National Spectrum Managers Association

Global Navigation Satellite Systems

A Worldwide Resource and Global Utility

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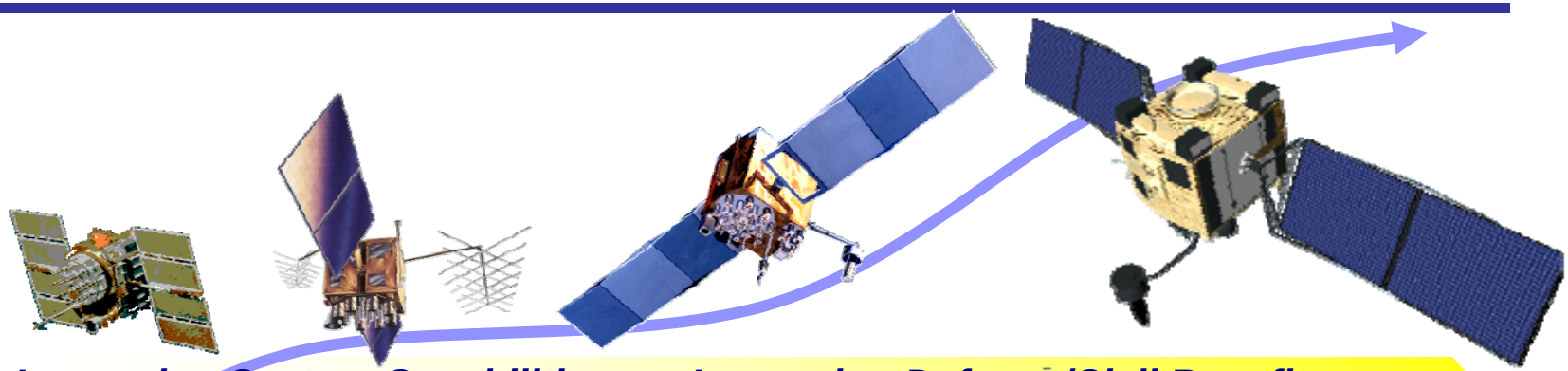
History

- There are currently two operating Global Navigation Satellite Systems (GNSS):
  - The United States Global Positioning Service (GPS)
  - The Russian Global Orbiting Navigation Satellite System (GLONASS)
- Both GPS and GLONASS were originally developed as military navigation systems with limited dual use capabilities.
- After the downing of Korean Airlines Flight 007 in 1983, the President of the United States, by Executive Order, declared GPS free to users throughout the world. The Russian President followed shortly thereafter, providing GLONASS to the world for free use for navigation.
- GPS has always been a “free use” system compliments of the U.S. Taxpayer. The only direct cost to the user is that of the receiver.
- In May 2000, the United States removed the intentional degradations in the GPS signal known as Selective Availability (S/A).
- The European Union is developing a third global MEO navigation system called Galileo, which will be compatible with GPS.
- September 2005, the U.S. launched the first of the new GPS satellites with the new L2C signal, known as the Block IIR-M (Replenishment-Modernized)
  - Declared operational December 2005.
- New L5 signal to begin in 2009. Block IIF (Follow-on)
- New L1C with GPS III

GPS Modernization Plan



Increasing System Capabilities ◆ Increasing Defense/Civil Benefit

Block
IIA/IIR

- **Basic GPS**
- **Std Service (16-24m SEP)**
  - **Single frequency (L1)**
  - **C/A code navigation**
- **Precise Service (16m SEP) Two frequencies (L1&L2)**

L1 1575.42 MHz

Block
IIR-M

IIA/IIR capabilities +

- **2nd Civil Signal on L2**
- **Earth coverage M-Code on L1 & L2**

+ L2C 1227.6 MHz

Block
IIF & III

IIF: IIR-M capability + 3rd Civil Signal

III:

- **Increased Accuracy**
- **Controlled Integrity**
- **Legacy Signals supported**

+ L5 1176.45 MHz

Civil Benefits of GPS Modernization

- New L2C, L5 and L1C signals provide
  - Reduced vulnerability to interference
  - Calculation of ionospheric corrections at user site with additional signals
- Improvements in service performance in accuracy, availability integrity, and reliability
  - Provide centimeter-level accuracy for scientific and survey applications
- New spectrally separated signals from M-code
  - Preserve civil use outside areas of military ops
- New commercial opportunities
- Opportunity to converge services with other emerging global satellite navigation systems such as Galileo

Galileo

Both the United States and the EU signed an agreement in June 2004 that GPS and Galileo signals would be interoperable, but it has taken several years for the agreement to be approved by member states.

