16th meeting of the International Committee on Global Navigation Satellite Systems,

Abu Dhabi, United Arab Emirates

10 – 14 October 2022

Joint Statement

1. The sixteenth meeting of the International Committee on Global Navigation Satellite Systems (ICG) was held in Abu Dhabi, from 10 to 14 October 2022 to continue reviewing and discussing 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 countries, organizations and associations regarding GNSS services and applications.

2. H.E. Salem Al Qubasi, Director General of the United Arab Emirates Space Agency delivered an opening statement on behalf of the United Arab Emirates. A representative of the Office for Outer Space Affairs of the United Nations Secretariat also addressed the meeting.

4. The meeting was held with in-person and online attendance by representatives of Australia, China, India, Italy, Japan, Malaysia, New Zealand, the Republic of Korea, the Russian Federation, the United Arab Emirates, the United States of America and the European Union, as well as the following intergovernmental and non-governmental organizations: Arab Institute of Navigation (AIN), Asia-Pacific Space Cooperation Organization (APSCO), Civil Global Positioning System Service Interface Committee (CGSIC), Committee on Space Research (COSPAR), European Space Agency (ESA), Interagency Operations Advisory Group (IOAG), International Bureau of Weights and Measures (BIPM), Federation Aeronautique International (FAI), International Federation of Surveyors (FIG), International Association of Geodesy (IAG), International Association of Institutes of Navigation (IAIN), International GNSS Service (IGS) and the International Telecommunication Union (ITU). Representatives of the Office for Outer Space Affairs also participated.

5. Representatives of Pakistan, Türkiye, the African Regional Centre for Space Science and Technology Education - in English Language (ARCSSTE-E, Nigeria), the Centre for Space Science and Technology Education in Asia and the Pacific (CSSTEAP, India), the Regional Centre for Space Science and Technology Education in Asia and the Pacific (RCSSTEAP, China), International Maritime Organization (IMO), Radio Technical Commission for Maritime Services (RTCM) were invited to attend as observers. RTCM was recognised as a new observer of ICG.

6. The ICG discussed the request from 04 January 2021 for membership status in the ICG from Pakistan. There was no consensus on Pakistan's membership, while there were no objections so far.

7. ICG conducted an expert seminar entitled “Low Earth Orbit Positioning, Navigation and Timing (LEO-PNT)”. Presentations described LEO PNT as a new concept being studied by which PNT services can be offered through LEO satellite constellations.

8. ICG noted that the working groups had focused on the following issues: systems, signals and services; enhancement of GNSS performance, new services and capabilities; information dissemination and capacity-building; and reference frames, timing and applications.

9. The Working Group on Systems, Signals and Services (Working Group S), through its subgroups and task forces, continued the work outlined in its workplan during the intersessional period between ICG-15 and ICG-16. Under the leadership of the Subgroup on Compatibility and Spectrum Protection, the Working Group continued its campaign to promote adequate protection of GNSS spectrum by reviewing relevant GNSS/RNSS-related ITU activities. The Subgroup agreed to conduct a workshop on interference detection and mitigation prior to the next ICG meeting, focused on utilizing ADS-B and AIS for interference detection, and further investigating national processes for notification of interference testing. The Working Group also finalized a recommendation regarding the resilient use of GNSS for critical infrastructure, which was adopted by the full Committee. A potential future recommendation related to notification for GNSS testing was discussed, but no consensus was reached.

10. The subgroup on Interoperability and Service Provision held a virtual meeting during the intersessional period focused on continuing to make progress on the objectives in its workplan. The Performance Standards group held monthly virtual meetings combined with the International GNSS Monitoring and Assessment (IGMA) Task Force. The Performance Standards group continued work on a “Hints and Tips” document and agreed to organize a workshop in 2023 to examine existing and future Low Earth Orbit (LEO) PNT systems, including those provided by commercial industry. The IGMA Task Force continued to make progress on calculation methodologies and data formats for the Joint ICG-IGS Trial Project and plans to hold an in-person workshop focused on addressing issues that cannot be resolved through virtual meetings. The IGMA Task Force also plans to meet in 2022 or 2023 to review the Terms of Reference for the Trial Project. The IGMA Task Force and Performance Standards groups plan to continue to hold combined virtual meetings on a monthly basis. During a joint working group session on timing interoperability, discussion focused on the need for an in-person workshop to be held in conjunction with Working Groups B and D, to discuss timing interoperability in more detail. There was broad consensus that the timing needs for terrestrial users are different from space users. Finally, the Precise Point Positioning (PPP) Interoperability Task Force continued pulling together information on planned systems through collection of information from service providers on the characteristics of their services. The Task Force plans to hold a meeting and

workshop in 2022 or 2023 to continue discussing future plans and identify ways to further enhance interoperability.

