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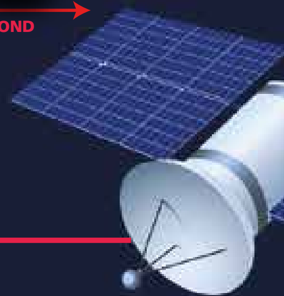

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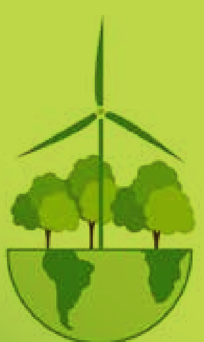

Combating Air Pollution in NCT of Delhi: Strategic Pathways


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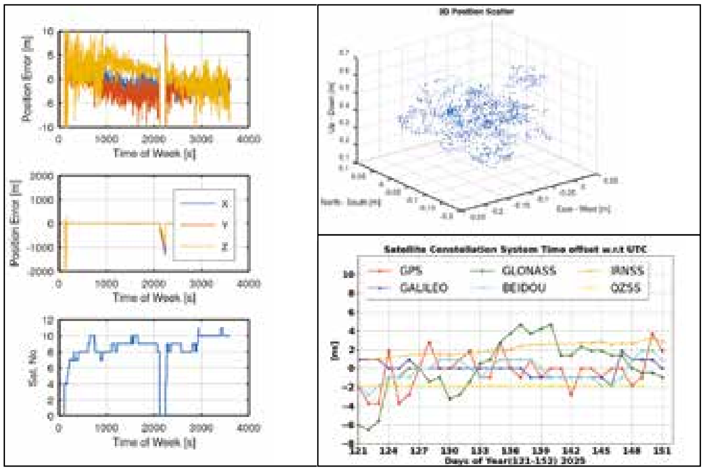

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Coordinates Volume 21, Issue 6, June 2025

Articles

Columns

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

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Bal Krishna, Editor
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gSim – Low Cost Dual Frequency GPS & Galileo Simulator

We proved the concept of the generation of perfectly coherent dual-frequency navigation signals using an SDR transceiver.

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Summary

- GPS L1/L5 and Galileo E1/E5a software simulator that uses cheap off-the-shelf SDR transceivers augmented by a gSim Converter for signal generation
- Customizable static and movement user scenarios, including LEO orbit
- Generation of line of sight and up to two reflected or spoofed signals with the same or different navigation message
- Modelling the errors in the navigation message channel
- Rich set of navigation scenarios for demonstration of the simulator function, performance, and capability

Introduction

The massive use of GNSS navigation products both for stand-alone and embedded systems and applications raises the need for custom testing of these devices. This paper describes a novel approach to the development of the multi-frequency and multi-system GNSS simulator. The development itself was initiated by our colleagues from the automotive and railway industries, who questioned the high prices of the commercial GNSS simulators and also our need for complex testing of the CubeSat GPS receivers [1]. The first idea was to use common off-the-shelf SDR (Software Defined Radio) [2] transceivers for signal transmission. The same approach also uses an open-source GPS simulator [3].

Let us recall that GNSS systems operate on the timing principle. The receiver calculates the position from the so-called pseudoranges, which are calculated from the time of arrival of satellite signals to the receiver. Since satellite signals are perfectly synchronized by onboard atomic clocks [4, 5] the simulated signals must have the same properties. The critical problem is then to achieve perfect coherence of the code and carrier frequency and coherence between signals at different navigation frequencies.

The low-cost SDR transceivers can generate a signal with a bandwidth of several tens of megahertz; in the case of multiple frequency generation, several transceivers have a dual-channel architecture, but the generation of perfectly coherent signals on both channels is not possible in their simple cost-reduced approach. The ideal solution (Figure 1.) is to generate coherent complex envelope signal samples for all supporting frequencies. The samples are then digitally upconverted onto the carrier frequency by DUCs (Digital Up Converter), summed up and converted to the digital domain by DAC (Digital to Analogue Converter), and reconstruction Low Pass Filter (LPF) [6]. Unfortunately, the hardware capable of the described approach is expensive and is one of the main factors that determines the price of the simulator.

The approach used in the gSim simulator is different, as described in Figure 2. We generate one intermediate frequency data stream that comprises the signal of all satellites on both supporting frequencies. Such signal is firstly modulated onto the intermediate frequency using a standard commercial SDR transceiver. The resulting signal is then shifted onto the navigation carriers by a following frequency converter (gSim Converter) using band-pass filters to suppress undesired spectral components produced by the mixer. More details are in the Hardware section or [6].

Software

The aim of the software is to generate signal samples for SDR transmitter based on the scenario and other supporting data. The main design requirements are:

1. Dual frequency GPS L1C/A & L5 and Galileo E1b&c and E5aI&Q signals with future update to add GPS L1C and BeiDou B1C & B2a
2. Capability of static and dynamic user motion scenarios
3. Estimation of the navigation satellite clock, ephemeris, and other supporting data for any time derived from navigation messages measured by a monitoring receiver
4. One update of the navigation message per simulation
5. Generation of a line of sight and up to two reflected signals
6. Modulation of one reflected (spoofed) signal by a different navigation message
7. Modification of the content of the navigation message and modelling of the errors in the navigation data channel
8. Simple software control for common scenarios
9. Possibility to use a third-party data processing or mathematical software for the realization of complex simulation scenarios

The gSim is designed as a Linux command-line application that consists of four processing modules. The data transfer and mutual link between modules are clarified by the data flow chart in Figure 3.

There are three basic groups of files in the processing chart: input, intermediated, and output files. The input and intermediated files are human-readable files that can be manually modified by any text editor or by automated text processing with third-party software [6]. This enables the design of complex simulation scenarios, construction of complex multipath and signal propagation environments, spoofing attacks, modelling the errors of the control segments, signal propagation, etc.

Simulation scenario setup

The simulation scenario is defined by a human-readable *INI File* that uses standard syntax based on key-value pairs. gSim *INI file* is organized into eight sections. The user can set the basic simulation parameters like simulation start time and duration, switch on and off particular GNSS signals, individually set their level and number of reflected signals, sampling frequency, intermediate frequency, frequency offsets of individual systems and signals, configuration of SDR transceiver, navigation messages, folder structure, and many others.

The user position or its movement is defined using the *User Position file*. The last part of input files is *Source GNSS Constellation Files*, which store GPS and Galileo orbital parameters.

Constellation Preprocessor

The first data processing is the transformation of the source GNSS constellation data to the time of the simulation. The gSim enables one update of the navigation messages in signal content during simulation. Therefore, it is necessary to generate up to two *navigation messages constellations*, one that is modulated before the update and the second one after the update. The last satellite *position constellation files* are used to calculate the positions of the navigation satellites.

This complex data processing is done by a ***Preprocessor*** module in two possible modes. The automatic mode operates with a simplified setting where the user must set only the start

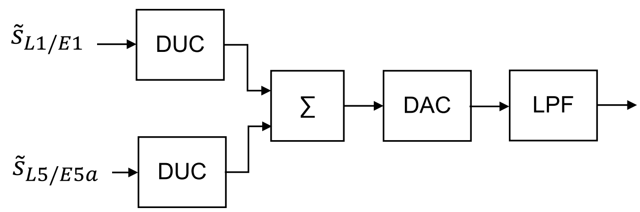

Figure 1: Digital GNSS simulator approach

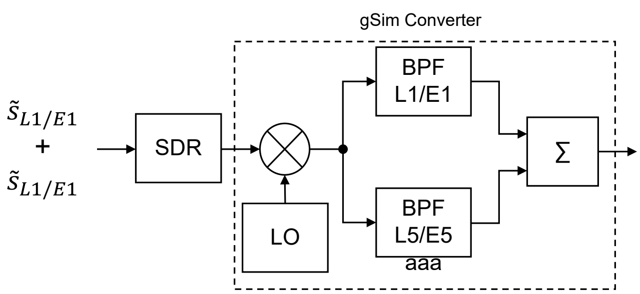

Figure 2: gSim simulator approach

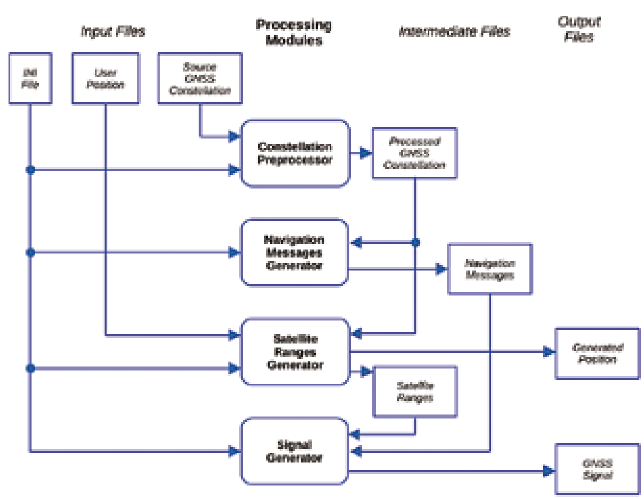

Figure 3. gSim software data flow chart

time of the simulation. The preprocessor then automatically generates regular navigation updates and reference times.

In manual mode, all the processes are under complete user control. It is possible to set extraordinary navigation messages update independently for each satellite, set irregular user reference times, etc.

Navigation Messages Generator

The ***Navigation Messages Generator*** creates navigation messages for all satellites based on the navigation message constellations. The results are human-readable *Navigation Messages files* that contain commented navigation messages that can still be modified before signal generation. The user can change almost all the values of individual items, set the errors in the communication channel. The full set of possible adjustments can be found in [2,3].

Satellite Ranges Generator

The purpose of the ***Satellite Ranges Generator*** is to calculate the ranges files of individual navigation satellites that contain signal delay on both supported frequencies. The setup of the gSim enables to introduce to the signal ranges both ionospheric and tropospheric delay.

With the help of suitable third-party software like GNU Octave, SciLab, Matlab, Python, the user can add up to two reflected signals, model the signal propagation, introduce the spoofed signals, and many other phenomena.

Signal Generator

The final processing block is a ***Signal Generator*** that finally builds the resulting baseband signal samples of the GNSS signal. The signal generator is designed as a multithread application and is capable of using all the processing power of a multicore processor for signal generation (with the proper choice of initial parameters in input files).

GUI

To simplify gSim control, the simulator uses a GUI (Figure 4) that was developed to enable more user-friendly access to simulation setup in comparison with plain text files editing. The GUI allows you to open and edit input and intermediate files, run individual processing models, and transmit the generated signal using an SDR transceiver. Last, the GUI displays the gSim Converter status and controls the electronic attenuators built into the gSim Convertor, thereby controlling the generated signal level.

Hardware

The hardware interconnection is quite simple, as can be seen from one possible configuration shown in Figure 5. The hardware setup consists of a PC computer (not shown) for signal generation and playback. The SDR transceiver modulates the signal at an intermediate frequency. The simulator can set the sampling frequency, intermediated frequency, and the frequency offset of individual GNSS signals in a wide range. That enables to fit the simulator to various SDR transmitters.

The intermediate frequency signal is then moved to the final navigation carriers L1/E1 and L5/E5a with the help of gSim Converter (Figure 2). The signal level is adjusted by built-in digital attenuators and an external 30 dB attenuator. The last block in the picture is the GNSS receiver under test.

Simulation Scenarios and Test Results

In the frame of the gSim project, several simulation scenarios were prepared for general gSim testing and demonstration of its performance. The simulation scenarios cover static,

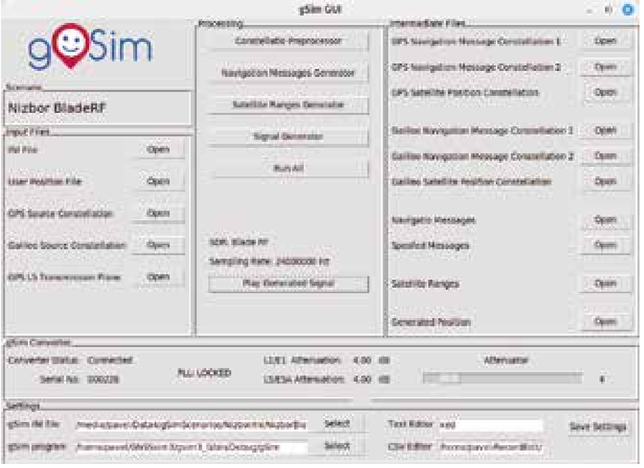

Figure 4. gSim GUI

Figure 5. Hardware setup

dynamic and time/leap second changes and are fully described in [8].

Absolute position precision

The simulator enables testing of the GNSS receiver absolute position errors of the static and moving user computation. The examples of the test results for static and moving users are in Figures 6 and 7. The dynamic position error analysis is done with the help of a *Generated Position file* that contains precise time and coordinates of the generated signal, see Figure 7.

Besides classical simulation scenarios for position error investigation, gSim enables testing of receiver's response to errors in the communication channels, modification of the content of the navigation message, and many others.

Multipath Error Envelope

The reflected signal generator enables the simulation of complex multipath environments or testing the sensitivity of the navigation receiver to the reflected (multipath) signals. The classical method is based on the investigation of the pseudorange errors caused by one reflected signal for various phase shifts between the Line of Sight and the reflected signal [9]. The maximal positive and negative errors are then expressed as a multipath error envelope.

The methodology of testing the dual frequency receiver using gSim is straightforward. We affect the signal on one frequency with the multipath signal, while the signal on the second frequency is without the multipath signals. This approach enables an easy evaluation of the multipath impact by comparing the multipath-affected reception to the default "clean" reception. The example of the multipath error enveloped measured on GPS L1 C/A and Galileo E1 signals are in Figures 8. and 9.

The simulation was realized using a simple GNU Octave script [8] that adds reflected signals with attenuated amplitude with growing delay and small Doppler shift to the Satellite Range File of selected GPS and Galileo satellites. The raw pseudoranges measured by a GNSS receiver under test were analyzed using the Octave script.

LEO Orbit

gSim can also be used to test space-based GNSS receiver applications like e.g. LEO orbit satellites position determination, Figure 10. An example of the application is a test of the pNav L1 GNSS

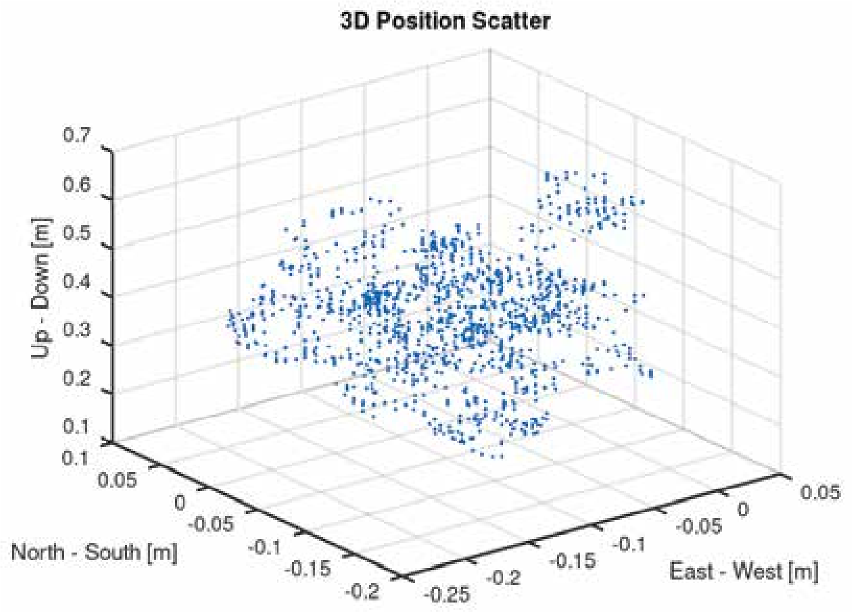

Figure 6. Typical static position error of dual frequency GPS-Galileo receiver

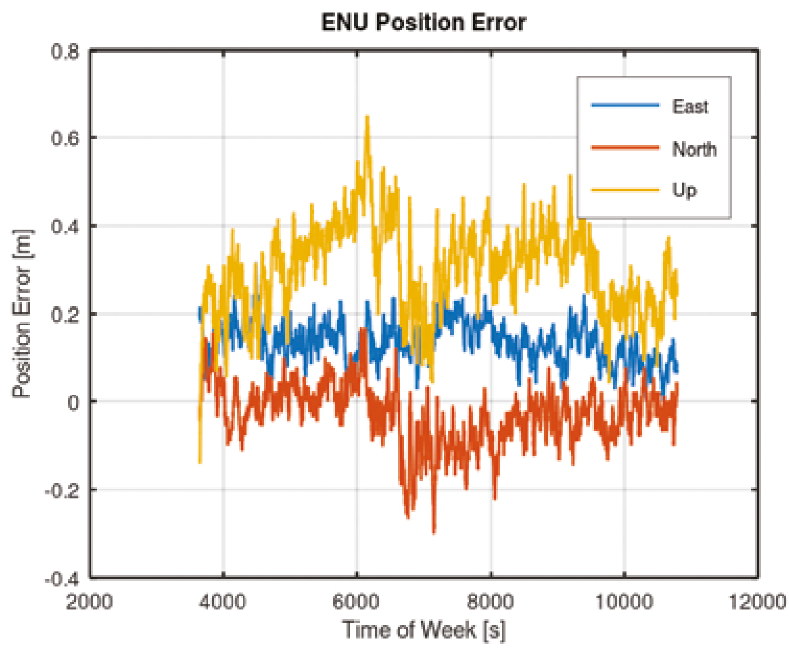

Figure 7. Typical moving user position error of dual frequency GPS-Galileo receiver

receiver designed for small satellites equipped with an orbital propagator, allowing a deduced reckoning navigation. The algorithm is based on the numerical solution of the satellite equation of motion. The results of the gSim generated signal transmitted to pNav receiver can be seen in Figure 11.

