United Nations A/AC.105/1019

General Assembly

Distr.: General
27 March 2012

Original: English

Committee on the Peaceful Uses of Outer Space
Fifty-fifth session
Vienna, 6-15 June 2012

Report on the United Nations International Meeting on the Applications of Global Navigation Satellite Systems, held in Vienna from 12 to 16 December 2011

I. Introduction

1. In "The Space Millennium: Vienna Declaration on Space and Human Development",[1] the States participating in 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, recommended that activities of the United Nations Programme on Space Applications promote collaborative participation among Member States at both the regional and the international level by emphasizing the development of knowledge and skills in developing countries and countries with economies in transition.

2. Since 2001, the Office for Outer Space Affairs of the Secretariat, within the framework of the United Nations Programme on Space Applications, has been organizing a series of regional workshops on the applications of global navigation satellite systems (GNSS) aimed at increasing awareness among scientists, engineers, decision makers, university educators and policymakers of the benefits of satellite navigation technology and establishing a broad framework for regional and international cooperation.

3. The results of the regional workshops and the three international meetings carried out between 2001 and 2004[2] contributed to the work of the Action Team on GNSS, one of the 12 action teams established by the Committee on the Peaceful Uses of Outer Space to implement the priority recommendations of UNISPACE III.

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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.

[2] See A/AC.105/846.

V.12-52022 (E) 100412 110412

4. In 2005, the efforts of the Action Team on GNSS, consisting of 38 countries and 15 intergovernmental and non-governmental organizations, led to the establishment of the International Committee on GNSS (ICG), under the umbrella of the United Nations. The establishment of ICG demonstrated that GNSS had become a truly international resource and also demonstrated the willingness of providers and users of positioning, navigation and timing services to ensure that GNSS services continued for the benefit of all humankind in the future.

5. In deliberations within ICG, global and regional system providers agreed that, at a minimum, all GNSS signals and services must be compatible. To the maximum extent possible, open signals and services should also be interoperable, in order to maximize the benefits for all GNSS users. To benefit from those achievements, GNSS users needed to stay abreast of the latest developments in GNSS-related areas and build capacity for using GNSS signals.

6. In order to promote the use of GNSS and their applications in developing countries and in countries with economies in transition, the Office for Outer Space Affairs, within the framework of the United Nations Programme on Space Applications, organized a series of the workshops on applications of GNSS. The overall objective of the workshops was to define the needs and requirements of end-users of GNSS and to provide a framework for scientific research enabled by GNSS. The programme of the workshops was aimed at contributing to the creation of a knowledgeable workforce, necessary for the advancement of science applications of GNSS in the regions.

7. Regional workshops on applications of GNSS, organized by the United Nations, the European Space Agency (ESA) and ICG, were hosted by the Government of China[3] and the Government of Zambia[4] in 2006, the Government of Colombia[5] in 2008, the Government of Azerbaijan[6] in 2009, the Government of the Republic of Moldova[7] in 2010 and the Government of the United Arab Emirates[8] in 2011. The workshops were a continuation of the four regional workshops and three international meetings that were held between 2001 and 2004. In 2001, workshops were hosted by the Government of Malaysia,[9] for the region of Asia and the Pacific, and Austria,[10] for the benefit of countries in Central and Eastern Europe; in 2002, workshops were hosted by the Government of Chile,[11] for the benefit of countries in Latin America and the Caribbean, and the Government of Zambia,[12] for the benefit of countries in Africa and West Asia. Three international meetings were held at the United Nations Office at Vienna in 2002, 2003 and 2004.

8. At its fifty-third session, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and expert meetings related to socio-economic benefits of space activities, small satellites,

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[3] See A/AC.105/883.
[4] See A/AC.105/876.
[5] See A/AC.105/920.
[6] See A/AC.105/946.
[7] See A/AC.105/974.
[8] See A/AC.105/988.
[9] See A/AC.105/771.
[10] See A/AC.105/776.
[11] See A/AC.105/795.
[12] See A/AC.105/785.

basic space technology, human space technology, space weather, GNSS and search and rescue, planned to be held in 2011 for the benefit of developing countries.[13] Subsequently, the General Assembly, in its resolution 65/97, endorsed the United Nations Programme on Space Applications for 2011.

9. 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 International Meeting on the Applications of Global Navigation Satellite Systems in Vienna from 12 to 16 December 2011. The Meeting was co-sponsored by the United States of America, through ICG.

