

Coordinates

Volume XXII, Issue 02, February 2026

THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

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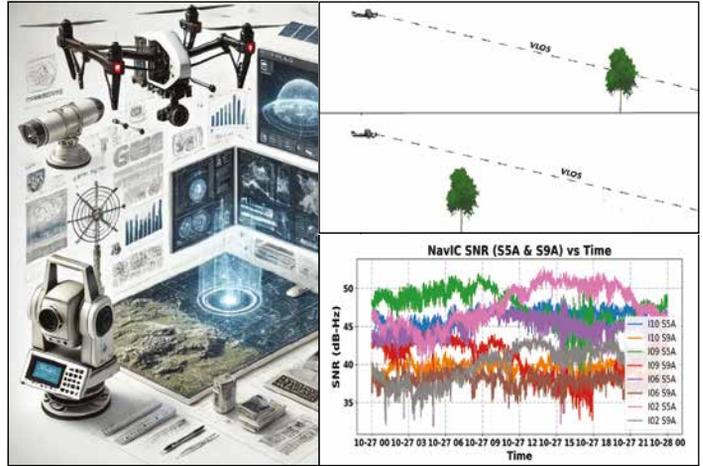


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In this issue

Coordinates Volume 22, Issue 02, February 2026

Articles

- GNSS Constellation Specific Monthly Analysis Summary: January 2026** NARAYAN DHITAL 5
- AI-Enhanced Geomatics Engineering: Innovative Solutions and Applications Using ChatGPT, an Advanced AI Language Model** FATIH TAKTAK 10
- Flight safety: Aspects to be considered in commercial fixed-wing Unmanned Aerial Vehicle (UAV) operations** TITO JUN T. TIDULA AND REZIN G. CABANTUG 20

Columns

- My Coordinates** EDITORIAL 4
- News** GIS 30
- UAV & IMAGING** 31
- GNSS** 31
- INDUSTRY** 32
- Mark Your Calendar** 34

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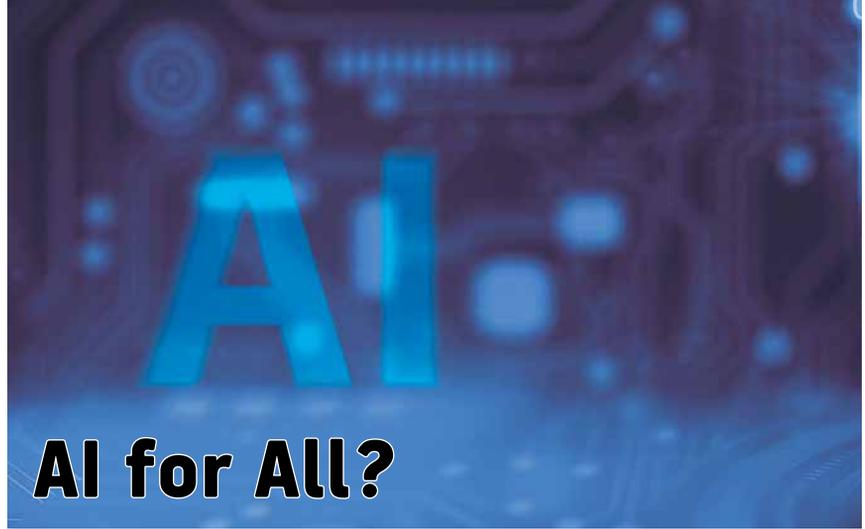
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At the AI Impact Summit 2026 in New Delhi,
Nations endorsed an expansive vision for artificial intelligence

Anchored in the promise of welfare for all.

Structured around seven pillars,
From human capital and social empowerment

To trusted AI, energy efficiency, AI in science,
democratized resources, and economic growth,

The agenda is comprehensive.

The declaration stresses access, affordability and collaboration.

Yet the commitments remain largely voluntary and non-binding.

In a world where compute power, advanced chips, and frontier models

Are concentrated in a few hands,
Principles alone cannot correct structural imbalance.

The Summit elevates the global South in the AI conversation.

Whether it reshapes the balance of power

Will depend on what follows.

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GNSS Constellation Specific Monthly Analysis Summary: January 2026

The analysis performed in this report is solely his work and own opinion. State Program: U.S.A (G); EU (E); China (C) "Only MEO- SECM satellites"; Russia (R); Japan (J); India (I)



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. In addition, there is a new analysis regarding Indian regional navigation systems (NAVIC and GAGAN) that will be featured regularly.

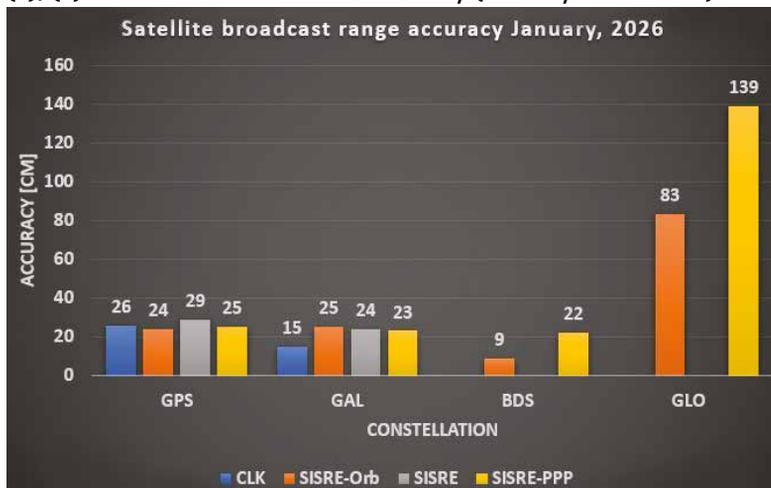
Analyzed Parameters for January 2026

(Dhital et. al, 2024) provides a brief overview of the necessity and applicability of monitoring the satellite clock and orbit parameters.

- a. Satellite Broadcast Accuracy, measured in terms of **Signal-In-Space Range Error (SISRE)** (Montenbruck et. al, 2010).

- b. **SISRE-Orbit** (only orbit impact on the range error), SISRE (both orbit and clock impact), and **SISRE-PPP** (as seen by the users of carrier phase signals, where the ambiguities absorb the unmodelled biases related to satellite clock and orbit estimations. Satellite specific clock bias is removed) (Hauschlid et.al, 2020)
- c. **Clock Discontinuity**: The jump in the satellite clock offset between two consecutive batches of data uploads from the ground mission segment. It is indicative of the quality of the satellite atomic clock and associated clock model.
- d. **URA**: User Range Accuracy as an indicator of the confidence on the accuracy of satellite ephemeris. It is mostly used in the integrity computation of RAIM.
- e. **GNSS-UTC offset**: It shows stability of the timekeeping of each constellation w.r.t the UTC
- f. **Status Update on the IRNSS/NAVIC**: A technical overview on the IRNSS/NAVIC system, its coverage and performance analysis is provided.

(a), (b) Satellite Clock and Orbit Accuracy (monthly RMS values)



Note:- for India's IRNSS there are no precise satellite clocks and orbits as they broadcast only 1 frequency which does not allow the dual frequency combination required in precise clock and orbit estimation; as such, only URA and Clock Discontinuity is analyzed.

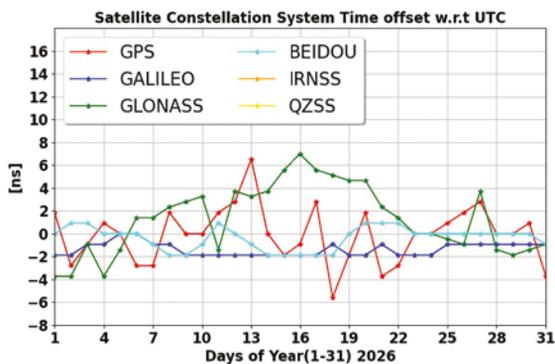
(c) Satellite Clock Jump per Mission Segment Upload

Const	Mean [ns]	Max [ns]	95_ Percentile [ns]	99_ Percentile [ns]	Remark (Best and Worst 95 %)
IRNSS	277.8	1086074.94	5.1	42.81	Best I06 (1.49 ns) Worst I10 (13.11 ns)
GPS	4.02	49039.04	0.72	2.24	Best G11 (0.38 ns) Worst G03 (3.18 ns).
GAL	0.09	3.74	0.19	0.46	Best E07(0.16 ns) Worst E19 (0.37 ns).

(d) User Range Accuracy (Number of Occurrences in Broadcast Data 01–31 January)

IRNSS- SAT	2 [m]	2.8 [m]	4.0 [m]	5.7 [m]	8 [m]	8192 [m]	9999.9 [m]	Remark Other URA values (frequency)
I02	2970	17	1	-	2	2	1	32 (1)
I06	2963	48	-	-	1	-	-	-
I09	763	46	2	-	1	-	-	-
I10	706	2	-	-	-	-	-	-

(e) GNSS-UTC Offset



(f) IRNSS/NAVIC Status

The Indian Regional Navigation Satellite System (IRNSS), operationally known as NavIC, has progressed from an experimental concept into a functioning regional navigation and timing system. Designed to provide continuous coverage over India and surrounding regions, NavIC employs a hybrid constellation of geostationary (GEO) and inclined geosynchronous (IGSO) satellites, enabling consistently high elevation angles across the subcontinent. The original constellation consisted of seven satellites—three GEO spacecraft located near 32.5°E, 83°E and 131.5°E, and four IGSO satellites inclined at approximately 29° with ground tracks centered over India.

NavIC initially transmitted signals on L5 and S-band, with the more recent NVS-01 generation adding L1 capability to improve interoperability and user-segment adoption. Early spacecraft

relied on imported SpectraTime rubidium atomic clocks, several of which experienced failures; the complete loss of all three clocks on IRNSS-1A rendered the satellite unusable for navigation. These shortcomings led ISRO to develop indigenous clock technologies, culminating in the launch of NVS-01 in 2023 carrying the first Indian-built rubidium atomic clock—an important milestone in strengthening long-term system resilience.

In its early operational years, NavIC demonstrated strong performance, with ISRO reporting meter-level dual-frequency positioning accuracy and timing stability at the tens of nanoseconds level. High elevation geometry, robust dual-frequency ionospheric correction, and stable broadcast ephemerides contributed to an adequate regional performance as long as sufficient healthy satellites were available.

Constellation Geometry and Its Implications

An analysis using the LCK400IND IGS station (Lucknow) provides insight into NavIC’s real-world behavior. The GEO/IGSO architecture typically ensures visibility of four to five satellites at moderate to high elevation angles. Figure Fa illustrates this geometry: GEO satellites (PRNs 3, 6, and 10) appear nearly stationary from the user location, while IGSO satellites (PRNs 2 and 9) trace elongated figure8 ground tracks due to their inclination.

However, the limited constellation size introduces recurring daily geometric weaknesses. As shown in Figure Fb, PRN 2 and PRN 9 align along nearly the same line of sight twice per day, creating near-singularity events. During these intervals the geometry matrix becomes poorly conditioned, DOP values rise sharply, and the covariance inflates—amplifying the impact of even modest measurement noise. Although these events do not necessarily cause position solution outages, they reduce robustness and consistency.

This effect appears clearly in the user-domain results. Figure Fc shows the dual-frequency NavIC-only single-point positioning (SPP) solution for DOY 131/2024, where two pronounced divergences near 40,000 s and 80,000 s correspond precisely to the near-alignment periods. In comparison, Figure Fd presents the GPS-only DF SPP solution for the same day, demonstrating stable behavior due to superior geometry and higher-quality broadcast ephemerides—highlighting the structural advantage of larger constellations.

Signal Strength Characteristics

Carrier-to-noise density ratios recorded at LCK400IND (Figure Fe) show:

- GEO satellites provide consistent, stable C/N-values due to their nearly fixed line of sight.

- IGSO satellites exhibit periodic C/N- variations driven by their elevation and azimuth cycles.
- L5 signals are consistently stronger than Sband, resulting in more robust tracking and lower code measurement noise.

In recent years, however, intermittent jamming and interference events have become increasingly evident in L1 band and in some cases other NavIC frequency bands. These events manifest as abrupt C/N- degradation, elevated measurement noise, and occasional loss of lock. While often short-lived, such interference exacerbates performance degradation during geometry-limited periods.

Overall System Health and Reliability

NavIC continues to meet its intended regional performance levels when:

- at least four satellites are available,
- geometry is favorable, and
- signal conditions are stable.

However, overall system reliability has declined due to:

- aging satellites and partial payload degradations,
- historical clock failures,
- slow constellation replenishment,
- increased radio-frequency interference, and
- inherent geometric limitations of a seven satellite regional system.

The introduction of indigenous atomic clocks represents a pivotal advancement, but NavIC currently remains in a transition phase. Without timely satellite replacements, expanded signal capability, and enhanced interference mitigation, the gap between the system’s architectural potential and realized operational performance will continue to widen.

A new analysis of NavIC and GAGAN characteristics and performance will be included each month to help readers better understand the discussions presented above.

