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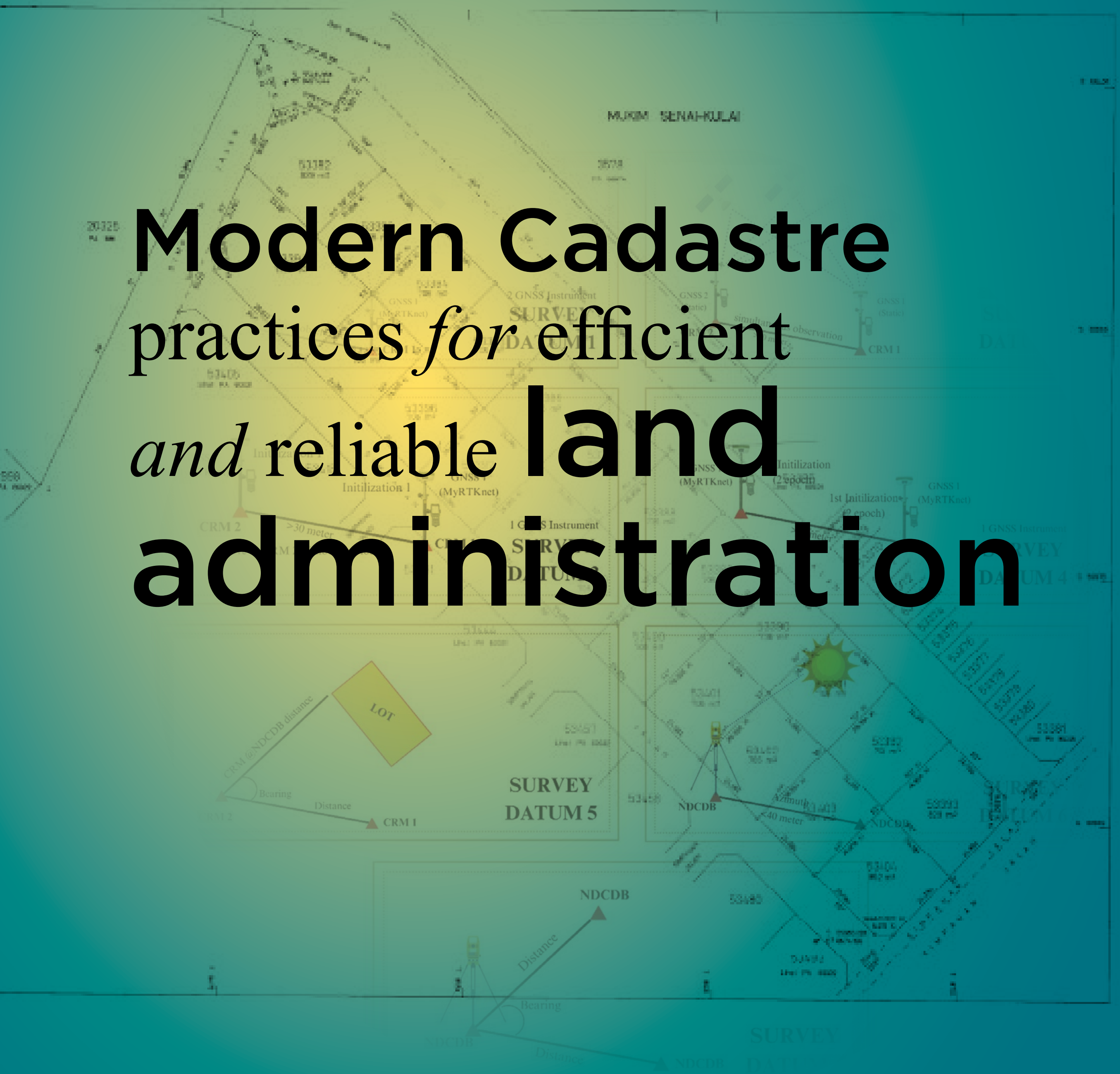

Modern Cadastre practices *for* efficient *and* reliable land administration

Authorization of cadastral surveyors in Norway

In Coordinates

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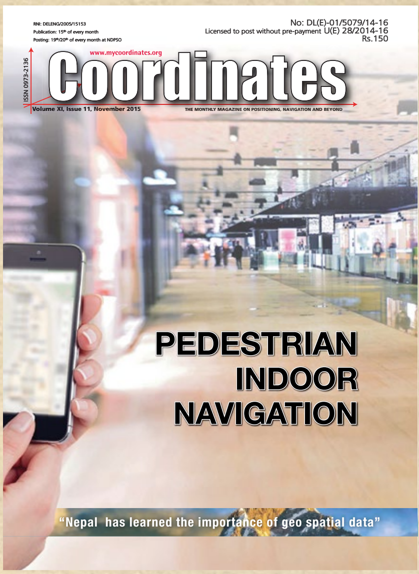

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The future of the map – the map of the future

Prof Dr Georg Gartner
Research Group Cartography, Department of Geodesy and Geoinformation,
Vienna University of Technology, Vienna, Austria

New and innovative technologies have an important impact into what cartographers are doing. Maps can be derived automatically from geodata acquisition methods such as laser scanning, remote sensing or sensor- networks. Smart models of geodata can be built allowing in-depth analysis of structures and patterns. A whole range of presentation forms is available nowadays, from maps on mobile phones all the way to geoinformation presented as Augmented Reality presentations.

Pedestrian Indoor Navigation with Smartphones

Jhen-Kai Liao, Kai-Wei Chiang and Chih-Hung Li
National Cheng Kung University, Taiwan

This study uses the indoor control point as the update measurement in the extended Kalman Filter (EKF) to aid the Inertial Navigation System (INS) without GNSS. The walking velocity from a pedometer and step length model is applied as the constraint of moving direction in EKF.

Geospatial Portal as an important SDI building block for Disaster Response and Recovery

Biredra Bajracharya

Regional Programme Manager, MENRIS programme, International Centre for Integrated Mountain Development (ICIMOD), Nepal

The NDRRIP was developed by ICIMOD to fill the gap of such a platform and to support earthquake response and recovery efforts. As the country recovers, ICIMOD is working on working on extending the platform to tailor information needs with various analytical features. It is hoped that such a unified platform with geospatial tools will improve reconstruction efforts by enabling judicious planning and decision making on resource allocation and mobilisation and will help foster coordination among various responders on the ground.

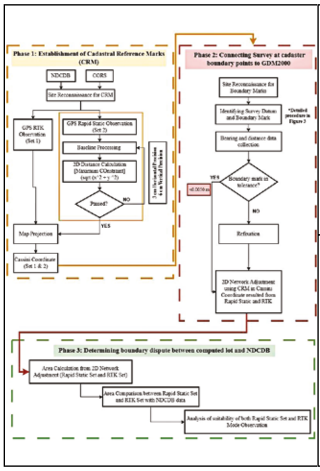
Drones in support of upgrading informal settlements: potential application in Namibia

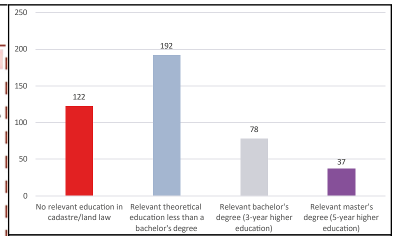
Grenville Barnes
University of Florida, Gainesville, FL USA

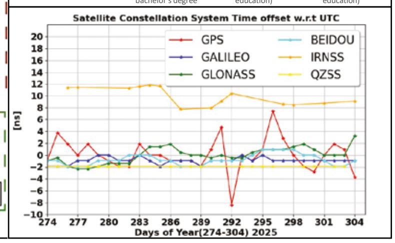
Walter Volkmann
MicroAerial Projects LLC, Gainesville, FL USA

Anna Muller
Shackdwellers Federation of Namibia

Namibia is fortunate to have a small group of model airplane enthusiasts (amongst them a land surveyor)who have exploited the large open spaces to pioneer the use of open source and do it yourself (DIY) UAV technology for aerial mapping and aerial surveillance for the protection of endangered wild life. The UAV community in Namibia has the capacity to design, configure and assemble multi-rotor as well as fixed wing platforms for Namibian applications.







In this issue

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Articles

Columns

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

Europe leads the world on digital rights.

Now, delaying AI safeguards and easing data rules

Indicates a troubling shift.

The EU seems to be blinking first,

In a high-stakes tech power struggle.

Pushing strict AI rules to 2027,

May fuel innovation or leave citizens exposed.

But loosening personal data protections,

Strikes at the core of Europe's digital dignity.

Anonymous today, identifiable tomorrow,

Blurs the personal data space.

Europe must compete in the AI race,

But should it, by surrendering its soul?

Bal Krishna, Editor
bal@mycoordinates.org

Suitability analysis of satellite surveying using GNSS for modern cadastre practice

The research contributes to the optimization of cadastral processes and highlights the importance of selecting appropriate GNSS techniques based on factors such as distance to CORS and traceability requirements.

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Abstract

Modern cadaster systems uses space-based positioning techniques like GNSS, which are affected by orbital, atmospheric errors, and carrier phase ambiguity. To ensure consistency in cadaster mapping using geocentric Cassini GDM2000, Malaysia uses a cadaster system that utilizes Cadastral Reference Mark (CRM). This study examined two GNSS positioning methods for cadaster surveying, Rapid Static and Real-Time Kinematic (RTK), for CRM establishment with three objectives: creating CRMs using these methods, surveying cadaster lots and adjusting measurements using CRM positions, and analyzing the effectiveness of the techniques' by comparing area changes and coordinate offsets with NDCDB data. GNSS baseline vectors from CRM were linked to the nearest Continuously Operating Reference Station (CORS) using both methods, and network adjustments were made in GDM2000. The coordinate of CRM in Cassini GDM2000 was transformed by using map projection. Analysis showed that both Rapid Static and RTK methods achieve similar accuracy levels when the distance to reference station is lower than 20 km. Both GNSS measurement methods demonstrate their effectiveness in cadastral surveying by achieving the 5% tolerance required for areas under 40 hectares, as specified by the regulations. However, RTK does not provide measurement traceability as compared to Rapid Static mode. The study utilized CORS from MyRTKnet and NRCnet in GDM2000 coordinate system. The analysis from this studies will be beneficial for understanding positioning solution from Real-Time GNSS measurements and their applicability in cadastral surveying. By establishing CRMs through these methods, the research contributes to the optimization of cadastral processes and highlights the importance of selecting appropriate GNSS techniques based on factors such as distance to CORS and traceability requirements. This research supports Malaysia's National Geospaital Policy and contributes to Sustainable Development Goals, particularly SDG 9 (Industry, Innovation and Infrastructure) and SDG 11 (Sustainable Cities and Communities), by advancing efficient and reliable land administration practices.

1. Introduction

Optimizing the accuracy of the National Digital Cadastral Database (NDCDB) is crucial for modernizing land management and facilitating sustainable development. The NDCDB is currently being used as a coordinate-based cadastral database in Malaysia, based on the geocentric datum (GDM2000) with a uniform spatial accuracy of less than 10 cm throughout the entire Peninsular Malaysia [1]. GDM2000 is a Malaysian Geodetics Datum that replaced the old datums (MRT48 and BT68). This network is further enhanced with the help of the Peninsular Malaysia Geodetic Scientific

In this research, two types of data were utilized. The first data comprises cadastral survey data, which consists of instrumentation calibration data, solar observations data, traversing data, and refixation data. The second data involves GNSS measurement; RTK and Rapid Static observation conducted over 30 minutes

Network (PMGSN94) and East Malaysia Geodetic Scientific Network 1997 (EMGSN97). The vector displacement limit of boundary mark is 0.05 m for urban, town, and new development while other areas is limited to 0.010 m [2, 3]. All measurements in Peninsular Malaysia must use the Cassini Geocentric Coordinates System for cadastre purpose.

Cadastral Reference Marks (CRM) are fixed geodetic control points used in cadastral systems to support the accurate survey and establishment of land parcel boundaries[4]. The method to establish CRM is outlined in *Pekeliling Ketua Pengarah Ukur dan Pemetaan Malaysia* (2009a). The distance between the two new CRM must not less than 30 m, observed simultaneously and connected to GDM2000. It is also recommended to choose CORS that are located near the survey site to ensure optimal accuracy and reliability of the positioning data. GNSS-based CRM measurement ensures accurate and reliable NDCDB. The selection of GNSS method is dependent on its accuracy, cost, and the size of the survey area. It is important to look over the project's needs. To stay accurate, the CRMs need to be regularly maintained. Thus, CRM establishment in Malaysia requires a detailed evaluation of RTK and Rapid Static GNSS positioning methods [5, 6].

Common positioning methods include Static, Rapid Static, and RTK, which enable centimeter-level accuracy. The approach chosen greatly affects cadastral survey accuracy. RTK and Rapid Static GNSS have been studied in many circumstances for their pros and cons [5, 7]. Tropospheric delay and RTK performance in dense urban environments have also been studied [8, 9]. However, little study has been carried out to investigate the suitability of Rapid Static and RTK GNSS positioning methods for CRM establishment in Malaysia.

CRM can be established using RTK and Rapid Static method. GNSS Rapid Static mode provides higher accuracy positioning with improved horizontal and vertical root mean square error (RMSE) in certain conditions compared to other GNSS positioning techniques such as RTK, Differential GNSS (DGNSS), and Precise Point Positioning (PPP) [10, 11]. GNSS Rapid Static Mode, despite its advantages in achieving high-accuracy positioning with a shorter observation time, has notable limitations. This technique may require a longer observation time to achieve the accuracy that may be affected by the atmospheric conditions [12]. Multipath interference and atmospheric effects can reduce the accuracy, but these problems can be solved with careful planning and specialized equipment. RTK, on the other hand, can be used for measuring, mapping, farming, and controlling machines at the centimeter level in real-time [12]. RTK is an advanced surveying method designed for achieving high-accuracy positioning in a relatively short observation time. Despite its advantages, this technique has several limitations that need to be considered [13], including difficulties in receiving the signal due to its environment and measurements are prone to multipath errors. To get the best result, RTK should be conducted in a clear, unobstructed area [14].

2. Study area, dataset and methodology

The study is for this research, as shown in Figure 1, is located in Taman Desa Skudai, Johor, and includes cadastral Lots 53382-53393 and 53394-53404. This area was selected due to its urban development and typical residential lot configurations, which present real-world conditions for assessing GNSS-based cadastral surveying methods. Additionally, the area's proximity to existing Continuously Operating Reference Stations (CORS) within a 20km radius makes it suitable for evaluating the performance of both Rapid Static and RTK GNSS techniques. Lot data were obtained from the eBiz JUPEM portal to ensure consistency with official cadastral records.

