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CENTRE FOR JOINT WARFARE STUDIES

GIS AND THE INDIAN ARMED FORCES: CHALLENGES AND THE WAY FORWARD

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CENTRE FOR JOINT WARFARE STUDIES

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GIS AND THE INDIAN ARMED FORCES-CHALLENGES AND THE WAY FORWARD

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"Future conflicts will be unpredictable. The constantly-evolving world order has forced everyone to re-strategise. Constant vigil on the northern and western borders as well as the entire coastline must be maintained. We need to be ready to deal with all future challenges."

Shri Rajnath Singh
Defence Minister of India

Introduction

Recent years have seen intensifying discussions on various facets of warfare - the nature and characteristics, the multi-domain requirements of operations, the multifaceted threats, trajectories of responses, timelines of war and its tempo and the impact of technology on the overall battlespace. Despite the best of analysis and arguments by experts, the contemporary battlefields continue to throw up surprises. Among all this complexity, there is yet consensus and clarity on the importance of information superiority and effective command and control being key enablers for mission achievement, in all kinds of military operations.

Armed forces commanders continuously aspire to shorten the Observe, Orient, Decide, Act (OODA) loop and are seeking technological solutions to achieve this. This not only entails enhancing the intelligence cycle, but also the cognitive aspects of situational awareness (SA) and decision-making matrices. Providing a visual geographical context to the information allows better perception and enhances intuitive understanding. Militaries are aspiring to enhance the synergy in joint, multi-domain operations and an important aspect of this aspiration is to develop a common understanding of the geospatially relevant battlespace.

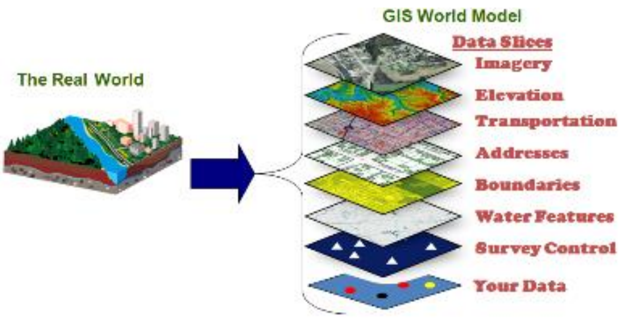
Maps and geospatially relevant images have been the mainstay of all recent armed forces campaigns and how the world views them. Advances in spatial data collection, classification and accuracy have allowed more and more digitised maps available at different scales. Acknowledging the importance of geospatial intelligence, India signed the Basic Exchange and Cooperation Agreement for Geospatial Cooperation (BECA) with USA in 2020, enabling India to access advanced satellite imagery, topographical and aeronautical digital data in real-time from the US. This information has ostensibly been of help to India in repelling a Chinese armed forces incursion in contested border territory.
[1]

Private companies have been offering geo-referenced remote sensing imagery from space. Google Maps has been utilised extensively to monitor the situation and for creating custom-made maps for use by the Ukrainian forces. Google Maps are also expected to play a part in any future peace negotiations, treaty monitoring, and potential war crimes, as well as identify any environmental disaster that may result from the invasion.[2] Clearly, private players are making increasing contribution to military missions and their capabilities need careful evaluation for the impact that they could have on national security preparedness and response.

Geospatial Intelligence (GEOINT)

Geospatial intelligence can be described as aggregating geographically referenced information from multiple sources, cartography and map making in support of armed forces and intelligence needs. It is widely acknowledged that 80% of all data that is generated is spatial in nature. Digital GEOINT became commonplace with the introduction of Global Navigation Satellite Systems, such as the U.S.' Global Positioning System (GPS) and the Russian GLONASS, as these enabled introducing the location and time elements to the data being collected.

Geographic Information System (GIS) is a generic term denoting the use of computers, technologies and systems that is expressly used to synergise collection of data, its integration, storage, analysis and distribution and depiction of information related to positions on Earth's surface onto a digital map. Introduction of the temporal element, by collection of data over a period of time, has resulted in two data streams, asset data (fixed and slow changing) and event data (updated in real time). Geospatial digital tools have enabled digital terrain modelling and projection of geographical and armed forces data, involving positions and activities, onto digital maps for better appreciation of relationships, patterns and trends. Geospatial data helps enhance SA, but it is GIS that enables this data to produce actionable knowledge and solutions and contribute to the decision-making process.

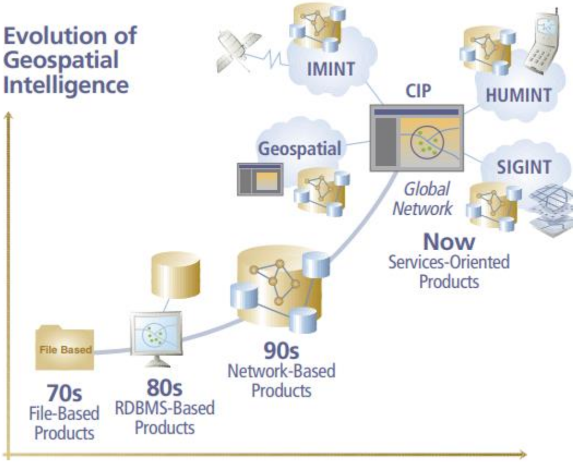


Evolution

The first recorded instance of use of geographically referenced information for making useful inferences was by John Snow in London in 1854. During an outbreak of a cholera pandemic, he along with other experts used a map to trace the cases of the outbreak to a single infected water pump.[3] By the 1960s, the potential value of computer mapping had been clearly appreciated. The term Geographic Information Systems is widely attributed to Roger Tomlinson and colleagues, who used it in 1963 to describe their activities in building a digital natural resource inventory system for Canada. Tomlinson saw that if a map could be represented in digital form, then it would be easy to make measurements of its basic elements, specifically the areas assigned to various classes of land use.[4]

A major impediment to adoption of geospatial technology was the reluctance among governments to share data because of its potential sensitivity and security implications, as also sharing of technology. A watershed in political acceptance of the technology was crossed in the U.S. in 1994 when President Clinton signed Executive Order 12906: 'Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure'.[5] The assumption was that GIS was valuable and that data should be coordinated and shared to use the technology more effectively. The NSDI is defined as "the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve utilisation of geospatial data."[6] The usage continued to be restricted however, by the limitations of the machine performance and output devices of the time. As a result, the technology had few application use cases and remained confined to governments and big corporations and to some extent by the militaries of advanced countries.

The rapid growth of GIS in recent years has been driven by the rapid technological advances, a reduction in costs of technology, availability of cheaper and larger quantities of remote sensing imagery and the commercial competition that has been affected by all these. Of particular importance have been the enhancements in sensor capability, data management software and the networking capabilities. Position and time relevance have become integral to most modern applications and a growing number of users are looking at harnessing the power of GIS across a wider range of sectors. Governments are utilising geospatial information for governance, identifying economic parameters and trends, responding to disasters, recognising and addressing environmental concerns and for making business decisions. Introduction of commercial applications that make use of location-based services, such as those of ecommerce companies like Amazon, rideshare platforms like Uber, food delivery companies like Zomato, supply chain management and many others has helped geospatial technology emerge from the shadow of armed forces or government departments into global limelight. Today GIS is a vibrant, active and rapidly expanding field which generates considerable public and private interest, debate and speculation.



Organisational changes and visionary leadership are required as any new discipline matures, for a coordinated approach to its growth, adoption and employment as also to provide oversight. The US, the pioneer and leader in most technologies, learnt its lessons from Operations Desert Shield and Desert Storm and established the National Imagery and Mapping Agency (NIMA) in 1996, consolidating multiple agencies to undertake both intelligence and combat support roles. In 2003, it was renamed the National Geospatial-Intelligence Agency (NGA) to look after the newly defined intelligence discipline of GEOINT and the National System for Geospatial Intelligence was established. This helped define the doctrine related to the innovative discipline and the organisation has supported all armed forces operations of the U.S. since, including the 2011 raid on Osama bin Laden’s compound in Abbottabad, Pakistan.[7]

Survey of India (SoI) was raised by the British army in 1767 and the department has been providing the critical mapping and international boundaries related inputs for the three Services. It has now evolved into the nation's principal mapping agency, surveying the country and providing base maps of various resolutions and scales. Organised into only 5 Directorates in 1950, mainly to look after the mapping needs of the Armed Forces in North West and North East, the department has now grown into 22 Directorates spread across the country to look after the civil requirements. The SoI has set up digital centres to generate digital topographical database for the entire country and for use in development of GIS systems for meeting the needs of national security, sustainable national development and new information markets.[8] Until now, it has had a significant representation from the armed forces, as they remain the principal consumers of its data and services.

