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Coordinates

Volume XXII, Issue 03, March 2026

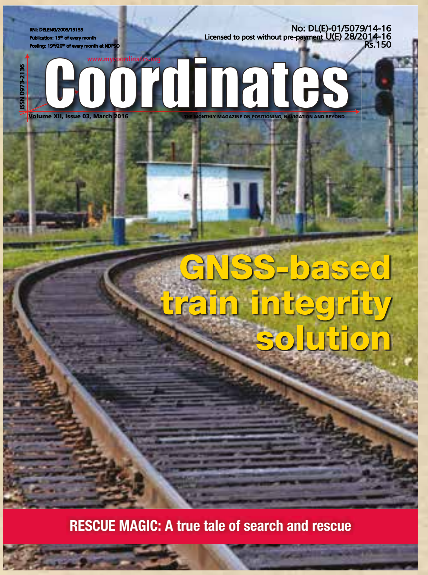
THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

Will the Agentic AI rewrite the rules of geospatial intelligence?

Risk-informed spatial planning of Shimla region

In Coordinates

10 years before...



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RESCUE MAGIC - A true tale of search and rescue

Masterchief Quartermaster (Retd.) Rick Hamilton
CGSIC Executive Secretariat, GPS Information Analysis Team
Lead, U.S. Coast Guard Navigation Center

One afternoon, the rescue center got a call from an Auxiliarist named "Mamasita." Mamasita lived up on the west side of the Island of O'ahu. She was talking on her Citizen Band (CB) radio with a man that was in trouble on the water. The Coast Guard operates on HF (high- frequency) and VHF radios (very- high-frequency) but not CB. So, for CB, a hold-over from the 1970s long- haul trucker community, we depend on the help of the talented, all-volunteer assistance of the Coast Guard Auxiliary.

Planning MSW landfill site using GIS based multi- criteria evaluation

Shashi Shekhar, Scientific Officer, Himachal Pradesh Pollution Control Board

The results have shown that few suitable sites are present in the study area, however, there is no very high suitable zone owing to several restricting factors prevailing in the region. But there is high/moderate suitable zone around. These sites are easily accessible by the small roads but they are away from rail/roads of high significance.

Cadastre as a crucial component of SDI ensuring sustainable development

Dr Ludmila Pietrzak, Vice President of Association of Polish Surveyors, Warsaw, Poland
Prof Elzbieta Bielecka, Professor of Military University of Technology, Faculty of Civil Engineering and Geodesy, Warsaw, Poland

The importance of cadastral data was reflected in INSPIRE. A cadastral parcel is one of the themes of the first annex to the INSPIRE directive. The INSPIRE directive focuses only on geographical part of cadastral data, so the parcel is defined as "areas defined by cadastral registers or equivalent".

The importance of hydrographic surveying

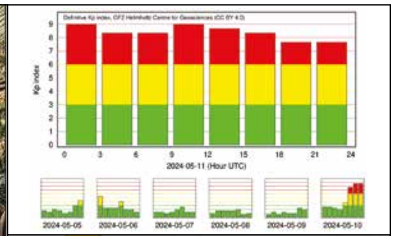
Surv Isaac Larbie, MGhIS Geomatic Engineer, Surveying and Mapping Division, Ministry of Lands and Natural Resources, Ghana

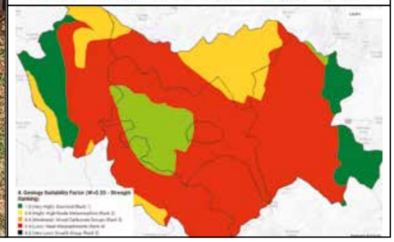
If hydrographic surveying is conducted on our water bodies, the results would be used to determine the level of safety in its use for the development of a Water Transportation System. It would also create the awareness in the importance of hydrographic surveying to determine the safety in the use of the water body.

An analytical assessment of a GNSS-based train integrity solution

A Neri, RadioLabs, Corso d'Italia 19, Rome, Italy
F Rispoli, Ansaldo STS, Via Mantovani 3-5, Genoa, Italy
P Salvatori, Università degli Studi Roma TRE, Via Vito Volterra 62, Rome, Italy

The train integrity monitoring represents a fundamental innovation for the train control systems such as the ETCS L3 system. GNSS is the candidate technology to allow the continuous monitoring of the train length and for estimating the position where the last carriage of a decoupled train is stopped.





In this issue

Coordinates Volume 22, Issue 03, March 2026

Articles

Columns

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Editor Bal Krishna
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Cover image generated using AI

This issue of Coordinates is of 36 pages, including cover.

NavIC at a Crossroads

India’s quest for strategic autonomy in navigation gave birth to *Navigation with Indian Constellation* (*NavIC*).

It was never merely a technological project.

It was a statement of sovereignty in positioning, navigation and timing.

The recent failure of the atomic clock onboard IRNSS-1F

Is therefore, more than a technical glitch.

It exposes the fragility of a system still in transition.

Global dependence on satellite navigation continues to deepen

Across aviation, maritime, telecom, finance and critical infrastructure.

PNT is no longer a niche capability.

It is a foundational infrastructure.

The lesson is not about a failed clock.

It is about the cost of interrupted capability.

Bal Krishna, Editor
bal@mycoordinates.org

Will the Agentic AI rewrite the rules of geospatial intelligence?

If we want real time "geo intelligent" agents, we must confront the gap between elegant demos and messy, dynamic reality.

Nirmalendu Kumar
Additional Surveyor General, Survey of India (Retd)
Managed Mapping and Surveying Operations for whole southern India

Agentic AI is about to collide with geospatial intelligence in a way that may fundamentally change how we sense, predict, and act in space and time. However, the research proves reality rarely matches hype. If we want real time "geo intelligent" agents, we must confront the gap between elegant demos and messy, dynamic reality.

Why it is not a cake walk for Agentic AI

Realtime predictive spatial intelligence sounds elegant, but the research shows it is intrinsically hard even for advanced agentic AI. To understand why, it is useful to contrast what these systems must do with what we traditionally expect from geospatial technology. A human geospatial analyst usually works with reasonably stable data and clear time windows, whereas a realtime agent must sense a changing world, maintain a living model of space, predict what will happen next, and act quickly enough for its decisions to matter. This means perception, modelling and action are tightly coupled in a continuous loop rather than separate stages in a workflow.

At the heart of the difficulty is how space itself is represented. Geospatial professionals are comfortable with raster, vector, scenes and 3D city models, but Agentic AI needs internal spatial representations that support fast decisions under uncertainty. Survey work on spatial AI agents and world models shows that no single representation is adequate across scales: agents need precise metric maps for navigation, graphlike structures for connectivity and higherlevel semantic views for planning, and they constantly convert between these, losing either detail or speed each time. At the same time, large language models, which underpin many agentic systems, have been shown to struggle with even simple spatial layouts when precise geometry is required. They can produce route descriptions or spatial explanations that sound plausible but violate basic geometry, which is unacceptable once those outputs drive movement or control rather than human reading.

The challenge deepens in genuinely threedimensional environments. Studies of modern visionlanguage systems show that when obvious semantic cues are removed, performance on questions that require understanding depth, occlusion and perspective collapses. In practice this means that, beyond lab demos, many models do not truly "understand" that something temporarily hidden behind a building or another object is still there and moving. For realtime predictive systems this is critical: a traffic management agent, for example, must reason about vehicles and flows it cannot currently see, based on partial geometry and past observations. From a geospatial perspective, this is like having a visually appealing base map while the underlying geometry and attributes are inconsistent; what looks fine to the eye becomes dangerous once automated decisions depend on it.

Realtime prediction is also fundamentally a problem of planning under uncertainty in a world that never sits still. Classical GIS analysis assumes that data is stable enough during the computation to produce a meaningful result. In contrast, robotics and planning research shows that when the environment is dynamic and uncertain, the combined spatial and temporal state space explodes. Exact optimal planning becomes too slow, while faster approximations risk unsafe or highly suboptimal behavior. Agents are forced into constant replanning as new information arrives, exactly when latency budgets are tightest. Conceptually, it is like trying to run a full dynamic network analysis for an entire city every second, with stochastic travel times and moving obstacles, while vehicles are already acting on your previous recommendation.

Even if one assumes perfect algorithms, the data reality is messy. Realtime agentic systems typically depend on multiple sensors—GPS, cameras, LiDAR, domainspecific probes—often deployed on constrained edge devices. Research on sensor fusion and edge computing emphasizes that these sensors are noisy, partially occluded, prone to drift and sometimes unavailable. The devices that must combine these streams and run predictive models are limited in power and compute, especially at the network edge where low latency is most valuable. Patterns in the environment also change traffic schemes, land use, human behavior and climatelinked dynamics all shift over time, so predictive models degrade unless they are continuously adapted, which again consumes resources and engineering effort. For a geospatial practitioner, this means that the tidy assumptions of complete, uptodate layers are rarely held in the field where agents must act.

Taken together, these strands of research explain why agentic AI does not magically deliver robust realtime predictive spatial intelligence. The systems are built on spatial representations that do not yet unify scales and geometry cleanly, on language and perception models that are still weak at true 3D and metric reasoning, on planning methods that struggle with highdimensional uncertainty, and on data pipelines that are noisy, incomplete and resourceconstrained. For geospatial professionals, the practical implication is to treat “realtime predictive spatial intelligence” as a demanding systemsengineering challenge rather than a readymade capability. Instead of promising full autonomy everywhere, a more realistic and productive stance is to design constrained, wellscoped applications—limited spatial extents, bounded prediction horizons, and hybrid humanintheloop arrangements—where current agentic and spatial AI can be reliable, while acknowledging the many open problems that still separate marketing phrases from operational reality.

What is being done to make AI spatially intelligent

Researchers worldwide are pursuing three main architectural approaches to make agentic AI spatially intelligent: **world modelbased planning**, **visionlanguageaction (VLA) models**, and **hybrid structured reasoning** over spatial data. Each build on different foundations and targets different use cases, from robotics to autonomous GIS.

World modelbased agents are currently the most popular for embodied spatial intelligence. These systems maintain an internal simulator of the environment that lets the agent predict future spatial states and test actions mentally before committing. Surveys on world models for embodied AI highlight two families: **gridbased models** that extend occupancy grids with dynamics (common in robotics and autonomous driving) and **scenegraph models** that represent objects, their relations, and motion in a structured format. The advantage is sample efficiency: agents learn faster by imagining rather than always trying actions in the real world. However, these struggle with long horizons and high uncertainty, especially beyond indoor or controlled settings.

Visionlanguageaction (VLA) models take a more endtoend approach, training multimodal transformers to map raw perception directly to actions. The comprehensive survey “From Perception to Action” shows VLAs excelling at shorthorizon navigation and manipulation because they implicitly learn spatial relationships from massive datasets. Examples include robotics arms that pick objects based on natural language instructions and navigation agents that follow vague commands like “go to the kitchen and find the coffee.” The geospatial equivalent would be agents that interpret satellite imagery or street views and act without explicit feature engineering. The weakness is brittleness in unfamiliar scenes and poor interpretability of the learned spatial representations.

For more structured spatial tasks, researchers are building **hybrid systems** that combine LLMs with explicit geospatial tooling. The autonomous GIS research agenda proposes agents that use **geographic knowledge graphs** as retrievalaugmented generation (RAG) backends, allowing LLMs to query spatial databases, compose geoprocessing workflows, and generate maps or reports. Similarly, neuroscienceinspired frameworks advocate for modular architectures with distinct modules for egocentrictoallocentric conversion, cognitive maps, and spatial memory, which mirror human spatial cognition. These are particularly promising for GIScience applications where decisions must respect formal geometry, topology, and scale.

At the perception layer, all approaches depend on advances in **multimodal spatial encoders**. Graph neural networks (GNNs) are widely used to reason over scene graphs or road networks, while diffusionbased 3D scene generation helps agents imagine unobserved spaces. For geospatial scale, foundation models trained on massive satellite and streetlevel datasets are emerging to provide zeroshot spatial understanding.

In practice, these approaches are converging, robotics labs focus on embodied world models and VLAs for micro/meso scale, while GIScience communities explore LLMdriven autonomous workflows over macroscale data. The “Spatial AI Agents and World Models” survey identifies six structural barriers that remain open, scaling representations across spatial hierarchies, safety guarantees for longhorizon planning, simtoreal transfer, multiagent coordination, edge deployment, and grounding abstract spatial reasoning in physical action. Progress is rapid, but truly general spatial intelligence for agents is still years away.

For geospatial practitioners, the message is clear: nearterm value lies in hybrid systems that leverage existing GIS tooling with agentic orchestration, rather than betting everything on fully endtoend embodied intelligence.

Challenges in integrating Agentic AI with geospatial intelligence

Integrating agentic AI with geospatial intelligence promises to revolutionize spatial analysis and decision-making, but researchers have identified profound technical, data, operational, and human challenges that make this convergence far from seamless. *At the core lies a fundamental mismatch between the precision demands of geospatial work and the probabilistic, pattern-matching nature of agentic systems*. Traditional GIS excels at exactly spatial operations—overlays, network analysis, topological relationships, but large language models and autonomous agents struggle with geometric accuracy, scale, and multi-step workflows. Agents often find selecting right tools very difficult, it mishandles parameters, or generate geometrically impossible results, particularly when processing remote sensing data or complex vector operations. Computational barriers compound this, geospatial foundation models demand immense GPU resources for training and inference, while edge deployment for real-time field applications (drones, vehicles) faces memory and power constraints that current architectures cannot overcome.

Data quality represents another intractable hurdle. Geospatial datasets are notoriously heterogeneous, with resolution mismatches, biome-specific variations, preprocessing requirements, and multimodal complexity (RGB, SAR, LiDAR, vector) that overwhelm agentic perception. Even when data exists, accessibility remains poor. Government spatial repositories are siloed, poorly indexed, and require specialist knowledge to unlock. Agents lack robust geospatial grounding, struggling with non-standard formats and temporal dynamics. Integration friction emerges when bridging these data realities with GIS platforms. APIs are inconsistent, documentation incomplete, and parameter complexity leads to cascading failures in autonomous workflows.

Beyond technical limits, human and organizational challenges loom large. Agentic outputs demand professional validation for accuracy, bias, and accountability, yet “black box” decision processes erode trust. Skill gaps create bottlenecks. While natural language interfaces democratize access for non-experts, GIS professionals must still verify results, slowing adoption. Ethical concerns amplify these issues, privacy risks from location data access, bias amplification from uneven training datasets, and reliability gaps for high-stakes applications like disaster response or urban planning.

The research consensus points toward pragmatic hybrid solutions rather than full autonomy: LLMs for natural language interpretation paired with deterministic GIS engines for computation, constrained scopes for near-term reliability, improved multimodal data pipelines, and mandatory human-in-the-loop validation. Progress is undeniably rapid, but integrating agentic AI with geospatial intelligence remains a systems engineering challenge requiring incremental bridging of precision gaps, data silos, and trust barriers before it can deliver operational reality.

Future of Agentic AI in real time geo-intelligence

These threads converge on a provocative precipice: GeoAI is not mere augmentation; it is redefining cognition itself. From explicit spatial biases to agentic edge intelligence, generative fluency, analyst empowerment, and autonomous execution, we stand at the cusp of systems that don’t just process places, they understand, predict, and converse with them. Yet shadows linger data biases amplifying inequities, hallucinations eroding trust, ethical voids in AGI’s rise. Will we engineer GeoAGI that anticipates urban floods with empathetic precision, or unleash unchecked spatial surveillance? The challenge thrills: harness this symbiosis to not only map our world, but to steward its futures—before the maps rewrite us.

How you see this playing out in practice

- Which real, operational use case do you believe is most ready for agentic AI today (e.g., traffic management, disaster routing, defense ISR, urban utilities)—and what made it ready?
- Where do you see the biggest risk of over promising—where marketing narratives about “real time geo intelligent agents” most diverge from what your systems can tolerate?
- If you had to define one non-negotiable design rule for deploying agentic AI in your geospatial context (technical, ethical, legal, or operational), what would it be?
- Which current assumptions in geospatial AI (static datasets, offline models, one shot predictions) completely break when you move to agents that perceive, plan, and act continuously?

Thoughtful, critical responses to these questions would be far more valuable than generic agreement, and they can help steer how we architect the next generation of GeoAI systems. If you’re working on concrete implementations—agent toolchains over EO data, autonomous GIS workflows, spatial copilots for analysts, or edge deployed geo agents, I would love to hear what’s working, what’s failing, and what evaluation benchmarks you wish the geospatial community should take. Please provide a critical comment for this article, specifically focusing on its assumptions, edge cases, and the divergence between theoretical agentic AI capabilities and industry realities. Thoughtful, critical perspectives will help evolve this important aspect of agentic Geo AI. I would sincerely appreciate discussing potential synergies with teams operating in this space.

GNSS (SBAS) Constellation Specific Monthly Analysis Summary: February 2026

The analysis performed in this report is solely his work and own opinion.