This study used National Research & Development CORS Network (NRCnet) and MyRTKnet. NRCnet was set up based on collaborative work amongst universities, government agencies, and positioning industries in Malaysia. MyRTKnet is Malaysia's GNSS based network that provides real-time positioning services. It consists of a network of CORS distributed across the country. Both network offers satellite measurement correction in support of GNSS applications such as navigation and positioning [15]. This research has three (3) phases. Phase 1 involved using RTK and Rapid Static GNSS methods to establish CRMs, with data sourced from the NDCDB and linked to CORS stations. Phase 2 includes a traversing survey at cadastral lots using total station, while Phase 3 compared these findings with NDCDB data. The study analyzed duration, accuracy, precision, and area comparability of both methods. An overview of research methodology is illustrated in Figure 2.

In this research, two types of data were utilized. The first data comprises cadastral survey data, which consists of instrumentation calibration data, solar observations data, traversing data, and refixation data. The second data involves GNSS measurement; RTK and Rapid Static observation conducted over 30 minutes. These GNSS measurements

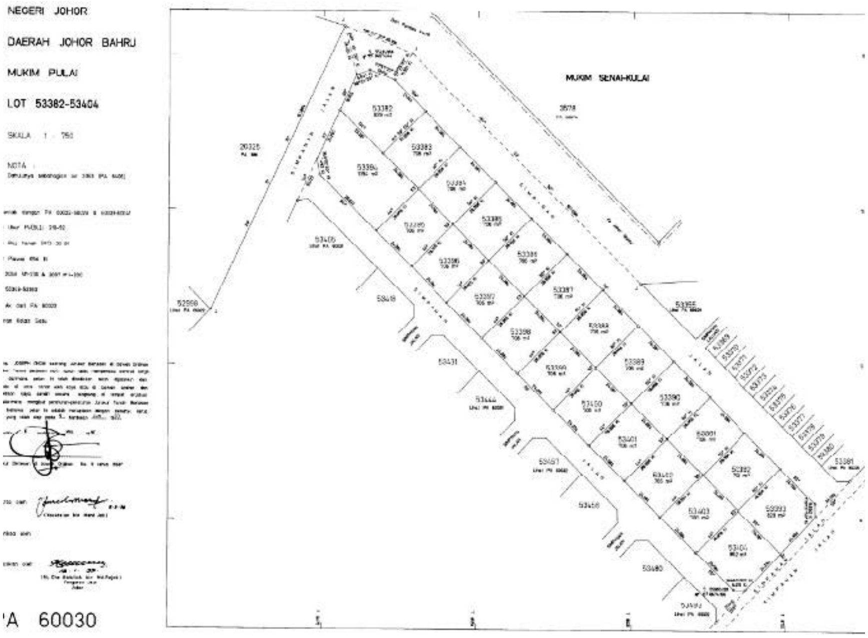

Figure 1. Certified plan of the survey lot

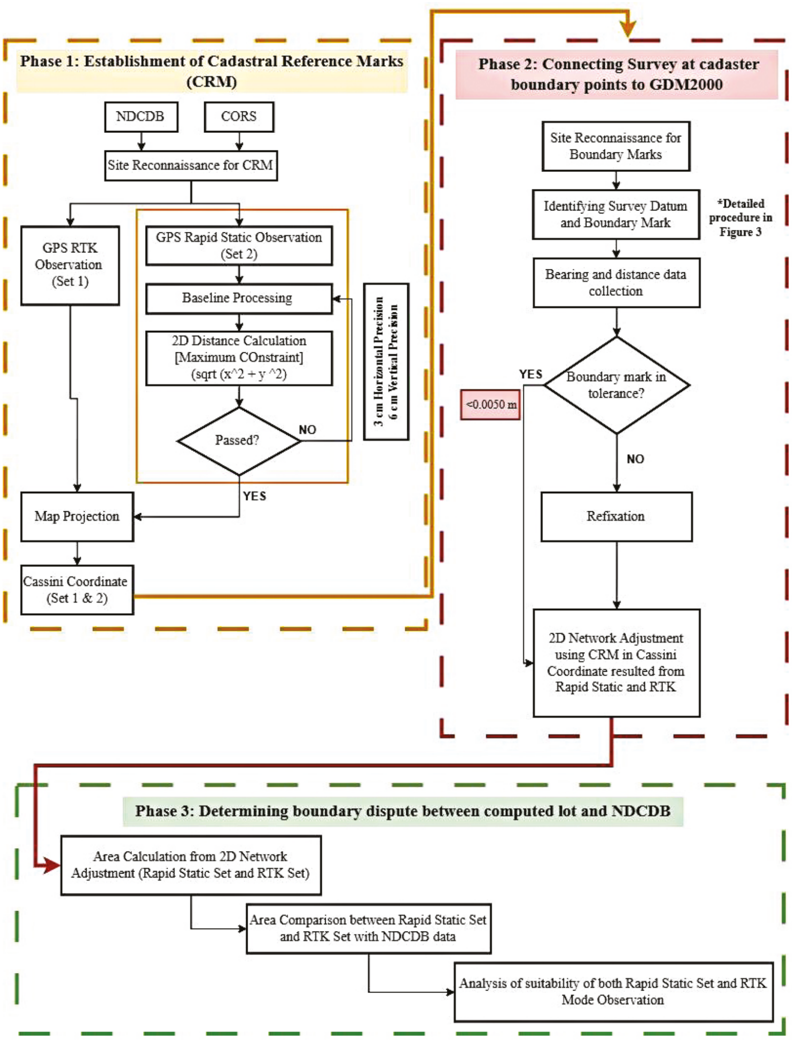

Figure 2. Research methodology

are subsequently compared with the NDCDB provided by Department of Survey and Mapping Malaysia (Jabatan Ukur dan Pemetaan, JUPEM). Following data collection, the results are visualized using AutoCAD software to analyze the impact of both GNSS measurement methods and the NDCDB.

2.1 Phase 1: Establishment of Cadastral Reference Marks

The NDCDB is a comprehensive digital database managed by the JUPEM, containing cadastral and land-related information. The first step is data acquisition. In this step, two types of data are acquired which are NDCDB and CORS data. The NDCDB is obtained from JUPEM. Next, is to identify the nearest CORS from the survey area. Choosing the closest reference station optimized the signal quality and minimized potential errors, contributing to the overall precision of GNSS observations. Ideally, all CORS data should also be sourced from JUPEM if the station is located near the site.

Three (3) nearby CORS have been identified: JHJY, SPGR, and ISK1. Among them, JHJY and SPGR are part of the MyRTKnet network, and their coordinates can be accessed directly from the MyRTKnet website. ISK1, on the other hand, belongs to the NRCnet. All of these station coordinates are given in GDM2000. While NRCnet has demonstrated the capability to achieve centimeter-level precision, similar to MyRTKnet, external tests confirms that NRCnet's precision is comparable to MyRTKnet's high level of accuracy, making it equally reliable for applications requiring centimeter-level accuracy. The coordinate solution in GDM2000 has been produced by [15]. Detailed network analysis can be found in the paper. However, in this study, one of the NRCnet station is chosen due to its closer proximity, ensuring higher accuracy and reliability for the measurements. Specifically, the JHJY from MyRTKnet and ISK1 from NRCnet stations were utilized to optimize data collection. Site reconnaissance is the next step to take before performing the

GNSS survey. This step is to identify any potential challenges that might affect the survey process. It is essential to choose a suitable survey place that ensures a clear sky view and is situated away from the buildings. This can help to minimize multipath errors, which may impact the accuracy of the GNSS survey data. The quality can be quantified using Dilution of Precision (DOP). A DOP below 3 is essential for precise and dependable GNSS observations, especially in real-time positioning situations [16].

Two GNSS positioning methods have been applied in this study; Rapid Static and RTK method. In this case, four CRMs were established to form a stable and redundant geodetic control network, ensuring sufficient geometric strength for network adjustment and minimizing positioning errors. The number and distribution of CRMs were based on JUPEM's cadastral survey guidelines. The RTK observation was connected to ISK1. The RTK data is real-time coordinates in GDM2000 that can be obtained directly at the survey area from the GNSS controller. The Rapid Static observation was conducted for 30 minutes on each point. This duration aligns with commonly accepted GNSS surveying standrads and guidelines, which suggest observation times of 15-45 minutes depending on satellite geometry, multipath environment, and baseline length. GNSS data were processed using the Trimble Business Centre (TBC) software. The Rapid Static observation was processed using the single baseline processing and connected to ISK1 and JHJY. The coordinates from the processed GNSS data were compared, and a 3D positional difference threshold of less than 3 cm was applied to ensure compliance with cadastral accuracy standards. This tolerance aligns with the accuracy requirements set by the

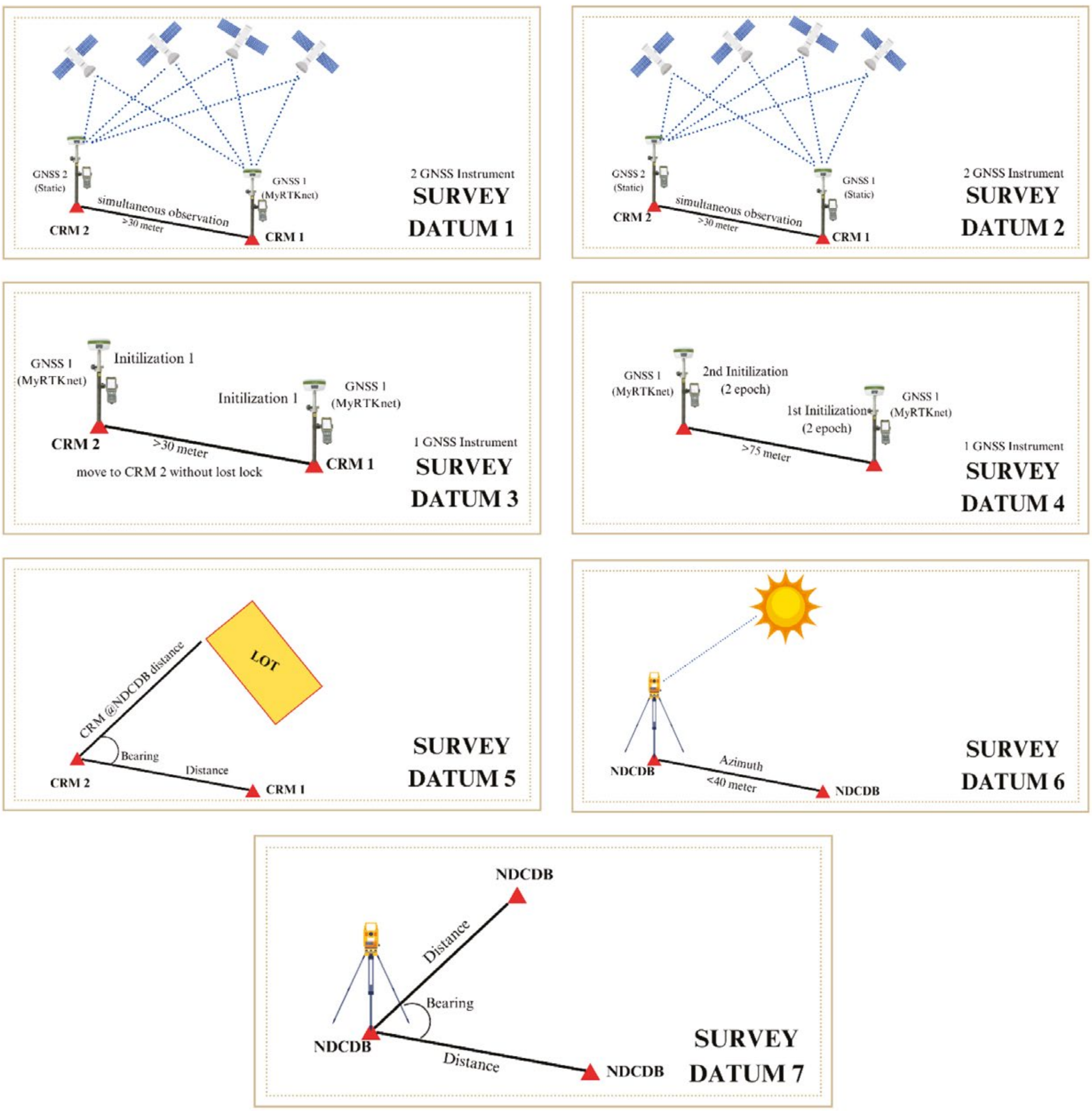

Figure 3. Detailed for identifying survey datum

JUPEM for first-order cadastral control points, and is consistent with international GNSS survey practices for high-precision applications. The final coordinates are calculated by averaging the coordinates of points based on two different CORS.

The coordinate of the GNSS measurement was transformed by using the Coordinates Transformation Program (CTP). The purpose of using this CTP software is to transform coordinates from GDM2000 into MRT48 and projected to Old Cassini Soldner. Steps for this datum transformation and map projection need to follow the survey regulation by JUPEM [17]. The parameters required for the transformation, including datum shift and ellipsoid parameters, were bought from the JUPEM, ensuring accuracy and official compliance in the transformation process.

2.2 Phase 2: Connecting Survey at Cadastre Boundary Points to GDM2000

Before data collection, there are two important aspects involved, which are identifying the datum for starting a survey job and verifying the position of the boundary mark. Detail for identifying the survey datum is in Figure 3. The allowable displacement limits of boundary marks shall not exceed 10". The cadastral survey datum is a standard requirement for conducting survey as a reference point for starting the cadastral work based on the requirement for survey outlined in PKUP2009 [18].

According to JUPEM, for a new survey to determine the coordinates, each cadastral survey should be based on qualified datum. Each cadastral survey should be based on a satisfactory datum consisting of one of the following options: (1) at least two CRMs points where distance is not less than 30 m with simultaneous observations by using MyRTKnet method for the first CRM and static method for second CRM, or (2) at least two CRMs points where distance at least 30 m, with simultaneous observations using the static method for both points, or (3) at least two newly established CRM points, where distance at least 30 m, with observations made using MyRTKnet for both points in the same initialization process. This process should be repeated in a second initialization, or (4) at least two CRMs where distance at least 75 m apart, with observations using either MyRTKnet in real-time or the static method for both points in two initializations, or (5) if two old CRM points are used, their positions must be verified by a third point using a bearing and distance observation, either from nearby old CRM points or from the National Digital Cadastral Database (NDCDB); or (6) two survey points from the NDCDB, where distance at least 40 m, where the original positions have been verified by direct measurements or traverse calculations, along with the sun observations for azimuth or MyRTKnet observations, or (7) two adjacent survey points from the NDCDB, where positions have been confirmed and verified by a third point using bearing and distance observations or traverse, with the points remaining in their original positions. This option ensures a reliable datum is established for precise and consistent cadastral measurements.

Among the conditions stated to start the survey job is using two boundary marks with solar observations. The datum that needs solar observation is two boundary marks from NDCDB with distance not less than 40 meters where the original position of these marks has been proved by direct measurement or traverse [19]. Solar observations are only done when the sun's altitude is at least 10°, either in the morning or in the evening. At least two sets of continuous observations of the sun are made. If there is a difference in grid bearing of more than 10" between the first and second sets, a third set is needed. Both crosshairs must be used to find the reference mark in each set of data. There should also be at least 30 m between the observation point and the reference mark that is being used. These simple rules make sure that the solar observations made during the study are correct and reliable.

