REPORT OF THE ACTION TEAM ON GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

Follow-up to the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III)

UNITED NATIONS

ST/SPACE/24

REPORT OF THE ACTION TEAM ON GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

FOLLOW-UP TO THE THIRD UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE (UNISPACE III)

UNITED NATIONS
2004

This document has not been formally edited.

Cover page photo credit: karelphoto.com

Introduction

This special publication has been compiled by the United Nations Office for Outer Space Affairs on the basis of results of the work and contributions from experts and members of the Action Team on Global Navigation Satellite Systems (GNSS) established by the Committee on the Peaceful Uses of Outer Space (COPUOS). The Action Team was established to carry out the recommendation relating to global navigation satellite systems made by the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held from 19 to 30 July 1999, in Vienna, Austria.

The Action Team worked under the leadership of the United States of America and Italy and was composed by Member States of the United Nations as well as entities of the United Nations system, other intergovernmental organizations and non-governmental entities. Starting from November 2001, the Action Team has accomplished its programme of work, meeting on the margins of the sessions of COPUOS and those of the Scientific and Technical Subcommittee of COPUOS, and during meetings of experts on GNSS organized under the United Nations Programme on Space Applications, as well as through work carried out by Internet and teleconferences.

This report represents the final product of the work of the Action Team and contains information on relevant national and international activities on promoting use, access to and quality of GNSS services. It includes proposals for specific recommendations to COPUOS and other relevant United Nations bodies, non-governmental entities, as well as United Nations Member States and international organizations concerning development, co-ordination and increased use of GNSS, particularly for the benefit of developing countries. These recommendations were selected among a large number of proposals and recommendations made at the four United Nations/United States of America regional workshops and the two international meetings of experts on the use and applications of GNSS.

This publication intends to disseminate information on the concept of worldwide navigation satellite systems and the many and ever-growing possibilities to use GNSS applications for human development and welfare, as contained in the “Space Millennium: Vienna Declaration on Space and Human Development” and recommended at UNISPACE III.

CONTENTS

ANNEXES

REPORT OF THE ACTION TEAM ON GLOBAL NAVIGATION SATELLITE SYSTEMS (GNSS)

FOLLOW-UP TO THE THIRD UNITED NATIONS CONFERENCE ON THE EXPLORATION AND PEACEFUL USES OF OUTER SPACE (UNISPACE III)

I. INTRODUCTION

A. Background of Action Team

1. The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III), held from 19 to 30 July 1999, at Vienna, Austria, adopted a strategy to address global challenges in the future through space activities. The strategy as contained in "The 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".

2. 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 (COPUOS) 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.

B. Terms of reference

3. The Action Team reported to the Committee and its Scientific and Technical Subcommittee at their forty-fourth and thirty-eight sessions in 2001 respectively concerning its objectives, work plan and final product. The terms of reference of the Action Team included its purpose, a list of related activities, work plan, product and schedule of meetings and membership 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 other international organizations on actions that should be taken;

[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.

- To promote GNSS user interests, increase the level of awareness, improve the quality and facilitate utilisation of GNSS services, particularly in developing countries; and
- To propose specific recommendations on global co-ordination and co-operation.

Related activities

- National and international meetings and conferences concerning GNSS applications;
- Series of United Nations/United States of America Regional Workshops and the International Meeting of Experts on the Use and Applications of GNSS, organised within the framework of the United Nations Programme on Space Applications in 2001 and 2002;
- United Nations Office for Outer Space Affairs/American Institute of Aeronautics and Astronautics International Workshop on Space Co-operation, Working Group on GNSS (Seville, March 2001);
- Regular meetings of the Civil GPS Service Interface Committee and its International Subcommittee (CGSIC/ISC);
- Relevant meetings of the International Telecommunication Union (ITU), including World Radiocommunication Conference 2003 (WRC-2003);
- Relevant meetings of the European Union (EU) and the European Space Agency (ESA);
- Relevant meetings of the International Maritime Organization (IMO); and
- Relevant meetings of the International Civil Aviation Organization (ICAO).

Work plan

- To compile information on national and international outreach activities designed to promote the use of GNSS for sustainable development, economic growth and scientific research;
- To compile information on the level of awareness and capacity of developing countries to use GNSS services and applications;
- To conduct an inventory of requirements of developing countries for GNSS services and applications and identify gaps in meeting those requirements;
- To consider ways in which entities of the United Nations system, non-governmental entities and international organizations and Member States of the United Nations could play a role in filling those gaps;
- To 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; and
- To evaluate the results of the series of the United Nations regional workshops on GNSS organised within the framework of the United Nations Programme on Space Applications, with a view to identifying common themes.

Product

4. The product of the work of the Action Team is a report 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 to the Committee on the Peaceful Uses of Outer Space and other relevant United Nations bodies, non-governmental entities, as well as United Nations Member States and international organizations concerning development, co-ordination and increased use of GNSS, particularly for the benefit of developing countries. The report would be submitted through the Scientific and Technical Subcommittee to the Committee.

Schedule of meetings

5. Meetings of the Action Team have been scheduled on the margins of the meetings of the Committee on the Peaceful Uses of Outer Space and its Scientific and Technical Subcommittee, as well as in conjunction with the activities organised by the Office for Outer Space Affairs.

6. The Action Team has held ten meetings as indicated below:

- First meeting (Vienna, 30 November 2001), in conjunction with the Second United Nations/United States of America 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 (Vienna, 5-14 June 2002);
- Fifth meeting (Vienna, 15 November 2002), in conjunction with the United Nations/United States of America 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), during the forty-sixth session of the Committee;
- Eighth meeting (Vienna, 11 December 2003), in conjunction with the United Nations/United States of America International Workshop on the Use and Applications of Global Navigation Satellite Systems;
- Ninth meeting (Vienna, 27 February 2004) on the margins of the forty-first session of the Scientific and Technical Subcommittee (Vienna, 16-27 February 2004); and
- Tenth meeting (Vienna, 1 June 2004) on the occasion of the forty-seventh session of the Committee on the Peaceful Uses of Outer Space (Vienna, 2-11 June 2004).

C. Membership of Action Team

7. The membership of the Action Team is open to any interested Member States of the United Nations as well as entities of the United Nations system, other intergovernmental organizations and non-governmental entities. As of September 2004, the membership consists of the following Member States and organizations:

8. Member States:

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

9. Organizations:

United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), International Civil Aviation Organization (ICAO), 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 the International Space Year (EURISY), International Association of Geodesy (IAG), International Association of Institutes of Navigation (IAIN), International Cartographic Association (ICA), International Federation of Surveyors (FIG), International GPS Service (IGS).

II. OVERVIEW OF PLANNED AND EXISTING GNSS AND AUGMENTATIONS

A. Existing and planned GNSS

1. GPS

Presidential decision directive policy goals

10. In the management and use of GPS, the United States seeks to support and enhance its economic competitiveness and productivity while protecting its national security and foreign policy interests. The United States goals are to:

- Strengthen and maintain United States national security;
- Encourage acceptance and integration of GPS into peaceful, civil, commercial and scientific applications worldwide;
- Encourage private sector investment in and use of United States GPS technologies and services;
- Co-operate with other governments and international organizations to ensure an appropriate balance between the requirements of international civil, commercial and scientific users and international security interests;
- Advocate the acceptance of GPS and United States Government augmentations as standards for international use;
- Purchase, to the fullest and feasible extent, commercially available GPS products and services that meet United States Government requirements. No activities that preclude or deter commercial GPS activities, except for national security or public safety reasons, will be conducted; and
- A permanent interagency GPS Executive Board, jointly chaired by the Departments of Defense and Transportation, will manage the GPS and United States Government augmentations.

11. Other departments and agencies will participate as appropriate. The GPS Executive Board will consult with United States Government agencies, United States industries and foreign governments involved in navigation and positioning system research, development, operation and use. This policy will be implemented within the overall resource and policy guidance provided by the President.

Agency roles and responsibilities

12. The Department of Defense will:

- Continue to acquire, operate, and maintain the basic GPS;
- Maintain a Standard Positioning Service (as defined in the Federal Radio Navigation Plan and the GPS Standard Positioning Service Signal Specification) that will be available on a continuous and worldwide basis;
- Maintain a Precise Positioning Service for use by the United States military and other authorised users;
- Co-operate with the Director of Central Intelligence, the Department of State and other appropriate departments and agencies to assess the national security implications of the use of GPS, its augmentations, and alternative satellite-based positioning and navigation systems; and

- Develop measures to prevent the hostile use of GPS and its augmentations to ensure that the United States retains a military advantage without unduly disrupting or degrading civilian uses.

13. The Department of Transportation will:

- Serve as the lead agency within the United States Government for all Federal civil GPS matters;
- Develop and implement United States Government augmentations to the basic GPS for transportation applications;
- Take the lead in promoting commercial applications of GPS technologies and the acceptance of GPS and United States Government augmentations as standards in domestic and international transportation systems, in co-operation with the Departments of Commerce, Defense and State; and
- Co-ordinate United States Government-provided GPS civil augmentation systems to minimise cost and duplication of effort, in co-operation with other departments and agencies.

14. The Department of State will:

- Consult with foreign governments and other international organizations to assess the feasibility of developing bilateral or multilateral guidelines on the provision and use of GPS services, in co-operation with appropriate departments and agencies;
- Co-ordinate the interagency review of instructions to United States delegations to bilateral consultations and multilateral conferences related to the planning, operation, management, use of GPS and related augmentation systems; and
- Co-ordinate the interagency review of international agreements with foreign governments and international organizations concerning international use of GPS and related augmentation systems.

Reporting requirements

15. Beginning in 2000, the President was to make an annual determination on continued use of GPS Selective Availability (SA). To support this determination, the Secretary of Defense, in co-operation with the Secretary of Transportation, the Director of Central Intelligence, and heads of other appropriate departments and agencies, shall provide an assessment and recommendation on continued SA use. This recommendation shall be provided to the President through the Assistant to the President for National Security Affairs and the Assistant to the President for Science and Technology.

16. The President has approved a comprehensive national policy on the future management and use of the United States Global Positioning System (GPS) and related United States Government augmentations. The Global Positioning System (GPS) was designed as a dual-use system with the primary purpose of enhancing the effectiveness of United States and allied military forces to provide position, navigation and timing services to both civil and military users.

17. In 1983, the United States made a policy decision to provide GPS civil service on an open basis, free of direct user charges. This policy decision was further documented in a 1996 Presidential Decision Directive that also set up the Interagency GPS Executive Board to manage the system. GPS provides a substantial military advantage and is now being integrated into

virtually every facet of United States military operations. GPS is also rapidly becoming an integral component of the emerging Global Information Infrastructure, with applications ranging from mapping and surveying to international air traffic management and global change research.

18. The growing demand from military, civil, commercial and scientific users has generated a United States commercial GPS equipment and service industry that lead in several countries around the world. Augmentations to enhance basic GPS services could further expand these civil and commercial markets. In May 2000, in accordance with the policy stated in the Presidential Decision Directive, Selective Availability, the intentional degradation of GPS civil services was set to zero. Since that time, GPS users frequently see accuracy readings in the range of ten meters or better.

19. The "basic GPS" is defined as:

- The constellation of satellites, the navigation payloads that produce the GPS signals, ground stations, data links and associated command and control facilities which are operated and maintained by the Department of Defense;
- The "Standard Positioning Service" (SPS) is the civil and commercial service provided by the basic GPS; and
- The "Augmentations" as those systems based on the GPS that provide integrity and real-time accuracy greater than the SPS.

20. This policy presents a strategic vision for the future management and use of GPS, addressing a broad range of military, civil, commercial and scientific interests, both national and international.

21. Some web sites related to the subject are indicated below:

- Global Climate Observing System (GCOS):
  http://www.wmo.ch/web/gcos/gcoshome.html
- Global Positioning System (JPL):
  http://samadhi.jpl.nasa.gov/msl/Programs/gps.html
- Global Positioning System Product Team (FAA):
  http://gps.faa.gov/
- Interagency GPS Executive Board:
  http://www.wmo.ch/web/gcos/gcoshome.html
- International Institute for Applied Systems Analysis (IIASA):
  http://www.iiasa.ac.at/
- NASA GPS Application Exchange:
  http://gpshome.ssc.nasa.gov/
- Navstar Global Positioning System Joint Program Office
  http://gps.losangeles.af.mil/
- National Aeronautics and Space Administration (NASA):
  http://www.nasa.gov/home.html
- National Geodetic Survey
  http://www.ngs.noaa.gov/
- Office for Outer Space Affairs, United Nations Office at Vienna:
  http://www.oosa.unvienna.org/index.html

- Planet Quest:
  http://planetquest.jpl.nasa.gov/
- U.S. Coast Guard Navigation Center:
  http://www.navcen.uscg.gov/
- U.S. Mission to the European Union: GPS and the EU's GALILEO System
  http://www.useu.be/Galileo/
- U.S. Space Objects Registry:
  http://www.usspaceobjectsregistry.state.gov/

Global Positioning System description

22. GPS is a Satellite Navigation System with many millions of civil users worldwide. GPS provides specially coded satellite signals that can be processed in a GPS receiver, enabling the receiver to compute position, velocity and time. At least four GPS satellite signals are necessary to compute positions in three dimensions and the time offset in the receiver clock. With a Receiver Autonomous Integrity Monitoring (RAIM) capable receiver and six in view GPS satellites allow the users to achieve RAIM. The Space Segment of the system consists of the GPS satellites. These space vehicles (SVs) send radio signals from space. The nominal GPS Operational Constellation consists of 24 satellites plus on-orbit spares that orbit the Earth in 12 hours. There are often more than 24 operational satellites as new ones are launched to replace older satellites.

23. The satellite orbits repeat almost the same ground track (as the Earth turns beneath them) once each day. The orbit altitude is such that the satellites repeat the same track and configuration over any point approximately each 24 hours (4 minutes earlier each day). There are six orbital planes (with nominally four SVs in each), and inclined at about fifty-five degrees with respect to the equatorial plane. This constellation provides the user with between five and eight SVs visible from any point on the Earth.

Control Segment

24. The Control Segment consists of a system of tracking stations located around the world, including the GPS Master Control and Monitor Network. The Master Control facility is located at Schriever Air Force Base (formerly Falcon AFB) in Colorado. These monitor stations measure signals from the SVs, which are incorporated into orbital models for each satellite. The models compute precise orbital data (ephemeris) and SV clock corrections for each satellite. The Master Control station uploads ephemeris and clock data to the SVs. The SVs then send subsets of the orbital ephemeris data to GPS receivers over radio signals.

25. The GPS User Segment consists of the GPS receivers and the user community. GPS receivers convert SV signals into position, velocity, and time estimates. Four satellites are required to compute the four dimensions of X, Y, Z (position) and Time.

26. GPS receivers are used for navigation, positioning, time dissemination, remote clock comparison and for other research purposes. Navigation in three dimensions is the primary function of GPS. Navigation receivers are made for aircraft, ships, ground vehicles and for hand carrying by individuals. Enhanced positioning is possible using GPS receivers at reference locations providing corrections and relative positioning data for remote receivers. Surveying, geodetic control, and plate tectonic studies are some examples.

27. Time and frequency dissemination, based on the precise clocks on board the SVs and controlled by the monitor stations, constitutes another use for GPS. Astronomical observatories, telecommunications facilities, and laboratory standards can be set to precise time signals or controlled to accurate frequencies by special purpose GPS receivers. Research projects have used GPS signals to measure atmospheric parameters. The elaboration of the international reference time scales relies mostly on clock comparison using the atomic clocks on board GPS satellites.

Precise Positioning Service (PPS)

28. Authorised users with cryptographic equipment and keys and specially equipped receivers use the Precise Positioning System. The United States and allied military, certain United States Government agencies and selected civil users specifically approved by the United States Government can use the PPS.

29. PPS Predictable Accuracy:

- 22-meter horizontal accuracy
- 27.7-meter vertical accuracy
- 200-nanosecond time Coordinated Universal Time (UTC) accuracy

Standard Positioning Service (SPS)

30. Civil users worldwide use the SPS without charge or restrictions. Most receivers are capable of receiving and using the SPS signal.

The GPS Standard Positioning Service

31. The GPS SPS is a positioning and timing service provided on the GPS L1 signal. The L1 signal, transmitted by all GPS satellites, contains a Coarse/Acquisition (C/A) code and a navigation data message. The GPS L1 signal also contains a Precision P (Y) code that is reserved for military use and is not a part of the SPS.

32. The L-band SPS ranging signal is a 2.046 MHz null-to-null bandwidth signal centred about L1. The transmitted ranging signal that comprises the GPS-SPS is not limited to the null-to-null signal and extends through the band 1563.42 to 1587.42 MHz. GPS satellites also transmit a second ranging signal known as L2. The L2 signal is not part of the SPS. Therefore, SPS performance standards are not predicated upon use of L2, or use of L1/L2 carrier tracking for other than code acquisition and tracking purposes.

33. Until such time as a second coded civil GPS signal is operational, the United States Government has agreed to not intentionally reduce the current received minimum Radio Frequency signal strength of the P (Y)-coded signal on the L2 link, as specified in ICD-GPS-200C or to intentionally alter the P (Y)-coded signal on the L2 link. This does not preclude addition of codes or modifications to the L2 signal, which do not change, or make unusable, the L2 P (Y)-coded signal as currently specified.

Global Positioning System overview

34. Detailed information is provided below to promote a common understanding of the nominal GPS baseline configuration.

35. The GPS baseline system is comprised of three segments, whose purpose is to provide a reliable and continuous positioning and timing service to the GPS user community. These three segments are known as the Space Segment, Control Segment and User Segment.

36. The User Segment is comprised of receivers from a wide variety of United States and international agencies, in addition to the growing private user base. The GPS space segment consists nominally of a constellation of 24 operational Block II satellites (Block II, IIA and IIR).

37. Each satellite broadcasts a navigation message based upon data periodically uploaded from the Control Segment and adds the message to a 1.023 MHz Pseudo Random Noise (PRN) Coarse/Acquisition (C/A) code sequence. The satellite modulates the resulting code sequence onto a 1575.42 MHz L-band carrier to create a spread spectrum ranging signal, which it then broadcasts to the user community. This broadcast is referred to in this Performance Standard as the SPS ranging signal.

38. Each C/A code is unique and provides the mechanism to identify each satellite in the constellation. A block diagram illustrating the Block IIA satellite's SPS ranging signal generation process is provided in Figure 1-1. The GPS satellite also transmits a second ranging signal known as L2, that supports PPS user two-frequency corrections. L2, like L1, is a spread spectrum signal and is transmitted at 1227.6 MHz.

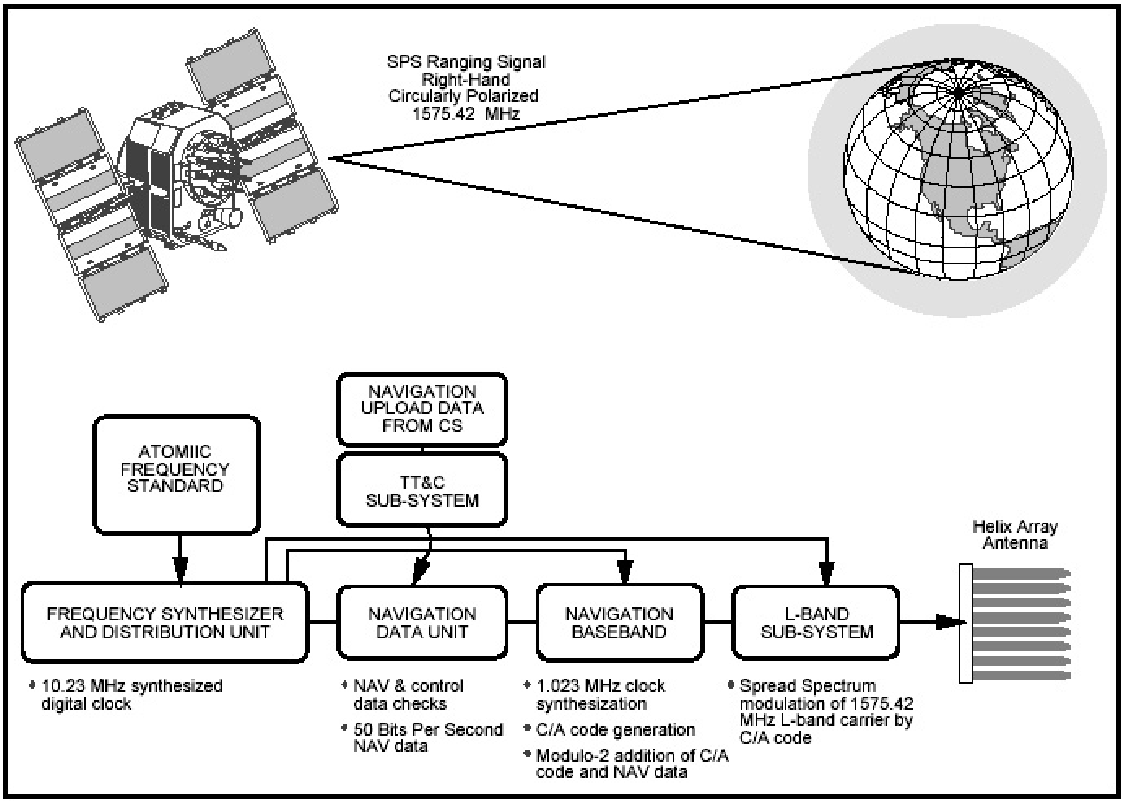

Figure 1-1. Block IIA SPS Ranging Signal Generation and Transmission

Service Availability Standard

39. The United States Government commits to maintaining the Position Dilution of Precision (PDOP) in accordance with the following tolerances.

Table 1-2. Position Dilution of Precision Availability Standard

PDOP Availability Standard	Conditions and Constraints
≥ 98% global Position Dilution of Precision (PDOP) of 6 or less. ≥ 88% worst site PDOP of 6 or less.	• Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1).

40. In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day). At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged).

41. The United States Government's commitments for maintaining PDOP (Table 1-2) and constellation SPS SIS URE (see Section on Service Reliability Standard) result in support for a service availability standard as presented in Table 1-3.

Table 1-3. SPS Service Availability Standard

Service Availability Standard	Conditions and Constraints
≥ 99% Horizontal Service Availability average location. ≥ 99% Vertical Service Availability average location.	• 36-meter horizontal (SIS only) 95% threshold. • 77-meter vertical (SIS only) 95% threshold. • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1).
≥ 90% Horizontal Service Availability worst case location. ≥ 90% Vertical Service Availability worst case location.	• 36-meter horizontal (SIS only) 95% threshold. • 77-meter vertical (SIS only) 95% threshold. • Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. • Based on using only satellites transmitting standard code and indicating "healthy" in the broadcast navigation message (sub-frame 1).

Service Reliability Standard

42. The United States Government commits to providing SPS service reliability in accordance with the following tolerances:

Table 1-4. Service Reliability Standard

Service Reliability Standard	Conditions and Constraints
≥ 99.94% global average.	• 30-meter Not-to-Exceed (NTE) SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.
≥ 99.79% worst case single point average.	• 30-meter NTE SPS SIS URE. • Standard based on a measurement interval of one year; average of daily values from the worst case point within the service volume. • Standard based on 3 service failures per year, lasting no more than 6 hours each.

43. The probability of Hazardously Misleading Information (HMI) shall be less than 0.002. A HMI event occurs when the SIS URE is greater than 30 meters, while the satellite is set healthy but the User Range Accuracy (URA) multiplied out to 4.42 standard deviations is less than 30 meters.

Accuracy Standard

44. The United States Government commits to providing SPS SIS User Range Errors (UREs) in accordance with the tolerance established in Table 1-5. The United States Government does not directly monitor or verify SPS URE performance, but rather meets this standard through the monitoring of PPS UREs.

Table 1-5. Constellation SPS SIS URE Standard

SPS SIS URE Standard	Conditions and Constraints
≤ 6 meters RMS SIS SPS URE across the entire constellation.	• Average of the constellation's individual satellite SPS SIS RMS URE values over any 24-hour interval, for any point within the service volume.

45. The United States Government does not intend to impose range rate or range acceleration errors on the SPS signal.

46. The United States Government's commitments for maintaining PDOP (Table 1-2) and constellation SPS SIS URE (Table 1-5) result in support for position and time transfer accuracy standards as presented in Table 1-6. These accuracy standards were established based on the worst two of 24 satellites being removed from the constellation and a 6-meter constellation RMS SIS URE.

Table 1-6. Positioning and Timing Accuracy Standard

Accuracy Standard	Conditions and Constraints
Global Average Positioning Domain • ≤ 13 meters 95% All-in-View Horizontal Error (SIS Only). • ≤ 22 meters 95% All-in-View Vertical Error (SIS Only).	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.
Worst Site Positioning Domain • ≤ 22 meters 95% All-in-View Horizontal Error (SIS Only). • ≤ 77 meters 95% All-in-View Vertical Error (SIS Only).	• Defined for position solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours for any point within the service volume.
Time Transfer Accuracy 40 nanoseconds time transfer error 95% of time (SIS Only).	• Defined for time transfer solution meeting the representative user conditions. • Standard based on a measurement interval of 24 hours averaged over all points within the service volume.

GPS Status and Problem Reporting Standard

47. The United States Government provides notification of changes in constellation operational status that affect the service being provided to GPS users, or if the United States Government anticipates a problem in supporting performance standards established in this document. The current mechanism for accomplishing this notification is through the Notice: Advisory to Navigation Users (NANU). NANUs are a primary input in the generation of GPS-related Notice to Airmen (NOTAM) and United States Coast Guard Local Notice to Mariners (LNM). Most outages affect both PPS and SPS users. However, since the GPS Control Segment currently monitors PPS, not SPS, in near real-time, notification of SPS unique service disruptions may be delayed. Since NANUs are currently tailored to PPS outages, notification of SPS unique outages may require the use of the general "free text" NANU vice a tailored template.

48. In the case of a scheduled event affecting service provided to GPS users, the United States Government will issue an appropriate NANU at least 48 hours prior to the event. In the case of an unscheduled outage or problem, notification will be provided as soon as possible after the event.

49. The Block II satellites are designed to provide reliable service over a 7.5 - to 10-year design life, depending on the production version, through a combination of space qualified parts, multiple redundancies for critical subsystems, and internal diagnostic logic. The Block II satellite requires minimal interaction with the ground and allows all but a few maintenance activities to be conducted without interruption to the ranging signal broadcast. Periodic uploads of data to support navigation message generation are designed to cause no disruption to the SPS ranging signal, although Block II/IIA satellites may experience a 6 to 24 second disruption upon transition to the new upload.

50. The GPS Control Segment (CS) is comprised of four major components: a Master Control Station (MCS), Backup Master Control Station (BMCS), four ground antennas, and six monitor stations. The MCS at Schriever Air Force Base, Colorado, is the central control node for the GPS satellite constellation. Operations are maintained 24 hours a day, seven days a week throughout each year.

51. The CS's four ground antennas provide a near real-time Telemetry, Tracking, and Commanding (TT&C) interface between the GPS satellites and the MCS. The six monitor stations provide near real-time satellite ranging measurement data to the MCS and support near-continuous monitoring of constellation performance. The current CS monitor stations provide approximately 93% global coverage, with all monitor stations operational, with a 5° elevation mask angle. The actual elevation angle that a monitor station acquires any given satellite varies due to several external factors.

52. SPS performance standards are based on signal-in-space performance. Contributions of ionosphere, troposphere, receiver, multipath or interference are not included.

Predictable Accuracy

53. The United States Government commits to maintaining the Position Dilution of Precision (PDOP) in accordance with the following tolerances: Position Dilution of Precision Availability Standard: PDOP Availability Standard = 98% global Position Dilution of Precision (PDOP) of 6 or less = 88% worst site PDOP of 6 or less. In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day).

54. At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged). The United States Government's commitments for maintaining PDOP and constellation SPS SIS URE result in support for a service availability standard as presented in Table 1-3. The SPS Performance combines a constellation availability of 24 operational satellites at 95% probability.

Service Availability

55. The percentage of time over a specified time interval that the predicted position accuracy is less than a specified value for any point within the service volume.

Service Availability Standard

56. The United States Government commits to maintaining the Position Dilution of Precision (PDOP) in accordance with the following tolerances:

Position Dilution of Precision Availability Standard:

57. PDOP Availability Standard

> 98% global Position Dilution of Precision (PDOP) of 6 or less;
> 88% worst site PDOP of 6 or less.

Conditions and Constraints

58. Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval. Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).

59. In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day). At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged).

60. SPS Service Availability Standard conditions and constraints:

> 99% Horizontal Service Availability average location.
> 99% Vertical Service Availability average location.
> 90% Horizontal Service Availability worst case location.
> 90% Vertical Service Availability worst case location.

61. The United States Government commits to providing SPS service reliability in accordance with the following tolerances:

Service Reliability Standard Conditions and Constraints:

>= 99.94% global average 30-meter Not-to-Exceed (NTE) SPS SIS URE.

- Standard based on a measurement interval of one year; average of daily values within the service volume.
- Standard based on 3 service failures per year, lasting no more than 6 hours.

>99.79% worst case single point average, 30-meters Not-to-Exceed (NTE) SPS SIS URE.

- Standard based on a measurement interval of one year; average of daily values from the worst case point within the service volume.
- Standard based on 3 service failures per year lasting no more than 6 hours each.

Standard Global Average Positioning Domain Accuracy:
> 13 meters 95% All-in-View Horizontal Error (SIS Only).
> 22 meters 95% All-in-View Vertical Error!

(SIS Only) Worst Site Positioning Domain:

- Defined for position solution meeting the representative user conditions.
- Standard based on a measurement interval of 24 hours for any point within the service volume defined for time transfer solution meeting the Accuracy = 36 meters 95% All-in-View Horizontal Error (SIS Only).

>77 meters 95% All-in-View Vertical Error (SIS Only) Time Transfer Accuracy.
>40 nanoseconds time transfer error 95% of time (SIS Only) representative user conditions Standard based on a measurement interval of 24 hours averaged over all points within the service volume.

Service Availability Standard

62. The United States Government commits to maintaining the Position Dilution of Precision (PDOP) in accordance with the following tolerances:

= 98% global Position Dilution of Precision (PDOP) of 6 or less.
= 88% worst site PDOP of 6 or less.

- Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
- Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).
- In support of the service availability standard, 24 operational satellites must be available on orbit with 0.95 probability (averaged over any day). At least 21 satellites in the 24 nominal plane/slot positions must be set healthy and transmitting a navigation signal with 0.98 probability (yearly averaged).
- Constellation availability: Representative Performance of 25-28 healthy satellites.

63. The United States Government’s commitments for maintaining PDOP and constellation SPS SIS URE result in support for a service availability standard as presented below.

SPS Service Availability Standard/Service Availability Standard Conditions and Constraints:

= 99% Horizontal Service Availability average location.
= 99% Vertical Service Availability average location.

