



# General Assembly

Distr.: General  
24 November 2021

Original: English

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## Committee on the Peaceful Uses of Outer Space

### Activities carried out in 2021 in the framework of the workplan of the International Committee on Global Navigation Satellite Systems

#### Report of the Secretariat

#### I. Introduction

1. The International Committee on Global Navigation Satellite Systems (ICG) meets annually to review and discuss developments in the field of global navigation satellite systems (GNSS) and to allow ICG members, associate members and observers to address recent developments in their organizations and associations with regard to GNSS services and applications. In order to provide civil services related to GNSS that benefit users worldwide, ICG continues to pursue the establishment of a GNSS system of systems.
2. The Office for Outer Space Affairs, as the executive secretariat of ICG, coordinates the planning meetings of ICG and its Providers' Forum, as well as the intersessional meetings of the ICG working groups held in conjunction with sessions of the Committee on the Peaceful Uses of Outer Space and its subsidiary bodies. The Office also coordinates the implementation of the ICG programme on GNSS applications.
3. The Office is actively involved in all of the ICG working groups associated with the ICG workplan and leads its working group on information dissemination and capacity-building.
4. The present report contains a description of the activities undertaken or supported by the Office for Outer Space Affairs during 2021 and the main results achieved. Detailed information on the activities, as well as educational resources, is available on the ICG information portal.<sup>1</sup> The report has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its sixty-fifth session, to be held in 2022, and to its subcommittees.

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<sup>1</sup> [www.unoosa.org/oosa/en/SAP/gnss/icg.html](http://www.unoosa.org/oosa/en/SAP/gnss/icg.html).



## **II. Activities of the International Committee on Global Navigation Satellite Systems carried out in 2021**

5. Pursuant to the ICG workplan for 2021 and the recommendations contained therein, the Office for Outer Space Affairs, in partnership with members, associate members and observers of ICG and international entities, focused on: (a) disseminating information through the information centres hosted by the regional centres for space science and technology education, affiliated to the United Nations; (b) promoting the use of GNSS as tools for scientific applications; and (c) building the capacity of developing countries in using GNSS technology for sustainable development.

### **A. Information dissemination through the information centres hosted by the regional centres for space science and technology education, affiliated to the United Nations**

6. The Office for Outer Space Affairs supports the operation of the regional centres for space science and technology education, affiliated to the United Nations, in Africa (Morocco and Nigeria), Asia and the Pacific (China and India), Latin America and the Caribbean (Brazil and Mexico) and Western Asia (Jordan).

7. The centres, also acting as information centres for ICG, focused on satellite navigation programmes, through the nine-month postgraduate courses on GNSS, and regional activities to facilitate the development of GNSS-related applications.

8. The second edition of the ICG publication entitled *The Interoperable Global Navigation Satellite Systems Space Service Volume* ([ST/SPACE/75/Rev.1](#)) was made available to the regional centres, both for training purposes and to disseminate information on the multi-GNSS space service volume. The publication serves as a single information resource and contains a concise overview of the characteristics of individual GNSS providers and their contribution to the interoperable GNSS space service volume.

### **B. Promoting the use of global navigation satellite system technologies as tools for scientific applications**

#### **1. Space weather effects on global navigation satellite systems**

9. Space weather is recognized as the cause of significant errors experienced by GNSS and their users. It represents the largest contributor to errors in GNSS single-frequency positioning applications. The effects of space weather are more variable and highly unpredictable over the low-latitude ionospheric regions.

10. The Office for Outer Space Affairs, in cooperation with the Abdus Salam International Centre for Theoretical Physics (ICTP) in Italy, the Institute for Scientific Research at Boston College in the United States of America, Pwani University in Kilifi, Kenya, and the National Institute of Geophysics and Vulcanology in Italy, organized the Eastern Africa GNSS and Space Weather Capacity-building Workshop. The workshop was held virtually from 21 to 25 June 2021 and was supported by the Kenya Space Agency, the International Union of Radio Science (URSI) and the Scientific Committee on Solar-Terrestrial Physics.

11. The main scientific and technical topics covered at the workshop were GNSS generalities, space weather and Sun-Earth coupling, ionospheric monitoring and modelling, ionospheric irregularities, and space weather services and programmes. With regard to the ionosphere-related topics, focus was placed on low-latitude ionospheric regions.