Narayan Dhital
Actively involved to support international collaboration in GNSS-related activities. He has regularly supported and contributed to different workshops of the International Committee on GNSS (ICG), and the United Nations Office for Outer Space Affairs (UNOOSA). As a professional employee, the author is working as GNSS expert at the Galileo Control Center, DLR GfR mbH, Germany.

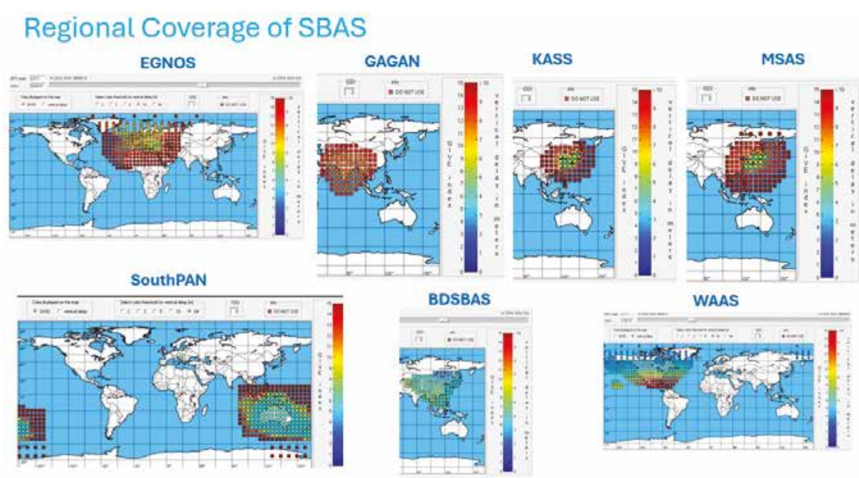
Introduction

This article continues the monthly performance analysis of the GNSS constellation. Readers are encouraged to refer to previous issues for foundational discussions and earlier results. However, due to time constraints and planned restructuring of monitoring parameters, this month's issue focuses solely on the global SBAS performance during recent high solar storms. The results were also presented at the UNOOSA, Space Weather Initiative workshop, Vienna, June 2025. From next month, it is planned to have a consolidated GNSS (GPS, GAL, BDS) +SBAS+NAVIC performance monitoring monthly.

Readers are also encouraged to go through the previous article on the SBAS performance to get technical details on the system (https://mycoordinates.org/pdf/aug23.pdf ; https://mycoordinates.org/gagan-performance-assessment-for-aircraft-precision-approach/)

1. SBAS Performance

SBAS networks—including EGNOS (Europe), WAAS (USA/Mexico), GAGAN (India), MSAS (Japan), KASS (Korea), BDSBAS (China) and SouthPAN—augment GNSS by transmitting ionospheric corrections, integrity bounds, and protection levels. The coverage map below provides an overview on the geographical regions and associated grids for each SBAS system. These are essential for enabling aircraft precision approach operations such as APVI, APVII, and LPV200. Ionospheric disturbances, especially during geomagnetic storms, pose the greatest natural hazard to GNSS-based navigation, increasing ionospheric delay, error uncertainty (GIVE/GIVEI), and integrity risk. The May 2024 storm provided a unique opportunity to observe SBAS behavior under extreme space-weather conditions.



2. Understanding the Metrics

To interpret SBAS performance plots, three metrics are fundamental:

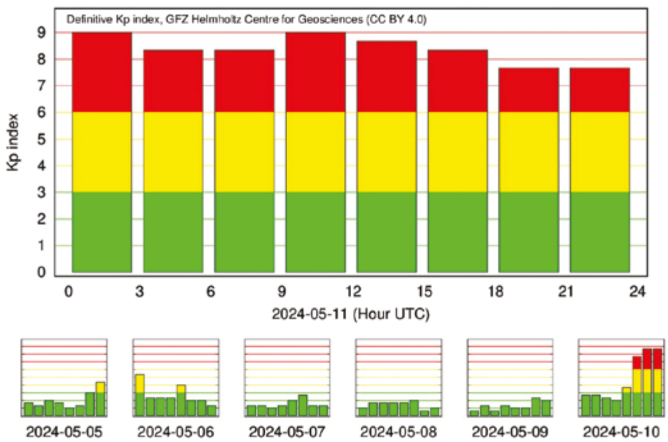
HPL (Horizontal Protection Level): Represents the confidence bound on horizontal position error. When HPL exceeds aviation alert limits, operations such as RNP 0.3 or RNP 0.1 become unavailable which also means APV-I/II/LPV becomes unattainable.

VPL (Vertical Protection Level): Vertical integrity bound, more sensitive to ionospheric errors. Thresholds include APVI (50 m) and APVII/LPV200 (35 m). Any spike above these limits makes approach procedures unavailable.

GIVEI (Grid Ionospheric Vertical Error Indicator): Encodes SBAS confidence in ionospheric corrections at each grid point. Higher values indicate higher uncertainty. GIVEI = 15 denotes an unmonitored ionosphere region, forcing SBAS to inflate protection levels dramatically. These metrics explain most behavior observed during the May 2024 storm.

3. Space Weather Event: May 10–11, 2024

The May 2024 storm reached G4–G5 levels (as shown in the bar graph, source: GFZ), triggered by multiple Earth-directed coronal mass ejections (CMEs). The storm produced intense ionospheric gradients and plasma disturbances across mid and highlatitude regions. Seven IGS stations (provided in the table) across SBAS service regions—ROAG (Spain), HOFN (Iceland), NIST (USA), INEG (Mexico), BHPL (India), STK2 (Japan), and YONS (South Korea)—served as representative monitoring points.



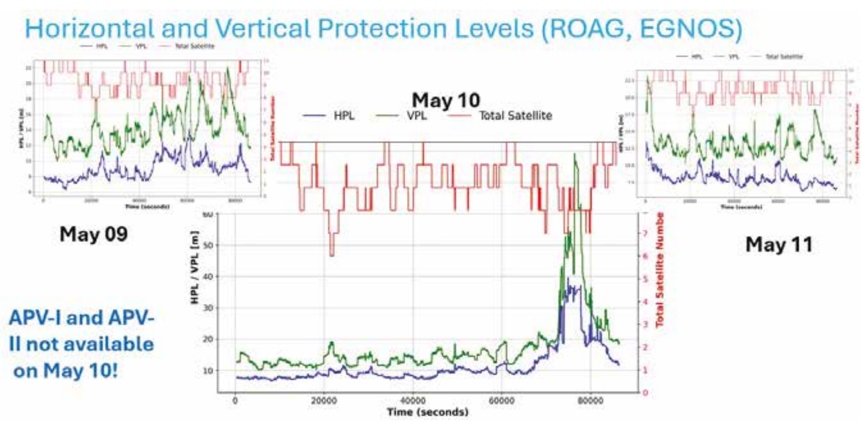
Airspace	Lat	Lon	SBAS System
ROAG (Spain)	36.463	-6.206	EGNOS (GEO- 123)
HOFN (Iceland)	64.267	-15.198	EGNOS (GEO- 123)
NIST (USA)	39.995	-105.263	WAAS
INEG (Mexico)	21.856	-102.284	WAAS
BHPL (India)	23.289	77.467	GAGAN
STK2 (Japan)	43.529	141.845	MSAS
YONS (S. Korea)	37.541	127.001	KASS

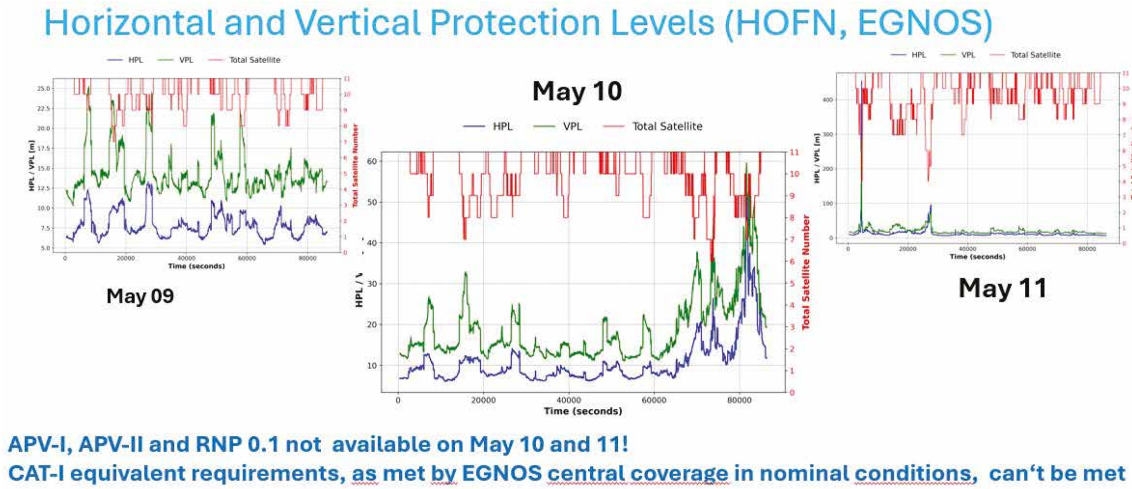
4. SBAS Performance Results: Detailed Interpretation

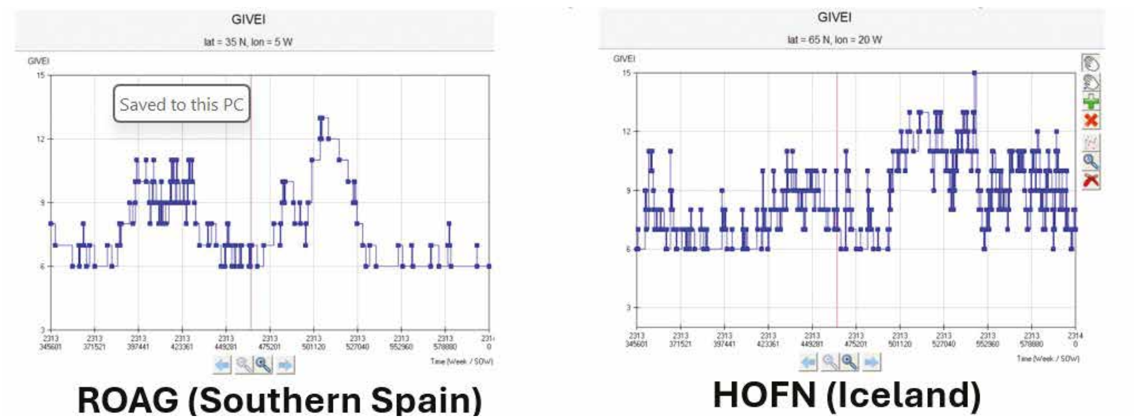
This section interprets HPL, VPL, and GIVEI behaviors for each SBAS during the storm compared to nominal conditions.

4.1 EGNOS: ROAG (Spain) & HOFN (Iceland)

ROAG showed strong VPL inflation on May 10, exceeding APVI/II thresholds. HPL rose moderately. As an edge-of-coverage location, ROAG is sensitive to ionospheric gradients. HOFN exhibited severe degradation across 10–11 May, including GIVEI = 15 events indicating unmonitored conditions. High-latitude auroral activity directly contributed to integrity loss.

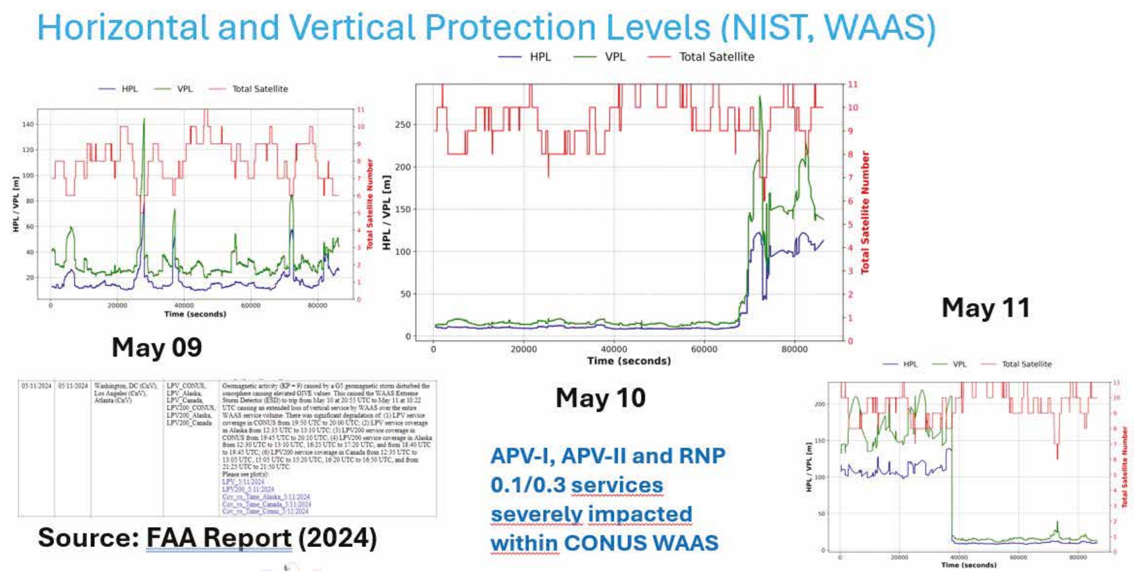






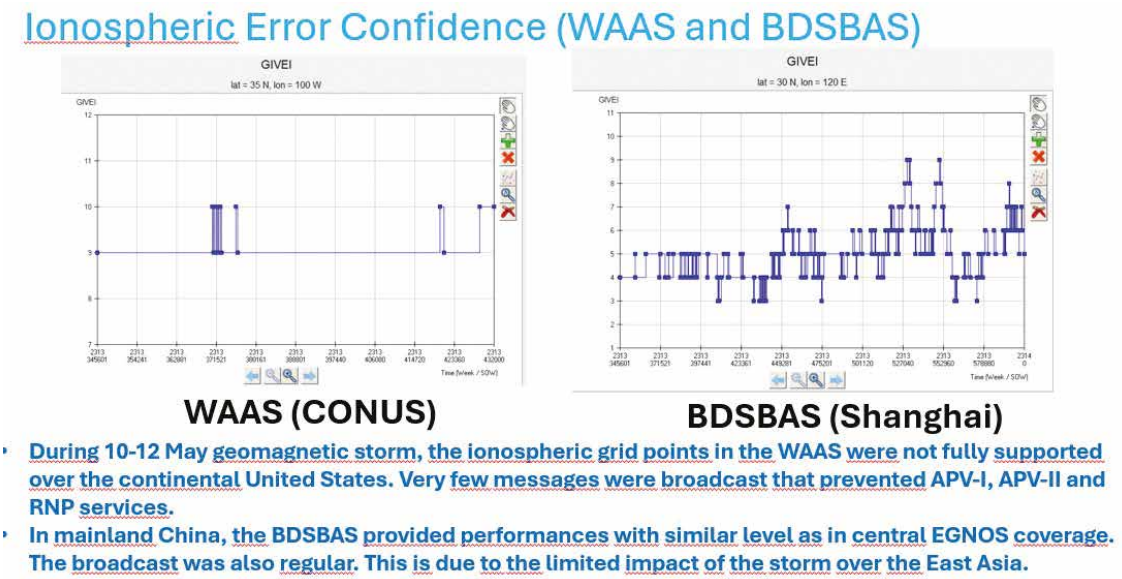
4.2 WAAS: NIST (USA) & INEG (Mexico)

NIST experienced VPL spikes due to reduced WAAS broadcast support for ionospheric grid points. INEG, near the southern WAAS boundary and equatorial anomaly region, saw stronger degradation and prolonged APV unavailability. Edge effects and equatorial plasma bubble activity significantly impacted performance.



