Global Navigation Satellite System

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Global Navigation Satellite System (GNSS) is the standard generic term for **satellite navigation systems** that provide autonomous geo-spatial positioning with global coverage. A GNSS allows small electronic receivers to determine their location (longitude, latitude, and altitude) to within a few metres using time signals transmitted along a line of sight by radio from satellites. Receivers on the ground with a fixed position can also be used to calculate the precise time as a reference for scientific experiments.

As of 2007, the United States NAVSTAR Global Positioning System (GPS) is the only fully operational GNSS. The Russian GLONASS is a GNSS in the process of being restored to full operation. The European Union's Galileo positioning system is a next generation GNSS in the initial deployment phase, scheduled to be operational in 2010. China has indicated it may expand its regional Beidou navigation system into a global system. India's IRNSS, a next generation GNSS is in developmental phase and is scheduled to be operational around 2012.

Contents

GNSS classification

GNSS that provide enhanced accuracy and integrity monitoring usable for civil navigation are classified as follows:[1]

- **GNSS-1** is the first generation system and is the combination of existing satellite navigation systems (GPS and GLONASS), with Satellite Based Augmentation Systems (SBAS) or Ground Based Augmentation Systems (GBAS). In the United States, the satellite based component is the Wide Area Augmentation System (WAAS), in Europe it is the European Geostationary Navigation Overlay Service (EGNOS), and in Japan it is the Multi-Functional Satellite Augmentation System (MSAS). Ground based augmentation is provided by systems like the Local Area Augmentation System (LAAS).

- **GNSS-2** is the second generation of systems that independently provides a full civilian satellite navigation system, exemplified by the European Galileo positioning system. These systems will provide the accuracy and integrity monitoring necessary for civil navigation. This system consists of L1 and L2 frequencies for civil use and L5 for system integrity. Development is also in progress to provide GPS with civil use L2 and L5 frequencies, making it a GNSS-2 system.[1]

A GNSS may have several layers of infrastructure:

- Core Satellite navigation systems, currently GPS, Galileo and GLONASS.
- Global Satellite Based Augmnetation Systems (SBAS) such as Omnistar and Stafire.
- Regional SBAS including WAAS(US) , EGNOS (EU), MSAT (Japan) and GAGAN (India).
- Regional Satellite Navigation Systems such a QZSS (Japan), IRNSS (India) and Beidou (China).
- Continental scale Ground Based Augmentaion Systems (GBAS) for example the Australian GRAS and the US Department of Transportation National Differential GPS (DGPS) service.

- Regional scale GBAS such as CORS networks.
- Local GBAS typified by a single GPS reference station operating Real Time Kinematic (RTK) corrections.

History and theory

Early predecessors were the ground based DECCA, LORAN and Omega systems, which used terrestrial longwave radio transmitters instead of satellites. These systems broadcast a radio pulse from a known "master" location, followed by repeated pulses from a number of "slave" stations. The delay between the reception and sending of the signal at the slaves was carefully controlled, allowing the receivers to compare the delay between reception and the delay between sending. From this the distance to each of the slaves could be determined, providing a fix.

The first satellite navigation system was Transit, a system deployed by the US military in the 1960s. Transit's operation was based on the Doppler effect: the satellites traveled on well-known paths and broadcast their signals on a well known frequency. The received frequency will differ slightly from the broadcast frequency because of the movement of the satellite with respect to the receiver. By monitoring this frequency shift over a short time interval, the receiver can determine its location to one side or the other of the satellite, and several such measurements combined with a precise knowledge of the satellite's orbit can fix a particular position.

Part of an orbiting satellite's broadcast included its precise orbital data. In order to ensure accuracy, the US Naval Observatory (USNO) continuously observed precisely the orbits of these satellites. As a satellite's orbit deviated, the USNO would send the updated information to the satellite. Subsequent broadcasts from an updated satellite would contain the most recent accurate information about its orbit.