10. To mark the growth and results that the Action Team on GNSS had achieved over the previous 10 years and to look at what could be best achieved through a new approach in the next 5 to 10 years, the results of the previous regional workshops were provided to the Meeting, and participants sought to provide further follow-up to the projects and recommendations discussed in those workshops. The Meeting provided an opportunity to build upon the results of each workshop, contributing to the definition of a plan of action and of functional partnerships for the long term, while also strengthening existing strategies at the regional level. It was also an opportunity to build upon a number of ongoing initiatives, such as the International Space Weather Initiative, the Multi-GNSS Demonstration Campaign, the realization of the regional reference frames and systems, the activities of the regional centres for space science and technology education, affiliated to the United Nations, which also act as the ICG information centres, and a long-term fellowship programme for training in GNSS and related applications. In addition, proposals to be forwarded to the seventh annual meeting of ICG, to be held in 2012, were discussed at the Meeting.

11. Participants noted with appreciation that the achievements of providers and users of positioning, navigation and timing services in promoting GNSS over the past 10 years had been reflected in the publication entitled “10 years of achievement of the United Nations on Global Navigation Satellite Systems” (ST/SPACE/55), prepared by the United Nations Office for Outer Space Affairs as the executive secretariat of ICG.

12. The present report contains information on the background and objectives of the Meeting and provides a summary of the conclusions, observations and recommendations made by the Meeting participants.

A. Background and objectives

13. GNSS consists of constellations of satellites that provide continuously optimized location and time information, transmitting a variety of signals on multiple frequencies available at all locations on Earth. GNSS comprises the Global Positioning System (GPS) of the United States, the Global Navigation Satellite System (GLONASS) of the Russian Federation, Galileo of the European Union and Compass/BeiDou of China. India and Japan have developed regional GNSS capability by launching a number of satellites into space that augment the capabilities already supplied by the global systems to provide additional regional

[13] See A/65/20, para. 79.

coverage. The six global and regional GNSS providers have grouped together in a Providers' Forum[14] in order to conduct discussions of mutual interest focused on improving coordinated service provision to benefit humankind.

14. When GPS, GLONASS, Galileo, and Compass are fully operational and interoperable, four times as many satellites than currently exist may be available for positioning, navigation and timing, providing more types of signals broadcast on more frequencies. However, to achieve a true system of GNSS, a host of questions concerning compatibility and interoperability need to be addressed by system providers. Additionally, GNSS user community inputs regarding interoperability and the provision of improved capabilities should be considered.

15. The aim of the five-day International Meeting was to contribute to international cooperation by providing an opportunity to exchange updated information on the use of GNSS technology and its applications. The specific objectives of the Meeting were: (a) to examine the trends that are apparent in the worldwide development of GNSS and how they will affect the growing population of users of satellite-positioning technologies; (b) to review ongoing and planned initiatives as well as case studies that could contribute to the wider use of GNSS technology and its applications, including the possibility of one or more national, regional and international pilot projects in which interested institutions could incorporate the use of GNSS technology; (c) identify a functional partnership that could be established to promote innovative GNSS-enabled applications, as well as recommend how such a partnership could be established through voluntary actions that could include Governments, international organizations, research and development institutions, academia and other relevant stakeholders; and (d) define recommendations and findings to be forwarded for consideration by ICG and its working groups.

B. Programme

16. At the opening of the Meeting, introductory and welcoming statements were made by the Director of the Office for Outer Space Affairs and the representative of the United States, as co-chair of the Action Team on GNSS. In the keynote presentation, entitled "ICG and its programme on GNSS applications", a representative of the Office for Outer Space Affairs described the work carried out by the Office in supporting activities to promote the use of GNSS-based applications.

17. A total of 41 presentations were made by invited speakers from both developing and developed nations during the six thematic sessions, which were focused on the following topics: policies and strategies for promoting sustainable development; international, regional and national initiatives and experiences; GNSS reference station network and services; space weather and GNSS; capacity-building, training and education in the field of GNSS; and GNSS-based application areas. Additionally, two discussion panels were held on the topics "Building upon the results of the regional workshops/training courses: contribution to capacity-building for sustainable development in the use of enabling space technologies" and "Further

[14] See A/AC.105/901.

development of information centres for ICG". Four discussion sessions enabled further deliberation on the main topics and led to the development of a common strategy aimed at increasing the use of GNSS technology and contributing to the level of cooperation, including possible collaboration with industry leaders and linkages with current and planned system and augmentation system providers.

