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Committee on the Peaceful Uses of Outer Space
Scientific and Technical Subcommittee
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Item 9 of the draft provisional agenda*
Recent developments in global navigation satellite systems

Report on training courses on global navigation satellite systems held at the United Nations affiliated regional centres for space science and technology education in 2008 through 2010

Section 1 — UNISPACE III and the recommendations of the Action Team on global navigation satellite systems

The Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE III) adopted a strategy to address global challenges in the future through space activities. The strategy, contained in "The Space Millennium: Vienna Declaration on Space and Human Development",[1] included key actions to use space applications for human security, development and welfare. One such action 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. The use of the signal from global navigation satellite systems (GNSS) constitutes one of the most promising space applications that can be used to implement this action.

In 2001, Member States accorded high priority to a limited number of selected recommendations of UNISPACE III. The Committee on the Peaceful Uses of Outer Space established action teams under the voluntary leadership of Member States to implement those priority recommendations. The Action Team on GNSS was

* A/AC.105/C.1/L.306.

[1] Report of the Third United Nations Conference on the Exploration and Peaceful Uses of Outer Space, Vienna, 19-30 July 1999 (United Nations publication, Sales No. E.00.I.3), chap. I, resolution 1.

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established under the leadership of the United States of America and Italy to carry out the recommendation relating to GNSS.

The work of the Action Team on GNSS included comprehensive reviews of existing and planned GNSS and augmentations, their applications by system provider and user communities, as well as activities carried out by various entities to promote GNSS. The Action Team also examined the requirements of developing countries and gaps in meeting those requirements, as well as existing education and training opportunities in the field of GNSS.

The Action Team on GNSS, consisting of 38 member States and 15 intergovernmental and non-governmental organizations, recommended, inter alia, that an international committee on GNSS should be established to promote the use of GNSS infrastructure on a global basis and to facilitate exchange of information. The Committee on the Peaceful Uses of Outer Space included this recommendation in the Plan of Action proposed in its report[2] to the General Assembly on the review of the implementation of the recommendations of UNISPACE III. In 2004, in its resolution 59/2, the Assembly endorsed the Plan of Action. In the same resolution, the Assembly invited GNSS and augmentation system providers to consider establishing an international committee on GNSS in order to maximize the benefits of the use and applications of GNSS to support sustainable development.

The work of the Action Team on GNSS serves as a model for how the United Nations can undertake action to follow up on global conferences and yield tangible results within a fixed time frame.

Section 2 — Regional centres for space science and technology education, affiliated to the United Nations as ICG Information Centres

Efforts to build capacity in space science and technology are considered a major focus of the Office for Outer Space Affairs and are of specific interest to ICG. Such efforts should aim to provide support to the regional centres for space science and technology education affiliated with the United Nations, which would also act as ICG information centres; to foster a more structured approach to information exchange in order to fulfil the mutual expectations of a network linking ICG and the regional centres; and to connect the institutions involved or interested in GNSS applications with GNSS system providers. The regional centres for Africa are located in Morocco and Nigeria; for Asia and the Pacific, in India; and for Latin America and the Caribbean, in Brazil and Mexico. Information on the regional centres is available on the website of the Office for Outer Space Affairs (www.unoosa.org).

For developing countries, GNSS applications offer a cost-effective way of pursuing sustainable economic growth while protecting their environment. Satellite navigation and positioning data are now used in a wide range of areas that include mapping and surveying, monitoring of the environment, precision agriculture and natural resources management, disaster warning and emergency response, aviation, maritime and land transportation and research areas such as climate change and ionospheric studies.

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[2] A/59/174.

In its resolution 61/111 of 14 December 2006, the General Assembly noted with appreciation that the International Committee on Global Navigation Satellite Systems (ICG) had been established on a voluntary basis as an informal body to promote cooperation, as appropriate, on matters of mutual interest related to civil satellite-based positioning, navigation, timing and value-added services, as well as the compatibility and interoperability of GNSS, while increasing their use to support sustainable development, particularly in developing countries.

At its fifty-second session, the Committee on the Peaceful Uses of Outer Space noted with appreciation that the regional centres for space science and technology education, affiliated to the United Nations, would serve as ICG information centres.

The successful completion of the work of the ICG, particularly in establishing the interoperability among the global systems, will allow a GNSS user to utilize one instrument to receive signals from multiple systems of satellites. This will provide additional data, particularly in urban and mountainous regions and greater accuracy in timing or position measurements. To benefit from these achievements, GNSS users need to stay abreast of the latest developments in GNSS-related areas and build the capacity to use the GNSS signal.

Section 3 — Training for capacity-building in developing countries

In 2008, an international training course on satellite navigation and location-based services was organized jointly by the Office for Outer Space Affairs and the Regional Centre for Space Science and Technology Education in Asia and the Pacific. Participants were familiarized with relevant technologies to help them to gain an in-depth understanding of how those technologies could be used in an operational scenario. The course was hosted by the Space Applications Centre of Indian Space Research Organization (ISRO), in Ahmedabad, India, from 18 June to 18 July 2008, and was co-sponsored by the Government of the United States through ICG.

In 2009, the Office for Outer Space Affairs supported training courses on GNSS held at the African Regional Centre for Space Science and Technology — in French language, in Rabat, from 28 September to 24 October 2009, and at the Regional Centre for Space Science and Technology Education for Latin America and the Caribbean in Tonantzintla, Mexico, from 16 to 20 November 2009. Through ICG, the training courses also received support from the Government of the United States and the European Space Agency (ESA).

