areas. Remote sensing applications include monitoring deforestation in areas such as the Amazon basin, the effects of climate change on glaciers and Arctic and Antarctic regions, and sounding of coastal and ocean depths. Military collection during the cold war made use of stand-off collection of data about dangerous border areas. Remote sensing also replaces costly and slow data collection on the ground, ensuring in the process that areas or objects are not disturbed. (For more details please refer to Appendices)

More and more, high and very high resolution optical space sensors are available. Ground Sampling Distance (GSD) of the imaging system of optical space sensor is an important value, also the type of imaging with a Transfer Delay and Integration sensor (TDI) or by reducing the angular speed with a permanent rotation of the satellite during imaging is important, like the accuracy of the attitude control and determination unit. The radiometric and spectral resolution has to be taken into account. For operational use, the swath width, viewing flexibility and imaging capacity has to be respected. The very high resolution optical satellites can change the view direction very fast, allowing a stereoscopic coverage within the same orbit, but this is reducing the amount of scenes which can be taken from the same orbit. On the other hand, stereo combinations taken from neighboring paths are affected by changes in the object space, atmospheric conditions or different length of shadows.

The object identification is strongly dependent upon the GSD. Individual buildings can be identified up to 2m GSD, while with 62cm also building details can be seen. Building extensions are represented only in maps up to a scale of 1:5,000 while in 1:25,000 maps, buildings are shown mainly as symbols. Caused by the required generalization, in 1:50,000 maps, only the character of a settlement is available. On a scale 1:5,000 the building details and in 1:25,000 the rough shape is shown, while in 1:50,000 only symbols for the houses are present. This confirms the mentioned rule of thumb for a required GSD of at least 0.1mm in the publishing scale. Therefore while collecting spatial data for large scale mapping use of Differential GPS will ensure better positional accuracy. (For More details please refer to Appendices)

## 5.2 Aerial Photography

Direct georeferencing (DG) system, for aerial photography, provides the ability to directly relate the data collected by a remote sensing device to the Earth, by accurately measuring the geographic position and orientation of the device without the use of traditional ground-based measurements. Examples of where DG systems are used in the airborne mapping industry include: scanning laser systems or LIDAR, Interferrometric Synthetic Aperture Radar systems (InSAR), multispectral and hyperspectral scanners, large format digital line scanners, large and medium format digital frame cameras, and traditional large format film cameras, Current state-of–the-art direct georeferencing systems are available with leading manufacturers. The additional sensors mounted on camera help to acquire positional data of the laser scanner and its orientation. They use carrier phase differential GNSS measurements integrated with an Inertial Measurement Unit (IMU). However, it may be noted that for better accuracy traditional georeferencing methods are more reliable. (For more details about the service providers in this area please refer to Appendix II)The key component of the DS system is the GNSS-Aided Inertial Navigation software. This software runs in real-time on the processing Computer System and in post-processing software suite. It performs the integration of the inertial data from the IMU with the data from the GNSS receiver.

## 5.3 Comparison between Satellite Imaging and Aerial Mapping

### 5.3.1 General Differences

With the higher resolution and unrestricted access to images taken by satellites, a competition between aerial images and space data is existing, starting for a map scale 1: 5,000. However, high resolution stereo satellites are still under evaluation for detailed mapping. The comparison among LIDAR, Satellite Image, Aerial photo are given in table 5.1

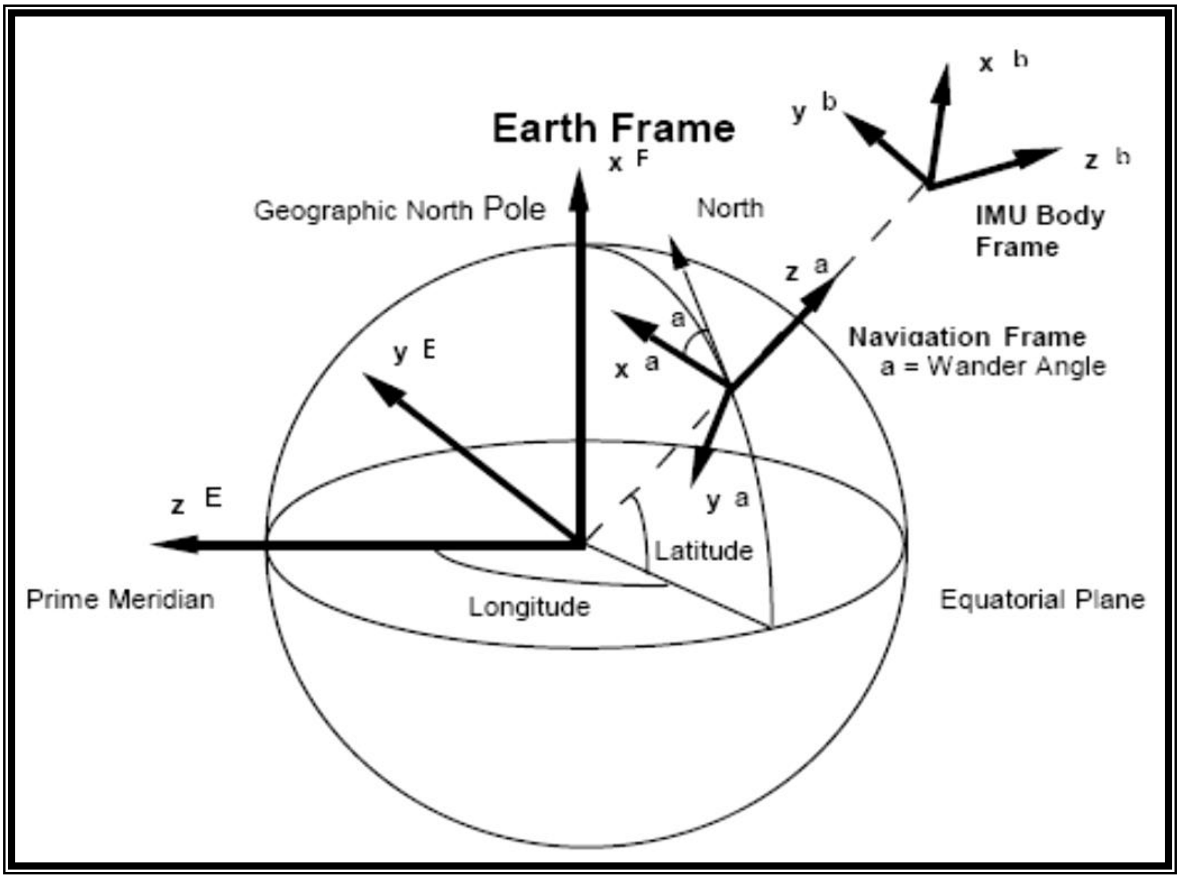



Fig 5.1 Aerial Photography

| Features | | LiDAR | High Resolution satellite stereo | Aerial Photogrammetry/ Photo Scale |
|---|---|---|---|---|
| **Contour Interval** | | | | |
| **Contour Generation** | 0.5 m | ✓ | × | ✓(1:5,000) |
| | 1 m | ✓ | × | ✓(1:10,000) |
| | 2 m | ✓ | × | ✓(1:25,000) |
| | 5 m | ✓ | ✓Geoeye, Worldview and Ikonos (1m and below) | ✓ (1:40,000 andAbove) |
| | 10 m and Above | ✓ | ✓(Many Satellites) | |
| **Target Map Scale** | | | | |
| **3D Feature Extraction** | 1:500 | Feature Collection possible, but for Higher accuracy images are required | | ✓ (1:3,500) |
| | 1:1000 | | | ✓ (1:6,000) |
| | 1:2500 | | | ✓ (1:12,500) |
| | 1:5000 | | | ✓ (1:30,000) |
| | 1:7,500 and Above | | ✓Geoeye and Worldview (0.5m) | ✓ (1:40,000 and above) |
| **Base Map creation** | 1:500 | Feature Collection possible, but for Higher accuracy images are required | | ✓(1:3,500) |
| | 1:1000 | | | ✓(1:6,000) |
| | 1:2500 | | | ✓(1:12,500) |
| | 1:5000 | | | ✓(1:30,000) |
| | 1:7,500 and Above | | ✓Geoeye and Worldview (0.5m) | ✓(1:40,000 and above) |
| **Output Resolution** | | | | |
| **Ortho Photo Generation** | 0.1 m | | | ✓(1:5,000) |
| | 0.25 m | | | ✓(1:15,000) |
| | 0.5 m | | | ✓(1:30,000) |
| | 1 m | LiDAR alone will generate DEM's | ×Geoeye, Worldview and Ikonos (1m and below) | ✓(1:50,000 andAbove) |
| | 2.5 m | | ×Geoeye, Worldview, Ikonos, Cartosat1(2.5m and below) | |
| | 5m and Above | | × (Many Satellites) | |

Table 5.1: Comparison between Lidar, High-resolution Stereo Satellite Image and Aerial Photo

### 5.3.2 Comparison of Accuracy of Imaging

The most significant plus points of such datasets includes:-

- Less numbers of images compared with aerial photos (minimizes triangulation time).
- The flying restriction issues.
- Medium scale mapping can be done with this technique. Feature extraction
- meeting 1:7,000 scales and above is possible.
- Satellite stereo is not a full replacement for traditional aerial photogrammetry, since feature extraction for higher mapping scales is still an area to be looked upon. A comparison of the accuracies obtainable by these techniques is given below in the table.

| Scale | Accuracy | | Remark |
|---|---|---|---|
| | Aerial Photography | Satellite stereo Imagery | |
| **1:10,000** | 20 cm ( X,Y)<br>40 cm (Z) | Greater than 3 m<br>(6 meter) | Both satellite and aerial provide comparable results. Satellite requires more GCP points for registration purpose |
| **1:5,000** | 10 cm<br>20cm ( z) | 2.5 - 3 m | Aerial can give better and more accurate. Aerial flying requires minimum GCPs |
| **1:1,000** | 5 cm | 1.2 m | Satellite cannot give this scale and accuracies |

**Table 5.2: Comparison between Satellite Imagery and Aerial Photography**

**Note: The scale and contour figures given in tables 5.1 & 5.2 are the standard format used in large scale mapping and hence no further reference is required.**

## 5.4 Comparison of Ground Sampling Distance (GSD) Between Satellite Imaging and Aerial Photogrammetry

A brief comparison of the various techniques of mapping is given in table 5.3

| S.No. | Parameters | Satellite mapping | Aerial mapping | Vehicle mounted ground survey |
|---|---|---|---|---|
| 1 | **Resolution** | Max: 40 cm (Geoeye) | Better than 10 cm | Better than 5 cm |
| 2 | **Mapping Scale** | 1:10,000 | 1:2000 or better | 1:500 or better |
| 3 | **Type of imaging** | Stereo | Stereo | Stereo |
| 4 | **Derived Product** | DEM/DTM/DSM | DEM/DTM/DSM | DEM/DTM/DSM |
| 5 | **Contour** | 1 meter | Better than 0.5 meter | Better than 10 cm |
| 6 | **GCP requirement** | Yes [atleast 14 per frame of 10 Km x 10 Km at minimum spacing of 5 Km or better traceable to reference datum of International Geocentric Reference frame (ITRF)] | Not required as on board Dual Frequency Differential GPS processing integrated with Satellite Based Augmentation Service (SBAS). Automatically performances Geo referencing of images. | Not required as on board Dual Frequency Differential GPS processing integrated with Satellite Based Augmentation Service (SBAS). Automatically performances Geo referencing of images. |
| 7 | **GCP Accuracy (95% confidence)** | Required on the ground | Automatically done | Automatically done |
| | **Horizontal** | Better than 30 cm | Better than 5 cm | Better than 5 cm |
| | **Vertical** | Better than 20 cm | Better than 5 cm | Better than 5 cm |
| 8 | **3D imaging** | Rough estimate | Accurate | Accurate |

**Table 5.3: Comparison between Satellite Imagery, Aerial Photography and Vehicle Mounted Ground Survey**

Based on experiences, optical images should have a ground sampling distance (GSD) of 0.05mm up to 0.1mm in the map scale corresponding to a map scale of 1: 20,000 up to 1: 10,000 for a GSD of 1m. **GSD is the distance of the centre of neighborhood pixels projected on the ground.** Because of over or under-sampling, the GSD is not identical to the projected size of a pixel, but for the user, the GSD appears as pixel size on the ground.

| GSD | Target map scale | Comparisons | |
|---|---|---|---|
| | | **Aerial** | **Satellite** |
| **AT GSD 10 cm** | 1:500 | 0.05 m | Not Good |
| | 1:1,000 | 0.05 m | Not Good |
| **AT GSD 20 cm** | 1:2,000 | 0.10 m | Not Good |
| | 1:2,500 | 0.10 m | Not Good |
| | 1:3,000 | 0.10 m | Not Good |
| | 1:4,000 | 0.10 m | Not Good |
| | 1:5,000 | 0.10 m | Not Good |
| **AT GSD 50 cm** | 1:8,000 | 0.25 m | 2.5 m |
| | 1:9,000 | 0.25 m | 2.5 m |
| | 1:10,000 | 0.25 m | 2.5 m |
| | 1:16,000 | 0.25 m | 2.5 m |
| | 1:20,000 | 0.25 m | 10.0 m |

**Table 5.4: Comparison of GSD for Satellite Imagery and Aerial Photography**

A target scale of 1:6000 and less is not possible with resolution 0.5 m as some of the finer features like poles, manholes will not be visible on these satellite images and therefore for such map scales, Aerial photo is used. With the present commercial stereo satellite imagery available a target scale of 1:7,000 or more is possible.

- The accuracy achieved for Geoeye test data shows that the map scale of 1:7,000 and above is achievable as per ASPRS standards reference (Table) for aerial images, but the problem lies with the GSD of the satellite Data, for Geoeye has a GSD of 0.5m.
- Quick bird is limited to 6,900 lines/second with orbit speed 7,638m/sec and footprint speed 7,134m/sec - with 0.62m GSD slow down factor 1.61 required.
- EROS-B – 2,400 lines/sec→ slow down factor at least 4.2.
- EROS-A – 750 lines/sec → slow down factor at least 5.2 limiting imaging capacity, with EROS only individual areas, no large continuous coverage Important also is the internal storage and downlink capacity.

| Satellite | Collection rate | Approximate theoretical collection capacity / day |
|---|---|---|
| IKONOS | 2,365 km²/min | 150,000 km²/day |
| Quickbird | 2,666 km²/min | 135,000 km²/day |
| OrbView-3 | 1,483 km²/min | 80,000 km²/day |
| WorldView-1 | 4,512 km²/min | 750,000 km²/day |
| GeoEye-1 | 2,842 km²/min | PAN: 700,000 km²/day; PAN+ms: 350,000 km²/day |
| WorldView-2 | 4,686 km²/min | 975, 000 km²/day |

Table 5.5: Current Satellite Collection Rates

## 5.5 Aerial Mapping

### 5.5.1 Map Checking

All photogrammetric maps need checks of representative samples of each map for accuracy and completeness by using photogrammetric plotters. Visual checks are needed for missing contours, wrong symbology, incorrect fonts and font sizes, and other cartographic errors. It is also needed to be visually ensured that all planimetric features have been compiled on the maps by using a stereoscope and the aerial photographs. Map checking is a critical task to ensure accuracy in the production of photogrammetric mapping.

### 5.5.2 Map Accuracy

Recommended photogrammetric map accuracy standards are as follows:

- The position of all coordinate grid ticks and all monuments shall not vary more than 0.3 mm from their coordinated position.
- At least 90 percent of all well-defined planimetric features shall be within 0.6 mm of true ground position, and all shall be within 1.3 mm of true ground position.
- At least 90 percent of all contours shall be within one-half of the contour interval of true elevation, and all contours will be within one contour interval of true elevation, except as follows:
- In densely wooded areas where the ground is obscured by dense bush or tree cover, contours shall be plotted as accurately as possible while making maximum use of spot elevations obtained from the stereoscopic model in places where the ground is visible. In those areas where spot elevations can be obtained photogrammetrically, at least 90 percent of all contours shall be within one contour interval or one-half of the average height of the ground cover, whichever is greater, of true elevation. Contours in such areas will be shown with dashed lines.
- Orchard, vineyards, and other areas devoted to crops will be considered as open areas and are therefore not subject to larger tolerances in vertical accuracy.
- In areas not obscured by grass, weeds, or brush, at least 90 percent of all spot elevations will be within 0.25 contour interval of true elevation, and all shall be within 0.50 contour interval of true elevation.

In addition to the accuracy specified above for contours and spot elevations, the following shall apply:

- The arithmetic mean of contours and spot elevations in open areas shall not exceed plus or minus the following values for the points tested on each map sheet.

| Number of Points Tested | Maximum Arithmetic Mean |
|---|---|
| 20 | +/-0.24 Contour Interval |
| 40 | +/-0.18 Contour Interval |
| 60 or more | +/-0.12 Contour Interval |

Any contour that can be brought within the specified vertical tolerance by shifting its position by 0.6 mm will be accepted as correctly compiled.

## 5.6 Methodology for Map Generation

### 5.6.1 Data Package

The map file will be divided into rectangular sheets and the individual files will have an added standard surround and coordinate grid with identifying text. Each sheet must be a standard size of 2000m from east to west and 1000m from north to south for hard copy production at a scale of 1:2000. The coordinate grid may be constructed of lines depending on the coordinate system to a resolution of 100m

- All digital mapping must be based on the coordinate system used in the aerial triangulation and numeric adjustments.
- The map must be loaded into a three with an international coordinate system set.
- All digital compilation must be done using an order stereo-plotter workstation.
- All features mapped from aerial photography into digital format must be encoded with a feature code number and graphic group numbers that will be listed in the feature code table.
- In addition, each entity must have a symbology of level, color, style, and weight that will be listed in the feature code table.
- The grid line must end at the neat line and must be annotated with a coordinate value located at the end of the grid line and between the neat line and the border.
- All graphic elements of the surround and grid must be symbolized and feature coded as noted in feature code table.
- Each sheet must be self-contained within its own digital file.
- Each digital file must be named and referred to by its six-digit identification number as determined by the coordinate position of the lower-left corner of the sheet.
- The first three digits will be the first three numbers of the easting and the last three digits will be the second, third and fourth numbers of the northing. For example, the sheet with its lowerleft corner at coordinate 368000.000, 5021000.000 will be denoted 368021.dgn.

Each map sheet within a project area must include all planimetric and hypsographic data, including adjoining sheet hypsographic data, in one digital file. Three dimensional linestring, points, cells and text as specified in the feature code table must be used in the creation of the planimetric map and hypsographic mode.

| The data package will contain | | |
|---|---|---|
| 1 | Feature Capture | All Linear features must be digitized, where possible, in a clockwise manner or with the feature on the right hand side of the linestring. |
| 2 | Topological Structuring | All line work comprising of an area feature must be mathematically close by similar coordinate values and linear features adjoining or connecting to other features must mathematically join by similar coordinate values. |
| 3 | Use of Annotation | Annotation must be included wherever graphic features do not adequately describe the mapping content. In addition, annotation may be used to name roadways, bodies of water, bridges and other cultural points of interest where applicable |
| 4 | Co-incident Features | Co-incidental linear feature edges whether sharing a common elevation or not must be captured in their entirety and must be totally self-contained |
| 5 | Use of Planimetric Features in Hypsographic model | Thelinearorpointfeaturesmustbeusedtogeneratebothhardcopypositionaldataan dhypsographic modeling data. |
| 6 | Use of Virtual Hypsographic Segments | Where planimetric information does not adequately describe the hypsographic nature of the terrain, virtual hypsographic data must be included for use in the hypsographic model. Line string can be used to depict linear break information across terrain and points can be used to depict high and low points in the terrain. Additional points must be included in a grid pattern anywhere within the mapping area where there is an absence of hypsographic data for a radius greater than 10m. |
| 7 | Depiction of Vertical Surfaces | True vertical surface cannot be modeled within the terrain model and therefore vertical surfaces such as retaining walls must be captured with a lower edges offset by a distance of 1 mm to 1 cm in the direction down slope from the top edge. |
| 8 | Depiction of Obscured Surfaces | Obscured surfaces, such as terrain beneath bridges and terrain near the buildings, must be approximated by virtual hypsographic segments placed underneath the obscuring surface. These must be approximated by using terrain information, as close to the area as possible, by assuming no terrain undulation beneath the obstructing surface. |
| 9 | Additional Hypsographic Model Area | To ensure model consistency at or near the mapping limits, a buffer 20m wide outside the mapping area must include all available hypsographic modeling data feature coded as "map edge hypsographic data". A 20m strip of hypsographic mapping detail from adjoining sheets on the outer edge of the map neat line must be included. These mapping features, regardless of feature type must be coded as "adjoining sheet hypsographic data". |
| 10 | Testing the Hypsographic Model | Generating contour lines at 50cm intervals must be done for fully testing of the hypsographic model. |

TABLE 5.5.1: DETAILS OF DATA PACKAGE

# 6 Technical Details of Major Satellite Imagery for Preparing Maps on Scale 1:10,000

## 6.1 Available Sensor Resolutions in Satellite Mapping

Some of the available sensor resolutions are:

| SATELLITE | RESOLUTION |
|---|---|
| **GeoEye-1** | 0.41 meter resolution- Panchromatic / Multispectral |
| **Worldview-2** | 0.46 meter resolution- Panchromatic/Multispectral |
| **Worldview-1** | 0.46 meter resolution- Panchromatic |
| **Quickbird** | 0.6 meter resolution- 5 bands (Red - Green - Blue - Pan - NIR) |
| **Ikonos** | 0.8 meter resolution- 5 bands (Pan, blue, green, red, NIR) |
| **Aster** | 15 meter resolution- 14 spectral bands (Visible and Near Infrared - 3 bands), (Short Wave Infrared - 6 bands) and (Thermal Infrared - 5 bands) |
| **Landsat 7 TM** | 15 meter resolution- 8 spectral bands (Visible, Infrared, NIR, Thermal, Low Gain, High Gain, Mid IR, and Pan) |
| **EO-1 Sensor Hyperion** | 10 meter resolution- 220 spectral bands |
| **Rapid Eye** | 5m resolution |

**Table 6.1: Sensor Resolutions of Various Satellites**

## 6.2 Technical Details of Indian Satellites

### 6.2.1 Resourcesat -1

Resourcesat–1 is conceptualised and designed to provide continuity in operational remote sensing with its superior capabilities. The main objective of Resourcesat-1 is not only to provide continued remote sensing data for integrated land and water management and agricultural and its related applications, but also to provide additional capabilities for applications. Apart from making data available in real time to the Ground Stations in it visibility area, Resourcesat-1 with its ability to record data anywhere in the world with its advanced On Board Solid State Recorder, has entered into new dimensions of meeting the requirements of Resource Managers globally.

| PARAMETERS | SPECIFICATIONS |
|---|---|
| Orbit/Cycle Visits / year | 341 |
| Semi major axis | 7195.11km |
| Altitude | 817 km |
| Inclination | 98.69 deg |
| Eccentricity | 0.001 |

| | |
|---|---|
| Number of Orbits/day | 14.2083 |
| Orbit period | 101.35 min |
| Repetivity | 24 days |
| Distance between adjacent paths | 117.5 km |
| Distance between successive ground tracks | 2820 km |
| Ground trace velocity | 6.65 km/sec |
| Equatorial crossing velocity | 10:30 AM at descending node<br>± 5 min |

**Table 6.2: Technical details of Resourcesat- 1**

The Resourcesat - 1 is designed to provide multispectral, monoscopic and stereoscopic imageries of the earth's surface with its advanced on-board sensors. Linear Imaging and Self Scanning Sensor (LISS-III), an Advanced Wide Field Sensor (AWiFS) and a High Resolution Multispectral Sensor LISS-IV constitute main payload of Resourcesat. Technical details, sensor specifications and pay load details are given in table no. 6.2, 6.3, & 6.4 respectively.

**SENSOR SPECIFICATIONS**

| | LISS- IV | | LISS III | | AWiFS | |
|---|---|---|---|---|---|---|
| **IGFOV** | 5.8 m at nadir | | 23.5 m | | 56 m at nadir | |
| | (Across Track) | | | | (Across track) | |
| **Spectral Bands** | B2 | 0.52 - 0.59 | B2 | 0.52 - 0.59 | B2 | 0.52 - 0.59 |
| | B3 | 0.62 - 0.68 | B3 | 0.62 - 0.68 | B3 | 0.62 - 0.68 |
| | B4 | 0.77 - 0.86 | B4 | 0.77 - 0.86 | B4 | 0.77 - 0.86 |
| | | | B5 | 1.55 - 1.70 | B5 | 1.55 - 1.70 |
| **Swath** | 23.9 km (Mx), 141 km 740 km (Combined)<br>70 kms (Mono) , 370 km (Each head) | | | | | |
| **Integration time** | 0.877714 msec, 3.32 msec, 9.96 msec | | | | | |
| **Quantization** | 10 bits, 7 bits ,10 bits | | | | | |
| | Selected 7 Bits will be SWIR band has 10 bit transmitted by the data quantization, selected handling system 7 bits out of 10 bits will be transmitted by the data handling system | | | | | |
| **No. of gains** | Single gain 4 for B2, B3 and B4.<br>(Dynamic range obtained by sliding 7 bits out of 10 for B5<br>(Dynamic range obtained by sliding 7 1 bits out of 10 bits) | | | | | |

**Table 6.3: Sensor details of Resourcesat-1**

| PAYLOAD | RESOLUTION (METERS) | SWATH (KM) | REVIST | IMAGE SIZE KM X KM | OVERLAP KM | SIDELAP EQUATOR KM |
|---|---|---|---|---|---|---|
| **LISS III** Visible | 23.5 | 141 | 24 Days | 142 x 141 | 7 | 23.5 |
| **LISS III** SWIR | 23.5 | 141 | 24 Days | 142 x 141 | 7 | 23.5 |
| **LISS IV** Mono | 5.8 | 70 | 5 Days | 70 x 70 | 2.5 | 5 Within LISS III |
| Mx | 5.8 | 23 | 5 Days | 23 x 23 | 14.2 | |
| **AWIFS** | 56 (Nadir) 70 (End pixel) | 737 | 5 Days | 738 x 737 | 82 % | 84 % |

**Table 6.4: Payload details of Resourcesat- 1**

Data products can be categorized as standard and value added products. Value added products are generated by further processing of standard corrected data. Data products are supplied in both photographic and digital media. Various options like different digital formats, resampling methods, etc. are available to the user community. Data products are classified into:

- Scene based standard products
- Scene based georeferenced products
- Map based geo-coded products
- Floating geo-coded products
- Ortho-rectified geo-coded products
- LISS IV Products LISS III Products

The oblique viewing capability of LISS-IV sensor can be used to acquire stereo pairs

| S.No | LISS IV Product Type | Level of Correction | Area Covered (Km x Km) | No. of Bands | Output |
|---|---|---|---|---|---|
| **1.** | Scene based | Standard | 23 x 23<br>70 x 70 | 3 Mx bands<br>Mono | Digital / Photographic<br>Digital / Photographic |
| | | Georeferenced | 23 x 23 | 3 Mx bands | Digital |
| | | | 70 x 70 | Mono | Digital |
| **2.** | Map sheet based | Geocoded | 7.5' x 7.5' | 3 Mx bands | Digital / Photographic |
| | | | 7.5' x 7.5' | Mono | Digital / Photographic |
| | | | 15' x 15' | Mono | Digital / Photographic |
| **3.** | Point based | Geocoded | 5' x 5' | 3 Mx bands | Digital / Photographic |

| | | | | | |
|---|---|---|---|---|---|
| | | | | Mono | Digital / Photographic |
| **4.** | Basic stereo pair | Radiometrically corrected | 70 x 70 Km | Mono | Digital |
| **5.** | Ortho Image | Ortho Rectified (External DEM) | 7.5' x 7.5' (Stereo graphic) | Mono | Digital / Photographic |
| | | Orthorectified (External DEM) | 7.5' x 7.5' | Mono | Digital / Photographic |
| | | Orthorectified (External DEM) | 15' x 15' | Mono | Digital / Photographic |
| **6.** | LISS III + LISS IV (Mono) Geocoded | Merge | 15' x 15' | 3 | Digital / Photographic |
| | | | 70 x 70 Km | 3 | Digital / Photographic |

**Table 6.5: LISS Product details of Resourcesat-1**

| S.No | AWiFS Product Type | Level of Correction | Area Covered (Km x Km) | No. of Bands | Output |
|---|---|---|---|---|---|
| **1.** | Path row based (with or without shift) | Raw | 370 x 370 | 4 | Digital |
| | | Radiometrically corrected | 370 x 370 | 4 | Digital |
| | | Standard | 370 x 370 | 3 4 | Photographic Digital |
| | | Geo referenced | 370 x 370 | 4 | Digital |
| **2.** | Map sheet based | Geo coded | 1 0 x 1 0 | 3 4 | Photographic Digital |

**Table 6.6: AWiFS Product Details of Resourcesat-1**

Users can view the data using our advanced digital browsing facility and place indents using the User Order Processing System (UOPS). Those who have further data requirements and OBSSR requirements, can provide details through UOPS so that the satellite is suitably programmed and the data are made available to the user. These data products can be delivered by conventional methods of speed post / courier or by electronic delivery. The LISS & AWIFS product details of Resourcesat 1 are given in table 6.5 & 6.6 respectively.

### 6.2.2 Cartosat-1

There is now an increasing demand for large scale and topographic mapping to meet this requirement. DOS has launched the Cartosat-1satellite which is dedicated to stereo viewing for large scale mapping and terrain modeling applications.

| ORBIT DETAILS | | |
|---|---|---|
| **01** | **Orbit** | **Polar Sun Synchronous** |
| **02** | **Orbital Altitude** | **618 km** |
| **03** | **Orbits / cycle** | **1867** |
| **04** | **Semi Major Axis** | **69996.14** |
| **05** | **Eccentricity** | **0.001** |
| **06** | **Inclination** | **97.87 o** |
| **07** | **Local Time** | **10.30 AM** |
| **08** | **Revisit** | **5 days** |
| **09** | **Repetition** | **126 days** |
| **10** | **Orbits / day** | **14** |
| **11** | **Orbital Period** | **97 minutes** |

**Table 6.7: Orbit Details of Cartosat-1**

| S.No. | Parameter | | Specifications |
|---|---|---|---|
| 01 | Swath | Fore | 29.42 km |
| | | Aft | 26.24 km |
| 02 | IGFOV | Fore | 2.452 m (Across track) |
| | | Aft | 2.187 m (Across track) |
| 03 | Ground sample distance | | 2.54 m (Along Track) |
| 04 | Spectral band | | 0.5 - 0.85 microns |
| 05 | Quantisation | | 10 bits (1024) |
| 06 | Number of detectors | | 12k |
| 07 | Pixel size | | 7 x 7 micron |
| 08 | Integration time | | 0.336 ms |
| 09 | Focal length | | 1954 mm |
| 10 | Data rate per Camera | | 336 Mbps |
| 11 | Data compression Ratio | | 3.22:1 (nominal) depends on terrain |
| 12 | Type of compression | | JPEG |
| 13 | Data rate transmitted to ground | | 105 Mbps/camera |

**Table 6.8: Technical Details of Cartosat-1**

The data rate requirement for 2.5 m resolution system is about 336 Mbps for a 10 bit quantization. This high bit data is compressed by 3.2:1 by JPEG compression technique. A spherical phased array antenna with steerable beam is used to transmit the data to the required ground station. A solid state recorder with 120 GB capacity to store about 9 minutes of Payload data is available for global operation of the payloads. The table 6.7 & 6.8 show the orbit details and technical details of Cartosat 1

**Cartosat - 1 Product**

Cartosat-1 data products are of two categories.

- Standard product (radiometrically corrected, georeferenced).

- Precision product (ortho rectified product).

Standard products are generated after accounting for radiometric and geometric distortions while precision products are ortho rectified. Ortho rectified products are corrected for terrain distortions and camera tilt effects with the help of control points and using Stereo Strip Triangulation (SST) based DEM (only for Indian region). All Cartosat-1 data products are supplied with 10 bit radiometry for both PAN Fore and Aft cameras. Both standard &Ortho product details are given in table 6.9 and 6.10

| Standard Products | | |
|---|---|---|
| 01 | Radiometrically corrected / Basic Stereo | Stagger corrections, line loss corrections, radiometric correction at scene level |
| 02 | Standard Georeferenced | Radiometric and geometric corrections (north-oriented) at scene level using system knowledge |
| 03 | Orthokit products (Mono / Stereo) | Radiometric corrections along with Rational Polynomial Coefficients (RPCs) |
| 04 | Ortho product | Terrain corrected products using TCPs and DEM from SST software (only for Indian region) |

**Table 6.9: Standard Product details of Cartosat-1**

| S.No. | Area Coverage | Level of Processing | Precision (Ortho) Products<br><br>Digital data Format | Media | Accuracy specifications | | Remarks |
|---|---|---|---|---|---|---|---|
| | | | | | Location Accuracy | Internal Distortion | |
| 01 | Mapsheet based/Float 7.5' * 7.5' * | Precision (Ortho) Terrain corrected | GeoTIFF | CD-ROM | ≦ 25m | Around 10m | Using DEM and TCPs |
| 02 | Float 5' * 5' * | Precision (Ortho) Terrain corrected | GeoTIFF | CD-ROM | ≦ 25m | Around 10m | Using DEM and TCPs |
| 03 | Float 3.75' * 3.75' * | Precision (Ortho) Terrain corrected | GeoTIFF | CD-ROM | ≦ 25m | Around 10m | Using DEM and TCPs |
| 04 | Float 2.25' * 2.25' * | Precision (Ortho) Terrain corrected | GeoTIFF | CD-ROM | ≦ 25m | Around 10m | Using DEM and TCPs |

**Note :**

All the Geocoded products ortho corrected.
* Restricted Area Masking is done, wherever required.

**Table 6.10: Precision (Ortho) Product details of Cartosat-1**

### 6.2.3 Cartosat-2

CARTOSAT-2 is an advanced remote sensing satellite capable of providing scene-specific spot imagery. The panchromatic camera (PAN) on-board the satellite can provide imagery with a spatial resolution better than one meter and a swath of 9.6 km. The satellite can be steered up to ±45 deg along and ±26 deg across the track. The data from the satellite can be used for detailed mapping and other cartographic applications at cadastral level, urban and rural infrastructure development and management, as well as applications in Land Information System (LIS) and Geographical Information System (GIS).Several new technologies like two mirror on axis single camera, carbon fabric reinforced plastic based electro-optic structure, lightweight, large size mirrors, data compression, advanced solid state recorder, high-torque reaction wheels and high performance star sensors, imaging along the corridor or any direction have been employed in Cartosat-2. Table 6.11 shows the orbit parameters of Cartosat.2

| Orbit Parameters | |
|---|---|
| Orbit | Polar, Sun-synchronous |
| Orbital Altitude | 630.6 km |
| Semi Major Axis | 7008.745 km |
| Inclination | 97.914 degrees |
| Local Time | 9:30 A.M |
| Revisit | 4/5 days |
| Repetivity | 310 days |
| Orbits/day | 14.78 |
| Inter-path distance | 8.75 km |
| Distance between successive orbits | 2711.9 km |
| Orbital period | 97.446 minutes |
| Spatial resolution | < 1m |
| Swath | 9.6 km |
| Spectral band | 0.5 - 0.85 microns |
| Type of compression | JPEG like |
| Quantization | 10 bits |
| ROLL tilt | ±26 deg |
| OBSSR Capacity | 9 minutes of data/64GB |

**Table 6.11: Technical Details of Cartosat- 2**

Cartosat-2 capabilities include:-

- Cartosat-2 sensor scans up to 2732 lines/second
- Various dimensions of AOI can be acquired. For example an AOI (Area of Interest) of 28 km x 28 km can be acquired within a single pass using Paint-Imaging.
- The satellite is also capable in collecting spot images of size 9.6 x 9.6 km. About fifteen spot images of size - 9.6km x 9.6km can be acquired in a given orbit. This helps in servicing more number of users in a single orbit.
- Revisit of same area depends upon acceptable across-track tilt and gap between paints depend upon the pitch biases used.

| Area Length (km) | Area Width (km) = n x 9.6 where n: no of scans within one paint. | Total Area (km2) | Difference in View Angle between successive scans (deg) | Along-Track Bias variation (deg) |
|---|---|---|---|---|
| 9.6 | 4 x 9.6 = 38.4 | 368.6 | 120 | +/- 260 |
| 28.0 | 3 x 9.6 = 28.8 | 806.4 | 180 | +/- 260 |
| 50.0 | 2 x 9.6 = 19.2 | 960.0 | 220 | +/- 260 |

**Table 6.12: Cartosat-2 Products**

Cartosat-2 products are of two categories,

- AOI based standard product (radiometrically corrected/geo referenced orthokit)
- AOI based precision product (ortho corrected)

Standard products are georeferenced and AOI based products, generated after accounting for radiometric and geometric distortions.

