UNISPACE III ACTION TEAM ON GLOBAL NAVIGATION SATELLITE SYSTEMS

Summary

GNSS constitute one of the most promising space applications that can be used to implement the recommendations adopted during the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III).[i] The positioning and timing capabilities based on GNSS space technologies are generating extensive emerging markets for new services and advanced applications when used either as stand-alone systems or in synergy with other systems. In recent years, the use of satellites for navigation, positioning and timing has become an increasingly significant economic activity, with industry revenues projected to grow from over $7 billion in 2000 to over $9 billion in 2002.

User communities worldwide (working, for example, in disaster management, monitoring of the environment, geomatics, precision agriculture, resource conservation, surveying, mapping, transport and timing) are becoming increasingly convinced of the need to develop GNSS that provide a safer, more reliable navigation and positioning service for civil use. That implies improving the performance of the current service in terms of accuracy, integrity, continuity and reliability.

International cooperation at both the political and the technical level is needed for the successful implementation of satellite navigation and positioning technology. System provider entities, potential contributor and end-user States, as well as users from industry, service providers and international organizations, need to cooperate closely to ensure the provision of a safe, seamless global satellite navigation and positioning system.

Since it is universally accepted that differences in the pace of development around the world should not lead to incompatibility between the elements of navigation and positioning systems, it is desirable for the providers of GNSS to achieve full compatibility and interoperability of regional satellite navigation systems throughout the implementation process.

Background

The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held in July 1999, adopted a strategy to address global challenges in the future through space activities. The strategy as contained in "Space Millennium: Vienna Declaration on Space and Human Development"[1] included a few key actions to use space applications for human security, development and welfare. One of such actions was "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."

In 2001, Member States accorded high priority to a limited number of selected recommendations of UNISPACE III. The Committee on the Peaceful Uses of Outer Space established action teams under the voluntary leadership of member States to implement those priority recommendations. The Action Team on Global Navigation Satellite Systems (GNSS) was established under the leadership of the United States of America and Italy to carry out the recommendation relating to global navigation satellite systems.

The Action Team reported to the Committee and its Scientific and Technical Subcommittee at their sessions in 2001 concerning its objectives, work plan and final product. The terms of reference of the Action Team included the purpose, work plan, product and schedule of meetings as indicated below.

Purpose

To survey current international and regional efforts to achieve a seamless multi-modal satellite based navigation and positioning system throughout the world;
To assess institutional models of international co-operation and co-ordination systems and services and GNSS users' interests;

To propose specific recommendations for [the Secretariat and Member States of] the United Nations and

[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.

other international organisations on actions that should be taken

To promote GNSS user interests, increase the level of awareness, improve the quality and to facilitate utilisation of GNSS services, particularly in developing countries;

To propose specific recommendations on global co-ordination and co-operation.

Work Plan

Compile information on national and international outreach activities designed to promote the use of GNSS for sustainable development, economic growth and scientific research;

Compile information on the level of awareness and capacity of developing countries to use GNSS services and application;

Conduct an inventory of and identify gaps in meeting the requirements of developing countries for GNSS services and applications;

Consider ways in which organs of the United Nations system, non-governmental entities and international organisations and Member States of the United Nations could play a role in filling those gaps;

Request other entities of the United Nations, through the Office for Outer Space Affairs, to report on their use of GNSS to meet their respective mandates;

Evaluate the results of the series of United Nations Regional Workshops on GNSS organised within the framework of the United Nations Program on Space Applications, with a view to identifying common themes.

Product

A report was completed with information on relevant national and international activities on promoting use, access to and quality of GNSS services. The report includes proposals for specific recommendations for the Committee and other relevant United Nations bodies, non-governmental

entities, as well as United Nations Member States and international organisations concerning development, co-ordination and increased use of GNSS, particularly to the benefit of developing countries.

Schedule of meetings

Meetings of the Action Team were scheduled on the margins of the meetings of the Committee and its Scientific and Technical Subcommittee and the activities organised by the Office for Outer Space Affairs.

