Geographic Information Systems: Enabling Knowledge-Based Operations

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Information superiority is ensured through Intelligence, Surveillance and Reconnaissance (ISR) operations that enable getting the right information to the right people to make the best possible decisions. Progressive methodologies for ISR include increasing the density of sensors as also improving the involved processes qualitatively through the use of computational, digital and networking tools for integration, processing and dissemination of data. Mapping sciences and myriad dependent disciplines have undergone progressive changes because of associated advancements in remote sensing, Global Navigation Systems (GNS), Geographic Information Systems (GIS) and the associated technology. These now allow intelligence to be geographically referenced and placed over digital maps in layers, allowing better visualisation and assimilation by the user than if the information was examined in isolation. Understanding of Geospatial Intelligence (GEOINT) technology and its potential at all levels of Service hierarchy would be the key enabler for its optimum application and integration into the armed forces' doctrines and planning.

The National Geospatial-Intelligence Agency (NGA) of the US defines GEOINT as "the exploitation and analysis of imagery and

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geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information."[1] Geospatial information is information that has a geographical or location context. It includes the basic topographical information found on a map as also different location-related datasets of spatial and non-spatial information. The non-spatial tabular or textual information that can be associated with the map through links to the spatial data is called attribute data and it helps enhance the understanding of the spatial picture. Integration of the time (temporal) reference frame to the data provides the fourth dimension (4D), permitting creation of dynamic scenarios that allow realistic depictions of motion and effects of time. These then facilitate accurate assessment through methods like change analysis and pattern recognition.

A Geographic Information System (GIS) integrates hardware, software, and data for capturing, managing, analysing, and displaying all forms of geographically referenced information.[2] Some definitions also include operating personnel and procedures into the ambit. Systems that can process and depict the temporal frame are called dynamic GIS. Further advances in related technology have resulted in more sophisticated capabilities, progressing beyond depiction of basic topographical information and layers of datasets to development of highly interactive analytic environments and visualisations and value adding applications that can provide for more informed decision-making. GIS is a generic term and different systems can be customised to cater to specific domains depending on the requirements, methodologies, software, etc.

Geolocation forms the very basis of planning and execution of all conventional military operations and GIS technology has the potential not only to revolutionise the military intelligence domain but also the conduct of operations. Military efforts should aim at using these capabilities of GIS to create a dynamic geospatial intelligence 'knowledge' base and devise capabilities for its use towards improving situational awareness and for providing the context for decision-makers. GIS would form an integral part of the future network-centric operations.

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The conventional process of intelligence gathering involved obtaining imagery of mostly static and invariant targets from a single or similar source. A number of run-ins over the target ensured sufficient spread of data to infer change or activity. The stages of processing, analysis and dissemination were time intensive and each was generally separated from the others owing to technological limitations or to address security concerns. Providing geospatial relevance was an exhaustive process in itself with the sensor's flight path being correlated with the captured terrain. Technology has continued to make incremental advances in addressing the complexities of these processes providing ever improving end products while reducing the corresponding timelines. The stages leading to GEOINT remain the same as for conventional ISR but with the added geospatial relevance to data. They include data acquisition, processing, integration of disparate types of data from varied sources, data analysis to derive needed information, dissemination of intelligence and its preservation for future use. These processes have progressively become less distinct, at times even overlapping to provide a comprehensive fluid

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environment with continuous data input, processing and dissemination; influencing and being influenced in a closed loop system. Further application through tools, techniques and processes such as data mining, analytics and information management through GIS maximise the value and utility of these data sets.

Acquisition: The first aspect of acquisition is identifying the information resources required to address specific intelligence tasks and their subsequent deployment. Understanding that no one sensor can provide all the necessary data, there has been an endeavour to increase their numbers, platforms and types. Space-based and manned aerial sensors are complemented now by Unmanned Aerial Vehicle (UAVs), terrestrial and marine sensors, sub-surface sensors and also human-borne ones. The optical cameras and basic radars have been joined by infrared, multispectral and hyperspectral sensors, Synthetic Aperture Radars (SAR), acoustic sensors and full motion video (visible, infrared, or radar) capability. The resolutions—temporal, spatial, radiometric[3] and spectral—continue to become finer. Sensor capabilities are also being developed/ enhanced to address underground targets, foliage penetration, detection of moving objects, and novel denial and deception measures. Data acquisition through novel sensing modalities like biological and chemical is another prospective innovation.