In 2010, the training course on global navigation satellite systems and location based services organized by the African Regional Centre for Space Science and Technology Education in English from 4 to 29 October 2010 in Ile-Ife, Nigeria, was the last to be organized in all the UN- affiliated regional centres. The training course benefited from and built upon the experiences of the three previous courses on GNSS that were supported by the Office in 2008 and 2009.

These courses were part of the work of the Office to develop an in-depth GNSS curriculum for introduction at all the regional centres and other institutions of higher-level education. The courses also aimed at establishing and strengthening networks in the regions for the exchange of information.

The training courses were modular in format and consisted of a series of lectures and practical experiences. The modules dealt with basic concepts of satellite navigation and applications of satellite navigation with special emphasis on location-based services. The practical exercises dealt with different types of GNSS receivers, both in stand-alone mode and integrated with communications systems, and included computer-based exercises using Matrix Laboratory (MatLab) programme simulation. The training courses reports are available at the ICG information portal (www.icgsecretariat.org).

As a further step in this process, the GNSS curriculum will supplement the proven standard model education curricula of the regional centres, developed through the United Nations Programme on Space Applications and comprising the following core disciplines: remote sensing and geographic information systems, satellite communications, satellite meteorology and global climate, and space and atmospheric sciences.

To begin work on developing a curriculum for a basic course on GNSS, a group of educators and experts on GNSS was established. In that regard, the Office for Outer Space Affairs collected information on relevant GNSS curricula taught in selected universities that have a long tradition in both GNSS technology and its applications and in the development of materials designed to teach basic principles and concepts of communications and navigation. Such information would used as background material and made available to the regional centres for space science and technology education, affiliated to the United Nations. Web-based distance learning programmes had been taken into consideration as being vital for a variety of user levels.

The expert group would work by electronic means and by meeting around ICG and its GNSS programme activities during the course of 2011 with a view to concluding an educational curriculum on GNSS.

The first draft curriculum had been structured by the centre for space science and technology education in Asia and the Pacific (CSSTEAP) to meet effectively work market demands for high-level technicians endowed with a broad vision on the navigation/localization state-of-the-art but also with specific skills. The duration of the proposed course would be 10 weeks consisting of 150 hours of theory (lectures and tutorials) and of 150 hours of laboratory experiments, field visits, project work and seminars. The topics covered in the modules and duration are shown in attachment 1. The course prerequisite is graduate in Electronics and Communications Engineering.

The attached GNSS glossary (attachment 2) has been produced as a direct response to the needs of GNSS user community in the framework of the ICG Providers' Forum workplan. The purpose of this glossary of terms is to provide definitions of terms as they are used in the context of the United Nations General Assembly (UNGA) documentation in the A/AC.105/ series on the meetings of the ICG that had been held since 2005. Some of the definitions were arrived after considerable debate within the ICG Providers' Forum membership, and some continue to be debated. Therefore, it is intended to be read in conjunction with the ICG documents, which are available in all official languages of the United Nations and can be downloaded from the ICG information portal at www.icgsecretariat.org

Annex 1

Modules for the curriculum on global navigation satellite systems

Module	*Topic*	*Duration in hours*
I:	Introduction	5
	Overview of GNSS	
	Frequency Spectrum	
	Comparison of GNSS with other navigation systems	
II:	Basic techniques of communications and navigation	60
	Coordinate system	
	Orbital Parameters	
	Determination of satellite position	
	Time Synchronization and Time transfer	
	Position determination techniques	
	Satellite constellation and Dilution of precision due to satellite geometry, bounds on DOP, GDOP, HDOP, VDOP, PDOP, TDOP	
	Modulation: and multiple access	
	Channel error correction: Basics of channel error detection and error correction techniques in satellite communication channels	
	Propagation	
	Interference	
III:	Technologies: GNSS primary systems	20
	Global systems: GPS, GLONASS, Galileo, Compass etc.	
	Regional systems	
IV:	Technologies: Augmented systems	20
	Errors in GNSS: fundamental error equation, effect of GDOP, six classes of ranging errors	
	Effects of errors: error apportionment and error tables, user equivalent range error, position accuracy with one sigma and three sigma errors	
	Error mitigation techniques: RTK, differential GPS, local area DGPS, wide area DGPS,	
	Error augmented systems: WAAS, EGNOS, GAGAN etc.	
V:	Receivers	30
	Receiver architecture: technology, RF front end, signal processing system hardware and software techniques,	
	Software defined radio	
	Signal tracking: maximum likelihood estimate of delay and position, Delay lock tracking of signal, coherent and non coherent delay lock tracking of pseudo noise sequences, mean square error estimation, vector DLL, receiver noise performance, maximum likelihood estimate, early late gating	

Module	*Topic*	*Duration in hours*
	Navigation algorithm: measurement of pseudo range, Doppler, decoding and using of navigation data, single point solution, dynamics of user, Kalman filter and other alternatives	
VI:	Applications	15
	Navigation: Primary applications	
	Navigation and communication: Integrated application	
	Communication, Navigation and Surveillance: Integrated application	
	Revenue model for value added services	
VII:	Laboratory experiments, field visits, project work	150
	Basics of MATLAB	
	GNSS receivers	
	GNSS data and coordinate conversion	
	Experiment with DGPS	
	Experiment with RTK receivers	
	Experiment to demonstrate accuracy improvement using SBAS	
	Design Aspects of Software for Integrating Location Based Services with Position	
	Design of Application: Combining Satellite Navigation with Satellite Communication: Fleet monitoring	
	Design of Application: Combining Satellite Navigation with Satellite Communication: Disaster management	
	Design of Computer Simulated Receiver based on Software Defined Radio	

Annex 2

Glossary of GNSS terms and definitions

Accuracy — A measure of how close an estimate of a satellite position is to the true location. Accuracy is the degree of conformance between the estimated or measured position and/or velocity of a platform at a given time and its true position or velocity. Radionavigation system accuracy is usually presented as a statistical measure of system error and is specified as:

- Predictable — The accuracy of a radionavigation system's position solution with respect to the charted solution. Both the position solution and the chart must be based upon the same geodetic datum
- Repeatable — The accuracy with which a user can return to a position whose coordinates have been measured at a previous time with the same navigation system.
- Relative — The accuracy with which a user can measure position relative to that of another user of the same navigation system at the same time.