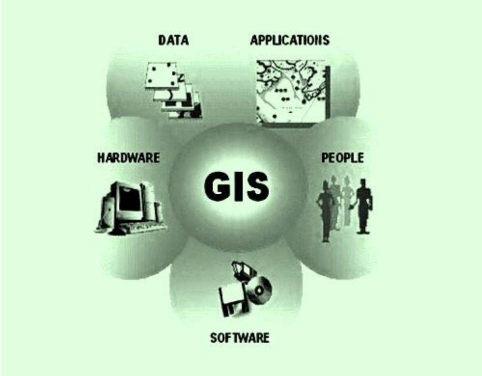
Projection and Datum

The foundation of any geospatial system is a map, plotted against a reference datum that is based on a model of the Earth called a reference ellipsoid. Map projections are utilised to convert the spherical earth onto a flat surface and this leads to various kinds of distortions that need to be compensated for. These two factors define the interoperability of maps. Indian maps have been based on the Everest datum, but lately they have been converted to the more globally acceptable WGS84 that is also being employed predominantly by remote sensing platforms.[9] Owing to the shape of the Earth, it is near impossible, technologically or economically, to have a common datum across the world. The solution is to employ mathematical conversions for accurate map to ground plotting and for merging of map areas.

Digital maps allow visualisation of maps at various scales without compromising too much on the accuracy. It is important to know that a pdf file of a map cannot be used in a GIS as its resolution, projection and datum is fixed.[10] The datum and projection matching, as also magnetic variation and gravitational information are necessary for more precise armed forces requirements. It is necessary that the spatial data for the use by armed forces units resides within the framework of single datum for coordinating joint service operations. This becomes more complex when multinational forces are deployed.

Components

A Spatial Data Infrastructure (SDI) is a data infrastructure implementing a framework of geographic data, metadata (data about data), users and tools that are interactively connected in order to use spatial data in an efficient and flexible way. It is composed of different technical and non-technical components – sensors, data, services, standards, technology, organisational and institutional aspects (people) etc. and their coordinated actions.



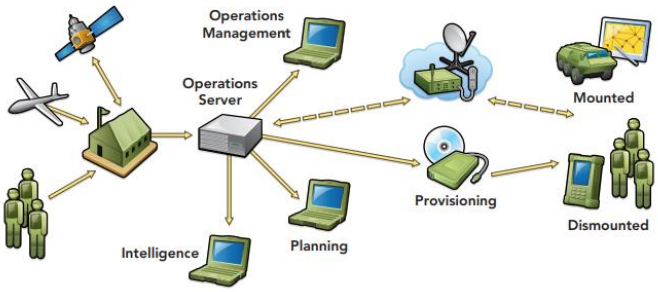
- Sensors with more varied spatial, spectral and radiometric resolutions are enhancing the detectability of features, both in the geographical and temporal space. Cross domain integration of sensors that provide accurate georeferenced imagery helps compose an integrated picture of the operational space.
- The increase in the numbers and types of sensors has resulted in generation of large volumes of varied data, along with its large attribute files, that needs to be managed. This requires hardware as well as a database management software capable of creating, organising, managing, analysing, maintaining and distributing GEOINT and products. Servers have become essential for handling of geospatial data, products and services, as also for enabling scalable storage.
- The large volume of data being generated and processed needs to flow seamlessly among the various nodes through a reliable communication network.
- At the user end, applications are needed that should be able to support desktop, mobile, and web mapping applications.
- Human resource is the most important element as the users are either data consumers, data providers or data administrators.

Military GIS

Geographical relevance and cartography have always been critical for planning and execution of all military operations. A geographical framework helps commanders better understand the relationships between dispersed military elements in the area of interest. Militaries are making endeavours in transiting from paper maps, in field and in operational planning rooms, to digital GIS systems that allow multi-factor integration of geospatial, planning, and adversarial data. Such digital maps can be accurately visualised over a wide variety of scales, while geo-processing tools enable processing and manipulation of data and its presentation as overlays. When integrated with C4ISR systems, they assist in decision making by referencing all information geographically and allowing commanders to visualise the time referenced planning and execution of operations. As digital maps become more detailed and accurate, they have become integral to navigation, engagement and targeting. An effective GIS would have application across the spectrum of operations to include low intensity conflict and peace time contingencies.

Land Operations. Land operations make extensive use of geography for defining the strategy and tactics. Georeferenced imagery provides useful insights for visualising and analysing adversary's dispositions. A sophisticated GIS can provide terrain insights for optimising own force and weapon deployments and manoeuvre, mission planning and communications planning. A GIS can help define the ideal route for the deployment of units and ensure efficient transportation through tracking and visualising the movement of vehicles on interactive maps. Coupled with imagery, it can be utilised for devising the camouflage, concealment and deception strategy. GIS would be a key enabler for ensuring efficient and effective resource allocation and utilisation in planning and execution of force protection and security and support operations. Updated dynamic information would help battlefield management, enable better command and control and better response to contingencies. Delta is an intelligence collection and management system developed by Ukraine in accordance with NATO standards to help its armed forces track the movements of Russian forces. The application provides comprehensive real-time information with high-level integration from multiple sources on a digital map that can run on any electronic device, from a laptop to a smartphone. The system has been placed in a cloud outside of Ukraine to protect it from Russian cyberattacks.[11]

GIS, with inputs from varied sources, including open sources (OSINT) has been seen to help overcome the clutter and the relative lack of clarity of operations in an urban environment. Satellite enabled navigation when supplemented by innovative indoor navigation technologies and supported by digital representations of physical and functional characteristics of places would be a key enabler in indoor operations. An example is that of Indian Army's 'SANCHAR', a network-independent, real-time tracking and messaging module that has been used during relief operations in Turkey in an urban environment. The system was dependent on Google maps and GPS constellations and helped team coordination and monitoring through a communication capability of 1.5-2 kms.[12]



Naval Operations. The maritime domain has unique nautical imperatives and challenges related to the area of operations, the threat scenarios, operational concepts and the multitude of sensors and equipment. Operations in the domain require electronic charts for defining the geographic positions and characteristics and their correlation with several complex attributes, to include ocean characterisation, sea traffic, radar signatures and so on. Tools allow data to be converted to tailored oceanographic, hydrographic, bathymetric, geophysical and acoustic products and services that could be provided as additional layers of information. These are utilised for navigation through ports and the open ocean and to plan for strategic, operational, tactical and humanitarian missions.[13] Companies are already offering maritime specific geospatial products and services, to include nautical charts, oceanographic data, models and products, port approach maps and advanced geophysical and acoustic analyses.

The Navy is required to undertake complex operations involving securing Sea Lines of Communications (SLOCs), preservation of national influence in maritime neighbourhood, multinational maritime engagement and strategic military assistance. Operations and exercises could involve small sets of ships to fleet operations (including aircraft carrier deployments) and operating with navies of other nations, involving local waters to seas across the globe. The National Maritime Domain Awareness (NMDA) project of the Indian Navy is using geospatial data from multiple sources, including terrestrial, aerial and space-based sensors and the data being shared by other marine-affiliated entities.[14]

Air Operations

Air operations require precise spatial information for navigation to enable coordination of aerial traffic, synergising operational missions and defining safe corridors for these missions. The positional requirements are like those of land operations with the addition of precise altitude information. Geospatial precision is of critical importance to targeting and in conduct of Battlefield Air Support (BAS), missions carried out in proximity of own ground forces, to avoid fratricide. Real-time update of information during the mission is a necessity of the modern battlefield, requiring adequate line of sight and beyond line-of-sight networking for aerial platforms.