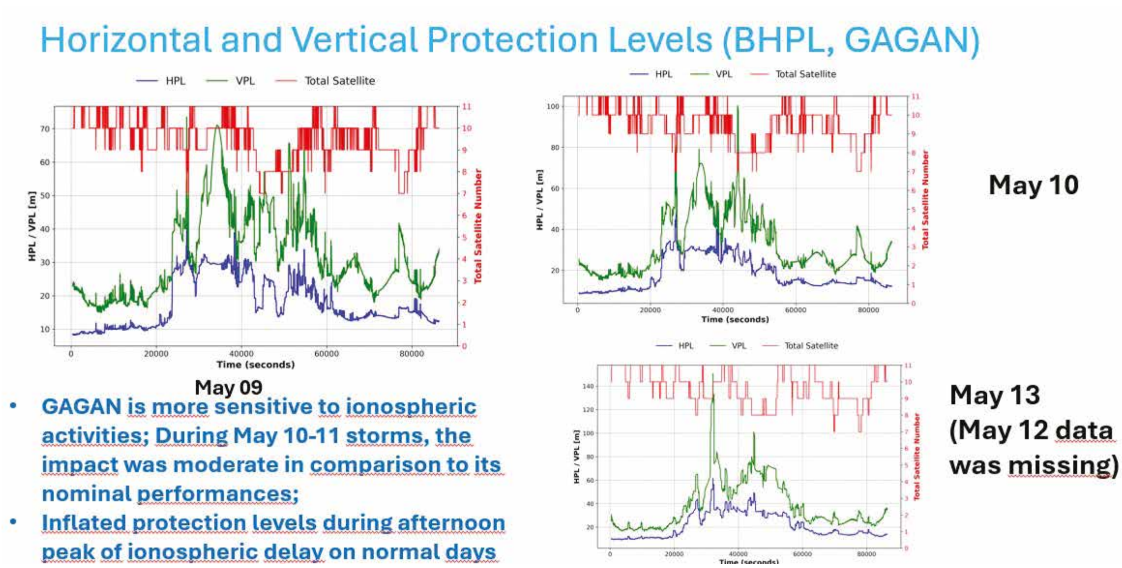
4.3 BDSBAS (Shanghai Region)

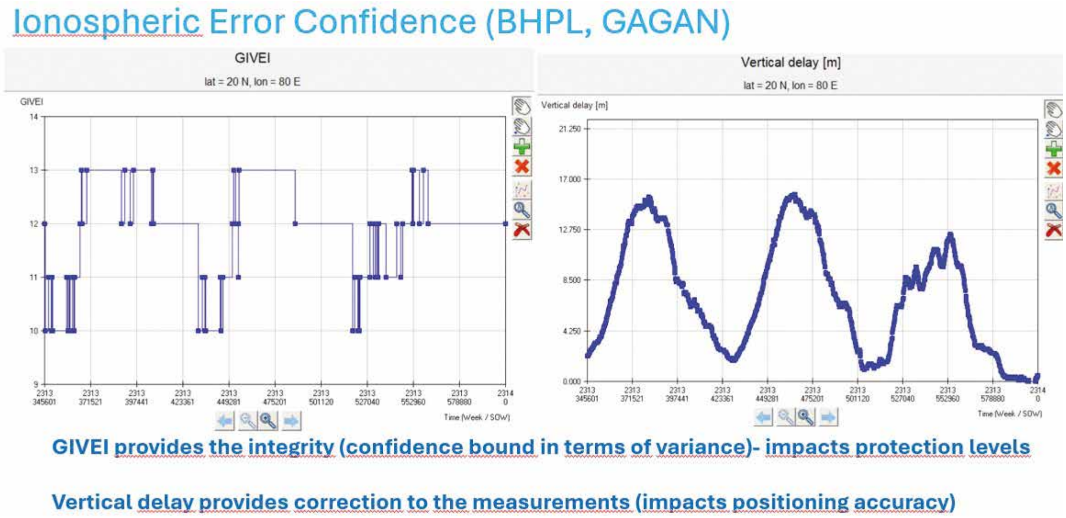
BDSBAS demonstrated stable HPL/VPL values and low GIVEI even during storm peaks. The storm's weaker impact over East Asia and BDSBAS's dense monitoring network contributed to its strong robustness, the highest among all SBAS examined.



4.4 GAGAN (India)

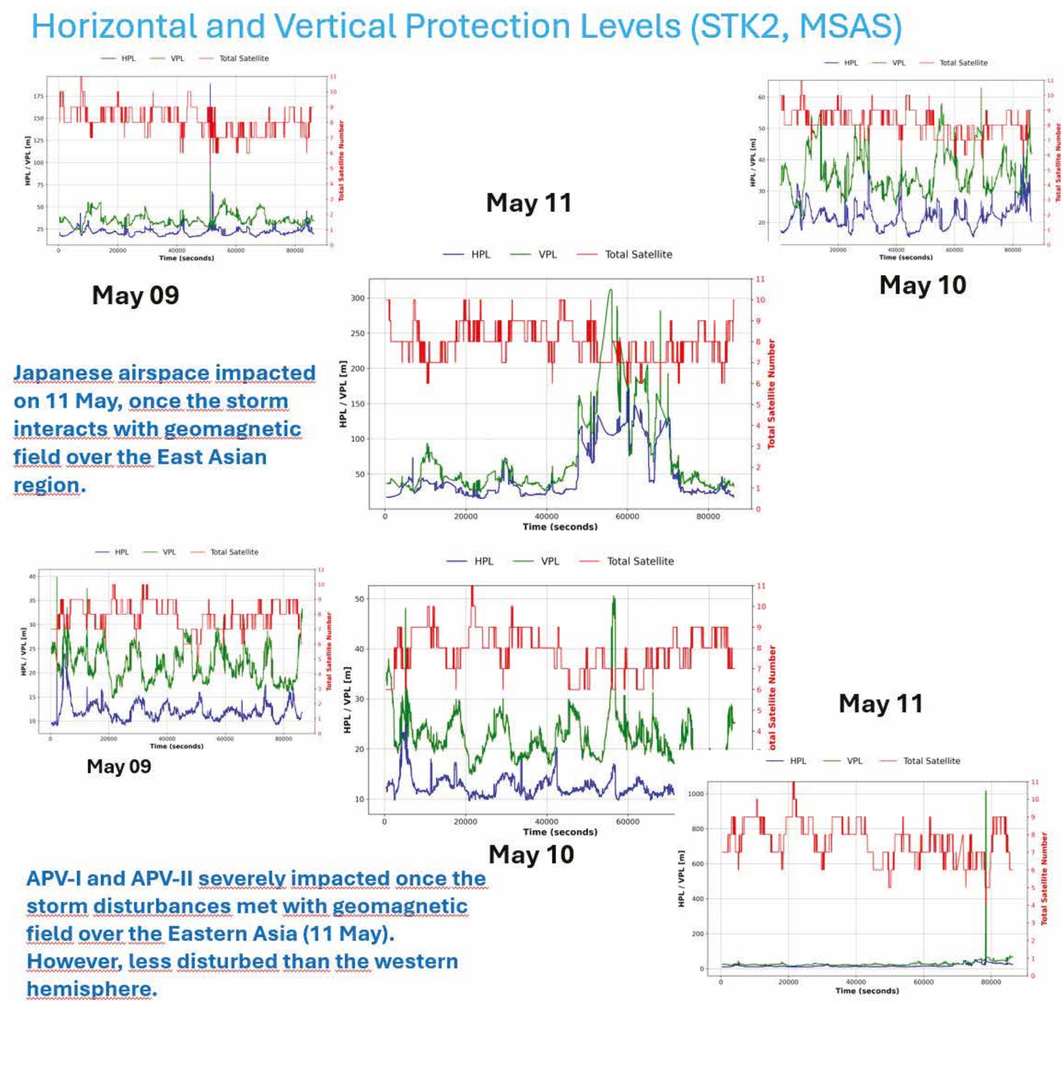
GAGAN showed moderate storm-related degradation. Even nominal days displayed afternoon VPL rise due to equatorial ionization anomaly (EIA) behavior. This region is inherently variable, and storm activity amplified natural fluctuations but did not trigger unmonitored conditions in this specific storm day.

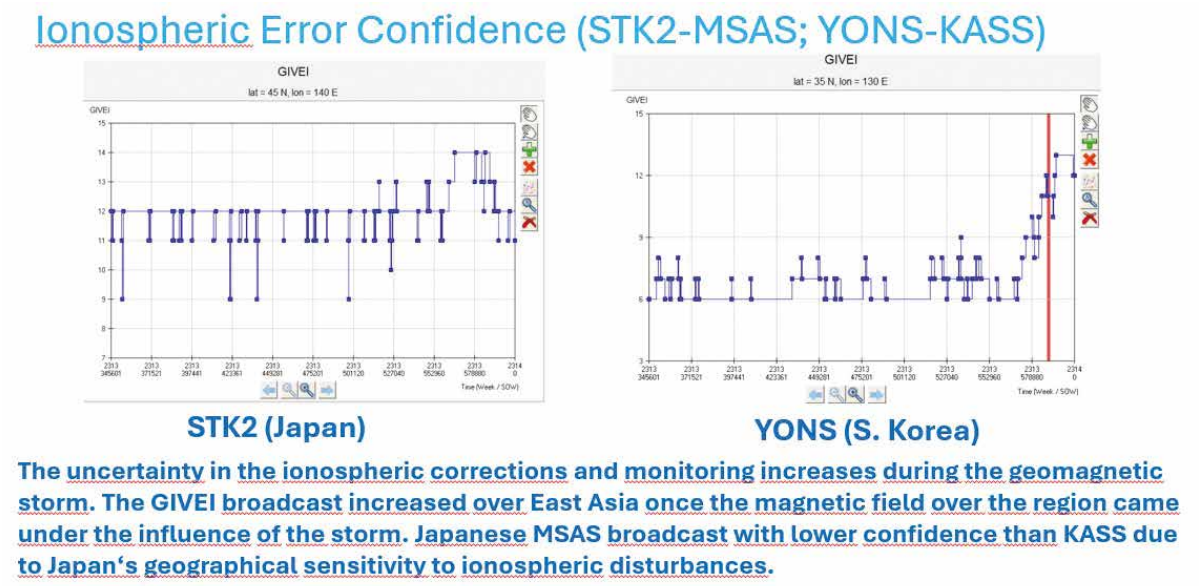




4.5 MSAS (Japan) & KASS (South Korea)

MSAS experienced significant degradation on May 11 as the storm footprint advanced over East Asia. GIVEI rose sharply, reflecting increased uncertainty. KASS showed milder degradation due to less geomagnetic sensitivity and a more modern monitoring architecture.





5. GIVEI Analysis

Across all SBAS systems, GIVEI increased during storm peaks, driving VPL/HPL inflation. GIVEI = 15 occurred in Iceland, forcing EGNOS to classify the ionosphere as unmonitored. Systems with dense monitoring networks, such as WAAS CONUS and BDSBAS, maintained better stability.

6. Discussion

Edge-of-coverage SBAS regions (ROAG, HOFN, INEG) experienced the strongest degradation. GIVEI behavior directly explained VPL/HPL spikes: as uncertainty increased, integrity bounds inflated. System resilience strongly correlated with ionospheric model density and geographic sensitivity.

System-to-System Comparison
BDSBAS: Highest resilience.
EGNOS (central): Moderate resilience.
WAAS (CONUS): Moderate, impacted by limited iono message broadcasts.
GAGAN: Moderate degradation, affected by equatorial anomalies even on nominal days.
MSAS: Strong degradation on May 11.
KASS: Moderate degradation, more stable than MSAS on nominal days.

7. Conclusions

All SBAS systems experienced significant performance degradation during the May 2024 storm, especially for approach-level services. BDSBAS proved to be the most resilient. VPL/HPL inflation was driven primarily by rising ionospheric uncertainty (GIVEI). Current SBAS threat models become strongly conservative during disturbed conditions due to lack of biasvariance separation.

Future improvements should focus on enhanced ionospheric threat models, separation of bias and variance components, higher density monitoring networks (particularly at coverage edges), deployment of DFMC SBAS, and integration of real-time space weather analytics.

All these topics will be covered on a regular basis from next month's consolidated and extended GNSS performance analysis. SouthPAN (Australian SBAS) performance will also be included.

Data sources and Tools:

https://cddis.nasa.gov (Daily BRDC, RINEX OBS); http://ftp.aiub.unibe.ch/CODE_MGEX/CODE/ (Precise Products); BKG "SSRC00BKG" stream; IERS C04 ERP files
SBAS Mentor, ESA
gLAB GNSS, https://gage.upc.edu/en/learning-materials/software-tools/glab-tool-suite
serenad-public.cnes.fr (SBAS data)

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I, Sanjay Malaviya, hereby declare that the particulars given above are true to the best of my knowledge and belief.

March 1, 2026 Signature of publisher

Time-base accuracy evaluation of static, RTK, and PPK surveys in differential GNSS

Each procedure for static, PPK and RTK has its own advantages and short falls.

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Abstract

The Differential Global Positioning System (DGNSS), have three types of observations Static, Post processed Kinematics (PPK) and Real-Time Kinematic (RTK) focuses on real-world efficiency-accuracy trade-offs. In "time-based survey methodology" in GNSS applications, particularly focusing on accuracy and efficiency for India/ In DGNSS surveying methods that rely on the timing of satellite signals and observations achieve high positional accuracy which is time dependent. To confirm the most accurate methods, DGNSS observations were taken using the three methods by fixing a base station, Rover station. Also, the different time of observation is considered to focus on accuracy and efficiency. It has been inferred for all the GNSS surveying procedures, the correction of all skills, that help to accomplish high positional accuracy. Static surveying is time-consuming but of high performance, whereas PPK rectifies errors after data collection, RTK provides positional perfections in real-time. Selecting an observational procedure shall offer empirical accurate data for surveyors to enhance fieldwork procedures. However, the time-based evaluation (30 minutes vs 1-hour static data showed an error difference of <=0.12”) is particularly valuable for resource-constrained projects. However, broader applicability requires deeper statistical validation.

1. Introduction

Capturing 3D geospatial information, the foundation data should be fast, accurate, comprehensive, reliable, cost-effective etc. The large-scale (1:1,000 or 1:500) topographic data is presently widely used for cadastral or town planning surveys. For 3-D formation, the Digital Elevation Model (DEM) data (50cmX50cm grid with 10cm vertical accuracy) can be used. Contours having an interval of 1cm, Orthophotos at 5-10cm ground sampling distance (GSD) and GIS layers considered as per Amrut of 290 layers. The present practice of capturing data is redundant, dissimilar, disconnected, done in silos, dissimilar, poor in scale, coverage and incomplete so for one data multiple surveys are conducted. It is pertinent to have one survey that should be unanimously applied and should be realistic and good (Specht, 2023). The orthodox method of data capturing is done by using total station, GNSS, Satellite imageries and drone photographs but these are unsuitable as cannot be applicable in inaccessible terrain, remote areas, erroneous, inaccurate, Time-consuming, uneconomical, inaccurate etc. da. Silva et al., (2025).

There are numerous Satellite Navigation (SATNAV) systems operating around the world. Some are global and others only provide service within a certain region. The term Global Navigation Satellite System (GNSS) is defined as the collection of all SATNAV systems and their augmentations. The various SATNAV systems are the U.S. Global Positioning System (GPS), the European Galileo system, the Russian Federation Global Navigation Satellite System (GLONASS), the Chinese BeiDou Navigation

Satostellation Elite System (BDS), India's Navigation with Indian Constellation (NavIC), and Japan's Quasi-Zenith Satellite System (QZSS). Each system operates with enhanced accuracy and reliability. By triangulating signals from multiple satellites, GNSS receivers can have better coordinates within meters or centimetres accuracy (Walker et al, 2020, Nanda et al, 2023, Ramiro et al, 2025).

These satellite-based systems provide accurate positioning, navigation, and timing to users around the globe, enabling a wide array of applications across various sectors. Originally developed for military purposes, GNSS has become integral to civilian life, influencing everything from everyday navigation in vehicles to precision agriculture, aviation, and disaster response (Steuer et al., 2025). The GNSS used as it is having accurate navigation (10-20cm), weather independent, worldwide coverage, no line of sight needed, high geodetic Accuracy, 24-hour operation, quick and economic, a common coordinate system, a wide range of applications, competitively priced, and accessible for both civilian and military (Shi et al, 2020, Nanda et al, 2024, Popove et al, 2025; Preety et al., 2022) The comparison of the 3-survey methods Static, PPK and RTK along with drone image of the area of CUTM (Atik et al. 2025) are applied which is given in Table-1.

GNSS: Hence GNSS as an innovative technique in modern surveys as location tracking, enhances safety in transportation, and supports emergency services, like autonomous vehicles and drone operations.

Furthermore, GNSS plays a crucial role in scientific research, environmental monitoring, and telecommunications. Whether navigating city streets or conducting complex scientific measurements, GNSS remain at the forefront of modern navigation solutions (Vetrella et al, 2016, Li et al., 2025, Weng et al, 2025; Chillab et al., 2023).

Geographical Positioning System: (GPS): GNSS is an aligning arrangement of a network of satellites that uninterruptedly transmit coded information. The transmitted information is received by receivers to exactly recognize locations on Earth by measuring distances from the satellites (Kim et al, 2017; Gao et al, 2023).

The Global Positioning System (GPS) is a U.S.-maintained usefulness that provides users with positioning, navigation, and timing (PNT) services. The GPS is composed of three main segments: the Space Segment, the Control Segment, and the User Segment. The Space Segment consists of GPS satellites orbiting Earth, the Control Segment manages and monitors those satellites, and the User Segment comprises GPS receivers that receive signals from the satellites to determine the location.

GPS has many advantages over Traditional Terrestrial Surveying Techniques which rely on line of sight between the survey instrument and a target with high geodetic accuracy, indiscriminate reception place, three dimensional and free. On the existence of obstructions, the survey work can be carried out by traverse method. GPS is widely used for navigation, mapping, and tracking, but it does have a few limitations i.e. Signal obstruction (urban canopy, Dense Forests and Tunnels, Indoor), heavy rain, solar storms, Electronic Interference, Jamming and Spoofing. GPS adds to the advanced framework in blockchain, the Internet of Things (IoT) and artificial intelligence (AI), in emergency handling and public safety arrangements, (Mekik et al, 2009; Majumdar et al, 2025)

Sources of error in GNSS: The errors incorporated in the GNSS system are Satellite errors (orbit uncertainty and satellite clock model), Receiver errors (Receiver clock and noise), observation errors (Ionospheric delay and Tropospheric delay) and station errors (station co-ordinates, Signals effect error and multipath). To avoid these large cumulative errors, the Differential GPS/GNSS is incorporated (IIRS – E book- 2023).

