



# General Assembly

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## Committee on the Peaceful Uses of Outer Space

### **Report on the United Nations/Abdus Salam International Centre for Theoretical Physics Workshop on the Use of Global Navigation Satellite Systems for Scientific Applications**

**(Trieste, Italy, 1-5 December 2014)**

#### **I. Introduction**

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), in particular through its resolution entitled “The Space Millennium: Vienna Declaration on Space and Human Development”, recommended that activities of the United Nations Programme on Space Applications should promote collaborative participation among Member States, at both the regional and international levels, in a variety of space science and technology activities, by emphasizing the development and transfer of knowledge and skills to developing countries and countries with economies in transition.<sup>1</sup>

2. At its fifty-sixth session, the Committee on the Peaceful Uses of Outer Space endorsed the programme of workshops, training courses, symposiums and expert meetings relating to environmental monitoring, natural resource management, global health, global navigation satellite systems (GNSS), basic space science, basic space technology, space law, climate change, human space technology and the socioeconomic benefits of space activities to be held in 2014 for the benefit of developing countries (A/68/20, para. 66). Subsequently, the General Assembly, in its resolution 68/75, endorsed the United Nations Programme on Space Applications for 2014.

3. Pursuant to General Assembly resolution 68/75 and as part of the United Nations Programme on Space Applications, the Office for Outer Space Affairs of the

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<sup>1</sup> *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, sect. I, para. 1 (e)(ii), and chap. II, para. 409 (d)(i).



Secretariat organized, in cooperation with the Abdus Salam International Centre for Theoretical Physics, the United Nations/Abdus Salam International Centre for Theoretical Physics Workshop on the Use of Global Navigation Satellite Systems for Scientific Applications. The Workshop was hosted by the International Centre for Theoretical Physics in Trieste, Italy, from 1 to 5 December 2014.

4. Previous regional workshops on the applications of GNSS organized by the United Nations had been hosted by the Governments of China and Zambia in 2006 (A/AC.105/883 and A/AC.105/876, respectively), 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 in 2011 (A/AC.105/988), Latvia in 2012 (A/AC.105/1022) and Croatia in 2013 (A/AC.105/1055). These workshops had focused on capacity-building in the use of GNSS in various applications that support sustainable development.

5. The United Nations International Meeting on the Applications of Global Navigation Satellite Systems (A/AC.105/1019) was held in Vienna in 2011. Its purpose was to strengthen the dialogue between GNSS providers and end users with a view to defining requirements for future GNSS services and identifying any improvements needed.

6. The present report describes the background, objectives and programme of the Workshop and provides a summary of the observations and recommendations made by the Workshop's participants. The report has been prepared for submission to the Committee on the Peaceful Uses of Outer Space at its fifty-eighth session and its Scientific and Technical Subcommittee at its fifty-second session, both in 2015.

## **A. Background and objectives**

7. GNSS is an enabling technology that can make major contributions to economic growth and social betterment worldwide. GNSS data were now used in a wide range of areas, which include mapping and surveying, monitoring of the environment, precision agriculture and natural resources management, disaster warning and emergency response, and transportation by air, sea and land. In addition, GNSS signals have been used successfully in sounding the atmosphere and ionosphere, the oceans and land surfaces, including for measuring soil moisture.

8. Since 2009 the Abdus Salam International Centre for Theoretical Physics and the Institute of Scientific Research of Boston College (United States of America) have cooperated with the Office for Outer Space Affairs in conducting activities that focus on building capacity for satellite navigation science and technology in Africa. Participants in those activities have received training from international experts in topics ranging from GNSS to terrestrial reference systems and frames. Sessions have also been held on space weather and ionospheric research in an effort to initiate space science research programmes in Africa and support existing groups and projects focusing on the use of GNSS in ionospheric research.

