Lecture 2: A Brief History of Navigation
~~Emphasizing~~ Skipping everything but GNSS

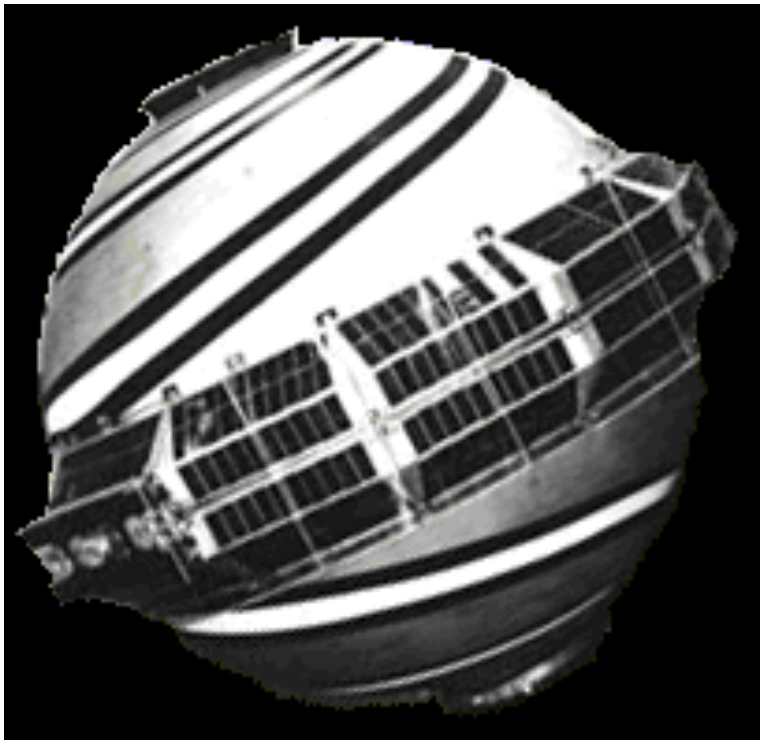
Transit

Late 1950's after Sputnik, APL at the Johns Hopkins University developed the system based on Doppler positioning. Sponsored by the Navy to provide position fixes & reset INS for submarines.

There were 4-7 satellites in LEO polar orbits (90 minute period). One satellite in view at a time.

Measurement of Doppler and rate of change of Doppler and knowledge that you're on the sea surface pinned it.

Requires user motion to be slow or very well known.



From Smithsonian website:
http://www.nasm.si.edu/exhibitions/gps/before.html

NAVSTAR GPS

- Navy Timation – Building on Transit, the Navy invested heavily in the development of atomic clocks suitable for operation on orbit. To allow for hyperbolic positioning from satellites they planned to add side tones. Plan for 21-27 satellites in 8 hour orbits

- USAF – 621B – started in 1963 Concept of using pseudorandom noise codes (PRN's) to allow for spread spectrum ranging and communications. Plan for 16 satellites in geosynchronous 24 hour orbits – eggbeater configuration

- In 1973/1974 the DoD formed a Joint Program Office to bring together competing elements and create a NAVSTAR GPS to meet all needs.

Civil GPS, Summary of Key Events

- 1973– GPS Joint Program Office established
- 1978 - First Global Positioning System satellite launch
- 1983 - President Reagan offers GPS to the world “free of charge”
- 1993 - GPS Standard Positioning Service available
- 1994 - FAA approves GPS for use in National Airspace System
- 1996 - Presidential Decision Directive, first National GPS policy
- 1998 - Two new GPS civil signals (L2 and L5) announced
- 1999 - Third civil signal (L5) at 1176.45 MHz announced
- 2000 - Congress funds GPS Modernization in DoD budget
- 2000 - Selective Availability set to zero
- 2004 – President Bush signs U.S. Space-Based PNT Policy
- 2007 – Selective Availability eliminated in GPS III
- 2010 – President Obama announces National Space Policy including GPS

NATIONAL SPACE POLICY EXCERPT
June 28, 2010

http://www.pnt.gov/policy/2010-spacepolicy.shtml

- Maintain and Enhance Space-Based Positioning, Navigation, and Timing Systems. The United States must maintain its leadership in the service, provision, and use of global navigation satellite systems (GNSS). To this end, the United States shall:
  - Provide continuous worldwide access, for peaceful civil uses, to the Global Positioning System (GPS) and its government-provided augmentations, free of direct user charges;
  - Engage with foreign GNSS providers to encourage compatibility and interoperability, promote transparency in civil service provision, and enable market access for U.S. industry;
  - Operate and maintain the GPS constellation to satisfy civil and national security needs, consistent with published performance standards and interface specifications. Foreign positioning, navigation, and timing (PNT) services may be used to augment and strengthen the resiliency of GPS; and
  - Invest in domestic capabilities and support international activities to detect, mitigate, and increase resiliency to harmful interference to GPS, and identify and implement, as necessary and appropriate, redundant and back-up systems or approaches for critical infrastructure, key resources, and mission-essential functions.