At approximately 2100 s, the signal was intentionally attenuated by the attenuator in the gSim Converter. The receiver lost satellites and went into interpolation mode. After the signal was restored, the receiver continued with standard navigation using simulated GPS satellites.

Other test scenarios

Leap Second

gSim can test the receiver response to the leap second event [10]. The creation of the simulation scenario is simple; the user

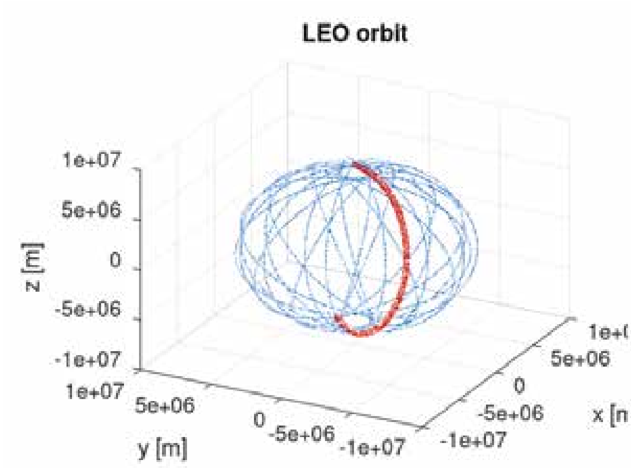

Figure 10. LEO orbit

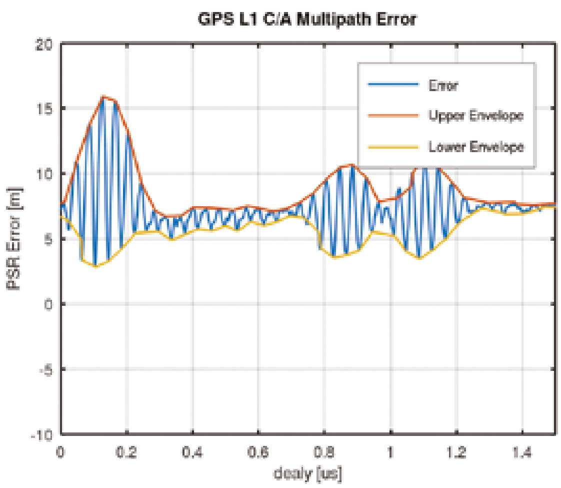

Figure 8. Multipath Error Envelope of the GPS L1 C/A channel

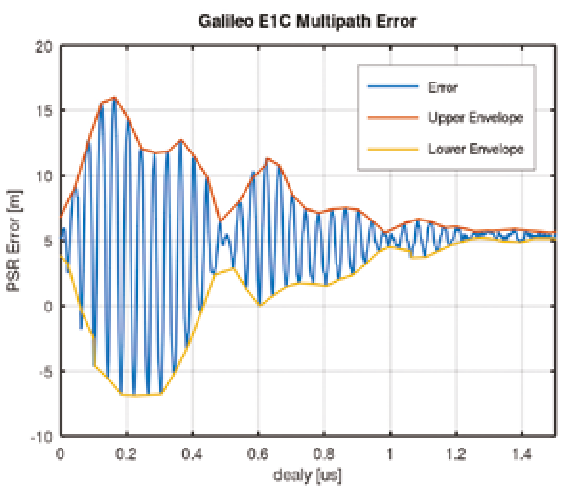

Figure 9. Multipath Error Envelope of the Galileo E1 channel

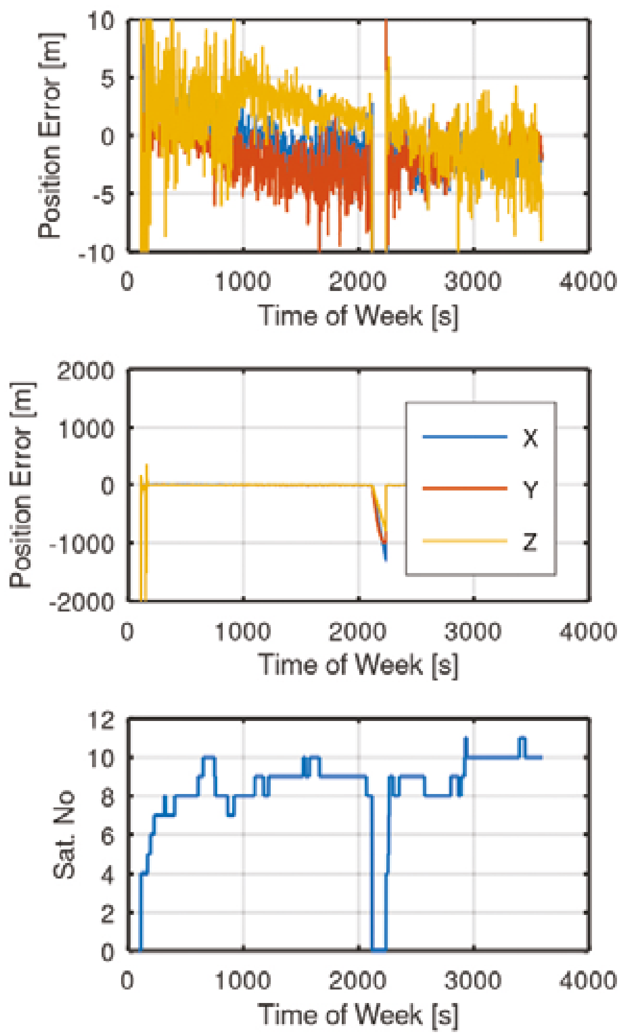

Figure 11. pNav receiver test results for LEO orbit simulation

generates simulation scenarios for the midnight when the leap second is inserted or removed. The next step is to manually set the UTC parameters in navigation message constellations modulated before and after midnight. Details for parameter adjustment are thoroughly described in [3].

Dynamic stress

The next interesting task that the gSim can be used for is testing dynamic stress errors or receivers [11]. Let us note that the GNSS receiver channels use DLL, PLL, and FLL (Delay, Phase, and Frequency Locked Loops) for signal tracking. Such feedback loops are sensitive to the dynamic stress of the tracked parameters [11]. gSim enables the creation of scenarios to investigate those errors.

Intelligent spoofing

GNSS jamming and spoofing [12] are emerging problems nowadays with a broad range of positioning services. gSim enables the simulation of satellite signals and one spoofed signal that can be modulated by a different navigation message. This allows complex receiver testing for spoofed signals and modelling sophisticated spoofing attacks.

Conclusions

The developed dual-frequency GPS Galileo simulator based on the low-cost SDR can be used for testing and verification of GNSS receivers operation under various controlled conditions. We proved the concept of the generation of perfectly coherent dual-frequency navigation signals using an SDR transceiver. The simulator is available on the gSim website for public use in its simplified mode, along with the documentation and demonstration simulation scenarios. The large simulator flexibility was reached by the decomposition of the data and signal processing into four phases with simple well-described interfaces that enable the use of third-party mathematical or data processing software like GNU Octave, or Python for the realization of complex scenarios. The modular concept enables to use all or just selected parts of the gSim for simulation signal preparation or adjustment of generated GNSS signals.

Acknowledgments

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References

[1] P. Kovar, Experiences with the GPS in Unstabilized CubeSat, International Journal of Aerospace Engineering. 2020, 2020 ISSN 1687-5966.

[2] D. M. Molla, H. Badis, L. George and M. Berbineau, "Software Defined Radio Platforms for Wireless Technologies," in *IEEE Access*, vol. 10, pp. 26203-26229, 2022, doi: 10.1109/ACCESS.2022.3154364

[3] Takuji Ebinuma, Gps-sdr-sim, https://github.com/osqzss/gps-sdr-sim, access Jan 1. 2025

[4] C. Dionisio *et al*., "gLab a fully software tool to generate, process and analyze GNSS signals," *2010 5th ESA Workshop on Satellite Navigation Technologies and European Workshop on GNSS Signals and Signal Processing (NAVITEC)*, Noordwijk, Netherlands, 2010, pp. 1-7, doi: 10.1109/NAVITEC.2010.5707988.

[5] C. J. Hegarty, "GNSS signals — An overview," *2012 IEEE International Frequency Control Symposium Proceedings*, Baltimore, MD, USA, 2012, pp. 1-7, doi: 10.1109/FCS.2012.6243707.

[6] AMD RF Sampling, https://www.amd.com/en/products/adaptive-socs-and-fpgas/technologies/rf-sampling.html#resources

[7] Pavel Kovar, gSim User Guide, www.gSim.cz/Downloads/

[8] Pavel Kovar, gSim Simulation Guide, www.gSim.cz/Downloads/

[9] Irsigler, Markus, Hein, Günter W., Eissfeller, Bernd, "Multipath Performance Analysis for Future GNSS Signals," *Proceedings of the 2004 National Technical Meeting of The Institute of Navigation*, San Diego, CA, January 2004, pp. 225-238.

[10] M. Hack, X. Meng, S. Froehlich and L. Zhang, "Leap Second support in computers," *2010 IEEE International Symposium on Precision Clock Synchronization for Measurement, Control and Communication*, Portsmouth, NH, USA, 2010, pp. 91-96, doi: 10.1109/ISPCS.2010.5609776.

[11] M. Abedi and T. Jin, "Improvement in tracking loop threshold of high dynamic GNSS receiver by installation of crystal oscillator on gyroscopic mounting," *2015 Joint Conference of the IEEE International Frequency Control Symposium & the European Frequency and Time Forum*, Denver, CO, USA, 2015, pp. 522-527, doi: 10.1109/FCS.2015.7138898.

[12] X. Ouyang, F. Zeng, P. Hou and R. Guo, "Analysis and Evaluation of Spoofing Effect on GNSS Receiver," *2015 IEEE 12th Intl Conf on Ubiquitous Intelligence and Computing and 2015 IEEE 12th Intl Conf on Autonomic and Trusted Computing and 2015 IEEE 15th Intl Conf on Scalable Computing and Communications and Its Associated Workshops (UIC-ATC-ScalCom)*, Beijing, China, 2015, pp. 1388-1392, doi: 10.1109/UIC-ATC-ScalCom-CBDCom-IoP.2015.250.

GNSS Constellation Specific Monthly Analysis Summary: May 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. As a complementary extension to last month's article on the application of variational equations in parameter estimation, this issue includes a focused analysis on **reduced-dynamic orbit determination**. Specifically, it will explore how satellite orbits—such as those of LEO missions—can be estimated by combining GNSS observations with physical models of orbital dynamics, supported by the solution of variational equations. This approach bridges the gap between purely kinematic and fully dynamic orbit determination, offering a robust framework for high-precision orbit estimation even in the presence of data gaps or modeling uncertainties.

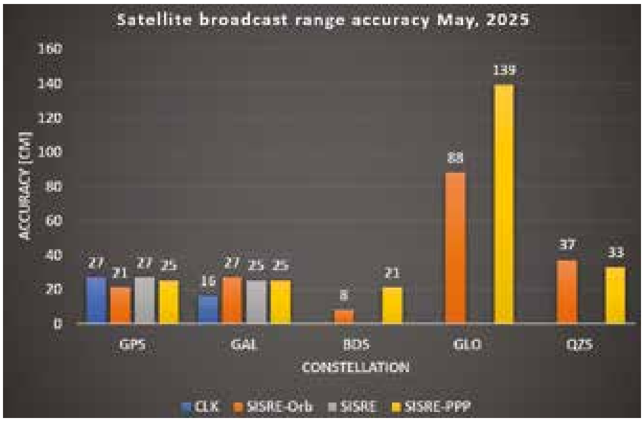
Analyzed Parameters for May 2025

(**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. **Variational Equations and Satellite Orbit Estimation**: The variational equations are a key set of differential equations to reliably capture the dynamics of the satellite motion in the orbit determination process. The solution to these equations is indicative of quality of the initial orbit determination and force models. This further helps to filter noisy measurement as well as cover the measurement gaps and iteratively improve the quality of estimated final orbits.

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)



Note: For Galileo there were several days with degraded performances. The NAGU for the degradation was provided for 12th to 19th May, citing testing activities, by the authority. https://www.gsc-europa.eu/sites/default/files/NOTICE_ADVISORY_TO_GALILEO_USERS_NAGU_2025016.txt
On 14th May, for example, the Galileo performances look like this- CLK: 51 cm; SISRE-Orb: 29 cm; SISRE: 58 cm; SISRE-PPP: 58 cm.

(c) Satellite Clock Jump per Mission Segment Upload

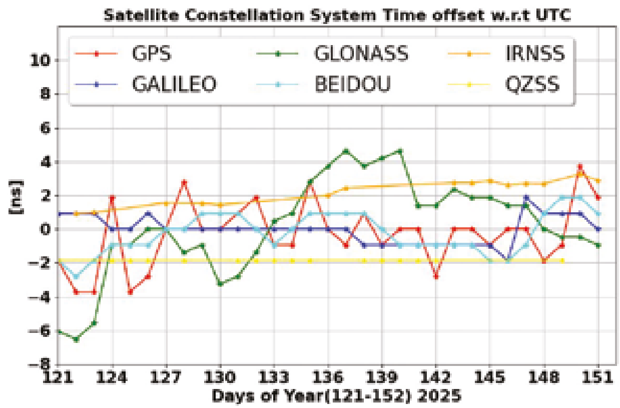
Const	Mean [ns]	Max [ns]	95_ Percentile [ns]	99_ Percentile [ns]	**Remark (Best and Worst 95 %)**
IRNSS	4.08	1314.54	4.76	19.83	Best I06 (3.62 ns) Worst I10 (8.56 ns) Big jumps for each satellite in multiple days; relatively a bit lesser in magnitudes than previous months
GPS	0.41	8.61	0.88	2.54	Best G14 (0.40 ns) Worst G26 (3.43 ns) G26 appears to be noisier after May 08 onwards. G07 also has relatively large jumps. G03 has largest jump on 02 May but it was declared unusable.
GAL	0.10	253.45	0.18	0.47	Best E07 (0.14 ns) Worst E19 (0.35 ns). A lot of Galileo satellites have degraded clocks for the month. The expected degradation was informed via NAGU for the 12 to 19 May. There was a large clock jump for E11 on the 2nd of May.

Note: it is envisaged to have a deeper analysis, in next month's article, on the degraded Galileo performances for the period of 12 – 19 May 2025.