DGNSS: The GNSS is available globally and free to use by civilians, without any cost. Some errors are incorporated into the information by single point positioning due to satellite clock error, orbital error, ionospheric delay, tropospheric delay, receiver clock error and partial multipath error. These errors can be purged by the Differential Global Navigation

Fig. 1. Drone image of the study area (Centurion Univ. of Tech. & Management)

Fig. 2. Differential geographic positioning system (Base, Rover Station & Controller)

Satellite System (DGNSS). DGNSS is an enhancement of standard GNSS, which has improved accuracy, integrity, and reliability by using a network of fixed ground-based reference stations.

GNSS addresses the drawbacks by using ground-based reference stations, also known as base stations, and that broadcast correction to GNSS signals with position accuracy (Krasuski et al, 2021; Bakul et al, 2022; Spchet, 2023)

These reference stations are positioned at precisely known locations. They monitor uninterruptedly the GNSS received signals and calculate the errors in those signals. The error information is then transmitted to DGNSS-enabled rover receivers in the field. DGNSS. These instruments often consist of a GNSS receiver, a data processing unit to apply the corrections, and a communication link to receive the correction data from the reference station (Table 1).

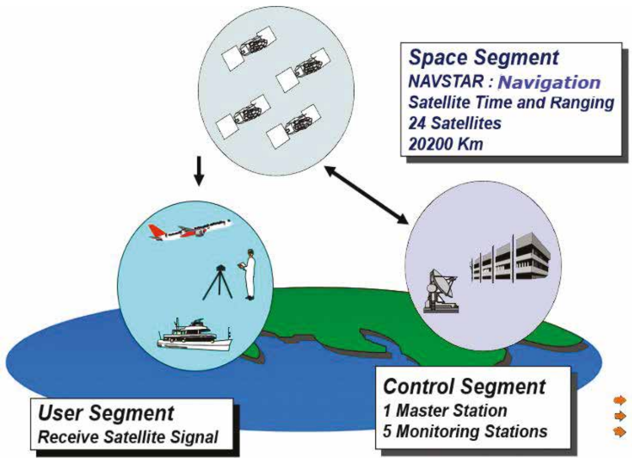

Fig. 3. Various Global Positioning Segments (Space, User and control segment)

Advantages/disadvantages of DGNSS: The advantages of DGNSS are increased positioning Accuracy, offering centimetre-level precision, popularity and, wide availability, Real-time Positioning: Many DGNSS systems provide real-time corrections, high-accuracy positioning for time-sensitive applications, Enhanced Reliability in data positioning data and versatile applications (Pretty et al, 2022; Chilab et al, 2023). The disadvantages of DGNSS are requiring correction Signal, being unavailable in remote or obstructed areas, increased initial equipment Cost, the potential for signal interference, limited range, and complexity (Biswas et al, 2022). The GNSS survey includes testing different positioning surveys can be of two types static and Kinematic in GNSS (Dardanelli et al, 2021; Alkan et al, 2025).

Time-Based Surveying with DGNSS: The time of the extent is the receiver time of the acknowledged signals. The accuracy in receiving satellite information the timing is critical. They should maintain correct time called real time and differential correction is to be incorporated to get the most processed information. The surged accuracy improves to 1-3cm from 15m in the case of Single point positioning by GNSS is 3-5m. and can have applications in the case of land surveys, and geodetic and hydrographic surveys. They can also be used for structural health monitoring, precession farming and disaster monitoring like earthquakes, Volcanic eruptions, landslides, etc (SOI 2009).

Pseudo Range (PR): The PR (in meters) is the distance between the receiver antenna and the satellite antenna together with receiver and satellite clock offsets including atmospheric delays. Mathematically; $PR = distance + c(receiver\ clock\ offset - satellite\ clock\ offset + other\ biases)$ so that the PR reflects the real-time (stored in m) behaviour of the receiver and satellite clocks. Where, the measured range between the satellite and receiver.

Distance: True geometric distance between the satellite and the receiver, Velocity (C) is the Speed of light (299,792,458 meters per second (m/s), Receiver clock offset (error in receiver's time). Satellite clock offset (error in satellite's time). The other biases: Include ionospheric delay, tropospheric delay, multipath errors, hardware delays, etc.

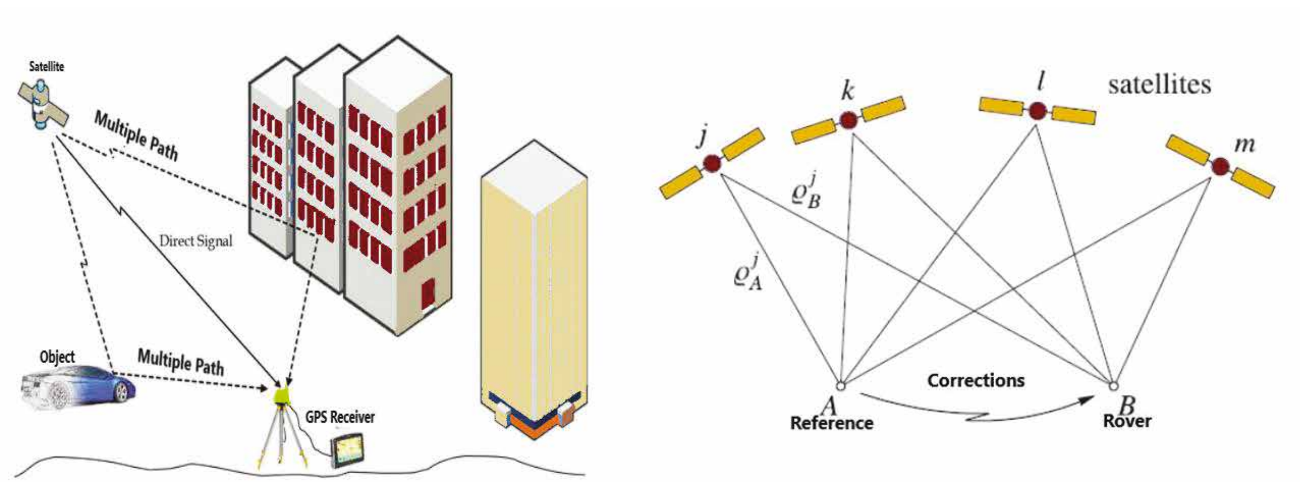

Fig. 4 (a-b). (a) Various corrections in satellite installation in GNSS like multipath etc

Parts of DGNSS: For the DGNSS survey, we need a minimum of two receiver antennae, one is for Base Station and one or more Rover Station. The various components are GNSS Satellites (A constellation of satellites orbiting Earth, transmitting signals for location determination), Base Station (Reference Station), Rover Receivers (A mobile GNSS receiver used in the field to control position, receiving satellite signals and correct data) (Fig 3). Communication Link, and Data Processing Unit: Hardware or software in the rover that applies the corrections received from the base station to improve the accuracy of its position. Antennas, power supplies, soft wares for all stations/rovers, data storage and mounting equipment used for fixing.

Why DGNSS: The absolute position determination with GNSS is less accurate than relative positioning between two stations. Error sources in GNSS locations include the strata in the atmosphere, satellite problems, and the receiver. These errors can introduce delay and distortion GNSS signals, that affect the accuracy and efficiency. These acting errors (biases) where the error occurs are of three categories:

i. Errors related to distance: mainly ephemeris and propagation errors, are nearly the same for neighbouring stations, as long as they are sufficiently close, and hence disappear in the differences.
ii. Errors related to time: are coped with by synchronized or nearly simultaneous observations.
iii. Uncorrelated errors : affect both participating stations and need a calibra tion

Corrections in DGNSS: The reference station commonly calculates pseudo-range corrections (PRC) and range rate corrections (RRC) which are transmitted to the remote receiver in real-time. The remote receiver applies the corrections to the measured pseudo ranges and performs point positioning with the corrected pseudo ranges. The use of the corrected pseudo ranges improves the position accuracy concerning the base station.

The Applications OF DGNSS: are precision agriculture (Guiding tractors for precise planting, spraying, and harvesting, optimizing crop yields and reducing resource waste), construction surveying (for accurate positioning for construction layout, ensuring buildings and infrastructure are built according to design specifications, Hydrographic Surveying: Marine Navigation, Aviation, Mapping underwater (navigation, dredging, and coastal zone management). The other applications are geographic Information Systems (GIS): Autonomous Vehicle Navigation, etc. (Gleason, 1996)

Objectives: There exist three types of DGNSS surveys. The objective of the work is to find out.

i. The Basic ideas about DGNSS (Differential global navigation satellite system)
ii. To find out the accuracy of three types of survey(Static, PPK and RTK)
iii. To find the accuracy obtained based on the timing of observations.

Table 1. Budgeting of GNSS error in the atmosphere in meters

Error	Ionosphere	At. Clock	Ephemeris	Troposphere	Receiver	Multipath	Total
Value (m)	4.0m	2.1m	2.1m	0.7m	0.5m	1.0m	10.4m

Source: Maj Gen. R C Padhi, (SOI); https://orsac.odisha.gov.in/pdf/GNSS and DGNSS.pdf

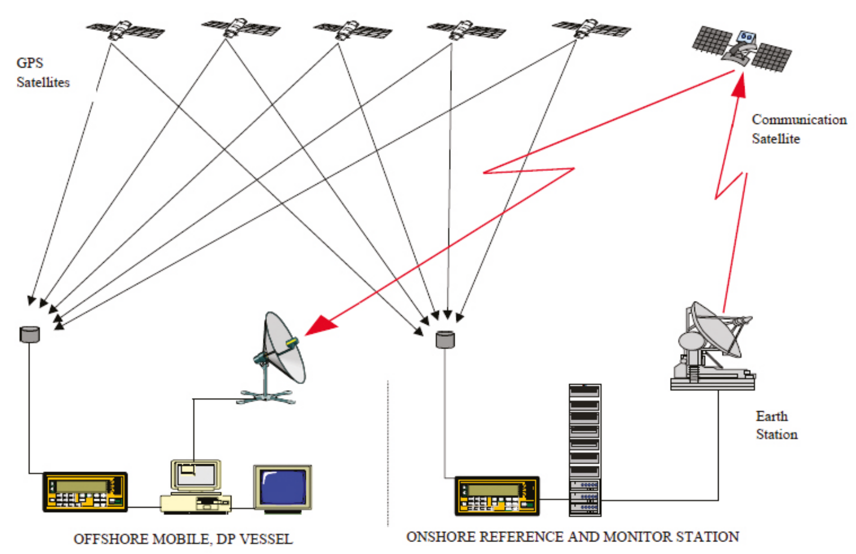

Fig. 5. A typical satellite-based DGNSS with onshore/ offshore stations

3. Methodology

Data Collection & Processing Timing Requires long observation times (minutes to hours, depending on baseline length and required accuracy) and all data processing happens in the post-processing stage. The receiver remains stationary for the entire observation. Provides real-time centimetre-level accuracy by static and PPK method of survey. Collects raw GNSS data at both the base station and rover. No real-time communication is involved during the observation phase. The base station data is downloaded later for post-processing. All data processing occurs post-mission using specialized software. The rover receives corrections from a base station via a radio link and calculates its position on-the-fly, during the data collection process in RTK. It May or may not require static initialization, depending on the specific RTK approach. RTK requires a continuous, reliable radio/ cellular data link to transmit corrections from the base station to the rover in real time for base station communication.

Methodology For Static Survey: Static GNSS (Global Navigation Satellite

System) surveying is a precise technique used in geodesy, engineering, and cadastral applications to determine accurate positions by collecting data over long observation periods. It involves Setup for Site Selection and includes a location with a clear, unobstructed view of the sky for optimal satellite signal reception. Avoid areas near tall buildings, under tree canopies or foliage, inside buildings or under roofs, and the power lines for better accuracy of points. The survey started with Trimble access being connected with the base and rover station. After completion of the survey, all information/ data are backed up for later processing by Trimble Business Center. (TA: Trimble Access software and Trimble Business Centre).

Methodology For PPK Survey : PPK (Post-Processed Kinematic) GNSS surveying is a technique that allows for high-accuracy positioning by recording GNSS data at both a base station and a rover, then correcting the rover's positions after the survey using post-processing software. The base station records GNSS

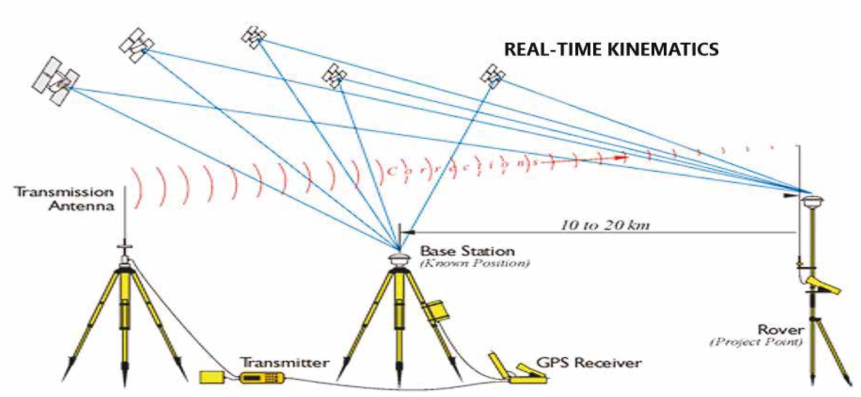

Fig. 6. The satellite constellation in Real-time kinematics (RTK)

Table 2. Difference Between Various survey methods in GNSS (STATIC, RTK & PPK)

Aspect	STATIC	RTK	PPK
Accuracy/ reliability	Highest (mm-Sub-cm)	Very High	High (cm level) based on signal/data link quality)
Horizontal/Vertical Accuracy	± 2 5 mm + 0.5 ppm / ± 5 10 mm + 1 ppm	± 2 5 mm + 0.5 ppm/ ± 5 10 mm + 1 ppm	NA
Obs ^{n}. Time needed Processing time	Long observation time (15 minutes or more Hours (post-processing needed)	Real time (instant) Minutes to hours (post-processing)	Continuous/ record in fly, OT Short (sec min) Instant
Need Set up (GNSS) Receiver/ base station need, Link Communiqué	Base and Rover stn. for a long period; BS needed; No communication link	Need; operating reference stn (CORS). (radio, NTRIP,), communiqué linked;	continuous Operating reference st n . (CORS). Rover moves with data reception, No link.
GNSS Receiver	Dual frequency DF)	DF + RTK enabled	DF + Onboard Logging
Data processing	Postprocessing	Real Time	Faster post processing
Advantages (Pros)	Geodetic/tectonic monitoring; Highest accuracy; great for long baselines.	High accuracy; no need for real time data link.	Drone mapping, Topographic survey; Real time results; fast and efficient
Disadvantages	More Time needs post-processing	Post-processing needs; setup complex	Requires communication link; range limited
Distance Cover a. Baseline range b. Suitability for remote area	 a. 10 100s km b. Excellent	 a. <20km(more with RTK network) b. Limited (if no communication link)	 a.< 40km can be longer with good data b. Excellent
Ambiguity Resolution	Longer observation times, growth success rate/reliability in doubt resolution.	Initialization time is needed to solve the ambiguity.	Post-processing, and longer processing times for better accuracy/ reliability, even with short observation times.
Movement & Dynamics	The rover receiver must remain stationary over each point for the entire observation period.	Used in the kinematic model, continuous positioning while the rover is in motion requires Static initialisation.	Best for kinematic applications, provides accurate positioning even when the rover requires Static initialisation.
Typical Applications	Creating control networks, warp monitoring, high accuracy geodetic surveys where high accuracy is needed, and time isn't a major constraint.	Stakeout, topographic surveys, construction layout, and other applications where real time positioning is essential.	Aerial/ drone mapping), mobile mapping, areas with poor communication coverage, and situations for high accuracy but real time processing is not required.
Best for	Long baselines, long observations	Real-time stakeouts, topo surveys	UAV, dynamic surveys without real-time corrections
Min: Minute; Hrs: Hours; CP's: Control points, BS: Base station RS: Rover Station			

Source of information: SOI manual published from time to time (Dardanelli et al., data at a known location. Rover (mobile receiver) collects data at unknown positions (e.g., UAV flight paths or land points). After data collection, the rover's data is corrected using the base station's data in post-processing software, correcting for satellite and atmospheric errors. Unlike RTK, it doesn't require a real-time link. After fieldwork, data from both is processed together to apply differential corrections. PPK is robust against signal interruptions and works over longer distances. Although post-processing is needed, it's ideal for high-precision applications where real-time accuracy isn't critical. This makes it suitable for aerial surveys, mapping, and challenging environments.