Sensor swarms or arrays and geospatial scheduling of disparate sensors[4] aim at maximising coverage areas and optimising collection periods. The use of multiple sensors provides flexibility to cope with different target conditions, improve target characterisation and defeat enemy concealment, denial, and deception strategies by revealing activity concealed from a single sensor or domain. For example, a moving target can be detected by terrestrial sensors and tracked through 'cued in' optical sensors by day and hyperspectral sensors by night to provide uninterrupted data on its activity. Linking these sensors into a sensor network will further enhance capabilities that would enable seamless tracking, eliminate individual sensor limitations and inaccuracies, and provide redundancy. Sensor networking is an ongoing work that would require much more efforts at optimisation.

The Interferometric Synthetic Aperture Radar (IFSAR)[5] technique enhances surface mapping capability as also the ability to detect small changes on the surface. The Light Detection and Ranging (LiDAR), onboard airborne or space-based platforms, allows production of high-resolution digital elevation data and, coupled with hyperspectral radars, generates hydrographic survey data by day or night. These developments have enabled large scale generation of highly detailed and accurate three-dimensional models of terrain and structures with unprecedented speed and precision.

GIS allows integration of a wider variety of data from other intelligence disciplines such as Signals Intelligence (SIGINT) Human Intelligence (HUMINT), Measurement and Signatures Intelligence (MASINT)[6] and Open-Source Intelligence (OSINT).

Processing: This stage involves conversion of collected raw data into usable forms and formats suitable for integration, analysis, production, and application by end users. Extract, Transform, Load (ETL) tools enable translation of data directly or indirectly to the desired format. Data processing further includes individually processing the acquired data to filter and extract, enhance or segment out the required task-specific content. One of the major requirements at this stage would be to eliminate duplicate data and geotagging would be a great enabler towards this. This process has traditionally relied on manual interpretation of the gathered data but there is a constant endeavour towards automation

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through techniques for object recognition, feature extraction, feature tracking, and change detection.

Integration: The data, both spatial and non-spatial, needs to be integrated and geographically referenced to a map projection in an earth coordinate system. Different places on earth are projected onto flat surfaces through different projection methods and each method has its inherent errors of shape and scale. Integration should allow spatial data to be transferred from one coordinate system to another to enable creation of seamless digital maps and, consequently, a common database across large areas. These maps then need to be provided with foundation GEOINT – the overlay of geographic features for visualisation of the environment and to provide context to the information for analyses.

Similarly, huge volumes of data produced from diverse sensors of varied complexity—of different scale, resolution, accuracy, format or geometric type—would require integration into a combined and coherent observation to optimise handling and to provide for better analysis. For example, imagery captured at different times of the day at varying angles (rendering different shadows) requires human intervention or advanced algorithms for integration. Including non-imagery intelligence into this assortment further complicates the process.

The methodology of integration involves detaching the multi-sourced data from its initial frame and integrating it at several spatial and temporal scales into a smart comprehensive picture that is then referenced onto the foundation that has been developed. More layers of mission specific data, details, features, and intelligence information may then be added. This process, known as densification, may also be used to continually update the product to meet evolving needs and changing circumstances.

Integration applies not only to data items, but also to different data catalogues of varied intelligence elements and agencies to economise efforts and to prepare a comprehensive picture in support of national security objectives. The end product may be presented in hard copies as printed maps or charts. However, contemporary ISR would benefit from digital files and publications that could be presented as digitised 'smart' maps and charts along with the attributed data on suitable displays that would also support digital simulation and modelling databases.

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Veracity of data would have a bearing on the operational planning and the system should be able to evaluate participatory sensing data for inaccuracies and errors. These would include inputs on the reliability of data source and system synchronisation, the currency and accuracy of the data, incomplete data and also the presence of denial and deception measures. The derived intelligence can then be categorised for its dependability towards decision-making.

Analysis: It is important that the first three stages generate sufficient data and convert it into usable information so that it is amenable to analysis. During this phase, analysts extract intelligence by identifying relationships, patterns, trends and anomalies among this information. They also identify targets for future acquisitions. Correlating information with historic trends and previous assessments, stored in the databases, enables them to generate a more complete and accurate assessment of the operational environment. Military databases provide, among other things, information of the Orders of Battle (ORBATs), doctrinal templates (own and enemy's), and remote sensing imageries of the geographical

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regions of the adversaries for correlation.[7] Despite advances in computation capabilities that are resulting in an ever increasing use of electronic data mining,[8] human intellect would forever be required to address the unpredictable complexities of data. Accordingly, Commercial off the Shelf (COTS) GIS packages are providing ever improving analytical tools and products, with options to allow consumers to develop their own applications or variants for analyses and manipulation of data. Simulation techniques that allow development of contextual models of geographically referenced scenarios would further assist the analysts in exploiting the intelligence.