Minimum AOI is 25 sq Km and Maximum AOI is 2500 sq km.

Cartosat-2 browse images are uploaded on to website www.nrsc.gov.in regularly. Cartosat-3 has been launched and the details are awaited.

## 6.3 Technical Details of International Satellites

### 6.3.1 Quickbird

Quickbird was launched on October 18, 2001 from Vredenburg Air Force Base in California. Quickbird collects over 75 million square kilometers of imagery annually.

| Quickbird Specifications | | |
|---|---|---|
| **Imaging Mode** | **Panchromatic** | **Multi-spectral** |
| Spatial Resolution | 0.61 meter GSD at Nadir | 2.4 meter GSD at Nadir |
| Spectral Range | 445-900 nm | 450-520 nm (blue)<br>520-600 nm (green)<br>630-690 nm (red)<br>760–900 nm (near IR) |
| Swath Width | 16.4 km at nadir | |
| Off-Nadir Imaging | 0-30 degrees off-nadirHigher angles selectively available | |
| Dynamic Range | 11-bits per pixel | |
| Mission Life | 8+ years | |
| Revisit Time | Approximately 3.5 days (depends on Latitude) | |
| Orbital Altitude | 450 km | |
| Nodal Crossing | 10:30 am | |

**Table 6.13: Quickbird Details**

### 6.3.2 Geoeye-1

GeoEye-1, the world's highest-resolution commercial color imaging satellite, was launched on September 6, 2008 from Vandenburg Air Force Base in California. This newest satellite offers extraordinary detail, high accuracy and enhanced stereo for DEM generation. GeoEye-1will simultaneously collect Panchromatic imagery at 0.41m and Multispectral imagery at 1.65m.

GeoEye-1 has the capacity to collect up to 700,000 square kilometers of Panchromatic imagery (and up to 350,000 square kilometers of Pan-Sharpened Multispectral imagery) per day.Geoeye-1 Specifications:

| Imaging Mode | Panchromatic | Multi-spectral |
|---|---|---|
| Spatial Resolution | .41 meter GSD at Nadir | 1.65 meter GSD at Nadir |
| Spectral Range | 450-900 nm | 450-520 nm (blue)<br>520-600 nm (green)<br>625-695 nm (red)<br>760-900 nm (near IR) |
| wath Width | 15.2 km | |
| Off-Nadir Imaging | Up to 60 degrees | |
| Dynamic Range | 11 bit per pixel | |
| Mission Life | Expectation > 10 years | |
| Revisit Time | Less than 3 days | |
| Orbital Altitude | 681 km | |
| Nodal Crossing | 10:30 am | |

**Table 6.14: Geoeye-1 Details**

### 6.3.3 Ikonos

Ikonos, the world's first high-resolution commercial color imaging satellite, was launched on September 24, 1999 from Vandenburg Air Force Base in California. The Ikonos satellite collects Panchromatic imagery at 0.82m and Multispectral imagery at 3.2m at Nadir

| Ikonos Specifications | | |
|---|---|---|
| **Imaging Mode** | **Panchromatic** | **Multispectral** |
| Spatial Resolution | 0.82 meter GSD at Nadir | 3.2 meter GSD at Nadir |
| Spectral Range | 450-900 nm | 450-520 nm (blue)<br>520-600 nm (green)<br>625-695 nm (red)<br>760-900 nm (near IR) |
| Swath Width | 11.3 km at Nadir | |

| | |
|---|---|
| Off-Nadir Imaging | Up to 60 degrees<br>Higher angles selectively available |
| Dynamic Range | 11 bit per pixel |
| Mission Life | Expectation > 10 years |
| Revisit Time | Less than 3 days |
| Orbital Altitude | 681 km |
| Nodal Crossing | 10:30 am |

**Table 6.15: Ikonos**

### 6.3.4 Worldview-1

WorldView-1 (a Panchromatic only satellite) was launched on September 18, 2007 from Vandenburg Air Force Base in California. WorldView-1 was the first satellite in the "next generation" of satellites to be added to the Digital Globe constellation of satellites. WorldView-1 is capable of collecting up to 750,000 square kilometers (290,000 square miles) per day of half-meter imagery

| **WorldView-1 Specifications** | |
|---|---|
| **Imaging Mode** | **Panchromatic** |
| Sensor resolution | 0.50 meter |
| Spectral range | 440-850 nm |
| Swath width | 77 km at nadir |
| Off-nadir imaging | 0-30 degrees off-nadir<br>Higher angles selectively available |
| Dynamic range | 11-bits per pixel |
| Mission life | 7 years Expected end of life 2015 |
| Revisit time | 1 day at 1 nadir |
| Orbital altitude | 630 km sun synchronous orbit |
| Nodal crossing | 10:30 am |

**Table 6.16: Worldview-1 Details**

### 6.3.5 Worldview-2

| Imaging Mode | Panchromatic | Multispectral |
|---|---|---|
| Spatial resolution | 0.46 meter GSD at Nadir0.52 meter GSD at 20 degrees off-Nadir | 1.84 meters GSD at Nadir2.08 meters GSD at 20 degrees off-nadir |
| Spectral range | 450-800 nm | 400-450 nm (coastal)<br>450-510 nm (blue)<br>510-580 nm (green)<br>585-625 nm (yellow)<br>630-690 nm (red)<br>705–745 (red edge)<br>770–895 (near IR-1)<br>860-900 nm (near IR-2) |
| Swath width | 16.4 km at nadir | |
| Off-nadir imaging | Nominally +/- 45 degrees off-nadir = 1,355 swath width<br>Higher angles selectively available | |
| Dynamic range | 11-bits per pixel | |
| Mission life | 7.25 years | |
| Revisit time | 1.1 days at 1m GSD or less<br>3.7 days at 20 degrees off-nadir or less(0.52 meter GSD) | |
| Orbital altitude | 770 km | |
| Nodal crossing | 10:30 am | |

**Table 6.17: Worldview-2 Detail**

### 6.3.6 Rapid Eye

| Imaging Mode | Panchromatic | Multispectral |
|---|---|---|
| Spatial resolution | 0.5 meter GSD at Nadir | |
| Spectral range | 450-800 nm | 440-510 nm (blue)<br>520-590 nm (green)<br>630-685 nm (red)<br>690-730 nm (red edge)<br>760-850nm (red)<br>705–745 (near IR) |
| Swath width | 77 km | |
| Off-nadir imaging | Nominally +/- 45 degrees off-nadir = 1,355 swath width<br>Higher angles selectively available | |
| Dynamic range | 12-bits per pixel | |
| Mission life | 7 years (launched in 2008) | |
| Revisit time | 24hrs | |
| Orbital altitude | 630 km | |
| Nodal crossing | 11:00 am | |

**Table 6.18: Rapid Eye Detail**

# 7 Required Accuracies

Earlier during non-digital era, the accuracies were determined in relation to plotable point on the hard copy map. But this basis was no longer acceptable with the introduction of digital data. The demand for more accurate geospatial data became essential for various applications. In case of disaster management and mitigation, higher is the need of the hour. Accordingly, different options have to be assessed against time and resources required for such purposes.

Several experiments have been conducted by the mapping agencies, committees and the companies supplying data or equipment. These efforts do indicate the options available to of us. Nevertheless, the basic sources of spatial data have been the aerial photography and satellite remote sensing data. The other sources are Air-borne Laser Terrain Mapping (ALTM), GPS and ground surveys. These sources can only be used for mapping for a very localized area.

## 7.1 Topographic Mapping Standards

Based on type of topographic map or requirements, various topographic mapping standards are being followed by different nations. Though, each country follows its own standards, American Society of Photogrammetry & Remote Sensing (ASPRS) is being widely accepted and being followed by many mapping organizations across the world on 1:10,000 scale, ASPRS standards are given in table 7.1, 7.2 & 7.3

| Sl. No. | Map class | Accuracy (RMSE meters) | Remarks |
|---|---|---|---|
| 1. | Class - I | 0.25 mm of map scale; 2.5 | At well defined points (The term “well defined points” pertains to features that can be sharply identified as discrete points). |
| 2. | Class - II | Twice of class – I: 5 | |
| 3. | Class - III | Thrice of class – I: 7.5 | |

**Table 7.1: Topographic Map Planimetric (X or Y) Accuracy (RMSE in meters): for 1: 10,000 Scale (ASPRS)**

| Sl. No. | Map class | Accuracy (RMSE meters) | Remarks |
|---|---|---|---|
| 1. | Class - I | DTM accuracy is 1 / 3 of contour interval 1.67m | At well defined points (The term “well defined points” pertains to features that can be sharply identified as discrete points). |
| 2. | Class - II | DTM accuracy is 1 / 1.5 of contour interval 3.3m | |
| 3. | Class - III | DTM accuracy is of contour interval 5m | |

.**Table 7.2: Topographic Map Vertical (Z) Accuracy (MSL Heights) for 1:10.000scale**

| Sl No. | Description | Value |
|---|---|---|
| 1. | Satellite Imagery | 2.5 m PAN + 5.8 MX merged product. |
| 2. | Planimetric accuracy | 5 m |
| 3. | Datum | WGS84. |
| 4. | Projection | LCC / TM (in view of National Map Policy for open series maps projection LCC / TM projection may be changed on UTM). |
| 5. | Theme Content | Content and classifications are given in NNRMS – 2005 document. |

**TABLE 7.3: THEMATIC MAP STANDARDS FOR 1: 10,000 SCALE (NNRMS – 2005)**

The table 6.4 indicates relationship between the spatial resolution of different remote satellite data, achievable accuracies (horizontal andvertical) and potential purposes for which the maps were brought out on the basis of such data.

| Spatial resolution | Mapping scale | Achievable horizontal accuracy | Contour interval | Purpose of the map |
|---|---|---|---|---|
| 5 – 7 cm | 1:500 | 12.5 cm | 30 cm | Engineering design-based mapping particularly for facilities management |
| 10 – 15 cm | 1:1,000 | 25 cm | 60 cm | Engineering design-based mapping particularly for facilities management |
| 25 – 30 cm | 1:2,500 | 60 cm | 1.5 m | Topographic mapping for planning and general use |
| 40 – 50 cm | 1:5,000 | 1.25 m | 2.5 m | Topographic mapping for planning and general use |
| 2 – 2.5 m | 1:10,000 | 5 m | 10 m | Topographic mapping for planning |
| 4 – 5 m | 1:25,000 | 8 m | 15 m | Topographic mapping for high level planning |
| 5 – 7 m | 1:50,000 | 15 m | 20 m | Topographic mapping for very high level planning |
| 10 m and above | - | - | - | Topographic mapping is not possible at these resolutions |

**Table 7.4: Image Resolution, Mapping Scales, Accuracies and Contour Interval**

In September, 2008 the Hon'ble Minister (S&T and ES) has informed DST and SOI to expedite the creation of data on 1:10,000 scale from suitable satellites (for priority areas) and to make use of the very narrow window in October 2008 for cloud free images. It may be mentioned here that a typical topographical sheet will have information which can be broadly identified under following heads:

- **Heights** shown in the form of contours, spot heights and some time by hill shading,
- **Surface features** like broad land use/land cover such as roads, rivers, water bodies, settlements, forests etc
- **Place names**, road names, river names etc
- **Ancillary information** such as projection, scale, year of survey, authority, reference box etc.

It was decided to use the latest remote sensing data for **surface features** (item 2) which is compatible with the mapping at 1;10,000 scale. The best Indian IRS remote sensing data now available is at 2.5m from Cartosat-1 which is not the best resolution at this scale.

Regarding the **place names** etc. (item 3), we have to depend on the recently completed field work at 1:50,000 scale. The additional place names can be compiled from different sources available in the different offices of the Survey of India. This will help us in creating **Version 1** data. **Version 2** data can be developed after conducting special field work for additional place names at a suitable time. Regarding **ancillary information** (item 4), the details are generally available in the SOI offices.

Regarding **heights** (item 1), we have following three options:

- Field work with traditional and modern equipments. This method will take several decades hence not proposed.
- Use of air photos and PT sections developed by 1: 40,000 and 1:50,000scale air photos for 1:25,000 scale mapping earlier. Here only about 60 per cent of the country is covered. The condition of the air photos/PT sections may not be appropriate to undertake mapping at 1:10,000 scale topographical mapping. The search for such items and then to scan it for Digital Elevation Model (DEM) generation will take a long time. In some places, fresh photography will become necessary considering the (a) scale of photography, (b) condition of photography, and (c) location of such materials.

  Further, with the PT sections which have to be scanned can only generate contour interval (CI) of 5m while 2.5m CI can be extrapolated. The general requirement is of 2m CI with extrapolation of 1m. Hence, there will be a limitation if we use PT section developed earlier for 1:25,000 scale topographical maps.

- The third option is of using remote sensing satellite data having stereo capabilities, *i.e.* which can generate height or CI at 2m/1m. The Indian satellite Cartosat 1 which has the stereo capability is not good enough to provide such CI. Hence we have to consider other options. Here we have following two options :

  (a) Worldview Stereo product by M/s Digital Globe having resolution of 0.5m.
  (b) Geoeye stereo products by M/sGeoeye again having a resolution of 0.5m.

Both the above satellites are US based and are willing to provide data as per the US regulation, *i.e.* at 0.5m resolution. Worldview stereo data is available while the former satellite has just then launched and the first product was to be made available from November 2008 onwards. Further, considering the Worldview data only available for this purpose, an experiment was conducted to find out the accuracy of such data by the SOI officers. The summary of the Root Mean Square Error (RMSE) for the Ground Control Points (GCPs) and Ground Heights (GHKs) is as follows:

Ground X (4 observations):0.4616519m

Ground Y (4 observations):0.4202892m

Ground Z (4 observations):0.4508022m

[

The above errors are within the limits for mapping at 1:10,000 scale with 2m/1m CI. Hence the data can be accepted.

Further, recently, the Department of Science & Technology has appointed a committee headed by the Secretary, Ministry of Earth Science for preparing a *Report of the Task Force: Procedures for Mapping on 1:10,000 scale*.

According to the report, it was observed that Cartosat-I and LISS IV merged images could be good source for generation of 10K thematic maps for the entire country. These datasets are available for more than 97 per cent of geographical area of India. It is expected that maps with limited topographical information on 1:10,000 scale can be generated with 3-4m planimetric and 3-4m vertical accuracies using this dataset. The project will be executed by Survey of India, Indian Space Research Organisation and partner institutes. The total cost of the project is estimated to be Rs 1,700 crore. A total number of 80,000 sheets covering an area of approximately 58 million sqkm each will be prepared. The cost per sheet is estimated to be approximately Rs 2 lakhs. The geospatial data thus generated could be further improved in due course of time with higher resolution of IRS satellites**.**

Further, there have been a lot of discussions about the possibility of using satellite remote sensing data for the purpose of mapping, particularly level of accuracies in X, Y and Z direction, and interpretation of features. The availability of RS data has been discussed earlier. After certain experiments, the above Task Force observed that

- 5 or 7metre interval contours can be generated from DTM of Cartosat – I in plain areas.
- 10 meter contours in hilly areas on 1: 10,000 scale can be generated from DTM of Cartosat – I
- 2 meter contours can be generated from DTM of Geo Eye andWorldview on 1: 10,000 scale
- Settlements in rural areas are seen very clearly and each house is mapable in Geo Eye and World View – I where as in Cartosat the settlements are seen as dots or points.

The technical details of the experiment are summarized in the following table:

| Sl. No. | Task | Cartosat | Geoeye | Worldview |
|---|---|---|---|---|
| 1. | Sensor details | Cartosat– I | Geoeye - I | |
| 2. | Data | | | |
| | 1) Data Quality | | | |
| | 2) No. of Scenes | 2 | 8 | 4 |
| | 3) Size of Scene | 27 X 27 km | 6 X 5 km | 20 X 15 km |

| | | | | |
|---|---|---|---|---|
| | 4) Importing Time | Easily imported into photogrammetric project as the number of images covering the project area are very few. | Takes more time for importing as there are more number of images covering the same study area. | Easily imported into photogrammetric project as the number of images covering the project area are very few. |
| | 5) Import | Importing is available in all versions | Staging is required in all versions | Importing in latest versions |
| | 6) Date of Pass | 28Feb 07 | | |
| | 7) Resolution | 2.5 m | 0.5 m | 0.6 m |
| | 8) Lateral Overlap (%) | 15 | 15 | 15 |
| | 9) Forward Overlap (%) | 100 | 100 | 100 |
| | 10) AFT and Fore | | | |
| 3. | Control Network | | | |
| | 1) No. of GCPs required 100 sq km | 1 GCP per 100 sq km (minimum 5 per scene) Most cost effective in terms of GCP collection | 16 GCPs per 100 sq km | 3 GCPs per 100 sq km |
| 4. | Photogrammetric process | | | |
| | 1) Block adjustment | | | |
| | (a) The points | 9 point pattern per scene 0.1 pixel | 9. points pattern per scene 0.2 pixel | 9 points pattern per scene |
| | (b) RMSE | | | |
| | 2) 2D feature Extraction(visual or automated or both, using standard interpretation keys and needs ground truthing) | Extraction of 2D features is difficult. | Extraction of 2D features is relatively comfortable. | Extraction of 2D features is relatively comfortable. |
| | (a) Built-up | Individual buildings not visible. Built-up area is captured as a single polygon. | Most of the buildings are clearly visible. Built-up area is captured as single buildings and group of buildings. | .Most of the buildings are clearly visible. Built-up area is captured as single buildings and group of buildings |
| | (b) Transportation | Only main roads and village roads are clear and they are captured. | All types of roads are clearly visible and they are captured. | All types of roads except foot paths are clearly visible and |

| | | | | |
|---|---|---|---|---|
| | | Cart tracks and foot paths are not clear and also not visible. So very less cart tracks and foot paths are captured. | | they are captured. Foot paths are not clearly visible. |
| | (c ) Water bodies | Major streams captured as single line. | Major streams captured on both edges and minor streams captured as single line. | Major streams captured on both edges and minor streams captured as single line. |
| | (d) Other land use | Captured as agricultural land, wasteland, plantation land and forest. | Captured as agricultural land, wasteland plantation land and forest | Captured as agricultural land, wasteland, plantation land and forest. |
| | (e) Topographical features | Spot heights | Spot heights | Spot heights |
| | (f) Utility features | Tree symbol. | Tree and poles symbol etc. | Tree and poles symbol etc. |
| | 3) DEM | 10m contour interval has been generated. | 2m contour interval has been generated. | 2m contour interval generated. |
| | 4) Contour Generation | Manually digitized for 10m | Manually digitized for 2m | Manually digitized for 2m |
| | 5) Ortho Image | 2.5 m GSD | 0.5 m GSD | 0.5 m GSD |

**Table 7.5: Comparison of Different Satellite Data**

**Task Force Observations:**

- From the accuracy achieved during the process so far indicates that the Data captured in 3 D mode from both the different set of satellites will satisfy the positional accuracy level required for 1: 5,000 scale.
- The accuracy of ortho photos evaluated against the limited ground points, mainly in the plain area, indicates that Data captured in 2 D environment will satisfy the positional accuracy level required for 1: 6,000 – 1: 8,000 scale

The height accuracy achieved indicates the accuracy level of 1 – 1.5 meters.

- IDEM can be generated using manual mass points and break lines (2 m contour interval from DTM of Geoeye and Worldview – I; and 10 m contour interval from DTM of Cartosat – I).
- Mass points need to be measured carefully at all strategic points and break lines need to delineated carefully.
- Level of identification is better than Cartosat – I data in the study area.

- But field verification is a must to pick up point features and attribute other features.
- The final conclusion can be drawn only after evaluating the aspects of identifying the features (Points and Linear) required for large scale, 3D perceptions, accuracy of contour generated and accuracy of ortho images for different types of terrain including hilly area.
- As the number of scene increases for both types of data, substantially for Geoeye in comparison to Cartosat image, considering the cost effectiveness and complexity of data handling, these data can only be used for smaller area for specific purpose. For area having large coverage or say for national level, Cartosat data should be preferred if the achievable accuracy serves the purpose.

Exercise in productive environment accompanied with ground verification and supplementation in different types of retrain should be carried out to find out the achievable accuracies, limitation in data capturing, cost and time factor. The recommendations of the Task Force are as follows:

- Task Force recommends that the Cartosat – I stereo satellite data will be sufficient to generate thematic maps with limited topographic information on 1:10,000 scale, in view of achievable planimetric accuracy of the order of 3–5 m and contours of 10 m interval can be derived. Elevation data already available with Survey of India for 60% of area in the form of maps on 1: 25,000 scale with contour interval of 5/10 m can be integrated with the data derived from satellite images.
- The content of the map should include contours, built up area, hydrography, communications, land cover, administrative boundaries, annotation, utilities and infrastructure details which are identifiable through Cartosat data with limited field observations and existing topographical mapping data.
- Indian dataset to be utilized for project as ensures complete coverage across the country for recent years. Cartosat – I and LISS IV orthorectified fused image will be sufficient enough to generate thematic maps with limited topographic information.
- The pilot studies established the standards and procedures for generation of thematic layers and also overlaying of cadastral information, linking of Record of Rights and other respective stakeholder's attribute data to generate thematic geospatial information at the resolution of 1:10,000 required for various developmental programmes including grass root level support & planning, infrastructure, disaster management programmes and environmental studies.
- It is recommended that dual frequency GPS base station and rovers should be used for collection of horizontal and vertical Ground Control Points (GCP) in the field. GTS bench marks with $4^{th}$ decimal meter can be provided by SOI for calculation of ortho heights above Mean Sea Level (MSL). All control points to befitted in WGS84 system

and are to be post pointed on satellite imagery

- Where maps on scale 1:25, 000 are not available, DEM's can easily be generated from the stereo images on digital photogrammetric work stations provided the height control points (BMs) are established, post-pointed and georeferenced. It is suggested that 5 m contour will be interpolated for plain areas from 10m DEM and also suggested that 10m contour interval will be for hilly / forest areas to be depicted on map (10m contour and 5m interpolated with different symbology).
- It is recommended that all the thematic layers be generated up to level III of NRDMS data models provided in Appendix IV and NRSC created topographic data models provided in Appendix IV.
- AQC system based on NSD / OGC / ISO standards and sampling methods will be used in the process of creating topographical database. The approved confidence level in these cases for QC shall be 95%.

# TECHNOLOGY FOR1:2000 AND LESSER (1:500, 1:300 & 1:200) SCALE MAPPING

# 8 ALS Methodology and Map Preparation on Scale1:2000 Images for Generating Critical Facilities Maps (CFM)

## 8.1 Airborne Laser Scanning (ALS)

Since the year 1994, a new airborne terrain modeling technology is available to the surveying industry. The term "Airborne Laser Scanner" (ALS), evolved as the hardware utilized in the aircraft, is a logical advancement of the Airborne Laser Profilers used primarily by the forestry industry for many years.

Other titles attributed to the same piece of hardware include "LIDAR" (the term favoured in the United States), and "Airborne Laser Terrain Mapper (ALTM)", the brand name used by the major hardware manufacturer in this field. The three fundamental components of an ALS system are shown in Fig 8.1.

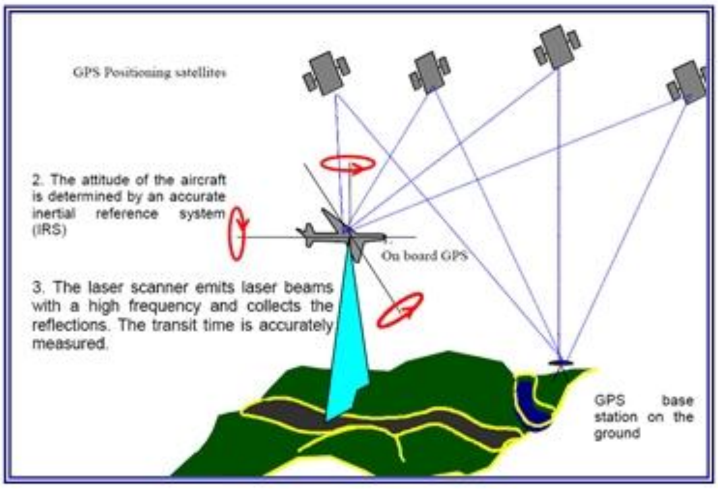



**FIGURE 8.1: THREE COMPONENTS OF ALS SYSTEM**

The main features of ALS are the following:

1. Aircraft position is determined by kinematic dual frequency GPS, typically at 1 second epochs
2. Aircraft orientation or attitude is continually monitored by a sensitive Inertial Reference System (IRS), typically at 50 times per second
3. Terrain measurement device emits a number of discrete laser beams (typically 5000 to 25000 per second), measuring the time taken for the beam to reflect from the ground back to the aircraft.
4. The laser beam is directed in a swath across the ground by a rotating mirror.
5. Post-processing software combines the scanner's position, its attitude and the distances measured to compile a digital elevation model.
6. The operational parameters of laser frequency, swathe width, flying height and aircraft velocity can be tailored to meet the optimum point density for each project.
7. Typically this can range from an average point spacing of 10 meters down to 1 meter or less, covering a swathe width of up to 700 meters.

8. The scanner emits a laser of 1.04 micron wavelength which is not in the visible spectrum and is eye-safe.

9. The scanner automatically shuts down if the system receives a return signal corresponding to a range of less than 300 meters.

At a typical operating altitude, the emitted beam is approximately 300mm in diameter at the end of the swathe. If operating over vegetation, some of the return signal is reflected from the top of the canopy, some penetrates to the canopy substrata and some penetrates to the ground. Various scanners are configured to record the distance from the first reflection it receives back ("first pulse"), from the last reflection it receives ("last pulse") or some can record multiple returns from the one emitted pulse.

An integral part of the ALS solution involves software that applies morphological filters to separate objects from "ground" and "non-ground". The software requires the operator to define the classification characteristics such as terrain angle, search distance and expected deviation. It uses a recursive algorithm based on changes in slope of the terrain to determine which laser strikes meet those criteria and should be called "ground" and which do not ("non-ground"). Further processing can categories "non-ground" points into more specific datasets. These could include "pylons", "conductors" and "vegetation" for power line surveys; or "crowns" and "tallest trees in a cell" for forestry modeling.

## 8.2 Comparison between Airborne Laser Scanning and Aerial Photogrammetry

| Features | Airborne Laser Scanning | | Aerial Photogrammetry | |
|---|---|---|---|---|
| Accuracy precision | ♦ | 0.15m to 0.20m RMS | ♦ | Relative to photo scale, 0.08mto 20m |
| Resolution | ♦ | Typical point spacing 3m | ♦ | Resolution defined by project requirements |
| Ground support | ♦ | Requires base station within 50 km ground-truth points provide survey redundancy | ♦ | ground control required may be supplemented with Sky control |
| Data acquisition | ♦ | Can be done under cloud and at night | ♦ | Must be done during the day, preferably without cloud shadow |
| Timing | ♦ | Sizeable datasets available within a week or two | ♦ | Sizeable datasets available within a month or two |
| Data format /Classification | ♦ | Random spot heights semi-automatic classification | ♦ | Vector line strings manual classification |
| Penetration | ♦ | Data points measured under trees | ♦ | Operator interprets the ground under trees |
| Imagery | ♦ | Separate sensor required | ♦ | Byproduct |
| Cost | ♦ | High startup cost | ♦ | Proportional to area |

TABLE 8.1: COMPARISON OF ALS AND AERIAL PHOTOGRAPHY

## 8.3 Technical Details of Airborne Laser Scanning

### 8.3.1 Accuracy/Precision

The inherent accuracy of a single ALS spot height is in the order of 0.15m to 0.20m rms. This assumes that the GPS base station is within 50km of the operating aircraft, that a successful kinematic GPS adjustment was possible and that the equipment is in correct calibration. For more details, please refer to appendices.

The accuracy of the terrain model formed from an ALS dataset is therefore a function of the point spacing of points classified as "ground", and the regularity of the terrain. If a project does not require this level of accuracy, there is relatively little, one can do to reduce the cost of the survey.

This is in stark contrast to photogrammetry where accuracy is a function of ground control accuracy and photoscale. It is important to realize that, in most cases, photogrammetric accuracy refers to points acquired "on clear ground". The accuracy of photogrammetric data acquired on unclear ground (i.e., heavily vegetated areas) is generally unknown.

### 8.3.2 Resolution

Like accuracy, there is much less flexibility in defining the resolution of an ALS survey than for a photogrammetric survey. One can fly higher and faster to decrease the point density of ALS, but only within the narrow bounds of hardware capabilities.

The resolution of a photogrammetric dataset is much easier to control and is usually an important component of a project's specification. The ability to depict changes of grade, spot height intervals and other topographic features, all within pre-defined parameters, are advantages of the photogrammetric environment.

### 8.3.3 Ground Support

ALS requires only a single GPS base station logging at 1 second epochs within 50km of the operating aircraft. That is what it requires, but conventional surveying principles dictate that a certain level of redundancy be introduced. Typically this involves a field survey team coordinating 100 ground-truth points in a clear flat area within the project. These points are used to check for gross errors in the ALS survey and to determine the achieved accuracy of the ALS survey.

The ground-truth points also allow the ALS data to be re-datum(ed) onto the site's height datum. As it is GPS based, the ALS survey is acquired and computed in WGS84 ellipsoidal heights. The 100 ground-truth points can all be contained within a single area anywhere within the ALS data coverage. Conversely, ground control for photogrammetry is usually required in pre-determined positions, spread right across the site, and often extending beyond the mine site's area of control.

In recent years, the number of ground control points required in broad-acre projects has significantly decreased, by recording the positions of photo centers at the time of exposure and incorporating these into the photogrammetric block. Field test points are always recommended to validate the photogrammetric dataset.

### 8.3.4 Data Acquisition

Although the laser will not penetrate clouds or operate in rain, the ALS system can be used under clouds and at night. Operationally, this allows the ALS data acquisition to proceed with fewer interruptions than aerial photography. Operating at night offers a degree of flexibility for time specific site requirements such as tidal flows, blasting/dust hazards, and prevailing cloud conditions. Aerial photogrammetry requires daylight hours with sun angles high enough to prevent shadows obscuring salient features.

### 8.3.5 Timing

Data delivery of large terrain models acquired by ALS can be far quicker than comparable datasets defined by aerial photogrammetry. However, as the size of the dataset decreases, so too does the timing advantage offered by ALS. Aerial photogrammetry is regularly used to define stockpile volumes where volume reports are sent to site 2days after acquisition. The ALS data reduction and volume computations could be done in the field, but with significant cost implications.

### 8.3.6 Data Format/Classification

Perhaps the most significant difference between ALS and aerial photogrammetry is in the deliverable product. ALS is an automated process where literally millions of spot heights are thrown across the project area to define the terrain shape. These spot heights can be subsequently thinned to remove those points that do not contribute to the terrain definition, but the raw product is a collection of random spot heights.

Contrasting this is the traditional photogrammetric product where a trained operator manually digitizes and codes the data at the time of acquisition. The operator joins like points to form vector strings such as high-wall crest, drain or embankment. These vectors feed easily into mine planning or CAD software packages.

### 8.3.7 Penetration

As previously stated, ALS has an advantage over aerial photogrammetry in areas covered by vegetation. For the photogrammetrist to measure under trees, the piece of ground must be visible on two adjoining aerial photos and not be covered by shadow.

The rule of thumb for ALS is that, if you can walk through the forest and see daylight above that is the proportion of points which will penetrate through the canopy and strike the ground. In the mining industry, this feature of ALS would be most relevant in the exploration phases where terrain models are required underneath vegetation.

### 8.3.8 Imagery

There is no imagery produced from the laser system itself, but many ALS aircraft incorporate a separate imaging system to complement the laser terrain model. Sensors in regular use include videos, digital cameras and conventional metric survey cameras.

## 8.4 Cost of Imaging through ALS

When compared to field surveying, aerial photogrammetry has always carried the stigma of carrying a high startup cost where the first terrain point measured can be quite expensive, but subsequent points become more affordable. Factors that affect costing in ALS surveys is given in Table 8.2.

| | |
|---|---|
| • Site location | Affects ferry times. |
| • Project timing | Can the survey be timed to coincide with other work in the area. |
| • Project shape | Long rectangular areas are more efficient to capture than narrow windy ones where the aircraft spends more time lining up than actually over the site |
| • Required point density | Higher point densities demand narrower swathes and slower Aircraft |
| • Post-processing required | Open area where most laser strikes could be classified as "ground" would be cheaper than a heavily vegetated exploration lease where the client requires the laser strikes divided into ground, canopy top and non-ground |
| • Accuracy required | More demanding accuracies (generally below 0.20m rms) require closer attention be paid to the overall error budget. Issues of GPS adjustment, geoid modeling, point densities, etc. become more critical. |

TABLE 8.2: FACTORS EFFECTING COST OF ALS

Because much of the cost of an ALS survey is in positioning the aerial survey unit, increases in the size of the survey area do not affect cost. This is particularly true if the project area is enlarged simply by increasing the length of the survey lines. This is in contrast to photogrammetric data acquisition where the cost of the survey is much more proportional to the extent of the project area.

# 9 LIDAR Based Aerial Photogrammetry for Preparation of 1:2000 images for Generating Critical Facilities Maps (CFM)

Aerial photography or aerial photogrammetry is divided into two major categories, precision and general.

- Precision photography, 152 mm focal length, (230 mm X 230 mm format) is used for mapping and other applications requiring measurements on photogrammetric plotters.
- General aerial photography is used for highway inventory and other non-metric uses where precise measurements are not required

Direct georeferencing (DG) system, for aerial photography, provides the ability to directly relate the data collected by a remote sensing device to the Earth, by accurately measuring the geographic position and orientation of the device without the use of traditional ground-based measurements.

Precision photography can also be used for general purposes (enlargements, etc.). Black and white, color, and black and white and color infrared film may be specified. Focal lengths of 152 mm, 210 mm, and 305 mm, all 230 mm X 230 mm format, are available. Additionally, 610 mm focal length, 230 mm X 460 mm format cameras are available.

Photography may be flown at altitudes ranging from 1,000 to 20,000 feet. Photo scales from approximately 1:600 to 1:36 000 are available. Enlargements of new and existing photography up to 10 times and larger, in some cases, are available. Enlargements (or reductions) can be printed on several types of material depending on the proposed use of the photography. Aerial photography is one of the least expensive components in the photogrammetric mapping process and can be obtained in a short time.

All horizontal and vertical ground control will be provided by ITRF. These elevations refer to the datum set by the Geodetic Survey of India for mean sea level, will be in metric.

## 9.1 Photography for Planning Purposes (Over Flights)

Small scale photography, 1:9600 and smaller, is useful to aid survey parties in planning and locating photo control pre-marked positions. This is especially true in areas where the existing maps are out-of-date or in rural and mountainous areas where it is difficult to locate specific positions on existing quad maps. Aerial photography is relatively inexpensive compared to the time surveyors may spend to locate points on inadequate maps.

## 9.2 Color and Infrared Photography

Black and white photography is better than color and color infrared (IR) for metric (mapping) photogrammetry. Color photography is superior for photo interpretation in some applications, e.g., environmental purposes, accident investigation, public displays, and geological purposes. Infrared photography, both color and black and white, is best suited for land use studies and locating water features or diseased vegetation.

## 9.3 Special Aerial Photography (Accident Studies, Flood and Earthquake Damage)

Special photography can be done if there is a natural or man-made disaster. For example, one day after the 1989 Lomo Prieta earthquake, the U.S. Air Force photographed the entire area affected by the earthquake. A panoramic camera mounted in a aircraft, flying at an altitude of 65,000 feet was used for the photography. With the latest technology, it is now possible to take high resolution digital photographs of disaster affected areas, with low flying aircrafts / helicopters. The timeframe of processing is low enough to make it near real time for generation of disaster maps of immediate integration in disaster plan. For more details, please refer to appendices.

## 9.4 Highway Inventory Photography

Highway Inventory Photography is generally done in 1:2400, 230 mm X 460 mm format, non-stereo, non-metric, aerial photography of the State Highway System. The entire system should be photographed every five years. Approximately one-fifth of the highway system may be photographed each year with emphasis on newly completed projects. Special flights of 230 mm X 460 mm format photography may be done at any time. This photography is for pictorial coverage only; maps cannot be compiled using this photography.

Highway Inventory Photography is widely used for a variety of tasks including traffic and accident studies, highway improvement planning, public meeting displays, survey and mapping control planning, and mapping ground cover information. This photography can be enlarged up to 10 times with usable photographic resolution.

## 9.5 Mosaicing of Images

Mosaics are made from multiple individual aerial photographs that are fitted together systematically to give the appearance of one photograph. Mosaics are useful where it is required to have photographic detail available over a large area. A skilled mosaic maker can cut and match the photographs in such a manner that the joins are difficult to detect by the untrained eye.

However, it is virtually impossible to assemble a mosaic where all the joined images match perfectly due to a variety of geometric and photographic conditions that cannot be controlled.