- 36 meter horizontal (SIS only) 95% threshold.
- 77 meter vertical (SIS only) 95% threshold.
- Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
- Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).

= 90% Horizontal Service Availability worst case location.
= 90% Vertical Service Availability worst case location.

- 36 meter horizontal (SIS only) 95% threshold.
- 77 meter vertical (SIS only) 95% threshold.
- Defined for position solution meeting the representative user conditions and operating within the service volume over any 24-hour interval.
- Based on using only satellites transmitting standard code and indicating “healthy” in the broadcast navigation message (sub-frame 1).
- Constellation RMS User Range Error = SPS Performance Standard (October 2001) = 6 meters with Representative Performance = 1.6 meters.
- Service Reliability = SPS Performance Standard (October 2001) = 99.94% global, 99.79% worst site, with Representative Performance = 100% global and 100% worst site.

GPS Predictable Accuracy

64. The specific capabilities provided by SPS are established by DoD and DOT and are published in the Global Positioning System Standard Positioning Service Performance Standard (formerly known as the SPS Signal Specification, Ref. 7) available through the USCG Navigation Information Service. The figures are 95% accurate and express the value of two standard deviations of radial error from the actual antenna position to an ensemble of position estimates made under specified satellite elevation angle (five degrees) and PDOP (less than six) conditions. For horizontal accuracy figures, 95% is the equivalent of 2drms (two-distance root-mean-squared), or twice the radial error standard deviation. For vertical and time errors, 95% is the value of two-standard deviations of vertical error or time error.

65. Receiver manufacturers may use other accuracy measurements. Root-mean-square (RMS) error is the value of one standard deviation (68%) of the error in one, two or three dimensions.

66. Circular Error Probable (CEP) is the value of the radius of a circle, centred at the actual position that contains 50% of the position estimates. Spherical Error Probable (SEP) is the spherical equivalent of CEP, which is the radius of a sphere, centred at the actual position that contains 50% of the three dimension position estimates. As opposed to 2drms, drms, or RMS figures, CEP and SEP are not affected by large blunder errors making them an overly optimistic accuracy measure.

67. Some receiver specification sheets list horizontal accuracy in RMS or CEP and without Selective Availability, making those receivers appear more accurate than those specified by more responsible vendors using more conservative error measures.

GPS satellite signals

68. The SVs transmit two microwave carrier signals. The L1 frequency (1575.42 MHz) carries the navigation message and the SPS code signals. The L2 (1227.60 MHz) and L1 frequencies (1575.42 MHz) are used to measure the ionospheric delay by PPS equipped receivers. Three binary codes shift the L1 and/or L2 carrier phase. The C/A Code (Coarse Acquisition) modulates the L1 carrier phase. The C/A code is a repeating 1 MHz Pseudo Random Noise (PRN) Code. This noise-like code modulates the L1 carrier signal, "spreading" the spectrum over a 1 MHz bandwidth.

69. The C/A code repeats every 1023 bits (one millisecond). There is a different C/A code PRN for each SV. Their PRN number, the unique identifier for each pseudo-random-noise code, often identifies GPS satellites. The C/A code that modulates the L1 carrier is the basis for the civil SPS. The P-Code (Precise) modulates both the L1 and L2 carrier phases. The P-Code is a very long (seven days) 10 MHz PRN code. In the Anti-Spoofing (AS) mode of operation, the P-Code is encrypted into the Y-Code.

70. The encrypted Y-Code requires a classified AS Module for each receiver channel and is for use only by authorised users with cryptographic keys. The P (Y)-Code is the basis for the PPS. The Navigation Message also modulates the L1-C/A code signal. The Navigation Message is a 50 Hz signal consisting of data bits that describe the GPS satellite orbits, clock corrections, and other system parameters.

71. The GPS Navigation Message consists of time-tagged data bits marking the time of transmission of each sub-frame at the time they are transmitted by the SV. A data bit frame consists of 1500 bits divided into five 300-bit sub-frames. A data frame is transmitted every thirty seconds. Three six-second sub-frames contain orbital and clock data. SV Clock corrections are sent in sub-frame one and precise SV orbital data sets (ephemeris data parameters) for the transmitting SV are sent in sub-frames two and three. Sub-frames four and five are used to transmit different pages of system data. An entire set of twenty-five frames (125 sub-frames) makes up the complete Navigation Message that is sent over a 12.5 minute period.

2. GLONASS

Russian satellite navigation policy

72. The Global Navigation Satellite System "GLONASS" is able to provide unlimited number of air, maritime, and any other type of users with all-weather three-dimensional positioning, velocity measuring and timing anywhere in the world or near-Earth space.

73. Designed mainly for military purposes, the Russian GLONASS system had been fully deployed in 1995 with a constellation of 24 satellites. At the same time, GLONASS is available for civil users with the L1 signal of the Standard Accuracy without any selective availability. Since that time, the Russian Government has declared open access free of charge to the standard accuracy positioning service for civil users.

74. Since 1999, the Russian authorities have consistently implemented actions to present GLONASS service for civil users. Two basic decisions (Presidential Directive of 18 February 1999 (38) and following the Governmental Decision of 29 March 1999 (346)) defined the GLONASS status as a dual-use system opened for international co-operation. Two State Customers of the GLONASS system have been defined: the Ministry of Defense and the Russian Aviation and Space Agency (civil institution, now the Russian Federal Space Agency).

75. As a dual-use system GLONASS is available for the civil community worldwide and includes the following characteristics:

- Free use of the civil signal globally;
- Civil signal specification available for both users and industry (Interface Control Document); and
- No selective availability for civil signal since start of operation (has not been foreseen by design).

76. In the following governmental decision on the GLONASS use (3 August 1999 (896)) the combined GNSS receivers (GLONASS/GPS) application has been recommended for users.

77. GLONASS, as a system opened for international co-operation, has been presented as a basis to implement international global navigation satellite systems. The negotiations with the European Union (EU) at the beginning phase could lead to the EU/Russia international GNSS based on GLONASS and GALILEO. At least three global basic systems will combine the core GNSS: GPS, GLONASS, GALILEO. The main objective is to ensure compatibility and interoperability, by providing better performance and reliability of the navigation service for users all over the world.

78. In continuation of practical implementation of the authority decisions, the Federal GLONASS Mission Oriented Program was approved by the Government in August 2001 (Governmental Decision 587, 20 August 2001). The Program guarantees the GLONASS State funding for 10 years, from 2002 to 2011. The budget for the Program has been allocated to be annually adjusted.

79. There are six State Customers of the Program: the Russian Federal Space Agency (FSA) , the Ministry of Defense (MOD), the Ministry of Industry (MOI), the Ministry of Transport (MOT), the Ministry of Science and Education (MOSE) and the Federal Geodesy and Mapping Service (FGMS). The Federal Space Agency is the general co-ordinator of the Program implementation. Each Agency or Ministry is responsible for their subprogram with specially defined goals.

80. The Program covers the following directions and subprograms:

- The GLONASS system maintenance, modernisation, deployment, operation and related research & development activities (Federal Space Agency and MOD responsibility);
- Navigation receiver and user equipment development for civil use, industry preparation for mass production of the GNSS equipment (Ministry of Industry responsibility);
- GNSS equipment and technology implementation for transport (aviation, maritime, rail-road, land transport, cars and trucks) - (MOT responsibility);
- GNSS technology applications for geodetic provision of the Russian territory. Modernisation of the geodetic system (RMGS responsibility); and
- GNSS receiver and user equipment development for special use (military and special forces) - (MOD responsibility).

81. The main features of the Federal GLONASS Mission Oriented Program are:

- This is the first case in the Russian (and Soviet) history when a single space mission, to be further developed, modernised and sustained, is in the framework of a specially dedicated federal program;
- The program covers all segments: space, ground control and user ensuring comprehensive and co-ordinated development;

- GLONASS system financing is clearly presented in the State budget Law with governmental obligations for 10 years. Co-ordinator of all activities in the framework of the GLONASS Program at the time of writing this report is the civil institution Federal Space Agency. The State budget money dedicated for GLONASS flows through the Federal Space Agency and Ministry of Defense in about equal shares.

82. The GLONASS Co-ordination Board was established in 2002 including all Program State Customers with a Federal Space Agency representative as a chair. To implement the permanent work for Program co-ordination and to co-ordinate activities to implement the strategy defined by the Co-ordination Board, the Executive Committee has been established including representatives of the Customers, leading research institutes and industry.

83. Since this event happened, the GLONASS system has become a real dual-use system, not restricted to military activities only. The strategy for development of GLONASS is generated by

the Board, mainly civil institutions. The Ministry of Defense has been assigned for the operation and maintenance of GLONASS.

GLONASS overview

84. Some web sites related to the subject are indicated below:

- General GLONASS information (Ministry of Defense, Russian Federation Co-ordination Scientific Information Center):
  www.glonass-center.ru (Russian and English)
- GNSS Performance and Application (Federal Space Agency, Central Research Institute, Mission Control Center, Information Analytical Center):
  www.mcc.rsa.ru/main_iac.htm or www.mcc.rsa.ru (Russian and English)
- GNSS Application and User Equipment (Federal Space Agency, Russian Institute of Space Device Engineering, Multifunctional Navigation Information Center):
  www.mnicrisde.ru (Russian, under development)
- GLONASS Satellite Data (Federal Space Agency, Scientific Industry Co-operation of Applied Mechanics):
  www.npopm.ru (Russian)

85. The user equipment performs passive measurements of pseudoranges and pseudorange rate of four (three) GLONASS satellites. It also receives and processes navigation messages contained within navigation signals of the satellites. The navigation message describes position of the satellites both in space and time. Combined processing of the measurements and the navigation messages of the four (three) GLONASS satellites allows user to determine three (two) position co-ordinates, three (two) velocity vector constituents, and to refer user time scale to the National Reference of Coordinated Universal Time UTC (SU). The navigation message includes the data that allows for planning observations, selecting and tracking the necessary constellation of satellites.

86. The GLONASS system consists of space and ground control segments and user segment as well. The space segment includes the constellation of 24 satellites in three orbital planes by 8 satellites in each, and evenly distributed, along the orbit and launch. The orbit parameters:

- Height 19100 km;
- Inclination 64.8°; and
- Orbit type circular with revolution of 11h 15m.

87. Three planes are shifted at equator plane by 120°. An interval of repetition for satellite tracks and visibility zones as observed on the ground is equal to 17 orbital periods (7 days, 23 hours 27 minutes 28 seconds).

88. Such orbit parameters ensure the high stability of the constellation, making unnecessary the orbit correction of the GLONASS satellite during its lifetime. GLONASS satellites have been designed for 3 and half years lifetime. Actual mean of the lifetime for GLONASS is about 4.5 years.

89. The ground control segment includes:

- The GLONASS system control centre located in Krasnoznamensk Space Center of the Space Forces (Moscow region);

- Four TT&C stations distributed along longitude at the Russian territory (St. Petersbourg, Moscow region, Enisseysk in Siberia, Komsomolsk in Far East);
- Central system clock based on assemble of precise frequency standards; and
- Signal monitoring system based on direct comparison of two-way and one-way signals.

90. This architecture design ensures separate calculation of satellite orbits (ephemeris) based on two-way tracking data by TT&C stations, and clock correction determination by the direct comparison of central clock and satellite clock time scales. This procedure has been designed to simplify the orbit determination and time correction procedure. However, it has not ensured the progressing requirements of users. In the modernisation plan of ground segment, the technology based on simultaneous determination of orbits and clock correction using the one-way data of spread monitoring network is foreseen.

91. The user segment includes:

- User receivers for different kinds of applications;
- Local and regional differential subsystems;
- Many managing and control systems based on combination of navigation, communication and mapping functions.

92. Each GLONASS satellite transmits navigation signals in two sub-bands of L-band (L1 ~ 1.6 GHz and L2 ~ 1.2 GHz).

93. GLONASS uses Frequency Division Multiple Access (FDMA) technique in both L1 and L2 sub-bands. This means that each satellite transmits navigation signal on its own carrier frequency in the L1 and L2 sub-bands. Two GLONASS satellites may transmit navigation signals on the same carrier frequency if they are located in antipodal slots of a single orbital plane.

94. The nominal values of L1 and L2 carrier frequencies are defined by the number of satellite frequency slot from -7 to 13 shifted aside the central frequency (in L1 = 1602 MHz, in L2 = 1246 MHz) by 562.5 kHz for L1 and by 437.5 kHz for L2. In total in L1 band, GLONASS occupies the frequency band from 1597.5 MHz to 1614 MHz and in L2 from 1241.5 to 1256.5 MHz.

95. GLONASS satellites such as GPS provide two types of navigation signals in the L1 and L2 sub-bands: standard accuracy signal and high accuracy signal.

96. The standard accuracy signal with clock rate 0.511 MHz is designed for use by civil users worldwide.

97. The high accuracy code with clock 5.11 MHz is modulated by a special code, and its unauthorized use (without permission of the Ministry of Defense) is not recommended.

98. The standard accuracy signal is available for any users equipped with proper receivers and having visible GLONASS satellites above the horizon.

99. An intentional degradation of the standard accuracy signal is not applied. The present standard accuracy signal provides the following accuracy performance (95%) for the user:

- Horizontal: 28 m

- Vertical: 60 m
- Velocity: 15 cm/s
- User time scale wrt UTC (SU) time: 1 micro second

100. The GLONASS constellation of satellites fully deployed 25 satellites in 1995 which were further degraded due to economical reasons in the Russian Federation in the nineties. Currently, the GLONASS service is available for users with limitations. According to the Federal Program, the GLONASS satellite constellation will be restored consistently having 18 satellites in space by 2006 (minimal required constellation) and 24 satellites by 2010 at the latest.

101. Based on the present and future user requirements, the GLONASS system will be modernised according to the Modernisation Plan.

GLONASS modernisation and services

102. The trend of realisation of the long term Federal Mission Oriented Program "Global Navigation System", adopted by the Government of the Russian Federation in August 2001, opened up the encouraging long-range outlook of GLONASS maintenance and development. New services such as Search and Rescue, Integrity and Real-Time Precise Positioning assumed to be implemented. The modernisation program is aimed to bring the following benefits:

- For civil users:
  - More robust navigation against interference, compensation for ionospheric delays due to new signals.
  - Higher accuracy, availability, integrity and reliability.
- For military users:
  - Enhanced ability to deny hostile GLONASS use.
  - More robust navigation against interference.
  - Enhanced time of autonomy operation.
  - Higher accuracy, availability, integrity and reliability.
  - Supplementary tasks.
- For customers:
  - Less expenses for constellation maintenance due to enhanced satellite lifetime and group launch up to 6 satellites.
  - Less expenses for ground operation due to operation automation.

- For international co-operation:
  - Compatibility and interoperability of GLONASS, GPS and GALILEO.

103. The development of GLONASS assumes the following phases: the first concerns sustaining the current system by launch of the present design GLONASS satellites. The standard service is provided to civil users with limited constellation. The gap in GLONASS service will reduce as the number of GLONASS satellites in the constellation increases.

104. The next phase of modernisation is based on deployment from 2003 to 2006 of GLONASS-M satellites with extended lifetime to 7 years. The first civil signal at L1 will be moved to the international conventional frequency band (1593 – 1610.5 MHz). The second civil signal will be implemented at L2 frequency band to be also moved as a sequence of L1 shift (1238 – 1253.5 MHz). The upper limit of positioning accuracy with help of two civil signals shall

be less than 30 m (95%). In that time period the modernisation of ground control segment is planned assuming the deployment of one–way receiving station network for orbit determination and clock correction determination. The integrity monitoring system based on the spread one-way receiving station network shall be implemented as well.

105. From 2007 to 2008, the new generation satellites GLONASS-K with extended performances will be launched transmitting the third civil signal at L3 frequency band (1190.5 – 1212 MHz). The search and rescue service is expected to be implemented on board of GLONASS-K. Positioning accuracy will be available of the order of 5-7 m (95%). Modernisation of ground segment assumes the global integrity monitoring system deployment and global differential system implementation to provide for users the integrity information and higher real-time accuracy of positioning.

106. Study of requirements for the next GLONASS generation (code name is GLONASS-KM) has been initiated in 2002.

107. Generally, the full (24 satellites) GLONASS constellation transmitting two civil signals should be available from 2010. Three civil signals from the full GLONASS constellation are planned to be available after 2012.

GLONASS application

108. Being a part of the GNSS system, GLONASS in combination with GPS can benefit users by providing more reliable navigation with better availability of navigation service, particularly in urban and canyon conditions. Due to higher orbit inclination than GPS, the GLONASS service is better presented in the polar regions of the Earth. The frequency division of the GLONASS navigation channels provides users with the robust navigation in the conditions of interference and greater anti-jam capability.

GLONASS augmentation

109. The Federal Space Agency, in the framework of the Federal GLONASS Mission Oriented Program, has launched the project for the GLONASS augmentation system development. The main objectives of the system are:

- GNSS integrity monitoring service for civil users; and
- Real-time sub-meter positioning accuracy.

110. The system architecture consists of the following components:

- Monitoring station network on the Russian territory receiving the GNSS signals, mainly placed with the existing geodesy sites including IGS and SLR stations;
- Data acquisition system based on the existing telecommunication network with modification to ensure the necessary level of the data protection, data delivery delay and reliability;
- Two hot redundant data processing centres dedicated for data pre-processing, precise orbit and time correction determination in real time mode, integrity information generation;
- An analysis centre for a deep, posterior analysis of GNSS ephemeris, time and integrity data; and

- The network of upload stations to upload ephemeris/time corrections and integrity information on-board of GLONASS-K satellites directly.

111. The analysis centre also serves as an interface to the global IGS network whose data could be involved into processing to generate precise orbits, clock and integrity information.

112. Few options are under consideration for data delivery to users. The main option is data broadcasting in the third civil GLONASS signal at the L3 GLONASS frequency band. The second option is to use the SISNET technique based on mobile Internet service. TV and FM channels are also under evaluation.

113. This augmentation system according to the requirements is under the civil operator control and fully independent from the GLONASS control segment. The augmentation system operator shall be fully in charge of the service provision, including legal and financial obligations.

International co-operation

114. GLONASS, as a dual-use system under interagency board control, is opened for international co-operation. The negotiations with the European Union (EU), the European Space Agency (ESA), the United States, India, China and other countries are under way. The objectives of the international co-operation are:

- Develop GLONASS, GPS, GALILEO and their augmentations in such a way to have compatible, complementary and interoperable systems;
- Benefit users by reliable, accurate and highly available navigation service; and
- Beneficial use of satellite navigation services in world market.

3. GALILEO

European satellite navigation policy

115. The European Union considers that satellite navigation will become the primary means of navigation for civilian users worldwide in the future. Satellite navigation, positioning and timing will become an integral part of the Trans European Network covering transport, energy and telecommunication links. In addition to general users, many safety-critical services in transport and other areas of economy will increasingly depend on satellite navigation services. Hence the decision by the EU and the ESA to jointly develop GALILEO.

116. Transport needs are a major factor behind the European satellite navigation policy. The European Commission White Paper on transport policy has highlighted the importance of decoupling economic growth from transport needs to meet the goal of sustainable development. This goal can be achieved by shifting the balance to transport modes, which are more environmentally friendly (particularly rail and maritime), eliminating bottlenecks and by placing users at the heart of transport policy. As a result, the GALILEO satellite navigation system is foreseen as an instrument to reach these goals.

117. Rational use of space-based and terrestrial navigation aids is one way to enhance transport safety while keeping costs under control. The European Commission (EC) promotes a co-ordinated policy at the European level to efficiently use these facilities across all modes of

transport. In the context of ICAO and IMO, the Commission believes that satellite navigation is a key element in improving safety while allowing savings through decommissioning of terrestrial infrastructure. These benefits fall to industrialised and developing countries alike due to the global character and technical design of GALILEO.

118. The usefulness of GNSS is not limited to the transport community. The studies financed by the EC and ESA conclude that it has obvious applications in future UMTS location-based services, dealing with natural disasters and civil protection matters and enabling the emergency services (firefighters, police, sea and mountain rescue, etc.) to provide more rapid assistance to persons in danger. The same can apply to managing humanitarian aid in regions affected by natural or man-made disasters. Other proposed applications include guidance for the blind, monitoring of persons affected by Alzheimer's disease with memory loss, and orientation aids for the leisure industry such as hiking.

119. This technology can be used as a surveying tool for town planning purposes and major public works, as well as for geographical information systems to manage agricultural land more efficiently and help protect the environment. The accuracy of measurements will also provide early warning of earthquakes, contributing thus to prevent natural disasters and save human lives.

120. Time synchronisation is an important "invisible" application of satellite navigation that will penetrate modern economies. Electricity grids, mobile telephony and banking networks need the extreme accuracy of the satellites' atomic clock for reference purposes. On-line systems and e-commerce have already created needs for accurate and legally accepted electronic methods such as time stamping to improve the traceability, tractability and liability of the user information.

121. With its global coverage, GALILEO will be of key importance to countries whose infrastructures on the ground are less developed, particularly in tropical and equatorial zones, not least because of the possibilities it offers in the field of mapping and civil engineering. It will help to manage the crucial natural resources, the airspace and to promote international trade.

122. The multitude of already existing applications caused concern in the European Union in the early 1990s about the limits and risks of the adequacy of the existing satellite navigation services in the future.

123. It was, in fact, questioned at that time whether systems created to serve primarily the defense interests of the United States (GPS) and the Russian Federation (GLONASS) would be able to fulfil the growing needs of Europe in the civilian fields described above.

124. To what degree can the European society depend on services over which it has no control? How does one solve the lack of prompt warnings of possible malfunctioning of these services to the users? How does one improve the availability and coverage problems of users worldwide and particularly in the areas at geographical disadvantage in the northern and southern hemispheres? Also, should the European Union remain a "free rider" in this global and strategic technology?

125. Moreover, how far can the risks to reliability and vulnerability of the navigation signal be contained? Cases of service disruption have been reported over the past years and they have had different origins including unintentional interference, satellite failure and signal degradation. As a matter of fact, by 2007-2008 the dependence of the European Union on GNSS and its applications will be as far-reaching as that of the United States.

126. The EU and ESA have concluded in successive stages that uncertainties of this kind, the monopolistic role of the GPS and the lack of civil control do limit the usefulness of currently available GNSS applications in the service of future economies. They have committed themselves to share with the current GNSS States the burden of providing independent satellite navigation services for users worldwide. In addition, GALILEO aims to contribute significantly by reducing the shortcomings described above and by providing additional navigation signals broadcast in various frequency bands.

127. Innovative thinking concerning service guarantees, technological solutions, protection methods, services, the role of the private sector and international co-operation constitute elements of the European satellite navigation policy. GALILEO will take us a further step towards a Global Navigation Satellite System where the user can count on a truly continuous and reliable service anywhere in the world backed up by several signals from interoperable constellations.

128. This strategy is laid down in the communications of the EC on GALILEO in 1999, 2000 and 2002. The Ministries of Transport of the European Union meeting in the Council adopted in 2001 a resolution, highlighting the objective of European autonomy for such a strategic and crucial technology for the benefit of societies and economies in general. The Research Ministers of ESA then agreed on an integrated vision for the provision of European GNSS Services by the combined use of EGNOS (European Geostationary Navigation Overlay Service) and GALILEO services.

129. A crucial step was taken on 26 March 2002 when the Council of the European Union decided on the development phase of GALILEO and confirmed their financial support to it, approving thus the establishment of a GALILEO Joint Undertaking to manage the development activities. The Council of ESA agreed on half of the contribution by the EC and ESA on 26 May 2003. This means that GALILEO continues to be financed 50% by the EC and 50% by the European Space Agency during the development phase.

From policy to projects: GALILEO and EGNOS

130. The instruments to achieve the European objectives of increased availability, reliability, autonomy and user friendliness in satellite navigation are twofold and comprise the regional EGNOS system and the global GALILEO system.

131. Europe has developed since 1995 the EGNOS system in order to improve the quality of services provided and inform users about the integrity of the GPS and GLONASS constellations. EGNOS is the forerunner of GALILEO and the first European contribution to global satellite navigation. Since 2000, EGNOS has provided a test signal in an area covering all European States and some demonstrations activities have been performed to provide an EGNOS test signal outside Europe such as in the Middle East and in Africa. The system will be fully operational by 2004.

132. Besides its own operational objective as the European Satellite Based Augmentation System along the United States WAAS and the Japanese MSAS, EGNOS has demonstrated the potential of civil GNSS and Europe’s determination for interoperability with the other satellite navigation systems. EGNOS and GALILEO will be integrated into each other by the end of this decade.

133. GALILEO, unlike EGNOS, is a global stand-alone system. It will be the first civil satellite positioning and navigation system under control of European public authorities that will be operated by a private entity.

134. GALILEO will provide the required stability for European investments in this area and in industries around the world in innovative market segments. GALILEO will also offer, alongside an open service similar to the GPS civilian service, new features to improve and guarantee services, thereby creating the conditions for responding to obligations imposed by regulated, safety of life or commercial applications. GALILEO will be compatible and interoperable with other systems at user level to facilitate their combined use all over the world. For higher reliability, common failure modes between EGNOS and GALILEO on one hand, and GALILEO and GPS on the other hand, will be prevented. Special attention has been given to the security aspect of GALILEO, with the aim to protect its infrastructure and to prevent the potential misuse of its signals.

System description

135. Some web sites related to the subject are indicated below:

- http://europa.eu.int/comm/dgs/energy_transport/galileo
- http://www.esa.int/export/esaSA/navigation.html
- http://www.galileoju.com

Services and activities of GALILEO

136. Four navigation services and one service to support Search and Rescue operations have been identified to cover the widest range of user needs, including professional users, scientists, mass-market users, safety of life and public-regulated domains. Following consultations with various user groups and international standardisation organizations such as ICAO and IMO, the following set of GALILEO Satellite-only services will be provided worldwide:

- The Open Service results from a combination of the basic signals, free of user charge to the general public. It provides position and timing performances competitive with the two other GNSS systems.
- The Safety of Life Service is a service of a very high quality for safety-critical applications, such as aviation and maritime transport. It will improve the Open Service by providing quick warnings (integrity) to the user if it fails to meet safety margins of accuracy. Guarantees are considered for this service.
- The Commercial Service facilitates the development of professional applications and offers enhanced performance compared with the Open Service, particularly in terms of higher data rates, service guarantees and accuracy.
- The Public Regulated Service (PRS) provides position and timing to public authorities responsible for civil protection and security. Two PRS navigation signals with encrypted ranging codes and data will provide a higher level of protection, e.g. against interference or jamming.

- The Search and Rescue Service (SAR) broadcasts globally the alert messages received from distress emitting beacons. It will contribute significantly to enhance the performances of the international COSPAS-SARSAT Search and Rescue system.
- GALILEO will provide a basic performance of 4m-horizontal accuracy and 8m-vertical accuracy at 95% confidence level.

137. Ten signals will be needed to provide these services. They will be broadcast on frequency bands E5A-E5B, E6, E2-L1-E1 allocated to radionavigation systems by the World Radiocommunications Conferences of the International Telecommunication Union (ITU) in 1997 and 2000.

138. Foreseen GALILEO carrier frequencies:

E5a (=L5)	f_{E5a}	= 1 176.450 MHz
E5b	f_{E5b}	= 1 207.140 MHz
E6	f_{E6}	= 1 278.750 MHz
L1	f_{L1}	= 1 575.42 MH

139. Considering the limited availability of spectrum for satellite navigation, an overlay of frequency bands used by GPS and GALILEO is inevitable. Such sharing complies with international ITU principles when there is no harmful interference to either of the two systems. It also contributes to interoperability by facilitating the joint use of the GALILEO and GPS for better performance.

140. The European Union is raising awareness and promoting GNSS through a variety of activities and instruments linked mainly to the GALILEO programme. These include promotion of the technology at high political level by the EC and the European Parliament.

141. At the user level, the EC contributes to the work of the standardisation and user organizations, GALILEO user forums, sponsoring of GNSS conferences, through EC publications, the GALILEO newsletter and the GALILEO website (http://europa.eu.int/comm/dgs/energy_transport/GALILEO).

142. At the scientific and industrial levels the EU finances extensive research and development activities in co-operation with the ESA. A number of non-EU countries have already participated in these activities.

143. The GALILEO Joint Undertaking will gradually take over and expand many of these activities particularly in end-user, industrial and scientific arena. The regulatory and international policy activities remain with the EC.

144. On a technical level, the EC and the ESA have performed demonstrations and tests of EGNOS services in various parts of Europe and in Africa together with local authorities. More of these activities will follow in other continents.

Technical architecture and programme schedule

145. GALILEO architecture has been designed to meet the service needs explained above. The GALILEO global component, comprising the constellation of 27 active satellites, plus three in-orbit passive spare satellites on three orbital planes in Medium Earth Orbit and its associated ground segment, will broadcast the signals in space required to achieve the so-called satellite-only services. The ground segment includes two control centres, a network of uplink stations, sensor stations and a GALILEO communications network.

146. The regional components are foreseen to independently provide integrity to GALILEO in certain regions, in addition to the global integrity service.

147. These GALILEO satellite-only services can be enhanced locally with the help of local elements that may be deployed for extra accuracy or integrity around airports, harbours, railheads and in urban areas. Consequently, the global component will be designed from the start so as to easily interface with these elements.

148. In the same way, the interoperability between GALILEO and external components will be a major driver of the GALILEO design to allow for the development of applications embedding or combining GALILEO services and external systems services (e.g. navigation or communication systems, mobile phones).

149. For example, the combined use of GALILEO and GPS standard positioning service will result in a 95% availability of satellite signals in an urban environment. For comparison, relying on GPS only gives today a 55% availability.

150. Interoperability, added performance, safety, new applications and wider use of the technology are key factors in the definition and development of GALILEO.

151. The GALILEO programme involves the following phases:

- Development and in-Orbit validation (2003-2005);
- Deployment (2006-2007); and
- Operations (from 2008).

152. The definition phase has been completed earlier. The manufacturing of the satellites and the related ground segment and launching of the first satellites will be completed during the Development and In-Orbit Validation Phase. This phase is co-funded by EC and ESA. The cost of developing and deploying the system, including the launch of 30 satellites and commissioning of the ground infrastructure is 3.4 billion Euros.

153. The GALILEO Joint Undertaking is an enterprise that has overseen the program implementation since September 2003 and is preparing the grounds for the deployment of infrastructure.

154. The first two experimental GALILEO satellites are currently being built so as to retain the priority allocated when the frequencies were applied for within the ITU.

155. In the deployment phase the private sector will contribute through a concession scheme to ensure the user-orientation of GALILEO services. The GALILEO Joint Undertaking published an

invitation to tender to this effect on 20 October 2003. The operating revenues will partially remunerate the concession holder.

156. It is foreseen that a GALILEO Supervisory Authority will manage public interests relating to the GALILEO programme. It will act as a licensing authority vis-à-vis the future private concessionaire to be designated before the end of 2004 and will endeavour to ensure that the operator complies with the contract, including the public service obligations in terms of continuity and guarantee of services.