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

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	2934	47	5	1	1	-	-	-
I06	2983	4	-	-	2	-	-	-
I09	550	5	-	-	1	-	-	-
I10	599	3	-	-	-	-	-	-

(e) GNSS-UTC Offset



(f) Variational Equations and Satellite Orbit Estimation

Continuing from last month's introduction to variational equations in dynamical parameter estimation, this section presents a practical example of satellite orbit determination using GNSS observables and dynamic modeling. The principles discussed here are equally applicable to GNSS network processing for both GNSS and LEO satellite orbit determination. However, for clarity and tractability, the focus is on the orbit determination of a Low Earth Orbit (LEO) satellite, which offers a more manageable framework compared to the complexity of a full GNSS network solution involving multiple ground stations and satellites.

In essence, LEO orbit determination is the inverse of GNSS satellite orbit determination from ground networks. In the LEO case, the positions of GNSS satellites are assumed known (from precise ephemerides), and the LEO satellite's trajectory is estimated. Conversely, in GNSS network processing, the ground station positions are known, and the satellite orbits are estimated.

To support the analysis, the open-source GNSS processing software **GROOPS (Mayer et.al, 2021)** is used leveraging publicly available data from the **International GNSS Service (IGS)** and **TU Graz** for reference and auxiliary inputs. For rigorous review and testing purposes, **(GROOPS et.al, 2025)** and **(Strasser et.al, 2022)** are recommended.

Before jumping to the analysis, however, a short recap on the topic is provided. The variational equations give the **partial derivatives of the satellite state vector with respect to its initial conditions**. Simultaneously, the satellite's orbit is propagated from the initial state using a dynamic model. This propagated trajectory represents a particular solution to the initial value problem defined by the satellite's equations of motion.

Initial conditions for the orbit can be derived from either:

- A prior orbit solution (e.g., from orbit identification), or
- A purely kinematic solution based on GNSS observations from the LEO satellite's onboard receiver.

In this analysis the example from GROOPS is taken (https://groops-devs.github.io/groops/html/cookbook.kinematicOrbit.html) and adapted for reduced dynamic orbit estimation where the GRACE satellite's dynamics are modeled using well-established force models and auxiliary data. The output of this process includes:

- The propagated orbit for 24 hours
- The corresponding partial derivatives (Jacobian matrix consisting of state transition and sensitivity matrices) evaluated at the epochs of the GPS observations (the GRACE FO satellite has onboard receiver providing only GPS observables).

Iterative Estimation and the Role of Jacobians

If the initial orbit is reasonably accurate, the variational equations can be used to linearize the system and apply **least squares estimation** to refine the orbit. The Jacobian matrix, derived from the variational equations, plays a central role in this process. A well-conditioned Jacobian provides strong dynamical constraints and enables accurate fitting of the GNSS observations.

However, if the initial orbit or Jacobians are poorly approximated, the residuals between observed and computed measurements will be large. In such cases, the least squares solution will yield significant corrections to the initial state, necessitating further iterations. These iterations continue until the propagated orbit becomes **insensitive to small perturbations in the initial conditions**, indicating convergence.

Failure to converge typically points to:

- Modeling errors in the satellite dynamics,
- Inaccuracies in the GNSS observation model, or
- Systematic biases in the measurements.

Thus, the **stability and conditioning** of the Jacobian matrix are critical. A well-conditioned Jacobian ensures that the linearized system accurately reflects the underlying nonlinear dynamics, enabling robust estimation even in the presence of measurement gaps or noise.

Mathematical Formulation

The correction to the initial state vector δ**x** is obtained by solving the **normal equations**:

$\delta x = (H^T W H)^{-1} H^T W\, r$ (**Equation 1**)

Where:

- **H** is the Jacobian matrix, consisting of state transition matrix, sensitivity matrix and GNSS measurement sensitivity matrix (please refer to previous month's issue on this topic)
- **W** is the weight matrix (inverse of measurement variances),
- **r** is the residual vector (observed minus computed measurements).

The **condition number** of the Jacobian matrix, defined as the ratio of its largest to smallest singular values, quantifies the sensitivity of the solution to perturbations. A high condition number indicates an ill-conditioned system, which can lead to unstable or unreliable estimates.

The effect of the solutions of the variational equations can also be seen through the fitting residuals captured by the a-posterior sigma value of the GNSS observations fitting after solving the normal equations. This is given by:

$\sigma_0 = \sqrt{\frac{r^T W r}{n-m}}$ (**Equation 2**)

Where:

- nn is the number of observations,
- mm is the number of estimated parameters.

Illustrative Results

The following plots (Figure F1-F4) illustrate the impact of variational equation solutions on orbit accuracy for the GRACE satellite in the Celestial Reference Frame, compared against the final precise orbit product from TU Graz:

1. **Top Plot (Figure F1)**: Orbit derived from a purely kinematic solution (epoch-wise), without using dynamic models. Note the presence of gaps due to missing GNSS measurements.
2. **Middle Plot (Figure F1)**: Orbit obtained by fitting GNSS observations to a dynamically propagated orbit, using an initial state offset by several hundred meters. The variational equations are solved once, without iteration. The a posteriori sigma (Equation 2) for the fitting is a bit higher. The residuals (r) (Equation 1) on the observations fitting are also high for first few iterations as the system attempts to correct the initial approximation.
3. **Bottom Plot (Figure F1)**: Final orbit after multiple iterations in solving the variational equations and least squares fitting with GPS observations. and r get smaller with each adjustment in the Jacobians and each iteration in the fitting. Despite gaps in GNSS measurements, the dynamic model fills in the trajectory, resulting in a continuous and accurate orbit as shown in **Figure F2**. For broader overview on the reduced-dynamic approach for the orbit determination of GRACE-FO satellite, readers are recommended (**Jiabo et.al, 2021**)

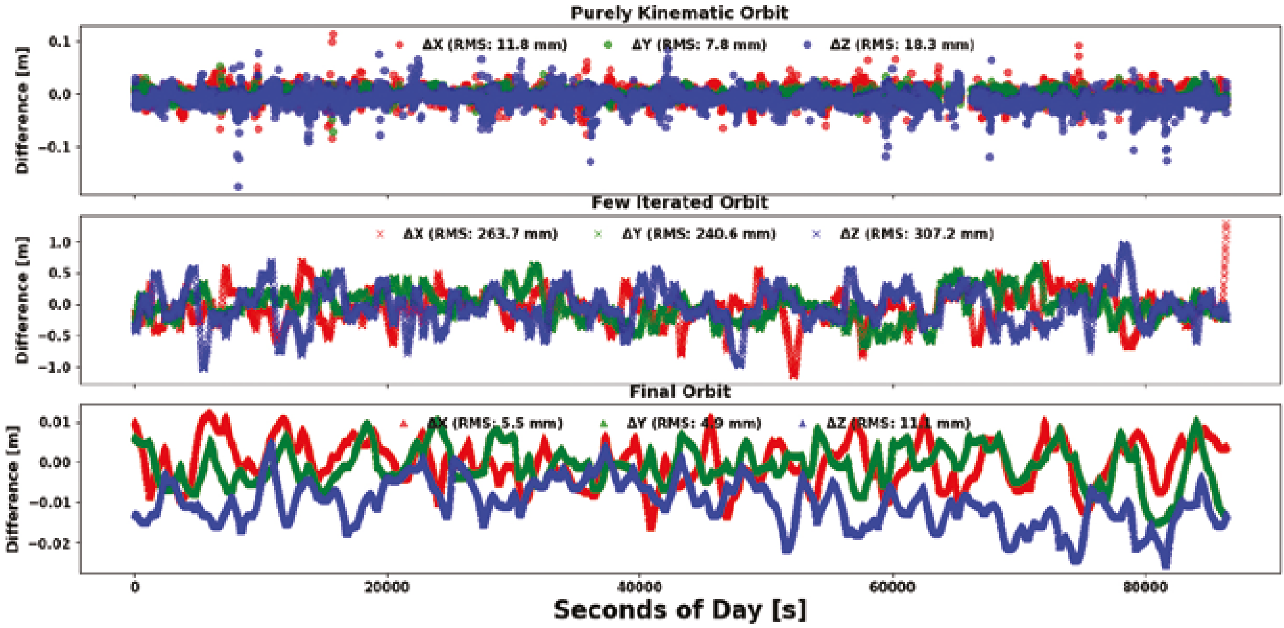


Figure F 1: Satellite orbit estimation results for the GRACE Follow-On mission using onboard GNSS receiver data from January 1, 2020. The top plot shows the purely kinematic orbit solution, derived without applying any dynamic constraints. The middle plot presents a reduced-dynamics solution obtained after a few iterations starting from an initial orbit approximation that was offset by several hundred meters from the true trajectory. The bottom plot displays the final orbit solution, achieved through further iterations of the variational equations, resulting in a trajectory that closely matches the true orbit.

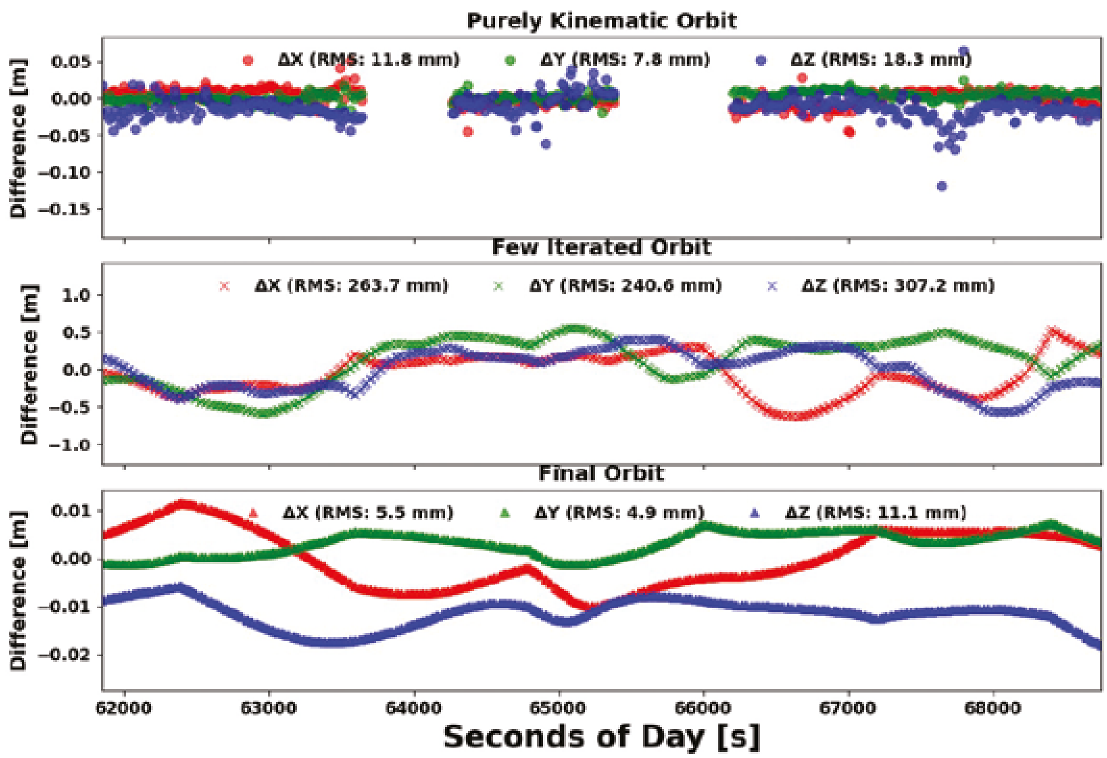


Figure F 2: Zoomed-in view of the GRACE Follow-On orbit solutions from Figure F1, focusing on a time window with missing GNSS measurements. The top plot shows the purely kinematic solution, which exhibits clear data gaps due to the absence of observations. In contrast, the middle plot presents a reduced-dynamics solution obtained after a single iteration using the Jacobian matrix from the variational equations, already showing improved continuity. The bottom plot illustrates the final orbit solution after multiple iterations, demonstrating that the dynamical model successfully bridges the measurement outages and maintains orbit consistency.

These results underscore the importance of accurate initial conditions, well-conditioned Jacobians derived from the solution of variational equations, and iterative refinement in achieving high-precision orbit determination. As the estimate improves, the Jacobian is evaluated **closer to the true trajectory**, where the system behaves more **linearly**. This makes the elements of Jacobians derived from solving the variational equations **more stable and smaller in variation**.

In **Figure F3**, the plots illustrate the behavior of the satellite orbit propagated from two different initial conditions: one based on an initial state offset by several hundred meters from the true orbit, and the other derived from an iteratively

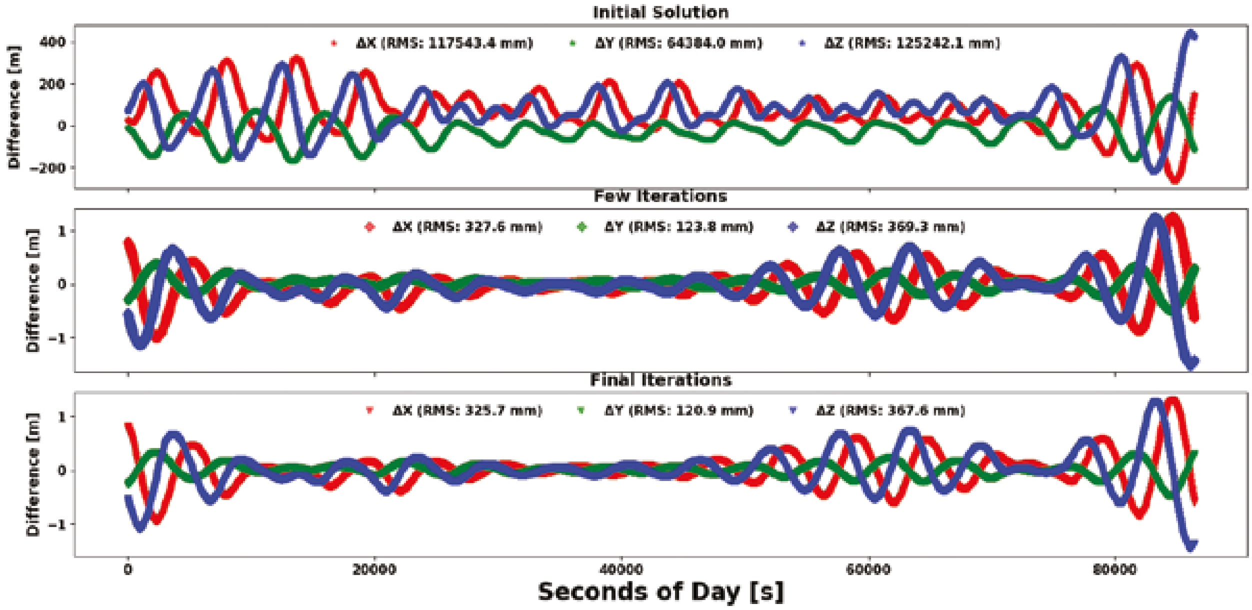


Figure F 3: Evolution of satellite orbit accuracy as a function of the initial conditions and iterative solutions of the variational equations. The plots illustrate how the orbit, initially propagated from a coarse approximation, gradually improves through successive iterations of fitting to GNSS observations. The oscillatory behavior observed in the early iterations reflects the influence of various geophysical forces and potential residuals due to mismodeling in the dynamic model. As the initial orbit is refined, the propagated trajectory becomes less sensitive to small perturbations in the initial state—an effect captured by the decreasing magnitude and variability of the partial derivatives obtained from the variational equations.