## 9.6 Aero Triangulation

Aero Triangulation is the process of expanding a skeletal network of project field control to provide the dense control network required to reference each individual photogrammetric stereo model to the project datum.

- Aerial triangulation will be used to provide horizontal and vertical control to each stereo model.
- Bridging will be done with the use of plugged tiles and analytical or independent aerial triangulation method must be used to produce bridging data.
- Any necessary aerial triangulation will be accomplished by the use of a first-order instrument having performance characteristics of stereo plotting instrument.
- Pass points will be selected with a point transfer device having performance characteristics of high quality point transfer device.
- Dia-positives (positive prints on film or glass plates) are pugged (small holes drilled into the photographic emulsion) to provide a visually identifiable point that can be measured in the stereo model.
- Each premark and pug point is precisely measured using the stereo plotter coordinate system.
- The measured points are transformed to a coordinate system based on the camera fiducial (index) points with the center of the photograph as the XY coordinate origin.
- The point positions are also corrected for lens and film distortion, earth curvature, and atmospheric refraction.

| Method for compilation of map | |
|---|---|
| 1 | Initial approximations of the XY ground coordinates and the flying heights of the first and last photo in each flight line are provided as input into the aero-triangulation program. |
| 2 | The program uses these values to calculate the XYZ coordinates and the direction of flight for each photo in the flight line. The rotations about the X and Y axes are assumed to be zero. |
| 3 | Then, based on the fact that the center of the lens, a photo point, and a corresponding ground point lie on a straight line and using the measured pugs and premarks, the photos are moved and rotated in space until all the lines are straight. This, of course, is all done by computer using an iterative process until preset accuracy requirements are achieved. |
| 4 | The results of these calculations are the space coordinates and the rotations about XYZ axes of all the photos and the XYZ ground coordinates of all Pre mark and Pug points. |

TABLE 9.1: METHOD OF MAP COMPILATION

These values provide the information necessary to control the individual models and compile the maps, measure photogrammetric data such as digital terrain model points, and read cross-sections.

## 9.7 Topographic Mapping

Topographic mapping from aerial photography is the most requested photogrammetric product (except photographic reproductions). The most common mapping scales are 1:**2000, 1:500 and 1:200 with 0.5 m and 0.25 m contour intervals**, respectively.

The same photography can be used to produce direct digital mapping, digital terrain models, terrain line interpolation, and photogrammetric cross-sections. The maps and other products are made using computer-driven (analytical) plotters. The photography to produce the above products is flown between 1,000 and 2,400 feet above the ground for 1:500 mapping and 1,000 to 1,500 feet above the ground for 1:200 mapping.

The nominal planning mapping width for a single flight line, with a 152 mm focal length camera, is the same as the flying height above the ground or between 305 m (1,000 feet) and 730 m (2,400 feet) for the above examples. The planning mapping widths allow for a lateral flying tolerance of 13 mm at photo scale on either side of the flight line. After the photography is taken, generally, it can be used to map within 25 mm of the edge of the photographs (the central 180 mm). This provides mapping widths of 355 m and 850 m, respectively, for flying altitudes of 1,000 and 2,400 feet.

## 9.8 Digital Map Types

Some of the currently available digital maps technology is for creating:

- 2-D hand digitized (flat digital maps)
- 2-D direct digital (flat digital maps)
- 3-D direct digital (contours and spot elevations only)
- 3-D direct digital (contours, spot elevations, roadway, water, retaining walls, and other features)
- 3-D direct digital (contours, spot elevations, roadway, water, retaining walls, break lines, and other features)

## 9.9 Digital Terrain Models

Digital terrain models (DTMs) are mathematical representations of the ground. The data is gathered photo grammetrically by collecting the ground break data on regular interval “scan lines”, similar to field cross-sections, plus collecting the “break or critical line” data (drains, ridges, retaining walls, etc.). Digitized contours can also be used for DTM input but must include break lines for a more accurate representation of the ground. Small DTMs can be created in the field using the Total Station Survey

System. The surface representing the ground is created by triangles formed from the DTM points that have X, Y, and Z coordinates. These files are called triangulated irregular network (TIN) files

Contours or cross sections are then formed by linear interpolation of the lines connecting the apexes of the triangles. Once the DTM is created, accurate contours can be plotted for any area. In addition, cross-sections can be computed for any alignment within the DTM limits.

## 9.10 3-D Direct Digital Mapping

Direct digital maps can be compiled in 3-D directly from the aerial photography into a CAD file. Traditionally, maps were compiled on a manuscript, then inked or scribed in final form, and then digitized. This process requires “drawing” the maps three times with the consequent possibility of errors.

Using direct digital mapping, the map is compiled directly into the CADD file by the photogrammetric plotter operator, edited on a workstation, and plotted as a final product. This method eliminates the drafting and digitizing steps and reduces the possibility of error. The deliverables are mylar final plots and the CADD file on tape.

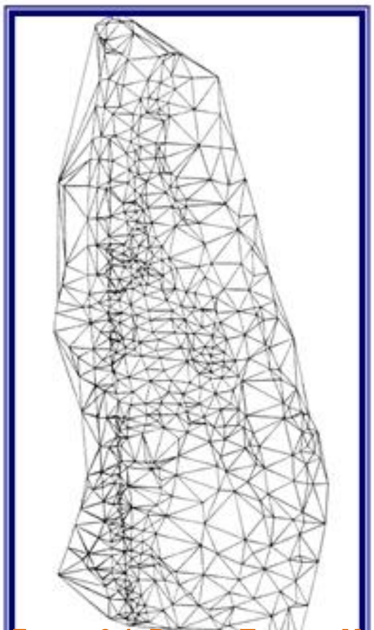


FIGURE 9.1: DIGITAL TERRAIN MODELS

The 3-D features include contours, spot elevations, roadway delineation, waterways, retaining walls, and terrain break lines. These features are used as input to the digital terrain modeling system that will produce cross-sections on any alignment or contour maps at any interval

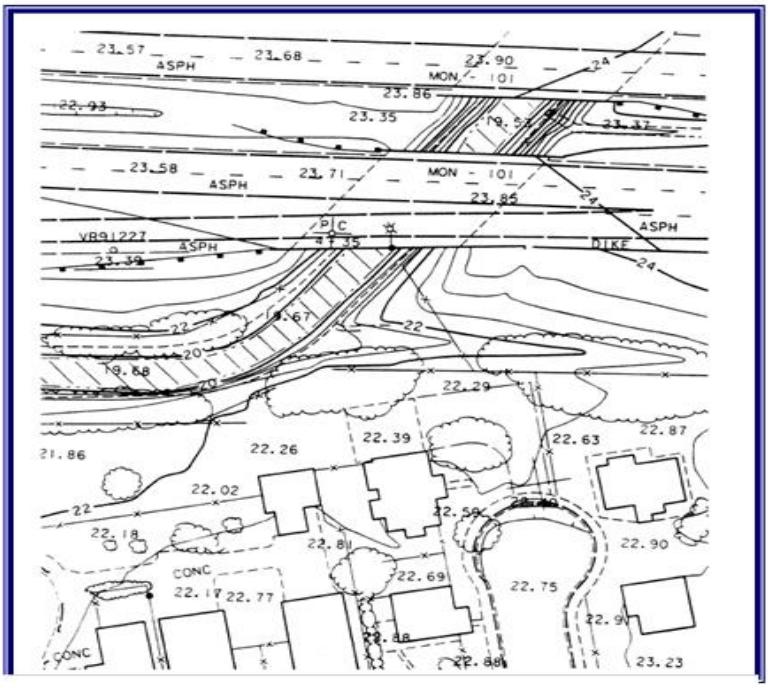



FIGURE 9.2: 1:500 MAPPING (SAMPLE. REDUCED TO 80%)

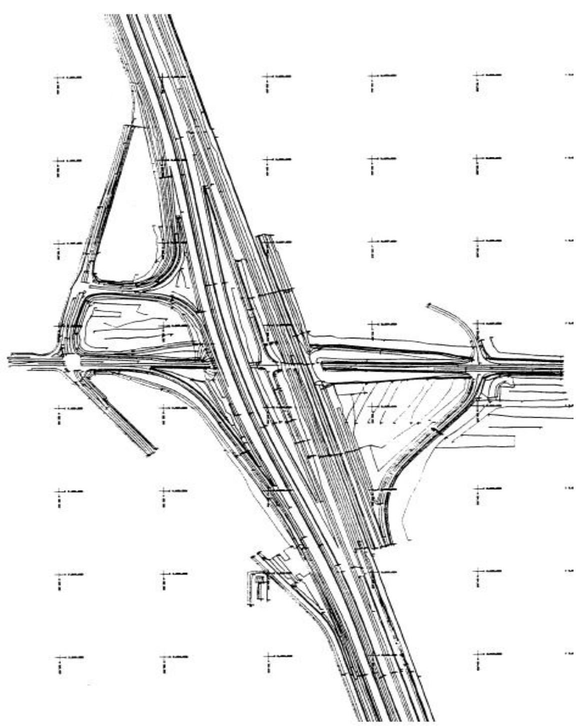
## 9.11 Structure Site Maps

Structure site maps such as bridges are compiled at a scale of 1:2000 to 1:200with 0.25 m contour intervals. The structure sitemaps are separate map sheets from the 1:500design maps, but are usually compiled from the same photography. The structure sites are compiled simultaneously and the extra contours and spot elevations are eliminated in the copied, 1:500, map files. In order to have the structure sites exactly match the 1:500 mapping, both scales must be compiled in combination. If the structure sites are done separately, after the1:500 mapping, they will not match exactly. Whenever structure sites are needed, it is recommended that they be ordered with the1:500 mapping even if the exact locations are not known.

## 9.12 Photogrammetric Terrain Line Interpolation

Terrain line interpolation is a method of gathering terrain data for cross-sections that allows for the generation of new, normal cross-sections for any alignment change. “Critical lines”, i.e., break lines are measured photogrammetrically throughout the mapping limits.

A centerline and cross-section lines are mathematically superimposed over the break lines. Cross-section “shots” are computed by linear interpolation along the break lines at the points where they intersect cross-section lines. Cross-section shots are recorded only where the cross-sections intersect the break lines. Where the break lines are perpendicular to the centerline, it is possible for the cross-section normal to miss the break lines and no cross-section shots will be available. In these areas, special lines are created approximately parallel to the centerline by interpolation between the break lines. Thus, shots will occur when the cross-sections intersect the interpolated lines.



**9.3: PHOTOGRAMMETRIC TERRAIN LINE INTERPOLATION**

The TLI method will create valid cross-sections for any alignment within the mapping limits. This method is a simplified digital terrain model.

The same procedure is used in the field to get pavement break lines using a total station. These lines can be combined with the photogrammetric lines to create cross-sections with field-surveyed pavement accuracy. The TLI files that are created photo grammetrically are normally prepared for cross-section processing.

## 9.13 Technology Update for Aerial Photography

### 9.13.1 GNSS-Aided Inertial Navigation for Aerial Photography

GNSS-Aided Inertial Navigation for Direct Georeferencing of aerial imagery and other sensors such as LIDAR is a well accepted technology that has been in use since the mid 1990's. Position accuracies of 10 cm RMS horizontal and 15 cm RMS vertical are routinely achieved using post-processed Kinematic Ambiguity Resolution (KAR) differential GNSS processing along with specific operational restrictions that are necessary due to the nature of the airborne environment. For more details, please refer to Appendices.

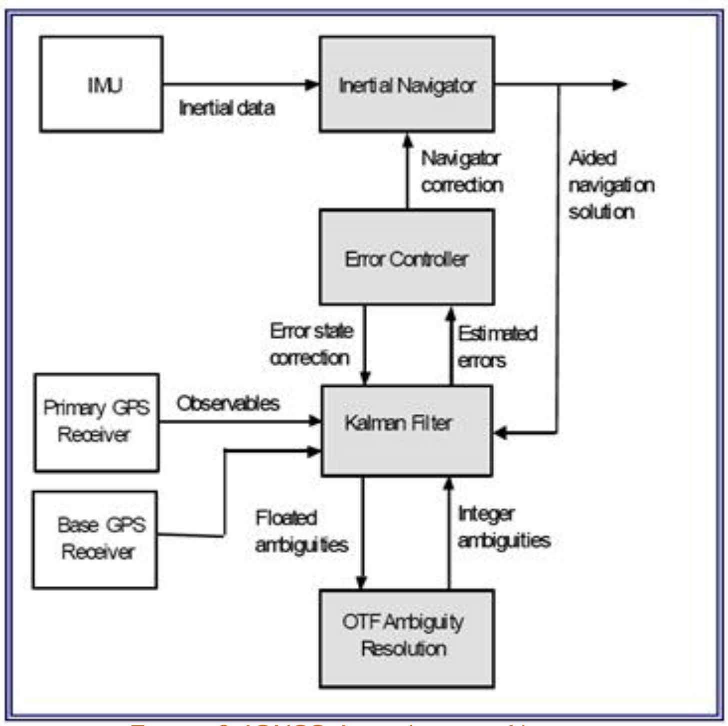



FIGURE 9.4GNSS-AIDED INERTIAL NAVIGATION

These include:

- Flying turns of less than 20deg bank angle, Flying less than 30 km from a reference GNSS receiver in order to correctly fix integer ambiguities, and
- Keeping the maximum baseline separation to less than 75 km once the ambiguities are fixed.

Each of these restrictions significantly reduces the efficiency of airborne mapping, and hence increases the overall cost.

High accuracy carrier phase differential GNSS processing involves searching for the correct number of integer cycles of the L1 carrier signal between the rover antenna and each satellite.

Since the correct number of integer cycles is originally unknown, they are referred to as the cycle ambiguities. Estimation of the ambiguities requires a continual lock on the signal to each satellite in order for the solution to remain converged. If the aircraft turns with a bank angle greater than 15 to 20 deg, the wing can block the view of the satellites from the GNSS antenna, causing the solution to reset and begin another search.

Flat turns increase the time required to fly the survey, and are problematic in restricted flight zones where there may not be enough room to safely maneuver. They also increase the stress level on the crew, which leads to fatigue and potential operational errors.

In order to overcome these limitations, new technology is now available that provides the ability to fly turns with greater than 20 deg bank angle, and fly at distances up to 70 km from the nearest GNSS reference station, without sacrificing accuracy or reliability.

These problems are solved via technology, which implements an Inertially-Aided Kinematic Ambiguity Resolution (IAKAR) algorithm to compute the GNSS ambiguities. In this approach the inertial data and raw GNSS observables (phase and range measurements) are processed in a single tightly integrated Kalman filter, which allows the inertial data to be used to solve for the integer ambiguities. With IAKAR, if there is a cycle slip or outage in the GNSS data, the inertial data keeps a “memory” of the ambiguity, allowing the correct integer ambiguity to be quickly reestablished immediately after the outage. For airborne applications this means there is no longer any need to fly flat turns to avoid signal outage. Flying a turn at 15 deg bank angle at a typical survey speed of 150 knots, gives a turn rate of about 2 degs/sec and a turn radius of about 2.3 km. The time to complete a 180 deg turn will take minimum of about 1.5 minutes.

In contrast, if the aircraft bank angle is not restricted, the same turn can be made in approximately half the time and radius, simply by banking at 30 degs instead of 15 degs. This savings means the mission can be flown in less time (reducing fuel costs), or more lines can be flown per mission. Furthermore, the smaller radius of the turns also allows more flexibility for flying missions in restricted airspace.

At distances greater than 20 to 30 km from a reference station, the residual ppm error caused by the atmosphere delaying the GNSS signals reaches a magnitude such that the correct carrier ambiguities can no longer reliably be estimated. Hence with traditional KAR differential GNSS processing, it is always necessary to be within 30 km of a reference station sometime during the mission in order to resolve the ambiguities.

Once the correct ambiguities are resolved, the aircraft can fly up to about 75 km from the nearest reference station before the magnitude of the ppm error exceeds level required for high-accuracy applications.

# 10 Mapping Quality Control in Aerial Mapping for Preparing of 1:2000 Images for Generating Critical Facilities Maps (CFM)

## 10.1 Map Checking

All photogrammetric maps need checks of representative samples of each map for accuracy and completeness by using photogrammetric plotters. Visual checks are needed for missing contours, wrong symbology, incorrect fonts and font sizes, and other cartographic errors. It is also needed to be visually ensured that all planimetric features have been compiled on the maps by using a stereoscope and the aerial photographs. Map checking is a critical task to ensure accuracy in the production of photogrammetric mapping.

## 10.2 Map Accuracy

Recommended photogrammetric map accuracy standards are as follows:

- The position of all coordinate grid ticks and all monuments shall not vary more than 0.3 mm from their coordinated position.
- At least 90 percent of all well-defined planimetric features shall be within 0.6 mm of true ground position, and all shall be within 1.3 mm of true ground position.
- At least 90 percent of all contours shall be within one-half of the contour interval of true elevation, and all contours will be within one contour interval of true elevation, except as follows:
- In densely wooded areas where the ground is obscured by dense bush or tree cover, contours shall be plotted as accurately as possible while making maximum use of spot elevations obtained from the stereoscopic model in places where the ground is visible. In those areas where spot elevations can be obtained photo grammetrically, at least 90 percent of all contours shall be within one contour interval or one-half of the average height of the ground cover, whichever is greater, of true elevation. Contours in such areas will be shown with dashed lines.
- Orchard, vineyards, and other areas devoted to crops will be considered as open areas and are therefore not subject to larger tolerances in vertical accuracy.
- In areas not obscured by grass, weeds, or brush, at least 90 percent of all spot elevations will be within 0.25 contour interval of true elevation, and all shall be within 0.50 contour interval of true elevation.
- In addition to the accuracy specified above for contours and spot elevations, the following shall apply:
- The arithmetic mean of contours and spot elevations in open areas shall not exceed plus or minus the following values for the points tested on each map sheet.

| Number of Points Tested | Maximum Arithmetic Mean |
|---|---|
| 20 | +/-0.24 Contour Interval |
| 40 | +/-0.18 Contour Interval |
| 60 or more | +/-0.12 Contour Interval |

- Any contour that can be brought within the specified vertical tolerance by shifting its position by 0.6 mm will be accepted as correctly compiled.

## 10.3 Methodology for Map Generation

### 10.3.1 Data Package

The map file will be divided into rectangular sheets and the individual files will have an added standard surround and coordinate grid with identifying text. Each sheet must be a standard size of 2000m from east to west and 1000m from north to south for hard copy production at a scale of 1:2000. The coordinate grid may be constructed of lines depending on the coordinate system to a resolution of 100m

- All digital mapping must be based on the coordinate system used in the aerial triangulation and numeric adjustments.
- The map must be loaded into a three with an international coordinate system set.
- All digital compilation must be done using an order stereo-plotter workstation.
- All features mapped from aerial photography into digital format must be encoded with a feature code number and graphic group numbers that will be listed in the feature code table.
- In addition, each entity must have a symbology of level, color, style, and weight that will be listed in the feature code table.
- The grid line must end at the neat line and must be annotated with a coordinate value located at the end of the grid line and between the neat line and the border.
- All graphic elements of the surround and grid must be symbolized and feature coded as noted in feature code table.
- Each sheet must be self-contained within its own digital file.
- Each digital file must be named and referred to by its six-digit identification number as determined by the coordinate position of the lower-left corner of the sheet.
- The first three digits will be the first three numbers of the easting and the last three digits will be the second, third and fourth numbers of the northing. For example, the sheet with its lower left corner at coordinate 368000.000, 5021000.000 will be denoted 368021.dgn.

Each map sheet within a project area must include all planimetric and hypsographic data, including adjoining sheet hypsographic data, in one digital file. Three dimensional line string, points, cells and text as specified in the feature code table must be used in the creation of the planimetric map and hypsographic mode.

| The data package will contain | | |
|---|---|---|
| 1 | Feature Capture | All Linear features must be digitized, where possible, in a clockwise manner or with the feature on the right hand side of the linestring. |
| 2 | Topological Structuring | All line work comprising of an area feature must be mathematically close by similar coordinate values and linear features adjoining or connecting to other features must mathematically join by similar coordinate values. |
| 3 | Use of Annotation | Annotation must be included wherever graphic features do not adequately describe the mapping content. In addition, annotation may be used to name roadways, bodies of water, bridges and other cultural points of interest where applicable. |

| | | |
|---|---|---|
| 4 | Co-incident Features | Co-incidental linear feature edges whether sharing a common elevation or not must be captured in their entirety and must be totally self-contained. |
| 5 | Use of Planimetric Features in Hypsographic model | The linear or point features must be used to generate both hard copy positional data and hypsographic modeling data. |
| 6 | Use of Virtual Hypsographic Segments | Where planimetric information does not adequately describe the hypsographic nature of the terrain, virtual hypsographic data must be included for use in the hypsographic model. Line string can be used to depict linear break information across terrain and points can be used to depict high and low points in the terrain. Additional points must be included in a grid pattern anywhere within the mapping area where there is an absence of hypsographic data for a radius greater than 10m. |
| 7 | Depiction of Vertical Surfaces | True vertical surface cannot be modeled within the terrain model and therefore vertical surfaces such as retaining walls must be captured with a lower edges offset by a distance of 1 mm to 1 cm in the direction down slope from the top edge. |
| 8 | Depiction of Obscured Surfaces | Obscured surfaces, such as terrain beneath bridges and terrain near the buildings, must be approximated by virtual hypsographic segments placed underneath the obscuring surface. These must be approximated by using terrain information, as close to the area as possible, by assuming no terrain undulation beneath the obstructing surface. |
| 9 | Additional Hypsographic Model Area | To ensure model consistency at or near the mapping limits, a buffer 20m wide outside the mapping area must include all available hypsographic modeling data feature coded as "map edge hypsographic data". A 20m strip of hypsographic mapping detail from adjoining sheets on the outer edge of the map neat line must be included. These mapping features, regardless of feature type must be coded as "adjoining sheet hypsographic data". |
| 10 | Testing the Hypsographic Model | Generating contour lines at 0.5m intervals must be done for fully testing of the hypsographic model. |

**TABLE 10.1: DETAILS OF DATA PACKAGE**

# 11 Land-Based Vehicle Mounted Precision Mapping System for Preparing of 1:2000 & Lesser Scale Images for Generating Critical Facilities Maps(CFM)

## 11.1 Airborne Mapping

Airborne mapping techniques do not lend themselves well to mapping roads in dense urban canyons and tree canopy areas. Detailed and accurate road mapping information, especially that required for GIS databases, can often only be obtained by land-based methods. However, GPS satellite shading and multipath reception can also complicate accurate and reliable land-based GPS positioning in these types of areas.

In Land based vehicle mounted mapping system, the spatial data capture from a moving vehicle using direct georeferencing requires accurate position (of the vehicle relative to the object of interest) and orientation (to determine where the sensor is positioned relative to the vehicle and object of interest). Unlike the bird's eye perspective of aerial mapping, it can enumerate roadside assets, roads and laneways, buildings and other attributes of interest, require repeatable dynamic data capture from the ground level for proper identification. With a more suitable resolution and with a high degree of measurable accuracy, a Geographic Information System becomes complete and accurate enough for practical civil applications

FIGURE 11.2: MOUNTED MAPPING SYSTEM

Mapping right-of-way assets, pavement conditions, signage use, temporal changes, safety barrier status, building frontages, line-of-sight, vandalism, and other urban geographic interests requires the most advanced and dependable ground level data collection solution available and to be practical enough to keep up with demand, it must be mobile.

## 11.2 Technology Update for Vehicle Mounted Precision Mapping System

Now an updated vehicle mounted precision mapping system is available with aided inertial navigation system designed for precise position and orientation measurements for survey and vehicle control applications. Utilizing IARTK (Inertially Aided Real-Time Kinematic) technology this system provides continuous, robust, and reliable position and orientation data in difficult GPS environments.

Transportation planners require current information on road location, surface condition, road centerline position, and details on the multitude of highway signage related to transportation routes. In addition, GIS professionals also require information on the placement of various utility infrastructure features, such as hydro poles, fire hydrants, manholes and drainage catch-basins etc., to help them plan, maintain and predict various scenarios based on asset location and condition.

Majority of these features are often associated with dense urban environments where one is likely to encounter urban canyons, tree-lined streets with overhanging foliage, underpasses and elevated roadways.

| | EarlierproblemsassociatedwithLandbasedvehiclemounted systems |
|---|---|
| 1 | Earlier used Land-based GPS positioning was used with marginal success as a mapping data acquisition tool to accurately position planimetric features in open, unobstructed areas. |
| 2 | Commercial users of GPS systems generally find under ideal conditions a GPS system will offer excellent positional accuracy, however, this approach remains ineffective in a dense urban environment. |
| 3 | GPS satellite shading and dropout, the result of tall buildings blocking reception, and multipath issues generated by signals bouncing off reflective surfaces, cause stand-alone GPS systems to be completely inadequate in obtaining reliable positioning information in a downtown core area. |
| 4 | Vehicle-mounted mobile GPS positioning is further complicated in urban or tree canopy areas as the structures that cause poor GPS reception also cause the satellites to go in and out of view, limiting a GPS receiver's ability to provide continuous, accurate positional information. |
| 5 | Following a GPS dropout or phase lock outage, a typical land-based dual frequency GPS receiver requires 30 to 120 seconds of reacquisition lock before providing RTK (real-time kinematic) level accuracy. |
| 6 | During this time period, particularly if using a mobile land-based system, the accuracy of the data generated for position determination degrades very quickly, effectively making the system unusable. |

Table 11.1: EARLIER PROBLEMS ASSOCIATED WITH LAND BASED VEHICLE MOUNTED SYSTEM

An alternative land-based system designed to accurately position all difficult-to-locate cartographic features, such as those associated with mapping for transportation planning, or planimetric data-gathering for GIS databases, is now available.

This system is an aided inertial navigation system designed specifically for precise position and orientation measurements for survey and vehicle control applications. The system utilizes IARTK (Inertially-Aided Real-Time Kinematic) technology, providing continuous position and attitude data under the most demanding and difficult GPS conditions.

| Advantages ofInertially-Aided Real-Time Kinematic system | |
|---|---|
| 1 | A mobile mapping vehicle equipped with this technology allows the operator to generate reliable and precisely positioned map data in areas where known GPS outages are routinely encountered, such as those found in a city's urban canyons. |
| 2 | Mapping roads and road corridors in a modern city where high rise buildings are commonplace is easily done. |
| 3 | Generating map data for multilevel highways, or centerline road mapping under bridges and in tunnels can be done with no problem |
| 4 | Likewise, heavily forested areas and mountainous terrain, locations which are particularly susceptible to GPS outages, can be successfully mapped with a degree of accuracy previously unavailable. |

TABLE 11.2: ADVANTAGES OF RTK SYSTEM

In its tightly coupled navigation mode (IARTK), this system does not use the position and velocity data provided by the GPS receiver, rather system automatically integrates raw GPS satellite data directly into the system. This allows the system to utilize position-aiding data from just one GPS satellite observable (CA code), when all others are experiencing lockout. The system comprises four primary components.

- An Inertial Measurement Unit (IMU)
- A two-receiver GPS azimuth measurement sub-system
- A Distance Measurement Indicator (DMI), and
- A computer system

| Description of Inertially-Aided Real-Time Kinematic system components | | |
|---|---|---|
| 1 | Inertial Measurement Unit (IMU) | The vehicle-mounted system integrates inertial data from an IMU, containing accelerometers and gyros for each axis. The IMU is designed to measure the position and orientation differences and provide a true representation of motion in all axes. |
| 2 | Distance Measurement Indicator (DMI) | Velocity aiding and linear distance travelled data is derived from the DMI attached to one of the vehicle's rear wheels. |
| 3 | Two-receiver GPS azimuth measurement sub-system | The embedded GPS receivers in the computer provide additional position and velocity information with further heading assistance coming from the two-receiver GPS azimuth measurement sub-system. The RTK corrections data are received from external sources. The system automatically integrates raw GPS satellite data directly allowing the system to utilize position-aiding data from just one GPS satellite observable (CA code), when all others are experiencing lockout. |
| 4 | Computer system | Real time data processing. |

TABLE 11.3: DESCRIPTION OF RTK SYSTEM

This robust positioning solution in its simplest form is a combination of GPS data and dead reckoning navigation. In conjunction with the combined integration of two-receiver GPS azimuth measurement sub-system heading aiding, and DMI integrated velocity aiding, the position-error growth during a GPS outage is thus severely restricted. In this configuration, this system is able to deliver decimeter-level positioning accuracy, which gracefully degrades over time with distance travelled, together with attitude accuracies of better than 0.05 degrees.

## 11.3 Applicability of Vehicle Mounted Precision System in India

In India, the city consists of several lanes and by lanes that are attached with the highways. Aerial photography is able to capture the major characteristics, however, minor characteristics require better resolution.

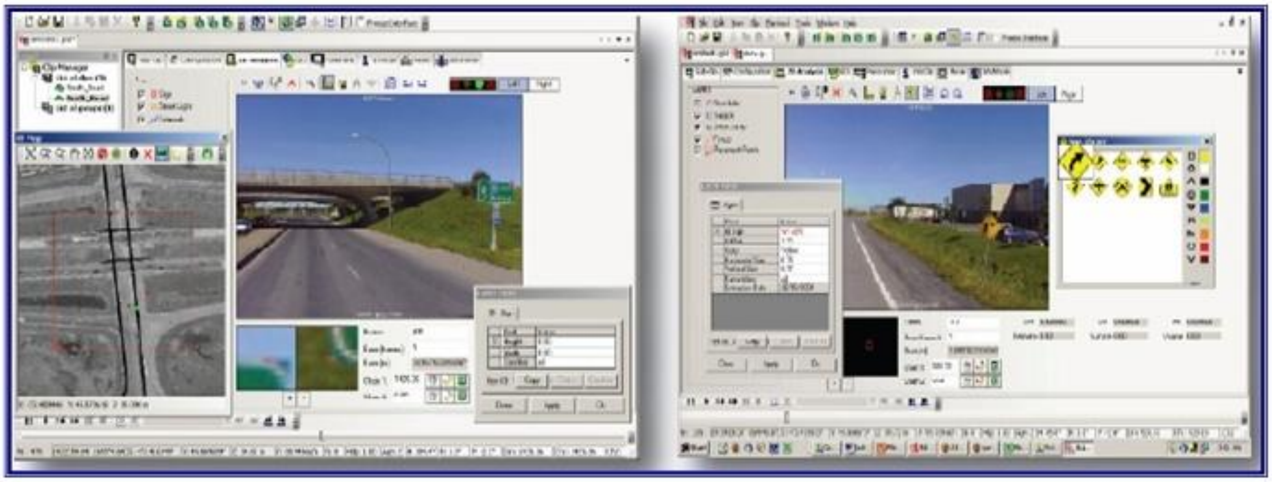


FIGURE 11.3: APPLICATION OF VEHICLE MOUNTED PRECISION MAPPING SYSTEM

This method, vehicle mounted precision mapping system, is an ideal method to acquire and characterize information that is vital for infrastructure planning, management and mapping. It assists in acquiring video log data for right of way analysis, pavement condition analysis, electric pole inventory, street/trackside asset management and many other civil infrastructure GIS data. This data is specially effective as commercial product for private sector firms and can be marketed by NATMO. The system consists of Laser scanning cameras, computer hardware and processing software. The mobile mapping solution should have Global Navigation Satellite System (GNSS) capability. The data should be in multiple data formats supported for export into various GIS databases with multi-user environment.

Methodology involved in Mobile Mapping System: There are different but standard procedures followed in Mobile Mapping System. Data capturing can be done using the device mounted on the vehicle at each point of interest ie., (Critical Facilities) while the vehicle is on move. With the help of supporting software the captured data can be directly downloaded for updatation of map.

This Mobile Mapping System can be a cost effective way to obtain high quality geospatial data. This data can be used for

| | |
|---|---|
| 1 | 3D city model generation |
| 2 | Utilities and infrastructure planning and analysis |
| 3 | Earthworks monitoring and volume calculations |
| 4 | Site planning |
| 5 | Bridge management |

| | |
|---|---|
| 6 | Street side asset inventory |
| 7 | Trackside inventory for railways |
| 8 | Sign condition assessment |
| 9 | Traffic data collection in real time |
| 10 | Disaster Management |

TABLE 11.4: UTILITY OF MOBILE MAPPING SYSTEM

Advantages of system will include

- GPS receivers, which have the capability of displaying the speed, will be useful for determining the speed of the vehicle, even though the display might show a non-zero value of speed sometimes, when the speed of the vehicle is zero.
- The number of satellites the receiver is able to track (NSAT) and the PDOP give an indication about the reliability of the speed data. It was found that the error in speed increased when the PDOP values were high (greater than three) and the NSAT value was three.
- GPS, when integrated with GIS, is a valuable tool for travel time studies. The conclusion that they gave was: GPS stands ready as a valuable tool for IVHS applications, given adequate attention to its possible shortcomings.

## 11.4 Asset Mapping Using Vehicle Mounted Precision Mapping System

Traditional methods of data acquisition (e.g. manual cataloging of assets, closing roadways to assess pavement condition) are more expensive than mobile mapping when considering the cost of labor and processing data.

Urban planning requiring better street level data of neighborhoods or GIS data departments requiring more timely and accurate data to update databases, the needs of various organizations overlap and by collecting the highest accuracy data possible on a single pass makes the data product more ubiquitous. By serving the unique needs of all stakeholders, this makes the data more affordable and valuable.

FIGURE 11.4 : SOFTWARE WINDOW FOR ASSET MAPPING

| Asset mapping may include | | |
|---|---|---|
| 1 | Public Sector | • Street side asset inventory for urban asset collection<br>• Track side inventory for rail applications (signs, track switches etc.) |
| 2 | Transportation | • Sign database construction and condition assessment<br>• Video log data / right of way data collection |
| 3 | Utilities/ Public Works | • Pole / transformer inventory for Telecom, Electric, Cable |
| 4 | Real Estate (Addressing, Assessment) | • Video data of property assessment for municipal taxation data records |
| 5 | Public Safety | • Security, Emergency Services<br>• Geo-referenced video of road infrastructure and buildings providing accurate spatial data for situational awareness |

TABLE 11.5: ASSET MAPPING

The next generation Mobile Mapping software is now available for Direct Georeferencing of mobile mapping sensors, for asset mapping, using GNSS and inertial technology. Optimized for all environments and platforms (air, land, and marine), and compatible with a variety of mapping sensors, this smart software solution achieves both maximum accuracy and maximum efficiency for Direct Georeferencing. The complete post-processing toolbox delivers a streamlined field-to-office workflow for best results possible. It contains all the tools that you need to:

- Direct data download from internet
- Produce highly accurate position and orientation solutions from the GNSS and Inertial data logged by the system
- Obtain maximum immunity to GNSS outages in dense urban environments and vegetation covered areas
- Achieve stable, reliable, repeatable, and more accurate results
- Utilize post processing with raw GNSS outages virtually anywhere
- Import, manage and assess the data from system and GNSS reference stations
- Automate data output in choice of format (Support for numerous mapping applications)

## 11.5 Feature Digitizing Methodology in 1:2000 Imaging for Critical Facilities Mapping

The simultaneous capture of high-resolution imagery and laser scanner data has opened up new applications and created new workflows previously not possible. This includes:

- 3D modelling
- 4D modelling with time and
- 5D modelling with time and cost

Models can now be generated efficiently with minimal turnaround time and then served over the internet to all stakeholders. These stakeholders can then perform additional virtual measurements and capture additional attributes without a site revisit. And they can even process the models with their own domain-specific applications.

| Features used for digitizing | | |
|---|---|---|
| 1 | Buildings | The dimensions of buildings must be determined by the outline of their roof and must be indicated by a linestring with elevation true to the elevation of the roof edge. To aid in hypsographic modelling, a virtual hypsographic linestring must be added at the building beneath the building outline by estimating the ground level around the building. |
| 2 | Transportation Surface Features | All Roads, access ways, driveways, parking areas, ramps, improved tracks and trails must be indicated by a linestring showing their edges and featured coded based on their composition as indicated in the feature code table. |
| 3 | Railway Features | Railway tracks must be feature coded as indicated in the feature code table and must be captured by using one linestring along the centerline, between the two existing rails. Any additional hypsographic modelling information required along the track must be captured by virtual segment or embankment linestring positioned on either side of the track. |
| 4 | Cultural Features(area) | Area features must be listed in the feature code table and should be included to describe land use. Area features must close either to themselves, other features, or map neat line. Text must be included to describe its local name where applicable. |
| 5 | Pit/Pile Features | Pits, piles and embankments must be depicted by a linestring appropriately feature coded. Additional virtual hypsographic information must be added to ensure correct hypsographic modelling. |
| 6 | Hydrographic Features | All hydrographic features within the mapping limits must be captured and feature coded. Additional virtual hypsographic information must be added to ensure correct hypsographic modelling. |
| 7 | Vegetation Areas | In areas of vegetation, a linestring, placed at ground level and feature coded appropriately must encircle the vegetation area. Particular care must be taken to capture the true shape of clearings in extensively wooded areas. |
| 8 | Bridges | An outline by linestring of each bridge must indicate its position and deck elevation and must enclose an area. The feature coding of the linestring must indicate bridge use. Any additional information such as road edge, retaining walls and guard rails contained within the bridge area must be captured using the appropriate feature coding with the exception that their level must be 42 to avoid their use as hypsographic modeling data. |
| 9 | Retaining Walls | The top outside edges of a retaining wall must be captured and feature coded appropriately. In addition, the base of the retaining wall, estimated where obscured, must be collected as a virtual hypsographic linestring offset from the face of the upper retaining wall feature by at least 1mm or as measured if retaining wall has a discernable slope. |

| | | |
|---|---|---|
| 10 | Spot Heights | Placed at hill tops or within swales, cartographically placed in open flat areas or on hydrographic features, a spot height value must be entered into the design file and must include a point feature and a separate text feature with correct feature coding as specified in the feature table. |
| 11 | Contours | Contours, at 0.5cm intervals, will be calculated for the mapping area from the hypsographic data and included in the mapping file. Major contours will be contours every two meters starting from the even 10 meter contour. There will be three minor contours between each major contour. Both major and minor contours will have an appropriate cartographic tick mark placed indicating the direction of the depression. Contours will not appear within buildings. Major contours will be annotated at an interval of approximately 100 meters along the contour line with an integer value facing up-hill. This being the standard format followed in selection of contour interval, deviation from this general rule is possible depending on the functional requirements and terrain types. The contour lines and annotation will be feature coded. |
| 12 | Data Accuracy | All basic information concerning the datum of the map, such as control monuments, triangulation stations, traverse station, photo centers, and projection information, must be placed within 0.1mm of their true position. |

TABLE 11.6: FEATURES FOR DIGITIZING

All features are captured at their true position. Accuracies are as follows:

| Scale of Photography | Absolute Positional Accuracy | Absolute Vertical Accuracy |
|---|---|---|
| 1:6250 | 0.30m | 0.25m |

# 12 Key Elements to be Considered for GIS Acquisition &Cost Analysis

## 12.1 Economic Analysis for GIS Acquisition

### 12.1.1 Main Cost Headers

Acquiring a GIS system is a capital investment that may represent several thousand U.S. dollars. As contended by Sullivan (1985), standard investment appraisal methods can be applicable to information technologies such as GIS. The questions in the box below will help planners to roughly estimate and compare the major cost and benefits associated with a GIS acquisition.