Acquisition Time — The time it takes a satellite receiver to acquire satellite signals and determine the initial position.

Air Traffic Control (ATC) — A service operated by appropriate authority to promote the safe and efficient flow of air traffic.

Almanac — Coarse satellite orbital data used to calculate satellite position, rise time, elevation, and azimuth.

Ambiguity — The unknown integer number of cycles of the reconstructed carrier phase contained in an unbroken set of measurements from a single satellite pass at a single receiver.

Anti-Spoofing — Encryption of the Authorized code to protect the signals from being "spoofed" through the transmission of false signals.

Area Navigation (RNAV) — A method of navigation which permits aircraft operation on any desired flight path within the coverage of station referenced navigation aids or within the limits of capability of self-contained aids, or a combination of these.

Atomic Clock — A very precise clock that operates using the elements Cesium or Rubidium.

Availability — The availability of a navigation system is the percentage of time that the services of the system are usable.

Azimuth — A horizontal angle measured clockwise from a direction (such as North).

Bandwidth — A measure of the width of the spectrum of a signal (frequency domain representation of a signal) expressed in hertz.

Baseline — The length of the three-dimensional vector between a pair of stations for which simultaneous GPS data has been collected and processed with differential techniques.

Beacon — A stationary transmitter that emits signals in all directions (also called a nondirectional beacon).

Bearing — Term used in navigation to describe the angle between a reference direction (e.g., geographic north, magnetic north, grid north) and the trajectory.

Beat frequency — Either of the two additional frequencies obtained when signals of two frequencies are mixed.

Binary Phase Shift Key (BPSK) modulation — Phase changes of either 0° or 180° (to represent binary 0 or 1, respectively) on a constant carrier frequency, f.

C/A code — The Coarse/Acquisition GPS code modulated on the GPS L1signal.

Cartesian Coordinates — The coordinates of a point in space given in three mutually perpendicular dimensions (x, y, z) from the origin (Cartesian Coordinate System).

Cartography — The art or technique of making maps or charts.

Carrier — A radio wave having at least one characteristic (e.g., frequency, amplitude, phase) which may be varied from a known reference value by modulation.

Carrier-aided Tracking — A signal processing technique that uses the GNSS carrier signal to achieve an exact lock on the pseudo random code generated by the GNSS satellite.

Carrier phase — The fraction of a cycle, often expressed in degrees, where 360 degrees equals a complete cycle.

Carrier beat phase — The phase of the signal which remains when the incoming Doppler shifted satellite carrier signal is beat (the difference frequency signal is generated) with the nominally constant reference frequency generated in the receiver.

Carrier frequency — The frequency of the un-modulated fundamental output of a radio transmitter. Channel -a channel of a GNSS receiver consists of the circuitry necessary to track the signal from a single GNSS satellite.

Chip — The time interval of either a zero or a one in a binary pulse code.

Chip rate — Number of chips per second (e.g., C/A code: 1.023*106 cycles per second).

Clock Bias — The difference between the indicated clock time in the GNSS receiver and true universal time (or GNSS satellite time).

Clock offset — Constant difference in the time reading of two clocks.

Coarse/Acquisition Code (C/A Code) — The standard positioning signal the GNSS satellite transmits to the civilian user.

Coastal Confluence Zone (CCZ) — Harbour entrance to 50 nautical miles offshore or the edge of the continental shelf (100 fathom curve), whichever is greater.

Code — A system used for communication in which arbitrarily chosen strings of zeros and ones are assigned definite meanings.

Code Division Multiple Access (CDMA) — A method whereby many radio transmitters can use the same frequency, but each transmitter has a unique digital code which is *modulated with the digital information stream*.

Cold Start — The power-on sequence where the GNSS receiver downloads almanac data before establishing a position fix.

Compacted data — Raw data compacted over a specified time interval (compaction time) into one single observable (measurement) for recording.

Common-use Systems — Systems used by both civil and military sectors.

Compatibility — Refers to the ability of space-based positioning, navigation and timing services to be used separately or together without interfering with each individual service or signal:

- Radiofrequency compatibility should involve thorough consideration of detailed technical factors, including effects on receiver noise floor and cross correlation between interfering and desired signals. The International Telecommunication Union provided the framework for discussions on radiofrequency compatibility;
- Compatibility should also involve spectral separation between each system's authorized service signals and other systems' signals.

Compliance — The act adhering to, and demonstrating adherence to, a standard or regulation.

Conformal Projection — A map projection that preserves angles on the ellipsoid after they have been mapped on to the plane.

Constellation — A group of electronic satellites working in concert is a satellite constellation.

Continuity — The continuity of a system is the ability of the total system (comprising all elements necessary to maintain aircraft position within the defined airspace) to perform its function without interruption during the intended operation. More specifically, continuity is the probability that the specified system performance will be maintained for the duration of a phase of operation, presuming that the system was available at the beginning of that phase of operation.

