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Committee on the Peaceful Uses of Outer Space

Report on the United Nations/Croatia Workshop on the Applications of Global Navigation Satellite Systems

(Baška, Croatia, 21-25 April 2013)

I. Introduction

1. 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 addressed significant opportunities for human development through advances in space science and technology.[1] Among other achievements, it led to the establishment of the International Committee on Global Navigation Satellite Systems (ICG), a forum of providers and user communities in the field of global navigation satellite systems (GNSS).

2. One of the goals of ICG is to promote the greater use of GNSS capabilities to support sustainable development and promote new partnerships among Committee members and institutions, in particular taking into account interests of developing countries. The General Assembly, in its resolution 61/111, noted with appreciation that ICG had been established on a voluntary basis of mutual interest related to civil satellite-based positioning, navigation, timing and value-added services, as well as the compatibility and interoperability of GNSS, while increasing their use to support sustainable development, particularly in developing countries.

3. The Office for Outer Space Affairs, in its function as the secretariat of the Committee on the Peaceful Uses of Outer Space, also serves as the executive secretariat of ICG, in accordance with General Assembly resolution 64/86. In that capacity, the Office, within the framework of the United Nations Programme on Space Applications, conducts activities that focus on building capacity in the use of GNSS in support of sustainable development. Those activities concentrate on

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

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providing support for education and training in satellite navigation and location-based services, and space weather.

4. Regional workshops on applications of GNSS were held in China (A/AC.105/883) and Zambia (A/AC.105/876) in 2006, Colombia in 2008 (A/AC.105/920), Azerbaijan in 2009 (A/AC.105/946), the Republic of Moldova in 2010 (A/AC.105/974), the United Arab Emirates (A/AC.105/988) and Austria (A/AC.105/1019) in 2011 and Latvia in 2012 (A/AC.105/1022). Those workshops focused on initiating pilot projects and strengthening the networking of regional GNSS-related institutions.

5. A unique result of the deliberations of the above-mentioned workshops was the development of an educational curriculum on GNSS (ST/SPACE/59). The curriculum was developed taking into account GNSS course outlines used at the university level in a number of developing and industrialized countries. The published curriculum included a glossary of GNSS terms developed in the framework of the ICG Providers' Forum workplan.

6. The GNSS education curriculum was developed for nine-month postgraduate courses at the regional centres for space science and technology education affiliated to the United Nations, located in Brazil and Mexico (for Latin America and the Caribbean), India (for Asia and the Pacific), Jordan (for Western Asia) and Morocco and Nigeria (for Africa). An additional GNSS educational curriculum supplemented the proven standard model educational curricula of the regional centres for the following four core disciplines: remote sensing and geographic information systems; satellite meteorology and global climate; satellite communications; and space and atmospheric science (see www.unoosa.org/oosa/en/SAP/centres/index.html).

7. In view of the use of GNSS-based equipment for measuring space weather, and in an attempt to provide a forum for exchange among space weather scientists, GNSS experts and users, and providers and operators of instrument networks, ICG contributed to and co-sponsored several activities on the International Space Weather Initiative (ISWI).

8. With the support of the Office for Outer Space Affairs, ISWI had coordinated the operation of 16 space weather instrument arrays, including a number of different networks of ground-based global positioning system receivers, such as the African Global Positioning System Receivers for Equatorial Electrodynamics Studies (AGREES), the African Monsoon and Multidisciplinary Analyses (AMMA) and the Scintillation Network Decision Aid (SCINDA).

9. Organized by the United Nations, the National Aeronautics and Space Administration (NASA) of the United States of America and the Japan Aerospace Exploration Agency (JAXA), a series of three workshops on ISWI were held: in Egypt in 2010 (A/AC.105/994), in Nigeria in 2011 (A/AC.105/1018) and in Ecuador in 2012 (A/AC.105/1030).

10. The present report describes the background, objectives and programme of the Workshop and provides a summary of the observations and recommendations made by Workshop participants. It has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its fifty-seventh session and to its Scientific and Technical Subcommittee at its fifty-first session, both in 2014.