- Initial hardware price (CPU, monitor, printer, etc.)
- Additional components (peripherals, digitizers, adapters, etc.)
- Availability with standards duty-free components
- Maintenance agreement and other service Transportation/ delivery
- Installation
- Software price
- Updates/ Upgrading
- Training

The cost of maintenance and repair of all components of a GIS must also be considered in the investment analysis. The more sophisticated the system, and the more remote the home base of operation, the higher its maintenance cost. Software demands maintenance too, and arrangements should be made to subscribe to effective support from the provider of the software. The hiring of expertise to modify the software according to the project should be expected. A GIS is a dynamic tool; there will always be new data and new capabilities to be added, requiring additional efforts and expenses.

**KEY ELEMENTS NEEDED WHEN PLANNING A GIS ACQUISITION COST**

**CALCULATIONS:**

- What is the software purchase cost?
- What hardware configuration is needed to fit the software requirements?
- Is a new computer needed? What options have to be included? What is the cost of acquiring a new computer versus upgrading an existing one?
- What are the anticipated hardware repair and maintenance, and software support costs?
- What are the personnel requirements for the installation and operation of a GIS?
- Will existing personnel be used or will new personnel have to be hired? Is a computer programmer needed? What training costs are anticipated?
- What is the cost of allocating personnel to hardware and software maintenance?
- What is the expected cost for the data input process? How many staff need to be hired or assigned to digitize the information? What is the cost involved in maintaining the data generated for and by the system?

- Is a secure facility available suitably equipped for protection of computers and data files?

**BENEFIT CALCULATIONS:**

- What is the production or revenue loss mostly associated with lack of information? How does this compare with the information that would be available if a GIS were present?
- What are the costs savings from substituting labor-intensive drafting processes with a GIS?
- What are the benefits of integrating more timely information in the decision-making process, and of being able to perform sensitivity analysis on proposed development plan options?

## 12.2 Selection of Systems and Equipment

When a new system is to be established, planners must carefully select the appropriate hardware and software. The system should be simple and must, of course, fit the budget and the technical constraints of the agency. Large digitizers and plotters, which are capable of producing maps of cartographic quality, are expensive and difficult to maintain. Small equipment, which can be as effective as the larger models for map analysis, is becoming increasingly available at affordable prices. For more details, please refer to Appendices.

There are many GIS packages available, some more expensive and more powerful than others. Some

cheaper software's have good analytical capabilities, but lack computer graphics. Based on objectives, budget, and personnel constraints, planners should investigate the alternatives for GIS software with a simple interface, strong analytical and graphical capabilities, and an affordable price. Regardless of the selection, GIS software must be tested, and its claims must be verified against the needs of the user. As the software for GIS projects can cost more than the hardware it is designed to run on, the testing should be done on the hardware configuration to be used.

**Criteria to be Considered When Planning for a GIS Acquisition**

| Hardware- CPU/System Unit | Features and Peripherals |
|---|---|
| • Microprocessor<br>• Compatibility with standards<br>• Memory capacity (RAM)<br>• Disk drives<br>• Backup system<br>• Expansion capacity<br>• I/O channels<br>• Communication ports<br>• Warranty terms | • Keyboards<br>• Monitors (terminals)<br>• Printers<br>• Power supply<br>• Networking capacity |

| | |
|---|---|
| **System Software**<br><br>• Compatibility with standards<br>• Capability<br>• Flexibility<br>• Expandability<br>• Special features<br>• Documentation | **Utilities Software**<br><br>• Ease of use<br>• Integration with total system<br>• Languages<br>• Diagnostics<br>• Peripheral control |
| **Applications Software**<br><br>• Appropriateness to needs<br>• Performance (capacity, speed, flexibility)<br>• Interface capability<br>• Support<br>• Upgrade potential<br>• Documentation<br>• Training and other user services | **Vendor Support& Maintenance**<br><br>• Maintenance staff (size, experience)<br>• Existing customer base<br>• Service facilities<br>• Inventory of components<br>• Guaranteed response time<br>• Capacity to deal with entire system |
| **Training**<br>• Range of courses offered<br>• Staff experience<br>• Facilities<br>• Documentation/ aids | |

## 12.2 Commercial Aspects of Aerial Photogrammetric Components

### 12.2.1 Latest Lidar Based Aerial Survey System Cost

| Components | Cost |
|---|---|
| **Aerial monitoring system, comprising:**<br>• Inertial Measurement Unit<br>• Specialized Computer System | USD $ 3,41,594.00 |

| | |
|---|---|
| • External GPS with GPS Antenna Cable, 10 m<br>• 1 High-gain Antenna, GPS,GLONASS, L-Band<br>• 2 BNC Adapters<br>• Controller Software (PC not included)<br>• Power Cable Assembly<br>• I/O Analogue Cable Assembly with Industrial Ethernet Connector<br>• Industrial Ethernet Cable Assembly, RJ-45, crossover<br>• Event Cable<br>• Industrial Ethernet Cable Assembly, Straight through<br>• PCMCIA Flash Cards, Certified<br>• Manual & Shipping Case | |
| PCS Firmware Option - Free Inertial Navigator | USD $ 3,575.00 |
| GNSS-Aided Inertial Processing Tools Set | USD $ 27,423.00 |
| SAR Processing Tool Set | USD$ 9,295.00 |
| One-Year Maintenance for GNSS-Aided Inertial Processing Tools | USD $ 4,147.00 |
| One-Year Maintenance for SAR Processing Tools | USD $ 1,397.00 |

TABLE 12.1: LATEST LIDAR BASED AERIAL SURVEY SYSTEM COST

## 12.3 Commercial Aspects of Satellite Mapping

### 12.3.1 Resourcesat-1 High Resolution Satellite Imagery Costs

| Sensor | LISS-III | AWiFS | AWiFS |
|---|---|---|---|
| Non-Commercial use RRP | $550 | $550 | $550 |
| Product Specification: | Level 2 Path | Level 1 | Level 2 Map Oriented |
| Datum: | WGS84 | No Datum | WGS84 |
| Projection | UTM | Unprotected data | Lambert Conformal Conic (LCC) - Specifications |
| Resampling: | NN | Not Applicable | KD16 |
| Format: | Fast Format | LGSOWG | Geo TIFF |

| Processing Level: | Level 2 Radiometric and Geometric Correction Path based | Level 1 Radiometric Correction | Level 2 Radiometric and Geometric Correction – Map oriented |
|---|---|---|---|
| Scene Size: | 140 x 140km | 740 x 740 km, 4 quadrants | |
| Nominal pixel size: | 23.5 meters | 56 meters at nadir, 70 meters at field edge | |

TABLE 12.2: HIGH RESOLUTION SATELLITE IMAGERY COST

### 12.3.2 Cartosat-1 High Resolution Satellite Imagery Costs

| S.N | **Area Coverage (Scene based/ Float)** | **Accuracy Specifications** | | Remarks | Volumes | Price |
|---|---|---|---|---|---|---|
| | | Location | Accuracy | | | |
| 1 | Scene/Float Mono/Stereo * | 250m | Terrain dependent | Basic stereo pair | < $50K | $ 2280 |
| | | | | | $50K -$100K | $ 2150 |
| | | | | | > $100K | $ 2020 |
| 2 | Scene/Float (Mono) * | 250m | Terrain dependent | RAD product with RPC file | < $50K | $ 1200 |
| | | | | | $50K -$100K | $ 1095 |
| | | | | | > $100K | $ 1045 |
| 3 | Scene/Float (Mono) * | 250m | Terrain dependent | Geo- Referenced product | < $50K | $ 1200 |
| | | | | | $50K -$100K | $ 1095 |
| | | | | | > $100K | $ 1045 |
| 4 | Scene/float Mono *, AOI§ | 250m | Terrain dependent | Geo- Referenced product | < $50K | $ 1.70/SKM |
| | | | | | $50K -$100K | $ 1.50/SKM |
| | | | | | > $100K | $ 1.40/SKM |

TABLE 12.3: CARTOSAT-1 HIGH RESOLUTION SATELLITE COSTS

§ Minimum area of AOI is 25km x 25km. supplied with Meta file
* Restricted Area Masking is done, whenever required

**Precision Ortho Product Pricing**

| S.No | Area Coverage (Scene based /Float) | Level of Processing | Remarks | Volumes | Price |
|---|---|---|---|---|---|
| 1 | Mapsheet based /Float7.5' x 7.5' * | Precision (ortho) , Terrain Corrected | Using DEM and TCPs | < $50K | $880 |
| | | | | $50K -$100K | $820 |
| | | | | > $100K | $785 |
| 2 | Float 5' x 5' * | Precision (ortho) , Terrain Corrected | Using DEM and TCPs | < $50K | $735 |
| | | | | $50K -$100K | $684 |
| | | | | > $100K | $655 |

| | | | | | |
|---|---|---|---|---|---|
| 3 | Float 3.75' x3.75' * | Precision (ortho) , Terrain Corrected | Using DEM and TCPs | < $50K | $590 |
| | | | | $50K -$100K | $550 |
| | | | | > $100K | $525 |
| 4 | Float 2.25' x2.25' * | Precision (ortho) , Terrain Corrected | Using DEM and TCPs | < $50K | $590 |
| | | | | $50K -$100K | $550 |
| | | | | > $100K | $525 |

TABLE 12.4: PRECISION ORTHO PRODUCT PRICING

§ All Geocoded products are orthorectified
*Restricted Area Masking is done whenever possible

### 12.3.3 Quickbird High Resolution Satellite Imagery Costs

| Product Type | Specs | International List price (US$) | | International List Price Per Scene Archive Data (US$) | | International List price Per sqkm Archive Data (US$) | |
|---|---|---|---|---|---|---|---|
| System corrected, geo-referenced, Polyconic | Accuracy in mts-150,Format-GeoTiff Projection/ Datum | Per Scene | More than 1000 sq km | Archives 6-12 months old (Per Scene) | Archives 12-24 months old (Per Scene) | Orders more than1000 sq km for archive data 6-12 months old (per sq. km.) | Orders more than 1000 sq km for archive 12-24 month sold (per sq.km) |
| AOI (min.area 25 1 sq km) | Everest | 780 | 8.6 | 590 | 470 | 6.5 | 5.2 |
| | UTM/WGS84 | | | | | | |
| (Scene size9.6 km x 9.6km) | | | | | | | |

TABLE 12.5: QUICKBIRD HIGH RESOLUTION SATELLITE COSTS

| **Quickbird Pricing**<br>60cm and 2.4m Satellite Imagery - Pricing per square kilometer. | | |
|---|---|---|
| **Product Type** | **Image Library(Archive)** | **Select Tasking (New)** |
| Panchromatic, Multispectral (4-Band), Natural Color or Color Infrared | $14 | $20 |
| Pan-Sharpened (4-Band) or Bundle (Pan + MS) | $17 | $23 |
| **Quickbird Product Description** | **Price per MapSheet** | |
| 400 dpi DRG (Digital Raster Graphic), Full or Cropped, New Production | $99 | |

| | |
|---|---|
| 400 dpi DRG (Digital Raster Graphic), Full or Cropped, From Archive (click here for a PDF listing of archived data) | $79 |
| Digital Elevation Model (DEM), 10 - 90 meter (<1 - 3-arc second) resolution, seamed, edge- matched, RMSE-tested | $499 |
| 3D Vector Contours (add $99 per map sheet for edge-matching) | $449 |
| Vectorization of any "major" feature (roads, water), 1 layer | $249 |
| Vectorization of any "minor" feature, 1 layer | $149 |
| Full Vectorization Except Contours -- up to 8 features, 8 layers (except contours) | $549 |
| Full Vectorization Including Contours -- up to 9 features, 9 layers (including contours) | $799 |

TABLE 12.6: QUICKBIRD PRODUCT DESCRIPTION

**Quickbird Notes:**

- Minimum order area for archive imagery (if available) = 25 sq. km.
- Minimum order cost for new “Select Tasking” collection = $1,800 USD
- Unless already in archive, Quickbird does not collect stereo imagery
- Cloud Cover specification for “Select Tasking” orders is 15% or less
- Additional “priority” tasking levels available
- All prices in $USD and subject to change without notice
- Licensing fees will apply for 6+ end users (up to 5 included in base price)

### 12.3.4 Geoeye-1 High Resolution Satellite Imagery Costs

| Geoeye-1 Pricing<br>50cm and 2m Satellite Imagery - Pricing per square kilometer. | | |
|---|---|---|
| Product Type | Image Library (Archive) | Tasking Collection (New) |
| Archive (Geo™ Only > 90 days) | $12.50 | N/A |
| Geo™ | N/A | $25 |
| GeoProfessional™ | $30 | $30 |
| GeoProfessional™ - Precision Upgrade | $40 | $40 |
| GeoStereo™ | $40 | $40 |
| GeoStereo™ - Precision Upgrade | $50 | $50 |

TABLE 12.7: GEOEYE-1 HIGH RESOLUTION SATELLITE COSTS

**Geoeye-1 Notes:**

- Geoeye Products can be delivered as one of the following: Panchromatic, Multispectral (4-Band), Natural Color (3-Band), Color Infrared, 4-Band Pan-Sharpened or Panchromatic + Multispectral Bundle
- Minimum order area for archive imagery (if available) = 49 sq. km.
- Minimum order area for new tasking collection imagery = 100 sq. km
- Cloud Cover specification for new tasking collection orders is 15% or less (additional cloud cover options available)
- A 2km x 2km area may be guaranteed cloud free on new tasking collection orders
- Standard Geo New Tasking Collection imagery is collected between 60-90 degrees elevation angle - 72-90 degree elevation angle available for an additional $2 per sq. km.
- All prices in $USD and subject to change without notice
- Licensing fees will apply for 1+ end users

### 12.3.5 Ikonos High Resolution Satellite Imagery Costs

| **IkonosPricing:** 1m and 4m Satellite Imagery - Pricing per square kilometer. | | |
|---|---|---|
| **Product Type** | **Image Library (Archive)** | **Tasking Collection (New)** |
| Archive (Geo™ Only > 90 days) | $10 | N/A |
| Geo™ | N/A | $20 |
| GeoProfessional™ | $25 | $25 |
| GeoProfessional™ - Precision Upgrade | $35 | $35 |
| GeoStereo™ | $35 | $35 |
| GeoStereo™ - Precision Upgrade | $45 | $45 |

TABLE 12.8: IKONOS HIGH RESOLUTION SATELLITE COSTS

**Ikonos Notes:**

- IkonosProductscanbedeliveredasoneofthefollowingoptions:Panchromatic, Multispectral (4-Band), Natural Color (3-Band), Color Infrared, 4-Band Pan-Sharpened or Panchromatic + Multispectral Bundle
- Minimum order area for archive imagery (if available) = 49 sq. km.
- Minimum order area for new tasking collection imagery = 100 sq. km

- Cloud Cover specification for new tasking collection orders is 15% or less (additional cloud cover options available)
- A 2km x 2km area may be guaranteed cloud free on new tasking collection orders
- Standard Geo New Tasking Collection imagery is collected between 60-90 degrees elevation angle - 72-90 degree elevation angle available for an additional $2 per sq. km.
- Additional "priority" tasking level available (additional charges will apply)
- All prices in $USD and subject to change without notice
- Licensing fees will apply for 1+ end user

### 12.3.6 Worldview-1 High Resolution Satellite Imagery Costs

| Worldview-1 Pricing<br>50cm Satellite Imagery - Pricing per square kilometer. | | |
|---|---|---|
| Product Type | Image Library (Archive) | Select Tasking (New) |
| Panchromatic Only | $14 | $20 |
| Basic Stereo - Pan Only | $28 | $40 |

TABLE 12.9: WORLDVIEW-1 HIGH RESOLUTION SATELLITE COSTS

**Worldview-1 Notes:**

- Minimum order area for archive imagery (if available) = 25 sq. km.
- Minimum order cost for new "Select Tasking" collection = $1,800 USD
- There is a 210 sq. km minimum order area for all "Stereo" orders.
- Cloud Cover specification for "Select Tasking" orders is 15% or less
- Additional "priority" tasking levels available
- All prices in $USD and subject to change without notice
- Licensing fees will apply for 6+ end users (up to 5 included in base price)

### 12.3.7 Worldview-2 High Resolution Satellite Imagery Costs

| **Worldview-2 Pricing**<br>50cm and 2m Satellite Imagery - Pricing per square kilometer. | | |
|---|---|---|
| **Product Type** | **Image Library (Archive)** | **Select Tasking (New)** |
| 50cm Panchromatic, 2m Multispectral (4-Band) or50cm 3-band PS (color) | $14 | $20 |
| 50cm 4-band Pan-Sharpened or Bundle (50cm Pan +4-Band 2m MS) | $17 | $23 |

TABLE 12.10: WORLDVIEW-2 HIGH RESOLUTION SATELLITE COSTS

**WorldView-2 Notes:**

- Minimum order area for archive imagery (if available) = 25 sq. km.
- Minimum order cost for new “Select Tasking” collection = $1,800 USD
- There is a 210 sq. km minimum order area for all “Stereo” orders.
- Cloud Cover specification for “Select Tasking” orders is 15% or less
- Additional “priority” tasking levels available
- All prices in $USD and subject to change without notice
- Licensing fees will apply for 6+ end users (up to 5 included in base price)

### 12.3.8 Landsat Imagery Costs

| | Landsat 4,5TM | SPOT XS | SPOT P | IRS- 1C/D |
|---|---|---|---|---|
| Scene dimension (km) | 180 x 180 | 60 x 60 | 60 x 60 | 70 x 70 |
| Scene coverage ($km^2$) | 32.000 | 3.600 | 3.600 | 4.900 |
| Data cost per scene (US-$) | 4.400 | 1.870 | 2.090 | 2.500 |
| Data cost per 100 $km^2$ (US-$) | 0.14 | 0.52 | 0.58 | 0.51 |

TABLE 12.11: LANDSAT IMAGERY COSTS

| Landsat 7 ETM+ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **Archived SLC-On products** - all bands | | | | **SLC-Off products** - all bands | | | **SLC-Off Customer Composite Package** (Individual scenes for clients to manually combine - all bands) -Path image only. Fast L7A or HDF format | |
| Optical Data Processing Options | | | | Optical Data Processing Options | | | Select from between 2 to 6 scenes so long as:1 to 5 SLC-Off scenes are chosen, and. 0 to 1SLC-On scenes are chosen | |
| **Scene Size** | Path Image | Map Oriented Image | Ortho-corrected Image | PathI mage | Map Oriented Image | Ortho corrected Image | 2 scenes (minimum) | Each additional scene |
| **Small Scene** Up to 625 sq kme.g. 25 x 25 km | - | $450 | $550 | - | $400 | $500 | $550 | $25 |
| **Ninth Scene** Up to 3600 sqkme.g. 60 x 60 km | - | $600 | $700 | - | $450 | $550 | $600 | $25 |
| **Quarter Scene** Up to 8100 sq kme.g. 90 x 90 km | - | $700 | $800 | - | $550 | $650 | $700 | $25 |
| **Half Scene**Up to 16,900 sq km 130 x 130 km | - | $800 | $900 | - | $650 | $750 | $800 | $25 |
| **Full Scene** 185 x 185 km | $1,100 | - | - | $750 | - | - | $900 | $25 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Full Scene Up to 41,625 sq km eg 225 E-W x 185 km N-S | - | $1,100 | $1,200 | - | $750 | $850 | $900 | $25 |
| Double Scene 185 km across track and 355 km along track | $1,300 | - | - | $950 | - | - | $1,150 | $50 |
| Double Scene Up to 95,850 sqkmMax 270 E-W x 355 km N-S | - | $1,300 | $1,450 | - | $950 | $1,100 | $1,150 | $50 |
| Triple Scene Up to 185 km across track and 530 km along track | $1,500 | - | - | $1,150 | - | - | $1,400 | $75 |
| Triple Scene Up to 164,300 sq km Max 310 E-W x 530 km N-S | - | $1,500 | $1,700 | - | $1,150 | $1,350 | $1,400 | $75 |

TABLE 12.12: LANDSAT & ETM

# 13 CONCLUSION

## Combining 1:10,000 Multi-Hazard Maps (MHM) and 1:2000 Critical Facilities Maps (CFM) For Disaster Management

The Multi Hazard Maps (MHM) are large scale maps with 1 meter contouring and are useful in identifying the precise aerials covered under different type of hazards. However, within the hazard zones there are critical facilities such as populous cities and critical installation, where the impact of disaster requires to be evaluated precisely for mitigation. Thus, the critical facility maps (CFM) at the scale 1:2000 or less are essential for advance planning. The CFM combined with MHM gives the risk assessment maps, which have manifold utility. For example, the location of a critical facility in a hazardous area alerts planners and decision makers to the fact that in the future a certain facility may confront serious problems. The resources required and available to generate MHM and CFM are summarized below with brief comparison of techniques used:

To generate MHM the Stereo satellite multi spectral images are required with at least 40 CM resolution. Such data is available from many foreign commercial satellites and in near future ISRO is also planning to launch a satellite in Cartosat series to have the desired resolution. In order to analyze the Stereo satellite data with desired accuracy, a close network of ground control points are necessary. With proper choice of photo grammetry software, which have been discussed in details in previous chapters, the stereo satellite data can be analyzed to give detailed maps with attributes and DEM/DTM/DSM with 1 meter contours.

For making CFM, higher resolution data better than 10 cm resolution is required, which is not possible with the available commercial satellites. Thus, Aerial mapping is the only solution. With the growth of technology in recent years, both in software and hardware, the integrated hardware systems are available with high resolution IMU, the lasers, large format camera, differential GPS and high speed data acquisition and storages system. The hardware is light weight and can be easily mounted on light aircraft/helicopters to acquire the high resolution data of the cities and other critical installation. The powerful software has been developed for flight management system and onboard analysis of data. The great advantage of this advance technology is that, this does not require the multiple ground control points, which makes the data acquisition and analysis cheaper and cost compatible with stereo satellite data analysis.

Sometimes even aerial mapping is limited to resolve the fine features of thickly populated clusters such as many areas in Old Delhi. Similar is the case with almost all old cities in India, where dense population lies in lanes and by-lanes. The latest state of art technology vehicle mounted ground survey are available with high resolution IMU, the lasers, large format camera, differential GPS and high speed data acquisition and storages system. The hardware is light weight and can be easily mounted on light vehicle.

| S. No. | Parameters | Satellite Mapping | Aerial Mapping | Vehicle Mounted / Ground Survey |
|---|---|---|---|---|
| 1 | Resolution | Max: 40 cm (Geoeye) | Better than 10 cm | Better than 5 cm |
| 2 | Mapping Scale | 1:10000 | 1:2000 or better | 1:500 or better |
| 3 | Type of imaging | Stereo | Stereo | Stereo |
| 4 | Derived Product | DEM/DTM/DSM | DEM/DTM/DSM | DEM/DTM/DSM |
| 5 | Contour | 1 meter | Better than 0.5 meter | Better than 10 cm |
| 6 | GCP requirement | Yes (atleast 14 perframe of 10 Km x10 Km at minimum spacing of 5 Km or better traceable to reference datum of International Geocentric Reference frame (ITRF) | Not required as on board Dual Frequency Differential GPS processing integrated with Satellite Based Augmentation Service (SBAS) Automatically performances Georeferencing of images. | Not required as on board Dual Frequency Differential GPS processing integrated with Satellite Based Augmentation Service (SBAS). Automatically performances Geo referencing of images. |
| 7 | GCP Accuracy (95%confidence) | Required on the ground | Automatically done | Automatically done |
| | Horizontal | Better than 20 cm | Better than 5 cm | Better than 10 cm |
| | Vertical | Better than 30 cm | Better than 5 cm | Better than 15 cm |
| 8 | 3D imaging | Rough estimate | Accurate | Accurate |

TABLE 13.1: COMPARISON OF PERFORMANCE PARAMETERS OF SATELLITE, AERIAL AND GROUND SURVEY

An evaluation of vulnerability dependent upon a careful analysis of equipment and the type, use, and condition of the facility would then be carried out. If the vulnerability of critical facilities is assessed and appropriate reduction techniques are incorporated into each stage of the planning process, social and economic disasters due to natural and other hazards can be avoided or substantially reduced.

The Task Force constituted on Thematic Mapping suggested 1:10,000 scale mapping on first priority. With the present status of Indian satellite, topographic mapping using Cartosat – I data can be done with the following specifications of cloud free data of the country and high geometric fidelity for photogrammetric processing.

- 3 – 4m planimetric (positional) accuracy
- 3 – 4m height accuracy

Information content commensurate to 10 K topographic mapping

- Suggested to have 5m contour depiction on map (10m contour and \5m interpolated with dotted symbology)

Further, thematic mapping on 10K can be done using Cartosat – I and LISS – IV MX data with following specifications.

- Base, infrastructure, land use **/** land cover, soil ground water prospects maps and slope maps with 5 m plainmetric accuracy.
- The theme content may be commensurate to 10K scale.

However, the statistics of the DEM difference of Stereo Aerial photos and Cartosat 1 stereo image indicate height variation in the ranges of 3m.

As a compromise, the topographic mapping with above specifications can be taken up as 10K series – I maps and as and when Cartosat – III with 25cm spatial resolution data (as per ISRO website ) is available these maps can be updated with better specifications. This satellite is to be launched in 2012-13.

The higher resolution stereo data upto 40 CM resolution is commercially available, where DEM/DTM/DSM can be derived with 1.5 meter contour intervals, which can easily be extrapolated to get 1 meter contour interval with fair degree of accuracy.

The close network of secondary ground control points can be used to achieve consistent plainmetric or height accuracies due to non-metric nature of image acquisition geometry over the entire study zone.

This option gives a good beginning of getting accurate 1 meter contour interval on 10 K maps for hazard-zonation. The cost implication will only be difference of the cost of acquiring foreign commercial satellite data and the Indian satellite data as processing and other requirement will remain the same.

In order to get the most reliable 10K maps, an Aircraft equipped with latest state of instrumentation with processing software and large format camera is the preferred option. However, it requires meticulous project planning depending upon the priority and requirements of the area under mapping.

# APPENDICES

## *Appendix-I*

### APPROACH TO DEVELOP A GIS DATABASE FOR DISASTER MANAGEMENT IN INDIA

| FUNCTION | POTENTIAL APPLICATIONS | EXAMPLES |
|---|---|---|
| Data display | • Aid in the analysis of spatial distribution of socio-economic infrastructure and natural hazard phenomena | • What lifeline elements lie in high-risk areas? |
| | • Use of thematic maps to enhance reports and/or presentations | • What population could be affected? |
| | • Link with other databases for more specific information | • Where are the closest hospitals or relief centers in case of an event? |
| Land information storage and retrieval | • Filing, maintaining, and updating land-related data (land ownership, previous records of natural events, permissible uses, etc.) | • Display all parcels that have had flood problems in the past |
| | | • Display all non-conforming uses in this residential area |
| Zone and district management | • Maintain and update district maps, such as zoning maps or floodplain maps | • List the names of all parcel owners of areas within 30 m of a river or fault line |
| | • Determine and enforce adequate land-use regulation and building codes | • What parcels lie in high and extreme landslide hazard areas? |
| Site selection | • Identification of potential sites for particular uses | • Where are the hazard-free vacant parcels of at least 'x' ha lying at least 'y' in from a major road, which have at least z bed-hospitals within 10 km radius? |
| Hazard impact assessment | • Identification of geographically determined hazard impacts | • What units of this residential area will be affected by a 20-year flood? |

| | | |
|---|---|---|
| Development/Land suitability modeling | • Analysis of the suitability of particular parcels for development | • Considering slope, soil type, altitude, drainage, and proximity to development, which areas are more likely to be prioritized for development? What potential problems could arise? |

TABLE 1.1: EXAMPLES OF GIS APPLICATIONS FOR NATURAL HAZARDS MANAGEMENT AT THE LOCAL LEVEL OF PLANNING

## 1.1 Data Model

A standard data model should be defined, which will be applicable to the three tiers of databases. The preparation of a standard data model is necessary for the interoperability and consistency of data. The data model will define the various layers of the database, the features in each layer and their geometry. The database requires spatial information on the following:

| | |
|---|---|
| Topography<br>Contours/ elevations<br>Slopes/ aspects<br>Vegetation, soils<br>Bathymetry<br>Digital elevation models at various accuracies | Hydrology<br>Rainfall, air temperature<br>Net radiation<br>Wind speed and direction<br>Evaporation rate<br>Rivers and water bodies<br>Watersheds |
| Demography and Socio-Economy<br>Population density<br>Age and sex structure<br>Literacy rates<br>Household data<br>Political and administrative boundaries<br>Building footprints and settlements<br>Geology<br>Bedrock, fault lines, plate boundaries | Connectivity/ Infrastructure<br>Telecommunication<br>Transportation<br>Utilities<br>Social infrastructure like schools, religious institutions<br>Emergency Infrastructure like hospitals, police stations, fire stations |
| Land use<br>Residential, commercial<br>Industrial, agricultural<br>Restricted zones<br>Sensitive zones | Risk/Hazard/ Disaster Data<br>Type of disaster, date and time of occurrence, location and epicenter (for earthquakes), magnitude/severity, impact/damage<br>High risk areas/ industries<br>Flood plain and flash flood maps<br>Seismo-tectonic maps, storm surge maps |

TABLE 1.2: DATA MODEL

## 1.2 Design of Data Files

The next step is to design the cartographic layers to be entered into the system, and the spatial attributes to be assigned to them. In this regard, detail of the database, input scale, and resolution must be considered.

| SN | FEATURES | DESCRIPTION |
|---|---|---|
| 1 | Cartographic layers | Cartographic layers are the different "maps" or "images" that will be read into the system and later overlaid and analyzed to generate synthesis information.<br>For example, cartographic layers depicting past landslide events, geological characteristics, slope steepness, hydrology, and vegetation cover were entered and overlaid in a GIS to create a landslide hazard map |
| 2 | Selection of layers | There are three basic types of layers, and many different possible combinations among them: polygons (floodplains, landslide hazard areas), lines (fault lines, rivers, electrical networks), and points (epicenters, well locations, hydroelectric facilities).<br>Selection of the correct layer type for a database depends on anticipated uses and on the scale and resolution of the source data. A volcano, for example, may be represented as a point at 1:250,000 scales, but it could well be a polygon at 1:20,000.<br>Similarly, flood-prone areas may be represented as lines bordering rivers at scales smaller than 1:50,000, but as polygons on 1:10,000 scale maps.<br>Planners must keep in mind that point and line representations may well be used for depicting variable locations, but they are seldom used for GIS operations involving cell measurement. |
| 3 | Scale | Regarding scale, planners or GIS users can take advantage of the flexibility, some GIS offer, by entering data at various scales and later requesting the system to adjust the scale to fit the particular purpose or stage of planning.<br>Small to medium scales for resource inventory and project identification; medium scales for project profiles and pre feasibility studies;<br>Large scales for feasibility studies, hazard zone mapping, and urban hazard mitigation studies. |

| | | |
|---|---|---|
| 4 | Resolution | Resolution or spatial accuracy of the database will be reflected in the number of cells (columns and rows or Xs and Ys) making up the database. The greater the number of cells used to cover a given area, the higher the resolution obtained.<br>High resolution is not always necessary, and the tradeoff between what is gained in terms of analytical capacity and what is lost in terms of consumption of computer's memory and input time must be considered.<br>The type of graphic adaptor, the size of computer's memory, and the user's preference as to whether a full or partitioned screen should be used, are determining factors in this respect. |
| 5 | Performance | Finally, the design of the database should be tested for performance.<br>Following a pilot test, it is not uncommon to obtain a sizable set of database design rectification.<br>Guidelines are usually not only directed at the spatial accuracy of data and layer design, but also at the identification of possible obstacles for final system implementation, and the development of procedures or a methodology for performing tasks under normal operational conditions. |

TABLE 1.3: DESIGN OF DATA FILES

# Appendix-II

## GROUND CONTROL POINTS IN MAPPING OF SATELLITE IMAGES

## 2.1 Photogrammetric Ground Control

### 2.1.1 Datum

By definition, the horizontal datum is a rectangular plane coordinate system. All horizontal control shall begin and terminate on monuments that are in the National Geodetic Reference Database System (NGRDS), the vertical datum is normal to gravity. All vertical control shall begin and terminate on existing benchmarks that are in the National Geodetic Reference Database System (NGRDS). International Terrestrial Reference Frame (ITRF) is a realization of International Terrestrial Reference System (ITRS), which is a definition of geocentric system adopted and maintained by International Earth Rotation and Reference Systems Service (IERS). IERS was established in 1987 on the basis of the resolutions by IUGG and IAG. The origin of the system is the centre of mass of the Earth. The unit of length is meter. The orientation of the axes was established as consistent with that of IERS's predecessor, Bureau International de l'Heure, BIH, in 1984. The Z-axis is the line from the Earth's centre of mass through the Conventional International Origin (CIO). Between 1900 and 1905, the mean position of the Earth's rotational pole was designated as the Conventional Terrestrial Pole (CTP). The X-axis is the line from the centre through the intersection of the zero meridian with the equator. The Y-axis is the line from the centre to equator and perpendicular to X axis to make a right handed system. ITRF is a set of points with their 3-dimensional Cartesian coordinates and velocities, which realizes an ideal reference system, the International Terrestrial Reference System. Each ITRF is identified by the digits of the year as ITRFyy e.g. ITRF97, ITRF2000 etc. The latest is ITRF2005 which has the epoch 1$^{st}$ January 2000. For realization, the different techniques are used: Very Long Baseline Interferometry (VLBI), Lunar Laser Ranging (LLR), Satellite Laser Ranging (SLR), Global Positioning System (GPS) and Doppler Ranging Integrated on Satellite (DORIS). Each has strengths and weaknesses - their combination produces a strong multi-purpose Terrestrial Reference Frame (TRF). ITRF is the best geodetic reference frame currently available. The GRS80 ellipsoid is recommended by IERS to transform Cartesian coordinates to latitude and longitude.

India has an existing network of approximately 300 Ground Control Points (GCP). This network is to be used in the image acquisition for the hazard mapping database in this project. The number of stations directly realized by the geocentric geodetic system is not enough for practical use. Worldwide, there are several hundred realized stations in ITRF and about twenty stations in WGS84. Therefore, it is necessary to increase the density of the local stations based on the given stations in each nation or area.