157. Various studies conducted in 2000-2002 demonstrated the economic viability of the project in comparison to classical infrastructure projects.

Open to international co-operation

158. GALILEO innovates also in bringing non-EU and non-ESA countries in the programme from the start. Hence, countries such as Canada, the Russian Federation and Ukraine have already been involved in the definition of work of GALILEO.

159. On the political level, a formal co-operation agreement was signed by the EU and the People's Republic of China on 30 October. Negotiations are ongoing with the United States and the Russian Federation on a similar agreement with focus on interoperability.

160. Moreover, co-operation on various levels has been initiated, i.a. with the Mediterranean partner countries, South Korea and Australia.

161. The GALILEO Joint Undertaking, located in Brussels, is a tool for industrial co-operation, not only between the public and the private sectors in Europe, but also between public and private partners worldwide. It is one of the vehicles of EU policy to promote industrial co-operation with companies from outside the Union.

B. GNSS augmentations

1. MSAS & QZSS

MSAS

Overview

162. MSAS (MTSAT Satellite-based Augmentation System) is the wide-area augmentation system for GPS. Once in operation, this state-of-the-art system will assure full navigation services for aircraft in all flight phases within the Japanese FIR through MTSAT (Multi-functional Transport Satellite) launched by the Ministry of Land, Infrastructure and Transport. Aircraft can rely on the most efficient navigation system through reception of GPS signals and MSAS augmentation information, at anytime and any phase of flight.

Schedule

163. MTSAT-1R is scheduled for launch in Fiscal Year (FY) 2003. After that, MSAS operation is expected to commence once necessary data has been collected and performance levels have been verified. MTSAT-2 is scheduled for launch in FY 2004. Operation of MSAS

using MTSAT-1R and MTSAT-2 is expected to commence in the year 2006, given that the system performance levels using both satellites are satisfactory. MSAS is expected to offer highly reliable navigation services by utilising two MTSATs, and also reduction of aircraft separation. MSAS is expected to function as a shared infrastructure within the Asia and Pacific regions for GNSS use.

Interoperability and the future potential of MSAS

164. Satellite Based Augmentation Systems such as WAAS (Wide Area Augmentation System) of the United States, EGNOS (European Geostationary Navigation Overlay Service) of Europe, GAGAN (GPS And GEO Augmented Navigation) system of India and MSAS have interoperability at the signal in space level. This global integration of air navigation system allows aircraft to use WAAS, EGNOS, GAGAN and MSAS services with the same avionics. All service providers continue to examine the establishment of higher-level interoperability. In the future, these wide-area augmentation systems are expected to provide higher-quality services, which are truly global and seamless services through the improvement of system performance and expansion of service areas.

QZSS

Overview

165. The Japanese Quasi-Zenith Satellite System (QZSS) is a regional complementary and augmentative system for GPS. When completed, the QZSS will consist of at least three satellites to be operated on individual circular orbits at an inclination of 45 degrees over a geosynchronous period. Because the elevation angle is more than 70 degrees at all times, this satellite constellation ensures visibility of the region over Japan without blocking from buildings and mountainous features. The QZSS orbital characteristics are therefore extremely valuable for high-speed communication and high accuracy navigation services.

Schedule and development structure

166. In 2003, the Japanese Government started research and development on the QZSS. The first demonstration satellite is expected to be launched in 2008. The collaboration between the Government and the private sector is one of the most important aspects of the development process. Both groups are working together on the QZSS Development and Utilisation Board in order to facilitate the realisation of the QZSS system.

International co-operation

167. International co-operation between the GPS provider, the United States and Japan is essential for the development of the QZSS and the GPS/QZSS Technical Working Group that was established in October 2002 to encourage this kind of co-operation. With respect to QZSS utilisation, expanding the service area to other countries in the Asia and Pacific regions, especially to Australia, could be considered for the future.

168. Additional information about the QZSS, i.e., presentation materials introduced at the 5th Action Team meeting, is available at the GNSS Action Team web site (http://forum.itu.int/~gnss).

2. EGNOS

169. As previously mentioned, EGNOS (European Geostationary Navigation Overlay Service) is the forerunner of GALILEO and the first contribution of Europe to multimodal global satellite navigation. The project started in 1995 by the European Commission, ESA and the European Organisation for the Safety of Air Navigation (Eurocontrol) and is supported by several service providers with their own investments.

170. Currently, EGNOS has reached initial operational capability. An experimental service is available in an area covering Europe[2] and has been successfully tested in road, aviation and maritime navigation since 2001. Some demonstration activities have been performed and others are planned to be conducted outside Europe (e.g. Middle East, Latin America, Africa, the People's Republic of China). It comprises a space segment of two Inmarsat transponders (AOR, IOR) and the newly launched Artemis geostationary satellite. The ground segment includes a number of reference stations (RIMS) in Europe and beyond, a processing centre and uplink facilities.

171. The system will be fully operational by 2004. EGNOS will complement GPS and the Russian GLONASS systems in order to provide civil service to European citizens. It warns the users of system malfunctions of the GPS and GLONASS constellations by broadcasting on the L1 frequency band integrity signals on the health of the two constellations. The provision of this quality control service (integrity) is essential for safety critical applications.

172. EGNOS will also improve the accuracy of GPS and GLONASS by means of differential corrections. The correction data will improve the accuracy of the current services from about 20 meters to better than 5 meters.

173. Besides its own specific operational objective as the European SBAS, EGNOS is a unique instrument to gain experience not only in the development of GNSS technology but also, most importantly, in the operational introduction of GALILEO services.

174. The ICAO international SBAS (Satellite Based Augmentation System) standards guarantee the interoperability of EGNOS and the two other inter-regional augmentation systems MSAS and WAAS at user level. EGNOS will serve not only aviation but also other transport and non-transport applications.

175. EGNOS is an example of the European commitment to interoperability with already existing systems.

3. WAAS

176. The Wide Area Augmentation System (WAAS) has been developed by the United States Federal Aviation Administration (FAA) to augment the GPS SPS navigation signal. The system has been operational for non-safety of life since August 2000 and has been widely used by applications such as agriculture. It is estimated that there are over 1 million users in the agricultural field alone in the United States. In July 2003, the FAA commissioned the system for

---

[2] Egnos Test Bed data 2. Oct 2002

safety of life service and has been publishing the appropriate procedures for use by its aviation customers.

177. WAAS uses a system of master stations and ground reference stations to provide the necessary augmentations to the GPS SPS navigation signal and broadcast those signals via communication satellites to the receivers onboard the aircraft. The initial system consists of a network of 2 master stations and 25 precisely surveyed ground reference stations that are strategically positioned across the United States including Alaska, Hawaii and Puerto Rico to collect the GPS data and transmit the information to the master stations for correction. The end state WAAS will add communication satellites to provide dual coverage for the entire United States and additional 12 ground reference stations located in Alaska and along the northern and southern borders, with possible locations in Canada and Mexico.

178. WAAS is designed to provide the additional accuracy, availability, continuity and integrity necessary to enable users to rely on GPS for en-route through precision approach with vertical guidance for all qualified airports within the WAAS coverage area. This provides capability for the development of more standardised precision approaches, missed approaches, and departure guidance for approximately 4,100 runway ends and hundreds of heliports and helipads in the United States National Airspace System (NAS).

179. WAAS provides the capability for increased accuracy in position reporting, allowing for more uniform and high-quality worldwide Air Traffic Management (ATM). In addition, WAAS provides benefits beyond aviation to all modes of transportation, including maritime, highways and railroads. While WAAS may not provide any direct benefit to Air Traffic Control (ATC) communications, it may be an enabling technology for the future aviation data link architecture. It provides an alternative satellite-based system to maintain required levels of service in the NAS. Upon completion of the end state, WAAS will allow for the replacement of VORs, DMEs, NDBs and possibly Cat I ILS receivers with a single WAAS receiver.

180. WAAS provides improved safety when operating in reduced weather conditions due to precision vertical guidance on approach with 3-dimensional position guidance for all phases of flight. WAAS provides an inexpensive, instrument flight rules (IFR) area navigation system with global coverage, leading to: greater runway availability, reduced separation, more direct flight paths, new precision approach services and reduced disruptions (delays, diversions or cancellations).

181. There are also significant benefits to be realised by the FAA due to the reduction in maintenance and replacement costs associated with some older, expensive ground-based navigation aids to include NDBs, VORs and DMEs. FAA has commissioned WAAS on 10 July 2003.

4. GAGAN

182. The Indian Space Based Augmentation System (SBAS), called GAGAN (GPS And Geo Augmented Navigation), is being implemented by the Indian Space Research Organisation (ISRO) in collaboration with the Airports Authority of India (AAI) over the Indian airspace, for civilian aircraft navigation. The GAGAN system is expected to bridge the gap between the evolving European EGNOS system and the Japanese MSAS system. The GAGAN system will follow the recommendations of the Asia Pacific Air Navigation Plan for ICAO Regional Group (APANPIRG) as per the ICAO SARPs.

183. Three phases have been identified for reaching the Full Operational Capability (FOC) for the GAGAN system:

Phase 1: Technology Demonstration System (TDS);
Phase 2: Initial Experimental Phase (IEP); and
Phase 3: Final Operational Phase (FOP).

Phase 1: Technology Demonstration System (TDS)

184. Under the TDS, the Indian Space Research Organisation shall establish the necessary ground and space segment for demonstration of SBAS functioning for en-route, NPA1 and leading up to Cat I landing capability, initially over a limited airspace.

185. The ground segment configuration for the TDS phase is as follows:

- Up to 8 Indian Reference Stations (INRESs) at widely separated geographical area in India;
- An Indian Master Control Centre (INMCC) located at Bangalore;
- An Indian Navigation Land Uplink Station (INLUS) collocated with the INMCC;
- One Navigation Payload in the Indian Ocean Region (IOR) between the orbital locations 48 deg. E to 111.5 deg. E, compatible with GPS L1 and L5.

186. The Indian Space Research Organisation is looking into incorporating the GPS with the third civil frequency L5.

187. The major function of the Geostationary payload is:

- To relay Geostationary overlay signal compatible with GPS L1 & L5 frequency for use by modified GPS receivers (GNSS receivers).

188. The GPS L1 & L5 EIRP shall be 33.0 dBW. This EIRP can be adjusted within a suitable range through on-board attenuator settings. The total weight and power requirements of this payload are expected to be about 30.5 Kg and 145 Watts.

189. The first payload is expected to be made operational in the year 2005. A second payload shall be fabricated and flown in Phase 3.

190. Iono-Tropo modelling and scintillation studies in the L-band will be carried out over the entire Indian airspace as an integral part in the TDS Phase 1.

Initial Experimental Phase (IEP)

191. After the successful completion of the TDS, redundancies will be provided to the space segment, INMCC, INLUS and system validation carried out over the entire Indian airspace. The conventional navigational aids will continue to be operational as prime mode. IMCC will be configured for WAD technology and for operations with the Indian space segment. Based on the experience of the TDS, additional augmentation will be worked out.

Final Operational Phase (FOP)

192. During the Final Operational Phase (FOP), additional INRESs will be established as required and the communication systems will be established with all redundancies. INMCC and NLES will be augmented with operational hardware and adequate redundancy.

193. During the IEP and the FOP, parallel attempts will be made to develop SATNAV compatible GNSS receivers of international standards indigenously.

194. The present service includes coverage (satellite footprint) for WAAS (INMARSAT-III AOR-East & West), EGNOS (INMARSAT-III, AOR-East & IOR), MSAS (INMARSAT-III, POR) & GAGAN (proposed Indian coverages together with INMARSAT-III IOR and MSAS).

5. Others

Canadian Coast Guard Marine Differential Global Positioning System (DGPS) Navigation Service

195. The Canadian Coast Guard DGPS Navigation Service provides a maritime differential GPS correction service for suitably equipped radio users. These corrections are broadcast from a network of Canadian Coast Guard operated MF marine radio beacons. Canadian coverage areas include the east and west coasts of Canada to approximately 60° N., the Great Lakes and Saint Lawrence Seaway. The current network consists of 20 beacons. Broadcast formats are based on international standards and are compatible with the worldwide network of DGPS marine beacon station broadcasts. See http://www.ccg-gcc.gc.ca/dgps/main_e.htm for additional information and updates.

Canadian Active Control System and Canada-wide DGPS service

196. Natural Resources Canada has established the Canadian Active Control System (CACS) through which enhanced GPS positioning is enabled and directly related to the Canadian Spatial Reference System (CSRS). Real-time and post-processing GPS applications are possible at accuracies ranging from centimetres to metres. The CACS consists of a network of GPS tracking stations across Canada, real-time data links and a central server computing system. CACS products include GPS data, precise GPS orbits and clocks. As part of a global collaboration, CACS data and products are regularly contributed to the International GPS Service (IGS) (http://igscb.jpl.nasa.gov/).

197. A real-time wide-area augmentation, based on the CACS, has been implemented to produce real-time GPS corrections (GPS•C) for Canadian users. Real-time broadcast of these corrections via MSAT to the user and development of an initial user receiver is underway through a partnership between the Canadian federal Government and the Canadian provinces. This project is known as CDGPS or Canada-wide Differential GPS project (http://www.cdgps.com/). More details about the Canadian Active Control System are available at:
http://www.geod.nrcan.gc.ca/index_e/aboutus_e/programs_e/progacp_e.html

NAV CANADA's role and GPS augmentation strategy

198. NAV CANADA is the non-share capital, private corporation that owns and operates Canada's civil Air Navigation Service (ANS). NAV CANADA provides, maintains and enhances

an air navigation service dedicated to the safe movement of air traffic throughout the country and through oceanic airspace assigned to Canada under international agreements. The company's infrastructure consists of seven Area Control Centres, one stand-alone terminal control unit, 78 flight service stations, 42 control towers, 41 radar sites and approximately 1,400 ground-based navigational aids across Canada.

199. For the aviation community, GPS signals meet accuracy requirements for en-route through non-precision approach. GPS by itself does not meet integrity or accuracy requirements for aircraft precision approach operations. NAV CANADA has commissioned over 250 GPS stand-alone approaches providing increased airport usability in many cases.

200. Recent developments in the United States Wide Area Augmentation System (WAAS) program suggest that it may be possible to obtain service from WAAS in southern Canada. NAV CANADA is exploring this possibility. The only viable way to obtain full WAAS service in Canada, however, is to field a network of reference stations linked to FAA master stations in the United States; this network would be called the Canadian WAAS, or CWAAS. NAV CANADA and the FAA have been planning accordingly since the mid 1990s. No decision has been made to fund CWAAS; such a decision depends on factors related to the ability of CWAAS to deliver levels of service that would bring benefits to aircraft operating in Canada.

201. NAV CANADA is also investigating the use of the Local Area Augmentation System (LAAS) installations in Canada as this technology develops.
[Reference: NAV CANADA Satnav Transition Strategy May 2002
http://www.navcanada.ca/contentEN/serviceprojects/satnav/
See also http://www.navcanada.ca/contentEN/news/corpDocs/techWatch/default.asp for NAV CANADA updates and http://www.tc.gc.ca/tdc/projects/air/b/9855.htm for information about GPS advanced aviation navigation program at Transport Canada.]

University of Calgary's regional differential RTK test network

202. The University of Calgary is deploying a test network that will initially consist of 16 stations spaced at 40 to 70 km to study multiple reference station DGPS RTK and real-time water vapour estimation on a regional basis.

Canadian commercial GPS differential services

203. There are some Canadian companies offering GPS augmentation services covering various parts of Canada. This is done from wide coverage by broadcasting corrections via a communication satellite to local services broadcasting via radio frequencies from a single base station. The services also range from low accuracy single frequency pseudorange corrections to local, high accuracy, dual frequency RTK type services. Most major cities in Canada have some sort of commercial GPS augmentation service.

III. OVERVIEW OF EXISTING ACTIVITIES TO PROMOTE GNSS

A. Civil GPS Service Interface Committee (CGSIC)

204. The Civil GPS Service Interface Committee (CGSIC) is part of the Department of Transportation's program to respond to the needs of civil GPS users, and to integrate GPS into civil sector applications. CGSIC is the recognised worldwide forum for effective interaction between all civil GPS users and the United States GPS authorities. CGSIC comprises members from United States and international private, government, and industry user groups. Three subcommittees focus on specific user groups: International, Timing, and United States' States and Localities. CGSIC meets semi-annually and is open to anyone interested in civil GPS issues. A summary record of each meeting is available from the NIS. Information from CGSIC members and meetings is provided to United States GPS authorities for consideration in GPS policy development and GPS service operation.

205. The Civil Global Positioning System (GPS) Service Interface Committee (CGSIC) was established to identify civil GPS user needs (e.g. navigation, timing and positioning) in support of the Department of Transportation's (DOT) program to exchange information concerning GPS with the civil user community, the GPS "outreach" program. In fulfilling this responsibility, the CGSIC will report its activities to the Interagency GPS Executive Board (IGEB) and the Office of the Assistant Secretary for Transportation Policy (OST/P). The CGSIC is a support to the Committee and to the Interagency GPS Executive Board (IGEB).

The roles of the CGSIC are to:

- Provide a forum to collect and exchange information on the worldwide civil user community's GPS needs;
- Identify information requirements, and methods to distribute this information to the worldwide civil GPS user community;
- Conduct GPS information studies on civil user needs as requested by the IGEB or identified by the Committee; and
- Identify any GPS matters of concern - "issues" - that may need resolution and submit them to appropriate authorities for consideration.

Committee composition

206. The CGSIC is comprised of representatives from relevant private, government and industry user groups, both within the United States and international. The Committee structure consists of a Chair, a Deputy Chair, a Secretariat, and an Executive Board. The Committee is chaired by a representative from the Assistant Secretary for Transportation Policy who provides policy guidance and oversight to the Deputy Chair. The Deputy Chair is provided by the United States Coast Guard Navigation Center (NAVCEN), and is responsible for the CGSIC Secretariat. The Secretariat manages the Committee, maintains membership lists, co-ordinates Committee meetings, and represents the Committee at GPS related meetings.

207. The Executive Board consists of the Chair, the Deputy Chair, the Deputy Chair for International Affairs, the Subcommittee officials and representatives from the Secretariat and the three modal areas:

- Aviation: a representative designated by the Federal Aviation Administration to address aviation concerns;
- Land: a representative designated by the Federal Highway Administration to focus on land, reference station, and timing concerns; and
- Marine: a representative designated by the United States Coast Guard to address maritime matters.

Subcommittees

208. The CGSIC may create standing subcommittees, ad hoc subcommittees, or special working groups to identify specific areas of civil GPS user needs and facilitate technical information exchange. The following standing subcommittees have been established:

- International Subcommittee (ISC);
- Timing Information Subcommittee (TISC); and
- United States States and Localities Subcommittee (SFSC).

209. The International Subcommittee officers consists of a Chair, Regional Vice-Chairs and representatives from industry, government, and academia. Country points of contact are appointed to co-ordinate activities in a country.

210. Standing committee chairs will be elected by the subcommittee members for a two-year term. Elections will be held in conjunction with a general meeting.

211. The CGSIC is open to anyone with an interest in GPS. It is open to the GPS user community worldwide. To join, the following information should be sent to the Executive Secretariat: *Name, Affiliation, Address, Phone, FAX, E-mail address, and How do you use GPS*?

212. The person sending the required information will then be placed on the mailing list for announcements and meeting summary reports and on the GPS List server to receive GPS and radionavigation announcements.

Civil GPS Service Interface Committee Charter

213. The CGSIC was chartered by the DOT POS/NAV Executive Committee and interfaces with the Office of the Assistant Secretary for Transportation Policy, the United States Coast Guard's Operations Policy Directorate, the DOT POS/NAV Executive Committee, the Interagency GPS Executive Board (IGEB) Executive Secretariat, and the GPS Interagency Advisory Council (GIAC).

Administrative guidelines

214. The administrative guidelines for the CGSIC are:

- The Committee will meet as often as needed, but not less than annually. The date, time, and location will be announced at least two months before each meeting;
- A Summary Record of each meeting should be mailed to members as soon as possible after the meeting on the United States Coast Guard's Navigation Center's Website;
- Attendance is open to anyone with a need to exchange information or provide input regarding civil GPS requirements, both domestic and international; and

- The Chair or Deputy Chair will make every effort to attend all subcommittee meetings. If unable to attend, the Chair or Deputy Chair will answer questions submitted in writing.

215. The Commanding Officer of NAVCEN will co-ordinate meeting arrangements, agendas, produce Summary Reports, and maintain membership lists.

Navigation Information Service

216. The United States Coast Guard Navigation Information Service (NIS) is the central point of distribution of GPS information in support of non-aviation users. The NIS distributes operational notices on GPS status and reference documents to facilitate system use and receiver design. The NIS also collects GPS incidents reports, forwarding them for analysis. Notice Advisories to Navstar Users (NANUs), and status messages are available by e-mail subscription, as well as on the website.

217. The NIS is staffed 24 hours a day, seven days a week, and supports users by telephone, fax, and e-mail. The NIS maintains a web site (http://www.navcen.uscg.gov) with current GPS information.

B. GLONASS service interface

218. The Coordination Scientific Information Center (KNITs) of the Ministry of Defense is authorized for official distribution of GLONASS Interface Control Document. It is available at the KNITs web site at www.glonass-center.ru

219. In order to support activities of the GLONASS's Co-ordination Board two bodies have been assigned to exchange information concerning GLONASS with the civil user community: the GNSS Information Analytical Center of the Mission Control Center Korolyov and the Multifunctional Navigation Information Center of the Russian Institute of Space Device Engineering, Moscow (MNIC RISDE).

220. The GNSS Information Analytical Center of the Mission Control Center Korolyov (IAC MCC) was established in 1995 by the Russian Space Agency to support and co-ordinate civil community in GNSS applications. Presently, IAC MCC is officially acting as Analysis Center of the International Earth Rotation Service (IERS), International Laser Ranging Service (ILRS) and International GLONASS Service - Pilot Project of IGS (IGLOS-PP). In a routine mode IAC MCC is permanently conducting:

- The real-time monitoring and a posterior analysis of the GLONASS/GPS navigation field;
- GLONASS precise orbit determination based on laser data; and
- GLONASS/GPS precise orbit and time corrections determination based on one-way phase data of global network (experimental service).

221. The following products of IAC MCC are currently available for users:

- GLONASS/GPS integrity data (real-time, monthly bulletin);
- Precise GLONASS orbits based on SLR and one-way data; and
- PZ-90-GLONASS/ITRF transformation parameters.

222. The information is openly available at the IAC MCC web site www.mcc.rsa.ru

223. The Multifunctional Navigation Information Center of the Russian Institute of Space Device Engineering at Moscow (MNIC RISDE) was established by the Russian Aviation and Space Agency in 2002 aiming at the following purposes:

- Realisation of common governmental policy in the area of co-ordinates-time provision to users;
- Co-ordination of works in connection with development of perspective systems intended to provide users with co-ordinates-time data;
- Establishment, development and evolution of the navigation technologies and services market in the Russian Federation; and
- Integration with international systems and services.

224. The information is openly available at the MNIC RISDE web site www.mnicrisde.ru

225. In close co-operation, all three centres provide user community with comprehensive information on GLONASS status, development plans and application benefits.

C. United Nations agencies (IMO, ITU, ICAO)

226. The International Civil Aviation Organization (ICAO), recognising the limitations of the present air navigation systems and the need to meet future requirements, has taken steps to promote the introduction of satellite-based technologies for communication, navigation and surveillance (CNS) elements in support of global air traffic management (ATM). A fundamental prerequisite for the implementation of the systems on a global basis includes the development of uniform Standards and Recommended Practices (SARPs).

227. ICAO has developed SARPs for global navigation satellite system (GNSS),[3] which include provisions for core satellite constellations (GPS and GLONASS) and aircraft-based, ground-based and satellite-based augmentation systems, to improve the overall GNSS performance as required for aeronautical applications. Work is also underway to develop ICAO standards for GNSS enhancements and new elements such as GPS L5, an additional civil frequency for GPS, standards for aeronautical applications of GALILEO and enhancements to GLONASS.

228. The ICAO Assembly at its thirty-second session in 1998 adopted the Charter on the Rights and Obligations of States relating to GNSS Services (Resolution A32-19) and the Legal Framework for GNSS (Resolution A32-20), which state fundamental principles applicable to GNSS. An ICAO Secretariat study group was established to consider, *inter alia*, the creation of an appropriate long-term legal framework to govern the operation of GNSS. In 2001, the thirty-third session of the ICAO Assembly decided that further work should be carried out in this respect. Regarding financial and other related aspects of GNSS, a study is under way to estimate acceptable and equitable cost allocation shares for major user groups.

[3] According to the definition of GNSS in ICAO standards, GNSS is the system which comprises two types of elements: core satellite constellations (GPS, GLONASS and future GALILEO) and augmentation systems (aircraft-based, ground-based and satellite-based).

229. The International Telecommunication Union, Radiocommunication Sector (ITU-R) is continuing its technical studies related to the use of GNSS and for the efficient use of associated radio frequency spectrum in the Study Group 8 – Working Party 8D (http://www.itu.int/ITU-R/study-groups/rsg8/rwp8d/index.asp), and ICAO, IMO and ITU are continuing co-operation to protect aeronautical applications of satellite-based CNS systems and radionavigation satellite service (RNSS). At the World Radiocommunication Conference 2000 (WRC-2000), spectrum was allocated for additional GNSS applications, including aeronautical applications, and follow-up actions were to be taken at WRC-2003.

230. The World Radiocommunication Conference 2003 (WRC-2003) (9 June – 4 July 2003, Geneva) was expected to consider the following agenda items related to the RNSS: revision of the results of studies concerning RNSS in accordance with Resolutions 604, 605 and 606, adopted at WRC-2000 (agenda item 1.15). Resolution 604 (WRC-2000) relates to the compatibility between the RNSS operating in the frequency band 5010-5030 MHz and the radio astronomy services (RAS) operating in the band 4990-5000 MHz. Resolution 605 (WRC-2000) relates to the compatibility between the RNSS and ARNS operating in the frequency band 1164 – 1215 MHz. And Resolution 606 (WRC-2000) relates to the compatibility between the RNSS and the radiolocation service (RLS) in the frequency band 1215 – 1300 MHz, respectively. WRC-2003 is also considering use of the band 108-117.975 MHz for the transmission of radionavigation satellite differential correction signals by ICAO standard ground-based systems (agenda item 1.28). More information on the WRC-03 agenda items is available from ITU-R website, http://www.itu.int/ITU-R/conferences/wrc/wrc-03/index.asp

231. ICAO and the International Maritime Organization (IMO) are continuing co-ordination and exchange of information on various aspects of GNSS development and implementation. IMO, recognizing that requirements of ICAO for accuracy, reliability and availability of GNSS are more stringent, accepted such requirements as more than adequate for maritime applications. Both organizations continue to exercise a co-ordinated approach to ITU in supporting the evolution of GNSS towards a future system capable of supporting advanced applications for aeronautical and maritime navigation.

232. At its twenty-second session (19-30 November 2001), the IMO Assembly adopted resolution A.915(22) on “Revised maritime policy and requirements for a future global navigation satellite system (GNSS)”. The revised policy provided revised operational requirements for a future GNSS, revised and updated relevant definitions and a glossary used in GNSS, and also updated the minimum user requirements for a future GNSS, providing minimum requirements for general navigation and minimum maritime user requirements for positioning. It also updated the indicative timetable for development of GNSS. It was also expected that the twenty-third session of the Assembly of IMO in November 2003 would adopt a resolution on the Worldwide Radionavigation System revoking the existing resolutions A.529(13) and A.815(19) relating to accuracy standards for navigation and operational requirements for worldwide radionavigation systems, respectively.

233. The United Nations Office on Drugs and Crime (UNODC) is extensively and increasingly using GPS devices in the context of its global illicit crop-monitoring programme. The GPS data are mostly used for ground-truthing purposes to support the analysis of satellite imagery. GPS data are also used to establish and update a list of human settlements in rural areas of the countries where the Programme implements annual crop surveys and alternative development programmes.

234. The United Nations Office for the Coordination of Humanitarian Affairs (OCHA) has received from the Inter Agency Standing Committee (IASC) the guardianship of the Humanitarian Information Center (HIC) concept. The work of the HIC requires accurate knowledge of location as a requisite input into the planning and co-ordination of field operations. The HIC uses the technology of satellite-based navigation, GPS, and geographic information systems (GIS) combined to provide field personnel with a full picture and command of the locations and distribution of populations, roads, distribution centres, and key facilities for all logistics, analysis and planning activities. Associated with the use of GPS and related to the challenging environment in which delivery of humanitarian assistance takes place, the HIC has been championing the development of standard Metadata and geo-codes (P-codes) which define unique identification numbers for areas and facilities in an operating theatre. These standard procedures and products have become an increasingly common feature of humanitarian information management systems.

235. The Office of the United Nations High Commissioner for Refugees (UNHCR) is using GPS devices in field operations to collect relevant operational geographical information in order to improve its assistance towards refugees. Currently, more than 45 country operations are using GPS in activities relating to site planning, staff security, environmental assessment, logistics, among other things. The collected GPS data are often combined from satellite imagery and managed within a GIS for further analysis and mapping outputs. Expansion of the use of GPS devices is foreseen in refugee operations for the coming years. Basic training and technical booklets are also developed by UNHCR via its geographic information and mapping unit and are provided to staff members and partners.

236. The United Nations Office for Project Services (UNOPS) is implementing the UNOSAT project[4] on behalf of the United Nations Institute for Training and Research (UNITAR). UNOSAT uses GPS to collect field information for inclusion in local GIS and UNOSAT's global web-based database. In addition, GPS is used to geo-reference and field-validate satellite imagery and imagery-derived products. In support of remote field data collection activities, the World Health Organization (WHO) has been routinely using GPS to map and track infectious diseases at the community level. GPS is now routinely used by village outreach teams for onchocerciasis, Guinea worm, African trypanosomiasis (sleeping sickness) and lymphatic filariasis, among others. Such systems are increasingly being used during the investigation of disease outbreaks for rapid mapping of cases and deaths. Within the context of complex emergency situations, they are being used to map internally displaced persons and refugee camps and to carry out rapid epidemiological assessments.