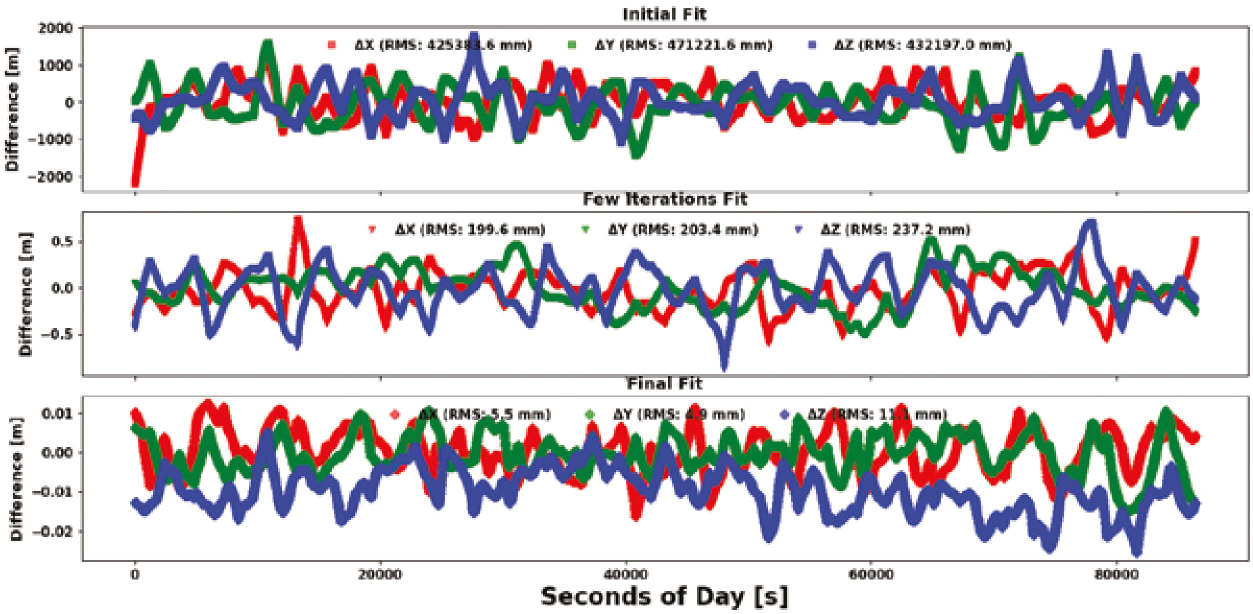


Figure F 4: Application of the variational equations to correct the initial orbit trajectory and reduce residuals. The top plot shows the initial orbit derived from a purely kinematic solution, perturbed with random noise on the order of several hundred meters. This initial trajectory exhibits significant deviations from the true orbit. After fitting the propagated orbit to GNSS observations using the Jacobian matrix—comprising the state transition and sensitivity matrices—the orbit solution is progressively refined. The middle and bottom plots illustrate the improved trajectories after successive iterations, demonstrating a substantial reduction in residuals and convergence toward the true orbit.

adjusted solution. The latter, obtained through successive corrections using the variational equations, yields an initial state that closely approximates the true orbit. This comparison clearly demonstrates that, when the initial conditions are sufficiently accurate, the physics-based dynamical model can propagate the orbit with high fidelity. It also demonstrates that even though the orbit trajectory is a particular solution of the initial conditions, the **rate at which the trajectory diverges** from a nearby depends on sensitivity information of the Jacobin. The iterative refinement of the Jacobian significantly enhances the accuracy and smoothness of the orbit solution, highlighting the importance of both precise initial values and well-conditioned variational solutions (Jacobian) in the orbit determination.

Similarly, the final analysis presented in **Figure F4** demonstrates how an initially approximated orbit can be progressively refined through dynamic fitting and iterative updates of the Jacobian matrix. As the propagated orbit is adjusted to better fit the GNSS observations, the corrections to the initial state bring the trajectory closer to the true orbit. Consequently, the Jacobian matrix—comprising the state transition and sensitivity components—is evaluated along a trajectory that more accurately reflects the system›s true dynamics. In this region, the system exhibits more linear behavior, resulting in Jacobian elements that are more stable and exhibit reduced variability. This improved conditioning enhances the reliability of subsequent corrections and contributes to the convergence of the orbit determination process.

Monthly Performance Remarks:

1. Satellite Clock and Orbit Accuracy:
    - The performance of Beidou (improved), QZSS (slightly degraded) and GLONASS (slightly degraded) constellations showed a small change. For Galileo and GPS, the overall performances remain the same. However, for Galileo there was a noticeable performance degradation between 12th and 19th May due to testing activities.
    - The satellite clock jump on E11 (discontinuity > 250 ns) is reported for the 2nd of May. No NAGU and health issues are found so far. This event will be analyzed and reported again next month.
    - The URA and satellite clock discontinuity for IRNSS showed some improvement. The URA values are less scattered than previous month.
2. UTC Prediction (GNSS-UTC):
    - All constellations reported relatively stable and consistent UTC predictions.

References

Alonso M, Sanz J, Juan J, Garcia, A, Casado G (2020) Galileo Broadcast Ephemeris and Clock Errors Analysis: 1 January 2017 to 31 July 2020, MDPI

Alonso M (2022) Galileo Broadcast Ephemeris and Clock Errors, and Observed Fault Probabilities for ARAIM, Ph.D Thesis, UPC

Bento, M (2013) Development and Validation of an IMU/GPS/Galileo Integration Navigation System for UAV, PhD Thesis, UniBW.

BIMP (2024 a) https://e-learning.bipm.org/pluginfile.php/6722/mod_label/intro/User_manual_cggtts_analyser.pdf?time=1709905608656

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

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

Bruggemann, Troy & Greer, Duncan & Walker, R.. (2011). GPS fault detection with IMU and aircraft dynamics. IEEE Transactions on Aerospace and Electronic Systems - IEEE TRANS AEROSP ELECTRON SY. 47. 305-316. 10.1109/TAES.2011.5705677.

Cao X, Zhang S, Kuang K, Liu T (2018) The impact of eclipsing GNSS satellites on the precise point positioning, Remote Sensing 10(1):94

Chen, K., Chang, G. & Chen, C (2021) GINav: a MATLAB-based software for the data processing and analysis of a GNSS/IMU integrated navigation system. *GPS Solut* **25**, 108. https://doi.org/10.1007/s10291-021-01144-9

Curran, James T. & Broumendan, Ali. (2017). On the use of Low-Cost IMUs for GNSS Spoofing Detection in Vehicular Applications.

Dhital N (2024) GNSS constellation specific monthly analysis summary, Coordinates, Vol XX, Issue 1, 2, 3, 4

Dhital N (2025) GNSS constellation specific monthly analysis summary, Coordinates, Vol XXI, Issue 1

GINAv (2025). https://geodesy.noaa.gov/gps-toolbox/GINav.shtml

Goercke, L (2017) GNSS-denied navigation of fixed-wing aircraft using low-cost sensors and aerodynamic motion models, PhD Thesis, TUM.

GROOPS (2025) GROOPS Documentation and Cookbook. https://groops-devs.github.io/groops/html/index.html

Guo, Jing & Chen, Guo & Zhao, Qile & Liu, Jingnan & Liu, Xianglin. (2017). Comparison of solar radiation pressure models for BDS IGSO and MEO satellites with emphasis on improving orbit quality. GPS Solutions. 21. 10.1007/s10291-016-0540-2.

Guo F, Zhang X, Wang J (2015) Timing group delay and differential code bias corrections for BeiDou positioning, J Geod,

Hauschlid A, Montenbruck O (2020) Precise real-time navigation of LEO satellites using GNSS broadcast ephemerides, ION

IERS C04 (2024) https://hpiers.obspm.fr/iers/eop/eopc04/eopc04.1962-now

IGS (2019) GNSS Attitude Quaternions Exchange using ORBEX

IGS (2021) RINEX Version 4.00 https://files.igs.org/pub/data/format/rinex_4.00.pdf

InsideGNSS (2024) Working papers: upgrading galileohttps://insidegnss.com/working-papers-upgrading-galileo/

Jiabo G, Xingyu Z, Yan C, Mingyuan Z (2021) Precision Analysis on Reduced-Dynamic Orbit Determination of GRACE-FO Satellite with Ambiguity Resolution, Journal of Geodesy and Geodynamics (http://www.jgg09.com/EN/Y2021/V41/I11/1127)

Kj, Nirmal & Sreejith, A. & Mathew, Joice & Sarpotdar, Mayuresh & Suresh, Ambily & Prakash, Ajin & Safonova, Margarita & Murthy, Jayant. (2016). Noise modeling and analysis of an IMU-based attitude sensor: improvement of performance by filtering and sensor fusion. 99126W. 10.1117/12.2234255.

Li M, Wang Y, Li W (2023) performance evaluation of real-time orbit determination for LUTAN-01B satellite using broadcast earth orientation parameters and multi-GNSS combination, GPS Solutions, Vol 28, article number 52

Li W, Chen G (2023) Evaluation of GPS and BDS-3 broadcast earth rotation parameters: a contribution to the ephemeris rotation error Montenbruck

Liu, Yue & Liu, Fei & Gao, Yang & Zhao, Lin. (2018). Implementation and Analysis of Tightly Coupled Global Navigation Satellite System Precise Point Positioning/Inertial Navigation System (GNSS PPP/IMU) with IMUfficient Satellites for Land Vehicle Navigation. Sensors. 18. 4305. 10.3390/s18124305.

Mayer-Guerr, T., Behzadpour, S., Eicker, A., Ellmer, M., Koch, B., Krauss, S., Pock, C., Rieser, D., Strasser, S., Suesser-Rechberger, B., Zehentner, N., Kvas, A. (2021). GROOPS: A software toolkit for gravity field recovery and GNSS processing. Computers & Geosciences, 104864. https://doi.org/10.1016/j.cageo.2021.104864

Montenbruck O, Steigenberger P, Hauschlid A (2014) Broadcast versus precise ephemerides: a multi-GNSS perspective, GPS Solutions

Liu T, Chen H, Jiang Weiping (2022) Assessing the exchanging satellite attitude quaternions from CNES/CLS and their application in the deep eclipse season, GPS Solutions 26(1)

Montenbruck O, Steigenberger P (2024) The 2024 GPS accuracy improvement initiatives, GPS Solutions

Montenbruck O, Steigenberger P, Hauschlid A (2014) Broadcast versus precise ephemerides: a multi-GNSS perspective, GPS Solutions

Montenbruck O, Hauschlid A (2014 a) Differential Code Bias Estimation using Multi-GNSS Observations and Global Ionosphere Maps, ION

Montenbruck, O., Schmid, R., Mercier, F., Steigenberger, P., Noll, C., Fatkulin, R., Kogure, S. & Ganeshan, A.S. (2015) GNSS satellite geometry and attitude models. Advances in Space Research 56(6), 1015-1029. DOI: 10.1016/j.asr.2015.06.019

Niu, Z.; Li, G.; Guo, F.; Shuai, Q.; Zhu, B (2022) An Algorithm to Assist the Robust Filter for Tightly Coupled RTK/IMU Navigation System. *Remote Sens.* **2022**, *14*, 2449. https://doi.org/10.3390/rs14102449

Schmidt, G, Phillips, R (2010) IMU/GPS Integration Architecture Performance Comparisons. NATO.

Steigenberger P, Montenbruck O, Bradke M, Ramatschi M (2022) Evaluation of earth rotation parameters from modernized GNSS navigation messages, GPS Solutions 26(2)

Strasser S (2022) Reprocessing Multiple GNSS Constellations and a Global Station Network from 1994 to 2020 with the Raw Observation Approach, PhD Thesis, Graz University of Technology

Suvorkin, V., Garcia-Fernandez, M., González-Casado, G., Li, M., & Rovira-Garcia, A. (2024). Assessment of Noise of MEMS IMU Sensors of Different Grades for GNSS/IMU Navigation. *Sensors*, *24*(6), 1953. https://doi.org/10.3390/s24061953

Sylvain L, Banville S, Geng J, Strasser S (2021) Exchanging satellite attitude quaternions for improved GNSS data processing consistency, Vol 68, Issue 6, pages 2441-2452

Tanil, Cagatay & Khanafseh, Samer & Pervan, Boris. (2016). An IMU Monitor agaIMUt GNSS Spoofing Attacks during GBAS and SBAS-assisted Aircraft Landing Approaches. 10.33012/2016.14779.

Walter T, Blanch J, Gunning K (2019) Standards for ARAIM ISM Data Analysis, ION

Wang, C & Jan, S (2025). Performance Analysis of MADOCA-Enhanced Tightly Coupled PPP/IMU. NAVIGATION: Journal of the IMUtitute of Navigation March 2025, 72 (1) navi.678; DOI: https://doi.org/10.33012/navi.678

Wang N, Li Z, Montenbruck O, Tang C (2019) Quality assessment of GPS, Galileo and BeiDou-2/3 satellite broadcast group delays, Advances in Space Research

Wang J, Huang S, Lia C (2014) Time and Frequency Transfer System Using GNSS Receiver, Asia-Pacific Radio Science, Vol 49, Issue 12

https://cggtts-analyser.streamlit.app

Yang N, Xu A, Xu Z, Xu Y, Tang L, Li J, Zhu H (2025) Effect of WHU/GFZ/CODE satellite attitude quaternion products on the GNSS kinematic PPP during the eclipse season, Advances in Space Research, Volume 75, Issue 1,

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

Data sources and Tools:

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

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

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

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

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

Combating Air Pollution in NCT of Delhi: Strategic Pathways

The Delhi Pollution Control Committee (DPCC) on 9th May 2025 invited concept notes from the IITs, professionals and NGOs on combating air pollution in Delhi. The author submitted this paper to the DPCC

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Air pollution is the presence of contaminants or pollutant substances in the air that interfere with human health and welfare and produce harmful effects, including premature and pre-natal deaths. Urban air pollution is estimated to cost approximately 1% of GDP (source: Lancet Commission on pollution and health, 2019). The Supreme Court of India in its order dated 21st March 2024 stated that "Without a clean environment which is stable and unimpacted by the vagaries of climate change, the right to life is not fully realised. The right to health (which is a part of the right to life under Article 21) is impacted due to factors such as air pollution, shifts in vector-borne diseases, rising temperatures, droughts, shortages in food supplies due to crop failure, storms, and flooding...". As such, right to health and clean air is the right to life under the Constitution.

As per the Central Pollution Control Board, most of the top polluted cities are in North India, with Delhi at 14th rank, having severe levels of $PM_{2.5}$ and PM_{10} (Table. 1).

According to Environment Pollution Control Authority (EPCA), the severity of air pollution is categorised as moderate, poor, very poor, severe, severe+ or emergency, which is based on the levels of $PM_{2.5}$ and PM_{10} in the air. (Table 2):

Table 1: Most Polluted Cities in India

Rank	City	AQI	Condition	State
1	Jind	448	Severe	Haryana
2	Baghpat	440	Severe	Uttar Pradesh
3	Ghaziabad	440	Severe	Uttar Pradesh
4	Hapur	436	Severe	Uttar Pradesh
5	Lucknow	435	Severe	Uttar Pradesh
6	Moradabad	434	Severe	Uttar Pradesh
7	Noida	430	Severe	Uttar Pradesh
8	Greater Noida	428	Severe	Uttar Pradesh
9	Kanpur	427	Severe	Uttar Pradesh
10	Sirsa	426	Severe	Haryana
14	Delhi	407	Severe	Delhi

As on 4th Nov. 2018 during 24 Hours (4pm-4pm)
Source: CPCB, 2018

Table 2: Severity Measure of Air Quality

Moderate	When $PM_{2.5}$ is between 60-90 µg/m^3 or PM_{10} is between 10-250 µg/m^3
Poor	When $PM_{2.5}$ is between 91-120 µg/m^3 or PM_{10} is between 251-350 µg/m^3
Very Poor	When $PM_{2.5}$ is between 121-250 µg/m^3 or PM_{10} is between 351-430 µg/m^3
Severe	When $PM_{2.5}$ level is above 250 or PM_{10} is level above 430 µg/m^3
Severe+ or Emergency	When $PM_{2.5}$ levels cross 300 µg/m^3 or PM_{10} levels cross 500 µg/m^3 (five times above the standard and persists for 48 hours or more)

Source: EPCA (2018)

Sources of Air Pollution

Air-pollution is a multi-headed problem which emanates from various sources (Table 3). The major components of air quality have been shown in Fig. 1.

The major sources of air pollution are urban transport, dust from construction and demolition activity, the use of 'dirty' fuels such as diesel, use of coal for industries and electricity generation, use of wood and coal for cooking, industrial pollution, ozone depleting air-conditioners and burning of agriculture and urban wastes. While primary particles like SO_2 and NO_2 are directly released into the atmosphere are from sources, such as industries and vehicles and secondary particles, such as sulphates, nitrates and organic aerosols are formed from these primary particles through reaction by solar radiation, relative humidity and presence of metals.