There requirement for uninterrupted site selection, proper levelled and stable base station set up, and Rover set up with a well-connected receiver, antenna, and data collector. The set-up must have a proper power connection and data collector system. The completion of the survey all information/ data are backed up and start processing (Shao et al. 2015; Cirillo et al., 2022; Chao et al. 2023). Various applications of PPK survey are Various application of PPK survey are Land and topographic surveys, Construction site layout, Aerial mapping by drones, pipeline and utility surveys and Monitoring earthworks and infrastructure projects.

B.RTK SURVEY: RTK (Real-Time Kinematic) survey is a DGNSS technique providing centimetre-level accuracy in real-time. A base station transmits corrections to a rover, enabling instant, precise positioning. It requires a constant communication link, typically radio, between the base and the rover. RTK is efficient for surveying and construction needing immediate results. However, its performance depends on signal strength and short distances. Obstructions can degrade accuracy, but its speed and precision are valued for many tasks.

The applications are Land Surveying (Boundary mapping, property surveys, and topographical surveys, Construction: Site layout, road alignment, and excavation control, Agriculture: Precision farming, planting, and irrigation layout, Aerial Mapping: Used with drones to geotag images for photogrammetry, and Utilities and Infrastructure: Pipeline and utility alignment surveys.

The appraisal among the three methods of DGNSS survey applications by Static, PPK (Post processed kinematics) and RTK (Realtime kinematics) in GNSS Survey is in Table 2.

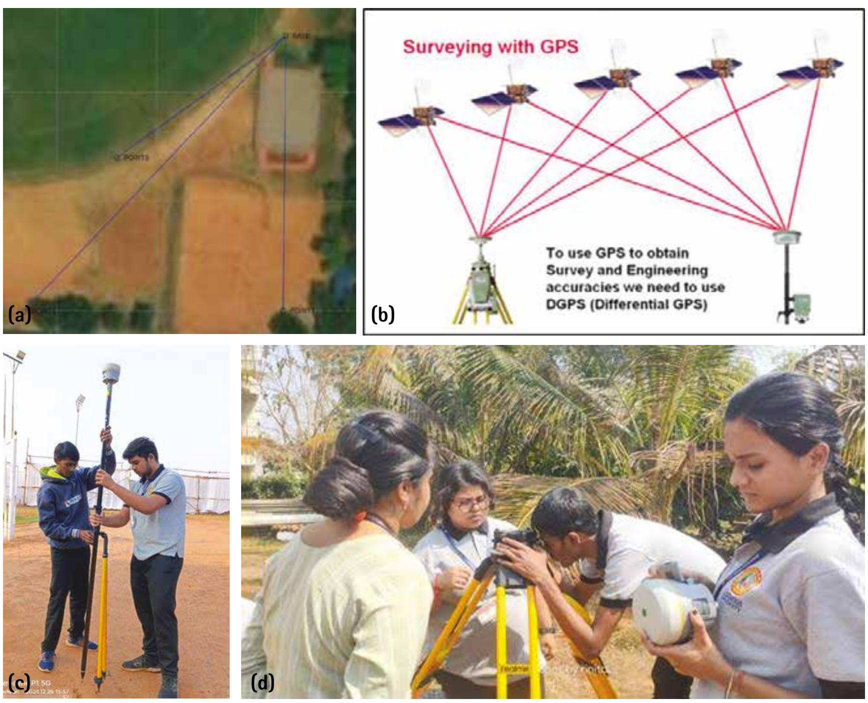

Fig. 7. (a-d): The field observations at the field of CUTM with fixing rover with bipod

DOP and PDOP in Satellite Navigation: In satellite navigation (like GPS), DOP (Dilution of Position) and PDOP (Position Dilution of Precision) are numerical values that measure the quality of the geometry (3-D) for visible satellites disturbs the precision of the fixed position whereas DOP accesses the impact of satellite geometry on position precision. The lower value of PDOP indicates better satellite geometry and more accurate positioning. The DOP value 1 is ideal. In India it is accepted a PDOP value of 2-4 has accurate positioning with good satellite geometry and a higher value (>7) has weak satellite geometry and the positioning is not reliable as per European GNSS Glossary 2018, (Cui et al, 2021; Susi et al. 2023; Jing et al, 2025)

Equipment needed for Base Rover GPS: The DGNSS equipment used in the study of TRIMMBLE and RTK observation is the GPS base station, GPS rover(s) and the communication link between the base and the rover(s). The GPS base station and each GPS rover must contain: (i) a GPS receiver, (ii) a GPS antenna (iii) a Communication link (Radio and radio antenna or cell phone), a Survey Controller (Real-time surveys must have a controller at the rover receiver) and Power supply (AC power supply or portable batteries) along with the Appropriate cabling.

FIELDWORK: Four locations were practical to work. We measure these four points with DGNSS in STATIC mode for one hour, STATIC mode for 30 minutes, RTK mode for 10 minutes, and PPK mode for 10 minutes. Then we process the data in TBC (Trimble Business Centre). We put the known co-ordinate in Base Station co-ordinate then process the baseline accompanying others processing and print the map.

4. Results

Each procedure for static, PPK and RTK has its own advantages and short falls.

List 1 Time based comparision				
	1 HOUR OBSERVATION		30 MINUTES OBSERVATION	
POINT NAME	LATITUDE	LONGITUDE	LATITUDE	LONGITUDE
BASE	N20°10'30.57900"	E85°42'26.54327"	N20°10'30.44993"	E85°42'26.57772"
POINT1	N20°10'28.94265"	E85°42'26.53903"	N20°10'28.81324"	E85°42'26.57431"
POINT2	N20°10'28.92774"	E85°42'24.75236"	N20°10'28.81169"	E85°42'24.89789"
POINT3	N20°10'29.84439"	E85°42'25.38622"	N20°10'29.71527"	E85°42'25.42130"

List 2 Comparision Between STATIC, RTK & PPK		
STATIC		
POINT NAME	LATITUDE	LONGITUDE
BASE	N20°10'30.44993"	E85°42'26.57772"
POINT1	N20°10'28.81324"	E85°42'26.57431"
POINT2	N20°10'28.81169"	E85°42'24.89789"
POINT3	N20°10'29.71527"	E85°42'25.42130"
RTK		
POINT NAME	LATITUDE	LONGITUDE
BASE	N20°10'30.44546"	E85°42'26.57997"
POINT1	N20°10'28.81055"	E85°42'26.57578"
POINT2	N20°10'28.79340"	E85°42'24.78890"
POINT3	N20°10'29.71043"	E85°42'25.42411"
PPK		
POINT NAME	LATITUDE	LONGITUDE
BASE	N20°10'30.63007"	E85°42'26.53351"
POINT1	N20°10'28.99480"	E85°42'26.52866"
POINT2	N20°10'28.97888"	E85°42'24.74370"
POINT3	N20°10'29.89545"	E85°42'25.37753"

Results are for different methodologies has been verified for each processes and documented for their appropriate use. Selecting an observational procedure shall offer empirical accuracy. The observational results are in list 1 and list 2.

5. Discussion

The difference between the coordinates of those points is:

i. The coordinates of the Base station in one-hour observation are N20°10'30.57900" Lat. & E85°42'26.54327" Long. and in 30 minutes observation is N20°10'30.44993" Lat. & E85°42'26.57772" Long. The difference between the two latitudes is 00°00'00.12907" second and Longitude -00°00'00 .3445". The difference is very minimal.
ii. The coordinates of Point 1 in one-hour observation is N20°10'28.94265" Lat. & E85°42'26.53903" Long. And in 30 minutes observation is N20°10'28.81324" Lat. & E85°42'26.57431" Long. The difference between the two coordinates is
iii. The coordinates of Point2 in one-hour observation is N20°10'28.92774" Lat. & E85°42'24.75236" Long. And in 30 minutes observation is N20°10'28.81169" Lat. & E85°42'24.89789" Long. The difference between the two latitudes is 00°00'00.11605" second and Longitude -00°00'00.14553". The difference is very minimal.
iv. The coordinates of Point 3 in one-hour observation is N20°10'29.84439" Lat. & E85°42'25.38622" Long. And in 30 minutes observation is N20°10'29.71527" Lat. & E85°42'25.42130" Long. The difference between the two latitudes is 00°00'00.12912" second and Longitude -00°00'00.3508". The difference is very minimal.

The difference in the coordinates in latitude and longitude is minimal in fractions of a second which can be neglected.

The difference between the coordinates of these three points in STSTIC RTK & PPK mode are

a. The coordinates of a Base station in STATIC observation is N20°10'30.44993" Lat. & E85°42'26.57772" Long. In RTK observation is N20°10'30.44546" Lat. & E85°42'26.57997" Long. In PPK observation is N20°10'30.63007" Lat. & E85°42'26.53351". The difference is very minimal.
b. The coordinates of Point1 station in STATIC observation is N20°10'28.81324" Lat. & E85°42'26.57431" Long. In RTK observation is N20°10'28.81055" Lat. & E85°42'26.57578" Long. In PPK observation is N20°10'28.99480" Lat. & E85°42'26.52866". The difference is very minimal.
c. The coordinates of Point1 station in STATIC observation is N20°10'28.81169" Lat. & E85°42'24.89789" Long. In RTK observation is N20°10'28.79340" Lat. & E85°42'24.78890" Long. In PPK observation is N20°10'28.97888" Lat. & E85°42'24.74370". The difference is very minimal.
d. The coordinates of Point1 station in STATIC observation is N20°10'29.71527" Lat. & E85°42'25.42130" Long. In RTK observation is N20°10'29.71043" Lat. & E85°42'25.42411" Long. In PPK observation is N20°10'29.89545" Lat. & E85°42'25.37753". The difference is very minimal.

The comparison of DGNSS static survey coordinates with one-hour versus 30-minute observation times reveals minimal discrepancies. Latitude differences range from 0.116" to 0.129", while longitude differences span -0.146" to -0.353". This consistency suggests that reducing the observation time to 30 minutes may be viable in similar conditions without significant loss of accuracy. However, this depends on factors like satellite geometry, atmospheric conditions, equipment, and the desired accuracy. Further investigation is advised to confirm this finding for broader applicability. A shorter duration will save on field time and resources (Mc, Mohan et al 2021; Zhang et al. 2024).

Coordinate comparisons between Static, RTK, and PPK DGNSS methods reveal "very minimal" differences. While all provide reasonable consistency, the choice depends on project needs. Static offers the highest accuracy, RTK balances speed and precision, and PPK suits environments lacking real-time links. Variations reflect method-specific error characteristics and factors like atmospheric conditions. Project tolerances must guide method selection. Acknowledging these minimal differences remains crucial in ensuring appropriate application and data reliability. Analysis preprints highlighting the different problems and challenges allied with the GNSS receivers. It's appropriate to use and best combination to receive accurate and exact data (Diouf et al. 2024).

6. Conclusion

In summary, DGNSS observation time tests (30 vs. 60 minutes) showed minimal coordinate differences, suggesting reduced times may be viable. Comparing Static, RTK, and PPK methods also revealed "very minimal" differences, yet method selection depends on project needs. Static offers the highest accuracy, RTK balances speed and precision, and PPK is suited to environments lacking real-time communication links. Key factors influencing accuracy include atmospheric conditions, satellite geometry, and equipment. Acknowledging and understanding method-specific error characteristics remains crucial for reliable data.

In the DGNSS survey, more time can provide more accuracy in STATIC mode. And STATIC, RTK & PPK mode has different usages and different advantages. The results in the case of various methods of DGNSS Survey are:

- Static: Best for high-precision control over long distances and non-time-sensitive applications.
- PPK: Ideal for mobile mapping or UAV surveys where real-time corrections are not available.
- RTK: Best for real-time applications in the short-to-medium range, such as construction, Topo surveys, and precision farming.

Disclaimer (Artificial Intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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Competing Interests

Authors have declared that no competing interests exist.

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Risk-informed spatial planning of Shimla region

A Geospatial assessment of urban expansion suitability using multi-criteria framework

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Abstract

Rapid urbanization in fragile Himalayan ecosystems necessitates robust land-use planning that balances development needs with environmental conservation. This study utilizes a Multi-Criteria Decision Support (MCDS) system, implemented via the Weighted Linear Combination (WLC) method within the Google Earth Engine (GEE) cloud computing platform, to delineate and quantify optimal areas for urban expansion around the Shimla region, Himachal Pradesh, India. Five critical factors—Slope, Land Use/Land Cover (LULC), Aspect, Road Proximity, and Geology—were integrated after normalization, weighted based on the Analytical Hierarchy Process (AHP), and strictly constrained by exclusionary zones (including steep slopes (>45°), protected areas, and water body buffers). The analysis identifies distinct suitability zones (Low, Moderate, High), highlighting key areas for planned development and also estimates suitable areas around six proposed satellite towns nearby Shimla. The efficiency of GEE for handling multi-source, high-resolution datasets (NASADEM, ESRI LULC 10m) demonstrates a powerful, replicable, and cost-effective framework for sustainable planning in complex, mountainous environments, offering a critical tool for regional development authorities. However, it is emphasized that high-resolution LULC data, DEM datasets, and detailed geological information are essential to support any policy decision on identifying such zones.

1. Introduction

Global urban growth demands a critical shift from uncontrolled sprawl to sustainable, scientifically informed expansion. In challenging geographical areas, such as the Himalayan mountain range, this requirement is amplified due to inherent geo-environmental risks (landslides, seismic activity) and ecological fragility. As per the latest seismic zonation study of India, Himachal Pradesh falls largely within a very high seismic risk zone, indicating significant vulnerability to strong earthquakes. The Shimla region, a major administrative and tourist hub, faces severe pressure on its limited developable land, often leading to haphazard construction in unsafe and ecologically sensitive zones. This paper formalize this challenge by presenting a remote sensing-based geospatial modeling approach to map urban suitability. The chosen methodology integrates diverse physical factors using MCDS-WLC, offering an objective and quantitative basis for future land-use policy in the Shimla planning area.

2. Background

Shimla's planning perspective is deeply rooted in its colonial-era origin, where the town evolved along ridges and spurs due to steep topography. Early development followed a linear ridge-based pattern, with British planners prioritizing administrative functions, pedestrian movement, and climate-responsive architecture. Over time, Shimla's growth expanded increasingly into peripheral slopes, creating challenges related to infrastructure, land stability, and service delivery. Contemporary planning efforts now focus on sustainable hill-town development, resilience to seismic and slope hazards, and decongestion while preserving the unique heritage character of the city.

2.1 Rationale

Urban growth in the Himalayan region is driven by tourism, administrative concentration, and educational opportunities. However, conventional expansion patterns are unsustainable due to topographical limitations, geological fragility, and inadequate infrastructure resilience. Shimla, categorized under very high seismic risk zone making it particularly vulnerable to slope instability and seismic hazards.

The Town and Country Planning Department of Himachal Pradesh, under its Vision 2040 Framework, emphasizes geospatially guided land-use decisions. The National Mission on Himalayan Studies (NMHS) and National Clean Air Programme (NCAP) also advocate geospatial tools for integrating environmental sustainability into urban planning.

In this policy environment, Geospatial Suitability Analysis (GSA) emerges as a scientific foundation for implementing controlled expansion, zoning regulation, and hazard-sensitive construction.

2.2 Objectives of the Study

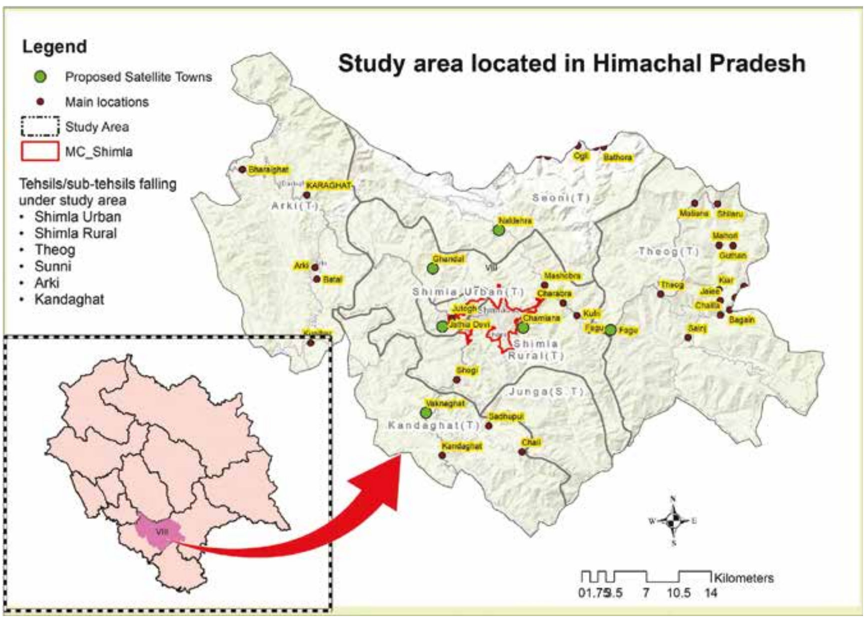
1. To delineate spatially suitable areas for future urban development in the Shimla region using a multi-criteria analytical framework.
2. To integrate geotechnical, ecological, and infrastructural factors through weighted modeling using Analytic Hierarchy Process (AHP)-derived weights.
3. To generate a high-resolution suitability map as a decision-support tool for planners and policymakers.