### 2.1.2 Ground Control Points

Horizontal control points shall be set up as station points in a closed traverse whenever practicable. If field conditions dictate otherwise, control points shall either be tied to the traverse from two different stations or have the angles and distances for single ties measured at least twice. Each control photograph shall be examined carefully in the field to insure that the object described in the photograph is indeed the corresponding object in the field.

Vertical control points shall be set up as turning points on differential level runs. Side shots used for photo control points are not acceptable. Trigonometric leveling is acceptable in lieu of differential leveling if field conditions so dictate. However, all distances shall be measured using electronic distance measuring devices in order to insure that the accuracies listed in Table 2-2 can be obtained.

| MAPPING SCALE | HORIZONTAL | VERTICAL |
|---|---|---|
| 1: 300 | 60 millimeter | 15 -do- |
| 1: 500 | 90-do- | 20 -do- |
| 1: 1 000 | 150-do- | 30 -do- |
| 1: 2,000 | 300 -do- | 90 -do- |
| Note: | Standard error, defined as the square root of the sum of the squares of the errors from "n" measurements divided by "n", in position and elevation of each control point shall not exceed the recommended accuracies shown. | |

TABLE 2.1: RECOMMENDED ACCURACIES

### 2.1.3 Targeting Control Points

Either control points can be pre-targeted (prior to flight), or photo-identifiable points can be selected for use upon viewing existing aerial photographs. The Contractor shall prepare and establish targets in the field for a permanent photographic record to be made by means of aerial photography.

**Targets serve to make evident the locations of control points** so that the existence and position of each point is easily and accurately discernible when its corresponding image is viewed in an aerial photograph. Targets also pinpoint supplemental control points which enable aerial photographs to be oriented within photogrammetric instruments for use in the stereoscopic compilation of map manuscripts. Additional targets will be provided over existing baseline and right of way monuments or control points. This will permit orienting the maps to plan stationing and plan right of way lines.

Targets shall be placed in the median and shoulder zones of the roadway in question and on flat ground whenever practicable. Steep slopes, sharp ridges and ditches should be avoided. All targets shall be placed on contrasting background so as to be readily distinguishable in aerial photographs.

Each target shall be placed with its center directly over and at the exact elevation of the steel rod or other appropriate manifestation of the control point in question. The target legs should not slope appreciably from the center. Normally, target spacing shall be at an interval equal to one-fifth (1/5) of the flight height. However, for those projects where the required flight height is 365 M or less, targets shall be placed so that at least two (2) will appear in the overlap between adjacent photographs.

The recommended guidelines for sizes and center-to-center intervals of white targets have been shown in the table given below. The linear dimensions of a black target should be two to three times those tabulated below to allow for image spread in the aerial negatives.

| MAPPING SCALE | FLIGHT HEIGHT | MAXIMUM INTERVAL | TARGET LEG WIDTH | LEG LENGTH |
|---|---|---|---|---|
| 1:300 | 459 M | 110 M | 0.15 M | 0.6 M |
| 1:500 | 612 M | 192 M | 0.15 M | 0.9 M |
| 1:1 000 | 1 285 M | 384 M | 0.20 M | 1.5 M |
| 1:2,000 | 2 570 M | 768 M | 0.46 M | 3.0 M |

TABLE 2.2: DESIGN GUIDELINES FOR WHITE TARGETS

Target shape shall be in the form of either a symmetrical cross, a "T", or a "Y" in that order of preference. The stem of the "T" and each leg of the "Y" shall be equal in length to one half (1/2) of there commended leg length. Targets shall be prepared by painting or printing them on cardboard, muslin or similar cloth, or they shall be constructed of lime placed on the ground, or they shall be painted on the roadway surface. In all cases, a cross, "T" or "Y" template shall be used as a guide.

## 2.2 Technology Updates for Acquisition of Ground Control Points for Aerial Photography

### 2 .2.1 Virtual Reference Stations

For land-based applications a significant productivity improvement in Real-Time Kinematic (RTK) positioning has been achieved using the concept of a "**Virtual Reference Station**" or VRS. Here observables from a dedicated network of GNSS reference stations are processed to compute the atmospheric and other errors within the network. These are then interpolated to generate a complete set of GNSS observations as if a reference station was located at the rover.

There are a number of significant benefits to a VRS approach:

- Distance to the nearest reference station can be extended well beyond 30 kilometer
- Time to fix integer ambiguities is significantly reduced
- Overall reliability of fixing integer ambiguities increased
- Cost of doing a survey is reduced by eliminating the need to set up dedicated base stations.
- No special processing is required in the RTK engine, as it is the case for a centralized multi-base approach

| Salient Features of VRS | |
|---|---|
| 1 | Real-time positional accuracies using a VRS approach are at the cm RMS level anywhere within the network. |
| 2 | New software is now introduced as post-processed version of VRS technology. Software can be optimized for large changes in altitude by the rover, and extended to work with reference stations separated over very large distances. |
| 3 | With this approach, it is only necessary to be within the network and at least 70 km to the nearest reference station to initially resolve the correct ambiguities. |
| 4 | Once resolved, the aircraft can then fly up to 100 km away from the nearest station within the network, while still achieving positioning accuracy at the 10 - 15 cm RMS level. |
| 5 | It is possible to achieve better than decimeter RMS accuracies with a sparse network of **only 4 reference stations** separated by over 100 km, but the results are highly dependent upon the particular data set. |
| 6 | A rigorous adjustment of all the reference station antenna positions within the selected network over an 18-24 hour period is available. |

TABLE 2.3: FEATURES OF VIRTUAL REFERENCE STATIONS

### 2.2.2 Data Quality Control in VRS

This quality control function ensures that all the reference station data and coordinates are correct and consistent before the rover data is processed. Such a concept is done routinely in land survey as part of best practices, but has been a weak point in the aerial mapping and survey industry.

Too often data from a single reference station or a CORS network are used without proper quality control. Quality failures can include incorrect published antenna coordinates, incorrect datum or poor observables, any of which can result in accuracy and reliability failures in the final product.

But now, this technology enables missions to be flown with bank angles above 20 degrees, with the only restriction that the turns are less than about 70 km from the nearest reference station.

# Appendix-III

## MINISTRY OF DEFENCE INSTRUCTIONS REGARDING AERIAL PHOTOGRAPHY

No.28 (14)/2006-D (GS-III)
Government of India
Ministry of Defence
New Delhi
Dated: the 1st May 2006

To
The Chief Secretaries I
State Governments and Union Territories

Sub: Instructions for Conduct and Clearance of Aerial Photographic Survey/Aircraft Borne Remote Sensing data and Imageries, their acquisitions, storage and issue.

Sir,

In super session of this Ministry's OM No.F.2(2)/55/D(GS-III) dated 28.10.57, F.2(2)/57/D(GS-IV) dated 17.8.61 and 18(8)/82/D(GS-III) dated 31st January 1989, the following instructions are hereby issued for aerial photography/Aircraft Borne Remote Sensing Data and Imageries, their acquisitions, classification, storage and issue:

1. **Application for Aerial Photography / Air Borne Remote Sensing Data and Imageries (ABRSD&I) through Analogue Metric Camera (AMC), Air Borne Laser Terrain Mapping (ALTM), Synthetic Aperture Radar (SAR), Hyper Spectral Scanner (HSS), Geophysical Sensor, Electromagnetic Sensor, Digital Camera or other approved techniques of aerial survey. (Cases for aerial commercial photography for live news to be covered by Director General of Civil Aviation in accordance with Ministry of Defence (MOD) guidelines:-**

   a) Security clearance for Aerial Photographic requirements of agencies other than Survey of India (SOI)/National Remote Sensing Agency (NRSA) for Aerial Photography) of smaller areas.

1.1. All applications (Appendix 'A' attached herewith) for aerial photography/ABRSD&I will be made to the Director General of Civil Aviation (seven copies) at least 6 weeks before the date on which the photography is desired to be carried out. The application must clearly indicate inter alia the purpose for which aerial photography/ABRSD&I is required and details about the flying agency to be engaged for the tasks.

1.2. The Director General of Civil Aviation (DGCA) will make references to the three Service Intelligence Agencies, Intelligence Bureau (IB) and AHA/GSGS simultaneously along with Ministry of Defence/D(GS-III) depicting the area to be photographed. After obtaining the requisite clearance/comments from all concerned, Ministry of Defence / D (GS-III) will issue security clearance for such aerial photography incorporating such condition(s) as deemed necessary.

1.3. The DGCA shall incorporate all the conditions/restrictions as imposed by the Ministry of Defence in their clearance as enumerated above in the flight permit to be issued by them.

b) Security Clearance for Aerial Photographic requirements of SOI/NRSA

1.4. Survey of India (SOI) shall also obtain the security clearance from the Ministry of Defence for aerial photographic requirements projected to them by the Central/State Government Departments/Agencies. After obtaining the clearance from the Ministry of Defence, the aerial photography task may be allotted to IAF/NRSA/other agencies as per clearance obtained. SOI shall directly send application to three Service Intelligence Agencies, IB/MHA, AHQ (GSGS) with copy to MOD(GS-III) and DGCA.

1.5. In case of NRSA/Govt. bodies and the requirements projected to NRSA by the State/Central Government Departments/agencies, the application may be submitted directly to three Service Intelligence Agencies, IB/MHA, AHQ (GSGS) and MOD/D (GS-III) with copy to DGCA for their aerial photographic/remote sensing requirements in respect of those areas for which aerial photographic coverage is not available with the SOI or the existing coverage is not suitable for their purpose.

c) Security clearance for Disaster related activities

1.6. However, in cases of disaster related activities, the following procedure will be followed for NRSA/Govt. agencies:-

i. For disaster-related activities, the NRSA/Govt. agencies will carry out aerial surveys with prior intimation to the MOD and IB/MHA.

ii. In case, the MOD feels the need for a Security Officer on board the aircraft during such survey(s), they may send an officer from the Air Force Station at Hyderabad/Air HQ (Directorate of Intelligence). NRSA's aircraft will be equipped with state-of-the-art positioning systems which will record the track flown by the aircraft. The record will be made available on demand by the IAF.

1.7. A Core Group consisting of members from security agencies would be formed to clear such disaster related data on priority.

1.8. The validity period of the permission for Aerial Photography will be twelve months from the date of issue of the permission by MOD.

**2. Photo-flights and Deployment of Security Officer**

Execution of all types of aerial photography tasks/acquisition of aircraft borne remote sensing data and imageries shall be taken up only after clearance from the Ministry of Defence/D(GS.-III) in all cases except conditions specified in para 1.6 of this OM or when the task is executed by the Indian Air Force.

On such flights, as and when required on security considerations, MOD will depute a suitably briefed security officer to be on-board the aircraft as specified in the clearance note issued by the Ministry of Defence / D(GS-III) based on the information received from various Intelligence Agencies.

Requirement of security officer in case of Central/State Govt./UTs and NRSA may be dispensed with on aerial surveys that do not envisage flying over Vulnerable Areas/Vulnerable Points (Vas/VPs)/Sensitive Areas. In cases where the aerial photography/survey is planned in the vicinity of Vas/VPs, the requirement of the security officer may be assessed accordingly by security agencies. The need for deputing a security officer or otherwise shall be clearly mentioned at the time of conveying approval.

For tasks that are undertaken for the Central/State Governments/UTs and where Vas/VPs are involved, security officers vetted by IB/MHA are required to be detained. MOD may permit deployment of responsible Central/State Govt. security officers in lieu of Defence Security Officer) who shall be overall responsible for conduct of the task in accordance with the MOD clearance/guidelines as per the sensitiveness of the tasks on case to case basis.

The requirement of onboard security officers for aerial photography/aerial surveys carried out by Indian Private operators will be assessed case by case. In case of foreign crew/operators, the requirement of onboard security officer will be mandatory.

Security officer, for task planned to be undertaken close to International Border/ Line of Control/ Coast Line and restricted zone, will be considered by the respective Services (Air Force/Army/Navy) as per the concerned area. Air Force security officer will be detailed for all areas except those areas where army/navy security officers are provided as per the requirement.

In case of special aerial survey other than the aerial photography, where foreign aircrafts/equipments/any advanced technology is being involved, joint inspection by the concerned specialists Govt. agencies will be carried out before the survey task is undertaken.

The duties of the security officer shall be as indicated at Appendix 'B' to these instructions. In exceptional cases, where it is not possible to send a security officer in the aircraft due to paucity of space, the film rolls/photographic storage medium to be used in such flights shall be signed and accounted before and after the flight by the security officer designated for the flight.

**Post Survey Security Vetting and Final Clearance**

All aerial photography/survey tasks will be security vetted by all concerned intelligence and security agencies irrespective of tasks undertaken with or without on board security officer before final classification/clearance. The operators/users will give an undertaking to the effect that under no circumstances they will create any duplicate copy of the aerial photography/ survey data till security vetted by MOD agencies and cleared.

However, MOD may grant waiver in exception to the provisions contained in the para 2.9 above on case to case basis in the following circumstances. MOD shall keep all intelligence agencies informed of such waiver.

a) In case of Disaster related tasks where urgency is considered in national interest.

b) In case of aerial survey/photography undertaken by the Central/State Govt. agencies which does not involve flying over or in vicinity of Vas / VPs / Border / Coastal areas / Restricted Areas, the post vetting of data may be dispensed with one case to case basis provided the aircraft is equipped with state-of-the-art positioning systems which will record the flight track flown by the aircraft and the record of the flight path will be made available to MOD on completion of aerial survey tasks.

In case of private and foreign operators, the surveyed data be processed under the supervision of security officer and the data kept under safe custody till security vetted by

MOD agencies. The processed negatives/prints/digital data will be accounted for in proper ledger form. The operator will indicate, at the time of initial application, the location where the processing of data/aerial photographs will be carried out.

The negatives/digital data depicting the sensitive area/Vas & VPs and other specific areas which were prohibited for photography while according flight clearance and which might have inadvertently been photographed shall be obtained during the post survey security vetting bythe MOD agencies. The original negatives/digital data of the above stated areas will be blacked out/deleted and contact prints, if any, will be destroyed in the presence of the Defence Security Officer.

Where the exposed films or ALTM data/Digital Aerial Image/ special survey data (Geo-physicall/hyper-spectral/electro-magnetic/anyotheradvancedtechnology survey data) have to be conveyed outside India due to non-availability of facilities to develop/process them in the country, Ministry of Defence will be informed by the organization of this fact at the time of seeking initial permission for the task. Ministry of Defence in consultation with Intelligence Agencies will consider grant of clearance accordingly and lay down appropriate conditions in the clearance.

The organization shall abide by all conditions laid down by the Ministry of Defence and shall provide requisite assistance to the Security Officer/representative of the Air HQrs in discharging his duties.

### 3. SECURITY CLASSIFICATION

Aerial photographs/aircraft borne remote sensing data and imageries will be classified on the following basis:

**a) Secret**

i. All IAF airfields and other installations of operational nature

ii. DRDO establishments, Army and Naval Installations/ Ships, Cantonments.

iii. All the civil installations pertaining to energy like atomic energy, oil, thermal/hydel projects and the installations under the Department of Space or the installations which are so recommended by the Ministry of Home Affairs (IB).

**b) Restricted**

i. 50 kms belt along the border and coastline

ii. Areas falling in J&K, North Eastern States, Andaman & Nicobar, Lakshadweep Islands

All civil airfields and other civil installations like steel projects, heavy engineering projects, AIR/Doordarshan installations, fertilizers factories and communication centers or the installations which are so recommended by the Ministry of Home Affairs/IB.

**Note:** All trans-border AP/ABRSD&I will be treated as ‘Restricted’ unless otherwise specified by the Ministry of Defence.

c) Unrestricted:

All AP/ABRSD&I other than those covered by higher classifications will be placed in the 'unrestricted' category which will be indicated on case to case basis while giving the clearance.

d) Aerial photographs/ABRSD&I objects such as mobile military hardware/installations/ships in transit not specifically covered by sub paras (a) & (b) above but which may acquire special security significance under certain circumstances are to be graded in consultation with the appropriate agencies (Air/Army/Naval HQs) and IB for Civil Vas/VPs.

**4. PROCEDURE FOR SECURITY CLASSIFICATION**

Since giving security grading to each photograph of the aerial photography tasks is likely to take some time, an initial security grading for purposes of storage and handling is necessary. The procedure for initial classification shall be as follows:-

**INITIAL CLASSIFICATION**

i. All AP/ ABRSD&I tasks will be initially graded as 'Secret' only. Classification lower than 'Secret' shall not be given except when considered for the unrestricted tasks.

ii. Intelligence Agencies and AHQ/GSGS will submit their recommendations for initial classification (1:50,000 scale map sheets) for the entire country to Director, Survey (Air), Survey of India. They will submit by 30th June every year a list containing 1:50,000 sheet numbers of which aerial photography tasks will be classified (initial classification) as 'Secret'. Aerial photography tasks falling in the remaining sheets will be classified (initial classification) as 'Restricted'.

iii. On the basis of recommendation submitted by the Intelligence and AHQ/GSGS, Director, Survey (Air), Survey of India will inform the flying agencies regarding the issue of task specifications. Director, Survey (Air), Survey of India will indicate the initial security grading of each task to NRSA/Other Agencies at the stage of coverage intimation.

iv. The first set of prints generated by the flying agencies regarding the internal use for the purpose of security, preparation of cover plots, etc. shall bear the initial security classification 'Secret'.

v. The initial classification will remain valid till the final classification is made and intimated to the flying agencies and the scrutinizing offices.

vi. Aerial photographs/imagery/ALTM data/Digital aerial data will not be issued till final classification has been made. However, in case of aerial photographs undertaken on behalf of the Survey of India, the first set of prints generated by the flying agencies may be issued to the scrutinizing officer, viz. Director, Survey (Air), Survey of India and No.12 GASL Platoon, etc.

**FINAL CLASSFICATION**

The following shall be the procedure for final security classification:-

i. All flying agencies including IAF and NRSA will send the cover plots of the aerial survey photography tasks to Director, Survey (Air), Survey of India, immediately after the tasks are completed. Director, Survey (Air), Survey of India will send copies of the cover plots to the three Services Intelligence Agencies, Intelligence Bureau (Ministry of Home Affairs) and AHQ/GSGS and convene meetings periodically during which the representative of the intelligence agencies and AHQ/GSGS will decide on the security grading of each photograph of the entire tasks. In case an Intelligence Agency cannot be represented in the meeting, it must send its comments well in advance to Director, Survey (Air), Survey of India for consideration in the meeting.

ii. Security grading of each photography will be decided as per norms laid down in para 3 above.

iii. Director, Survey (Air), Survey of India will inform the details of the security gradings decided in the meeting to the concerned flying agencies and also the officer carrying out scrutiny who will thereafter incorporate these security grading on each photo negative as well as on each photograph of the first set of the prints.

iv. For aerial photography tasks, which are not indented by Survey of India and carried out by NRSA and other agencies for themselves or for other indenters, similar procedure as out-lined above will be followed. The coordination will be done by NRSA/other agencies at Delhi or Hyderabad NRSA office or any other mutually agreed location to finalize the initial/final security grading after due vetting of each task. In case of NRSA (Govt. tasks) representatives of AHQ/GSGS and Air Hqrs (Dte of Intt) may visit NRSA, Hyderabad to scrutinize and black out/delete the data depicting the sensitive information. After final classification, NRSA/other agencies will send cover plots of the tasks to the Director, Survey (Air), Survey of India for records. No distribution of the products will, however, be made before the final classification is completed.

v. In case of ALTM data/Digital Aerial Image, security clearance will be done through secured automated digital clearance system which will be developed and installed by NRSA. The data will be transferred on line to (a) central agency designated by MOD for undertaking joint clearance or otherwise to various security agencies through secured VPN duly encrypted. The duly vetted/classified data and recommendations for deletion of Vas/VPs shall be transferred back to the data generating agency on line. However, in case where data transfers on line is not possible, the same may be sent on sealed CD/Magnetic storage medium under personal responsibility of the data generating agency or conventional methods of obtaining clearance on hard copies may be followed.

**5. STORAGE AND ISSUE**

i. Negative rolls/digital data shall be classified as per the initial/ final security classification.

ii. All the photography/imagery/remote sensing data will have the security classification in bold capital letters on the reverse centre of every print (unless they are pasted or mounted, in which case it should be marked in top centre to ensure that security classification is visible)/the data storage device (CD/DVD ROMS/DAT drive/Magnetic tapes etc.) and shall be kept in safe custody under authorized official and accounted for.

The digital data stored on hard disk/servers will be password protected and be known to only authorized officials. No unauthorized copies to be made at any stage.

iii. In the case of photographs/imagery/remote sensing data in book form or album from the front and back cover will also be marked as stated above.

iv. All the prints taken should be serially numbered, accounted distribution and list maintained.

v. All transfers of photographs/imagery/remote sensing data between officers or individual holder whether by hand or through registration will be made under proper acquaintances with full signature name and designation of the authorized officials (written legibly).

vi. All the photographs/imagery will be issued against the index form 0.57(P) and properly vouchered for.

vii. If the receipt voucher for photographs/imagery does not reach the issuing authority within a reasonable time, the issuing authority will ascertain whether the document has in fact been received or not.

viii. All the entries in the stock register should be authenticated with the signature of the Officer-in-Charge (who should be Gazetted Officer in the case of Government organization or senior officer in NRSA/other agencies)specially designated by the Head of the organization of photographs. The stock register may be suitably devised to contain all relevant information and technical details pertaining to the aerial photography/survey carried out including tasks/sortie name, number, area covered, date of task, security classification, number of copies and type of survey etc.

ix. An Aerial Imagery Transaction Registry will be maintained by Director, Survey (Air), Survey of India, to keep record of indenters and to monitor the safe custody certificates in respect of classified aerial image data.

**6. CUSTODY AND HANDLING OF AERIAL PHOTOGRAPHS/DATA**

i. "Secret" aerial photographs and remote sensing data/imageries/ALTM data/Digital Aerial Image will be regarded as under the personal charge of the officer to whom their issue is last recorded and by whom a receipt has been given. One copy of the negative/ digital data of the aerial imagery taken by IAF/NRSA/other agencies will be handed over to Director, Survey (Air), Survey of India as record in safe custody.

ii. Other aerial photograph and remote sensing data/imagery will be regarded as on the charge of the person to whom the custody of these documents has been entrusted by the officer in charge of the establishment.

iii. Officer in charge of the photographs and remote sensing data/imagery are personally responsible for their safe custody.

iv. Entry to the areas where photographs and remote sensing data/imagery are stored/handled, should be restricted only to the persons authorized to do so.

v. When an officer who has charge of aerial photographs/ remote sensing data is about to vacate his appointment whether on transfer or on retirement, he/she will hand over both the lists and photographs/remote sensing data/ imagery as per the list to his successor after obtaining a proper receipt under intimation to the issuing authority.

vi. When an officer proceeds on leave not exceeding 15 days, handling or taking over of classified aerial photographs/ imagery/remote sensing data may be left to his discretion.

vii. In the event of a holder being taken ill or dying suddenly, these will be taken over by the new incumbent of the appointment after they have been checked by a Board of Officers. Their findings may be brought to the notice of the issuing authority.

viii. Should it be necessary to transfer photographs/imagery/ remote sensing data from one officer to another, proper handling over certificates must be obtained and forwarded to the issuing authority.

ix. NRSA/other agencies will ensure that the computer on which the ALTM data/ Digital Aerial Image / other surveyed data are stored should be duly password protected and in Stand Alone mode without internet connectivity. The computer system shall be kept in secured environment and entry of unauthorized personnel be prohibited. MOD may review the security arrangements if so desired.

x. For disaster related tasks, NRSA shall be authorized to issue the photographs/ALTM data/Digital Aerial Image to the officers of the Central and State Govt. under the condition that the photographs/data will be strictly for use of the concerned State Govt. and will not be passed on to any agency within or outside the Government. The concerned officer to whom the data is issued will be responsible for safe keeping of the photographs/data. However, if the photographs/data is to be passed on to any nongovernment organization usual procedure will be followed. Director, Survey (Air), Survey of India will maintain data base expressly devoted for monitoring of aerial photographs / imagery collection and supply status. Day-to-Day status of any order should be updated for the indenters to be able to know online.

**7. PERIODICAL CHECKS AND INSPECTION**

The aerial photographs / remote sensing data / imagery will be checked by the custodian annually ending 31st December. Certificate to his effect will be endorsed on the register. The aerial photographs/ remote sensing data/imagery will be recorded in an aerial photography transactions registry maintained by nodal agencies which will be subject to external audit. All the photographs/imagery/remote sensing data held on charge of a particular officer will be checked by a Board of Officers as on 31st December of every year and a certificate to this effect along with a copy of the proceedings submitted to the head of the office by 20th January of the successive year. External Audit of storage and transactions of aerial photographs/digital aerial data should be done every year by the Intelligence Agencies

**8. TIME FRAME FOR COMPLIANCE OF THE PROCEDURE**

8.1 All efforts will be made to adhere to the following time frame prescribed for various steps involved in the procedure –

a) Fifteen working days from the date of receipt of application at MOD/Service Hqrs for initial vetting and grant of permission. For this purpose, the Committee of three services of the armed forces and representatives of IB/MHA may meet twice in a month on designated days at MOD/D(GS-III).

b) Request for on-board officer in accordance to MOD guidelines/clearance must be made with clear fifteen working days prior for detailing in time.

c) Thirty days period for post survey security vetting/clearance and final classification of surveyed data. However, the time frame may vary in some cases based on the quantum of work and other considerations.

## 9. GENERATION OF MAPS AND RECORDS

The policy regarding authorization for generation of maps by various agencies will be broadly covered by the National Map Policy, 2005 approved by the Government.

Yours faithfully,

( S. K. Yagnik )
Director (G)

Copy forwarded to:-

All Ministries/Departments of the Govt. of India
General Staff Branch (MI Directorate)
Army Headquarters, Military Survey
Naval Headquarters, (Naval Intelligence)
Air Headquarters, (Dte. Of Intelligence)
Headquarters, IDS, MOD, New Delhi

Coy also to :-

Surveyor General of India, Dehradun
Director General of Civil Aviation, New Delhi
National Remote Sensing Agency, Hyderabad

MDO LETTER NO.28(14)/2005-D(GS-III)

APPLICATION FOR GRANT OF PERMISSION FOR AERIAL PHOTOGRAPHY/ REMOTE SENSING SURVEY

1. Name and Detail of the company/Agency seeking permission for aerial photography/Remote Sensing Survey with its registered office address:

2. Details of the person(s)/company who is to take photographs/aerial survey on behalf of the agency at para 1 above:

   a) Name (Expanding initials) :

   b) Father's name :

   c) Date and place of birth:

   d) Present address:

   e) Permanent address:

   f) Nationality (if foreigners, information in Sr. No.(g) & (h) may also be provided)

   g) Passport No., date of issue &issuing authority

   h) Visa particulars including type, No., date, validity &issuing office

3. a) Purpose of aerial photography/aerial survey

   b) Objects to be photographed with the exact location (six copies of map scale 1:250,000 or a tracing of the same scale are to be attached) with latitude/longitude:

   c) Scale of Photography

   d) Focal length of camera

   e) Height of the flight

   f) Format size

   g) Type of Camera/sensor being used

   h) Type of data

4. Proposed date when aerial photography/aerial survey is to be undertaken

5. Description of Aircraft, along with the name and address of the pilot and of the owner of the aircraft

6. Name of the Aerodrome to take off

7. In case of the task to be carried out for State/Central Government, the copy of authority from the concerned State Government may be attached

8. If permission is granted, I/we undertake to comply with the following conditions and any other conditions as prescribed:

i. The photography/remote sensing survey will be confined to the exact area as applied and cleared by the Ministry of Defence.

ii. No photography/survey will be undertaken in the area so specified by the Ministry of Defence.

iii. The exact date and time of actual photography/remote sensing survey will be intimated to Air Hqrs (Directorate of Intelligence) at least two weeks in advance to enable them to detail a Security Officer

iv. The Aircraft/helicopter used for aerial photography/remote sensing survey will have seating capacity for Security Officer apart from pilot and photographer.

v. The Security Officer of the Ministry of Defence will accompany the flight undertaken for aerial photography, if considered necessary. The security officer when deputed will initial each film/digital media taken for aerial photography. His decision with regard to all photographic matters shall be final and binding.

vi. We shall take out an insurance policy of Rs.20,00,000 (Rupees twenty lakhs only) in favour of the security officer and assign it to the President of India to indemnify the Govt. of India from any charges on account of non-effective benefits admissible to the Security officer and/or his family in the event of any mishap to the aircraft.

vii. No defence installations will be photographed/over flown unless specifically cleared by the Ministry of Defence

viii. Air Hqrs. (Directorate of Intelligence) will be intimated on completion of photo/survey task and for detailing another Security Officer to check the cover plots/photo products/digital data as required.

ix. In cases where it is not considered necessary to depute security officer by the Ministry of Defence, the exposed film will be processed and plotted but not issued for use till Security vetted by a representative of the Air Hqrs (Directorate of Intelligence)

x. In case so specified by the Ministry of Defence in their clearance letter, the film/digital image after exposure will be processed in the presence of Air Force representative designated who will vet them from security angle before releasing them.

xi. Government will not be liable for any loss or damages of films/digital data while in their custody

xii. Travelling allowance/daily allowance in respect of the Security Officer/Joint Inspection Team (specified by MOD on case to case basis) as admissible under the existing rules will be paid by us.

xiii. Where exposed films/digital data have to be conveyed outside India because facilities to develop/process them do not exist in the country, Ministry of Defence will be informed of this fact at the initial stage of application by us and we undertake to abide by the conditions/arrangements laid down/suggested by the Ministry of Defence.

(Signature of the Applicant)

Dated: …………………

To
The Director General of Civil Aviation
DGCA Complex, Opp Safdarjung Airport,
New Delhi - 110 003.

MOD LETTER NO.28 (14)/2005-D (GS-III)

DUTIES OF SECURITY OFFICER DEPUTED TO BE ON BOARD THE AIRCRAFT DURING AERIAL PHOTOGRAPHY/REMOTE SENSING SURVEYS

1. The Security Officer will be responsible for the overall conduct of the task in accordance with the MOD clearance/guidelines.

2. The Security Officer will ensure the following:-

a) BEFORE FLIGHT

i. The Captain of the aircraft proceeding on survey flight has a valid DGCA permit for undertaking aerial photography/aerial survey of the area and the flight has been duly cleared by the Air Traffic Control.

ii. All the conditions mentioned in the DGCA permit are satisfied.

iii. To check that the aircraft is not carrying any photography sensor other than the one authorized/cleared by MOD.

b) IN FLIGHT

i. The photography is limited to the area cleared for photography/remote sensing.

ii. No Defence installations/Vas & VPs known to the Security Officer are photographed/imaged.

c) AFTER FLIGHT

i. Obtain a certificate from the Captain of the aircraft indicating the details of quantity of recording material i.e. film rolls, discs, digital tape, etc. used during the flight. The recorded/surveyed data will be duly classified as per initial classification in accordance with MOD guidelines.

ii. Submit are port to the Air Hqrs alongwith the traces/maps/areas photographed and the certificates mentioned at sub-para (c) (i) above.

Note 1: When the security officer cannot accompany the flight due to paucity of space, the film rolls/data storage medium will be signed by him before and after the flight and duly accounted for.

Note 2: The flying agency is to ensure that the Captain of the aircraft is in possession of the followingto be shown to the Security Officer on demand:

i. Valid DGCA permit

ii. A copy of the Ministry of Defence clearance

iii. One set of Maps on which the area of photography/survey is marked.

iv. Proof of life insurance coverage for the security officer for an amount of Rs.20, 00,000 (Rupees twenty lakh only).

| S.I. Con… | National Atlas | Census | R.L. Singh | Aro-climatic Regions |
|---|---|---|---|---|
| NORTHERN ZONE | GREAT PLAINS | GREAT PLAINS | GREAT PLAINS | - |
| Western Himalaya | Western Plains | Punjab | Rajasthan Plain | Western Dry Areas |
| Himalaya | Northern Plains | Haryana | Punjab Plain | Trans-Genetic Plain |
| Rajasthan | Eastern Plains | Arid Rajasthan | Upper Ganga Plain | Upper Gangetic Plain |
| Aravalli | - | Upper Ganga | Middle Ganga Plain | Upper Gangetic Plain |

TABLE APP 3.1: IDENTIFICATION OF MESO REGIONS

| Regions | Soils | Above MSL (m) | Cropping/ Farming | Pop. Density /sq km | Rainfall in cm | Land capability |
|---|---|---|---|---|---|---|
| Rajasthan plain | Desert / Greybrown | <150-600 | MF/DF | <100 / E:200-300 | W-E: <20-40 | PL |
| Punjab Plain | OA | 150-300 | GF | E-W: 200-400 | S-N:<40 - >100 | VGL |
| Upper Ganga Plain | YA/Tarai | <150-300 | GF/JF | 500-1000 | SW-N: <80- >100 | VGL |
| Middle Ganga Plain | YA/L | <150 | GF/JF | 500-1000 | >100 | VGL/GL |
| Lower Ganga Plain | YA/L | 0-150 | GF | W-E: 400-1000 | S-N: 100 | VGTL/NGL |
| Assam Valley | YA/Tarai | <150 | GF | NE-W: 100-500 | N: >400 Gauhati<200 | GL |

OA - Old Alluvial; YA - Young Alluvial; L-Lateritic; GF- Grain Farming; MF - Millet Farming; GL-Good Land; VGL Very Good Land; MGL - Moderately Good Land;

TABLE APP 3.2: MESO REGIONS OF INDIA

Cartosat Data Utilisation for 1:10,000 Topographic Mapping

To meet the national requirement to develop Large Scale National Topographic Data base (LSNTDB) to support the planning development activities, ISRO/NRSC has taken up the Large Scale Mapping (LSM) activity for creation of cartographic geospatial database using high resolution satellite data under Cartosat data utilization program. In pilot phase of LSM different mapping methods and standards were established suite terrain relief (table -1) and also accomplished topographic mapping of 6000 sq. km. on 1:10,000 scale covering 40 sites in different parts of India.

| No. | Terrain/Type | Mapping/Map updating Procedure |
|---|---|---|
| 1 | High relief areas and metro cities | 3D mapping from Stereo high resolution satellite data |
| 2 | Relatively flat areas | 2D mapping from monocular high resolution satellite data |
| 3 | Moderately relief areas | 2D mapping from ortho-image generated from monocular high resolution satellite and external DEM |
| 4 | Existing digital 2D maps | 2D map updating using monocular high resolution satellite data |
| 5 | Existing digital 3D maps | 3D map updating using Stereo high resolution satellite data |

TABLE APP 3.3: MAPPING METHODS

Cartosat -1/2 datasets were used in many operational projects like Jaipur, Hyderabad, Rajkot and a few towns of HP for preparation of 1:10,000 scale topographic mapping. Further, a committee with members from SOI, NSDI, ISRO/DOS, MOD was set up under DST"s OM No.SM/13/09/2008 dated 21.11.2008 for assessing the technological suitability of high resolution satellite imagery for preparation of 1:10 K topographical maps pertaining to entire India. To demonstrate the capabilities/suitability of Cartosat data, Chairman ISRO, Director NRSC has suggested to take an operational project on 1:10K topographic mapping from Cartosat data of Jagat singhpur district, Orissa.