Control segment — Ground-based GNSS equipment operated by the service provider that tracks the satellite signals, determines the orbits of the satellites, and transmits orbit definitions to the memories of the satellites.

CORS — The National Geodetic Survey (NGS), an office of NOAA's National Ocean Service, coordinates a network of continuously operating reference stations (CORS).

Coordinates — A set of numbers that describes your location on or above the earth. Coordinates are typically based on latitude/longitude lines of reference or a global/regional grid projection (e.g., UTM, Maidenhead).

Coordinated Universal Time (UTC) — UTC, an atomic time scale, is the basis for civil time.

Coverage — The coverage provided by a radionavigation system is that surface area or space volume in which the signals are adequate to permit the user to determine position to a specified level of accuracy.

Cutoff angle — The minimum elevation angle below which no more GNSS satellites are tracked by a GNSS receiver to track and compute position.

Cycle slip — A discontinuity of an integer number of cycles in the measured carrier beat phase resulting from a temporary loss of lock of a GNSS satellite signal.

Data message — Also known as Navigation Data. Data transmitted by GNSS satellites, which is used to compute satellite's location and satellite clock corrections.

Datum — A mathematical model which depicts a part of the surface of the earth. latitude and longitude lines on a paper map are referenced to a specific map datum.

dB — Decibel, a logarithmic unit of measurement in acoustics and electronics

Deflection of the vertical — The angle between the normal to the ellipsoid and the vertical (true plumb line).

Delay lock — The technique whereby the received code (generated by the satellite clock) is compared with the internal code (generated by the receiver clock) and the latter shifted in time until the two codes match.

DGPS — Differential GPS. The term commonly used for a GPS system that utilizes differential code corrections to achieve an enhanced positioning accuracy.

Differential — A technique used to improve radionavigation system accuracy by determining positioning error at a known location and subsequently transmitting the determined error, or corrective factors, to users of the same radionavigation system, operating in the same area.

Differenced measurements — Is the instantaneous difference in phase of a received signal, measured across receivers, across satellites and across time.

Differential positioning — Determination of relative coordinates between two or more receivers which are simultaneously tracking the same GNSS signals.

Differential Correction — Technique of comparing GNSS data collected in the field to GNSS data collected at a known reference point, whose coordinates are well known.

Diurnal — The apparent motion of stars around the Earth, caused by the Earth's rotation around its axis. More generally it means repeating daily as in e.g. diurnal effect.

Diurnal phase shift is the phase shift of electromagnetic signals associated with daily changes in the ionosphere. Diurnal temperature variation is the daily temperature shift that occurs from daytime to night.

Dilution of Precision (DOP) — It is a statistical measure of the receiver-satellite(s) geometry. Geometric Dilution of Precision (GDOP) is composed of Time Dilution of Precision (TDOP) and Position Dilution of Precision (PDOP), which are

composed of Horizontal Dilution of Precision (HDOP) and Vertical Dilution of Precision (VDOP). GNSS Accuracy = GDOP x UERE (Also, see User Equivalent Range Error (UERE)).

DME — Distance Measuring Equipment is a transponder-based radio navigation technology that measures distance by timing the propagation delay of VHF or UHF radio signals.

DOP holes — DOP holes are SV (space vehicle) configurations (positions in the sky) that create problems in SV navigation systems.

Doppler shift — The apparent change in frequency of a received signal due to the rate of change of the range between the transmitter and receiver.

DORIS (Doppler Orbitography and Radio-positioning Integrated by Satellite) — A French system that uses Doppler measurements to record the flight of satellites installed with special receptors.

Dual-Use System — System used for civil as well as defence purposes.

Dynamic Positioning — The process of collecting GNSS data while the GNSS antenna is in motion.

Earth Centred, Earth Fixed (ECEF) — A Cartesian coordinate system cantered at the Earth's centre of mass. The Z-axis is aligned with the earth's mean spin axis. The X-axis is aligned with the zero meridian. The Y-axis is 90 degrees west of the X-axis, forming a right-handed coordinate system.

Eccentricity — The ratio of the distance from the centre of an ellipse to its focus to the semimajor axis. e = (1 – b2/a2)1/2 where a and b are the semimajor and semiminor axis of the ellipse, respectively.

EGNOS — The European Geostationary Navigation Overlay Service (EGNOS) is Europe's satellite-based GPS and GLONASS augmentation system.

Ellipsoid — In geodesy, unless otherwise specified, a mathematical figure formed by revolving an ellipse about its minor axis (sometimes also referred to as spheroid). Two quantities define an ellipsoid; these are usually given as the length of the semimajor axis a and the flattening f. (see Eccentricity)

Ellipsoid height — The vertical distance of a user above the ellipsoid.

En Route — A phase of navigation covering operations between a point of departure and termination of a mission. For airborne missions the en route phase of navigation has two subcategories, en route domestic and en route oceanic.

Ephemerides — Plural of ephemeris.

Ephemeris — A list of positions or locations of a celestial object as a function of time.

Ephemeris error — Difference between the actual satellite location and the location predicted by the satellite orbital data (ephemerides).

Epoch — A particular fixed instant of time used as a reference point on a time scale.

Equipotential Surface — A mathematically defined surface where the gravitational potential is the same at any point on that surface.

ESD — static electricity and electrostatic discharge

FDMA — Frequency Division Multiple Access.

FEC — Forward Error Correction is a system of error control for data transmission, whereby the sender adds redundant data to its messages, also known as an error correction code.