The IAF has a relatively well-developed GIS based C4ISR system in the form of the IACCS that has gone through several iterations and testing through exercises and in operations. While the system has developed well to meet the air force’s requirements, it still lacks the connectivity with other agencies that is required for a comprehensive air picture and for synergised air defence operations.

Defence Infrastructure Management. The large military bases, as also large deployments, with their associated complex infrastructure and environment could be better managed through GIS. A common GIS base would have appropriate overlays and tools for managing operations, administration, maintenance and logistics, facility management, training and conduct of exercises. Contingency responses, with linked documents and pre-programmed standard instructions could be planned for, practiced and coordinated over these systems. A critical function that could gainfully exploit these systems is base security, which could depend on geolocation for automated actions and responses. For example, virtual perimeters called ‘geofences’ can be created to enforce more automated restricted access areas and activate responses automatically in case of any violations.

Logistic Management. Logistics management involves making available the right equipment, ammunition and other resources at the right place at the right time. GIS logistics management solutions are the foundation for most supply chain planning and execution systems. These include planning optimal routes, tracking of consignments and responding to contingencies.

Modelling, Simulation and Training. As the armed forces modernise, they are exploring modelling and simulation to get better results in terms of skill sets and efficiency, while saving costs. GIS adds realism to the training and exercises and can provide options for introducing situations, as also overlays for assessments. Battlefield simulations could be created for better appreciation by the commanders and for advanced analysis, planning and even assessments of various plans of action. For example, simulation models are of great help in enabling strike pilots to 'fly through' their missions while benefitting from visualisation of threat envelopes and time dependent safe corridors.

<u>OSINT</u>. OSINT has slowly grown in relevance in conflicts, especially at the lower end of the spectrum and those involving populated areas. This has been made possible through near ubiquity of handheld and wearable digital devices and the proliferation of related applications with georeferencing capability. The greatest example has been that of the Russian-Ukraine conflict, wherein academics in California utilised geospatial technology (Google Maps) to first detect the Russian advance into Ukraine on 24 February 2022, much before the official identification and declaration. The Russian traffic jam north of Kiev was similarly followed by them before the rest of the world caught up.[15] Subsequently, the whole war has seen use of geospatially relevant information, in the form of videos, images or other trackable data, being uploaded or utilised to locate and report on Russian military positions and movements, identify battle damage and monitor sensitive areas and installations, all of which have helped in the Ukrainian deployments and operations. It is also enabling governments and media across the world to follow the relatively obscure campaign through near-real-time datasets, upgraded through OSINT. The utilisation of OSINT by militaries however, needs means and methods of integration and faces the challenge of veracity, requiring a machine and human element to be introduced into the data stream to authenticate data coming from a wide variety of devices and applications.[16]

<u>Joint Operations</u>

The boundaries between war fighting domains are getting increasingly blurred and faster manoeuvre capability and response potential has incrementally accelerated the operational tempo. Achieving jointness in operations and the formulation of integrated commands would necessitate cross-domain SA and understanding of the battlefield and battleplans among participating elements. Increased choices among weapons and effects at greater weapons ranges have resulted in overlaps that offer choices for optimum utilisation, but also necessitates continuous and simultaneous planning and execution at all levels. Synergised application of combat power in time and space would require coordinated command and control across all domains – land, sea, air, space, cyber – spanning the entire range and levels of military operations. This would also optimise joint sustainment and reduce chances of fratricide.

An integrated environment demands analysis across all domains and this entails an information framework riding on an integrated GIS relevant across all domains, by having a common digital map at its foundation. The system by providing analytic and decision support tools to joint force commanders, intelligence analysts and combatants operating in various domains would enable them to better understand common operational and tactical situations and enable rapid, collaborative decision making and execution of synergised multidomain manoeuvres towards national security objectives.

Data Management

Data management is dependent on its 5Vs - velocity, volume, variety, veracity and value. The large areas being covered, myriad of highly sophisticated sensors, the greater ability for user-generated data and ever more OSINT data being produced has resulted in availability of varied (variety) and vast amounts (volume) of spatially referenced and aspatial attribute data at an unprecedented rate (velocity). This data, available in varied kinds of formats, needs to be verified for its correctness and accuracy (veracity) and integrated into a unified geodatabase. For this the data must undergo processing procedures like georeferencing and ortho-rectification. This data needs to be catalogued and preserved in digital form, for it to be accessed, linked and analysed, for the value compounds when one data set is used in conjunction with another (value). Data interaction is also required for creating associated overlays that assist in visualisation and decision making. The geodatabases need to be always kept mission ready and be accessible to multiple agencies or users on demand. This would eliminate data redundancy and fragmentation and streamline data maintenance.

While data production has been given much importance through investments in platforms and sensors, it is data consumption that would define its expediency. Therefore, data management is no longer about aggregation and storage, but also involves data processing and analysis with minimum latency, utilising Big-Data Analytics and Data-Mining tools. Data must be related to context or it would become unmanageable, as too much data has the potential to impede rather than help decision making by cluttering rather than providing clarity.

Networking

Rapid distribution and absorption of information is important to accelerate actions and responses in a highly dynamic operational space. Networks are required with sufficient capability and capacity to handle the continuous flow of complex data streams (to include videos, high resolution imagery and data with large attribute files), as also ensure data management functions and processes. The modern battlefield requires sufficient last mile connectivity to make the intelligence and geospatial tools available onto mobile platforms and handheld devices and enable combatants to upload real time information towards more effective SA and decision making. This would require an optimum combination of terrestrial, wireless and satellite-enabled communication architecture. Advance information and communication technology (ICT) and algorithms has allowed flow of information in “quick, imaginative, and agile” manners – prioritising and selecting the data and the receiver while ensuring layered security and optimising the spectrum utilisation while ensuring resilience and redundancy of the network.

Human-Machine Interface (HMI)

The sense of vision is the most perceptive of the human senses. Ideal visualisation of simple, intuitive, geo-referenced intelligence within a spatial framework using colours, shapes and symbols greatly enhances the human comprehension. Information rich layers placed over foundational maps help provide cognitive advantage and these could be further enhanced through depiction in terms of clusters, charts and graphs that would help in interpretation and analysis. The layers also facilitate display of relevant information without cluttering the digital map. The aim should be to design and engineer an HMI that improves assimilation and enables the interaction with minimal task complexity, by using point and click digital tools that enable users to view and analyse spatially referenced information and address multiple GIS functions. The HMI should also allow creation of complex geodatabase queries and visualisation of the output onto digital maps at all scales.

A military GIS should be designed for contextual representation that caters to areas of influence at various levels of command and mission specific requirements. Joint operations would require a georeferenced common picture of the battlespace encompassing information spanning all domains that is easily interpretable by using standardised recognisable icons and symbols. Users should be able to develop their own overlays from the existing geo-datasets. The system would benefit from the ability to automatically prioritise maps to match the mission requirements and for provisioning pre-designed map templates that cater to a variety of missions. The interfaces could also be utilised to issue orders, track the blue and red force, designate zones and display special information. An integrated, multi-domain operation would benefit from a display of the dynamic coordination lines, such as the Forward Line of Own Troops (FLOT), for better targeting and reduced chances of fratricide. In order to meet the demands of the collaborative defence environment and last mile connectivity, the visualisation should be relevant to different devices, to include wearables or platform mounted screens.

Immersive display technologies like Augmented Reality/Virtual Reality and now the evolving Metaverse, have the potential to greatly enhance intuitive understanding. High resolution imagery coupled with geospatial data could also be effectively utilised to generate 3-dimensional models that would assist in appreciating the terrain and environment. A digital twin is a digital representation of a physical object, process, service or environment that behaves and looks like its counterpart in the real-world. Geospatial information would allow geographically referenced digital twins to be generated for simulations. These when combined with advanced analytical, monitoring and predictive capabilities would assist in reasoning and decision making. [17]

Decision Assist

The increasing computational power and the introduction of various technologies have allowed better analyses and understanding of data and visualisation of the relationships between different data sets. The large repositories of indexed data and reasoning engines are helping generate insights, patterns and trends inside the data as analytical outputs. This has helped contemporary GIS evolve beyond enhancing SA to providing decision support and even decision assist. More complex algorithms can cater to things like risk assessment, vulnerability analysis, mitigation strategies and operational paradigms. Users could rewind the battle picture or could also provide links to important relevant documents, for example doctrinal information or previous knowledge of the adversary, that could help enhance understanding. Processing of these could help offer decision assist through predictive and prescriptive analysis and decision support by offering courses of actions and their probable outcomes at exponentially faster speeds. Target prioritisation and collaborative targeting for impact and optimisation of resources would also benefit from these, as would the timeliness of decision cycles at all levels of command. The system could also provide pre-ordained responses for handling emergent contingencies.