The Action Team has held eight meetings as indicated below:

First meeting (Vienna, 30 November 2001), in conjunction with the Second UN/USA Regional Workshop on the Use and Applications of GNSS (Vienna, 26-30 November 2001);

Second meeting (Rome, 25 January 2002), in conjunction with the twenty-second session of the Inter-Agency Meeting on Outer Space Activities (Rome, 23-25 January 2002);

Third meeting (Vienna, 27 February 2002), on the margins of the thirty-ninth session of the Scientific and Technical Subcommittee (Vienna, 25 February – 8 March 2002);

Fourth meeting (Vienna, 4 June 2002), in conjunction with the forty-fifth session of the Committee on the Peaceful Uses of Outer Space (5-14 June 2002);

Fifth meeting (Vienna, 15 November 2002), in conjunction with the UN/USA International Meeting of Experts on the Use and Applications of GNSS (Vienna, 11-15 November 2002);

Sixth meeting (Vienna, 18 February 2003), on the margins of the fortieth session of the Scientific and Technical Subcommittee (Vienna, 17-28 February 2003).

Seventh meeting (Vienna, 10 June 2003), on the margins of the forth-sixth session of the Committee on the peaceful Uses of Outer Space (Vienna, 11-20 June 2003)

Eighth meeting (Vienna, [11] December 2003), in conjunction with the UN/USA International Workshop on the Use and Applications of GNSS (Vienna, 8-12 December 2003)

The membership of Action Team was open to any interested member States of the United Nations as well as entities of the United Nations, other intergovernmental organisations and non-governmental entities. The membership consisted of the following member States and organisations:

Member States:

Australia, Austria, Belarus, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, France, Germany, Hungary, India, Iran (Islamic Republic of), Iraq, Italy, Japan, Lebanon, Malaysia, Mongolia, Morocco, Pakistan, Philippines, Poland, Portugal, Republic of Korea, Russian Federation, Saudi Arabia, Syrian Arab Republic, Turkey, the United States of America

Organizations:

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), International Telecommunication Union (ITU), Bureau International des Poids et Mesures (BIPM), European Commission (EC), European Space Agency (ESA), European Organisation for the Safety of Air Navigation (Eurocontrol), American Institute of Aeronautics and Astronautics (AIAA), Civil GPS Service Interface Committee (CGSIC), European Association for International Space Year (EURISY), International Federation of Surveyors (FIG), International Association of Institutes of Navigation (IAIN), International GPS Service (IGS).

Satellite navigation builds upon terrestrial-based radio navigation that has been used by aviation and shipping over the past 100 years. Navigation satellites broadcast signals that are used by a receiver to determine exactly the receiver’s position, velocity and precise time worldwide. User receivers of satellite navigation signals measure the distance of the receiver equipment to the satellite using a technique called “passive ranging”. In this technique, the distance to each satellite is derived from the measurement of the time the navigation signal needs to travel from the satellite to the receiver. The three-dimensional position of the receiver can be calculated if signals from at least three satellites are

available. The signal from a fourth satellite is used to avoid the need for a precise atomic clock at the receiver.

Standard GNSS signal processing provides around 100-metre accuracy at the location of the receiver, while precision signal processing provides around 20-metre accuracy. If, in addition to the signals from the satellites, a user receiver also receives the signal of a ground-based reference station, the accuracy at the location of the user receiver is around one metre. Reference stations make differential GNSS (DGNSS) services possible.

GPS, a dual-use system implemented by the United States, is fully operational and provides an open, civil navigation service free of direct user fees. The space segment of GPS consisted of 28 operating satellites, in order to ensure that there were 24 operating satellites on 6 orbital planes, with 4 operating satellites per plane, at any given time. Outreach activities and international cooperation, such as those with the Russian Federation, Europe and Japan, remained an important part of the policy of the United States. The principles for cooperation included no direct user fees, open signal structure, open market-driven environment and protection of the current radio-navigation spectrum.

