Positioning

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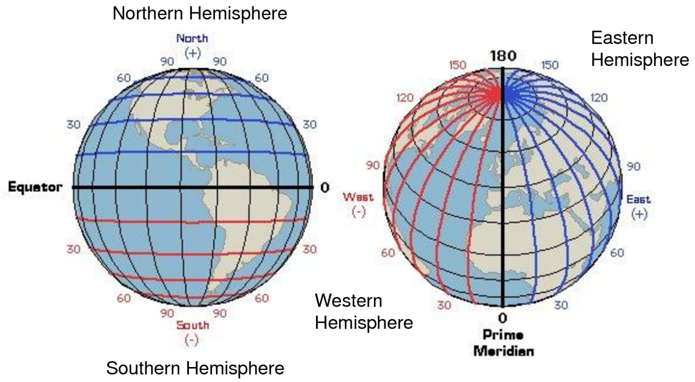
Learning Objectives

- Understand the different segments of GPS
- Understand the basic ideas of how GPS provides a location on the earth's surface
- Be familiar with causes of GPS receiver inaccuracy

Coordinates



Latitude & Longitude

Global Navigation Satellite Systems

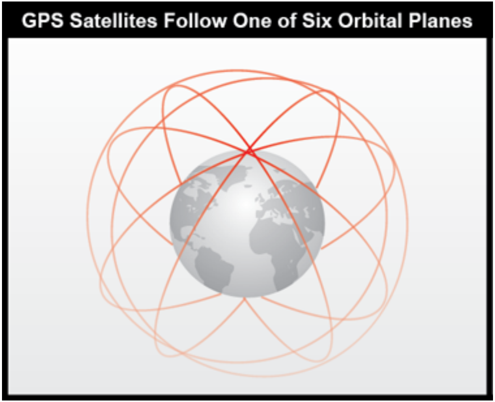
- NAVSTAR (USA)
- GLONASS (Russia)
- Galileo (Europe)
- Beidou (China)

GPS (NAVSTAR)

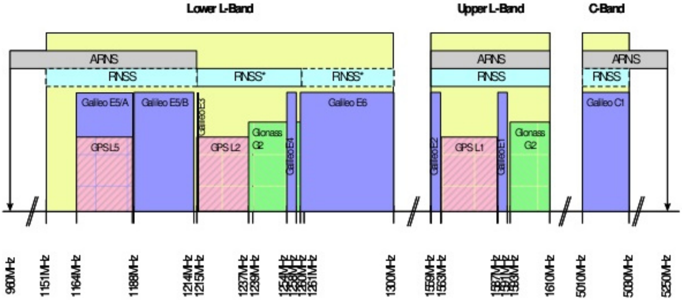
- 24 satellite constellation in medium earth orbit
- Global coverage, all weather conditions
- Transmission on L-band radio frequencies

History: 1973 secretary of defense approval; first four satellites launched in 1978; 24th in 1993; fully operational in 1995. Selective availability dropped since 2000.

Orbitals (GPS)

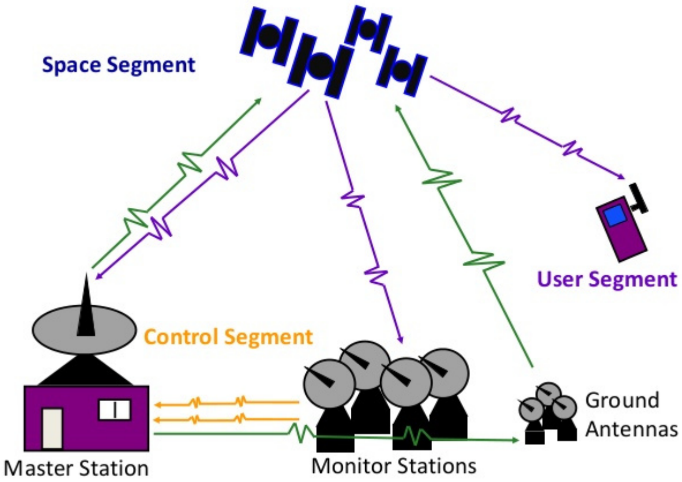


Signal Spectrum



RNSS* shared with other services

The Three Segments of the GPS



GPS Space Segment

- 7.5 years lifespan
- Four atomic clocks, batteries, two solar panels (1136 W)
- $\approx$ 2 tons in weight
- Orbits separated by 60 degrees, 20.200 km elevation
- 11h 55 minutes orbital period
- 28 deployed, 24 operational, 4 backup
- 5 to 8 satellites visible from any point on Earth

Transmissions

- S-band for control
- L-band for navigation (1575.42 and 1227.60 Mhz)
- Data Rate: 50 bit/second

User Segment

- Satellites transmit position and time
- Receivers calculate latitude, longitude, altitude and velocity

