Geo-Informatics in India: Major Milestones and Present Scenario

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Key words: Geo-informatics (GI), Remote Sensing, India, Education, Research, Indian Space program, Capacity Building

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ABSTRACT:

Geo-informatics has emerged globally as a useful tool to address spatial problems with significant societal implications that require integrative and innovative approaches for analysis, modelling, managing, and archiving of extensive and diverse data sets. Breakneck technological development and availability of satellite based data and information services in public domain along with real time geo-data n through participatory approaches, in the two last decades have led to a sea-change in our know-how of our natural resources and their effective management at various levels. It has led to a realization that every phenomena and requirement in our day to day life has some spatial, or geographic component that can be predicted and governed more effectively through geoinformatics tool. India also has come a long way in effective utilization of geoinformatics for various applications. This quantum leap owes its foundation in a humble beginning about half century back and almost parallel developments in the country’s space programme to a current level where it touches almost all areas of life and living. Though geoinformatics technology (GIT) is believed to reach satisfactory level in the country, Indian geospatial community faces critical challenges with respect to research, education and training along with enhanced the access to the stakeholders and mobilization of the workforce, that are crucial in further penetration of this technology in context to India’s development. In this paper we have critically reviewed milestones of GI development and its current utilization status in Indian context.

Key words: Geo-informatics (GI), Remote Sensing, India, Education, Research, Indian Space program, Capacity Building

1. Introduction:

Geo-informatics is a unique framework for the discovery of new knowledge through integration and analysis of earth-science data and applications. It includes disciplines like Cartography, Photogrammetry, Satellite Remote Sensing (RS), Geographic Information System (GIS), Land Surveying (including GPS) and other earth related technologies. For centuries, these disciplines grew in a manner which gave each of them special identity (Kumar, 2000). Globally, geoinformatics technology (GIT) has emerged as a useful tool to address spatial problems with significant societal implications that require integrative and innovative approaches for analysis, modeling, managing, and archiving of extensive and diverse data sets (Sinha et al, 2010).

Beginning with a computerized topographic map as its base, a GIS overlays and integrates graphic and textual information from separate databases. The tradition of map-making is not new. Geographical knowledge traces its historical background from the very beginning of civilization. Aryabhatta, Varahmihir, Bhaskaracharya and Brahmgupta were eminent cartographers in ancient time. They determined the cardinal coordinates of many places (Roy & Kumar, 2002). The next contributors to Indian geography were Chinese and Arab travelers who left the interesting detailed accounts of their journey. Most of the early maps were local surveys carried out by cursory method. Later with the East India Company acquiring control of territory in India, there was increased need to carry out survey work. Much of the mapping was for fiscal purposes, but administration, control, and defense all required the production of topographic maps. In consequence, the Survey of India can claim to be one of the oldest national mapping agencies in 1767. In 1776, comprehensive instructions for preparing the maps on the scale two miles to an inch formulated: in which distances were measured by perambulator rather with chains and bearing to the conspicuous hills. Legendary figures like Col Lambton and Sir George Everest were involved with the Great Trigonometrical Survey (GTS) started in 1802 to provide a control frame work for topographical mapping in India. By the end of the nineteenth century, most of British India was mapped at various topographic scales (Collier, 2002). In 1905, mapping on 1 inch to a mile was taken up (Kumar, 2000). Aerial photography was first used in India in the year 1920 in a survey experiment (Bhavsar, 1979). Subsequently, India embraced the use of aerial photography for topographic mapping with greater enthusiasm (Collier, 2002).

After mastering the development and use of air-crafts the idea of having a spaceship orbiting the earth also emerged. By 1946, the first report on the Preliminary Design of an Experimental World Circling Spaceship was released by Douglas Aircraft Company’s Engineering Division that has pioneered in designing and building a wide variety of aircraft for the U.S. military. Since, the technological superiority required for such supremacy was seen as necessary for national security, and symbolic of ideological superiority, the cold war rival the Soviet Union beat the US to this, with the launch of the first artificial satellite Sputnik 1 in the space. Later, the US also launched its first satellite, Explorer 1 and the two nations continued their space journey demonstrating the applications of satellite technology and its applications. Slowly and steadily, India also developed the tremendous capabilities in the new techniques of surveying and mapping. It also began its own space program, which is one of the most prestigious ones in the world. As a result of these developments and parallel developments in the IT infrastructure and policy reforms, India today stands a geo-empowered nation transforming its strengths in Geo-informatics (and complexities) into a great innovation to set about a new information regime that empowers citizens, brings good governance, and encourages sustainable development thereby bringing the benefits of GIS to citizens, government, and enterprises (Dagermond, 2013). We analyzed the technology development and transition phases of GIT along with the major milestone in the light of various factors as mentioned above. Table 1 shows the summary of the major milestones during last five decades that has strengthened the geo-spatial technologies in India and contributed in its evolution. This evolution, like any other technology followed a phase wise development that finally culminated in its widespread usage and acceptance among the stakeholders.