11. Under the Working Group's workplan focused on System of System Operations, the providers continued to provide feedback on the 2020 report from the Inter-Agency Space Debris Coordination Committee that followed a recommendation from ICG-13 to study the issue of debris mitigation practices relevant to the MEO and IGSO orbital regimes used by GNSS. The Working Group intends to complete a response to the report and further discuss ways that ICG providers can work together to mitigate the risk of satellite collisions. Finally, the working group received presentations from system providers who are looking into methods for authentication of open civil signals.

12. The Working Group on Enhancement of GNSS Performance, New Services and Capabilities (Working Group B) has progressed in its activities.

13. The Working Group B Space Use Subgroup (SUSG) informed the Working Group on the progress made since the fifteenth meeting of ICG. The SUSG met thirteen times in this period, including one face-to-face meeting in Vienna in June 2022. The SUSG reviewed the progress on its work plan for the period 2021–2022, including the five work packages: WP1–WP5. The activities of nearly all work packages have started and meetings were held on a regular basis. Good working progress was made for all the initiated WPs.

14. The SUSG also summarized interactions with IOAG via the ICG-IOAG liaisons. The proposed areas of coordination between the two organizations relate to development of lunar PNT architectures and include establishing necessary liaison roles, documenting lunar use cases, encouraging lunar flight experiments, and making recommendations to maximize interoperability, compatibility and availability of the combined GNSS and lunar PNT "system of systems".

15. Since ICG-15, the Application Subgroup (AppSG), under WG-B, has been working on an initiative, "GNSS applications: for present and future". The current AppSG activities focus on studying GNSS application cases which exist on the market or under final development before market release. The AppSG activities are intended to provide assistance, lessons-learned and guidance to GNSS users. This initiative will lead to a booklet as a research report entitled "GNSS Applications for Sustainable Development – Case Studies".

16. The GNSS application on disaster prevention and mitigation is among the focus areas that AppSG is working on. WG-B and AppSG recognize that the proposed study area, namely "GNSS applications for disaster risk reduction", intersects with the current AppSG activities and therefore support the recommendation to study novel GNSS applications on the disaster prevention systems. WG-B and in particular the AppSG will actively contribute to the new joint task force of WG-D and WG-B on "Applications of GNSS for Disaster Risk Reduction".

17. Further enhancements are identified to create opportunities for greater participation and to attract new contributions to AppSG. The AppSG intends to participate in important GNSS conferences and events to promote GNSS application development and to obtain information about trends in GNSS applications in line with the new initiative. AppSG also intends to support the UNOOSA GNSS Application Workshop.

18. WG-B appreciates the variety of the contributions such as the Galileo EWS, BDS SAR, Space Service Volume Applications and LunaSAR, illustrating the convergence of science, PNT and communication systems. The WG-B notes the efforts towards interoperability of the Emergency Warning Services. The growing importance of the scientific and commercial (such as agriculture applications) use of GNSS is noted by WG-B.

19. WG-B recognizes the early development of lunar search and rescue capabilities and the importance of interoperability among lunar communication and navigation providers intending to offer these services. The WG-B discussed and agreed upon the recommendation that developers of lunar communication and navigation services consider the integration of Search and Rescue services, and that these services be interoperable and easily accessible.

20. WG-B recognises the potential impact of the rising solar activities of 25th solar cycle could have on GNSS services and satellites. Further discussions among experts through workshops should be conducted to understand the possible impact of space weather events and the need for alert systems. This will be subject to further discussion in WG-B 2023 intersessional meeting.