C. Attendance

18. 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 Meeting, were invited to participate in the Meeting. Participants were selected on the basis of their scientific background and their experience in programmes and projects in GNSS technology and its applications.

19. Funds provided by the United Nations and the Government of the United States, through ICG, were used to defray the costs of air travel and accommodation for 23 participants. A total of 75 specialists in satellite navigation systems were invited to attend the Meeting.

20. The following 35 Member States were represented at the Meeting: Algeria, Austria, Brunei Darussalam, Burundi, China, Colombia, Costa Rica, Croatia, Ecuador, Egypt, France, Germany, India, Indonesia, Israel, Italy, Japan, Latvia, Madagascar, Morocco, Nigeria, Pakistan, Philippines, Republic of Moldova, Romania, Russian Federation, Serbia, Spain, Swaziland, Thailand, Tunisia, Turkey, United Arab Emirates, United States and Uzbekistan. The Office for Outer Space Affairs, ESA, the International Association of Institutes of Navigation, the International GNSS Service, the International Telecommunication Union and the Space Generation Advisory Council were also represented.

II. Summary of presentations

21. 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 Meeting, emphasizing the important role of ICG as a forum for all the major players in the field of GNSS to ensure compatible, interoperable GNSS services for the benefit of all.

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

III. Summary of discussions and recommendations

23. Participants were divided into four working groups on the basis of their areas of expertise and interest: the future of ICG; GNSS applications and space weather effects on GNSS; regional reference frames and systems; and the GNSS education

curriculum and ICG information centres. Each working group met to discuss activities that would contribute to an increase in the use of GNSS technology, and constraints and opportunities inherent in the current institutional environment. The recommendations resulting from the working group meetings were presented to the plenary for discussion and are summarized below.

A. Working group on the future of the International Committee on Global Navigation Satellite Systems

24. At the seventh meeting of the Providers' Forum, held in conjunction with the Sixth Meeting of ICG, it was agreed that the future role and work of ICG and its Providers' Forum should be reviewed. The decision to begin discussions on the future development of ICG, as a new item on the agenda of the Providers' Forum meeting,[15] emphasized that ICG should play an important role in future GNSS developments and their implications for civil use and performance. ICG member States focused on the issues related to the effective functioning of ICG and its current format as a body established to promote cooperation on matters of mutual interest related to civil satellite-based positioning, navigation, timing and value-added services, as well as the compatibility and interoperability of GNSS.[16]

25. The meeting of the working group on the future of ICG was chaired by the United States, as co-chair of the Action Team on GNSS. In considering the structure, role and objectives of ICG and its Providers' Forum in general, the working group prepared an informal note on a number of possible options and modalities that could strengthen the effectiveness of ICG in the future. Importantly, that information note was not exhaustive with respect to the range of possible actions or the full diversity of questions put forward. Its purpose was to stimulate discussion by setting out just some of the possible cross-cutting elements of a broad strategy for action to be considered as part of the discussion at the eighth meeting of the Providers' Forum, to be held on 4 June 2012 in Vienna.

B. Working group on GNSS applications and space weather effects on GNSS

26. The working group identified GNSS as a global public good for worldwide enhancement of the quality of life, particularly through utilization in such areas as (a) applications for individual handsets and mobile phones, (b) road transport, (c) aviation, (d) maritime transport, (e) precision agriculture and environment protection and (f) civil protection and surveillance.

27. Placing emphasis on application development, the working group strongly recommended protection of the GNSS spectrum and noted that the use of GNSS applications for sustainable development in areas such as navigation, surveying and mapping could yield significant societal benefits.

28. In the context of future development of GNSS and its applications, the working group identified the achievement of interoperability between different

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[15] See A/AC.105/1000.

[16] See General Assembly resolution 61/111.

global navigation satellite systems and the provision of sustained and balanced quality of positioning, navigation and timing GNSS services as the key elements for achieving maximum civil user benefit. It was noted that the combination of GNSS constellation and augmentation satellites would provide far better satellite geometry and signal availability than one GNSS alone, and it would make a great difference for both present and future applications. In this regard, multi-GNSS demonstration campaigns were encouraged.

