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Report on the United Nations/United Arab Emirates/ United States of America Workshop on Applications of Global Navigation Satellite Systems

(Dubai, 16-20 January 2011)

I. Introduction

1. By its resolution 54/68, the General Assembly endorsed "The Space Millennium: Vienna Declaration on Space and Human Development",[1] which had been adopted by the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in Vienna from 19 to 30 July 1999. In the Vienna Declaration, the States participating in UNISPACE III called for action to be taken to improve the efficiency and security of transport, search and rescue, geodesy and other activities by promoting the enhancement of, universal access to and compatibility of space-based navigation and positioning systems.

2. Since 2001, the Office for Outer Space Affairs of the Secretariat has organized a series of regional workshops and international meetings to promote the use of global navigation satellite systems (GNSS). At the workshops and meetings, participants have presented information on the status of existing and near-term navigation satellite systems and their augmentations, as well as examples of GNSS applications that support sustainable development. In its resolution 65/97, the General Assembly welcomed the progress made by the International Committee on Global Navigation Satellite Systems (ICG) towards achieving compatibility and interoperability among global and regional space-based positioning, navigation and timing systems and in the promotion of the use of GNSS.

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[1] *Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999* (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1.

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3. At its fifty-third session, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and conferences scheduled for 2011 (A/65/20, para. 79). Subsequently, the General Assembly, in its resolution 65/97, endorsed the United Nations Programme for Space Applications for 2011.

4. Pursuant to General Assembly resolution 65/97 and as part of the United Nations Programme on Space Applications, the Office for Outer Space Affairs held the United Nations/United Arab Emirates/United States of America Workshop on Applications of Global Navigation Satellite Systems in Dubai from 16 to 20 January 2011. The Emirates Institution for Advanced Science and Technology hosted the Workshop on behalf of the Government of the United Arab Emirates. The Workshop was co-sponsored by the United States of America through ICG.

5. The present report contains information on the background and objectives of the Workshop and provides a summary of the presentations and observations made by the Workshop participants.

A. Background and objectives

6. The use of the signals received from existing GNSS, the best known of which are the Global Positioning System (GPS) of the United States and the Global Navigation Satellite System (GLONASS) of the Russian Federation, has become a cross-cutting tool to support growth in precise positioning applications. With Europe's Galileo satellite navigation system and China's Compass/BeiDou navigation system currently being developed and deployed, the number of satellites available at any given time will greatly increase, thereby enhancing the quality of the services and increasing the number of potential users and applications. Furthermore, a number of space-based augmentation systems and regional navigation satellite systems will add more satellites and signals to multiple systems of satellites and, as a result, improve positioning performance in terms of accuracy, availability, reliability and integrity. To benefit from these achievements, countries need to stay abreast of the latest developments in GNSS-related areas and build the capacity to use the GNSS signal.

7. The five-day workshop on applications of GNSS was aimed at increasing awareness among decision makers and policymakers of the benefits of satellite navigation technology and establishing a broad framework for regional and international cooperation. Participants in the workshop addressed recent developments in current and planned global and regional navigation satellite systems. Various sessions featured discussions about perspectives and critical issues regarding the increasing number of applications for satellite navigation.

8. The objectives of the Workshop were the following: to demonstrate the benefits and opportunities with regard to maximizing the use of multiple GNSS; to communicate with providers about compatibility and interoperability requirements; to present users with the equipment and the ground augmentation infrastructure needed to support high-accuracy applications such as geodesy, surveying and mapping; and to bring together a panel of experts to focus on developing a curriculum for a basic course on GNSS. The Workshop was structured so as to provide participants with detailed examples of various GNSS applications and tools

that could help participating countries and organizations integrate GNSS services into their infrastructure. The specific objective was to strengthen regional information and data exchange networks with regard to the use of GNSS technology, including for various training programmes and for meeting capacity-building needs.

B. Programme

9. At the opening of the Workshop, introductory and welcoming statements were made by the Minister of Higher Education and Scientific Research of the United Arab Emirates and the Director General of the Emirates Institution for Advanced Science and Technology on behalf of the Government of the United Arab Emirates, as well as by representatives of the Office for Outer Space Affairs and the Department of State of the United States. Representatives of the Office for Outer Space Affairs and King Abdulaziz City for Science and Technology of Saudi Arabia made keynote presentations. The Workshop was inaugurated by the Crown Prince of Dubai.

10. The Workshop was divided into plenary and parallel working group sessions, each focusing on a specific issue. Presentations by invited speakers, describing satellite navigation and how it could be used in an operational scenario, were followed by an interactive discussion period. A total of 37 papers were presented by invited speakers from both developing and developed countries. Working group sessions provided participants with an opportunity to focus on specific problems and projects related to GNSS, geodetic reference networks and specific applications, as well as education and training opportunities in the field of GNSS.

