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THE MONTHLY MAGAZINE ON POSITIONING, NAVIGATION AND BEYOND

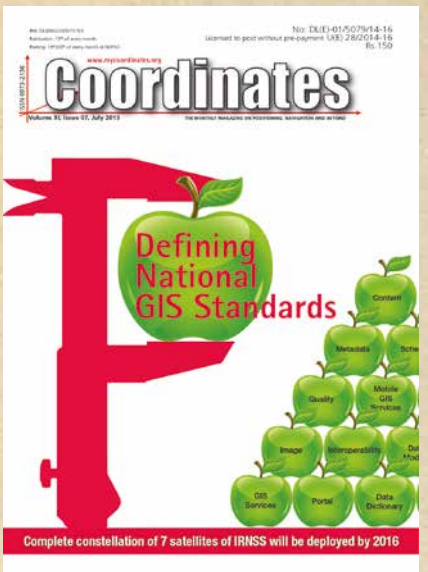
BEAUTIMETER

Harnessing GPT for assessing architectural and urban beauty based on the 15 properties of living structure

Emerging technologies and their integration in surveying profession

In Coordinates

10 years before...



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ACCSEAS: The Innovative North Sea e-navigation Demonstration

Dr Alwyn I Williams, George Shaw and Dr Nick Ward
General Lighthouse Authorities for UK and Ireland, Trinity House, The Quay, Harwich, United Kingdom

ACCSEAS has gone a long wayto investigate the human factor of e-Navigation technology, and has proposed further work to ensure that as the concept evolves, the training evolves alongside it. This will give e-Navigation the best opportunity to provide the maritime users of the North Sea Region, and beyond, much needed tools to tackle the challenges of the future.

Overview for the prediction of larger earthquakes in Japan

Dr Shunji Murai
Professor Emeritus, University of Tokyo, Japan and Advisor to Japan Earthquake Science Exploration Agency (JESEA), Japan

Dr Harumi Araki
Head, Environmental Geological Laboratory, Japan and Advisor to JESEA, Japan

Since the type and depth of earthquakes are so different, the occurrence patterns are different which makes it dif¿cult to predict the exact time of an earthquake. However “where” and “how large” can be roughly predicted while “when”ranges from a few weeks to several months depending the earthquake type which as yet is unknown in advance.

Role of surveyors in urban regeneration projects in Turkey

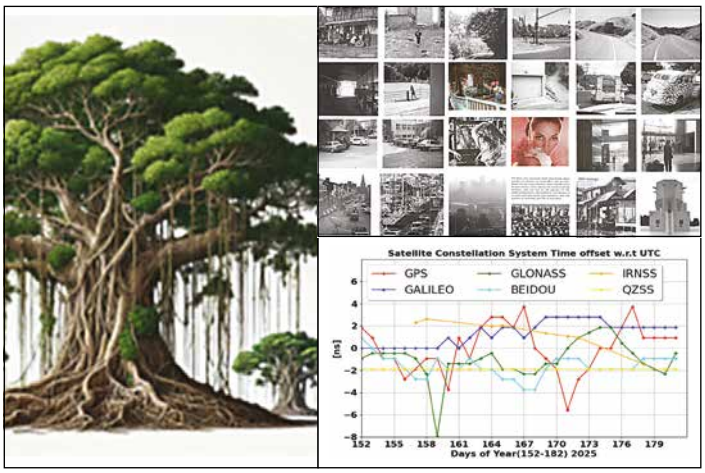
Yunus Konbul
Izmir Katip Celebi University, Department of Geomatics Engineering, Turkey

According to the answers, surveyors’ core responsibilities are land management and related services such as GIS management, mapping and title transfers. However, they take part in financial issues as well, such as project feasibility calculations, cost analysis and mostly real estate appraisal. One another important contribution of surveyors is in the social field.

Defining National GIS Standards

Mukund Rao, VS Ramamurthy and Baldev Raj
National Institute of Advanced Studies (NIAS), Bangalore, India

The National GIS Standards needs to be compliant with international ISO TC211 processes – especially as India is already committed to ISO standardisation efforts through the Bureau of Indian Standards (ISO is a multi-lateral body for standardisation and India is represented by BIS). A Expert Standing Committee can be tasked to help National-GIS to review, update the National GIS Standards from time-to-time.



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Articles

Columns

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Editor Bal Krishna
Owner Coordinates Media Pvt Ltd (CMPL)

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July 2025 brought catastrophe to Central Texas,

Where floods claimed 52 lives along the Guadalupe River.

In India, Varanasi's 84 ghats submerged under July 2025 floods.

Southern Australia's January 2025 wildfires scorched vast landscapes.

These disasters, fuelled by climate change,

Highlight the urgency of resilient navigation tools.

GNSS-guided drones in the USA,

Early warning system in India,

And satellite based tracking in Australia's fire response,

Highlight the roles that technologies play.

It also holds a potential to develop

An AI-integrated PNT system,

That can enhance forecasting early warning initiatives,

And help navigate the climate chaos.

Bal Krishna, Editor
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Beautimeter: Harnessing GPT for assessing architectural and urban beauty based on the 15 properties of living structure

Our findings suggest that by leveraging GPT technology, Beautimeter offers architects, urban planners, and designers a powerful tool to create spaces that resonate deeply with people.

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Abstract

Beautimeter is a new tool powered by generative pre-trained transformer (GPT) technology, designed to evaluate architectural and urban beauty. Rooted in Christopher Alexander's theory of centers, this work builds on the idea that all environments possess, to varying degrees, an innate sense of life. Alexander identified 15 fundamental properties, such as levels of scale and thick boundaries, that characterize living structure, which Beautimeter uses as a basis for its analysis. By integrating GPT's advanced natural language processing capabilities, Beautimeter assesses the extent to which a structure embodies these 15 properties, enabling a nuanced evaluation of architectural and urban aesthetics. Using ChatGPT4o, the tool helps users generate insights into the perceived beauty and coherence of spaces. We conducted a series of case studies, evaluating images of architectural and urban environments, as well as carpets, paintings, and other artifacts. The results demonstrate Beautimeter's effectiveness in analyzing aesthetic qualities across diverse contexts. Our findings suggest that by leveraging GPT technology, Beautimeter offers architects, urban planners, and designers a powerful tool to create spaces that resonate deeply with people. This paper also explores the implications of such technology for architecture and urban design, highlighting its potential to enhance both the design process and the assessment of built environments.

1. Introduction

Within the field of design, architectural and urban beauty has long been a central focus, yet few scholars have explored it as deeply as Christopher Alexander [1–3] and his co-workers [4,5]. Among Alexander's significant contributions is his theory of centers, which suggests that a built environment's beauty and coherence derive from the presence and arrangement of centers—distinct parts that contribute to a larger, cohesive whole. This theory posits that spaces possess an inherent 'aliveness' or 'livingness' when these centers resonate with our inner experiences, fostering a deep, intuitive connection with those who inhabit or perceive these spaces [3]. Although the theory of centers offers profound insights into architectural and urban design, its practical application presents notable challenges. The theory's reliance on subjective perception of centers makes consistent evaluation across individuals and contexts complex, and the need for nuanced interpretation limits its scalability in broader architectural and urban design contexts.

The central element of Alexander's work is the concept of living structure,

or "livingness", which refers to the degree to which the qualities of a space or environment enhance life and resonate with human experience. A living structure (its 15 fundamental properties being detailed further in Section 2) has a profound coherence, harmony, and interconnectedness, where each part makes a meaningful contribution to the overall whole. More than just being a physical characteristic, this livingness is a quality that emerges from the interplay of various elements within a space, creating a unified and vital environment. Alexander [3] contended that the existence of living structure in a built environment makes a space feel alive, inviting, and capable of nurturing human well-being [1,6]. Essentially, the theory of centers assesses the degree of living structure within a space. When individuals engage with this theory, they reflect on whether space embodies a living structure that resonates with their own sense of aliveness [7]. This reflective process allows for a personal evaluation of urban and architectural beauty, examining how the functional and aesthetic qualities of a space align with the patterns of life that individuals intuitively recognize within themselves.

New opportunities to address these challenges have arisen because of recent advancements in artificial intelligence (AI), particularly in natural language processing. Generative pre-trained transformer (GPT) technology, which is exemplified by tools such as ChatGPT [8], has shown exceptional ability to understand and generate human-like texts. These technologies excel at processing and analyzing large volumes of data, including both images and texts, which makes them ideal for tasks that demand personal and introspective assessments [9–11]. We have built on this potential to develop a novel tool called Beautimeter, which identifies and scores the presence of the 15 fundamental properties to evaluate the living structure within spaces. Beautimeter provides a systematic way to assess urban and architectural beauty by quantifying each property, enabling a broad and consistent evaluation of how well a space aligns with the principles of living structure. This approach offers profound insights into how individuals perceive and interact with built environments by grounding evaluations in the tangible presence of these key properties.

This paper outlines the development and application of Beautimeter, exploring how GPT technology was used to create the tool, demonstrating its use via case studies, and discussing the implications of our findings for architectural and urban design and evaluation. The results of the case studies suggest that Beautimeter outperforms, by far, average human judgment in assessing architectural and urban beauty. In this paper, we have connected the seemingly subjective perception of centers or living structure with the capabilities of AI, contributing to the discourse on how AI technology can deepen our understanding of beauty and help create urban environments that resonate with life-enhancing qualities.

The remainder of this paper is organized as follows. We begin with a theoretical framework outlining the theory of centers and its significance in relation to architectural and urban beauty, emphasizing the concept of living structure. The next section covers the development, design, functionality, and implementation of Beautimeter. We then present case studies where Beautimeter was applied to various images, including city scenes, buildings, paintings, and carpets, along with an analysis of the results. In the discussion section, we examine the broader implications of Beautimeter and this study overall in relation to using AI to assess architectural and urban beauty, including the ethical considerations of AI usage. We conclude with a summary of key insights and reflections on Beautimeter's potential impact on the fields of architecture and urban design.

2. Theoretical Framework

In this section, we look at the foundational concepts underpinning the development and application of Beautimeter. We begin by introducing the concept of living structure and the 15 fundamental properties that characterize spaces with a high degree of life, followed by two early surveys conducted by Alexander [3]. We aim to provide a theoretical framework that forms the foundation of Beautimeter.

2.1. Living Structure and the 15 Fundamental mental Properties

Alexander (2002–2005) conceived and developed the concept of living structure from his earlier work on pattern languages and Turkish carpets [1,2,12]. His concept of living structure extends beyond biological systems to include the structural qualities of any object or system. For example, the banyan trees shown in Figure 1 continue to embody living structures even when they are no longer biologically alive, showing that the idea of living structure continues beyond the biological realm into the realm of structural organization. Essentially, a living structure is characterized by the presence of a recurring pattern containing significantly more small substructures than large ones, which creates a rich hierarchy of forms. This trait applies whether the structure is biologically alive or not. Investigating the number of substructures in a structure, and the hierarchy that these substructures form, shows the degree of livingness or life in the structure [13]. Humans can intuitively perceive this living quality, or the quality without a name (QWAN) [1], and often associate it with a sense of beauty. Living structure is to beauty what temperature is to warmth; the greater the degree to which a structure embodies the characteristics of living structure, the more the structure resonates with the innate human sense of beauty.

The 15 properties of living structure provide insights into what makes certain objects, spaces, or designs feel alive and harmonious (Figure 2). Rather than being abstract concepts, these properties are deeply rooted in how people perceive and interact with the world around them. These properties reflect the underlying order and coherence that contributes to a structure's livingness or beauty, whether the structure

is a building, a natural form, or even a city. When architects, planners, and urban designers understand and apply these properties, they can create environments that resonate with the intrinsic patterns of life and foster spaces that are functional and aesthetically pleasing. Among the 15 properties, the levels of scale property refers to the presence in a structure of multiple scales of size, from the smallest detail to the largest form, which creates a sense of balance and cohesion. Strong centers highlight the significance of focal points in a design, drawing the eye and creating a sense of order. Another key property is thick boundaries, which define the edges of substructures and spaces; this helps delineate and protect the integrity of forms. Alternating repetition and gradients introduce variation and transitions within a design, making it dynamic and engaging. Properties like local symmetries and positive space also contribute to a structure's sense of fullness and order. The 15 properties combine to deliver a comprehensive framework with which to understand and create living structures, with the beauty and coherence of the design being tied to its transformational and living geometric characteristics.

The 15 properties can be distilled into two overarching laws—the scaling law [15] and Tobler's law [16]—that are foundational for understanding and characterizing living structure. Firstly, the scaling law is essentially the levels of scale property, asserting that, across any given structure, a hierarchy exists in which there are far more small substructures (or centers) than large ones. This distribution is seen across several levels of scale, from the smallest components within a system to the most significant elements. Having many small centers contributes to the overall structure's richness, complexity, and coherence, enabling it to exhibit the qualities of life and vibrancy that are characteristics of a living structure. The scaling law shows the importance of having a fine-grained hierarchy to create environments that resonate with human experience, and many of the 15 properties (e.g., alternating repetition, contrast, roughness, positive space, and local symmetries) recur at different levels of scale.

Tobler's law, which is often cited as the first law of geography, complements the scaling law by stating that the substructures within each level of scale tend to be more or less similar in terms of size [16]. Tobler's law ensures that there is balance and harmony among the substructures at every level of a structure, adding to the environment's overall coherence and "aliveness". Together, the scaling law and Tobler's law provide a framework for understanding living structures. The former draws attention to

Figure 1. (Color online) Banyan trees, whether alive or dead, remain a living structure. (Note: The figure generated by Dall-E 2 suggests that the concept of living structure is a reference to its underlying form and organization rather than its biological state, alive or dead. The choice of banyan trees for this example was inspired by the concept presented in a classic paper that Alexander [14] wrote, entitled A City is Not a Tree. In this context, the interconnecting branches of a banyan tree create a complex network that makes it resemble a city more closely than a 'typical' type of tree would, where two parallel branches can only connect through their parent branches).