Key elements

- Worldwide, 24-7 operations, all weather
- LPI – low probability of intercept
- Passive – receive only on the ground
- MEO – medium altitude ~20,000 km altitude
- 180 day autonomous operation

- First satellite launched in February 1978.
- Block I – 11 navigation development sats
- Block II – first in 1989
  added a nuclear detection capability
  SA, and A-S features
- Achieved full operational capability 1995
- Modernization under way
- Block IIF – First May 2010

Launch of the last Block II R-M satellite,
Aug 2009 http://pnt.gov/public/images/

INTERNATIONAL COOPERATION

- **European Union** – June 2004: cooperation on GPS and Galileo. July 2007 common civil signal defined.
- **Russia** – 2004: civil interoperability at the user level between GPS and Russia's GLONASS system
- **China** – 2008: part of UN international committee on Global Navigation Satellite Systems provider forum
- **India** – Feb 2007: cooperation on GPS and space-based PNT. Interoperability between GPS and India's GPS And GEO-Augmented Navigation (GAGAN) system.
- **Japan** – 1998: cooperation in the use of GPS. Interoperability between GPS and Japan's MTSAT-based Satellite Augmentation System (MSAS), and Quasi-Zenith Satellite System (QZSS)
- **Australia** – April 2007: cooperative relationship on GPS and space-based PNT 2007. Interoperability between GPS and Australia's Ground-based Regional Augmentation System (GRAS) and Ground Based Augmentation System (GBAS).

Office for Outer Space Affairs
United Nations Office at Vienna

ICG

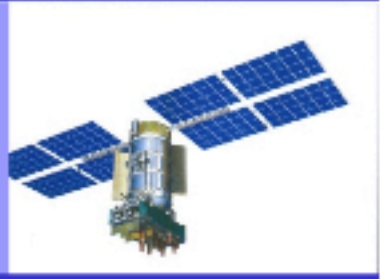
UNOOSA: Further mechanism to promote GNSS applications (ICG Leaflet)

The United States: Global Positioning System (GPS)

GPS is a United States space-based radionavigation system that provides reliable positioning, navigation, and timing services to users on a continuous worldwide basis – freely available to all. The outstanding performance of GPS over many years has earned the enduring confidence of millions of international users. With its ongoing modernization programs, GPS will continue to provide superb quality and performance in the future.

The Russian Federation: GLObal NAvigation Satellite System (GLONASS)

The Russian navigation satellite systems, GLONASS, is based on a constellation of active satellites which continuously transmit coded signals in two frequency bands, which can be received by users anywhere on the Earth's surface to identify their position and velocity in real time based on ranging measurements. In the future a third frequency for GLONASS signal transmission will be introduced. In some areas of application use of combined GPS, GLONAS and Galileo constellation appears to be preferable option.

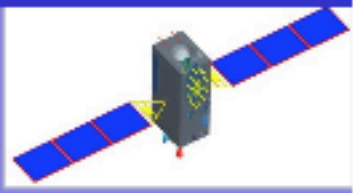


The European Community: European Satellite Navigation System (GALILEO)

GALILEO, an initiative launched by the European Commission and the European Space Agency, will be a global navigation satellite system, owned by the European Community, providing highly accurate, guaranteed global positioning services under civilian control. The Galileo Open Services signal will be interoperable with the GPS civil signal, as well as with GLONASS.

The People's Republic of China: COMPASS/BeiDou

The existing three satellite COMPASS/BeiDou navigation system has played an important role in offering efficient positioning, timing, communication services and differential GPS information in surveying, telecommunications, transportation, meteorology, forest fire prevention, disaster forecast and public security areas. On the basis of the COMPASS/BeiDou Navigation Test System, China has started to build system with global coverage.



Why is GNSS so significant?

- Unprecedented accuracy – “stand alone” position good to few meters, differential good to < 1m, “survey” at the mm-cm
- Cost – system is paid for entirely by government (i.e. taxpayers).
  - No fees to manufacturers or users
  - Receivers can be produced for < $100
- Global availability – all weather, all the time, everywhere, seamlessly
- Applications – land, marine, airborne, satellites, time transfer – you name it.

References

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