12. The lecturers at the workshop included GNSS experts from India, Italy, Finland, France, Kenya, Nigeria, South Africa and the United States, as well as from ICTP and the Office for Outer Space Affairs.

13. A total of 156 specialists, 27 per cent of whom were women, from 25 countries were invited to participate in the workshop. Detailed information about the workshop is available on the ICTP website.<sup>2</sup>

14. A session on space weather impacts on GNSS, held in a hybrid format (in person and online) on 30 August 2021, was organized in conjunction with the thirty-fourth General Assembly and Scientific Symposium of URSI, held in Rome from 28 August to 4 September 2021. Presentations were made on ionospheric total electron content (TEC) anomalies caused by space weather conditions, TEC calibration using GNSS receiver networks, and a case study on positioning accuracy during a solar flare event.

15. Funds provided by ICG were used to support two scientists from Argentina and Côte d'Ivoire.

16. The Office for Outer Space Affairs organized an expert seminar entitled "Space weather and GNSS", held in Vienna on 28 September 2021 in conjunction with the fifteenth meeting of ICG. The purpose of the seminar was to discuss space weather effects on the signals transmitted by GNSS, including the effects of ionospheric perturbations and solar radio bursts. The presentations made during the seminar by the representatives of China, India, France, the United States and ICTP are available on the ICG information portal.<sup>3</sup>

## 2. Global navigation satellite systems data processing

17. A GNSS involves a constellation of satellites orbiting Earth, continuously transmitting signals that enable users to determine their position, with global coverage.

18. The positioning principle is based on solving an elemental geometric problem involving the distances (ranges) between a user and a set of at least four GNSS satellites with known coordinates. These ranges and satellite coordinates are determined by the user's receiver, using signals and navigation data transmitted by the satellites. The resulting user coordinates can be calculated to an accuracy of several metres. However, centimetre-level positioning can be achieved using more advanced techniques.

19. The Centre for Spatial Information Science at the University of Tokyo and the ICG working group on information dissemination and capacity-building held an online training programme on GNSS data processing for high-accuracy positioning using low-cost receiver systems from 19 to 21 January 2021.

20. Through hands-on practice, the participants familiarized themselves with GNSS data processing for high-accuracy positioning using real-time kinematic positioning software and Multi-GNSS Advanced Demonstration Tool for Orbit and Clock Analysis (MADOCA) precise point positioning software. Sample GNSS data logged by base stations and field receivers (both static and dynamic) and GNSS data from Android devices were provided to increase understanding of issues regarding data quality and accuracy and related problems. Theoretical and practical lectures on high-accuracy data processing requirements and GNSS data types, errors, coordinate systems and applications were given by invited experts from India, Japan and the European Commission. Experts from the European Space Agency and the Office for Outer Space Affairs also contributed.

21. A total of 294 specialists, 24 per cent of whom were women, from 65 countries were invited to participate in the training programme. Detailed information about the programme is available on the ICG information portal.<sup>4</sup>

22. A one-day workshop on GNSS for policymakers and decision makers was held virtually on 28 January 2021. The workshop provided information on the following

<sup>2</sup> See <http://indico.ictp.it/event/9621/>.

<sup>3</sup> See [www.unoosa.org/oosa/en/ourwork/icg/meetings/icg-15/icg-annual-meeting-2021\\_-presentations.html](http://www.unoosa.org/oosa/en/ourwork/icg/meetings/icg-15/icg-annual-meeting-2021_-presentations.html).

<sup>4</sup> See [www.unoosa.org/oosa/en/ourwork/icg/activities/2021/CSISTokyo/presentations.html](http://www.unoosa.org/oosa/en/ourwork/icg/activities/2021/CSISTokyo/presentations.html).

topics: introduction to GNSS and its applications; GNSS accuracy, errors and coordinate systems; overview of GNSS data processing software and hardware requirements; interpretation of GNSS specifications; and low-cost GNSS receiver systems, and receiver selection guidelines.

