NAVSTAR GPS
Global Positioning System

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Tools used prior to invention of GPS

- Design of GPS based on the similar ground-based radio navigation systems (WW2 era)
  - LORAN and the
  - Decca Navigator
- Another inspiration for the invention of GPS occurred when the Soviet Union launched Sputnik in 1957.
- It was discovered that because of the Doppler effect, the satellite's exact position around the globe could be accurately calculated.
- The first satellite navigation system, which was used by the United States Navy, was successfully launched in 1960.
- 7 years later, the U.S. Navy launched a more sophisticated satellite navigation system which included the ability to place accurate clocks in space, a technology the GPS system relies upon.

GPS Emerges

- GPS was developed by the U.S. Department of Defense.
- Formerly known as the Navstar Global Positioning System, it was first brainstormed at the Pentagon in 1973, as the US government was looking for a satellite system that was error-proof.
- The first experimental “Block-I” GPS satellite was launched in February of 1978.
- GPS satellites were initially manufactured by Rockwell International; however, they are now manufactured by Lockheed Martin and Boeing.
- By the mid-1990’s, the GPS system was fully operational with 24 satellites.

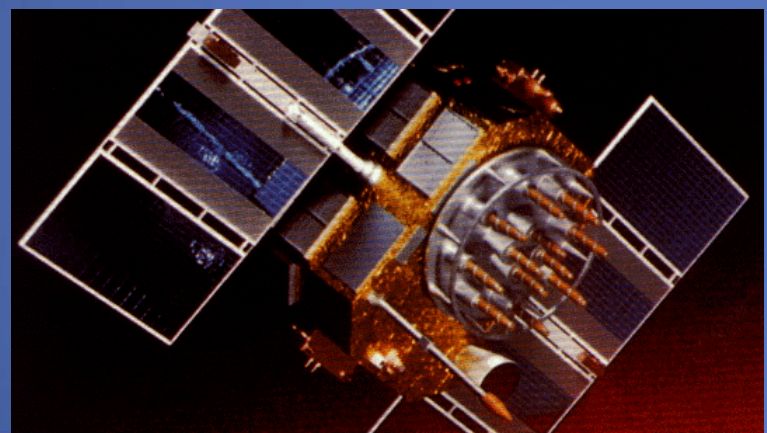
Basics

Satellite system

- 24 satellites (+ backups) in geosynchronous orbit around the earth
- Satellites keep accurate time using atomic clock
- Satellites send out a signal with several pieces of information
  - Satellite location (“almanac”)
  - Time

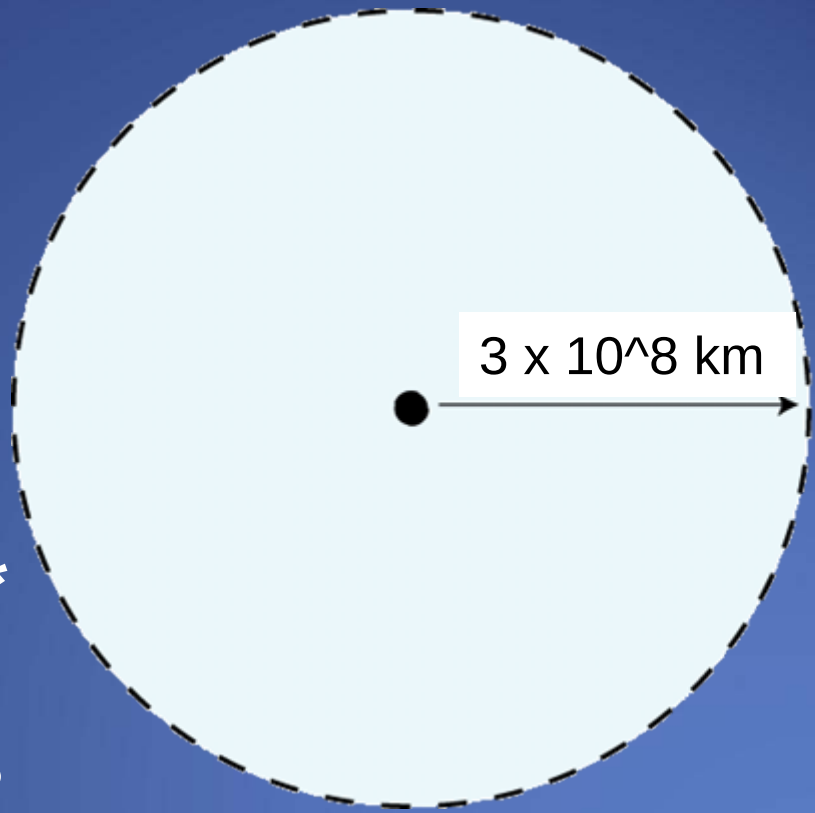
Ground system

- Receive two essential pieces of information: time and ID number
- Triangulate position