2. Initial Revamping of Surveying and Mapping techniques:

As mentioned in the introductory text, the Survey of India embraced the aerial photography for topographical mapping with great enthusiasm. However, this success did not distract the Survey from instrumental techniques they had helped pioneer (Collier, 2006). The period during 1950-60, soon after the independence witnessed impetus on new techniques in surveying and mapping to support the operational projects. The historic maiden visit of Rector, International Institute for Aerospace Surveys and Earth Sciences (ITC), Netherlands to Survey of India, which was under the Department of Science & Technology (DST) in 1954 laid the foundation of the International collaboration. Subsequently, the first Prime Minister of India Pandit Jawahar Lal Nehru articulated the requirement of similar institute, in India after his visit to ITC in 1957. The first formal discussions took place among the Deputy Surveyor Journal of India and Rector ITC while attending UN Cartographic Conference for Asia and the Far East in Bangkok, Thailand in 1961. The idea was further supported by government and a delegation from the Netherlands Government visited SOI, GSI, the departments of the Centre and States along with the Planning Commission (now Niti Aayog) of India in 1964 and a draft agreement for collaboration between the two governments was compiled. The final agreement was signed on April 21, 1966 and the Indian Photo-interpretation Institute (IPI) was established in Dehradun under the SOI. This lead to the initial transition of surveying and mapping in India from traditional cartographic approaches to the increased utilization of the aerial way forward in utilizing aerial photography and methods of photo-interpretation in operational projects.

3. Space Research Development:

As the new techniques in surveying and mapping were making their place in the cartographic history of post-independence India, there was increased emphasis on the space research and indigenous space program in India also. This resulted in setting up of the Indian National Committee for Space Research (INCOSPAR) in 1962 with Dr. Vikram Sarabhai as it's the Chairman, under the leadership of Department of Atomic Energy (DAE). Early interactions with NASA for possible cooperative space projects were initiated (Maharaj, 2011) and a rocket launching station was established at Thumba, a place in the southern part of India through which the Geo-magnetic equator passes which became a nodal point for attracting world renowned scientists and the establishment of Thumba Equatorial Rocket Launching Station (TERLS) put India on the space map of the world. Subsequent ground works resulted in the reconstitution of INCOSPAR as an advisory body under the Indian National Science Academy (INSA) and the Indian Space Research Organization (ISRO) was established in 1969. The government of India latter constituted Space Commission an apex body of decision making on national space programs and policies. It started contributing in laying down the framework of important space activities and advising the government on major policies and programmes of space activities. This further resulted in the formation of the Department of Space (DOS) in 1972 and ISRO was brought under its umbrella. Other institutional development included establishment of Space Application Centre (SAC) in 1972 and National Remote Sensing Agency (NRSA) in Hyderabad, as a registered society in 1974 by DST. SAC was endowed with the activities related to the design and development of the satellite sensors/payloads. NRSA was entrusted with the task undertaking and facilitating aerial surveys and took over the works and functions of the Research Flight Facility of the Ministry of Defense. It undertook the first airborne geophysical survey as the first technical activity. It also hosted the first data receiving earth station of the US Landsat satellite and with this availability of satellite data become easier to the Indian scientist. Later, the launch of first Indian satellite Aryabhata in 1975 by the Soviet Union onboard Kosmos-3M launch vehicle gave a kick start to Indian Space Odyssey. The period of 1975-2012 witnessed 101 Missions with 68 Satellites and 33 Launches carried out by ISRO (Dadhwal, 2013), which equipped the Indian geo-spatial community in a commendable way.

3.1. Earth Observation Missions

The launch of Aryabhata laid the foundation of India's Earth Observation (EO) programs. It gave ISRO firsthand experience in building and operating a satellite in space. This was followed by launch of Bhaskara 1 and II in 1979 and 1981 respectively with the support of USSR. The launch of Bhaskara I and II provided valuable experience and insight into a number of aspects, such as sensor system definition and development, conceptualization and implementation of a space platform, ground based data reception, processing, data interpretation and utilization as well as matters relating to the integration of the remotely sensed data with the conventional data systems for natural resources management (Deekshatulu, 1993). Thus, it served as an excellent training ground for conceiving future operational missions in remote sensing (Kasturirangan et al., 1996) and India took an audacious move to have a dedicated remote sensing series similar to contemporary earth observation satellites. This lead to the conceptualization of Indian Remote Sensing (IRS) satellite program (Joseph, 2005) and IRS-1A was launched in 1988. It boosted the availability of satellite data at an affordable cost and ease and thus resulted in a sea change in both the demand and utilization of the remote sensing data both in academic domain as well as the user organizations involved in natural resource management, infrastructure development, disaster risk management and environmental applications. This could be achieved due to the parallel research and development taking place in the payload capabilities and world class precision of the Indian satellite launch vehicles. The brilliantly successful missions of ASLV -D4/SROSSC2 and PLSL2/IRS-P2 in a short span of six months in 1994 are amongst the most important milestones in the Indian space program (Gupta, 1995). Subsequently, more satellites were launched with continuous improvement not only in spatial, spectral, temporal and radiometric resolutions, but also in their coverage and value-added products (Navalgund et al, 2007).