237. Members of the World Meteorological Organization (WMO), as well as international space organizations that operate space-based environmental satellite systems contributing to the World Weather Watch's space-based component of the Global Observing System, have plans to

[4] Implemented through a United Nations private sector consortium consisting of UNOPS, UNITAR and several private companies involved in satellite image distribution and analysis and geographical information management, UNOSAT became operational in 2002. The objective of UNOSAT is to encourage, facilitate, accelerate and expand the use of accurate geographical information derived from Earth observation satellite imagery for United Nations entities involved in humanitarian aid and development assistance projects. By providing services for updated and accurate geographical information and promoting universal access to products derived from satellite imagery through the Internet and multimedia tools, UNOSAT contributes to the physical planning process for local authorities, project managers and field operators working in disaster management, risk prevention, peacekeeping operations, environment rehabilitation, post-conflict reconstruction and social and economic development.

analyze the time signal from Global Positioning System Occultation Sensors (GPSOS) as described in paragraphs 238 to 241 below.[5]

238. Geometric determinations of location depend on inferences about the atmospheric temperature and moisture concentrations. They provide valuable complementary information to tropospheric infrared and microwave sounders about the tropopause and stratosphere. Ray bending and changes in the phase and amplitude of the transmitted signals allowing inference of the upper atmosphere temperature profile to the order of 1 deg K or better between altitudes of 8 to 30 km in layers (with footprints ranging between 1 km x 30 km to 1 km x 200 km extent) with near global coverage. The coverage would be expected to be evenly spread over the globe, except for polar regions. The system measures upper atmospheric virtual temperature profiles; therefore, data from the lower atmosphere would require alternate data to separate vapour pressure and temperature traces.

239. The Global Positioning System Occultation Sensor (GPSOS) will measure the refraction of radio-wave signals from the GPS constellation and GLONASS. This uses occultation between the constellation of GPS satellite transmitters and receivers on LEO satellites. The GPSOS will be used operationally for spacecraft navigation, characterizing the ionosphere, and experimentally to determine tropospheric temperature and humidity. A similar system, GPSMET, flew in 1995. A GPS occultation system was provided for launch on the Oersted/Sunsat mission and variations will also be included on CHAMP, SAC-C and GRACE, all scheduled to be launched before 2001. The National Oceanic and Atmospheric Administration (NOAA) was planning to manifest a GPSOS on all NPOESS platforms.

240. The European Polar-orbiting Satellite (METOP), due to be launched in 2004, is expected to fly a GPS Radio occultation Atmospheric Sounder (GRAS). GRAS will provide “all weather” temperature profiles with high vertical resolution in the upper troposphere and stratosphere, and humidity profiles in the lower troposphere.

241. A promising research GPS system is COSMIC (Constellation Observing System for Meteorology, Ionosphere and Climate). The National Space Program Office (NSPO) in the People’s Republic of China, the University Corporation for Atmospheric Research (UCAR), the Jet Propulsion Laboratory (JPL), the Naval Research Laboratory (NRL), the University of Texas at Austin, the University of Arizona, Florida State University and other partners in the university community are developing COSMIC, a project for weather and climate research, climate monitoring, space weather, and geodetic science. COSMIC was planning to launch eight LEO satellites in 2002, with each COSMIC satellite retrieving about 500 daily profiles of key ionospheric and atmospheric properties from the tracked GPS radio-signals as they are occulted behind the Earth limb. The constellation will provide frequent global snapshots of the atmosphere and ionosphere with about 4000 daily soundings (See web site, http://www.cosmic.ucar.edu/cosmic/index.html).

D. International organizations

European Group of Institutes of Navigation

242. The European Group of Institutes of Navigation (EUGIN) is an international association, with scientific and educational purposes. More precisely, the objectives of EUGIN are:

---

[5] The description is an excerpt from the *World Weather Watch, Technical Report No. 20, Observing Systems Technologies and their Use in the Next Decade, WMO/TD No. 1040.*

- Provide consultancy and advice to European institutions in the fields of navigation, traffic management and related communication and training;
- Favour, by whatever methods are possible, actions assisting in the development of pan European policies and strategies in the general field of navigation and traffic management, and in particular in the emerging field of satellite navigation;
- Foster co-operation and information exchange between its members and any competent authorities or organizations active in the above-mentioned fields of expertise;
- Provide information in its field of expertise to the public by organising conferences and symposia; publishing books and papers; and participating in electronic methods of data dissemination; and
- In general, to undertake anything which has a bearing directly or indirectly in whole or in part on EUGIN's objectives as given here, or which would be liable to facilitate or aid their realisation.

243. Member institutes of EUGIN are: French Institute of Navigation (IFN), German Institute of Navigation (DGON), Italian Institute of Navigation (IIN), Netherlands Institute of Navigation (NIN), Nordic Institute of Navigation (NNF), Royal Institute of Navigation (RIN), Austrian Institute of Navigation (OVN), Spanish Institute of Navigation (INAVE) and the Swiss Institute of Navigation (SION).

International GPS Service

244. The Global Positioning System (GPS) provides unprecedented potential for precise ground- and space-based positioning, timing and navigation anywhere in the world. Extremely precise use of GPS, particularly for Earth Sciences applications, stem largely from activities of the International GPS Service (IGS), established in 1994. More than 200 organizations in 80 countries contribute daily to the IGS, which is dependent upon a cooperative global tracking network of over 350 GPS stations. Data are collected continuously and archived at globally distributed Data Centers. Analysis Centers retrieve the data and produce the most accurate GPS data products available anywhere, e.g., GPS orbits at the 3-5 cm level 3D-wrms, sub-centimeter station positions, velocities at the millimeter level and time transfer at the sub-nanosecond level. IGS provides users easy access to the precise international terrestrial reference frame (ITRF), generated in partnership with the International Earth Rotation and Reference System (IERS) and other complementary geodetic techniques such as satellite laser ranging, and very long baseline interferometry. Since 1998 the IGS operates a pilot project based on a sub-network of GLONASS stations. Analysis Centers produce the precise relation between the GPS-GLONASS systems and the best orbits for the GLONASS constellation, ~ 25cm 3D-wrms. IGS plans to incorporate GALILEO signals when they become available in order to derive the greatest scientific benefit from combined GNSS applications.

245. IGS data and data products are made accessible to users reflecting the commitment of the organizations to an open data policy. The IGS serves many thousands of users and is viewed as a very successful scientific federation and a model for international co-operation. IGS is a recognised scientific service of the International Association of Geodesy (IAG).

Bureau International des Poids et Mesures (BIPM)

246. The BIPM is located at Sèvres, in the outskirts of Paris, France. The task of the BIPM is to ensure worldwide uniformity of measurements and their traceability to the International System of Units (SI). It performs this task with the authority of the Convention of the Metre, a

diplomatic treaty between fifty-one nations, by operating through a series of Consultative Committees, whose members are the national metrology institutes of the member states of the Convention, through its own laboratory work. The BIPM carries out measurement-related research. It takes part in, and organises international comparisons of national measurement standards, carrying out calibrations for Member States.

247. The International System of Units (SI): The 11th "Conférence Générale des Poids et Mesures" (1960) adopted the name "Système International d'Unités" (International System of Units, international abbreviation SI), for the recommended practical system of units of measurement. The 11th CGPM laid down rules for the prefixes, the derived units, and other matters.

248. The base units are a choice of seven well-defined units which by convention are regarded as dimensionally independent: the metre, the kilogram, the second, the ampere, the kelvin, the mole, and the candela. Derived units are those formed by combining base units according to the algebraic relations linking the corresponding quantities. The names and symbols of some of the units thus formed can be replaced by special names and symbols which can themselves be used to form expressions and symbols of other derived units.

249. The SI is not static but evolves to match the world's increasingly demanding requirements for measurement.

250. Regarding scientific activities, the scientific work at the BIPM centres on seven principal topics: length, mass, time, electricity, radiometry and photometry, ionizing radiation and chemistry. In addition, a small activity is maintained in thermometry and in the measurement of pressure and humidity to meet the internal needs of the BIPM laboratories.

251. The Time Section of the BIPM calculates and disseminates the two conventional time scales, International Atomic Time (TAI) and Coordinated Universal Time (UTC). Both scales are elaborated on the basis of clock data from laboratories distributed worldwide.

252. A network of stations is organised to allow distant clock comparison. Two methods are used at present in TAI to compare remote clocks: time transfer by using the constellation of Global Positioning System (GPS) satellites, and two-way satellite time and frequency transfer (TWSTFT). Research work is conducted at the Time Section to improve the quality of the time links. The BIPM, jointly with the International GPS Service (IGS), have investigated the utilisation of GPS geodetic-type receivers in TAI; as one of the conclusions of this work, time links by using dual-frequency multi-channel GPS geodetic-type receivers have been incorporated to TAI. Time transfer by using GLONASS satellites is also under study.

253. International Atomic Time is the uniform time scale calculated at the Time Section of the BIPM since 1988. The unit of TAI is the second of the International System of units (SI), defined as a fraction of the period of an atomic transition; it is realised on the basis of the measurements reported by laboratories operating primary frequency standards.

254. GNSS have a key role in time dissemination and in clock comparison. The navigation message broadcast by the GPS satellites provides access to precise time. The GPS time is the time scale elaborated by combining the ensemble of clocks operating for that purpose. It is steered to UTC (USNO), one of the best local representations of UTC.

255. Methods to compare distant clocks are necessary to calculate the clock differences which are the base of the computation of TAI. In the last decade, the time community has largely exploited the Global Positioning System (GPS) satellites for time transfer using receivers adapted for time comparisons. In 1981, the first GPS time links were introduced in TAI. The technique, still in use today, was the GPS common-view single channel C/A-code. It allows time comparison with an uncertainty of one part in 10^{14} for average times of a few days. The stability reached by TAI for periods of a month is of two parts in 10^{15}.

256. In the last years, multi-channel GPS and GPS-GLONASS receivers have been commercially developed. The stability of time transfer increases in a factor of about three when multi-channel satellite observations are used. GLONASS P-code signal has always been available to civil users; it has been demonstrated that it reduces the noise level by a factor of about five relative to GPS C/A-code time comparisons.

257. The GPS carrier-phase technique allows frequency comparison at a level of one part in 10^{15}, and it will be a useful tool in accurate time transfer after some remaining problems be investigated and solved.

258. The technique of two way time and frequency transfer by telecommunication satellite (TWSTFT) has been largely investigated: in optimal conditions (daily and sub-daily observations) it has a better performance than the GPS C/A single/multi-channel single frequency time transfer techniques used in TAI. About ten TWSTFT links are used at present in the calculation of TAI.

Present organization of time links

259. The establishment of TAI and UTC is based on atomic clock data coming from worldwide distributed laboratories, and therefore it is strongly dependent on the means of time comparison. The international time scales computed at the BIPM are based on data of some 220 clocks located in about 50 time laboratories distributed all over the world. The quality of clocks participating in TAI has evolved in the last decade, with the development of more precise caesium commercial clocks. Caesium clocks of the new type are stable in about one part in 10^{14} over periods of a day. Very accurate methods of time transfer are necessary so that the comparison does not degrade the accuracy of the atomic clocks.

260. The present organization of the international time links at the BIPM is based on two-time comparison techniques: common views on GPS satellites and TWSTFT.

261. The introduction of GPS into time transfer in the 1990's led to an improvement of one order or more of magnitude with respect to other methods used at that moment for clock synchronisation. Clock comparison plays a key role in the elaboration of the international time scales. Clocks situated at distant laboratories, spread all over the world, can be compared with an uncertainty of several nanoseconds by using GPS. About 80% of the clock comparisons for TAI are exclusively done by using the clocks on board GPS satellites, with the 20% remnant being provided by another technique and the corresponding time link by GPS as a backup.

262. The GPS common-view method is used in the calculation of time links at the BIPM. In the common-view technique, two stations simultaneously observe the same GPS satellite. Both stations record the difference between each local clock and GPS time at the same instant and using the same clock on board the satellite in common view. When making the difference of

records in both stations the contribution of the satellite clock vanishes, not biasing with its errors the time comparison. At present, GPS C/A-code common-views allow to obtain 2-10 ns level in time synchronization. The common-view method reduces some uncertainties of physical origin and, a factor which was relevant until the middle of the year 2000, it cancelled the deliberate degradation introduced in GPS time (Selective Availability), with this degradation being eliminated on 2 May 2000.

263. GPS observations are dependent on the effects of the propagation medium on the signal. One channel GPS C/A-code time receivers track one satellite at a time. As the C/A-code is transmitted in only one frequency, there is no possibility to determine the delay introduced by the propagation of the signal along the ionosphere. Much progress has been done by using the International GPS Service (IGS) products to correct GPS data. All the GPS common views obtained with single-frequency receivers in TAI are corrected by using the IGS total electron content (TEC) maps. All GPS links in TAI are corrected using IGS precise satellite ephemeredes.

264. During 2003, GPS multi-channel dual-frequency receivers had been incorporated into the network of time links for TAI: BIPM had four of these links officially in the calculation in June 2004, with uncertainties of 1 ns or less.

265. The BIPM establishes and distributes twice a year schedules for the observation of GPS satellites. These schedules are necessary to organize the common views that are the basis of the clock links.

266. The development of multi-channel multi-code receivers permits to increase in an order of magnitude the number of observations with respect to the single-channel mode. Multi-channel C/A-code receivers observe all GPS satellites in view using 13-minute tracks every 16 minutes at the standard hours. No GPS schedule is necessary to programme the observations since the receiver automatically tracks all satellites in view. Data are stored in a single file with a standardized format. Under this constraint, the number of satellite tracks increases by a factor of 10 with respect to the number of single-channel common-view tracks. This implies an improvement in the quality of time and frequency transfer. However, multi-channel observations may be subject to systematic variations. Environmental conditions affect receivers by imposing systematic effects. Temperature stabilized antennas (TSA) have been developed at the BIPM and are currently commercially available.

267. TWSTFT is a technique that allows the comparison of two distant clocks by using as transponder a geostationary telecommunications satellite. The theoretical precision expected in time transfer of several hundred picoseconds has been reached in the first semester of 2004, when the time laboratories operating TWSTFT stations in Europe and North America started scheduling daily and sub-daily observations.

268. The network of clock comparisons at the BIPM is at present supported by common views on GPS satellites and by links using TWSTFT.

Future prospects

269. The stability of the atomic time scale has been improved due to the replacement in most laboratories of the old caesium clocks by the more high-performance new-type ones. The algorithm used in the calculation of TAI assigns relative weights to participating clocks, thus assuring that the stability is highly dominated by the best clocks. Primary frequency standards

measurements are used to evaluate the departure of the scale unit of TAI relative to the SI second; they are either excellent commercial caesium clocks or clocks developed at some laboratories which have long-term stability. Time transfer techniques need to be accurate enough for the comparison of precise clocks. GPS C/A-code single-channel and multi-channel common views plus TWSTFT are used to compare the clocks participating in TAI, leading to a stability of about 2 parts in 10^{15} for periods of about one month.

270. Clock comparison by using the GLONASS satellites could be used in the future in TAI, provided that the Russian satellite constellation be complete and stable.

271. The number of common views, when using multi-channel GPS/GLONASS receivers, increases in a factor of 20 with respect to single-channel one-system mode. Both GPS and GLONASS observations can be combined, provided that the differences between the systems are minimized. At the basis, the two systems adopt different references for space and time. While GPS is steered on UTC (USNO), GLONASS relies on UTC (SU). The terrestrial frames respectively adopted (ITRF for GPS and PZ-90 for GLONASS) differed up to 20m. Following the recommendations of the International Committee of Weights and Measures (CIPM) in 1996, efforts have been made to synchronise GLONASS time reference as close as possible to UTC, and to bring GLONASS terrestrial references in conformity to the ITRF.

272. A stability of about 200ps could be achieved using the precise code transmitted by the GLONASS system in a single-channel mode. This value is reduced by a half when operation in multi-channel mode on short baselines takes place.

273. GLONASS P-code has two clear advantages. The chip length being $1/5^{th}$ that of GPS C/A-code allows more precise pseudo-range measurements. As the precise code is transmitted in both L1 and L2 frequencies, the ionospheric delays can be precisely determined.

274. The BIPM expects, in the future, to take advantage of the existence of independent global navigation satellite systems to have redundant clock comparisons, thus making them more reliable. The GLONASS satellites cannot be at present officially used for the construction of the international time scales since the system does not completely satisfy the stability required for the purpose. Studies are undertaken at the BIPM concerning the utilisation of GLONASS precise-code for clock comparison. GALILEO will certainly bring much improvement to the international time links for TAI.

International Federation of Surveyors (FIG)
What is FIG?

275. The International Federation of Surveyors (FIG – French acronym) is a federation of national professional surveying associations and is the only international body that represents all surveying disciplines. FIG was founded in 1878 in Paris. It is recognised as a non-governmental organization by the United Nations. Over 110 countries are represented in FIG. In addition, there are 230,000 surveyors around the world in the Member Associations.

The technical work of FIG

276. The following 10 Commissions carry out the technical work of FIG:

1. Professional Standards and Practice.

2. Professional Education.
3. Spatial Information Management.
4. Hydrography.
5. Positioning and Measurement.
6. Engineering Surveys.
7. Cadastre and Land Management.
8. Spatial Planning and Development.
9. Valuation and Real Estate Management.
10. Construction Economics and Management.

277. GNSS is being applied in many of the topics covered by the above Commissions and that application occurs at various levels of accuracy.

278. As an example of close involvement in GNSS topics, Commission 5 has several relevant Working Groups:

- 5.1-Standards, Quality Assurance and Calibration (for equipment and techniques);
- 5.2-Reference Frame in Practice;
- 5.3-Integrated Positioning, Navigation and Mapping System; and
- 5.4-Low Cost Surveying Technology and Techniques for Developing Countries (Joint with Commissions 3 and 7).

279. FIG Commission 5 also administers the Memorandum of Understanding (MoU) between FIG and the International Association of Geodesy.

280. FIG also has a Standards Network that acts across all the Commissions in order to co-ordinate any work on Standards and have a single point of contact between FIG and relevant bodies such as the ISO.

Global issues and the surveyor

281. FIG is actively working with relevant United Nations Organizations to address global issues such as reducing urban poverty and progressing sustainable development. Relevant organizations include:

- United Nations Habitat (a MoU exists with FIG);
- United Nations Food and Agriculture Organization (FAO) (a MoU exists with FIG);
- The various United Nations mandated regional Committees on Spatial Data Information Infrastructure, especially those in regions with developing countries; and
- The United Nations Action Team on GNSS.

282. By way of example, FIG is helping to address Habitat's overriding goal, which is urban poverty reduction. Habitat is advancing that through two global campaigns:

- Secure Tenure.
- Urban Governance.

283. Both of these campaigns require accurate spatial information. With “Secure Tenure”, for example, it is currently widely accepted that geodesy, surveying and mapping are vital for granting secure title to land. For developing countries, once secure title is established, a property

market can begin to develop. That allows people to use equity in their ownership of land to access capital, which in turn enables steps toward a mature economy. Given this, geodesy and surveying are important disciplines at the foundation of economic development.

284. FIG is also participating in the relevant standards being developed within the frameworks of the International Standards Organization (ISO). Two examples are:

- ISO Technical Committee 211 on Geographic Information and Geomatics.
- ISO Technical Committee 172, which addresses Surveying Instruments.

The role of GNSS and spatial information

- Several studies have shown that over 80% of Government decisions involve a Spatial component – "Where?".
- Accurate and Timely Spatial Information is required to deal with the priorities of Habitat, FAO, etc.
- GNSS is a key technology for capturing accurate spatial information.

The nature of the GNSS surveying market

285. It is important to recognise that GNSS surveyors are intelligent users at the "top end" of the market. The history of the take-up of GNSS in the mass-market shows that users start off happy with the accuracy being achieved. However, many mass-market users quickly identify a need for improved accuracy for certain applications. In that context, surveyors have always been 5 to 10 years ahead of the mass market in their requirements for accuracy, reliability and for real-time results. Therefore, at any given time, the surveying market can be thought of as a snapshot of the mass-market in the future.

286. It is also important to recognise that while the GNSS surveying market is small compared to the mass-market applications, the dollar values of the equipment, software and of the application projects are high.

Future issues in GNSS surveying

287. The latest GNSS surveying techniques squeeze millimetres from the least possible amount of data, in real time, using all satellites in view and with multiple frequencies. The majority of the work is using GPS and is already very efficient. The advantages for surveyors from future developments in GNSS will be even greater efficiency, but more importantly increased reliability:

- As L2 C/A GPS receivers come online, equipment and data processing will become less complicated. Theoretically this should enable less expensive survey grade GPS receivers. It will be interesting to see if that will be realised;
- The additional L5 frequency on GPS will give even better redundancy, accuracy, efficiency and reliability;
- The availability of GLONASS has demonstrated the advantage of extra satellites, especially for those applications where satellite masking occurs, such as in urban canyons, under tree canopies or in open cut mines; and
- GALILEO will increasingly add all of this.

288. A common concern for surveyors is that existing GNSS surveying receivers are the most complex and therefore the most expensive on the market. This requires that equipment must be useful for several years so that return on investment can take place. This is especially true for private surveying companies and in developing countries. Therefore, the cost to upgrade equipment to take advantage of new developments is a significant issue for surveyors and will effect how quickly new GNSS capabilities will be taken up and applied. This could be magnified by the fact that many current surveying users are already getting good performance from the capabilities offered by GPS as it is at the present moment.

The role of FIG in GNSS development

289. FIG can play a number of roles in progressing the goals of the United Nations Action Team on GNSS. FIG is well placed to help for the following reasons.

290. FIG is already committed to assisting with issues concerning developing countries and has several MoU with key United Nations Organizations.

291. National delegates to many FIG Commissions are working in GNSS applications every day and at various levels of accuracy. FIG's national delegate network could be very useful for new users to contact existing educated users in their countries or regions.

292. FIG Commissions can assist with implementing and publicising reports and road maps through its existing network of contacts and through its existing outreach activities such as regional conferences in regions with developing countries.

293. In relation to GNSS education, FIG has a Surveying Education Database with over 240 institutes offering 425 courses, in 64 countries. Given the prominence of GNSS as a tool for surveyors, many of these courses will include GNSS content. Importantly, that content will be tailored to deal with local issues such as dealing with the current geodetic reference frame in a given country or region.

294. FIG is also working closely with IAG on issues such as Reference Frame matters and is well placed to help GNSS users understand the concerned issues.

Final comment

295. As a final comment, FIG supports the need for a global GNSS Co-ordination Board under the auspices of the United Nations.

E. United Nations Programme on Space Applications

296. The Office for Outer Space Affairs of the United Nations Secretariat is responsible for planning and managing the United Nations Programme on Space Applications. The Programme was established in 1971 to create awareness of policy makers and interested government agencies of the benefits that could be derived from space applications**.** The Programme also developed training and education programmes to enable officials from developing countries to gain practical experience in these applications. The mandate of the Programme was expanded by the Second and Third United Nations Conferences on the Exploration and Peaceful Uses of Outer Space, held in Vienna, Austria, in 1982 (UNISPACE 82) and 1999 (UNISPACE III), respectively. The activities of the Programme on Space Applications are funded by regular budget of the United

Nations and voluntary contributions through the Trust Fund for United Nations Programme on Space Applications.

297. The overall strategy of the Programme is to concentrate on a few themes of major importance for developing countries and to establish objectives that can be achieved in the short and medium terms. For each theme, individual activities build on the results of previous activities aimed at achieving concrete results in a period of two to five years. The use and applications of global navigation satellite systems is one of such themes of focus of the Programme.

298. With the funds provided by the Government of the United States of America, the Programme organized a series of four regional workshops and two international expert meetings on the use and applications of global navigation satellite systems in 2001, 2002 and 2003. The regional workshops were held in Kuala Lumpur, Malaysia, in August 2001, Vienna, Austria, in November 2001 and December 2003, Santiago de Chile, in April 2002 and Lusaka, Zambia, in July 2002. Each of the regional workshops aimed to bring the benefits of the availability and use of the GNSS signals to the awareness of decision-makers and technical personnel from potential user institutions and service providers in the private sector, particularly those in developing countries. Each workshop also aimed to identify actions to be taken and partnerships to be established by potential users in the respective region to integrate the use of GNSS signals in practical applications in order to protect the environment and promote sustainable development. The results of these workshops and their recommendations were reviewed at the international meeting of experts on GNSS held in Vienna in November 2002.

299. Within the framework of the Programme on Space Applications, the Office intends to provide technical assistance, within the limits of its resources, in initiating and supporting the pilot projects resulting form the above series of regional workshops and the international meeting.

F. Other entities

The German Institute of Navigation (DGON)

300. In Germany, many conferences in relation with ground-based (e.g. Loran-C) and satellite-based navigation (e.g. GALILEO) take place every year. Technical issues and navigation applications are in the centre of interest of the numerous presentations and discussions. One institute that organises navigation conferences should be mentioned: the German Institute of Navigation (DGON). DGON is working as a German umbrella association for several conferences.

301. The German Institute of Navigation (DGON) (www.dgon.de) is a non-profit making organization of public interest. The institute was founded in 1951. Its main objectives are:

- Assistance of scientific activities related to navigation and position finding; and
- Support of research & development activities.

302. Finally, the provision of opportunities to present and introduce new applications in the field of navigation, localisation and positioning are also part of the Institute’s supporting activities. This is to advance and to offer practicable contributions for improving safety and economy of maritime, air, land, space and inland waterway traffic and adherent means of communication, including telematic, radar, transponder, gyro and robotic engineering.

The Italian Institute of Navigation (IIN)

303. The Italian Institute of Navigation (IIN) (www.iin.it) is also a non-profit making organization of public interest. The institute was founded in 1959. Its main objectives are to promote the development of navigation sciences and technologies and disseminate the knowledge related to such fields.

304. To these aims, the Institute fosters co-operation between end users, industries and research institutes.

305. The Italian Institute of Navigation takes active participation in European and International initiatives in the field of navigation. It is a member of the European Group of Institutes of Navigation (EUGIN), and also of the International Association of Institutes of Navigation (IAIN). The Institute takes active participation in the works of ICAO and IMO.

306. The Italian Institute of Navigation actively promotes conferences in relation to navigation every year.

Korea GNSS Technology Council (GTC)

Republic of Korea

307. With the support of Korea's Ministry of Information and Communication, the Korea GTC was organised in 1994 by individual experts from many universities, research institutions, and industries associated with GNSS technology to promote the exchange of academic and technical information and to support research and development activities with respect to GNSS technology.

308. GTC has hosted annual national conferences entitled "GPS workshop" where technical and policy issues on the essence of GNSS technology and its wide applications are presented and discussed. In addition, tutorial sessions on the fundamentals of GNSS including GPS, DGPS, GPS receivers technologies have been offered.

309. GTC has also organised since 1999, on an yearly basis, the "International Symposium on GPS/GNSS" in order to promote international co-operation. GTC also agreed to co-host an annual international symposium with Japan and the People's Republic of China in 2001, for the purpose of promoting awareness with respect to GNSS-related activities, especially in the Far East Asia region, and increase information exchange for GNSS experts and decision-makers. In addition, the Far East Asia regional symposiums have been held in Korea (2001), People's Republic of China (2002) and Japan (2003).

IV. GNSS APPLICATIONS

A. General applications of GNSS

310. The core constellations of GNSS (GPS and GLONASS) are being used in a variety of applications. Some of the most promising areas of applications are:

- Intelligent Transportation Systems-ITS (Ground, Air and Marine Transportation Control);
- Original Equipment Manufacturer (OEM);
- GPS cards;
- Survey mapping/GIS;
- Military; and
- Timing and frequency dissemination.

311. There are many other areas in which the GNSS market is expected to grow significantly in the near future. These areas are:

- Mobile phones;
- Development of intelligent highway systems;
- Anti-collision systems in railways and land transport; and
- Precision agriculture.

312. In future, the GNSS market will predominantly consist of the use of GNSS chipsets in mobile phones. GPS is currently the de-facto standard for satellite-based navigation services. The GPS market in the year 2000 was worth US $ 8 billion, and in 2003 worth about US $ 15 billion. It is estimated that the world market for GNSS in the year 2005 would be in the vicinity of US $ 20 billion.

313. The use of GNSS in intelligent highway systems, train collision avoidance systems and precision farming is expected to increase phenomenally after 2005. However, this component of the market is expected to remain concentrated in the developed countries.

Priority themes for use of GNSS technology for social and economic development of developing countries

314. The existing core constellations from the United States, the Russian Federation, the planned European GALILEO and space-segment augmentations by the United States, Europe, Japan, India and several other countries have provided an opportunity for the developing countries to use GNSS in various applications for improving the quality of life. Some of the applications are:

a) Use of GNSS chipsets in mobile phones:

- The GPS market in the year 2002 was estimated to be about US $ 13 billion. The largest component of sales has been in the car navigation market so far. It is estimated that mobile phones would be equipped with position location chipsets for emergency services; and
- The mobile phone market for GNSS chipsets is expected to dominate the sales in the future. Many developing countries, where the density of mobile phones is low, are

estimated to benefit from these new phones which are equipped with position location facilities.

b) Modernisation of the airspace:

- Selection of appropriate technology (SBAS, GBAS, etc.) for a given developing country, consistent with the ICAO CNS/ATM regional plans;
- Decision by developing countries on the extent and scope of co-operation with the existing and planned constellations; and
- Assistance to the developing countries in implementing the ground segment accordingly.

c) Use of GNSS for intelligent vehicle highway systems:

- Use of GNSS technology in railway safety as anti-collision systems;
- Navigation of other land mobile systems together with mobile phones; and
- Inexpensive wagon tracking and car navigation systems.

d) Meeting the needs of emergency and natural disaster mitigations.

e) Precision agriculture.

f) Applications of GNSS in other lands (car navigation) and marine-based applications.

g) Advancement in other areas of scientific endeavour where navigation techniques can be used such as accurate weather predictions and Earth sciences applications.

h) Timing and frequency transmission for telecom applications.

B. Applications predominant in specific regions

1. Europe

315. There is a large and increasing number of satellite positioning and navigation applications in the Eastern and Central European region. The summary of activities given below is by far not exhaustive, rather indicative of the variety by topics and countries. This compilation is largely based on the presentations given at the Second United Nations/United States of America Regional Workshop on the Use and Applications of Global Navigation Satellite Systems (GNSS) for the benefit of countries in Central and Eastern Europe, held from 26 to 30 November 2001 in Vienna, Austria.

316. There is a wide range of existing applications of GNSS in environmental monitoring. Among the examples, an air pollution information system has been developed in Austria using mobile air quality measurement sites. In Azerbaijan, aircraft experiments have been conducted to monitor the critical environmental zones. Land and water bodies have also been generally surveyed with GNSS in many countries. In addition, radon field mapping has been assisted by GNSS in Slovakia, as well as mapping of climate phenomena. In Hungary, sites of regular soil monitoring have been re-occupied using GNSS measurements. Moreover, to ensure that the system works without interference, the radio interference affecting GNSS signals is also investigated.

317. Agricultural applications include monitoring of crop and soil as well as surveying the fertility of agricultural fields in order to control the application of chemicals and fertilizers. For example, a GNSS-assisted agricultural monitoring programme on the field scale is going on in Romania.

318. There is a widespread use of GNSS in the field of transportation in this region as well. This includes car navigation, fleet management, journey data logging, car theft reconnaissance, road and railroad surveys, airport surveys, flight navigation, air traffic control, etc.