A. Background and objectives

11. At its fifty-fifth session, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and expert meetings related to environmental monitoring, natural resources management, global health, GNSS, space weather, basic space technology, space law, climate change, human space technology and the socioeconomic benefits of space activities to be held in 2013 for the benefit of developing countries (see A/67/20, para. 89). Subsequently, the General Assembly, in its resolution 67/113, endorsed the United Nations Programme on Space Applications for 2013.

12. Pursuant to Assembly resolution 67/113 and as part of the United Nations Programme on Space Applications, the United Nations/Croatia Workshop on the Applications of Global Navigation Satellite Systems was organized by the Office for Outer Space Affairs of the Secretariat and the Faculty of Maritime Studies of the University of Rijeka on behalf of the Government of Croatia. The Workshop was co-sponsored by the United States (through ICG) and hosted by the Faculty of Maritime Studies of the University of Rijeka in Baška, Krk island, Croatia, from 21 to 25 April 2013.

13. The main objective of the five-day Workshop was to provide a forum in which participants could share their technical expertise and experiences in specific GNSS-related projects through formal presentations and panel discussions. Furthermore, the Workshop was to develop a regional plan of action that would contribute to the wider use of GNSS technology and its applications, including the possible establishment of specific pilot projects in which interested institutions could work together at the national and/or regional level.

B. Programme

14. At the opening of the Workshop, introductory and welcoming statements were made by the President of Croatia (via video message), the representatives of the Ministry of Education, Science and Sports and the Ministry of Maritime Affairs, Transport and Infrastructure of Croatia and by the Rector of the University of Rijeka and the Dean of the Faculty of Maritime Studies of the University of Rijeka. Statements were made by representatives of the Office for Outer Space Affairs and the United States Embassy in Zagreb, as co-organizers and co-sponsors of the Workshop. The mayor of the municipality of Baška and the President of the Royal Institute of Navigation of the United Kingdom of Great Britain and Northern Ireland also addressed the Workshop.

15. A total of 27 presentations were made by invited experts from both developing and developed countries during the four technical sessions, which focused on the following themes: (a) GNSS user applications: case studies and opportunities for collaboration, (b) GNSS reference station networks and services, (c) space weather and GNSS and (d) capacity-building, training and education in the field of GNSS. Each technical session was followed by a panel discussion that addressed the challenges identified in the papers presented and future technology trends related to new GNSS signals.

16. The final day of the Workshop was dedicated to the two working group sessions. The first working group focused on GNSS applications and space weather effects on GNSS; the second working group discussed issues related to reference frames and coordinate systems. The observations and recommendations emerging from those working group discussions were summarized and presented at the closing session, when a final discussion was held and recommendations were adopted.

17. A one-day course for Workshop participants, held just prior to the technical sessions, provided in-depth information on specific GNSS-related disciplines. The instructors were GNSS experts from the Faculty of Maritime Studies of the University of Rijeka (Croatia), the Russian Space Agency (Russian Federation) and Beihang University (China). A representative of the Office for Outer Space Affairs gave an introductory talk on ICG, its work and potential for the future and its efforts to build capacity in space science and GNSS technology through the ICG programme on GNSS applications.

18. The course introduced current and planned systems and discussed the concepts of global positioning, navigation and timing and the signal used to precisely determine the location of the receiver and its accessibility for various end users. The course also focused on the GNSS positioning error budget and ionospheric effects on GNSS performance and operation. In the course, each participant carried out a performance analysis of Receiver Independent Exchange (RINEX)-format GNSS positioning data, using an open source programme package. Electronic notes have been made available on the website of the Office for Outer Space Affairs (www.unoosa.org).

19. An informative technical tour of the space weather laboratory of the Faculty of Maritime Studies of the University of Rijeka (see www.pfri.uniri.hr) was organized for Workshop participants. The tour included a demonstration of navigation simulators for various ships of different sizes.