3. Study Area

The study area encompasses the Shimla planning region and its immediate periphery in Himachal Pradesh, India (approximate co-ordinates: 77.0°E to 77.3°E and 30.9°N to 31.3°N). This mountain region is characterized by rugged topography, steep slopes, and varied lithology belonging to the Lesser Himalayan tectonic belt.

3.1 Risk-Informed Urban Suitability Assessment for the Expansion

The Multi-Criteria Decision Support (MCDS) analysis using the Weighted Linear Combination (WLC) method serves as a proactive and strategic planning instrument tailored to the heightened vulnerability of the Shimla region. With increasing incidences of cloudbursts, erratic rainfall, landslides, and the region's location within a high-seismic zone, traditional urban expansion approaches have become inadequate. This study advances a risk-informed spatial planning framework that shifts the focus from mere land availability to long-term safety, geological stability, and environmental sustainability. It supports informed decision-making for future urban extensions, satellite towns, and counter-magnet towns in and around Shimla.



Map-1: Study area comprising tehsils Shimla Urban, Shimla Rural, Theog, Sunni, Arki and Kandaghat of Shimla and Solan districts

3.1.1. Core Objective: Disaster Risk Reduction (DRR) and Geological Stability

The central purpose of this assessment is to minimize exposure to landslide- and earthquake-prone areas, which have caused extensive damage across Himachal Pradesh.

- Geological Suitability:

The model assigns substantive weight to geological conditions, ranking land parcels based on rock strength and structural stability. This directs development away from weak, fractured, or weathered formations (e.g., Siwalik Group) and toward more competent lithologies (e.g., Granitoids/High-Grade Metamorphics) capable of withstanding intense rainfall and seismic forces.

- Landslide Risk Mitigation:

Recognizing slope as a primary driver, the model applies the highest weight to the slope factor and enforces a strict exclusion of areas with slopes >45°. This ensures that no infrastructure is placed in excessively steep or unstable zones, safeguarding human life and built assets.

3.1.2 Hydro-Climatic Resilience and Protection of Natural Water Systems

To respond to rising incidences of cloudbursts, flash floods, and extreme runoff events, which are now a day's regular occurrences, the study strengthens the natural hydrological system through targeted constraints.

- Protection of Rivers and Water Bodies:

A 50-meter buffer around all lakes, reservoirs, and rivers prevents encroachment onto floodplains and riparian zones. This preserves the natural absorptive and dissipative capacity of these systems during extreme rainfall, thereby enhancing resilience for both new and downstream settlements. Recent years have seen a rise in building/infrastructure collapses along riverbanks, especially in Kullu, Manali, and Rampur, during periods of extreme rainfall.

- LULC-Based Environmental Safeguards:

Dense forest areas (LULC = 10) are excluded to protect natural interception and infiltration processes that regulate surface runoff, recharge groundwater, and reduce flood severity. It is important to emphasize that the forests of Himachal Pradesh play a crucial role in safeguarding the environment and maintaining the integrity of the ecosystem.

3.1.3 Ecological Safeguards and Environmental Integrity

Sustainable Himalayan development necessitates the protection of ecologically sensitive zones and natural habitats, particularly in regions like Shimla where fragile slopes, dense forests, and limited carrying capacity demand careful planning. The city's unique topography, rich biodiversity, and dependence on natural drainage systems make the preservation of surrounding forested areas and ecological buffers essential for reducing disaster risks, maintaining water security, and ensuring long-term environmental stability.

- Exclusion of Protected and Reserve Areas:

Wildlife sanctuaries, protected areas, and reserve forests are treated as strict "no-development zones," reinforced with a 10-meter protective buffer. This ensures urban growth is confined to ecologically permissible regions while fulfilling legal and biodiversity conservation mandates.

- Geomorphological and Geotechnical Prioritization:

The integration of factors such as aspect (e.g., prioritizing sun-facing slopes for energy efficiency and improved snow clearance) alongside detailed geological parameters ensures that only well-assessed, environmentally compatible sites are identified for development.

3.2 Socio-economic perspective: Decongesting Shimla

Shimla city has exceeded its carrying capacity due to tourism and administrative growth. The identification of suitable satellite towns and decentralised development is central to reducing environmental stress in the urban core. Keeping above in mind, consecutive State Governments proposed six potential satellite town locations namely Jathia Devi, Ghandal, Naldehra, Fagu, Kufri, and Shoghi. These are evaluated to provide policy-relevant recommendations for managed expansion.

4.1 Key Satellite Town Initiatives

1. **Jathia Devi Township (near Shimla):** The main objective to establish a planned, modern city (sometimes likened to a smaller version of Chandigarh) about 14 km from Shimla to alleviate pressure on the capital. The plan is to relocate various government offices, create planned housing societies, and provide comprehensive infrastructure like hospitals, schools, and commercial zones. It has been notified as a Planning Area and is currently in the development phase, with the government exploring funding through the Union Ministry of Housing and Urban Affairs and a Public-Private Partnership (PPP) model.
2. **The Shimla Development Plan (SDP)** has also proposed the development of multiple other satellite towns/counter-magnet towns to decentralize development. These proposed locations include:
   - Ghandal
   - Naldehra
   - Fagu
   - Chamiyana
   - Vaknaghat (proposed as a "Cyber City" to attract IT-related activity).

4. Detailed Methodology

4.1 Theoretical Framework: MCDS and WLC

Multi-Criteria Decision Support (MCDS), particularly the Weighted Linear Combination (WLC) technique, is the standard methodology for continuous suitability mapping in Geographic Information Systems (GIS). WLC operates on the principle that the final suitability score (S) for a location is the weighted sum of normalized scores for each influencing factor (Fi), applied only to non-constrained areas.

Equation 1:

$$S = (\Sigma\, wi * Fi) * \Pi\, Cj$$

Where:
S: Final suitability score (0–1)
wi: Weight of factor i (Σ wi = 1)
Fi: Normalized factor score (0–1)
Cj: Binary constraint j (0 = excluded, 1 = allowed)

4.2 Role of Google Earth Engine (GEE)

Google Earth Engine (GEE) provides a cloud-native environment for processing petabytes of geospatial data. For this regional study, GEE permitted efficient handling of high-resolution DEMs and the ESRI Global LULC 10m product, reducing processing time and enabling reproducible workflows. Other open source GIS desktop application like QGIS has also been utilized.

5. Study Parameters and Their Role in Urban Suitability

The study incorporates six distinct

geospatial parameters to build a robust model for urban expansion suitability in the complex terrain near Shimla. These factors translate environmental and infrastructural realities into quantifiable scores. Elevation provides the fundamental topographic context, although its ruggedness is often captured by slope and aspect. Slope is the most critical factor, as it directly dictates geotechnical safety; areas with Slope} > 45^0 are strictly excluded (0.0), while flat land 15^0 receives the highest score (1.0).

Aspect is incorporated for micro-climatic preference, quietly favouring sunny, south-facing slopes (1.0) over colder, north-facing slopes. The Geological Factor adds a layer of stability analysis by ranking rock groups based on their strength, giving strong formations high scores and weak groups low scores.

Environmental protection is ensured by designating sensitive land uses (like wildlife sanctuaries) and dense forest cover as strict exclusionary constraints 0.0 score. This policy is reinforced by the 0.0 score assigned to specific categories within LULC selection, prioritizing development on open or bare land (1.0). Distance from water bodies is also treated as a strict constraint by enforcing a buffer 50m where development is completely disallowed to protect riparian ecosystems and prevent flood/landslide risks. Finally, nearness to roads acts as a powerful accessibility driver, where land closest to existing infrastructure 500m receives the highest suitability scores, ensuring planned expansion is efficient and cost-effective. These standardized scores, weighted by their importance (e.g., Slope: 0.30, LULC: 0.25), are combined via the WLC method to produce the final, objective suitability map.

Table 1. Geospatial data sources

Factor	Data Source (GEE Asset / Custom)	Resolution	Constraint/Exclusion
Elevation / Slope / Aspect	NASA / NASADEM_HGT/001	-30 m	Slope > 45° excluded
LULC	ESRI Global LULC 10m	10 m	Water, Tree Cover, Built areas flagged
Protected Areas	Custom vector asset	Digitized from local resources	PA + 10 m buffer excluded
Water Bodies	Custom vector asset	Digitized from local resources	WB + 50 m buffer excluded
Road Proximity	Custom roads vector	Digitized from local resources	Factor only
Geology	Custom geology vector	Digitized from local resources	Factor only

Table 2. Factor Weights (AHP)

Factor	Weight (Wi)
Slope	0.30
LULC	0.25
Geology	0.20
Road Proximity	0.15
Aspect	0.10

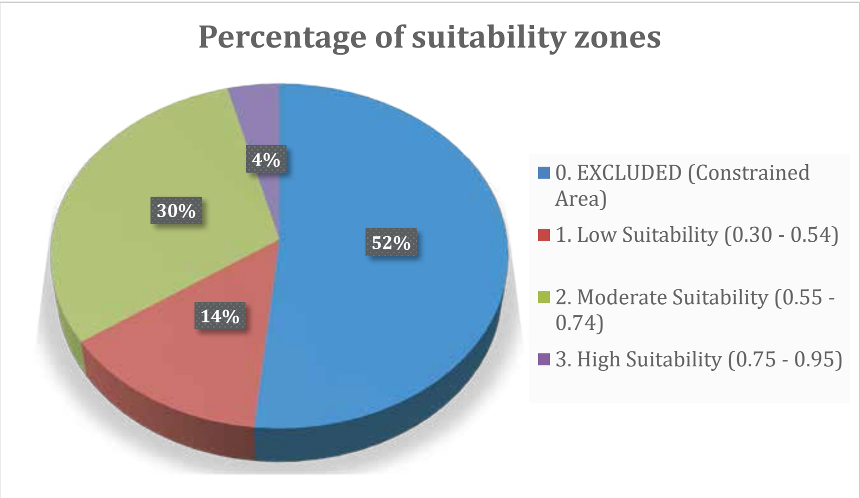


Table 3 Suitability Zones and Area Distribution

Class ID	Suitability Zone (Score Range)	Interpretation
3	High (0.75–0.95)	Optimal land for planned expansion
2	Moderate (0.55–0.74)	Developable with mitigation measures
1	Low (0.30–0.54)	Restricted development; higher environmental risks
0	Excluded (0.0)	Protected or high hazard areas

6. Data Sources and Constraints

Data sources and constraints used in the analysis are summarized in table 1:

7. Factor Standardization (0–1 Score) and Justifications

Each non-constrained factor was standardized to a 0 to 1 suitability scale based on planning guidelines for mountainous areas. Slope received the highest weight due to safety considerations; LULC prioritized non-sensitive land; geology scored lithologies by stability; road proximity captured accessibility; aspect favored south-facing slopes for micro-climate advantages.

8. Weight Determination (AHP)

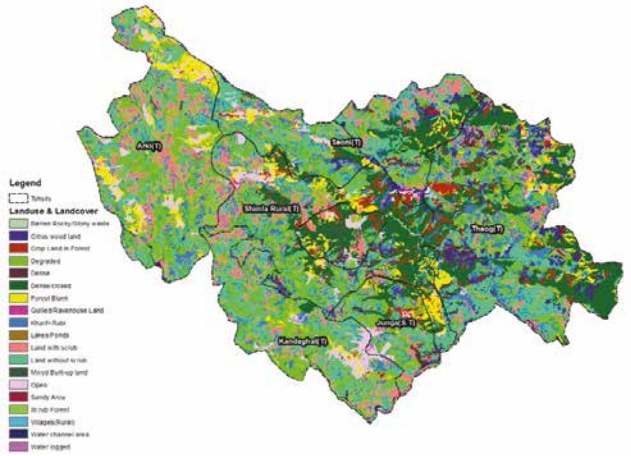
Weights were derived from a presumed AHP consultation reflecting priorities: slope (0.30), LULC (0.25), geology (0.20), road proximity (0.15), aspect (0.10). A pairwise comparison and consistency ratio check are recommended for participatory weighting in operational settings.

9. Suitability Calculation

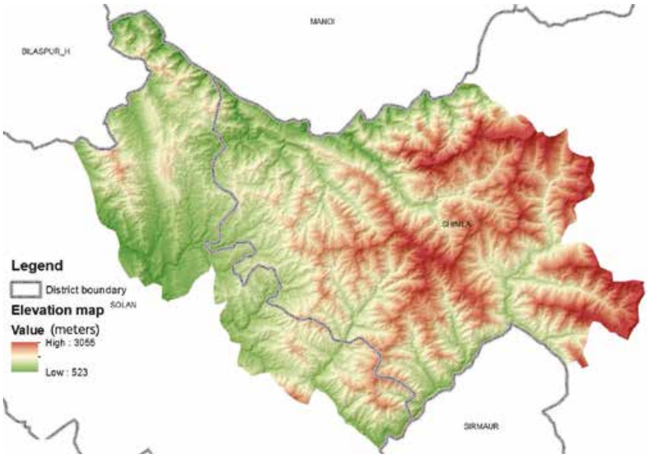
The final suitability was computed using the WLC formula applied in GEE:

Suitability = (0.30 × F_slope) + (0.25 × F_LULC) + (0.20 × F_geology) + (0.15 × F_roads) + (0.10 × F_aspect)

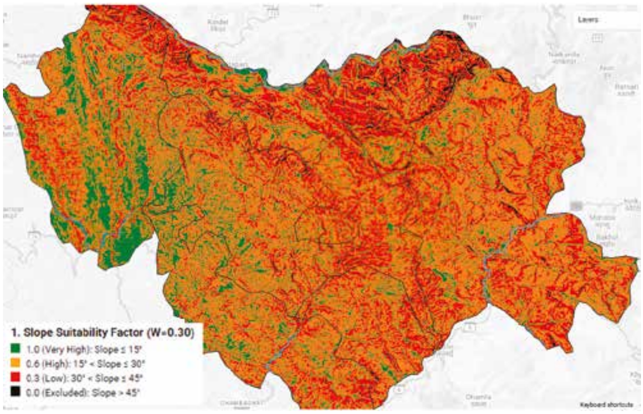
The resulting raster was then masked by the Final_Constraints layer, so excluded areas receive a score of 0.



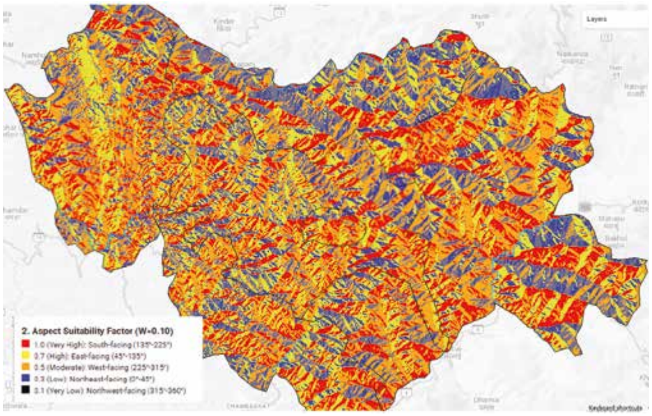
Map-2 Land Use and Land Cover



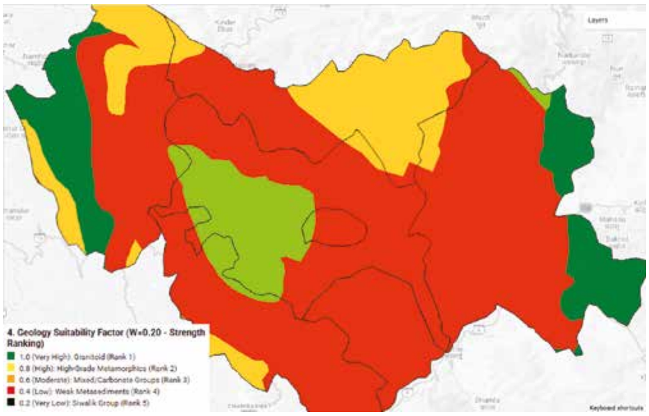
Map-3 Elevation in meters



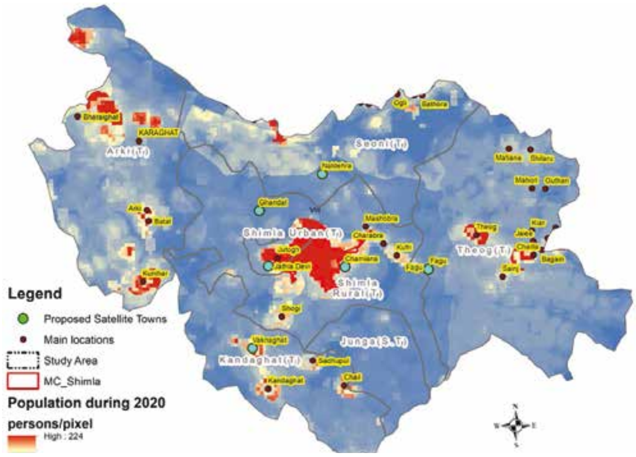
Map-4 Slope of study area



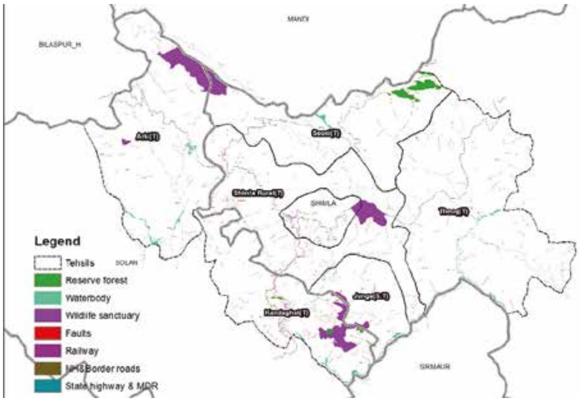
Map-5 Aspect of Study area



Map-6 Geological formation

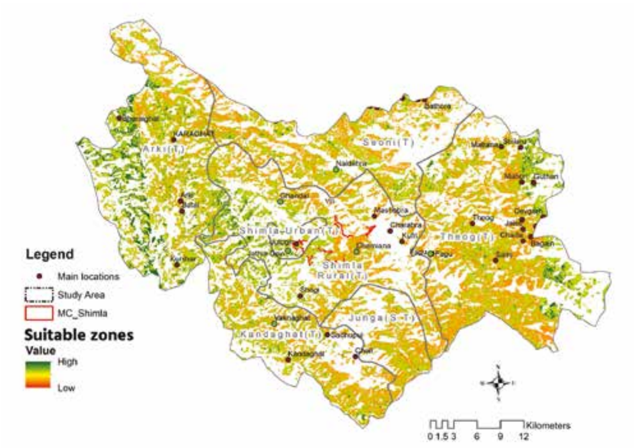


Map-7 Number of population concentrated 100m*100m area during the year 2020 & proposed satellite towns



Map-8 Protected area network

Map-9 All constraind areas



Map-10 Final Suitability Map of study area

10. Results

The WLC model produced continuous suitability scores ranging from 0.30 (lowest non-excluded) to ~0.95 (highest). Areas with score 0 are excluded by constraints in table 3.