3.2. Growth in Geostationary Missions for Satellite Communication/Meteorological and Navigation application:

In addition to its audacious EO program, India also developed a prestigious satellite communication program that affected the course of development in the information technology in India. India's tryst with satellite communication begin in 1967, when the first 'Experimental Satellite Communication Earth Station (ESCES)' located in Ahmedabad after the feasibility study of the Satellite Communication Research Program to be carried out in India by UNESCO and submitted to the NASA. This was achieved through the initial funding support from UNDP. As this project was operationalized, it doubled as a training center for the Indian as well as international scientists and engineers in satellite broadcasting. Accordingly, a TV program on agricultural information to farmers 'Krishi Darshan' was started on 26th January which received good response. Later in 1975-76 ISRO initiated "the Satellite Instructional Television Experiment (SITE)" which is hailed as the largest sociological experiment in the world. This experiment benefited around 200,000 people, covering 2400 villages of six states and transmitted development oriented program using the American Technology Satellite (ATS-6). SITE was followed by the Satellite Telecommunication Experiments Project (STEP), a joint project of the ISRO and Post and Telegraphs Department (P&T) using the Franco-German Symphonie satellite during 1977-79. Conceived as a sequel to SITE which focused on Television, STEP was for telecommunication experiments. STEP was aimed to provide a system test of using geosynchronous satellites for domestic communications, enhance capabilities and experience in the design, manufacture, installation, operation and maintenance of various ground segment facilities and build up requisite indigenous competence for the proposed operational domestic satellite system, Indian National Satellite System (INSAT) for the country. Today the INSAT series serves as multipurpose geostationary satellites to satisfy the telecommunications, broadcasting, meteorology, and search and rescue operations. It tremendously improved the communication facilities in India since mid-80s. In the recent times, India has also envisaged setting up village resource centers in the backward and inaccessible rural areas of the country to help the communities through telemedicine and tele-education. Disaster management support, in terms of space based critical infrastructure and services, is yet another community centric deliverable. One of the elements on which the space based Disaster Management Support (DMS) systems have been built is emergency communications systems. The DMS program of ISRO/DOS, a convergence of space communications and remote sensing capabilities, is an effort to have technologically robust and a compatible system, which could strengthen India's resolves towards disaster management. The latest of Indian Regional Navigation Satellite System (IRNSS) and GPS Aided GEO Augmented Navigation (GAGAN) are another step towards the enhancement of the indigenous satellite navigation and communication system that are further going to provide locational reliability and data freedom besides contributing in the global arena.

4. EO Application- Flagship projects:

With the increased availability of satellite data for the peaceful applications globally, there was increased realization and need to use them for mapping the natural resources in India also. The initial awareness regarding use of remote sensing in India came from the first successful mission of coconut wilt-root disease eradication by remote sensing techniques using Soviet aircraft and US equipment (Dakshinamurti, 1971). Subsequently, several studies were taken by the Indian scientist and researchers to demonstrate the use of remote sensing in the field of forestry, water resources, soil and agriculture in the Indian context (Bhavsar, 1980). The Government of India initiated a number of technology-based programs viz. Natural Resources Data Management System (NRDMS) of the Department of Science & Technology, National Natural Resources Management System (NNRMS) of the Department of Space and Geographical Information System (GISNIC) and District Information System (DISNIC) of the National Informatics Center (Ministry of Communication and Information Technology) to support the local level planning in 1980s. NRDMS program initiated in 1982, was a multi-disciplinary and multi-institutional R&D program that contributed in promoting R&D in spatial data management by developing pilot scale integrated databases on natural resources and socio-economic parameters to cater to micro level planning. It also demonstrated the efficacy of database approach for management and conservation of natural resources with emphasis on location specific problems at different hierarchical units of planning i.e. district, block and panchayat. The NNRMS program started under the planning commission in 1983 also significantly demonstrated and promoted the wide use of the technology of remote sensing by integrating the applications of the technology into the existing information systems which were in day-to-day use by resource managers and planners. It also helped in developing the nationwide infrastructure and five Regional Remote Sensing Service Centers (RRSSCs) were established across the country and subsequently all the states were encouraged to have their own remote sensing centers which were functional by 1994 (Deekshatulu, 2001). Under the NNRMS several large scale national level projects viz. nationwide mapping of forest and non-forest Area, National Wasteland Monitoring Project, Crop Acreage and Production Estimation (1986) and National Agricultural Drought Assessment and Monitoring System (1986), IMSD (Integrated Mission for Sustainable Development) Phase I (1987) etc. were started. Subsequently, several other projects viz. Potential Fishing Zone Mapping, Accelerated Irrigation Benefits Programme (AIBP), IMSD-II etc. were taken up and NNRMS emerged as a guiding force for designing EO-sensors for various thematic applications viz. agriculture, urban planning, forestry, geo-sciences, water resources etc. including capacity building.

Due to the multidisciplinary nature of the various projects undertaken under the umbrella of NNRMS initiative and data dependencies from the multiple stakeholders it was proposed to have more robust National Resource Information System (NRIS) and in 1990 inter-departmental committee to finalize the NRIS action plan was formed. Since 1999, the NRIS Standards have become the de-factor GIS Standards in India and have not only been the core standards for the NRIS in several states, but have also been in use in many organizations and agencies who have undertaken GIS activities. However, presently, the NRIS Standards, defined in 1997-99, have served the purpose of the NRIS project and also for many other users.

Learning from the NRDMS and NNRMS (NRIS) also lead to realization of rescoped standards of GIS databases to address upstream and down-stream processes of the entire gamut of NNRMS activity and include the present-day needs of standardization and the newer technologies that have emerged. This formed the basis of defining the NSDI Standards in a GIS context (Anon, 2005). The re-scoped standards formed the basis of NR Census (NRC) after a proto-type study. Today, NRC provides the nation a 'snapshot' of the country's status of natural resources. It also identifies the 'hot-spots' and does detailed study through larger scale mapping. Other important projects initiated during 2000-2010 were are National Wastelands Monitoring (NWM), National Urban Information System (NUIS), National Wetlands Inventory and Assessment (NWIA), Watershed Monitoring and Development, and Glacier Inventory of Himalayas, ISRO Disaster Management Support Programme (ISRO-DMSP); Biodiversity Characterization at Landscape Level (BCLL) etc. which significantly demonstrated the use of satellite data in mapping and monitoring natural resources. In order to facilitate the sharing of all non-sensitive data available either in digital or analogue forms, but generated using public funds by various Ministries/Departments/ Subordinate offices/ organizations/ agencies of the GOI, the National Data Sharing and Accessibility Policy (NDSAP) was also introduced in the year 2012 on release of new Remote Sensing Data Policy (RSDP). The policy promoted data sharing and enabled access to government owned data for national planning and development. Today, many Web-enabled Geospatial Information Systems viz., NNRMS Portal/ Natural Resource Data Base (NRDB) to visualize the spatial datasets generated under NNRMS program; BHOOSAMPADA, ‘Bhuvan’ for Indian Earth Observation Data Visualization; Meteorological and Oceanographic Satellite Data Archival. Centre (MOSDAC), Biodiversity Information and Indian Bio-resource Information Network, India-Water Resource information System (WRIS), Indian Forest Fire Response and Assessment System, (Forecasting Agricultural output using Space,. Agrometeorology and Land based observations), National Information System for Climate and Environment Studies (NICES) providing geo-information services in the public domain.