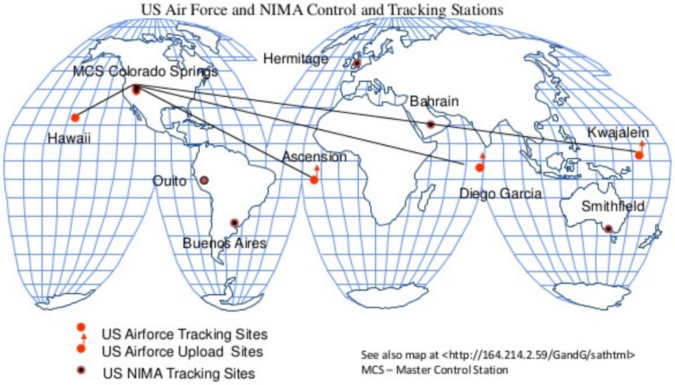
Extra Satellites

Improve...

- availability
- accuracy
- efficiency

Some systems combine support for NAVSTAR, GLONASS and/or Galileo.

Ground control segment



Monitor stations

- Placed in Alaska, Washington (DC), Ecuador, Argentina, UK, Bahrain, South Korea, Australia and New Zealand
- Collect raw satellite signal data (incl. atmospheric distortions)
- Retransmit it to master control station
- Transmit data commands to GPS satellites in view
- Used for clock-correction ("GPS time")

Data transmitted

- Coded ranging signals for trilateration (to determine travel time of radio signal)
- Clock information (GPS time) and clock correction information (conversion to UTC)
- Ephemeris position information (where the satellite is)
- Almanac on GPS constellation, including location and health
- Atmospheric data

Basic steps

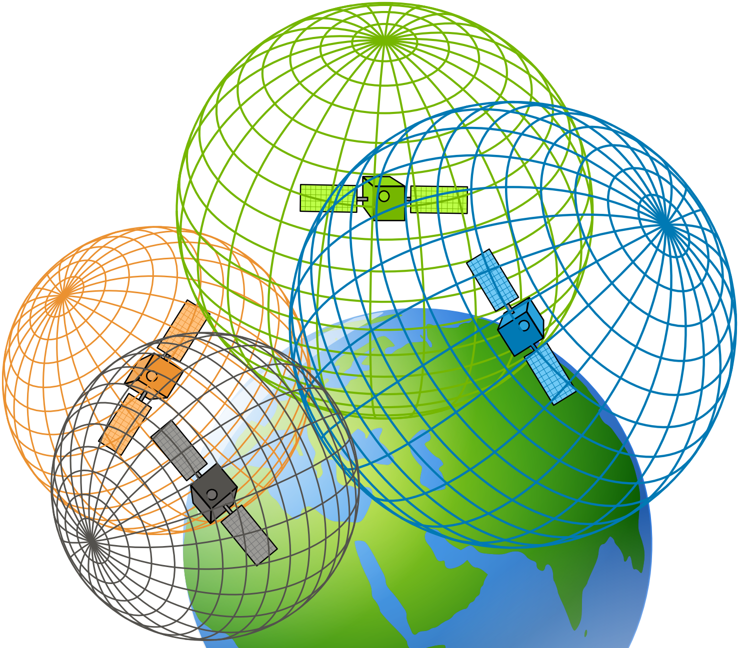
- Ranging: Determine distance from SV
- Timing: obtain very precise current time
- Positioning: Determine position of SV in space
- Trilateration: Intersection of spheres
- Correction of errors: correction for ionospheric and tropospheric interference

Accurate Timing

- SV has highly accurate atomic clocks (nanoseconds!)
- Receiver has way less accurate clocks
- 10 ms $\equiv$ 3000 km error!

$\Rightarrow$ Resolve discrepancy in clocks using fourth satellite (solve for four variables: X, Y, Z and T)

Trilateration



Receiver start-up

1. Acquire one satellite to get time and almanach
2. Acquire 2 other satellites to get 2-D position
3. Acquire 4th satellite to get 3-D position
4. Acquire any other visible satellite to improve accuracy

Remember: data rate was 50 bit/second!

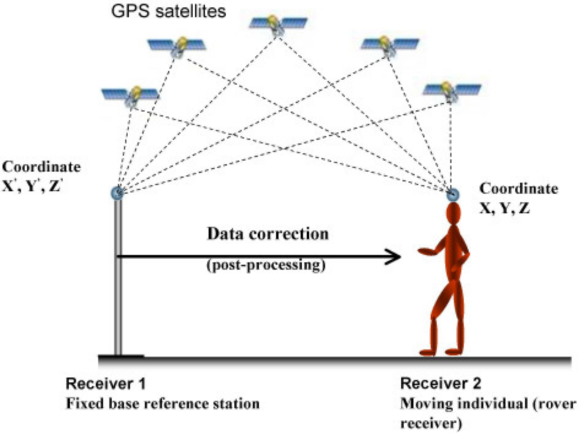
Practical consequences

- Hot start: few seconds (almanach OK, time OK, position close to last one)
- Warm start: few minutes (almanach OK, time approximately OK)
- Cold start: tens of minutes (time off, almanach expired, last position off)