GLONASS is a dual-use system operated by the Russian Federation. Now operational with limitations the constellation will consist of 24 operating satellites on 3 orbital planes, with 8 operating satellites per plane. The GLONASS programme main goals include the guaranteed provision of service for international users, strengthening of international cooperation, development of equipment for users that would be competitive on the international market, creation of a new geodesy network and development of scientific and technological bases for further satellite navigation development.

European countries, through the European Union and the European Space Agencies are developing a system known as Galileo. Galileo is planned to be operational from the year 2008. Among its goals are achieving sovereignty, autonomy and a guarantee of service for European countries; benefits to industry; certifiable safety of life applications; and availability of complementary and backup systems to GPS and GLONASS. Galileo will provide a variety

of global services free of charge to all users, while value-added services would be provided at a cost.

In addition to the primary systems, current and planned, there are a number of augmentations operating or in the development stages. Augmentation systems have been and being developed to reinforce the integrity, accuracy, continuity and availability of GNSS signals. Examples of satellite-based augmentation systems (SBAS) included the Wide Area Augmentation System (WAAS) of the United States, the European Geostationary Navigation Overlay Service (EGNOS) of Europe, the Multifunction Satellite Augmentation System (MSAS) and the Quasi-Zenith Satellite System (QZSS) of Japan, and the GPS And Geo Augmented Navigation satellite (GAGAN) of India.

Developing Country Needs and Concerns

The Action Team recognized that GNSS application and user needs in the industrialized world were fairly well understood. Consequently, the Action Team focused on what should be done to promote the use of GNSS in developing countries.

GNSS is an extremely valuable tool across a broad range of applications and requirements. GNSS technology provides an opportunity for developing countries to take advantage of applications that improve the quality of life, benefit social and economic progress, and support priorities for sustainable development. The technical advances in GNSS over the last 20 years have resulted in streamlined processes, software, instrumentation, and relatively inexpensive basic user equipment.

However, the benefits of GNSS are not fully recognised and taken advantage of particularly in developing countries for a variety of reasons. In order to help developing countries benefit from GNSS applications, the United Nations Office for Outer Space Affairs (OOSA) organised, within the framework of the United Nations Programme on Space Applications, a series of workshops focusing on capacity building in the use of GNSS in various areas of applications. Four regional workshops (Kuala Lumpur, Malaysia, August 2001; Vienna, Austria, November 2001; Santiago de Chile, April 2002, and Lusaka, Zambia, July 2002) and one international expert meeting were organised with the technical and financial support of the Government

of the United States of America. Co-sponsorship was also provided by the European Space Agency (ESA).

The regional workshops provided an opportunity for outreach and assessment of the particular needs of developing countries. A questionnaire was developed and circulated to participants by the OOSA and the results made available to the meeting of experts in November of 2002. This information along with communications with various workshop participants aided in the identification of key areas of interest and the challenges facing people wishing to integrate GNSS into their field of work or application.

The needs of developing countries are concentrated in the following directions:

Institutional Needs

1. Education of decision and policy makers to support application efforts. Government support for GNSS technology, and increasing level of interest and awareness of 'new way' to do things. Lack of official policies related to use of GNSS as a key factor for social and economic development. View beyond national borders.
2. Capacity building
3. Reports and recommendations should be sent via UN channels to governments of all countries involved. Benefits of GNSS technology and applications should be highlighted to policy/decision makers to increase financial and political support.
4. Explore establishment of an international GNSS organization to promote and foster technology and applications.
5. UN Workshops should continue, resulting recommendations should be implemented. These are seen as very valuable in building capacity and understanding, providing network of professionals, educators and students.

Technical Needs

6. Ionospheric effect, integrity, continuity, availability accuracy. Understanding ionospheric effects on GNSS applications especially at equatorial areas.
7. Future developments of GPS/ Galileo and various augmentations – how developing countries should approach. Difficult to follow and understand plans and technical impact.