319. The GNSS (GPS) technique revolutionized the way in which geodetic measurements are made. Nowadays, national, regional and global geodetic reference networks are based largely on GNSS measurements. In Hungary, as an example, the GPS-based horizontal land surveying reference network consists of more than 1100-point marks. A particular technology has been developed and now routinely applied for the densification of the levelling network as well. The State land surveying authority is building up and maintaining a national reference network of permanently operational GNSS stations. The GNSS technique is also successfully used in State border surveys.

320. The regional co-operation on the use of GNSS (GPS) technique for high-precision geodetic and geophysical applications has a long-standing tradition in Eastern and Central Europe. Within the framework of the Central European Initiative (CEI), Working Group ”Science and Technology”, Section C ”Geodesy”, a project called Central Europe Regional Geodynamics Project (CERGOP) was launched as early as in 1993. The 14 participating countries (Albania, Austria, Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Germany, Hungary, Italy, Poland, Romania, Slovakia, Slovenia and Ukraine) realised that the new global space geodetic technique provides a unique opportunity to integrate the geodynamic research in the region, both the reference network (the Central European GPS Geodynamic Reference Network, CEGRN) and the scientific data reduction and interpretation methodology. The main objectives of CERGOP were to investigate the present-day geotectonic features in the Central European region, and to provide a stable reference network for smaller-scale (sub-regional or local) deformation studies.

321. The first phase of CERGOP was concluded in 1998. However, due to the success of the collaboration and the long-term nature of the geotectonic processes, the project is being continued. At present, the Consortium for Central European GPS Geodynamic Reference Network (CEGRN) contains 63 geodetic sites, with 29 permanent GPS stations distributed in the participating countries. The network is re-measured at least once in every 2 years. Presently, data from 6 monitoring campaigns are available. The measurements are conducted and analysed with the highest possible precision. The first scientific analysis of GPS data between 1994 and 1997 provided a RMS repeatability of around 2 mm in the horizontal and 5-6 mm in the vertical component of the site positions for each of the four observing campaigns. According to the results concerning the present-day tectonics of the region, the northern part of Central Europe seems generally stable since the velocities are under 2 mm per year. The southern sites close to the plate boundary zone, however, show displacements of several mm per year.

322. In 2001, representatives of 13 Eastern and Central European countries signed the Memorandum of Agreement of the CEGRN Consortium (www.fomi.hu/cegrn). As the new organizational structure of CERGOP, the Consortium is a non-profit organization of institutes that supports and promotes co-ordinated establishment and maintenance of CEGRN sites. It monitors the network by using GNSS (GPS) measurements on a permanent and regular basis, as well as the maintenance of a data centre and processing centres. The scientific work was divided

between 13 study groups. By the establishment of the CEGRN Consortium, an organization that conforms to the European research policy trends, the participating countries would like to ensure the long-term continuation of the project. The CERGOP-2 project was funded within the EU's fifth Framework Programme.

323. Considerable experience is gained with differential GNSS service in many countries of the region. Differential methods are used, e.g., in the Czech Republic where the Technical University operates a reference station in Prague. The corrections are transmitted to the roving receivers via FM and long-wave radio. It is known that advanced national and regional DGNSS systems would significantly improve the positioning accuracy and boost the applications. To this end, the establishment of a multi-purpose GNSS reference network (EUPOS, European Position Determination System) is currently under consideration by an international working group of experts. The network would adopt the standards successfully developed in Germany for their SAPOS (Satellite Positioning Service) system.

324. In many countries, there is a need to increase the awareness of policy makers of the benefits of GNSS, and at the same time, to increase funding available to establish a national infrastructure. Furthermore, the proper governmental organizational structure to deal with GNSS issues needs to be established, which is sometimes difficult due to the multi-disciplinary nature of GNNS issues. In Austria, as a good example, satellite navigation activities are co-ordinated and managed by the GALILEO Contact Point Austria (www.galileo-austria.at) established at the Austrian Space Agency (ASA, www.asaspace.at), and by the Austrian Institute of Navigation (OVN, www.ovn.at). A national testbed – the Austrian Radionavigation Technology and Integrated Satnav services and products Testbed (ARTIST) - has been established by the Federal Ministry of Transport, Innovation and Technology (BMVIT) in order to demonstrate through pilot projects the value of navigation services of the European GALILEO satellite system to be operational by 2008. Through the ARTIST Programme, various application areas will be demonstrated and evaluated with respect to their innovative character and profitability. In particular, the objectives of ARTIST are to test and establish new and promising market segments for satellite navigation applications, to increase the awareness of the capabilities of satellite navigation applications in general, and to stimulate Austrian institutions to increasingly participate in the international navigation applications networks. All Austrian institutions related to navigation and its applications are encouraged to participate in the ARTIST Programme.

325. The main topics of the first "Call for Proposals" opened in April 2002, funded by the BMVIT with an amount of € 2.000.000. Topics comprised: fleet management, including all modalities and inter-modalities, agriculture and forestry. The large number of project proposals received (22) was an impressive response to the efforts of the BMVIT to support and strengthen the navigation market in Austria. The duration of the projects shall be approximately one year. Thus, it will be possible to evaluate the project findings and results within a reasonable timeframe to initiate follow-up activities in the most promising areas. In addition to the Call for Proposals, participants were invited to elaborate ideas in the area of satellite navigation, its applications and value-added services. The ideas were not bound to the main topics of the Call for Proposals, but were open to address all areas where satellite-based navigation is expected to play a major role. The project proposals and ideas received by the GALILEO Contact Point Austria are to be evaluated by an international expert committee. A second Call for Proposals with focus on applications in the areas of tourism and leisure time, personal navigation, search- and rescue services, and fleet management, was expected to open on 1 April 2004. The Call would close on 7 June 2004. Institutions or entities interested in participating in the ARTIST-Programme were invited to contact the GALILEO Contact Point Austria at Austrian Space Agency (ASA) .

326. The regional activity in the field of GNSS is reflected in various conferences. From 1991 to 1999, biennial scientific symposia titled “GPS in Central Europe” were held in Hungary with participants from the region and other areas. The topics covered included geodesy, height determination, geodynamics, reference frames, meteorology, differential GPS, instrumentation, data analysis techniques and several other issues. The proceedings of the symposia were published by the Satellite Geodetic Observatory of the Institute of Geodesy and Cartography, Hungary (www.sgo.fomi.hu) and the Institute of Geodesy and Geodetic Astronomy, Warsaw University of Technology, Poland (gik.pw.edu.pl/igga.html) in the Reports of Geodesy series.

327. Another important event in Austria was the holding of the European Navigation Conference on Global Navigation Satellite Systems, hosted by OVN on behalf of EUGIN, from 22 to 25 April 2003 at the Congress Centre in Graz, Styria (ENC – GNSS, www.gnss2003.com). The ENC – GNSS 2003 was the seventh conference in the GNSS series held under the auspices of the European Group of Institutes of Navigation (EUGIN). The conference focused on the actual status as well as on future developments in satellite navigation systems, with special emphasis on GALILEO.

328. In Italy, the use of satellite-based navigation systems is continuously growing in the various transport sectors: civil aviation, maritime and ground (road and rail) as well as in numerous fields of “non-transport” applications such as geodesy, agriculture, GIS, and RTK.

329. The Italian Ministry of Transport, based on the promotional activities conducted by the Italian Space Agency and the Italian Institute of Navigation, has undertaken an attempt to promote the debates for a national Radio Navigation Plan, allowing to co-ordinate radio navigation systems on the territory in a harmonised and cooperated fashion.

330. The Italian Space Agency (ASI- www.asi.it), being one of the major contributors to the European Programme GALILEO, is fostering the development of Applications of Satellite Navigation in co-operation with Governmental Operational Entities (ENAC, ENAV, Italian Coast Guard) in order to pave the way for GALILEO.

331. As far as the Reference Networks for precise positioning is concerned, the Italian Space Agency is owner of the main network in Italy, which is part of an international geodesy network.

Research activities

332. The use of GPS techniques in Portugal goes back to the 1980s, when a large observation campaign was organised by the Faculty of Sciences, University of Porto, in co-operation with the Geodetic Institute, University of the Armed Forces of Munich, to monitor plate-tectonic movements in the Azores-Gibraltar area .

333. Since then, many research projects have been carried out, going from studies of plate tectonics and volcanism to the study of high atmosphere from on-board GPS measurements, passing by different projects on Earth, including navigation and attitude determination and control. In some cases, besides GPS, also the GLONASS system has been used. As a result, a large number of scientific papers have been published and several Ph.D. thesis have been written in Portuguese universities as well as in research institutes. At present, attention is also being given to the development of GNSS and GALILEO.

Services

334. The Portuguese Geographical Institute, responsible for geodesy and mapping, has been using GPS in different applications. The establishment and maintenance of a permanent GPS network for EUREF as well as the dissemination of the data also falls under its responsibility (http://www.igeo.pt).

335. Similarly, the Military Geographical Institute (http://www.igeoe.pt) and the Hydrographical Institute (http://www.hidrografico.pt) have current applications with GPS.

Other activities

336. In Portugal, GPS is widely used in different fields, both by public institutions as well as by private firms. In areas such as the environment, forestry, Earth resources, mapping, navigation, fleet management and control, and dam monitoring, GPS is a technique of fundamental importance, giving rise to a considerable market of GPS equipment. All of the main trademarks are represented in the country.

337. Since Portugal is a member of the EU and ESA, particular attention is being given to all the development phases of GALILEO.

2. Latin America and the Caribbean

338. In the late 1970s, activities related to GNSS started in Argentina. Most of these activities have been developed at La Plata National University (Universidad Nacional de La Plata), in its Faculty of Astronomical and Geophysical Sciences (FCAGLP).

339. The contribution of the astronomers and geodesists of the FCAGLP covers several aspects of the GNSS work: scientific research, training, development and transfer of "know-how" and practical applications.

340. This section of the report summarizes the contribution of two groups at the FCAGLP to GPS work:

> 1. Satellite Geodesy Group (SGG): particularly oriented towards the practical applications of GPS; and
>
> 2. Georeferenciación Satelital (GESA) or Satellite referencing on the Earth: which develops research work on GPS, organizes lectures, courses and seminars, being very familiar with education at the university level (pre- and post-degree levels).

Augmentation Systems

341. In Brazil, SBAS (Space Based Augmentation System)'s testbed was underway. The topics related to the subject are ionosphere and scintillation modelling. There is also a project for a geostationary satellite.

342. In addition, there was the GBAS (Ground Based Augmentation System): development of DGNSS network and development of pseudolite.

GNSS SBAS-WAAS trials in the Latin American and the Caribbean regions

343. WAAS-type SBAS trials in the Latin American and the Caribbean regions, denominated CSTB (CAR/SAM Test Bed), have been conducted under a ICAO-UNDP regional technical co-operation project for Latin America and the Caribbean. This project was being executed thanks to the co-operation of the Government of the United States, through the FAA, with the participation and co-operation of the following States and Organizations: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Panama, United States, Venezuela and COCESNA. ICAO signed a Memorandum of Understanding with the FAA to borrow the equipment required for the trials, and to obtain the support necessary for training and trial analyses.

344. The CSTB trial platform consists of 13 reference stations, two master stations, and one ground station for linkage to the geostationary satellite. This platform has been fully installed, and only the Earth station for the satellite link was pending. Since the beginning of the project (June 2001) important trials have been conducted that have led to significant results for the Latin American and the Caribbean regions, which will contribute to the implementation of a regional SBAS augmentation system to support air navigation phases (en-route and NPA). Furthermore, personnel from the aeronautical administrations involved in the project have received training on installation of reference stations, data processing, SBAS performance analysis, and management of data processing tools (FAA GPS solution), since this is a new technology. The project was expected to be completed by mid 2004.

GNSS SBAS-EGNOS trials in the Latin American and the Caribbean regions

345. This has been executed thanks to co-operation from the European Community, through ESA, and from the participating State and international organizations. EGNOS-type SBAS trials, denominated EDISA, are also being carried out through a ICAO/UNDP regional technical co-operation project for Latin America and the Caribbean, with the participation of the following States and international organizations: Colombia, Cuba, Spain, COCESNA and the European Community. Phase I of this project envisaged the implementation of the EDISA platform, which consists of three reference stations (RIMS), as well as very small aperture terminal (VSAT) communication stations installed next to each RIM. The information collected by the RIMS is sent to a master station in Europe for processing and issuance of the augmentation signal through the INMARSAT AOR-E geostationary satellite. This signal can be used by duly-equipped aircraft. The project started in early 2003; the trial platform has been fully installed and flight tests for en-route, NPA and APV1 functions have been carried out in the States involved. Personnel from these States have received training on data processing and analytical tools (Pegasus plus EUROCONTROL), in order to raise awareness among States as to the benefits of satellite navigation, the future of GNSS, and especially the European strategy in the GNSS field. The results of the trials confirmed the performance anticipated by simulations: accuracy better than 10 meters and integrity level up to APV I (approach with vertical guidance with a vertical alert limit of 50 meters). The trials provided useful information in support of the ICAO activities in the definition of the GNSS strategy for the region. Areas of synergy with the WAAS trials were also identified (ionosphere and troposphere).

346. This project also contemplated a second phase, which was expected to start once the first phase had been completed. It included personnel training activities, trials with an architecture different to the one used in Phase I, collection and analysis of GNSS data, use of the Pegasus Plus tool, studies to be submitted to the GREPECAS ATM/CNS Subgroup, and other activities which

will be significantly useful to all States for building GNSS technical capability and human resources in the Latin American and the Caribbean regions.

Satellite Geodesy Group (SGG)

347. The activities of the group are concentrated on two regions of the country: Tierra del Fuego, the island in the far South of the Argentinean territory, and the Province of Buenos Aires, on the Rio de la Plata.

348. In 1993, the first Argentinean provincial network was built up, measured and calculated by the SGG in Tierra del Fuego. This network has been used to develop a GIS in a modern geodetic framework in co-operation with the Tierra del Fuego Geodetic Service.

349. This network has been measured several times to detect tectonic movements. In 1999, the first signal of displacements between the Scotia and the South American plates was reported by the SGG.

350. At 2002, the network was being expanded to improve the resolution of these results. In 1999, the Geographic Military Institute established the first levelling line in Tierra del Fuego. A co-operation agreement was carried out to measure this line with GPS in the framework of the province network. The differences between mean sea level heights and GPS ellipsoidal heights allowed the SGG to obtain valuable information on the geoid behaviour in the Tierra del Fuego region. However, the spatial distribution of this data was quite poor since there were large regions difficult to reach.

351. In 2002, a co-operation programme with the University of Dresden (Germany) was launched. The project would use the Fagnano lake surface as a gigantic level measuring with GPS in special buoys, together with tide gauges information. These new measurements are expected to significantly improve the Tierra del Fuego geoid model.

352. It is also important to note that a permanent GPS station has been operated in Rio Grande (IGS-riog) by SGG in co-operation with the GFZ (Germany).

353. The Buenos Aires province is the richest region of Argentina. Its area is comparable to that of Germany. In 1977, La Plata University and the Government of the Province of Buenos Aires signed an agreement to establish a high precision GPS network in the province. The task was achieved by the SGG working in co-operation with the local geodetic service.

354. In 1998, a first network containing 200 points was finished and in 2002 a densification was carried out adding 100 new points. This network was developed using the same marks of the national levelling network allowing the direct determination of a centimetre accurate geoid model for the region. In 2000, the Buenos Aires geodetic service established the obligation to refer all the rural parcels to this network as a first step for a local GIS.

355. It is also important to point out that the first permanent GPS station in Argentina (IGS-lpgs) was installed in 1995 in this Faculty by the SGG in co-operation with the GFZ (Germany).

356. Other activities of the Group:

- Measurements and process of about 300 sites along the Argentinean coastline to define the 200 miles marine border by co-ordinates (in co-operation with the Hydrographic Naval Service);
- Co-operation in several scientific campaigns (SAGA in co-operation with GFZ, San Juan tectonic displacements with the San Juan National University, Central Andes Project for the Memphis University, etc.);
- Several GPS services (to georeference satellite images, photogrametric plates, to establish local reference frames, to validate GPS equipment, etc.); and
- About 20 courses on GPS applications on different fields.

Georreferenciación Satelital (GESA)

357. In Argentina, the GNSS activities developed by the group GESA (Georreferenciación Satelital) in the last fifteen years in the country are described in this report. GESA is a group of the La Plata University specialized in the application of GNSS to scientific research, innovation and technology transfer to the private sector through the provision of high-quality services. Our activities are developed at the Faculty of Astronomical and Geophysical Sciences (FCAG, Facultad de Ciencias Astronómicas y Geofísicas) of the La Plata National University (UNLP, Universidad Nacional de La Plata). The group was created in 1988 and its first goal was to spread GNSS techniques in the university and the local surveyors. The first National Seminar on GPS was organized in 1988 with the co-operation of other members of the FCAG.

358. An important achievement has been the design of a national survey network with more than one hundred points based on the new techniques. This has been made possible thanks to an agreement between the Military Geographic Institute of Argentina (IGM, Instituto Geográfico Militar) and the American University consortium UNAVCO. The potentiality of this network interested the "Economic development and financial cleanse Project for the Argentinean Provinces" (Proyecto de Saneamiento Financiero y Desarrollo Económico de las Provincias Argentinas). Such project asked GESA to perform the calculation and compensation of the net that became the present National Geodetic Reference System POSGAR 94 (IGM resolution 13/97).

359. Since 1992, members of GESA give lectures on GNSS in different regions of Argentina. The attendees come mostly from universities and survey organizations. All the members of GESA participate in scientific projects undertaken in co-operation with prestigious universities and international research centres. Since 1994, GESA has established co-operation with the Institut für Navigation (Stuttgart University, Germany), the Deutsches Geodätisches Forschungsinstitut (München, Germany), Observatoire de Paris (Paris, France), the Technische Universität (TU Wien, Vienna, Austria) and the Aeronomy and Radio-Propagation Laboratory Abdous Salam International Center for Theoretical Physics (ICTP), (Trieste, Italy). Several graduate and postgraduate students developed their Ph.D.s or their research work under the direction of GESA scientists. GESA members have a considerable experience providing technical services to official institutions and private enterprises by means of contracts.

Scientific research - Terrestrial Reference Frame

360. Space Geodesy has contributed substantially to the study of our planet and to the comprehension of its physical processes. Examples of this are the geometry and kinematics of the solid Earth, the polar caps and the oceans, the irregularities of the Earth rotation and their

relationship with the exchange of angular momentum between its inner components and bodies of the Solar System. Similarly, the temporal variations of the terrestrial gravity field due to the balance of masses that take place in the planet are also relevant. This significant progress has been made possible thanks to the global system of observation supported by various organizations in many countries, under the co-ordination of the International Earth Rotation Service (IERS).

361. The primary goals of IERS are the establishment and maintenance of the Celestial Reference Frame (ICRF) and of the Terrestrial Reference Frame (ITRF) and the monitoring of the Earth Orientation Parameters (EOP). The IERS is supported by the operation of several international services that co-ordinate the observation programs and analysis of data from different observation techniques: Very Large Baseline Interferometry (VLBI); Satellite Laser Ranging (SLR); Global Positioning System (GPS) and DORIS. Particularly relevant is the International GPS Service (IGS).

362. The products of the IGS are obtained from the observations collected by a global network formed by more than 300 Permanent Stations (PS). The products are derived by seven global centres of analysis, with which collaborate five regional centres. The regional centre for South America is administrated by the Deutsches Geodätisches Forschungsinstitut (DGFI). Since 1995 the group maintains a strong scientific co-operation with the DGFI. More than 200 institutions (among them the FCAG through GESA, the National Commission of Space Activities (Comisión Nacional de Actividades Espaciales-CONAE) and the National University of Salta have contributed to the IGS in more than 75 countries. Four Argentinean PS integrate the global network of the IGS: UNSA, CORD, LPGS and RIOG.

363. The ITRF has been expanded in the American continent thanks to the SIRGAS project. This project started in 1993 under the sponsorship of the International Association of Geodesy (IAG), the Pan American Institute of Geography and History (PAIGH) and the National Imagery and Mapping Agency (NIMA) from the United States. The activities are co-ordinated by three working groups:

1. Reference Systems: whose objective is to establish a South American reference frame linked to the ITRF, including co-ordinates and velocities from all the stations;
2. Geocentric Datum: with the task of increasing the number of stations in the SIRGAS frame in the Latin American countries; and
3. Vertical System: whose aim is to establish a unique vertical frame for the whole continent.

364. GESA has defined and calculated the National Reference Frame POSGAR 94, which was adopted in 1997 as the standard reference frame for Cartography and Geodesy in Argentina. Later on, this was linked to the ITRF yielding the most precise and accurate geodetic reference frame available in Argentina up to date, called POSGAR 98. GESA has also calculated the geodetic network of eight Argentinean provinces.

Earth rotation

365. The irregularities of the Earth rotation have deserved the interest of astronomers, geodesists and geophysicists from end of the 18th century. In order to characterize these irregularities, five Earth orientation parameters (EOP) are used: two of them describe the position of the instantaneous pole of rotation in the ITRF; one gives the velocity of rotation with respect to the celestial system; and the other two represent the direction of the instantaneous axis of rotation

with respect to the celestial system. The EOP provides also the tie between the celestial and the terrestrial reference frames.

366. The study of the EOP constitutes an excellent challenge for geophysics since their variations offer important information on the interactions between the different components of the Earth system, that is to say, the atmosphere, hydrosphere, cryosfere and solid Earth. Its determination has practical applications for navigation and satellite positioning, for the study of the dynamics of the Moon by means of Lunar Laser Ranging, for the observations of extragalactic radio sources using precise VLBI and for maneuvers of interplanetary probes.

367. The temporal resolution of the EOP series obtained from VLBI and GPS is better than two hours. Using wavelets transform, temporal variations of EOP at very high frequencies with periods between 5 and 8 hours have been detected. A resonant effect of the atmosphere could be the excitation source, but the exact origin of such effect is still under discussion.

368. A new method has been developed to combine time series of Earth rotation parameters (ERP). This method is based on an Extended Kalman Filtering considering the Earth rotation phenomena as a non-linear effect. A new multi-technique was obtained combining ERP data time series that were in good agreement with all the combined series calculated by the International Services. An advantage of this solution was that it did not require the inclusion of any extra data such as atmospheric angular momentum or any smoothing process.

Sea Surface Topography

369. Much effort has been centred on the study of some natural phenomena that could indicate that the physical conditions of the Earth's system are changing. The conditions, known as "global changes" are: weather, oceanic and geophysical changes, which provoke the increase of the Earth's average temperature, variations in average temperature of the seasons in average values of regional rains. A direct consequence of these changes could be the mean sea level (MSL) increase. For many years the MSL was assumed to remain constant and coincident with the geoid.

370. Up to the time of writing this report, it was known that both hypothesis were wrong: on one hand, the MSL vary with time due to changes in the atmospheric pressure, the temperature, and possibly due to the global change; on the other hand, the MSL differs from the geoid due to oceanic current, and it is consequently named sea surface topography (SST). In order to provide some examples, on the East coast of South America, maximum variations in the MSL of about -6 mm/year have been detected in the Caribbean and of about +10 mm/year on the Uruguayan coast; the SST having changed approximately two meters from Caribbean to Antarctica.

371. The SST and its variations can be studied from satellite altimetry data (Topex-Poseidon, ERS) or from time series of tide gauge records. The combination of both techniques is the key of this kind of study. The IGS has summoned the international community to participate in the pilot project TIGA (GPS Tide Gauge Benchmark Monitoring; http://op.gfz-potsdam.de/staff/schoene/TIGA_CfP.pdf), whose principal objective is to establish a service of GPS stations continuously operating near the tide gauges and to detect systematic effects through analysis of their observations. These results should enable scientists to obtain reliable information about the vertical motion of the Earth's crust.

372. In order to decouple from the tide gauge records the movements of the Earth's crust, four permanent GPS stations (PS) (from 1998) have been installed near the tide gauge of Mar del

Plata, Puerto Belgrano, Puerto Madryn y Puerto Deseado. From these data the first vertical velocity estimation of Earth's crust in some of the tide gauge involved was computed.

Ionosphere

373. The ionosphere is the part of the upper atmosphere where the free electron density is high enough to disturb the propagation of radio frequency electromagnetic waves. Free electrons are mainly produced by the photoionisation of neutral atoms and molecules of the atmosphere evoked by the UV solar radiation. However, many complex physical phenomena in the solar-terrestrial environment participate in the production and loosing of electrons and in conditioning their spatial distribution and temporal variations.

374. The first studies that made use of GPS observations to determine empirical ionospheric models can be traced back to the late 1980s. In that connection, GPS can be presently considered the most powerful means to study the ionospheric weather. Even if the ionospheric research has not been the objective of the IGS, one of the IGS products provides a real topography of this medium. The IGS maps of total electron content are of high quality and with a good global coverage.

375. An ionospheric model has been developed to analyse the total electron content from GPS observations and has been used to study the geographic and time variability of this parameter at regional and global scales, in quiet and perturbed geomagnetic conditions. A three-dimensional topography of the electron density has also been developed using GPS ground and space receivers.

Innovation, development and transference

376. In the last decade, the Argentinean geodetic reference frame has substantially evolved, despite the difficulties of developing geodetic infrastructures in parallel by the individual provinces and the nation. At the beginning of the 1990s, those activities were decentralised by the creation of the program called "Programa de Saneamiento Financiero y Desarrollo Económico de las Provincias Argentinas", a program for financial monitoring and economic development of the Argentinean provinces, supported by international credit allotted to the provinces. During the last decade, the Ordnance Survey Offices from different provinces had invested a large amount of money to establish traditional geodetic networks, with the purpose of eliminating the problems related to land registry.

377. Until the mid 1990s, the geologic, geodetic and geodesic surveys and the general cartography of Argentina were linked to the traditional geodetic network called Campo Inchauspe 69. The joint effort of IGM and GESA contributed to a new national geodetic network based on GPS measurements, named POSGAR 94 (Posiciones Geodésicas Argentinas de 1994). This new network is ten times more precise and a hundred times more accurate than the previous one; it was officially adopted in Argentina as the geodetic and cartographic standard (Disposición 13/97 del IGM).

378. The IGM jointly with GESA improved the POSGAR 94 network, by linking it to SIRGAS (Sistema de Referencia Geocéntrico para las Américas) and to the international system, ITRF. GESA was responsible for the calculation of this improved network, POSGAR 98.

379. Argentina has at present a "first order" reference frame (POSGAR 98), materialised by about 130 points, with the addition of points in the different provinces with variable accuracy and precision, with a total of about 2000 points in the Argentinean territory. GESA has also computed the fundamental geodetic net of the three provinces Chubut, Río Negro and Tucumán and some mining geodetic networks.

380. POSGAR 98 is an excellent example of an achievement by ITRF; however, its quality degrades with time. Unfortunately, there are no available precise tectonic velocities to update the co-ordinates. The modern tendency to solve this trouble is to establish a "zero-order" reference frame materialized by a set of PS operating continuously. In the same way, it is possible to determine very accurate co-ordinates and tectonic velocities keeping thus the good quality of the reference frame.

381. Several PS have been installed in the country in the last years. At the time of writing this report, there were approximately 17 of them. Most of the GPS receivers were introduced by scientific groups from Germany and the United States. Argentina contributes to this programme by providing the necessary infrastructure and the human resources by means of agreements with foreign scientific groups. Almost twenty local institutions have participated in this enterprise with different levels of commitment.

382. GESA also has responsibility for six fully operative PS located at La Plata, Mar del Plata, Bahía Blanca, Rawson, Puerto Deseado and Río Grande. All of them are the result of the scientific co-operation of GESA with two German institutions: Deutsches Geodätisches Forschungsinstitut (DGFI) and the Geoforschung Zentrum Potsdam (GFZ).

383. Besides the scientific profit, those PS are used by different practical applications. All of them have contributed to the Argentinean Network for Continuous Satellite Monitoring (Red Argentina de Monitoreo Satelital Continuo, R.A.M.Sa.C.). The Naval Hydrographic Service (SHN, Servicio de Hidrografía Naval) also uses the PS of Mar del Plata and Puerto Deseado. The surveying group of Universidad Nacional del Sur utilizes the PS of Bahía Blanca. Finally, the Ordnance Survey and Territorial Information Office of the Province of Chubut (Dirección de Cadastro e Información Territorial) uses the PS of Rawson.

384. Co-operation was achieved in the framework of inter-institutional contracts and agreements. Likewise, GESA actively contributes to the formation of human resources by giving lectures in meetings and courses organized by professional surveying councils in the Argentinean provinces as well as by universities. These activities have allowed for the creation of an effective link with a wide sector of the community of users of the geo-positioning by satellite. On one side, there was a need to contribute to the dissemination of scientific knowledge among the users, particularly those concepts related to reference frames and co-ordinates management. On the other side, the urgent necessities of the users have oriented a part of activities related to the development of procedures or technologies for users.

Future activities

385. Present efforts have focused on creating the synergy necessary to set up a group of dispersed potentiality in different universities, research institutes and many organisms with influence over the planning, the carrying out and the control of development policies. This proposal tends to achieve results in the national and international framework, as well as in the scientific and technological domains.

386. In the international framework, the goal is to create a Regional Centre of the IGS to contribute to the densification of the ITRS and to the development of the Tide Gauge Bench Mark Monitoring project (tide gauge control with GPS for the mean sea level study). In the national framework, a "zero order" geodetic reference frame is expected to be materialized in order to develop a modern space data structure and an EP-based GPS service.

387. The technology transfer to the community such as land registry, remote sensing, natural resources, natural environment, agriculture, navigation, GIS surveyor, plays an important role in the future. It can also contribute with a high academic level of human resources training.

388. In that sense the priorities are:

- To set up the basis for a very high quality GPS data acquisition, management, storage and distribution permanent service, produced by the EP net in Argentina;
- To develop the procedures for precise co-ordinates and velocities determination of all the EP, relative to the best global terrestrial reference frame;
- To develop the procedures to produce atmospheric corrections (ionosphere and troposphere) for the GPS users, as well as other technological applications;
- To transfer the development to the IGM, as well as the required training for the maintenance and usage, creating a data and products centre with full access to national and international users;
- To encourage other institutions to make use of the developments for the implementation of new stations or nets;
- To keep on contributing to the Argentinean vertical frame, into the guidelines defined by the international SIRGAS project;
- To make scientific use of the database;
- To transfer the scientific results to the national and international community;
- To encourage the creation of high level centres working on GPS technique in Argentina; and
- To train human resources for scientific research and to organize updating courses for professionals.

389. In Brazil, activities on satellite geodesy started in the 1970s with Transit-Doppler. At the time of writing this report, the IBGE (the Brazilian Agency for Cartography and Geodesy) had been operating an active GPS network of 15 stations (dual frequency) spreading around the country, which had been used for positioning, ionosphere modelling and meteorology. INCRA (in charge of rural cadastre) has started operation of 49 continuous GPS stations (only L1).