### Brief Methodology

The area of extent for Jagat singhpur district (3020 sq. km) covers 15 stereo scenes of Cartosat-1. The parameters to be considered for the procurement of the data are:

1. Cartosat-1 Stereo orthokit product, Cloud cover or fog over the area of interest: Less than 10%

2. Spatial reference: Horizontal datum is WGS 84Ellipsoid and Vertical Datum is orthometric heights and UTM Projection

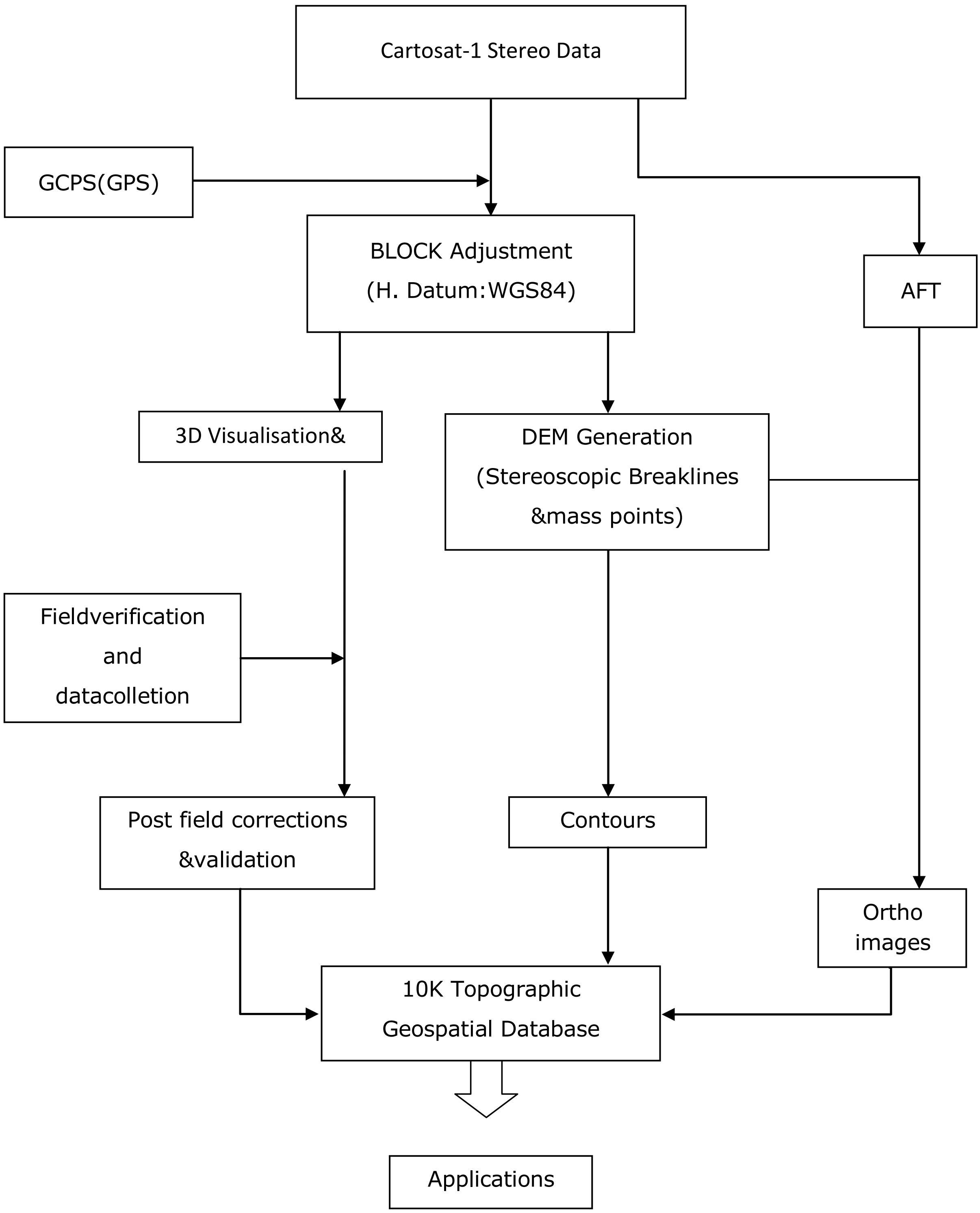



FIGURE 3.1: FLOW CHART FOR 1:10000 SCALE MAPPING USING CARTOSAT-1 DATA

# Appendix-IV

## DATA MODEL

### TABLE 4.1 - SETTLEMENTS AND CULTURAL DETAILS

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| Building Footprint | Building Footprint hidden or missing from Level 0 | (Class) | (Sub-Class) | (Ownership) | (No. of Floors, Name, Address) |
| | | Residential | | Central Govt. | |
| | | | House Living | State Govt. | |
| | | | | PSU | |
| | | | | NGO | |
| | | | | Private | |
| | | FinanceBanks | | | |
| | | | Nationalized Bank | | |
| | | | Private Bank | | |
| | | | Chit Funds | | |
| | | | Others | | |
| | | Farms | | | |
| | | | Poultry Farm | | |
| | | | Dairy Farm | | |
| | | | Vegetable | | |
| | | | Others | | |
| | | Recreation | | | |
| | | | Cinema | | |
| | | | Theatre | | |
| | | | Community Centre | | |
| | | | Library | | |
| | | | Club | | |
| | | | TV station | | |
| | | | TV Tower | | |
| | | | Radio station | | |
| | | | Film city | | |
| | | | Film Studio | | |
| | | | TV studio | | |
| | | | Parks | | |
| | | | Others | | |
| | | Business | | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| | | | Trade Centre | | |
| | | | Show rooms | | |
| | | | Retail outlets | | |
| | | | Service Centre | | |
| | | | Cold Storage | | |
| | | | Ware house | | |
| | | | Others | | |
| | | Hotel | | | |
| | | | Star Hotels | | |
| | | | Other Hotels | | |
| | | | Motel | | |
| | | | Lodge | | |
| | | | Dharmshala | | |
| | | | Restaurant | | |
| | | | Dhaba | | |
| | | | Mess | | |
| | | | Others | | |
| | | Hostel | | | |
| | | | School / college | | |
| | | | Working women | | |
| | | | Youth Hostel | | |
| | | | Others | | |
| | | Guest house | | | |
| | | | Govt. | | |
| | | | Private | | |
| | | | Semi - Government | | |
| | | IT Park | | | |
| | | Others | | | |
| | | Offices | | | |
| | | | State Govt. | | |
| | | | Central Govt. | | |
| | | | Union Territory | | |
| | | | Semi- Government | | |
| | | | Embassies | | |
| | | | Private | | |
| | | Court | | | |
| | | | Supreme Court | | |
| | | | High Court | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| | | | District Court | | |
| | | | Metropolitan/city Court | | |
| | | | Session Court | | |
| | | | CAT | | |
| | | | SAT | | |
| | | | Consumer Court | | |
| | | Police station | | | |
| | | Police Outpost /Chauki | | | |
| | | Post Office | | | |
| | | Telegraph Office | | | |
| | | Jail | | | |
| | | Defence | | | |
| | | Paramilitary Forces | | | |
| | | | CRPF | | |
| | | | BSF | | |
| | | | ITBP | | |
| | | | CISF | | |
| | | | SSB | | |
| | | | AR | | |
| | | | Others | | |
| | | Religious | | | |
| | | | Temple | | |
| | | | Chhatri | | |
| | | | Gopuram | | |
| | | | Mosque | | |
| | | | Idgah | | |
| | | | Tomb | | |
| | | | Shrine | | |
| | | | Church | | |
| | | | Christian Memorial | | |
| | | | Gurudwara | | |
| | | | Buddhist Kyaung | | |
| | | | Pagoda | | |
| | | | Ashram/ Matha | | |
| | | | Others | | |
| | | Antiquities | | | |
| | | | Palace | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| | | | Fort | | |
| | | | Cave | | |
| | | | Battle field | | |
| | | | Monument | | |
| | | | Mughal Kos Pillar | | |
| | | | Deserted site | | |
| | | | Watch tower | | |
| | | | Museum | | |
| | | Utility Center | | | |
| | | | Airline Booking Office | | |
| | | | Rail Reservation Office | | |
| | | | Bus booking center | | |
| | | | Marriage/Banquet Hall | | |
| | | | Telephone Booth | | |
| | | | Milk Booth | | |
| | | | Bill Payment Centre | | |
| | | | Post Box | | |
| | | | ATM Centre | | |
| | | | Public Toilet | | |
| | | | Medicine shop | | |
| | | | Courier service | | |
| | | | Cable service | | |
| | | | Cyber Cafe | | |
| | | | Travel Agency | | |
| | | | Any other | | |
| | | Educational Institution | | | |
| | | | Nursery | Govt./Private | |
| | | | Kinder Garden | Govt./Private | |
| | | | Primary School | Govt./Private | |
| | | | Upper Primary | Govt./Private | |
| | | | High school | Govt./Private | |
| | | | University | Govt./Private | |
| | | | General College | Govt./Private | |
| | | | Engineering college | Govt./Private | |
| | | | Medical College | Govt./Private | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| | | | Management College | Govt./Private | |
| | | | Law College | Govt./Private | |
| | | | Biotechnology | Govt./Private | |
| | | | Finance | Govt./Private | |
| | | | Polytechnic | Govt./Private | |
| | | | ITI | Govt./Private | |
| | | | Others | Govt./Private | |
| | | | Coaching centre | Govt./Private | |
| | | Other Institutions | | | |
| | | | Aanganbadi | | |
| | | Welfare/relief/ health care | | | |
| | | | Dispensary/PHC | Govt./Private | |
| | | | Clinic | Govt./Private | |
| | | | Hospital | Govt./Private | |
| | | | Blood Bank | Govt./Private | |
| | | | Veterinary Hospital | Govt./Private | |
| | | | Veterinary Dispensary | Govt./Private | |
| | | | Cyclone shelter | Govt./Private | |
| | | | Old Age Home | Govt./Private | |
| | | | Orphanage | Govt./Private | |
| | | | Relief camps | Govt./Private | |
| | | | Rehabilitation Centre | Govt./Private | |
| | | | Social welfare centre | Govt./Private | |
| | | | Ambulance service | Govt./Private | |
| | | | Fire station | Govt./Private | |
| | | | Human rights offices | Govt./Private | |
| | | | Grave Yard | | |
| | | | Others | Govt./Private | |
| | | | Wall | | |
| | | | Fence | | |
| | | | Hedge | | |
| | | | Others | | |

TABLE 4.2 – HYDROGRAPHY

| Level 0 (2D Feature extraction) | Level 1 (Ground truthing) | Attribute1 | Attribute2 (Name) | Attribute3 (Name) |
|---|---|---|---|---|
| Inland Water bodies | | | | |
| STREAMS | | (Classification) | | |
| | | Perennial | | |
| | | Non Perennial | | |
| RIVERS | | | | |
| River Bank | | (Classification) | (Relative Height) | |
| | | Bank Broken | | |
| Centre Line of River < 3 m | | | | |
| River bed/ Water Body features | | (Classification) | | |
| Both banks > 3m | | | | |
| | | Sand | | |
| | | Rocks | | |
| Reservoir | | | | |
| Lake | | | | |
| Pond | | | | |
| Tank | | | | |
| Abandoned Quarry with water | | | | |
| | Spring | (Classification) | | |
| | | Thermal | | |
| | | Mineral | | |
| | | Extinct | | |
| | Fountain | | | |
| River/ Stream/ Waterbody features | | | | |
| River island | | | | |
| Water channel | | | | |
| Water Limit | | | | |
| | Waterfall | | | |
| | Rapid | | | |
| Irrigation Structures | | | | |
| Dam | | (Classification) | | |
| | | Masonary | | |
| | | Rockfilled | | |
| | | Earth | | |
| | River Training Works and Embankments | | | |
| | Guide Bank | | | |
| | Pitched Bank | | | |

| Level 0 (2D Feature extraction) | Level 1 (Ground truthing) | Attribute1 | Attribute2 (Name) | Attribute3 (Name) |
|---|---|---|---|---|
| | Protective Embankment | | | |
| | Km stone on Protective Embankment | | | |
| Canals | | (Classification) | (Status) | (Perenniality) |
| Both banks> 3m | | Main | Under Construction | Permanent |
| | | Branch | Disused | Seasonal |
| | | Major Distributary | | |
| | | Minor Distributary | | |
| | | Field Channel | | |
| | | Field Drain | | |
| Canal Bank | | | | |
| Centre Line of Canal <3m | | | | |
| | Tunnel | | | |
| | Canal Features | | | |
| | Communication Works | | (Location) | |
| | Viaduct | | On Road | |
| | Road Siphon | | On Railways | |
| | Cart/ Cattle/ Animal Pass | | | |
| | Distance Stone on canals | | | |
| | Cross Drainage Works | | | |
| | Aqueduct | | | |
| | Drainage Siphon | | | |
| | Super-passage | | | |
| | Level Crossing | | | |
| | Regulation Works | | | |
| | Distributary Head Regulator | | | |
| | Cross Regulator | | | |
| | Navigation Lock | | | |
| | Flood Gate | | | |
| | Tide Gate | | | |
| | Falls | | | |
| | Escapes | | | |
| | Sluice | | | |
| | Canal Headworks | | | |
| | Weir | | | |
| | Barrage | | | |
| | Canal Head Regulator | | | |

TABLE 4.3 - OCEAN COASTLINE FEATURES

| Level 0 (2D Feature extraction) | Level 1 (Ground Truthing) | Level 3 | Level 4 |
|---|---|---|---|
| | Coast Line | | |
| | High Water Line | | |
| | Low Water Line | | |
| Coastal Water Bodies | | | |
| Tidal Stream | | | |
| Tidal River | | | |
| Tidal River Bank | | | |
| Centre Line of Tidal River | | | |
| Ocean/Sea/ Gulf/ Bay | | | |
| Lagoon | | | |
| Creek | | | |
| Estuary/ Kayal | | | |
| | Backwaters | | |
| | Coastal Natural Features | | |
| | Coastal Island formed by HW Line | | |
| | Cliff along coast | | |
| | Rock submerged with danger line | | |
| Coastal Man made features | | | |
| | Anchorage | | |
| | Beacon, Steamer Signal, Navigation Mark | (Illumination) | |
| | | Lighted | |
| | | Unlighted | |
| Jetty | | (Classification) | |
| | | Open | |
| | | Masonary | |
| | Pier | (Classification) | |
| | | With Berth | |
| | | Without Berth | |
| | Light house | | |
| | Lightship | | |
| | Buoy | (Illumination) | |
| | | Unlighted | |
| | | Lighted | |
| | Tide Gauge | | |

Table 4.4 – TRANSPORTATION

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| Road < 3 m (Center line) | | (Class) | (No. of Lanes) | (Name) | (Surface) |
| | | Express high way | | | Black Topped |
| | | National high way | | | Cement Concrete |
| | | State highway | | | WBM |
| | | Major District road | | | Earthern |
| | | Other District Road | | | |
| | | Urban Roads | | | |
| | | Rural Roads | | | |
| | | Village Road | | | |
| | | By-Pass | | | |
| | | Service Road | | | |
| | | Service Lane | | | |
| Road > 3m (Both Edges) | | | | | |
| | Road Infrastructure | | | | |
| | Pavement | | | | |
| | Traffic signal light post | | | | |
| | Traffic signal | | | | |
| Traffic island | | | | | |
| | Tunnel | (Name) | | | |
| | Bridge | (Bridge Number) | | | |
| | Distance | (Number) | | | |
| | Stone | | | | |
| | Causeway | | | | |
| Flyover | Flyover | | | | |
| | Subway | | | | |
| | Cant (Elevated Wall) | | | | |
| | Embankment | | | | |
| | Cutting | | | | |
| Level Crossing | | | | | |
| | Toll gate | (Number of passages) | | | |
| | Pass | | | | |
| Speed Bump/ Speed Hump | Speed Bump/ Speed Hump | | | | |
| Median strip | Median strip | | | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| Tracks | | | | | |
| | Track Infrastructure | | | | |
| | Bridge | | | | |
| | Distance Stone | (Number) | | | |
| | Ford | | | | |
| | Ferry | | | | |
| | Transport Utilities | | | | |
| | Bus Stop/Shelter | | | | |
| Car Park | Car Park | | | | |
| | weigh station or Weigh Bridge | | | | |
| Railway | | (Class) | (No. of Lines) | (Electrified) | |
| | | Broad Gauge | Single Line | Yes | |
| | | Narrow Gauge | Double Line | No | |
| | | Other Gauge | Multiline | | |
| Metro Rail Overground | | | (No. of Lines) | | |
| | | | Single Line | | |
| | | | Double Line | | |
| | Metro Rail Underground | | (No. of Lines) | | |
| | | | Single | | |
| | | | Double | | |
| Mono Rail | | | | | |
| Railway Siding | | | | | |
| Railway Infrastructures | | | | | |
| Platform | | | | | |
| Platform crossing bridge | | | | | |
| | Station Building | (Station Name) | (Underground /Overground) | | |
| | | | Yes | | |
| | | | No | | |
| | Distance Stone | | | | |
| | Bridge | | | | |
| Level Crossing | | (Control) | | | |
| | | Manned | | | |
| | | Un manned | | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 | Attribute 3 | Attribute 4 |
|---|---|---|---|---|---|
| | Tunnel | (Number) | | | |
| | Electric Sub station | | | | |
| | Signal Cabin | | | | |
| | Carriage Shade or House | | | | |
| Railway Embankment & Cuttings | | (Height) | | | |
| | Embankment | | | | |
| | Cutting | | | | |
| Air Port | | | | | |
| RunWay | | | | | |
| Aerodrome limit | | (Walled) | | | |
| | | Yes | | | |
| | | No | | | |
| | Aerodrome | | | | |
| Air traffic control (ATC) Tower | | | | | |
| Landing ground limit | | (Walled) | | | |
| | | Yes | | | |
| | | No | | | |
| Landing ground strip | | | | | |
| | Helipad | | | | |
| | Steamer Service | | | | |
| | Steamer route | | | | |
| | Steamer station | | | | |
| | Steamer signal post | | | | |

TABLE 4.5 - LAND COVER/LAND USE

| **Level 0 (2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 (Name) | Attribute 3 |
|---|---|---|---|---|
| **Built- up Area** | | | | |
| | | Residential Area | | |
| | | Industrial Area | | |
| | | Commercial Area | | |
| | | Bus terminus area | | |
| | | Railway Yards | | |

| **Level 0 (2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 (Name) | Attribute 3 |
|---|---|---|---|---|
| | | Air Port area | | |
| | | Harbor Port area | | |
| | | InstitutionalArea | | |
| | | Religious Area | | |
| | | Recreational Area | | |
| | | Public/Semi Public Area | | |
| | | Open Space / Vacant Land Area | | |
| | | Other Area | | |
| | | Mixed Area | | |
| | | Mondi or bazar | | |
| Cultivation Area | | | | |
| Plantation Area | | (Type of Plantation) | | |
| | | Tea, Coffee, Spices, Rubber, Coconut, Arecanut, Citrus Wood Land, Bamboo, Casuarina, Conifer, Cactus, Plantain, Betelnut, Palm (palm oil), Medicinal Plants, Nursery, Fruits, Avenue of Trees, Grass etc. | | |
| | Aquaculture | | | |
| Forest Area | | (Density) | | |
| | | Open | | |
| | | Dense | | |
| Scrub Area | | | | |
| Wastelands | | | | |
| Rann Dry | | | | |
| Coastal sand unsubmerged | | | | |
| | Gullied/ Ravenous Land / Broken Ground | | | |
| | Broken Ground along Coast | | | |
| | Barren Land | | | |
| Sandy-deserted Land | | | | |
| | Mining/Industrial waste Land | | | |
| | Barren Rocky/Stony waste/ Sheet Rock | | | |

| **Level 0 (2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1 | Attribute 2 (Name) | Attribute 3 |
|---|---|---|---|---|
| Inland Wetlands | | | | |
| Water-Logged | | | | |
| Marshy/Swamp | | | | |
| Ox-Bow Lakes | | | | |
| Reeds | | | | |
| Coastal Wetlands | | | | |
| Rann Wet | Rann Wet | | | |
| Marsh Vegetation | Marsh Vegetation | | | |
| Mangrove swamp | Mangrove swamp | | | |
| Algae | Algae | | | |
| Mudflat | Mudflat | | | |
| High Tidal Flat-with salt encrustations | High Tidal Flat-with salt encrustations | | | |
| Sand submerged | Sand submerged | | | |
| Spit | Spit | | | |
| Bar | Bar | | | |
| Shoals | Shoals | | | |
| Beach Ridges | Beach Ridges | | | |
| Plantations on sand | Plantations on sand | | | |
| Coral-Reef | Coral-Reef | | | |
| Rocky Coast | Rocky Coast | | | |
| Grass Land/ Grazing Land | | | | |
| Snow Cover | | | | |
| Quarries | | | | |

TABLE 4.6 : UTILITIES

| Level 0 **(2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1(Class) | Attribute 2(Sub-Class) | Attribute 3(Ownership ) | Attribute 4(Name with Address) |
|---|---|---|---|---|---|
| | Transmission Line | | | | |
| | Telephone Line | Underground Line | | | |
| | | Overhead Line | | | |
| | Telephone Line Infrastructure | | | | |
| | Telephone Pole | | | | |

| Level 0 (2D Feature Extraction) | Level 1 (Ground truthing) | Attribute 1 (Class) | Attribute 2 (Sub-Class) | Attribute 3 (Ownership) | Attribute 4 (Name with Address) |
|---|---|---|---|---|---|
| | Cable Joint Chamber | | | | |
| | Communication Tower | | | | |
| | Telephone Exchange | | | | |
| | Telephone Net Junction | | | | |
| | Power Line | (Classification as per Transmission Voltage) | (Transmission Voltage) | (Classification Usage) | |
| | | Extra High Voltage (EHV) | | Domestic | |
| | | High Tension (HT) | | Industrial | |
| | | Low Tension (LT) | | Commercial | |
| | | | | Agricultural | |
| Power Line infrastructure | Power Line infrastructure | | | | |
| | Pylon Tower | | | | |
| Pylon | Pylon | | | | |
| | Pole | | | | |
| Grid Substation | Grid Substation | | | | |
| | Electric Substation | | | | |
| | Transformer | | | | |
| | Electric Lamp Post | | | | |
| | Electric Power Plant | (Classification) | | | |
| | | Thermal | | | |
| | | Nuclear | | | |
| | | Hydel | | | |
| | | Solar | | | |
| | | BioGas | | | |
| | | Bio Fuel | | | |
| | | Wind Mill | | | |
| Pipe Line | Pipe Line | | | | |
| | Gas Pipe Line | (Classification) | (Gas Transmitted) | | |
| | | Main Line | CNG | | |
| | | Locality Distributaries | LPG | | |

| Level 0 **(2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1 (Class) | Attribute 2 (Sub-Class) | Attribute 3 (Ownership) | Attribute 4 (Name with Address) |
|---|---|---|---|---|---|
| | | Minor Distributaries | | | |
| | Water Pipe Line | (Classification) | (Classification as per Usage) | | |
| | | Main Line | Industrial | | |
| | | Locality Distributaries | Commercial | | |
| | | Minor Distributaries | Domestic | | |
| | | | Agriculture | | |
| | Water Pipe Line Infrastructure | | | | |
| | Pump House | | | | |
| | Water Treatment Plant | | | | |
| | Pumping Station | | | | |
| | Karez | (Usage) | | | |
| | | Used | | | |
| | | Disused | | | |
| | Navigation Lock | | | | |
| | Oil Pipe Line | | | | |
| Oil Pipe Line Infrastructure | | | | | |
| Oil Storage Tanks | | | | | |
| Oil Refinery | Water Utility | | | | |
| | Well | | | | |
| | Tube Well | | | | |
| | Hand Pump | | | | |
| | Water Tank | (Classification) | | | |
| | | Ground Level | | | |
| | | Overhead | | | |
| | | Underground | | | |
| | Man Holes | | | | |
| | Sewerage Line | | | | |
| | Main Sewerage Line | | | | |
| | Connected Sewerage Line | | | | |
| | Sewerage Infrastructure | | | | |
| | Man Holes | | | | |

| Level 0 **(2D Feature Extraction)** | Level 1 (Ground truthing) | Attribute 1 (Class) | Attribute 2 (Sub-Class) | Attribute 3 (Ownership) | Attribute 4 (Name with Address) |
|---|---|---|---|---|---|
| | Net Junctions | | | | |
| | Utility Stations | | | | |
| | Pumping Station | | | | |
| | Sewerage Treatment Plant | | | | |
| | Sanitary Landfill | | | | |
| | Water harvesting structure | | | | |
| Storm Water Drain Line | | (Construction Material) | (No. of Lines) | | |
| Surface Drain | | Gutter | Single | | |
| | Underground Drain | Stone | Double | | |
| Slope Drain | | Paved | | | |
| | Storm Drain Water Infrastructure | Masonary | | | |
| | Storm Drain Inlet | | | | |
| | Storm Drain Manhole | | | | |
| | Filling Station | (Fuel) | | | |
| Conveyor Belt | Conveyor Belt | | | | |
| | Ropeway | | | | |
| | Solid Waste Management | | | | |
| Solid Waste Site | Solid Waste Site | (Classification) | | | |
| | | Compositing Site | | | |
| | | Dumping Yard | | | |
| | | Landfill | | | |
| | Solid waste collection points | (Classification) | | | |
| | | Primary | | | |
| | | Secondary | | | |

TABLE 4.7 - GOVERNMENT/ADMINISTRATIVE/FOREST BOUNDARIES

| Level 0 (2D Feature extraction) | Level 1 (Ground Truthing) | Attribute1 | Attributes2 |
|---|---|---|---|
| | International | | |
| | International Bdy. | | |
| | Line of Control | | |

| Level 0<br>(2D Feature extraction) | Level 1<br>(Ground Truthing) | Attribute1 | Attributes2 |
|---|---|---|---|
| | Line of Actual Control | | |
| | International Boundary Pillar | (Number) | |
| | Observation post | | |
| | Boundary fence | | |
| | State | | |
| | State Boundary | (Name) | |
| | State Boundary Pillar | (Number) | |
| | District | | |
| | District Boundary | (Name) | |
| | District Boundary Pillar | (Number) | |
| | Subdivision | | |
| | Subdivision Boundary | (Name) | |
| | Subdivision Boundary Pillar | (Number) | |
| | Tahsil/Taluk/Mandal/Pragana | | |
| | Block | (Name) | |
| | Village | | |
| | Revenue Village Boundary | (Name) | |
| | Panchayat Boundary | (Name) | |
| | Village Boundary Pillar | (Number) | |
| | Urban Boundaries | | |
| | Cantonment Bdy | (Name) | |
| | Municipal/Corporation Boundary | (Name) | |
| | Constituency | | |
| | Assembly | (Name) | |
| | Parliamentary | (Name) | |
| | Police Station Limit | (Name) | |
| | Forest Boundary | | |
| | Reserved | (Name) | |
| | Protected | (Name) | |
| | Forest Boundary Pillar | (Number) | |

# Appendix-V

## TECHNICAL STRENGTH OF SURVEY OF INDIA

As has been discussed earlier, aim of the National Mission is for generating the National Topographical Database (NTDB) of the entire country on 1: 10,000 scale. Each of these steps and the method of their execution are as given below:

### 5.1 Procurement of Suitable Satellite Imagery

The following satellite imageries have been considered appropriate for the generation of 1:10,000 NTDB.

a) Cartosat stereo satellite imagery with 2.5 m resolution for forest area (6.24 lakh sq.km), too many details are not required. Hence, Cartosat stereo imagery is considered adequate for these areas. QuickbirdPAN sharpened (0.61m resolution) multi-spectral mono-satellite imagery may also be used.

b) Worldview satellite imagery with 0.5 m resolution.

For the rest of the country (26.64 lakh sq.km.) Stereo Satellite Images with approximately 100% overlap over the AOI are to be used with:

- stereo metadata file (.STE)
- collection angles (Convergence Angle, BIE and Asymmetry)
- Tasking Order
- Product Size (Worldview)
- Min size: 17.6 x 14km and
- Max size: Up to 17.6 x 28km

Each component is its own file and comes with its own Rapid Positioning Capability, also called Rational Polynomial Coefficients (RPC).

### 5.2 Provision of Ground Control Points

International Terrestrial Reference Frame (ITRF) is a realization of International Terrestrial Reference System (ITRS), which is a definition of geocentric system adopted and maintained by International Earth Rotation and Reference Systems Service (IERS).IERS was established in 1987on the basis of the resolutions by IUGG and IAG. The origin of the system is the centre of mass of the Earth. The unit of length is meter. The orientation of the axes was established as consistent with that of IERS‟s predecessor, Bureau International de l‟Heure, BIH, in 1984. The Z-axis is the line from the Earth‟s centre of mass through the Conventional International Origin (CIO). Between 1900 and 1905, the mean position of the Earth‟s rotational pole was designated as the Conventional Terrestrial Pole (CTP). The X-axis is the line from the centre through the intersection of the zero meridian with the equator. The Y-axis is the line from the centre to equator and perpendicular to X axis to make a right handed system. ITRF is a set of points with their 3-dimensional Cartesian coordinates and velocities, which realizes an ideal reference system, the International Terrestrial Reference System. Each ITRF is identified by the digits of the year as ITRFyy e.g. ITRF97, ITRF2000 etc. The latest is ITRF2005 which has the epoch 1st January 2000. For realization the different techniques are used: Very Long Baseline Interferometry (VLBI), Lunar Laser Ranging (LLR), Satellite Laser Ranging (SLR), Global Positioning System (GPS) and Doppler Ranging Integrated on Satellite (DORIS). Each has strengths and weaknesses - their combination produces a strong multi-purpose Terrestrial Reference Frame (TRF). ITRF is the best geodetic reference frame currently available. The GRS80 ellipsoid is recommended by IERS to transform Cartesian coordinates to latitude and longitude.

## 5.3 Densification of Geocentric Geodetic Datum

The number of stations directly realized by the geocentric geodetic system is not enough for practical use. Worldwide, there are several hundred realized stations in ITRF and about twenty stations in WGS84. Therefore, it is necessary to increase the density of the local stations based on the given stations in each nation or area. Examples of densification projects are NAD83 in North America, SIRGAS in South America and ETRF in Europe.

## 5.4 International Scenario

Most of the international community is switching over to the geocentric reference system. The GRS67, GRS80, WGS84 and ITRS are results of the efforts to arrive at the best possible geocentric system. The developed countries have already defined their datum on geocentric system. Some of the developing countries are on the way of finaliszing their datum. At the XX General Assembly of the International Union of Geodesists and Geophysicists (IUGG) in 1992, the International Association of Geodesy (IAG) made the following recommendations in its Resolution no. 1[IAG, 1992]:

“1) that groups making highly accurate geodetic, geodynamic or oceanographic analysis should either use the ITRF directly or carefully tie their own systems to it”

“2) that for high accuracy in continental areas, a system moving with a rigid [tectonic] plate may be used to eliminate unnecessary velocities provided it coincides exactly with the ITRS at a specific epoch,”

It is clear that these recommendations allow for the use of other systems provided they are carefully tied to the ITRS. It is also to be noted that in ITRF the motions of the individual tectonic plates will cause horizontal coordinates to constantly change in time. It is therefore necessary to specify which epoch ITRF coordinates refer to and to account for tectonic motion when changing epochs. The countries defining their own datum connect it with ITRF to comply with the above recommendations of IAG.

## 5.5 Establishment of Indian Geodetic Datum 2007 (IGD-2008) Strategy

The ideal solution for the present scenario may be establishment of the datum based on dense network of Permanently Operating GPS Stations. This provides the users an easy and quick access to the control. Developed countries like USA and Canada have thousands of such stations in the form of CORS and CACS respectively. However, for a developing country like India, it is not practicable to establish thousands of permanent GPS stations with facilities to transmit the differential corrections. It requires huge amount of money to establish and maintain such a system. The best option for India is to have a balanced approach using available permanent GPS stations along with dense network of campaign mode stations.

## 5.6 Observation Techniques

In India, the only space-based technique available at present is Global Positioning System. So, the establishment of IGD2008 will be based on the GPS technique. In future, if VLBI stations are set up in India, they will be used as the highest accuracy points along with the GPS stations to connect the Indian datum with ITRF as other developed countries have also done.

## 5.7 Data Sources

Realization of a geodetic datum requires the setting up of an accurate national network of control points. It should include all the continuously operating GPS stations and the campaign mode ground control points. India has the data sources in the form of permanent GPS stations, GPS stations at tidal observatories and campaign mode stations of GCP Library.

## 5.8 Permanent GPS Stations

India has a dedicated network of 41 permanent GPS stations out of which 5 are maintained by Survey of India and rest by other government and autonomous organizations like Wadia Institute of Himalayan Geology (WIHG), Geological Survey of India (GSI), Indian Institute of Geomagnetism (IIG), Indian Institute of Astrophysics (IIA) and several other organizations. These Permanent GPS stations have been established to monitor the Geo-Tectonic activities in the country as a long term program funded by the Department of Science and Technology, Govt. of India. GPS data from all these stations is received in the National GPS Data Centre, Geodetic Research Branch, Survey of India. All these stations will be used for realization of the datum. All such stations can be termed 'as Continuously Operating Reference Stations' (CORS).

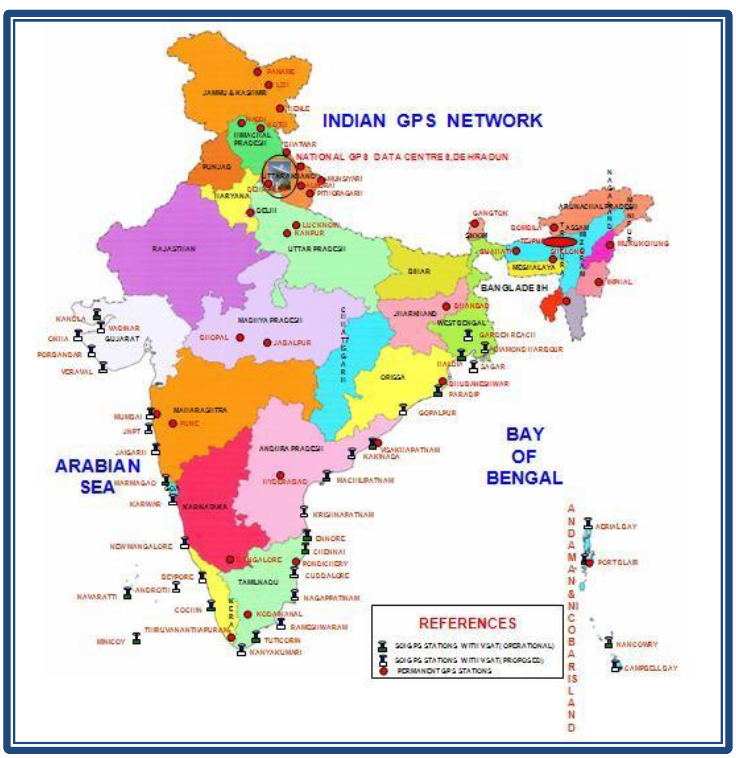



FIGURE 5.1: INDIAN CORS NETWORK

## 5.9 Continuously Operating Reference Stations in India

| | | | |
|---|---|---|---|
| Aizwal | Dhanbad | Kothi | Pondicherry |
| Almora | Gulmarg | Kolhapur | Port Blair |
| Anini | Gangtok | Leh | Pune |
| Bhatwari | Guwahati | Lucknow | Rajkot |
| Bhopal | Hanle | Mumbai | Shillong |
| Bhubaneshwar | Imphal | Munsiari | Tezpur |
| Bomdila | Jabalpur | Naddi | Trivendrum |
| Chitrakut | Jaipur | Nagpur | Tirunelveli |
| Dehradun (SOI) | Kanpur | Panamik | Visakhapatnam |
| Dehradun (WIHG) | Kodaikanal | Pithoragarh | Lumami |
| Delhi | | | |

TABLE5.1: LIST OF CORS STATIONS IN INDIA

## 5. 10 GPS Stations at Tidal Observatories

In addition to the Permanent GPS stations, there are 14 GPS Stations maintained by Survey of India at Tidal Observatories, which have been established as part a of modernization of Indian Tide Gauge Network. These tidal observatories are equipped with real time transmission facilities through dedicated VSAT network. GPS data is transmitted in real time to National GPS Data Centre. Few more GPS receivers will be added to this network very soon.

| | | | |
|---|---|---|---|
| Kandla | Kawaratti | Machhilipatanam | Port Blair |
| Marmagoa | Minicoy | Vishakhapatanam | Nancowry |
| Cochin | Tuticorin | Paradeep | |
| Chennai | Ennore | Haldia | |

TABLE 5.2: GPS TIDAL OBSERVATORIES

FIGURE 5.2: VSAT ANTENNA AT GEODETIC & RESEARCH BRANCH, DEHRADUN FOR CONTINUOUSLY RECEIVING DATA FROM REMOTE LOCATIONS

## 5.11 Ground Control Points Library

Initiation of the GCP Library project has paved way for the realization of Indian Horizontal Datum IHD-2008, as it was commenced for setting up of precise and consistent framework of reference points in Geocentric Co-ordinate System spread across the entire country. Setting up of the GCP Library is planned to be completed in three phases:

Phase I:, 300 Zero Order (highest precision) Ground Control Points at spacing of 250-300 km has already been recently established in Geocentric Coordinate System for the whole country. These Zero order Control points define the Indian horizontal geodetic datum. GPS observations are carried out for 72 hours at these stations and their locations are independently computed using 3 to 4 IGS (International GPS Service) stations which define the International Geocentric Reference frame ITRF - YY where 'YY' represent the epoch. The latitude and the longitude of the Zero order Control points are computed using Scientific GPS software Bernese to an accuracy of mili arc second amounting to 3 cm on ground. In addition to having precise horizontal coordinates (latitude and longitude) they are also provided with precise heights above mean sea level using leveling - Job has been completed.