29. The working group noted that space weather could influence the functioning and reliability of spaceborne and ground-based systems and services or endanger property or human health. It also noted that space weather accounted for the most substantial errors experienced by global navigation satellite systems and their users. Predictions of space weather were important to the GNSS community. Scientific efforts applied to monitoring and predicting space weather and resources available and under development to aid GNSS users in dealing with all possible adverse effects of space weather needed to be increased. In this regard, the International Space Weather Initiative was emphasized.

30. The working group strongly recommended the development and publication of a GNSS educational curriculum to be provided particularly to the United Nations-affiliated regional centres for space science and technology education.

31. The working group specifically highlighted the multi-GNSS demonstration campaign undertaken in the region of Asia and the Pacific, taking into account the fact that that region was a unique area where multi-GNSS constellations and new, modernized signals could be utilized sooner than in other regions of the world, thanks to the contributions from regional constellations such as the second stage of Compass/BeiDou of China, IRNSS of India and QZSS of Japan, in addition to global GNSS constellations such as GPS, GLONASS and Galileo.

32. The working group recognized a number of important multi-GNSS benefits: (a) multi-GNSS use could provide not only an increment in the number of navigation satellites but also additional signals and frequencies; (b) multi-GNSS use was a method to reduce the vulnerability and increase the reliability and robustness of GNSS services; and (c) the incremental increase in the number of visible satellites using the same frequency could support Receiver Autonomous Integrity Monitoring (RAIM) technologies.

33. The working group recommended that the international GNSS community should participate in Multi-GNSS Asia, the International GNSS Service multi-GNSS tracking experiment and the International GNSS Monitoring and Assessment Service to test, validate and demonstrate multiple constellation applications and their benefits in the early deployment stage of multi-GNSS and modernized signals.

C. Working group on regional reference frames and systems

34. The working group recognized that reference networks, comprising permanent stations operating GNSS receivers on a continuous basis, provided the fundamental infrastructure required to meet the needs of geodesy, geosciences, navigation, surveying, mapping and other applications.

35. The working group encouraged national and regional authorities to support initiatives of regional reference frames and systems such as the International Association of Geodesy Reference Frame Sub-Commission for Europe, the European Position Determination System, the Geocentric Reference System for the Americas, the African Geodetic Reference Frame and the Asia-Pacific Reference Frame. A consolidated list of reference frames and systems that are used by national authorities, agencies or regional organizations, and their prospective plans for future development, should be made available on the ICG information portal.

36. The working group encouraged the use of multi-constellation GNSS signals in reference networks.

37. The regional reference frames should use, if possible, the same frame (best or latest version) realization to ensure transborder data-exchange compatibility and interoperability. The best solution would be to achieve consensus with neighbouring countries on one reference frame realization.

38. The utilization of the GNSS real-time kinematic (RTK) technique had encouraged users to apply GNSS reference receivers to support the growing number of applications of high-accuracy positioning for engineering, precision agriculture and other endeavours. In this regard, the working group called for the set-up of more permanent stations, or for the consideration of the existing dense GNSS Continuously Operating Reference Station (CORS) network infrastructure in order to improve the velocity field of reference frame and provide more adequate information for static and kinematic applications.

39. Depending on the expected accuracy and the type of measuring method required (static or RTK), the definition of the frame as a static reference frame or as a frame realization with applied velocities should be defined. For the determination of velocity of reference frame, repeated static measurements were required. The best method to monitor this was to install GNSS CORS.

40. The working group felt that the establishment of GNSS positioning services, such as RTK networks, was an urgent need for many countries. The working group recommended the provision of a document to the public that described the procedure for setting up a national GNSS positioning service. Geodynamic activities in specific regions needed to be considered and could result in different recommendations for stable regions and regions prone to large tectonic movements.

D. Global navigation satellite systems education curriculum and International Committee on GNSS information centres

41. The working group noted the available capacity-building opportunities and the status of operations of the United Nations-affiliated regional centres for space science and technology education, located in Brazil and Mexico for Latin America and the Caribbean, in India for Asia and the Pacific, and in Morocco and Nigeria for Africa. The working group had before it the updated education curricula for (a) remote sensing and GIS, (b) satellite meteorology and global climate, (c) satellite communications and (d) space and atmospheric science (see www.unoosa.org/oosa/en/SAP/centres/index.html).

42. Since 2008, all United Nations-affiliated regional centres for space science and technology education are acting as ICG information centres.

