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Report on the United Nations International Meeting on the Applications of Global Navigation Satellite Systems

(Vienna, 5–9 December 2022)

I. Introduction

1. The term "global navigation satellite system" (GNSS) refers to a constellation of satellites that transmit positioning and timing data to GNSS receivers. The receivers then use those data to determine location. Current GNSS include the Global Positioning System (GPS) of the United States of America, the Global Navigation Satellite System (GLONASS) of the Russian Federation, the BeiDou Navigation Satellite System (BDS) of China and the European Satellite Navigation System (Galileo) of the European Union. There are also two regional systems, the Navigation with Indian Constellation (NavIC) system of India and the Quasi-Zenith Satellite System (QZSS) of Japan, and various augmentation systems designed to improve one or more GNSS qualities, such as accuracy, robustness and signal availability.

2. A satellite-based augmentation system is a wide-area differential GNSS augmentation system that uses several geostationary satellites to broadcast primary GNSS data that have been enhanced by ranging, integrity and correction information provided by a network of ground stations covering large areas, which improves precision and reduces position errors to less than 1 metre.

3. GNSS technologies are now ubiquitous in everyday life: they are incorporated in electronic devices and are used by the public, surveyors and geoscientists on a regular basis. In developing countries in particular, GNSS applications offer cost-effective solutions that make it possible to foster economic and social development without neglecting the need to preserve the environment, thus promoting sustainable development.

4. The International Committee on Global Navigation Satellite Systems (ICG) has encouraged tangible international cooperation and facilitated compatibility and interoperability among the different GNSS services with a view to ensuring that satellite-based positioning, navigation and timing services together provide global coverage for the benefit of all. ICG acts as a platform for open discussions and the exchange of information under the umbrella of the United Nations.

5. The Office for Outer Space Affairs and ICG work together to raise awareness of the important role of GNSS in our societies and to promote international collaboration in this field. In order to focus on GNSS technology and applications, the United Nations International Meeting on the Applications of Global Navigation Satellite

Systems was organized by the Office for Outer Space Affairs in cooperation with the ICG working groups. The meeting was held in Vienna from 5 to 9 December 2022 in hybrid format.

6. The present report describes the background, objectives and programme of the meeting and provides an overview of the highlights of each session and the observations made. It has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its sixty-sixth session, to be held in 2023, and to its subcommittees.

A. Background and objectives

7. The meeting provided an opportunity to build on the results of a series of regional workshops and training courses on GNSS, contributing to the formulation of a plan of action and the definition of functional partnerships in the long term while also strengthening existing strategies at the national, regional and global levels. Details of all the regional workshops on GNSS applications, organized jointly with ICG, have been made available on the website of the Office for Outer Space Affairs.[1] The meeting was also an opportunity to build on a number of ongoing initiatives, such as the International Space Weather Initiative,[2] the multi-GNSS demonstration project,[3] the implementation of regional reference frames[4], and the activities of the regional centres for space science and technology education,[5] affiliated to the United Nations, which also act as ICG information centres.

8. The objectives of the meeting were to reinforce the exchange of information among countries; share information on national, regional and global projects and initiatives, which could benefit regions; and identify actions that could be taken and partnerships that could be established by potential user institutions, in particular in developing countries. The meeting was also intended to increase participants' awareness of the intrinsic value of GNSS signals in the sustainable development context.

9. The meeting discussions were also linked to the 2030 Agenda for Sustainable Development and its targets under the Sustainable Development Goals, such as Goal 9, on industries, innovation and infrastructure, and Goal 11, on sustainable cities and communities.

B. Programme

10. At the opening of the meeting, introductory and welcoming statements were made by the representative of the Office for Outer Space Affairs.

11. The programme was divided into seven sessions: (a) GNSS and satellite-based augmentation systems update; (b) GNSS applications and reference frame networks; (c) GNSS applications and performance; (d) applications of low-cost GNSS receivers; (e) GNSS observations for ionospheric monitoring and modelling; (f) GNSS applications: case studies; and (g) capacity-building and national programmes. In total, 36 presentations were made during the meeting. Speakers were selected on the basis of their scientific or engineering background, the quality of the abstracts of their proposed presentations and their experience in programmes and projects using GNSS-based technology and its applications.

12. On 6 and 7 December 2022, the experts of the Task Force on Interference Detection and Mitigation of the ICG working group on systems, signals and services (Working Group S), in accordance with the Task Force workplan, held a seminar on

[1] www.unoosa.org/oosa/en/ourwork/psa/gnss/past-workshops.html.

[2] http://iswi-secretariat.org.

[3] www.multignssasia.com.

[4] www.unoosa.org/oosa/en/ourwork/icg/resources/Regl-ref.html.

[5] www.unoosa.org/oosa/en/ourwork/psa/regional-centres/index.html.