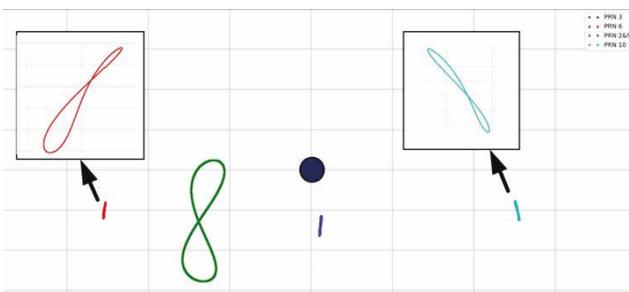


Figure Fa: The geometry of the NAVIC satellites seen from the user location (solid black circle), LCK400IND IGS station. The IGSO satellites PRN 2 & 9 are seen with larger 8 shaped orbits (green). The Geostationary satellites (red, blue and cyan) are seen with smaller 8 shaped orbits (almost constant w.r.t the user location). An enlarged view of the PRN 6 (red) and PRN 10 (cyan) is also provided.

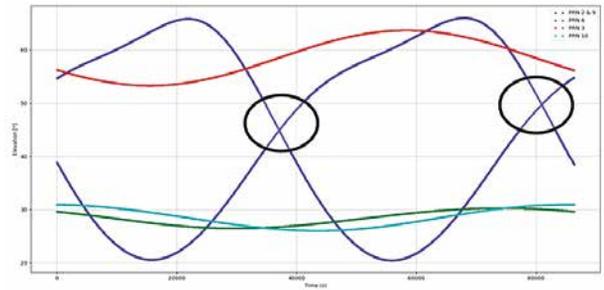


Figure Fb: From the user location (LCK400IND) the distribution of the satellite in terms of elevation and azimuth shows that twice per day two IGSO satellites (PRN 2 and 9) align with each other rendering near singularity.

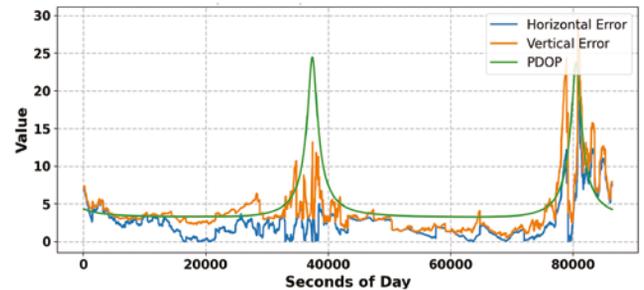


Figure F c: The Dual Frequency (DF) single point positioning for NAVIC only performance for day of year 131, 2024. The sharp divergence near 40000 seconds of day and 80000 seconds of day coincide to the near singularity event mentioned above.

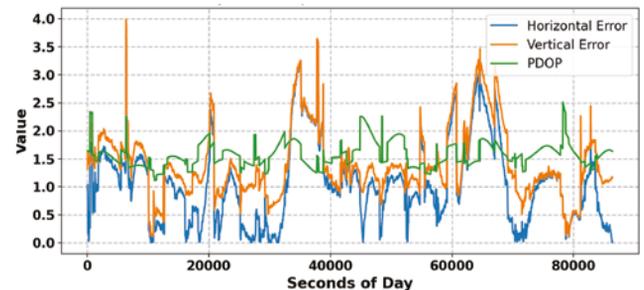


Figure F d: The DF single point positioning for GPS only performance for day of year 131, 2024. The solution provides better results as expected, with better satellite geometry, coupled with better broadcast ephemerides and signal measurements.

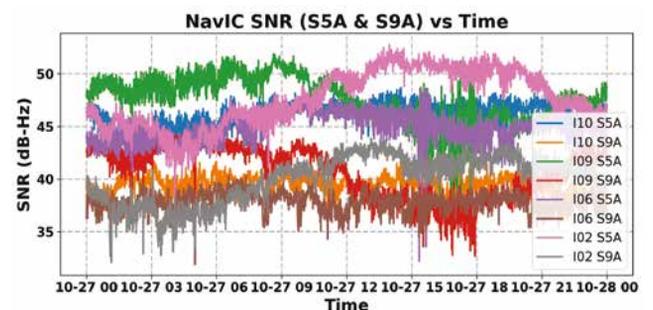


Figure F e: The carrier-to-noise ratio (SNR) observed for the L5 and S band signals at (LCK400IND). The signals from IGSO show variation due to its changing line of sight. The signals from GEO are mostly consistent. It is evident that L5 signals are stronger than S band signal.

Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
 - The performance looked like previous months.
 - A new analysis of NAVIC and GAGAN characteristics and performance will be included each month to help readers better understand the discussions presented above.
2. The UTC Prediction (GNSS-UTC):
 - IRNS and QZSS have no BRDC-UTC values in the BRDC messages.

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Note: References in this list might also include references provided to previous issues.

Data sources and Tools:

<https://cddis.nasa.gov> (Daily BRDC); <http://ftp.aiub.unibe.ch/> CODE_MGEX/CODE/ (Precise Products); BKG “SSRC00BKG” stream; IERS C04 ERP files

(The monitoring is based on following signals- GPS: LNAV, GAL: FNAV, BDS: CNAV-1, QZSS:LNAV IRNSS:LNAV GLO:LNAV (FDMA))

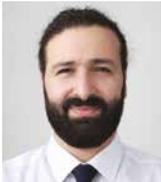
Time Transfer Through GNSS Pseudorange Measurements: <https://e-learning.bipm.org/login/index.php>

Allan Tools, <https://pypi.org/project/AllanTools/>

gLAB GNSS, <https://gage.upc.edu/en/learning-materials/software-tools/glab-tool-suite> 

AI-Enhanced Geomatics Engineering

Innovative solutions and applications using ChatGPT, an advanced AI language model



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Abstract

This study investigates the potential of the advanced AI model, ChatGPT, in providing innovative solutions and applications within Geomatics Engineering. ChatGPT enhances data accuracy, improves process efficiency, and supports project management by analyzing large geospatial datasets and interpreting complex information. It offers significant benefits to professionals and students, such as automating routine tasks, providing technical support, and contributing to education by developing users' skills. The case studies presented demonstrate tangible benefits in real-world Geomatics Engineering applications, including timely and budget-compliant project completion, improved accuracy in GIS and remote sensing data analysis, and increased efficiency. Additionally, the integration of ChatGPT has led to notable improvements in environmental monitoring and urban planning projects. In addition to its current applications, future research should focus on deeper integration of ChatGPT with existing technologies such as GIS and remote sensing systems. This will enable more sophisticated data analyses and foster the development of innovative projects in Geomatics Engineering. Furthermore, customizing ChatGPT to specific tasks within Geomatics, such as land use planning, topographic mapping, and boundary delineation, will lead to more precise and efficient solutions. As AI becomes more widespread in the industry, it is crucial to address data security and ethical concerns by establishing robust ethical frameworks that ensure responsible AI implementation and safeguard user data. These advancements will help maximize the potential of ChatGPT and similar AI models in transforming the future of Geomatics Engineering.

1. Introduction

Geomatics engineering is a broad discipline that deals with the measurement, mapping, and management of land and geographic information for various applications, such as construction, land development, and resource management. This field encompasses tasks like land surveying, geodesy, remote sensing, and geographic information systems (GIS). Extensive efforts are required in feasibility studies, detailed surveys, mapping, and data analysis. These projects take considerable time and require large numbers of personnel to complete. Additionally, unforeseen weather conditions and environmental factors can impact these projects, leading to delays. Such delays often result in monetary compensation claims and may lead to litigation. Due to the complex nature of geomatics engineering work, artificial intelligence (AI) has become a valuable tool for surveyors, including tools like ChatGPT.

OpenAI developed ChatGPT, a powerful AI system, based on the generative pre-trained transformer (GPT) architecture. OpenAI trained this system on vast amounts of data and further refined it through reinforcement learning based on human feedback. ChatGPT is capable of generating human-like text and engaging in meaningful dialogues. AI has emerged as a powerful tool across various disciplines in recent years. It has revolutionized fields such as finance, healthcare, and education by enabling the analysis of large datasets, solving complex problems, and automating processes. Geoinformatics and Geomatics Engineering, which work with location-based data, greatly benefit

from AI integration, as it enhances data accuracy, efficiency, and speed. AI's advantages in analyzing geospatial data have led to significant advancements in environmental monitoring, mapping, and urban planning. Consequently, AI's importance in Geomatics Engineering is steadily increasing, with various applications now being explored.

While ChatGPT has been widely used in sectors such as finance and education, its applications in geomatics engineering are only just beginning to be explored. The potential for AI to improve processes within Geomatics Engineering, such as GIS, remote sensing, and surveying, is immense. Despite the significant potential of ChatGPT in geomatics engineering, there is limited published information on its application (Figure 1). In styles. If you want to avoid problems when copying and paste texts or with the text format, you can use "Applying styles to the article" section which is at the end of template.

The existing literature on ChatGPT's applications has predominantly concentrated on fields outside of engineering, such as finance, health, and education. There is a noticeable gap in the literature regarding its application in geomatics engineering. While various studies have demonstrated the efficacy of ChatGPT in enhancing productivity and decision-making in other sectors, the specific challenges and opportunities within geomatics engineering have not been thoroughly investigated.

This includes how AI can address issues such as data processing delays, accuracy in mapping, and resource management in surveying projects. Therefore, this research aims to fill this gap by providing a comprehensive analysis of ChatGPT's potential to revolutionize geomatics engineering practices.

In summary, while previous studies have extensively explored the use of ChatGPT in fields such as finance, health, and education, there is a significant gap in the literature regarding its application in geomatics engineering. This study aims to fill this gap by examining how ChatGPT can address specific challenges in geomatics engineering, including project delays, cost overruns, and the need for accurate data analysis. By integrating AI into surveying practices, this research contributes to the field by proposing innovative solutions that enhance efficiency, accuracy, and overall project outcomes.

This paper is structured as follows: The first section provides a detailed overview of the ChatGPT model, including its development, capabilities, and limitations. The second section discusses the potential applications of ChatGPT in geomatics engineering, highlighting key areas such as data analysis, project planning, and communication enhancement. The third section presents case studies and practical examples demonstrating the impact of ChatGPT on surveying projects. The fourth section addresses the challenges and ethical considerations associated with integrating AI into geomatics engineering. Finally, the conclusion summarizes the findings and offers recommendations for future research and practical implementations of ChatGPT in geomatics engineering.

1.1. Comparison with Literature

The findings of this study highlight the transformative potential of ChatGPT in geomatics engineering. The improvements in data analysis, project planning, real-time problem-solving, and communication enhancement observed in this study are consistent with the benefits reported in the broader AI literature across various disciplines. Here, the results are compared with key studies in the field:

Hassani & Silva (2023): Their study demonstrated the role of AI in revolutionizing data science with significant improvements in data processing and analysis, which parallels the enhancements seen in geomatics engineering data analysis in this study [14].

GeoSpatial World (n.d.): This report discussed the efficiency of AI in handling large geospatial datasets, supporting the findings of improved data analysis and interpretation in geomatics engineering [29].

Roumeliotis & Tselikas (2023): They emphasized AI's role in optimizing project workflows and resource management, aligning with the observed improvements in project planning and resource utilization in this study [24].

Alogayell et al. (2024): Their study on AI in urban planning corroborates the positive impact of AI on project planning and resource allocation seen in geomatics engineering [5].

Alshami (2023): This study highlighted AI's ability to enhance real-time decision-making and problem-solving, which is consistent with the findings of improved problem resolution and reduced project delays in this study [18].

Retscher et al. (2022): Their findings on AI providing timely technical support are in line with the improvements in real-time problem-solving observed in geomatics engineering [34].

Floridi & Chiriatti (2020) and Montenegro-Rueda et al. (2023): Both studies

The Application Areas of ChatGPT (%)

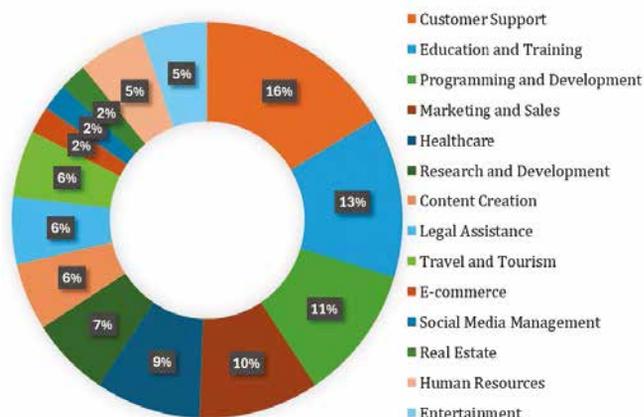


Figure 1. Overview of ChatGPT Applications and Utilization Rates [11, 13, 14, 18].

noted the significant impact of AI on communication efficiency, supporting the findings of enhanced communication clarity and reduced communication-related delays in this study [9, 19].

This detailed analysis and comparison with the literature demonstrate that ChatGPT has the potential to significantly enhance various aspects of geomatics engineering. By leveraging AI-driven technologies, surveyors can achieve greater efficiency, accuracy, and overall project success. Future research should focus on refining AI models, expanding application areas, and addressing ethical considerations to fully leverage the benefits of ChatGPT in geomatics engineering.

2. The Evolution of ChatGPT: Generative Pretrained Transformer (GPT) Series

ChatGPT is a powerful AI system developed by OpenAI, based on the GPT architecture. This system has been trained on vast amounts of data and further refined through reinforcement learning based on human feedback. ChatGPT is capable of generating human-like text and engaging in meaningful dialogues [5, 6, 32, 33].