After an acceptable tolerance is reached, data collection can be started by traversing around the lot. The survey qualities can be qualified as first-class if the misclosure does not exceed 1'15". This error can be minimized by ensuring the face left and face right for every station reading does not exceed 10". Every day before starting work, there must be a daily check in the field to make sure that the measures from the previous day are acceptable. According to survey regulations in 2009, this daily check should not exceed 0.01 m [18]. This ensures that any discrepancies or errors in previous measurements are identified and rectified promptly, maintaining the integrity and reliability of the survey data.

The final procedure is to conduct a refixation process. Refixation is the process of replacing boundary marks that has been found to move from its original position above the permitted limit. The limit of the displacement vector of the boundary mark is 0.05 m for urban or town and new development areas, while the limit of displacement vector for other areas is 0.10 m [19]. Before the refixation is carried out, the baseline must be identified. An allowable baseline must not exceed 30 m as stated in the regulation. After all the measurements have been carried out the next stage is to perform adjustment using Least Squares Adjustment. There are several criteria when adjusting, some of which are; (i) raw observation of bearing and horizontal distance will be used for adjustment. (ii) for minimum constraint, only one control station is constrained, and the rest are used for checking and (iii) for maximum constraint, all but one stations are constrained and the unconstrained station is used as a checking station. Checking is done by comparing the 2D distance between the estimated and known coordinate using equation 1. The output from the adjustment process contains the adjusted coordinates which help to achieve precise and dependable results for this study.

$$\text{2D Distance} = \sqrt{(N_{Estimated} - N_{Known})^2 + (E_{Estimated} - E_{Known})^2} \quad (1)$$

where;
N = Northing
E = Easting

Table 1. The coordinate data after baseline processing using the Rapid Static method

Rapid Static Method							
ISK1				JHJY			
Point	Latitude	Longitude	Height (m)	Point	Latitude	Longitude	Ellipsoidal Height (m)
CRM1	N`1°32'21.24691"	E103°38'19.25205"	49.445	Point	Latitude	Longitude	49.408
CRM2	N1°32'23.28553"	E103°38'17.21040"	52.187	CRM1	N`1°32'21.24693"	E103°38'19.25199"	52.168
CRM3	N1°32'26.99190"	E103°38'13.56552"	46.967	CRM2	N1°32'23.28525"	E103°38'17.20934"	46.941
CRM4	N1°32'25.26667"	E103°38'18.52977"	49.774	CRM3	N1°32'26.99212"	E103°38'13.56575"	49.751

2.3 Phase 3: Determining Boundary Dispute between Computed Area Lot and NDCDB

The last phase is the area calculation that involves the adjusted coordinates obtained from the 2D Network Adjustment to compute the area of cadaster lots. These methods are also known as the Double Meridian Distance (DMD) methods that are used by the JUPEM as shown in equation 2.

$$2A = \begin{bmatrix} E_1 & N_1 \\ E_5 & N_5 \\ E_4 & N_4 \\ E_3 & N_3 \\ E_2 & N_2 \\ E_1 & N_1 \end{bmatrix} \qquad (2)$$

where;
A = Area
E = Easting
N = Northing

The Northing and Easting coordinates are listed and cross-multiplied. The resulting data is then divided by two to obtain the area of each lot. The final step is the comparison of the area between Rapid Static mode, RTK mode, and data from the NDCDB. The acceptance tolerance between both GNSS measurement and NDCDB must not exceed 5% for areas under 40 hectares. The comparative analysis, through these steps, is instrumental in determining the suitability of Rapid Static and RTK mode for cadastral surveying in Malaysia.

3. Result and analysis

This section is divided into three subsections according to the achievement of the objectives of the study, which are; (i) CRM establishment. (ii) Connecting survey at cadaster boundary points to GDM2000. (iii) Determining boundary dispute between computed lot and NDCDB.

3.1 Phase 1: Cadastral Reference Marks Establishment

The coordinate for CRM1, CRM2, CRM3, and CRM4 in GDM2000 is shown in Table 1. The result in Table 1 shows

Table 2. The coordinate difference based on JHJY and ISK1 CORS station

DIFFERENCE JHJY–ISK1			
Point	**ΔE** (cm)	**ΔN** (cm)	2D Distance (cm)
CRM1	-1.10	0.20	1.12
CRM2	-1.30	0.30	1.33
CRM3	-1.70	0.80	1.88
CRM4	-1.80	-0.20	1.81

Table 3. The coordinate data using the RTK method

ISK1		
Point	Latitude	Longitude
CRM1	N`1°32'21.24693"	E103°38'19.25199"
CRM2	N1°32'23.28525"	E103°38'17.20934"
CRM3	N1°32'26.99212"	E103°38'13.56575"
CRM4	N1°32'25.26633"	E103°38'18.52939"

Table 4. Result for minimum constraint on CRM points coordinates (Rapid Static)

Fixed Stations	2D Distance between Known and Adjusted Coordinates			
	CRM 1(cm)	CRM 2 (cm)	CRM 3 (cm)	CRM 4 (cm)
CRM 1		1.37	0.88	1.67
CRM 2	1.37		1.28	1.86
CRM 3	0.88	1.28		2.41
CRM 4	1.67	1.86	2.41	

Table 5. Result for maximum constraint on CRM points coordinates (Rapid Static)

Checking point	2D Distance between Known and Adjusted Coordinates		
	ΔE (cm)	**ΔN**(cm)	2D Distance (cm)
CRM 1	-0.48	-0.94	1.05
CRM 2	-0.40	1.33	1.39
CRM 3	-1.32	-1.12	1.73
CRM 4	0.82	-0.27	0.87

Table 6. Result for minimum constraint on CRM points coordinates (RTK)

Fixed Stations	2D Distance between Known and Adjusted Coordinates			
	CRM 1 (cm)	CRM 2 (cm)	CRM 3 (cm)	CRM 4 (cm)
CRM 1		3.07	2.14	1.22
CRM 2	3.07		4.28	4.29
CRM 3	2.14	4.28		2.02
CRM 4	1.22	4.29	2.02	

Table 7. Result for maximum constraint on CRM points coordinates (RTK)

Checking point	2D Distance between Known and Adjusted Coordinates		
	ΔE(cm)	**ΔN**(cm)	2D Distance (cm)
CRM 1	1.41	-0.06	1.41
CRM 2	-2.84	0.53	2.89
CRM 3	0.27	2.25	2.26
CRM 4	0.03	-1.05	1.05

Table 8. The comparison area of the observation

Lot No	Rapid Static vs NDCDB	RTK vs NDCDB
53382	4.11%	3.73%
53383	-0.91%	-1.18%
53384	-1.69%	-1.96%
53385	-0.96%	-1.16%
53386	0.10%	-0.08%
53387	0.09%	0.00%
53388	0.34%	0.24%
53389	0.37%	0.27%
53391	0.24%	0.11%
53392	0.19%	0.07%
53393	5.90%	6.00%
53394	0.24%	0.50%
53395	1.96%	2.33%
53396	1.90%	2.28%
53397	1.80%	2.19%
53398	1.79%	2.17%
53399	1.54%	1.63%
53400	1.56%	1.43%
53401	1.63%	1.46%
53402	2.69%	2.59%
53403	4.98%	4.97%
53404	1.08%	1.01%

the coordinates in latitude, longitude, and ellipsoidal height. Table 2 below describes the difference in the coordinates based on two CORS stations, which are JHJY from MyRTKnet and ISK1 from NRCnet. The coordinate is compared in difference northing (ΔN), easting (ΔE), and 2D distance.

Based on Table 2 above, all the differences are generally small, with the maximum 2D distance difference is 1.88cm for CRM3. All CRM is below the acceptable range at 3 cm. The final coordinate used is from the average value from JHJY and ISK1. Table 3 shows the data for RTK that have been surveyed to four CRM points. RTK provides users with the coordinates only without a proper checking procedure. Further research can be done to propose a checking procedure for the establishment CRM using RTK.

3.2 Phase 2: Connecting Survey at Cadaster Boundary Points to GDM2000

Site reconnaissance was made at the survey lot, and it turns out that only two boundary marks were acceptable within the tolerance according to the survey regulation. Therefore, solar observations are performed to determine the true north direction. Two sets of sun observation have been carried out on station 2 with back bearing to station 1. The grid bearing to the sun of the first set is 150°22’45” while the second set is 150°22’41”. The difference between these two sets is 4”. The data is still in the tolerance that is required by the survey regulation. There were 10 stations established to form a closed closed-loop traverse. The result of bearing misclosure is 3”. The result of the misclosure is acceptable because the value is below 1’15” as stated in the survey regulation. The results of the computation of linear misclosure for the traversing shows that linear misclosure for the traverse is 1:19744, which exceeds 1:8000 and fulfills the requirement for the first-class survey. After a traverse survey, it was found that the 27 out of 42 boundary marks had either shifted from their original positions or were not found. Table 4 and Table 5 show the result of minimum constraint and maximum constraint for Rapid Static measurements respectively, while Table 6 and Table 7 present the minimum constraint and maximum constraint for RTK measurements.

Based on Table 5, the highest value for checking point using Rapid Static is CRM 3 which are 0.017 m. Meanwhile, in Table 7, the highest value for checking point using RTK is CRM 2 which are 0.029m. CRM 1, CRM 2, CRM 3 are used for maximum constraint. The 2D difference for this set is the lowest because its value is within the acceptance tolerance of 3 cm. The final coordinates of CRM are used in a Least Square Adjustment to determine the final coordinate of all the boundary points allowing to make area calculation. 2D Adjustment using Rapid Static performed better than RTK. This is because Rapid Static involves a longer observation time, which introduces measurement redundancy and allows for more accurate modeling of environmental factors, such as atmospheric delays and signal multipath effects, leading to improved baseline processing.

3.3 Phase 3: Determining Boundary Dispute between Computed Lot and NDCDB

From the adjusted coordinates, the area of all the survey lots is calculated using the Double Meridian Distance (DMD) method. Table 8 shows the comparative analysis area of the survey lot areas as calculated by three different methods.

Based on table 7, lot no. 53382, 53393, and 53403 show the top 3 largest differences in terms of percentage. Lot no 53393 exceeds the 5% tolerance allowed by the regulations, which raises some concerns. The reference mark has shifted, which has affected the accuracy of the boundary measurements. This makes it crucial to carry out refixation to correct the survey data and ensure the boundaries are accurately marked. From the table 9, one can observe that the variations in the area comparison to NDCDB between Rapid Static and RTK are almost the same, implying that both techniques produce somewhat similar results. In most of the lots, RTK has larger variations than Rapid Static. Both GNSS measurement methods provide reasonable accurate areas.

The comparative analysis between Rapid Static and RTK GNSS methods shows that both methods achieve similar accuracy levels. These methods have their own pros and cons beyond just the accuracy.

A few lots show notable overestimation, which would need more research to determine the underlying reasons.

4. Discussion

The comparative analysis between Rapid Static and RTK GNSS methods shows that both methods achieve similar accuracy levels. These methods have their own pros and cons beyond just the accuracy. Rapid Static can make the surveying process more time-consuming compared to faster methods like RTK. One notable disadvantage of RTK GNSS is the lack of traceability. RTK gives real-time corrections without storing the raw data for post-verification. The lack of traceable data might cause errors in quality assurance, limiting the ability to perform detailed checks and corrections after data collection. Despite these disadvantages, both GNSS measurement methods demonstrate their effectiveness in cadastral surveying by achieving the 5% tolerance required for areas under 40 hectares, as specified by the regulations.

There are several limitations in the study, including the size of the lot selected, which is considered small. This restricts the ability to generalize the results to larger or more complex environments, where factors such as signal obstructions or longer baseline distances could impact the performance of both methods. Additionally, the use of only one CORS for RTK limits the ability to assess the effects of varying baseline lengths on positioning accuracy. Employing a network of multiple CORS stations would likely provide more comprehensive data, enhancing the understanding of how baseline variations affect GNSS accuracy, especially in larger surveys. Furthermore, the study utilized NRCnet rather than more widely adopted MyRTKnet, which may affect the applicability of the results to local GNSS applications, particularly in Malaysia.

Future studies could compare these two networks to explore differences in correction services and how they influence positioning precision. Lastly, the RTK GNSS data was collected during a single session using only the ISK1 base station. Conducting multiple sessions or establishing a second base station could have shortened the baseline and potentially improved the accuracy, providing more robust data for comparison. Despite these limitations, the study highlighted the effectiveness of both methods in achieving the required accuracy for cadastral surveying, while also identifying areas for further research and improvement.

5. Conclusion

This comprehensive analysis was able to achieve all the objectives through the three phases. For the first phase, four CRM were established and coordinated into GDM2000. As for the second phase, two sets of network adjustments were performed to get the adjusted coordinates based on the two GNSS positioning methods. Finally, for the third phase, an analysis of the suitability of both RTK and Rapid Static mode observations was made to achieve the aim of the studies. The results show that both methods achieved accuracy within the 5% tolerance limit, with Rapid Static providing slightly better precision. This suggests that the Rapid Static method may offer a more reliable approach for CRM establishments.

The study's limitations include using a small survey area, and the use of only one CORS. Future work will involve expanding the survey area, employing multiple CORS stations, comparing NRCnet with MyRTKnet, and conducting additional sessions or adding base stations to improve positioning accuracy.

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Data availability statement

The data used to support the findings of this study are included within the article.

Conflicts of interest

The authors declare no conflict of interest.

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Authorization of cadastral surveyors in Norway

This article describes how cadastral surveying and mapping have developed in Norway, the background to the introduction of an authorization system, how the new authorization system will be organized, and the status of issuing surveyor's certificates.

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Abstract

After January 1, 2026, the person responsible for conducting a cadastral survey in Norway must have state authorization (surveyor's certificate). This article describes how cadastral surveying and mapping have developed in Norway, the background to the introduction of an authorization system, how the new authorization system will be organized, and the status of issuing surveyor's certificates. Finally, it discusses the contribution of the authorization system to the establishment of an expert surveying profession in Norway. The article is written in English to distribute knowledge about the Norwegian authorization system to international land administration experts.

Introduction

Historical development of cadastral surveying in Norway

The following historical analysis of cadastral surveying in Norway is based on Mjøs (2020). The Norwegian cadastral system is a German-style system. It has its starting point in land books and tax registers that came into being in the 1600s in Norway, initially without requirements for surveying property boundaries.

During the 1700s, provisions for cadastral surveying prior to registration of title deeds were introduced in the country's two largest cities, Bergen (1700) and Oslo (1738). In 1764 legislation was introduced for mandatory boundary descriptions, by laymen, when land was subdivided in rural areas. A small group of authorized private surveyors was established in the latter 1700s, whose initial task was to survey and map property disputes. In 1790, a general provision was introduced for cadastral surveying before registration of title deeds in cities and towns; however, this had little impact.