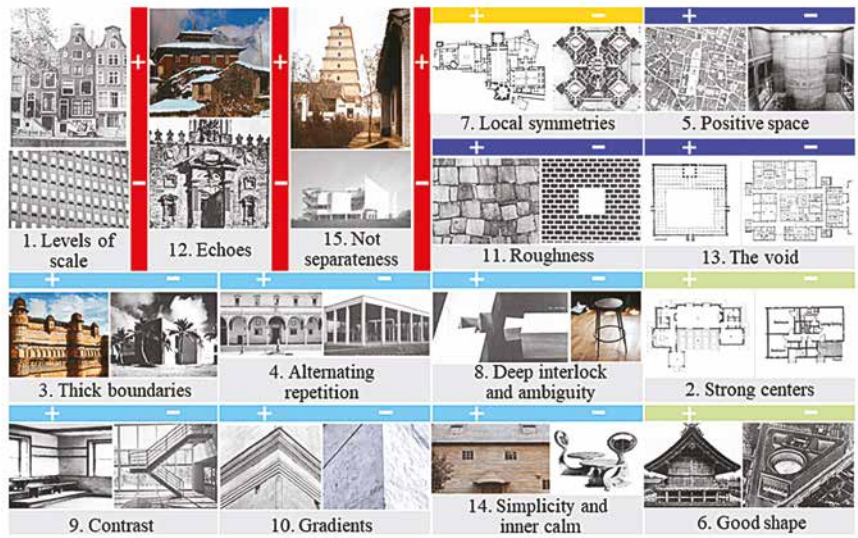

Figure 2. (Color online) Illustration of the 15 properties of living structure. (Note: Each of the 15 key properties of living structures is accompanied by positive (+) and negative (-) examples, primarily based on Alexander (Chapter 5 of Book 1) [3]. The properties are categorized into five groups, each of which is marked by a different color. The red group includes global properties that operate across multiple scales, while the two blue groups focus on properties at the local level. The local symmetries property is the earliest of the 15 properties, whereas the two properties strong centers and good shape are inherent to living structure itself, making them redundant).

the need for a hierarchical distribution of sizes across scales, while the latter ensures that there is a proportional and harmonious arrangement of elements within each level (e.g., alternating repetition, contrast, roughness, positive space, and local symmetries). From a living structure perspective, the scaling law should be recognized as the primary law because the hierarchical richness it describes is fundamental to the creation of living structures. Meanwhile, Tobler's law provides a secondary effect, ensuring that the relationships among the elements within each scale are balanced and coherent.

2.2. Two Surveys Using the Mirror-of-the-Self Test (MOST)

The MOST is an important part of Alexander's broader architectural and urban theory, which emphasizes the creation of environments that resonate with people at an intrinsic level. The MOST was developed as an introspective tool and designed to assess whether a space possesses what Alexander [1,2] termed QWAN [17]; that is, a sense of life, beauty, or wholeness (Alexander 2002–2005) that evokes a deep connection among the people who inhabit or perceive it. The MOST is based on Alexander's belief that all spaces can reflect, to some degree or other, people's emotional and psychological states. Based on his own work on pattern languages [1,12] and on what makes buildings and environments feel "alive", Alexander [3] argued that people are able to intuitively recognize to what degree an architectural or urban environment reflects their sense of self, not just in an aesthetic sense, but related to a deeper—often unconscious—connection with the environment.

The MOST is part of Alexander's wider theoretical framework, which centers around the concept of living structure. Alexander argued that living structures are characterized by a high degree of order and coherence and multiple interrelated centers or substructures [18,19]. These substructures are brought to life by applying the 15 fundamental properties listed in Figure 2. Each property contributes to the overall harmony and life of a space and makes the space resonate with the human spirit. The MOST is inherently objective, although it relies on an individual's intuitive response to a space, asking individuals to state whether they view themselves as reflected in the space and whether the space feels like a natural extension of their inner world. The MOST focuses on a space's emotional and psychological impact, aiming to determine the degree to which a space or an object has the life-giving qualities that, according to Alexander, are essential to achieve a truly human-centered built environment.

In 1992, Alexander [3] surveyed architecture students at the University of California, Berkeley, regarding their perceptions of life in architectural and urban designs. The students were presented with the two contrasting images shown in Figure 3—a slum house in Bangkok and a postmodern octagonal tower—and asked which building they felt had more life. Notably, 81% of the students (89 out of 110) felt that the Bangkok slum house had more life, and none chose the postmodern tower. This overwhelming majority among students who had been trained in contemporary architectural and urban models highlighted a disconnect between their education and their instinctive perceptions and challenged prevailing architectural and urban ideals.

In 1985, at a conference in New York, Alexander [3] conducted a similar exercise, asking 100 participants to state which of two objects—a gray steel stool and a blue-painted wooden bench (see Figure 3)—better reflected their sense of self. Only one of the 100 participants chose the steel stool. While he defended his choice as subjective at first, he later changed his mind and opted for the wooden bench. Examples like this underline the profound emotional influence of Alexander's approach and reveal universal truths regarding how people intuitively relate to designs that reflect their inner sense of life and self.

3. Development of Beautimeter

A significant innovation in assessing architectural and urban beauty emerged with the integration of GPT technology, specifically ChatGPT [8], into the theory of centers. Our goal in incorporating GPT was to standardize and scale the evaluation process, enabling broader application and analysis. The natural language processing capabilities of GPT allow it to interpret and respond to prompts related to the beauty and coherence of architectural and urban images through the lens of the theory of centers and its 15 fundamental properties. The primary challenge was ensuring that GPT could navigate the nuanced and objective nature of these assessments while remaining aligned with the principles of life-enhancing design. The resulting system prompts GPT to evaluate architectural and urban images using a structured yet adaptable rubric, leading to the generation of an overall beauty score that reflects the combined influence of the 15 properties.

3.1. Design and Functionality

The development of Beautimeter aimed to create a user-friendly tool powered by GPT that incorporates the theory of centers and the 15 fundamental properties of beauty. The design process began by defining the core functionality: enabling GPT to analyze two architectural and urban images and to determine which one embodies a higher degree of beauty based on these properties. This was achieved by translating the properties into a scoring system that GPT could effectively utilize. By leveraging GPT's advanced natural language processing capabilities, Beautimeter prompted users to present two images of our daily lives (direct image inputs), indicating which is more beautiful and providing the corresponding score for each image.

Behind Beautimeter is a prompt such as the following:

"Given the two input images, I would like to know which is more beautiful or has a higher degree of beauty according

Figure 3. (Color online) Two pairs of images for the two surveys. (Note: Bangkok slum house versus a postmodern house, and a painted blue bench versus a gray steel stool).

to the 15 properties of living structure defined by Christopher Alexander. Score the two images based on the 15 properties, with 15 being the highest and 0 being the lowest; in other words, each of the 15 properties is scored between 0 and 1. Please refrain from articulating or elaborating on details".

GPT processes the prompt and compares the images based on the encoded understanding of the 15 properties or the theory of centers in general and generates an overall beauty score for each image. The user interface (UI) of Beautimeter (Figure 4) was designed to be intuitive so that users could easily upload or capture any images and obtain results. The tool presents users with the comparison task, processes their input images, and then concisely displays the results (Figure 4). The UI also allows users to track their evaluations and compare results over time, thus offering a deeper understanding of how different spaces resonate with the principles of life-enhancing design.

3.2. Implementation

The implementation of Beautimeter faced virtually few challenges, demonstrating the powerful capabilities of GPT rather than the complexities of my research. As an expert of living structure theory, I can objectively assess the effectiveness of GPT in understanding the theory of centers and the 15 properties. We found that the natural language processing capabilities of GPT were inherently sufficient to reflect the nuances of the 15 properties. We tested the tool on a variety of images, including buildings and urban environments. Notably, despite our efforts to fine-tune the model, we discovered that

Figure 4. (Color online) Beautimeter: a GPT-powered tool for measuring beauty.

GPT's out-of-the-box performance was already robust enough to meet our needs.

Throughout the development process, our focus was on maintaining the integrity of Alexander's principles while leveraging GPT's strengths. The implementation was straightforward, resulting in a tool that is both technically sound and aligned with the results of the MOST conducted by Alexander [3]. Ultimately, Beautimeter automates and enhances the assessment of architectural and urban beauty, offering users a profound understanding of human experience without the need for extensive adjustments.

4. Case Studies for Verification

We conducted a series of experiments as case studies that aimed to assess the ability of Beautimeter to evaluate and compare the aesthetic qualities of various architectural and urban images. We examined pairs of images, each of which represented varying degrees of beauty or life, as defined by Alexander [3], seeking to validate Beautimeter's effectiveness at capturing the nuanced and seemingly subjective nature of human aesthetic judgment. The subsections below outline the methodology and results of the experiments and present some key insights into the relationship between living structure and perceived beauty.

4.1. Experiments with Pairs of Images

We investigated Beautimeter's applicability by conducting a series of experiments that involved evaluating 46 pairs of images. The images were sourced from *The Nature of Order, Book 1* [3]—specifically, Chapter 2, "Degrees of Life" (Figure 5), and Chapter 8, "The Mirror of the Self" (Figure 6)—which include buildings, city scenes, paintings, and artifacts. These experiments explored the living structure concept by asking GPT which image in each pair showed a stronger sense of beauty or life. In the original context, Alexander [3] provided a form of ground truth by suggesting that the left-hand image in each pair generally embodied more beauty or life than the right-hand image.

To ensure the reliability and accuracy of Beautimeter's assessment of architectural and urban beauty, we focused the validation process on GPT's ability to

interpret essential properties tied to the 15 properties of living structure. Specifically, we emphasized properties such as levels of scale, echoes, and the notion of "not separateness"—all of which are crucial to understanding architectural and urban beauty beyond simple visual attributes like color or texture. Through this validation, we ensured that GPT's understanding goes beyond surface-level features to accurately reflect deeper qualities of spatial harmony, integration, and coherence that align with the principles of living structure.

Our experiment sought to test this hypothesis by scoring each image, based on the 15 properties, via Beautimeter. The aim was to quantify the seemingly subjective yet consistent nature of human perception regarding what constitutes a living structure. Beautimeter was presented pairs of images and asked to evaluate which one exhibited a higher degree of beauty or life. Beautimeter generated a score for each image based on the 15 properties. The scoring did not include any specific articulation or elaboration and instead focused solely on the overall perception of beauty, as informed by these properties.

4.2. Results and Discussion

Using the image pair of the Bangkok slum house and a postmodern house (Figure 3), let us first generate Table 1 to break down the beauty scores based on the 15 properties of living structure. The table provides a detailed evaluation of how each property contributes to the overall perception of beauty in both images. The traditional Bangkok slum house exhibits a higher degree of living structure, with strong centers, well-defined positive space, and a rich interplay of scales and textures. In contrast, the postmodern house, while geometrically structured, lacks integration between its elements and scores lower in almost all of the properties. This breakdown example not only clarifies how GPT interprets these images but also highlights the importance of the synthesis of properties in shaping a more profound sense of beauty or life.

Tables 2 and 3 summarize the results of the experiments. The tables quantify the degree of beauty, as perceived through the lens of the 15 properties, which provide insights into the concept of living structure. Table 2 displays the scores for the image pairs from Figure 5, with the left- and right-hand images scored separately. Alexander proposed that the left-hand-side images generally possess more beauty or life than those on the right, yet the yellow-highlighted results in the table show instances where the right-hand-side images received higher scores than those on the left. Table 3 quantifies the results of the image pairs from Figure 6, and there are again cases where images on the right were rated higher than those on the left by Beautimeter (again highlighted in yellow). The deviations shown in these two tables underline the complexities involved in applying the 15 properties to diverse visual contexts, revealing the power but also limitations of GPT when evaluating beauty or life across different types of images.

The results above offer insights into the complexity of human perception when evaluating the concept of living structure or QWAN. Most of the results align with Alexander's original assessments, where the left images score higher than the right ones. However, there are five exceptional cases where the right images outperform the left. While the reasons for this are uncertain, these cases are rare and may be considered outliers. Nevertheless, we could argue that beauty or life, as perceived in these instances, is not merely the sum of individual properties but rather the integration and synthesis of various elements working together. Our

Figure 5. (Color online) Sixteen pairs of images, A1–A16, numbered sequentially in reading order; for each, the left-hand image is more beautiful than the right-hand one.

Figure 6. (Color online) Thirty pairs of images of different things, B1–B30, numbered sequentially in reading order (in each pair, the image on the left represents something with a higher degree of life or beauty than the image on the right).

Table 1. Beauty score breakdown for the Bangkok slum house (left) and the postmodern house (right) based on the 15 properties.

Property	Left Image	Right Image	Property	Left Image	Right Image
Levels of Scale	0.9	0.6	Contrast	0.85	0.7
Strong Centers	0.85	0.7	Gradients	0.78	0.6
Boundaries	0.88	0.65	Roughness	0.9	0.5
Alternating Repetition	0.87	0.6	Echoes	0.86	0.55
Positive Space	0.9	0.7	The Void	0.96	0.4
Good Shape	0.83	0.68	Simplicity and Inner Calm	0.88	0.6
Local Symmetries	0.8	0.7	Not-Separateness	0.92	0.4
Deep Interlock and Ambiguity	0.82	0.62	**SUM**	**13**	**9**

Table 2. Beautimeter scoring results for the image pairs shown in Figure 5. (Note: Two exceptional cases highlighted in yellow).

ID	Left	Right	ID	Left	Right	ID	Left	Right	ID	Left	Right
A1	12.5	7.0	A2	12.5	8.5	A3	11.0	10.0	A4	12.5	11.0
A5	9.5	11.5	A6	13.0	9.5	A7	6.0	8.0	A8	12.0	10.5
A9	11.0	10.0	A10	11.5	10.0	A11	12.0	11.0	A12	12.5	11.0
A13	13.0	9.5	A14	12.5	8.0	A15	13.0	9.0	A16	13.5	8.5

Table 3. Beautimeter scoring results for the image pairs shown in Figure 6. (Note: Three exceptional cases highlighted in yellow).

ID	Left	Right	ID	Left	Right	ID	Left	Right	ID	Left	Right	ID	Left	Right
B1	7.2	6.5	B2	7.8	7.1	B3	8.4	7.6	B4	8.9	8.1	B5	9.2	7.3
B6	11.0	8.4	B7	10.8	9.1	B8	11.3	9.5	B9	11.7	7.8	B10	8.9	7.7
B11	9.1	8.2	B12	8.4	7.6	B13	10.6	8.8	B14	10.3	7.9	B15	9.6	8.3
B16	10.7	8.9	B17	9.8	8.4	B18	10.5	9.2	B19	9.7	8.9	B20	9.4	8.6
B21	11.0	8.5	B22	9.2	8.0	B23	10.9	9.3	B24	10.5	9.7	B25	9.8	8.4
B26	10.9	8.7	B27	9.1	11.3	B28	10.2	9.4	B29	9.8	10.7	B30	8.7	9.3

findings highlight the importance of the 15 properties as a framework for assessing beauty, emphasizing the need to account for the integration of these properties rather than just their individual presence. Beautimeter, while a powerful tool for quantifying human perceptions, requires further refinement to better capture the interplay between these properties. For example, greater weight may need to be given to some properties, such as the levels of scale, echoes, and not separateness, which might be more significant than local properties. As architecture and urban design continue to evolve, tools like Beautimeter can play a vital role in ensuring that the spaces we create resonate with the deep, intuitive sense of beauty and life inherent in our environments.