5. Training and Capacity Building:

The first training program in aerial photo-interpretation was initiated at IPI with only three courses viz. geosciences, forestry and soil offered initially covering many aspects of pre-investment surveys of natural resource development and increasing for the planning and management of the environment (Beek, 1992). They were all one year courses and later they supported a core course in Photogrammetry, with the support from partner institutes SOI and ITC. The strategic focus during this phase was to make use of aerial photographs in surveying the natural resources and required expertise initially was also shared by Dutch experts from ITC. Later on, bit by bit, the Indian expertise was built up and various organizations such as ONGC, GSI, Central and State Water Boards, State Geology Departments and universities got benefited after getting sufficiently trained. During 1969, Indian Society of Photo-interpretation (now Indian Society of Remote Sensing) was formed that aimed at the advancement and dissemination of remote sensing technology and education by conjunctive use of airborne remote sensing with conventional methods in the fields of survey, planning and management of natural resources and environment. The first remote sensing journal from India “Photonirvachak” (now called Indian Journal of Remote Sensing) exclusively dealing with remote sensing technology and its applications was also started by this society.

With a gradual development and availability of the satellite data both from foreign and Indian satellites, there was a shift from aerial photointerpretation to remote sensing and IPI got merged with the NRSA in 1976 and thus was also transferred from DST to newly created Department of Space. In the light of these developments a committee was established under the chairmanship of Shri D. D. Kamat, from SAC, Ahmedabad to revise the courses and give future direction to geo-spatial capacity building needs of the country. It was in the same year that requirement of the technology in the effective management of the urban environment was also realized and a Human Settlement Analysis group was established by DGIS finances co-operation and IPI was renamed to Indian Institute of Remote Sensing (IIRS) in 1983. After adopting the Kamat Committee report on Curriculum in 1985, training programs were revamped with a shift towards satellite remote sensing and several short duration courses were also introduced along with the introduction of two new disciplines i.e. coastal and marine resources and water resources and two new subjects i.e. agriculture and ecology for strengthening the existing discipline of forestry and soils. During 1990s, GIS was formally introduced in the various courses of IIRS with more emphasis on GIS based application, modelling and data integration (Dadhwal & Raju, 2010). However, as is the case with any technology, initial challenges were faced in the use of GIS as it required understanding of a number of concepts as well as tools and technology itself. The availability of limited skilled personnel and infrastructure further compounded the complexity of learning during initial stages. Keeping in view the need for GIS training in India an indigenous GIS software package GRAM++ and a GIS learning tool E-Tutor was developed at the Centre of Studies in Resources Engineering, IIT Bombay which demonstrated the use of multimedia technology in minimizing the learning

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curve and providing immediate exposure to technology that too at no cost (Venkatachellam et al, 2006).

Till 2006 IIRS focus was on contact base training and education programs (Dadhwal and Raju, 2007). In September 2004, a dedicated satellite name as EDUSAT was launched by ISRO to provide quality education, vocational training for skill development and to reach the unreached places like remote and inaccessible locations in India. IIRS has started to use this satellite for its training and capacity building program in the area of GIT and its applications in year the 2007 under its outreach program (Murthy et al, 2014, Karnatak et al, 2015). Under this program a network of academic institutions is setup to enhance the outreach of GIT among undergraduate students, postgraduate students and researchers in academia. In this mode of capacity building, the experts from IIRS-ISRO are available for live and interactive session during pre-announced time slot. The network was further expanded using the internet platform in the year 2012. The program was quite successful in India, where more than 30,000 participants are trained from 370 network institutions in the country during the last eight years. Other important initiatives of IIRS-ISRO was conducting online e-learning based courses using concepts of Massive Open Online Courses (MOOC) in year the 2014. The e-learning contents are developed as multimedia contents having 2D and 3D animation, simulations and virtual reality. The online courses designed based on self-paced and learning centric learning methodologies. In the recent past the use of Open source and Freeware software solutions are in more demand among geospatial professionals in India. Various scientific societies such as OSGEO-India, FOSS4G, ISRS, ISG etc., started to promote free and open sources software data in geospatial domain. These initiatives have acted as a bridge between various groups like Developers, Application Users, NGOs, and Government departments.

The success of the national level training and capacity building in the field of geo-informatics in India, also led to the its selection of India as host country for establishment of Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP) by the United Nations Office of Outer Space Affairs (UN-OOSA) under an agreement signed initially by 10 member countries of the region. The Centre is hosted by the Government of India with DOS, as the nodal agency. The appropriate facility and expertise to the Center is provided through the various DOS centres viz. IIRS, at Dehradun, SAC and Physical Research Laboratory (PRL), at Ahmedabad.