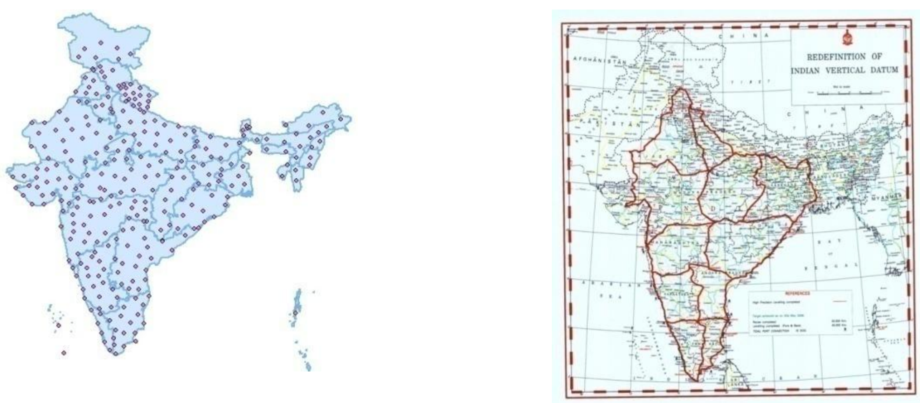



FIGURE 5.3: INDIAN GCP LIBRARY

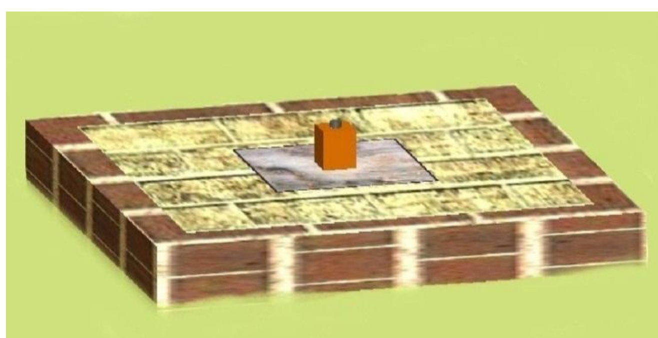


FIGURE 5.4: MONUMENT DATA PROCESSING

## 5.12 Design of GCP Library Phase-I Monument -Data Processing and Adjustment

Connection with ITRF

As per the IAG recommendations, the datum will be connected with ITRF. India has two IGS stations, one at Bangalore (IISC) and another at Hyderabad (HYDE). In addition to these, the IGS stations available around the Indian subcontinent Beijing (BJFS), Ankara (ANKR), Wuhan (WUHN), Lhasa (LHAS), Poligan /

Bishkek (POL2) and Kitab (KIT3) will also be used as fiducial points. The Indian Permanent GPS Stations will be connected with these IGS stations to get the datum in terms of ITRF.

## First Adjustment

**Phase-I:** The GCP Library stations were observed independently and the data had been processed with respect to IGS stations to determine the coordinates in terms of ITRF. These coordinates can be used for general mapping purposes until the datum is realized. The network adjustment has to be carried now. As already mentioned above, the GCP Library Phase-I stations were observed independently and not in well defined network mode. For adjustment, a network was required to be formed. When the Continuously Operating Reference Stations are included in the network, hundreds of baselines are formed by the common observations among CORS and Phase-I GCPs. By carefully selecting few hundred baselines out of these baselines, a network of more than 300 interconnected triangles was formed. The network is formed in such a way that all the GCPs and most of the Continuously Operating Reference Stations are connected.

In the first step, all the baselines are being computed using Bernese GPS Data Processing Software. The second step will be connecting the CORS to the IGS stations. This is necessary to connect the Indian datum with the ITRF as per the IAG recommendations. The CORS network will be adjusted and coordinates will be computed on the epoch 1st January 2007, taking the IGS stations as fiducial stations. This will be done using scientific GPS data processing software Bernese 5.0. The CORS will then be used as known stations and the GCP Phase-I network will be adjusted. The slope distances will be computed using Bernese 5.0 and will be reduced to ellipsoidal arc distances using a computer program. These ellipsoidal arc distances will be taken as observables and the adjustment will be carried out using ADJUST program developed by National Geodetic Survey (NGS), USA and freely available on the internet. This realization will be based on ITRF2005 which has the epoch 1st January 2000. Using the velocity model, the epoch of this realization will be kept as 1st January 2007.

**Phase II:** Additional 2200 GCPs of First Order Ground Control Points will be established at an average of 30 km spacing all over the country. GPS observations are carried out for 6-8 hours at these stations and the base lines are computed using adjustment software. The station coordinates are adjusted with Zero order control points as per usual survey principle “whole to part” .The expected accuracy of horizontal coordinate is in the order of 0``.002 amounting to 6 cms on ground. The First order control points will be connected by leveling .Work on this under progress. It can be completed in 12 months, if top priority is given to this job and some tasks/resources are outsourced and extra equipments are procured urgently.

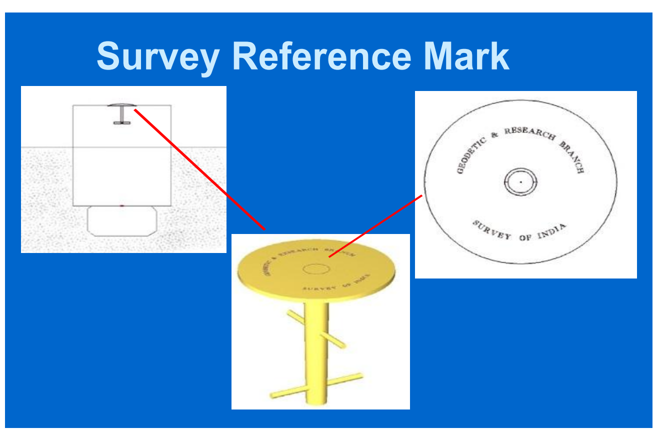



FIGURE 5.5: REFERENCE MARK

**Phase III (image control points):** Each image scene will require at least five GCPs for geo-referencing. It will require approx 25,500 GCP sat a spacing of 10 km (approx) to cover 1000 scenes of Cartosat and 7440 scenes of Worldview.1-2 hours GPS observations will be carried out at these points depending on the baseline length from first order GCPs and will be processed in office using specialized software. If required GCPs may be adjusted with zero order control points. The expected accuracy of coordinates is in the order of approximately 25 cm on ground. Offsets for providing GCPs are to be avoided. GCPs observation and adjustment should be part of the integrated network of zero and first order GPS network of triangles. Location of GCPs can only be decided by marking them first on imageries after their availability. This is a huge task and can be completed by outsourcing only. This phase III job can be started after the availability of imageries and phase II GCPs whichever is later. By employing 80 teams along with vehicle, the job can be completed in 1 year time. By outsourcing some of the tasks this job can be completed in 9 months time.

## Block Adjustment

As it has been proposed to use digital photogrammetry techniques in generation of the large scale maps, Survey of India will carry out block adjustment for mapping and generate digital terrain model. Block adjustment is done to reference the satellite imageries with the ground and bring all the satellite imageries in the same national reference frame. Digital Terrain Model is created to remove the distortion due to height variation from the satellite imageries and to create ortho images. DEM is a different product which can be subsequently used for terrain analysis and it can also be used as an input in GIS data in unrestricted zone. The fundamental concepts involved in block triangulation, DEM generation and ortho rectification are detailed below:

### Block Triangulation

Block triangulation is the process of establishing a mathematical relationship between the imageries contained in a project, the sensor model, and the ground. Once the relationship has been defined, accurate imagery and geographic information concerning the Earth's surface can be created.

The information resulting from block triangulation is required as input for the orthorectification, DEM creation, and stereopair creation processes. With the advent of digital photogrammetry, classic aerial triangulation has been extended to provide greater functionality. Mathematical technique known as block adjustment provides three primary functions:

- Block adjustment determines the position and orientation sensor model in a project as they existed at the time of image exposure. The resulting parameters are referred to as exterior orientation parameters. Block adjustment determines the ground coordinates of any tie points manually or automatically measured on the overlap areas of multiple images. The highly precise ground point determination of tie points is useful for generating control points from imagery in lieu of ground surveying techniques. Additionally, if a large number of ground points are generated, then a DEM can be interpolated using the 3D surfacing.

- Block adjustment minimizes and distributes the errors associated with the imagery, image measurements, GCPs, and so forth. The block adjustment processes information from an entire block of imagery in one simultaneous solution (i.e., a bundle) using statistical techniques (i.e., adjustment component) to automatically identify, distribute, and remove error. Because the images are processed in one step, the misalignment issues associated with creating mosaics are resolved.

Satellite Photogrammetry

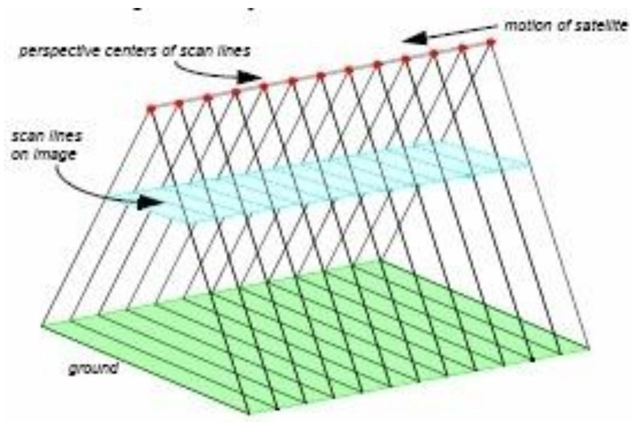



FIGURE5.6: **INTERIOR ORIENTATION IN SATELLITE IMAGERY SCENE**

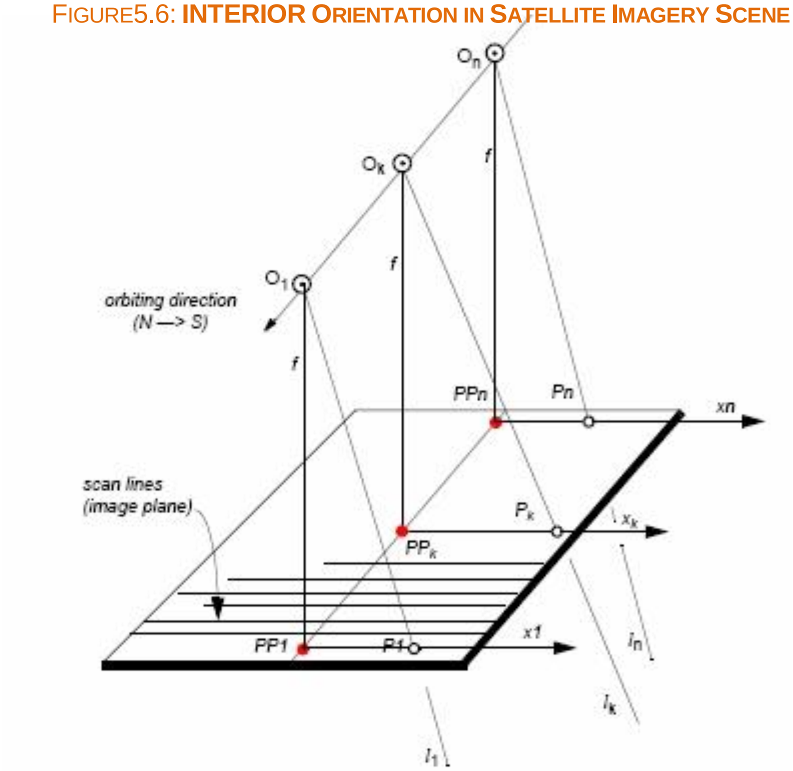



FIGURE 5.7: **IMAGING PROCEDURE**

For each scan line,a separate bundle of light rays is defined,

WherePk = image point

Xk = x value of image coordinates for scan line,

kf = focal length of the camera

Ok = perspective center for scan line k, aligned along the orbit

PPk = principal point for scan line k

Lk = light rays for scan line, bundled at perspective center Ok

## Exterior orientation in satellite imagery

Satellite geometry is stable, and the sensor parameters, such as focal length, are well-known. However, the triangulation of scenes is somewhat unstable because of the narrow, almost parallel bundles of light rays. Ephemeris data for the orbit are available in the header file of SPOT scenes. They give the satellite's position in three-dimensional, geocentric coordinates at incremental intervals. The velocity vector and some rotational velocities relating to the attitude of the camera are given, as well as the exact time of the center scan line of the scene. The header of the data file of an Imagery scene contains ephemeris data, which provides information about the recording of the data and the satellite orbit. Ephemeris data that can be used in satellite triangulation include:

- position of the satellite in geocentric coordinates (with the origin at the center of the Earth) to the nearest second
- velocity vector, which is the direction of the satellite's travel
- altitude changes of the camera
- time of exposure (exact) of the center scan line of the scene

The geocentric coordinates included with the ephemeris data are converted to a local ground system for use in triangulation. The center of a satellite scene is interpolated from the header data. Light rays in a bundle defined by the satellite sensor are almost parallel, lessening the importance of the satellite's position. Instead, the inclination angles (incidence angles) of the cameras onboard the satellite become the critical data. Inclination is the angle between a vertical on the ground at the center of the scene and a light ray from the exposure station. This angle defines the degree of off-nadir viewing when the scene was recorded.

A stereo scene is achieved when two images of the same area are acquired by different sensors at different inclination angles. For this to occur, there must be significant differences in the inclination angles. Satellite block triangulation provides a model for calculating the spatial relationship between a satellite sensor and the ground coordinate system for each line of data. This relationship is expressed as the exterior orientation, which consists of:

- the perspective center of the center scan line (i.e., X, Y, and Z),
- the change of perspective centers along the orbit,
- the three rotations of the center scan line (i.e., omega, phi, and kappa), and
- the changes of angles along the orbit.

In addition to fitting the bundle of light rays to the known points, satellite block triangulation also accounts for the motion of the satellite by determining the relationship of the perspective centers and rotation angles of the scan lines. It is assumed that the satellite travels in a smooth motion as a scene is being scanned. Therefore, once the exterior orientation of the center scan line is determined, the exterior orientation of any other scan line is calculated based on the distance of that scan line from the center and the changes of the perspective center location and rotation angles.

Bundle adjustment for triangulating a satellite scene is similar to the bundle adjustment used for aerial images. A least squares adjustment is used to derive a set of parameters that comes the closest to fit the control points to their known ground coordinates, and to intersect tie points.

The resulting parameters of satellite bundle adjustment are:

- ground coordinates of the perspective center of the center scan line rotation angles for thecenter scan line coefficients, from which the perspective center and
- rotation angles of all other scan lines are calculated
- ground coordinates of all tie points

**Collinearity equation and satellite block triangulation**

Modified collinearity equations are used to compute the exterior orientation parameters associated with the respective scan lines in the satellite scenes. Each scan line has a unique perspective center and individual rotation angles. When the satellite moves from one scan line to the next, these parameters change. Due to the smooth motion of the satellite in orbit, the changes are small and can be modeled by low-order polynomial functions.

## 5.13 Digital Terrain Model (DTM) and Digital Surface Model (DSM)

A digital terrain model (DTM) is a 3D digital representation of the Earth's terrain or topography. Automatic DTM extraction involves the automatic extraction of elevation information from imagery and the subsequent creation of a 3D digital representation of the Earth's surface. A DTM represents the elevation associated with the Earth's topography and not necessarily the human-made (e.g., buildings) or natural (e.g., trees) features located on the Earth's surface.

A digital surface model (DSM) represents the elevation associated with the Earth's surface including topography and all natural or human-made features located on the Earth's surface. The primary difference between a DSM and a DTM is that the DTM represents the Earth's terrain whereas a DSM represents the Earth's surface. Figure below illustrates a DSM.

DIGITAL SURFACE MODEL OF AN AREADTM OF SAME AREA

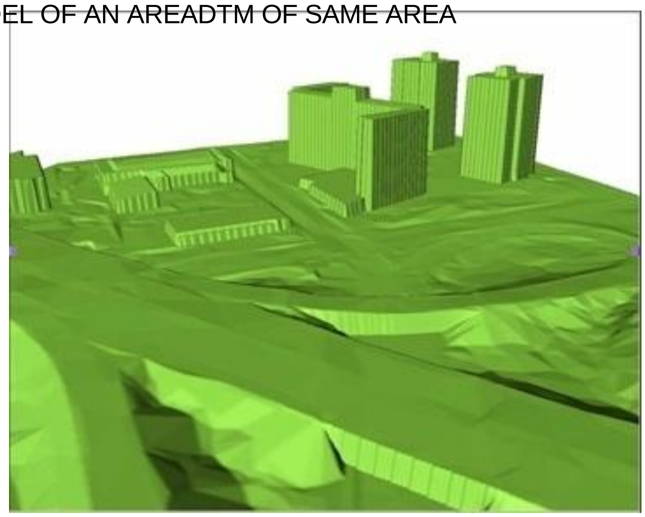


FIGURE 5.8: DSM MODELING

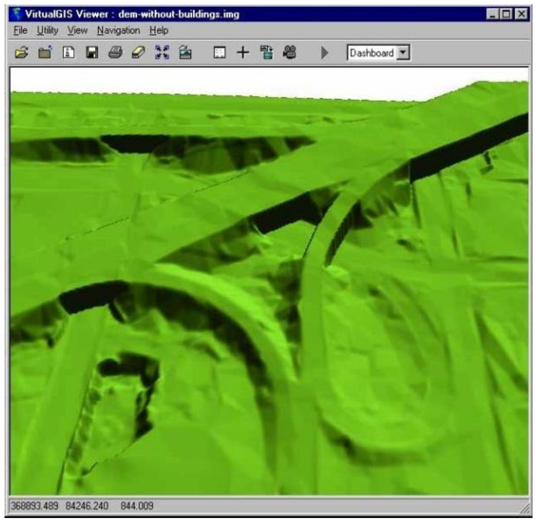



FIGURE 5.9: DTM MODELING

Digital Photogrammetry allows for the automatic extraction of DSMs and DTMs. In order to automatically extract topography only, specific parameters governing the elevation extraction process must be specified. However, typically additional editing outside of the DTM extraction process is required to obtain a 3D topographic representation only. This process is referred to as DTM editing. DTM editing techniques are used to remove invalid elevation points in order to create an accurate representation of the Earth's topography and surface.

Imagery serves as the primary source of data input for the automatic extraction of DTMs. DTMs can only be extracted if two or more overlapping images are available. Prior to the automatic extraction of DTMs, sensor model information associated with an image must be available. This includes internal and external sensor model information.

Using Ortho BASE Pro, the interior orientation of an image must be defined and the exterior orientation of the image must be estimated or known from another source such as airborne GPS/INS. Without the internal and external sensor model information establishment, elevation information cannot be extracted from overlapping images.

**Why are DTM's required?**

Topography governs many of the processes associated with the Earth and its geography. GIS professionals involved with mapping and geographical modeling must be able to accurately represent the Earth's surface. Inadequate and inaccurate representations can lead to poor decisions that can negatively impact our environment and the associated human, cultural, and physical landscape. DTMs are required as a necessary form of input for:

- Determining the extent of a watershed. Combining DTMs over a large region, a DTM is used as a primary source of input for determining the extent of a watershed.
- Extracting a drainage network for a watershed. Many GIS packages automatically delineate a drainage network using a DTM, primarily a DEM, as a primary source of input.
- Determining the slope associated with a geographic region. Slope is required when designing road networks, pipeline infrastructure, and various other forms of rural and urban infrastructure.

- Determining the aspect associated with a geographic region. Aspect illustrates and displays the direction of a slope. Aspect influences the growth of vegetation due to the availability of sunlight, the location of real estate, and intervisibility studies.

- Modeling and planning for telecommunications. A height model is required as a primary source of input for planning the location of radio antennas and performing point-to-point analysis for wireless communications.

- Orthorectifying. The orthorectification process requires highly accurate DTMs for the creation of map-accurate imagery for use in a GIS. Using DTMs lessens the effect of topographic relief displacement on raw imagery.

- Preparing 3D Simulations. DTMs are the fundamental data source required for preparing 3D perspectives and flight simulations. Without DTMs, 3D simulations cannot be created.

- Analyzing Volumetric Change. Comparing DTMs of a region from different time periods allows for the computation of volumetric change (e.g., cut and fill).

- Estimating River Channel Change. Rates of river channel erosion and deposition can be estimated using DTMs extracted from imagery collected at various time periods.

- Creating Contour Maps. Contour maps can be derived from DTMs. Using a series of mass points, contour lines for a given range in elevation can be automatically extracted.

In general, DTMs are a first generation data product derived from imagery using the principles of 3D geographic imaging. Second generation data products such as slope and aspect images, contour maps, and volumetric change analyses can be derived from DTMs for use in various GIS and engineering applications.

**Control for satellite block triangulation**

Both GCPs and tie points can be used for satellite block triangulation of a stereo scene. For triangulating a single scene, only GCPs are used. In this case, space resection techniques are used to compute the exterior orientation parameters associated with the satellite as they existed at the time of image capture. A minimum of six GCPs is necessary. Ten or more GCPs are recommended to obtain a good triangulation result. The best locations for GCPs in the scene are shown in Figure below.

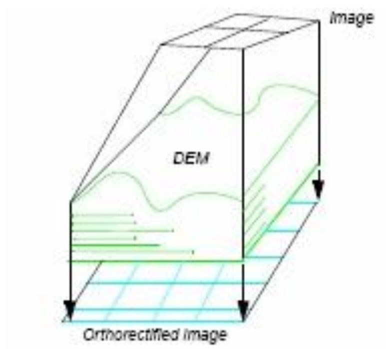
## 5.14 Orthorectification

Orthorectification is the process of reducing geometric errors inherent within photography and imagery. The variables contributing to geometric errors include, but are not limited to:

- camera and sensor orientation
- systematic error associated with the camera or sensor
- topographic relief displacement
- Earth curvature

By performing block triangulation or single frame resection, the parameters associated with camera and sensor orientation are defined. Utilizing least squares adjustment techniques during block triangulation minimizes the errors associated with camera or sensor instability. Additionally,the use of self-calibrating bundle adjustment (SCBA) techniques along withAdditional Parameter (AP) modeling accounts for the systematic errors associated with camera interior geometry. The effects of the Earth's curvature are significant if a large photo block or satellite imagery is involved. They are accounted for during the block triangulation procedure by setting the proper option. The effects of topographic relief displacement are accounted for by utilizing a DEM during the orthorectification procedure.

The orthorectification process takes the raw digital imagery and applies a DEM and triangulation results to create an orthorectified image. Once an orthorectified image is created, each pixel within the image possesses geometric fidelity. Thus, measurements taken off an orthorectified image represent the corresponding measurements as if they were taken on the Earth's surface (see Figure below).




An image or photograph with an orthographic projection is one for which every point looks as if an observer were looking straight down at it, along a line of sight that is orthogonal (perpendicular) to the Earth. The resulting orthorectified image is known as a digital ortho image (see Figure below).

Relief displacement is corrected by taking each pixel of a DEM and finding the equivalent position in the satellite or aerial image. A brightness value is determined for this location based on resampling of the surrounding pixels. The brightness value, elevation, and exterior orientation information are used to calculate the equivalent location in the ortho image file.

After the block adjustment, digital terrain model and ortho rectified images will be generated for data acquisition.

(a) **Cartosat Imagery**

| | |
|---|---|
| Total Area to be covered | = 6.24 Lakh/Sq Kms |
| Area covered by one scene | = 700 sq. km |
| No. of scene (including overlaps) | = 1,000 Nos (Approx) |
| Georeferencing, DEM generation & Ortho photo generation | = Two days per scene |

(b) **View World Imagery**

| | |
|---|---|
| Total Area to be covered | = 26 Lakh / SqKms |
| Area covered by one scene | = 420 sq. km |
| No. of scene (including overlaps) | = 7440 Nos. (Approx.) |
| Geo-referencing, DEM generation & Ortho photo generation | = Two daysper scene |
| Ortho mosaicing as per Sheet layout | = One day per scene |

Total of 1270 man/ months are required to complete the task. By using 140 photogrammetric workstations in double shifts, this task can be completed in 5 months time.

## 5.15 Feature Extraction and Database Generation

Feature extraction for 1:10 K mapping will be done from ortho rectified images. Feature extraction is a systematic collection of all details appearing on ground which are also visible on the ortho rectified imagery by digitization into vector form, i.e. conversion of data from raster to vector. Feature extraction will be carried out as per the standards set by Survey of India as Survey of India is responsible for the Quality Control and Standardization of the entire data base. Features will be extracted from ortho images to create digital topographical data base as per the data model list is enclosed. Feature Extraction in restricted areas will be carried out in Survey of India premises. The feature extractions in un-restricted areas will be carried out at the vendor's site. Guidelines for 2D feature extraction can be worked out.

**FIGURE 5.10 (A, B): ORTHO IMAGERY**

## 5.16 Ground Truthing and Attribute Collection

Ground truthing and attribute are to be done by the same Industry which has carried out feature collection. After the feature extraction, the topographical data needs to be verified in the limited manner to the extent of picking up missing details on the ground, correction of misclassification of features and also attribute information (Toponomyetc) is to be collected on ground. Field verification will preferably be carried out by using latest techniques such as Tablet PC integrated with GPS and attribute collection as per the list attached at Appendix- IV

Limited field verification for ground truth and attribute data collection will be carried out simultaneously on paper plots covering area of 5Km X 5Km, one for each sheet. The paper plots will be generated from the 2D feature collection and will contain all features, point, line and area with feature IDs printed on each feature. Each feature will be verified on the ground for the classification accorded to the feature during digitization and if necessary the classification will be altered as per ground truth.

The important missing features such as main power lines, distance stones etc. will be added as per list under level 1 of data model structure enclosed as Appendix- 'A'. Dummy / Arbitrary will be given to such additional features collected in the field. Attribute of each feature will be collected as per list given under level 2 of data model structure enclosed as APPENDIX 'A'. The feature list given at a APPENDIX' A' also contains all features with attributes, classified as Vital Areas, Vital Points/Installation. After the ground truthing and attribute collection, the industry will be required to submit the entire database to SOI for security vetting. SOI will ensure that all Vital Areas & Vital Points as finalized by MOD and National Map Policy are removed from database which is to be made available in public domain.

# Appendix-VI

## POSSIBLE PPP MODEL WITH SOI UNDER NEW MAP POLICY

It may be opportune at this moment, for better appreciation of the constraints of the SOI, to briefly dwell upon the various processes and procedures followed for the generation of a base map by the SOI. The primary source for generation of map is “Aerial Photographs” (AP’s).Securing AP’s itself is a tedious and time consuming process. First a dedicated aircraft with special fitments has to be available. Aircrafts are available only with the IAF, which insists for a rigorous security regime entailing a slew of clearances. On the day of aerial surveys, the sky has to be cloud free. In fact, there is an extremely narrow window of 30 days or so, when we have cloud free days within the year. It is reasonable and realistic to presume that aerial survey of the entire country can take a minimum of 3 years. In order to get a 3 dimensional view of each “scene” on the ground, which is a must for vertical elevations of the ground (contours), we should have image of the same area from two vantage points thereby enabling “stereoscopic vision”. The AP’s so obtained have to be corrected for a series of noise errors for relief distortions. After completion of all these processes, we get what are known as “orthophoto images”. It is from orthophotos that we derive maps after extensive ground truthing aided with the use of Ground Control Points (GCP’s). A summarized version of this elaborate and sequential process is given below:

i. Procurement of AP’s

ii. Providing Ground Control Points (GCP’s)

iii. Geo-rectification of AP’s

iv. Generation of Digital Elevation Model (DEM) and Orthophotos

v. Conversion of images from raster to vector form

vi. Collection of attribute data

vii. Ground truthing

viii. Attachment of Attribute Data

ix. Data archival, management

It is strict adherence to a well laid out protocol, consisting of hierarchical verifications, that the SOI maps so generated are extremely accurate. While accuracy is the strength of SOI, its bane is slowness. The country can’t wait for decades for larger scale and updated base maps. It is impossible to flog the SOI to run faster because of a number of inherent constraints. Firstly, in survey and mapping, a lot of technological changes have already come and the sector continues to advance technologically in leaps and bounds. New hardware and software, which replaces human drudgery, fatigue and error are coming and getting obsolete by newer ones. Government procurement can’t keep pace with this. Even when procured, usage of these hard/software use constant and continuous training, which a decimated and ageing organization (average age is above 50years) like SOI can ill afford.

## Opportunity cost of not having accurate and up-to-date maps

It is said that geographical location is the fourth "driver" of any investment decision, the others being cost, revenue and benefits. No prudent investor can wish away the need of maps. If not available, he will make by undertaking own surveys. Apart from causing delays and cost escalations, such maps are low quality and not geo-referenced, which can't be used by anybody else or even by the same investor for his subsequent expansion. There is thus tremendous duplication of survey and mapping in the country. If accurate, up-to-date and geo-referenced base maps are readily available, the invest or can have the map of his "theme" generated expeditiously and without costs. Such investors are umpteen and there are enough private players who can generate the "theme maps" out of the base maps. Therefore, infrastructure development and growth of GT sector in a country are synergistically related.

## The National Map Policy, 2005

The Government of India, taking cognizance of the situation prevailing in the geospatial sector promulgated, in the year 2005, a National Map Policy for India. In broad terms, it seeks to reconcile the concerns of national security and the needs of sustainable development. The twin objectives of the NMP are (i) To provide, maintain and allow access and make available the National Topographic Database (NTDB) of the SOI conforming to national standards; and (ii) To promote the use of geospatial knowledge and intelligence through partnerships and other mechanisms by all sections of the society and work towards a knowledge- based society. To ensure that in furtherance of the new policy, national security objectives are fully safeguarded, there will be two series of maps called the Defence Series maps (on Everest/WGS 84 Datum and Polyconic/UTM Projection) and Open Series Maps in UTM Projection and WGS 84 datum. The OSM's are primarily for supporting development activities in the country and will have no VA's and VP's shown. The Ministry of Defence shall give a one-time clearance to these OSM's upon which they become unrestricted for use and value addition in the open domain.

## The volume of work

The creation of the NTDB on 1:10,000 scale is a mammoth task. This is quite clear, even mechanically going by the number of sheets required to cover the entire country against each scale, as given below;

| Scale | No. of Sheets |
|---|---|
| 1 : 10,000 | 1,32,000 |
| 1 : 25,000 | 19,343 |
| 1 : 50,000 | 5,060 |
| 1 : 250,000 | 394 |
| 1 : 1 Million | 36 |

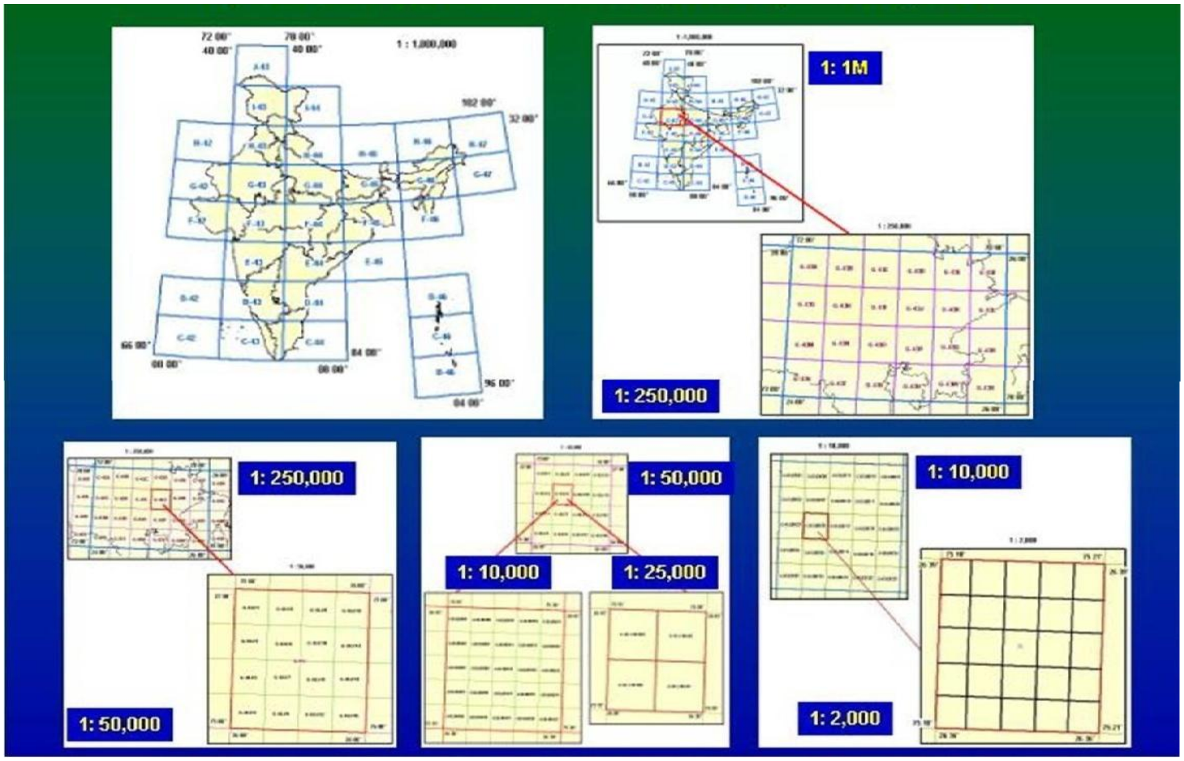



FIGURE 6.1: MAMMOTH SCALE OF MAPPING TASK

#### LAY OUT OF SHEETS

The SOI had a strength of around 28,000 employees during 1970s and 1980s - the period in which the survey and mapping for the NTDB on 1:50,000 was undertaken and completed. Assuming the same conditions and technology regime, a rough estimate shows that SOI will take not less than half a century to complete the task of making the NTDB on 1: 10,000 scale. The assumption made above is not true; technology has vastly improved - this is a positive change. But the negative changes are too many. The strength of SOI has gradually reduced to 13000employees in 1999. The ban on fresh recruitment has caused further decimation - it stands as 7000 in July 2008. With every passing month, it is further reducing due to superannuation. Average age of existing employees has also increased considerably. The overgrown employees can’t catch up with the technological upheavals taking place in the sector. Secondly, the SOI is deploying its considerable strength for discharging its sovereign functions like completion of national priority projects like joint surveys of international boundaries, publishing of OSM/DSM on 1:50K scale, village boundary database, large scale mapping for metros and cities, preparing and printing of geographical maps, creation of high precision GCP library, redefinition of vertical datum, geoid modeling, modernization of Tide Gauge network for Early Tsunami Warning System, standardization of geographical names and completion of various projects for Planning Commission (NIC), NUIS, MOEF, 3-D mapping of Delhi, engineering projects like Hydro electricproject/tunnel alignment etc. It is abundantly clear from the quantum of the work and that the SOI, by itself, will not be able to complete the work given its constraining factors. Innovations in both technology and management are required to accomplish the task.

#### SATELLITE STEREO IMAGES TO BE USED AS INPUTS

The most crucial input in map making is availability of latest aerial photographs. As mentioned earlier, it is a futile exercise to attempt expediting this process. Alternatives need to be pursued - this is the technological innovation to be employed. Fortunately, modern remote sensing satellite products are now available which give stereo images and which have enough accuracy standards required. Cartosat (Indian satellite meant for cartographic purposes with accuracy of7.5 meters and resolution of 2.5 meters) and Worldview (US satellite for cartographic purposes with accuracy of 1.5 meters and resolution of 50 cm) can easily replace aerial photographs for generating the NTDB of 1: 10,000 scale. SOI has already carried out trials using Cartosat and has yielded positive and encouraging results. Switch over to satellite imagery shall be the most revolutionary and path breaking decision to aid in the expeditious generation and regular updating of the NTDB.

### ELICITING PRIVATE PARTICIPATION

The management innovation, which can be brought about is bringing private participation. Further, encouragement of private participation is a major objective of the National Map Policy, 2005. Therefore, in conformity with and in pursuance of the NMP, the private sector could be pressed into a fruitful partnership with the SOI in the generation of the NTDB on 1: 10,000 scale. The basic approach in the partnership will be for SOI to retain all core (strategic) functions in map making, while the repetitive, yet laborious and non strategic functions will be opened to the private sector through a transparent and competitive bidding procedure. The PPP model envisaged here will have the following components and structure;

a) use suitable and appropriate satellite stereo images instead of aerial photographs as the input for generation of maps;

b) identify the principal steps of generation of maps from satellite stereo images and divide these steps into core (or strategic) steps and into routine (or non strategic) steps;

c) entrust the core steps with the SOI and routine steps to the private sector;

d) require the SOI to ensure quality checks at all stages;

e) stipulate that SOI shall have ownership rights over the entire database and the private party ownership rights on unrestricted areas in which it had performed the steps as mentioned in (c) along with the SOI. It is more appropriately to be termed as “co-ownership” rather than “joint ownership”.

f) envisage that the respective owners can do value addition, resell the data complying with guidelines, rules and regulations as may be prescribed by the Government from time to time. This may therefore, conform to a BUILD, OWN, OPERATE (BOO) model.