Future refinements of Beautimeter could involve weighing these properties based on empirical studies or expert consensus. Previous research suggests that certain properties resonate more strongly with human perception, particularly those that contribute to a sense of coherence and wholeness. By integrating weighted scoring derived from experimental data or structured expert evaluations, the model could more accurately reflect how beauty is perceived in architecture and design. This remains an open area for further investigation and refinement.

While Beautimeter offers a structured approach to assessing living structure, it is not without limitations. One such case of misjudgment, A5, is presented in Table 2, where the tool assigned a higher life score to the right image (an open, sunlit, outdoor setting with a human figure) than to the left image (a dark, enclosed, tunnel-like space). As a researcher studying Alexander's theory of living structure, I remain unconvinced by this assessment. This discrepancy may arise from either a misjudgment by Alexander himself or an error in GPT's evaluation. However, it is important to note that such inconsistencies are rare, occurring in fewer than 10% of cases.

Beautimeter relies mainly on the 15 properties of living structure to automatically assess and score pairs of images in terms of their livingness thanks to the advancements in GPT technology. While Beautimeter is largely relying on the number of the 15 properties, other methods gauge architectural and urban beauty in a more quantitative manner [20,21]. An example is based on the formula $L = S \times H$, where L represents the livingness or perceived beauty of a structure, S represents the number of substructures, and H denotes their hierarchical levels. This formula, which is derived from previous work [13], offers an objective and mathematical way of assessing architectural and urban beauty by analyzing the structural and hierarchical properties of spaces.

Beautimeter does not utilize the $L = S \times H$ formula directly, but the two approaches are complementary because they address different aspects of architectural and urban evaluation. Beautimeter captures the number of the 15 properties, while the L score offers a quantitative measure and focuses on the structural characteristics that contribute to the sense of life in a built environment. The two methods together offer a comprehensive toolkit that enables architects and urban designers to explore the structural integrity and also the emotional impact of the spaces they create. Such a dual perspective elaborates on what makes some environments feel more alive and beautiful than others, which can lead to more holistic and human-centered architectural and urban designs.

5. Implications of Beautimeter and This Study

Beautimeter represents a significant advancement in assessing and designing architectural and urban spaces, reshaping our understanding of beauty in the built environment. This section explores its philosophical and practical implications, focusing on the contrasting organic and mechanical views of space. The organic perspective fosters a holistic approach, promoting designs that

enhance community engagement and sustainability, while the mechanical view often prioritizes efficiency at the cost of aesthetic and emotional considerations. This dichotomy is vital, as it influences the effectiveness and ethical implications of Beautimeter, underscoring the need for a thoughtful application that respects the complexities of urban life and the responsibilities of designers.

A central aspect of Alexander's work is the distinction between the organic and mechanical views of space and the world. The organic view [3,22,23] perceives space as a living entity that is strongly connected to human experience and emotions, and every element contributes to a coherent whole that resonates with life and beauty. The mechanical view [24], by contrast, treats space merely as a physical construct that is defined by functional and Euclidan geometric properties and often lacks emotional and experiential richness. The MOST is founded on the belief that we and the universe are ultimately made of the same fundamental substance: living structure. Therefore, when we engage with a more 'living' environment or object, our own sense of self and life is enhanced.

Beautimeter can potentially have a significant impact on architectural and urban design. By providing architects and urban designers with a tool for assessing architectural and urban beauty, Beautimeter offers a new way of evaluating how well a space resonates with its users. This could lead to designs that are increasingly attuned to human needs and experiences and foster environments that function effectively but also evoke a strong sense of place and belonging [6,25,26,27,28]. Architects and urban designers could use Beautimeter during the design phases to test configurations and elements so that the final design aligns with the organic view of space. Such an approach could help avoid the creation of spaces that are technically functional but fail to resonate emotionally with their inhabitants. Beautimeter's ability to provide real-time feedback on the emotional impact of design choices could revolutionize how spaces are conceived and built. However, the use of AI in such a domain also raises certain limitations. While GPT technology can understand and process human responses, it lacks the innate human ability to fully grasp the subtleties of emotional and sensory experiences. Therefore, Beautimeter should be used as a complement to human judgment and intuition in the design process rather than as a replacement for it.

Beautimeter can have significant implications for areas of design and planning other than just architecture and urban planning and design. In fields where human experiences play a critical role, such as interior design, public space planning, and landscape architecture, the ability to assess how spaces resonate with individual people could lead to more thoughtful and user-centered designs. Moreover, as cities and public spaces become increasingly complex and diverse, tools like Beautimeter can help urban planners create environments that cater to a range of emotional and cultural needs.

Beautimeter is built on universal geometrical properties that capture beauty and coherence in physical spaces, informed by living structure principles that resonate across cultures. While these properties are universal, their interpretation is culturally adaptable, distinguishing them from an international style or so-called Alexander style. Instead, the Alexander style exists in its underlying living structure. The tool allows urban planners to customize the 15 properties to reflect local traditions, cultural symbols, and aesthetic values, ensuring that spaces are not only universally appealing but also culturally meaningful. By integrating living structure with cultural and emotional data, Beautimeter helps create environments that are both visually harmonious and deeply resonant with their users.

Using AI to assess and influence human perception of space highlights some important ethical considerations. An example is the potential for AI to oversimplify or misinterpret the complexities of human experience, which could lead to designs that may appear effective in theory but, in reality, fail to meet the deeper needs of users. There is also the risk of AI reinforcing biases in design, especially if the training data or algorithms are not carefully curated to reflect diverse perspectives. The potential impact of AI on the role of architects or urban designers is another ethical consideration. There is a risk that the more prevalent role of AI tools like Beautimeter could diminish the human element in design, with decisions being increasingly driven by data rather than intuition and creativity. Therefore, it is important to find the balance between the benefits of AI-assisted design and the need to preserve the organic, human-centered approach that is at the heart of Alexander's philosophy.

6. Conclusions

The development and application of Beautimeter, which integrates advanced GPT technology, represents a significant advancement in assessing and understanding architectural and urban beauty and even beyond. By harnessing the intelligent capabilities of GPT, Beautimeter offers a scalable and consistent method for evaluating whether architectural and urban spaces resonate with the intrinsic sense of life and beauty emphasized by Alexander's theory of centers. Our research also suggests that the MOST is a reliable method, and human instinct, if used appropriately, is a dependable tool for gauging architectural and urban beauty. Thus, Beautimeter not only automates the evaluation of architectural and urban beauty but also enhances its applicability and accessibility across a wide range of urban and architectural environments. Exploring Beautimeter's application via a number of case studies has shown the potential of the tool to connect human aesthetic judgment with the processing power of AI.

Our results highlight some of the complexities and nuances involved in perceiving beauty, revealing the strengths but also the limitations of

By harnessing the intelligent capabilities of GPT, Beautimeter offers a scalable and consistent method for evaluating whether architectural and urban spaces resonate with the intrinsic sense of life and beauty emphasized by Alexander's theory of centers. Our research also suggests that the MOST is a reliable method, and human instinct, if used appropriately, is a dependable tool for gauging architectural and urban beauty.

using AI to quantify such personal yet shared experiences. While Beautimeter successful offers valuable insights into the living structure of spaces, it also underscores the importance of maintaining a balance between AI-driven analysis and the inherently human elements of architectural and urban design. While the images examined in this paper provide a meaningful representation of diverse cultural and stylistic contexts, the current dataset is limited in size. To enhance the robustness of our approach, we plan to substantially expand the dataset in future iterations, incorporating a broader range of images from various cultural, historical, and architectural styles. This will ensure a more comprehensive and inclusive evaluation of architectural and urban beauty, further strengthening the generalizability and accuracy of the Beautimeter tool.

The implications of this study extend beyond architecture and urban design, suggesting new possibilities for using AI in urban planning, design, and other fields where human experience is central. However, while integrating AI into these traditionally human-centric domains, we must remain aware of ethical considerations and ensure that technology enhances rather than diminishes the organic, intuitive aspects of design. Moving forward, Beautimeter will not only serve as a tool but also as a reminder of the ongoing dialogue between technology and the timeless principles of beauty that guide architectural and urban practice.

Funding

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Institutional Review Board Statement
Not applicable.

Informed Consent Statement
Not applicable.

Data Availability Statement

Most images studied in this paper are sourced from Christopher Alexander's seminal work, The Nature of Order [3]. This collection serves as a foundational reference for validating the effectiveness of Beautimeter. Additionally, two images depicting banyan trees were generated using DALL-E 2. The GPT technology employed in this research is the latest iteration, ChatGPT-4o, which offers enhanced precision and versatility, making it particularly powerful for Beautimeter. All images and data have been archived and can be accessed here: https://www.researchgate.net/publication/390597156_BeautimeterExperimentalData.

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This paper was prepared with the assistance of ChatGPT-4; however, the author takes full responsibility for any errors or oversights. We would like to express our sincere gratitude to the three anonymous reviewers for their constructive comments, which have greatly enhanced the quality of this work. The author expresses deep gratitude to the Christopher Alexander & Center for Environmental Structure Archive for granting permission to use their images, with special thanks to Maggie Alexander. Additionally, the anonymous referees provided invaluable feedback that significantly enhanced the quality of this study. I would also like to acknowledge my student, Qianxiang Yao, who created the video abstract while taking my course, Visualization for Urban Informatics.

Conflicts of Interest

The authors declare no conflict of interest.

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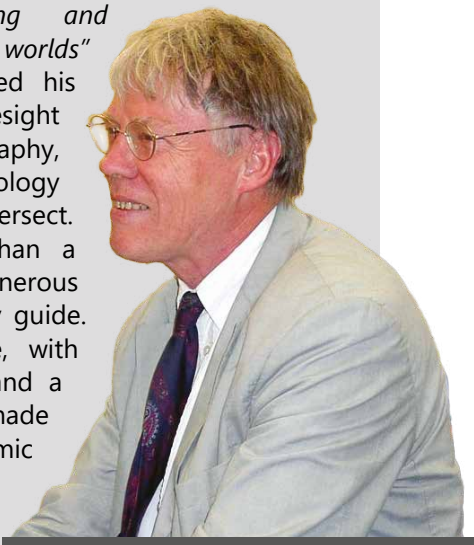
In Memory of Professor Ferjan Ormeling
(1942–2025)

It is with profound admiration and heartfelt remembrance that I wish to pay tribute to Professor Ferjan Ormeling, a towering figure in cartography, a generous mentor, and a steady guide in my academic life. His passing is a great loss to the global cartographic community, yet his legacy lives on — in the students he mentored, in the ideas he shaped, and in the vision he inspired.

In late 1992, supported by a full Dutch government scholarship, I began my PhD journey at the International Institute for Aerospace Survey and Earth Sciences (ITC), now the Faculty of Geo-Information Science and Earth Observation at the University of Twente in the Netherlands. My doctoral research focused on cartographic visualization for facilitating spatial analysis and was initially supervised by Professor J. C. Muller, an authority in cartographic generalization. When Professor Muller left ITC for Ruhr University Bochum, Germany, Professor Wolfgang Kainz took over as my main supervisor. I first met Professor Ferjan Ormeling in 1993 after formulating my research proposal. As ITC did not yet have university status, PhD candidates were required to have an external supervisor – or promotor, as the Dutch call it. Professor Kainz accompanied me to Utrecht University to meet Ferjan, who graciously agreed to take on that role. Given my background in cartography and the nature of my research, Ferjan's involvement brought both intellectual depth and invaluable perspectives.

Our collaborations spanned from 1995 to 2000 and explored what was then uncharted territory in the field: the visualization of cyberspace, the use of hypermap techniques, and the representation of uncertainty in geospatial data. In one of our earliest joint publications, entitled *"Hypermap techniques in fuzzy data exploration"* (1995), we investigated how to depict imprecise and inaccuracies. This thread continued in our work on the visualization of uncertainty through modified HLS color models and perceptual analysis. Ferjan had a remarkable ability to see ahead of his time. He was particularly fascinated by the emerging virtual world, and our co-authored works entitled *"Cybermap: the map for cyberspace"* (1997) and *"Mapping cyberspace: visualising, exploring and analysing virtual worlds"* (1999, 2000) reflected his curiosity and foresight into how geography, cognition, and technology were beginning to intersect. Ferjan was more than a scholar; he was a generous mentor and a steady guide. He led by example, with humility, precision, and a quiet humor that made the hardest academic puzzles feel like joint adventures. He never imposed ideas; he invited exploration.



Professor Ferjan Ormeling
Mentor, Scholar, and Cartographer with Boundless Imagination

His influence continues to guide my work to this day. My current projects – MapGEN, which seeks to automate the generalization or generation of small-scale maps from a single large-scale database, and HDMap4Drones, which aims to build digital mapping infrastructure for low-altitude spaces – are deeply rooted in Ferjan's vision. These efforts reflect the principles he championed: clarity in complexity, coherence in structure, and a deep respect for the role of cartography in shaping how we understand and navigate the world.

As I reflect on our time and collaboration together, I recognize that Ferjan didn't just help me become a better scholar, he shaped the way I see space, structure knowledge, and relate to the academic world. For that, and for his trust and kindness, I am forever grateful. Professor Ormeling's map of the world, and of knowledge, remains etched in our memories, in our work, and in the future of cartography.

Bin Jiang, Professor of Urban Informatics, and Acting Master of Residential College 1
The Hong Kong University of Science and Technology (Guangzhou)

GNSS Constellation Specific Monthly Analysis Summary: June 2025

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

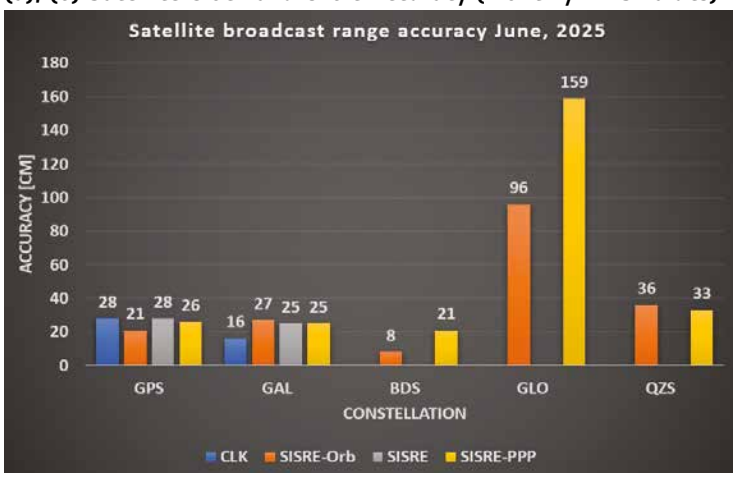
This article continues the monthly performance analysis of the GNSS constellation. Readers are encouraged to refer to previous issues for foundational discussions and earlier results. In addition, there is a section that explores the Galileo constellation performance degradation observed in May, 2025. The goal is to analyze the potential satellite fault event.