21. The Working Group on Information Dissemination and Capacity-building (Working Group C) addressed all areas of its workplan. Representatives of China, India, Italy, Japan, the Russian Federation, Malaysia, Pakistan, the United States, the Republic of Korea, the United Arab Emirates, and ESA participated in the work of the Working Group. Presentations were made on GNSS education programmes provided by their respective organizations. The Working Group received an update on the activities undertaken or supported by the Office for Outer Space Affairs during 2022 and the main results achieved.

22. The Working Group noted the work of the United Nations-affiliated regional centres for space science and technology education, also acting as information centres for ICG. The Working Group would continue to collaborate with the regional centres to further develop the GNSS curriculum and MOOC (Massive Open Online Courses), as well as to provide support in carrying out seminars and training courses on GNSS and its applications.

23. The Working Group's project team made a progress to (1) explore Low-Cost GNSS Receivers that could be used to compute total electron content (TEC) related parameters; (2) explore software that could be used for processing data from low-cost GNSS receivers to compute TEC; and (3) design prototype low-cost GNSS receiver for space weather related applications.

24. The Working Group on Reference Frames, Timing and Applications (Working Group D) noted progress on the geodetic and timing references by the GNSS and RNSS Providers. Specific progress was noted: (1) release of satellite metadata for better orbit dynamic modeling; (2) alignments of GNSS reference frames to the ITRF, and (3) progress and decision to draft a recommendation on timing interoperability for ground users.

25. WG-D noted that the templates on geodetic and timing references currently provided on the ICG website should be updated by the GNSS and RNSS Providers to contain the most current information. Moreover the tracking of updates on the web repository should be improved.

26. WG-D reiterates that satellite metadata information such as physical and geometrical properties related to the shape, mass, optical properties, dimensions and locations of radiating antennas permits improved orbit modeling, which in turn increases the accuracy of satellite ephemerides and clock correction determination. This information will hugely benefit the scientific and research community. WG-D acknowledges that there has been some progress made in the provision of satellite properties by the GNSS and RNSS Providers based on Recommendation #23 "Improving the accuracy of multi-GNSS orbits determined by the IGS" in accordance with the whitepaper titled "Satellite and Operations Information for Generation of Precise GNSS Orbit and Clock Products" released by the IGS. The IGS collects and makes available GNSS satellite properties to the user community. Access to satellite metadata is essential for enabling scientific applications and for high accuracy precise positioning. WG-D also noted that provision of GNSS satellite Phase Center Offsets (PCOs) significantly contributes to the determination of the scale of the GNSS/IGS reference frame and allows intercomparing with SLR and VLBI scales used to determine ITRF scale. WG-D acknowledges significant progress in the release of additional satellite metadata by Galileo, QZSS, and BDS; and the Galileo PCOs were used in the determination of the scale of the GNSS/IGS reference frame in Repro3 solution, contributing to the realization of ITRF2020. GNSS providers are solicited to continue publishing satellite metadata, including PCOs.

27. WG-D noted little progress on Recommendation #12 "Interoperability of geodetic references among the different GNSS systems". Some Providers are providing GNSS data from their tracking stations to the IGS. WG-D will continue to monitor progress (in conjunction with IGMA); demonstrate the benefits and encourage all GNSS Providers to contribute. WG-D continues to contribute to the IGMA initiative, in particular through involvement in the IGMA-IGS Joint Trial Project.

28. In a meeting of the WG-D Task Force on Timing, ESA and CNES presented their works in the field of accurate multi-GNSS time monitoring, emphasizing the crucial need for accurate calibration of multi-GNSS receiver chains.

29. WG-D noted the progress by the BIPM towards implementation of Recommendation #20 "BIPM publication of [UTC – GNSS times] and [UTC – UTC(k)_GNSS]". Details on the procedure leading to the publication for all four GNSS have been presented. Concerning Recommendation #16A "Information on the works related to the proposed redefinition of UTC", BIPM presented the status of the discussions on the continuous UTC with possible upcoming agreement at the General Conference on Weights and Measures (Conférence Générale des Poids et Mesures, CGPM) in November 2022 and at the World Radio Conference (WRC) in 2023.

30. WG-D noted the status of GNSS calibrations performed in the frame of BIPM for the computation of UTC. The 2020 calibration included Galileo in addition to GPS, and in 2022 BIPM will include BDS as well.