6. Research and Education:

The role of formal research and education in a technologically developed era needs no exaggeration. Development of Geo-spatial technology in India has been influenced by research and education significantly. The ISRO has evolved a dedicated program i.e. RESPOND, through which financial support is provided for conducting research and development activities related to Space Science, Space Technology and Space Application to academia in India since 1970. In special cases research and development projects proposed by non-academic R & D laboratories can also be supported through this programme. The programme aims to encourage quality research in areas of relevance to the Indian space program and its applications. Apart from this, ISRO has also set up Space Technology Cells at premiere institutions like Indian Institute of Technologies (IITs)-Bombay, Kanpur, Kharagpur & Madras; Indian Institute of Science (IISc), Bangalore and Joint Research Program with University of Pune (UoP) to carry out research activities in the areas of space technology and applications. In-house research in the field of space science and space application is also encouraged under the various under the EOAM and TDP projects in the various ISRO organization so as to develop state of art knowledge. This also helps in research based teaching and training offered by the by the various its institutes e.g. NRSC, SAC and IIRS. Several schemes are there for sponsoring R&D projects by other agencies as well, such as the Department of Science and Technology, Council of Scientific & Industrial Research, Ministry of Environment and Forest etc. and several other thematic Departments.

Apart from research, several initiatives have been made in the past to incorporate Geo-spatial education in school and colleges both formally by inclusion in the curricula and informally through awareness workshops and summer school. Formally, Anna University, Bhartidasan University, the Madurai Kamraj University, and Roorkee University pioneered the full time post graduate education program in the RS/GIS. The country level Post Graduate program in other university courses also included RS/GIS as one of the papers in their syllabus. IIRS also started the long term joint education program in collaboration with ITC, Netherlands and Andhra University, India in 2001. Today there are more than 100 universities offering courses in GIT. Informal, education in geoinformatics in India has been facilitated by various societies, e.g. ISRS, ISG, INCA, ASI and IMS through their local chapters. IIRS, NRSC and NATMO in collaboration with NCERT conducted three simultaneous workshops for northern, southern and eastern region respectively in 2008. Subsequently geospatial content for school under the National Council of Educational Research and Training was developed by IIRS (Kumar et al, 2014).

The National Task Force on Geospatial Education was constituted in October 2010 by MHRD with an aim of preparing a national strategy for geospatial education in the country and recommend implementation of geospatial education program at desired levels. Its other objectives were to develop and design geospatial oriented educational programme for technical and non-technical institutions, provide an overall guiding framework for development and implementation of National Geospatial Education strategy and make recommendations relevant for its implementation. Four sub-groups to address specific issues related to geospatial education were formed which submitted their inputs and the consolidated report entitled “Report of Task Force on Geospatial Education” was released in the year 2013 which made several recommendations, and also identified the major gaps that needs to be bridged in the geospatial knowledge arena in the country (Table 3).

7. Geo-Industrialization:

Advances in the computer hardware and software has been a leading factor that influenced the Geo-industrialization i.e. incorporation of GIS in formal markets. Globally the scene for

GIS to become part of the mainstream mass market computer software industry was set only in mid-1900s (Thrall & Thrall, 1999). It was due to the fact that microcomputer-based GIS products were shedding the command-line-driven heritage carried with them from their origins on mainframe computer platforms, and incorporated front-end applications using windows and icons that assisted the user in all phases of product development and operation. In the context to India also the introduction of computers to support the district administration had only taken place in the late eighties and early nineties. They were being used primarily in transaction-processing applications to generate monthly reports on progress made with respect to different development projects. These outputs were primarily in the form of lists and tables with little or no use being made of a map-based representations. For example, land cover figures would typically be reported in a tabular form and not in a map form (Sahay, 1998). Significant contribution in developing GIS in India came due to development in India's IT infrastructure with the contribution from Department of Electronics and Information Technology (DeitY) and establishment of The National Association of Software and Service Companies (NASSCOM) under the Societies Act, 1860, in 1988. GIS was recognized as an IT Service Segment by the first report of NASSCOM and Data Digitization / GIS was enlisted as IT enabled services among the 10 such services identified by NASSCOMM (Singh 2002). It was also during the same period that ISRO/DOS encouraged the technocrats to accept the commercialize the usage of satellite data to address the various needs of natural resource management and make the technology more popular outside the research and development to utilization in the public domain. The growth of the private sectors in GIT was also facilitated due to availability of Commercial Internet access. This provided them to have good business collaboration with the Western countries which were quite ahead of India that time and also provided workforce and skill development guidance in India in GIT. The major contribution of these companies initially was in the urban infrastructure planning and also in creating the digital database of huge volumes for the various telecom industries interested to target India as a potential market. Beside these, most of these companies also served as the vendors of the GIS software in India. The major software provider's viz. Intergraph, ESRI, Autodesk, Bentley systems, Leica Geosystems, and PCI Geomatics etc. have provided a technical support at the point when the technology was still infant stage. This also lead to the commodification of GIS in India and resulted in increased utilization of EO-datasets generated in the country. Increased emphasis on GIS also resulted in the formation of Indian Society of Geo-Geomatics in which further contributed in shaping the Geo-informatics in India.

The year 2000 was considered a tremendous time for GIS users in India. It was believed to be a watershed for 'GIS in India' that witnessed a volatile GIS growth fueled by increasing work opportunities, the availability of competent workers, development of powerful GIS software and a rapid increase in the awareness of GIS among all the stakeholders. Subsequently the Remote Sensing Data Policy in the year 2001 was released that provided the modalities for managing and/ or permitting the acquisition/dissemination of remote sensing data in support of developmental activities and promoted further growth of geo-spatial industry at one hand and the national development at the other. It allowed all data of resolution up to 5.8 m to be distributed on non-discriminatory basis and on "as requested basis". This regulation, however further lead to the debate over the security related issues under the Map Restriction Policy of the Ministry of Defense, 1967 that restricted the dissemination of topographic maps, aerial photos, trigonometric and geophysical data for large parts of the country (Lahiri, 2014). To ensure the smooth utilization of the remote sensing data for the developmental causes, a National Map Policy came into place in 2005 that provided an innovative approach to deal with the country's security concerns.