Analyzed Parameters for June 2025

(**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**).

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



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. **Galileo Constellation Anomaly, May, 2025**: The degradation in some of the Galileo satellites is cross-checked with satellite health status and corresponding integrity threshold.

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.

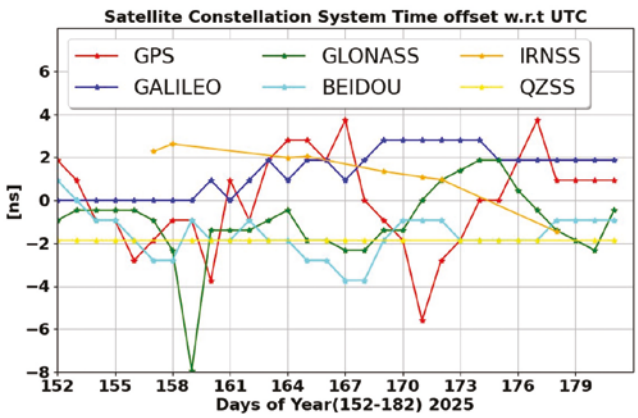
(c) Satellite Clock Jump per Mission Segment Upload

Const	Mean [ns]	Max [ns]	95_ Percentile [ns]	99_ Percentile [ns]	Remark (Best and Worst 95 %)
IRNSS	1.96	130.24	3.62	7.86	Best I06 (3.03 ns) Worst I10 (6.13 ns) Big jumps for each satellite in multiple days; relatively a bit lesser in magnitudes than previous months
GPS	5.74	64835.39	0.79	2.75	Best G04 (0.38 ns) Worst G26 (4.43 ns) Large jumps for G21.
GAL	17.76	1486990.16	0.18	0.44	Best E15 (0.14 ns) Worst E19 (0.36 ns). E12 and E24 had large jumps on different occasions. This will be analysed further.

(d) User Range Accuracy (Number of Occurrences in Broadcast Data 01-30 June)

IRNSS-SAT	2 [m]	2.8 [m]	4.0 [m]	5.7 [m]	8 [m]	8192 [m]	9999.9	Remark Other URA values (frequency)
I02	2868	44	-	-	1	-	-	-
I06	2913	2	-	-	1	-	-	-
I09	437	5	-	-	1	-	-	-
I10	467	3	-	-	1	-	-	-

(e) GNSS-UTC Offset



(f) Galileo Constellation Degradation May, 2025

Although the NAGU was released, the full details on the degradation of satellites from 12th May to 19th May are not available yet. Not surprisingly, there is a strong concern from the community regarding the transparency of the Galileo service operations as indicated by the following questions raised to the European Commission (source: https://www.europarl.europa.eu/doceo/document/E-10-2025-002019_EN.html#:~:text=Galileo%2C%20the%20EU's%20global%20navigation,3.)

"Galileo, the EU's global navigation satellite system, is central to the EU's drive for technological sovereignty. However, recent observations by experts raise doubts about system performance and institutional transparency. On 7 May 2025, the EU Agency for the Space Programme (EUSPA) issued a notice[1] warning of potential service degradation 'up to (...) disruption of service' without a clear explanation. Moreover, an independent observer has reported that multiple satellites are broadcasting outdated data, potentially causing positioning errors affecting navigation and transport. At the same time, cryptographic authentication appears to be malfunctioning, weakening safeguards against spoofing and giving rise to concerns about secure use in critical services such as emergency response.

1. Can the Commission confirm the nature and scope of the reported system issues, including outdated satellite data and authentication malfunctions, and clarify what steps have been taken to mitigate risks to users?
2. What measures is the Commission taking to ensure the continuous accuracy and integrity of Galileo's broadcast data, especially in the light of recent anomalies?
3. What protocols are in place to ensure timely and transparent communication with users and researchers during service degradations, and does the Commission consider the recent EUSPA notice adequate in this regard?"

In the monthly performance analysis reported for May, there were Signal-In-Space degradation, triggered by satellite clock error, observed for multiple satellites. The goal in this section is to analyse the message contents of the broadcast navigation and correlate the health status indicator to the computed performance. The integrity parameter, inflation factor K, derived from the probability of the satellite fault event is used together with Signal In Space Accuracy (SISA) value and compared against the SISRE. If the SISRE is above K times SISA and satellite is indicated as healthy, then it is a satellite fault event not captured by the system. The detail discussion on this approach was provided in the monthly performance analysis report in June and July, 2024 (**Dhital et.al, 2024b)**. Readers are encouraged to go through those articles as the computation details and concepts are not provided in this section. In the following, only the relevant plots and analysis of the observed phenomenon are included to be succinct.

Figure F1 shows the evolution of the satellite health status from the 12th May until the 19th May, 2025. As E14 and E18 are exception satellites that are not used in the service provision, only E23 appears to show unhealthy status for few hours on the

15th and 16th of May. This suggests that during the constellation testing phase (as mentioned in the NAGU) the satellites were set as healthy and to be used for the services with expected performance degradation. However, if the satellite errors are exceeding the integrity level supported by the inflation factor K=4.17 to over bound the Gaussian distribution

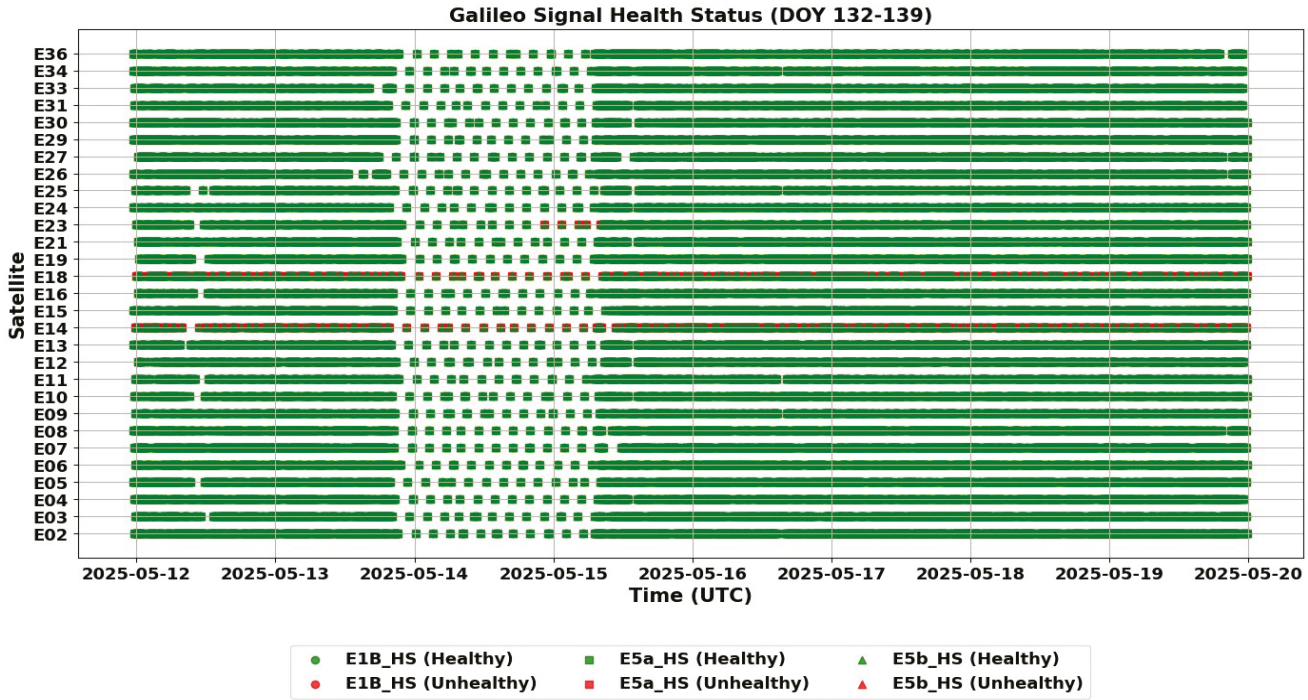


Figure F 1: The health status of different Galileo signals for each satellite for 12–19th May, 2025. E14 and E18 are exemptions as they are not used in the service provision. Only satellite E23 broadcast unhealthy status for some hours on 14th to 15th May. The sparse dots are due to the unavailability of regular data in the navigation messages.

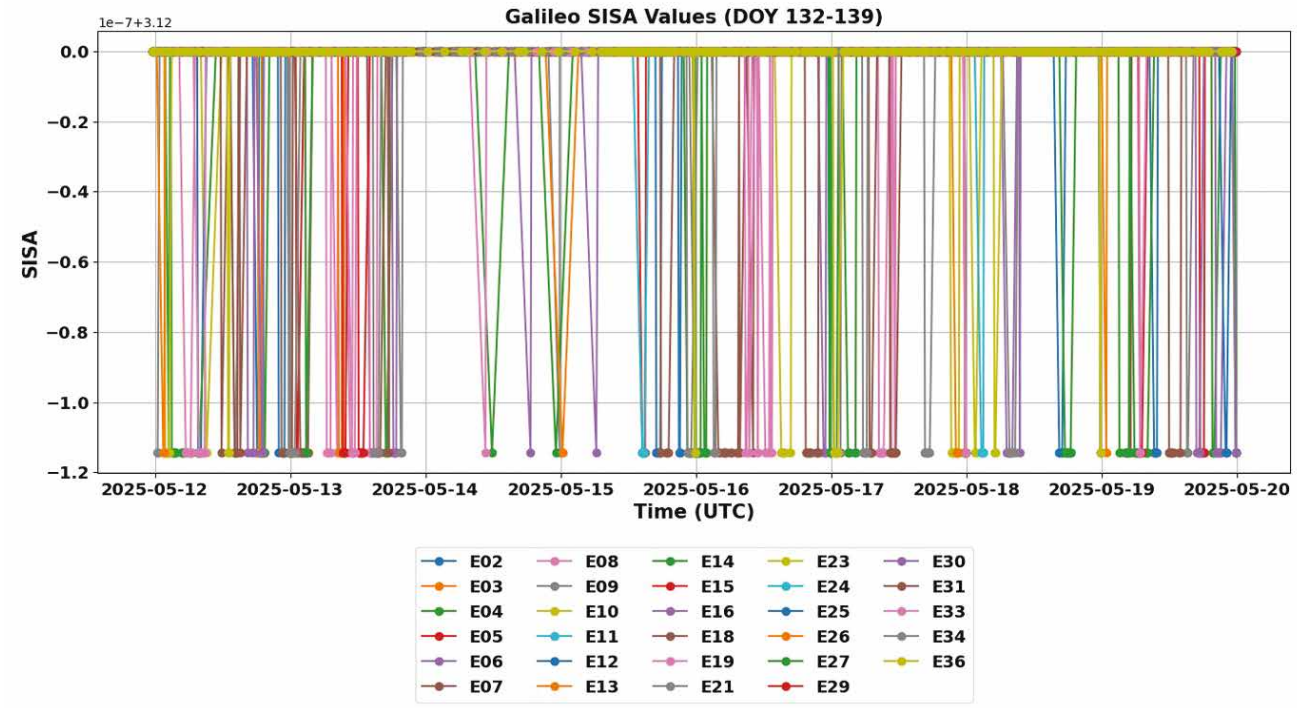


Figure F 2: The evolution of SISA value for each Galileo satellite. All satellites are broadcasting 3.12 m as SISA with some epochs showing close to 3.12 (they are most likely a computational rounding error). The inflation with K factor of this Gaussian overbound would be 3.12 times 4.17 equalling 13 m.

of the accuracy provided by SISA, it is to be noted as satellite fault event. The SISA value broadcast by the satellite is the Gaussian Overbound of the expected accuracy of the satellite system coming from clock and orbit errors. Figure F2 shows that all satellites were transmitting nominal value of 3.12 m for most of the time. On occasions they sent close to 3.12 m which is negligible and likely be the computational rounding error. The inflated overbound is 3.12 times 4.17

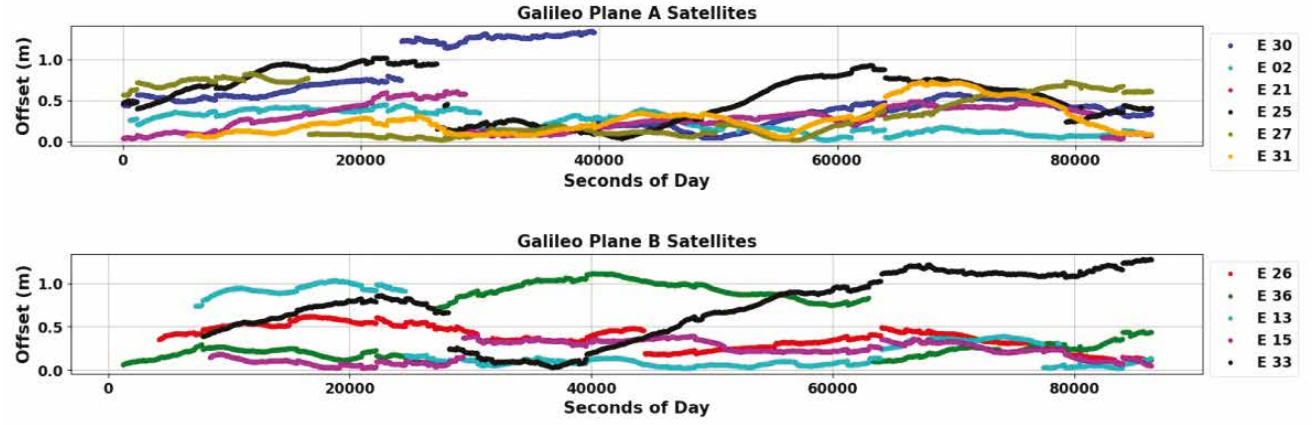


Figure F 3a: SISRE value for individual Galileo satellites (plane A and B) for 14th May, 2025. Most of the time the errors are below 1 m. And they are way below 13 m, which is the threshold for the integrity event.