31. WG-D acknowledged the great progress in the development of the NavIC iRAFS (indigenous Rubidium Atomic Frequency Standard) by India, which presented an application scenario of NavIC derived timing for quantum communications experiments and the testing that was carried out using NavIC

to support quantum communication by entanglement. India also provided a presentation on NavIC-enabled IGS stations.

32. WG-D examined developments on Recommendation #21-B "On the monitoring of offsets of GNSS times". It acknowledged the work carried out by the Consultative Committee for Time and Frequency (CCTF) and its working groups and task groups, emphasizing that the current predictions of UTC broadcast by the GNSS through the message [$bUTC_{GNSS}$-GNSS time] provide a ready-to-use and robust method to determine GNSS-to-GNSS timing offsets (GGTO), in addition to existing methods (see next paragraph). WG-D also noted that the CCTF 2021 *Recommendation_GNSS 1* invited receiver manufacturers to consider this possibility for interoperability.

33. WG-D concluded that the inter-system bias can be determined using three different methods:

    a. the direct determination using the GNSS measurements when enough satellites are in view (single-station method),
    b. use of direct broadcast GNSS-to-GNSS time offset, or
    c. the [$bUTC_{GNSS}$ - GNSS time] predictions currently broadcast by the GNSS.

34. Studies showed that the difference between broadcast predictions of UTC has negligible impact for mass-market ground users. Therefore, there is no need to create an ad hoc time scale as a common pivot for timing interoperability. WG-D acknowledged the fact that the needs of space users may lead to different requirements. The evaluation of these space users' needs has been initiated by WG-B. WG-D proposed follow-on discussions on timing interoperability for space users should be carried out in a joint meeting with WG-B, -S and -D.

35. Notably, at the joint session with WG-S, -B, and -D on timing interoperability, it was finally agreed to develop a joint ICG WG-S, -B, and -D Recommendation that aligns to the 2021 CCTF *Recommendation_GNSS 1* for ground users. This Recommendation is expected to be ready for consideration at ICG-17.

36. WG-D noted the recent efforts of the United Nations Committee of Experts on Global Geospatial Information Management (UN GGIM) and its Subcommittee on Geodesy (SCoG), namely the ongoing work of building and maintaining a Global Geodetic Reference Frame (GGRF), as well as the plans for establishment of a UN Global Geodetic Centre of Excellence (GGCE) at the UN campus in Bonn, Germany.

37. WG-D expressed its support for the GENESIS scientific program, including the GENESIS mission. The GENESIS mission, by providing space ties between four different geodetic techniques, has the potential to notably improve the determination of the terrestrial reference frame as well as support the International Association of Geodesy, Global Geodetic Observing System (IAG-GGOS) requirements, and in alignment with the United Nations General Assembly Resolution (A/RES/69/266, Global Geodetic Reference Frame (GGRF) for Sustainable Development). This mission will provide a wide range of benefits not only for geodesy, but also for precise navigation, earth science, and climate change monitoring, to name a few. In addition, its spirit of social benefit through technological community-building, aligns strongly with the spirit of international collaborations in geodesy, noting that global users of openly available data and products will benefit from these advances. Furthermore, the option of embarking

advanced time transfer techniques, in addition to the primary geodetic objectives, would be very useful to compare ground clocks in view of the redefinition of the SI-second. Thereby, the ICG WG-D supports the GENESIS mission project and strongly encourages ESA to carry out this fundamental mission.

38. WG-D proposed to establish a Joint Task Force on "Applications of GNSS for Disaster Risk Reduction" to be based in WG-D and co-chaired between WG-B and -D. This task force would center on novel applications of GNSS data and infrastructure to support sustainable development and disaster risk reduction, and would be in alignment with the United Nations Sustainable Development Goals and Sendai Framework for Disaster Risk Reduction. The first application to be considered by this group would be the use of GNSS to enhance tsunami early warning systems.

39. WG-D, together with WG-S and -B, highlighted the importance of harmonizing key aspects of System Provided PPP services, in particular definition of PPP terminology, as well as the coordinates reference frame and timing system. WG-D reiterated that interoperability of the GNSS precise positioning requires interrelationship of the timing and geodetic references to reduce ambiguities for users with regard to the interpretation of navigation and timing solutions. WG-D found it desirable, from the user point of view, to relate or align different GNSS frames to the ITRF.