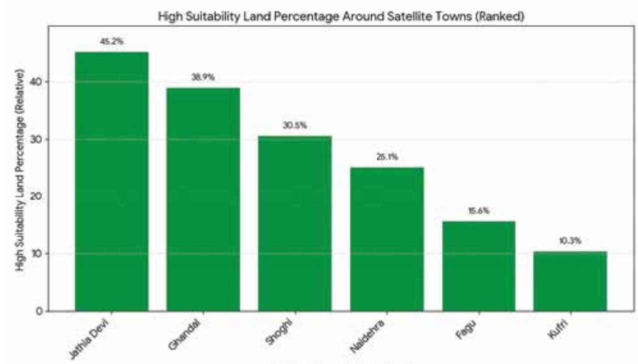
10.1 Constraint Analysis

Constrained zones are areas that are completely excluded from development or suitability analysis due to safety, environmental, or regulatory limitations. These zones typically include steep slopes, water bodies and their buffers, dense forests, wildlife sanctuaries, and other ecologically sensitive or hazard-prone regions. Any land falling under these categories is treated as a no-development area to prevent environmental damage, reduce disaster risk, and ensure sustainable planning. By identifying constrained zones early, planners can focus only on land that is truly safe and suitable for future growth.

10.2 Satellite Town Suitability Assessment

High suitability percentage (Class 3: 0.75–0.95) within 10 km buffers around six towns:

Town Name	High Suitability Percent (Relative)	Rank
Jathia Devi	45.2%	1
Ghandal	38.9%	2
Shoghi	30.5%	3
Naldehra	25.1%	4
Fagu	15.6%	5
Kufri	10.3%	6



This ranking suggests that areas targeted for satellite town development, like Jathia Devi and Ghandal (which are in slightly gentler terrain often mentioned for expansion), possess a higher proportion of highly suitable land within their 10km buffer compared to areas like Kufri and Fagu, which are generally at higher altitudes with more environmental constraints (steeper slopes, protected areas, etc.)

11. Discussion and Conclusion

This study demonstrates that an MCDS-WLC framework implemented within GEE can efficiently produce high-resolution suitability maps for complex mountainous regions. The methodology supports planners by identifying safer, accessible, and less ecologically sensitive areas for satellite town development. However, integration of socio-economic datasets and participatory weighting would strengthen decision legitimacy.

6.1 Scope and Future Work

Future research should integrate socio-economic parameters such as utilities, land markets, and population distribution, along with dynamic climate-vulnerability indicators. Validation using machine-learning techniques, including Random Forests, would further strengthen the reliability of the analysis. However, it is emphasized that high-resolution LULC data, DEM datasets, and detailed geological information remain essential prerequisites for supporting any policy decisions related to the identification of such zones.

12. Policy Directions

The findings support evidence-based zoning and hazard-resilient urban planning aligned with Himachal Pradesh's Vision 2040.

Future Enhancements:
1. Integrate landslide susceptibility and seismic risk layers.
2. Include socio-economic parameters like land cost and livelihood access.
3. Conduct structured AHP validation surveys.
4. Extend to temporal simulations for future land use projections.

12.1 Constraints of the Study

Key limitations include the static AHP weights (not participatory), generalized geology maps that may miss micro-scale hazards, and the potential for scale artifacts due to raster aggregation.

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China launches Yaogan satellite

China conducted a pair of launches sending a second Yaogan-50 satellite into a highly retrograde orbit and completing a Kuaizhou-11 solid rocket rideshare mission. A Long March 6A rocket lifted off at 8:22 a.m. Eastern (1322 UTC) March 15 from Taiyuan Satellite Launch Center in north China. The China Aerospace Science and Technology Corporation (CASC) announced launch successful. *spacenews.com*

TelePIX wins Hungary satellite camera deal

TelePIX has signed a contract to supply a high-resolution electro-optical (EO) camera system to the Hungarian government's national Earth observation satellite program "HULEO (Hungarian Low Earth Orbit).". The HULEO program is aim to secure independent satellite capabilities operating in low Earth orbit (LEO). Core processes such as design, integration, and testing of the satellite system will be carried out in Hungary, and some advanced technologies will be introduced through international cooperation. *https://biz.chosun.com*

UK space agency contract to GMV

GMV has been awarded a contract by the UK Space Agency (UKSA) to develop advanced algorithmic capabilities for space launch monitoring, supporting the analytical requirements of the UK National Space Operations Centre (NSpOC). The activity focuses on the development and demonstration of data processing algorithms designed to detect, identify, and characterise space launch events using heterogeneous observational data sources. The work contributes to the continual enhancement of the UK's Space Domain Awareness (SDA) capability, enabling more timely detection of catalogue changes and improved understanding of launch related activity.

RS7 Handheld SLAM Scanner launch

CHC Navigation announced the RS7, a new handheld SLAM (simultaneous localization and mapping) scanning solution. Built for BIM documentation, indoor surveying, renovation planning and complex spatial analysis, it is designed to help professionals capture high density 3D data efficiently and convert it into practical deliverables through CHCNAV's software and cloud ecosystem. *chcnav.com*

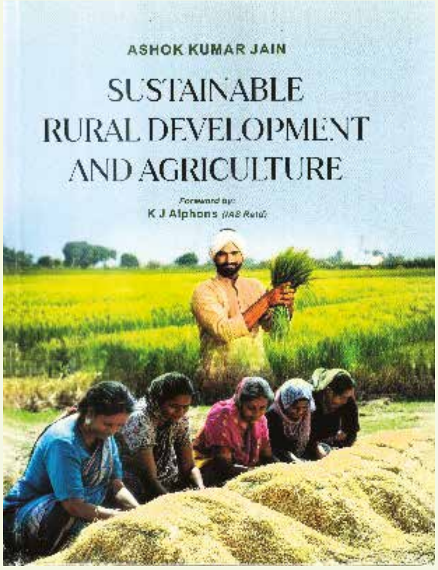
Vietnam opens space center with Japan's support

Vietnam officially inaugurated the Vietnam National Space Center (VNSC) on March 13 with the participation of Prime Minister Pham Minh Chinh. The project was developed with official development assistance (ODA) from Japan, highlighting the growing technological cooperation between the two countries. The main objective of the Vietnam National Space Center is to establish the infrastructure needed for technology transfer related to Earth observation satellites while simultaneously building a strong domestic workforce in space science and engineering. The center will also play an important role in improving Vietnam's capabilities in disaster monitoring, climate change response, natural resource management, and environmental observation.

During the opening ceremony, the Prime Minister called for the launch of the LOTUSat1 satellite by late 2027. The 600-kilogram Earth observation satellite was jointly developed by Vietnam and Japan and was initially scheduled for launch in 2025. However, the mission was delayed following issues with the EpsilonS rocket developed by the Japan Aerospace Exploration Agency. *www.azernews.az*

Sustainable Rural Development and Agriculture

Ashok Kumar Jain
Discovery Publishing House, New Delhi (2026)
P-304, ISBN 978-93-6224-221-1, Rs 4000/-



The book **'Sustainable Rural Development and Agriculture'** by Ashok Kumar Jain highlights the role of rural development and agriculture in making Viksit Bharat The agriculture sector in India contributes about 17.4% of GDP and engages 55% of India's workforce. On the other hand, urban sector contributes the GDP about 4 times the rural, while engaging half of the rural population. This indicates the dichotomy of rural and urban incomes, which needs to be addressed in the plans of Viksit Bharat by the year 2047.

The book 'Sustainable Rural Development and Agriculture' in its 11 chapters covers a wide canvas, viz. Challenges of Rural Development, Sustainable and Climate Resilient Agriculture, Spatial Surveys, Mapping and Analytics. Rural Development Planning and Infrastructure, Rural Housing, Sustainable Energy, Sustainable Water Management, Biodiversity, Landscape and Urban Farming, Environmental Services, Conservation of Rural Heritage, and Disaster Resilience. These have been explained in a simple language. The pragmatic examples provide reference points for understanding the nuts and bolts of the sustainable rural development and climate resilient agriculture.

The author emphasises that it is time to focus upon climate resilient and precision agriculture, together with adoption of new technologies for weather forecast, efficient water and fertiliser use. The optimisation strategies should focus not only on crop production and quality, but also reduce the inputs, labour, time and resources, and climate and disaster management by leveraging new technologies such as GIS, GPS mapping, digital twins, satellite/drone imagery and artificial intelligence. Digital technology and AI are changing the planning and management from a reporting function into a foresighting function for predictive decisions and focus on outcome rather than administration. Having worked as an Eminent Citizen with the Ministry of Rural Development, the author in his book provides a synthesis of academic knowledge and practical experience.

According to A.K. Jain, the author, the rural-urban gap is not only in incomes, but also in education, healthcare, sanitation, infrastructure services, roads, transport, water, energy and technology. On an average rural women spend 5 hours in a day for cooking and suffer from respiratory, lung and other ailments due to smoke, reflecting environmental and gender injustice. This necessitates a deep concern and paradigm shift towards rural development, governance and financing.

The Central Government has launched several flagship schemes of rural development and agriculture, such as Viksit Bharat -GRAM-G (that had recently replaced the MGNREGA), Jan Jeevan Mission, PM Awas Yojana, Livelihood Mission, Poshan, Ayushman Bharat, SBM-Rural, Watershed Programme, Solar Power, Fisheries, Lakhpati Didi, Telecom Infrastructure, Gram Swaraj, Agro-Infra Fund, Handloom Development, Shyama Prasad Mukherjee Rurban

Mission, Svamitra, and Adi-Adarsh Gram Yojana. Under the Pradhan Mantri Awas Yojana (Gramin) under which 20.5 million houses are being built. The author emphasises the need to establish linkages between rural and urban development, and between sustainability and conservation for which invoking new technologies.

As summed up by K.J. Alphons in his Foreword, *'Ashok Kumar Jain's book juxtaposes the phenomenon and positionality of evidence, economy and ecology. It weaves commonalities strand by strand in what emerges as a rich array of interconnected themes under one cover. The author has integrated the diverse issues of rural development and agriculture comprehensively, concisely and clearly. The text has been lavishly illustrated that lightens its denseness and makes the reading easier and interesting'.*

Bachelor's-level geospatial intelligence programme by NUS

The National University of Singapore (NUS) will offer a new major in geospatial intelligence that will train students to harness geospatial data and emerging technologies such as artificial intelligence (AI). NUS' new Bachelor of Science (Honours) in Geospatial Intelligence Cross-Disciplinary Programme (GIX), the first bachelor's degree of its kind in Asia, meets this demand and builds a talent pipeline in geospatial intelligence.

The four-year programme is offered by the College of Humanities and Sciences (CHS), led by the Department of Geography at the Faculty of Arts and Social Sciences, in collaboration with the School of Computing (SOC), which contributes expertise in AI, data science and computational methods. The joint programme leverages world-leading expertise from the Department of Geography and SOC, which are both ranked No.1 in Asia for their respective subjects and in the top ten globally, and the strategic positioning of NUS in Singapore where high-density land utilisations present unique sets of geospatial challenges. *asmmag.com*

Woolpert and Saildrone partnership

Woolpert and Saildrone have partnered to acquire and process bathymetric survey data for the National Oceanic and Atmospheric Administration's Ocean Exploration and Office of Coast Survey in support of safe navigation and national ocean mapping initiatives, including the National Strategy for Mapping, Exploring, and Characterizing the United States Exclusive Economic Zone and Seabed 2030 initiative.

The Mariana Islands' strategic location and vast marine ecosystems make it a critical region for monitoring and analysis. The data will be used by NOAA to help enhance its understanding of sensitive habitats, marine geohazards, oceanographic conditions, seafloor composition, and ecosystem management within the U.S. exclusive economic zone in the vicinity of the Mariana Islands. It will also help expand taxonomic reference libraries for understudied marine organisms. *woolpert.com*

International Standard sets new foundation for interoperability

A new industry standard, ISO/TS 15143-4, is poised to streamline how construction project data moves from the office to the jobsite, addressing long-standing challenges around interoperability, efficiency, and collaboration. Known as "Part 4: Worksite topographical data" of the ISO 15143 series of standards, the framework represents a significant step forward in aligning technology across equipment, contractors, and project partners, all while laying the groundwork for future innovation.

At its core, Part 4 is designed to enable primary workflow efficiency by supporting seamless data flow from office-based teams to field operations, even if the solutions are from different providers. The current iteration of the standard focuses on transferring critical design and project information—such as design files and site calibration details — to machines on the jobsite. By improving the speed and reliability of this office-to-field exchange, the standard helps ensure crews have accurate, up-to-date information when and where they need it. *www.iso.org*

Seekr launches geospatial reasoning engine

Seekr has announced the launch of the geospatial reasoning engine, including a comprehensive licensing agreement with Wyvern, as the inaugural data partner in hyperspectral imaging. This alliance accelerates enterprise access to scalable, high-resolution hyperspectral imaging powered by AI-driven analysis that can reason, detect changes over time, and identify meaningful patterns in activity for both national security and commercial use cases including wildland fire management, supply chain intelligence, and countless other actionable VLM-based insights. *www.seekr.com*

Navigation with Indian Constellation is down!

India's indigenous satellite navigation system, Navigation with Indian Constellation (NavIC), is facing scrutiny after reports that an atomic clock onboard one of its satellites has stopped functioning, raising concerns about the reliability of the country's homegrown positioning network.

"IRNSS-1F satellite, launched in March 2016, has completed its design mission life of 10 years on March 10, 2026. On March 13 2026, the onboard Atomic clock stopped functioning. However, the satellite will continue to function in orbit for various societal applications to provide one-way broadcast messaging services," Isro said in a statement. *www.indiatoday.in*

Efforts to detect attacks on navigation signals

BEACONSAT is the largest satellite ever developed in Austria and also the country's first military satellite. The project is being led by the Lower Austrian start-up GATE Space, based in Schwechat. The launch is planned for February 2027 aboard a SpaceX Falcon 9 rocket.

BEACONSAT is designed to detect and analyze jamming and spoofing attacks on GNSS. This refers to targeted attempts to interfere with and manipulate navigation signals such as GPS or Galileo. Austria is thus responding to a security policy development that is no longer abstract, but has real implications for aviation, transport, energy supply, and military operations.

Satellite-based navigation is a key technology today. If the signal fails or is manipulated, system-critical processes are disrupted. Jamming creates interference by superimposing and blocking navigation signals. Spoofing involves feeding in false position data so that receivers calculate a manipulated position. Such incidents are particularly frequent in geopolitically tense regions. In aviation, repeated disruptions have been recorded in the recent past, which have also affected civilian aircraft. *www.bmimi.gv.at*

ESA's HydroGNSS on track to scout for water

Just three months after launch, the European Space Agency's twin HydroGNSS satellites are already proving their capabilities in orbit. By exploiting reflected signals from navigation satellites – the sophisticated technique they use to generate Delay Doppler Maps in order to 'scout' for water across Earth's surface – these compact satellites are beginning to reveal the scientific potential they were built to unlock, even while still in their commissioning phase.