Resources and Financial Needs

8. Required instrumentation, ancillary equipment, computer and software costs have generally declined, it is still too expensive in comparison to economic levels of developing countries. Maintenance and recurring costs are difficult to obtain.

Training and Education

9. Training programs should be recommended by the UN and developed. Observations, analysis and implementation – covering all aspects. Specialty, or professional training programs and opportunities, e.g., civil aviation, precision measurements, remote sensing.

10. Education, training, and access to qualified people and information.Scarce availability of experts, new students, university or other training programs. Lack of experts in the various areas noted above. Networking with GNSS experts in other fields difficult.

INSTITUTIONAL MODELS FOR INTERNATIONAL COOPERATION

As future components of the overall GNSS architecture develop worldwide, the need for an international framework to support operational co-ordination and exchange of information among system designers and operators and national and international user communities will be increasingly important. The focus should no longer be on explaining the basic principles of GNSS or on trying to educate the general public, the scientific community at large or policymakers about the benefits of GNSS. System operators of GNSS and their augmentations must move beyond simple outreach. The assumption is that current and future system operators will soon move from a strictly competitive to a more collaboration mode where there is a shared interest in the universal use of GNSS services regardless of the system. If this is to be the case, then the real challenge now is to provide assistance and information for those countries seeking to integrate GNSS and its augmentations into their basic infrastructure at all levels (i.e. commercial, scientific and government).

The framework to be discussed will be most favourable to service providing governments if flexible mechanisms are pursued the focus of these mechanisms is providing improved service to users.

The following categories of the international co-operation of the GNSS service providers are considered for implementation:

- Coordination
  - among the core GNSS service and augmentation providers
  - national planning and/or regional planning
- Dissemination - of information on GNSS to users and provision of technical assistance for the integration of GNSS into national infrastructures
- Collection - of users needs and desires regarding GNSS

A. Coordination

1. Coordination among the GNSS service providers

On the basis of work done at the UN workshops and Action Team meetings the following objectives for international GNSS co-operation has been identified with respect to GNSS development and the provision of basic GNSS services:

- To reduce the complexity and cost of user equipment, GNSS providers should pursue greater compatibility and interoperability among all future systems (GPS III, Glonass K, Galileo, augmentations) in terms of signal structures, time and geodetic reference standards.
- To protect the investment of the current user base, GNSS providers should ensure that current services are continued for existing user equipment on a free and non-discriminatory basis for a reasonable time frame (e.g. existing user equipment life time).
- To ensure continuity and integrity of GNSS services and augmentations, operators should take steps with national administrations to protect against interference with national and regional infrastructures (satellite, ground stations).
- To ensure continuous reception of GNSS services, all nations should prioritise the protection of radio spectrum allocated for GNSS services from interference, both domestically and internationally.
- It is essential to develop appropriate security mechanisms to prevent hostile use of civil GNSS services in areas of conflict without degrading civil service on a global basis. Core GNSS

components such as GPS, GLONASS, Galileo and augmentations (local, regional or global) must be taken into account.

In order to collectively discuss each of these recommendations and to identify actions for implementation, the establishment of a service provider co-operation mechanism such as a "GNSS Co-ordination Board" (GCB) could be established. This would be achieved through a multilateral arrangement between the governments and/or organisations that currently provide or plan to provide global GNSS services and maintain corresponding infrastructure i.e. the United States, the Russian Federation, and the European Union.

The GCB could also include current and future providers of regional augmentation systems (India and Japan). In addition to the objectives above the Board should look into ways of optimising compatibility, interoperability, availability and reliability of the core systems. Among other things, the GCB could facilitate information exchanges between GNSS providers on system modernisation/development to ensure compatibility and interoperability. The GCB should also identify mechanisms for and implementation of measures to protect the reliability and integrity of signals at the national, regional and global levels; and co-ordinate modernisation/development activities to meet user needs, particularly in the developing world.