Dissemination: Timely dissemination of relevant GEOINT through secure means is equally important for it to serve as the foundation and common frame of reference for planning and execution of any joint operation. End users vary from the highest echelons of command down to the smaller formations and the system ideally should allow both pulling of data on demand and pushing data back to the system. While the ubiquity of access to data may seem desirable, the amount of information that can be efficiently delivered and visualised is dictated by the end user's location, type of information required, availability of network of sufficient bandwidth to handle appropriate levels of data, user device capacities to handle data and security concerns. This entails developing middleware to filter the geospatial intelligence for content delivery based on these factors as well as establishment of reliable security protocols with both physical as well as technological barriers to promote safe data exchange. These measures, along with continuous system management would also prevent data overload in an environment where everyone would demand the maximum.

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The sense of vision is the most perceptive among all human senses. Suitable visualisation of operational spaces and activity patterns of all sizes and scales across different types of displays, with correct and effective representation of data, best characterises the benefits of GIS. Developing salient displays is benefiting from human cognition research and human-machine interaction studies. Data presentation is on digital GIS maps—multi-scale interactive maps that can be depicted at different scales (zooming in and out) without affecting the accuracy and clarity of the overlaid information. Optimised data display shall use common display standards and symbology and interactive tools shall be able to customise data presentation contextual to the targeted user's needs, be it for analysis or for operational use. The user can query a multitude of perennial and dynamic data in support of the task at hand. Colour, contrast and shading are the primary methods of depiction of the geospatial picture and thematic representations. Equally important is an uncluttered (layered data on call rather than as standard display) display of non-imagery data or attributed data that is clearly visible under all light conditions. Recent developments allow time-based and animated display of dynamic information.

Common Operational Picture (COP): Military operations are best served through the creation of a Common Operational Picture (COP), a comprehensive visual depiction of a specific geographical area that enables users to quickly orient and visualise their mission space. Threat, risk and vulnerability assessments, and planning of military objectives and missions can be done more realistically on three-dimensional models and simulations. Overlaying of information like the weather picture, order of battle, intelligence reports and potential hot spots would enable better analyses and decision-making. A COP that can be accessed by different levels of command simultaneously would allow synchronised conduct of operations more flexibly and rapidly.

Preservation: Data management also involves preserving formatted and archived geospatial information and its indexing for efficient cataloguing and retrieval for reuse and for change analysis. The deluge of information is a challenge as is the sheer redundancy of most of it and there is little choice but to resort to automation with advanced algorithms for geocoding and georeferencing. Powerful search engines, akin to Google, are required for proficient browsing, sifting and rapid retrieval of information from image and data archives. Establishing data standards would enable exchange of data among friendly sources. Indexing and updating can benefit from creation of autonomous metadata[9] (documentation about data) repositories that would also help in avoiding duplication of data. Preserved data requires periodic review to maintain its relevance for subsequent use.

Most technologies related to GIS, as described above, are in different phases of maturity with expertise related to dynamic GIS being mostly in its nascent stages. For an efficient GIS, the requirement is to build upon the supporting elements and domains.

Spatiotemporal Database Systems: Spatiotemporal Database Management Systems (ST-DBMS) need to be capable of handling and processing the vast amounts of diverse data. The term Big Data has been coined for data sets so large and complex that they cannot be handled efficiently by common database management systems. Different solutions are being researched to address the challenges of Big Data and these would be equally applicable to the GEOINT domain.

IT Infrastructure: Highly capable data transfer networks would be the key to improving the timeliness and relevance of all ISR efforts. Progressive improvements in Information Technology (IT) infrastructures and operational processes and enhanced computational techniques are required to reduce latency in intelligence generation and delivery processes. Efficient grids would also enable distributed computing[10] and provide collaborative analysis environments for evaluation of similar information by horizontally integrated[11] analysts. Cloud storage and computing, that allows the power of multiple systems to boost capacity and capability, is transforming data handling. It would also allow selective procurement of data by consumers, reducing data storage costs, with the ability to modify demand to suit the changing requirements. Military GIS would benefit from suitable cloud infrastructure that would involve selected machines with the concurrent security infrastructure to guard against potential vulnerabilities.