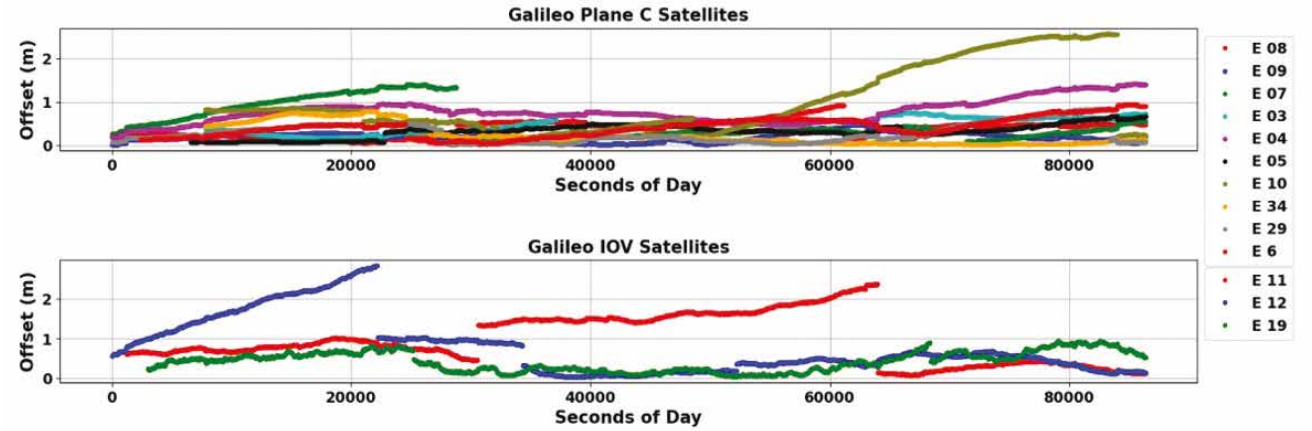


Figure F 3b: SISRE value for individual Galileo satellites (plane C and IOV satellites) for 14th May, 2025. Most of the time the errors are below 1 m. And they are way below 13 m, which is the threshold for the integrity event.

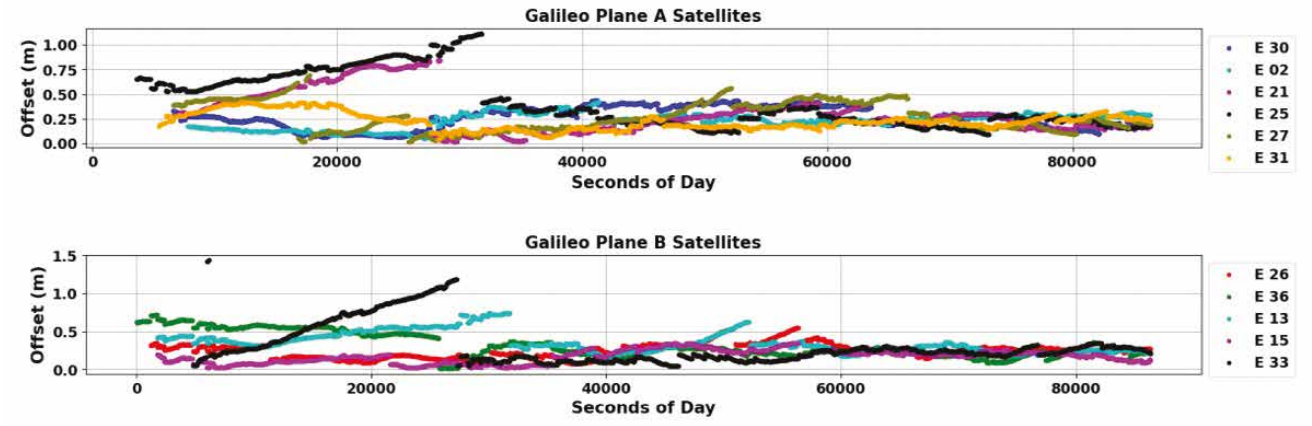


Figure F 4a: SISRE value for individual Galileo satellites (plane A and B) for 15th May, 2025. Most of the time the errors are below 1 m. And they are way below 13 m, which is the threshold for the integrity event. After mid-day, the errors are converged to a more stable value.

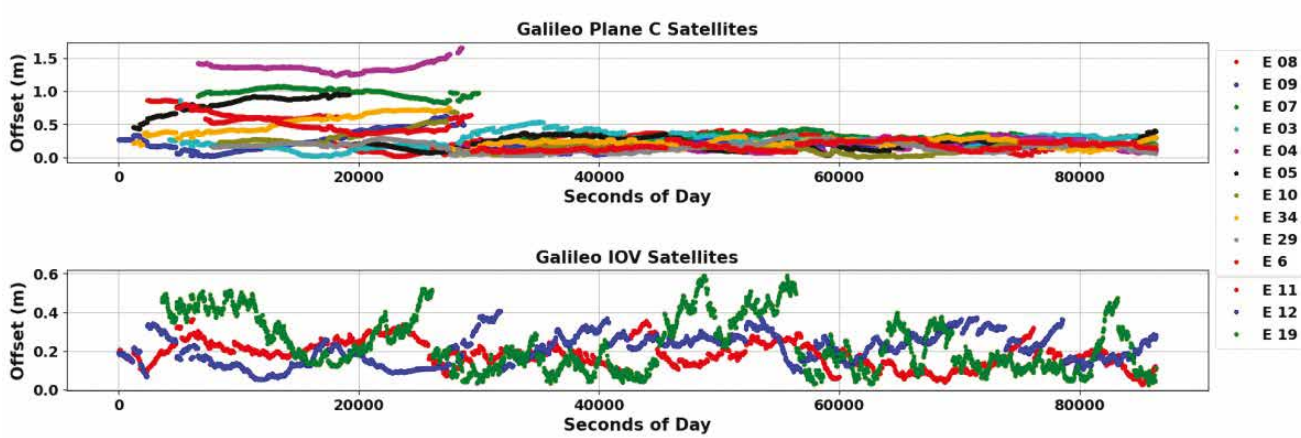


Figure F 4b: SISRE value for individual Galileo satellites (plane C and IOV satellites) for 15th May, 2025. Most of the time the errors are below 1 m. And they are way below 13 m, which is the threshold for the integrity event.

(inflation factor K) equaling around 13 m. The goal here is to check if the satellite SISRE between 12th and 19th May went over 13 m for any instance.

It is observed that the threshold of 13 m was never crossed and even on the most degraded day on the 14th and 15th, May, the SISRE for individual satellite was far below the threshold.

The inflated over bound based on above Figure F 2 is now compared against the computed the SISRE from Figure F3 and F4 (for 14th and 15th May, respectively). It is clearly visible that the SISRE for most of the satellites went higher from the mid-day on the 14th and stayed elevated until the mid-day 15th May. However, the higher errors never came near to the threshold of 13 m. This indicates that there was no satellite fault event during the Galileo constellation degradation between 12th to 19th May, 2025.

Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
   - The performance of GLONASS degraded by 10-15 cm. For other constellation, the overall performance looked similar to past month.
   - There were a couple of satellite clock jumps for both GPS and Galileo constellations. They will be analyzed in future issues.
   - The URA and satellite clock discontinuity for IRNSS showed some improvement. The URA values are less scattered than previous month. Only URA 2, 2.8 and 8 are broadcast.
2. UTC Prediction (GNSS-UTC):
   - All constellations except GLONASS reported relatively stable and consistent UTC predictions.

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

Emerging Technologies and their integration in Surveying Profession

The integration of IPS, VPS, SLAM, AI, and Machine Learning into the surveying profession signifies a major advancement from conventional practices.

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Abstract

The Surveying profession is experiencing a paradigm shift due to the emergence of advanced technologies such as Indoor Positioning Systems (IPS), Visual Positioning Systems (VPS), Simultaneous Localization and Mapping (SLAM), Artificial Intelligence (AI), and Machine Learning (ML). These technologies address the limitations of traditional tools like GPS and total stations, especially in environments where visibility, accessibility, or real-time data processing pose challenges. IPS facilitates precise indoor positioning where GPS fails, VPS leverages visual data for accurate localization in urban or structured environments, while SLAM enables real-time mapping in unknown or dynamic terrains. AI and ML further enhance surveying by automating data analysis, feature recognition, and predictive modeling. This paper discusses how these technologies reshape surveying practices and argues for their integration into higher education curricula. Emphasis is placed on equipping students with hands-on experience and theoretical understanding, ensuring they are prepared for the demands of a rapidly evolving geo-spatial industry.

Keywords: Artificial, Education, Machine, Positioning and Surveying.

Introduction

A lot of us here today can attest that we are used to the normal or the generic Surveying which if asked, we would mention cadastral, engineering, hydrography, geodesy, seismics or special surveys but most practiced is **cadastral**.

Most Surveyors registered by Surveyors Council of Nigeria (SURCON) mostly want to delve into private cadastral practice and I permit me to say that the word cadastral surveying is synonymous to private practice as acclaimed by many private practitioners. So, I think we are still orbit around the cadastral axis just like the Israelites in the wilderness for 40 years. However, we will not fail to commend the massive growth in the evolution of surveying equipment, data acquisition methods, data processing and visualization as the practice progressed from the ancient to the modern data acquisition method. The thought of the theme of the 2015 FIG working week: *From the wisdom of the ages to the challenges of the modern world.* Where measurements were obtained using **Human Legs by pacing, Gunter's chain with arrows, Tapes, Compass, Sextant etc.** Evolved to Theodolite, Electronic Distance Measurement (EDM), Total Station and the multiple frequency Differential Global Positioning System (DGPS), Light Detection and Ranging (LiDAR), Light Amplification Stimulated Emission Radiation (LASER), Multi-spectral imaging systems etc.

Brown and Smith (2020) in their article *Advancements in Surveying: The Role of Emerging Technologies in Data Acquisition*, 'The technological growth in surveying data acquisition has transformed traditional methods, with innovations like LiDAR, drones, and satellite imagery enabling surveyors to capture precise spatial data faster and more efficiently than ever before'. He emphasized that these advancements not only increase data accuracy but also expand the capabilities of surveyors

These are emerging as transformative tools in surveying as these technologies allow surveyors to capture, process, and analyze spatial data in new ways, enabling detailed indoor mapping, urban navigation, 3D mapping of complex environments, and predictive analytics and it is of importance that higher education inculcates in into her curricula.

to access previously unreachable areas and perform real-time analyses. These methods of data acquisition have increased the surveying horizon, but with limits and you know the end of one thing is the beginning of a new one. Also, we record an **increasing** number of young surveyors eager to take this technology to the next future. Now it is pertinent for us to ask ourselves, **what next?**

The field of surveying is rapidly advancing due to the integration of innovative technologies that provide improved accuracy, efficiency, and automation. These technologies are;

a. Indoor Positioning Systems (IPS).
b. Visual Positioning Systems (VPS).
c. Simultaneous Localization and Mapping (SLAM).
d. Artificial Intelligence (AI) and Machine Learning (ML).

These are emerging as transformative tools in surveying as these technologies allow surveyors to capture, process, and analyze spatial data in new ways, enabling detailed indoor mapping, urban navigation, 3D mapping of complex environments, and predictive analytics and it is of importance that higher education inculcates in into her curricula. Let's buttress on each technology and how they are reshaping surveying practices and academic programs.

2.1 Indoor Positioning System

As stated earlier, these equipment types have limits, so we are looking out for technologies that overcame the limitations of traditional tools. As we know, GPS signals are ineffective in confined or enclosed spaces, where underground structures, walls and ceilings obstruct satellite signals. How then do we map indoor positions? Well, that is what the Indoor Positioning System (IPS) addresses.

2.1.1 What is IPS?

The Indoor Positioning System (IPS) is a technology designed to provide accurate, real-time location information within indoor spaces, where GPS signals are **unreliable** or **unavailable**. IPS uses a combination of technologies like Wi-Fi, Bluetooth, magnetic field mapping, and even infrared signals to pinpoint a device or user's location with high accuracy, down to a few meters or even centimeters, depending on the setup (Luo et al., 2020).

2.1.2 How IPS Works

IPS operates through a network of sensors and transmitters installed in an indoor environment. Unlike GPS, which relies on satellites that lose signal strength indoors, IPS uses nearby signals such as **Wi-Fi, Bluetooth, magnetic fields, and radio waves** to determine a device's position? This system uses two main methods: **triangulation and fingerprinting**. In *triangulation*, IPS calculates distances between the device and multiple transmitters to pinpoint the location, similar to how GPS calculates outdoor locations. In *fingerprinting*, IPS identifies unique signal patterns that are matched to specific points within a building, enabling precise indoor mapping. Advanced IPS setups also incorporate sensor fusion, combining data from gyroscopes, accelerometers, and compasses in mobile devices to achieve even greater accuracy and real-time tracking of movement indoors.

2.1.3 Relevance of IPS in Shaping the Surveying Profession

IPS plays an essential role in transforming the surveying profession by enabling accurate indoor mapping and positioning, especially in areas where traditional methods are challenging. For example, it allows surveyors to create precise indoor maps of complex structures like airports, hospitals, shopping malls, and large industrial sites. These maps are crucial for applications such as facilities management, emergency planning, and indoor navigation. IPS also enhances surveying efficiency by automating location tracking and reducing the need for manual measurements. With IPS, surveyors can manage and monitor assets in real time, streamline workflows, and increase the accuracy of spatial data. This technology opens up new possibilities in surveying and is becoming increasingly important as demand grows for detailed indoor data in urban planning, construction, and logistics (Torres-Sospedra & Montoliu, 2021).

2.2 Visual Positioning Systems

Visual Positioning Systems (VPS) address critical limitations in both GPS and IPS by providing precise positioning in environments where traditional systems struggle, especially when neither satellite signals nor Wi-Fi triangulation is adequate for accuracy. VPS uses a device's camera and computer vision to analyze visual features in the environment, creating a more reliable positioning system for complex outdoor and indoor settings, particularly urban environments with high-rise buildings or indoor areas lacking structured signal coverage (Fischler & Bolles, 1981; Ishikawa et al., 2022).

2.2.1 How VPS Works

The VPS operates by capturing images through a **device's camera**, comparing them to a *reference database* of images and spatial data to determine the **exact location**. This reference database might be composed of previously captured photos or 3D models of the area, allowing VPS to *see* and *identify* specific landmarks and features that GPS or IPS would miss. The system uses machine learning and computer vision algorithms to match what the camera sees with pre-mapped images or models, accurately identifying position and orientation. Unlike GPS or IPS, which rely solely on signals, VPS takes advantage of the visual information in the environment to provide location data, even in areas with low connectivity or dense urban structures.

2.2.2 Relevance of VPS in Shaping the Surveying Profession

The VPS has transformative potential in surveying by enabling highly accurate, feature-rich mapping and positioning in areas with complex structures. Surveyors can use VPS for precise navigation and mapping in urban centers, construction sites, or any setting where environmental details are necessary for accurate spatial analysis. For example, VPS enhances the ability to navigate *densely built urban* areas where GPS accuracy is reduced, as it uses visual cues that can be more reliable than satellite signals. This technology also supports **augmented reality** (AR) applications, allowing surveyors to visualize spatial data in real-time while in the field, enhancing their ability to make immediate assessments and decisions.

2.3 Simultaneous Localization and Mapping

Simultaneous Localization and Mapping (SLAM) addresses the challenge of creating real-time precise maps of *unknown environments* while *simultaneously determining* the user or device's location within that map. SLAM fills a vital gap by allowing for accurate positioning and mapping in settings where pre-existing maps or positioning data are unavailable, making it highly valuable for dynamic and unstructured environments like construction sites, mines, forests, or any area undergoing rapid change.