9. The following are the workshops and training courses on the use of GNSS for scientific applications that were carried out between 2009 and 2014 and co-sponsored by the Government of the United States and the European Union

through the International Committee on Global Navigation Satellite Systems (ICG), which also provided substantive technical support:

(a) Workshop on satellite navigation science and technology for Africa, held in Trieste, Italy, from 23 March to 9 April 2009 (A/AC.105/950, paras. 10-11);

(b) Workshop on satellite navigation science and technology for Africa, held in Trieste, Italy from 6 to 24 April 2010 (A/AC.105/996, paras. 13-14);

(c) Workshop on the use of science applications of GNSS in developing countries, held in Trieste, Italy, from 11 to 27 April 2012, followed by a seminar on the development and use of the NeQuick ionospheric model, also held in Trieste, on 30 April and 1 May 2012 (A/AC.105/1034, paras. 14-17);

(d) Workshop on GNSS data application to low-latitude ionospheric research, held in Trieste, Italy from 6 to 17 May 2013 (A/AC.105/1060, paras. 13-15);

(e) The “African school on space science: Related applications and awareness for sustainable development of the region”, held in Kigali from 30 June to 11 July 2014 (A/AC.105/1084, paras. 12-14).

10. The main objective of the five-day Workshop was to provide a forum in which participants could share their technical expertise in and experiences with science applications of GNSS. The specific objectives were to (a) increase awareness among decision makers and representatives of the research and academic community of ongoing activities and trends in the use of GNSS technology, applications and services; (b) review case studies and initiatives, both ongoing and planned, including one or more possible national, regional or international pilot projects that could contribute to widening the use of GNSS, particularly in scientific exploration; (c) assess recent scientific and technical results in monitoring space weather, its effect on the ionosphere and, consequently, on GNSS positioning; and (d) draw up findings and recommendations, to be forwarded as a contribution to ICG and its working groups.

## **B. Programme**

11. At the opening of the Workshop introductory and welcoming statements were made by the representatives of the Abdus Salam International Centre for Theoretical Physics and the Office for Outer Space Affairs, as co-organizers and co-sponsors. The Workshop was divided into eight plenary sessions and two panel discussion sessions. Presentations by invited speakers, describing their achievements in research, education and outreach activities related to science applications of GNSS, were followed by brief discussions. The invited speakers, who came from both developed and developing countries, presented 46 papers. The panel discussions provided participants with an opportunity to focus on specific problems and projects related to coordination and cooperative research, development and training programmes relating to the use of GNSS.

12. The Workshop focused on the following topics: satellite-based navigation and augmentation systems, international initiatives on GNSS implementation,

capacity-building, GNSS observation data for atmospheric studies, general GNSS applications, GNSS positioning, GNSS for monitoring applications.

13. At the concluding session of the Workshop the observations and recommendations emerging from the panel discussions were summarized and adopted.

### **C. Attendance**

14. Representatives of academia, research institutions, national space agencies, international organizations and industry from developing and developed countries concerned with the development and 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 with programmes and projects in GNSS technology and its applications.

15. Funds provided by the United Nations and the Abdus Salam International Centre for Theoretical Physics were used to defray the costs of air travel and accommodation for 26 participants. A total of 66 specialists in satellite navigation systems were invited to attend the Workshop.

16. The following 34 States members of the Committee were represented at the Workshop: Argentina, Azerbaijan, Bangladesh, Bosnia and Herzegovina, Bulgaria, Cameroon, China, Colombia, Congo, Côte d'Ivoire, Ecuador, Egypt, Estonia, France, India, Indonesia, Israel, Italy, Kazakhstan, Latvia, Mexico, Nepal, Nigeria, Pakistan, Peru, Portugal, Republic of Moldova, Russian Federation, Spain, Ukraine, United States, United Republic of Tanzania, Uzbekistan and Viet Nam.

17. The Workshop was also attended by representatives of the European Union and the European Space Research and Technology Centre of the European Space Agency. The Office for Outer Space Affairs and the Abdus Salam International Centre for Theoretical Physics were also represented.

## **II. Summary of presentations**

18. Representatives provided overviews of the following satellite-based navigation systems, in operation or under development: the Global Positioning System (GPS), the Global Navigation Satellite System (GLONASS), the Galileo satellite navigation system, and satellite-based augmentation systems such as the Wide-area Augmentation System (WAAS) and the European Geostationary Navigation Overlay System (EGNOS). It was noted that these GNSS systems were currently being used along with the BeiDou Navigation Satellite System (China), the Indian Regional Navigation Satellite System and the Quasi-Zenith Satellite System (Japan) in numerous applications ranging from the practical to the scientific. Using a combination of multiple systems can significantly improve many applications, as using more satellites strengthens the orbit geometry, resulting in higher accuracy and wider coverage of GNSS signals.