Economic mapping to modernize the tax system was started in 1804–05. This first economic mapping was stopped in 1815 due to poor finances and resistance from the farmers. The land consolidation courts were established in 1859 and would carry out extensive land rearrangements in rural areas, particularly at the end of the 1800s and into the 1900s. The land consolidation courts would prepare large quantities of maps showing property boundaries before and after the land consolidation process (Jordskifteverkets kartarkiv, 2022). The land consolidation maps were island maps and not linked to the geodetic network, and they were not updated.

Oslo and Bergen obtained new provisions on mandatory surveying prior to registration of title deeds in building laws (1828 and 1830) and, in these first building laws, requirements for a chief surveyor and competence requirements for the chief surveyor.

Around 1900, many cities introduced mandatory surveying prior to registration of title deeds on their own initiative and governmental approval , and with the Building Law of 1924, mandatory cadastral surveying was introduced in all towns and cities. The organization of the surveying activities was left to the cities themselves to design. The competence requirements had been removed from the legislation.

In 1934, the land consolidation courts were authorized to carry out boundary surveys and decide on boundary disputes as separate cases. The small group of private authorized surveyors that had operated throughout the 1800s disappeared around World War II, probably outcompeted by the land consolidation courts.

After World War II, planning and rebuilding became important; however, there was a lack of maps in relevant scales in rural areas. Around 1960, nationwide economic map-ping was begun outside the cities and below the timberline. Initially, only properties larger than 5,000 m^2 were to be signaled and mapped by aerial photogrammetry and the landowners' marking of their boundaries in the terrain. Roughly calculated, 50% of the boundaries were initially registered in the economic mapping project.

There was a need to update the new economic maps. The laymen who carried out land subdivisions in the countryside had neither the tools nor the knowledge for such work. This led to the introduction of nationwide cadastral surveying in 1980. The system of precise cadastral surveying and mapping that was in place in cities and towns was extended to cover the whole country, however from that point on only when a property was sub-divided. The task of carrying out cadastral surveying was assigned to the municipalities, as an obligation and monopoly task from January 1, 1980. It was up to the individual municipality to set requirements for the surveyor's education and practice. The education system was not strengthened, and there were no requirements for central authorization. In principle, anyone could be appointed by a municipality to carry out a cadastral survey. The municipality could also outsource the cadastral survey to others, typically private surveyors.

As described above, before 1980 there were different basic models for subdividing, surveying, and recording of information about property boundaries in cities and towns, and in rural areas. It was the basic model for rural areas that was continued. It was land subdivisions that triggered cadastral surveying. Unsurveyed properties could, as before, be sold and title deeds registered, now also in cities and towns, without this triggering a cadastral survey. In the preparatory work for the new legislation, it was assumed that the many unsurveyed areas and properties would be surveyed through public initiatives, but this was not implemented. The many unmapped properties remained unmapped and there was a lack of surveyors, especially in rural municipalities. Many properties were established with delayed field surveying – it could take many years until the actual field survey was implemented, and quality could be poor. In 1996, the government appointed a committee to investigate the future cadastral surveying organization, and in a report presented in 1999 it was proposed to introduce a system of authorized private surveyors to replace the municipal cadastral surveyors (NOU1999:1). In 2005, the parliament passed a new cadastral law which would introduce a system of authorized surveying companies, but the privatization proposal had been met with opposition from, among others, the municipal cadastral surveyors, and after a new government had come to power, the proposal was reversed in 2007 and the municipal system for cadastral surveying was continued. The Cadastre Act of 2005 came into force in 2010. In 2014, the privatization proposal was taken up once again, now by the geomatics companies. The proposal won the attention of the ruling political parties, and in 2016 a law proposal was again put forward that would lead to the introduction of private authorized surveyors to replace the municipal cadastral surveyors.

The proposal again met opposition, and in 2018 the parliament rejected the privatization proposal but decided to introduce authorization and competence requirements.

More detailed provisions on the authorization system were left to the Ministry of Local Government and Modernization to draw up. In 2020 the Ministry adopted changes to the Cadastral Bylaw detailing the new authorization provisions for cadastral surveyors in Norway. It was decided that the authorization arrangement would enter into force on January 1, 2024. In 2022 this was changed to January 1, 2026.

The legal effects of a cadastral survey

The cadastral surveyor's main task and responsibility is to survey boundaries identified by the adjoining landowners. The cadastral surveyor has no authority to determine the legal boundary. If different boundaries are claimed, the surveyor shall survey both claims, which must be registered in the cadastre, or the boundary must be registered as disputed. If the parties cannot reach an agreement, one of them can go to court – normally the land consolidation court – to settle the disagreement, or they can choose to live with the disagreement. The cadastral surveyor is only exceptionally used as an expert witness in court.

Education of cadastral surveyors

The Ministry estimated in 2016 that there were 500–600 man-years engaged in cadastral surveying in the municipalities. The Norwegian Mapping Authority made a new estimate and concluded in 2019 that a total of approximately 900 individuals worked with cadastral surveying in the municipalities or other public or private sectors (Kommunal- og moderniserings departementet, 2019, p. 4).

In a survey of competence within municipal cadastral surveying in 2017, it was found that 18% of the responding surveyors did not have relevant education and a further 45% of cadastral surveyors had less than a bachelor's degree (Kristiansen et al., 2017, p. 46–50). The survey included 429 respondents from 232 municipalities (out of a total of 426 municipalities in Norway in 2017). The survey showed that the dominant providers of education for cadastral surveyors are the Western Norway University of Applied Sciences in Bergen, the Norwegian University of Life Sciences in Ås, and the Norwegian University of Science and Technology in Gjøvik.

Introduction of authorization of the cadastral surveyor

In the next paragraphs, the Cadastre Act and Cadastral Bylaw to a large extent will be cited when the normal and transitional arrangements for the introduction of authorization are described.

Section 35 of the Cadastre Act requires that the surveyor appointed by the municipality to carry out a cadastral survey must have a valid surveyor's certificate (i.e., be authorized). Following Section 38 of the Cadastre Act, the Ministry can, upon application, issue surveyors' certificates to persons who are of legal age and suitable to carry out cadastral surveying, have approved education, and have at least two years of relevant experience after completing their education and have passed an approved authorization test. The Norwegian Mapping Authority is a delegated authorization authority and issues surveyor's certificates. For applicants with professional qualifications from EEA states or Switzerland, the Professional Qualifications Act and regulations on the approval of professional qualifications apply, and they do not need to pass the authorization test.

Applicants can be authorized according to a "normal arrangement", or until December 1, 2025, according to a "transitional arrangement".

The transitional arrangement (until December 31, 2025)

The transitional arrangement for authorization is found in Section 70 of the Cadastral Bylaw. The National Mapping Authority shall, upon application and passing an authorization test, issue a surveyor's certificate to anyone who, before July 1, 2025, has built up relevant practice by having been employed in a municipality, state, or private enterprise to carry out cadastral surveying following the Cadastre Act, or having led such work. The last period of employment must have had a duration of at least six months and may at the earliest have ended on January 1, 2020. The total practice must correspond to four full-time years. One year's practice counts as a maximum of one year's work. Interruptions in practice, except for leave, sick leave, and the like in the same employment relationship, cannot exceed two years in total. The requirement for practice can be reduced by up to two man-years for those who have completed and passed education in relevant subjects from a college, university, or vocational school. The requirement is reduced by one-twelfth of a year's work per five approved study credits. The rules on employment and practice apply correspondingly to those who have carried out cadastral surveying following the Cadastre Act of 2005 or have led such work in their sole proprietorship if the man-year effort can be documented.

The Norwegian Mapping Authority can issue a surveyor's certificate to persons who do not meet the required practice when there are strong reasons to do so. Through this rule the Norwegian Mapping Authority can also make exceptions to the requirement to pass the authorization test.

Until December 1, 2025, a municipality can appoint surveyors without a valid survey-or's certificate to carry out a cadastral survey. If the cadastral survey is not completed by December 31, 2025, the municipality must appoint an authorized cadastral surveyor to complete the survey.

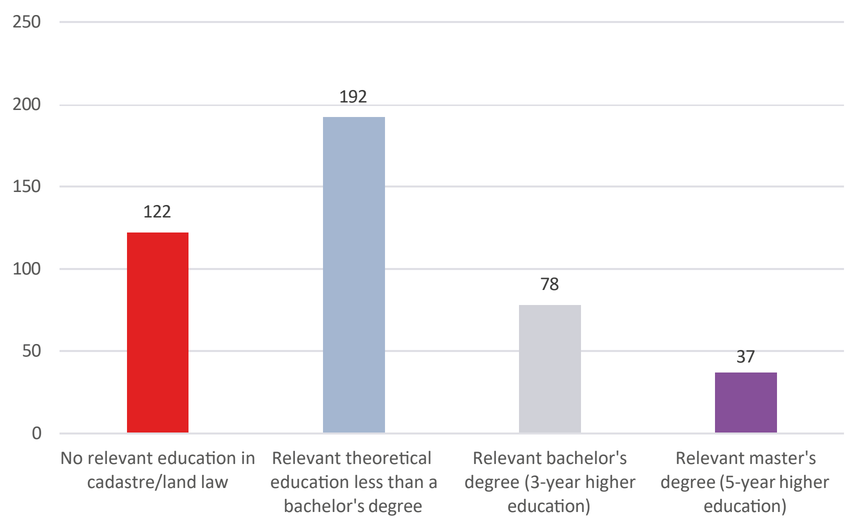

Figure 1. Competence Level for 429 Cadastral Surveyors. Source: Kristiansen et al., 2017.

The normal arrangement

The normal arrangement for authorization is found in Section 64b of the Cadastral Bylaw. The normal requirement is to have obtained a bachelor's or master's degree with a study program that has been approved by the Norwegian Mapping Authority and two years of practice for the person who is to be authorized as a cadastral surveyor.

The study program must qualify the candidate to carry out cadastral surveys following the Cadastre Act. The Norwegian Mapping Authority can, upon individual application, approve other obtained bachelor's or master's degrees with a subject area that, in combination with additional education, includes 120 study credits in legal issues, cadas-tre, and geomatics subjects. The Norwegian Mapping Authority can decide that other higher legal, cadastral, or geomatics education completed before January 1, 2021, can replace the approved bachelor's or master's degree. Persons assigned a surveyor's certificate must have practiced at least two years' work with cadastral

Table 1. Cadastral Surveyor's Certificates by March 1, 2024

1	2	3	4	5	6
Affiliation	Number of applicants	Number of authorized	Transitional arrangement	Normal arrangement	Professional Qualifications Act
Municipality	498	427	413	11	3
County authority	31	25	23	2	
Longyearbyen	3	2	2		
The Norwegian Public Roads Administration	15	14	14		
Land consolidation courts	2	2	2		
Private enterprise	43	30	30		
Private person	9	3	2	1	
SUM	601	503	486	14	3

surveying and land registration work and, during this time, have completed ten cadastral surveys following the Cadastre Act of 2005. The practice must have been built up during the last eight years before the application was submitted and completed after obtaining the bachelor's or master's degree.

Continuing education is not required.

Status for issuing of cadastral surveyor's certificates by March 1, 2024

The Norwegian Mapping Authority began authorizing cadastral surveyors on January 1, 2021. Table 1 below shows the status of applications and the awarding of surveyor's certificates by March 1, 2024. The overview has been prepared by the Norwegian Mapping Authority.

The applicants' institutional affiliations are shown in column 1. Column 2 shows the number of applicants, and column 3 shows the number of applicants who have obtained authorization per March 1, 2024. Column 4 shows how many have obtained authorization under the transitional arrangement, and column 5 shows how many have obtained authorization under the normal arrangement. Of the 14 applicants who have been authorized according to the normal arrangement, the dominant educational background is a bachelor's degree from the Western Norway University of Applied Sciences, possibly a master's degree from the Norwegian University of Life Sciences. The surveyors approved after the Professional Qualifications Act (column 6) are two from Poland (master's degree from the University of Warmia and Mazury in Olsztyn) and one from Spain (master's degree from University of Jaén) (personal communication, Kristin Schnell Rolfsøn, March 15, 2024).

Register of cadastral surveyors

To take care of the responsibility as authorization authority and to be able to confirm who is an authorized cadastral surveyor, the Norwegian Mapping Authority shall, following the Cadastral Bylaw § 64c, maintain an overview of received applications and who has been assigned a surveyor's certificate, with information on, among other things, authorization number, name, social security number, date of award and date for possible withdrawal.

This overview can be searched for by names and surveyor numbers on the Norwegian Mapping Authority's web pages (Kartverket, 2024).

A private website that shows an anonymized geographical overview of authorized surveyors has also been established, where the surveyors can have their names and contact information displayed in return for a fee (Autorisert landmåler, 2024).

Final comments and remarks

This article describes the development of cadastral surveying in Norway and the processes that have led to the authorization arrangements that have been decided to be implemented from January 1, 2026. The process of authorization started with a proposal in 1999 to introduce a system of authorized private surveyors to replace municipal cadastral surveyors. Privatization was not accepted; however, authorization will be introduced.

It is an open question to what extent the municipalities will be able to recruit surveyors from January 1, 2026 who meet the normal requirements for authorization. Another question is how the two-year practice requirement for authorization can be met when the annual workload of cadastral surveying in many rural municipalities does not fill a man-year, and the former surveyor has left when the newly educated surveyor starts.

Many people refer to cadastral surveyors as a profession. The concept of profession is debated and is given different substance by different actors. The usual meaning of the term is that a profession performs tasks that require skill to perform and that there are requirements for, among other things, education, practice, ethical code (self-justice), and autonomy (Carson and Skauge, 2023; Smeby and Gundersen, 2024). When looking at the Norwegian authorization arrangement, surveyors can be authorized without the normal requirements for education, practice, and authorization tests being met. Cadastral surveying is a task governed by detailed rules rather than by the practitioners being given autonomy. On this basis, we are talking about the establishment of a professional group that takes care of the task of surveying and mapping property boundaries, rather than a profession of expert surveyors. But over time this group of cadastral surveyors has the potential to develop into a profession as we see in other countries, where the surveyor has the authority to, for example, determine the legal boundary, if provisions are made for it and the goal of the cadastral surveying system is made clear.

A good starting point will be to facilitate research on the fundamental nature of cadastral surveying and establish a common understanding of the basic elements of cadastral surveying among practitioners, authorities, and academics. Take as an example the understanding of the relationship between the landowners' freedom of contract regarding property boundaries and the effects of the cadastral survey. Upon this basis the foundation for an expert surveying profession in Norway can be built.