2.3.1 How SLAM Works

SLAM combines sensor data from sources like cameras, LiDAR, radar, and inertial measurement units (IMUs) to build a map and track movement in real time. As the device (such as a robot, drone, or handheld unit) moves through an environment, it detects landmarks or features around it. The SLAM algorithms then use these landmarks to build a continuously updated map, all while tracking the device's changing position within that environment. By processing this data rapidly, SLAM can estimate both the layout of the area and the device's exact location with minimal delay (Thrun et al., 2005; Cadena et al., 2016). This process involves complex mathematical models and probabilistic algorithms that predict and correct any position discrepancies, making SLAM an ideal tool for dynamic or unknown environments.

2.3.2 Relevance of SLAM in Shaping the Surveying Profession

SLAM technology is revolutionizing surveying by enabling accurate mapping in areas where conventional methods may be too slow or impossible to implement. Surveyors can utilize SLAM-based devices to quickly map complex indoor spaces, densely vegetated outdoor areas, or construction sites, often in less time than traditional surveying techniques require. SLAM also enables the use of autonomous or remotely operated robots and drones to map hazardous or inaccessible locations, reducing safety risks for surveyors. Furthermore, SLAM's real-time mapping capabilities mean surveyors can instantly assess and adapt to the environment, enabling immediate decisions and reducing the need for repeat visits to the field. By incorporating SLAM into surveying workflows, professionals gain a powerful tool for high-precision mapping in dynamic environments, vastly improving data quality and efficiency.

2.4 Artificial Intelligence and Machine Learning

Artificial Intelligence (AI) and Machine Learning (ML) fill a significant gap in traditional surveying by *automating data analysis, pattern recognition* and *decision-making processes*, which are often time-consuming and complex. AI and ML enable surveyors to handle vast datasets more effectively, extract meaningful insights from them, and make predictive analyses, transforming how surveying projects are planned, managed, and executed.

2.4.1 How AI and ML Work in Surveying

AI refers to the simulation of human intelligence by computers, which can be applied to automate tasks, recognize patterns, and make decisions based on data. ML, a subset of AI, involves training algorithms to learn from data and improve over time. In surveying, AI and ML systems are trained on large datasets that may include remotely sensed datasets, LiDAR scans, GPS data, or even historical surveying records. These algorithms can then recognize patterns in the data, such as identifying terrain features, categorizing land use, or predicting structural changes over time (Goodfellow et al., 2016). For example, AI-driven image recognition algorithms can analyze aerial or satellite images and automatically identify features like roads, buildings, vegetation, and water bodies, vastly reducing the time surveyors would need for manual digitization. Additionally, ML models can make predictions, such as forecasting flood risks in specific areas based on previous data, which enhances planning for environmental or infrastructure projects.

2.4.2 Relevance of AI and ML in Shaping the Surveying Profession

AI and ML are reshaping surveying by enabling rapid data processing and

A significant gap remains in higher education, where many surveying students graduate without exposure to these emerging tools. This highlights the urgent need to embed these technologies into the curriculum through practical training, interdisciplinary projects, and partnerships with industry.

automation of repetitive tasks, leading to increased efficiency and precision. Surveyors can use AI to streamline data collection and processing, allowing them to focus on higher-level analysis and decision-making. In environmental surveying, for instance, AI can be used to analyze land use changes over time, helping surveyors make data-backed recommendations for land management. For GIS and remote sensing, AI tools are becoming essential for automated image classification, feature extraction, and anomaly detection, all of which can dramatically enhance the accuracy of spatial data. These advancements not only increase productivity but also enhance data accuracy, reducing the potential for human error in complex surveying tasks (Bengio, 2012). Incorporating AI and ML into higher education allows surveying students to gain skills in data science, image processing, and predictive analysis, preparing them for a technologically advanced industry. As AI and ML continue to evolve, they will remain at the forefront of innovations in surveying, ensuring that professionals can tackle increasingly complex projects with efficiency and foresight.

3.1 Relevance of integrating these new technologies in the Surveying and Mapping

The integration of IPS, VPS, SLAM, AI and ML represents a transformative leap forward in the surveying profession, addressing previous technological limitations and setting new standards for accuracy, efficiency, and safety. These technologies enable surveyors to conduct highly precise measurements in environments where traditional methods may fall short, such as indoors, in dense urban areas, and in dynamic or unstructured environments. IPS and VPS make it possible to map indoor and complex spaces where GPS is ineffective, while SLAM offers real-time mapping capabilities in unknown or changing environments, making it invaluable for construction and environmental surveying. AI and ML automate data processing, pattern recognition, and predictive analytics, allowing surveyors to manage and interpret vast datasets more effectively, which enhances data quality and speeds up decision-making processes. The collective impact of these technologies goes beyond technical efficiency; they empower surveyors to tackle projects with a level of precision and insight previously unattainable. Automated feature recognition, predictive modeling, and real-time spatial analysis mean that surveyors can focus more on strategic planning and less on time-consuming manual tasks. This not only reduces errors and improves accuracy but also opens new applications for surveyors, such as urban planning, disaster response, and environmental management (Campbell, 2011).

4.1 Integrating these Technologies into the Higher Education Curricula

From everything we have heard, how many of us have this knowledge? It would have sounded more familiar if we had been taught or grounded in these areas during our higher education. Doesn't this indicate the importance of incorporating these technologies into the curriculum of our higher institutions? As surveying evolves into a data-driven field, it's essential for educational institutions to prepare students for a landscape that demands proficiency in these emerging technologies. To incorporate these technologies into the curriculum, institutions should consider adding specialized courses in topics like indoor mapping (IPS and VPS), robotics and automation (for SLAM), and data science (AI and ML). Practical training sessions, using advanced equipment like drones, LiDAR scanners, and mobile mapping systems, will ensure students gain hands-on experience with these tools (Chen et al., 2020). Additionally, institutions should establish partnerships with tech firms and industry experts to create internship programs and guest lectures, providing students with real-world applications and industry insights. Furthermore, integrating interdisciplinary projects where students from surveying, computer science, and engineering work together can foster a broader understanding of how these technologies interconnect in practice. By embracing this integrated, tech-forward curriculum, higher education can ensure that the next generation of surveyors is well-prepared to lead in a rapidly advancing profession.

Conclusion

The integration of IPS, VPS, SLAM, AI, and Machine Learning into the surveying profession signifies a major advancement from conventional practices. These technologies collectively overcome key limitations of traditional equipment, offering improved accuracy, speed, and adaptability across diverse environments. As the demand for smart cities, indoor mapping, automation, and real-time data increases, the role of these innovations becomes indispensable. However, a significant gap remains in higher education, where many surveying students graduate without exposure to these emerging tools. This highlights the

urgent need to embed these technologies into the curriculum through practical training, interdisciplinary projects, and partnerships with industry. By doing so, institutions will produce surveyors who are not only competent in classical techniques but also fluent in modern geospatial technologies, positioning them to lead in an increasingly digital and data-driven world.

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DIGIPIN launched

IIT Hyderabad (IITH), in partnership with the Department of Posts and the National Remote Sensing Centre, ISRO, has launched DIGIPIN—a compact, human-readable, geospatial addressing system set to redefine how India navigates, delivers, and connects.

DIGIPIN offers a precise, intuitive, and inclusive code that represents the exact latitude and longitude of any location in India, from dense cityscapes to isolated maritime regions. Built as a digital public infrastructure layer, it aims to streamline postal operations, emergency responses, e-commerce delivery, and public services.

Notably, DIGIPIN maintains privacy, containing no personal identifiers and requiring only location-enabled devices to retrieve codes. Its machine-readability allows applications such as printing barcodes on consignments, integrating with digital wallets, and use in high-priority zones like disaster relief and public utility mapping. *pragativadi.com*

ISRO hands over 10 advanced technologies to Indian firms

The Indian Space Research Organisation (ISRO) has transferred ten of its start-of-the-art technologies to six Indian industries across the upstream, midstream, and downstream segments. The tripartite Technology Transfer Agreements (TTAs), facilitated by the National Space Promotion and Authorisation Centre (IN-SPACe), were signed between NewSpace India Limited (NSIL), the recipient industries, and IN-SPACe.

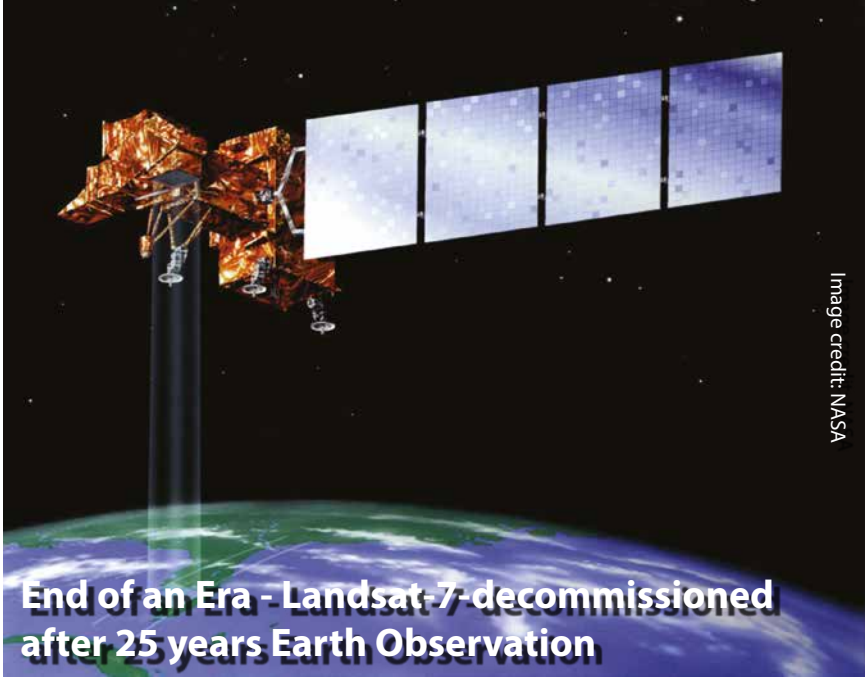
Among the technologies transferred are two advanced inertial sensors—the Laser Gyroscope and the Ceramic Servo Accelerometer—developed by ISRO's Inertial Systems Unit, for potential use in satellite launch vehicles. These technologies have been transferred to Zetatek Technologies Pvt. Ltd., Hyderabad.

In the midstream segment, three technologies related to ground station operations—S/X/Ka tri-band dual circular polarised monopulse feed, tri-axis antenna control servo system, and Ku/C/L and S Band Cassegrain feed—developed by ISRO have been transferred to Avantel and Jisnu Communications, both Hyderabad-based firms.

On the downstream front, two geospatial models developed by SAC/ISRO for pest forewarning and semi-physical crop yield estimation were transferred to Amnex Info Technologies, Ahmedabad, for deployment in agricultural decision-making and crop protection.

A compact, multi-parameter, portable bathymetry system developed by NRSC/ISRO has been transferred to Jalkruti Water Solutions Pvt. Ltd., Ahmedabad, to enable UAV-based integration for water resource monitoring.

Further, VSSC/ISRO's ceramic-based flame-proof coating technology—initially developed for launch vehicle applications—has been acquired by Ramdev Chemicals, Ahmedabad, for wider industrial applications. *www.fortuneindia.com*



End of an Era - Landsat-7 decommissioned after 25 years Earth Observation

After 25 years of capturing Earth's changing landscape, the Landsat 7 satellite received its final transmission from the U.S. Geological Survey and was officially decommissioned June 4, closing a remarkable chapter in space-based observation.

While Landsat 7's long watch over Earth comes to an end, Landsat 8, launched in 2013, and Landsat 9, launched in 2020, continue to work together to create a complete snapshot of Earth every eight days. Their successor—Landsat Next—is currently planned to launch in the early 2030s and provide even greater coverage and detail.

Launched in 1999 as a joint mission of the USGS and NASA, Landsat 7 significantly enhanced Earth observations and provided a key part of the Landsat program's five decade-plus record of imaging the planet's surface. The satellite's imagery will remain archived at the USGS Earth Resources Observation and Science Center, continuing to support scientific discovery and decision-making for the future.

"The Landsat satellites have delivered over 50 years of extraordinary science data, economic value and national security benefits by informing decisions in every sector of the economy—from monitoring drought in the West to guiding disaster recovery," said Sarah Ryker, USGS Acting Director. "For 25 of those years, Landsat 7's data helped farmers, land managers, city planners, and scientists, as well as communities around the world better understand and manage land, water, and other natural resources."

Landsat 7 achieved many milestones over its 25 years of operation and was the first Landsat to downlink data to the newly established USGS ground station in Sioux Falls, South Dakota. It was also the first Landsat satellite to be fully operated 24/7 by the USGS after being launched by NASA.

Its Enhanced Thematic Mapper Plus sensor delivered improved high-resolution imagery that expanded its capabilities, capturing critical historical events such as the aftermath of 9/11, Hurricane Katrina, and the Deepwater Horizon oil spill. The satellite also contributed to important projects, including the Landsat Image Mosaic of Antarctica, and inspired the "Earth As Art" collection, showcasing stunning visuals of the planet.

After ending its official mission in 2024, the USGS prepared Landsat 7 for decommissioning to follow responsible space practices and U.S. policies on keeping space clear of debris. The final steps included carefully lowering the satellite's orbit to decrease the risk of collisions and ensuring that all energy sources, such as fuel and batteries, are depleted to prevent the satellite from accidentally turning back on or creating debris. As Landsat 7 begins this decommissioned phase, it will drift silently in orbit for about 55 years before reentering Earth's atmosphere. *www.usgs.gov*

National Geospatial Awards 2025

The jury/ organizing committee of the National Geospatial Awards 2025 (Edition 02) has voted to honour "Jawaharlal Nehru Technological University, Hyderabad", with the 'Best University (National) Award', during the 'Open Source GIS Day' celebrations at IIT Bombay on 17 July 2025. This award is being bestowed for VTU and its affiliated colleges' active contributions to Geospatial Sciences and Technology, and participation in FOSSEE GIS's Open Source GIS activities.

The jury has also voted to honour Dr. Vijaya Lakshmi Thatiparthi (University College of Engineering, Science and Technology with the National Geospatial Faculty Fellow (Jury) Award during the event for his exemplary contributions to the first of geospatial sciences and technology.

Esri India Launches GeoAI Competency Centre

Esri India Technologies announced the opening of a new GIS and AI competency centre in Noida on July 1. The company will invest over ₹150 crore in this initiative over the next five years. The centre aims to accelerate the use of AI in GIS applications across various sectors in India.The new facility will expand Esri India's workforce with AI specialists, data scientists, GIS experts, and domain professionals.