C. Attendance

20. Representatives of academia, research institutions, national space agencies, international organizations and industry from developing and developed countries concerned with the development and the use of GNSS for practical applications and scientific exploration, including space weather effects on GNSS, were invited to participate in the Workshop. Participants were selected on the basis of their scientific or engineering background, the quality of the abstracts of proposed presentations and their experience in programmes and projects in GNSS technology and its applications.

21. Funds provided by the United Nations, the Government of Croatia and the Government of the United States (through ICG) were used to defray the costs of air travel and accommodation for 15 participants. A total of 65 specialists in satellite navigation systems were invited to attend the Workshop.

22. The following 25 Member States were represented at the Workshop: Albania, Algeria, Bosnia and Herzegovina, Bulgaria, Chile, China, Croatia, Czech Republic, Estonia, Germany, Hungary, India, Indonesia, Israel, Latvia, Republic of Moldova,

Pakistan, Romania, Russian Federation, Saudi Arabia, Netherlands, Turkey, United Kingdom, United States and Uzbekistan. The Office for Outer Space Affairs was also represented.

II. Summary of presentations

23. Brief presentations and statements by panellists at the beginning of each session provided participants with the opportunity to exchange views about the latest developments in GNSS and its wide variety of uses, such as highly accurate surveying, in-car navigation, network synchronization and climate research. The sessions were particularly useful in identifying issues and clarifying potential approaches, as well as for networking with GNSS providers and industry.

24. A number of presentations raised issues related to the protection of critical GNSS infrastructure from intentional or unintentional interference, and highlighted many opportunities and challenges that multiple satellite constellations created for GNSS users.

25. Participants were also provided with an overview of multi-constellation GNSS, including the modernized Global Positioning System (GPS) of the United States, the Russian Federation's Global Navigation Satellite System (GLONASS), the European Galileo system, China's BeiDou system, the Indian Regional Navigational Satellite System (IRNSS) and Japan's Quasi-Zenith Satellite System (QZSS). It was noted that those multi-GNSS constellations and satellite-based augmentation systems, providing more types of signals broadcasted on a greater number of frequencies, would bring improved performance and new capabilities to users around the globe. Therefore, appropriately equipped users would benefit from enhanced accuracy (more observations, less multipath and ionospheric error); improved availability (approximately four times more the number of accessible satellites and better interference detection); and higher integrity (system and signal diversity, reduced interference vulnerability).

26. A number of presentations showed that multi-GNSS would have a significant impact on the ground infrastructure of permanent continuously operating reference station (CORS) networks that supported high precision positioning applications. The primary emphasis was on how CORS network processing could be facilitated and automated through the provision of interactive online tools and how data were made available to the public.

27. To benefit from those achievements, GNSS users needed to stay abreast of the latest developments related to GNSS and build the capacity to use new GNSS signals. However, in order to achieve a true system of systems, GNSS providers had to address a host of questions concerning compatibility and interoperability.

28. The presentations made at the Workshop and the abstracts of the papers, as well as the Workshop programme and background materials, have been made available on the website of the Office for Outer Space Affairs.

III. Observations and recommendations

29. Society's reliance on high-integrity position, navigation and timing data was growing. The availability of GNSS meant that those systems could be used as primary sources of data for an increasing number of products and services. However, different tasks and challenges remained on the user level in order to optimize the utilization of GNSS signals for specific applications.

30. Space weather effects, in particular ionospheric disturbances, were one of the largest sources of error for GNSS users. Although the ionosphere had been studied for many years, its effects on GNSS signals continued to be a source of concern and investigation. Therefore, the space weather and GNSS communities, working together, could advance understanding of the vulnerabilities of GNSS and strengthen resistance to space weather.

31. International collaboration could maximize the use of all GNSS signals, thereby reducing GNSS vulnerability. That would require the development and certification of receivers that incorporated hundreds of GNSS signals.

32. Thus, the United Nations-backed ICG, which brought together GNSS and augmentation system providers and key user communities, could play a special role on compatibility and interoperability issues in order to enhance positioning, navigation and timing services for users worldwide.