Since compatibility and interoperability are highly dependent on the establishment of standards for service provision and user equipment, standard setting will be another topic that the Co-ordination Board would need to address. However, the Board should probably avoid efforts to set standards itself and should instead look for applications where no standards currently exist, such as land transport, and recommend possible organisations that could appropriately set new standards. Consultation with existing standard setting bodies such as the International Civil Aviation Organization, the International Maritime Organization, and the International Telecommunications Union will also be required. In addition, the UN Committee on the Peaceful Uses of Outer Space, through it Programme on Space Applications, could play a useful role in demonstrating for developing countries the practical benefits of GNSS and assisting the GCB in integrating GNSS into developing country infrastructures.

Such a board would provide a mechanism for coordination among service providers:

- Coordination of activity and plans of system modernisation and development:
  - to ensure compatibility and interoperability in terms of signal structure, time and geodetic reference standards
  - to establish standards for service provision and user equipment
  - to reduce the complexity and cost of user equipment
  - to ensure continuity of existing services for a reasonable time frame to protect the investment of the current user base
  - to maintain the use of the systems on a free and non-discriminatory basis
  - to advocate long-term protection of the spectrum reserved for GNSS

- Elaboration and implementation of security measures:
  - to protect against threats to physical GNSS infrastructure of satellites and ground stations to ensure continuity of GNSS services
  - to prevent hostile use of civil GNSS services in areas of conflict without degrading civil service on a global basis

The following membership could be envisaged for the GNSS Co-ordination Board:

- Core GNSS system providers, and developers/customers of GPS, GLONASS, GALILEO
- Global user organisations such as the International GPS Service (IGS)
- Providers of augmentation systems such as WAAS, EGNOS, MSAS and the Quasi-Zenith Satellite System (QZSS).

Preparation of major user equipment suppliers in the GCB sessions may benefit in further GNSS applications.

2. National/Regional Planning and Governance

Establishing national and/or regional planning groups for GNSS that would address regulations, user needs, etc., is clearly an important objective. Many countries are searching for an organisational model to use at the national level for co-ordinating and governing GNSS use.

The existing GNSS service providers or new entities could be used as such co-ordinating bodies. In some cases the bodies are lead by various science and transport authorities (e.g. air navigation service providers).
The United Nations Regional Centers for Space Science & Technology are a possible avenue that could be given the task, in conjunction with the GCB, for GNSS planning and organisation on the regional level. However, due to lack of resources, some governments might have to consider delegating the responsibility of co-ordinating the development of relevant national navigation infrastructure to the existing service providers.

B. User Support and Information Dissemination

The need for a link between users, equipment manufacturers, service providers and core system providers was highlighted in several of the regional workshop reports and in the deliberations that occurred during the Vienna Meeting of GNSS Experts. The objective is to increase awareness among users, provide information that is critical to users with respect to GNSS service provision, and to ensure that core system providers take into account user feedback.

The type of information that needs to be relayed from service providers to users includes, but is not limited to the following:

- Dissemination of GNSS system status information such as satellite health and satellite maintenance and testing schedules — scheduled and unscheduled satellite outages within the core GNSS architecture have a direct impact on the level of service that is available for a given GNSS application. Predictive tools exist in some application sectors such as aviation that can allow users to determine when poor service availability is likely and then plan accordingly.
- Provision of timely notification of service denial or degradation through intentional or unintentional interference is critical. The dependency of users on GNSS is comparable to if not greater, to other familiar services and utilities such as telecommunications and electrical services. The intentional disruption of GNSS services could, therefore, pose great risks to users that could lead to life-threatening situations. Such intentional disruptions could be hostile in nature, or they could be the result of necessary actions taken by

sovereign nations whose national security may be at risk from the potentially hostile use of GNSS by other nations or terrorists. Such denials of service, even for appropriate national security reasons, can potentially jeopardise the safety of civil users. Therefore, users could benefit from a mechanism that allows for timely notification of local and/or regional service denial.

Implementation mechanism

User Information Centers should be established by each individual service provider. The maintenance of a globally focused web site would be a major task of these centres.