GIS mapping may clear doubts over number of functional public taps in Kochi, India

The number of functional public taps in Kochi, a bone of contention between the Kochi Corporation and the Kerala Water Authority (KWA), is likely to be finalised soon, thanks to an app-driven GIS mapping of public taps across the State held earlier this year.

The KWA and the Local Self-Government department (LSGD) conducted the week-long GIS mapping in March after many

local bodies complained about disparity in the number of functional public taps.

According to the KWA, the initial mapping found no disparity in the total number of public taps within the Kochi Corporation limits from the figure reached during a Kochi city-specific GIS mapping held in 2021. "Nearly 5,200 public taps were found in that mapping conducted jointly with the Corporation, which had contested the number of taps and the functional ones among them. The latest mapping also threw up the same number, though the separation of functional and dysfunctional ones among them would be known only in the final report," said KWA sources.

MapmyIndia gains on ₹233 crore mapping data deal from overseas client

MapmyIndia has secured a map data licensing contract worth approximately ₹233 crore from a private sector international client.

The company did not disclose the name of the client, stating that it is "competitive sensitivitive data."

The project, classified as a domestic-use map licensing deal, will be executed over a period of seven years, the company said in a regulatory filing. *www.cnbctv18.com*

GIS survey may get Rs 20 crore incentive from Centre

After completing the aerial survey to get the 3D map of 240 square km of Hubballi-Dharwad, Karnataka's first full-fledged pan-city 3D GIS survey project has entered the mobile LiDAR mapping stage of collecting 3D data of the urban area. Soon, this project will enter the most important phase of door-to-door survey which may last for six months.

The Hubballi-Dharwad Municipal Corporation (HDMC) is spending Rs 23.1 crore from its own resource for this survey of a 15-month duration. The civic body expects the GIS survey to help bring all properties into the tax net with accurate assessment, resulting in a drastic increase in its revenue.

According to HDMC Commissioner, "As we will get all details of roads, properties, open spaces and even trees on a single platform, this will also be useful for urban planning. For example, we should not have to go for another detailed physical survey of a road for its development plan, as road length, width and even encroachments will be available at fingertips in the 3D model database,"

The contracts to conduct GIS survey in 12 zones of the HDMC are awarded to Genesys International Corporation Limited and RSI Softech India Private Limited. The project includes 3D mapping, ground truthing, database creation, property tax management software development, and updating it for next three years. *www.deccanherald.com*

Remote GeoSystems secures patent

Remote GeoSystems, Inc. announces the award of US Patent Number 12,244,844 for using software-based methods for taking video and GPS log files and combining them to create a single video file with continuously-embedded GPS location data throughout the video. These software-based methods differ from existing methods that require complex and expensive gyro-stabilized gimbal cameras and specialized video recording hardware – usually mounted on manned aircraft platforms – during the video recording mission.

This patent, and its functional availability in the company's LineVision software, solves a long-standing challenge for many users trying to incorporate video from small drones, action cameras, cell phones and other consumer-oriented video cameras into professional GIS and defense-oriented mapping software.

ESA teams up with Leonardo against satnav jamming

The European Space Agency (ESA) and Leonardo are embarking on a joint project to explore smart antennas. Representatives of ESA and Leonardo signed a contract at the Paris Air Show to research and develop machine learning techniques to steer antenna arrays to block out unwanted signals. The project will be developed under the umbrella of ESA's Navigation Innovation Support Programme (NAVISP).

Smarter antenna designs for resilience

Conventional antennas catch signals from all directions. A controlled reception pattern antenna (CRPA) can focus on signals coming from specific satellites and ignore signals or interference coming from other directions. These types of antennas are used in satellite navigation receivers to block jamming and counterfeit signals. They rely on electronics that control how they adjust their patterns (beamforming).

Under contract with NAVISP, Leonardo — together with ELT Group as subcontractor — will explore the reduction of the distance between the antenna elements to reduce the size and weight of the antenna array, and the use of machine learning to determine the best antenna setup and adjust the settings faster. This approach will lead to smaller, smarter and more effective antennas, especially useful in space-limited environments such as aircraft. *esa.int*

PNT portal

A new information portal for PNT and GNSS is now active. The European GNSS Center of Excellence (GNSS-COE) is designed to provide expertise to help development of critical PNT and GNSS applications.

"We support the development of applications both in the design definition phase, as well in the validation phase of these applications," according to the site. Among the offerings are

masterclasses, resilience assessment, mitigation methods, and a newsfeed.

The portal, a National GNSS Knowledge Center project, was funded under the European Space Agency's NAVISP Element 3, which supports member states' PNT initiatives and national strategies. *pntportal.eu*

ESA and Neuraspace collaborate to reduce signal noise

Neuraspace is working with ESA to revolutionise satellite navigation and orbit management through innovative use of GNSS technologies.

The joint project, developed with the support of ESA's NAVISP (Element 2) programme, is titled "Stop Getting Noise – Automated GNSS Processing for Smarter Orbits". It seeks to address critical operational challenges faced by commercial satellite operators, launch service providers and defence and government agencies.

The challenges to be addressed include the urgent need for more scalable, accurate, and autonomous orbit determination, particularly for satellite mega-constellations, in an increasingly congested space environment. Whereas defence and government agencies demand high-confidence SDA solutions amid increasing geopolitical tensions, satellite operators require reliable orbit tracking and early mission support. *neuraspace.com*

Space Force accepts new GPS control system

The Space Force officially took ownership of the GPS Next Generation Operational Control System, or OCX, from contractor RTX on July 1.

Accepting OCX does not mean it is already being used operationally, however. Integrated systems testing and readiness exercises must follow first. But if all goes well, OCX will enter operations late this year, said Col. Stephen Hobbs, commander of Mission Delta 31.

It has been a long and arduous road to develop OCX, which began with prototyping contracts back in 2007. In 2012, the Air Force estimated that OCX would enter operations by June 2017 with a program cost of $3.7 billion, per the Government Accountability Office. If current estimates hold, it will enter service in December with a program cost of $7.7 billion.

The Air Force selected Raytheon to build the system in 2012; by 2016, delays and extra costs had mounted so much that the Air Force had to declare a Nunn-McCurdy breach, indicating "critical" cost and schedule overruns. Even after the program was certified to continue, delays continued. *airandspaceforces.com*

UK and France partner on navigation systems

UK and French experts will work more closely to increase the resilience of both countries' critical infrastructure to the signal-jamming seen in the war in Ukraine, as part of a suite of joint science and tech work. As part of a raft of UK-France joint science and tech efforts, researchers from both countries will work together on technologies complementary to the likes of GPS, which are highly resistant to this sort of jamming.

An example is e-LORAN, a program driven by the UK government, working closely with the National Physical Laboratory and private sector companies. The system uses ground-based radio towers, which are much more challenging to block, for a reliable "backup" to GPS, so that UK infrastructure can keep running even when GPS fails.

The UK's Science and Tech Secretary used a joint visit to Imperial College London, with French President, Macron, to set out how this sort of collaboration makes both the UK and France stronger and safer. Whilst speaking at Imperial, Peter Kyle also pointed out the tens of millions of pounds in investment being brought into the British tech sector through UK-French trade, as well as the new jobs and growth that this partnership creates.

Additionally, the UK and France are launching a partnership on supercomputing. The partnership will be led by the Bristol Centre for Supercomputing, the home of Isambard-AI, and the French computing centre GENCI, who lead France's AI Factory.

Closer ties between both nations' world-leading compute power, and sharing AI best practice, will turbocharge the breakthroughs in AI, transforming public services and improving lives. These efforts build on the AI Opportunities Action Plan, the UK government's blueprint to fuel the use of AI across the economy. *www.gov.uk*

SouthPAN satellite navigation program clears Critical Design Review milestone

GMV has announced that the Southern Positioning Augmentation Network (SouthPAN) has successfully completed its Critical Design Review (CDR), marking a pivotal milestone towards delivering advanced satellite-based augmentation services (SBAS) across Australia and New Zealand. Led by Lockheed Martin Australia, with GMV as a key strategic partner, SouthPAN is an innovative project jointly supported by the Australian and New Zealand governments, set to provide groundbreaking satellite navigation and precise positioning services throughout Australasia.

The Critical Design Review represents a vital checkpoint in the lifecycle of a safety-critical system such as SouthPAN, validating that the design meets stringent performance, safety, and security requirements necessary for civil aviation operations. As part of this milestone, the SouthPAN team provided comprehensive certification artifacts aligned with international aviation standards, including ARP 4754A for systems development processes, DO-254 for hardware, and DO-278A for software assurance. The successful completion of the CDR demonstrates that the system's

architecture and implementation will satisfy the rigorous design assurance levels mandated for Safety-of-Life applications. Achieving this milestone confirms the readiness of the system's design for operational deployment and marks a critical step forward towards its future certification for Safetyof-Life services in the aviation sector.

SouthPAN is notable as the first SBAS globally designed from its inception as a service rather than as a conventional turnkey system. This innovative service-oriented approach enables scalability and potential expansion into other regions, while establishing clear customer-provider interactions governed by service-level agreements (SLAs) and adherence to defined key performance indicators (KPIs).

Fraunhofer IAF presents compact integrated quantum magnetometer

Fraunhofer IAF's latest version of its compact integrated quantum magnetometer is a diamond-based system characterized by its robustness, high integration density, and measurement sensitivity. It offers new measurement possibilities for a wide range of applications, including navigation.

Developed by the Fraunhofer Institute for Applied Solid State Physics IAF it is based on nitrogen vacancies (NV) in diamond and provides access to the smallest magnetic fields with a previously unattainable degree of flexibility and precision. The miniaturized measuring system offers new possibilities in applications that require precise measurement with minimal interference, such as in biochemical measurements of nerve pathways or in microelectronics. *iaf.fraunhofer.de*

Turkey to develop homegrown satellite navigation system

Turkey plans to develop its own satellite navigation system and mapping application to reduce foreign technological dependence.

The Regional Positioning and Timing System (BKZS) was announced in the "2030 Industry and Technology Strategy". The BKZS project will provide Turkey with precise positioning and timing data through the country's own satellites, according to the strategy document.

The BKZS system is designed as a regional alternative to global navigation satellite systems such as the United States' GPS. While not aiming to replace GPS worldwide, the project seeks to reduce Turkey's reliance on foreign positioning technologies, especially in sensitive sectors.

TÜBİTAK's National Metrology Institute and the Turkish Space Agency are jointly testing a domestically produced rubidium atomic clock. The strategy paper states that cube satellite designs have been completed and are moving to the production phase. *turkishminute.com*

TDK expands MEMS inertial sensors portfolio

TDK Corporation has expanded its MEMS inertial sensors portfolio with the Tronics AXO315®T0, a high-temperature MEMS accelerometer with ±14 g input range and a digital interface for measurement while drilling (MWD) applications in the energy market. With a typical bias drift of less than 1 mg without recalibration after 1000 hours at high temperature, AXO315T0 brings a digital and low-SWaP alternative to legacy quartz accelerometers, paving the way for a new generation of MWD tools able to operate for long periods at high temperatures with no compromise on performance. tdk-electronics.*tdk.com*

Xsens Avior OEM IMU

Xsens has launched Xsens Avior, a lightweight, OEM form factor inertial measurement unit (IMU) with a compact 36.8mm x 40mm footprint which offers enhanced performance in a wide variety of industrial and commercial applications.

It is suitable for products manufactured in high volume thanks to its vertical 10×2-pin socket connector for simple board mounting, and its tolerance of any mounting orientation in all three axes. *www.movella.com*

Kongsberg provides maritime gyro compasses

Although traditional gyrocompasses are immune to GNSS signal-based attacks by design, many modern navigation systems incorporate GNSS data to enhance positioning accuracy. For maritime operators, having an autonomous and reliable source of heading and positioning data ensures safety and maintains operational continuity in contested or signal-denied environments.

Kongsberg's MGCs offer resilience, using high-grade strap-down inertial sensors that detect the Earth's rotation without the need of external input. This allows them to determine true north and maintain precise heading without relying on GNSS. Unlike traditional mechanical gyros, Kongsberg's MGCs can estimate latitude internally. This ensures consistent accuracy from equatorial regions to the poles. *www.kongsberg.com*

HBK shrinks tactical-grade navigation into a 15g GNSS/INS

MicroStrain by HBK has launched the 3DM-CV7-GNSS/INS, an ultra-compact, tactical-grade inertial navigation system (INS) designed for seamless integration into space-constrained platforms. Weighing 15.6 grams and measuring 38x30x10mm, the 3DM-CV7-GNSS/INS offers tactical-grade performance without size, weight, or cost trade-offs. Its user-friendly functionality, adaptive extended Kalman Filter, and full industrial temperature calibration deliver robust and reliable data acquisition across a wide range of real-world scenarios. *www.hbkworld.com*

GNSS RTK 4 Click board

GNSS RTK 4 Click is a compact add-on board from Mikroe that provides high-precision GNSS positioning with real-time kinematics (RTK). The board features the LG290P a quad-band GNSS module from Quectel capable of receiving signals from GPS, GLONASS, Galileo, BDS, QZSS and NavIC while using SBAS for enhanced accuracy. *www.mikroe.com*

Taoglas introduces Patriot antenna

Taoglas has released the Patriot series, a compact, multi-function combination roof mount antenna designed for connected vehicle fleets across emergency services, utilities, and commercial sectors. It delivers robust multi-network connectivity while reducing vehicle roof clutter and simplifying installation. Supporting 5G and 4G cellular (600–6000 MHz), with both dual-band GNSS (L1 and L1/ L5) and a secondary GNSS (L1), Wi-Fi® (2.4, 5.8, and 7.1 GHz), SDARS (2.3 GHz), and LMR/TETRA (380–400 MHz and 700–900 MHz), the Patriot enables concurrent broadband, navigation, telemetry, and voice services. A dedicated whip element with full P25 VHF/UHF/700-900 MHz support is available in various lengths to meet frequency requirements. *www.taoglas.com*

Q-CTRL's maritime quantum navigation solution

Q-CTRL has unveiled ground-breaking advancements in software-ruggedized quantum sensing for navigation in a major field trial with Australian Defence on board the Royal Australian Navy's Multi-role Aviation Training Vessel (MATV), MV Sycamore.

In these trials, Q-CTRL field deployed a quantum dual gravimeter, which measures tiny variations in Earth's gravity as part of a next-generation quantum-assured positioning, navigation, and timing (PNT) system operable when GPS is unavailable or untrusted.