33. The development of multi-GNSS infrastructures would have a major influence in the creation and development of new GNSS-related applications and foster the growing global GNSS market and related job opportunities, including new GNSS-related jobs such as application developers, analysts, risk assessors and space weather forecasters. It was therefore essential to build capacity to use the GNSS signals and ensure there was a prepared workforce for the growing opportunities in the GNSS sector at the system, space and ground infrastructure levels.

34. The regional centres for space science and technology education affiliated to the United Nations could focus on the field of GNSS from both the theoretical and practical points of view. The centres, also acting as the information centres for ICG, could foster a more structured approach to information exchange in order to fulfil the expectations for a network linking the regional centres and ICG and connecting institutions involved or interested in GNSS applications with GNSS providers. Linkages would be facilitated by different possible means, such as the provision by ICG of educational material, tutorials and expertise, particularly in combination with projects in the respective regions.

35. In that context, Workshop participants recommended the following:

(a) The annual United Nations workshops on GNSS and their applications should continue in the future in order to provide a forum in which users and system providers could exchange experience and practice in research and innovation in GNSS, and contribute to the global debate on the interoperability of GNSS and interference detection and mitigation;

(b) A space weather-GNSS programme should be developed and supported to collect information on the impact of space weather on GNSS, leading to further research and scientific papers to be published in international journals, and to

provide education and outreach on the use of GNSS information for scientific applications (such as weather forecasting, geodynamics and ionospheric studies);

(c) A web-based GNSS education training portal should be developed on the basis of existing web-based systems for online distance learning. A GNSS applications database, to be accessed through the ICG information portal and the websites of the ICG information centres, would describe each specific GNSS application and how it worked. A complete list of GNSS reference material and open source software should be developed and made accessible;

(d) The effectiveness of the support provided by the Office (through ICG) to existing programmes for postgraduate study on GNSS and related applications, training courses on science applications of GNSS, seminars on reference frames and ISWI schools for specialists from developing countries should be measured. Providing additional new GNSS education opportunities at different levels would be the best way to cover the different needs in the GNSS field and ensure that such capacity-building activities were accomplished efficiently and for the benefit of all Member States;

(e) New technical knowledge generated by ICG and through its activities should be effectively communicated to the public and the GNSS-related scientific research community and industry at large via the ICG information portal, and through the use of existing electronic infrastructure and brochures.

36. The participants in the Workshop noted the following:

(a) The Russian Education Centre led by the joint stock company Russian Space System was developing education infrastructure on GLONASS/GNSS, including distance learning educational courses and programmes. It was noted that the courses provided through a distance-learning degree programme could be a fast and effective way to provide training in GNSS at both the professional and postgraduate levels;

(b) The international centre for GNSS science, technology and education hosted by the Beihang University of China would act as an information centre for ICG and provide capacity-building and technical guidance in all aspects of science, technology, applications and education in the field of GNSS.

37. The participants in the Workshop also noted that a scientific and research laboratory was under development in Baška, Krk island, Croatia, with the aim of providing the framework for a GNSS science, research and education programme to study the local dynamics of space weather and the ionosphere, and GNSS performance. The laboratory was to be equipped with a number of mostly passive sensors for ionospheric and geomagnetic dynamics in order to forecast ionospheric disturbances and assess their impact on technological systems, including satellite navigation systems. In addition, a series of reference GNSS receivers were to be deployed for continuous monitoring of GNSS performance for a wide variety of users, including the study of space weather GNSS vulnerabilities and risks.

38. An important function of the Baška research laboratory was to promote the transfer of knowledge and the results of research. That would contribute to the exchange of research and of lecturers and students and to close international scientific collaboration, and to raising awareness among the public of the importance of strengthening the resilience of GNSS. Initially, the laboratory would

operate as a remote unit of the Faculty of Maritime Studies of the University of Rijeka, with the expectation that it would evolve into a stand-alone institution for GNSS science, research and education.

39. The participants in the Workshop expressed their appreciation to the Faculty of Maritime Studies of the University of Rijeka for their hospitality and the substance and the organization of the workshop.

40. Participants also expressed their appreciation for the significant support provided by the United Nations and the Government of Croatia, as well as the Government of the United States (through ICG).