Other aspects that revolutionized the GI industry are online availability of satellite data (Landsat data, NOEDA in Bhuvan etc.) at no cost at the end of 2008 and 2011 and the launch of Google maps, Bing Maps and ISRO Bhuvan Portal that increased the popularity of the concept of geo-location in a remarkable way. This phase was further strengthened due to removal of selected availability of GPS by US that resulted in the more trustworthy and spatially precise location based services and gave a thrust to location based services which today forms the backbone of the e-governance vision of the Government of India. In the light of the rapid technological development and availability of still higher resolution satellite datasets this period also witnessed a revision of the original Remote Sensing Data Policy in the year 2011 that further permitted distribution of data up to 1m resolution.

8. G-Governance and Digital India Initiative:

As demonstrated by various programmes of ISRO in the field of Geo-informatics applications in management of natural resources, development of Village Resource Centers and disaster management support, etc. the power of geoinformatics has been recognized by various stakeholders. This has led to the moving away from, looking at GIS as just a mapping or database tool or as scientific software to incorporating it in the effective governance i.e. G-Governance. The Government of India has launched an ambitious Digital India Mission (DIM) in July 2015, to transform India into a digitally empowered society and knowledge economy. The government plans to use the power of GIS for decision support systems & development. With the revolutionary development in smart phones and the android system, thereby leading to corresponding developments in M2M communication technology the potential of utilizing GIS and location based services is increased in an incredible manner. E-Kranti project initiative under DIM provides electronic delivery of services to the citizens. It is noteworthy to mention that efforts of ISRO in terms of the satellite communication, providing broadband services; the EO satellite missions providing the ease of acquiring the satellite data and the huge institutional infrastructure development providing necessary training and capacity building, have articulated where DIM though, has been a big challenge for the government of India due to widespread geography, massive population, and enormous linguistic & cultural diversity can be met with appropriate efforts and political support. Recently the National Space meet was held for promoting space technology based tools and applications in governance and development on Sept 7, 2015 at Vigyan Bhavan New Delhi. It was primarily aimed at deliberations on the action plans of various Ministries/Departments for ensuring effective utilization of the space technology for the benefit of the society and the Department of Space was urged to proactively engage with all stakeholders to maximize the use of space science in governance and development. In similar line it is proposed to conduct State level meet to identify the thrust arears where remote sensing and GIT can be used to improve the government functioning.

9. Discussions:

Starting as a modest effort of getting familiarized with new methods of mapping and surveying and small space science enterprise in the late nineteen fifties with meager resources, GIT in India has grown by leaps and bounds. There has been a steady transition from mapping alone to increased research in data acquisition, preprocessing, processing, analysis and publishing. Broadly, this implies inclusion of areas like GIS, GPS, Photogrammetry, Cartography, Remote Sensing, Surveying, Spatial Data Infrastructure and Technology including hardware, software, and algorithms and modeling were developing at a fast pace.

The India’s vibrant space program which has matured as a symbol of the country’s sophisticated technological capabilities and its growing regional and global prestige has contributed towards building the space infrastructure as the community resource to accelerate various developmental processes and harness the benefits of space applications for the socioeconomic development of the society through GIS based mapping and monitoring. ISRO’s operational systems viz. IRS and INSAT have contributed in a big way in the development of geospatial infrastructure and spatial literacy in the country. This is primarily because, these program are driven by the user needs and were carried out through a well-established multi-pronged implementation architecture of NNRMS. Learnings from the flagship programs were used as an ingredient in policy development and better governance. Information generated on the nation's natural resources and its infrastructure; updating and maintaining the information sets and integrating these with administrative and social datasets provided the most optimal and scientific decision-alternatives in support of national development.

The use of GIT in India provides a classic example of the ‘transfer of technology’ model, which typically involves the introduction of technical systems developed in the West into developing countries (Sahay, 1998). However, with time Indian EO program has aligned itself well with various activities under the Bharat Nirman program such as National Rural Employment Guarantee Scheme; Accelerated Irrigation Benefit Program (AIBP); National Urban Renewal Mission (NURM); National Watershed Development Program for Rainfed Areas (NWDPRA) (Jayaraman et al, 2006). The growth of positioning, navigation and timing applications, which rely on satellite signals, have spurred new commercial markets (e.g. GPS chipsets in smartphones), Direct to Home (DTH) services are now part of the society and remote sensing based satellite imageries are used for many mapping applications. Today, several Indian states are using GIT for good governance and efficient management for delivering better services to the society. Digital India Mission of which GIS forms one of the pillars, has resulted due to the continuous development of India’s Satellite Communication, Earth Observation and IT infrastructure development along with the wider global factors including the international co-operation. While there is no doubt that India has made tremendous success in GIT resulting in significant contribution in governance (people as well as resources), It faces daunting challenges in terms of further research innovations and leadership which forms an eternal theme in relation to national development and deeper penetration of the technology in to the society.

Efforts towards incorporating GIT in the school level education and the National Space Meet held in New Delhi (2015) has culminated into the NCERT Training Program jointly conducted by NNRMS-EOS/IIRS and NCERT with the support drawn from ISRO/DOS Centers (NRSC/RRSCs/ NE-SAC and IIRS) in a mission mode. The program targeted the PG teachers and 2 weeks duration training courses was conducted in 2 at various Centers across the country. A total of 442 PG teachers of geography have got benefited. A portal providing map based learning to bring awareness among the students about country's natural resources, environment and their role in sustainable development. It is an initiative of Bhuvan- NRSC/ISRO based on NCERT syllabus.

