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**Recent developments in global navigation satellite systems**

# Summary of the United Nations/Nepal workshop on the applications of global navigation satellite systems

## (Kathmandu, 12-16 December 2016)

## I. Introduction

1. Since the beginning of the space age, international cooperation in the peaceful uses of outer space has evolved in such a way as to provide the impetus for a consideration of international mechanisms and infrastructures for space cooperation and coordination mechanisms at the international, regional, interregional and national levels (see A/AC.105/L.297).

2. The International Committee on Global Navigation Satellite Systems (ICG), established in 2005 under the umbrella of the United Nations, work to promote the introduction and utilization of global navigation satellite systems (GNSS) services and their future enhancements, including in developing countries, providing assistance, as necessary, for the integration of GNSS into existing infrastructure. ICG also assists GNSS users with their development plans and applications by encouraging coordination and serving as a focal point for information exchange.

3. The Office for Outer Space Affairs, in its capacity as the Executive Secretariat of ICG and its Providers' Forum, is promoting the use of GNSS throughout its programme on GNSS applications.

4. Numerous potential applications have already been identified based on the quality and reliability of GNSS signals, but the list is certain to grow, offering a cost-effective way of pursuing sustainable economic growth while protecting the environment.

5. As part of the United Nations Programme on Space Applications, a United Nations/Nepal workshop on the applications of global navigation satellite systems was organized by the Office for Outer Space Affairs in cooperation with the Ministry of

Land Reform and Management of Nepal. The Workshop was hosted by the Department of Survey on behalf of the Government of Nepal in Kathmandu, from 12 to 16 December 2016. It was co-sponsored by the United States and the European Union through ICG, and GfRmbH Galileo Control Centre, German Space Agency (DLR), Germany.

6. Organized by the United Nations, previous regional workshops and international meetings on the applications of GNSS were hosted by the Governments of China (A/AC.105/883) and Zambia (A/AC.105/876) in 2006, Colombia (A/AC.105/920) in 2008, Azerbaijan (A/AC.105/946) in 2009, the Republic of Moldova (A/AC.105/974) in 2010, the United Arab Emirates (A/AC.105/988) and the Office for Outer Space Affairs (A/AC.105/1019) in 2011, Latvia (A/AC.105/1022) in 2012, Croatia (A/AC.105/1055) in 2013, the Abdus Salam International Centre for Theoretical Physics in Trieste, Italy (A/AC.105/1087) in 2014 and the Russian Federation (A/AC.105/1098) in 2015. Those workshops addressed a wide array of GNSS applications for socioeconomic benefits and focused on initiating pilot projects and strengthening the networking of GNSS-related institutions in the regions.

7. The present report describes the background, objectives and programme of the workshop and provides a summary of the observations and recommendations made by the participants.

## A. Background and objectives

8. Efforts to build capacity in space science and technology are considered a major focus of the Office for Outer Space Affairs and are of specific interest to ICG with particular reference to GNSS and its applications. Such efforts aim to provide support to the regional centres for space science and technology education affiliated to the United Nations, which also act as information centres for ICG. The ICG information centres are working towards the establishment of a network of institutions involved or interested in GNSS. They are also identifying new applications that could be developed in the regions on the basis of GNSS services. The centres coordinate their activities closely with ICG and its Providers' Forum through the ICG Executive Secretariat. Additional information is available at: http://www.unoosa.org/oosa/en/SAP/centres/index.html.

9. Building resilient societies through better coordination and forging of global partnerships is one of the key challenges in the 21st century and an integral part of meeting the commitments set by the 2030 Agenda for Sustainable Development. Recognizing space weather as a global challenge and the need to address the vulnerability of society as a whole, one of the potential activities of ICG is to address the importance of space weather for GNSS systems and their users. Space weather is defined as "the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems, as well as endanger life and health". Space weather can interrupt communication and navigation systems; harm satellite electronics; and expose aircraft passengers flying over the poles and very high altitudes to increased levels of radiation. For GNSS users, space weather is the single largest contributor to the single frequency global positioning system (GPS) error budget, and a significant factor for differential GNSS users. Since more and more nations of the world are becoming dependent on GNSS systems and signals, it is necessary to inform and educate users of the threat of space weather on GNSS systems and applications. Additional information is available at: http://www.iswi-secretariat.org/.

10. Development projects, applications, services or products requiring georeferencing, require a uniform coordinate reference system. Most countries have some form of national reference frame or system. These reference frames/systems are usually based on local origin or datum point, which restrict their use to a particular country. It makes cross-border mapping, development and planning projects difficult, and therefore calls for the establishment of a common and uniform continental reference coordinates frames and systems.

11. In line with the cross-cutting areas, as identified in document A/AC.105/L.297, the main objective of the workshop was on the importance and need of cooperation to apply GNSS solutions through the exchange of information and the scaling up of capacities among countries in the region.