For GPS, the Navigation Information Service managed by the U.S. Coast Guard Navigation Center is the primary means of disseminating information to civil users. This is primarily accomplished through a web site that includes links to many sources of GPS information.

For GLONASS, similar web sites exist that are managed by the Russian Military and the Russian Aviation and Space Agency.

Similarly, the European Commission also provides a web-based portal for the Galileo project.

Regionally focused web pages would be the responsibility of selected regional or national points of contact.

Dissemination of information between users themselves can also be improved by organising national GNSS user groups as providers of input to the consolidated web site. Existing user groups with government sponsorship include the U.S. Civil GPS Service Interface Committee. Industry groups include the U.S. GPS Industry Council, Japan GPS Council, and the Scandinavian GNSS Industry Council. The federated web-based information system of the International GPS Service serves the scientific and research community, as well as high-accuracy users of any category.

This web-based information resource should probably take advantage of existing web sites such as those previously mentioned to the maximum extent possible. However, since this resource will be used by all nations of the world and their GNSS user communities, great care will need to be taken to ensure that the information available is easy to

access for all. This will require web site design or re-design that includes options for text only to allow usable access to those with low data throughput rates. Translation of as many documents and materials included in the nested set of web sites as possible should also be considered.

The UN Office for Outer Space Affairs, could combine all web sites into a single site to act as portal for any user of any GNSS service or regional component of a service (International GNSS User Information Center).

C. Collection of users needs and desires regarding GNSS

Collection of information from user community could be implemented by the following means:

- with help of information exchange based on the means of international GNSS User Information Center internet technique
- based on the regional workshops with participation of the GNSS Co-ordination Board representatives

Meetings between GCB and User Community should be organised under UN leadership twice a year in the regions. Conducting workshops in connection with well-attended international GNSS meetings may be desirable.

RECOMMENDATIONS

A number of sources provided a series of recommendations for promoting a more efficient use of the technology of GNSS around the world. The four regional workshops held in 2001 and 2002, the International Meeting of Experts held in late 2002, responses to questionnaires sent to experts, participants and service providers at those meetings as well input from members of the Action Team on GNSS are just a few. These are summarised below.

Recommendations Regarding Institutional Framework to Service Providers

1. Creation of a GNSS Co-ordinating Board

Such a Board would provide a mechanism for co-ordination among service providers to address among others the following recommendations:

i) Co-ordination of activity and plans of system modernisation and development:

- to encourage compatibility and interoperability in terms of signal structure, time and geodetic reference standards
- to establish standards for service provision and user equipment
- to reduce the complexity and cost of user equipment
- to ensure continuity of existing services to protect the investment of the current user base
- to maintain the use of the systems on a free and non-discriminatory basis
- to advocate long-term protection of the spectrum reserved for GNSS

ii) Elaboration and implementation of security measures to protect against threats to physical GNSS infrastructure of satellites and ground stations to ensure continuity of GNSS services.

The GNSS Coordinating Board could be established through a multi-lateral agreement among providers of GNSS and regional augmentations systems. The Board might be modelled after the Committee on Earth Observation Satellites (CEOS[2]),

[2] www.ceos.org/pages/overview.html

with secretariat responsibility rotating among the members on an annual basis. This possibility could be examined. The UN Office for Outer Space Affairs and ICAO could be affiliated at some level in order to provide an exchange of information on user needs and to support the broader objective of integrating GNSS and its augmentations into the basic infrastructures of developing countries.

2. Development of User Information Centers and Websites

Each GNSS and/or regional augmentation provider should establish user Information Centers. The maintenance of a website would be a major task of these centers. The United Nations, the GNSS Coordinating Board or other international body should combine all web sites into a single site to act as a portal for any user of GNSS and/or augmentations. Such a portal could become part of OOSA web site to be maintained by OOSA in co-operation with the GNSS Coordination Board.