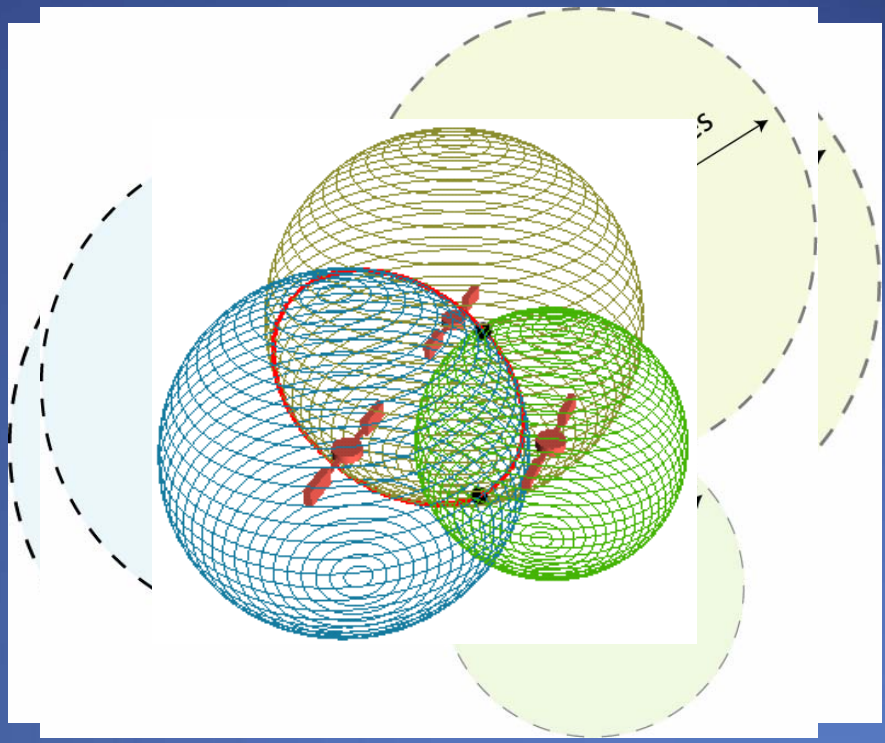
Triangulation

- Speed of Light x Time = Distance
- If it's 12:00:00 at the satellite, and 12:00:01 here…
  - **the speed of light * 1 second = 299 792.458 kilometers** distance



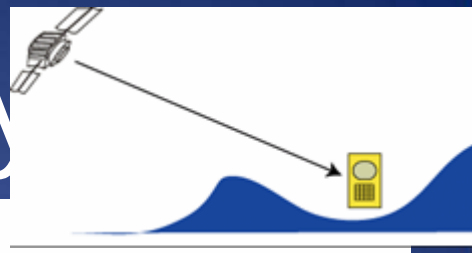
Triangulation

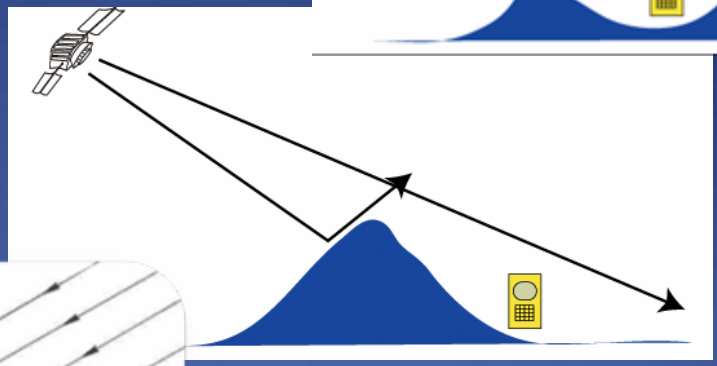
- If we know our distance from multiple points, we can triangulate our location, even in 3d

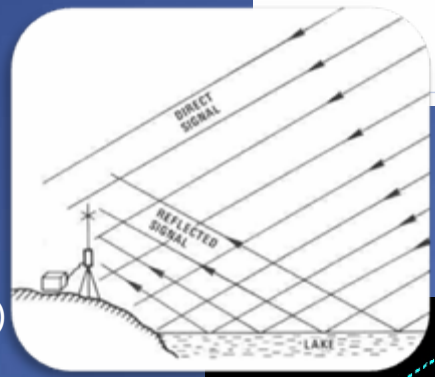


Errors and Accuracy

- Atmospheric effects
- Other electromagnetic waves
- Jamming sources
- Selective Availability