Since then, two Galileo test satellites have been launched. In late April, the second Galileo test satellite, Giove-B, carried into space by the Soyuz-Fregat rocket launched from Kazakhstan, successfully transmitted radio signals which will one day be used with the GPS as the basis for satellite navigation in Europe.

The agreement between the EU and the US specifies that while Galileo satellites will produce Galileo signals and GPS satellites will produce GPS signals, both signals on the ground will be compatible and interoperable, allowing users in the future to use a device that contains both GPS and Galileo chipsets (still to be defined).

Planned Galileo Services

- **Open Access**
  Free to air; Mass market; Simple positioning
- **Commercial**
  Encrypted; High accuracy; Guaranteed service
- **Safety of Life**
  Unencrypted; Integrity; Authentication of signal
- **Search and Rescue**
  Near real-time; Precise; Return link feasible
- **Public Regulated**
  Encrypted; Integrity; Continuous availability

GPS-Galileo

***Agreement on GPS-Galileo Cooperation* signed at U.S.-EU Summit on June 26, 2004**

- Each system managed, operated, and funded independently
- GPS and Galileo will be compatible and, for civil users, interoperable at the user level
  - Geodesy nearly identical, approximately 2cm
  - Radio frequency compatible
  - Timing different, but each system will transmit timing offsets
- If cooperation continues, users will enjoy better accuracy and availability

Proposed GNSS Systems

- Stand Alone GNSS Systems
  - The **COMPASS** system (also known as Beidou-2) is a project by **China** to develop an independent satellite navigation system. The current Beidou-1 system (made up of 4 satellites) is experimental and has limited coverage and application. However, with the COMPASS system, China plans to develop a truly global satellite navigation system consisting of 35 satellites (both GEO and MEO orbits).
- Regional GNSS Augmentations
  - 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. The government approved the project in May 2006, with the intention to implement it within six to seven years.
  - The Quasi-Zenith Satellite System **(QZSS)**, is a proposed three-satellite regional time transfer system and enhancement of GPS covering **Japan**. The first satellite is scheduled to be launched in 2009.

COMPASS

China is planning to build a navigation satellite constellation known as **Compass Navigation Satellite System (CNSS)**, or “BeiDou” in its Chinese name. The system will be based on its current Compass Satellite Navigation Experimental System (BeiDou-1), which will be able to provide navigation and positioning services to users in China and its neighboring countries by 2008. The system will be gradually expanded into a navigation satellite constellation comprising 5 Geostationary Earth Orbit (GEO) satellites and 30 Medium Earth Orbit (MEO) satellites, which can provide navigation and positioning services to global users.

IRNSS

The **Indian** government is developing an independent regional satellite navigation system that would launch starting in 2008 to expand on the capabilities provided by the GPS system.

The **Indian Regional Navigation Satellite System (IRNSS)** seven-satellite constellation would be a stand-alone system and independent of an Indian project to enhance GPS signals in the region.

QZSS

The **Quasi-Zenith Satellite System** (QZSS) is a proposed three-satellite regional time transfer system and enhancement to the Global Positioning System that would be receivable within Japan. The first satellite is currently scheduled to be launched in 2009.

QZSS can only provide limited accuracy on its own and is not currently required in its specifications to work in a stand-alone mode. As such, it is viewed as a GNSS Augmentation service. Its positioning service could also collaborate with the geostationary satellites in Japan's Multi-Functional Transport Satellite (MTSAT), currently under development, which is a Satellite Based Augmentation System similar to the U.S. Federal Aviation Administration's Wide Area Augmentation System (WAAS).

The satellites would be placed in a periodic Highly Elliptical Orbit (HEO). These orbits allow the satellite to dwell for more than 12 hours a day with an elevation above 70° (meaning they appear almost overhead most of the time) and give rise to the term "quasi-zenith" for which the system is named.