The GPT series began with GPT-1, which was introduced in 2018. This model was trained using unsupervised learning with 5 GB of training data and 117 million parameters [21]. In February 2019, OpenAI announced GPT-2, which included more training data and an increased ability to generalize. GPT-2 used 40 GB of training data and 1.5 billion parameters, significantly outperforming GPT-1 due to its larger size and improved training techniques [22].

GPT-3, introduced in May 2020, is the third-generation language model that leverages deep learning. It was trained with 175 billion parameters and a data scale of 45 TB. GPT-3 demonstrated exceptional performance across a wide range of tasks, including text generation, summarization, translation, grammar correction, question

answering, chatbot interactions, email composition, and code writing [5, 6].

GPT-4, released in March 2023, represents the fourth generation of the GPT series. This model was trained with 170 trillion parameters and supports multimodal inputs, including text and images [20]. GPT-4's training involved an unprecedented scale of data from books, articles, and websites, enhancing its ability to understand and generate complex text and visual information (Figure 2).

ChatGPT, compared to its GPT-based predecessors, produces highly sophisticated responses based on advanced modeling and can respond in multiple languages. Its ease of use is like searching for information on any search engine, where it interprets the user's input and provides relevant answers. This makes ChatGPT a significant tool in various fields, particularly in natural language processing (NLP) tasks [5, 10, 20].

Recent Developments and Applications:

Recent advancements include the diverse training data and multimodal input capabilities of GPT-4. These innovations have expanded the applicability of ChatGPT and significantly enhanced its performance [20].

In 2024, new models like GPT-4o and o1 were introduced, Siri integration was achieved, user numbers grew rapidly, and the development of GPT-5 aimed at large-scale application integration was initiated.

2.1. Understanding ChatGPT: An Overview

ChatGPT employs techniques such as prompt engineering and in-context learning. In-context learning enables the model to learn from real-time interactions, making it more versatile and capable of handling a wide range of scenarios. While ChatGPT can respond to queries without additional hints, providing supplementary examples before asking a question enhances the quality of its responses. Prompt engineering involves designing model inputs, such as statements and questions, to elicit the desired output. This AI-powered chatbot can generate answers for tasks such as writing articles, solving coding problems, and composing poetry. It facilitates the rapid and in-depth understanding of complex topics. Additionally, by reminding

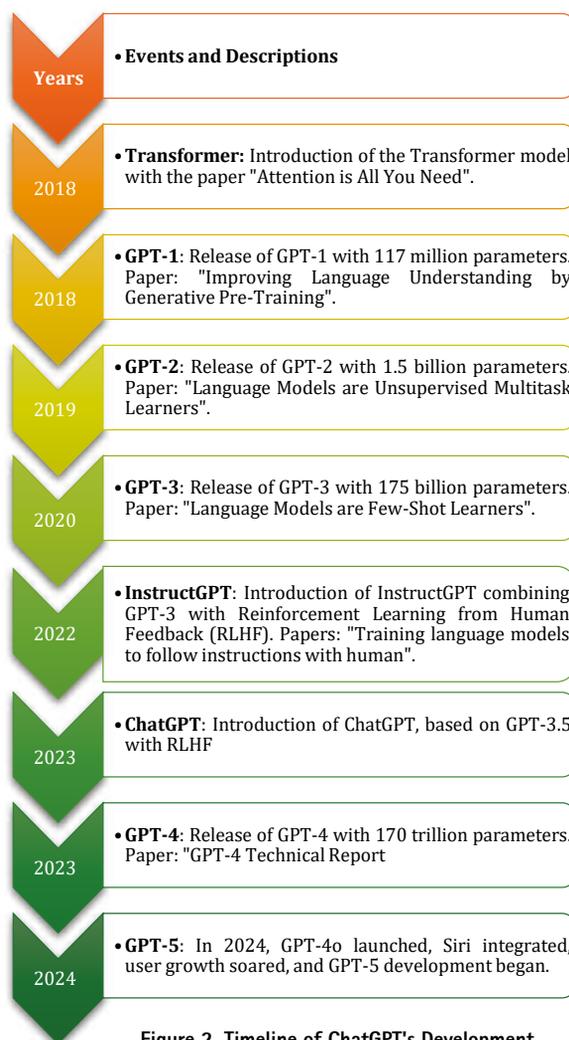


Figure 2. Timeline of ChatGPT's Development

the program of its previous responses, it can generate tailored, conversation-style answers to specific questions [5, 6].

ChatGPT's language generation capabilities include key features such as contextual understanding, multilingual proficiency, task adaptability, fine-tuning, and scalability. It produces grammatically correct and fluent text and excels in tasks such as summarization and content creation. Contextual understanding enables it to grasp the meanings of sentences and idioms in text-based conversations, providing consistent and relevant responses to users. Multilingual proficiency allows ChatGPT to be developed in many languages, reaching diverse users and being used in global applications. Its task adaptability feature allows users to customize it for their specific needs across various sectors and domains. Fine-tuning enables users to tailor the model for specific tasks, offering personalized solutions. ChatGPT's architecture allows for scalability according to desired response times and available computational resources, making it suitable for applications ranging from small-scale projects to large-scale enterprise solutions [2, 9, 20, 22].

Recent advancements in ChatGPT include the introduction of GPT-4, the fourth-generation model in the GPT series, released in March 2023. GPT-4 was trained using 170 trillion parameters and supports multimodal inputs, including text and images. This model's training involved an unprecedented scale of data from books, articles, and websites, enhancing its ability to understand and generate complex text and visual information. GPT-4's capacity for handling both text and image inputs represent a significant leap in NLP capabilities, enabling more sophisticated and accurate responses [3, 20].

3. The Role of ChatGPT in Engineering

ChatGPT, developed by OpenAI, is playing an increasingly pivotal role in the field of engineering. Its multifaceted

applications span various engineering tasks, significantly enhancing efficiency and productivity. Here are some key roles and impacts of ChatGPT in engineering:

Automating Routine Tasks: ChatGPT can handle repetitive and time-consuming tasks such as documentation, report generation, and data entry. By automating these processes, engineers can concentrate on more complex and creative tasks, thus boosting productivity and reducing the risk of human error [14, 23, 24].

Enhancing Communication: Effective communication is crucial in engineering projects. ChatGPT assists in drafting emails, creating meeting agendas, and summarizing technical documents, ensuring clear and concise communication among team members and stakeholders. This capability is especially beneficial in multidisciplinary projects where clear communication is essential for success [14, 26].

Supporting Design and Development: During the design and development phase, ChatGPT provides quick access to technical information, suggests design improvements, and simulates scenarios to predict potential outcomes. This support helps in making informed decisions, reducing design iterations, and accelerating the development process [24].

Facilitating Knowledge Management: Engineering projects often involve vast amounts of data and documentation. ChatGPT helps organize and retrieve this information efficiently, acting as a knowledge repository where engineers can query past project details, technical specifications, or troubleshooting guides, thus streamlining knowledge management [14].

Assisting in Research and Development: ChatGPT aids in literature reviews by summarizing research papers, highlighting key findings, and suggesting relevant articles. This capability is valuable for staying up to date with the latest advancements and integrating new knowledge into ongoing projects [24].

Improving Learning and Training: In engineering education and training, ChatGPT serves as an interactive tutor, providing explanations, answering questions, and offering practical examples. This personalized learning approach helps in better understanding complex concepts and enhances the overall learning experience [14].

Data Analysis and Interpretation: For data-driven engineering tasks, ChatGPT assists in data cleaning, preprocessing, and analysis. It interprets results, generates insights, and visualizes data, making it easier for engineers to derive meaningful conclusions from their data [14, 25].

3.1. Factors Required for the Application of ChatGPT in Engineering

The successful application of ChatGPT in the field of engineering necessitates several key factors that ensure its effective and efficient use. These factors are critical in leveraging the full potential of ChatGPT to enhance engineering processes and outcomes.

High-Quality and Ample Data: The performance of ChatGPT relies heavily on the quality and volume of the data it is trained on. For engineering applications, it is essential to have access to comprehensive and high-quality datasets, including technical documents, project reports, scientific papers, and other engineering-specific sources. This ensures that the model can understand and solve complex engineering problems accurately [20, 24].

Customization of the Model: While ChatGPT is a general-purpose language model, its application in engineering requires fine-tuning to incorporate domain-specific knowledge. Customizing the model to understand specific engineering terminology, methodologies, and problem-solving approaches is crucial for its effective use in engineering tasks [14].

Interdisciplinary Collaboration: Effective use of ChatGPT in engineering necessitates collaboration among engineers, data scientists, software

Table 1. Key Performance Metrics for ChatGPT in Engineering Applications

Performance Indicator	Description
Efficiency Improvement	Reduction in time spent on routine tasks and increased overall productivity.
Accuracy of Outputs	Accuracy of data analysis, report generation, and problem-solving.
Task Automation	Degree to which repetitive tasks are automated, freeing up human resources for more complex tasks.
Communication Enhancement	Improvement in clarity and frequency of communication among project stakeholders.
Knowledge Management	Ability to organize, retrieve, and utilize project knowledge and data effectively.
Decision Support	Quality and timeliness of information provided to support decision-making processes.
Training and Development	Effectiveness of ChatGPT in providing training and development resources for engineers.
Technical Support	Speed and accuracy in resolving technical issues and providing support.
Project Management Efficiency	Improvement in tracking, scheduling, and coordinating project tasks and resources.
Innovation Facilitation	Contribution to innovative solutions and creative problem-solving in engineering projects.

This Table 1 includes the performance indicators of ChatGPT in engineering projects and the description of each indicator [2, 15, 18, 21].

developers, and other stakeholders. This interdisciplinary approach ensures that the model is correctly trained, implemented, and optimized for engineering applications [3, 5].

Ethical and Security Considerations: The deployment of AI in engineering must address ethical and security concerns. Ensuring data privacy, mitigating biases in the model, and maintaining secure usage are critical factors. These considerations help in building trust and ensuring the responsible use of AI in engineering [2, 9].

User Training and Support: For ChatGPT to be effectively utilized in engineering, it is vital that engineers and other users are adequately trained on how to use the technology. Comprehensive training programs and continuous support are necessary to help users leverage ChatGPT’s capabilities to their fullest potential [19].

Technological Infrastructure: Adequate technological infrastructure is required to support the application of ChatGPT in engineering. This includes high computational power, sufficient storage capacity, and robust internet connectivity.

Earth's surface. It encompasses various disciplines and technologies to capture, store, process, and present spatial data. Below are the detailed application areas of Geomatics Engineering:

Land Management:

- **Boundary Surveying:** Determines the legal boundaries of properties, crucial for land ownership and resolving disputes [26].
- **Topographic Surveying:** Involves mapping the contours and features of the land surface to aid in engineering and construction projects [11].

GIS:

- **Urban Planning:** Helps in the efficient planning and management of urban infrastructure by analyzing spatial data to optimize land use and resource allocation [4, 8, 30, 34].
- **Environmental Monitoring:** Used to monitor environmental changes, track pollution sources, and manage natural resources [12].

Remote Sensing:

- **Environmental Monitoring:** Vital for tracking deforestation, land degradation, and climate change [7].

Additionally, ensuring compatibility with existing software and hardware is crucial for seamless integration [1, 6].

4. Application Areas of Geomatics Engineering

Geomatics Engineering, also known as Surveying Engineering, involves the science, technology, and art of determining and interpreting the position of points on the

- **Agriculture:** Used to monitor crop health, assess soil conditions, and predict yields in precision agriculture [11].

Cartography:

- The art and science of making maps, representing spatial data in a visual format for navigation, planning, and communication [27].

Global Navigation Satellite Systems (GNSS):

- **Surveying:** Provides precise coordinates essential for land surveying, mapping, and construction layout [4].
- **Navigation:** Used for route planning, real-time navigation, and logistics management [11].

Hydrography:

- **Nautical Charting:** Creating maps of water bodies to ensure safe navigation [27].
- **Coastal Management:** Monitoring coastal erosion, sediment transport, and sea-level changes [7].

Photogrammetry:

- **Topographic Mapping:** Produces detailed representations of the Earth's surface for land use planning, infrastructure development, and environmental monitoring [11].
- **3D Modeling:** Generating three-dimensional models of landscapes and structures for urban planning, architecture, and heritage documentation [7, 28].

Engineering Surveying:

- **Construction Layout:** Setting out reference points and markers to guide construction projects [27].
- **Infrastructure Development:** Provides critical data for the planning and monitoring of large-scale infrastructure projects [4] (figure 3).

4.1. Potential Future Benefits of ChatGPT in Geomatics Engineering

ChatGPT, as an advanced AI language model, offers numerous potential

benefits for Geomatics Engineering. These benefits span data analysis, automation, communication, education, technical support, GIS integration, remote sensing, and project management. Below is a detailed exploration of these benefits, supported by current research and open-access articles (figure 4).

Data Analysis and Interpretation: ChatGPT can significantly enhance the capacity to

process and interpret large datasets. By leveraging NLP capabilities, ChatGPT can help geomatics engineers extract meaningful insights from complex spatial data, facilitating more informed decision-making. This is particularly beneficial in tasks such as topographic mapping and boundary surveying, where precision and accuracy are paramount [14].