<u>Interoperability</u>

Achieving synergy of analysis, planning and execution among the armed forces would depend upon having a standardised common spatial information infrastructure, catering to decision making across multiple domains. The whole of nation approach to national security would require coordination with agencies beyond the armed forces through mechanisms for efficient information sharing as also interactions of respective GIS. The biggest challenge to these is the technological compatibility or interoperability of the components or of the heterogeneous systems. This applies equally to the various levels and multiple applications that form part of the systems – maps, sensors, data management, communication networks and displays. Adherence to a single set of approved information technology and data standards and to common protocols for information handling would be the key enablers of the desired interoperability. The advantages proffered by interoperability are:

- Use of common data resources would rationalise the enormous expense involved in spatial data production.
- Standardisation would ensure quick and smooth ingestion of data into the SDI and facilitate data sharing.
- Ensuring standardised metadata standards would help in cataloguing of data and save valuable high-performance computing time by easing the workflow processes.
- Use of common mapping procedures would enable a foundation map that could be utilised at varied scales without affecting the accuracy of location data.
- Geo-referenced, structured data would assist in achieving display of the data in a common and standards-compliant mapping format, eliminating confusion or potential for errors.
- This would empower centralised decision making and decentralised execution.

- It would minimise the effort required in developing new applications and streamline information management by reducing the number of applications in use.
- Standardised tools developed and based on defined minimum standards and common user requirements and processes would offer ease of use and user transition between systems, thereby reducing training requirements.
- Interoperability among systems and standardisation of data protocols would also allow more autonomous data handling and processing to be enmeshed into the systems, which would provide advantages in terms of accuracy and timeliness.
- Adhering to globally defined standards would also allow integration while operating with militaries or civil authorities of other nations.
- It would ensure more widespread implementation and faster certification and approval process.
- It would also facilitate future upgrades as technologies move upwards in their maturation cycles.

Global Efforts at Standardisation

Open Geospatial Consortium (OGC). An understanding exists for the need of a global GIS, to be developed through an agreed set of authoritative core global reference datasets. These would benefit multilateral initiatives, activities and responses. The not-for-profit Open Geospatial Consortium (OGC), formed in 1994, is an international consortium of more than 500 businesses, government agencies, research organisations and universities driven to make geospatial (location) information and services FAIR – Findable, Accessible, Interoperable, and Reusable. It allows for coordinated efforts at preparation, improvement and maintenance of these core global reference datasets, as well as those addressing sensor, web processing and mobile needs. Use of the OGC standards by all providers of geographic information systems, earth imaging systems and spatial database systems has enabled fielding of more interoperable systems, adding tremendous value to those systems and simulating the growth of GIS. Open GIS is being pursued to exploit the full potential of geospatial big data and to spur technological and industrial innovation and remove data barriers between different industries, creating economic and social value for all connected nations.[18]

30 other ICT standards development organisations worldwide provide standards that serve as a foundation for OGC's standards. ISO (International Standards Organisation) and CEN (Comité Européen de Normalisation) are also seeking to standardise almost all aspects of GIS, from metadata to database interfaces. The ISO Task Committee (ISO/TC) 211, also established in 1994, looks after the standardisation in the field of digital geographic information. It has 36 participating members, including India, and until now, has published 89 ISO standards, while 27 of these are under development. The Global Earth Observing System of Systems (GEOSS) architecture leverages OGC and complementary ISO standards to facilitate international sharing of earth observations and assets.[19]

Defence Geospatial Information Working Group (DGIWG). The benefits of standardisation have been appreciated by some of the more advanced militaries that are expected to collaborate in future operations. DGIWG is a multi-national body established by a memorandum of understanding between the defence organisations of NATO as also a few other nations. Its main objective is to provide strategic guidance and recommendations to its membership on the standardisation of geospatial data, products, and services. The organisation works in cooperation with ISO to utilise international standards and utilises the geospatial web service standards developed by the OGC.[20]

United Nations. The United Nations' Economic and Social Council (ECOSOC) conducts analysis and seeks to achieve agreement on global norms towards collective solutions to advance sustainable development. It has established the Committee of Experts (UN-GGIM) as the apex intergovernmental mechanism for making joint decisions and setting directions regarding the production, availability and use of geospatial information within national, regional and global policy frameworks. It aims to address global challenges regarding the use of geospatial information and to serve as a body for global policymaking in the field of geospatial information management.[21] The second United Nations World Geospatial Information, held every four years, was conducted in Hyderabad, India in October 2022. Discussions included those related to the Integrated Geospatial Information Framework (IGIF), a United Nations endorsed Framework that was developed in collaboration between the United Nations and the World Bank. The IGIF is expected to provide a basis and guide for developing national and sub-national arrangements in geospatial information management and related infrastructures.[22] Legal frameworks for safeguarding the availability and usage of geospatial information and institutional frameworks to ensure data standards, interoperability, and accessibility have also been discussed.[23] India is bidding for the chairmanship of the newly constituted Working Group on IGIF under the UNGGIM-AP (Asia Pacific).[24]

Geospatial in India

In India, geospatial is still in the nascent stages of development and implementation. A major constraint has been the restrictive policies related to generation and sharing of geospatial data, owing to political and economic complexities, policy coordination and the perceived risks. This has resulted in its low footprint across government or non-government organisations. There are few coordinated efforts at generation of such data. The resultant stringent bureaucratic procedures that add time and costs to the projects have impeded the growth of the technology and the sector. The same perceptions also preclude private participation in the 'sensitive' domain. For instance, a proposal for geospatial mapping of border areas, including coastlines, by private players (MapmyIndia) did not find much favour with the armed forces citing security reasons.

As India endeavours to leverage its expertise in digital technology towards its economic growth, efforts are afoot to exploit the full potential of the information age through public and private participation. The central government has now recognised that sound policy framework that facilitates the availability and accessibility of geoinformation is crucial for exploiting the full potential of geospatial data as an enabler for governance and development and its economic potential. As per the Department of Science and Technology website, "Encapsulating these maps and images into a National Spatial Data Infrastructure (NSDI) has been recognised and the emphasis is on information transparency and sharing, with the recognition that spatial information is a national resource and citizens, society, private enterprise and government have a right to access it, appropriately."[25] In February 2021, Ministry of Science and Technology, released new "Guidelines for acquiring and producing Geospatial Data and Geospatial Data Services including Maps", which deregulated the previous protocol and liberalised the acquisition, production, and access of data in the field.