“Local” GNSS Augmentations

- The **Wide Area Augmentation System** (**WAAS**) is an air navigation aid developed by the Federal Aviation Administration to augment the GPS, improving its accuracy, integrity, and availability. WAAS is intended to enable aircraft to rely on GPS for all phases of flight, including precision approaches to any airport within its coverage area.

- The **European Geostationary Navigation Overlay Service** (**EGNOS**) is a satellite based augmentation system (SBAS) under development by the European Space Agency, the European Commission and EUROCONTROL. It is intended to supplement the GPS, GLONASS and Galileo (when it becomes operational) systems by reporting on the reliability and accuracy of the signals.

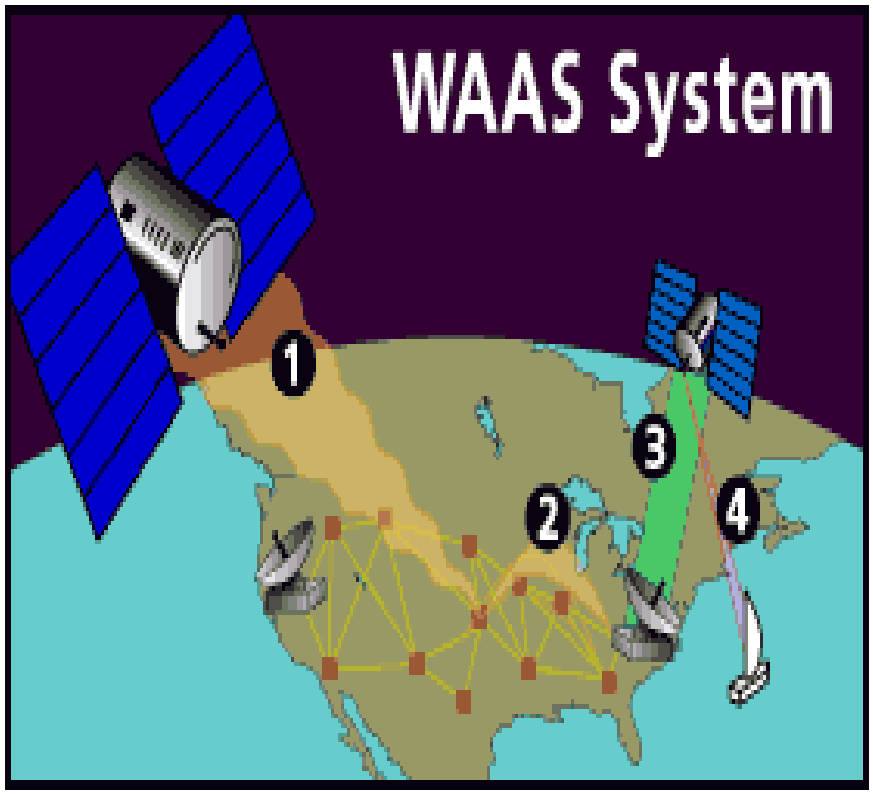
- **Nationwide Differential Global Positioning System** (**NDGPS**) is an enhancement to the GPS that uses a network of fixed ground based reference stations to broadcast the difference between the positions indicated by the satellite systems and the known fixed positions. These stations broadcast the difference between the measured satellite pseudoranges and actual (internally computed) pseudoranges, and receiver stations may correct their pseudoranges by the same amount.

- **Multi-functional Satellite Augmentation System** (**MSAS**) is a Japanese Satellite Based Augmentation System which supports Differential GPS (DGPS) designed to supplement the GPS by reporting, then improving, on the reliability and accuracy of those signals.

Wide Area Augmentation System (WAAS)

The Federal Aviation Administration (FAA) and the Department of Transportation (DOT) are developing the **WAAS** program for use in precision flight approaches. Currently, GPS alone does not meet the FAA's navigation requirements for accuracy, integrity, and availability.

WAAS corrects for GPS signal errors caused by ionospheric disturbances, timing, and satellite orbit errors, and it provides vital integrity information regarding the health of each GPS satellite.