390. In 1997, a research group on Satellite Geodesy (GEGE) started activities for development, applications and teaching. It is currently developing its activities at UNESP – Presidente Prudente, São Paulo.

391. Regarding satellite georeferencing, a federal law was recently approved in Brazil, which requires that all rural land parcels (approximately 5 million units) have to be connected to the Brazilian Reference Frame. GNSS has been playing a very important function on this particular activity.

392. Concerning the ionosphere, a group of researchers in Brazil (ITA, INPE and UNESP) have been involved in the development of an ionosphere model based on GPS data from the

Brazilian Continuous GPS Network (RBMC) and IGS, in order to obtain better insight and provide a better solution to the ionosphere problem in that region.

393. In Colombia, there has been active work and commitment in implementing the activities for the implementation of and the transition to GNSS systems. Colombia's advantages include a large forest area, two oceans and fairly mountainous terrain, in addition to its strategic geographical location in the centre of the American continent and in the equatorial region. All these factors compel the country to work for improvement of navigation technologies as a way to develop its aviation system and other fields of its national economy. Colombia's policy in respect to GNSS in the first phase of research and development has been that of opening up to international co-operation, in order to technically evaluate all the possibilities of GNSS systems.

394. A working paper presented during the Eleventh Air Navigation Conference, which took place from 22 September to 3 October 2003 in Montreal, Canada, elaborated on the status of GNSS implementation in Colombia, the work that has been made in terms of progress and on strengths and challenges with respect to transition to GNSS. The paper concluded that "it is important for States which are neither owners nor developers of a given GNSS technology to evaluate each of the possible technological solutions with respect to satellite navigation". This should be done with a view to obtain more information in order to make a judgement at the time of defining the most suitable technological solution according to cost and benefit criteria. Another important hint for developing countries was based on the conclusion of the paper that "work and progress in GNSS do not necessarily require large investments on the part of States; tasks such as linking up with universities and research centres and appropriate training of human resources are very significant elements in the transition to a contribution by States for GNSS".

3. Asia and the Pacific

395. Regarding EGNOS Trials in the People's Republic of China, in early 2004, ESTB trials were conducted in the country in co-operation with several institutes in the region (Chinese Seismological Bureau, Daliah Maritime Institute, Chiangjiang Waterway Institute). The improvements in accuracy brought about by the experimental EGNOS signal were demonstrated in a boat navigating on the Yangtze River supported with the deployment of a set of mobile ESTB stations.

396. In India, the data regarding the number of airports, facilities at these airports, and air passenger forecasts are given in the paragraphs below.

397. There are 449 airports and airstrips in India. Among these, the Airports Authority of India (AAI) owns and manages 82 airports and 28 civilian enclaves. Most of the airports are equipped with NDB. There are 80 VORs, 76 DMEs and 39 ILSs at the Indian Airports maintained by AAI. The principal communication system in India has been HF, which is progressively being changed to VHF.

398. For surveillance, the Airports Authority of India has 14 MSSRs (Mono-pulse Secondary Surveillance Radars), 8 Airport Surveillance Radars (ASRs), 2 Air-Route Surveillance Radars (ARSRs) and 2 ASDEs (Airport Surface Detection Equipments). Two airports (Chennai and Kolkata) have been equipped with Automatic Dependence Surveillance (ADS) and Controller-Pilot Data Link Communication (CPDLC). There are about 350 registered aircrafts in India with various air carriers, air taxis and aircrafts for business.

Air Passenger Forecasts

399. In India, a certain study conducted by the National Council of Applied Economic Research (NCAER) of India has forecast that for domestic passengers the estimate for income sensitivity is 1.0 in the country. In other words, in the long run an increase of 6 per cent in GDP is likely to be associated with 6*1 = 6 per cent increase in air travel, assuming prices do not change. For international passengers in India, the estimate of income sensitivity is 1.3 – much higher than the estimates for domestic travel. For Asia and the Pacific region, ICAO studies have predicted the highest growth rate. It is matched with the rate of GDP growth in those areas.

400. Forecasts by ICAO show that there will be an increase in scheduled passenger traffic. However, for most countries this growth will be in favour of services operated on international routes rather than those for domestic routes.

401. In the world, passenger traffic is expected to grow, with growth likely to be larger on international routes than on domestic ones. Almost no growth will be recorded in Europe for domestic passenger traffic. Latin American countries will also see very little growth on domestic routes as compared with international routes. Maximum growth will occur in Asia for both international and domestic routes.

402. The Asia Pacific region is expected to grow by 7 per cent per annum till 2003 and the same trends can be expected to continue till 2010, accounting for more than half of the world air travel by then. And India, already with its strategic position as an air corridor linking Western Europe and South-East Asia, is expected to contribute largely to this increase in air travel. With increasing economic linkages between India and the Asia-Pacific countries, air travel in the future is likely to see increased scales.

403. To forecast figures for India, the GDP is the single most important determinant in forecasting air transport. As mentioned before, income sensitivity of domestic air passengers of 1.1, consistent with the world trends - with an estimate being 1.3 for international passengers and the estimate being 1 for domestic passengers. The estimate of price sensitivity is taken to be – 0.6, so a 5 per cent decline in prices would lead to a 3 per cent increase in air passengers.

404. GPS is being used in conjunction with the GSM mobile phones for vehicle tracking systems. The car navigation market in India is still in its nascent stages. There is a potentially huge market for GNSS in train anti-collision systems, intelligent highway systems and leisure, which remains to be exploited. As up to date, there is no service requirement for mobile phones to be equipped with positioning devices such as the US E911 or the equivalent European standard E112.

405. In Malaysia, the main applications of GNSS are still in the surveying and mapping sector. Furthermore, works on active research have also been carried out by the Malaysian Agricultural Research and Development Institute (MARDI) in the application of GNSS in the fields of precision agriculture for rice and horticultural crop production. The scope of the works included mapping, monitoring and variable rate application of farm inputs. The potential for GNSS application in other crops, such as oil palm, has also been explored. It is envisaged that the market growth of GNSS usage increase significantly with these R&D initiatives.

406. The new national datum named the Geodetic Datum of Malaysia, GDM2000, has been launched with a geocentric datum based on several years of GPS data. The new datum will unify

all mapping-related works in the country, streamlining between the national topographic mapping with GIS databases and utility maps. The navigation applications comes next with applications in the marine sector, leading the way with the establishment of a DGPS infrastructure, the SISPELSAT in 2003. This service is intended to serve the marine community within the East and West Coast of the Malaysian peninsula. Land navigation sector uses GNSS as embedded technology in vehicle navigation and fleet management, as well as vehicle security systems. In addition, the other important applications of GNSS in Malaysia has been in time keeping with the Malaysian Standard Time being kept and maintained by SIRIM via GPS.

407. In Japan, use of GPS is wide ranging, and with the car navigation system — a key user of GPS in the country — the economic benefits to the information technology industry are noticeable. A nationwide DGPS service using a FM sub-carrier has been contributing to further growth of the car navigation business since the service went into operation in May 1997. This commercial DGPS service is provided by a private sector "Gpex", established by 17 companies within the Japan GPS Council. GPex operates seven DGPS Reference Stations throughout the country, and the set of DGPS augmented data are broadcast all over Japan, with DARC type FM multiplex formula one of the ITU-R standards, via the public FM broadcasting network of the existing 41 transmitting stations. The DGPS data have compatibility with the RTCM SC-104 format and NRSC/RBDS format.

408. The user can obtain accurate navigation guidance free of charge, provided that DGPS receiver and FM auto-tuning hardware are installed. As the VICS service (Vehicle Information and Communication Systems, traffic information services), one of the ITS programs in Japan, is also using the same DARC type FM multiplex, many components can be commonly used for the designing of receivers and antennas. This may result in reduced production costs for hardware and could also have a synergy effect in both marketing and improving ecology. It is estimated that approximately 1.2 billion litres fuel could be saved as a result of significant increases in the sale of car navigation products and VICS services by 2010. As a consequence, there would be a large decrease in CO2 emissions.

409. The car navigation market in Japan is continuing to grow even after reaching an annual sales level of over a million units in 1998. Annual sales in fiscal year 2000 were nearly 2 million units. The DVD display especially has gained popularity and is the driving force in the car navigation market creating new demand instead of replacement demand. Also, the number of users of the FM-DGPS service has been steadily increasing. The FM-DGPS shipping ratio has come to exceed 50 % of all car navigation products in fiscal year 2000, in spite of the SA being turned off.

410. New trends in "car-multimedia", a topic discussed in many educational seminars and also associated with sophisticated car navigation products combined with DVD display, mobile communications, traffic control information and other attractive information contents, have become popular recently.

Differential GPS (DGPS)

411. Differential GPS (DGPS), using maritime radio beacon signal, is a system enhancing accuracy of GPS into less than 1m and also broadcasting warning information such as unscheduled outage. DGPS is based on international standards. In DGPS, A GPS receiver located at an exactly defined point (reference point) measures the position, and then calculates differential correction of GPS signal using the difference between the measured position and the reference

point. These calculated errors are processed as Differential Data and then sent through the MF radio beacon station. The DGPS receiver corrects the position by using these Differential Data.

412. An additional important function of DGPS is Integrity Monitoring. Once troubled with GPS satellites or DGPS data, there could be a remarkable decrease in the positioning accuracy, putting users of this system in serious danger without warning. However, the DGPS centre has the function to monitor the whole GPS system and DGPS itself in 24 hours operation. So, if an inappropriate correction is detected, the DGPS centre provides warning message to users through the related DGPS site.

413. The user is requested to install both DGPS-ready GPS receiver and DGPS beacon receiver to determine the position (these combined receivers are prepared by manufacturers). For more detail information on receivers, it is recommended to contact dealers to check whether a GPS receiver may be available for DGPS.

414. Japan Coast Guard (JCG) provides maritime DGPS service for all coastal water around Japan except for some of the isolated islands (for example, Ogasawara Islands).

GEONET

415. Since 1987 the agency of Geographical Survey Institute (GSI) has employed many GPS-based precision-surveying systems. As a result, Japan has achieved the establishment of the continuous GPS-fixed reference station network throughout the country, named GPS Earth Observation Network (GEONET).

416. The main purpose of GEONET is to monitor crustal deformations helpful to research on earthquakes and volcanic eruptions. Data obtained by GEONET are also available for surveying and other applications.

417. The crust of the Earth can be deformed by various reasons. Tectonic events such as a large earthquakes or seismic swarms cause sudden and large deformation of the crust, whereas plate motions or magma movements deform the crust slowly and gradually. For the prediction of earthquakes or volcanic eruptions, the accurate detection of such deformation is essential.

418. Because of its around-the-clock operation and highly accurate positioning capability, GEONET is an ideal tool for detecting crustal deformations. The observation data collected at GPS-based Control Stations are expected to play a key role in the study of earthquake prediction.

419. The data and information about crustal deformation detected by GEONET are provided to the public on the GSI web page (http://www.gsi.go.jp).

420. In the Republic of Korea, nationwide GNSS activities have widely and rapidly spread out in a variety of application fields: aviation, maritime navigation, car navigation, fleet management system, time and frequency dissemination, survey, geodesy and GIS, etc. According to the market forecasting by the Korean Ministry of Industry and Energy, the Korea GPS market is expected to grow up to more than 900 million US Dollars as of 2005.

421. The Korean national time and frequency services have been conducted by the Korea Research Institute of Standards and Science (KRISS); whereas research and implementation activities in survey, geodesy and GIS fields have been conducted with focus on crustal movement

monitoring, national reference of geodesic co-ordination management, cadastral mapping, maritime mapping and earthquake monitoring by many governmental ministries and research institutions.

422. While R&D activities on land navigation are mainly dominated by industries; air and maritime navigation activities are mainly conducted by governmental ministries. Many implementations, feasibility studies, and research activities on CNS/ATM are underway led by the Ministry of Construction and Transportation (MCT) in conjunction with the Korea Airport Corporation and Korea Aerospace Research Institute. The Korea Aerospace Research Institute has developed a testbed for LAAS for increasing air navigation performances and aviation safety and has also finished flight evaluation tests. It has also developed a DGPS receiver prototype used for maritime DGPS network. Recently, the MCT has performed a feasibility study on the strategy of a nationwide WAAS establishment. Final outcome of the study will be an initiative for the Government to finalize its decision-making process on the WAAS strategy.

423. Since the directives of the Prime Minister on GPS use was announced in 2000, the establishment of NDGPS networks have been underway by combining the new and existing infrastructure, including nationwide reference stations and integrity monitoring stations led by the Ministry of Marine and Fishery (MOMAF).

424. Recently, a new project named "National Transportation Core Technology Development" was launched in 2003 by the initiative of a consortium of government ministries. About 3 billion US Dollars will be invested through 2007 to upgrade the level of air, maritime, land navigation in order to upgrade current transportation systems to the next generation level and promote navigation safety.

4. Africa

Training opportunities

425. There are different opportunities for training of professionals from tropical countries on GNSS and their applications at Portuguese Universities and Research Institutes, mainly residents from African countries with which Portugal had cultural ties. African students have been able to follow their studies in Portugal for the degrees mentioned in the section on "Training Opportunities in GNSS".

426. Since a large amount of work was done in the past in the field of surveying and mapping and taking into account that GNSS is now of primary importance for the continuation of related activities, there are special opportunities for training of professionals from tropical countries at the Portuguese Tropical Research Institute (IICT). This Portuguese Institute is devoted to the co-operation with tropical countries, mainly African countries with historical ties to Portugal (http://www.iict.pt).

GNSS activities

427. Several co-operation activities have been undertaken between IICT and African countries in the area of surveying and mapping involving GNSS techniques. Recent GPS observations for such purposes were carried out in the Republic of Mozambique. At the Republic of Cape Verde, besides activities of that kind, co-operation work has extensively used GPS for monitoring volcanic activity in Fogo Island.

EGNOS trials in Africa Region

428. ASECNA (Agence pour la Sécurité de la Navigation Aérienne en Afrique et Madagascar) has performed flight trials at Yaounde, Cameroon, on the occasion of the fourteenth ICAO AFI APIRG meeting (AFI Planning and Implementation Regional Group), which took place in May 2003. The trials were conducted with the EGNOS System Test-Bed with a set of RIMS installed in the Central, Equatorial African region. Longer term data collection have confirmed the feasibility of a SBAS service on the region for APV I performance (approach with vertical guidance and a vertical alert limit of 50 meters). Detailed analyses of ionosphere scintillation phenomena are on going. The ESTB trials will be extended to the South Africa region during 2004.

Training opportunities in GNSS in Africa

429. Following the United Nations General Assembly Resolution 45/72 of December 1990, the United Nations established two regional training centres on space science and technology education in Africa, namely in Nigeria and Morocco. These centres have been conducting both short- and long-term training on various aspects of GNSS.

430. In addition to that, as far back as 1975, two regional centres have been established to be leading application-training centres in the fields of GNSS for surveying, mapping and remote sensing. These centres, which are located in Nairobi, Kenya and Ile-Ife, Nigeria, in conjunction with the affiliated United Nations regional centres mentioned above, are well equipped with high calibre professionals with capacity to meet the training requirements of the African countries.

431. A list of higher institutions in Africa, where professional and academic training can be acquired, is provided below.

a) Nigeria

- African Regional Centre for Space Science and Technology Education,
  Ile-Ife, Nigeria.

- Regional Centre for Training in Aerospace Surveys (RECTAS),
  Ile-Ife, Nigeria.

- University of Lagos, Department of Geography
  Address: University of Lagos, Senate House, 7th Floor, P.M.B. 1014, Unilag Post Office, Akoka, Lagos, Nigeria.
  Tel.: 234-1-823938, 820311-20
  Fax: 234-1-820397, 822644
  E-mail: adeniyi@nigeria.pinet.net
  Contact person: Prof. P. 0. Adeniyi

- University of Ibadan, Federal University of Technology on Minna, Ahmadu Bello University Zaria, University of Benin, University of Ilorin, Kaduna Polytechnic, River State University of Technology, Obafemi Awolowo University, University of Maiduguri, Nnamdi Azikwe University, Nsukka.

Programs: B.Sc/M.Sc/Ph.D. in geomatics, molecular physics, astronomy, spectroscopy, orbital mechanics, environmental sciences, nano-technology, photonics, etc.

b) Egypt

- National Authority For Remote Sensing and Space Sciences
  Address: Academy of Scientific Research and Technology, 101 Kasr El-Eini, Cairo, Egypt
  Tel.: (20) (2) 3557110, 3540173
  Fax: (20) (2) 3557110. Contact person: Prof. Dr. Hussein A. Younes
  Principal function(s) of institution: Research and development, image production, training.

c) Libyan Arab Jamahiriya

- Libyan Center For Remote Sensing and Space Science
  Address: P.O. Box 82819, Tripoli, Libya
  Tel.: 218-21-607004 - 14
  Fax: 218-21-607015
  Contact person: General Director
  Principal function(s) of institution: Training, research, development and services.

d) Morocco

- African Regional Centre for Space Science and Technology Education.

- Royal Centre For Remote Sensing (CRTS)
  Address: 16 bis, Avenue de France, Agdal, Rabat, Morocco
  Tel.: (212-7) 77 63 07/06
  Fax: (212-7) 77 63 00
  E-mail: crts@mtds.com
  Contact person: Mrs. Amal Layachi
  Principal function(s) of institution: co-ordination and promotion of remote sensing, development projects, satellite data distribution, training and research.

e) Uganda

- University of Makerere
  Kampala, Uganda.
  Area of specialization: Four years B.Sc. course in geomatics.
  Survey Training School
  Address: P.O. Box 89, Entebbe, Uganda.
  Tel.: (256) 20842
  Contact person: Commissioner, Department of Surveying and Mapping.
  Principal function(s) of institution: training.

Academic and Scientific Programs:

- Area(s) of specialization: Remote sensing.
  Summary of courses and research activities: photogrammetry, remote sensing.
  Duration/Frequency/Language(s) of instruction: 2 years/Annually/English.

f) South Africa

- Council For Scientific and Industrial Research (CSIR)
  Address: P.O. Box 395, Pretoria 0001, South Africa.
  Tel.: (27) (12) 841-9211
  Fax: (27) (12) 86-2856
  Contact persons: Prof. D. A. Scogings/Mr. S. E. Piper, Department of Surveying and Mapping, University of Natal, King George V Avenue, 4001, Durban.

Academic and Scientific Programs:

- Area(s) of specialization: remote sensing, satellite communications, and satellite meteorology.

- Summary of courses and research activities:
  Courses: an introductory course in remote sensing is offered annually, usually at the University of Natal or, alternatively, at the University of Cape Town. The course covers basic principles of remote sensing, with an emphasis on satellite data and digital image processing. No formal courses in satellite meteorology are offered. However, the South African Weather Bureau conducts in-house training on the applications of satellite meteorology.

- Research: remote sensing projects are funded in the following fields: agriculture, forestry, hydrology, land cover mapping, natural vegetation, geosciences, oceanography, data processing techniques and algorithm development. Projects in satellite meteorology are carried out by the South African Weather Bureau and certain divisions of CSIR. Climate variability over Southern Africa and the behaviour of the Agulhas Current.
  Duration/Frequency/Language(s) of instruction: Variable/Annually/English.

- Facilities: direct reception of LANDSAT data, image-processing facilities available at various CSIR Institutes: Satellite Remote Sensing Centre, National Physical Research Laboratory, National Institute for Informatics and National Research Institute for Oceanology. The Division of Microelectronics and Communications Technology operates the Satellite Applications Centre. This facility receives, records and archives meteorological data from geostationary and polar orbiting meteorological spacecraft. Advanced image processing facilities are available for radiometric and geometric manipulation of meteorological data. In addition, image-processing facilities exist in a number of other CSIR divisions.

- Number of trainees: depends on programme.
  Entry requirements: B.Sc, M.Sc. or appropriate experience.
  Degree/Diploma/Certificate awarded: None.
  Geographical preference: Southern Africa.

- University of Cape Town
  Address: Department of Geomatics.
  Private bag Rondebosch 7701
  Cape Town, South Africa.
  Tel (27) (21) 650-3573
  Fax: (27) (21) 650-3572
  E-mail: heinz.ruther@eng.uct.ac.za
  Contact person: Heinz Ruther
  Principal functions of institution: University Department with undergraduate and postgraduate degrees (Ph.D. and M.Sc.).

Academic and Scientific Programs:

- Area of specialization: geomatics (research thrust digital photogrammetry, GPS, GIS, land tenure).

- Courses: change of all courses to geomatics.

- Research: (research thrust digital photogrammetry, GPS, GIS, land tenure)
  Duration/Frequency/languages of instruction: 4 years undergraduate/2 years M.SC./2-3 years Ph.D..

- Facilities: digital stations Integrapg Image Z, Leica Helava, 4 Ashtek GPS, GIS software (Arc Info), and standard survey equipment.
  Number of trainees: 50 undergraduates and 30 postgraduates
  Entry requirements: matriculation with special requirements for Math and Science degree/diploma/certificate awarded: B.Sc. (Survey), M.Sc. (Survey), Diploma in GIS, Ph.D..

- University of Natal
  South Africa.
  Programme: Four B.Sc/M.Sc. in geomatics.

g) Botswana

- University of Botswana
  Programme: B.Sc. in mapping and remote sensing.

h) Zambia

- University of Zambia
  Programme: five-year B.Sc. in geomatics.

i) Kenya

- University of Nairobi, Jomo-Kenyatta, University of Agriculture and Technology, Moi University, Egerton University, Kenyatta University.
  Programmes: four-year B.Sc. degree programme in geomatics.

- Kenya Institute of Surveying and Mapping, Kenya Polytechnic

Programme: three-year advance diploma in geomatics.

- Regional Centre for Mapping of Resources for Development
  Programme: One to six months short-term training courses in geomatics.

j) Tanzania

- University of Dar-es-Salaam
  Programme: four-year B.Sc. course in geomatics.

k) Sudan

- University of Khartoum
  Programme: B.Sc./M.Sc. in geomatics.

l) Ethiopia

- University of Addis-Ababa
  Programme: B.Sc. in geography-remote sensing.

V. NEEDS AND CONCERNS OF DEVELOPING COUNTRIES

432. 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.

433. 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 Office for Outer Space Affairs has 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, Chile, April 2002, and Lusaka, Zambia, July 2002) and two international expert meetings (Vienna, November 2002 and December 2003) 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.

434. 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 Office for Outer Space Affairs and the results made available to the meetings of experts in November 2002 and December 2003. This information, along with communications with various workshop participants, aided the Action Team in the identification of key areas of interest and the challenges facing people wishing to integrate GNSS into their field of work or application.

A. Needs of developing countries

435. The needs of developing countries are listed in the following directions:

a) Institutional Needs

- Improve communication between GNSS service providers and 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.

- Each developing country has to take measures for capacity building in the use of GNSS technology in terms of infrastructure, training and manpower development.

- Reports and recommendations should be sent via United Nations channels to Governments of all countries involved. Benefits of GNSS technology and applications should be highlighted to decision and policy makers to increase financial and political support.

- Explore possibility of establishment of an international GNSS mechanism to promote and foster technology and applications.

- Continuation of the United Nations workshops should be encouraged and the resulting recommendations should be implemented. These are seen as very valuable in building capacity and enhancing understanding, as well as providing a network of professionals, educators and students.

b) Technical Needs

- Ionospheric effect, integrity, continuity, availability accuracy. Understanding ionospheric effects on GNSS applications especially at equatorial areas.

- Future developments of GPS/GALILEO and various augmentations – how developing countries should approach the issue. Difficulties to follow and understand plans and technical impact. Clear and regular communication with developing countries so that they have an opportunity to assess the likely impact of future developments of GPS/GALILEO and various augmentations.

- Need to provide technical support from infrastructure and services related to navigation.

c) Resources and Financial Needs

- The required instrumentation, ancillary equipment, computer and software are still costly for developing countries given their economic levels, in spite of the decline in costs in general. It is difficult to obtain resources to cover maintenance and recurrent costs.

- The international committee on GNSS should lead the sourcing of fund to help reduce cost of implementing GNSS-related projects.

d) Training and Education Needs

- Development of advanced training programs by the United Nations to cover various applications, such as civil aviation, precision measurements and remote sensing, and to cover all aspects, including observations, analysis and implementation.

- 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 is also difficult. Language books (GNSS in Spanish, etc.).

e) Priorities in Application

Regional Spatial Data Infrastructure (SDI), Geographic Information Systems (GIS), National SDI

- The use of GNSS positional information was stressed in each region as the method for referencing SDI and GIS, which are critical elements of any national cartographic infrastructure.

Surveying, Mapping, Land Use

- Precise reference frame (global, international, continental and national), e.g., AFREF project. Updating of maps, initial mapping of land use, land use planning and evaluation, urban planning. Cadastral mapping, land ownership and boundary control. Environmental protection. Topographic and thematic mapping. Geological surveys.

Asset Tracking, Automated Vehicle Tracking

- Use of GNSS in real time for charting moving platforms, cars, buses, supply trucks, safety device for auto anti-theft.

Precision Agriculture

- Need to co-ordinate the use of GNSS in crop, soil and various agriculture mappings together with monitoring and subsequent analysis of data for optimum field application of chemical and fertilizer, where real time GNSS-based navigation is important.

Natural Hazards and Disaster Mitigation, Disease Vector Mapping

- Location of information on disasters, positional information for emergency and relief vehicles.

B. Civil aviation

436. Latin America and the Caribbean region, as well as other regions of the world, have been participating actively in research, development, analysis and study tasks aimed at the implementation and use of GNSS systems in airspaces.

437. Latin American and Caribbean States and their aeronautical entities, in their transition to GNSS, should consider that, unlike conventional navigation systems, improvements and developments introduced in satellite navigation will benefit all economic sectors of a State. Therefore, the involvement of other development sectors of a State should be considered of great importance for obtaining greater institutional, financial, economic and technical support for upgrading, developing and implementing GNSS. Transportation and communication authorities, mapping institutes and other national agencies of the State should make maximum efforts to be engaged in this process. A note should be taken that the promotion of national and international GNSS management bodies and associations would permit a more significant development and greater support for investments and for the transition to the GNSS.

438. The availability of geostationary satellites to correct the signals from the satellite constellation in the Latin American and the Caribbean regions is a latent need, since the existing geostationary satellites that cover these regions would not be sufficient to transmit the correction signals over such a broad area as the Caribbean and South America, in addition to the initial target areas of the systems currently providing coverage, i.e., WAAS and EGNOS.

439. Manpower deficiencies regarding personnel duly trained in the verification of signals in the GNSS SIS space, in correspondence to ICAO SARPs, and on air safety considerations, is a factor that should be taken into account in order to properly conduct GNSS performance analysis and research.

440. Lack of personnel highly trained in satellite navigation issues in the aeronautical entities points to the need to train experts to the same or higher level of expertise than experts currently have with respect to conventional systems, so that they may duly implement GNSS, in keeping with the ICAO SARPs.

441. Similarly, operational personnel with training in the design of GNSS procedures is limited. Likewise, adequate on-board and ground equipment for GNSS verification is lacking, together with SBAS service volume simulation tools. Consequently, this would be another task to carry out in order to improve the situation.

442. Improvements are being made to CNS/ATM systems in seven ICAO regions through the work of ICAO and planning and implementation regional groups, the International Air Transport Association (IATA) and the regional workshops on the use and applications of GNSS. GNSS has provided operational procedures, which have resulted in enhanced safety and efficiency together with reduced dependency on ground aids to aeronautical navigation. The work is under way with the ultimate goal of transition to satellite-based navigation for all phases of flight while maintaining the role of conventional navigation systems as a GNSS back-up during the transition. Although the use of satellite technologies in support of aeronautical applications is steadily growing, their implementation is not progressing as fast as initially expected and the transition from the existing to satellite-based systems is a long-term commitment. The work is under way with the ultimate goal of transition to satellite-based navigation for all phases of flight while maintaining the role of conventional navigation systems as a GNSS back-up during the transition. Although the use of satellite technologies in support of aeronautical applications is steadily growing, their implementation is not progressing as fast as initially expected and the transition from the existing to satellite-based systems is a long-term commitment.

443. ICAO, recognizing the limitations of the present air navigation systems and the need to meet future requirements, has taken steps to promote the introduction of satellite-based technologies for communication, navigation and surveillance (CNS) in support of global air traffic management (ATM). These systems will fulfil future civil aviation requirements well into the present century.

444. In 1983, ICAO established a Special Committee on Future Air Navigation Systems (FANS Committee) to develop a concept that became known as the 'FANS concept' and also promoted CNS and ATM systems largely based upon satellite technologies. In 1991, after further development work, the ICAO Tenth Air Navigation Conference endorsed this concept for the future air navigation system worldwide.

445. By 1996 the proposed CNS/ATM concept had matured and developed into a detailed and definitive plan and was published as the ICAO Global Air Navigation Plan for CNS/ATM Systems. This plan was envisaged as a "living document" offering practical guidance to States in seven ICAO regions and respective planning and implementation regional groups (PIRGS) covering technical, operational, economic, financial, legal and institutional matters and providing advice on implementation strategies and technical co-operation. The Global Plan has a clear relationship with the Regional Air Navigation Plans to be used to move towards the ultimate goal of a global, integrated ATM system.

446. In addition to activities of PIRGs that develop air navigation plans and co-ordinate implementation activities in the regions, ICAO is using three different mechanisms to provide assistance to States for the implementation of CNS/ATM systems on continuous basis. These

include Special Implementation Projects, Technical Co-operation Projects and International Financial Facility for Aviation Safety. In addition, ICAO is undertaking periodical technical visits to States, developing regional guidance material and conducting regional workshops.

447. Trials are being carried out in the Caribbean, South American (CAR/SAM) and African (AFI) regions of ICAO at the regional and national levels to collect data for the definition of the GNSS architectures in these regions. These trials involve WAAS and EGNOS testbeds in the CAR/SAM States and an EGNOS testbed in the AFI States.

448. The lessons learnt and proposals stemming from the experiences gained with GNSS development and implementation were reviewed by the ICAO Eleventh Air Navigation Conference (Montreal, Canada, 22 September – 3 October 2003). These concerned a broad range of issues, including human resources, regional training capabilities, and the need for integration of technical co-operation projects and financing aspects. Human resource training and financing issues were reported as major challenges in implementing complex technology systems such as GNSS. The conference encouraged States and service providers that develop and introduce satellite-based augmentation systems to provide their technical and financial support and participation in the activities leading to the extension of their SBAS service areas into neighbouring States and regions. States participating in SBAS implementation activities would co-ordinate with other participating States to optimize their effort, minimize duplication of service and facilitate participation of service providers.