These guidelines, coupled with policy changes aimed at more liberalisation in associated sectors like space, have led to exuberance in the domain. According to India Geospatial Artha Report 2021, the Indian geospatial economy is currently valued at Rs 38,972 crore and has the potential to grow to Rs 63,100 crore by the end of 2025, at a CAGR of 12.8%.[26] ‘GIS in India,’ a comprehensive directory of GIS companies, has listed 340 of them in India offering geospatial content and services.[27] The potential of the sector has also been well demonstrated in the initial public offering (IPO) of MapmyIndia that got over subscribed (154 times) and listed at 54% premium.[28] A lot of business is coming from government departments, many of which are using the technology for land management. SVAMITVA (Survey of Villages and Mapping with Improvised Technology in Village Areas) Scheme is a Central Sector scheme launched in April 2020, for mapping 6 lakh villages. [29] The other noticeable activity has been the launching of a city mapping programme by Genesys International in India for 100 cities in India.[30]

Indigenisation. The national mandate on indigenisation, followed by greater openness about data sharing and a defined geospatial policy provides much clarity and encourages private participation. However, the issue of providing a level playing field for private participation is dependent on interpretation and implementation of the well-intended policies. Indigenously developed efforts, besides being more cost-effective, would provide the edge by having access to keys to customise the software for more efficient operations and to continuously update the data. It would also prevent data leakage that could be inimical to national interests. However, they would need to match up to the quality and features provided by the existing foreign developed applications, while adhering to best practices and standards. Users might not be too inclined to support indigenously built applications that have not been deployed or proven. Bhuvan is an indigenous online mapping application service operated by National Remote Sensing Agency (NRSA), an entity of Indian Space Research Organisation (ISRO) [31] utilising imagery from its satellites and Bharat Maps is a similar application hosted by the Ministry of Electronics and Information Technology (MEITY).[32] Both claim to have features similar to Google Earth, while offering better accuracy, resolution and information content over the Indian subcontinent and being more bandwidth-friendly. Most importantly, they both project India’s borders accurately. DRDO’s INDIGIS also has multiple claims regarding its efficacy to meet the requirements of national security.[33] However, their utilisation remains low owing to their less than optimum functionality, visualisation and HMI. Consequently, major potential users, including the armed forces, continue to depend on Google Maps as the software of choice. MapmyIndia has now tied up with ISRO to build a fully indigenous, mapping portal and provide geospatial services by combining ISRO's catalogue of satellite imagery and earth observation data and its own digital maps and technologies.[34]

Requirements of a Joint Military GIS

The requirements of a GIS for the armed forces would be vast and complex, considering the vast area of interest and the unique military challenges and would demand innovative specific solutions. These should address each of the components of the GIS, while following some basic principles, to ensure efficiency and effectiveness.

- The integrated GIS should have a common base map that would serve as a foundation for SA, decision making and command and control. The ideal approach would be to establish an interoperable, secure, enterprise-class spatial infrastructure with a common spatial context that consolidates all relevant information onto an integrated information display in the form of a common operating picture (COP). It should be designed and engineered with interoperability at its core. This would also ensure adherence to the standards during procurement or development of components. However, the practicality of such an approach requires careful analysis for its feasibility, efficacy and cost-effectiveness.

- A more adept military GIS would store a variety of operational map templates that could be used to create operational overlays, saving critical time when conducting planning and analysis. Similarly, the operational picture could be optimised to suit the area of responsibility and to fit the missions. It should be able to offer user-friendly tools and the ability for combatants to customise maps and overlays.

- A critical requirement of modern C4ISR systems is the integration of the mobile elements into the architecture. These platforms and entities should be able to use application templates on their mobile/ wearable units for specific requirements, including navigation, intelligence operations that include receiving and uploading data (for commanders make informed decisions) and limited C2 functions.

- All command echelons should see a near real-time, synchronised view to help make faster, smarter decisions and fight from the same map. Even as the military

GIS would require specific additional layers and overlays and applications, it would have to have suitable interfaces to synchronise actions among different entities.

- While the command posts are the repository of information, they are dependent on the field units for collaboratively updating the system with their own situation and actions, to include routine updates or special events or occurrences. This push and pull capability add complexity to the SDI, requiring implementation of a security matrix that includes dynamic, layer-level security controls to control the flow of information.
- In today's security climate where war fighting, national security, and force protection must interlock seamlessly, adherence to open standards would help better integrate with external agencies for coordinated, national level responses.
- The relatively underappreciated element of weather, current and forecasted, as well as other relevant environmental factors could be integrated for planning safe operations.
- The most important requirement of armed forces equipment and systems is ruggedness to cater to the extreme operating environment and easy maintainability.

Challenges

The armed forces the world over have failed to achieve the optimum or desired levels of sophistication or implementation of GIS due to varied challenges. Some of these, with emphasis on India are:

- **Data duplication.** Geospatial data has always been considered sensitive, resulting in severe restrictions and official impediments to its sharing, even among the government departments. This reluctance has caused resource wastage as multiple agencies resort to collection and processing of data pertaining to the same geographic location. This also results in a lack of awareness about geospatial data as also a lack of clarity on the control of the data. This precludes collaboration and co-creation, as also impedes asset maximisation.
- **Diversity of components.** The emphasis on platforms tends to overshadow the value addition through advanced systems. Consequently, the importance of standardisation of hardware and software tends to get lost in the din of more

diverse sensors being peddled, most with differing standards that would require APIs and other software applications for data fusion. This adds on to the effort and time into the data cycle.

- **Domain Specific Requirements.** An enterprise multi-domain GIS would have to face the challenge of responding to demands specific to each service. These could relate to the area of interest, the swath coverage required, the coordinate system being used and the dynamic aspects of geospatial information based on the type of mission being undertaken. For example, land forces operating on large scale maps are more accustomed to the grid system, while the air force, using relatively smaller scale maps, prefers the lat/long representation. Similarly, the land component might require relatively slower refresh rates spanning a wide swath, whereas an air picture would demand a high update rate in specific identified areas, which itself would change over the course of the mission.

- **Operationalisation of NavIC.** Geospatial applications being developed indigenously depend majorly upon the U.S. GPS, as the full operational status of NavIC for providing PNT services to the terrestrial users has yet to be achieved. This impacts on the standardisation of services being developed as also on the security of the usage and data.

- **Communication Architecture.** While defined standards are already benefitting the establishment of enterprise communication networks and expansion of existing ones, legacy systems remain a concern and would require varied networking and software solutions to ensure seamless geospatial communication across the ecosystem.

- **Vulnerabilities.** A highly integrated mammoth GIS enabled multi-dimensional C4ISR system would require its vulnerabilities to be addressed and might face limitations in terms of connectivity, resilience and agility. The biggest challenge for a GIS system, or any digital C4ISR is that of redundancy. A combatant will always be more comfortable holding a map that cannot be hacked, jammed or damaged, or run out of battery.

- **Centralisation over Delegation.** Growing transparency has resulted in an environment where tactical actions could have key strategic consequences, requiring high-level headquarters to have an increasingly fine resolution view of the situation. By increasing the overall awareness, a GIS could potentially take away the option of decentralised execution, that it itself proffers.

- **Lack of Awareness.** A major hindrance to adoption of new technology is the limited understanding of technological advances that has previously plagued other ICT enabled applications. This has been a major roadblock to harnessing full benefits of the sector. The lack of awareness, among potential users in government and private sectors, of the domain and its utility has been a major impediment to developing of geospatial capability. Currently, there are few endeavours to educate the users of the potential of the technology and its applications.

- **User Expectations.** Users demand tends to be in extreme owing to the lack of awareness. The desire for having access to unlimited intelligence always needs to be tempered by educating them on system capability and bandwidth availability. This would help develop an affordable, yet efficient system.

- **Human Resource.** Geographic Information Science (GISc) is a specialised subject that covers geodesy, an understanding of cartography with its projections and resolutions and lately, the geospatial data management. Operationalising and maintaining a GIS system would thus require specialised involvement in various processes. The National Geospatial-Intelligence Agency (NGA) of the U.S., through its National Geospatial Intelligence College, trains many personnel and makes available trained geospatial intelligence specialists who provide tailored information to command officers during the on-the-ground operations.[35] However, after years of being the leaders in GIS technology and applications, it is now facing an alarming shortage of geodesists, particularly within its defence and intelligence communities, as highlighted in a recent report. The report maintains that the reduced investments and incentives in academic research and education in geodesy could have an adverse impact on its future GIS programs and downstream geospatial technologies. [36] The report has also brought out the emergence of China as the largest investor in geodetic training and research, resultantly having "more PhD geodesists than the rest of the world combined."[37] This is of particular importance considering the growing economic and security dependence on geospatial services. India also lacks a structured educational programme in geospatial technology, resulting in a lack of interest and awareness and a pool of skilled manpower.