Table 3: Sources of Air Pollution

Source Category	Types of Sources
Area Sources	Domestic cooking Bakeries Crematoria Hotels and Restaurants Open eat outs Open burning (refuse/biomass/tyre etc. burning) Paved and unpaved roads Construction/Demolition/Alteration activities for buildings, Roads, flyovers Waste Incinerators DG Sets
Point Sources	Large scale industries and Power plants Medium scale industries Small scale industries (36 industrial estates)
Line Sources	2 Wheelers (Scooters, Motorcycles, Mopeds) 3 Wheelers (CNG) 4 Wheelers (Gasoline, Diesel, CNG) LCVs (Light Commercial Vehicles) Trucks (Trucks, min-trucks, multi-axle trucks) Buses (Diesel, CNG)

Source: **Jain A.K. (2019) Spatial Planning for Clean Air, ITPI Journal, July-September**

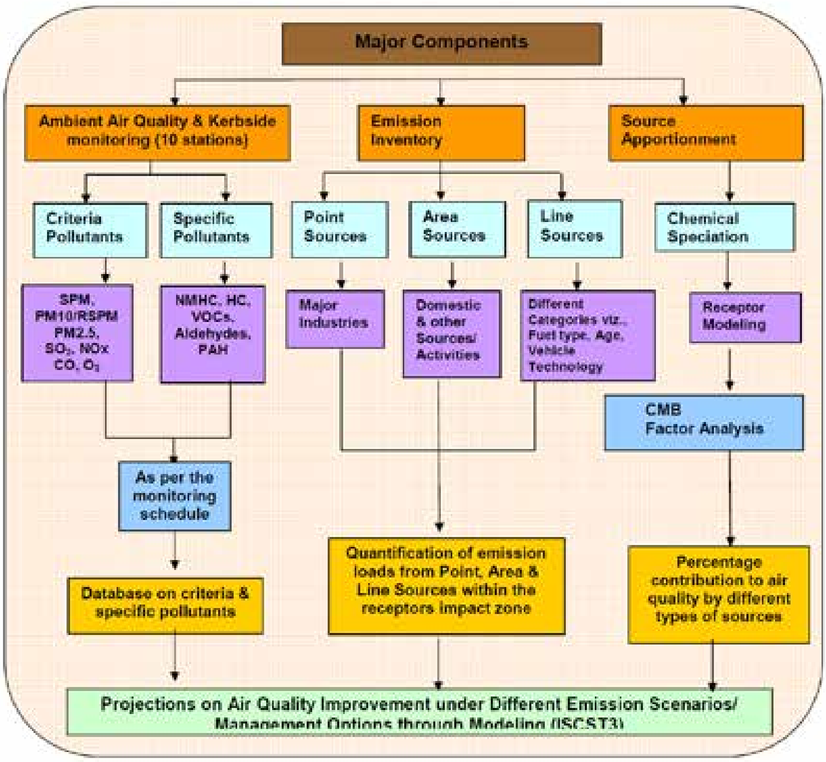

Fig. 1: Major Components of Air Quality
Source: NEERI

The mean values for zinc, copper, molybdenum and chromium reported in East Delhi ranged, respectively from 119.9 to 1364.5 microgram per cubic metre, 112.8 to 1614.5 mg per cubic mt., 40.6 to 376.3 mg pcm and 68 .7 to 244.4 mg per cubic metre (CPCB, 2024). The ambient air quality criteria (aaqc) for zinc is 120 microgram per cubic metre, for copper 50 and for molybdenum 120 and for chromium 0.5 microgram per cubic metre.

A consequence of rapid motorization in India, especially in large cities like Delhi, is visible by air pollution. Environmental footprints of urban transport include the number of resources (including embedded energy) used in their production, amount of waste produced by their disposal, and continued use of fossil fuels. In Delhi 72 per cent of emissions (suspended particulate matter) are from motorized vehicles. Of these, the private vehicles, which are 90 per cent of total motorized transport, carry 31 per cent of vehicular trips are responsible for 90 per cent of emissions. Violent traffic and transport impact the health and safety of the people.

Air Quality Monitoring and Inventory

Air quality data is significant to gaining a thorough understanding of local air pollution. Recent technological advancements have made it possible to gather data, with new low-cost monitoring devices and advanced methods of collating and analysing it. This helps to gain a robust understanding of pollution levels, their causes and effect.

Now-a-days smart electricity poles with sensors are available to monitor pollution parameters along with light, CCTV, wi-fi, etc. The New Delhi Municipal Council (NDMC) has been using them in New Delhi. Citywide air quality monitoring networks and data from these can provide consumers with a continuous feed of air quality in their area (Fig. 2).

The Google plans to map street by street air pollution that will be available to the common man. The active sensors will measure CO_2, CO, NO_x, NO_2, ozone and particulate matter.

Continuous Emission Monitoring (CEM) and Air quality Data can be used to identify major components, sources, quantification and projects. It can also help the government to apply monetary incentives and penalties for polluting companies. Delhi Pollution Control Committee (DPCC) can provide tax benefits and ease other regulations on emission-efficient industries while penalizing inefficient ones. It can also use this data to introduce a cap-and-trade system, instead of the existing 'command-and-control' regulations. The data can be used to analyse the issues, sources and project various options and actively schedule to assign the responsibilities, project management, including timelines and monitoring.

Regulating the air pollution from different stakeholders is difficult because its impact is geographically dispersed, often across the States and jurisdictional lines.

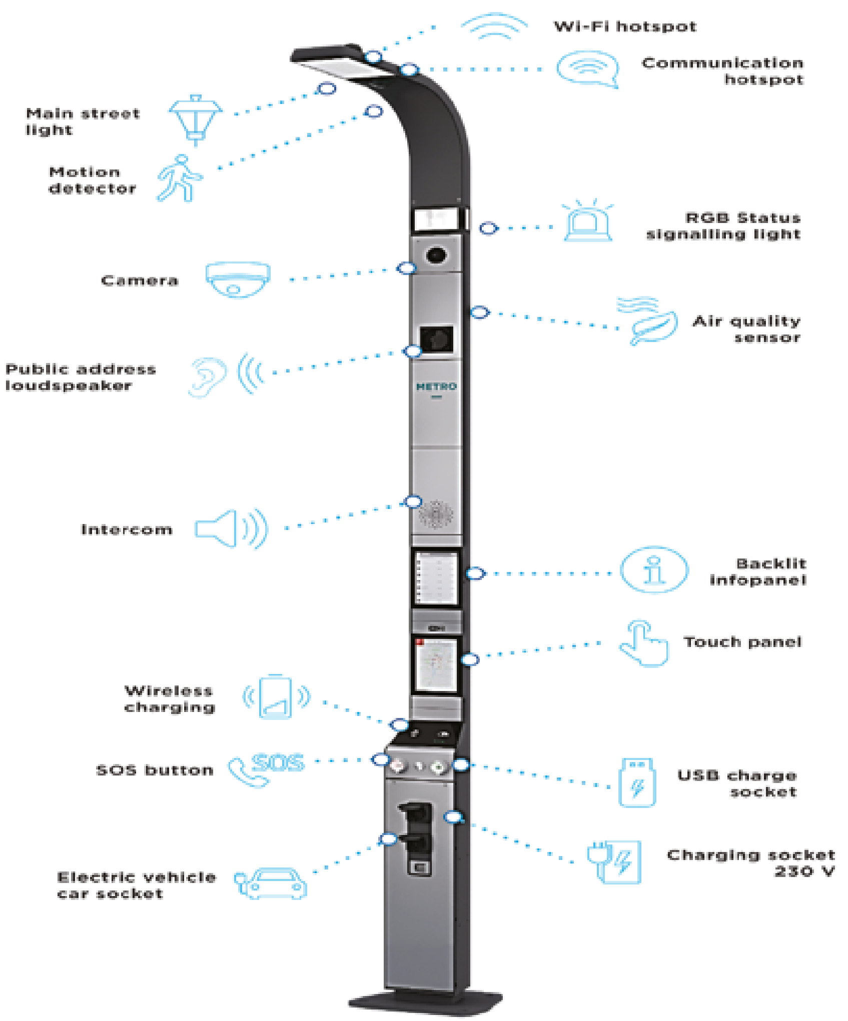

Fig. 2: Intelligent Smart Pole
Source: http://www.elkoep.com/smartpole

For instance, around half of Delhi's air pollution during the months of October and November is attributed to the burning of agricultural waste in neighbouring states. This means that apart from localized solutions to the air pollution, the Delhi Government must also coordinate with the governments of Punjab, Haryana, Uttar Pradesh and Uttarakhand to control this external source of pollution.

National Clean Air Programme (NCAP)

The National Clean Air Program (NCAP) and Graded Response Action Plan (GRAP) have led to the preparation of comprehensive, data based and timely measures for prevention and mitigation of air pollution.

Under the National Air Quality Monitoring Programme (NAMP) four air pollutants *viz.* Sulphur Dioxide ($S0_2$), Oxides of Nitrogen ($N0_{2/}NO_x$), Suspended Particulate Matter (PM_{10}) and Fine Particulate Matter ($PM_{2.5}$) have been identified for regular monitoring at all the locations. In addition, real-time Continuous Ambient Air Quality Monitoring Stations (CAAQMS) monitor 8 pollutants viz. PM_{10}, $PM_{2.5}$, $S0_2$, NOx, ammonia (NH_3), CO, ozone (0_3) and benzene.

National Ambient Air Quality Standards (NAAQS) define the ambient air quality with reference to various pollutants notified by the Central Pollution Control Board under the Air (Prevention and Control of Pollution) Act, 1981. Major objectives of NAAQS are (i) to indicate necessary air quality levels and appropriate margins required to ensure the protection of vegetation, health and property, (ii) to provide a uniform yardstick for assessment of air quality at the national level, and (iii) to indicate the extent and need of monitoring programme. National Air Quality Index (AQI) comprises six categories, namely Good, Satisfactory, moderately polluted, Poor, Very Poor, and Severe. Each of these categories is decided based on ambient concentration values of air pollutants and their likely health impacts. For eight pollutants (PM_{10}, $PM_{2.5}$, $N0_2$, $S0_2$, CO, 0_3, NH_3 and Pb) National Ambient Air Quality Standards have been prescribed.

Vehicles have been identified as major source of pollution. In this regard Bharat Stage IV (BS-IV) norms has been launched for mandatory implementation since 1sl April 2017 and BS-VI since 1st April 2020. Other measures include use of cleaner/ alternative gaseous fuels, like CNG, LPG and ethanol blending in petrol in order to reduce vehicle exhaust emissions, promotion of public transport, Pollution Under Control Certificate, lane discipline, vehicle maintenance, etc. It is estimated that a 5% blending can save around 1.8 million barrels of crude oil.

The renewable ethanol content, which is a by-product of the sugar industry, is expected to result in a net reduction in the emission of carbon dioxide, carbon monoxide (CO) and hydrocarbons (HC). Ethanol itself burns cleaner and burns more completely than petrol it is blended into. In India, ethanol is mainly derived by sugarcane molasses, which is a by-product in the conversion of sugar cane juice to sugar.

Graded Response Action Plan (GRAP)

The Graded Response Action Plan for Delhi and NCR identifies the key pollution sources i.e. vehicles, road dust, biomass burning, construction, power plants and industries. The episodic pollution emanates from stubble biomass burning, solid waste burning, firecrackers, etc. The Graded Response Action Plan includes appropriate measures for each source of pollution. The measures are graded from public health emergency level to Very Poor, Poor and Moderate AQI. The CPCB and NEERI have developed a matrix of Area Source, Control Options and Targets (Table 4).

Clean Air and Sustainable Development Goals

In order to arrest air pollution, the following agenda of sustainable development goals (2030) can be adapted:

i. Double the rate of improvement of energy efficiency and renewable energy.
ii. Prohibit thermal power stations for energy production.
iii. Halve the number of deaths per 100,000 persons caused by air pollution
iv. Halve the number of health complications per 100,000 caused by air pollution

Table 4: Area Source Control Options and Alternative Targets

Control Option	Type of industries	Recent Scenario (2012)	Targets for Next 5 Years
Domestic	Use of cleaner fuels viz. LPG, PNG	50% solid fuel, kerosene for domestic use to be shifted to LPG/PNG	100% solid fuel, kerosene for domestic use to be shifted to LPG/PNG
Hotels, Restaurants Bakeries	Use of cleaner fuels viz. LPG/PNG	100% to be shifted to LPG/PNG	100% to be shifted to LPG/PNG
Crematoria	Use of cleaner fuels viz. electricity	50% to be operated on electricity	100% to be operated on electricity
Incinerators	Installation of control equipment viz. wet scrubber	100% to be installed	100% to be installed
Generator sets	Adequate supply of grid power	Use of generator sets till adequate grid power available	No use of generator sets
Open burning	Strict compliance with ban on open burning	100% compliance	100% compilance
Locomotives	Use of cleaner fuels viz. electricity	100% to be operated on electricity	100% to be operated on electricity
Construction	Better construction practices viz proper loading and unloading of materials, water spraying, etc.	50% reduction from construction activities	100% reduction in construction activities under BAU 2017

Sources: Compiled from CPCB and NEERI

Based on the identification of major sources of air pollution and analysis of ambient air quality, various scenarios of emission control from point sources and area sources need to be worked out.

Urban Planning for Clean Air

According to the Intergovernmental Panel on Climate Change, urban areas account for more than half of global primary energy use and energy related CO_2 emissions. They account for 67 to 76% of global energy use and similar amount of CO_2 emissions. Infrastructure and urban form are interlinked and shape the land use, transport choice, housing and affect the sustainability and efficiency of city. This needs adopting a low carbon (thus low emission) urban form and structure.

The critical aspects of low carbon urban form for clean air comprise the following:

- Density/ FAR optimisation and linked with mixed land use
- Connectivity, walkability and transport
- Accessibility for all
- Zero polluting Industries and renewable power
- Phasing out fossil fuels
- Dust control
- Green and net zero buildings
- Landscape as sink of air pollution and urban heat

Density/FAR Optimisation and Mixed-use

Compact, high-density, mixed-use development near public transportation infrastructure provides housing, employment, entertainment and civic functions within walking distance of the transit system. Pedestrian-oriented design encourages people and workers to use their cars less and ride public transit more. It aims to:

- Reduce/discourage private vehicle dependency and induce public transport use – through policy measures, design interventions and enforcement.
- Provide public transit access to the maximum number of

people through densification and enhanced connectivity.

City-level integrated plans for reducing need to travel involves maximizing densities in order to facilitate maximum number of people walking or cycling or use NMT or feeder services to access public transit facility. Higher the density, lower is the per kilometre infrastructure cost. A balanced mix of jobs and housing along mass transit corridors coupled with caps on parking supply, higher housing affordability through design and technology options, improved efficiency and equity are necessary for pollution control.

It is being increasingly realized that the structural solutions, like flyovers built at enormous cost, provide only a temporary relief and fail to keep pace with the growth of traffic. For a synergy between land use and public transport system, it is necessary to restructure the city by Transit Oriented Development, higher density, FAR and mixed land use for a compact and smart growth.

Connectivity, Walkability and Transport: Prime Minister Narendra Modi while inaugurating the Global Mobility Summit in September 2018, encapsulated 7 Cs of mobility- common, connected, convenient, congestion-free, charged, clean and cutting-edge. He underlined the need to use clean energy for transport as a powerful weapon against climate change. This means a pollution-free clean drive leading to clean air and better living standards. He championed the idea of clean kilometres which could be achieved through bio-fuel, electric or solar charging and electric vehicles (PIB 2018).

Studies show that road transportation needs 4 to 5 times the energy that is needed by a train. The energy used by a car to carry a passenger over one kilometre is 3 to 4 times that of a bus. Greenhouse gas emission per passenger of public transport (bus, rail and trams) is about one-twelfth that of a car. Although Non-Motorised Transport (NMT) including walking is ideal from the point of view of emissions, in terms of kilometres travelled, these cover only 1 to 2 per cent of the total kilometres travelled, even if the proportion of trips are as high as 40%. It implies that rail based public transport, bus, cycle and walking provide a greener transportation by reduction in use of fossil fuels and air pollution. A compact and smart city with mixed land use, cleaner, fast and low energy public transport provides sustainable mobility. In terms of capacity, costs and emissions, walking is most competitive, economical, and environmentally sustainable mode of mobility.