11. Workshop thematic sessions focused on the following topics: trends in satellite-based navigation systems; GNSS services and reference frames; GNSS augmentation and applications; activities in the field of GNSS applications; education and training on GNSS; and case studies.

12. The Workshop was conducted in Arabic and English, with the use of simultaneous interpretation.

C. Attendance

13. Representatives of universities, research institutions, national space agencies, international organizations and industry, from developing and developed countries from all regions, involved in all the aspects of GNSS covered by the Workshop were invited by the United Nations, the Emirates Institution for Advanced Science and Technology and ICG to participate in the Workshop. Participants were selected on the basis of their scientific background and their experience in programmes and projects in GNSS technology and its applications.

14. Funds provided by the United Nations and the Government of the United Arab Emirates, as well as the Government of the United States through ICG, were used to defray the costs of air travel and accommodation for 20 participants and two representatives of the Office for Outer Space Affairs. A total of 100 specialists in satellite navigation systems were invited to attend the Workshop.

15. The following 33 Member States were represented at the Workshop: Algeria, Azerbaijan, Bangladesh, China, Côte d'Ivoire, Croatia, Egypt, Germany, Indonesia, Iraq, Japan, Kazakhstan, Kyrgyzstan, Latvia, Lebanon, Malawi, Morocco, Myanmar, Pakistan, Republic of Korea, Republic of Moldova, Romania, Russian Federation, Saudi Arabia, Spain, Thailand, Tunisia, Turkey, United Arab Emirates, United Kingdom of Great Britain and Northern Ireland, United States, Uzbekistan and Yemen. The Office for Outer Space Affairs was also represented.

II. Summary of presentations

16. Brief presentations and statements by panellists, at the beginning of each session, provided participants with the opportunity to share and receive up-to-date information on satellite-based navigation systems for use in a variety of innovative and emerging applications. The keynote addresses set the tone for the discussions carried out during the Workshop, emphasizing the important role of ICG as a forum for all the major players in the field of GNSS for ensuring compatible, interoperable GNSS services for the benefit of all. Additionally, the need for national space policies that could address countries' scientific interests and activities in the space arena was presented by the representative of King Abdulaziz City for Science and Technology.

17. The presentations made at the Workshop and the abstracts of the papers, as well as the Workshop programme and background materials, are available from the website of the Office for Outer Space Affairs (www.unoosa.org).

18. Participants noted that GNSS systems had become a critical component of today's global information infrastructure, enabling many new applications that provided broad capabilities in facilitating innovations in efficiency, safety, security, environment and science around the globe. It was noted that, while GPS had been in operation since the mid-1990s, a GPS modernization programme was currently under way, bringing additional and new capabilities to users of positioning, navigation and timing services. GPS IIIA satellites would be the first GPS satellites to broadcast the new fourth civil signal, L1C, which would be compatible and interoperable with services from other GNSS. Meanwhile, the approval of the GLONASS federal programme marked the revival of that system. The deployment of the full 24-satellite constellation would ensure continuous global navigation service for worldwide users. The next generation, GLONASS-K, would broadcast the first code division multiple access (CDMA) channelization protocol, in addition to the system's usual frequency division multiple access (FDMA) transmissions. That would bring the system into closer alignment with other GNSS, which all used the CDMA protocol.

19. It was noted that the focus of satellite navigation systems was to provide global accurate and reliable positioning, navigation and timing services. Participants noted the progress in the development of the European satellite navigation system Galileo and the fact that Surrey Satellite Technology Limited was responsible for the navigation payloads on board that would form the heart of the first batch of 14 Galileo satellites. Each payload would be comprised of a number of subsystems that would combine to generate the navigation messages broadcast by the satellites directly to users' receivers. One medium-Earth orbit satellite, four geosynchronous

satellites and two inclined geostationary orbit satellites had been launched with orbit determination precision smaller than 10 m and time synchronization precision smaller than 2 ns during China's Compass deployment phase. It was noted that Japan's Quasi-Zenith Satellite System (QZSS) would vastly improve GNSS accuracy over Japan and the Asia and Pacific region, transmitting signals compatible and interoperable with existing and future modernized GPS signals.