Interoperability: Intelligence sharing towards achievement of common goals, such as joint operations, counter-insurgency or disaster management operations, necessitates horizontal integration of geographic information between different agencies and at times with friendly countries. This entails interoperable common and aligned open standards and defined interoperability specifications for data format, systems architectures and semantics, and creation of common standard ontologies.[12] Interoperability would be further bolstered by formulation of common symbology and display standards and ensuring adherence through joint training.

Interoperability among diverse international agencies has been boosted through the efforts of the Open Geospatial Consortium (OGC) Inc., an international industry consortium of private companies, government agencies, universities, and individuals participating in a process to develop open and extensible[13] geoprocessing specifications. Defining these specifications has enabled creation of consensus software, applications and programming interfaces to address a large number of domains, including those related to GEOINT. Besides increasing interoperability, it has helped reduce expenditures as consumers can access common ontologies, develop interoperable user applications and avoid creating

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duplicative standards. OGC standards are being adhered to by most industries and governments for their programmes.

Automation: A highly manoeuvrable battlespace, increased operational tempo and time-sensitive targeting necessitate timeliness and relevance of geospatial intelligence. The requisite compression of the time interval among the stages would evidently be achieved by reducing the human element and increasing automation in these processes. However, as already explained above, full automation is not totally achievable nor desirable for ISR functions. It would be prudent to study the stages which would be best supported by automation and how it would assist in the rest by taking up the routine cognitive tasks, thereby enabling the interpreters to focus on analysis and generation of contextual solutions. For example, the onboard Global Positioning System (GPS) derived georeferencing capability (geotagging) can obviate the time intensive process of manual data input and its georeferencing.

Decision Support System (DSS): Increasing the power of computational analysis and reasoning engines is enabling tailored, customer specific (or customer appropriate) and customer friendly GIS applications, devised for both analysis and operational stages, to enhance decision-making at all levels of command. Decision support systems go beyond the 'observe and orient' of the Observe, Orient, Decide, Act (OODA) loop to help commanders in deciding, planning, executing as also monitoring and supporting military operations. Blue force tracking is a GIS-based concept of the US military that enables colour coded depiction of disposition of own and enemy field forces on the map for better assimilation by the commanders. Applications for change detection and analysis are enabling, through intrinsic temporal queries, comparison of the detected change in an area of interest against all known similar narratives of activity patterns in the past for trends or to track any significant anomalies. These could include troop or convoy movements or deployments. It would save the huge efforts otherwise required for persistent monitoring and analysis of recurring data. Predictive analysis applications forecast changes based on military dynamics, doctrinal templates, behaviour and statistics; and then enable visualisation of these predictions through geospatial narratives on the user displays. Applications like multi-criteria decision analysis methods coupled with GIS support decision-makers in analysing a set of alternative spatial solutions and provide a prioritised list of acceptable courses of action. Advances in modelling and simulation would enable virtual replications with drive through/ fly through capability to test these alternates during conflicts and for more effective war-gaming and training during peace-time.

Applications for combat enabling operations include radio frequency identification, a GIS-based application that provides real-time monitoring and control of assets for more efficient logistics. Similar applications could be enabled for internal security operations. Other peace-time applications include border control and military installation management. GIS applications facilitate better emergency planning, response, mitigation and recovery efforts during disaster relief operations. Mitigation of disasters can be supported by analysing and displaying area and community vulnerabilities. Data elements from past disasters can help build predictive models that can facilitate development of sound procedures and protocols for future responses.