Recommendations Regarding Institutional Framework to the UN Office of Outer Space Affairs

1. Continue to hold regional workshops

The UN regional workshop series has been helpful to service providers as a means of collecting inputs from users. It was very useful as a means of promoting the use of GNSS and their augmentations in developing countries. Therefore, the workshops should continue in same manner with a focus on user inputs. Conducting workshops in connection with well-attended international GNSS meetings may be desirable.

2. Support the establishment of national (and perhaps even regional) GNSS planning and co-ordination groups. Appropriate organisational models and best practices should also be provided.

3. Commission an assessment of current institutional models. Assess international co-operation and co-ordination, and identify those with potential applicability to evolving GNSS systems and services. Careful consideration should be given to flexible, informal mechanisms and existing organisations that already attempt to provide informational services in GNSS users.

There is loose organisation at the national level with regards to provider-user coordination and no one organisation that assumes end-to-end responsibility for GNSS. Applications are often fragmented and atomised. And developments are under-funded. There is a lack of knowledge and understanding at high decision-makers level on how to utilise the new technology and incorporate appropriate processes at the organisational level. Clearly, there is a need to improve communications between service providers and these decision-makers to demonstrate the cost-effectiveness of GNSS technology by showing examples of applications and solutions to problems.

The main difficulty is to find common interest with specialists in various fields, e.g. aeronautics, marine, land navigation, mobile robots etc. Effort is required to unify an approach to navigation and positioning to optimise synergy that will include many diverse applications and users.

4. Stimulate Capacity Building for GNSS Education and Training

The regional conferences have identified that there are very few experts in this new technology, particularly in the least developed nations of the world. This underscores the need to:

- Develop the skills and knowledge of university educators, research and scientists, through theory, research, field exercises and pilot projects.
- The Centers for Space Science and Technology Education affiliated to the United Nations should consider including GNSS programs in their training activities.
- Train the final users in the multiple GNSS applications to create a critical mass of trained personnel at the regional and national levels.

It was also noted that there is a need for publication of GNSS-related materials in languages other than English.

The national/regional/international symposia/events on development and application of modern space technologies organised by national/ regional/international associations/organisations as a way for increasing the awareness and qualification to be supported by UN (for example annual symposium in Sofia)

5. Help promote the use of GNSS

Reports of the UN/USA workshops should be sent, through official UN channels, to governments of developing countries in particular. This would assist in promoting GNSS applications.

Recommendations Specific to GNSS Applications

Aviation

1. Encourage research activities related to the development of ionospheric models including measurements related to GNSS and the exchange of such information.

GNSS signal has been available over many years. However, parameters such as GNSS integrity, continuity, availability and accuracy still do not meet more stringent requirements that certain applications, like aviation, expect. Region-specific phenomena such as geomagnetic equator anomaly have significant impact on determining regional solutions for central and Southern Hemisphere rather than the Northern Hemisphere. Collecting and analysing ionosphere data to determine optimal algorithms for ionosphere model of the region will be a challenge that would increase international understanding for sharing information between independent GPS augmentation systems, and the shared use of communication satellites.

The ionosphere interference of GNSS (GPS) signal, due to the geomagnetic equator effect, prevents meeting some specific requirements (parameters) of aeronautical activities in terms of integrity, continuity, availability and accuracy.

2. Consider the implementation of a “One African Sky” concept in the upper end route similar to the “Single European Sky” initiative currently underway in Europe.

Successful implementation of GNSS in other parts of the world show that utilisation of this technology and receipt of associated benefits, will require that institutions that were built around ground based aviation must change to fully exploit the technology. They must also allow for the expansion of air travel and resulting expansion of the African economies. The timing of the new African Union allows the opportunity for a fresh look at these structures and processes.

3. UN/OOSA and ICAO should continue to encourage adoption of GNSS within the African continent.

Toward that end, it is recommended that UN/ICAO host within a short period of time a GNSS Executive Level Session with all the African Directors General of Civil Aviation to begin to address the challenges above.