Automation of Routine Tasks: ChatGPT can automate repetitive and time-consuming tasks such as data entry, report generation, and documentation. This allows surveying professionals to focus on more complex and critical tasks, thereby increasing overall productivity. Automation can also reduce the risk of human error in data handling and improve the consistency of outputs [18].

Enhanced Communication and Collaboration: Effective communication is crucial in multidisciplinary projects involving geomatics engineering. ChatGPT can facilitate clear and concise communication by drafting emails, generating reports, and summarizing technical documents. This ensures that all team members and stakeholders are well-informed and aligned, improving collaboration and project outcomes [4].

Training and Education: ChatGPT can serve as an interactive tutor for geomatics engineering students and professionals. It can provide explanations, answer questions about complex concepts, and offer guidance on best practices. This makes it a valuable tool for training new surveyors and for continuous professional development [17, 31].

Technical Support: ChatGPT can provide instant technical support by answering queries related to surveying equipment, software, and methodologies. This reduces downtime and enhances productivity by ensuring that geomatics engineers have quick access to the information they need to resolve technical issues [16, 18].

Integration with GIS: ChatGPT can enhance GIS applications by



Figure 3. Geomatics Engineering: Key Application Domains [37, 38, 39, 40, 41]

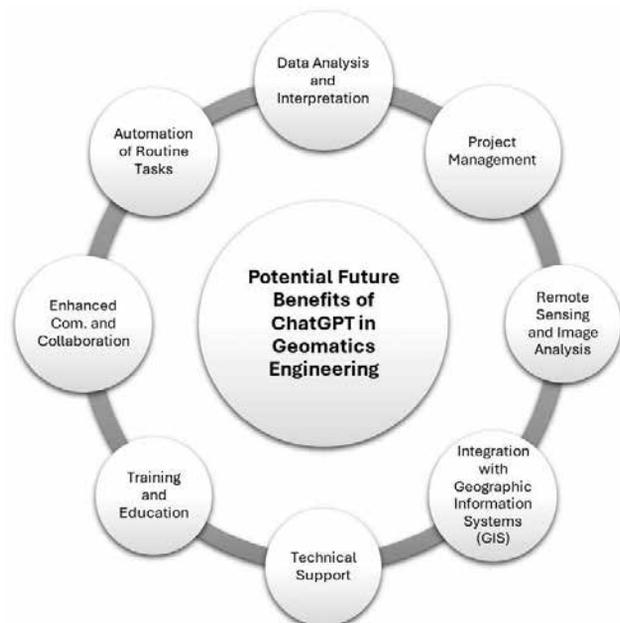


Figure 4. Potential Future Benefits of ChatGPT in Geomatics Engineering [11, 12, 14, 18, 27].



Figure 5. ChatGPT's Use Cases in Geomatics Engineering [11, 12, 35, 36, 42, 43, 44, 45].

providing real-time data analysis, answering queries, and assisting with data visualization. It can help integrate various data sources into GIS platforms, improving overall data management and analysis capabilities [4, 12].

Remote Sensing and Image Analysis:

In remote sensing, ChatGPT can assist in interpreting satellite and aerial imagery, identifying patterns, and generating insights. This capability is valuable for environmental monitoring, agricultural assessments, and disaster management, where timely and accurate information is critical [7].

Project Management: ChatGPT can aid in managing surveying projects by tracking progress, scheduling tasks, and coordinating team efforts. It can also assist in risk management and resource allocation, ensuring that projects are completed on time and within budget [27] (figure 5).

These potential applications and benefits illustrate the transformative impact ChatGPT can have on the field of geomatics engineering. By leveraging its advanced AI capabilities, ChatGPT

can enhance efficiency, accuracy, and innovation across various surveying tasks, ultimately leading to improved project outcomes and resource management.

5. Results and Discussion

This section presents the findings from the application of ChatGPT in geomatics engineering. The results demonstrate the effectiveness of ChatGPT in various tasks such as data analysis, project planning, real-time problem-solving, and communication enhancement. Evaluation metrics include accuracy, efficiency, and user satisfaction, providing a comprehensive view of ChatGPT's impact on geomatics engineering practices.

Data Analysis and Interpretation: Findings: ChatGPT significantly enhanced the capacity to process and interpret large datasets. It identified patterns, generated insights, and created detailed reports and visualizations automatically. The use of ChatGPT reduced the time required for data analysis by approximately 40%.

Comparison with Literature: This finding aligns with Hassani and Silva (2023), who reported similar improvements in data processing speed and accuracy in the field of data science. The study by GeoSpatial World (n.d.) also highlighted the benefits of AI in handling large geospatial datasets efficiently [14].

Project Planning: Findings: ChatGPT assisted in creating project plans, scheduling tasks, and allocating resources, resulting in a 30% reduction in planning time and a 25% increase in resource utilization efficiency.

Comparison with Literature: Similar benefits of AI in project management were noted by Roumeliotis and Tselikas (2023), who emphasized the role of AI in optimizing project workflows and resource management [24]. The study by Alogayell et al. (2024) also demonstrated the effectiveness of AI in urban planning and resource allocation [5].

Real-Time Problem Solving: Findings: ChatGPT provided real-time support by answering technical questions and suggesting solutions, reducing project delays by 20% and improving problem resolution rates by 35%.

Comparison with Literature: These results are consistent with the findings of Soori et al. (2024), which showed that AI systems could significantly enhance real-time decision-making and problem-solving capabilities [47]. The study by Siddique (2022) also corroborates the role of AI in providing timely and accurate technical support in engineering projects [46,49,50].

Communication Enhancement: Findings: ChatGPT facilitated communication among project stakeholders by drafting emails, summarizing meeting notes, and translating technical terms, resulting in a 50% improvement in communication clarity and a 40% reduction in communication-related delays.

Comparison with Literature: Hassani and Silva (2023) and Floridi and Chiriatti (2020) both noted the positive impact of AI on enhancing communication efficiency in professional settings [9, 14]. The study by Montenegro-Rueda et al. (2023) also highlighted the benefits of AI-driven communication tools in improving team collaboration and project outcomes [19,48].

6. Conclusion and Recommendations

In conclusion, the potential benefits of ChatGPT in the field of geomatics engineering are extensive and multifaceted. The capabilities of AI-

Table 2. Application Areas and Benefits of ChatGPT in Geomatics Engineering

Application Area	Benefits
Data Analysis and Interpretation	Analyzes large datasets quickly and accurately, extracting meaningful insights.
Automation of Routine Tasks	Automates repetitive tasks such as data entry, report generation, and documentation.
Communication and Collaboration	Drafts emails, generates reports, and summarizes technical documents, improving team communication and collaboration.
Training and Education	Provides interactive training for students and professionals, answering questions and offering guidance on best practices.
Technical Support	Offers instant technical support related to surveying equipment, software, and methodologies, resolving technical issues quickly and effectively.
Integration with GIS	Enhances GIS applications with real-time data analysis and visualization, integrating various data sources.
Remote Sensing and Image Analysis	Interprets satellite and aerial imagery, identifying patterns and generating insights for environmental monitoring and agricultural assessments.
Project Management	Tracks project progress, schedules tasks, coordinates team efforts, and assists in risk management and resource allocation, ensuring projects are completed on time and within budget.

driven data analysis and interpretation enable engineers to make more accurate and rapid decisions, enhancing the overall efficiency and precision of tasks such as topographic mapping and boundary delineation. The automation of routine tasks, such as data entry and report generation, significantly streamlines workflows and increases productivity. ChatGPT's abilities to improve communication and collaboration facilitate more effective teamwork and project execution. Additionally, its contributions to education and technical support help to elevate the knowledge and proficiency of both students and professionals, thereby minimizing operational disruptions. The integration with GIS and remote sensing data analysis further enhances capabilities in environmental monitoring and urban planning. Furthermore, ChatGPT's project management support ensures that projects are completed on time and within budget, ultimately fostering more efficient and effective project outcomes.

To fully leverage the advantages offered by ChatGPT, it is recommended that geomatics engineering educational programs incorporate courses on AI and data analysis. This will prepare future professionals to effectively utilize these technologies. Continuous updating and adaptation of AI systems to meet the evolving needs of the industry is crucial. Ensuring that AI systems are developed and used in accordance with data security and ethical standards will enhance user trust and sustainability. Strengthening collaborations between academic institutions and industry can expand the application scope of ChatGPT, enabling the discovery of new uses through joint research projects. Furthermore, incorporating user feedback to continuously improve the system will make it more user-friendly and effective.

Expanding the application areas of ChatGPT beyond data analysis and automation to include innovative project management, remote sensing, and GIS applications will foster more comprehensive and innovative solutions in geomatics engineering. Future research should explore the deeper integration of

ChatGPT with existing tools like GIS and remote sensing systems, enabling AI to interact more dynamically with multi-layered geographic data. Additionally, specialized AI models tailored to specific geomatics tasks, such as land use planning, topographic mapping, or boundary delineation, should be developed to optimize AI performance for these specific needs. Research into integrating ChatGPT with other emerging technologies, like drones and IoT sensors, could also unlock new potential in autonomous data collection and analysis. This could streamline fieldwork and reduce human error in data processing.

Moreover, enhancing the autonomy of AI in project management and decision support systems could improve resource optimization and provide real-time recommendations, particularly in large-scale infrastructure projects. AI systems like ChatGPT should continue to evolve through user feedback to ensure they adapt to the unique challenges of geomatics engineering tasks. Ethical and data security frameworks must also be strengthened to address concerns over privacy and responsible AI use. Finally, research into long-term impacts and cross-disciplinary collaboration, along with continuous professional development programs, will be crucial to equipping engineers with the skills necessary to maximize the potential of AI technologies in the field. By implementing these recommendations, geomatics engineering can fully harness the transformative power of ChatGPT and AI to drive more efficient, innovative, and sustainable practices.

Author contributions

Fatih Taktak: Conceptualization, Methodology, Software, Field study, Writing-Original draft preparation, Validation., Visualization, Investigation, Writing-Reviewing and Editing.

Conflicts of interest

The authors declare no conflicts of interest.

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Flight safety: Aspects to be considered in commercial fixed-wing UAV operations

A holistic summary of important criteria needed for safe and successful flights



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Abstract:

Flight safety has become the main concern in drone operations nowadays and encompasses a mindset that embraces the discipline to protect the public, possessions, and industry. This paper presents important considerations for flight safety that the operator (researcher, industry user, etc.) should know about and adhere to in guaranteeing safe and successful flights. Nevertheless, flight safety is mainly reliant on the knowledge and skills of the operator in respect of the following: regulations around UAVs, operational systems around equipment and flight parameters, piloting and/or commanding skills, and the ability to make sound judgments on external circumstances that may hinder safe operations. Furthermore, this article also shows that drone operations are not only measured by successfully placing a UAV in the air and capturing the images below it, but achieving flight safety, and thereby flight success.

1. Introduction

The increasing use of unmanned aerial vehicles (UAVs) offers a range of opportunities for the improved management of crops, forests, fisheries, and other natural resources. A UAV, an unmanned aerial vehicle, also known as a drone, is considered to be a component of an unmanned vehicle system (UAS); it is the remote-controlled aircraft operated from a ground control station but without a person on board (Kardasz and Doskocz, 2016). Nowadays, UAVs

are rapidly replacing conventional aerial photography and providing high spatial resolution aerial photos.

Among UAVs, fixed-wing drones have been at the forefront of the market since 2019. This is due to their long-term endurance, making them suitable for commercial and military applications and the long-range monitoring of large-scale agricultural field (Zhang and Kovacs, 2012). They are able to map larger areas, to carry out environmental/forestry surveys, and to fly beyond the visual line of sight (BVLOS) (Small Drone Market, 2018). However, one downside of the fixed-wing drone compared to the multi-rotor drones is their inability to hover in the air (Singhal *et al.*, 2018) and the higher procurement and maintenance costs that they incur (DroneDeploy, 2017a). Operating a fixed-wing aircraft is complex and requires high levels of training and skills to launch, fly, and land it smoothly (Chapman, 2016; Boon *et al.*, 2017). Unlike other drones, preparing fixed-wing aircraft for flights requires a series of preparatory checks and tests on the equipment itself which ultimately extend to the assessment of the mission area to ensure flight safety.

Flight safety has now become the focus of discussion in UAV flight operations (Chamola *et al.*, 2020). Flight safety refers to a mindset including awareness, safety, and self-discipline that will protect the involved people, aircraft, properties, jobs, and the industry. The basic risk associated with flight safety starts with a simple case of ignorance of the law and the unpreparedness of the operator as a result of a lack of proper training that

could lead to human errors (Wackwitz and Boedecker, 2015), the unfamiliarity of the user in terms of the equipment used, a lack of knowledge regarding proper maintenance (Hobbs and Herwitz, 2006), and the complexity of the operation, all of which are aggravated by the pressure to succeed (QuestUAV, 2017).

This review paper aims to support beginners or novice researchers, industry users, and/or drone business owners engaged in fixed-wing drone operations. The paper covers several topics, including laws and regulations (Section 2), equipment familiarization (Section 3), pre-flight preparation and planning (Section 4), flight operation (Section 5), post-flight measures (Section 6), and image processing and analysis, that must be considered to ensure safe flight operations and successful missions.

For the clarity of this paper, all UAVs or drones mentioned in the succeeding discussions refer to fixed-wing drones used for commercial purposes (e.g., for monitoring the infrastructure and for aerial imaging, but with the exception of those purposes mentioned in the laws and regulations (Section 2), or as specified, which may also be applicable to multi-rotor or hybrid drones.