Modern systems are more direct. The satellite broadcasts a signal that contains the position of the satellite and the precise time the signal was transmitted. The position of the satellite is transmitted in a data message that is superimposed on a code that serves as a timing reference. The satellite uses an atomic clock to maintain synchronization of all the satellites in the constellation. The receiver compares the time of broadcast encoded in the transmission with the time of reception measured by an internal clock, thereby measuring the time-of-flight to the satellite. Several such measurements can be made at the same time to different satellites, allowing a continual fix to be generated in real time.

Each distance measurement, regardless of the system being used, places the receiver on a spherical shell at the measured distance from the broadcaster. By taking several such measurements and then looking for a point where they meet, a fix is generated. However, in the case of fast-moving receivers, the position of the signal moves as signals are received from several satellites. In addition, the radio signals slow slightly as they pass through the ionosphere, and this slowing varies with the receiver's angle to the satellite, because that changes the distance through the ionosphere. The basic computation thus attempts to find the shortest directed line tangent to four oblate spherical shells centered on four satellites. Satellite navigation receivers reduce errors by using combinations of signals from multiple satellites and multiple correlators, and then using techniques such as Kalman filtering to combine the noisy, partial, and constantly changing data into a single estimate for position, time, and velocity.

Civil and military uses

The original motivation for satellite navigation was for military applications. Satellite navigation allows for hitherto impossible precision in the delivery of weapons to targets, greatly increasing their lethality whilst reducing inadvertent casualties from mis-directed weapons. (See smart bomb). Satellite navigation also allows forces to be directed and to locate themselves more easily, reducing the fog of war.


Satellite navigation using a laptop and a GPS receiver

In these ways, satellite navigation can be regarded as a force multiplier. In particular, the ability to reduce unintended casualties has particular advantages for wars being fought by democracies, where public relations is an important aspect of warfare. For these reasons, a satellite navigation system is an essential asset for any aspiring military power.

GNSS systems have a wide variety of uses:

- Navigation, ranging from personal hand-held devices for trekking, to devices fitted to cars, trucks, ships and aircraft
- Time transfer and synchronization
- Location-based services such as enhanced 911
- Surveying
- Entering data into a geographic information system
- Search and rescue
- Geophysical Sciences
- Tracking devices used in wildlife management

Note that the ability to supply satellite navigation signals is also the ability to deny their availability. The operator of a satellite navigation system potentially has the ability to degrade or eliminate satellite navigation services over any territory it desires. Thus, as satellite navigation becomes an essential service, countries without their own satellite navigation systems effectively become client states of those which supply these services.

The same applies to the use of smart bombs: the operator of a satellite navigation system can effectively degrade the performance of smart bombs being used by other states using its satellite navigation system to that of gravity bombs, or even offset them from their targets in such a way as to render them useless.

Current global navigation systems

GPS

The United States' Global Positioning System (GPS), which as of 2007 is the only fully functional, fully available global navigation satellite system. It consists of up to 32 medium Earth orbit satellites in six different orbital planes, with the exact number of satellites varying as older satellites are retired and replaced. Operational since 1978 and globally available since 1994, GPS is currently the world's most utilized satellite navigation system.

GLONASS

The formerly Soviet, and now Russian, global navigation system is called GLONASS. It was a fully functional navigation constellation but since the collapse of the Soviet Union has fallen into disrepair, leading to moving gaps in coverage and only partial availability. It is expected to return to full global availablity by 2010 with the help of India, who is participating in the restoration project.[2][3]

Proposed global navigation systems

Compass

For more details on this topic, see Beidou navigation system.

China has indicated they intend to expand their regional navigation system, called *Beidou* or *Big Dipper*, into a global navigation system; a program that has been called *Compass* in China's official news agency Xinhua. The Compass system is proposed to utilize 30 medium Earth orbit satellites and five geostationary satellites. Having announced they are willing to cooperate with other countries in Compass's creation, it is unclear how this proposed program impacts China's commitment to the international *Galileo* position system.

DORIS

Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS) is a French precision system.[4]

Galileo

The European Union and European Space Agency agreed on March 2002 to introduce their own alternative to GPS, called the Galileo positioning system. At a cost of about GBP£2.4 billion,[5] the required satellites will be launched between 2006 and 2008 and the system will be working, under civilian control, from 2010. The first experimental satellite was launched on 28 December 2005. Galileo is expected to be compatible with the modernized GPS system that will be operational by after 2012. The receivers will be able to combine the signals from both Galileo and GPS satellites to greatly increase the accuracy.