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Organisation

Recognising the emergence of geospatial information as an intelligence source in its own right, the National Imagery and Mapping Agency of the US was renamed National Geospatial-Intelligence Agency (NGA) in November 2003. It fully absorbed the other mapping and imagery departments of the US government and also some elements of the intelligence and reconnaissance agencies. Its National System for Geospatial Intelligence (NSG) is described as a combination of technology, policies, capabilities, doctrine, activities, people, data, and organisations necessary to produce GEOINT in an integrated, multi-intelligence environment.[14] The NSG community consists of members of both the intelligence community and defence Services as also international partners, industry and academia. The NGA's task is to set standards for end-to-end architecture related to GEOINT, produce geospatial information products, ensure training, develop related planning, policies, and guidance and supply technical guidance for systems using GEOINT.[15]

Other countries have progressed relatively slowly on GIS, it being a relatively new and highly technology intensive domain which has ramifications for national security. The related domains continue to be under different departments with each having its own segregated policies. However, there is now a universal realisation that reliable access to consistent and accurate geodetic data and products would be a key enabler in land sector and administrative reforms and would also provide value addition to commerce, resource mapping and utilisation, citizen services, disaster relief, etc.[16] It is also evident that businesses would only develop data that is dictated by their economic interests and development of comprehensive GIS as well as provision of large repositories of geospatial data would primarily be the responsibility of the governments.

India's success in satellite imaging programmes as also aerial imaging and ground surveys, coupled with its advanced IT capabilities has enabled designing and developing of a few isolated data sharing and GIS programmes by individual ministries and states and a private initiative too. Some departments have also procured COTS systems to meet their specific needs. However, these are compartmentalised efforts that are not inherently compatible with other similar programmes and are also limited in the amount and kind of knowledge that they can provide. Also, data generation by multiple agencies is inefficient and uneconomical. The National Spatial Data Infrastructure (NSDI) was set up in 2006 as a national infrastructure for the availability of, and access to, organised spatial data. While it has provided a gateway for sharing of geospatial data, there have been problems related to access to data of some agencies due to the absence of an integrated national geospatial strategy and related policies.

As part of the Twelfth Five-Year Plan, India intends to implement the National Geographical Information System (NGIS) project,[17] costing about Rs 3,000 crore. An Interim Core Group (ICG) (from the Ministry of Earth Sciences) collaborated with different organisations to prepare a blueprint for the development of the NGIS which was submitted to the Planning Commission in October 2011. The national GIS envisions a well maintained collection of geospatial datasets to allow national use and also plans to address the challenges of sharing, standards and duplication. The vision covers the technological as well as organisational aspects of the GIS, and lists the different departments and agencies that would form part of the NGIS. Its implementation is expected to be a time-bound mission with phased deliveries of the scale (1:50000 initially, subsequently upgraded to 1:10000 and higher in specific areas), resolution and covered area. The visible element would be the portal—with authentication and verification processes to segregate the users—which would act as a single gateway for accessing all GIS services.[18] It has also identified specific applications that would be part of the initial programme with an envisaged plan to involve other user ministries and state governments as stakeholders for designing future applications.

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Defence GIS

Defence GIS would be developed separately with provision for data exchange with the national GIS through defined secure interfaces. An independent GIS is mainly to obviate security concerns as well as to cater to the somewhat different requirements of the forces. Foremost among them is the area of interest which in the case of the armed forces extends well beyond the international borders. Requirements for round the clock surveillance, better terrain analysis and effective targeting would mean that the demand for newer and advanced sensors, higher resolutions and advancing to realistic 3D visualisations would also be pursued predominantly by the military. The requirements of GIS applications might also differ from the civil ones.

Individual Service intelligence requirements vary both in terms of space and time and these would be best served by specific GIS. The Indian Army's CIDSS (Command Information Decision Support System) and the IAF's Integrated Air Command and Control System (IACCS) are two such geospatial systems in various stages of implementation. However, this should not prejudice the development of a comprehensive system – capable of handling the spatiotemporal needs of all three Services – for the conduct of joint operations towards a common objective. The initial aim would be to integrate the existing Service specific systems that may have heterogeneous elements, through secure interfaces and then to have a common defence database compatible to these systems. An indigenous project would provide the edge by allowing access to source keys to customise the software for more efficient operations and to enable regular updates. All aspects of standardisation and interoperability would need addressing at all stages of development and these would benefit from the national data sharing standards that have already been laid out by National Spatial Data Infrastructure (NSDI). The combined Defence Communication Network and Service networks that are being developed to support the network-centric environment would enable the systems' integration. However, last mile connectivity issues would need resolving to make data available in the field.

Inputs from all levels are critical for devising and procuring applications as well as for designing optimum interfaces for the equipment. The system would benefit from doctrinal adaptation and from formulation of relevant procedures and policies that, in turn, would define the infrastructure. Skilled professionals across different specialities are required to develop the specific programmes and applications as also to manage the network issues. Additionally, appropriate training at various levels of hierarchy is a must and should involve joint and inter-Services workshops.