2. Know the rules: the UAV operation regulations

Owing to the fast-growing UAV industry (Stöcker *et al.*, 2017; Prisznyák, 2018), UAV regulations are in place to ensure public safety (Dronenerds, n.d.). UAVs are the objects in airspace that could impose potential risks to other airspace users, as well as to third parties on the ground, including, but not limited to people, animals, and properties. Therefore, in order to control the process and reduce the potential risks, increasing numbers of countries are now imposing regulations on UAV operations (Chamola *et al.*, 2020; Stöcker *et al.*, 2017; Zhang *et al.*, 2018).

A comprehensive review by Stöcker *et al.* (2017) on the current scenarios of UAV

regulations, and accordingly, on the drafting of UAV regulations, focuses on three aspects, namely, : (1) regulating the use of airspace as UAVs could seriously endanger manned aircraft; (2) mandating operational limitations to guarantee appropriate flights; and (3) setting administrative procedures on granting flight permission, pilot licenses and on authorizing data collection flights. Furthermore, as shown in Table 1, the regulation of UAVs has been incorporated into six components, namely, applicability, technical requirements, operational limitations, administrative procedures, human resource requirements, and the implementation of ethical constraints.

Applicability defines the scope of the regulation related to the type, weight, and purpose of a UAV operation. Stöcker *et al.* (2017) compared the applicability regulations of 19 countries, including the United Kingdom, Australia, Malaysia, the United States, Canada, France, the Netherlands, Germany, Italy, Austria, Spain, Azerbaijan, Chile, Columbia, South Africa, Japan, Nigeria, Rwanda, and China. Fifteen (15) countries include the use of UAVs for recreation in their regulations, while the other four (4) include the use of UAVs for commercial flights only. A commercial flight is defined as a flight engendering profit. Furthermore, most countries impose constraints based on weight and associated risks, with heavier drones subject to stricter flight conditions. On the other hand, the United States and

Japan have introduced a minimum weight threshold in their regulations: in fact, all drones below the threshold are not subject to their regulations (Hermann and Markert, 2020). Similarly, some countries include the maximum take-off mass, above which drones are controlled in terms of the regulations for manned aircraft (European Aviation Safety Agency, 2015).

Technical requirements cover the necessary instruments and sensors that are included in drones, such as, amongst others, their collision-avoidance mechanisms, blade materials, GPS/GNSS devices, command and control requirements, autopilot systems, and recovery capabilities.

The integration of collision-avoidance capabilities in UAVs is widely discussed (Yu and Zhang, 2015), although the U.S. has not yet incorporated these into their regulations, as the technology is still young and no instruments have been issued with airworthiness certification (Federal Aviation Administration, 2016). Some countries focus on specific requirements, while others prioritize the command and control system and the special safety instruments that allow flights to be terminated in case of malfunctioning or the loss of command and control links (Stöcker *et al.*, 2017). Therefore, it is important to consider a specific country's minimum technical requirements when purchasing UAVs to avoid issues when licensing them for commercial use.

Table 1. A summary of UAV regulation (Shrestha *et al.*, 2019).

Criteria	Factors
Applicability	Regulations regarding the UAVs, their type, weight, and purpose of operation
Technical Requirements	Regulations that focus on the necessary instruments and sensors, such as avoidance mechanisms, blade materials, GPS/GNSS devices, command and control requirements, autopilots, and recovery capabilities. Regulations on the command and control system and the special instrumentation to deal with failure and safety.
Operational Limitations	Regulations on the operational limitations such as the no-fly zone, maximum flight altitude, Visual Line of Sight (VLOS) and Beyond Visual Line of Sight (BVLOS).
Administrative Procedures	Regulations on UAV registration (platform and devices), flight permission and insurance policies.
Human Resource Requirements	Regulations on the qualifications of the operators to operate a UAV (e.g., practical training, theoretical knowledge testing, aeronautical tests and medical assessments).
Ethical Constraints	Regulations on data protection, privacy and data-sharing policies.

Operational limitations are the most common criteria constituting the UAV regulations, which cover flight restrictions (Shrestha *et al.*, 2019; Stöcker *et al.*, 2017; Tsiamis *et al.*, 2019). Operational limitation parameters include the allowable distance to conduct a UAV flight from an airport/landing strip or aerodrome; limitations on their operation over a populous area, over a restricted area (i.e. controlled airspace, military camps, hospitals, and nuclear power plants); the maximum flight altitude, and Visual Line of Sight (VLOS) and Beyond Visual Line of Sight (BVLOS). The horizontal flight distance, where a flight is not permitted to invade the space accommodating people, property or an airport/landing strip, is called a no-fly zone. The common UAV regulations prohibit flying within a 30 to 150m radius of people and within a five-kilometre radius of an airport/landing strip and aerodrome. This regulation is due to the potential danger posed to people and manned aircraft which are taking off or landing. The maximum flight altitude (above ground level) is within a maximum range of 90 to 152m (Stöcker *et al.*, 2017). The horizontal distance between the operator and the UAV could be either VLOS or BVLOS. In VLOS conditions, the operators are able to visually monitor the UAV with their own eyes (International Civil Aviation Organization, 2015), while BVLOS conditions refer to the situations in which the UAV is beyond the operator's visual range but still within the range of remote control (South African Civil Aviation Authority, 2017). Some are countries allowing only VLOS, while others permit BVLOS flights under special flight conditions or via exceptional flight approval conditions (Stöcker *et al.*, 2017).

Administrative procedures impose the need to obtain flight permission, for UAV registration, and for insurance. Generally, the level of effort in applying for permission to fly depends on the complicated nature/difficulty of a UAV operation. Owing to different UAV operations, each application procedure is multi-layered and may be within different contexts. Some countries do not require an application procedure for UAVs above

the maximum take-off weight (MTOW), while others require registration for every single flight. Similarly, in the case of the national and/or local authorities, flight permission is a common practice in most countries. The approval of the landowner on whose property the UAV is about to take-off is also obligatory (Shrestha *et al.*, 2019; Stöcker *et al.*, 2017). As reported by Stöcker *et al.* (2017), insurance registration is required in most countries. Any damage or harm caused through the flight operation is borne by the insurance provider; thus, the insurance company should have the capacity to compensate the affected parties for possible damages in the case of accidents (Boucher, 2015).

Human resource requirements govern the regulations for the qualification of pilots and their license to operate a UAV (Shrestha *et al.*, 2019; Stöcker *et al.*, 2017). The most common requirement for a UAV pilot is practical training, theoretical knowledge tests, aeronautical tests, and a medical assessment. Japan does not require UAV pilots to hold an aviation license, while other countries, such as the UK and Germany, request only basic competencies for the affirmation of UAV pilots (Masterlist of Drone Laws (organized by State and Country, n.d.)). Likewise, most countries demand a pilot license or certification, especially when commercial flights are conducted (Stopforth, 2017). Nevertheless, UAV operations in Malaysia require two persons (a pilot and a commander), with both holding a valid pilot license (Department of Civil Aviation, Malaysia, 2017).

Owing to the increasing use of UAVs, privacy and data security are currently topics of discussion. Ethical constraints are an important component of UAV regulation since they deal with data protection and privacy. UAVs can be fitted with a variety of payloads, including cameras that can capture and record data on individuals, houses, buildings, and other objects that potentially breach people's privacy and data security (Shrestha *et al.*, 2019; Stöcker *et al.*, 2017). Despite the value of ethical restrictions, very few countries have integrated them into their UAV regulations. Instead, most urge UAV

operators to respect personal privacy, while others refer directly to their respective privacy laws (Stöcker *et al.*, 2017).

Failure to comply with UAV regulations is subject to legislation and penalties which depend on the policies of each country. Many countries issue a warning letter for minor offences, while others may enforce the suspension or revocation of a pilot license or certificate, impose civil penalties (fees), and even incarceration for felony offences, or a combination of these (Broadley, 2016; Wagstaff, 2015; LIDARNews, 2019).

3. Familiarize yourself with your drone: the first step for a safe flight

It takes a lot of time and effort, more than what is expected, to achieve success (QuestUAV, 2017). This involves continuously improving the operators' skills, their mastery of the UAV parts and functions, and their gaining in experience through every flight. Operator skills must, of necessity, be upgraded; continuous training, flight experience, and sharing in the knowledge of other operators can increase insights into the system (Easy Access Rules for Unmanned Aircraft Systems, 2021; O'Shea, 2020). For example, launching skills may differ depending on the type of drone. The proper posture and timing of release should be developed for bungee-launched fixed-wing drones (Shyu and Hsiao, 2014), while an accurate pitch should be observed in a hand-launched fixed-wing drone. In terms of landing, manually operated and/or parachute-landed drones require sufficient training and practice for an ideal landing approach and the correct timing for parachute release, respectively. For fixed-wing drones with autonomous landing equipment, continuous insights into proper planning for the landing site are necessary, especially in locations with undulating terrain. O'Shea (2020) stated that reaching out to the drone community and sharing professional experiences are important aspects in creating a positive safety culture in drone operation.

Typically, a fixed-wing UAV airframe includes the avionics system, main body (frame), motor, propeller and batteries, payloads, and wings, each with an aileron¹ and a wing tip (González-Jorge *et al.* 2017). There are several UAV manufacturers that integrate the ailerons and wing tips into the wing structure. They include senseFly, Hitec Commercial Solutions, DellAir, and Skywalker Drone Solutions LLC Company, to mention a few. Each UAV component has a specific mode of maintenance that could be either corrective or preventive, and the activities might be critical and time-consuming. The former mode of maintenance involves the repair or replacement of parts as a result of wear-and-tear or damage, while the latter involves inspection or the replacement of parts at predetermined intervals (Hobbs and Herwitz, 2006).

The UAV operating limitations must be known to the operator (Sims, n.d.). Operating limitations are any circumstances or inherent characteristics of UAV sensors or electronics that will hinder operations, including, but not limited to the flight crew, operating tolerance (in respect of weather conditions, wind, air temperature), and take-off and landing locations. In some instances, a two-man policy, with a pilot and a commander to operate the fixed-wing UAV unit, is recommended (Aeronautical Information Services Malaysia, 2008), each with specific functions for the success of the flight. Operating tolerance is another important factor (Liu *et al.*, 2021). Each type of UAV has its own upper and lower limits to deal with the wind and air temperature within which the UAV can be operated. Gao *et al.* (2021) state that operating outside the recommended weather operating tolerances is highly prohibited as it will damage the equipment. Thus, it is necessary to check with the manufacturer what the operating tolerances of the drone are before engaging in an actual flight. Furthermore, air temperature directly affects the performance of the UAV electronics, which may lead to systemic glitches and cause sudden malfunctions

in the UAV system. Typically, take-offs and landings require a large open space and flat land to facilitate the launching and recovery of the UAV after aerial imaging (Knoops, 2018). Fixed-wing UAVs have several ways of taking off, including those involving a bungee cord, a launch trail, those executed manually (by hand), and a combination of all three. On the other hand, the landing could be a belly landing or by parachute (McEvoy *et al.*, 2016). For the belly landings, grassy fields free of any obstructions, such as big stones or tree stumps, are necessary (Knoops, 2018).

The Ground Control Station (GCS) is a vital element in UAV flights. It allows for monitoring at high altitudes while the operator is on the ground (Vasile *et al.*, 2019). The GCS transmits guiding and payload commands and receives information on the flight status (e.g. location, altitude, velocity, direction) and the mission payload. For fixed-wing UAVs, this usually involves a laptop installed with a mission planner (Singhal *et al.*, 2018; Pepe *et al.*, 2018). The flight parameters, including failsafe behaviour, are programmed in the mission planner before they are uploaded to the UAV autopilot. Therefore, in-depth and detailed training on the mission planner software is very important, as any missed settings will jeopardize the safety of a flight operation (Singhal *et al.*, 2018).

4. Pre-flight preparation and planning and their importance

Pre-flight planning and preparation play an importance role in the safe and successful aerial imaging campaign (UAV Technology, n.d.; Zhang *et al.*, 2018). Pre-flight preparation and planning include a safety risk assessments; evaluations of the weather forecast, ideal flying time, the number of ground control points (GCP's), and equipment; material checks; and flight crew orientation.

In this article, safety risk assessment is defined as the physical and remote evaluation of the area to be flown to identify operational safety hazards

(Wackwitz and Boedecker, 2015). With knowledge regarding the mission area, the risk assessment should be carried out a day before each scheduled flight (QuestUAV, 2017). During the risk assessment stage, the area is examined for possible risks to the flight crew, equipment, and the inhabitants in the vicinity (Shawky, 2022). Flight crew security should be ensured, especially in those areas that are inhabited but unfamiliar to the crew. Upon seeing an UAV in the air, people may think that they are under surveillance and that their privacy is being threatened (Kardasz and Doskocz, 2016). Proper coordination with local officials before scheduled flights should, therefore, address this matter. The purpose should be explained, and those areas that the imaging may possibly cover should be disclosed. With this, the officials may inform the community not to be anxious when seeing a UAV passing over their respective areas or houses. Similarly, possible obstructions to the operator's good visual length of sight (VLOS), such as tall trees, buildings, the topography, and power lines, must be accounted for. Figure 1 shows the effects of obstructing the VLOS. As the operator approaches an obstruction, their perspective of the scene would be larger and might even block their visibility of the UAV during flight (Mejias *et al.*, 2021).