20. Countries in all regions were embracing the use and application of GNSS technologies, particularly GPS, in various geo-information applications, services and products. Regional GNSS networks were currently being used for tectonic studies and for reference frame densifications. As computing facilities and GNSS data analysis software improved, more users were able to process a global GNSS network. Participants noted that the Continuous Operating GNSS Network (COGNET) for Saudi Arabia would be realized through a set of continuously operating reference station observation systems at such a density that professionals could use it as reference from anywhere on the Arabian Peninsula for their geo-referencing activities and scientific applications in geodynamics, ionospheric and troposheric research. Other challenges were to make GPS observations of dynamic and co-seismic displacements at a frequent rate and in real time and to assimilate those data into an earthquake model within a few minutes of an event. As a result, a wide area of the Indonesian permanent GNSS stations network of continuous GPS networks operating in real-time mode throughout the archipelago was being developed.

21. The ongoing process of the establishment of high precise differential GNSS (DGNSS) positioning services and their respective GNSS reference station networks, which were related to the GNSS-consistent International Reference Frame with its different realizations, implied the replacement of georeferencing in the classical national reference frames with one related to the International Reference Frame. Participants noted that the LatPos system included continuously operated GPS base stations evenly distributed throughout the territory of Latvia. A GPS reference station made it possible for a user's GPS receiver to establish coordinates with the accuracy of 2 centimetres in real time and 5 millimetres if stored data were used. Data covering a longer period were also available for scientific purposes. Additionally, LatPos was expected to be able to receive signals from GLONASS and Galileo. Furthermore, the Monitoring by the Karlsruhe Approach (MONIKA) and software for monitoring GNSS reference stations, presented by the Republic of Moldova, could be used for permanent GNSS stations as a geosensor network for geodynamic research, as well as for the setting up of temporary GNSS arrays as a disaster monitoring and early warning GNSS service (e.g. for landslides, floods and construction areas).

22. The augmentation infrastructure of GNSS monitors the accuracy, availability, continuity and integrity of navigation satellite signals by analysing their performance at known points on the Earth's surface called reference stations. GNSS augmentation services then transmit error corrections and integrity information to user equipment in a timely and reliable manner. There are two transmission methods for augmentation services: satellite-based augmentation systems transmit services via communication satellites, and ground-based augmentation systems transmit services using terrestrial communications such as radio, mobile networks or the Internet. Participants noted that the Nationwide Differential GPS System provided

coverage throughout the United States and was used in transportation, maritime, safety, surveying and safety and security applications. The national continuously operating reference stations provided post-processed data that could be used for applications such as geological monitoring, monitoring of sea-level change, surveying and mapping, while ground-based augmentation systems were used to provide advanced capabilities for air navigation. The Wide-area Augmentation System of the United States was similar to the European Geostationary Navigation Overlay Service (EGNOS) for Europe, which had been designed to enable advanced air navigation capabilities but included other applications such as maritime navigation and agricultural use. Participants also noted the project for "GNSS introduction in the aviation sector" (GIANT), which demonstrated how GNSS systems met in particular the needs of regional airline, general aviation and helicopter operators; special efforts within the project were devoted to flight demonstrations. The project introduced the EGNOS-based localizer performance with vertical guidance applications.

23. With the successful launch of a QZSS satellite, Japan had started demonstrations of QZSS technology to further utilize GPS-compatible signals for navigation systems. The high-accuracy QZSS positioning system promised to expand the possibilities for a variety of applications, for example with regard to environmental conservation and the realization of a secure society by using an advanced traffic control system, including for rescue operations, agriculture and satellite remote sensing (e.g. mapping of growing conditions and distribution of soil components) and personal services using augmented reality technology. The status of GNSS applications within the civil air navigation service providers of the United Arab Emirates was presented. Navigation accuracy standards, air transport system procedures and development and training requirements needed to safely implement GNSS-related airspace updates were also addressed. Participants noted that the GNSS known as PAK-SBAS would be supported by a planned regional augmentation system through the use of the future Pakistan MM2 satellite to broadcast messages for GPS, Galileo and Compass. Using the ground stations, GNSS measurements and correction messages would be generated and sent to the MM2 geostationary satellite to be broadcast to end users.

24. Over the past decade, the number of applications that utilize GNSS has grown tremendously. Placing an emphasis on the development of applications, the presentations provided detailed examples of a broad range of applications, from the traditional location-based applications to those that combined GNSS with other sensors and systems to specific applications, such as remote sensing and space weather monitoring. As an example, Internet-based, wide-area real-time GPS could provide an integrated positioning system to attain sub-centimetre positioning accuracy. For increased demands on railroad operations, a GNSS-based module with multiple sensors would allow robust plausibility checks and provide a very reliable and integer position solution. Similarly, at sea, a delay-Doppler mapping GPS receiver had been used to explore the possibility of determining wind speed; the results indicated a good correlation between the measured and the modelled normalized signal power waveforms during changing surface wind conditions. For studying space weather, GPS and GLONASS offered a unique opportunity to monitor the total electron content of the ionosphere on a global scale.