GNSS spectrum protection and the tenth Workshop on Interference Detection and Mitigation. The purpose of the seminar and workshop was to describe the importance of GNSS spectrum protection at the national level and to explain how to reap the benefits of GNSS. The seminar focused on the following topics: introduction to GNSS; spectrum management and spectrum protection; and interference detection and mitigation. The seminar lecture notes[6] and the workshop briefings[7] are available on the website of the Office for Outer Space Affairs.

13. The programme of the meeting was developed by the Office for Outer Space Affairs in cooperation with the ICG working groups.

14. The presentations made at the meeting, abstracts of the papers presented and the programme of the meeting are available on the website of the Office for Outer Space Affairs.[8]

C. Attendance

15. A total of 219 specialists representing national space agencies, academia, research institutions, international organizations and industry from developing and developed countries concerned with the development and use of GNSS for practical applications and scientific exploration were invited to participate in the meeting.

16. Representatives of the following 28 countries participated in the meeting: Algeria, Australia, Canada, China, Croatia, Czechia, Ecuador, Finland, France, India, Indonesia, Italy, Japan, Kenya, Mongolia, Nepal, Nigeria, Pakistan, Peru, Philippines, Poland, Russian Federation, Rwanda, Saudi Arabia, Thailand, Türkiye, United Kingdom of Great Britain and Northern Ireland and United States of America. The European Commission was also represented. Representatives of the Office for Outer Space Affairs also participated.

II. Summary of discussions and observations

17. The meeting noted that GPS capability and service had continued to be upgraded through the integration of the next generation of satellites, GPS Block III, which were broadcasting the new L1C signal, in addition to L2C, L5 and the L1C/A signal. It also noted that in terms of multi-constellation and multi-frequency GNSS, the Galileo High Accuracy Service would provide cost-free and high-accuracy precise point positioning corrections and biases for Galileo signals (E1, E5a/b and E6) and GPS signals (L1C/A and L2C). The meeting further noted that the BDS constellation had continued to be improved and its applications expanded.

18. The meeting was provided with information on the communications satellite of Nigeria, NigComSat-1R, which was a hybrid satellite with a navigation (L-band) payload for a space-based augmentation system that was intended to provide a navigation overlay service similar to the European Geostationary Navigation Overlay Service. A summary and the outcomes of a continental cost-benefit analysis of the implementation of satellite-based augmentation systems in Africa, including the need for capacity-building activities to encourage the adoption of related applications in the aviation and non-aviation sectors, were also presented.

19. The meeting noted that the Algerian Space Agency was developing an Algerian satellite augmentation system that was compatible with International Civil Aviation Organization standards and based on the first Algerian communications satellite (Alcomsat-1). The system was aimed at improving the accuracy and integrity of

[6] www.unoosa.org/oosa/en/ourwork/psa/schedule/2022/un-international-meeting-gnss_gnss-spectrum-protection.html.

[7] www.unoosa.org/oosa/en/ourwork/icg/working-groups/s/idm10.html.

[8] www.unoosa.org/oosa/en/ourwork/psa/schedule/2022/un-international-meeting-gnss_presentations.html.

positioning information in Algeria and the surrounding areas, providing services for users in many fields, such as surveying, transportation, aviation, rail transport and maritime navigation.

20. The meeting also noted that ICG had taken a leading role in promoting collaboration in the use of GNSS services for a range of scientific, technological and commercial applications. Specific areas of interest to ICG and its working groups included systems, signals, and services (Working Group S); enhancement of GNSS performance, new services and capabilities (Working Group B); information dissemination and capacity-building (Working Group C); and reference frames, timing and applications (Working Group D).

21. It was further noted that GNSS-based techniques were extremely useful in monitoring natural hazards and disasters. Traditional GNSS techniques, already well established, were enabling the live monitoring of ground motion. GNSS-based remote sensing (ionospheric monitoring), developed recently, had facilitated much wider coverage of disasters through the atmospheric waves they induce, and was therefore particularly useful with respect to the coverage of oceans and thus for tsunami early warning systems. A joint task force on GNSS applications for disaster risk reduction had been established under ICG Working Group D. The task force would focus on novel applications of GNSS data and infrastructure to support sustainable development and disaster risk reduction and would be aligned with the Sustainable Development Goals and the Sendai Framework for Disaster Risk Reduction 2015–2030. The first application to be considered would be the use of GNSS to enhance tsunami early warning systems.

22. The meeting took note of various studies that used GNSS-based methods for urban traffic management, urban pollution monitoring and flood early warning systems. The improvement of international time transfer using GNSS observations and determining both measurement and systematic errors at the ground station using common clock scenarios was also presented.

23. The meeting also took note of applications that required high accuracy – to a few tens of centimetres – and discussed low-cost GNSS receiver systems that could be developed on the basis of commercial off-the-shelf GNSS receivers and antennas. Such receivers could be used for real-time kinematic and precise point positioning to provide centimetric or decimetric positioning accuracy. ICG Working Group C had established a project team that was exploring the possibilities offered by the use of low-cost GNSS receiver systems for applications related to space weather monitoring, such as computation of total electron content and scintillation.