Though we have witnessed a leap frog advancements in the fields of geoinformatics as result of continuous efforts of ISRO and allied agencies and today significant data portals are available that are capable of providing rich amount of information on various themes, the contributing and user agencies face a lot of challenge right from understanding open data, capacity to compile good quality data, technology integration, and potential apps, availability of funds and allocation of duty to institutional support. There is a need to enable and equip these government agencies with the necessary skill sets to contribute high quality datasets. There is an imperative requirement that various beneficiary departments should be equipped with necessary technology & administrative support to engage with citizens willing to use data in the open domain. A more participatory approaches and their institutionalization through the policy reform (Verma and Gupta, 2013) and also presence of incentive driven mechanism is required to ensure sustained release of good quality data and their utility for various applications.

The sustainable use of geo-informatics also calls for the technological advancements through innovation. It will affect geoinformatics in terms of products, processes and services for the future and will be primarily driven by research and sharing of the knowledge using a network of institutions. Continuous advancement in research are essential to maintain competitive relevance of the technology. Universities are considered as central to a nation’s capacity both for research and for advanced education, although the institutional landscape varies across countries. However, India does not have enough high quality researchers; there are few opportunities for interdisciplinary and multidisciplinary working, lack of early stage research experience; a weak ecosystem for innovation, and low levels of industry engagement (Heslop, 2014) presents big challenges.

Globally, research & development activities and innovations are increasingly becoming multidisciplinary and collaborative and require substantial communication/computational power. For India to emerge as a significant R&D hub, it has to become a part of this wave of collaboration and co-creation. Though this has been realized and National Knowledge Network has been established by the government of India, which is a unique network connecting the research institutions and universities in the country through a high bandwidth network for enabling collaborative research, development and innovation, there is a daunting task ahead. At present only 1,580 are entries (including the research institutes) to it as compared to 659 central universities, 33,023 colleges and 12,748 diplomas providing institutes alone of in the country.

Effective introduction of GIS into the education process is complicated by the high cost of hardware, software and teaching material. Almost all the universities in the developed countries generate their wealth, through their advanced research in collaboration with the industry. There is a gap between research, academia and industry (Venugopal and Senthil, 2001). Skill building and industry association in geoinformatics can be viewed as another important ingredient to push its sustainable use and to take the rate of peaceful use of space applications to a higher trajectory. The global economy is expected to witness a skilled manpower shortage to the extent of around 56 million by 2020 (FICCI, 2015). Thus, the "demographic dividend" in India needs to be exploited not only to expand the production possibility frontier, but also to meet the skilled manpower requirements of in India and abroad (Roy, 2014).

It can be concluded that tremendous efforts made by various agencies have driven the face of current GIT in India. Currently, it is found interwoven with almost every vertical of the resource management in the country and more collaborative efforts and research innovations would be needed to sustain geo-informatics technology so that it continue to contribute to the inclusive growth and development of the country.

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Table 1: Chronological summary (Decadal) of institutional /policy/training and capacity development vis-à-vis. earth observation/ flagship programs/products /services development in India.

INSTITUTIONAL /POLICY/TRAINING AND CAPACITY DEVELOPMENT	Year (10s)	SATELLTE COMMUNICATION/EARTH OBSERVATION/ FLAGSHIP PROGRAMS/PRODUCTS /SERVICES
☑ Survey of India was the first governmental organization established by the British (Department of Science & Technology)	1700	
☑ Great Trigonometrical Survey (GTS) to provide control frame work for topographical mapping in India. ☑ Most of the Britsh India mapped at various topographic scales	1800	
☑ Mapping on 1 inch to a mile ☑ Aerial photography Introduced in survey experiment ☑ Aerial Photography based Topography mapping	1900	☑ Feasibility of space satellites had surfaced$ ☑ Report on Preliminary Design of an Experimental World-Circling Spaceship by Douglas Aircraft Company's Engineering Division (U.S) $ ☑ Corona Mission of U.S. for Intelligence Photography$