Flattening — Relating to Ellipsoids. f = (a-b)/a = 1-(1-e2)1/2 where a = semimajor axis, b = semiminor axis and e = eccentricity (see Eccentricity)

FOC — Final Operational Capability is the point in time at which the final subset of a capability system can be operationally employed.

Full Operational Capability (FOC) — A system dependent state that occurs when the particular system is able to provide all of the services for which it was designed.

GBAS — Ground Based Augmentation System will support the precision approach and terminal area RNAV operations stages through the localized deployment of ground stations around the airport.

GDOP — Geometric dilution of precision (see DOP)

GEAS — Global Navigation Satellite System (GNSS) Evolutionary Architecture Study (GEAS).

Geocentric — Relating to the centre of the earth.

Geodesy — The study of the Earth's size and shape.

Geodetic Coordinates — Coordinates defining a point with reference to an ellipsoid using latitude, longitude and ellipsoidal height or using Cartesian coordinates.

Geodetic Datum — A mathematical model designed to best fit part or all of the geoid defined by an ellipsoid and the relationship between the ellipsoid and a point on the topographic surface established as the origin of datum.

Geographic Information System (GIS) — A geographic information system (GIS), also known as a geographical information system, captures, stores, analyzes, manages, and presents data that refers to or is linked to location.

Geoid — The particular equipotential surface which coincides with mean sea level, and which may be imagined to extend through the continents and is everywhere perpendicular to the direction of the force of gravity.

Geoidal Height — See Geoid separation.

Geoid separation — The distance from the surface of the reference ellipsoid to the geoid measured outward along the normal to the ellipsoid.

Geosynchronous Orbit – A specific orbit around where a satellite rotates around the earth at the same rotational speed as the earth. A satellite rotating in geosynchronous orbit appears to remain stationary when viewed from a point on or near the equator.

Global Navigation Satellite System (GNSS) – GNSS refers collectively to the worldwide positioning, navigation, and timing (PNT) determination capability available from one or more satellite constellations.

GPB — Gravity Probe B is the relativity gyroscope experiment being developed by NASA and Stanford University to test two extraordinary, unverified predictions of Albert Einstein's general theory of relativity.

GPS — The Global Positioning System (GPS) is a component of the Global Navigation Satellite System (GNSS) provided by the United States Government.

GNSS navigation message — In addition to the PRN ranging codes, a receiver needs to know detailed information about each satellite's position and the network.

GPS time — A continuous time system maintained by US Naval Observatory (see UTC(USNO))

GRACE — The Gravity Recover and Climate Experiment consists of two identical satellites launched in March 2002 and flying approximately 220 km apart in a polar orbit 500 km above the Earth whose primary mission is to conduct gravity field measurements.

Graticule — A plane grid representing the lines of Latitude and Longitude of an ellipsoid.

Gravitational constant — The proportionality constant in Newton's Law of gravitation: G= 6.672* 10.11 m3s•2kg•1

Greenwich Mean Time (GMT) — The mean solar time of the meridian of Greenwich. Used as the prime basis of standard time throughout the world.

Great circle course — Term used in navigation. Shortest connection between two points.

HDOP — Horizontal Dilution of Precision (see DOP).

HMI — Hazardously Misleading Information.

ICG — The International Committee on Global Navigation Satellite Systems. The ICG was established on a voluntary basis as an informal body for the purpose of promoting *cooperation, as appropriate, on matters of mutual interest related to civil satellite-based positioning, navigation, timing, and value-added services, as well as compatibility and interoperability among the GNSS systems, while increasing their use to support sustainable development, particularly in the developing countries. The ICG secretariat is provided by the UN Office for Outer Space Affairs (UNOOSA)*.

IDM — Interference Detection and Mitigation.

IGS — The International GNSS Service (IGS), formerly the International GPS Service, is a voluntary federation of more than 200 worldwide agencies that pool resources and permanent GPS & GLONASS station data to generate precise GPS & GLONASS products.

IGSO — Inclined Geosynchronous Orbit.

Inclination — The angle between the orbital plane of a satellite and some reference plane (e.g., equatorial plane).

Initial Operational Capability (IOC) — A system dependent state that occurs when the particular system is able to provide a predetermined subset of the services for which it was designed.

Integer bias term — See Ambiguity

International Bureau of Weights and Measures (BIPM) — The International Bureau of Weights and Measures (Bureau international des poids et mesures, in French), is an international standards organization, one of three such organizations established to maintain the International System of Units (SI) under the terms of the Convention du Mètre (Metre Convention). The organization is usually referred to by its French abbreviation, BIPM.

International Celestial Reference System — The International Celestial Reference System (ICRS) is the current standard celestial reference system adopted by the International Astronomical Union (IAU) whose origin is at the barycenter of the solar system, with axes that are intended to be "fixed" with respect to space.

International Earth Rotation and Reference Systems Service — The International Earth Rotation and Reference Systems Service (IERS) is the body responsible for maintaining global time and reference frame standards, notably through its Earth Orientation Parameter (EOP) and International Celestial Reference System (ICRS) groups. The organization was formerly known as International Earth Rotation Service until April 2, 2002 when it formally changed its name. The organization chose to retain the acronym IERS.

International Laser Ranging Service — The International Laser Ranging Service (ILRS) is a global network of observation stations measure the round trip time of flight of ultrashort pulses of light to satellites equipped with retroreflectors.