The installation of engine optimization and exhaust gas recirculation technologies and promoting rail and waterways for public transport and freight can reduce black carbon emissions by 90%. Some other critical areas to reduce emission from transport include:

- Adopt the concept of 15-minute city, as Paris has done.
- Development and spread of public transport with single ticket facility for various modes
- To increase the use of electric cars, e-rickshaws, and e-buses
- Building express cycle tracks along major roads, parks, drains, canals and railway/metro corridors
- Walk to work concept for integrated development of work centres/local areas/zones
- Initiating a consumer campaign for car-pooling, bus pooling and ridesharing
- Building support for tighter controls on vehicular emissions and stricter compliance with PUC norms.
- Providing N-99 pollution masks to traffic policemen, rag pickers, street vendors, sanitary workers, construction workers, students, etc.

Accessibility for All

Informal and intermediate modes of transport, which include 3 wheelers, vans, pickups, rickshaws, manual thelas and rehri, etc. cater to about 30 to 60% of passengers and goods movement in the cities like Delhi. As compared to small truck, the autos and rickshaws are substantially cheaper, which by multiple trips deliver as much as a 5-ton truck in a day. Courier services, perishables, such as milk, vegetables, fruits, groceries and other short-haul deliveries are increasingly being made by auto-rickshaw, van or tricycle, These reach in the narrow lanes and congested areas where public authorities do not allow trucks/public carriers during day time and also during frequent VVIP visits, processions, ceremonies, etc.

The urban form plays an important role in the safe urban mobility by accommodating all modes to travel, including walking, wheelchair, cycling, public transit and people by a safe, efficient and attractive road network, with generous footpaths and trees.

Safe and accessible cities are compact, walkable and sustainable, which provide comfortable, safe, affordable, reliable and non-polluting public travel modes. Most of the local facilities are reachable by a convenient 5-minute (400 to 500 meter) walking, with dedicated paths for walking and cycling. Neighbourhood facilities, shops, schools, parks, clubs and city centres are located along the pedestrian, cycle and public transport corridors.

The strategy for non-polluting and safe mobility covers the following:

- Reduce need to travel by Transit Oriented Development and Travel Demand Management, last mile connectivity and 15 minutes city concept
- Improvement of public transport, sidewalks, cycle tracks, NMVs underpasses and overpasses
- Safety oriented planning and engineering specifications, norms and practice
- Upgrading of traffic control - multi-functional and sophisticated signal control and ITS
- Drivers' license regime
- Work Zone Safety
- Intelligent Transport Systems (ITS), car, bus, truck pooling.

It is necessary to provide barrier free, wide and safer pedestrian corridors at grade which cater to wheelchair users. Public transport has to be disabled and wheelchair friendly with tactile flooring, low floor buses with footboard at level with the platform and proper lighting for the safety and security of pedestrians. A dedicated bicycle lane has to be built along every road. The signage, maps, variable message signs, pedestrian crossings, integrated fare collection systems, protection systems and communication are important elements of safe mobility.

The traffic calming involves reducing speeds, noise and volumes by various measures such as no horn zoning, traffic circles at intersections, raised crosswalks, and partial street closures to discourage short-cut traffic through residential neighbourhoods. Traffic calming is necessary in residential zones, and also in the areas fronting university, college, schools, hospitals, etc. Traffic calming/ noise control measures involve notifying No Horn Zones, constitution of area-wise noise control circles, preparation of Noise Monitoring and Control Plan (NMCP), hybrid electric vehicles, speed breaker/hump, landscape and noise buffers and rubberised road surface.

Zero Polluting Industries and Renewable Power

Industries and power have a crucial role in combating air pollution. These industries need to shrink their environmental footprint by following measures:

- Strengthening of enforcement and emissions monitoring
- Scaling up of Emissions Trading Schemes.
- The development and installation of emissions free technologies, especially in the power and brick-making industries.
- Installing continuous emissions monitoring technology (CEMS) at manufacturing locations and placing more accountability on industrial polluters
- Introduction of gaseous fuels and enforcement of stringent $SO_2/NO_x/PM_{2.5}$ standards for industries using solid fuels.
- Elimination of DG set usage by provision of 24x7 electricity and by innovative tail pipe control technologies.
- Use of agricultural stubble/residue in power plants and industries to replace high ash coal and open burning in fields.

Innovations at local level are important. Chakr Innovations Pvt. Ltd. proposed a technology that coupled with exhaust pipe of diesel engines absorbs PM emissions and converts the captured particulate matter into black ink and paints. In this project, the goal was to test the effectiveness of Chakr's device in reducing PM emissions and assess if this technology is a cost-effective way of reducing diesel genset pollution.

Another project, Charvesting, deploys charvesters that recycle rice straws into biochar with clean emissions using the biochar reactors. It helps farmers to comply with existing air pollution laws at minimal cost and effort, increase soil productivity and restore depleted land.

Phasing Out Fossil Fuels

Air pollution is caused by burning of fossil fuels, especially for cooking, wastes, etc. This can be mitigated by following measures:

- Strengthening and Incentivising Electric Vehicles
- Boosting of PNG Supply Network and clean-cooking stoves that use PNG/ LPG or solar energy.
- The implementation of gasification technologies to help convert waste into biomass pellets or electricity.
- Green hydrogen as a substitute for fossil fuels.

Dust Control

Dust is a major contributor to urban air pollution. It is necessary to adopt wall to wall paving of roads, green cover, trees and shrubs and the vacuum sweeping of roads. Dust particles can be controlled by screens, filters, flagging machines, vacuum cleaning, humidification, sprinkling of water and artificial rain.

Green and Net-Zero Buildings

The polluting agents found indoors are chemicals such as cleaning products, volatile organic compounds, dust, infectious agents, fragrances, cooking fumes, smoke, etc. Mold spores and various other particulate matters and toxic gases are the biggest pollutant found in the air. A humidity level of 65% or more, along with a temperature ranging between 10^0 and 32^0 C make a suitable environment for the mould spores to grow indoors. Mold growth can be prevented by increasing natural ventilation, covering cold surfaces like water pipes with insulation, and increasing the air temperature and keeping all hard surfaces clean by washing or wiping with detergent or other disinfectants.

Proliferation of low-carbon, net zero and green building technologies that produce as much energy as a building consumes, can help in controlling the air pollution, wider use of green rating, such as GRIHA, can help reducing the building's energy consumption and emissions. Passive design of buildings can reduce the need of air conditioning. For a comprehensive approach, it is necessary to prepare energy efficiency and low carbon neighbourhood plans.

Green Roof Mahila Housing SEWA Trust, in collaboration with the Energy Research Institute (TERI) and Energy Policy Institute at the University of Chicago, (India unit) has deployed cool roofing solution in a Delhi slum which attempts to lower indoor temperatures and energy consumption for cooling.

Landscape as Sink of Air Pollution and Urban Heat

Bio-morphic and green ecosystems that mandates coexistence of nature, greenery and water bodies can make a difference between life and death in the present air crisis scenario. The plants remove toxic pollutants from environment by the process of phytovolatilization (pollutant is released in volatile or gaseous form), phytoextraction (pollutant is accumulated in harvestable parts tissue like leaf surface), phytodegradation (pollutant is broken down into simpler molecular form), Phyto stimulation (organic pollutants from soil are broken down ensuring oxygen to the rooms) and Phyto-stabilization (pollutant is immobilized in soil).

It is often said that there is no more space for plantation and forestry in

Table 5: Technology, Citizen Engagement and Policy Matrix for Clean Air

	Manufacturing and Industry	Energy	Urban Mobility	Environmental Data	Building Construction	Farming
Technology	• Installing continuous emissions monitoring technology (CEMS) at manufacturing locations, placing more accountability on industrial polluters • -Development of low-emission commercial and industrial vehicles processes and logistics • Optimise industrial infrastructure and promote industrial restructuring • Accelerate technological innovations	• Emission and fossil free technology • Trigeneration • Renewable Energy/ PM Suryaghar Yojana (Rooftop Solar Systems) • Zero Net Energy Building • Use of Gaseous Fuels • Elimination of D.G. Sets • Smart Meters • Micro Grids • Battery swapping • Energy efficiency • Decentralised solar system	• Make Delhi a 15 minute city by mixed use and public transport • Development of low-emission public transport • Increase the use of electric cars/e-rickshaws • NMTs, pedestrians • Transport Demand Management • Transit Oriented Development • Delhi Electric Vehicle Interconnector (Delhi public bus scheme) • Faster Adoption and Manufacture of Electric Vehicles (FAME)	• Installing citywide air quality monitoring networks. • Communicating air quality data through mobile Apps	• Net zero/ Green building • Cool roof • Heat Mitigation Plan • Water Spray to off-set heat and dust • Passive design, Natural ventilation, • Swales, green strips, trees and Indoor plants • Green Rating • Dust Control • Air Filter	• Use of agriculture residue for power generation • Conversion of Agri-waste material into bio-char • Satellite surveillance • Gasification technology to convert bio-waste into pellets/ electricity • GIS/PVT System/ • Greenhouse Farming • PM Kusum Scheme (Solarisation) • Carbon Capture Technologies • Wind Power • Energy Storage • Biofuel stoves/ PNG, smokeless chullah
Citizen Engagement	• Applying public pressure on polluting industries • Promote citizen engagement in industrial environment management • Disclosure of air pollution data	• Renewal energy • Campaigns against Firecrackers, noise, insanitation, waste-burning, etc. • Facilitates reduced energy consumption	• Providing N-99 pollution masks and safety to traffic policemen, municipal workers, etc. • Initiating a public campaign for car pooling and ridesharing	• Vayu Apps • EIA • Early warning system • 5 Rs of Waste Management	• Green building movement • Incentives for GRIHA rating • Promote citizen participation	• Incentives and infrastructure for recycling agriculture residue
Policy	• A cap-and-trade emissions scheme for industries • Ensuring compliance of industrial emissions with the standards • Enforcement, Common Digital Platform • Institutional and legal review • Strengthen environment threshold and industrial layout • Clarify responsibilities of government, enterprises and civil society	• Emission Tracking Systems • Install clean energy production and supply	• Building support for tighter controls on vehicular emissions • Increased use of electric vehicles	• Actionable use of environmental data. • Implementation of Graded Response Action Plan and National Clean Air Program (NCAP)	• Facilitating the use of green rating for building's	• Schemes for management of agricultural waste and waste to energy • Blockchain Technology • Smart Digital Processes

Source: Author with inputs from Assn. for Settlement and Housing Activities (ASHA) and clean air 91.

Delhi. However, large greens can be created along the river Yamuna (1600 Ha), along the drains and canals, along Ring Railway Corridor, Metro and Rail Networks, defunct thermal power stations, adjacent to monuments in Mehrauli, Tughlakabad, IARI Pusa, Roshnara Park, Quadsia Park, etc. It is also time to design and develop vertical greens integral to multi-storied buildings.

It is well known that with climate change, Delhi is heating up, leading to increased use of energy for air conditioning/ cooling. The GNCTD has recently prepared a Heat Mitigation Plan, which needs to be implemented urgently. An important aspect of heat mitigation is improving air quality and pollution. As such, it is necessary to sustain existing trees and increase number of healthy trees, which reduce pollution levels. Evergreen trees with smaller, rough and variegated leaves are more efficient in trapping air pollutants than longer and smooth leaves.

Strategic Pathways Towards Clean Air

Strategic pathways involve a synergy of Technology, Citizen Engagement and Policy Matrix that addresses critical factors of air quality (industry, energy, urban mobility, environmental data, building and construction and farming). Table 5 provides a strategic pathway for clean air in Delhi. It starts with digital, real-time documentation of various sources of air pollution for the preparation of air pollution control plans. It underlines low carbon, low-emission alternatives such as, zero net energy buildings, blockchain technology and smart utilities involve Big Data Analytics, Supervising Control Data Acquisition Systems (SCADA), ERP solutions, GIS Integrated Control and Command Centres and Satellite Surveillance. The strategic pathways incorporate timelines, responsible department/ agency and monitoring mechanism. The public participation and behaviour change are its pillars. It involves close coordination among various departments, States, local and parastatal agencies.

In this regard, The PRAGATI (Pro-Active Governance and Timely Implementation) Platform being adopted for major infrastructure projects, and Whole of Government Platform being adopted for PM Gati Shakti Master Plan can enable easier collaboration for seamless implementation and citizen engagement.

References

Central Pollution Control Board (2018-2025) Reports on Air Pollution in India, New Delhi.

Delhi Pollution Control Committee (2018–2025) Real Time Ambient Air Quality Data of Delhi, India: http://www.dpccairdata.com/dpccairdata/display/index.php.

Environmental Pollution Control Authority (EPCA) (2018) Report Card on Delhi's Air Pollution, New Delhi

IPCC (2021) Climate Change Working Group, Impacts Adaptation and Vulnerability, IPCC, Cambridge University Press, UK and New York.

IPCC (2014) Climate Change Working Group, 6th Assessment Report, Cambridge University Press, UK and New York

Jain A.K. (2021) Environment, Urbanisation and Development, Discovery Publishing House, New Delhi

Jain A.K. (2019) Spatial Planning for Clean Air, ITPI Journal, New Delhi

Lancet Commission on Pollution and Health (2019) The Lancet Planetary Health, Vol. 3

World Health Organisation, (2018) WHO Global Ambient Air Quality Database, Geneva.

Thales invests €55M to boost next-gen resilient navigation in France

Thales has announced a major €55 million investment to strengthen its industrial sites in Châtellerault and Valence, France. This investment, which will be made between 2025 and 2028, will meet the growing demand for high-performance navigation solutions, both civilian and military.

In a context of increasing jamming and spoofing of GNSS signals, Thales is deploying a complete range of resilient navigation solutions that combine precision, autonomy, and security. These technologies are essential to ensure operational continuity, whether for critical military missions or civil aviation safety.

By integrating two technological pillars combining inertial systems and GNSS signal reception, Thales enables reliable navigation even in contested environments. Autonomous navigation capability is maintained at all times due to the high performance of the TopAxyz inertial navigation systems. Signal reception integrity is ensured by combining the encrypted, multi-constellation TopStar-M receiver with the TopShield anti-jamming solution. These innovations are supported by France's Directorate General of Armaments (DGA) under the OMEGA (Operation for the Modernization of GNSS Equipment of the Armed Forces) programme. The performance and unique combination of these solutions make Thales the European leader in resilient navigation.

At Châtellerault, the production capacity of inertial navigation systems will be increased fourfold, with a gradual ramp-up through 2028. In Valence, mass production of TopStar-M receivers and TopShield systems will begin in 2026.

Satellite-based toll collection may take few more years: NHAI

Officials from the National Highways Authority of India (NHAI) have said that the Global Navigation Satellite System (GNSS)-based electronic toll collection system will not be implemented anytime soon.

The officials, who were part of a pilot study in this regard, said that absence of On-Board Units (OBU) in many vehicles and privacy concerns regarding their exact location being shared are some of the reasons for this decision. It may take a few years for the launch of the satellite-based toll collection system.

An NHAI official said they selected Bengaluru-Mysuru access-controlled highway and Panipat-Hisar highway in Haryana last year for the pilot study along with the FASTag facility. Based on the distance travelled, the toll will be deducted/collected. A stretch of Bengaluru-Mysuru highway was selected and geo-fenced for the study. A report was submitted to NHAI officials after conducting the study last year," the official said. He said the project could not be implemented anytime soon because only a few vehicles have OBUs.

13 member states call for EU response to GNSS interference

13 EU member states, including Latvia, have called on the European Commission to respond to interference with Global Navigation Satellite Systems (GNSS) in EU countries.

The ministers for transport and digital affairs from 13 countries have sent a joint letter to the European Commission, urging immediate and coordinated action in response to interference with GNSS originating from Russia and Belarus. Following Lithuania's initiative, the letter also highlights the urgent need to accelerate the deployment of interference-resistant GNSS services, enhance the overall resilience of critical infrastructure, and strengthen safety and security across Europe.