ESA's first Scout mission has been developed under the Earth Observation FutureEO programme. At its heart lies an innovative method known as GNSS reflectometry. Navigation satellites such as GPS and Galileo continuously transmit L-band microwave signals that subtly change after reflecting off Earth's surface. HydroGNSS compares these reflected signals with the direct GNSS signals to extract valuable information on geophysical parameters linked to the water cycle.

Key to this process involves producing Delay Doppler Maps, which show how a GNSS signal changes after bouncing off Earth's surface. One axis represents delay (how long the signal takes to return), and the other shows Doppler frequency (how motion affects the signal).

When the signal reflects off a smooth, mirror-like surface – such as calm water or flat sea ice – it produces a strong, sharp peak. But over a rough ocean, the reflection spreads out into a weaker, curved 'horseshoe' shape. A helpful comparison is sunlight reflecting off the sea when viewed from an airplane: a perfectly smooth surface gives a bright point, while waves stretch the reflection into a wide glistening area. The strength and shape of this reflection depends on surface conditions. Roughness matters, but so do factors like soil moisture, whether the ground is frozen, and the presence of vegetation. *www.esa.int*

Spire GNSS-Reflectometry data enables Arctic-wide sea ice mapping

New research supported by the European Space Agency's (ESA) Third Party Missions programme has generated Arctic-wide sea ice freeboard maps using GNSS-Reflectometry (GNSS-R) data captured by Spire Global, Inc.'s GNSS-Reflectometry (GNSS-R) multipurpose listening constellation.

Led by the Technical University of Munich (DGFI-TUM) and the Norwegian Research Centre, the study leveraged Spire's grazing-angle GNSS-Reflectometry (GNSS-R) — a radio frequency (RF) sensing technique that analyzes reflected navigation signals — to retrieve sea ice freeboard measurements across an entire winter season. The results show strong alignment with established altimetry datasets, including ESA's CryoSat mission, validating the complementary role of commercial satellite data alongside government missions. While GNSS signals have long been used for positioning, this research highlights how reflected signal analysis can extend their value into large-scale Earth observation applications, delivering persistent coverage independent of sunlight or weather conditions. *spire.com*

Dubai Municipality joins International GNSS Services

Dubai Municipality has officially joined the International GNSS Services (IGS), marking a significant step in strengthening its geospatial infrastructure. The move aligns with the city's commitment to enhancing urban development and infrastructure planning through cutting-edge technology and precision mapping. *focus.hidubai.com*

NASA's Perseverance autonomously pinpoints its location on Mars

A new technology developed at NASA's Jet Propulsion Laboratory in Southern California enablesPerseverance to figure out its whereabouts without calling humans for help. Dubbed Mars Global Localization, the technology features an algorithm that rapidly compares panoramic images from the rover's navigation cameras with onboard orbital terrain maps. Running on a powerful processor that Perseverance originally used to communicate with the Ingenuity Mars Helicopter, the algorithm takes about two minutes to pinpoint the rover's location within some 10 inches (25 centimeters). Mars Global Localization was first used successfully in regular mission operations on Feb. 2, then again Feb. 16.

The upgrade is especially valuable given how well Perseverance's auto-navigation self-driving system has been working. Enabling the rover to re-plan its path around obstacles en route to a preestablished destination, AutoNav has proved so capable that the distance Perseverance can drive without instructions from Earth is largely limited by the rover's uncertainty about its whereabouts. Now that it can stop and determine its exact location, Perseverance can be commanded to drive to potentially unlimited distances without calling home. *www.nasa.gov*

NVIDIA launches space computing

NVIDIA Space-1 Vera Rubin Module is the latest part of the NVIDIA accelerated platform for space. Compared with the NVIDIA H100 GPU, the Rubin GPU on the module delivers up to 25x more AI compute for space-based inferencing, enabling next-generation compute for ODCs, advanced geospatial intelligence processing and autonomous space operations.

The NVIDIA IGX Thor™ and NVIDIA Jetson Orin™ platforms deliver energy-efficient, high-performance AI inference, image sensing and accelerated data processing to enable true edge computing on orbit in a compact module. NVIDIA data center platforms, including the NVIDIA RTX PRO™ 6000 Blackwell Server Edition GPU, deliver high-throughput, on-demand ground processing for geospatial intelligence.

GNSS protection system by InfiniDome

InfiniDome is set to debut its Aura GNSS protection system. It supports two to four antennas and protects two GNSS frequency bands while passing two additional bands. The system can generate up to three nulls per protected band, allowing it to suppress multiple interference sources at once. The product is offered in two configurations: an enclosed version weighing 500 grams and an OEM version at 375 grams, the latter designed for integration into platforms where size and weight are constraints.

Real-world PNT testing by SimXTRACT

Spirent Communications, now part of Keysight Technologies, has launched SimXTRACT, a GNSS test tool that bridges the gap between field and laboratory. It enables signals captured in field environments to be comprehensively decomposed into individual, discrete signals and applied to lab simulation for realism at every stage of the development test cycle. The introduction of SimXTRACT brings the advantages of both field and lab test methods together by taking real signals captured in field environments and accurately breaking them apart to create realistic simulator drive data for use in Spirent simulators. *www.spirent.com*

Oscilloquartz, Tupaia validate centimeter-level GNSS positioning

Oscilloquartz has entered a joint technology validation with Tupaia, demonstrating how mobile operators and enterprises can achieve high-accuracy GPS positioning using existing timing infrastructure. The validation, conducted through a real-world drive test across mixed highway and semi-urban environments, confirms that Oscilloquartz grandmasters can integrate with Tupaia's cloud services to enable advanced positioning without dedicated, standalone reference-station networks — reducing deployment complexity and cost. *www.tupaia-pos.com*

Viavi launches ePRTC360+ clock alternative

Viavi Solutions Inc. has launched the patent-pending Cesium-less ePRTC360+ holdover solution to safeguard at-risk critical power grids, transportation, aviation and public safety systems, 5G mobile networks and AI data center infrastructure against the increased threat of GNSS timing disruptions. It is the only alternative to Cesium clocks to meet ITU-T G.8272.1 standards. *www.viavisolutions.com*

u-blox introduces the F11 platform

u-blox has launched the u-blox F11 platform. The new L1/L5 dual-band standard-precision GNSS platform is designed to improve positioning accuracy while reducing power consumption to as low as 7 mW in typical configurations using Low Energy Accurate Positioning (LEAP) mode for tracking and wearable applications. The platform enables device manufacturers to achieve longer battery life, faster and more reliable position fixes, and greater design flexibility. *www.u-blox.com*

Advanced Navigation launches of Chimera Land

Advanced Navigation has launched Chimera Land. A new class of navigation, the 3D Laser Velocity Sensor is specifically designed to solve the primary challenge for underground mining: maintaining precise vehicle positioning in deep, dark, and unmapped environments where GPS cannot reach.

When fused with an Advanced Navigation inertial navigation system, Chimera Land allows underground vehicles to maintain stable navigation over extended distances and time. Instead of needing to "ask" an external beacon or satellite for its location, the sensor uses specialized lasers to measure a vehicle's ground-relative 3D velocity, with unprecedented accuracy. By feeding this precise data into the vehicle's inertial navigation system (INS), the sensor eliminates the inherent "drift" that typically comes with standalone INS. *www.advancednavigation.com*

Iridium launches next-generation IoT platform

Iridium Communications Inc. has unveiled the Iridium 9604, a compact, three-in-one IoT module that integrates Iridium Short Burst Data® (SBD®) satellite service, LTE-M cellular connectivity, and GNSS positioning into a single platform. It reduces solution complexity, lowers costs, and accelerates time to market, making dual-mode IoT connectivity viable for price-sensitive, high-volume deployments. The Iridium 9604 beta program — launched earlier this year and oversubscribed by a select group of companies — has generated positive industry feedback. *www.iridium.com*

Telit Cinterion expands next-generation GNSS portfolio

Telit Cinterion has announced an expansion of its next-generation GNSS portfolio by adding two new dual-band positioning modules: the ultracompact SE873K5-D and the high-end SE869eK5-DRK. Built on the latest AG3335 chipset series from long-time partner Airoha, the new modules advance Telit Cinterion's GNSS roadmap. They support space- and power-constrained IoT devices and use cases that require continuous, ultraprecise positioning. *www.telit.com*

Snapdragon Wear Elite platform by Qualcomm

Wear Elite is a personal AI platform designed to unlock the next generation of truly personal, always-on, intelligent wearable computing devices. It works across WearOS by Google, Android and Linux with a neural processing unit (NPU) for on-device AI and advanced suite of ultra-low power connectivity solutions. It introduces a multimode connectivity architecture integrating six advanced technologies: GNSS, 5G RedCap, MicroPower WiFi, Bluetooth 6.0, UWB and NBNTN. The company's GNSS solution enables advanced processing for precise location context that helps AI better understand where users are and adapt interactions accordingly. *www.qualcomm.com*

Hemisphere GNSS and Calian unveil new high-precision antenna

Hemisphere GNSS, a brand of CNH, together with Calian Group Ltd, have released the A65 GNSS antenna, a jointly developed, next-generation solution engineered to deliver exceptional accuracy, superior interference protection, and robust GNSS tracking performance. It is designed as a drop-in replacement for the widely deployed A45 antenna, offering users a seamless upgrade path to the latest precision technology. *www.hemispheregnss.com*

ANELLO Photonics and Mythos AI collaboration

ANELLO Photonics announced a strategic collaboration with Mythos AI to accelerate the deployment of resilient, plug-and-play navigation solutions for the maritime sector. The collaboration brings together ANELLO's advanced inertial sensing technology and Mythos AI's intelligent autonomy software to address the growing need for resilient navigation in GPS-challenged environments. By combining ANELLO's SiPhOG™-based inertial navigation with advanced sensor fusion and AI-driven collaborative autonomy, the companies are establishing a new benchmark for GPS-independent performance, without increasing integration complexity. *www.anellophotonics.com*

TopStar Galileo OS and PRS core modules

Thales has developed TopStar Galileo core modules in two standardzed, easy-to-integrate versions. The small-form-factor Galileo OS (Open Service) or PRS (Public Regulated Service) sensors are designed to enhanced GNSS receivers and resilient multi-sensor navigation systems, ensuring safer and more reliable satellite-based navigation.

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https://conferences.igrsm.org

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www.ion.org

The Galileo PRS core module integrates a certified, single-chip, application-specific integrated circuit (ASIC) security module that incorporates all the necessary Galileo PRS security and navigation functions. It provides dual-frequency (E1/E6) iono-free Galileo PRS positioning, velocity and timing services. It also provides pseudorange and delta pseudorange raw data, along with GPS C/A (coarse acquisition). *www.thalesgroup.com*

SparkFun announces quad-band GNSS rover

SparkPNT TX2 is a quad-band GNSS rover that combines an IP67-rated aluminum enclosure with support for Galileo's High Accuracy Service (HAS) and standard RTK correction workflows. The receiver is built around the Quectel LG290P quad-band GNSS engine and supports multi-constellation tracking. Galileo HAS support provides sub-20 cm accuracy globally without subscription-based correction services, while RTK workflows via NTRIP or u-blox PointPerfect can achieve centimeter-level positioning.

Digital Mapping Group unveils mapping app FastXY

Digital Mapping Group has released FastXY, a powerhouse mapping application for iOS and Android. It is designed to transform standard mobile devices into professional-grade data-collection tools for GIS and architecture, engineering and construction (AEC) professionals. *http://gps-mapping.com*

Honeywell launches HGuide i700 IMU

Honeywell has launched the HGuide i700, an inertial measurement unit (IMU) that delivers high-accuracy performance for unmanned air, land and sea vehicles. By pairing near navigation-grade capability with a no-license-required (NLR) classification, it provides integrators worldwide with a powerful new option for critical sensing and navigation. *aerospace.honeywell.com*


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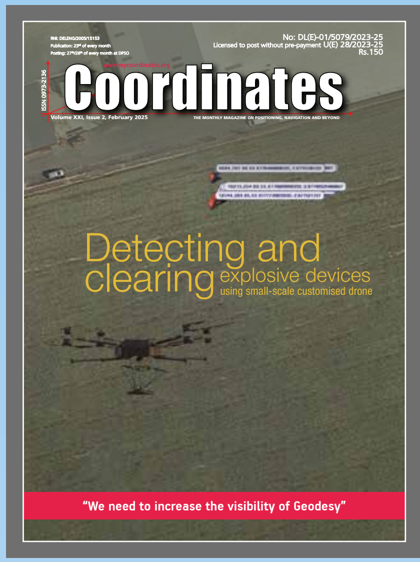
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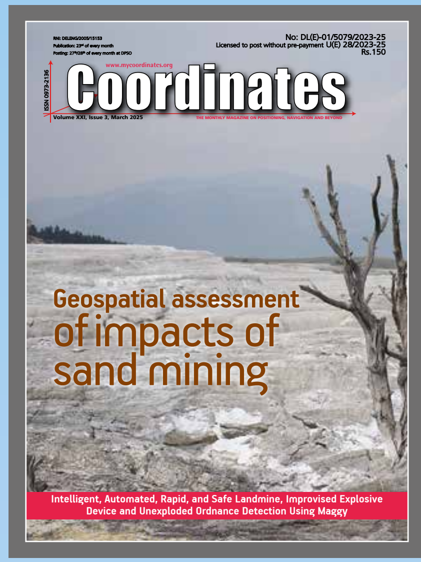
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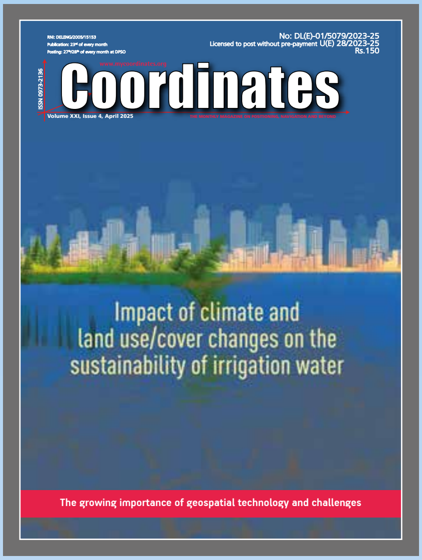
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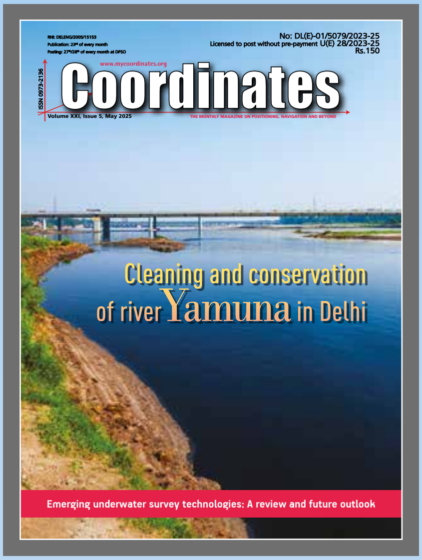
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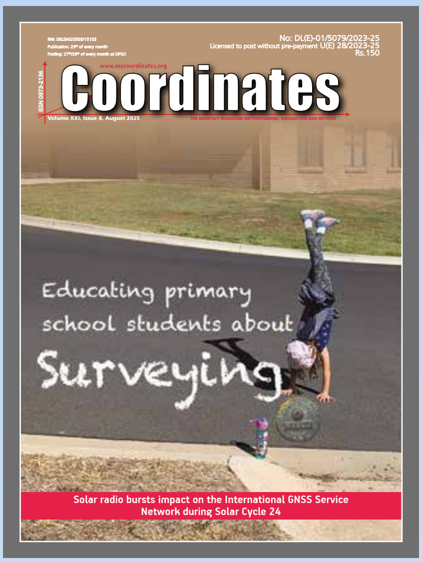
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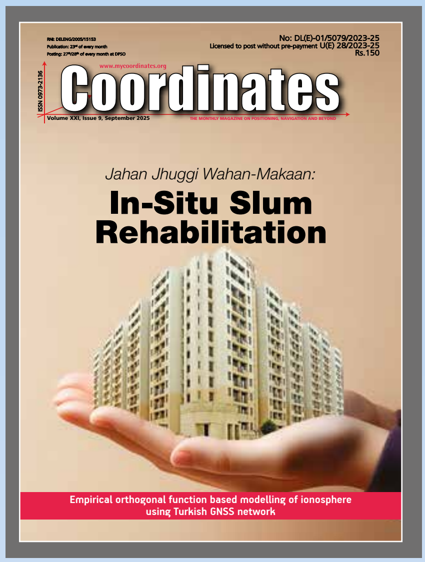
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