- **<u>Budgetary Allocation</u>.** This is an important issue since armed forces developers and procurement staff is rarely confronted with the true costs of geographical data. The discussion on geospatial technology for security purposes also tends to get focussed on the upstream – platforms and sensors, while the downstream of processing, distribution and modelling are the driving force of GIS. The importance of GEOINT and GIS in optimising force structures and deployment and resource utilisation and the consequent cost benefits need to be acknowledged to make a strong case for their adoption. Further benefits would come by using emerging technologies and applications.

<u>Commercial Participation</u>

Technological prowess and advancement are no longer a governmental prerogative. Commercial capabilities and capacities are already proving themselves in the technology intensive domains of space and cyber and this is evident in the ongoing Russian-Ukrainian conflict. There is a growing acceptance and proliferation of competences developed for commercial purposes by private companies and governments are looking at integrating these new realities into national security and defence policies.

Geospatial technology is finding increasing applications in the commercial domain. Entities utilising it are finding ways to enhance capabilities and processes in terms of location accuracy, data management and extraction of useful information through automated means, smoothening the flow of information and enhancing the visualisations and user interfaces to consistently improve upon the ease of access and customer experience. Companies are working towards providing customised datasets and value-added products and to deliver solutions rather than standalone data. They are developing and updating software that utilises mathematical extrapolation and modelling and statistical analysis to help make use of this data for planning, predicting, optimising the supply chains or service deliveries and most importantly for enhancing understandings of the geographical influences on businesses for bettering their decisions.

Requirements of a military GIS are not very different and capabilities developed for the commercial domain could be utilised effectively. There are some points for consideration for commercial participation towards a GIS for the armed forces.

- Companies and governments trying to leverage GIS need resources with expertise, spanning field data collection and survey, data annotation, data digitization, data migration, application development, enterprise GIS implementations, spatial analytics, and AI/ML solutions.[38] There are recurring costs to this, as also for pursuing better resolutions and accuracy of data.

- Advanced, Commercial off the shelf (COTS) capabilities guarantee all the benefits of mature, stable and maintained software, obviating the requirement for designing and developing from the scratch. They could be explored to develop customised geospatial solutions that meet the dynamic needs with greater control and agility.[39]

- The domain of GIS is dominated by certain international vendors, who have been consistently upgrading their capabilities and developing and offering innovative products for civil as well as military applications. In the U.S., civil military integration ensures that private companies contribute to national security tasks. Google Maps, with its offerings of many services and ability to develop custom applications by users, has been at the centre of the geospatial aspect of the recent wars, having been utilised by various governmental agencies, commercial entities and RS companies alike.

- Even though the armed forces continue to consume large amount of remote sensing imagery from these private companies, the commercial paradigm of obtaining the data, rather than owning the system might not be best suited for the sensitive domain.

- Governments and the armed forces remain the most important customers for these companies operating on a niche technology.

- It is important to acknowledge that experts in technologies better understand the realistic technological potential and feasibility, but would need user involvement to get the operational perspective.

- Commercial companies usually present challenges related to costs, responsiveness and reliability.[40]

A study conducted in South Africa concluded that the Free and Open-Source Geographic Information Software (FOSSGIS) products might not be mature enough, nor user-friendly enough to be used in armed forces operations. It however brought out that Open-Source desktop GIS software/product could be utilised effectively to plan and execute a mission successfully in Military Operations Other Than War (MOOTW), especially those with limited budgets and at short notice, such as in the case of disaster relief.[41] However, this is expected to change with greater technology advancement and adoption.

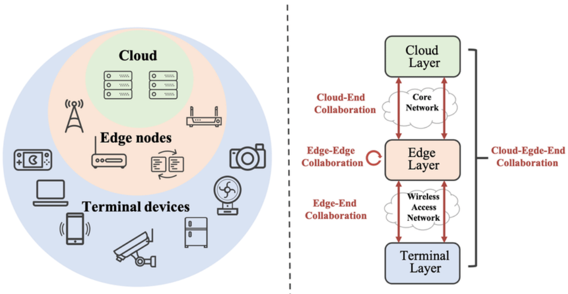
Emerging Technologies

A GIS involves coming together of multiple technologies and disciplines and is impacted by advancement in each of these. Increasing technological prowess, maturity and sophistication is allowing greater abilities and efficiencies in the processes, resulting in smarter maps and digital models. Applications are allowing these to be interactively queried, making planning, execution and control more effective. Information superiority will require staying ahead in technological innovation and adoption, even as the proliferation of technology is narrowing the gap between competing nations.

Emerging technologies have major relevance for or dependencies on geospatial, some of them requiring location data or technologies for their effectiveness, while the others just empower the geospatial. These include technologies like cloud, Artificial Intelligence (AI), blockchain and enhanced visualisation and improved applications such as decentralised databases, distributed networks, Internet of Things and big data powered by blockchain. All of them are at varying degrees of maturity and have the potential to increase the capabilities involved in all processes related to GIS, including information gathering and processing, enhancing the capability to carry this intelligence and in user friendly interfaces to access, manipulate and utilise this data more effectively. A major challenge related to all new technology is that of integrating it with operational application.

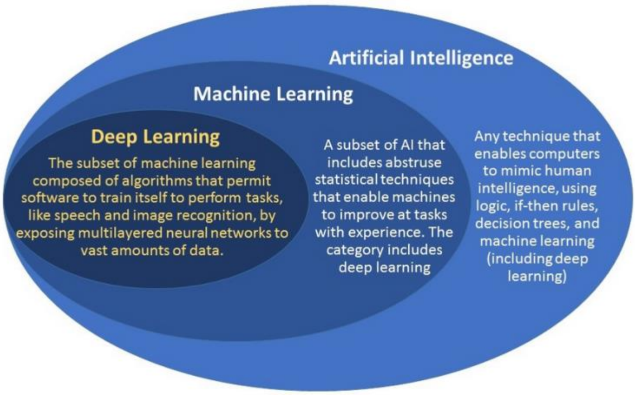
Cloud Technology. Cloud computing is generally referred to as a software architecture designed to effectively pool together large amounts of low-cost modular storage and servers. This system enables processes to employ distributed capacity very efficiently, at low cost and with high availability and empower scalable application. For a GIS, this would enable distributed analytics and a distributed, scalable, decision support environment. Dispersed cloud capability can also allow for modular plug and play sub-systems for specific missions, scaling of infrastructure to meet the demand, while optimising the use of resources. An enterprise defence GIS cloud would enable harnessing the power of geospatial intelligence across a wider range of verticals. While it would provide the benefits of any cloud architecture, its design would cater to specific security and system requirements.

Distributed Architecture. Cloud technology and an efficient network would enable a distributed architecture for efficient management of the large number of resources. The central or nodal repository would provide the standard foundational GIS layers, core GIS services and geo-database with strategic implications. Edge servers could be utilised for storing, processing and analysing more location specific data, requesting for additional information, whenever required. This would declutter the system and reduce the pressure on the network. Collaboration of edge and cloud would improve system performance, while reducing the latency related to processing and flow of data. An edge framework would also support more modular capability that would allow selection of mission specific combinations of platforms and sensors onto a standardised GIS. Such an approach would also allow varied systems to be integrated innovatively for emerging contingencies. Such a system would require standardisation of components, with centralised updating of base data and would benefit from adherence to formats requiring low storage footprint. Geospatial data could also be downloaded onto mobile devices for operations in areas with low/nil network coverage or for lowering the electromagnetic signatures.



Automation is often used interchangeably with the AI, but it relates more to robotic processes, which in case of GIS would involve use of mathematical and statistical functions for various processes. Automation of cartographic techniques has already been achieved to a large extent in the armed forces as well as the commercial domains, although the complexity involved has precluded total replacement of the human element. These include data fusion, filtering out the relevant information, cataloguing the data for future reference, integrating data and automatic attribute extraction. Automation reduces the processing timelines and increases accuracy by reducing the human involvement. Automated outputs could include depiction of weapons ranges and coverage to derive and illustrate the threat and avoid areas in time and space over a foundational digital map for the air mission mentioned earlier.