In the letter addressed to the High Representative for Foreign Affairs and Security Policy and Vice-President of the European Commission, Kaja Kallas; Commissioner for Defense and Space, Andrius Kubilius; Commissioner for Sustainable Transport and Tourism, Apostolos Tzitzikostas and other members of the European Commission, the ministers emphasize that since 2022, two types of interference to GNSS - jamming and spoofing - have been observed in the airspace of the Baltic Sea Region, posing a threat to various modes of transport, particularly civil aviation and maritime navigation.

The joint letter signed by the ministers of Lithuania, Latvia, Estonia, Germany, Slovakia, Finland, Slovenia, the Czech Republic, Italy, the Netherlands, Spain, Denmark, and Romania, also states that that GNSS interference cases are not random incidents but a systematic, deliberate action by Russia and Belarus, which can be used as a hybrid attack on strategic radio spectrum, essential for modern technology, regional safety, and security, particularly in transport.

Furthermore, the ministers call on the EU to increase diplomatic efforts to address the interference and apply pressure on the responsible parties, including legal action against responsible individuals and entities involved in the deliberate interference with GNSS signals, to enhance European safety and security.

Among other immediate actions, the ministers propose to intensify radio frequency monitoring and enhance civil-military coordination mechanisms among Member States for shared monitoring, data exchange, and possible response to GNSS interference. They also advocate for accelerating the deployment of interference-resistant GNSS services, particularly the anti-spoofing features of the Galileo program, and for upgrading and modernizing conventional navigation infrastructure.

In late February, Lithuanian presidential national security advisor Marius Cesnulevicius said that GPS interference had to do with Russia's step taken to defend itself from Ukraine's retaliatory strikes on Russian territory, adding that Lithuania was not a specific target. *www.baltictimes.com*

IATA and EASA release joint strategy to counter GNSS interference risks

The International Air Transport Association (IATA) and the European Union Aviation Safety Agency (EASA) have published a comprehensive plan to mitigate risks stemming from GNSS interference. The plan was part of the conclusions from a jointly hosted workshop on the topic of GNSS interference.

With incidents of GNSS signal jamming and spoofing rising, especially in Eastern Europe and the Middle East, the workshop called for a broader, more coordinated response. The plan focuses on four areas: improving information gathering, strengthening prevention and mitigation, making better use of infrastructure and airspace management, and enhancing coordination among agencies.

According to IATA, the number of GPS signal loss events increased by 220% between 2021 and 2024. "With continued geopolitical tensions, it is difficult to see this trend reversing in the near term," said Nick Careen, IATA senior vice president for operations, safety, and security. "The next step is for ICAO to move these solutions forward with global alignment on standards, guidance, and reporting. This must command a high priority at the ICAO Assembly later this year."

Detailed Workshop Outcomes

The workshop concluded that four workstreams are critical:

1. Enhanced Reporting and Monitoring
   - Agree on standard radio calls for reporting GNSS interference and standardized notice to airmen (NOTAM) coding, i.e. Q codes.
   - Define and implement monitoring and warning procedures, including real-time airspace monitoring.
   - Ensure dissemination of information without delays to relevant parties for formal reporting.
2. Prevention and Mitigation
   - Tighten controls (including export and licensing restrictions)

on jamming devices.

- Support the development of technical solutions to:
  - reduce false terrain warnings;
  - improve situational interference with portable spoofing detectors; and
  - ensure rapid and reliable GPS equipment recovery after signal loss or interference.

3. Infrastructure and Airspace Management
   - Maintain a backup for GNSS with aminimum operational network of traditional navigation aids.
   - Better utilize military air traffic management (ATM) capabilities,including tactical air navigation networks and real-time airspace GNSS incident monitoring.
   - Enhance procedures for airspace contingency and reversion planning so that aircraft can navigate safely even in the event of interference.
4. Coordination and Preparedness
   - Improve civil-military coordination, including the sharing of GNSS radio frequency interference (RFI) event data.
   - Prepare for evolving threat capabilities, including those related to drones.

The workshop was held May 22-23 at EASA headquarters in Cologne, Germany. *www.iata.org*

DHS S&T releases tool to strengthen GNSS for critical infrastructure

The Department of Homeland Security (DHS) Science and Technology Directorate (S&T) launched an important new resource on GitHub to help safeguard critical infrastructure: the Global Navigation Satellite System (GNSS) Test Vector Suite and Distribution Methodology. This effort supports Executive Order 13905, which aims to protect essential Positioning, Navigation and Timing (PNT) systems used in industries like energy, transportation and telecommunications.

PNT systems rely on accurate GNSS signals to function properly. If these signals are disrupted – whether by natural events, technical failures, or cyber threats – critical services could be impacted. To address this risk, the GNSS Test Vector Suite and Distribution Methodology provides critical infrastructure owners and operators the tools to independently identify and define appropriate test scenarios that support standards conformity assessments, to help evaluate and improve the resilience of their systems.

The GNSS Test Vector Suite includes a standardized set of test scenarios and tools that allow developers and testers to assess how well their equipment can handle challenges like signal interference or spoofing attempts. The process works as follows:

1. The GNSS Test Vector Suite generates simulated data
2. The data is converted into signals that mimic real-world GNSS systems
3. These signals are fed into designated GNSS devices or other PNT equipment, enabling users to evaluate how their systems respond to simulated disruptions

By offering this testing capability, S&T is helping critical infrastructure operators identify vulnerabilities in PNT systems and ensure they meet established resilience standards. This is a critical step in protecting the essential systems that Americans rely on every day. *www.dhs.gov*

Topcon and Vemcon sign MoU

Topcon Positioning Systems has has signed a Memorandum of Understanding (MOU) with Vemcon GmbH to initiate a collaboration to expand the availability of advanced excavator technology solutions across the EMEA regions and additional global markets. The collaboration would bring together complementary strengths from both organizations: Vemcon's expertise in 2D assistance systems and Topcon's advanced 3D machine control technology and global GNSS network. *topcon.com*

GeoTerra selects Vexcel's UltraCam Merlin 4.1

GeoTerra, USA has acquired the UltraCam Merlin 4.1 2010 digital aerial camera system by Vexcel Imaging. This marks GeoTerra's transition to Vexcel's fourth-generation camera systems and reinforces their commitment to delivering versatile, reliable, and high-accuracy imagery for engineering and government mapping projects at all levels. *www.vexcel-imaging.com*

"Full Stream Ahead,"successfully launched

Rocket Lab successfully launched its 65th Electron rocket to date on a mission in support of its customer, BlackSky, and the next launch for its Gen-3 satellite constellation.

Teams launched the mission, dubbed 'Full Stream Ahead,' from Pad A at Rocket Lab's launch complex in Mahia, New Zealand, at 11:57 a.m. NZT on June 3 (7:57 p.m. EDT, 2357 UTC on June 2).

The mission placed the latest of BlackSky's Gen-3 satellites into a mid-inclination, low Earth orbit at 470 km (292 mi) in altitude. According to the company, it's Earth-observing service features "very high-resolution imagery and AI-enabled analytics for daily intelligence operations." BlackSky said it would use its Spectra tasking and analytics platform "to demonstrate how various AI and machine learning techniques affect tasking, multi-INT collection, automatic tipping-and-cueing, direct downlink and moving target engagement processing timelines within an exercise environment." *www.blacksky.com*

RIEGL celebrates grand opening of new hangar in Krems

RIEGL proudly celebrated the grand opening of its new state-of-the-art hangar in Krems, Austria, located conveniently only a short driving distance from the RIEGLWorld Headquarters in Horn. This special occasion marks a significant step in RIEGL's strategic expansion in the field of airborne LiDAR, reinforcing the company's long-term commitment to technological excellence, operational efficiency, and customer-focused innovation.

The newly inaugurated hangar will serve as the central base for RIEGL's airborne operations, currently housing two survey aircraft—a Diamond DA62 MPP and a Cessna T206H— both ready to be equipped with RIEGL's high-performance LiDAR systems for final calibrations and testing. The facility is designed to support the full spectrum of airborne system integrations, calibrations, and testing, enabling faster deployment and enhanced service capabilities for clients worldwide. *www.riegl.com*

Maxar and Saab form strategic partnership

Maxar Intelligence have announced a strategic partnership with Saab to jointly develop next-generation multi-domain battlespace solutions, with a specific focus on advanced space-based C5ISR systems (Command, Control, Communications, Computers, Cyber, Intelligence, Surveillance and Reconnaissance) for the digital battlefield and GPS resilience for autonomous drone systems. These solutions will help Europe accelerate the development of more advanced sovereign space-based capabilities.

Through a Teaming Agreement, Saab can access Maxar's geospatial intelligence and advanced mission products like Raptor, as well as draw upon the company's technical expertise. The deal expands on Maxar's existing relationship with Saab, which has most recently focused on deploying Maxar's Raptor product for autonomous drone navigation and operation in GPS-denied environments. *www.maxar.com*

Planet Labs renews EO contract with the German Government

Planet Labs Germany GmbH announced the German Federal Ministry of the Interior and Community (BMI) and the German Federal Agency for Cartography and Geodesy (BKG) have signed a seven-figure contract with Planet with a one year term and an option to renew for two more years.

The deal includes a fixed rate of all of Planet's data products over Germany, including insights from Planetary Variables, water monitoring services from Planet's partner EOMAP and access to Planet's Insights Platform. *planet.com*

Taiwan developing space capabilities for all-weather imaging

Taiwan is advancing its space capabilities with plans to launch two sophisticated synthetic-aperture radar satellites, designated FORMOSAT-9, in 2028 and 2030 as part of a strategic initiative to bolster the island's surveillance of both territorial lands and surrounding waters. The Taiwan Space Agency unveiled these ambitious plans during a legislative briefing on Jun 18, highlighting a key advantage of the SAR technology: its unparalleled ability to penetrate cloud cover and capture high-resolution images regardless of weather conditions — a critical feature for Taiwan, where persistent cloud coverage often hampers conventional optical satellite imaging.

While the payload for the initial satellite would be sourced from international partners, the second satellite would feature domestically developed technology, reflecting Taiwan's push toward greater self-sufficiency in critical space infrastructure. *news.tvbs.com.tw*

Honda hails successful reusable rocket test

Honda has successfully tested an experimental reusable rocket as it seeks to expand into the space sector. It hopes to develop the tech prowess for a suborbital launch by 2029, conducted a test flight of its rocket on the northern Japanese island of Hokkaido.

The prototype device, around six meters (20 feet) tall, landed only 37 centimeters (a little more than a foot) from its designated landing spot after the one-minute flight. Demand for satellite launch rockets is expected to increase in coming years as expectations grow for "a data system in outer space," the Honda statement said. *www.cbsnews.com*

Mengzhou spacecraft for China's moon mission passes key test flight

China has completed the inaugural test flight of its next-generation Mengzhou crewed spacecraft, executing a critical zero-altitude escape trial at the Jiuquan Satellite Launch Centre in the Gobi Desert.

The successful test hints at differences in the plans of China and the United States to "return to the moon".

Developed for China's 2030 lunar ambitions, the modular Mengzhou spacecraft features two variants: a near-Earth version supporting space station operations with a seven-astronaut capacity and a deep-space model for lunar missions. Its reusable return capsule and advanced technologies place it among the world's most capable crew vehicles. *www.scmp.com*

India To Launch $1.5 Billion Joint Earth Mission With NASA In July

National Aeronautics and Space Administration (NASA) and the Indian Space Research Organisation (ISRO) are set to launch satellite NISAR (NASA-ISRO Synthetic Aperture Radar) from India's Satish Dhawan Space Centre this July. The $1.5 billion Earth-observing satellite, weighing nearly three tonnes, will monitor the planet's surface with unmatched precision, using advanced radar to scan land, ice, and water every 12 days.

Jointly developed by NASA's Jet Propulsion Laboratory and ISRO's Space Applications Centre, NISAR is the world's first Earth-observing satellite equipped with dual-frequency radar, L-band and S-band. Using Synthetic Aperture Radar (SAR) technology, it will actively beam radar signals to Earth and analyse the reflections to create high-resolution images. Unlike optical satellites that depend on sunlight and clear skies, NISAR can capture data day or night, and even “see” through cloud cover, smoke, or dense vegetation.

What sets NISAR apart is its commitment to open data. The high-resolution imagery and insights it collects will be made freely available to scientists, agencies, and governments across the globe. *www.ndtv.com*

Vietnam-France Satellite Agreement

Airbus Defence and Space, CNES, and Vietnam’s VAST have signed a Declaration of Intent to deepen cooperation on Earth observation, building on the VNREDSat-1 program. Signed during President Macron’s official visit to Hanoi, the agreement signals intent to jointly develop next-generation satellite systems leveraging Airbus and CNES’s CO3D technologies. It also includes plans for technology transfer, capacity-building, and expanded data collaboration.

Indonesia's Fishing Vessels Use Japan's Ocean Eyes Satellite Data

Japanese startup Ocean Eyes has launched its first overseas venture in Indonesia, deploying AI-enhanced satellite data from Japan’s Himawari satellites to improve fishing efficiency by predicting optimal catch zones up to 14 days in advance. By integrating hourly-updated environmental forecasts with maps of likely fish congregation areas, the system addresses declining fish hauls linked to warming seas and inefficient traditional methods.

Study warns of rise in magnitude 8 earthquake

Days before a devastating magnitude 7.9 earthquake struck Myanmar, flattening buildings and killing thousands, a team of Chinese seismologists published a study warning of a heightened risk of such disasters in the area.

With the death toll now estimated to have passed 3,000, the seismologists have predicted the March 28 quake will not be the last such incident, with their research indicating there is currently a higher risk of catastrophic earthquakes across China and neighbouring regions.

The timing of the research, which links seismic cycles to fluctuations in the Earth’s rotation, has sparked intense debate about whether the planet’s tectonic stress fields are entering a dangerous new phase.

The peer-reviewed study, led by senior engineer Zhu Hongbin with the Beijing Earthquake Agency, was published on March 20 in the Journal of Geodesy and Geodynamics, an academic publication run by the China Earthquake Administration.

They analysed around 150 years of seismic data – from 1879 to the present day – to identify six major earthquake “active periods” in China and adjacent regions.

Each period correlates with shifts in the Earth’s rotational speed – measured through changes in the length of a day (LOD) – and corresponding tectonic stress realignments, according to Zhu and his colleagues.

An active period from 1897 to 1912 clustered 12 major quakes along the Pamir-Baikal seismic belt in East Asia. Subsequent phases migrated clockwise: to the northeastern Qinghai-Tibet Plateau (1920-1934), its southeastern edge (1946-1957), Yunnan and north China (1970-1976), and the Bayan Har block on the eastern Tibetan Plateau (2001-2015).

The current phase, the sixth, centres on the Bayan Har block’s periphery, with researchers cautioning that stress fields may now pivot northeast, increasing the risk in Sichuan, Yunnan and the Himalayan front.

“The region may currently be entering the nascent phase of a new seismic active period,” Zhu’s team wrote. Since 1867, Earth’s LOD fluctuations have cycled through four major acceleration-deceleration periods and 16 shorter phases.

Deceleration phases amplify north-south tectonic stresses, historically triggering megaquakes in the Pamir-Baikal belt. Acceleration phases, however, intensify northeast-directed stress, destabilising the margins of the Tibetan Plateau.

The study highlights accumulating strain in locked segments of the Longmenshan Fault in southwest China, which was the site of the 2008 Sichuan earthquake, as well as the Eastern Himalayan Syntaxis, where GPS measurements show India’s northward push accelerating.

The Myanmar quake, occurring during a transitional LOD phase, happened to fall in one of the predicted high-risk areas due to heightened northeast-oriented stress. Satellite data reveals a 500km-long (310-mile-long) rupture zone extending all the way south to Thailand, with thrust mechanisms consistent with these forces.

Striking just 280km (174 miles) from the Tibetan Plateau’s southeastern edge, the Myanmar earthquake has intensified scrutiny of Zhu’s findings.

But while the tremor aligns with the predicted northeast stress shift, sceptics argue that global seismic activity in 2025 remains below historical averages.

“There’s no evidence Earth has entered a shaking mode,” Gao Mengtan, a senior researcher with the China Earthquake Administration, told state media on Monday.

“Seismic activities this year are actually quieter than before,” he said.