While it is clear that SOI can’t accomplish the task, still two more questions need to be addressed. The first one is; why this can’t be done by the private sector alone? There are also strong reasons for not giving this work entirely to the private sector. Firstly there are security considerations. The MHA and the MoD are the main arbiters in security perceptions. The country as a whole consisting of 3.3 million sq. km has 1.1 million sq km as “restricted areas”, the maps of which can’t be handled by any private person without express permission of the Government. The NMP, 2005 recognizes and acknowledges this fact. Information as regards the Ground Control Points (GCP’s) are also important and sensitive information. Any person who has details of all GCP information can make detailed maps of the country with data from foreign satellites. Similarly, gravity data, tide data and elevation data has defence implications. These items of information, important as they are, will be held by SOI exclusively as part of its sovereign functions and can’t be entrusted with the private sector. The second question is; how that the work that can’t be done by the SOI alone or the private sector alone can’t do it when working in combination? This means that it is important to see whether the arrangement leads to a win-win situation. Consider the following facts. The attractive points for the private sector are (i) That, the geo-rectified images are given to them free of costs

(ii) That, they share ownership rights of the completed data along with the SOI, which they can either sell or perform value addition and customization, (iii) That, they do not have to suffer the process delays associated with obtaining any licence or clearances for undertaking geospatial data business. As far as SOI is concerned, the advantages are the following. (i) At half the costs and in a fraction of the time frame, it is ready to generate a TDDB for the entire country. (ii) There shall be no compromise in accuracy, since quality control shall be with the SOI. (iii) There shall be no infringement of National Map Policy provisions or any threat to national security. Rather, the project would be in furtherance of the NMP to promote a flourishing geospatial industry in the country similar to the IT revolution that generated lot of employment opportunities.

There will be a clear stipulation of roles and responsibilities on either side, which are to be expressly incorporated in agreements to be signed between the SOI and the player. Such agreement will include standard conditions like arbitration clauses, penal clauses, security clauses and shall be prepared having regard to the following:

### APPORTIONMENT OF WORK BETWEEN SOI AND INDUSTRY:

There are a number of sequential steps to be completed for the conversion of stereo satellite images into corresponding maps. Some of these steps are the core steps, which are to be executed by the SOI exclusively, while the remaining though laborious, repetitive and routine are time consuming, resource intensive and critical. The steps which are to be executed by the SOI and private player are enumerated sequentially as given below;

| | | |
|---|---|---|
| i. | Procurement of suitable images | SOI |
| ii. | Providing Ground Control Points (GCP's) | SOI |
| iii. | Geo- rectification of satellite images | SOI |
| iv. | Generation of Digital Elevation Model (DEM) and Ortho-rectified images | SOI |
| v. | Conversion of images from raster to vector form | Private player |
| vi. | Collection of attribute data | Private player |
| vii. | Limited ground truthing (fill missing details) | Private player |
| viii. | Attachment of Attribute Data | Private player |
| ix. | Data archival, management | SOI & Pr. player |

A diagrammatic representation of this scheme is given below.

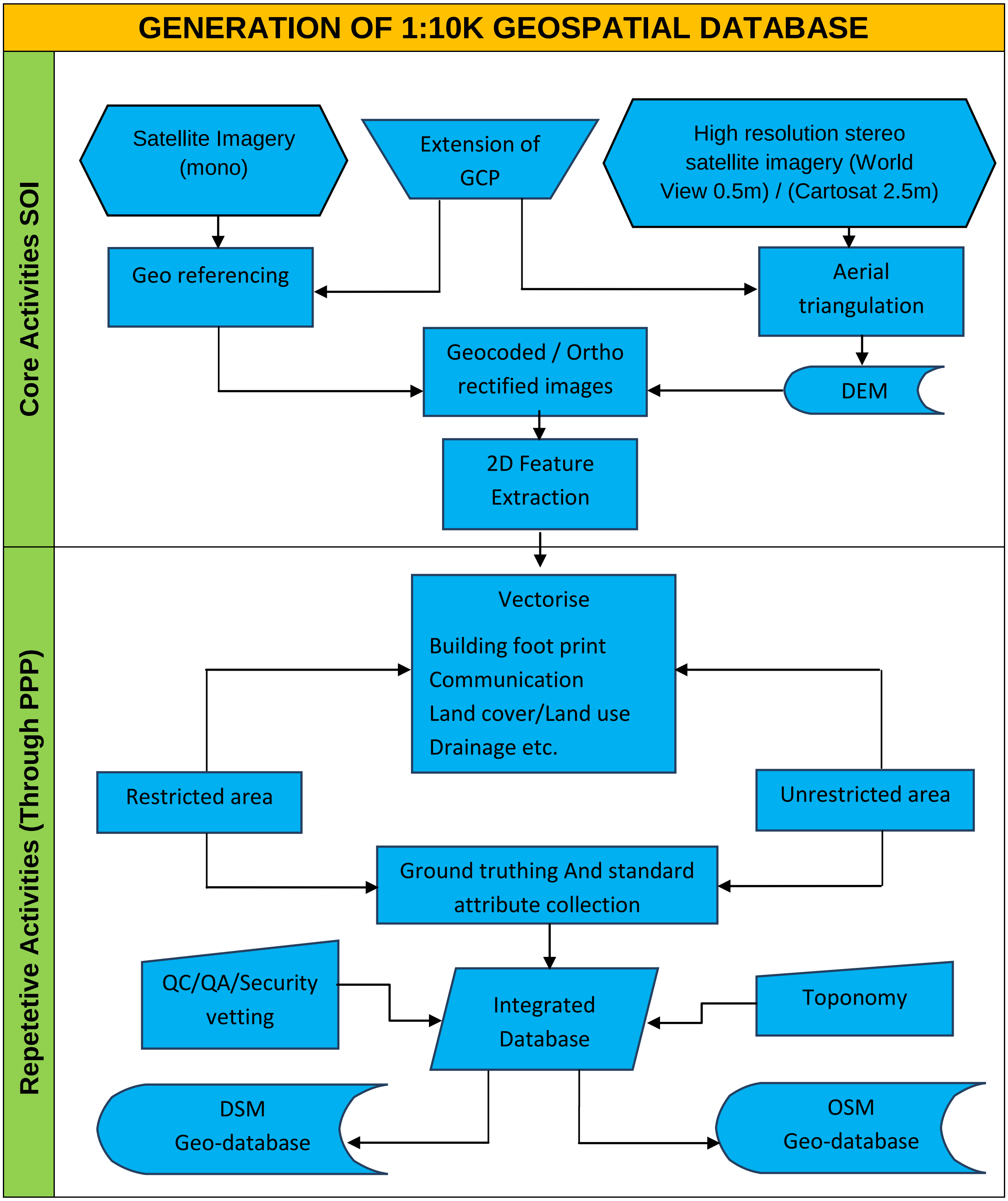



FIGURE 6.2: 1:10,000 DATABASE GENERATION PROTOCOL

### (a) SELECTION OF PRIVATE PLAYER

There will be strict pre-qualification criteria before a geospatial company will be short-listed for undertaking the partnership with SOI. The prospective bidder shall be a company registered in India with threshold levels of trained manpower, equipment, annual turn-over, experience in similar work etc, the details of which will be given in the tender documents.

#### (b) OWNERSHIP OF THE FINAL PRODUCT AND PRICING OF PRODUCTS

Specifications of the final product, to be supplied by the private player shall be fixed in advance and given in the tender document. The final product shall be co-owned by the SOI and the respective private player. However, in accordance with the National Map Policy, 2005, the private player shall have ownership rights of only those data pertaining to "unrestricted areas" notwithstanding the fact that the private player have contributed to making the data for the "restricted area". Clauses to this effect will be integral part of all agreements between SOI and the private player. The respective owners can do value addition, resell the data complying with and subject to such guidelines, rules and regulations as may be prescribed by the Government.

#### (c) APPORTIONMENT OF AREAS AMONG PRIVATE PLAYERS INTERSE

It is less likely that a single private player will be able to complete the entire work - division of work therefore among the players is indispensable. The proposed model envisages neither an arbitrary administrative decision nor any type of random lottery method for allotment of areas among the players. This has to be done in a transparent and competitive bidding scheme. The total area of the country shall be divided into say 10 zones, not necessarily contiguous in geographic terms, but which are approximately equal in area and business potential. Areas within India are not homogeneous from development point of view. For instance, areas in Andhra Pradesh and Karnataka are undergoing rapid infrastructural development and the demand for GT products of these areas is high. But GT products of Chattisgarh and Jharkhand may not have high demand, since these are mostly forest areas and development projects may not come here with the same gusto. So, the player who gets Karnataka and Andhra Pradesh gets more returns than his counterpart working in the forested states. The private players have to bid for the rights of each zone on the basis of the price at which they will make available one sheet of the area. That player who bids the minimum price per sheet of a zone will become the L-1 for that zone. In this way, the efficiency advantage of the private players due to competition is passed over the prospective map users. This scheme brings in two advantages (i) there will be a spurt in geospatial industry due the competitive prices (ii) prices of map products, which so far has been fixed administratively get fixed through markets.

#### (d) QUALITY CONTROL

The strongest point of SOI is the accuracy of its map products. The National Mission proposes that there should be no dilution in the brand equity of the SOI. The SOI will therefore have the right to reject data which does not conform to the standards laid down and the prospective private player has to redo the work to the extent, which in the opinion of the SOI will be required to maintain accuracy standards. The SOI, apart from checking the final deliverables will have the right to check the work of the private player at all stages and the private player has to abide by the instructions issued by employees of the SOI. Strict provisions to this effect will be incorporated in the agreements to be signed.

#### (e) SOI NOT TO SELL PRODUCTS AT LOWER PRICE

It has been stipulated that SOI and the private players will be co-owners of the final product. The price of the product has already been fixed based on a competitive bidding process. The SOI will be debarred from selling the data at a price lower than what has been quoted by the respective private player. Conversely, the private player can't refuse to sell at the predetermined price and jack up the prices, because then SOI can sell the same at the above prices. This arrangement also will form part of the agreement.

# ANNEXURES

## Annexure-I

# AERIAL MAPPING- LIST OF SOLUTION PROVIDERS

## 1.1 Keystone Aerial Surveys, INC

Provides airborne acquisition and image processing services to clients throughout North America. From collection of raw data to development of value-added products, Keystone offers complete image solutions tailored to your specific needs. Provide data for requirements including digital imagery, LiDAR, magnetometer, thermal, or film, Keystone has the airborne acquisition capacity to fly your project quickly and accurately. With decades of project management experience and a growing IT department, Keystone is able to offer a complete range of solutions from data collections of any size to high-quality derivative products and custom software applications. Keystone also offers an extensive library of imagery, including recently acquired, high-resolution digital imagery of nearly 300 US cities, as well as historic image archives dating back to the 1960s.

### PRODUCTS AND SERVICES

### Airborne Acquisition

Keystone currently operates fourteen survey aircraft equipped with flight managements systems, stabilized mounts, GPS, and several configurations of sensors.

### Image Products

To help you benefit from the full capabilities of our imagery, Keystone offers a variety of derived products. Keystone can help add more value to what we deliver.

### Product List

- Ultra CamX
- The Microsoft Vexcel UltraCamX

### CONTACT DETAILS

Northeast Philadelphia Airport, Grant Ave & Ashton Road, Philadelphia, PA 19114

## 1.2 OPTECH

Optech a privately owned company, Optech is the world leader in the development, manufacture and support of advanced laser-based survey and imaging instruments. With more than 250 staff worldwide, it offers both standalone and fully integrated Lidar and camera imaging solutions in airborne terrestrial mapping, airborne laser bathymetry, mobile mapping, laser imaging, mine cavity monitoring, and industrial process control, as well as space-qualified sensors for orbital operations and planetary exploration.

### PRODUCTS AND SERVICES

- **Lynx Mobile Mapper** for mobile surveys of urban, road, rail, and water assets
- **ALTM** Orion airborne laser terrain mapper for corridor mapping
- **ALTM** Gemini airborne laser terrain mapper for wide-area mapping
- **ALTM** Pegasus airborne laser terrain mapper and technology platform
- **ILRIS** Laser Scanner for tripod-based engineering, mining and industrial surveys
- **CMS** Cavity Monitoring System for safe, fast surveying of underground cavities
- **SHOALS** Airborne Laser Bathymeter for surveys of coastal and shallow water regions
- **Rendezvous** Lidar Sensor for space-proven autonomous spacecraft docking
- Industrial rangefinders for level monitoring and object positioning

### CONTACT DETAILS

| | |
|---|---|
| Optech Incorporated | Optech International, Inc. |
| 300 Interchange Way | 7225 Stennis Airport Drive. |
| Vaughan, Ontario | Suite 400 |
| Canada, L4K 5Z8 | Kiln, MS 39556, USA |
| Tel: +1 905 660-0808 | Tel: 1-228-252-1004 |

## 1.3 Applanix

Applanix Mobile Mapping and Positioning Solutions accurately and reliably capture and measure the world around us.

The World Leaders in products and solutions for Mobile Mapping and Positioning, Applanix lives up to every interpretation of the expression. Applanix technology, in use by our customers all around the world, is measuring, monitoring and modeling our planet Earth in virtually every environment imaginable.

Whether sizing-up a particular fissure in the ocean floor or monitoring the effects of seismic activity near an inland fault line; whether logging the straights and narrows of a sky scraping urban centre or flying the coast of a hostile environment; for mapping on the move, an Applanix equipped vehicle (for land, sea or air) lets you see and capture your world with speed and clarity.

#### PRODUCT AND SERVICES

* Airborne Mapping

•POSAV, •POSTrack, •POSPac MMS

* Land / Vehicle Mapping Solutions

• POS LV, • POSTG, •POSPac MMS

* Marine Mapping

• POS MV, •POSPac MMS,

### CONTACT DETAILS

85 Leek Crescent Richmond Hill Ontario L4B 3B3 Canada
T +1-905-709-4600 F +1-905-709-6027

## 1.4 Leica Geosystems

With close to 200 years of pioneering solutions to measure the world, Leica Geosystems products and services are trusted by professionals worldwide to help them capture, analyze, and present spatial information. Leica Geosystems is best known for its broad array of products that capture accurately, model quickly, analyze easily, and visualize and present spatial information.

PRODUCT AND SERVICES

- Leica ADS80 Airborne Digital Sensor
- Leica ALS60 Airborne Laser Scanner
- Leica ALS Corridor Mapper
- Leica WDM65 Waveform Digitizer Module for Airborne Laser Scanners
- Leica RCD100 Digital Camera System
- Leica RCD105 Digital Frame Camera
- Leica FCMS, Leica IPAS20, Leica IPAS Freebird, Leica RC30
- Leica PAV80, Airborne sensor related software

### CONTACT DETAILS

LEICA GEOSYSTEMS AG, Heinrich Wild Strasse
CH-9435Heerbrugg, St. Gallen, Switzerland

## 1.5 Fairchild Imaging

Fairchild Imaging develops and manufactures solid-state electronic imaging components, cameras, and systems. We are a company devoted to the creation of electronic imaging technology, development of that technology to production practicality, and manufacture to commercial success.

Fairchild Imaging offers custom capabilities in solid state electronic imaging arrays suitable for diverse applications such as astronomical imaging, aerial reconnaissance, aerial mapping, spectro graphic analysis, star tracking, missile seekers, dental and medical radiography, machine vision, x-ray diffraction and other state-of-the art military, industrial and scientific measurement applications.

**PRODUCT AND SERVICES**

- CCD Area Arrays
- Linear CCD Arrays
- TDI CCD Arrays

- CMOS Linear Arrays
- Line Scan Cameras
- Scientific Cameras

### CONTACT DETAILS

Fairchild Imaging, 1801 McCarthy Blvd. Milpitas, CA 95035, Ph: 1 800 325-6975, 1 (408) 433-2500, Fax: 1 (408) 435-7352, E-mail: sales@fcimg.com

# Annexure-II

## GROUND CONTROL POINT ACQUISITION- LIST OF SOLUTION PROVIDERS

### 2.1 Trimble

Trimble is a leading provider of advanced location-based solutions that maximize productivityandenhanceprofitability.TheCompanyintegratesitspositioning expertise in GPS, laser, optical and inertial technologies with application software, wireless communications, and services to provide complete commercial solutions. Trimble is transforming the way work is done through the application of innovative positioning. Trimble uses GPS, lasers, optical, and inertial technologies, as well as wireless communications and application specific software to provide complete solutions that link positioning to productivity.

#### PRODUCT AND SERVICES

- Geo Spatial, Infrastructure, Surveying, Field and Mobile Worker, Mapping & GIS, Utilities Field Solutions
- Fleet Tracking & Management, Precision GNSS + Inertial

CONTACT DETAILS

Trimble Navigation Limited, 935 Stewart Drive, Sunnyvale, California 94085
Headquarters Phone Number:+1 408 481 8000, Toll Free: 1 800 trimble (874 6253)

### 2.2 Topcon

From survey to inspection, Topcon Positioning Systems, Inc., provides the innovative positioning technology. Topcon acquired JPS, Inc., of San Jose, California, a leading provider of high precision GPS and GPS/GLONASS products adding the world's best GPS and GPS/GLONASS technology with the world's most advanced surveying and construction positioning instrumentation line-up.

#### PRODUCT AND SERVICES

**Laser:** Laser products have set the standards all other laser instruments are measured by.

**Optical O**ptical instruments designed using our exclusive optomechatronic technologies.

**GPS:** GPS+ has the ability to track not only both frequencies of all 24 GPS satellites, it can also receive the signals from the 14 GLONASS positioning satellites giving you precision accuracy around-the-clock

**Reference Networks:** Geodetic Reference Network reliably delivers precision real time GNSS data where you need it

**Mapping and GIS:** Modular GIS mapping and navigation solution

**Software:** Topcon offers a variety of software and utilities for all your Machine Control, GPS, and Surveying needs.

### CONTACT DETAILS

Topcon Positioning Systems, Inc, 7400 National Drive, Livermore, CA USA 94551, Phone: 925-245-8300, Fax: 925-245-8599

## 2.3 Leica Geosystems

With close to 200 years of pioneering solutions to measure the world, Leica Geosystems products and services are trusted by professionals worldwide to help them capture, analyze, and present spatial information. Leica Geosystems is best known for its broad array of products that capture accurately, model quickly, analyze easily, and visualize and present spatial information.

### PRODUCT AND SERVICES

**GNSS/GPS Systems:** Leica Geosystems offers the ideal solution for every GPS/GNSS application. Powerful GPS/GNSS technology for unmatched accuracy.

**GNSS/GPS Surveying Systems:** GPS/GNSS surveying systems combine state-of-the-art technology and powerful data management. They are the perfect solution for all GPS/GNSS applications.

**GPS/GIS Data Collectors:** GPS receivers for GIS Data Collection and mobile GIS.
GNSS Reference Networks: Whether providing corrections from just a single reference station, or an extensive range of services from a nationwide RTK network - innovative reference station solutions from Leica Geosystems offer tailor-made yet scalable systems, designed for minimum operator interaction whilst providing maximum user benefit.

### CONTACT DETAILS

Leica Geosystems AG, Heinrich Wild Strasse, CH-9435 Heerbrugg, St. Gallen, Switzerland, Phone: + 41 71 727 3131, Fax: + 41 71 727 4674

## 2.4 Novatel Inc

Novatel Inc. is a leading provider of precision Global Navigation Satellite System (GNSS) components and subsystems. The Company's vision is to provide exceptional return on investment (ROI) and outstanding service to its customers. An ISO 9001 certified company, Novatel develops quality OEM products including receivers, enclosures, antennas and firmware that are integrated into high precision positioning applications worldwide. These applications include surveying, Geographical Information System (GIS) mapping, precision agriculture machine guidance, port automation, mining, timing and marine industries. Novatel's reference receivers are also at the core of national aviation ground networks in the USA, Japan, Europe, China and India.

### PRODUCT AND SERVICES

Manufacture of full range of precise GNSS positioning products including GNSS:

- Receivers
    - OEM Receiver Boards
    - Enclosures
    - SMART Antennas

- Antennas
  - High Performance GNSS Antennas
  - Compact GNSS Antennas
  - Fixed Reference GNSS Antennas
- Inertial augmented systems
- Firmware Options
- Post-Processing Software

CONTACT DETAILS

1120 - 68th Avenue N.E., Calgary, Alberta, Canada, T2E 8S5

## 2.5 Sokkia

Sokkia Corporation is the United States subsidiary of Sokkia Co., Ltd., Tokyo, a world-leading manufacturer of precision measuring systems. Sokkia's diverse product line provides complete measurement solutions for surveying, mapping and GIS, industrial measurement and construction applications.

Sokkia provides turn-key solutions for surveyors worldwide. Sokkia Corporation markets Total Stations, Data Collectors, Digital Levels, and Lasers and a full complement of field accessories through a nationwide distribution network. For more than 85 years, Sokkia's complete line of surveying instruments, GPS products and accessories have provided its customers with quality found nowhere else. With Sokkia's products, you will be sure to have long-lasting, precise instruments for many years to come. Sokkia customers will continue to see this rugged and reliable quality in 2007 with innovations in the GPS product line, an expansion of construction-specific instruments and continued enhancements on Sokkia's fully-tracking robotic total station, the SRX.

**PRODUCT AND SERVICES**

- GPS: GNSS, Dual Frequency, Single Frequency, Reference Station, GIS
- Total Stations: SRX Robotic Total Station, SET X, Series 50RX Reflectorless, Total Station, Series 50X Total Stations, NET1, NET05 &NET05X 3-D Station, NET 1200 MONMOS, GPxX Gyro Station
- Software: Spectrum Link: Spectrum Survey Suite, GSR Reference Station Software, IMap.

**CONTACT DETAILS**

260-63, Hase, Atsugi, Kanagawa 243-0036 Japan,
TEL: +81-46-248-0068FAX: +81-46-247-6866

# Annexure-III

## SATELLITE IMAGERY- LIST OF SOLUTION PROVIDERS

## 3.1 Digital Globe Corporate

Digital Globe is a unique imagery provider because our founders were scientists and GIS mapping users who wanted commercial access to a consistent and rapidly expanding supply of high quality earth imagery and geospatial information products. We are a responsive, flexible and easy to work with company that understands what our customers require and value, a company that delivers images and information better than anyone else.

### PRODUCT AND SERVICES

Advanced Ortho Series
World View-2: Standard Satellite Imagery
World View-1: Standard Satellite Imagery
Quickbird: Standard Satellite Imagery
Quickbird: Ortho Ready Standard Satellite Imagery

### CONTACT DETAILS

DIGITALGLOBE CORPORATE, 1601 Dry Creek Drive, Suite 260, Longmont, CO 80503, Phone toll Free: 800.655.7929, Phone:303.684.4000

## 3.2 National Remote Sensing Center

National Remote Sensing Centre (NRSC) is one of the centers of Indian Space Research Organisation under the Department of Space, Govt. of India, engaged in operational remote sensing activities. The operational use of remote sensing data span wide spectrum of themes which include water resources, agriculture, soil and land degradation, mineral exploration, ground water targeting, geomorphologic mapping, coastal and ocean resources monitoring, environment, ecology and forest mapping, land use and land cover mapping and urban area studies, large scale mapping, etc.

### PRODUCT AND SERVICES

- User Services
- Image Search
- Aerial Data/Mapping
- Geospatial Solutions
- Bhoosampada
- Disaster Management

### CONTACT DETAILS

NATIONAL REMOTE SENSING CENTER, NRSC Data Centre [NDC],
Department of Space, Government of India, Balanagar, Hyderabad-500 037 Phone : 00 91 040 23878560 or 23879572 Extn:2327
E Mail: sales@nrsc.gov.in; Website: www.nrsc.gov.in

## 3.3 Geoeye

Geoeye, Inc. is a premier provider of superior satellite and aerial imagery, location information products and image processing services. Our products and services enable timely, accurate and accessible location intelligence that translates into timely and vital insights for our customers, anywhere and at any time. We own and operate a constellation of Earth-imaging satellites, including the world's highest resolution satellite, Geoeye-1, which provides our customers with the highest quality and most accurate satellite imagery available. We anticipate launching Geoeye-2, our next-generation satellite, in the 2012-2013 timeframe, to provide our customers with ongoing access to industry-leading imagery.

### PRODUCT AND SERVICES

Satellite Imagery Products

- Geo, GeoProfessional, GeoStereo

Aerial Imagery Products

- Digital Aerial Imaging, LiDAR Imaging

CONTACT DETAILS

GEOEYE, 21700 Atlantic Boulevard, Dulles, VA 20166, Phone: +1.703.480.7500 Fax: 703.450.9570, E-mail: info@geoeye.com

# Annexure-IV

## TOPOGRAPHICAL MAPPING- LIST OF SOLUTION PROVIDERS

Nascent as the geospatial industry in India is, there are no giant players from the industry. There are at least several major players and small players in the field who have technological expertise, financial capabilities and financial resources to do value addition on the unrestricted OSM's. A list of the well known private sector players along with their addresses and annual turnover is given below:

| S. No | Name | Location | Turnover |
|---|---|---|---|
| 1. | Auto desk India Pvt Ltd. | 406, 4th Floor, Rectangle-1, Saket District Centre, New Delhi-17 | |
| 2. | Bentley Systems India Private Limited | 203, Okhla Industries Estate, Phase-III, New Delhi | |
| 3. | Digital Globe | F2, 2A/1, Vaishali, Ghaziabad-201010 | |
| 4. | ESRI India (NIIT-GIS Ltd) | 8, Balaji Estate, Sudarshan Munjal Marg, KALKAJI, New Delhi - 19 | Rs 250 Million |
| 5. | IIC Technologies Pvt. Ltd. | 6-3250/2 Raod No.1, Banjara Hills, Hyderabad-500034 | Rs 250 Million |
| 6. | Infotech Enterprises Ltd. | Plot No. 011, Software Units Layout, Infocity, Madhapur | Rs 5425 Million |
| 7. | Leica Geosystems Gepspatial Imaging India Pvt Ltd | 3rd Floor, Enkay Square, 448A Udyog Vihar Phase 5, Gurgaon | Rs 10-25 Million |
| 8. | RMSI | A-7, Sec - 16, Noida – 201301 | |
| 9. | Rolta India Ltd | Rolta Tower A,Rolta Technology Park, MIDC, Andheri (East), Mumbay-400093 | |
| 10. | Speak Systems Ltd | B-49, EC, Kushaiguda, Hyderabad | |
| 11. | AAB Sys Information Technology Pvt. Ltd | Tower 2000, Mancheswar Industrial Estate, Rasulgarh, Bhubaneswar-751010 | Rs 18.5 Million |
| 12. | Aaron Tecch-Pro Pvt. Ltd | B1/608, Satyam Appts, 20B, Vasundhara Enclave, New Delhi - 10096 | Rs10 Million |
| 13. | ADCC Infocad Pvt. Ltd. | 10/5, IT Park, Opp. VNIT, Nagpur - 440022 | Rs 120 Million |
| 14. | Adroitech Information Systems Limited | D-194, Okhla Industrial Area, Phase I, New Delhi | |
| 15. | Anantha Solution Pvt. Ltd. | D. No:1- 60/1, Snehapuri, Naccharam, Hyderabad-500076 | Rs 10 Million |
| 16. | Annova Technologies | Block No 17A, SDF-1, VSEZ, Visakhapatnam-530046 | |
| 17. | Applied Computer Services Ltd. | 609, 6th Floor, Topaz building, Panjagutta, Hyderabad-500082 | |
| 18. | Assurgent Technology Solutions (P) Ltd. | C/O. S.T.P.I., Block-DP, Plot No. 5/1, Salt Lake Electronics Complex, Sector-V, Bidhan Nagar, Kolkata-700091 | Rs 30 Million |

| | | | |
|---|---|---|---|
| 19. | Aurovision | 5A,ReadymoneyTerrace, 2nd Floor, 167, Dr. Annie Besant Road, Worli, Mumbai-400018 | |
| 20. | C.E. Info Systems | B.44, Shivalik, Malviya Nagar, New Delhi-110017 | |
| 21. | Cyber SWIFT | Merlin Links, 5th Floor, 166B, S.P. Mukherjee Road, Kolkata - 700026 | Rs 10 Million |
| 22. | Compu Sense Automation | 404/405, ISCON Plaza, Satelite Road, Ahmedabad - 380015 | Rs 25-100 Million |
| 23. | Diamond Point International | 20 Ct Bed, 7th cross, BSK 2ndStage, Bangalore- 560070 | Rs 10-25 Million |
| 24. | Disa Information Systems Pvt. Ltd. | 10/C, !st Floor, M.G. Road, Indore-452009 | Rs 10-25 Million |
| 25. | DSM Soft (P) Ltd. | 5, Raja Street, T. Nagar, Chennai-600017 | Rs 10-100 Million |
| 26. | Earth Consultancy Services | C-440, New Ashok Nagar, New Delhi - 110096 | Rs 10-25 Million |
| 27. | East Collaborative Strategiess Pvt. Ltd | X-1, 802 9B Main, HRBR Block- 1, Kalyan Nagar, Bangalore-560043 | Rs 25-100 Million |
| 28. | Elcome Technologies Pvt. Ltd. | A-6, Info city, Sector-34, Gurgaon-122002 | Rs 250 Million |
| 29. | ENGECORC | En-Geo Consultancy & Research Centre, 59 Lamb Road, Guwahati-781001 | |
| 30. | Fed Soft | 28, Bhandup Industrial Estate, Bhandup, Mumbai -400078 | |
| 31. | Fleet locator | Flat 202, 2nd Floor, 1-011-15, A&B, Corner Stone Appt. Shyamlal Bldg, Begumpet, Hyderabad | Rs 10 Million |
| 32. | Group SCE India Pvt Ltd | 129 Railway Parallel Rd, Kumarapark West, Bangalore-560020 | Rs. 54.4 Million |
| 33. | Geo Infotech | Plot 219 Baya Baba Matha Road. Inix ix, Bhubaneshwar-751022 | 10 Million |
| 34. | Geo Edge Technologies Private Limited | SNV Chambers 483, 2nd Floor, Ponne Street, Ciombatore-641012 | |
| 35. | Genesys International Corp. Ltd | 73A, SDF III, SEEPZ, Andheri (East), Mumbai-400096 | |
| 36. | INCA India | C-22, Sector 57, Gautam Buddha Nagar, Noida-201301 | |
| 37. | IndiGeo Consultants Pvt. Ltd. | Apt 2, Raymond Court, Jeevanhalli Main Road, Banglore-560033 | |
| 38. | Info Genex Technologies Pvt Ltd | Suite 603, STPI, Maitrivanam, SR Nagar, Hyderabad-500038 | Rs 10 Million |
| 39. | Jishnu Ocean Technologies | PL-6-A-15, Sector-1, Khanda Colony, New Panvel | Rs. 10 Million |
| 40. | Kalyani Net Ventures Ltd. | Industry House, S.No.48, Mundhwa, Pune | Rs 25-100 Million |

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|---|---|---|---|
| 41. | Kampsax India Pvt Ltd | 121, Phase-I, Udyog Vihar, Gurgoan-122016 | Rs. 100-250 Million |
| 42. | Lepton Software Export & Research (P) Ltd | C-115, Ist Floor, Phase-I, Naraina Industrial Area, new Delhi-110028 | |
| 43. | Luminous Engineering and Technology Services Pvt Ltd | 43 Community Center, Naraina Industrial Area, Phase-I, New Delhi | |
| 44. | Mascon Multiservices and Consultants Pvt. Ltd. | 702, Galav Chembers, Nr. Sardar Patel Statue, Sayajiguj,Vadodara-390005 | Rs 60 Million |
| 45. | Manchitra Services Pvt. Ltd. | B-52,Sector-63, Noida-201301 | Rs 120 Million |
| 46. | Meghna Infitech Pvt. Ltd | 101-A, Doctor House, Ellis Bridge, Ahmedabad-380006 | Rs 10 Million |
| 47. | Micro Technologies India Limited | Plot No. 16, Sector-30A, Navi Mumbai, Mumbai - 400705 | Rs 1069.155 Million |
| 48. | Midwest 5 Infotech Pvt. Ltd. | 70 Kanakpura Main Road, J.P. Nagar, 6$^{th}$ Phase, Bangalore-560078 | Rs 10 Million |
| 49. | Minecode Solutions Pvt. Ltd. | 813, HSIDC, Udhyog Vihar, Phase V, Gurgaon-122016 | Rs 80 Million |
| 50. | OPSIS SYSTEM | BD-327, Sector-1, Slat Lake, Kolkata-700064 | Rs 10 Million |
| 51. | Pallavi Surveys | H-NO: 3-10, Gokhale Nagar, Ramanthapur Colony, Hederabad-500013 | Rs 5 Million |
| 52. | PCI Software Pvt. Ltd. | CB-55, Salt Lake, Kolkata-700064 | |
| 53. | PCI Geomatics Private Ltd. | 6 Pashan Greens, Ramnagar Colony, NDA Road, Pune-411021 | |
| 54. | Pixel Group | 8$^{th}$ Floor, VokkaligaraBhavana, Hudson Circle, Bangalore-560027 | |
| 55. | Prithvitech Consultants Pvt. Ltd. | 18/256, Indira Nagar, Lucknow-226016 | Rs 10 Million |
| 56. | Proficio Geotechnologies Pvt. Ltd. | No-10,3$^{rd}$ Cross, 4$^{th}$ Main Aecs Layout, Sanjay Nagar, Bangalore-560094 | Rs 10 Million |
| 57. | PSM Associates | Plot No : 1205/A, P.O: Nayapalli, Bhubaneswar-751012 | Rs 10 Million |
| 58. | Regency Infotech Pvt. Ltd. | 6-3-1113/2, 3$^{rd}$ Floor, Point of view Building, Begumpet, Hyderabad-500016 | |
| 59. | Ridings Consulting Engineers India Pvt. Ltd. | B-128, UdyogMarg, Sector-5, Noida-201301 | Rs 25-100 Million |
| 60. | Riddhi Management Services Pvt. Ltd. | FE 297, Salt Lake city, Kolkata-700106 | Rs 10-25 Million |
| 61. | Sarmang Software | 6/1 Hathibarkala, Dehradun, Uttarachchal | Rs 10 Million |
| 62. | Satpalda Trading Pvt. Ltd | 1006 Kanchenjunga Building, 18 Barakhamba Road, New Delhi-110001 | Rs 25-100 Million |
| 63. | SGS Infotech Pvt Ltd. | 407, UdyogVihar, Phase IV, Gurgaon-122015 | |

| | | | |
|---|---|---|---|
| 64. | Sidus Infotech Pvt. Ltd. | No-114, MIG, KHB Colony, 80ft Road, Basaveshwarnagar, Bangalore-560079 | Rs 10-100 Million |
| 65. | Sierra Atlantic Software Services Ltd. | 8-2-624/1, Road No.10,Banjara Hills, Hyderabad-54 | |
| 66. | Sokkia India Pvt. Ltd. | C-25 Ground Floor, Sector-8, Noida - 201301 | Rs 100 – 250 Million |
| 67. | SpaGeo Technologies Pvt Ltd | C-33, Indraprastha, Plot No. 114, I.P. Extn, New Delhi-110092 | |
| 68. | Spatial Data Pvt. Ltd. | 151/3, 1st Floor 18th Main, 11th Cross, Malleswaram, banglore-560003 | Rs. 10 Million |
| 69. | Spatial Developers | 20- North Chandmari Road, P.O: Nepukur, Barrackpore, 24 Parganas(N)-700122 | Rs 10 Million |
| 70. | Spime India Technologies | 93/45, First Avenue, Indira Nagar, Adyar, Chennai-600020 | |
| 71. | Sumadhura Geomatica Pvt. Ltd. | 1-10-248, Ashok Nagar, Hyderabad-500020 | Rs 25-100 Million |
| 72. | Sunsoft Technologies Inc | 3121, 19th Cross, R Road Banashankari 2nd Stage, Bangalore | Rs 25-100 Million |
| 73. | Topcon Surveying (India) Pvt. Ltd. | 1079, Sector -19, Faridabad-121002 | Less than Rs 10 Million |
| 74. | Trimble Navigation India Pvt. Ltd. | SF-04, JMD Regent Plaza, M. G. Road, Gurgaon - 122001 | |
| 75. | VISIONLABS (India) Pvt. Ltd. | 2nd Floor, 4 Motilal Nehru Nagar, Begumpet Main Road, Hyderabad-500016 | |
| 76. | WAPMERR India | 26 C/1, Khijrabad, Behind Loins Hospital, New Friends Colony, New Delhi | Rs 200 Million |
| 77. | Weston Solutions (India) Pvt. Ltd | 524, Road No 27, Jublee Hills, Hyderabad | Rs42 Million |
| 78. | Zymax Technologies | 5, ShyamPalli, Ground Floor, Jadavpur, Kolkata | Rs 10 Million |
| 79. | Navayuga Spatial Technologies Pvt. Ltd. | 1259, Laxmi Towers, Rd 36, Jublee Hills, Hyderabad-500033 | |

LIST OF TOPOGRAPHICAL MAPPING SOLUTION PROVIDERS

## Contact Us


Joint Secretary (Mitigation),
National Disaster Management Authority (NDMA)
NDMA Bhawan
A-1 Safdarjung Enclave
New Delhi – 110 029

Tel: (011) 26701720
Fax: (011) 26701864
Email: mitigation@ndma.gov.in
Website**:** www.ndma.gov.in