24. The meeting further noted that the low- and high-latitude ionosphere was particularly well known for the presence of a wide range of instabilities, which made the mitigation of ionospheric effects challenging. In order to study processes in those regions of the ionosphere where existing network coverage was sparse, an increase in instrument density was needed. For example, use of low-cost ground-based instrumentation such as the Compound Astronomical Low-cost Low-frequency Instrument for Spectroscopy and Transportable Observatory (CALLISTO) spectrometer to analyse solar radio bursts could be an effective way of providing early warning of space weather hazards that could affect GNSS operation.

25. A presentation was given on the possibility of mitigating GNSS ionospheric effects through awareness of space weather conditions in the positioning environment at the point of position estimation and through the use of self-adaptive correction models based on statistical learning.

26. A seminar was conducted by the ICG Working Group S Task Force on Interference Detection and Mitigation on spectrum management for radio navigation satellite services and the mitigation of radio frequency interference, collectively referred to as “spectrum protection”. Experts with experience in the development, operation and use of radio-navigation satellite services discussed how GNSS and GNSS receivers worked, why spectrum management was needed and the difference

between international and national infrastructure. Examples were given of interference concerns, such as licensed and illegal emissions, jammers and adjacent band interference. It was noted that the number of GNSS applications was practically unlimited and that GNSS was of crucial importance for national and global economies.

27. With respect to GNSS vulnerability and threats, the meeting noted that the satellite signals received by GNSS receivers were much weaker than the radio signals typically used by ground-based systems such as television stations or mobile phone networks, and it was therefore essential to keep the frequencies used by terrestrial services well separated from those used in GNSS. There were many potential interference sources that could degrade GNSS performance and prevent the use of GNSS.

28. Participants in the meeting were therefore encouraged to engage with spectrum regulators and decision makers in their respective countries to ensure that there was a solid understanding of the processes and the organizations involved in the regulation of the GNSS spectrum and that the GNSS spectrum was adequately protected. Only by ensuring that the GNSS spectrum was kept clean and free of interference could GNSS be used to maximum benefit.

29. The meeting noted that GNSS spoofing was one of the issues that might affect critical services that use positioning, navigation and timing data from GNSS signals. It also noted that the Galileo Open Service Navigation Message Authentication service was an authentication mechanism that would enable GNSS receivers to verify the authenticity of GNSS information, thus ensuring that the received data were indeed from Galileo and had not been modified in any way. QZSS would also provide signal authentication services for QZSS, GPS and Galileo signals.

30. The meeting was informed about the legislative challenges of emerging technologies that used GNSS, especially drones.

31. The meeting took note of the "GNSS applications for present and future" initiative of the ICG Working Group B Application Subgroup. The initiative was aimed at surveying GNSS applications that identified challenges and facilitated the development of solutions that served society. The activities to be undertaken by the Subgroup were intended to provide assistance and guidance to, and share lessons learned with, GNSS users. A research report entitled "GNSS applications for sustainable development: case studies", prepared by the Subgroup, presented studies of GNSS applications and provided guidance for current and potential GNSS users with a view to encouraging them to use GNSS systems and services or develop their own GNSS business.

32. The meeting also noted that it was necessary to develop human resources and skills in order to keep abreast of new GNSS applications and related markets, and that social and economic development at the country level could be enhanced by improving the skills and knowledge of university educators and young scientists through rigorous theoretical training, research, field exercises and pilot projects relating to GNSS technologies. Information on short- and long-term training courses on various aspects of GNSS, conducted at the regional centres for space science and technology education, affiliated to the United Nations, was brought to the attention of the meeting participants.

33. The meeting further noted that the GNSS education curriculum developed by ICG took into account GNSS course programmes at the university level in several developing and industrialized countries. The curriculum had been made available to the regional centres for space science and technology education, affiliated to the United Nations, and was available on the website of the Office for Outer Space Affairs.[9] The regional centres and other educational institutions could adapt the

[9] www.unoosa.org/res/oosadoc/data/documents/2012/stspace/stspace59_0_html/st_space_59E.pdf.

curriculum according to their needs and to issues of particular relevance to their respective regions by deciding on the coverage and content of the topics covered.

34. Participants expressed the view that hands-on workshops featuring guidance materials and exercises on GNSS applications in specific fields should be organized before the holding of future workshops on GNSS. It was proposed that, in order to enhance the scientific quality of GNSS research for the benefit of young scientists, follow-up training be organized for the purposes of promoting continuous learning and sustainably maintaining core competencies.

III. Concluding remarks

35. The discussion session provided guidance on how institutions could work together through regional partnerships to share and transfer knowledge and develop joint activities and project proposals. Participants provided positive feedback on the meeting, stating that the topics addressed met their professional needs and expectations.

36. It was also emphasized that the Office would continue its work on capacity-building to ensure that end users benefited from the multi-constellation GNSS.

37. Participants expressed their appreciation to the United Nations and the ICG working groups for both the excellent organization and the substance of the meeting.

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