The Myanmar disaster was followed by a magnitude 7.3 quake 100km (62 miles) northeast of Tonga on March 30, though fortunately there was no resulting tsunami risk for coastal regions. Meanwhile, smaller tremors rattled Tibet, Xinjiang and Guangdong last week, unnerving residents. *www.scmp.com*

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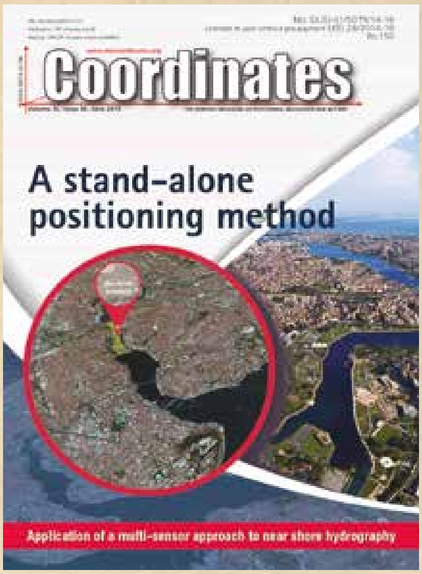

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Application of a multi-sensor approach to near shore hydrography

Andrew Waddington Director, LW Partners Ltd, UK

At the coastal margin, depths become critical for navigation, the environmental impact of humans is significant and the effects of onshore and offshore processes need to be fully understood. The coastal margin is where routine human activity is most influenced by, and affects, the hydrography.

Hydrographic survey of river Drava branches

Dino Dragun Senior Hydrographic Surveyor, GEOxyz International Surveys, Zwevegem, Belgium
Ana Gavran Head of the Hydrographic Department, MIG Ltd., Slavosnki Brod, Croatia
Vedran Car CEO, Cadcom Ltd., Zagreb, Croatia

The ultimate goal of this project is to establish a mathematical model, which is going to be used to analyze the possibility of establishing a system for Àood forecasting and simulation occurrence of Àood waves.

Determining the maritime baseline for marine cadastre

Robin Seet Assistant Director, Geodesy Section, Department of Survey and Mapping Malaysia (JUPEM), Kuala Lumpur, Malaysia
Dr David Forrest Senior University Teacher, School of Geographical and Earth Sciences, University of Glasgow, UK
Dr Jim Hansom Reader, School of Geographical and Earth Sciences, University of Glasgow, UK

The absence of an articulate policy on maritime baseline conservation has also caused ambiguity in the limits of federal – state maritime zones and thus, subjects it to unwarranted disturbance. Therefore, as part of this research, a draft proposal for a national maritime baseline policy is presented that might guide how the maritime baseline is to be managed and sustained.

On the transformation of time system in relativity based on SOFA and .NET

Shenquan TANG Master Candidate, School of Geodesy and Geomatics, Wuhan University, Wuhan, China
Jianan WEI Bachelor, Faculty of Built Environment, University of New South Wales, Kensington 2052, NSW, Austrailia
Erhu WEI Professor, Ph.D, Ph.D supervisor, School of Geodesy and Geomatics, the Key Laboratory of Geospace Environment and Geodesy, Ministry of Education, Wuhan University, Wuhan, China

This paper systematically describes the conversion between the TT, TCB, TDB, TCB-time system under the framework of the theory of relativity, and gives & explains some of the functional relationship between them.

A stand-alone positioning method for kinematic applications

M Halis SAKA Associate Professor, Gebze Technical University, Department of Geomatics Engineering, Kocaeli, Turkey
Reha Metin ALKAN Professor, Hitit University, Çorum, Turkey & Istanbul Technical University, Istanbul, Turkey
Ali ir Özperçin MSc Student, Gebze Technical University, Department of Geomatics Engineering, Kocaeli, Turkey

In this study, an algorithm is proposed to improve the positional accuracy within a few decimeters using a single geodetic receiver with carrier phase data. The results produced in this study showed that decimeter level positional accuracy could be achieved with the introduced algorithm.

Mosaic-G5 GNSS receivers

Septentrio has unveiled mosaic-G5 modules, its smallest GNSS receivers yet, measuring only 23 mm by 16 mm and weighing as little as 2.2 grams. The ultra-compact form factor and reduced power consumption of mosaic-G5 receivers enable reliable, high-accuracy positioning. The quad-band mosaic-G5 P3 and the triple band heading module mosaic-G5 P3H bring strong positioning reliability in challenging environments and are tailored for applications such as delivery or light show drones. *www.septentrio.com*

Students learn Real-World Surveying

A hands-on field exercise on *Surveying and Mapping Techniques* using the advanced CHCNAV LT800H GNSS tablet concluded successfully, equipping Diploma students of Geomatics Engineering at Military Technological College Oman with practical skills in geospatial data collection, analysis, and map creation.

The intensive exercise helped students to understand key surveying concepts, including types of surveys, GNSS fundamentals, and coordinate systems with a focus on Oman's national geodetic datum ONGD17. Learners were also trained on ArcGIS Pro, covering data types, symbology, and the field-to-map workflow. Students conducted a site visit and reconnaissance to understand and record difference mapping features in area of interest and set up the CHCNAV GNSS tab to carry out a detailed topographic survey.

FocalPoint partnership with STMicroelectronics

FocalPoint, UK has announced a strategic collaboration with STMicroelectronics. The joint offering provides automotive OEMs a combined solution that enhances navigation performance by improving GNSS reliability and accuracy — key to making autonomous vehicles safer. FocalPoint will integrate its S-GNSS® Auto software, powered by Supercorrelation™technology, onto ST's Teseo devices, known for their high performance and multi-constellation support. *focalpointpositioning.com*

New single-card resilient navigation system by Honeywell

Honeywell has launched the HGuide o480, a high-performance, single-card inertial navigation system (INS) engineered to deliver precise, resilient localization and attitude data in an ultra-low size, weight and power package. It can be integrated directly into the electronics stack of a range of applications requiring precise and robust localization. It can also reduce system size and integration complexity, enabling faster deployment and improved performance for unmanned and autonomous systems across air, land and sea. *www.honeywell.com*

A new era of laser-aided navigation begins

Advanced Navigation has successfully demonstrated a hybrid solution for long endurance GNSS-denied navigation, proving that a software-fused inertial-centered architecture is the defining standard for autonomy.

This advancement is achieved by integrating a strategic-grade fiber-optic gyroscope (FOG) inertial navigation system (INS) with a new class of navigation aid: a Laser Velocity Sensor (LVS). The result is a fused hybrid architecture that delivers unprecedented precision and reliability in even the most challenging environments.

At the center of every reliable navigation platform is a trusted source of truth: the INS. Advanced Navigation's FOG INS, which is sensitive enough to detect the Earth's rotation, provides that foundation by delivering precise attitude. Complementing this, the LVS uses infrared lasers to measure a vehicle's ground-relative 3D velocity with exceptional accuracy and long-term stability. Unlike conventional sensors, LVS performs reliably on both ground and airborne platforms, as long as it maintains a clear line of sight to the ground or a stationary surface. *www.advancednavigation.com*

Hi-Target and GMV form alliance

Hi-Target and GMV have established a strategic alliance to jointly develop integrated differential service solutions. By combining their complementary technologies, including user-grade GNSS hardware, correction services, and augmentation infrastructure, Hi-Target and GMV will facilitate the adoption of high-precision positioning across various industries and geographic regions. *www.gmv.com*

Taoglas launches Thunder Series antenna enclosures

Taoglas has launched its new Thunder Series — a high-performance outdoor antenna enclosure platform engineered to support direct integration and installation of industrial routers within the antenna package. Designed for demanding outdoor environments, the series helps engineers optimize installations, reduce signal loss, and significantly lower deployment costs. *www.taoglas.com*

Visual-aided navigation system for GPS-compromised flights

Inertial Labs has launched a visual-aided inertial navigation system (VINS) that enables aircraft to maintain accurate flightpaths when no reliable GPS/GNSS signal is available.

The launch comes as the U.S. Department of Transportation (DOT) reports an increase in GPS signal jamming and spoofing in North America and much of Western Europe. This affects commercial and military operations, with up to 700 global GPS spoofing and jamming incidents taking place daily. VINS enables Unmanned Aerial Vehicles (UAVs) to accomplish very long-range missions in the most GNSS-challenged environments. VINS uses a robust 3D vision-based positioning software from Maxar® Raptor™ to estimate a vehicle's absolute 3D position by applying Perspective and Point (PnP) principles to compare patterns captured from an onboard camera (day or infrared) with satellite imagery-derived Maxar Precision3D™ maps. *inertiallabs.com*

Anti-jamming antenna for critical, marine, and defence use

Calian GNSS has launched its next-generation anti-jamming controlled reception pattern antenna (CRPA). The CR8894SXF+ is an advanced CRPA, purpose-built to provide efficient interference protection and real-time situational awareness across critical infrastructure, marine, and defence environments where GNSS continuity is mission critical. The CRPA is specifically-designed to provide a low-power and lightweight solution in a compact size. *www.calian.com*

ASTRADIA: daytime star tracker for robust, reliable navigation

Sodern has launched Astradia: a daytime star tracker capable of aiding navigation systems, making them independent of GNSS radio-navigation signals.

Sodern is an endo-atmospheric star tracker which, when combined with an inertial navigation system (INS), provides daytime and nighttime attitude measurement, in order to guarantee precise, robust and reliable on-board geo-positioning data.

This high-performance tracker is thus autonomous, no longer reliant on radio-navigation signals, and aims to counter the natural drift in inertial navigation systems. It also offers the advantage of emitting no waves, which could otherwise expose an aircraft to detection. *sodern.com*

Peak System unveils PCAN-GPS Pro FD

PEAK System has introduced the PCAN-GPS Pro FD, a configurable sensor module for measuring the position, attitude and acceleration of objects. It has a robust aluminum housing suited for measurement in harsh environments.

The device is equipped with a powerful microcontroller (M7/M4 dual-core), a magnetic field sensor, a three-axis gyroscope, a three-axis accelerometer, and the u-blox NEO-M9N satellite receiver for GPS, Galileo, BeiDou, GLONASS, SBAS and QZSS. It delivers satellite navigation measurement data with update rates of up to 25 Hz. *www.peak-system.com*

u-blox launches triple-band GNSS module

u-blox has expanded its ZED form-factor portfolio with the ZED-F20P, a L1/L2/L5 triple-band GNSS module designed for high precision applications in ground and air robotics. It delivers deterministic, centimeter-level RTK and PPP-RTK accuracy tailored to the needs of lightweight and dynamic platforms. Its end-to-end silicon-to-firmware architecture supports 25 Hz update rates, robust security features, and low power consumption in a streamlined design. *www.u-blox.com*

Silicon Sensing and Kongsberg Discovery unite with disruptive ambitions

Silicon Sensing Systems Ltd and Kongsberg Discovery AS have signed a co-operation agreement to develop next generation MEMS-based gyro technology that will disrupt existing solutions. This agreement will merge the engineering skills of both companies to speed the evolution of products within each company. *siliconsensing.com*

Leidos using quantum technology to thwart GPS jamming

Leidos is developing an alternative navigation technology that measures variations in the Earth's magnetic field and harnesses the quantum properties of nitrogen in diamonds. Quantum sensing uses microscopic particles that can simultaneously exist in multiple states to more accurately detect aspects of geophysical properties like magnetic fields.

The sensor is being developed by Frequency Electronics, Inc. under subcontract to Leidos and in collaboration with MIT Lincoln Lab. Ultimately, Leidos intends to fly a MagNav system with the new magnetometer. If successful, the technology has the potential to significantly advance navigation technology for military use. *www.leidos.com*

PTx Trimble unveils next-gen guidance controller

PTx Trimble, formed as a joint venture in 2024 by AGCO and Trimble, is providing a new GNSS receiver for precision autoguidance: the NAV-960 guidance controller. The agriculture controller improves positioning accuracy and availability to deliver greater uptime while providing the computing power to support complex field operations and handle future developments. *ptxtrimble.com*

Leica Geosystems launches mobile mapping solution

Leica Geosystems has launched the Leica Pegasus TRK300, designed for various mobile mapping applications. It features a multi-beam scanner system with two scanning heads that quickly collect high-resolution data from multiple angles, minimizing data gaps. With a range of up to 300 meters, the system covers wide corridors and large open areas, reducing the need for multiple passes. This capability allows users to map more ground in less time without sacrificing data quality, resulting in a high-density point cloud suitable for asset mapping and smart city modeling. *leica-geosystems.com*

Safran launches of Skylight

Safran Electronics & Defense has launched Skylight, a multi-mode military GNSS receiver designed to withstand electronic warfare threats. It marks a major milestone as the world's first GNSS receiver flight-tested with compatibility for Galileo PRS (Public Regulated Service). Its performance was validated during flight trials aboard a combat aircraft. This receiver delivers encrypted, spoofing-resistant PRS signals, significantly enhancing security for operations in contested environments.

The GNSS receiver is also M-Code compatible, ensuring interoperability with U.S. and allied military systems. *www.safran-group.com*

Real-time GNSS RFI display for GPS jamming and spoofing detection

SeRo Systems announced that it is expanding its portfolio with the launch of its newest monitoring technology for improved aircraft situational awareness. The live GNSS RFI Situation Display (GRSD) is the first and only real-time solution that combines live air traffic information with SeRo's advanced GPS jamming and spoofing detection and short-term predictive alerts — offering enhanced visibility into the airspace. *www.sero-systems.de*

Juniper Systems adds RTK precision to Archer 4 GNSS Expansion Pod

Juniper Systems Inc. has announced that the GNSS Expansion Pod for the Archer 4 Rugged Handheld is now RTK capable. It is also launching a new application for the Archer 4 called Archer Connect. The Archer 4 with GNSS Expansion Pod and RTK connection is now an all-in-one centimeter mapping solution. *junipersys.com*

ComNav launches laser scanner

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

oneNav unveils world's first L5-direct™ ASIC

oneNav has announced the successful bring-up of the world's first L5-direct™ GNSS receiver ASIC. It is completely independent of vulnerable L1 signals, was rapidly developed and deployed leveraging the advanced GlobalFoundries (GF) 22nm FDX™ platform, benefiting from its exceptional mixed-signal capabilities and ultra-low power performance for both RF and digital domains. Its L5-direct utilizes a novel "GPU for GNSS" processor architecture that directly acquires and tracks L5 signals without relying on L1 signals, which are widely susceptible to jamming and spoofing—a critical vulnerability for aviation, defense, and consumer GNSS applications. *onenav.ai*

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www.tuwien.at

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14 - 18 July 2025
San Diego, USA
www.esri.com

September 2025

IAG Scientific Assembly 2025
1 - 5 September
Rimini, Italy
https://eventi.unibo.it/iag2025

Commercial UAV Expo 2025
2 - 4, September
Las Vegas
www.expouav.com

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

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

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

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

October 2025

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

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

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

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

November 2025

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

OS chooses KOREC and Trimble R980

KOREC will be supplying Ordnance Survey (OS) with 180 Trimble R980 GNSS Receivers. These receivers will be supported by KOREC for the duration of the five-year contract. The receivers brings together several top Trimble GNSS technologies and are particularly suitable for OS. *www.ordnancesurvey.co.uk*

New standard for long-endurance aerial missions

DJI has unveiled the Matrice 400 - UAV that offers a maximum flight time of 59 minutes and can carry payloads weighing up to 6 kg. It is equipped with a lidar and millimeter wave radar-based obstacle sensing system, enhancing its ability to navigate complex environments. It features an IP55 protection rating, allowing it to operate in harsh conditions and withstand extreme temperatures ranging from minus 20°C to 50°C, according to DJI. *www.dji.com*

Dragoon selects Teledyne FLIR Prism software

Teledyne FLIR OEM has announced Dragoon is using the Prism™ Supervisor and Prism SKR software for its AI-driven object detection, tracking, real-time autonomy flight control, and mission planning capabilities within its long-range unmanned platform prototypes under Project Artemis, a Defense Innovation Unit (DIU) initiative.

Project Artemis is a program designed to evaluate and deploy long-range loitering munitions capable of operating in highly contested electromagnetic environments and in large numbers. Dragoon is one of four organizations within Project Artemis tasked to demonstrate low-cost, adaptable, long-range, unmanned aerial systems (UAS) platforms with the potential to maximize operational flexibility. *www.flir.in*