Artificial Intelligence is an "umbrella" concept that is made up of numerous subfields such as machine learning and deep-learning. The increasing power of computational analysis and reasoning engines has led to a growing prevalence of AI, with its ability to enhance the functionality and applicability of automation. For a GIS, it has applications across a host of processes that require application of knowledge-based efforts, spanning the full spectrum.[42]



As compared to automation, AI helps better data corelation and interpretation and it could converge with GEOINT to deliver solutions. It could optimise sensor tasking and effort. It could improve the cataloguing efforts by applying intelligent algorithms and Machine Learning (ML) efforts. Similar sophisticated analytics could greatly enhance data retrieval for enhancing SA and decision making. AI has emerged as an important component of decision-making processes in civil and commercial sectors and algorithms could be suitably developed or modified for military applications. AI would go beyond change detection to providing a predictive analysis on the change and offering possible action options, thereby improving mission effectiveness. Systems could be programmed to generate preconfigured responses, such as those to Electronic Warfare and Information Warfare attacks. For an air mission commander, it could offer the mission profiles that could best avoid or overcome the threats and challenges, thereby minimising the risks. It could refer the adversary's known CONOPS to define probable deployments based on identification of just a few components. Similarly, AI could be effectively employed in security functions for supervising and monitoring and initiating initial response actions to any defined deviations. All of these would reduce the human effort, enhance SA and improve upon the responses.

AI would help ease the process of sharing of information to relevant decision-making nodes through 'push' rather than 'pull' processes, autonomously. The 'pull' principle, works on data being queried from the system, whereas the 'push' principle involves predictive provision of appropriate data to the user, based on the mission and operational environments. The tools already exist in the social media platforms, wherein advertisements are forwarded to consumers based on their surfing history, without being queried.

Machine Learning (ML) would utilise information on data consumption and utilisation that could be fed back to the system, improving upon future responses, with the potential to provide previously inaccessible insights, as has been evident in some of the applications using AI. ML would also gain from regular exercises and gaming of situations. This would help introduce the cognitive aspects of consumption of data, which is subjective and cannot be truly created through mathematical models based on data. As ML helps updating the system capabilities, they could be more reliably employed in more complex scenarios for decision assist function.

Deep Learning relates to the human cognition using data driven algorithms. Spatial ML coupled with deep learning techniques could greatly contribute to enhancing the understanding and response to complex scenarios by deriving deeper insights. This would help include the cognitive aspects of adversary's actions, including behaviour modelling, and reactions into the decision-making matrix, potentially improving the operations and responses. AI has gained much traction as a futuristic technological application, but faces multiple challenges to its effective implementation, adoption and scaling. These include the availability of sufficient high quality, verified and relevant data for processing and skill deficiencies for specific applications.

Blockchain. Blockchain technology is an open and distributed design that allows real-time and simultaneous transactions of tokens containing metadata of assets (could be money, imagery, data, maps, documents, etc.), without real transactions taking place. Blockchain technologies are now being explored beyond the crypto currency and financial sectors. Integrating location intelligence with the blockchain would entail adding the time and spatial references, enabling real time validation of data from various sources, thereby ensuring security of transmission and allowing tracking of sensitive information across time and space. Combining blockchain with a geographic information system (GIS) is allowing logistics companies to visualise every transaction on a map, revealing the condition of the shipment, the parties involved in the transaction, and its exact location, enhancing supply chain visibility. The Port of Rotterdam, Europe's largest shipping facility, has been testing blockchain for logistics.[43]

Many other companies are also exploring its potential. A private company, XYO Network, claims to be pursuing the world's first blockchain geospatial network backed with cryptography that anonymously collects and validates data with a geographic component. Its cryptographic protocol is designed to improve the validity, certainty, and value of data. It is partnering with HERE Technologies, a location solutions company to expand the availability of secure, verified geospatial data and to integrate this with blockchain-based smart contracts.[44]

In China, there have been developments of a protocol, based on the Consultative Committee for Space Data Systems (CCSDS) system, using the common format of Target Communication Framework (TCF) of sending data, to enable satellites to communicate and to share resources or apply communicative functions that do not repeat other satellites' functions. This, effectively, means that such a blockchain-based protocol could allow satellites, including those not created using the same operating systems, to simultaneous work together using common data sharing and communication.[45]

Blockchain can add onto the protocols of Public Key Infrastructure (PKI) to enhance data-integrity and security by ensuring traceability and adding credibility to the data. This greater trust and transparency of data would promote its sharing and increase the speed of transactions, encouraging decentralisation and distribution. Further up the technology maturation curve would be the geo-blockchain, relying and relevant to Internet of Military Things (IoMT), to identify data share between the complex network of humans and objects, supply chain management and tracking of mobile elements. This would allow more automation in terms of facilitating geospatial data sharing and management, thereby speeding up the processes.[46] Geo-blockchain presents some technological challenges, which include the demand it would place on computational, network and data storage capacities. [47]

National Geospatial Policy

The most significant step towards adoption of geospatial technology in India has been the notification of the National Geospatial Policy by the central government on 28 December 2022, replacing the National Map Policy of 2005. It has recognised the importance of sharing GEOINT data for economic progress and ensuring security and aims to overcome the silo approaches of various departments. It envisages a common base-map production and centrally produced spatial datasets, which could then be utilised by different consumers, reducing the associated costs and the duplicity of effort. The policy moves beyond deregulation of data to lay down an overarching framework for the development of a geospatial ecosystem, including goals and strategies to achieve it, with an intention to leverage it to move towards a digital economy and improve services to citizens.[48] It emphasises the importance of locally available and locally relevant maps and geospatial data, which would require development of adequate local geospatial infrastructure for providing data and geospatial services.

The policy encourages open standards and seeks to promote establishment and adoption of best practice standards and compliance mechanisms for enabling data and technology interoperability. It emphasises on use of national and international standards and best practices adopted by voluntary and open standards consensus bodies (such as those of UN-GGIM, including the IGIF) and seeks to limit establishment of new standards only when these do not exist for adoption by specific stakeholder communities.[49] Acknowledging the impact of technology on the sector, it mentions a Geospatial Knowledge Infrastructure (GKI) that would be enabled by integration of Geospatial data/technology/concepts with Fourth Industrial Revolution (4th Industrial Revolution) technologies and the growing digital infrastructure (Web, Cloud, Networks, etc.). [50]

It lays special emphasis on geospatial education to meet the skill and talent requirements through creation of a Geospatial Skill Council, which will formalise the framework for skill development in the country. [51] Identifying GSc as interdisciplinary, combining various technologies and affecting diverse fields, it calls upon developing some of the existing institutes into Centres of Excellence for providing relevant specialised courses and seeks active and intrinsic industry participation. It seeks to encourage education related to GSc from the school level and promote research in Geospatial Science and Technology for indigenous capacity building and identification of new areas of application and solution. [52]

The policy has mandated setting up of a Geospatial Data Promotion and Development Committee (GDPDC) at the national level as the apex body for implementation of the policy, its various provisions, formulation of guidelines and steering the course of the development of Geospatial sector in the country. Department of Science & Technology shall continue to be the nodal Department of the Government. GDPDC has also been given the power to decide on issues arising out of finalisation of negative attribute lists and frame regulations on those attributes.[53]

The unavailability of foundation data, especially at high-resolution, is a constraint and the policy envisages high resolution topographical survey & mapping to result into a highly accurate Digital Elevation Model (DEM) for the nation by 2030. Comprehensive High resolution Bathymetric Geospatial Data of inland waters and sea surface topography of shallow/deep seas, to support Blue Economy, is expected to be available by 2035. The policy also aims to create National Digital Twins of major cities and towns, each of which would be interconnected, to facilitate better decision-making. [54]

The policy, through data liberalisation and democratisation, along with the transformative initiatives in the space sector, expects to giving impetus to participation of commercial Indian industry in the hitherto highly regulated sector, to enhance capabilities and capacities. This is expected to bridge the geospatial data divide and enable the private sector to cater more and more to the geospatial/location data-related needs of the nations as also in the creation and maintenance of geospatial and mapping infrastructures. This is also aimed at supporting innovation and creation in the sector.