43. The development of a GNSS education curriculum was pursued in a series of regional workshops on applications of GNSS, organized by the United Nations, ESA and ICG since 2006. From 2008 to 2010, the ICG executive secretariat took the lead in organizing training courses on satellite navigation and location-based services in all United Nations-affiliated regional centres for space science and technology education. Those training courses addressed GNSS technology and its applications, including hands-on experience in the use of off-the-shelf software for specific applications and GNSS signal processing and facilitated the further development of the GNSS education curriculum.

44. The working group continued the development of the GNSS education curriculum by taking into account GNSS course outlines as used at the university level in a number of developing and industrialized countries. The incorporation of elements of GNSS science and technology into university-level education curricula served a dual purpose: it could enable countries to take advantage of the benefits inherent in the new technologies, which, in many cases, are spin-offs from space science and technology, or to introduce the concepts of high technology in a non-esoteric fashion and help create national capacities in science and technology in general. Currently serious efforts were being made worldwide to introduce GNSS, in terms of science, technology and applications, as a stand-alone discipline in university-level curricula.

45. The working group took note of the fact that the GNSS education curriculum under development differed from most of those available in literature and on the World Wide Web. The GNSS education curriculum was a unique result of the deliberations of the regional workshops on GNSS applications since 2006. The working group also agreed to develop as part of the GNSS education curriculum a module for hands-on GNSS exercises based on data and equipment used for space weather monitoring. Overall the GNSS education curriculum consisted of eight modules. In addition, a consolidated glossary of GNSS terms would be part of the curriculum.

46. On the basis of the working group's recommendations, the Meeting concluded that the increasingly important role of GNSS science, technology and education called for the establishment of an international centre for GNSS science, technology and education. That conclusion was underscored by the 10 years of achievement of the United Nations on GNSS.

47. The Meeting recommended that the United Nations should lead, with the active support of China and relevant scientific organizations, an international effort to establish an international centre for GNSS science, technology and education in an existing national educational and research institution. Beihang University (see www.buaa.edu.cn) of China offered to host the centre. The centre might grow into a network of centres, focusing on GNSS science, technology and education, around the world — all dedicated to the advancement of GNSS research, applications and education.

48. The centre would provide capacity-building and technical guidance to nations that wished to engage in GNSS science, technology and education. Capacity-building consisted of three main components:

(a) Training on GNSS instrumentation: positioning, navigation and timing, for either applications or research, requiring continuous data recording. The data would come from ground-based GNSS instruments that required proper maintenance. Recent reviews showed that, internationally, the number of individuals skilled in operating and maintaining these specialized instruments was not sufficient;

(b) Training on data-processing and analysis: raw data must be inspected, corrected, calibrated, interpreted, transformed and archived. Most of these activities required sophisticated software and long-term experience handling such data. Utilizing such software demanded advanced training for users of the data;

(c) Education and training in GNSS science, technology and applications: with processed and archived data available, the final process was to conduct scientific investigations and develop technology and applications based on the data, and to publish findings in the international scientific literature. The ability to perform this final process generally required a PhD or MSc-level education, which could be provided only by experts on all aspects of GNSS.

49. GNSS work was roughly divided into two spheres: (a) operating GNSS receivers and (b) scientific, technical and educational activities for GNSS.

50. Science, technology, applications and education were the domain of advanced institutions and universities; the centre must be part of such an advanced institution or university. Moreover, a proven record of capacity-building in space science and technology was an essential prerequisite for the host institution of the centre.

51. The centre must be an institution with a proven record in organizing regional and international GNSS activities, including GNSS schools, workshops, application campaigns, installation of GNSS technology in different regions of the world, training of instrument host staff and students, and regional and international outreach programmes. The centre must possess experience in promoting and supporting regional and international programmes, for example, in the utilization of GNSS for space weather monitoring.

52. The centre should implement the GNSS education curriculum developed in the series of United Nations workshops on GNSS applications organized since 2006. Further updating and upgrading of the GNSS education curriculum through special workshop sessions would be a responsibility of the centre. A special module of the curriculum should be devoted to all aspects of science, technology, applications and education in the field of GNSS receivers for space weather monitoring.

53. The centre would cooperate with the United Nations-affiliated regional centres for space science and technology education, located in India, Mexico, Brazil, Morocco and Nigeria, the international centre for space weather science and education, located in Japan, and other centres of excellence in space science, technology and education.

54. The centre would report annually to the ICG Working Group on Information Dissemination and Capacity-Building, led by the Office for Outer Space Affairs. The centre would also act as the information centre for ICG.