This first trial saw over 144 hours of continuous operation and successful data collection with no human intervention during real maritime operations. The newly announced trials of Q-CTRL's gravimetric navigation technology now open opportunities to bring quantum-assured navigation to maritime vessels where magnetic navigation can be less effective. *thequantuminsider.com*

Honeywell wins U.S. contracts

Honeywell has been selected by the U.S. Department of Defense's (DOD) Defense Innovation Unit (DIU) to participate in the Transition of Quantum Sensing (TQS) program. The program aims to accelerate adoption of quantum sensors to address near-term alternative position, navigation and timing (PNT) and intelligence, surveillance and reconnaissance (ISR) applications for the U.S. Joint Forces Command.

Honeywell has been chosen to support the TQS program under two DOD contracts: CRUISE (Compact Rubidium Unit for Inertial Sensing and Estimation)

and QUEST (Quantum Enabled Sensor Technologies for MagNav).

The CRUISE program, established by the DOD in partnership with Vector Atomic, will focus on developing quantum sensor-based Inertial Measurement Units (IMUs) to provide a standalone navigation solution without relying on traditional Global Navigation Satellite Systems (GNSS) susceptible to jamming and spoofing. Honeywell will support the development of this quantum-sensor-based technology, which will enable the measurement of acceleration and orientation from an IMU mounted to a vehicle to calculate changes in position and velocity. As a result, it will meet next-generation performance requirements at a lower size, weight and power than existing products. *aerospace.honeywell.com*

Septentrio strengthens Agnostic Corrections Program with onocoy

Septentrio announces that the onocoy GNSS correction service has been added to its Agnostic Corrections Partner Program. It operates a community-driven GNSS RTK network powered by Web3 and blockchain technology, to ensure secure, transparent, and efficient data sharing and transactions. Although privately operated, this network actively monitors its base stations to maintain service reliability and quality. *www.septentrio.com*

SandboxAQ and Acubed advance magnetic navigation technology

SandboxAQ and Acubed have released real-world test results from a five-month, nationwide project designed to test the accuracy of AQNav, which is an artificial intelligence-driven magnetic navigation (MagNav) system. It uses advanced quantum magnometers to read Earth's crustal magnetic anomalies, like a geoohysical fingerprint, then employs large quantitative models (LQMs) to filter out electromagnetic interference and precisely determine an aircraft's position without relying on satellite signals. *www.sandboxaq.com*

Topcon Agriculture launches UC7 Plus

Topcon Agriculture has introduced the next generation of its boom height control technology for agricultural spraying applications with the launch of the UC7 Plus. Compatible with most self-propelled and pull-type sprayers, the new technology features new sensor technology that improves performance and reliability. This includes the new dynamic chassis sensor (DCS-1) that enhances the stability and response of the boom control system, and the latest MS-1 sensors with MAX Sense ultrasonic technology for improved performance in challenging terrain. These sensors are designed to withstand the rigors of the field with corrosion-resistant GF nylon housing, a protective transducer screen, and multi-axis vents. *topconpositioning.com*

BlackNaute: the resilient PNT

Safran Electronics & Defense has introduced BlackNaute, a new autonomous positioning, navigation and timing (PNT) system. The system integrates Safran's HRG Dual Core inertial navigation technology, the Skylight multi-mode GNSS receiver board and an atomic clock to offer navigation resilience in challenging electronic warfare environments. *www.safran-group.com*

SatLab introduces HydroBoat 1200MB

SatLab has introduced the HydroBoat 1200MB, a compact uncrewed surface vehicle (USV) system engineered for 3D hydrographic surveying in inland and nearshore waters. The system integrates SatLab's autonomous vessel platform with the HydroBeam M2 multibeam echosounder, providing a portable solution intended to streamline data collection in shallow or confined environments. *satlab.com.se*

ComNav launches laser scanner

ComNav Technology has released the SinoGNSS LS600 laser scanner, a handheld 3D scanning device designed for professional use in both indoor and outdoor environments. It integrates lidar, GNSS, an inertial measurement unit (IMU) and dual-camera systems for detailed, colorized point clouds and precise positioning data production. The LS600's also includes advanced SLAM algorithms, which work in tandem with a built-in real-time kinematic (RTK) GNSS module. *www.comnavtech.com*

Exyn Nexys now compatible with Trimble DA2 GNSS system

Exyn has integrated the Trimble DA2 GNSS System, an RTK-capable GNSS receiver, with the Exyn Nexys autonomous mapping platform, bringing centimeter-level geospatial accuracy to SLAM-based mobile 3D mapping.

The new capability enables users to pair Exyn Nexys' lidar-based SLAM mapping with high-precision RTK corrections, allowing teams to georeference and anchor point clouds directly in the field without relying on ground control points or post-processing workflows. *www.exyn.com*

CHC Navigation unveils vehicle-mounted mobile mapping system

CHC Navigation (CHCNAV) has released the AU20 MMS, a vehicle-mounted mobile mapping system. The AU20 MMS features a sophisticated lidar system that uses fourth-generation real-time waveform processing technology. It achieves a scan rate of 2 million points per second and 200 revolutions per second, producing point cloud data with 5 mm accuracy and 3 mm precision. *www.chcnav.com*

Airbus awarded Hisdesat contract

Airbus Defence and Space has been selected as prime contractor for the development and manufacture of two new PAZ-2 radar satellites, securing continuity of the current Earth observation PAZ satellite, in service since 2018.

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https://eventi.unibo.it/iag2025

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www.expouav.com

Esri India User Conference 2025
September - Delhi 3rd & 4th, Kolkata 9th, Hyderabad 10th, Mumbai 12th
www.esri.in

ION GNSS+
08-12 September 2025
Baltimore, USA
www.ion.org

Uncrewed Aerial Vehicles in Geomatics 2025 (UAV-g)
10 - 12 September 2025 Espoo, Finland
https://uav-g2025.com

Baška SIF (Spatial Intelligence Forum) Meeting 2025
21 - 24 September 2025
Baška, Krk Island, Croatia
www.visitbaska.hr/en

October 2025

Intergeo 2025
7 - 9 October
Frankfurt, Germany
https://dvw.de/intergeo/en

The 8th ISPRS Geospatial Conference
13-15 October 2025
Tehran, Iran
https://geospatialconf2025.ut.ac.ir

The Arab Conference on Astronomy and Geophysics
13 - 16 October 2025
Cairo, Egypt
https://acag-conf.org

The 46th Asian Conference on Remote Sensing
27 - 31 October 2025
Makassar, Indonesia.
https://acrs2025.mapin.or.id/

November 2025

Canada's National Geomatics Expo 2025
3 - 5 November
Calgary, Canada
https://gogeomaticsexpo.com

13th International FIG Workshop on the Land Administration Domain Model & 3D Land Administration
3 -5 November 2025
Florianópolis, Santa Catarina, Brazil
https://gdmc.nl

The programme, led by Hisdesat for the Spanish Ministry of Defence, represents a key milestone for the Spanish space industry since around 65% of the satellites' content will be developed by Spanish industry, led by Airbus.

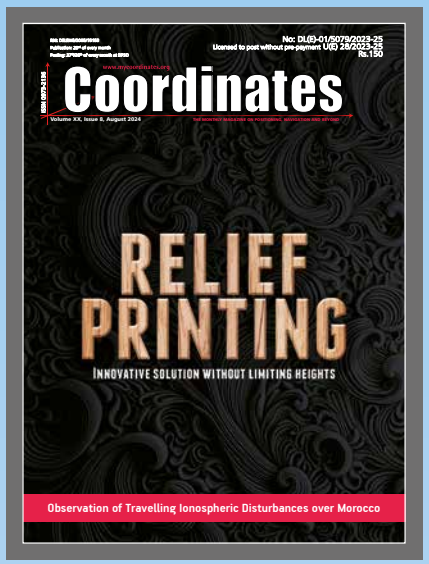
The PAZ-2 satellites, among the most advanced in the world, will be more capable than their predecessor, significantly improving the image quality and resolution to better than 25 centimetres, while increasing the coverage up to 6.7 million km² per day and satellite, and orbiting the Earth 16 times daily. These improvements will strengthen the intelligence and surveillance capabilities of the Spanish Armed Forces, as well as civilian applications in infrastructure monitoring, risk management, border control and disaster assessment, capturing radar imagery 24 hours a day and in all weather conditions.

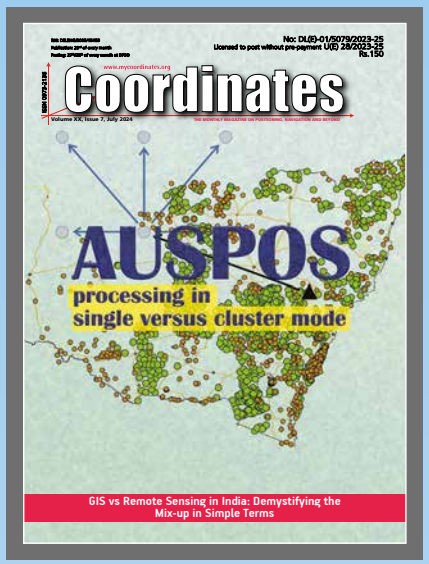
Eagleview and SkyWatch partnership

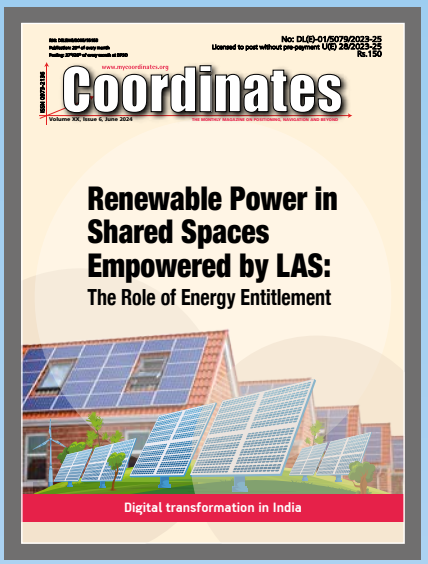
Eagleview and SkyWatch have announced a new collaboration that makes Eagleview's ultra high-resolution aerial imagery available across the SkyWatch platform. This new initiative is a response to the growing requests of customers in architecture, engineering, construction, and other industries. *skywatch.com*

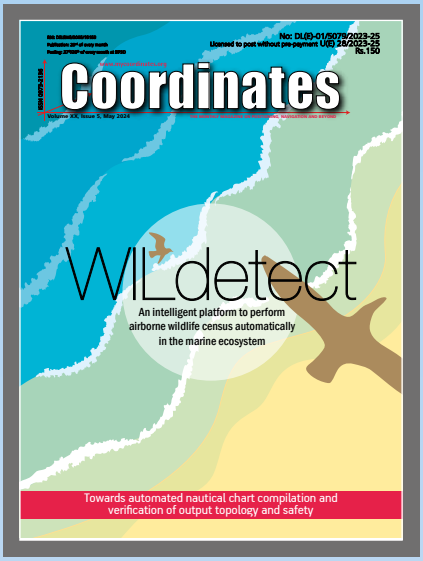
HAL to build, market ISRO's SSLV

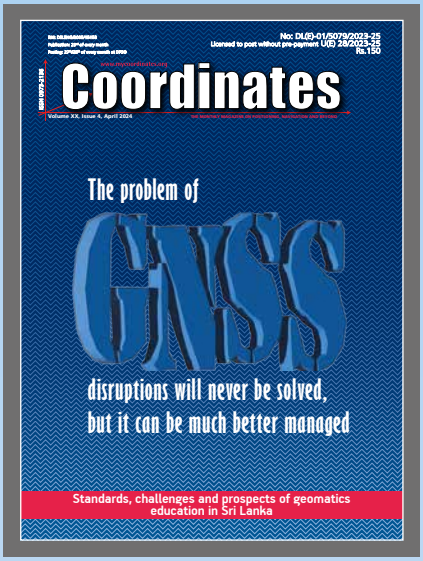
Hindustan Aeronautics Limited (HAL) has won the complete transfer of technology (ToT) for the Small Satellite Launch Vehicle (SSLV) from Indian Space Research Organisation (ISRO). This marks the first time an Indian firm has been granted full ownership of a rocket, including its design, build, and marketing rights. The Rs 511-cr deal was finalized by the Indian National Space Promotion and Authorisation Centre (IN-SPACe) following a two-stage selection process. Unlike earlier partnerships where ISRO retained ownership, HAL will have the freedom to modify SSLV's design and choose its partners. *daijiworld.com*

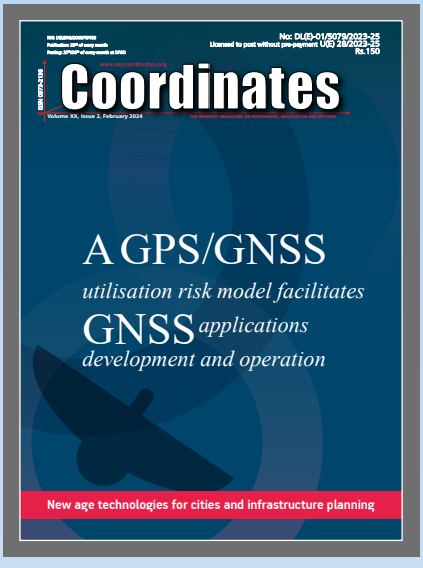


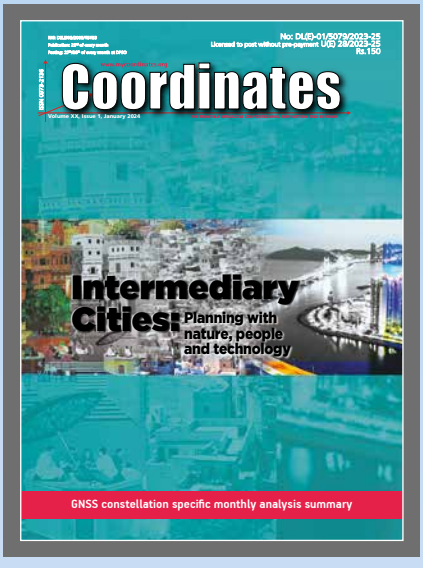


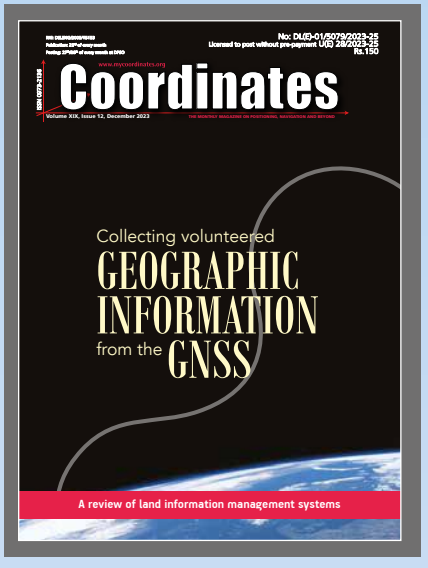












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