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ISRO offers advanced data for lunar polar studies

The Chandrayaan-2 Orbiter is in orbit around the Moon since 2019 and has been providing high quality data. One of the payloads, the Dual Frequency Synthetic Aperture Radar (DFSAR) is the first instrument that has mapped the Moon using L-band in full-polarimetric mode and in highest resolution (25m/pixel). This advanced radar mode sends and receives signals in both vertical and horizontal directions, making it ideal for studying surface properties.

Since launch, about 1400 radar datasets were collected and processed to create polarimetric mosaics of north and south polar region (80 to 90 deg latitude) of the Moon. Using the datasets, the scientists from Space Applications Centre (SAC), Ahmedabad have developed advanced data products, on potential presence of water-ice, surface roughness, as well as an important electrical property, namely dielectric constant which describes features like density and porosity of the Moon's surface. The algorithm for analysing the full-polarimetric data is developed and data products are generated indigenously by ISRO.

These advanced data products are significant in view of gathering a first-order information about Moon's polar regions. Such regions are expected to have preserved the early chemical conditions of the solar system, which are important clues to explain several facets of evolution of the planetary bodies. This kind of ready-to-use data products on lunar polar regions has always been sought after, because it will provide holistic information to characterise the polar regions for future lunar exploration. These products complement hyperspectral data in studying the distribution of minerals on the Moon.

The polar mosaics include key radar parameters that reveal the physical and electrical (dielectric) characteristics of the Moon's surface and subsurface.

The parameters include:

- Circular Polarization Ratio (CPR): Indicator of possible presence of water ice.
- Single bounce Eigenvalue Relative Difference (SERD): Represents surface roughness.
- T-Ratio: Related to the material's dielectric constant.
- Polarimetric decomposition components: Show different types of radar scattering (Odd, Even, Volume, Helix).

The derived Polar Mosaic products (Level 3C) are released for the users and freely available in Indian Space Science Data Centre (ISSDC) PRADAN website:

https://pradan.issdc.gov.in/ch2/protected/browse.xhtml?id=sar

The products can be visualized in CH2 MapBrowse: https://chmapbrowse.issdc.gov.in/MapBrowse/

www.isro.gov.in/Lunar_Polar_Region.html

GNSS Constellation Specific Monthly Analysis Summary: October 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 short overview on the Chi-Square residual RAIM and the associated integrity analysis mechanism.

Analyzed Parameters for October 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**).

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.

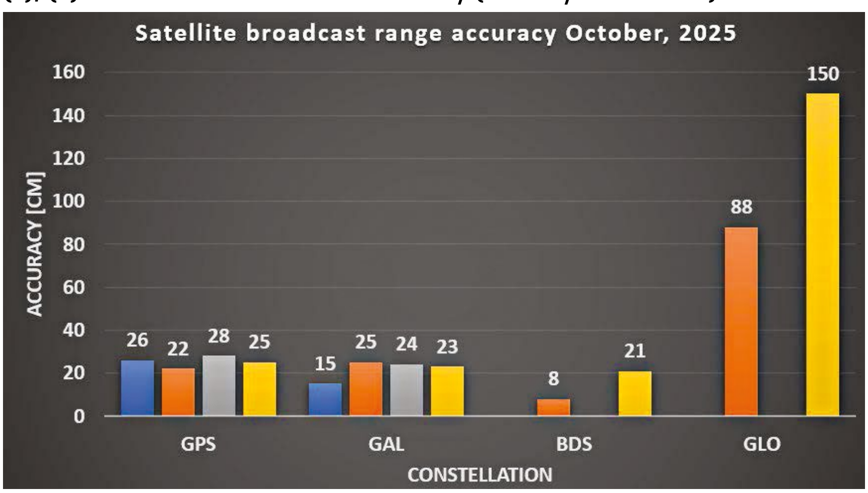
d. URA: User Range Accuracy as an indicator of the confidence on the accuracy of satellite ephemeris. It is mostly used in the integrity computation of RAIM.

e. GNSS-UTC offset: It shows stability of the timekeeping of each constellation w.r.t the UTC

f. Chi-Square Residual Based RAIM: It provides a reliable technique for a real-time fault detection as well as offline integrity analysis for the system design.

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.

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



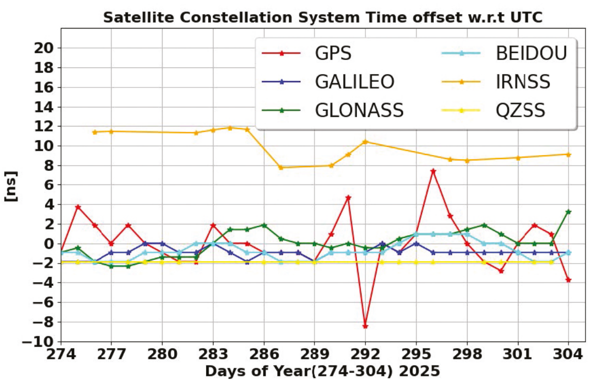
(c) Satellite Clock Jump per Mission Segment Upload

Const	Mean [ns]	Max [ns]	95_ Percentile [ns]	99_ Percentile [ns]	Remark (Best and Worst 95 %)
IRNSS	132.38	960427.24	4.48	45	Best I06 (3 ns) Worst I10 (16.99 ns) Big jumps for each satellite in multiple days.
GPS	78.20	362573.66	0.75	2.30	Best G16 (0.45 ns) Worst G03 (3.33 ns). The maximum jump was seen for G20 but that was covered by NANU. There was another big jump for G27 on DOY 296.
GAL	5.41	269575.3	0.18	0.42	Best E03 (0.13 ns) Worst E19 (0.36 ns). Large discontinuity for E07 on DOY 291 and for E02 on DOY 301. Further confirmation will be provided in next month's analysis.

(d) User Range Accuracy (Number of Occurrences in Broadcast Data 01-31 October)

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	2998	7	4	-	1	-	-	-
I06	2856	122	16	2	1	2	1	-
I09	745	16	1	1	2	3	-	11.3 (1)
I10	1026	3	1	1	1	-	-	-

(e) GNSS-UTC Offset



(F) Integrity Analysis: Chi-Square Residual Based RAIM

Receiver Autonomous Integrity Monitoring (RAIM) is a central concept of GNSS-based aircraft navigation, designed to ensure that position solutions remain trustworthy. RAIM operates in real time by performing two key functions: fault detection and fault exclusion. Detection is achieved through a global consistency check on measurement residuals after computing the least-squares navigation solution. If the residuals indicate inconsistency beyond a predefined threshold, RAIM flags a fault. Exclusion then isolates the faulty satellite by recomputing solutions with subsets of measurements until consistency is restored. This mechanism allows RAIM to maintain integrity even when a satellite provides erroneous data.

RAIM Detection Logic and Why Chi-Square

The detection test statistic in RAIM is based on the sum of squared residuals:

$$q^2 = r^T r / \sigma^2$$

where r is the residual vector and σ^2 is the measurement noise variance. Under the fault-free hypothesis (Ho), the residuals are linear combinations of Gaussian errors, so the sum of their squares follows a Chi-square distribution:

$$\Sigma Z_i^2 \sim \chi^2(df),\ Z_i \sim N(0,1)$$

This property makes Chi-square the natural choice for RAIM detection. Other distributions, such as Student's t or F-tests, assume unknown variances or ratio comparisons, which do not apply because RAIM knows the covariance from the measurement model. The detection threshold is:

$$T^2 = \chi^2 inv(1 - PFA, df)$$

If $q^2 > T^2$, RAIM declares a fault. For integrity analysis, fault hypotheses H_i are considered, where the test statistic becomes non-central Chi-square due to bias introduced by faults:

$$q^2 \sim \chi^2(df, \lambda),\ \lambda = ||\text{fault effect on residuals}||^2 / \sigma^2$$

The residual-based test statistic can also be expressed using the parity vector approach. The parity vector is obtained by projecting measurement errors onto the null space of the geometry matrix H, which isolates inconsistency among measurements. The parity vector p is computed as:

$$p = (I - H(H^T H)^{-1} H^T) z$$

where z is the measurement vector. The test statistic q^2 is proportional to the squared norm of the parity vector, making parity RAIM and residual RAIM mathematically equivalent. This formulation is widely used in RAIM literature for fault detection

Two example cases are considered here for the demonstration. Geometry matrix H1 representing a satellite to user geometry that is moderately poor and the H2 matrix that is geometrically very good. Based on above mathematical discussions, the fault case analyzed for each satellite and the worst fault satellite is identified along with the total contribution to the probability of the HMI.

$$H_1 = \begin{bmatrix} 0.3915 & -0.8395 & 0.3767 & 1.0000 \\ -0.1972 & 0.1501 & 0.9688 & 1.0000 \\ 0.3681 & 0.3577 & 0.8582 & 1.0000 \\ -0.4818 & -0.7583 & 0.4392 & 1.0000 \\ -0.9211 & 0.1670 & 0.3517 & 1.0000 \\ 0.6335 & -0.4473 & 0.6314 & 1.0000 \\ 0.6321 & 0.6378 & 0.4401 & 1.0000 \\ -0.5390 & 0.4766 & 0.6945 & 1.0000 \end{bmatrix} \quad H_2 = \begin{bmatrix} 0.7071 & 0.7071 & 0.0000 & 1.0000 \\ -0.7071 & 0.7071 & 0.0000 & 1.0000 \\ 0.7071 & -0.7071 & 0.0000 & 1.0000 \\ -0.7071 & -0.7071 & 0.0000 & 1.0000 \\ 0.0000 & 0.0000 & 1.0000 & 1.0000 \\ 0.5000 & 0.5000 & 0.7071 & 1.0000 \\ -0.5000 & 0.5000 & 0.7071 & 1.0000 \\ 0.5000 & -0.5000 & 0.7071 & 1.0000 \end{bmatrix}$$

Integrity Risk Analysis and Geometry Impact

For the first geometry (poor satellite geometry), the analytical bound is P(HMI) = 1.92×10^{-4}, with fault-free contribution 1.75×10^{-4} and faulted contribution 1.61×10^{-5}. Monte Carlo simulation with 10000 samples (Figure Fa) confirmed that if a fault occurs,

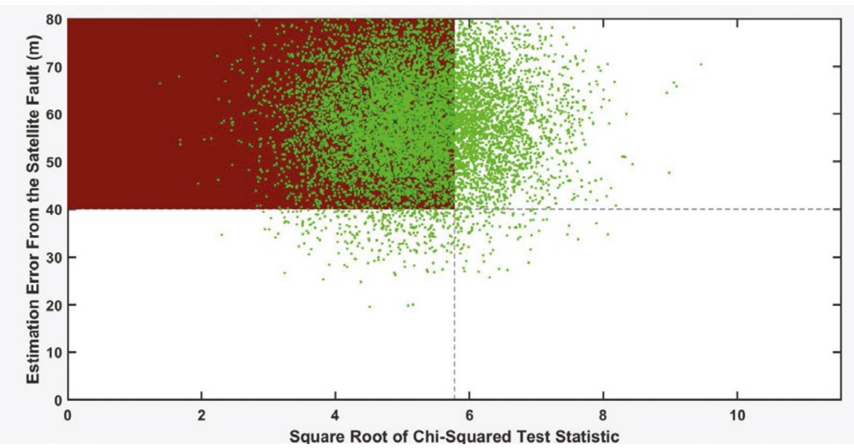


Figure F a: The integrity fault analysis for the first case with geometry matrix H1. The vertical dashed line in the middle represents the detection threshold. More than half of the Monte Carlo simulated samples (green dots) are below the threshold undetected and above the alert limit threshold (horizontal dashed line in the middle). This scenario represents a high integrity risk.

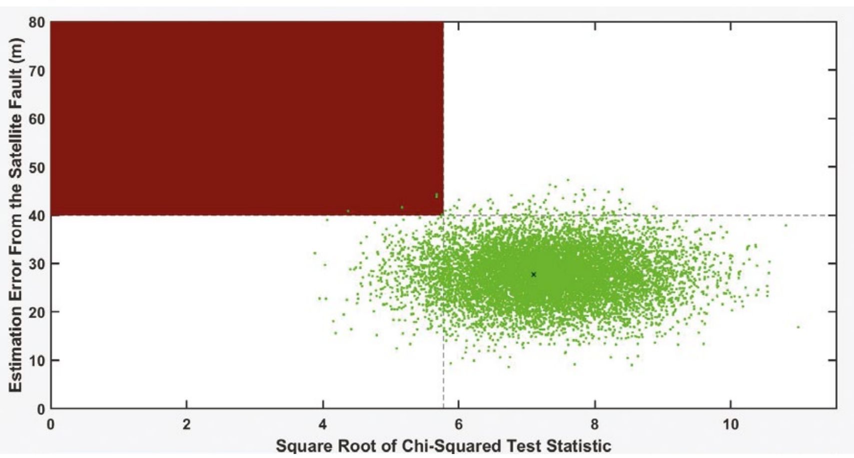


Figure F b: The integrity fault analysis for the second case with geometry matrix H2. The condition number of the matrix is very good meaning that very low measurement errors are propagated to the estimation solution. The detection threshold works well to detect the higher residuals. This scenario represents a low integrity risk.

the probability of exceeding AL without detection is 74.9%, which is extremely high. The fault analysis plot showed many points in the HMI region, and the worst-case fault produced a large position error (~50 m) but remained undetected because its test statistic was below the threshold. This happens when the fault projects weakly onto the residual space but strongly biases the position estimate—a geometric limitation of residual-based RAIM.

For the second geometry (better satellite distribution), the results improved dramatically: P(HMI) = 1.04×10^{-8}, with fault-free contribution negligible (7.0×10^{-14}) and faulted contribution 1.04×10^{-8}. Monte Carlo simulation gave $P(HMI|H_i)P(H_i) \approx 8 \times 10^{-9}$, here $P(H_i)$ is prior satellite fault probability of 10^{-5} and with , $P(HMI|H_i) \approx 0.0008$—a huge improvement over the previous case. The failure mode plot confirmed this: only few points in the HMI region, and the worst-case fault was detected because its test statistic exceeded the threshold. This demonstrates that satellite geometry strongly influences RAIM performance. A well-conditioned geometry reduces fault sensitivity slopes, improves detection, and lowers integrity risk.

Interpretation of Fault Analysis Plots

Both fault analysis plots (Figure Fa and Fb) visualize the relationship between the square root of the Chi-square test statistic (x-axis) and the position error caused by faults (y-axis). Key elements include:

• Green points: Monte Carlo samples under faulted conditions, showing variability of error and test statistic. Random noise is added to the fault vector (with only the worst-fault satellite having a non-zero value).

• Red shaded region: Hazardously Misleading Information (HMI) zone where position error exceeds the alert limit (AL) while the test statistic remains below the detection threshold.

• Dashed lines: Detection threshold (√T²) and alert limit (AL), defining the safety boundaries.

In the first geometry, many points fall in the HMI region, confirming high integrity risk and missed detections. In the second geometry, points cluster away from the HMI region, and the worst-case fault is detected, demonstrating the critical role of satellite geometry in RAIM performance. In this second geometry case, the RAIM can detect the fault and prevents an integrity event.