Furthermore, the proper selection of a GCS location is necessary. The GCS must be within or outside the mission area. For larger fields, it is recommended that the GCS location be established in the middle of afield (UAV Technology, n.d.). The location must be free of VLOS obstructions and have enough space for take-offs and landings. To better understand the vicinity of the mission area, Google Earth could help as it can show the topography of the area and the possible dead spots (Tahar *et al.*, 2012; Sims n.d.).

Weather is one of the major challenges that a UAV mission may face (Pepe *et al.* 2018; Tmušić *et al.* 2020). Important weather parameters in UAV operations are the probability of rainfall; wind speed and direction, cloud cover, and air temperature. Rainfall is one of the major hindrances

to UAV operations, as many UAVs are highly sensitive to water, and exposure to rain can damage the unit. Rainwater can also degrade the control link, while visibility difficulties might be experienced by the observer (National Civil Aviation Agency, 2018). Flying in strong winds, especially above the wind speed limit, may cause problems with navigation since the UAV may lose strength in order to overcome wind resistance or to quickly attain a higher speed (Dronegenuity, n.d.; National Civil Aviation Agency, 2018; Wang *et al.*, 2020). Similarly, high winds increase the flight duration and cause poor image quality (DroneDeploy, 2017b). Strong winds may also result in excessive shaking and will cause image blurring (Fernández-Guisuraga *et al.*, 2018). On the other hand, cloud cover may not affect the performance of the UAV but may affect the data it captures (Pepe *et al.*, 2018). MicaSense (n.d.) state that rolling clouds may cause deep shadows and significantly affect the results when a multispectral camera is used. Monitoring air temperature is essential to ensure that the UAVs are still within the operating limitations of the equipment's prescribed temperature.

The purpose of an aerial imagery campaign defines the parameters during pre-flight planning and should primarily be established to ensure the quality of the data gathered. This will determine the type of sensor to be used (RGB,

multispectral-, or hyperspectral-camera) and characterize the flight parameters, such as flight altitude, ground sampling distance, flight duration, flight pattern, and image overlap during the pre-flight planning stage (Ruzgiene, 2012). Flight parameters are variable but interrelated. For instance, with the same mission area and image overlap, an increasing flight altitude will, as a result of an increase in the coverage of the area per image taken, reduce both the resolution of the image (Pavelka *et al.*, 2018) and the duration of the flight (Mesas-Carrascosa *et al.*, 2015; Seifert *et al.*, 2019; Torres-Sánchez *et al.*, 2013). In the same way, an increase in the mission area and/or image overlap at the same flight altitude will concurrently increase the flight duration (Tidula *et al.*, 2020). Image overlap deals with the forward and side laps (Mesas-Carrascosa *et al.*, 2015). Forward overlap (forward lap) indicates the percentage of recurring views in two images in the direction that the UAV takes, while the side overlap (side lap) represents the overlap between two or more images on the adjacent track. A higher side lap, combined with a higher forward lap, increases the detail of the image reconstruction (Seifert *et al.*, 2019). As reported by Seifert *et al.* (2019) and Domingo *et al.* (2019), forward lap at >90% and side lap at 70% proved to be the most efficient with respect to flight time, coverage area, and processing time. The combination of flight altitude and

image overlap has different effects on the duration of the flight. A decreasing flight altitude involving the same image overlap increases the flight duration enormously (Seifert *et al.*, 2019), as does an increasing image overlap in conjunction with a constant flight altitude. Mission area lay-out (Knoops, 2018) and wind direction (Tmušić *et al.*, 2020) influence the flight pattern and may either increase or reduce the duration of the flight (Mesas-Carrascosa *et al.*, 2015). Ideally, for better fixed-wing stability while capturing images, the flight pattern should be perpendicular to the wind direction (Tidula *et al.*, 2020). For elaboration:

- if the wind direction is parallel to the longer side of the field, the flight pattern should be parallel to the shorter side of the field. However, owing to an increase in flight lines, such a set-up will increase the duration of the flight but lessen the negative effect of the wind on both the unit and the images captured. A flight line is a single strip that represents the path of a UAV while it is travelling in the air and taking images of phenomena on the surface of the Earth below (Ruzgiene, 2012). Considering the subtle wind, the flight pattern would in any case be ideal. The best practice is to set the flight pattern parallel to the longer side, thereby lowering the flight line and reducing the duration of the flight. When planning for areal coverage, a 10% security margin is recommended to maximize the spatial resolution (Mesas-Carrascosa *et al.*, 2015). A further consideration is that the duration of the flight should be limited to the battery of the UAV. Therefore, a large area should be divided into smaller areal components to accommodate several flights. This would be advisable when the amount of electricity required in the battery of a UAV is considered in order to ensure that it will land safely.

The ideal time to conduct aerial imaging is still unclear. Generally, best results are attained when the declination of the sun is greater than 30°. However, this recommendation is not always valid (Pepe *et al.*, 2018). Likewise, UAV Technology (n.d.) mentions that aerial imaging between 9:00 am and 11:00 am

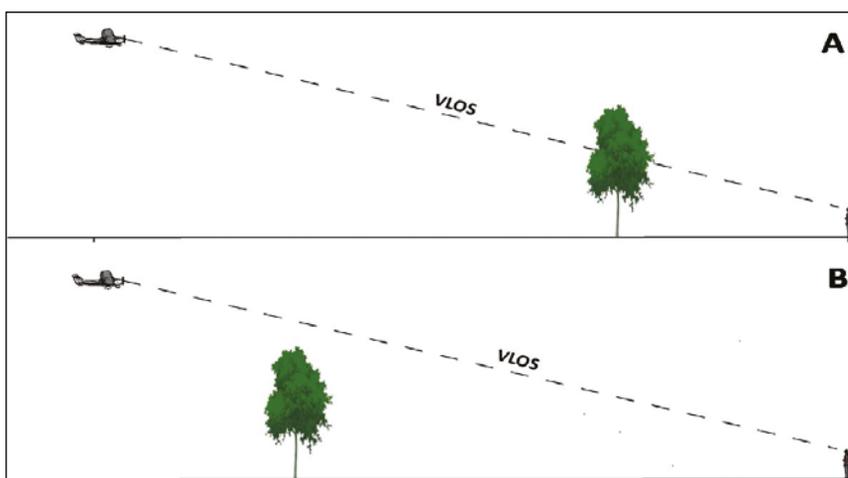


Figure 1. The observer's visual-line-of-sight (VLOS), as affected by the obstruction: (a) the obstruction is closer to the observer, (b) the distance between the obstruction and the observer is enough to satisfy the VLOS. The diagram shows that as the observer approaches the obstruction, the larger the perspective that it will create becomes. Visibility on the UAV will then be blocked.

is recommended in areas experiencing high temperatures (e.g., Mali and Northern Nigeria in West Africa), since high temperatures may cause the over-heating of the camera and/or the unit. Tidula *et al.* (2020) state that early to mid-morning and mid to late afternoon are the best times for aerial imaging in terms of the Mindanao, Philippines, setting. These periods give warmer light, very good views of the landscape (Sims, n.d.; Yeager, 2017) and the air over them is calmer. There are, however, places which experience strong winds and increased cloud cover in the afternoon, which makes early morning the ideal time for good imaging. Additionally, it should be noted that owing to specular reflectance from the land surface and other land cover types, flying at solar noon should be avoided (UAV Technology, n.d.).

The number of ground control points (GCPs) to be installed during a UAV flight should be identified. GCPs are marked on the ground in terms of the known geographic location and elevation both of which are used to calibrate the global accuracy of the captured images. A GCP could be a permanent mark, structure, or any object that can be set up by the operator before a flight and that would remain visible in an image at a desired flight altitude. Ideally, white clothes, jute sack, or a tarpaulin with a dimension of at least 1x1m are ideal up to a flight altitude of 121m. The distribution of GCPs, contributes to the accuracy of a project (Aerotas, n.d.). It should be carried out in such a way that the mission area is covered. For example, to ensure a good geometric correction in the distribution of five (5) GCPs, there would be one at each corner of the field and one in the middle (UAV technology, n.d.). The minimum number in the case of GCP image processing is three (3), but it is highly recommended to set up more ground control points (Oniga *et al.*, 2018). On testing three (3) to 40 GCPs in a one-hectare mission area, the Oniga *et al.* (2018) result showed that one GCP/200m² is necessary to attain high-quality results in the final product. Likewise, Tahar (2013) tested four to nine (4-9) GCPs in a 1.5km² (150ha) mission area. Their

finding showed that their eight (8) and nine (9) GCPs recorded good results in RMSE for the Easting and Northing coordinates. The results of the studies by Oniga *et al.* (2013) and Tahar (2013) signify that as the number of GCPs increases, so the final product obtained tends to be more accurate. Somehow, the accuracy of the GCP method is also affected by the Global Positioning System (GPS) used in capturing the coordinates. If applicable, a Real-time Kinematic/Post-processing Kinematic (RTK/PPK) GPS receiver must be used to capture the ground data of the GCPs. If possible, the GCPs should be laid out a day before the scheduled flight mission.

The preparation of the equipment and materials needed must be carried out a day before the scheduled flight. Preparation activity includes charging the UAVs, GCS/ laptops - and the transmitter batteries. The UAV airframe should be thoroughly inspected for any damage and if any, repairs should be carried out before conducting a flight. Furthermore, the free space on the UAV- and camera memory card should be verified to confirm whether it is still adequate for the imaging process. A list should be compiled to facilitate the packing of the systemic materials and equipment to the effect that no materials and equipment are overlooked (e.g., leaving SD cards behind² in a base station kilometres from the mission area).

The flight team could include a two-crew or three-crew setup. The additional crew member apart from the pilot and commander is known as the spotter. A pre-operational briefing should be conducted. This would include an overview of the mission, the role of each crew member, possible risks, and risk control measures. This can be carried out by any member of the team who should have a wide knowledge of the operation (Standard Operating Procedures Unmanned Aerial Vehicles, 2019).

5. Aerial imagery campaign

A systematic method in aerial imagery campaigns contributes largely to safe

and successful flight activities. Actual aerial imaging is the litmus test for the effectiveness of the pre-flight preparation. The flight crew should be mentally and physically prepared to make immediate decisions and to take appropriate action during these activities.

Generally, an aerial imaging campaign begins with an assessment of the area and the weather conditions. Any minor deviations identified during the prior risk assessment stage should be addressed properly (e.g. large crowds, the presence of farm equipment) to ensure that no one would be harmed in the case of a mishap. The wind speed should be measured using a wind meter to determine its suitability for imaging, and based on the UAV operating limitations, and without compromising the quality of the images. Should all be well, the imagery will be pursued; if not, the mission should be aborted.

Under favourable conditions, the flight crew should establish themselves at the selected GCS location that was chosen during the risk assessment stage (discussed in Section 4). This should be followed by preparations in respect of the equipment and the mission area. The GCPs should be laid out or checked, depending on whether this was done during the risk assessment stage by either the pilot or the spotter. In the case of bungee cord launching, either the pilot or the spotter, who remain at the GCS, will assemble the drone and install the launch line. Ideally, take-off should be against the wind to help the drone gain height through lift (Dronegenuity, n.d.; Quantum System, 2021). The commander should check for any possible changes in the flight parameters, especially for launching and landing in the case of a fully autonomous flight. The flight track should be reoriented, depending on the actual wind direction in the area. The recommended flight track should be perpendicular to the wind direction (McEvoy *et al.*, 2016; UAV Technology, n.d.). Pre-flight and pre-takeoff checks should be carefully followed before takeoff to ensure that all UAV components are functional (Allouch *et al.*, 2019; Standard Operating Procedures Unmanned Aerial

Vehicles, 2019). If any problems occur, the flight mission should not be pursued unless the observed problem has been resolved.

During a flight, each team member should focus on their specific functions. The pilot is responsible for the transmission /remote control of the UAV (a semi-autonomous drone) and should keep an eye on the UAV throughout the flight. The commander is in charge of the flight computer, gives up-to-date information to the pilot about the status of the UAV, and takes note of the observed behaviour of the drone, based on the observations of the mission planner and the pilot. In the presence of the spotter, they must assist the pilot and keep an eye on the UAV while it is in the air. The real-time monitoring of the link quality of the UAV and the GCS should be carried out, especially in cases of link degradation. Nevertheless, most automatic UAVs can operate autonomously in a safe manner, even in the case of link loss. In fact, they tend to finish the set flight plan without depending on the GCS (Allouch *et al.*, 2019). Throughout the entire flight duration, each of the team members should be vigilant in respect of abrupt changes to wind speed and direction, since as a result of its light weight and small size, sudden changes in wind speed and direction will negatively affect the behaviour of the drone (Wang *et al.*, 2019). A change in wind behaviour can be easily noticed through the movements of shrubs or trees in the surroundings. As shown in the mission planner, some UAVs have sensors that detect wind speed at their current flight altitude, while others do not. For the latter case, the wind strength at 121m (400ft) can be estimated to be double that of the wind speed at ground level (QuestUAV, 2017). Additionally, a strong wind may increase the duration of a flight and easily drain the UAV battery. For safe landing, only 80% of battery utilization should be allowed; the UAV should then be landed. This will help to prolong the battery life (UAV Technology, n.d.).