International Terrestrial Reference Frame — the International Terrestrial Reference Frame (ITRF) is a set of points with their 3-dimensional Cartesian coordinates which realize an ideal reference system, the International Terrestrial Reference System (ITRS), as defined by the International Union of Geodesy and Geophysics (IUGG) resolution No.2 adopted in Vienna, 1991.

International Terrestrial Reference System — The International Terrestrial Reference System (ITRS) describes procedures for creating reference frames suitable for use with measurements on or near the Earth's surface.

International Union of Geodesy and Geophysics — The International Union of Geodesy and Geophysics (IUGG) is the international organization dedicated to advancing, promoting, and communicating knowledge of the Earth system, its space environment, and the dynamical processes causing change.

International VLBI Service — The International VLBI Service (IVS) is an international collaboration of organizations which operate or support Very Long Baseline Interferometry (VLBI) components. (see VLBI)

Interoperability — Interoperability refers to the ability of open global and regional satellite navigation and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal.

- Interoperability allows navigation with signals from at least four different systems with minimal additional receiver cost or complexity;
- For many applications, common centre frequencies are essential to interoperability, and commonality of other signal characteristics is desirable;
- Multiple constellations broadcasting interoperable open signals will result in improved observed geometry, increasing end user accuracy everywhere and improving service availability in environments where satellite visibility is often obscured;
- Geodetic reference frame realization and system time steerage should adhere to existing international standards to the maximum extent practical.

Ionosphere — A region of the earth's atmosphere from about 50 to about 1000 km above the Earth, where free electrons exist (due to ionization caused by solar radiation, mainly ultraviolet rays), that affects transmission of GNSS signals.

Ionospheric Delay — A wave propagating through the ionosphere (which is a nonhomogeneous and dispersive medium) experiences delay. Phase delay depends on electron content and affects carrier signals. Group delay depends on dispersion in the ionosphere as well, and affects signal modulation (codes). The phase and group delay are of the same magnitude but opposite sign.

Jamming (electromagnetic) — The deliberate radiation, reradiation, or reflection of electromagnetic energy for the purpose of preventing or reducing the effective use of a signal.

Jason — An oceanography satellite launched December 2001 and flying in a 66° inclined orbit 1300 km above the Earth whose mission is to monitor global ocean circulation, study the ties between the oceans and atmosphere, improved global climate forecasts and predictions, and monitor events such as El Nino conditions and ocean eddies

Kinematic positioning — Determination of a time series of sets of coordinates for a moving receiver, each set of coordinates being determined from a single data sample, and usually computed in real time.

Keplerian orbital elements: Six parameters that allow determination of satellite position in Space viz.a: semimajor axis; e: eccentricity; :argument of perigee; : right ascension of ascending node; I: inclination; n:Mean Motion

Lambert Projection — A conformal conic map projection that projects an ellipsoid onto a plane surface by placing a cone over the sphere.

Latitude — The angle between the ellipsoidal normal and the equatorial plane. Latitude is zero on the equator and 90° at the poles.

L-band — The radio frequency band extending from 1000-2000 MHz. The frequencies of the L1 and L2 carriers transmitted by GNSS satellites lie within this L-band.

Least squares estimation — The process of estimating unknown parameters by minimizing the sum of the squares of measurement residuals.

Local Area Augmentation System (LAAS) — The Local Area Augmentation System (LAAS) is an all-weather aircraft landing system based on real-time differential correction of the GPS signal. Local reference receivers send data to a central location at the airport. This data is used to formulate a correction message, which is then transmitted to users via a VHF data link. A receiver on an aircraft uses this information to correct GPS signals. The International Civil Aviation Organization (ICAO) calls this type of system a Ground Based Augmentation System (GBAS).

Local Ellipsoid — An Ellipsoid that has been defined for and fits a specific portion of the earth. Local ellipsoids usually fit single or groups of countries such as the Everest Ellipsoid for India.

Local Time — Local time equals to GMT time + time zone.

Longitude — Longitude is the angle between the meridian ellipse which passes through Greenwich and the meridian ellipse containing the point in question. Thus, Longitude is 0° at Greenwich and then measured either eastward through 360° or, eastward and westward by 180°.

LPV — Loosely described as localizer performance with vertical guidance, provides lateral containment areas comparable to an ILS localizer and decision heights between those of LNAV/VNAV approaches and Cat I ILS approaches.

Lunar Laser Ranging (LLR) — LLR measures the round-trip travel times of light pulses between stations on the earth and four retroreflectors on the surface of the Moon.

MADRAS — Microwave Analysis & Detection of Rain And Atmosphere

Maidenhead – A coordinate system used in Amateur Radio in which the world is divided into 324 large areas based on latitude and longitude. These areas cover 10 degrees of latitude by 20 degrees of longitude and are called fields. Each field is divided into 100 squares. Each of these 100 squares represent 1 degree by 2 degrees.

MASER — Device that produces coherent electromagnetic waves through amplification due to stimulated emission. Historically the term came from the acronym “Microwave Amplification by Stimulated Emission of Radiation”, although modern masers emit over a broad portion of the electromagnetic spectrum.

Mask angle — The minimum acceptable elevation above the horizon that a GNSS satellite has to be at to avoid blockage of line-of-sight.

MBOC — Multiplex Binary Offset Carrier

M-code — GPS military signal.

MCS — Master Control Station

Meridian — An imaginary line joining north to south pole and passing through the equator at 90°.

Multipath — The propagation phenomenon that results in signals reaching the receiving antenna by two or more paths.

Multipath Error — A positioning error resulting from interference between radio waves which have travelled between the transmitter and the receiver by two paths of different electrical lengths.