19. It was noted that those improvements were particularly important for kinematic applications, for applications used at middle and lower latitude regions

and for applications used in difficult environments where the visibility of the sky is restricted, such as urban areas. Additionally, available signals and their frequencies, and the different characteristics of each GNSS satellite, would benefit scientific exploration, for example the monitoring of water vapour for weather forecasting and climate studies, the observation of the ionosphere's influence on radio communications, and the development of an advanced warning system for earthquakes.

20. A number of presentations showed that continuous observations collected by GNSS receivers provide an excellent tool for studying the Earth's atmosphere. GNSS is routinely used to observe the total electron content of the ionosphere and water vapour integrated in the troposphere. NeQuick, a quick-run ionospheric electron density model designed for transionosphere propagation applications, was demonstrated and its performance as the Galileo single-frequency ionospheric correction algorithm was evaluated.

21. The importance of having a network of continuously operating reference stations that provide GNSS data in support of three-dimensional positioning, meteorology, space weather and geophysical applications was outlined and some examples were given of infrastructure and multi-user systems that have been established.

22. The Office for Outer Space Affairs presented the work of ICG, highlighting its achievements in establishing interoperability and compatibility among the global systems. The ICG programme on GNSS applications, which has a special focus on organizing regional workshops and training courses for capacity-building in developing countries, was outlined.

23. The experience of the Abdus Salam International Centre for Theoretical Physics in delivering education and training in the field of satellite navigation science and technology was presented. The project entitled "Training EGNOS-GNSS in Africa", which aims to assist Africa's aviation sector, was also presented.

24. The presentations, the abstracts of the papers, the programme and the background materials are available on the website of the Office for Outer Space Affairs ([www.unoosa.org](http://www.unoosa.org)) and the website of the Abdus Salam International Centre for Theoretical Physics (<http://indico.ictp.it/event/a13233>).

### **III. Observations and recommendations**

25. During the discussion sessions, participants focused on several points, reaching agreement on recommendations that together would form a strategy for action and a framework for the advancement of science applications of GNSS in developing countries. Participants also emphasized the need to strengthen national capacity in GNSS science and applications, specifically through targeted training that is appropriate in the regional context and takes advantage of existing regional structures and specialized centres of excellence. The need to raise the awareness of decision makers was identified as a possible focus area.

26. Participants noted that within the GNSS community some users would benefit greatly from easier access to GNSS data and the products commonly used to process

them. To contribute to making the use of a standardized set of GNSS data and products available to the broader scientific and surveying communities, participants recommended that each institution maintain a web page with links to other websites that have information on freely available data, including links to the web pages of partner institutions. Additionally, participants stressed that in producing GNSS data, institutions should give priority to commonly used data standards, preferably the Receiver Independent Exchange Format (RINEX), to facilitate sharing both the content and structure of their data.

27. In that context, participants noted that a variety of public GNSS service providers offer data free of charge via the Internet, notably the International GNSS Service (IGS) tracking network. The primary data provided by IGS are GPS and GLONASS code and phase measurements in the form of RINEX files for each of the stations forming the IGS network. It was mentioned that general information on the IGS network and information on how to obtain RINEX data files was available from <http://igs.cb.jpl.nasa.gov>.

28. Participants recommended the establishment of a consolidated list of the available software packages that were used to process GNSS data for research applications. That list should be included in the ICG education resources page ([www.unoosa.org](http://www.unoosa.org)) and updated regularly.

29. Participants recognized the need for continuously building national and regional expertise through the provision of long-term and short-term training and education at the regional centres for space science and education affiliated to the United Nations, and through programmes offered by the Abdus Salam International Centre for Theoretical Physics, and other academic centres of excellence.

30. Participants also recognized the need for additional workshops to build on the results of the current Workshop, focusing on tropospheric and ionospheric modelling, integrated application of GNSS Earth observation techniques, and GNSS vulnerabilities and other topics.

31. Participants recognized that there were a number of ongoing initiatives that should be taken advantage of, and that proposing new projects and activities presented certain challenges. It was recommended that institutions build on the opportunities provided by such initiatives, because that would help to define a more effective strategy for cooperation at the international, regional and national levels.

32. The participants in the Workshop expressed their appreciation to the United Nations and the Abdus Salam International Centre for Theoretical Physics for the organization of the Workshop and for its substance. The Workshop provided a unique opportunity to channel support for further development and progress towards using GNSS technology in the participating countries.