These results highlight three critical insights: (1) Chi-square RAIM is effective for detecting large residual inconsistencies but cannot guarantee detection of all hazardous faults, especially under poor geometry; (2) Integrity risk analysis of the system is essential because detection alone does not ensure safety; (3) Satellite geometry is a dominant factor—better geometry reduces missed detection risk and improves integrity. Other methods such as Solution Separation RAIM and ARAIM monitoring use position-domain consistency rather than residuals, using Gaussian-based bounds instead of Chi-square. These methods will be explored in the coming issues.

Note: The concepts and the mathematics are mostly generated based on the following papers. Please consider these papers for detail understanding of the involved math and algorithms. The goal in this column is to demonstrate in a high level the impact of geometry on the Chi-Square residual RAIM and the integrity.

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Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
   - The performance of GPS, Galileo and Beidou remained similar.
   - Not much jumps in GPS satellite clocks. Galileo satellites had couple of discontinuities.

2. The UTC Prediction (GNSS-UTC):
   - GPS and IRNS provided comparatively worse performances. GPS had a large variation in the prediction.

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BIMP (2024 b) https://e-learning.bipm.org/mod/folder/view.php?id=1156&forceview=1

BIMP (2024 c) https://cggtts-analyser.streamlit.app

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

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

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

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

RIN updates navigation system guide for small craft

The Royal Institute of Navigation Small Craft Group has released Version 2 of a free navigation guide for small and leisure craft. “Electronic Navigation Systems: Guidance for safe use on leisure vessels” is offered as a free digital download and as a hard copy for purchase from Bookharbour.

Guidance includes

- safe use of electronic navigation and associated systems on leisure vessels
- “keys to safety” in many operational situations
- advantages and drawbacks of different systems and approaches.

Version 1 of the “Electronic Navigation Systems” booklet is still available as a free download. *https://rin.org.uk/page/ENav*

DGCA compiling data on GPS spoofing instances

India’s aviation regulator, the Directorate General of Civil Aviation (DGCA), is collecting data on GPS interference and spoofing to have a better understanding of the situation. The urge to collect data comes after the Delhi airport experienced issues sometime back.

Recently, several airlines have faced GPS spoofing at the New Delhi airport, with at least eight such instances on Nov. 5, said an unnamed DGCA official. The interference instances were noticed in domestic and international flights.

Generally, interference issues are reported in border areas, rather than at Indira Gandhi International Airport, the country’s busiest. Daily flight movements have increased to more than 1,500 following an airport terminal upgrade completed in October.

As many as 465 GPS interference and spoofing incidents were reported in the border region, mostly in the Amritsar and Jammu areas, between November 2023 and February 2025. *economictimes.indiatimes.com*

Sateliot, ESA launch project to break GPS reliance

Sateliot will test a pioneering system that allows its satellites to connect with IoT devices without relying on GNSS. The breakthrough opens new opportunities in sectors such as defense and security, where Europe’s technological autonomy and operation in GNSS-denied environments are strategic priorities.

Low-Earth orbit (LEO) satellite constellations, such as the one developed by Sateliot, provide coverage in areas beyond the reach of terrestrial networks — over half of the planet’s surface. However, until now, they depended on GNSS, increasing both the energy consumption of devices and terminal costs.

The FreeGNSSNetwork project, signed with the European Space Agency (ESA) and led jointly with GMV, eliminates this dependency using advanced algorithms that enable devices to calculate their position directly from the satellites’ signals. This maintains a stable and accurate connection even under complex conditions such as wartime scenarios. *https://sateliot.space*

ESA contracts SBQuantum for space-ready quantum sensors

SBQuantum has secured new contract with the European Space Agency (ESA). Funded through ESA’s FutureEO Programme, the deal is worth nearly $1 million USD (€800,000) and will see SBQuantum deliver a new prototype of its quantum magnetometer sensor, optimized for Earth Observation (EO) missions in space. The upgraded version of the device will remain the same size and weight while delivering a number of enhanced capabilities including improved sensitivity (sub 100 Picotesla), higher bandwidth (400 Hz) and greater accuracy (200 Picotesla) as required by ESA for advanced EO missions. *sbquantum.com*

When aid fails: Power, politics, and the price of good intentions

International aid was meant to heal broken economies and build fairer societies. Yet decades and billions later, the results remain uneven, often entangled in politics, flawed incentives, and misplaced priorities. In this wide-ranging conversation with *Coordinates*, development economist Dr. Emily Brearley speaks about the moral contradictions of aid, the misplaced faith in technology, and what it would take to rebuild development from the ground up.

Dr. Emily Brearley

Is a development economist with extensive experience in social and political economy, has recently published *Aid Inferno*. The book offers a candid examination of the effectiveness and efficiency of international development aid, with particular focus on land administration and the World Bank's role in shaping it. Drawing on her years of work with the World Bank across multiple regions, Dr Brearley brings an insider's perspective to the complex interplay of policy, power, and practice in global development. Originally from the United Kingdom, she is now based in Latin America.

1. What personal experiences made you begin to question the real purpose or impact of international aid?

I am cognizant that N=1 is anecdote who cares what I think? In the end, only robust data should carry intellectual weight. In truth, I always questioned the aid business because I was raised in a single parent household in the Thatcher years. We worried about money and the National Healthcare Service. We had a natural mistrust for anything that smacked of international and elite. Ironically, I would educate myself out of my social class and country, but I still went to egg-throwing protests when I moved to Washington D.C. because I felt in my tummy that the World Bank was a bad place. It was only when I got a job there—by cheekily writing to the Chief Economist and demanding he hire beyond the usual silver spoon connected elites—that I stopped questioning a little bit. I liked first class travel; all you can eat breakfast buffets and incredible access to the World's governments. I desperately wanted to make the world a better place and thought I could do so if I worked hard and kept my head down. But my conscience woulnd't let me ignore reality for long. In the book I provide a professional, yet accessible critique of aid, based on robust quantitative and qualitative data—I stand on the shoulders of development economics greats.

2. You write that "the aid business pretended to care." In your view, where did global aid go most fundamentally wrong? Is it the design, intent, or incentives?

In contrast to my rabble-rousing younger self, I now believe that the intentions of global aid were altruistic and practical—you can't trade with broken countries, and better off countries are less likely to go to war. It was the simplistic and overly optimistic conception of economic development (as enshrined in the Harrod Domar growth model) that proved to be a fatal design flaw—as economist Bill Easterly has pointed out ad nauseum while cashing his fat World Bank pension, dishing out cash to poor countries doesn't automatically make them rich. The World Bank's lack of humility and overweening desire for self-perpetuation created a

> "Land is the central development issue and the most concentrated asset, and so the World Bank, which never had much persuasive power over public policy didn't dare touch this third rail issue for fear it would undermine its longevity."

web of *warped incentives* to obscure its failure, reward and promote those staff most likely to lie on its behalf, and ensure that developing country governments that squander loans on white elephant projects or weaponry rather than invest it in schools and hospitals, go undetected.

3. The World Bank stands at the centre of your critique. Do you see its failings as unique to the institution, or as a reflection of the broader global financial system?

The World Bank IS the center of the development business because it has the most money and power. It is the Big Brother, with sister regional organizations (the Inter-American Development, Asian Development Bank, AfDB, EBRD etc.) and the sun around which most International NGOs revolve. Thus, just like in Star Wars, if you can pierce the Death Star with a well-aimed critique, the whole rotten development infrastructure will implode.

4. Your Malawi case study is striking. Why do you think land—so central to wealth, dignity, and power—has been consistently neglected or mishandled in development policy?

Slaying the dragon of unequal land distribution would have taken the type of courage the Bank never had. One of my favourite dinner party quotes is that on the eve of the Mexican revolution, the majority of North Americans owned land, and the vast majority of Mexicans did NOT. Our Western liberal order is *built* on equal land distribution—indeed the louche French cowboy economist Thomas Piketty has shown that land distribution after war leads to fairer societies. Land is the central development issue and the most concentrated asset, and so the World Bank, which never had much persuasive power over public policy didn't dare touch this third rail issue for fear it would undermine its longevity.

5. Tell us about the aid sector's fascination with geospatial technology and the assumptions that costly mapping projects replace real reform.

Look, I am an economist, not a software engineer. But I contend that most land issues could have been resolved with free Google Earth maps and a simple tenure process. The reason why governments don't ask for this is because they don't want to upset the power elites who keep them in office and donations. And the reason why the World Bank has pumped so much money—money that was borrowed in the name of the poorest people on earth—into tech that tends to break down, lose its expensive license after a year and ultimately become abandoned—is because it looks legit but is actually a bottomless pit of never-ending loans. Every land specialist at the Bank knows this, the great and good who attend the yearly "Land Conference" know this and my illiterate farmer clients from Malawi to Guatemala, know this.

6. How do you respond to those who believe imperfect aid is still better than none at all?

Show me. Don't tell me, show me with robust third-party data… I'm waiting!

7. You advocate for rescuing economics "from the neoclassical zealots." Please elaborate.

Economics is the language of power, and I want young people to study it, instead of taking those useless non-STEM courses with "studies" in the title. If you can't understand how the economy is run, you're at a distinct disadvantage. Sadly, because the neoclassical one-note economists over-egged the pudding, a lot of young people were put off the discipline because they believe it is synonymous with a type of capitalism that impoverishes people and the planet. They aren't taught that capitalism has been the greatest poverty-buster in history, and that it comes in many different flavours. We should see economics as a toolkit not a canon of rigid beliefs.

8. Do you think that development can be done differently? If yes, what are your suggestions?

Yes! Development 2.0 will be done differently. My elevator pitch to my new unsuspecting new boss U.S. Treasury Secretary Scott Bessent is: reduce the mission creep at the World Bank to focus *only* on that which is simple, transparent and doable (we have 80 years of data and shouldn't ignore it like goldfish). Bessent already understands that trade is more important than aid; and I would also like a renewed focus on banking transparency.

9. You ask, "Are we humans simply too selfish to really care about one another?" Has your answer changed after writing Aid Inferno?

I have always been an optimistic realist. When I worked in Ethiopia and was dealing with my own fair share of World Bank shenanigans, a brilliant physician and public servant came to speak at a brown bag lunch series I had organized. The story of how her family had been persecuted during the Derg, and her persistence in her studies and career despite this, left a deep impression on me. I asked her how she managed to find the strength to keep going, to keep the faith and fight for her clients. She leaned forward, her beautiful heart-shaped face and intelligent wide brown eyes glistening with power and said "*Don't Quit!*".

An Excerpt from AID INFERNO by EJ Brearley

Muli Bwanji [1]

Perhaps the most cynical stance by the World Bank is to completely ignore the most important determinant of wealth: Land. Classical economics views land as a commodity to be bought and sold on a functional market. It doesn't care about the emotional impact that land might have on its owner, or the more common feeling, of always being beholden to someone else for simply existing with two feet on the ground and having a bed to sleep in at night. It also doesn't care how the land was acquired or consider whether the set up was fair in the first place—remember those Monopoly games where a few select players started with more money and got two throws of the dice instead of one? That is the history of land ownership in a nutshell.

The only type of economists who had a lot to say about land distribution were the communists. Unfortunately, their poor historical track record was such that those ideas were banished; baby thrown well and truly out with the bathwater. This allowed capitalism to forget about history and this goldfish economics allowed World Bankers to studiously avoid any mention of the history of land acquisition and its skewed distribution. The focus was strictly on the purchase and management of land on the "market." But this approach assumed a level playing field that didn't exist, and a functioning market where there was none.

In developing countries, just like pre-industrial Europe, a few elites tend to own everything. The World Bank would claim this reality had nothing to do with them—they focused on economics, not politics, but we all know that it's impossible to disentangle the two. This aversion to historical precedent and its manifestation in the distribution of land assets in the present, means the Bank should have stayed out of the sector entirely. Unfortunately, it couldn't resist, because lending to a sector that is inherently corrupt and can therefore absorb huge amounts of cash, proved to be a lucrative revenue stream.

I saw this first hand when I worked for the World Bank's land unit. I was tasked by the Bolivian director to write a book on the history of the institution's land projects, detailing all the loans that had been extended over seventy years, across seven geographical regions of the world. Although his goal was primarily self-aggrandizement by means of a glowing review of his own projects, it seemed possible that one might skilfully but gently weave in some lessons learned, between the lines.

I spoke to long-retired economists who had begun their careers at the Bank from its inception and had to a man (and one woman) finally retired on good pensions with heavy hearts. Their efforts to work on meaningful land reform had all been thwarted by Management in their telling. Like many parts of the World Bank, the Land sector was one where the people who cared the most and possessed the requisite expertise had ended up leaving in frustration. I spoke to government ministers and to community leaders, to academics and journalists. I even spoke to Peruvian economist Hernando de Soto who was having a sexy moment back then, thanks to his best seller, *The Mystery of Capital*, which focused on the importance of land rights as a foundation for economic development. This was one of the central features of the Washington Consensus, and it certainly was not wrong. However, the proposed 'fix' in the Consensus was this pesky little term: "market-based reform." But when land has been unfairly concentrated in the first place, there is no functioning 'market', and resistance to any reform is strong among those who consider the land theirs by divine right.

Since the land unit was too timid to talk about the structure of land ownership, it had instead focused on the mapping digitization of land registries that existed only on paper, or not at all. The logic of all of this was that it would help the government tax the land—a primary source of income for rich countries; and it would facilitate the smooth sale and purchase of land and property assets. Unfortunately, by relying on the invisible hand and what the more cynical of us dubbed "Magic Tech," the World Bank achieved very little in terms of tangible results. That is because the core issue at the heart of land ownership was ignored: the social contract between the government, private sector and the general populace regarding who should own the land and what they should do with it.

When I visited African land ministries, I would often be directed to a big storage cupboard, where enormous dusty maps the size of ping-pong tables were piled high, stacked from wall to wall, a fire hazard in waiting. The software the Bank had pushed was too expensive to update and had been abandoned. These projects had also been shelved because it was too politically risky to give a clear picture of who owned what. Chaos served those elites who didn't want to pay land taxes or give the public easily accessible information. The hundreds of millions of dollars spent on digitization as the panacea also ignored the brilliant freebie of Google Earth, an online resource with sufficient resolution to do the job perfectly adequately. There was a lot of talk about the marvels of blockchain, and how it could fix the land registry problem by making digital records accessible to all. It indeed could have, but only if there was an interest in making large property owners pay taxes—those same folks who funded elections. Today, in most developing countries there remains no functioning property map/cadastre, and this is by design, not by accident.