Specific recommendations for the session are:

- Agree to a small number of regions;
- Set up a Task Force within each region to begin to harmonise structures;
- Establish cross-region mechanisms so those problems are solved once standardised procedures are adopted;
- Establish a uniform model for cost recovery;
- Have an existing higher education institution develop an academic program to support the implementation of GNSS under the leadership of the regional “advocates”;
- Today‘s safety statistics should be base lined, and targets for improvements be implemented with specific projects to enable these improvements.

Surveying, Mapping and Earth Science

1. Establish a continental reference for Africa (AFREF), consistent with the International Terrestrial Reference Frame (ITRF)

A uniform coordinate reference system is fundamental to any project, application, service or product that requires some form of georeferencing. Many developing countries, and particularly the African nations, would benefit greatly from a modern GNSS-based reference system that can be used for national surveying, mapping, photogrammetry, remote sensing, Spatial Data Infrastructure (SDI), Geographical Information Systems (GIS), development programs, and hazard mitigation (earthquake studies, fault motion, volcano monitoring, severe storms). Many existing national coordinate systems are based on reference figures of the Earth which are generally outdated and are restricted to a particular country, making cross-border or regional mapping, development, and project planning very difficult. A continental reference system for Africa should be organized through an international project to be known as AFREF with common goals and objectives throughout Africa, and with the commitment of African nations and the support of international partners. The benefits of GNSS technology

cut across applications and across countries. It is further emphasized that the importance of simultaneous development of Information and Communications Technology (ICT) and related infrastructure is necessary for sustainable use of GNSS. Policy and decision-makers should be made aware of the critical importance of the ICT in the development and success for the utilization of GNSS.

2. Expand the development of integrated Differential GNSS “full scale accuracy” infrastructure with well-defined unified standards on regional levels (i.e. in Europe: EUPOS)

A subject of further discussions within the framework of UN/USA regional workshops would be the problems on the multi-functional DGNSS applications in Central and Eastern European like EUPOS, its development for entire Europe and eventually as an element of GALILEO and EGNOS. Similar DGNSS systems can be developed for other regions in the world.

3. Increase the density of the Continuous Operating Reference Station (CORS) for the SIRGAS area of Latin America and the Caribbean in order to promote the use of GNSS, CORS (covering all the Americas) must complement the SIRGAS frame. In spite of the existence of the SIRGAS structure, these activities are facing deep financial difficulties that are obstructing the development of GNSS applications.

Other recommendations in this area included: The development of Spatial Data Infrastructure (SDI) based on a consistent geodetic reference frame enabled by GNSS; the monitoring of GNSS frequencies for interference on local and national levels; and the development of accurate geoid models.

Management of Natural Resources and Protection of the Environment

Precision agriculture has attracted many new users to GNSS application in management of natural resources and protection of the environment. The growth of GNSS users in these areas is expected to increase as seen from the four regional workshops. Other sources of funding should be explored to implement the establishment of a global information exchange network related to precision

agriculture and GNSS applications. Many suggestions and recommendations were made in these area at all four regional workshops. The significance of GNSS in the area of disaster preparedness and management was particularly highlighted.

However the plight of the African region is such that we have selected the following two initiatives as deserving the most attention on the part of the international community.

1. Initiate demonstration projects in the area of agriculture and health to convince and attract the attention of government policy and decision makers in Africa

Agriculture is the mainstay of the economies of most African nations. However, there is a lack of knowledge of the economic, political and professional benefits of the effective use of GNSS in agricultural development and diversification (in areas such as crop production, processing and planning, animal health and production and fisheries).

2. International donors should support disease vector mapping projects in Africa using GNSS

This will enhance understanding of the spread of killer epidemics such as AIDS and malaria prevalent in Africa. Governments do not appreciate the impact the technology of GNSS can have in enhancing health resources management and disease control.

Conclusion

These recommendations were selected among a host of proposals and recommendations made at the four regional workshops and the international meeting of experts. Many of them included additional information and suggestions as to whom and how they should be carried out. Reference should be made to the individual workshop reports.