449. The goal of transition to GNSS to support aeronautical navigation for all phases of flight and remove the requirement for conventional ground-based navigation aids is maintained. However, when implementing GNSS-based operations, States are expected to assess the likelihood and effects of GNSS vulnerabilities in their airspace and utilize, as necessary, the mitigation methods including effective spectrum management and protection of GNSS frequencies, on-board mitigation techniques and terrestrial navigation aids as a back-up during an evolutionary transition to GNSS. Therefore, the need for ground-based navigation aids or some of them will remain during the transition until such time when all requirements for safe and cost-effective operations using GNSS are met.

450. Following a recommendation of the Worldwide CNS/ATM Systems Implementation Conference (Rio de Janeiro, Brazil, 11 - 15 May 1998), ICAO has addressed the issue of cost allocation amongst all users of GNSS.

451. The Conference on the Economics of Airports and Air Navigation Services (Montreal, 19 to 28 June 2000) requested ICAO to continue its efforts in this area with a more comprehensive study, for which a broad-based coalition of civil aviation interests and non-aeronautical users would need to be established in order to estimate acceptable and equitable cost allocation shares for each major user group.

452. The "requirements-driven" approach was endorsed as one method that should be taken into account in the further work in two areas:

- Allocation amongst civil aviation users; and
- Allocation between civil aviation and other users.

453. As study results mature there may be a need to approach representatives of other user categories, possibly through the United Nations family, in order to have some support for the guidance on cost allocations that will be developed.

454. Improvements are being made to CNS/ATM systems in the African and Indian Ocean region through the work of such organizations such as ICAO, IATA and the regional workshops on the use and applications of GNSS. GNSS procedures are providing some airports with accurate landing, approach and departure procedures, which result in enhanced safety and efficiency together with reduced dependency on ground aids. However, little has been done so far to improve the standards of Air Traffic Management (ATM). ATM can be improved by the use of proven satellite procedures. The difficulties are institutional, not technical, and should benefit from United Nations expertise in this respect.

C. Telecommunications

455. In Brazil, A group of researches in Brazil at Instituto Tecnológico de Aeronáutica (ITA) and National Space and Research Institute (INPE) are involved with scintillation studies related to equatorial anomaly, which is important for satellite communication.

456. Development of microstrip antennas for special applications has also taken place in the field of GNSS (at ITA). In addition, signal processing adaptive antennas investigation for interference mitigation on GNSS applications have also been developed at Universidade de Campinas (UNICAMP) and Aeronautics Institute of the Aerospace Technical Center (CTA/IAE).

D. Conclusion

457. There is a need for developing countries to recognise the benefits of GNSS technology and its applications in many areas of economic and infrastructure development. Prominent among the application areas are the modern CNS/ATM systems, safe land transportation system, surveying mapping and remote sensing applications, as well as telecommunication infrastructure.

VI. EXISTING TRAINING OPPORTUNITIES IN GNSS

A. GNSS training opportunities offered by universities and research institutes

458. In Argentina, the faculty of the Astronomical and Geophysical Sciences of La Plata National University (Facultad de Ciencias Astronómicas y Geofísicas de la Universidad Nacional de La Plata), the group GESA (Satellite referencing on the Earth), integrated by astronomers, geodesists and geophysicists graduated in the country develop scientific and practical activities on GNSS and organize educational and training activities at different levels that include pre- and post-graduate courses for university students and courses for updating of professionals in GNSS activities (contact person: Dr. Claudio Brunini, cbrunini@fcaglp.fcaglp.unlp.edu.ar).

459. In Brazil, the existing training opportunities are available at the following institutions:

CRECTEALC: United Nations Regional Centre for Space Science and Technology Education for Latin America and the Caribbean.

- Undergraduate courses.

IME – Army Institute of Engineering.

- Graduate and undergraduate course on cartography and geodesy.

- INPE – National Space and Research Institute – São José dos Campos.
  Education and research on orbital dynamics and ionosphere modelling.

ITA – Instituto Tecnológico de Aeronáutica.

- Education and research on aeronautics applications of GNSS: ionosphere modelling and scintillation, GPS software receivers, multipath mitigation, microstrip antennas for GNSS, and related subject.
- Graduate courses.

UFPE – Universidade Federal de Pernambuco.

- Education and research on cartography, geodesy and photogrammetry.

UFPR – Universidade Federal do Paraná – Curitiba.

- Education and research on cartography, geodesy and photogrammetry.
- Graduate and undergraduate courses.

UFRGS - Universidade do Rio Grande do Sul.

- Undergraduate course on cartography, geodesy, photogrammetry and GIS.

UFV – Universidade Federal de Viçosa – Vinosa.

- Undergraduate course on geodetic surveying.

UNICAMP – Universidade de Campinas – Campinas.

- Education and research on signal processing.
- Undergraduate courses.

UNESP – Universidade do Estado de São Paulo – Campus Presidente Prudente.

- Education on cartography, atmosphere modelling, high precision GNSS.

- Graduate and undergraduate courses.

USP – Universidade de São Paulo – Campus Piracicaba.
- Education and research on geoprocessing, agricultural and natural resources, and precision farming.
- Graduate and undergraduate courses.

USP – Campus São Carlos.
- Education on ground transportation
- Undergraduate courses.

460. In Canada, significant research and development in GNSS takes place at three Canadian universities known for GPS-related studies. The three Canadian Universities actively offering GPS-related study programs are: University of Calgary (Geomatics Engineering) www.geomatics.ucalgary.ca, University of New Brunswick (Geodesy and Geomatics Engineering) http://www.unbf.ca/eng/GGE/HomePage.html and Laval University (Department of Geomatics Sciences of the Faculty of Forestry and Geomatics) http://www.scg.ulaval.ca/

461. The University of Calgary's graduate program includes at any time some 40 M.Sc. and Ph.D. graduate students involved in GNSS-related research. Two thirds are non-Canadian. Some of the research is described on:
www.geomatics.ucalgary.ca/research/GPSRes/GPSResIndex.html

462. The GNSS R&D facilities include two tops of the line GPS simulators, software simulators, dozens of GPS receivers, several inertial navigation platforms, an antenna range, and a 16-station DGPS RTK test network.

463. The Department of Geodesy and Geomatics Engineering at the University of New Brunswick (UNB) is one of Canada's leading centres for research in positioning and precision navigation using GNSS. The Department has a long history of making important contributions in satellite-based positioning, stretching back to the early 1970s when it pioneered the use of the United States Navy Navigation Satellite System in geodetic studies. By 1980 or so, interest turned to the Global Positioning System, although only a few prototype satellites were in orbit at that time. Working with government agencies and industry, the Department researchers tested some of the first commercially available GPS receivers and developed software for the planning, execution, and analysis of GPS surveys. GPS research activity grew in the 1990s and into the new millennium with contributions in many application areas including hydrographic surveying, engineering and deformation surveys, geodetic positioning, aviation, machine control, augmentation systems such as WAAS and the Canada-wide Differential GPS Service, atmospheric science, and the use of GPS on Low-Earth-Orbiting spacecraft. Recently, the Department inaugurated work on aspects of Europe's GALILEO system. UNB's targeted GNSS research is helping to provide accurate, reliable, and cost-effective positioning and navigation for Canadians and others around the world.

464. The Department of Geomatics Sciences at the University of Laval started its GPS (GNSS) research activities in 1990. Approximately 25 M.Sc. and Ph.D. students have graduated since then in this field. The research activities are described in the following bilingual web site: www.scg.ulaval.ca/gps-rs/. The team publications can also be obtained via this site. The GPS facility includes about 35 GPS receivers (12 GPS-GIS receivers, 4 dual frequency geodetic receivers and 6 GPS-RTK units, as well as 2 GPS-GLONASS and 12 handheld GPS receivers).

465. Many other GNSS-related education and training opportunities exist in Canada and are offered by other academic institutions and the GNSS-related industry in support to the many applications enabled through GNSS.

466. In Chile, the Universidad de Concepción offers a course on Geodesy and GNSS, Surveying and Applications. This course's cost is just 20% with student's assistance and 80% by distance. The focus of the course is to increase knowledge on GNSS technologies for positioning and engineering applications, such as forestry, mining, car tracking and deformation structure.

467. In Germany, the list of universities that offer training in GNSS can be found in Annex II at the end of this report.

468. Indonesia offers training opportunities in GNSS based at the Department of Geodetic Engineering Institute of Technology. The courses offered cover the following fields:

- Positioning by GPS: Concepts and Theory;
- GPS Survey: Planning, Execution and Data Processing;
- The Use of GPS for Cadastral Surveys;
- The Use of GPS for Forest Survey and Mapping; and
- The Use of GPS Survey for Natural Hazard Mitigation.

469. In Italy, there are many universities skilled in satellite navigation that also perform training activities. The Italian Space Agency (ASI) organises dissemination and training initiatives (see Annex III).

470. In Malaysia, the University of Technology, through the Department of Geomatic Engineering, teaches subjects on satellite navigation and GNSS surveying for Bachelors degree in geomatic engineering and postgraduate programmes (Master of Science and Ph.D.). Added to the programmes are also satellite navigation and GNSS surveying. This is done through research work and also several short courses on GNSS navigation, positioning and surveying for related government agencies and other organizations The National Land and Survey Institute (INSTUN), under the Ministry of Land and Cooperative Development, provides short trainings for GNSS applications.

471. Concerning activities in Poland, the paper entitled "Independent atomic time scale in Poland – Organization and results" (J. Azoubib, J. Nawrocki and W. Lewandowsk) elaborated on the Polish infrastructure in the related field. The Polish independent atomic time scale TA (PL) officially started on 4 July 2001. It is currently based on the indications of nine clocks from several Polish laboratories and Lithuania. The clocks at the laboratories are compared using TTS-2 multi-channel GPS receivers developed in co-operation with the Bureau International des Poids et Mesures (BIPM). The participating institutions are linked to the Central Office of Measures (GUM) in Warsaw. TA (PL) is computed as a weighted average of the participating clocks. The paper presented the clock ensemble, the data processing outline, and some experimental results.

472. The paper concluded that the results obtained, especially the long-term stability of TA (PL), were quite satisfactory. The simplest way to improve stability was to add more clocks. Two new clocks, one at the Tele-Radio Research Institute in Warsaw and the other at the Development Center of Polish Telecom were already working and being tested. Two more, from another Telecom laboratory, were expected to be added before the end of 2003. The short-term stability

will also be improved by the addition of an active H-maser working at the Astronomical Observatory of Toruń University.

473. Future developments in Poland include the following:

- Another active H-maser will be added by the GUM in 2004;
- TA (PL) will be computed every week;
- A number of local fibre-optics links will be installed between clocks in Warsaw;
- The GUM, the pivot laboratory of TA (PL), will be linked to TAI using the Two-Way Satellite Time and Frequency Transfer (TWSTFT) method; and
- From January 2003, the Coordinated Universal Time (UTC/PL) will take place based on TA (PL) and a phase micro-stepper.

474. In Portugal, the normal curricula for the B.Sc. degree in surveying engineering in universities include various subjects related to the use of GNSS in the field. The curriculum at the Faculty of Sciences, University of Porto, for example, includes "Satellite Positioning and Navigation" (see web site, http://sa.fc.up.pt/pe/(ENGENHARIAGEOGRÁFICA) in the last year of the degree course. Under this subject, students analyse GPS and GLONASS and the work to implement GNSS, including the future GALILEO.

475. The Portuguese Faculty of Sciences, University of Porto, offers a Master's degree course in satellite positioning and navigation. The course work consists of four semesters, with the first two devoted to a specialised course leading to a diploma and the last two for writing a thesis. The specialised course includes such subjects as reference systems, space dynamics, mapping and GIS, satellite positioning and navigation, positioning and navigation systems, fieldwork in satellite positioning and satellite navigation.

476. The Portuguese authorities have also approved the project entitled "The Space Technology and the Automatic Computing in the Teaching/Learning Process", which aims to disseminate the practical use of GPS in various positioning and navigation applications to high schools. The project is underway with the participation of a large number of high school teachers and students.

477. In the Republic of Korea, high-qualified researches and faculty have been working on teaching and researches on GNSS at more than 10 universities, as well as at several research institutions.

478. In the Russian Federation, the Moscow Aviation Institute (State Technical University status) has been historically dedicated to student education in the field of navigation. Currently, the special comprehensive course on GNSS is proposed and ranges from satellite design to GNSS applications.

479. The Moscow Institute of Geodesy and Mapping (State Technical University status) has also been traditionally proposing courses for students in the field of GNSS application.

480. The special satellite navigation training program has been developed on the basis of the Institute for Advanced Training of Rosaviakosmos (IPK "Mashpribor"). It has been initiated and sponsored by the Russian Aviation and Space Agency. The program includes the following priority directions:

- Theory and practice of GNSS space vehicle control;
- Principles of navigation measurements and data processing;
- Differential navigation and GNSS augmentations;
- GNSS applications; and
- Practical training with GNSS instruments.

481. The course is intended for specialists with high technical education who are willing to gain more practical experiences and improve their professional competencies.

482. This training program has been developed and tested by a team of leading Russian scientists and experts in the field of satellite navigation who represent the Russian aerospace industry and research institutes such as: the Mission Control Center of the Central Research Institute for Machine Building (TsNIIMASH) of Rosaviakosmos, the Research Institute of Space Systems (NIIKS), a subsidiary of "Khrunichev" Research and Production Center, and the Russian Institute of Space Device Engineering (RISDE).

483. In South Africa, universities and technikons (tertiary technical training institutions) provide GPS and GNSS training as part of surveys and in various engineering courses. In addition, the personnel of these institutions are prepared to provide short courses, either of a practical, hands-on or theoretical nature for appropriate fees. These can be and have been done beyond South Africa's borders. The two major universities providing training in GPS and GNSS in their degree courses for surveying are the University of Cape Town and the University of Natal; however, most engineering faculties include such training. For instance, GPS and GNSS training is an important factor for the training of mining engineers at the University of the Witwatersrand.

484. The University of Cape Town offers approximately 40 lectures on GNSS (mainly GPS), with the emphasis on GPS applications in surveying and geodesy (carrier phase differential GPS). These lectures are taught as part of a four-year course in Geomatics and cannot be taken separately. It also offers a two-day short course on GPS, with the emphasis on GIS/surveying applications of GPS (aimed at scientists and engineers who need to use GPS for data collection). The University of Natal offers similar courses.

485. In the United Kingdom of Great Britain and Northern Ireland, through the Institute of Engineering Surveying and Space Geodesy, the University of Nottingham offers a degree course dedicated to satellite positioning technology. Details can be found at http://www.nottingham.ac.uk/iessg/MSc2.html.

486. Through the EPSRC project of the Department of Geomatic Engineering, the University College London has offered Ph.D. opportunities in satellite geodesy and astrodynamics. Details can be found at http://www.ps.ucl.ac.uk/people/vacancies/PhDOpportunity.html.

487. The National Physical Laboratory has also organized a short-term course and workshop on next-generation global navigation satellite systems. Details can be found at http://www.npl.co.uk/npl/training/courses/nggnss.html.

488. In the United States of America, there are numerous research and training institutions that provide training on GNSS. This is not an endorsement that these are the best or only institutions that provide GNSS training, but are simply a sample.

489. Navtech Seminars, Innovative Solution International and Advanced Management Technology Incorporated provide technical courses and advanced GPS training in support of the FAA's SATNAV Program Office.

B. GNSS training opportunities offered by the United Nations, United Nations agencies and other intergovernmental organizations

490. ICAO is conducting activities to face new challenges concerning human resources involved in the introduction of advanced satellite-based CNS/ATM. ICAO addresses human resource planning and training issues through its TRAINAIR programme. The programme provides a mechanism for co-operation among training centres for the development of the many new training courses that are required to support the introduction of CNS/ATM. ICAO will continue to organize seminars and workshops on the implementation of GNSS-based aeronautical systems and procedures.

491. The European Commission (EC) carries out a series of information activities in order to raise awareness of satellite navigation and involve European and non-European parties in the conception of the GALILEO programme. Preparations were underway to move from ad hoc training activities towards more regular structures. Further co-operation was foreseen with the European Space Agency in this context.

492. The involvement of a number of non-European Union (EU) countries in Europe, North America, Africa, Asia, Middle East and Latin America in the GALILEO project is an example of “learning by doing” that combines scientific and industrial co-operation.

C. GNSS training opportunities offered by non-governmental entities

493. There are some suppliers of GPS equipment in South Africa, the major being Optron, supplying navigation and positioning systems for use in coastal and deep sea navigation, land navigation, land surveying, precision agriculture and forestry applications and precision excavation. In addition, applications in nature conservation include tracking of animal species being studied and location of examples of rare plant species. Since 1996, the Electricity Supply Commission and Telcom have also been using global positioning technology to assist in electrification and telephonic infrastructure development of rural areas in order to establish exact location of very remote users and equipment. All of this has given rise to a market for GPS equipment, which has gone hand in hand with training on that equipment provided ad hoc to purchasers and users. Optron supplies equipment and training to clients in most of sub-Saharan Africa and is prepared on a commercial basis to provide training to non-client users. Their main supplier of equipment is from the United States and, for business reasons, they do not support the Russian GLONASS system, though the principles of the GLONASS and other satellite systems are essentially the same.

494. There are many companies in Italy that are working in the research and development areas as well as in navigation application. Large suppliers and small and medium enterprises not only participate in the European navigation programmes like EGNOS and GALILEO, but are also involved in ground-based navigation equipment (see Annex IV).

495. Many companies in the Republic of Korea have been working in research and development in a variety of areas such as car navigation, informatics, GPS receivers, GIS firmware, etc.

D. GNSS training opportunities offered by Governments

496. Azerbaijan is planning to establish a global navigation satellite system in the near future for application in various areas of navigation. Within the framework of FAO, a group of remote sensing specialists of the Azerbaijan National Aerospace Agency (ANASA) as well as other interested organizations of Azerbaijan were provided with training in GNSS, such as the use of GPS- 12 CX Garmin.

497. In Germany, the Ministry of Transport and Ministry of Research and Education are responsible for the activities relating to GNSS. As the space agency, the German Aerospace Center (DLR) has many activities in the research area, and it finances national GNSS studies and contributes to the ESA GNSS programmes, such as EGNOS and GALILEO.

498. In Hungary, universities, high schools, commercial organizations and research institutions are involved in GNSS (GPS) education and training.

499. India has developed a detailed plan for introduction of satellite-based navigation services for civil aviation in phases. India is building a Satellite Based Augmentation System (SBAS) system over the Indian Airspace. This is a joint project between the Indian Space Research Organisation (ISRO) and the Airports Authority of India (AAI). The SBAS is being implemented by ISRO. To support the development of an SBAS system of international standards, several organizations, research institutes and academic institutions offer training in satellite-based navigation. The list of organizations that may be contacted for training is contained in Annex I. Annex I is categorised in terms of the subject such as: SBAS system studies, navigation payload, master control centre, iono-tropo models, research and training and receivers, academic institutions and receiver manufacturers. Apart from these, ISRO conducts several training courses specially design for developing countries on various related subjects from time to time.

500. In Italy, some limited training opportunities exist in public authorities.

501. In the Republic of Korea, the Civil Aviation Training Centre at Korea Airport Corporations (KAC), which is a non-profit organization founded by the Ministry of Construction and Transportation to supervise and manage the effective operation of domestic airports, has conducted an international training course on GNSS technology, consisting of the fundamentals of GPS and DGPS, data processing by GPS receivers, positioning and timing theory and experiments based on DGPS, a new CNS/ATM concept.

502. This training course was especially designed for developing countries in Southeast Asia to exchange information on international aviation affairs and promote the understanding of the relationships with each country in conjunction with the Korea International Cooperation Agency (KOICA), founded by the Ministry of Foreign Affairs and Trade (MOFAT).

503. The two-week training course has been offered annually since 2001 to 44 personnel related to air navigation safety facilities from 12 developing countries, including: Malaysia, the Philippines, Viet Nam and Thailand.

504. The Korean Centre has a plan to be a top-ranked international aviation training centre by the continuing efforts for expansion of the scope and number in international training courses, by enhancing co-operation with recognised worldwide aviation training institutions, and also by

enlarging an important number of facilities and excellent faculty members, thus developing worldwide standard tutorials.

505. In the Russian Federation, the Russian Aviation and Space Agency in the framework of the Federal GLONASS Mission Oriented Program has initiated and has also been sponsoring the special program for educational satellite navigation course preparation.

506. In Senegal, the personnel of the civil aviation authorities have been trained at the Air Safety and Navigation Agency in Madagascar (ASECNA) and at the National School of Civil Aviation (ENAC) in France.

507. The South African Government has three institutions, which particularly deal with GNSS and GPS. These are the Satellite Applications Centre, the Air Traffic Navigation Systems company and the Chief Directorate: Surveys and Mapping in the Department of Land Affairs.

508. The Satellite Applications Centre (SAC), at Hartebeeshoek, near Johannesburg, together with the Hartebeeshoek Radio Astronomy Observatory make use of permanent GPS stations for calibration purposes. They provide in-house training to personnel and visiting trainees; however, they do not have formal programmes of training in this area as such training is provided on an ad hoc, needs basis.

509. The Air Traffic Navigation Services Company (ATNS) provides air traffic control and associated services for continental South Africa and a large oceanic region. In addition to controlling all upper airspace and terminal control areas in South Africa, ATNS also provides services at 21 airports. Surveillance of the South African oceanic sectors is achieved through the use of satellites and communications, through data link with aircraft that are suitably equipped and certified. In addition, ATNS provides GNSS charts for a number of African countries. The ATNS has an Aviation Training Academy, situated at Johannesburg International Airport. Training in Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM) is provided for air traffic service personnel, air traffic service planners and for senior management to equip them appropriately. The practical application of GNSS and GPS applies only to the first two categories of personnel. Certain courses can be provided in other states, if the requirement exists. Training has been provided at various locations beyond South African borders to meet client needs.

510. Surveys and mapping in the Department of Land Affairs, which maintains the South African national mapping programme and trigonometric survey, has a training component which provides practical training for Technical Institute students and in-house trainees. However, most in-depth GPS application training is informal and on the job training. From time to time seminars are run on specific areas of interest such as the implementation of the network of permanent GPS base stations (known as TrigNet, established and maintained by the survey office) outside of the office.

511. In addition, there are training possibilities outside of the Government controlled bodies. In fact, most formal training is done outside of Government bodies.

512. In the United Kingdom of Great Britain and Northern Ireland, the National Physical Laboratory has organised a short-term course and workshop on next-generation global navigation satellite systems. Details can be found at http://www.npl.co.uk/npl/training/courses/nggnss.html.

VII. INSTITUTIONAL MODELS FOR INTERNATIONAL CO-OPERATION

513. 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 policy makers 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 collaborative 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 governmental).

514. The framework to be discussed will be most favourable to service providing governments if flexible mechanisms are put in place and the focus of those mechanisms is providing improved service to users.

515. The following categories of international co-operation in providing GNSS services are offered for consideration:

- <u>Co-ordination</u>
  - — among the core GNSS service and augmentation providers;
  - — national planning and/or regional planning.
- <u>Dissemination</u>
  - — of information on GNSS to users and provision of technical assistance for the integration of GNSS into national infrastructures.
- <u>Identification</u>
  - — of users' needs and desires regarding GNSS.

A. Co-ordination

Co-ordination among the GNSS service providers

516. On the basis of work conducted at the United Nations workshops and Action Team meetings, the following objectives for international GNSS co-operation have 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 (such as GPS III, GLONASS-K, GALILEO and 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 (e.g. satellites or ground stations);
- To ensure continuous reception of GNSS services, all nations should consider, as a matter of priority, the protection of radio spectrum allocated for GNSS services from interference, both domestically and internationally;
- Mechanisms to receive feedback from users should be enhanced. 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.

517. 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 an international committee on GNSS, could be established. This would be achieved through a multilateral arrangement between the governments and/or organizations that currently provide or plan to provide global GNSS services and maintain corresponding infrastructure, i.e. the Russian Federation, the United States and the European Union.

518. The international committee could also include current and future providers of regional augmentation systems. In addition to the objectives above the international committee should look into ways of optimising compatibility, interoperability, availability and reliability of the core systems. Among other things, it could facilitate information exchanges among GNSS providers on system modernisation and development to ensure compatibility and interoperability. The international committee 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 and development activities to meet user needs, particularly in the developing world.

519. 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 international committee would need to address. However, it should avoid efforts to set standards itself and should instead look for applications where no standards currently exist, such as land transport, and recommend possible organizations that could appropriately set new standards. Consultation with existing standard-setting bodies such as the International Civil Aviation Organization (ICAO), the International Maritime Organization (IMO), the International Telecommunication Union (ITU) and the International Organization for Standardization (ISO) will also be required. In addition, the Office for Outer Space Affairs, through the United Nations Programme on Space Applications, could play a useful role in demonstrating to developing countries the practical benefits of GNSS and assisting the international committee in integrating GNSS into infrastructures of developing countries.

520. The following membership could be envisaged for the international committee:

(a) Core GNSS system providers and developers/customers of GPS, GLONASS and GALILEO;

(b) Global user organizations such as the International GPS Service (IGS) the World Meteorological Organization (WMO), the United Nations

Environment Programme (UNEP), and the secretariat for International Strategy for Disaster Reduction (ISDR).

(c) Providers of augmentation systems such as WAAS, EGNOS, GAGAN, MSAS and the Quasi-Zenith Satellite System (QZSS).

521. Preparation of major user equipment suppliers in the international committee sessions may benefit in further GNSS applications.

National and regional planning and governance

522. Establishing national and/or regional planning groups for GNSS that would address regulations, user needs and so on is clearly an important objective. Many countries are searching for an organizational 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, various science and transport authorities (e.g. air navigation service providers) could lead the coordinating bodies.

523. The regional centres for space science and technology education affiliated with the United Nations are possible entities that could be given the task, in conjunction with the proposed international committee on GNSS, of GNSS planning and organization at 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.

Australian GNSS Coordination Committee

524. The Australian Government Minister for Transport and Regional Services, the Hon. John Anderson MP, established the Australian GNSS Coordination Committee (AGCC, www.agcc.gov.au) in May 2000. The Committee provides advice and recommendations to the Government on GNSS implementation. The Committee's terms of reference call for it to:

- Co-ordinate all land, sea and air aspects of GNSS;
- Promote the safe and effective utilisation and development of GNSS in Australia; and
- Co-ordinate national security issues, the application of augmentation systems, and the national use of GNSS in non-transport applications.

525. Membership is drawn from a range of users and providers across the following sectors: aviation, defense, emergency services, land and maritime transport, academia, communications, timing, geomatics and geophysics, security and industry providers.

526. Some of the Committee's achievements have been:

- Development of Australia's strategic policy on satellite navigation, Positioning for the Future, which was launched by the Minister for Transport and Regional services in August 2002;
- Initiation of action to ban GPS jamming devices in Australia;
- A study into the potential for interference to civil GNSS applications by sources such as UHF television transmissions;
- A study into GNSS usage and needs in agriculture;

- Facilitation of GPS spectrum band licensing under the Radiocommunications Act; and
- Maintenance of links with the United States to contribute to co-operation on GPS, and with the European Union to keep abreast of developments with the proposed GALILEO system.

527. The national strategic policy on satellite navigation “Positioning for the Future”, which was developed by the AGCC, is aimed at obtaining the best and most efficient use from GNSS technology. The policy is based upon eight principles:

- National coverage;
- Safety;
- Efficiency, economic and social benefits;
- Industry development;
- Flexibility of policy and strategy;
- Appropriate standards;
- Benefits to the environment; and
- National security.

528. The AGCC has recently been reviewed after its first three years of operation. The Committee will continue its work with some minor amendments to its terms of reference and membership (Department of Transport and Regional Services, Canberra, Australia, November 2003).

B. User support and information dissemination

529. 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 international expert meetings on GNSS held in Vienna in 2002 and 2003. 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.

530. 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; and

- 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 than, other familiar services and utilities such as telecommunication 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

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

532. For GPS, the Navigation Information Service managed by the United States 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.

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

534. Similarly, the EC also provides a web-based portal for the GALILEO project.

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

536. Dissemination of information among 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 United States Civil GPS Service Interface Committee. Industry groups include the United States 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.

537. 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 the 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 transmission rates. Translation of as many documents and materials as possible included in the nested set of web sites should also be considered.

538. The United Nations Office for Outer Space Affairs could combine all the web sites into a single site to act as portal for any user of any GNSS service or regional component of a service.

C. Identification of users' needs and desires regarding GNSS

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

- With help of information exchange based on the means of an international GNSS user information centre; and
- Based on the regional workshops with participation by representatives of the international committee.

540. Meetings between the international committee and user community should be organised under United Nations leadership twice a year in the regions. Conducting workshops in connection with well-attended international GNSS meetings may be desirable.

VIII. RECOMMENDATIONS

541. A number of sources have provided a series of recommendations for promoting a more efficient use of the GNSS technology around the world. The four regional workshops held in 2001 and 2002, the international experts meetings on GNSS held in late 2002 and 2003, the responses to the questionnaires sent to experts, participants and service providers at those meetings, as well as inputs from members of the Action Team on GNSS represent just a few of the sources. The recommendations are summarised below. The following recommendations are made for the United Nations Office for Outer Space Affairs to submit to the United Nations General Assembly for consideration:

A. Recommendations regarding institutional framework to service providers

Creation of an international committee on global navigation satellite systems

542. Creation of an international committee on GNSS would provide a mechanism for co-ordination among service providers to address, among other things, co-ordination of activities and plans for 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; and
- To advocate long-term protection of the spectrum reserved for GNSS.

543. 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.

544. The international committee could be established through a multilateral agreement among providers of GNSS and regional augmentations systems. The international committee might be modelled after the Committee on Earth Observation Satellites (CEOS[6]), with secretariat responsibility rotating among its members on an annual basis. This possibility could be examined further. The 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.

545. It is recommended that the international committee on GNSS be set up with the following objectives:

- To benefit users of navigation services through consultations among members of the committee;

- To encourage co-ordination among providers of GNSS core systems and augmentations in order to ensure greater compatibility and interoperability;

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

- To encourage and promote the introduction and utilisation of satellite navigation services, in particular in developing countries, through assistance with the integration of GNSS services into their infrastructures;

- To assist both the members of the committee and the international user community by, *inter alia*, serving as the focal point for the international exchange of information related to GNSS activities;

- To better address future user needs in the GNSS development plans and applications.

546. The international committee would have the following primary objectives:

- To optimise the benefits of GNSS and their augmentations through co-operation of its members in mission planning and in the development of compatible services, applications and policies;

- To assist its members and the international user community by, *inter alia*, serving as the focal point for international information exchange related to GNSS activities;

- To exchange policy and technical information among current and future operators of GNSS and their augmentations to encourage complementarity and compatibility of their systems;

- To respond to current and future user needs, particularly in developing countries, and to promote GNSS applications;

- To identify mechanisms for implementing measures to protect the reliability and integrity of signals at the national, regional and global levels; and

- To assist national and regional authorities, particularly in developing countries, with the integration of GNSS services into their civil, commercial, and governmental infrastructures, as well as to monitor and protect the integrity of GNSS signals at the national and regional levels.