Of the dozens of projects that I reviewed from across the globe for the book, only one had been successful under extraordinarily tragic circumstances. This story was related to me by an Aussie buddy and mentor, who hadn't just taken the red pill but would deal them out to disillusioned junior economists when they came to his door crying. Windows were sealed shut at the World Bank for a reason. He was one of those noble professionals who tried to do his best, using deep technical knowledge, within a system that would constantly try to reject and eject him. He had been part of a team to assist the Indonesian province of Aceh after it had suffered from the devastating Tsunami in 2004. An estimated twenty percent of its small island population had been killed in the devastating disaster, with people and property records washed away. Locals decided to rebuild their land maps and rights from scratch. This process was achieved quickly and efficiently, with a fraction of the usual fuss and cost, by using female community leaders to walk the land boundaries with surveyors who would then record the precincts on a map. How painful and utterly surreal that only after such a catastrophic disaster, should things be a little fairer.

As I spoke to an increasingly disgruntled number of people about the failures of World Bank land projects, I realized that I was never going to be able to show the book to my boss, since he would surely hate its whistlestop tour of World Bank land sector disasters—using ideology and wishful thinking to address the most intractable development issue est.1944. Then, what happened in Malawi rendered all this mute.

I was sent to the landlocked East African country of around twenty million people in 2013 to review a "best-practice" World Bank land reform project. My boss had designed it, and he had also decided that it was "best practice." He wanted this project to be the poster child for the land book and therefore a means to propel his career. When I looked at the Bank's track record in the country, I could see that millions of dollars had already been spent to banish poverty. The land sector had been a hub of activity for many donors, and hundreds of millions of dollars had already been spent to digitize the land records of this small country, which was the size of the state of Pennsylvania. Yet in every cadastre office I visited, even in the capital Lilongwe, there was no sign of digitization in progress. Instead, those familiar vast rooms with stacks of old physical records formed the basis of the controlled chaos of the country's cadastre. Like a pile of treasure maps waiting to be discovered, it was impossible for the average citizen to find out who owned the country they lived in or the land they farmed. No one was in a great rush to render transparent and searchable Malawi's heavily skewed land distribution, whereby a couple of rich white families, military members and politicians had secured ninety-nine-year leases from the government on vast tracts they no longer farmed or had ever paid taxes on.

Like so many other cases I had seen and heard about, expensive software had been purchased but was so complicated to install that by the time anyone had figured out how to digitize a single page, the license had run out. It's also the case that money designated for sophisticated software is particularly prone to go missing, since absolutely everyone involved has an incentive to keep the music playing before anyone must find a chair to sit down on. People expect computers to glitch and software to scramble, so it's a great way to lose money without questions being asked.

This was only the beginning. The most cynical component of the vast Malawi land loan was about to be revealed as I set out on field trips to far flung rural communities. I was about to discover the true horror of the *Malawi Community-Based Rural Land Development Project*—a delightful sounding name to which no one could possibly object. Initiated in 2004, this part of the loan supported a negotiated community-based land acquisition and development pilot, which included 15,000 land-poor households in a half dozen communities scattered across the sun bleached, barren interior. The 'negotiation' between the most powerful people in the country and its illiterate smallholder farmers was described as *"transparent, voluntary, legal, and resource-supported."* The "anything but Zimbabwe" approach meant that the Bank would ensure these land purchases were ruled by a fair market price, which would be covered by a public loan and repaid by future generations of Malawians.

The case of Zimbabwe was notorious. A country that had rejected the "market" mantra and took matters into its own hands when compensation from the Brits hadn't materialized as promised. In the early 2000s, then-President Robert Mugabe had evicted four thousand white commercial farmers from their largely productive estates. In theory, there was a need to correct the imbalance between black subsistence farmers and the heirs of white colonizers. Tragically in practice, the entire process was carried out with such wanton violence and destruction to property that the agricultural economy—Zim was once the breadbasket of Africa—was decimated. The approach taken by Mugabe gave the West legitimacy to ostracize him. Zimbabwe was shut out of international financial and aid markets for the cheek of reversing a policy of land expropriation using the same tactics as white colonizers. Two wrongs certainly don't make a right, but the Brits could have avoided all this destruction if they had given Zimbabwe the reparations they had promised. Current President Mnangagwa is taking a less confrontational route that allows for joint partnerships between black and white farmers. [2]

In Malawi, the gap between the Washington Consensus market model, and the real state of Malawian land rights, was vast. There was no market for land, since only a few international hotels and large businesses in Lilongwe had ever paid land taxes in the country's history. A market could not exist without a cadastre, or before the country had a proper regulatory and tax infrastructure. This would have been a monumental political shift, and a challenge to the status quo. Quite how to introduce a land tax, when there wasn't one before, and level it on the very same people who run the country and own the government, is a devilish conundrum. In the U.K., the ancestors of people who were related to Henry VIII, or had romantic dalliances with him, still own a disproportionate amount of land. The U.K. has not had land reform, and it is an old democracy. By contrast, America was built on land reform and retains the dynamic economy and meritocratic labour market that makes it a favoured country for immigration.

In Malawi, while most of the land was still owned by the government, most of it had been leased. However, there was a silver lining to these contracts, and at that moment many of the land leases were coming up for renewal. This meant that the World Bank's project designers could have simply let the old titles expire and then assist the government in the redistribution of agricultural land to needy subsistence farmers. This approach would not have necessitated a loan of course, but much cheaper technical assistance. And where is the fun in that? The bottom line was the land project responded to the wrong problem with the most expensive solution. The effect of the World Bank loan essentially created a false market price for agricultural land, that would have reverted back to government ownership in its absence.

Tangible proof of this was that each land parcel, regardless of location or productive capacity (the features that usually derive a market price), had sold for a similar price, with the US$40 million World Bank loan simply divided up equally among the lucky few to deceive the many. This was a cynical case of reverse cash transfer. Poor Malawians were being asked to take out a loan to pay the richest people in their country for land that belonged to the people already.

In a country of 4,000,000 hectares of arable land, the project only covered a tiny 22,000 hectares to be distributed among twenty communities which were then supposed to be given a *joint* land title. They were then required to move from their existing homes and settle the new land parcels, provide farm labour in an equitable fashion, and make the land productive—without transport, health or education infrastructure, or even agricultural extension services. Without anything in fact that would be needed to render the parched earth sitting under unpredictable skies, as a reliable source of food or income. Even worse, the dirty secret of the Bank's land director was that he was too busy taking selfies with government officials and smiling villagers to bother checking on the details of his best practice project. It turns out that none of the communities had received a new title deed from the government—the old ones were about to expire, which left them open to harassment from the previous owners.

We visited site after remote site. Travelling down long dusty roads with only a few lonely baobab trees punctuating the desolate and barren landscape. Malawi is still a predominantly rural country, with over two thirds of the population eking out an existence as subsistence farmers. A precarious and hard scrabble life made only worse by the loss of tree coverage and soil degradation, increased hot days, and intense rainfall spells due to global warming. The leading cause of death in the country is AIDS, but among children it is preventable malaria with one of the highest infant mortality rates in the world.

As we arrived in our sparkling white SUVs, villagers thronged outside their wooden shacks, singing to welcome us. Hundreds of little children, tummies bloated with malnourishment, gathered around our vehicles, shyly trying to touch our clothes or hold our hands. We didn't deserve such warm hospitality. As usual, I let the men in my group engage in the formalities while I slunk off around the side of the huts to sit with the women and hear the real story. In each community I was given a list of all the challenges they were facing under this new land arrangement, item after item. All I could do was write them down on my note pad, and express empathy. Not good at keeping a poker face, one woman even tried to comfort me by saying *"well at least you aren't here to steal our children like Madonna."*

As the 2014 World Cup reached the semi-final stage, I headed off to the airport in Lilongwe. I was discussing the entire mess with one of the hotel concierges, Gift, who was giving me a lift. He had a BA in agronomy and couldn't find a job in his field. Aware of the land shenanigans going on his country, he asked the question that I have been posed so many times across at least one hundred countries: why does the World Bank keep supporting corrupt governments?

The answer is because the World Bank is a Bank first, and a development institution a much more distant second, if indeed it ever remembers that part at all. The fundamental purpose of a bank is to lend money. The World Bank knows that it will always get paid back first, because it is often the lender of last resort for countries maxed out and unable to access financial markets. Gift's final observation was that if Uruguayan footballer Luis Suarez donated his salary to the people of Malawi, then just over eighteen million people could each receive around ten dollars. That would be the equivalent of one bag of maize, enough for two people for two months.

Once back in Washington D.C, I got a panicked call on WhatsApp from a Malawian colleague. Could the World Bank urgently provide security for his team because people in our best practice project were being pushed off their land at gunpoint? Having fobbed off the communities with almost-expired land titles, the former, extremely-well compensated owners were now back with their heavies. Who cared what the so-called government said? They felt that the land was their birth right and since they had a monopoly on violence, they couldn't be stopped.

When I showed my boss the text messages, he firmly told me that it was not our problem to solve and didn't renew my contract. Not to be deterred with lives on the line, I went to speak to then-President Jim Kim's Chief of Staff, to try and get some kind of assistance. Unfortunately, the Big Boss was allegedly far too busy with the kind of extra-curricular entanglement so common of unattractive, powerful men who run international organizations. Obama's pick to lead the World Bank had proven to be particularly unpopular with staff for his odd policy ideas and brusque, thin-skinned manner. He allegedly had a particular problem with smart women; back in those days we gig workers had devised a black-market bingo card to see which Senior female economist would suspiciously retire for "personal reasons" within a given month.

I even tried to get a British newspaper interested in reporting on the story, but as I had seen all those years before as a Guardian journalist trying to write about Latin American human rights abuses; it just wasn't deemed interesting unless lots of people were getting killed all at once or a hapless Westerner had been caught in the crossfire—never had I wished for a more dramatic or useful role for our Material Girl Madonna, than in the context of the Malawi Land Fund.

Recently the media platform Devex that focuses on development, wrote about the Malawi Land Project, noting that it had been shut down because *"families found the climate too harsh to farm and the area lacked sufficient social infrastructure. Many returned home."* [3] Mysteriously, the project documents have been scrubbed from the link in the piece. Meanwhile, the ownership and use of land remains a pivotal development challenge in the country. Malawi's new president is struggling to balance the potential revenue from international investment in large-scale agriculture, with the need to improve the lives of young people.

Endnotes

[1] A warm Malawian greeting.

[2] Under British colonial rule, Africans could not occupy or buy land freely. Mugabe's expropriations were violent, but the policy was popular. Yet without adequate agricultural extension assistance or farming experience, a lot of the farms failed, and Zimbabwe became a net importer of food.

[3] Devex News, 2nd May 2023. Malawi land reforms spark controversy, fear of lost investment.

India elected co-chair of UN-GGIM-AP

India has been elected as the Co-Chair of the Regional Committee of United Nations Global Geospatial Information Management for Asia and the Pacific (UN-GGIM-AP). It was represented in the election by Hitesh Kumar S. Makwana, IAS, Surveyor General of India.

The elections took place during the 14th Plenary Meeting of UN-GGIM-AP, held from September 24–26, 2025, in Goyang-si, Republic of Korea. The event, hosted by the National Geographic Information Institute, brought together delegates from member states, technical experts, and observers to deliberate on key issues in geospatial information management across the Asia-Pacific region. India will serve a three-year term aligned with the UN-GGIM Strategic Framework.

Makwana outlined India's vision for the upcoming term, emphasizing strong leadership, secure digital transformation, and good governance. He stressed the importance of promoting data-driven decision-making, transparency, and inclusivity while strengthening partnerships and building capacity to create measurable impact across the region.

UN-GGIM-AP is one of five regional committees under the United Nations Committee of Experts on Global Geospatial Information Management (UN-GGIM). Representing national geospatial agencies of 56 countries in Asia and the Pacific, the committee works to maximize the economic, social, and environmental benefits of geospatial information through cooperation, capacity development, and shared solutions. *ddindia.co.in*

US$4.3 million upgrade of Laos' geospatial infrastructure

The Government of Japan has granted approximately 649 million yen (US$4.3 million) to Laos to upgrade outdated topographic maps and establish an online geospatial data system. A signing ceremony for the Exchange of Notes on the Economic and Social Development Programme (Geospatial Data Platform) took place on October 22 at the Ministry of Foreign Affairs in Vientiane.

The notes were signed by Deputy Minister of Foreign Affairs Mrs Phongsamouth Anlavan and Japanese Ambassador Mr Koizumi Tsutomu. The grant will support Laos in modernising maps that were created between the 1950s and the 2000s, many of which are scanned paper documents that are incompatible with modern GIS systems.

It will also enable the production of new hazard maps using Japanese satellite data, update 1:50 000-scale topographic and landslide hazard maps, and build a national online geospatial data system. It will use imagery from Japan's Earth observation satellite Daichi to assess disaster risks, including landslides, and apply high-precision satellite positioning technology from the Quasi-Zenith Satellite System, known as Michibiki. *asianews.network*

MapmyIndia to digitally power Survey of India and Indian Oil

MapmyIndia has announced two major government partnerships: a ₹110 crore contract with Indian Oil Corporation (IOCL) and a deal to build Survey of India's National Geo-Spatial Platform.

For IOCL, the company will develop an integrated tracking and management system for 23,000 LPG trucks across 150 locations, featuring geofencing, route optimisation, fleet monitoring, and emergency response tools to improve efficiency and safety. It will also power Survey of India's National Geo-Platform, standardising core geospatial datasets and enabling data sharing across ministries, academia, and industry via web services and APIs.

IIT Bombay names Jamal Mohamed College geospatial hub

Jamal Mohamed College, Tiruchi, has been recognised by the Indian Institute of

Technology (IIT) Bombay as the Open Source Geospatial Knowledge Centre for the Tiruchi district. The recognition, granted under the Free/Libre and Open Source Software for Education, Geographic Information System (FOSSEE GIS) initiative, marks a major step in expanding open source learning and geospatial innovation in academia.

The formal acknowledgement was handed over by Mohamed Kasim Khan, National Coordinator, FOSSEE GIS, National Mission on Education through ICT, IIT Bombay, to A.K. Khaja Nazeemudeen, Secretary and Correspondent, Jamal Mohamed College. The event took place during a workshop that focused on the usage of free and open source software, hardware, and geospatial tools in academia and industry. *www.opensourceforu.com*

Norway set to lead in 3D city modelling

Detailed map data could soon bring Norwegian cities to life in three dimensions. A new pilot project suggests that Norway is exceptionally well placed to create realistic digital city models, thanks to its high-quality 2.5D vector data. The findings are presented in the newly released report called 'Preliminary Project – Volume Geometry in Norwegian Geodata Management', now available on the Norwegian Mapping Authority's website.

The study explored how municipalities currently use three-dimensional representations – known as volume geometry – in urban planning and building management, as well as the challenges they face in data quality and integration. Conducted between October 2024 and June 2025, the project was funded by Geovekstforum and the Research Council of Norway.

Iran prepares first Chabahar space launch

Iran plan to launch three Earth-observation satellites and carry out the first test launch from its new Chabahar space center, signaling a further expansion of its space program amid Western concerns over the dual-use nature of Iranian rocket technology. The Zafar-2, Paya and the second batch of Kosar imaging satellites are ready for launch.