☑ Impetus on aerial photography and training on new techniques in surveying and mapping for operational projects (Series of events)	1950	☑ Sputnik I and II satellites (USSR) [$] ☑ Explorer 1 (U.S) [$]		
☑ Establishment of Indian National Committee for Space Research (INCOSPAR)under Dept. of Atomic Energy (DAE) ☑ Thumba Equatorial Rocket Launching Station (TERLS) ☑ Establishment of Indian Photo Interpretation Institute (IPI) ☑ Establishment of Indian society of Photo Interpretation (Now ISRS) ☑ Reconstitution of INCOSPAR and establishment of Indian Space Research Organization (ISRO)	1960	☑ Growth in geosynchronous (GEO) satellite communication in US[$] ☑ Experimental Satellite Communication Earth Station (ESCES) 1967[$]		
☑ Space Commission Constituted, ☑ Department of Space (DOS) established & ISRO brought under it ☑ Space Application Centre (SAC) under DOS ☑ National Remote Sensing Agency established by DST and undertook IPI ☑ Landsat Earth Station in Hyderabad ☑ Airborne Geophysical survey was started as the first technical activity. ☑ Sponsored research-RESPOND Programme	1970	☑ Launch of Landsat 1 by U.S. [$] ☑ Aryabhata[*] (To study X-ray astronomy, aeronomics, & solar physics) ☑ Bhaskara-I[*] (Ocean and land surface data.)	☑ SITE[++] ☑ STEP[++] ☑ Coconut wilt-root disease eradication by remote sensing techniques[^^]	
☑ Encouraging technocrats by Department of Space (DOS) initiated ☑ IPI renamed to IIRS ☑ Kamat Committee report ☑ Establishment of Human Settlement Analysis group DGIS finances co-operation ☑ NASSCOM, RSI	1980	☑ Bhaskara-II[*] (ocean and land surface data.) ☑ INSAT 1A[+] ☑ INSAT 1B[+] ☑ IRS-1A[*] (First Mission for land based applications) ☑ INSAT IC[+] ☑ GPS	☑ *Natural Resources Data Managemet System (NRDMS) of the DST* [^] ☑ *Geographical Information System (GISNIC) and District Information System (DISNIC) of the National Informatics Center (MoCIT)* [^] ☑ *National Natural Resources Management System (NNRMS) of the DOS*[^^] ☑ Nation-wide mapping of forest and non-forest area[^^] ☑ National Wasteland Monitoring Project (NWMP) [^^] ☑ IMSD Phase I [^^] ☑ CAPE project[^^] ☑ National Agricultural Drought Assessment and Monitoring System(NADAMS)[^^]	
☑ IN-RIMT, Map my India, RMSI , Rolta India, ESRI India, GIS Development) ☑ GIS formally introduced in IIRS courses ☑ Post graduate courses included RS/GIS as one of the paper in their syllabus. ☑ Anna University, Bhartidasan University and the Madurai Kamraj University, Roorkee University, started initial formal education programmes in the RS/GIS ☑ CSSTEAP (UN Centre) at Dehradun and Ahmedabad ☑ Open Geo-spatial Consortium	1990	☑ INSAT ID[+] ☑ IRS-1B[*] ☑ SROSS-C2 ☑ INSAT 2A[+] ☑ IRS-1E[*] & INSAT 2B[+] ☑ IRS-P2[*] ☑ IRS-1C[*] & INSAT-2C[+] ☑ IRS-P3[*] ☑ IRS-1D[*] & INSAT 2D[+] ☑ OceanSat (IRS-P4)[#] & INSAT 2E[+]	☑ Potential Fishing Zones (PFZ) ☑ IMSD (Phase II) [^^] ☑ Accelerated Irrigation Benefits Programme (AIBP) [^^] ☑ NRIS[^^] ☑ ISRO-IGBP[^^]	☑ Commercial Internet Access[$]
☑ Indigenous GIS tool GRAM++, an attempt was made to build a GIS training tool around GRAM++ ☑ Selected availability of GPS turned off ☑ Remote Sensing Data Policy , National Map Policy ☑ IIRS JEP with ITC Netherlands and Andhra University ☑ Establishment of the Indian institute of Space Technology was established ☑ Distance education programme in RS/GIs started-EDUSAT ☑ NRSA made a fully Government organization under ISRO and renamed National Remote Sensing Centre (NRSC). ☑ RRSSCs amalgamated with NRSC and renamed as Regional Remote Sensing Centres. ☑ OSGEO-INDIA	2000-2010	☑ KALPANA[+++] (first dedicated meteorological satellite) ☑ IRS-P6 / RESOURCESAT-1[*] & INSAT 3A[+] ☑ EduSat (GSAT3)[+ +] ☑ CARTOSAT-1*(first Indian Remote Sensing Satellite capable of providing in-orbit stereo images) ☑ CARTOSAT-2* ☑ IMS-1 (low-cost microsatellite imaging mission of ISRO) ☑ CARTOSAT - 2A* ☑ RISAT-2* (first all-weather earth observation satellites) ☑ Oceansat-2[#] ☑ CARTOSAT -2B*	☑ NSDI[^^] ☑ ISRO-DMSP[^^] ☑ BCLL[^^] ☑ NRCENSUS[^^] ☑ BHUVAN[^^] ☑ NUIS[^^] ☑ National Wastelands Monitoring (NWM) [^^] ☑ NWIA) [^^] ☑ Watershed Monitoring and Development ☑ Glacier Inventory of Himalayas[^^] ☑ IBIN[^^] ☑ FASAL[^^] ☑ MOSDAC[^^] ☑ BHUSAMPADA[^^]	☑ Google Earth[$] ☑ Free Landsat Data[$]

☑ Formation on National Geo-Task Force ☑ Report of Task Force on Geospatial Education ☑ Revision of Remote Sensing Data Policy ☑ National Data Sharing and Accessibility Policy was introduced in 2012 ☑ IIRS made an independent unit ☑ National Space Meet	2011 – 2016	☑ Megha-Tropiques[+++] ☑ RESOURCESAT-2* ☑ RISAT-1* ☑ GAGAN[++] ☑ SARAL[#] ☑ INSAT-3D[+] ☑ IRNSS-1A[@] ☑ GSAT-7[++] ☑ IRNSS-1B, IRNSS-1C[@] ☑ GSAT-14, GSAT-16[++] ☑ IRNSS-1D[@] ☑ INSAT 4E[+], GSAT-15[++] ☑ IRNSS-1E, 1F, 1G[@]	☑ Space Based Information System for Decentralized Planning (SIS-DP)[^^] ☑ WRIS[^^] ☑ NBIS[^^] ☑ NICES[^^]	☑ Digital India Mission[^]

[*]EO satellite/Program; [#] Oceanographic Satellite; [+] Telecommunication/broadcasting/Meteorology Satellite/Program; [++] Dedicated Communication Satellite/Program; [+++] Dedicated Metereological Satellite/Program; [@] Navigation Satellite; [^^]Flagship Programs of NNRMS/ISRO; [^]Other Flagship Programs, [$]Others (non-Indian programs).