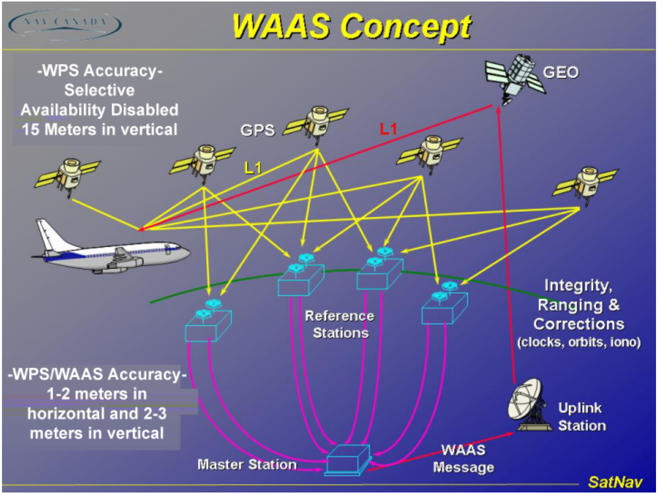
Sources of inaccuracy

- Atmospheric delay
- Multi-path error (reflection from buildings, etc.)
- Obstruction (blocked by buildings)

Differential GPS (DGPS)



Wide Area Augmentation System (WAAS)



US only (today).

Impact by error source[1]

	Standard GPS	DGPS
SV clocks	1.5 m	0.0 m
Orbit (Ephemeris)	2.5 m	0.0 m
Ionosphere	5.0 m	0.4 m
Troposphere	0.5 m	0.2 m
Receiver noise	0.3 m	0.3 m
Multipath	0.6 m	0.6 m
Selective availability	30.0 m	0.0 m
Accuracy (3-D)	93.0 m	2.8 m

[1] According to Trimble Navigation

GPS accuracy

- Standard position: approximately 100 m
- Precise position (selective availability): ≈ 10–25 m
- Differential GPS/WAAS (ionosphere/atmosphere correction): 1–7 m
- GPS with post-processing ("survey grade"): ≈ 1 cm

Main applications

- Military
- Search and rescue
- Disaster relief
- Surveying
- Navigation
- Geographic information systems (GIS)

Determining User Location using Phones

- Multitude of location sources (GPS, Cell-ID, WiFi)
  - Cell of origin
  - Time of arrival (GPS)
  - Angle of arrival
  - Signal strength
  - Video data
- User movement (accelerometer, magnetic field)
- Varying accuracy (even from same source)
- Varying cost (energy!)

Location-based services

Location is a *proxy* for context.

- Infrastructure context (networking, power)
- System context (applications in use, business processes)

Given enough context, we can derive the situation and provide situation-aware services.

Idea

Automatically adjust radio settings based on location

or

Automatically adjust speaker settings based on location

Location APIs

- `android.location.LocationManager`
- `android.location.LocationListener`
- `com.google.android.gms.location.FusedLocationProviderClient` (evil!)

Power Consumption of Data Transmission

Access	Activity	Watt	Ratio
3G	56.Kb/s stream	1.00	12.5
Edge	56.Kb/s stream	0.96	12.0
WiFi	56.Kb/s stream	0.75	9.3
—	Idle, LCD off	0.08	1
—	Idle, LCD on	0.27	3.4

Energy consumption of a Nokia N900 (by Neal Walfield).

Enable GSM

```
android.telephony.TelephonyManager.setDataEnabled (true);

android.telephony.TelephonyManager.getAllCellInfo ();
android.telephony.CellInfoGsm.getCellSignalStrength ();
android.telephony.CellInfoGsm.getCellIdentity ();
android.telephony.CellIdentityGsm.getBsic ();
android.telephony.CellIdentityGsm.getCid ();
android.telephony.CellIdentityGsm.getLac ();
```

Using CDMA (mostly US-only)

```
android.telephony.cdma.CdmaCellLocation.getNetworkId();
android.telephony.cdma.CdmaCellLocation.getBaseStationId();
android.telephony.cdma.CdmaCellLocation.getBaseLatitude();
android.telephony.cdma.CdmaCellLocation.getBaseLongitude();
```

Enable WLAN

```
android.net.wifi.WifiManager.isWifiEnabled();
android.net.wifi.WifiManager.setWifiEnabled (true);
android.net.wifi.WifiManager.startScan();
android.net.wifi.WifiManager.getScanResults();
```

Exercise

Implement an App that:

- Periodically checks user's location
- Determines "at home"
- Disables GSM
- Enables WLAN

Considerations:

- Definition of "at home"
- Respectful design?
- Automation when leaving "home"

Acknowlegements

This presentation used material from:

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