Experts have pointed to the lack of clarity regarding addressing the National security concerns, such as access control, securities and privacy policies, the development of secure and interoperable GIS applications in the areas of Defence (Tri-Services).[55] A contentious point in the policy for the armed forces is para 5.2.2.7, which states that SoI will be transformed into a civilian organisation and all the serving army officers in SoI will be reverted permanently.[56] It is pertinent to highlight that maps are difficult and expensive to produce and maintain, requiring a sophisticated infrastructure, while their reproduction or distribution is relatively more economical. Thus, a more coordinated national effort that caters to variable scale requirements of various entities, including the armed forces is the best way forward. The policy has also defined that SoI, while being the overarching nodal agency for Geospatial Data, would only be involved in the generation/ maintenance of minimal foundational data/ core functions.[57] This would also reduce the demands on defence specific organisations to collect and process the large amounts of data required at all scales and the manpower reverted to Military Survey could thus be better utilised for trans-border efforts and to design and make operational overlays to meet specific armed forces requirements.

Recommendations

GIS presents considerable challenges for developers of military specific systems. Some of the applications can be adopted from the civil sector, but many are unique to the armed forces and demand innovative solutions. Outsourcing of geospatial services might not be the most promising solution to meet the national security needs. Also, requirement of transborder base maps with contours and terrain profile are specific to the armed forces and intelligence agencies, as is the importance of accurate depiction of the international boundaries and claim lines.

Achieving a comprehensive GIS would require a top-down strategized view that appreciates the requirements in terms of infrastructure and services, while ensuring security and redundancies. Technologies and their applications do not develop and flourish in isolation and would require a similar strategic view of evolving technology upgrades and examining trends is essential to prediction and planning.

- At the outset, there is a requirement to establish a tri-services organisation, similar to NGA of USA, or inspired by the PLASSF of China. Such an agency should be entrusted with infrastructure and responsibilities related to geodatabases and GIS, with an appropriate structure and mandate for it.

- For its efficient functioning, the organisation should be made responsible for the joint/integrated policies regarding data storage and processing. It should have the requisite authority for regulating all data related functions across all domains.
- It would also be the interface with the system designers, ensuring convergence of user requirements and technological advancement and innovation.
- Integration is an ongoing process, challenging even technologically advanced nations. Concerns relate to the different versions of maps and data being generated and consumed and interoperability of components, systems and protocols. Development of futuristic C4ISR systems should be based on Enterprise Integration, which would involve creating an open digital ecosystem that would better enable connecting components and systems through adoption of these measures. Developing a Common Operating Environment (COE) would be achieved through integration of hardware and software systems, requiring standardisation of equipment and protocols.
- Standards need to be defined for implementation within the GIS to enable better integration as also develop and ensure common understanding. These should be applied at the system design stage itself. International efforts, such as DGIWG and IGIF could be studied for these efforts and adoption of best practices.
- Open architecture approaches would enable exploiting modern hardware and software solutions being developed commercially to achieve interoperability among digital devices. The armed forces could use the service-oriented architecture (SOA) approach, which has been developed in the commercial sector for enterprise software systems, to enable interoperability, increase efficiency and improve spatial and analysis capabilities. SOA allows users to combine functionality from existing services without requiring deeper integration of existing systems.[58]
- Pursuance of more integrated operations would ideally require investing in an enterprise GIS software specific to cross domain military requirements. However, an integrated GIS might be challenging in terms of its size, the

requirement of computational power and networking capability for continuous handling, processing and flow of vast amount of data. A more efficient system would involve multiple GIS systems, each catering to specific AOR or designed for specific roles, with secure points of integration. While each of these systems would have autonomous functioning, they would all have secure interoperability and networking.[59] Such an architecture would have the agility of selecting and plugging in individual systems or sensors to match the mission requirements. This would enable scalability, while reducing the processing and networking requirements, as also optimising the resource utilisation.[60] Scalable distributed architecture with edge computational capability would be enablers of such an approach.

- Human Machine Interfaces remain the Achille's heel for most government developed technologies and applications. This needs to be addressed through constant user involvement and exploiting COTS software for more willing technology adoption.

- All services need to assess the viability of creation of Digital Twins for simulation, modelling and training.

- The services are already in the process of establishing IT infrastructure and enabling integrated communication networks. These would need to be configured for handling and working with geospatial information. Last mile connectivity using 5g networks and SATCOM and mobile or handheld devices, configured for the GIS, needs to be planned for and ensured.

- Decision superiority does not automatically result from information superiority. Technological innovation must be supported by intellectual application in terms of organisational and doctrinal adaptation, relevant training and experience and the proper C2 mechanisms and tools. These must be pursued through persistence in employment, integration and training.

- Acquisition process would have to be streamlined to acquire or develop components that follow defined standards for interoperability. An integrated approach towards procurement and induction of hardware and software through HQ IDS would be ideal, but individual services must be mandated to implement defined standards, even when following their own paths for development and acquisition.

- There is a need to explore the potential of the futuristic technologies of the 4th Industrial Revolution to meet and upgrade the requirements of a GIS for the armed forces. Efforts by the armed forces would be best achieved through an integrated plan effected through HQ IDS that best utilises their resources. It would be prudent to exploit the indigenous capabilities that have fructified through investments in the civil enabled ecosystem for private participation. This would also benefit from involving and incentivising academia, laboratories and startups who are already working with disruptive and innovative technologies and applications.
- GSc is a specialised field that would require specialists, personnel who have a fundamental understanding of armed forces operations, coupled with a good knowledge of geospatial processing and integration for its effective implementation. Besides assisting the decision makers in their utilisation of the system, they would be responsible for the backend processes of populating, managing and maintaining the system. However, this would require innovative solutions, as creating such a specialisation could potentially infringe into the numbers available for the primary combatant functions. For example, the Navy's cadre of specialists in Oceanographers and cartographers could be further trained for GIS or could be assisted by GIS professionals in collection and analysing of data.
- Adequate education and training would ensure better technology absorption capability among combatants and spreading awareness of system capability and utilisation potential. In-service awareness could be achieved through courses and incorporating it in syllabus of career progression courses. Optimum utilisation of GIS during training and exercises needs to be ensured. These measures would result in its more efficient and creative use.
- Creation of a 'Data-Driven' and 'Data-Sharing' culture is essential to ensure more effective technology adoption. This would also require persistent efforts to understand and implement the psychological, behavioural, and cognitive processes of information consumption and analysis.
- Security of the GIS infrastructure and data would be imperative and would mandate indigenisation of components and software, as well as security of data.

Conclusion

Advanced and persistence surveillance has enabled transparency of the military operational space. Achieving information superiority in a modern battlefield involves geographical representation of this information as well as utilisation of advanced digital capabilities to provide knowledge and decision superiority. While a military GIS is not a substitute for mass and firepower, it can make their application more efficient and effective, thereby achieving disproportionate results and optimising resource utilisation. This is important as militaries face budgetary rationalisation, even as the threats continue to become more complex.

The Indian armed forces need to make a consolidated, informed and defined move towards a GIS enabled C4ISR architecture that supports joint multidomain operations and evolves to enable integrated application of force in the near future. Towards this, they need to be proactive in their approach to technology as the ongoing 4th Industrial Revolution is creating not only a quantitative, but a qualitative change in the information environment. Any lax in these would result in a critical lag in enabling of the C4ISR with its adverse impact on the battlefield. Technological advancements would need to be supplemented with appropriate policy measures, education and training to secure the maximum benefit.

Even though India has been among the leaders in implementation of information and communications technology, it has lagged in the development and employment of GIS. Having identified and acknowledged the importance of geospatial technology for socio-economic benefits, the Indian government has liberalised the data and laid out a framework for its effective utilisation through the National Geospatial Policy. A liberalised environment is expected to lead to greater private initiative and investment in the technology. The armed forces would benefit from a collaborative approach that identifies developments in the commercial sector that can be absorbed by the military GIS through use of common standards and architectures with suitable security protocols. Indigenous technology would also enable customisation and manipulation of applications to respond to evolving needs.

DISCLAIMER

The paper is author's individual scholastic articulation and does not necessarily reflect the views of CENJOWS. The author certifies that the article is original in content, unpublished and it has not been submitted for publication/ web upload elsewhere and that the facts and figures quoted are duly referenced, as needed and are believed to be correct.

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