12. In order to strengthen the ongoing processes in the lead up to the fiftieth anniversary of the first United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE+50), which will be held in 2018, the specific objectives of the five day United Nations/Nepal Workshop were to: (a) introduce GNSS and its applications to transport and communications, aviation, surveying, mapping and Earth science, management of natural resources, the environment and disasters, precision agriculture; high precision mobile application, as well as space weather effects on GNSS and dual-frequency receivers; (b) promote greater exchange of actual experiences with specific applications; (c) encourage greater cooperation in developing partnerships and GNSS networks, in the framework of the regional reference frames; (d) define recommendations and findings to be forwarded as a contribution to ICG and UNISPACE+50, in particular in forging partnerships to strengthen and deliver capacity-building in the use and applications of space science and technology.

## B. Programme

13. At the opening of the workshop, introductory and welcoming statements were made by the Minister of the Ministry of Land Reform and Management, Vice-Chairman of the National Planning Commission and Director-General of the Survey Department of the Ministry of Land Reform and Management of Nepal and by the representative of the Office for Outer Space Affairs.

14. The discussions at the workshop were also linked to the 2030 Agenda for Sustainable Development and to its targets set out for Sustainable Development Goals, such as, *Health* (GNSS positioning enables individual patients, staff or equipment to be monitored, and response teams directed more efficiently); *Energy* (GNSS reflectometry techniques can produce scatterometry models to assist in the optimum positioning of off-shore wind farms); and *Ecosystems* (GNSS reflectometry offers the potential for monitoring vegetation and biomass. It also has an important role in providing information for global monitors such as: carbon modelling, greenhouse gas emission inventories and deforestation control).

15. The workshop included six technical sessions on a variety of themes: (a) overview of GNSS; (b) GNSS applications and technology development; (c) environmental monitoring and management using GNSS; (d) GNSS reference frames and reference station networks; (e) real time kinematic: technology and applications; (f) GNSS implementation and uses: case studies.

16. A one day seminar on “Space weather and its effects on GNSS” was held during the workshop. The purpose of the seminar was to provide a background on the phenomena of space weather and illustrate its effects on GNSS. This seminar

described the challenging aspects of space weather phenomena, their impact on GNSS users, the variability of these impacts and the actions that might mitigate their effects.

17. Seminar on "GNSS spectrum protection and interference detection and mitigation" was also organized during the workshop. The purpose of this seminar was to highlight the importance of GNSS spectrum protection at the national level and explain how to reap the benefits of GNSS.

18. Free open source software (RTKLIB) demonstrations related with low-cost GNSS receiver system for real time kinematic (RTK) were made. The system was based on a very low cost GNSS receiver, Raspberry-Pi computer using RTKLIB.

19. The programme was developed by the Office for Outer Space Affairs and the Survey Department of the Ministry of Land Reform and Management in cooperation with ICG and the University of Tokyo, Japan.

## C. Attendance

20. Representatives of national space agencies, academia, research institutions, international organizations and industry from developing and developed countries concerned with the development and the use of GNSS for practical applications and scientific exploration 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 their 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 Nepal and co-sponsors were used to defray the costs of air travel and accommodation for 25 participants. A total of 154 specialists in satellite navigation systems were invited to attend the workshop.

22. The following 32 Member States were represented at the workshop: Australia, Bahrain, Bangladesh, Brazil, China, Croatia, Egypt, Estonia, Fiji, France, Germany, India, Indonesia, Japan, Lao People's Democratic Republic, Latvia, Malaysia, Mongolia, Morocco, Myanmar, Nepal, New Zealand, Pakistan, Philippines, Russian Federation, Saudi Arabia, Thailand, Turkey, Ukraine, United States of America and Uzbekistan. The European Union was also represented. Representative of the Office for Outer Space Affairs also participated.

# II. Observations and recommendations

23. The workshop addressed the use of GNSS for various applications that can provide sustainable social and economic benefits, in particular for developing countries. Current and planned projects that use GNSS technology for both practical applications and scientific explorations were presented. Cooperative efforts and international partnerships for capacity-building, training and research were discussed.

24. The presentations made at the workshop, abstracts of the papers given and the workshop programme and background materials are available on the website of the Office for Outer Space Affairs (www.unoosa.org).

25. Recognizing that GNSS technology has enormous potential to contribute to the management and protection of the environment, disaster risk reduction, agriculture and food security, emergency response, improving the efficiency in surveying and mapping, and to enhance the safety and effectiveness of transportation by land, sea

and air, low cost GNSS receivers, the participants put forward a number of observations and recommendations, which are summarized below.

## A. GNSS applications and technology development

26. Participants recognized that GNSS had very important applications in surveying and mapping and in the precise positioning. It was noted that GNSS technology played a prominent role in every infrastructure development of the country. Participants also recognized the importance of the use of GNSS technology to improve emergency response to natural disasters and reduce the associated risk and impact to human life. This was an extremely important application for GNSS requiring robust information technology and multi-agency cooperation and interoperability that included both governmental and non-governmental organizations. Overall the presentations featured works that leverage existing mobile phone and internet technologies coupled with GNSS to provide improved services for disaster management primarily through reducing location uncertainties and information timelines.