NASA — the National Aeronautics and Space Administration

NAVCEN — NAVCEN is another name for the U.S. Coast Guard Navigation Center.

Navigation messages/Navigation Data — Data modulated onto the satellite's signals.

Navigation — The process of planning, recording, and controlling the movement of a craft or vehicle from one place to another.

Navstar — original name for GPS.

NAVTEX — A system designated by the International Maritime Organization (IMO) as the primary means for transmitting coastal urgent marine safety information to ships worldwide.

NDGPS — Nationwide Differential Global Positioning System

Nonprecision Approach (NPA) — An aviation instrument approach procedure based on a lateral path and no vertical guide path.

NOAA — The National Oceanic and Atmospheric Administration

NOCC — The National Operations Control

NMEA — National Marine Electronics Association.

NPA — see Non Precision Approach

Observing Session — A period of time over which GNSS data is collected simultaneously by two or more receivers.

Orthometric height — The distance of a point above the geoid measured along the plumb line through the point (height above mean sea level).

Out-of-band emissions — Radio communication emissions, from a transmitter operating in its allocated frequency band, that occur in other frequency bands. Typically, the term refers to those emissions from a transmitter that present itself in the frequency bands adjacent to the allocated band of the transmitter.

P-code — The Precise GPS code broadcast by GPS

PDOP — Position dilution of precision. See Dilution of Precision

Phase observable — See Reconstructed Carrier Phase

PNT — Positioning, Navigation, and Timing

Point Positioning — Determination of Position (Latitude, Longitude and height above Spheroid), using Pseudorange observations.

Polarization — Property of waves that describes the orientation of their oscillations.

Positioning — The science of determining location.

Post processing — The process of computing positions real-time, using data previously collected by GNSS receivers.

Precise Positioning Service (PPS) — The highest level of point positioning accuracy provided by GPS.

Propagation — The movement of an electromagnetic (Radio) wave through a medium (for example, atmosphere or free space) at the speed of light. Dependent on the medium, the velocity and other characteristics of the wave are altered.

Proprietary — Indicates that a party, or proprietor, exercises private ownership, control or use over an item of property; that is, not in the public domain.

Pseudolite — The ground-based differential GNSS station which transmits DGNSS Corrections on a signal with a structure similar to that of an actual GNSS satellite.

Pseudo Random Noise (PRN) code — Any group of binary sequences that appear to be randomly distributed like noise, but which can be exactly distributed.

Pseudorange — A measure of the apparent signal propagation time from the satellite to the receiver antenna, scaled into distance by the speed of light. Pseudorange differs from the actual range by the influence of satellite and user clock.

Precise Time — A time requirement accurate to within 10 milliseconds.

Precision Approach — An instrument approach procedure, based on a lateral path and a vertical glide path, that meets specific requirements established for vertical navigation performance and airport infrastructure.

Radio astronomy — Radio astronomy is a subfield of astronomy that studies celestial objects at radio frequencies.

Radiodetermination — The determination of position, or the obtaining of information relating to positions, by means of the propagation properties of radio waves.

Radiolocation — Radiodetermination used for purposes other than those of radio navigation.

Radionavigation — The determination of position, or the obtaining of information relating to position, for the purposes of navigation by means of the propagation properties of radio waves.

Radio occultation — Radio occultation is a remote sensing technique used for measuring the physical properties of a planetary atmosphere.

RAIM — Receiver Autonomous Integrity Monitoring

RAIM hole — RAIM hole is defined to be where at least five GNSS satellites are not in view.

Range — Term used in Navigation for the length of the trajectory between two points. The trajectory is normally the great circle or Rhumb line.

Rapid static survey — Term used in connection with the GNSS for static survey with short observation times.

Raw data — Original GNSS data taken and recorded by a receiver.

Receiver channel — The radio frequency and digital hardware and the software in a GNSS receiver, required to track the signal from one GNSS satellite at one of the two GNSS carrier frequencies.

Reconstructed carrier phase — The difference between the phase of the incoming Doppler shifted GNSS carrier and the phase of a nominally-constant reference frequency generated in the receiver.

Relative positioning — See Differential positioning

Reliability — The probability of performing a specified function without failure under given conditions for a specified period of time.

Required Navigation Performance (RNP) — A statement of the navigation performance accuracy necessary for operation within a defined airspace, including the operating parameters of the navigation systems used within that airspace.

Rhumb line — Term used in navigation. Trajectory between two points with constant bearing.

RFI — Radio frequency interference

RINEX — Receiver INdependent EXchange format. Asset of standard definitions and formats to promote the free exchange of GPS data.

RNSS — Radionavigation Satellite Service

RTCM — Radio Technical Commission for Maritime services.

RTK — Real Time Kinematic. A term used to describe the procedure of resolving the phase ambiguity at the GNSS receiver so that the need for post-processing is removed.

Safety-of-life — Services used by safety critical users, for example maritime, aviation and trains, whose applications or operations require stringent performance levels.

Satellite Constellation — The arrangement in space of the complete set of satellites of a system like GPS.

Satellite Configuration — The satellite constellation at a specific time, relative to a specific user or set of users.

SATNAV operations — satellite navigation operations.

S-band — The S band ranges from 2 to 4 GHz, crossing the (artificial) boundary between UHF and SHF at 3.0 GHz. It is part of the microwave band of the electromagnetic spectrum.

SBAS — Satellite-Based Augmentation Service (i.e. WAAS, EGNOS, GAGAN, etc.).

Scintillation (Ionospheric) — Irregularly structured ionospheric regions that can cause diffraction and scattering of trans-ionospheric radio signals.