547. The membership of the international committee could be composed of national or international entities responsible for GNSS and their implementations.

a) International organizations and associations dealing with global GNSS service and applications – United Nations Office for Outer Space Affairs, International GPS Service, ICAO, IMO, IAIN, CGSIC and ITU.

- Developing countries may be invited to derive benefits from the establishment of the international committee to introduce services relevant to their needs in a cost-effective manner.

- There is a need to evolve compatible technical standards and users equipment among different users of GNSS worldwide.

548. In order to disseminate information about the formation of the international committee and to benefit from this Board, there is a need to organize regional workshops through the Office

for Outer Space Affairs, development of user information centres and web sites, and to take up projects such as AFREF, ITRF, EUPOS, SIRGAS and similar projects to achieve such objectives.

Members and observers [b, c]

549. National or international entities that are responsible for GNSS and their augmentations or are involved in promoting GNSS services and applications and that are eligible for membership or observer status in the committee are:

- GNSS system providers: GPS (United States), GLONASS (Russian Federation) and GALILEO (European Union);

- GNSS augmentation system providers: GAGAN (India), EGNOS (European Union), WAAS (United States) and MSAS (Japan) and other compatible systems; and

- International organizations and associations dealing with global GNSS service and applications may participate as members or observers. Potential members or observers[d] could include the Office for Outer Space Affairs, the International Civil Aviation Organization, the International Maritime Organization, the International Telecommunication Union, the Civil GPS Service Interface Committee, the International Association of Geodesy, the International Association of Institutes of Navigation, the International Cartographic Association, the International GPS Service, the International Society for Photogrammetry and Remote Sensing and the International Federation of Surveyors.

550. The addition of members will be with the consensus of current members of the committee.

Development of user information centres and web sites

551. Each GNSS and/or regional augmentation provider should establish user information centres. The maintenance of a web site would be a major task of these centres. The United Nations, the international committee or another international body should combine all the web sites into a single site to act as a portal for any user of GNSS and/or their augmentations. Such a

---

[b] The terms of reference of the international committee would need to specify the roles of "members" and "observers". While "members" would participate in the decision-making process of the Committee, "observers may not participate in the decision-making and would provide advice when requested, monitor the work of the Committee and report back to their legislative bodies. "Observers" would not be expected to assume the secretariat role, host meetings and provide support to a permanent secretariat that might be established. There should be, however, a meaningful role for "observers". The definitions of "members" and "observers" should be further examined, taking into account the experience of other international bodies, such as the Committee on Earth Observation Satellites.

[c] Consideration could be given to establishing a "Providers' Board" within the Committee, to take decisions among system providers.

[d] Regional co-ordination bodies, if any, could be included as observers.

portal could become part of the web site of the Office for Outer Space Affairs, to be maintained by the Office in co-operation with the international committee.

B. Recommendations regarding institutional framework addressed to the United Nations Office for Outer Space Affairs

Institutional models and capacity-building

Recommendation 1. The United Nations should continue to hold regional workshops.

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

Recommendation 2. Support should be given for the establishment of national (and perhaps even regional) GNSS planning and co-ordination groups.

553. Appropriate organizational models and best practices should also be provided.

Recommendation 3. An assessment of current institutional models should be commissioned.

554. Assess international co-operation and co-ordination, and identify those models with potential applicability to evolving GNSS systems and services. Careful consideration should be given to flexible, informal mechanisms and existing organizations that already attempt to provide informational services for GNSS users.

555. There is loose organization at the national level with regard to provider-user co-ordination and no single organization that assumes end-to-end responsibility for GNSS. Applications are often fragmented and developments are underfunded. There is a lack of knowledge and understanding at high decision-making levels on how to utilise the new technology and incorporate appropriate processes at the organizational level. Clearly, there is a need to improve communications between service providers and decision-makers to demonstrate the cost-effectiveness of GNSS technology by showing examples of applications and solutions to problems.

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

Recommendation 4. Support should be provided for capacity building for GNSS education and training.

557. The regional conferences have identified the fact 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, researchers and scientists through theory, research, field exercises and pilot projects;
- The regional centres for space science and technology education, affiliated with the United Nations, should consider including GNSS programs in their training activities; and
- Train the final users in the multiple GNSS applications to create a critical mass of trained personnel at the regional and national levels.

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

559. The national, regional and international symposia and other events on development and application of modern space technologies organised by national, regional and international associations and organizations could be considered as a way for increasing the awareness and qualification to be supported by the United Nations (for example, the annual symposium in Sofia, Bulgaria).

Recommendation 5. Help should be given in promoting the use of GNSS.

560. The Reports of the United Nations/United States of America regional workshops on GNSS (A/AC.105/771, A/AC.105/776, A/AC.105/785 and Corr.1 and A/AC.105/795) should be distributed, through official United Nations channels, in particular to Governments of developing countries. This would assist in promoting GNSS applications.

C. Recommendations specific to GNSS applications

Aviation

561. ICAO and its Planning and Implementation Regional Groups (PIRGs) continue to develop necessary provisions and implementation efforts that could support seamless GNSS guidance for all phases of flight and facilitate transition to satellite-based sole navigation service, with due consideration of safety of flight, technical, operational and economic factors.

562. Air navigation service providers are encouraged to move rapidly, in co-ordination with airspace users, with a view to achieving, as soon as possible, worldwide navigation capability to at least approach with vertical guidance (APV) performance. States and airspace users take note of the available and upcoming SBAS navigation services providing for APV operations and take necessary steps towards installation and certification of SBAS capable avionics.

563. States that develop and introduce satellite-based augmentation systems and other SBAS service providers are encouraged to provide their technical and financial support and participation in the activities leading to the extension of their SBAS service areas into neighbouring States and regions. States participating in SBAS implementation activities co-ordinate with other participating States to optimize their effort, minimize duplication of service and facilitate participation of service providers.

Recommendation 1. Research should be encouraged into the development of ionospheric models, including measurements related to GNSS, as also the exchange of related information.

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

565. The ionosphere behaviour near the geomagnetic equator interferes on GNSS (GPS) signal and prevents some specific requirements (parameters) of aeronautical activities in terms of integrity, continuity, availability and accuracy.

Recommendation 2. The feasibility of implementing a "One African Sky" concept in the upper en-route similar to the "Single European Sky" initiative currently under way in Europe should be considered.

566. Consider the implementation of a "One African Sky" concept in the upper en route similar to the "Single European Sky" initiative currently underway in Europe.

567. Successful implementation of GNSS in other parts of the world shows that utilisation of this technology and receipt of associated benefits will require regionally co-ordinated efforts and committed participation of States in order to fully exploit the technology. In addition to safety enhancements, it must also allow for the expansion of air travel and resulting expansion of the African economies.

Recommendation 3. The Office for Outer Space Affairs and ICAO should continue to encourage adoption of GNSS in support of civil aviation operations.

Surveying, mapping and Earth science

Recommendation 1. A continental reference for Africa, or African reference frame, consistent with the International Terrestrial Reference Frame, should be established.

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

569. A uniform co-ordinate reference system is fundamental to any project, application, service or product that requires some form of georeferencing. Many developing countries, and particularly the African countries, would greatly benefit from a modern GNSS-based reference system that could be used for national surveying, mapping, photogrammetry, remote sensing, Spatial Data Infrastructure (SDI), Geographical Information Systems (GIS), development programs, and hazard mitigation (studies and monitoring of earthquake, fault motion, volcano and severe storms). Many existing national co-ordinate 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 with common goals and objectives throughout Africa, and with the commitment of African countries 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 successful utilization of GNSS.

Recommendation 2. The development of integrated DGNSS "full-scale accuracy" infrastructure with well-defined unified standards at regional levels, i.e. the European Position Determination System (EUPOS) in Europe should be expanded.

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

571. A subject of further discussions within the framework of United Nations/United States of America regional workshops on GNSS could be the problems on the multi-functional DGNSS applications in Central and Eastern Europe. For example, EUPOS and its development for all of Europe and eventually as an element of GALILEO and EGNOS. Similar DGNSS systems could be developed for other regions in the world.

Recommendation 3. The density of the Continuous Operating Reference Station (CORS) should be increased for the areas of the Geocentric Reference System for the Americas (SIRGAS) of Latin America and the Caribbean in order to promote the use of GNSS and CORS (covering all of the Americas).

572. 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

573. Other recommendations in the area of surveying, mapping and Earth sciences include: (a) the development of Spatial Data Infrastructure (SDI) based on a consistent geodetic reference frame enabled by GNSS and other space techniques; (b) the monitoring of GNSS frequencies for interference at local and national levels; and (c) the development of accurate geoid models.

Management of natural resources, environment and disasters

574. 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 those areas is expected to increase, as seen from the four United Nations/United States of America regional workshops on GNSS. Other sources of funding should be explored to implement the establishment of a global information exchange network related to precision agriculture and GNSS applications in the management of the environment and natural disasters. Many suggestions and recommendations were made in those areas at all four regional workshops. The significance of GNSS in the area of disaster preparedness and management was particularly highlighted.

575. Management of the environment and natural disasters is of major concern in Africa and other parts of the world. However, the plight of the African region is such that the following two initiatives recommended below have been selected for priority attention on the part of the international community:

Recommendation 1. Demonstration projects should be set up in the area of agriculture and health to convince and attract the attention of government policy and decision makers in Africa.

576. Agriculture is the mainstay of the economies of most African countries. 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).

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

577. This will enhance understanding of the spread of killer epidemics such as the acquired immune deficiency syndrome (AIDS) and malaria prevalent in Africa. Governments could appreciate and consider the impact the technology of GNSS could have in enhancing health resources management and disease control.

Transportation

578. The Working Group on Transportation during the United Nations/United States of America International Workshop on the Use and Applications of Global Navigation Satellite Systems, held from 8 to 12 December 2003, Vienna, after having reviewed the survey report and the recommendations of the previous regional workshops and the expert meeting, recommended the following proposals aimed at promoting the appreciation of the potential socio-economic benefits of GNSS technology application in the area of transportation and timing.

579. The recommendations in the various segments of the transport industry are as follows:

Recommendation 1: Aviation

580. The Working Group on Transportation noted that the activities of international civil aviation organizations such as ICAO, IATA, FAA, US-DOT, APEC, and ASECNA had tremendously accelerated the adoption of GNSS (RNAV) technology in industry. A close collaborative relationship with ICAO was recommended in other to exploit and optimise resources for skills and capacity building, particularly for Air Traffic Controllers and Air Traffic Managers.

581. In line with the need to facilitate the concept of "One Africa Sky" initiative, the Office for Outer Space Affairs, in collaboration with ICAO and IATA, should convene a conference with all chief executives of the aviation industry in Africa to deliberate and strategize on the implementation modalities and requirements.

Recommendation 2: Road and Rail Transport

582. Vehicle tracking and fleet management system were identified as an application area where practical benefits of GNSS technology could be easily demonstrated and appreciated, particularly in developing countries where road transport systems have remained the backbone of mass movement and the haulage industry. The potential large market for the GNSS industry in this segment would justify the need to build an enabling infrastructure, as an awareness tool and also as an important marketing tool for the would-be service providers.

583. The need to develop the rail systems for sustainable transport has remained a key issue in developing countries. Consequently, the road and rail corridor digital mapping of the proposed Pan-African highway and intelligent transport system for Eastern Europe are recommended as a key pilot project for consideration, as outlined below.

Recommendation 3: Marine Transport

584. It was noted by the Working Group that relatively few GNSS application-related activities were reported in this sector, although it remains one of the early adopter of GNSS technology. The enhancement of night voyage has enabled GNSS technology to constitute a major contribution to the marine industry.

585. The need and importance of developing inland waterways and the international marine industry, both for goods and human transport, cannot be over-emphasised. Consequently, a pilot project related to the subject was proposed for Latin America and Asia for consideration.

586. Project Recommendations

Project 1:

- Promote the awareness of potential benefits with respect to GNSS applications for all modes of transportation to administrations and decision makers.

  Objectives:

- Assist decision makers to fully understand the multifold benefits and advantages of early implementation of GNSS technology, which could increase awareness of the many benefits of satellite navigation.

  Potential Impacts:

- Increase in the level of awareness of GNSS benefits at the policy level, and hence attraction of Member States for further investments in the area of GNSS and related areas.

Strategies:

Implementation Plan	Responsible Party	Time Frame
1. Introduction of documents to the decision-makers	United Nations, Member States, Service Providers	2004
Nature of the materials: Multimedia products in official languages of the United Nations	United Nations, Member States, Service Providers	
Sources of materials	Members of the Transportation Working Group, Service Providers	
Preparation of materials	Producers, Publishers	
Distribution of the materials	OOSA, National GCUBs Groups	
▪ Four Regional Workshops, conferences, seminars. ▪ Latin America [*] ▪ Africa ▪ Asia-Pacific ▪ Eastern Europe	United Nations, Member States, Service Providers	2004-2005
2. Initiate the establishment of national GCUB groups and support their activities	Member States	2004
▪ Define terms of reference	Member States	
▪ Identify team leader	Member States	
3. Initiate the establishment of regional GCUB groups and support their activities	Member States / United Nations	2005
▪ Define terms of reference	Member States / United Nations	
▪ Identify team leader	Member States / United Nations	

587. Possible funding sources and budget: United Nations, service providers, manufacturers, US - TDA, European Commission, ESA, Member States, the World Bank, Regional Development Banks, CIDA and JICA and others (US Dollars).

588. Informational brochure/package: $30,000
Multi-media: ten-minute video: $40,000

Technical exhibit: $30,000

Seed fund for establishing the national/regional groups: $100,000
Total: *$200,000*

---

[*] In the framework of the Fourth CEA (Americas Space Conference) to develop a Workshop in Colombia in 2004. National Space Research and Development Agency of Nigeria (NASRDA) in collaboration with other United Nations regional centres could oversee the organization on the implementation of the workshop activities. ISRO has indicated its readiness to host the seminar for the Asian region.

589. Project 2:

Pilot Projects (4 projects):

590. The following pilot projects are recommended for funding assistance. The scope of assistance required have to do first with a feasibility study which would be a requisite tool to access key financial institutions for pilot project financing. The two projects recommended are:

1. Intelligent Transportation System – for African and Eastern Europe Region:
   - Africa: Digital mapping of the Pan-African highway (road and rail)
   - Vehicle tracking and management system.

2. Inland waterway marine transportation system – for the Americas and Asia and the Pacific Region.

   Objectives:

- Cost-benefit analysis data concerning the benefits of GNSS for increasing safety, developing the economy or generally improving the transport infrastructure should be provided;
- Demonstrate the real and potential benefits of the applications of GNSS in the transportation sector;
- Support Member States to establish enabling-infrastructure for GNSS applications in the transportation sector; and
- Support Member States to access funding assistance for project implementation.

Potential Impacts:

- Fleet management system would provide a large market-based for the haulage industry and common transport establishment;
- Establishment of enabling-infrastructure for GNSS applications in the transportation sector would be in place; and
- Motivation of service manufacturers and enlargement of user communities.

Strategies:

Implementation Plan	Responsible Party	Time Frame
1. Project feasibility study	United Nations, International Institutions, Service Providers, Industries	2004
2. Pilot project implementation	Member States	2006

591. Possible funding sources and Budget: United Nations, service providers, manufacturers, US - TDA, European Commission, ESA, Member States, World Bank, Regional Development Banks, others.

592. Cost estimates (US Dollars):

Feasibility study ($20,000x4 regions):	$80,000.00
Pilot project implementation ($250,000x4 regions):	$1,000,000
Total:	*$1,080,000.00*

Conclusion

593. These recommendations were selected among a large number of proposals and recommendations made at the four United Nations/United States of America regional workshops and the two international meetings 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 (see A/AC.105/771, A/AC.105/776, A/AC.105/785 and Corr.1 and A/AC.105/795 and the meetings (A/AC.105/801 and A/AC.105/821).

Annex I: Indian universities, research institutes and companies			
University/research institute/company	**Name**	**Address**	**Telephone/ Fax**
ISRO HQ	Dr. S.V. Kibe SBAS, System Studies	Antariksh Bhavan, New BEL Road, Bangalore, 560 094 India	+91 80 341 5281/ +91 80 341 2141
ISRO Satellite Centre	Dr.Surendra Pal/KNSRao SBAS,System Studies	Vimanapura Post Bangalore, 560 017 India	+91 80 526 6588- +91 80 508 3306/ +91 80 508 3303
Space Applications Centre	K. Bandyopadhyay P/L,iono-models, System Studies	SAC P.O Ahmedabad, 380 053 India	+91 79 2691 2326/ +91 79 2676 5824
ISRO Telemetry Tracking & Command Network	P. Soma SBAS MCC, System Studies	A 1-6, Peenya Indl. Estate, Bangalore, 560 058 India	+91 80 837 6313/ +91 80 809 4203
Airports Authority of India	P. Ramalingam/ SH Khan CNS/ATM	Rajiv Gandhi Bhavan Rajiv Gandhi Marg 110 003 New Delhi	+91 11 2462 8818 +91 11 2461 8279/ +91 11 24610 847 +91 11 24611134
Civil Aviation Training College	B.R. Chaturvedi CNS/ATM	Allahabad, UP, India	+91 532 2580 435/ +91 532 2580 441
National Aeronautics Laboratories	Director,Research & Training	Airport Road Bangalore, 560 017 India	+91 80 526 0584/ +91 80 526 0862
NERTU	Dr. A.D. Sarma Research & Training	Osmania University Hyderabad, 500 007 India	+91 40 2709 8066 (Tel only)
HAL	S.K. Rawal	Hyderabad, India	+91 40 2387 9570 (Fax only)
IISc	Prof. Mahapatra Research & Training	Dept. of Aeronautics C V Raman Avenue Bangalore, 560 080 India	+91 80 309 2417/ +91 80 360 0134
ECIL	Mr Hon	Hyderabad, 500 062 India	+91 40 2712 3423/ +91 40 2712 1272
Accord Software & Systems Pvt. Ltd	Managing Director	37, Krishna Reddy Colony, Domlur, Bangalore, 560 071 India	+91 80 535 0105/ +91 80 535 2753
Aerospace Systems Ltd	Rear Admiral (Retd.) J.J. Baxi	‘Pragathi’, 70/1, Miller Road, Bangalore, 560 052, India	+91 80 225 7973/ +91 80 220 3350

Annex II: German universities, research institutes and companies			
University/ research institute/company	**Name**	**Address**	**Telephone**
TU Braunschweig Institut für Flugführung	Prof. Schänzer	Hans-Sommer-Str. 66 38106 Braunschweig	0531-391-3716 0531-391-5954
TU Braunschweig Institut für Regelungs- und Automatisierungstechnik	Prof. Schnieder	Langer Kamp 8 38106 Braunschweig	0531-391-3317
TU Dresden Geodätisches Institut	Prof. Augath	Mommsenstraße 13 01069 Dresden	0351-463-4249
TU Dresden Institut für Automatisierungstechnik	Prof. Janschek	G.-Schumann-Str. 11 01062 Dresden	0351-463-4025
TU Dresden Institut für Nachrichtentechnik	Prof. Finger	01062 Dresden	0351 463 3815
TU München Fachgebiet Raumfahrttechnik	Prof. Igenbergs	Boltzmannstr. 15 85748 Garching	089-289-16003
TU München Institut für Landtechnik	Prof. Auernhammer	Vöttinger Str. 36 85350 Freising	
Universität der Bundeswehr München Institut für Erdmessung und Navigation	Prof. Hein	Werner-Heisenberg-Weg 39 85777 Neubiberg	089-6004-3425
Universität der Bundeswehr München Institut für Erdmessung und Navigation	Prof. Eissfeller	Werner-Heisenberg-Weg 39 85777 Neubiberg	089-6004-3425
Universität Stuttgart Institut für Navigation	Prof. Kleusberg	Keplerstr. 11 70174 Stuttgart	
Universität Stuttgart Institut für Navigation	Dr. Thiel	Keplerstr. 11 70174 Stuttgart	
German Aerospace Centre Institute for Communication and Navigation	Prof. Schroth	Oberpfaffenhofen 82234 Weßling	08153-28-2325
ASTRIUM GmbH	Bornemann	81663 München	+49 89-607-2 4303

Annex II: German universities, research institutes and companies			
University/ research institute/company	**Name**	**Address**	**Telephone**
THALES ATM	Ernesti	Robert-Bosch-Str. 25 63225 Langen	+49 6103-9116-250
Socratec GmbH	Fraile-Ordonez	Maxhütter Str. 16 93158 Teublitz	+49 9471-3100-207
ViCon Engineering GmbH	Niklasch	Senftenauer Str. 95 80689 München	+49 89-7409432
Geo Forschungszentrum Potsdam	Reigber	Telegrafenberg A 17 14473 Potsdam	+49 331-288-1100
Telematica	Lechner	Baiernrainer Weg 6 83623 Linden	+49 8027-931-0
Vega Space System Engineering GmbH	Lewis	Julius-Reiber-Str. 19 64293 Darmstadt	+49 6151-8257-0
Krupp Timtec Telematik GmbH	Tombült	Heinrichstr. 51 44536 Lünen	+ 49 231-9860-211
DFS German Air Traffic Service Provider	Naerlich	Am DFS Campus 10 63225 Langen	+49 69-8054-2210
Kayser-Threde GmbH	Griethe	Wolfratshauser Str. 48 81379 München	
Aerodata Flugmeßtechnik GmbH	Vörsmann	Hermann-Blenk-Str. 36 38108 Braunschweig	
VCS GmbH	Leibnitz	Borgmannstr. 2 44894 Bochum	+49 234-92580
OHB GmbH	Fuchs	Karl-Ferdinand-Str 8 28359 Bremen	+49 421 2020 8
TERMA	Eberlei	Brunnenweg 19 64331 Weiterstadt	+49 6150 1059 0
AUDENS ACT	Schweickert	Postfach 1110 82224 Seefeld	+49 8153-916 700

Annex II: German universities, research institutes and companies			
University/ research institute/company	**Name**	**Address**	**Telephone**
IFEN	Pielmeier	Alte Gruber Str. 6 85586 Poing	+49 8121 2238 18
EUROTELEMATIK AG	Stich	Riedweg 5 89081 Ulm	+49 731 93697 0

Annex III: Italian universities and research institutes			
University/research institute	**Name**	**Location**	**E-mail**
CIRA	Prof. Filippone Edoardo	Capua	e.filippone@cira.it
CNR	Prof. Biorci Giuseppe		g.biorci@dcrire.cur.it
Istituto Elettrotecnico Nazionale "Galileo Ferraris"	Prof. Tavella Patrizia	Torino	tavella@tf.ien.it
Istituto Universitario Navale di Napoli	Prof. Vultaggio Mario	Napoli	Mario.vultaggio@uninav.it
Politecnico di Milano	Prof. Colaneri Patrizio	Milano	colaneri@elet.polimi.it
Politecnico di Torino	Prof. Dovis Fabio	Torino	Fabio.dovis@polito.it
Univ. Genova	Prof. Gera Gianluca	Genova	Gera@dibe.unige.it
Univ. Roma 3	Prof. Neri Alessandro	Roma	neri@uniroma3.it
Università degli Studi di Cagliari	Prof. Sanna Giovanna Maria	Cagliari	topoca@unica.it
Università degli Studi di Ferrara	Prof. Gatti Marco	Ferrara	mgatti@ing.unife.it
Universita' degli studi di Genova	Prof. Regazzoni Carlo	Genova	carlo@dibe.unige.it
Università degli Studi di Roma "La Sapienza"	Prof. Palmerini Giovanni B.	Roma	giovanni.palmerini@uniroma1.it
Università di Firenze	Prof. Calamia Mario	Firenze	calamia@ingfi1.ing.unifi.it
Universita' di Padova	Prof. Frezza Ruggero	Padova	frezza@dei.unipd.it
Università di Roma "La Sapienza"	Prof. De Matteis Guido	Roma	dematteis@dma.ing.uniroma1.it

Annex III: Italian universities and research institutes			
University/research institute	**Name**	**Location**	**E-mail**
Università di Tor Vergata	Prof. Sebastiani Mario	Roma	sebastiani@economia.uniroma2.it

Annex IV: Italian non-governmental entities		
Entity	**Name**	**E-mail**
ACS	Giuliano Crocelli	g.crocelli@acsys.it
AIR SYSTEMS	Michelangelo Serra	info@airsystems.it
ALENIA MARCONI SYSTEMS	Manlio Fiore	mfiore@amsjv.it
ALENIA MARCONI SYSTEMS	Marco Vittorio	mvittorio@amsjv.it
ALENIA SPAZIO	Sergio Greco	s.greco@rmmail.alespazio.it
ALENIA SPAZIO	Luigi Longoni	l.longoni@rmmail.alespazio.it
Antenna system design	Maurizio Lori	mlori_asd@yahoo.it
ARCHIMEDES	Luca Novelli	lnovelli@archimedes.it
CALZONI SPA	Luca Branca	lbranca@calzonispa.com
CARLO GAVAZZI SPACE	Roberto Aceti	raceti@cgspace.it
CARSO	Paolo Trampus	carso@sci.area.trieste.it
Centro Ricerche Fiat	Luigi Gortan	l.gortan@crf.it
CiaoLab	Angelo Ramolini	Angelo.ramolini@ciaolab.com
CIRA	Gennaro Russo	g.russo@cira.it
D'Appollonia	Andrea Barbagelata	Andrea.barbagelata@dappolonia.it
DATAMAT	Claudio De Bellis	debellis@datamat.it
DATASPAZIO	Paolo Gaburro	paolo.gaburro@dataspazio.it
EIS	Lero Trionfetti	l.trionfetti@eis.it
Elettronica	Cristina Von Beckh	Cristina.vonbeckh@elt.it
ELSACOM	Antonio Bove	bove.antonio@elsacom.com
ERICSSON	Massimo De Sanctis	massimo.desanctis@tei.ericsson.se
FABER srl	Massimo MENDIA	faberambiente@mclink.it
GALILEO AVIONICA S.p.A. BU Spazio	Ivo Varano	ivo.varano@officine-galileo.finmeccanica.it

Annex IV: Italian non-governmental entities		
Entity	**Name**	**E-mail**
IDS	Franco Bardelli	idspisa@ids-spa.it
IMI srl	Giorgio Perrotta	giorgio.intsrl@iol.it
IMT	Massimo Perelli	imtsrl@iol.it
INFO SOLUTION	Gaetano Moschetto	g.moschetto@infosol.it
Information Technologies Services ITS	Armando Orlandi	aorlandi@intese.com
INFORMATION TECHNOLOGY SERVICES S.p.A.	Pietro ALTIERI	paltieri@its.na.it
INTECS HRT	Marco Casucci	casucci@pisa.intecs.it
INTECS SISTEMI SpA	Massimo Micangeli	micangeli@Roma.intecs.it
INTERBUSINESS	Piergiorgio Gabriele	datalink@interbusiness.it
KAISER Italia	Valfredo Zolesi	v.zolesi@kayser.it
KELL	Fabrizio Aversa	faversa@kell.it
LABEN	Andrea Sacchetti	Sacchetti.a@laben.it
LEAT	Franco Galasso	f.galasso@leat.it
MAB ELETTRONICA	Maria Pia Nusiner	mabelet@tin.it
MARCONI Mobile SpA	Ernesto De Pieri	ernesto.depieri@marconi.com
Newlog Consulting	Romualdo Gobbo	Romualdo.gobbo@newlog.it
NEXT	Gianfranco Corini	gianfranco.corini@next.it
NOVOTECH Advanced Aerospace Technology s.r.l.	Prof. Ing. Francesco Marulo	marulo@unina.it
OERLIKON CONTRAVES	Carlo Tuninetti	c.tuninetti@oci.it
OPENET TECHNOLOGIES	Filomena Cuccarese	cuccarese@openet.it
PLANETEK	Giovanni Sylos Labini	sylos@planetek.it

Annex IV: Italian non-governmental entities		
Entity	**Name**	**E-mail**
RDLABS	Giovanni Pulcinella	RDLABS2002@libero.it
Resesarch Systems Italia	Alberto Meroni	alberto@rsinc.com
S.E.S.A.	Gennaro De Stasio	gdestasio@sesaspa.it
SATIMO	Gianni Barone	gbarone@satimo.com
SCE	Marco Isernia	marco.isernia@sce-group.it
SELESO	Luca Mangione	l.mangione@seleso.com
SERFINTEC s.r.l.	Dott.ssa Simonetta De Gregorio	serfintec@tin.it
SIA	Enrico Giordani	giordani@sia-av.it
SIRIO		carlo_narcisi@elemida.com
SKYDATA	Manuela Lamattina	segreteria@skydata.it
Società Italiana Avionica	Lorenzo Masera	masera@sia-av.it
Space Engineering	Luca Cellai	cellai@space.it
Space Software Italia	Sabino Cacucci	cacucci@ssi.it
Space Software Italia	Giovanni Macchia	macchia@ssi.it
Space to Earth Technology Srl	Marco Nardi	m.nardi@spacetoearth.com
TECHSEMA	Fabrizio Gardini	techsema@stele.it
TELEDATA - Bolzano	Johannes Zilger	teledata.gmbh-srl@eudoramail.com
Telematic solution	Stefania File	telematics@telematics.it
Telespazio	Stefano Carlini	stefano_carlini@telespazio.it
Thales ATM	Nicola Tacchio	Nicola.Tacchio@alcatel.it
Thales Communication	Mauro Montanari	mauro.montanari@it.thalesgroup.com

Annex IV: Italian non-governmental entities		
Entity	**Name**	**E-mail**
VITROCISET	Riccardo Grazi	riccardo.grazi@vitrociset.it antonella.arezzo@vitrociset.it

APPENDIX

List of web sites and resource documents.

References:

Fejes I. (2002): Consortium for Central European GPS Geodynamic Reference Network (CEGRN Consortium). Concept, Objectives and Organization. in: *Proc. 27th General Assembly of the European Geophysical Society, Symposium G10*, Reports on Geodesy 1(61) (in press)

Sledzinski J. (2001): Satellite Navigation Systems in geodetic and geodynamic programmes initiated and co-ordinated by the CEI (Central European Initiative). Results and achievements of the long-term international co-operation of 17 countries. *2nd UN/USA Regional Workshop on the Use of Global Navigation Satellite Systems,* Vienna, Austria, 26-30 November 2001

Grenerczy Gy., Kenyeres A., Fejes I. (2000): Present crustal movement and strain distribution in Central Europe inferred from GPS measurements, *Journal of Geophysical Research*, Vol. 105, No. B9, 21835

United Nations Office for Outer Space Affairs
PO Box 500, 1400 Vienna, Austria
Tel: +(43) (1) 26060-4950, Fax: +(43) (1) 26060-5830
E-mail: oosa@unvienna.org
Website: www.oosa.org