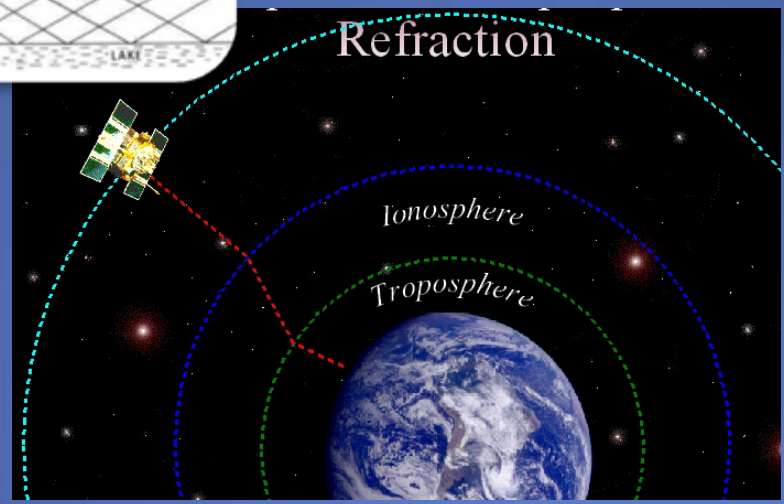




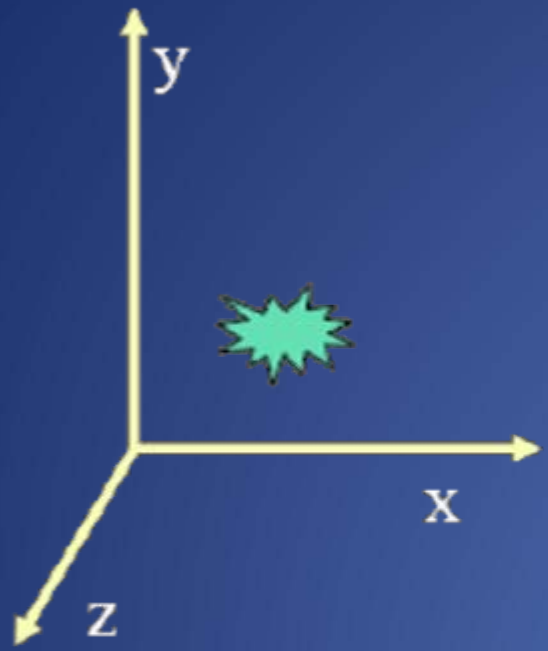


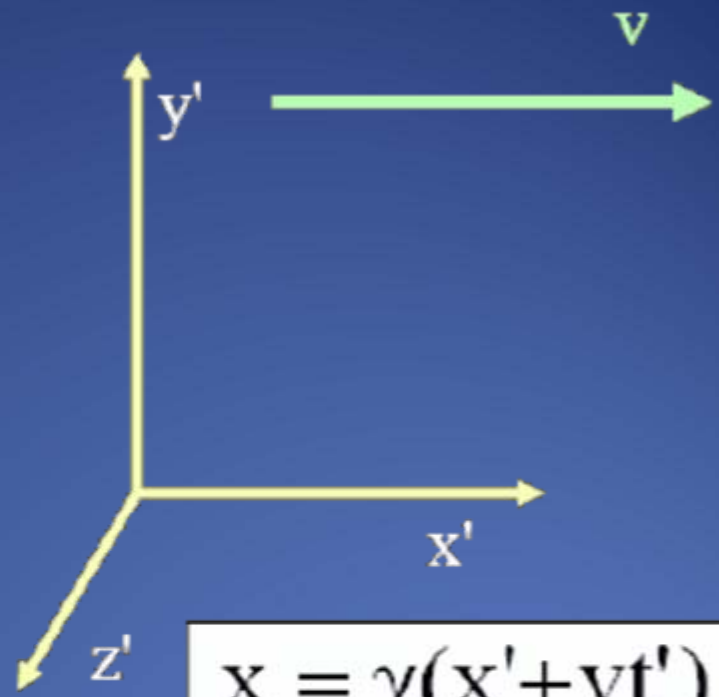
Sources of User Equivalent Range Errors (UERE)

Source	Effect
Ionospheric effects	± 5 meter
Ephemeris errors	± 2.5 meter
Satellite clock errors	± 2 meter
Multipath distortion	± 1 meter
Tropospheric effects	± 0.5 meter
Numerical errors	± 1 meter



Lorentz transformations





How are (x,y,z,t) related to (x',y',z',t')?

$$x = \gamma(x'+vt')$$

$$y = y'$$

$$z = z'$$

$$t = \gamma\left(t'+v\frac{x`}{c^2}\right)$$

Errors and Accuracy II

- Speed
  - Special relativity
  - 7.2 microseconds slower
- Gravitational potential
  - General relativity
  - 45.9 microseconds faster

This causes a discrepancy of 38 microseconds. So? Atomic clocks must be programmed to run slower.

