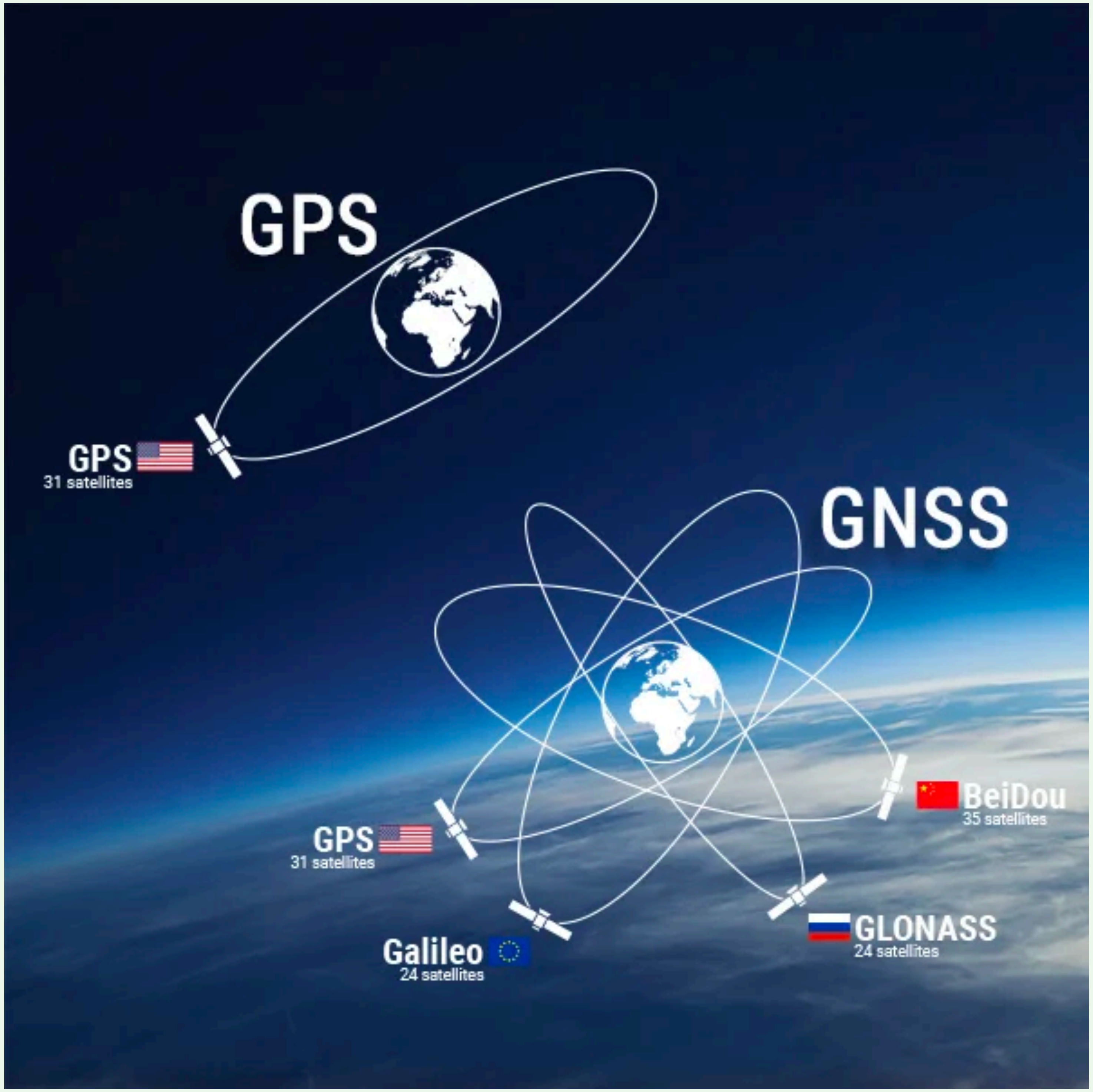
# GEOG 358: Introduction to Geographic Information Systems