27. GNSS reference frames, reference station networks and determination of vertical datums were the topics of major discussion, where the knowledge sharing was very essential. It was noted that continuously operating reference stations (CORS) play an important role in critical national priorities such as identifying seismic hazards, disaster recovery and mitigation and infrastructure development, particularly in developing countries. In order to take full advantage of emerging GNSS technology, the development of modernized national horizontal reference systems, including deformation models and vertical datums based on accurate local geoid models, are essential. Therefore international cooperation in terms of knowledge, resource and sharing of the information in development of CORS networks and geodetic reference systems was emphasized.

28. Key recommendations included the following: (i) continue the development and integration of information technology, geographic information system (GIS), mobile phone, GNSS and remote sensing technologies to achieve improved disaster management tools accessible to the public; (ii) engage public and private agencies and organizations to favorably affect public policy to ensure maximum benefit to the population being served. These activities may include, but are not limited to the following: (a) obtain endorsement for these efforts; (b) enable access to data bases and data sources in support of these efforts; and (c) develop a framework to formally manage requisite cross-agency cooperative and collaborative efforts needed to adopt and exploit the new capabilities.

## B. Space weather and its effects on GNSS

29. Participants recognized that the space weather seminar was very useful and more programs on the topic should be planned. The importance of space weather to civil aviation and future of space flight was highlighted. In that context, participants recommended that: (a) space weather discussion forums should be developed to educate the public as well as policy makers about space weather phenomena; (b) other workshops should provide opportunities for students and professionals to be involved in space weather data analysis and prediction.

### C. Capacity-building training and education in the field of GNSS

30. Participants recognized the need for the continuous building of national and regional expertise, through the provision of scholarships, long-term and short-term training and education at the United Nations-affiliated Regional Centres and other academic centres of excellence. In addition, participants stressed the need to make the existing educational opportunities available to a wider university community.

31. Participants recognized the need for additional workshops building upon the results of this workshop, including workshops focusing on training decision-makers (covering the integrated application of combined remote sensing, GIS and decision support systems).

32. Participants recommended that a regional geodetic capacity-building workshop with a focus on GNSS data processing and the use of open geodetic software should be conducted in cooperation with the International Federation of Surveyors (FIG) and the International Association of Geodesy (IAG), and that the reference frames should be made more visible and understandable to society.

33. It was noted that these workshops could be arranged to coincide with other related conferences and meetings, including FIG Working Weeks.

34. In order to enable knowledge sharing, participants recommended that institutions implement exchange programmes, providing opportunities for experts to visit and work with partner institutions. In particular, participants recommended that national, regional and international institutions make every effort to provide support to the Nepalese institutions through exchange programmes and technical support.

## III. Concluding remarks

35. Participants learned about the improvement in the existing infrastructure either by launching new satellites, in case of Galileo, Beidou Navigation Satellite System (BDS), Quasi-Zenith Satellite System (QZSS), Indian Regional Navigation Satellite Systems (IRNSS), or by modernization of the existing signals as with Global Positioning Systems (GPS) and Global Navigation Satellite System (GLONASS).

36. Participants took note of the release of new interference control documents (ICD) for all GNSS along with activities for international collaboration on compatibility and interoperability among the GNSS operators.

37. Participants recognized that the seminar on GNSS spectrum protection and interference detection and mitigation was successful in fulfilling its intended purpose of educating the workshop participants on the importance of GNSS spectrum protection, and challenging them to engage with their respective national spectrum management agencies to ensure continued access to the benefits GNSS provides.

38. Participants also recognized that CORS operators should be encouraged to facilitate the Earth's deformation studies. The importance of modernizing national geodetic reference systems was emphasized.

39. The participants found that low-cost GNSS receiver system for RTK using RTKLIB was very useful for education, training and even for survey and mapping, where required accuracy was within a sub-meter level. The participants also requested to improve the system to make it compatible for different types of base-station receiver makers. It was noted that the system would be developed in android platform in future.

40. Participants noted that the Public Health Concern Trust Nepal (PHECT Nepal) expressed an interest to integrate the GNSS technology as an integral part of telehealth in their rural health care model and that a workshop follow-up project “Integration of GNSS technology in rural healthcare model of Nepal” will be conducted.

41. The recommendations and observations put forward by the participants in the workshop provided guidance on how institutions could work together through regional partnerships. The Office for Outer Space Affairs should provide support for consolidation of the partnerships that were formed at the workshop. Those partnerships will result in the sharing and transfer of knowledge and the development of joint activities and project proposals.

42. Additionally, it was recommended that the Office should continue its work on capacity-building through the regional centres for space science and technology education affiliated with the United Nations and centres of excellence, and work further towards ensuring that end users will benefit from the GNSS multi-constellation.

43. The participants in the workshop expressed their appreciation to the United Nations, the Government of Nepal and co-sponsors for the substance and the excellent organization of the workshop.