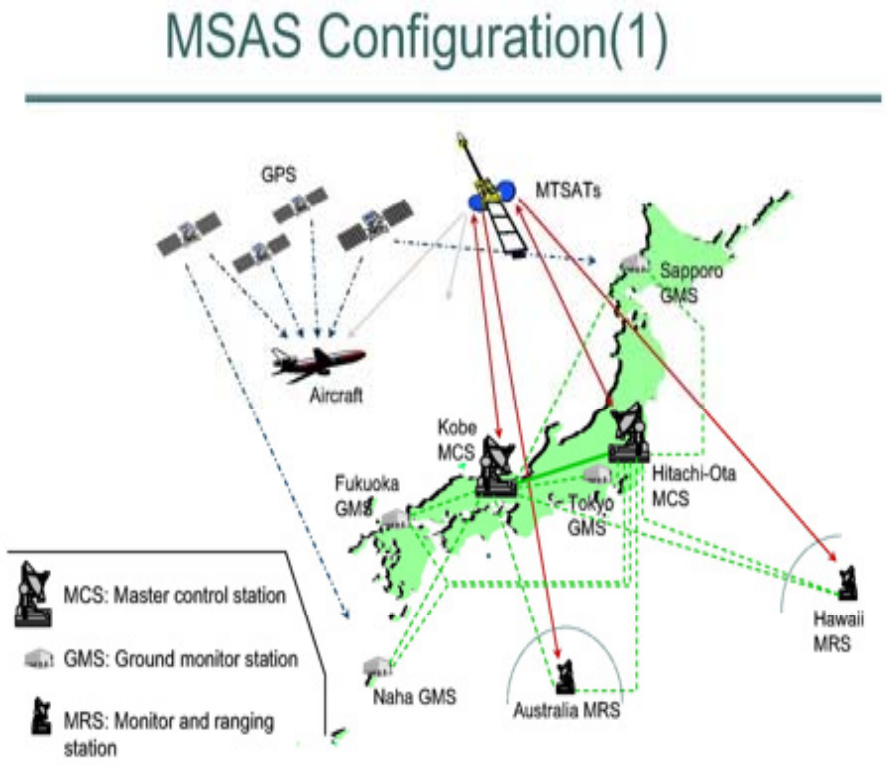
European **EGNOS**

EGNOS is a joint program of the European Space Agency, the European Commission and Eurocontrol. EGNOS is made up of a network of more than forty elements all over Europe that collect, record, correct and improve data from the GPS. The modified signals are then relayed via geostationary satellites to users' terminals, offering a positional accuracy of better than two meters, compared with 15 to 20 meters for GPS alone. In addition, **EGNOS** gives a guarantee of quality for these signals that GPS does not provide.

Europeans conducted a successful test using the **European Geostationary Navigation Overlay Service (EGNOS)** to guide an aircraft during landing.

Japanese **MSAS**

Japan's **Multi-functional Satellite Augmentation System** (**MSAS**) will improve the accuracy, integrity, continuity and availability of GPS satellite signals throughout Japanese Flight Information Region by relaying augmentation information to user aircraft via Japan's Multi-functional Transport Satellite (MTSAT) geo-stationary satellites. The system consists of a network of Ground Monitor Stations in Japan, Monitor and Ranging Stations outside of Japan, Master Control Stations in Japan with satellite uplinks, and MTSAT geo-stationary satellites.



Nationwide Differential GPS

A method of differentially correcting GPS receivers, known as **Differential GPS (DGPS)**, greatly improves their accuracy. DGPS is based on the principle that receivers located in close proximity will experience similar errors in satellite ranging signals. The method makes use of two GPS receivers; one stationary and located at a known point (reference receiver), the other operated as a mobile receiver. Since the coordinates of the reference receiver are known, it can correct satellite pseudorange to the true range. Through communication between the stationary and mobile receivers, the mobile receiver's pseudoranges are corrected to true ranges.

Summary

- GPS has evolved from its initial military application to a world-wide system free of user fees.
- It is very easy for users to begin using GPS
  - The user segment (navigators and other users with GPS receivers) has FREE access already!
  - The cost of the receiver is dependent upon the amount of money the user wants to spend for their application
- Use of GPS is unlimited in its application. One could say that use of GPS is only limited by the creativity of the user.
- GPS modernization is well underway and, as a result, will provide improved accuracy and timing.

Some GPS References

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Thank You