Landing the UAV is a very challenging aspect of drone operation, particularly in the case of semi-autonomous or manually-controlled fixed-wing drones. In full autonomy, or with no human intervention,

the drone will land according to the programmed path and location (Albeaino *et al.*, 2019). The UAV has the capability to regulate speed by reducing the available power and navigating through its autopilot towards the programmed landing direction and location. On the other hand, for manually controlled or semi-autonomous drones, the pilot is responsible for overseeing the landing of the UAV. The landing could be either a 'belly' or parachute landing, but both require skills and confidence since any control via the transmitter that is incorrect could lead to a bad or hard landing that will seriously damage the drone.

During retrieval, the UAV battery should be immediately disconnected, especially for manually controlled or semi-autonomous drones. The reason behind this is that in the case of a person unintentionally pressing the transmission throttle bar, the motor will power up and pose a danger to those around the drone. The spinning propeller may cut anything, including human skin. Furthermore, the crew should inspect the drone before returning to the location of the GPS. This would be to facilitate retrieval in case some parts might have detached during the hard landing. All defects found should be recorded upon the completion of imaging and should be addressed prior to the next operation.

6. Post-flight

Post-flight activities include post-flight debriefing and UAV maintenance. The team should conduct post-flight debriefing to discuss the flight outcomes, including any unusual circumstances that might have affected the safety of the flight. The log files prove useful in analysing the reasons for these occurrences and in developing measures to prevent their recurrence in the future (Allouch *et al.*, 2019). For example, during a flight, sudden changes in wind direction and speed, link loss, and unusual altitude drops might be observed. When the wind strengthens, it will be more difficult for the drone to move through the atmosphere which will increase the required flight time drastically (DeltaQuad

Operation Manual, n.d.; Mesas-Carrascosa *et al.*, 2015) and affect the quality of the captured images. In this case, the sound judgments of the flight crew, especially the pilot, are important, especially in cases where an emergency landing – due to the wind – is necessary. If unusual issues (e.g., an unexpected drop in altitude or frequent losses in connection, or even a malfunction of some sensors, thereby demanding corrective maintenance) occur, the flight must be aborted and the issue resolved before the next flight. .

UAV maintenance includes UAV checking, cleaning, repairs, and software updates. A post-flight maintenance checklist should be established to ensure that all required activities are carried out in an orderly manner and not skipped (Standard Operating Procedures Unmanned Aerial Vehicles, 2019). The maintenance logbook serves to document previous repairs and to easily identify parts that need to be replaced. This allows damage from previous flights to be easily traced and addressed prior to the next operation in order to ensure safe and successful flights. UAV maintenance is therefore always an integral part of the process for achieving flight safety and ensuring the longevity of the equipment. If necessary, the mission planner software should be updated immediately. Typically, a notification will appear on the mission planner interface that requires the system to be updated, as some systems do not allow the UAV to be flown with outdated flight-planning software.

7. Image processing and analysis

Image stitching can be achieved using image processing software. There are numerous software options, including Agisoft PhotoScan, Pix4D Mapper, Imagine UAV, and Drone Mapper, available, but they are not free (Legka and Aleksy, 2018). These software packages are typically able to process RGB, NIR, and multi-spectral images, to construct orthophotos, to build 3D-models, and to generate detailed elevation maps. However, each software differs in terms of some of its

specific functions. For example, unlike other software, Pix4Dmapper can support video and 360° image processing, while Agisoft PhotoScan can handle non-geo objects. The choice of image processing software should depend on the user's project needs, rather than merely on the processing of the captured UAV images.

Image processing requires a wide range of computational resources, which increase exponentially as more images are concurrently processed (Fernández-Guisuraga *et al.*, 2018). Therefore, investments in software should be accompanied by the appropriate hardware. For instance, a computer with a 2.93GHz processor, 48GB RAM, and a 1TB Memory, installed with Pix4DMapper, can process 2000 images in 12-15 hours without any software malfunctions, provided that the machine is dedicated solely to image processing (Tidula *et al.*, 2020).

Image analysis is usually performed after processing. It uses Geographic Information System (GIS) software to open and analyse stitched images. Several GIS applications are available, providing either an open-source or a paid license to users. The most popular open-source GIS software is Quantum Geographic Information System (QGIS), while ArcGIS is the most widely used paid license. The World Health Organization (WHO) (2018) compared several open-source GIS programmes to ArcGIS and found that QGIS is on par with it in terms of supported operating systems, GUI friendliness, cartography, supported data formats, data manipulation and analysis, and integration with other open-source GIS frameworks, base maps, scripting, training sources, and technical support. While ArcGIS supports better statistical analysis functions, QGIS outperforms it in terms of integration with the other open-source GIS platforms. The functionality of the GIS programme is affected by the computer resource, with at least 8GB RAMs but preferably 16GBs, or higher, and a minimum CPU speed of 2.2GHz required for optimal performance. Insufficient hardware configuration can cause GIS software to hang or crash when large GIS datasets are processed (Dempsey, 2013).

8. Conclusion

The use of fixed-wing drones has been increasing over recent years. To the best of our knowledge, this paper is the first to provide a holistic summary of important criteria needed for safe and successful flights. As discussed in this paper, primary factors for successful aerial imageries include obedience to UAV regulations, equipment familiarization, and pre-flight preparation. The post-flight maintenance ensures the longevity of the equipment and addresses any unusual issues that may compromise the safety of future flights. Moreover, post-flight maintenance provides opportunities for operators to improve their familiarity with the associated systems.

The quality of captured images can be affected by various factors, such as the time of day that they were taken, image overlap, wind speed, and the type of sensor used. Furthermore, the quality of the stitch images (orthomosaics) produced is largely dependent on both the quality of the individual images and the processing software used. Additionally, the functionality of the processing software is highly dependent on the available processing resource, since image processing involves a significant amount of computation that grows exponentially with the number of images being processed. Therefore, investing in fixed-wing drones requires adequate investment in both software and hardware to ensure that high-quality products can be produced.

Endnotes

¹ An aileron is a crucial part of an aircraft's flight control system – a device on the wing – that allows pilots to control the aircraft's orientation and movement (Lee, 2025)

² The time spent or wasted in accessing a SD card must be enough for the flight mission to be completed, especially at a location where the window of time for ideal imaging is minimal.

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Bharat-VISTAAR'-a multilingual AI tool

The Union budget of India proposes 'Bharat-VISTAAR' (Virtually Integrated System to Access Agricultural Resources) - a multilingual AI tool that shall integrate the AgriStack portals and the ICAR package on agricultural practices with AI systems. Bharat-VISTAAR is expected to

- Enhance farm productivity through scientific, data-backed advisory.
- Improve farmer decision-making by offering personalised and timely information.
- Reduce production risks by predicting and managing climate, pest, and market uncertainties.
- Promote technology adoption in small and marginal farming.
- Strengthen last-mile service delivery, bridging the gap between agricultural research and farm practices. <https://vistaar.da.gov.in>

Space technology to support different national initiatives in India

The Department of Fisheries with the technology developed by ISRO using NavIC and communication satellite has rolled out the Vessel Communication and Support System (VCSS) project under PMMSY to provide safety-of-life and disaster alerts to fishermen. This project is implemented in coastal states including West Bengal. BharatNet Programme also aims to provide broadband connectivity to Gram Panchayats. ISRO's Bhuvan Geoportal provides online services of remote sensing data, thematic maps and geotagging support, facilitating rural planning in line with Digital India needs. Towards agricultural monitoring, Jute Crop Information System is developed to address crop acreage, surveillance of crop condition and production estimate using geospatial approach. Production forecast for Potato, an important cash crop in West Bengal and Crop Area Estimation for Groundnuts is done through remote sensing based methods. Bangla Shasya Bima Scheme, a crop insurance mechanism involving geospatial approach is implemented in association with private insurance provider and technology partner. www.pib.gov.in ▽

White-label CAD solution in Japan

Pythagoras BV and Terra Drone have formed a strategic partnership to introduce a customized white-label software solution for the Japanese market. It combines Terra Drone's SLAM and UAV technologies with Pythagoras' CAD and point cloud processing software, creating an integrated platform tailored to Japanese surveying, engineering and construction workflows. www.pythagoras.net

UWB-based local positioning for UAVs

Belgium company Agilica is offering a GNSS-independent onboard positioning system using ultra-wideband (UWB) technology. The system enables precise, autonomous drone navigation and landing, even in dynamic, GNSS-denied environments or on moving targets. www.agilica.be

UAV Navigation and Ekolot collaboration

UAV Navigation-Grupo Oesia will collaborate with Ekolot Aerospace and Defense (EAD) to integrate its advanced flight control system into Zeus, Ekolot's new fixed-wing vertical take-off and landing (VTOL) platform.

The collaboration brings together UAV Navigation's guidance, navigation and control solutions with Ekolot's vision to create a new generation of VTOL aircraft. www.uavnavigation.com

UAE extends Emirates Mars Mission until 2028

The United Arab Emirates (UAE) Space Agency has announced the extension of the Emirates Mars Mission (EMM) until 2028. The mission, carried out by the Hope Probe, was originally launched as a two-year project and entered Mars' orbit in 2021. The extension seeks to maximize the scientific return on the UAE's space investments and gain valuable operational experience

for future deep-space missions. Since its arrival at Mars, the Hope Probe has gathered around 10 terabytes of data, shared in 16 datasets with over 200 global research institutions. The mission has also supported pioneering discoveries, including new observations of Mars' auroral activity and close flybys of Deimos, the smaller outer moon of Mars. <https://english.news.cn>

South Korean technology boosts 4iG's landmark satellite program

South Korean company TelePIX will equip future Hungarian satellites with state-of-the-art camera and sensor systems. Following a multi-stage selection process, Remred, a subsidiary of 4iG Space and Defense Technologies Ltd. (4iG SDT), has selected the South Korean company as the supplier for the camera systems for the HULEO satellites. Under the contract, TelePIX will manufacture camera and sensor sets for HULEO electro-optical satellites that are capable of producing VHR (very high resolution) images for Earth observation tasks and data collection. <https://hungarytoday.hu>

First in-orbit Test of ATLAS-1 laser terminals

Astrolight is set to demonstrate its low-SWaP ATLAS-1 laser communication terminals in space for the first time. The terminals will enable secure, high-bandwidth space-to-ground communication on two satellites, each carrying ATLAS-1, scheduled for launch this March aboard SpaceX's Transporter-16. The satellites support two separate missions coordinated by Astrolight's clients: the National Kapodistrian University of Athens and the Aristotle University of Thessaloniki in Greece.

As laser communication uses narrow, focused beams of infrared light, it can transmit data at up to 100 times faster rates than traditional radio frequency (RF) and is immune to electronic interference. 

UK invests in satellite timing to boost national PNT resilience

GMV is leading the development of a secure two-way satellite time and frequency transfer system under the European Space Agency's TOUCAN Project - the two-way satellite time and frequency transfer capability demonstration (TWSTFT).

The initiative safeguards critical infrastructure by reducing reliance on GNSS and enhancing national positioning, navigation and timing (PNT) capabilities. Funded by the UK Space Agency, the project is an important part of the UK Government's Framework for Greater PNT Resilience. www.gmv.com

SES extends EGNOS GEO-1 satellite service to power precise navigation

SES, a space solutions company, and the European Union Agency for the Space Programme (EUSPA) have announced an extension of the European Geostationary Navigation Overlay Service (EGNOS) GEO-1 satellite service agreement through 2030, with an option to extend until 2032.

By improving the accuracy and integrity of satellite positioning signals, EGNOS supports aircraft in landing in low-visibility conditions, as well as planning more efficient routes, reducing fuel burn and CO₂ emissions. www.ses.com

Pak-SBAS navigation system

Pakistan's national space agency SUPARCO (Space and Upper Atmosphere Research Commission) has announced successful launch of its Pak-SBAS satellite-based augmentation system (SBAS) device and service.

The service was rigorously tested in the extreme desert conditions of Cholistan during Cholistan Desert Rally 2026. The Cholistan desert experiences high speeds, unpredictable routes, and the absence of visual landmarks that demand exceptional positioning accuracy and signal reliability for autos and motorcycles. The system also will benefit the surveying

and mapping sectors by minimizing positional inaccuracies and reducing project costs. <https://suparco.gov.pk>

BeiDou-based short messaging service

China has launched a short messaging service leveraging BeiDou (BDS) to provide reliable communication during emergencies when ground-based mobile networks are unavailable. The service is to be a supplement to terrestrial mobile networks, expected to enhance safety and communication reliability for users across scenarios such as hiking in remote mountains, working at sea etc. China's three primary telecom operators — China Mobile, China Telecom and China Unicom — have all integrated the service. <https://english.news.cn>

Shipping industry receives guidance on GNSS-denied navigation

The International Chamber of Shipping (ICS) and its members have produced an informational poster for ship crews that highlights strategies when GNSS signals are jammed or denied. The Navigating in Areas of Unreliable Satellite Signals poster is available for free on the ICS website.