23. A total of 184 participants, 24 per cent of whom were women, from 54 countries were invited to participate in the workshop. Detailed information about the workshop is available on the ICG information portal.<sup>5</sup>

### **C. Building the capacity of developing countries in using global navigation satellite system technology for sustainable development**

#### **Regional workshops on applications of global navigation satellite systems and the International Space Weather Initiative**

24. The United Nations/Mongolia workshop on the applications of global navigation satellite systems<sup>6</sup> was organized by the Office for Outer Space Affairs in cooperation with the Mongolian Geospatial Association and the Agency for Land Administration and Management, Geodesy and Cartography of Mongolia. The workshop was held virtually from 25 to 29 October 2021. The main objectives of the workshop were to enhance the exchange of information between participating countries on the applications of GNSS solutions and, to that end, scale up capacities in the Asia and the Pacific region, including by sharing information on national, regional and global projects that may provide benefits for the region and thereby enhance cross-fertilization among those projects. The workshop was supported by ICG.

25. Consistent with the workplan of the ICG working group on systems, signals and services, the experts of the interference detection and mitigation task force of the working group conducted a seminar on 26 and 27 October 2021 on GNSS spectrum protection and interference detection and mitigation, in conjunction with the workshop. The purposes of the seminar were to describe the importance of GNSS spectrum protection at the national level and explain how to reap the benefits of GNSS. Lecture notes from the seminar are available on the website of the Office for Outer Space Affairs.<sup>7</sup>

26. In line with a new initiative of the applications subgroup of the ICG working group on enhancement of GNSS performance, new services and capabilities, entitled “GNSS applications for present and future”, the reports of the subgroup were presented at the session of the workshop devoted to GNSS applications, held on 29 October 2021. The reports covered the following topics: intelligent transport system applications and services; a GNSS-based emergency warning system in response to all types of hazards, from earthquakes to forest fires; GNSS user technology; high-precision products and services; and GNSS signal authentication applications.

27. An International Space Weather Initiative (ISWI) workshop on space weather: science and applications was organized by the Office for Outer Space Affairs in cooperation with the Vikram Sarabhai Space Centre of the Indian Space Research Organization. The workshop was held virtually on 2 and 3 November 2021. The focus of the workshop was on recent advances made in scientific research by utilizing ISWI instrument data. The workshop also focused on the following: (a) assessment of the status of both in-situ and space-borne space weather instruments, access to and availability of data, and collection and modelling efforts to advance space weather research and improve space weather forecasting; (b) continued efforts in space

<sup>5</sup> See [www.unoosa.org/oosa/en/ourwork/icg/activities/2021/CSISTokyo/presentations2.html](http://www.unoosa.org/oosa/en/ourwork/icg/activities/2021/CSISTokyo/presentations2.html).

<sup>6</sup> See the report on the United Nations/Mongolia workshop on the applications of global navigation satellite systems (A/AC.105/1252).

<sup>7</sup> See [www.unoosa.org/oosa/en/ourwork/psa/schedule/2021/2021-seminar\\_IDM\\_-presentations.html](http://www.unoosa.org/oosa/en/ourwork/psa/schedule/2021/2021-seminar_IDM_-presentations.html).

weather education, especially for young researchers, including increasing the participation of women from developing countries; and (c) forging international cooperation and collaboration in addressing issues related to space weather, such as cooperation towards establishing a truly global space weather monitoring capability.

28. A total of 323 specialists, 37 per cent of whom were women, representing national space agencies, academia, research institutions, international organizations and industry, from 54 countries were invited to participate in the workshop. Lectures were given by invited experts from India, Japan, the United Kingdom of Great Britain and Northern Ireland, the United States and ICTP. The representative of the Office for Outer Space Affairs made a presentation on the activities of ICG related to space weather and GNSS capacity-building.

29. Detailed information about the workshop is available on the website of the Office for Outer Space Affairs.<sup>8</sup>

### III. Technical advisory services

30. In order to inform a wide audience about the current status and future role of ICG in the multi-GNSS arena and to receive feedback from the entire GNSS community, the Office for Outer Space Affairs participated in and contributed to the following international conferences held in person and/or virtually in 2021:

(a) Munich Satellite Navigation Summit, on the theme “GNSS: providing solutions for life on Earth”, held in Munich, Germany, on 16 and 17 March 2021;

(b) Twelfth China Satellite Navigation Conference, held in Nanchang, China, from 26 to 28 May 2021;

(c) A discussion on satellite positioning systems on inland waterways held during the fifty-ninth session of the Working Party on the Standardization of Technical and Safety Requirements in Inland Navigation, held in Geneva from 23 to 25 June 2021;

(d) Thirty-fourth General Assembly and Scientific Symposium of URSI, held in Rome from 28 August to 4 September 2021.