Military Apps of GPS

- Purpose is to aid the demand for information required by the modern military commander in a fast-paced electronic battlefield

- GPS military applications include navigation, targeting, tracking, rescue, bomb and missile guidance, map updating, and facility management.

Military Apps of GPS

Military requirements of GPS are to be accurate, all weather, easy to use, and portable

GPS accuracy may vary from a few meters to a few tens of meters which meets navigation requirements

Differential GPS (DGPS) is required for precision air strikes down to the millimeter

Military Apps of GPS

- GPS satellite signals are not negatively affected to a very strong degree by bad weather
- GPS in today's world can be so small as to fit in a wristwatch

Military Apps of GPS in Iraq, Tactical Reference Points (Ramadi 05-06)

Convoy guidance

Nick-names given to insurgent-used buildings

Exact coordinates and imagery determined and shared with aerial support

Easily communicated targets were engaged without confusion during combat

Synchronization

- Frequently used by power grids, financial networks, and Communications systems.
  - Helps businesses achieve precise timing and operate at the highest level.
- Examples:
  - Investment Banks: use GPS to synchronize their global networks, and track transactions around the world.
  - Power companies: use GPS to quickly assess power blackouts and fix line breaks.

GPS is out of this world!

- Used in satellites that monitor the Earth from space.
  - Improves satellite performance and efficiency without much support from ground crews.
- Replaces expensive sensors and atomic clocks on-board spacecraft.
- Used in launch sequences for precise tracking and improved safety.

GPS in the air

- Provides 3-D positioning (latitude, longitude, and altitude) of airplanes from take-off to touch-down.
- Opens up new and efficient flight routes.
    - Ultimately saves airlines both fuel and time.
- Improves performance, air traffic, and flight scheduling during inclement weather.

All Aboard!

- Railways require GPS for accuracy and precision in locating trains and equipment.
  - Vital to railway safety and traffic control.
  - Allows trains to stay both on course and on schedule.
  - Provides accurate positioning for railway maintenance crews.

Seafaring

- Improves safety and efficiency of marine navigation.
  - Calculates speed, position, and heading to keep ships on course.
  - Provides accurate navigation charts with DGPS enhancement.
  - Improves traffic conditions on the sea, especially in busy commercial routes.
  - Heightens security both in and out of port.

GPS down on the farm

- System of agricultural precision:
  - Analyzes the entire field, the soil, and the crops that are planted.
    - » Improves production and allows farmers to effectively manage their fields.
  - Tractor navigation: allows farmers to work effectively even under the worst conditions.
  - Improves pesticide and herbicide distribution to help protect the environment.

Environment

- GPS provides for comprehensive analysis of environmental concerns and disasters
  - Assists in improving the accuracy of weather forecasts
  - Preservation of endangered species can be facilitated through GPS tracking and mapping
  - Helicopters utilize GPS to map the perimeter of forest fires to increase the efficiency of firefighting
- GPS data can be captured and analyzed at a quick rate
  - This can help in the characterizing and anticipation of future earthquakes and seismic activity

Public Safety & Disaster Relief

- GPS technologies can expedite disaster relief through precise pinpointing of disaster locations
  - GPS was utilized during the tsunami disaster in the Indian Ocean in 2004, Hurricane Katrina in 2005, and the Pakistan-India earthquake in 2005
  - Maps of the areas were created to assess damage and plan for rescue and aid operations
- GPS can be found in Mobile Phones and Vehicles
  - This provides an emergency location capability and immediate positional information
  - GPS reduces the delay of the dispatch of emergency services (i.e. police, fire, ambulance)

Space-Based Positioning, Navigation, and Timing Policy

- In 2005 President Bush issued a new policy covering all systems utilizing satellite-based technologies including GPS
  - The Department of Defense is the designated lead agency that represents the GPS community
  - The Department of Homeland security must work to protect GPS from intentional and unintentional interference and deny any hostile use
  - U.S. GPS technologies must exceed or at least be equivalent to international systems
  - GPS must provide on a continuous worldwide basis all services free of direct user fees and free access to information for further development
  - The use must be promoted and foreign development must be encouraged for the sake of mutual benefit from the systems

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