This reliance on GNSS, however, has created a growing vulnerability. Incidents of GPS jamming and spoofing, once a military concern, now increasingly affect merchant ships at sea and near ports. www.ics-shipping.org

European PAVE-SCAN project

The European Union PAVE-SCAN project aims to build European GNSS-based and AI-driven technologies to detect and assess roadway pavement problems. The proposed project aims for the development to market (TRL8-9) of European GNSS-based integrated low-cost sensor technologies and artificial-intelligence-driven open-architecture software solution — machine learning (ML) and machine vision (MV) — for the detection, classification and georeferencing of roadway pavement surface anomalies, and for the low-cost assessment of roadway pavements using participatory sensing.

The proposed system is of practical importance because it provides continuous information about roadway pavement surface anomalies — valuable for efficiently monitoring the transport infrastructure and for public safety. The vision for roadway condition assessment using smartphone-like technology is under the hypothesis that such technology can be used for crowd-sourced data collection and analysis in GIS-based pavement management systems (PMS). pave-scan.eu

Safran acquires Syntony

Safran Electronics & Defense has acquired Syntony GNSS, a simulator and receiver company founded in 2015 in Toulouse, France. The acquisition is intended to strengthen Safran's resilient PNT innovations. In 2023, Safran acquired Orolia, also for its GNSS and PNT expertise. Under the agreement, signed Feb. 13, Safran will take 100% of Syntony's share capital, subject to customary regulatory approvals. Financial terms were not disclosed. www.safran-group.com

Spirent partnership with ESA

Spirent Communications, now part of Keysight Technologies, has partnered with the European Space Agency (ESA) to lead an initiative aimed at increasing the resilience of positioning, navigation and timing (PNT) systems used in critical national infrastructure. Under the initiative, Spirent and partners will deliver a comprehensive test framework to drive measurable resilience in PNT systems for users, operators and providers of critical infrastructure in the United Kingdom. www.spirent.com

NovAtel updates firmware with advancements in GNSS reliability

NovAtel has released its latest firmware for the OEM7 family of GNSS receivers, featuring improvements in positioning reliability and accuracy. The firmware release sets new standards for innovation and reliability with the introduction of advanced tracking capabilities that enhance GNSS performance in challenging or obstructed environments. novatel.com

JAVAD introduces US-built GNSS board for LEO applications

JAVAD GNSS has announced the TR-2S LEO, a compact GNSS OEM board designed and manufactured at the company's headquarters in San Jose, California. The TR-2S LEO delivers high-precision GNSS positioning for low Earth Orbit (LEO) missions.

Developed for customers requiring high-integrity navigation performance under the demanding conditions of space, the TR-2S LEO integrates radiation-tolerant, space-hardened electronics with patented spoofing and jamming detection to support, secure and protect continuous GNSS operation. The board tracks 874 channels across all major GNSS constellations, enabling robust and real-time position, velocity, time and measurements (PVT) with multi-frequency resilience.

JAVAD GNSS brings more than two decades of flight heritage, with OEM boards deployed on most commercial launch vehicles worldwide, including the Vega program of the European Space Agency (ESA). The company continues to build upon its experience, now with focused concentration on LEO-based applications with technologies like the TR-2S LEO and the SpaceAnt-G3T OEM GNSS antenna. The SpaceAnt-G3T features a stable phase center and is usable for single-, dual- and triple-frequency applications. javad.com

Leica CityMapper-3 airborne hybrid system

Leica CityMapper-3 airborne hybrid system is a new solution designed to improve operational efficiency by combining the latest imaging and LiDAR technologies within a single, configurable platform, streamlining data acquisition across demanding urban and regional mapping applications. On the imaging side, CityMapper-3 is the first CityMapper to feature a Leica MFC250-based camera system, powered by Sony's IMX811 sensor, delivering up to a 30% increase

in acquisition efficiency compared to previous generations. The new multi-configuration architecture enables the swath width and resolution to be tailored to specific flight altitude and project requirements, while improved nadir and oblique performance allows details to be captured from every angle with greater precision, supporting deliverables from digital twins to 2D ortho imagery. <https://leica-geosystems.com>

Viavi launches ePRTC360+

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. The international ITU-T G.8272.1 standard stipulates that Enhanced Primary Reference Time Clock (ePRTC) holdover must have short-term drift of less than 30 ns when entering into holdover and a long-term drift of less than 100 ns over 14 days, all traceable to UTC. Previously achieved only by Cesium atomic clocks, VIavi's ePRTC360+ now also meets this standard. www.viavisolutions.com

Micro-Magic unveils high-precision MEMS IMU module

Micro-Magic has released the U4930 series - a six-axis MEMS inertial measurement module that can be widely used in navigation, control and measurement fields for vehicles, ships and drones. It integrates high-performance MEMS gyroscopes and MEMS accelerometers within an independent structure. www.memsmag.com

CR-S1 reality capture handheld scanning system by Topcon

Topcon Positioning Systems has introduced the CR-S1, a handheld scanning system that combines LiDAR,

panoramic cameras, visual SLAM cameras, and a GNSS antenna in a single device. It offers increased pointcloud density, extended scanning range, and upgraded panoramic imaging. It uses Topcon's Collage mass-data software ecosystem central to a connected workflow. www.topconpositioning.com

Inertial Labs launches IRINS LEO-aided INS

Inertial Labs has announced IRINS, a low Earth orbit (LEO)-aided inertial navigation system (INS) designed to allow full operation across land, air and sea in GNSS-denied, -degraded and -disrupted space operating environment.

Combining the capabilities of an INS, an altitude and heading reference system (AHRS) and a LEO PNT receiver, this platform marks a major milestone in Viavi's portfolio for assured PNT by bringing together the INS capabilities of inertial labs and the timing expertise of Jackson Labs. The IRINS embedded system has been developed to counter the exponentially rising number of spoofing and jamming attacks. www.viavisolutions.com

Taoglas unveils AI-driven antenna recommendation platform

Taoglas has launched its AI-driven Antenna Product Recommendation Engine, a platform that helps engineers and organizations select the company's antennas and RF components. Available worldwide, the tool provides both seasoned RF engineers and non-technical decision-makers with intelligent guidance to make informed choices. www.taoglas.com

ARK Electronics launches GNSS magnetometer unit

ARK Electronics has launched the ARK DAN GPS, a U.S.-built dual-band L1/L5 GNSS and industrial magnetometer unit. It is designed for dependable navigation and orientation in professional drone and autonomous platform applications.

Incorporating the u-blox DAN-F10N receiver, the system delivers resilient signal acquisition across L1, L5, E5a, and B2a frequency bands. Its integrated SAW-LNA-SAW design ensures robust immunity to interference, while proprietary dual-band multipath mitigation enhances positional reliability even in complex environments. arkelectron.com

Advanced GNSS-R terrain monitoring project

Divirod and Oki Electric Industry (OKI) have completed a project to monitor landslide risk and slope stability across vulnerable areas in the Fukuoka Prefecture of Japan. The project deployed Divirod's next-generation ground deformation and anomaly-detection technology to provide continuous, high-resolution monitoring of mountainous terrain prone to extreme rainfall and seismic activity. The initiative supports Japan's broader effort to enhance early-warning capabilities and strengthen climate resilience following recent years of severe rainfall disasters and complex terrain-related hazards.

For the project, Divirod designed a system comprised of GNSS-Reflectometry (GNSS-R) sensors and intelligent algorithms and deployed it across three areas of interest collecting continuous, all-weather measurements throughout the monitoring period. www.divirod.com

Aptella offers free RTK positioning for bushfire

Australia-based Aptella is offering free access to its AllDayRTK high-accuracy positioning service for volunteers and organizations involved in bushfire and flood recovery efforts. Extreme weather events often disrupt permanent GNSS base stations due to power outages and loss of internet connectivity. To address this challenge, AllDayRTK has developed a Synthetic Base Station system, enabling high-accuracy positioning even when permanent bases are offline. This technology creates a virtual reference station network that ensures continuity of service in disaster-affected

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31st March - 01st April

Singapore

www.geoconnectasia.com

April 2026

Assured PNT Summit

7 - 8 April 2026

Washington DC, USA

<https://pnt.dsigroup.org>

4th Geospatial Et Space Technology MENA Forum

8 - 9 April 2026

Dubai, United Arab Emirates

<https://menageospatialforum.com>

Pacific PNT conference

13 - 16, April 2026

Honolulu, Hawaii

<https://www.ion.org>

2026 Commercial UAV Forum

22 - 23 April

Amsterdam, The Netherlands

www.forumuav.com

European Navigation Conference 2026

28 - 30 April 2026

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<https://fig2026.org>

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<https://iccgis.cartography-gis.com>

August 2026

13th IGRSM Conference 2026

05 - 06 August

Kuala Lumpur, Malaysia

<https://conferences.igrsm.org>

regions, supporting emergency response teams and volunteers where traditional infrastructure cannot. www.aptella.com

Eos MDM Configurator designed to streamline deployments

Eos Positioning Systems has released the Eos MDM Configurator, a webbased tool that allows organizations to quickly create and deploy pre-configured Eos Tools Prosettings across large numbers of mobile devices via their third-party mobile device management (MDM) systems. Until now, administrators who wanted to deploy Eos Tools Pro through their MDM needed to write an XML configuration file manually — a process that was time consuming and potentially error-prone. The Eos MDM Configurator eliminates manual coding entirely. The tool guides users stepbystep through five GNSS categories, supplies a preview of the XML code, and allows the user to export their XML file, compatible with any thirdparty MDM solution. eos-gnss.com

CHC Navigation releases Apache 6 USV

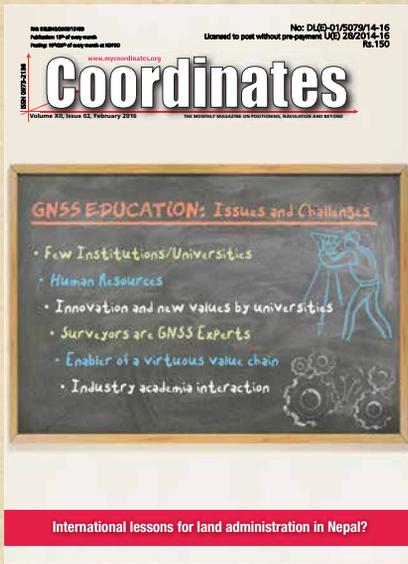
CHC Navigation (CHCNAV) has released the Apache 6-2026 Edition, an integrated unmanned surface vessel (USV) designed for high-resolution bathymetric and 3D mapping applications. It delivers a comprehensive solution for underwater surveying, object positioning, and offshore construction support in varying aquatic conditions. www.chcnv.com

Sub-centimeter aerial mapping at aircraft speeds

Phase One has announced the iXM-FS130, aerial mapping camera designed to unlock sub-centimeter ground sample distance (GSD) missions from a fixed-wing aircraft. It enables new mission profiles while protecting existing customer investments and workflows. It enables reliable 1 cm GSD image capture at airspeeds exceeding 120 knots, allowing operators to cover more area per flight and complete missions previously constrained by motion blur, overlap requirements, or re-flight risk. phaseone.com

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A Case study on PPP kinematic and RTK positioning methods in Urban Environment

Raghupati Shukla

PhD student, Curtin University, Australia

The case study presented shows that good software like Magic, CSRS- PPP and Trimble can achieve 70% availability to target applications such as (i) Ambulance tracking (ii) Fire Brigade (iii) Machine Automation with Metre to Cm level accuracy and using PPP-kinematic and RTK methods. However, signal blockage, poor satellites visibility and insufficient measurements can reduce availability to achieve target application.

GNSS education: Issues and challenges

People are needed who are pioneering services and put them to practice

-Univ Prof Dr Ing Habil Bernd Eissfeller Institute of Space Technology and Space Applications, University of Federal Armed Forces Munich, Neubiberg, Germany

Why Surveyors are GNSS Experts

Chris Rizos, Professor, Geodesy & Navigation, Surveying & Geospatial Engineering, School of Civil & Environmental Engineering, UNSW Australia (The University of NewSouth Wales), Sydney Australia

GNSS education has to be the enabler of a virtuous value chain

Prof Fabio Dovis, Politecnico di Torino – Dept. of Electronics and Telecommunications, Italy

The ultimate goal of the university is creating innovation and new values

Nobuaki Kubo, Tokyo University of Marine Science and Technology, Tokyo, Japan

Lack of ability to adapt the current Geomatics Engineering education programs to the upcoming fields

Reha Metin Alkan, Professor, Department of Geomatics Engineering, Istanbul Technical University, Istanbul, Turkey

Only a handful of Universities/ Institutions in India have GNSS as a separate course

Dr Anindya Bose, Department of Physics, The University of Burdwan, Golapbag, Burdwan, India

Navigating Kyoto

Hiroshi Shinohara

Director Quasi-Zenith Satellite System Services Inc. Japan

On November 18, 2015, the Quasi-Zenith Satellite System Service Co., Ltd. (QSS) conducted an experiment in Kyoto, Japan using a quasi-zenith satellite system (QZSS) in collaboration with the GNSS International Symposium, IS-GNSS2015, in order to verify the effectiveness of the QZSS in providing highly accurate bus location information and tour information for participants on a sightseeing bus tour.

International lessons for land administration in Nepal?

Assoc. Prof. Donald Grant and Assoc. Prof. David Mitchell
RMIT University, Melbourne, Australia

Some lessons for land administration in Nepal from the experiences in Haiti and New Zealand include: Leadership comes from the government – solutions often come from the people (they know what they need) and from land professionals (they know what will work). It is important to engage with ALL stakeholders and interests in land.



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