25. It was noted that the development of GNSS technology and its applications highlighted both the increased interest in satellite navigation and the urgent need for highly qualified personnel in that field. Participants noted that satellite navigation had been shown to be a complex environment in which several disciplines were involved, from the basic technologies covering an understanding of GNSS, its capabilities and limitations and the extent of its applications to the capabilities of creating market-oriented innovative and effective products. Participants noted the positive experience of the Romanian Space Agency, the Geoinformatics and Space Technology Development Agency of Thailand and Moscow State University of Geodesy and Cartography of the Russian Federation. Participants also noted the available capacity-building opportunities offered by the regional centres for space science and technology education, affiliated to the United Nations, which would also serve as ICG information centres.

26. The presentations on national programmes and case studies gave participants an additional opportunity to share their experiences and knowledge in the use of GNSS technology and its applications. Participants were shown examples of the use of data from GNSS, particularly GPS, in aviation, mapping, disaster management and emergency response. The presentations provided discussion points for the working group sessions.

III. Conclusions and recommendations

27. Two working groups were established to summarize issues and topics identified in the presentations delivered at the thematic sessions of the Workshop. The first working group focused on issues related to capacity-building, institutional strengthening and international cooperation; the second one discussed ways and means of following up geodetic projects, based on continuous observation and analysis of GNSS, that could support many geospatial applications across the region, as well as practical aspects of GNSS applications for sustainable development. Accordingly, steps needed to build infrastructure and requirements for any geodetic regional reference frame were defined. The deliberations were summarized and presented at the closing session, when a final round-table discussion was held and the conclusions and recommendations were adopted.

28. The Workshop noted with satisfaction that the regional centres for space science and technology education affiliated to the United Nations were operational in Brazil, India, Mexico, Morocco and Nigeria. The Workshop emphasized that the establishment of such a regional centre in western Asia would be beneficial.

29. The Workshop agreed that the regional centres affiliated to the United Nations, also acting as information centres for ICG, could play an important role in capacity development and knowledge-building in the field of GNSS.

30. The Workshop strongly supported the development of an educational curriculum on GNSS that would supplement the existing educational programme of the centres, namely remote sensing and geographic information systems, satellite communications, satellite meteorology and global climate, and space and atmospheric science.

31. The Workshop noted that the Office for Outer Space Affairs would establish a group of educators and experts to develop a curriculum for a basic course on GNSS. In that context, participants were ready to provide relevant curricula taught in their universities.

32. The Workshop recommended that the educational curriculum should address the mathematical, physical and geodetic foundations of geospatial positioning with GNSS, including the basis for understanding GNSS and its applications. It was also recognized that better atmospheric modelling (ionosphere, troposphere and scintillation) could improve GNSS accuracy for all users, and that therefore topics related to a global understanding of GNSS anomalies should also be addressed.

33. The Workshop encouraged knowledge transfer via e-learning systems using Web-based distance learning programmes. In that context, participants were ready to provide relevant information and educational materials for inclusion in the ICG information portal (www.icgsecretariat.org), which was vital for disseminating information.

34. Recognizing the present status of GNSS and the prospects for continued development of a wide variety of applications critical to science, commerce and infrastructure, the Workshop recommended that more workshops and training courses should continue to be held on specific areas of interest to end users.

35. Recognizing that positioning applications in hazard assessment, mining, agriculture, construction, emergency, land, utility and asset management had a demonstrated need for centimetre-level or better geodetic infrastructure, the Workshop encouraged the creation of an Internet discussion forum to facilitate the exchange of ideas and information on case studies and technical solutions and/or where questions could be posted. It was further noted that the existing GNSS forum of the International Telecommunication Union could be used to avoid duplication of efforts.

36. Recognizing a number of ongoing projects and initiatives on the establishment of regional reference frame networks, such as the African Geodetic Reference Frame project, the European Position Determination System, the International Association of Geodesy Reference Frame Sub-Commission for Europe, the Geocentric Reference System for the Americas and the Asia-Pacific Reference Frame Project, the Workshop suggested that the institutions that were part of the regional networks should provide information to all interested institutions on activities carried out and foster partnerships among the different initiatives. In that context, the Office for Outer Space Affairs, in cooperation with ICG, or ICG by itself should be invited to assist in soliciting seed funding and expertise for potential projects on the regional geodetic framework.

37. The feedback received from participants was very positive, with participants saying that the topics addressed met their professional needs and expectations. Several participants committed to using the knowledge gained from the Workshop to introduce improvements to ongoing activities in their home institutions.