IRNSS

The Indian Regional Navigational Satellite System (IRNSS) is a proposed autonomous regional satellite navigation system to be constructed and controlled by the Indian government. It is intended to provide an absolute position accuracy of better than 20 meters throughout India and within a region extending approximately 1,500 to 2,000 km around it. A goal of complete Indian control has been stated, with the space segment, ground segment and user receivers all being built in India. The government approved the project in May 2006, with the intention it be implemented within six to seven years.

GNSS Augmentation

GNSS Augmentation involves using external information, often integrated into the calculation process, to improve the accuracy, availability, or reliability of the satellite navigation signal. There are many such systems in place and they are generally named or described based on how the GNSS sensor receives the information. Some systems transmit additional information about sources of error (such as clock drift, ephemeris, or ionospheric delay), others provide direct measurements of how much the signal was off in the past, while a third group provide additional navigational or vehicle information to be integrated in the calculation process.

Examples of augmentation systems include the Wide Area Augmentation System, the European Geostationary Navigation Overlay Service, the Multi-functional Satellite Augmentation System, Differential GPS, and Inertial Navigation Systems.

Topics to be covered

- Differential satellite navigation
- GNSS reflectometry
- Phase-counting differential satellite navigation

See also

- Differential GPS
- Global Positioning System
- Galileo positioning system
- GLONASS
- Wide Area Augmentation System
- European Geostationary Navigation Overlay Service
- GNSS reflectometry
- GPS and Geo Augmented Navigation

External links

Information on specific GNSS systems

- ESA information on EGNOS (http://www.esa.int/esaNA/GGG63950NDC_egnos_0.html)
- Information on the Beidou system (http://www.astronautix.com/craft/beidou.htm)
- German Federal Waterways Administration Traffic Technologies Centre (http://www.wsv.de/fvt/funknavi/funknavi.html) Information on GPS / DGPS

Organizations related to GNSS:

- United Nations International Committee on Global Navigation Satellite Systems (ICG) (http://www.unoosa.org/oosa/en/SAP/gnss/icg.html)
- Korean GNSS Technology Council (GTC) (http://gnss.or.kr/e-html/introduction/intro_01.html)
- Institute of Navigation (ION) GNSS Meetings (http://www.ion.org/meetings/#gnss)
- The International GNSS Service (IGS), formerly the International GPS Service (http://igscb.jpl.nasa.gov/)
- International Global Navigation Satellite Systems Society Inc (IGNSS) (http://www.ignss.org/)
- International Earth Rotation and Reference Systems Service (IERS) International GNSS Service (IGS) (http://www.iers.org/MainDisp.csl?pid=84-63)
- UNAVCO GNSS Modernization (http://facility.unavco.org/science_tech/gnss_modernization.html)
- Asia-Pacific Economic Cooperation (APEC) GNSS Implementation Team (http://www.apecgit.org/)
- Fédération Aéronautique Internationale (FAI) GNSS Flight Recorder Approval Committee (GFAC) (http://www.fai.org/gliding/gnss/)

References

1. ^ http://www.ifatca.org/pdffiles/gnss.pdf IFATCA - A Beginner's Guide to GNSS in Europe
2. ^ India signs GLONASS agreement (http://www.rin.org.uk/pooled/articles/BF_NEWSART/view.asp?Q=BF_NEWSART_156825)
3. ^ India, Russia Agree On Joint Development Of Future Glonas Navigation System (http://www.spacedaily.com/news/gps-05zzzzzg.html)
4. ^ DORIS information page (http://www.jason.oceanobs.com/html/doris/welcome_uk.html)
5. ^ BBC - Galileo (http://news.bbc.co.uk/1/hi/sci/tech/5286200.stm)

Satellite navigation systems		
Historical	*Operational*	*Developmental*
Transit	**GPS** | / **GLONASS**	**Beidou** | **Galileo** | **IRNSS**
Related topics		
EGNOS | GAGAN | GPS·C | LAAS | MSAS | WAAS		

Categories: Satellite navigation systems | Time signal radio stations

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