31. The Office for Outer Space Affairs contributed to a virtual briefing to the Diplomatic Academy of Costa Rica on 20 May 2021. The briefing was organized by the Permanent Mission of Costa Rica to the United Nations (Vienna) to exchange views and experiences concerning advances in the space sector and its importance for the future sustainable development of the planet, communities and economies. A presentation on building the capacity of developing countries in using GNSS technology for sustainable development highlighted the activities of the ICG programme on GNSS applications and the work carried out by the ICG working groups.

32. The Office also contributed to a virtual joint meeting with the Space Research and Technology Agency of Uzbekistan. The meeting, facilitated by the Office of the United Nations Resident Coordinator for Uzbekistan, was held on 23 September 2021. The meeting provided an opportunity for the executive secretariat of ICG to present information on its education and training activities on GNSS and related applications, as well as its research and development programmes on GNSS.

33. The Office organized and chaired a preparatory meeting for the fifteenth meeting of ICG; the preparatory meeting was held virtually on 7 June 2021. The Office also organized a meeting of the Co-Chairs of the ICG working groups, held on 17 August 2021.

<sup>8</sup> See [www.unoosa.org/oosa/en/ourwork/psa/schedule/2021/2021-iswi-workshop-2021-presentations.html](http://www.unoosa.org/oosa/en/ourwork/psa/schedule/2021/2021-iswi-workshop-2021-presentations.html).

34. The Office organized and chaired the fifteenth meeting of ICG, held in Vienna from 27 September to 1 October 2021. The Providers' Forum, co-chaired by India and the European Commission, held its twenty-fourth meeting on 27 September 2021 and 1 October 2021. The meetings were held in a hybrid format.

35. In order to make further progress on the workplans of the ICG working groups and their recommendations, the working groups and their subgroups held a series of virtual intersessional meetings and workshops in 2021. The ICG working groups also met in Vienna on 27 and 29 September 2021, in conjunction with the ICG annual meeting.

36. The ICG working group on systems, signals and services, through its subgroups and task forces, made progress in advancing its workplan during the intersessional period between the fourteenth meeting of ICG in 2019 and the fifteenth meeting of ICG in 2021. Under the leadership of the subgroup on compatibility and spectrum protection, the ninth workshop on GNSS interference detection and mitigation was conducted online on 24 August 2021. At the workshop, a number of concepts and ideas were presented in relation to interference detection and mitigation capabilities and methodologies, as well as GNSS resilience. The working group continued its campaign to promote adequate protection of the GNSS spectrum by agreeing on a plan for completing a booklet on the importance of spectrum protection and interference detection and mitigation. The subgroup on interoperability and service provision held three virtual meetings during the intersessional period focused on making continued progress on its activities, consistent with its workplan.

37. The ICG working group on enhancement of GNSS performance, new services and capabilities made progress in its activities. The space use subgroup of the working group issued the second edition of the publication entitled *The Interoperable Global Navigation Satellite Systems Space Service Volume (ST/SPACE/75/Rev.1)*, which represents a thorough review and update of all of the content of the first edition, including the latest constellation data from all providers and adding real-world flight experiences of GNSS space users. In addition, the subgroup published a companion video on the space service volume.<sup>9</sup>

38. The project team on low-cost receivers for space weather of the ICG working group on information dissemination and capacity-building held an online meeting on 27 October 2021. The project team worked towards developing prototype systems to explore the possibility of using low-cost receiver systems for space weather monitoring.

39. The ICG working group on reference frames, timing and applications made specific progress on the refinement of the alignment of GNSS reference frames to the International Terrestrial Reference Frame and on the information on GNSS timing references and the comparison of GNSS time offsets.

40. In 2021, ICG activities were successfully implemented thanks to the support and voluntary contributions, both financial and in-kind, provided by ICG members. In addition, ICG members, associate members and observers provided technical advisory services and arranged for experts to make technical presentations and participate in discussions during activities described in the present report.

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<sup>9</sup> Available at [www.unoosa.org/oosa/en/ourwork/icg/documents/videos.html](http://www.unoosa.org/oosa/en/ourwork/icg/documents/videos.html).