As is evident, geospatial science and technology involves diverse disciplines and it would be impractical to expect any single entity to delve into all these specialities effectively. There is, therefore, a requirement to collaborate with academic and industry research networks to expand the scientific expertise availability through coherent and comprehensive research. The private sector, boosted by economic incentives, is experiencing a convergence of GEOINT disciplines and has already benefited from technological innovations and creation of value-added products and applications across different domains. There is surprisingly a large number of products and services available in the commercial space that could be imbibed in the defence GIS with the requisite modifications. For example, the proliferation of mobile applications to access geospatial imagery and data on tablets and smart phones would provide the same ability to mobile soldiers. Progress in location-based services would also be used to enable GPS-enabled mobile devices to display their relative location or to relay their position back to a central server for display or for further

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processing. Developments in indoor navigation capabilities would assist in operations in the urban environment. Defence research efforts can, thus, be restricted to development of applications in definite areas that these initiatives are not able to address. Requirements of dynamism, targeting and security protocols, due to the mission-critical nature of the work and classified nature of the equipment and information, are some aspects that would be specific to military applications.

GIS is a dual use technology that can be used for both civilian progress as well as a force multiplier for military operations where information dominance forms a decisive component. Future ISR efforts should aspire for persistent surveillance, full spectrum collection, data fusion and horizontal integration to provide a seamless knowledge-centric working environment. Identification of the correct requirements at the preliminary stages would help in establishing the optimum system architecture, as also identifying developments in the commercial sector that can be absorbed by the defence GIS through use of common standards and architectures with suitable security protocols. Constant upgradations would be required to meet the demand in speed, thoroughness, accuracy, fidelity and relevance of geospatial processing. While availability of COTS systems would narrow capability gaps among adversaries, indigenous technology would enable customisation and manipulation of applications to respond to evolving needs. Technological advancements would need to be supplemented with appropriate policy measures and training to secure the maximum benefit.

Notes

1. Geospatial Intelligence (Geoint) Basic Doctrine, National Geospatial Intelligence Agency, September 2006, at http://www.scribd.com/doc/126647485/NGA-SEPT06-Geospatial-Intelligence-Geoint-Basic-Doctrine

2. "What is GIS?" at http://www.esri.com/what-is-gis/overview#overview_panel
3. The radiometric characteristics describe the actual information content in an image; radiometric resolution defines the sensitivity for detecting differences in reflected or emitted energy.
4. Geospatial scheduling involves optimally planning or sequencing a suite of sensors—based on their suitability corresponding to the time of the day and intelligence requirements, to optimise coverage.
5. This geodetic method uses two or more SAR images to generate maps of surface digital elevation, using differences in the phase of the waves returning to the satellite. It can generate detailed surface data, including details of surface cover such as buildings, structures and vegetation canopy.
6. MASINT develops intelligence using quantitative and qualitative analysis of data to identify any distinctive features associated with the target, for example, distinctive infrared signatures, electronic signals, or unique sound characteristics collected by ground, airborne, sea, and space-based systems.
7. Regularly updated doctrinal templates of the enemy/insurgents stored in the database of the system can be used to predict the enemy's next course of action.
8. Data mining is the search for hidden patterns and relationships in large databases.
9. *Data About Data*; Metadata describes details of a particular set of data. It is essential for understanding information stored in databases. For example, an image metadata may describe its size, resolution, date of creation, its source sensor and location, its colour depth, etc.
10. Distributed computing refers to the use of distributed systems to solve computational problems. A problem is divided into many tasks, each of which is solved by one or more computers.
11. Horizontal integration refers to sharing of information among peer networks.
12. In information technology, ontologies are the structural frameworks for organising information.
13. In information technology, extensible describes a programme, programming language, or protocol that is designed so that users or developers can expand or add to its capabilities.
14. For details, see n. 1.
15. Ibid.
16. Shailesh Nayak and Mukund Rao, "National GIS: Shaping India," *Coordinates*, July 2011, at http://mycoordinates.org/national-gis-shaping-india-2/
17. "Government Planning GIS Project to Improve Service Delivery," *The Times of India*, April 2, 2013.
18. "Establishment of 'National GIS' under Indian National GIS Organisation (INGO), Government of India, Ministry of Earth Sciences, National GIS Interim Core Group, October 2011, at http://dod.nic.in/national_gis.pdf