The first experimental launch from the Chabahar Space Center – a coastal site under development in Iran's southeast – will take place next year. Iran had also signed its first private-sector contracts for satellite constellations, including the narrow-band Kosar system intended for emergency data transfer, and highlighted recent milestones such as the launch of private-built satellites on a Russian rocket, the successful 2023 flight of the solid-fuel Sorayya launcher, and the deployment of the Nahid-2 communications satellite in 2025. *www.iranintl.com*

Inflatable module tech in space factory race

China's "in-orbit factory" has taken shape following a technological breakthrough in the form of an inflatable, reconfigurable space module, as it joins the United States and other countries to build large-scale industrial production lines in orbit.

According to the developers, components of this smart morphing framework can be compactly folded during launch and inflated and unfolded once in orbit to form a vast, stable operational habitat, each a building block to create a manufacturing plant in space.

The advancement was recently detailed by the Institute of Mechanics, an affiliate of the Chinese Academy of Sciences (CAS).

According to a statement issued by the Beijing-based institute on November 3, it recently tested a key module of the space factory – known as the "reconfigurable flexible in-orbit manufacturing platform" – in collaboration with several other domestic research bodies.

The team tested the airtight connection between rigid structures and the flexible habitat, as well as the controlled deployment and stability of the environment for high-precision manufacturing tasks – all of which are key technical hurdles and requirements for an inflatable space factory.

Ground tests showed that the module's performance met, or even exceeded, requirements. The team also obtained crucial parameters, such as the critical pressure and gas consumption required for full deployment, during vacuum testing under simulated conditions in the northeastern Chinese city of Shenyang.

It represents a significant step towards space manufacturing by overcoming the limitations of rocket cargo compartment size and cutting the cost of building large orbital objects. *www.scmp.com*

Space42 completes first ApusNeo18 HAPS test flight in the UAE

Mira Aerospace, the High Altitude Platform Systems (HAPS) subsidiary of Space42, the UAE-based AI-powered SpaceTech company, announced the successful completion of the first public test flight of its advanced, solar-powered HAPS model, ApusNeo18. The aircraft carried an advanced Earth Observation payload developed in-house by Mira Aerospace, combining high-resolution optical and infrared sensors with real-time data transmission. *space42.ai*

More GHGSat monitoring microsats by SFL

SFL Missions has been awarded a contract by GHGSat of Montreal to develop two additional commercial microsatellites for the GHGSat greenhouse gas monitoring constellation.

GHGSat-C18 and -C19 are being built, integrated, and tested at the SFL Missions facility in Toronto where 37 satellites are currently under development for commercial, government, and research organizations worldwide. SFL Missions is developing GHGSat-C18 and -C19 on the same low-cost, high-performance 15-kg NEMO platform used to build 11 GHGSat satellites over the past decade. *sflmissions.com*

German Orbital Systems to deploy Neuraspace STM

CubeSat manufacturer German Orbital Systems has contracted Neuraspace to secure the 16U pilot satellite, Pathfinder A, of ESA's upcoming Celeste In-Orbit Demonstration constellation for LEO-PNT (Low Earth Orbit Positioning, Navigation and Timing) with space traffic management (STM) capabilities.

Neuraspace will provide real-time automated solutions for conjunction screening, analysis, and classification, as well as manoeuvring planning and optimisation. In addition, launch and early operations phase (LEOP) will be supported with GNSS data processing and dedicated tracking using the company's optical telescopes.

These services by Neuraspace will also contribute towards compliance to ESA's space debris requirements, with the intention to control collision risk and prevent space debris release and proliferation. Scheduled to be launched in the first quarter of 2026, the satellite will fly in LEO to demonstrate how PNT signals can ultimately provide guaranteed location accuracy, better signal robustness, increased resistance as well as faster signal acquisition. *www.groundstation.space*

NSSTC, Thales Alenia Space in satellite navigation partnership

The National Space Science and Technology Center (NSSTC), U.A.E. and Thales Alenia Space, a joint venture between Thales (67%) and Leonardo (33%), are cooperating to explore opportunities in low-Earth orbit (LEO) space navigation systems.

The LEO-PNT satellites seek to provide guaranteed and sovereign centimeter location accuracy, robustness, resistance against jamming and spoofing, and low latency. Recognizing the strategic importance of LEO-PNT, the NSSTC is working with Thales Alenia Space to explore opportunities in this domain.

The collaboration reflects a vision to explore pathways that can enhance the robustness and sovereignty of future navigation services while deepening international cooperation and knowledge exchange between the United Arab Emirates and Europe in the field of space technology. *www.thalesgroup.com*

Hexagon acquires Inertial Sense for GNSS+INS upgrade

Hexagon has announced an agreement to acquire Inertial Sense, a provider of tactical-grade global navigation solutions and inertial navigation systems (GNSS+INS), to strengthen the breadth of its positioning portfolio. Inertial Sense's capabilities will complement Hexagon's assured positioning, navigation, and timing (PNT) portfolio, which provides an affordable, high-performance navigation solution to its customers. *hexagon.com*

First global customer of UltraCam Dragon 4.2

Vexcel Imaging has announced that Dutch aerial survey company Slagboom & Peeters Aerial Surveys has purchased the very first UltraCam Dragon 4.2 hybrid aerial imaging and LiDAR system worldwide. Operating from Teuge Airport in the Netherlands, the company executes projects worldwide, offering services from true orthophotos and stereo imagery to geo-oblique images, 3D models, and LiDAR. By continually investing in the latest technology, including multiple UltraCam systems such as the UltraCam Eagle 4.1 and UltraCam Osprey 4.1, as well as the complete UltraMap Suite. *www.vexcel-imaging.com*

SandboxAQ, DIU advance quantum navigation tech

SandboxAQ has announced an agreement with the Department of War's (DoW) Defense Innovation Unit (DIU) to join its Transition of Quantum Sensing (TQS) program. This effort will focus on rapidly developing and testing advanced Magnetic Anomaly Navigation (MagNav) technologies for the U.S. military's use in autonomous systems.

The TQS program, managed under DIU's Emerging Technologies portfolio, accelerates the adoption of commercial quantum sensing technologies to ensure PNT resilience in environments where GNSS signals are unreliable or denied. SandboxAQ will deploy its dual-use AQNav software to enable robust, resilient navigation capabilities without reliance on external signals. *www.sandboxaq.com*

SI500 DAS antenna innovation

Sinclair Technologies has unveiled the new cutting-edge SI500 DAS Antennas series. Featuring a two-port MIMO design, it stands out as a seamlessly integrated remedy for enhancing wireless connectivity indoors. Operating across an extensive frequency spectrum from 617 MHz to 8500 MHz, this series caters to in-building communication needs. From supporting 5G networks and legacy systems to accommodating Wi-Fi 6E, upcoming 5G bands, and IoT systems, the SI500 guarantees a continuous and seamless indoor connectivity experience. *www.sinctech.com*

GNSS anti-jamming protection technology

infiniDome has introduced Aura, a new GNSS protection system built for platforms that cannot afford to lose their way. It is designed to redefine navigation resilience with smarter algorithms, faster interference response and a compact, rugged design capable of operating in contested environments. The system is available in two configurations: Aura, the enclosed version for rapid deployment, and AuraCore, the OEM module for integration. *infinidome.com*

Live digital stationing meets location precision

OnStation, the first-ever live digital stationing platform purpose-built for road construction documentation and inspection teams, is collaborating with

Trimble to integrate its GNSS receivers with the OnStation App. Together, the technologies provide key project personnel with instant, station-based context and precise location. When OnStation is paired with the Trimble Mobile Manager application, this integration enhances trust in location data for paving, inspections, and utilities, keeping project crews in sync. With everyone aligned, there's less risk of building in the wrong spot or misinterpreting plans. *www.onstationapp.com*

Swift Navigation, SIMCom advance cm-level positioning

Swift Navigation and SIMCom has partnered to deliver centimeter-level GNSS accuracy to high-volume robotics applications worldwide.

The collaboration integrates Swift's Skylark™ Precise Positioning Service with SIMCom's high-performance SIM66MD and SIM66D GNSS modules. www.swiftnav.com

€950,000 for GNSS-independent navigation tech

ALL.SPACE has been awarded €950,000 by the European Space Agency's Navigation Innovation and Support Programme (NAVISP). This award is to develop an alternative PNT capability designed to operate in GNSS-denied environments.

The project will build a proof of concept for Alt-PNT, harnessing ALL.SPACE's multi-orbit terminal technology to generate and analyse "signals of opportunity" that can deliver position and orientation data independently of traditional GNSS sources. *www.all.space*

Adtran launches Galileo OSNMA authentication for Oscilloquartz timing

Adtran has announced support for Galileo's Open Service Navigation Message Authentication (OSNMA) across its Oscilloquartz synchronization platforms, marking a major advance in GNSS security. OSNMA is the first GNSS authentication service designed for civilian use, and Adtran is the first in the timing industry to support it. By verifying that timing data originates from genuine Galileo satellites, OSNMA ensures authenticity and integrity at the point of reception. Available via firmware update for supported multi-band GNSS receivers, the new feature adds an extra layer of protection against spoofing and manipulation, empowering existing deployments to strengthen security without hardware changes or service disruption.

OSNMA support from Adtran brings a new level of GNSS security to critical infrastructure. Available for multi-band GNSS receivers in the OSA 5412, OSA 5422, OSA 5430 and OSA 5440 product lines, the feature integrates with Galileo's Open Service, using digital signatures and TESLA chain keys to authenticate navigation data. This ensures that timing and positioning information is verified as authentic and protected against spoofing or manipulation. *www.adtran.com*

Net Insight introduces Zyntai TimeNode 3100E

Net Insight launches TN3100E, a new TimeNode in the Zyntai family. It delivers multiband GNSS for superior accuracy, supports India's GNSS IRNSS/NavIC, and adds advanced anti-jamming and anti-spoofing features. It is the latest TimeNode hardware unit in the Zyntai product family. It provides enhanced GNSS functionalities designed for markets that depend on GNSS as time source in challenging environments where robust protection against interference is essential. *netinsight.net*

Microchip TimeProvider 4500 v3

Microchip Technology has released the TimeProvider® 4500 v3 grandmaster clock (TP4500) designed to deliver sub-nanosecond accuracy for time distribution across 800 km long-haul optical transmission. It provides a resilient, terrestrial solution in the absence of GNSS for precise timing, alleviating physical obstruction, security and signal interference costs associated with GNSS-dependent deployments. It supports time reference provided by UTC(k) UTC time provided by national labs, and is the first grandmaster to offer a premium capability that delivers High Accuracy Time Transfer (HA-TT) as defined by ITU-T G.8271.1/Y.1366.1 (01/2024) to meet 5 nanoseconds (ns) time delay over 800 km (equating to 500 picoseconds (ps) average per node, assuming 10 nodes. *www.microchip.com*

HydroGNSS Scout satellites ready for launch

Two European Space Agency (ESA) microsatellites will soon be launched to study climate variables linked to water using GNSS reflectometry. The twin HydroGNSS satellites will be launched later this month.

The HydroGNSS twins are the ESA's first Scout venture, part of the agency's Earth Observation FutureEO programme. They are designed to deliver cutting-edge science quickly and affordably, complementing ESA's larger Earth Explorer missions. *www.esa.int*High-accuracy GPS for better GrabMaps accuracy

Grab Singapore has launched a pilot programme that uses high accuracy lane-level GPS positioning to enhance the navigation experience for its driver- and delivery-partners in Singapore. The pilot, rolled out in collaboration with Oppo, Qualcomm Technologies, Inc, and Swift Navigation, also marks the first deployment of high- accuracy GPS positioning on mobile phones and app integration in Southeast Asia, delivering unprecedented outdoor location accuracy for Grab's partners. In dense urban environments such as Singapore's high-rise buildings, multi-level roads, and underground networks can degrade standard GPS accuracy above 20 metres, complicating navigation between pick-ups and drop-offs, and reducing ETA accuracy. *www.grab.com*

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www.geo-week.com

DGI 2026
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https://dgi.wbresearch.com

March 2026

Munich Navigation Satellite Summit
25 - 27 March 2026
Munich, Germany
www.munich-satellite-navigation-summit.org

Geo Connect Asia, Digital Construction Asia, Ocean Connect Asia, Drones & Uncrewed Asia
31st March - 01st April
Singapore
www.geoconnectasia.com

April 2026

Assured PNT Summit
7 - 8 April 2026
Washington DC, USA
https://pnt.dsigroup.org

2026 Commercial UAV Forum
22 - 23 April
Amsterdam, The Netherlands
www.forumuav.com

European Navigation Conference 2026
28 – 30 April 2026
Vienna, Austria
https://enc-series.org

May 2026

GeoIgnite 2026
11 - 13, May
Ottawa, Canada
https://geoignite.ca

GISTAM 2026
21 - 23 May
Benidorm, Spain
https://gistam.scitevents.org

FIG 2026
24 - 29 May
Cape Town, South Africa
https://fig2026.org

June 2026

ICCGIS 2026
14 - 19 June 2026
Nessebar, Bulgaria
https://iccgis.cartography-gis.com

October 2026

3rd Annual International Geotechnical Innovation Conference
12 - 13 October 2026
Jeddah, Saudi Arabia
https://geotechnicalinnovationconference.com

Iridium Unveils global GPS device protection

Iridium Communications Inc. has announced a leap forward in the security of GPS and other GNSS-reliant devices against jamming, spoofing and timing interruptions with the unveiling of a dedicated, miniature application-specific integrated circuit (ASIC), the Iridium® PNT ASIC. Engineered for seamless integration into a wide range of electronic devices, the Iridium PNT ASIC will deliver authenticated, pole-to-pole PNT data. It will provide a resilient alternative to traditional GNSS, offering protection against spoofing and jamming for consumer, industrial, and government applications. *Iridium.com*

Safran unveils Skydel NAVWAR

Safran Electronics & Defense has announced the launch of Skydel NAVWAR, a software solution designed to strengthen national defense capabilities against hostile drones. As the core of Safran's counter-UAV (C-UAV) systems, it disrupts unmanned aerial vehicle navigation by simulating authentic GNSS signals. It ensures real-time electronic deception to neutralize UAV threats. Its ability to embed on tactical platforms and integrate seamlessly with sensors and command-and-control systems allows operators to conduct remote spoofing operations with efficiency and precision – even when they are not physically present. *safran-navigation-timing.com*

Septentrio launches mosaic-G5 T timing module

Septentrio has launched a new timing module, the mosaic-G5 T. Measuring only 23 mm by 16 mm and weighing as little as 2.2 grams, this receiver unlocks new opportunities for system designers operating under strict size, weight and power (SWaP) constraints. Nano-second time precision is complemented by AIM+ Premium anti-jamming and anti-spoofing2 technology ensuring reliable service uptime and continuity. *www.septentrio.com*