Sidereal day — Time interval between two successive upper transits of the vernal equinox

Sidereal Time — Defined by the hour angle of the vernal equinox. Taking the mean equinox as the reference yields true or apparent Sidereal Time.

Site — A location where a receiver has been setup to determine coordinates.

SLR — Satellite Laser Ranging. The science of measuring distance to a satellite via laser pulses.

Space segment — The part of the whole GNSS system that is in space, i.e. the satellites.

Solar day — Time interval between two successive upper transits of the Sun.

Spurious — A mathematical relationship in which two occurrences have no causal connection, yet it may be inferred that they do, due to a certain third, unseen factor.

Squared reception mode — A method used for tracking GPS L2 signals which doubles the carrier frequency and does not use the P-code. Also called Codeless tracking.

Squaring-type channel — A GNSS receiver channel which multiplies the received signal by itself to obtain a second harmonic of the carrier which does not contain the code modulation.

Standard positioning service (SPS) — Level of point positioning accuracy provided by GPS based on the single frequency C/A-code.

Static Survey — The expression static survey is used in connection with GNSS for all nonkinematic survey applications. This includes the following operation modes: static survey; rapid static survey.

Stochastic — A process whose behaviour is non-deterministic in that a state's next state is determined both by the process's predictable actions and by a random element.

Stop & Go Survey — The term Stop & Go survey is used in connection with GPS for a special kind of kinematic survey. After initialization (determination of ambiguities) on the first site, the roving receiver has to be moved between the other sites without loosing lock to the satellite signal.

Surveillance — The observation of an area or space for the purpose of determining the position and movements of craft or vehicles in that area or space.

Surveying — The act of making observations to determine the size and shape, the absolute and/or relative position of points on, above, or below the Earth's surface, the length and direction of a line, the Earth's gravity field, length of the day, etc.

Telecommand — Command sent to control a remote system or systems not directly connected (e.g. via wires) to the place from which the telecommand is sent.

Telemetry — Technology that allows the remote measurement and reporting of information of interest to the system designer or operator.

Terminal — A phase of navigation covering operations required to initiate or terminate a planned mission or function at appropriate facilities. For airborne missions, the terminal phase is used to describe airspace in which approach control service or airport traffic control service is provided.

Terminal Area — A general term used to describe airspace in which approach control service or airport traffic control service is provided.

Time Zone — Time zone =Local Time -Greenwich Mean Time (GMT). Note that Greenwich Mean Time is approximately equal to GPS time.

Tomography — Imaging by sections or sectioning

Topography — The form of the land of a particular region.

Transformation — The process of transforming coordinates from one system to another.

Transit System — The predecessor to GPS. A satellite navigation system that was in service from 1967 to 1996.

Transverse Mercator Projection — A conformal cylindrical map projection which may be visualized as a cylinder wrapped around the earth.

Translocation — The method of using simultaneous data from separate stations to determine the relative position of one station with respect to another station. (see differential positioning)

Tropospheric propagation delay — Time delay affecting satellite signals due to tropospheric layers of the earth's neutral atmosphere

Ultra High Frequency (UHF) — The frequency range between 300 MHz and 3 GHz (3000 MHz).

UTC (NIST) — The National Institute for Standards and Time provides UTC(NIST), a time scale referenced to atomic oscillators located in Boulder, Colorado.

UTC (USNO) — A time scale referenced to atomic oscillators located at the US Naval Observatory.

Universal time — Local solar mean time at Greenwich Meridian UT

User Equivalent Range Error (UERE) — The contribution to the range measurement error from an individual error source, converted into range units, assuming that error source is uncorrelated with all other error sources.

User segment — The part of the GNSS system that includes the receivers of GNSS signals.

UTM — Universal Transverse Mercator Projection which is a form of Transverse Mercator projection.

UWB — Ultra Wide Band is a radio technology which typically employs relatively low power, extremely short pulse duration transmissions which reoccur on a relatively low duty cycle. The extremely short pulses have the effect of spreading the transmission over a large frequency range. Typically, hundreds of megahertz in bandwidth are used in the resulting transmission.

VDOP — Vertical Dilution of Precision (see DOP)

Very High Frequency (VHF) — The radio frequency range from 30 MHz to 300 MHz.

Very Long Base Line Interferometry — Very Long Baseline Interferometry (VLBI) is a technique used in radio astronomy where several widely separated radio telescopes observe simultaneously the same target and save the observational results with exact time stamps. The data is then combined together so that it is as if the telescopes had been a single instrument with very good resolving power.

WAAS — Wide Area Augmentation System. An air navigation aid developed by the Federal Aviation Administration to augment the Global Positioning System (GPS). (*United States of America*)

World Geodetic System (WGS) — A consistent set of constants and parameters describing the Earth's geometric and physical size and shape, gravity potential and field, and *theoretical normal gravity*.

World Geodetic System 1984 (WGS 84) — The system on which all GPS measurements and results are based.

WRC — The World Radiocommunication Conference (WRC) is organized by International Telecommunications Union, a specialized agency of the United Nations, to review, and, as necessary, revise the international Radio Regulations international treaty governing the use of the radio-frequency spectrum and the geostationary-satellite and non-geostationary-satellite orbits. It is held every two to four years.

Yaw — on moving object it refers to lateral motion around the y-axis (or left-right in the direction of travel).

Y-Code — An encrypted version of the P-code that is transmitted by a GPS satellite when in the anti-spoofing mode.

Zenith angle — Vertical angle with 00 on the horizon and 900 directly overhead.