## Global Navigation Satellite Systems (GNSS)



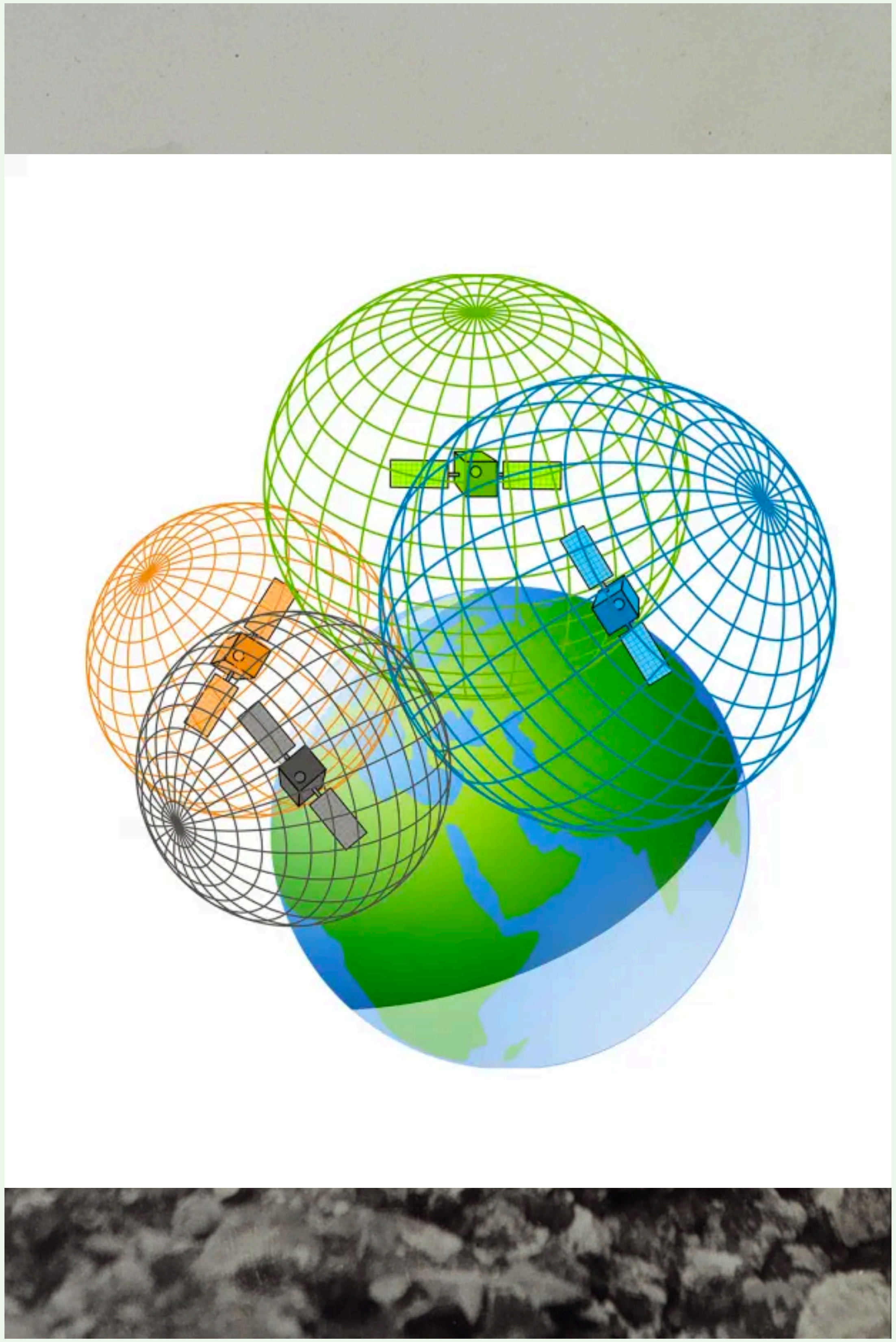

LANDSAT 9 THINGS

# Topics

- What is GNSS?
- How does GNSS work?
- Differential GNSS

# Measuring location

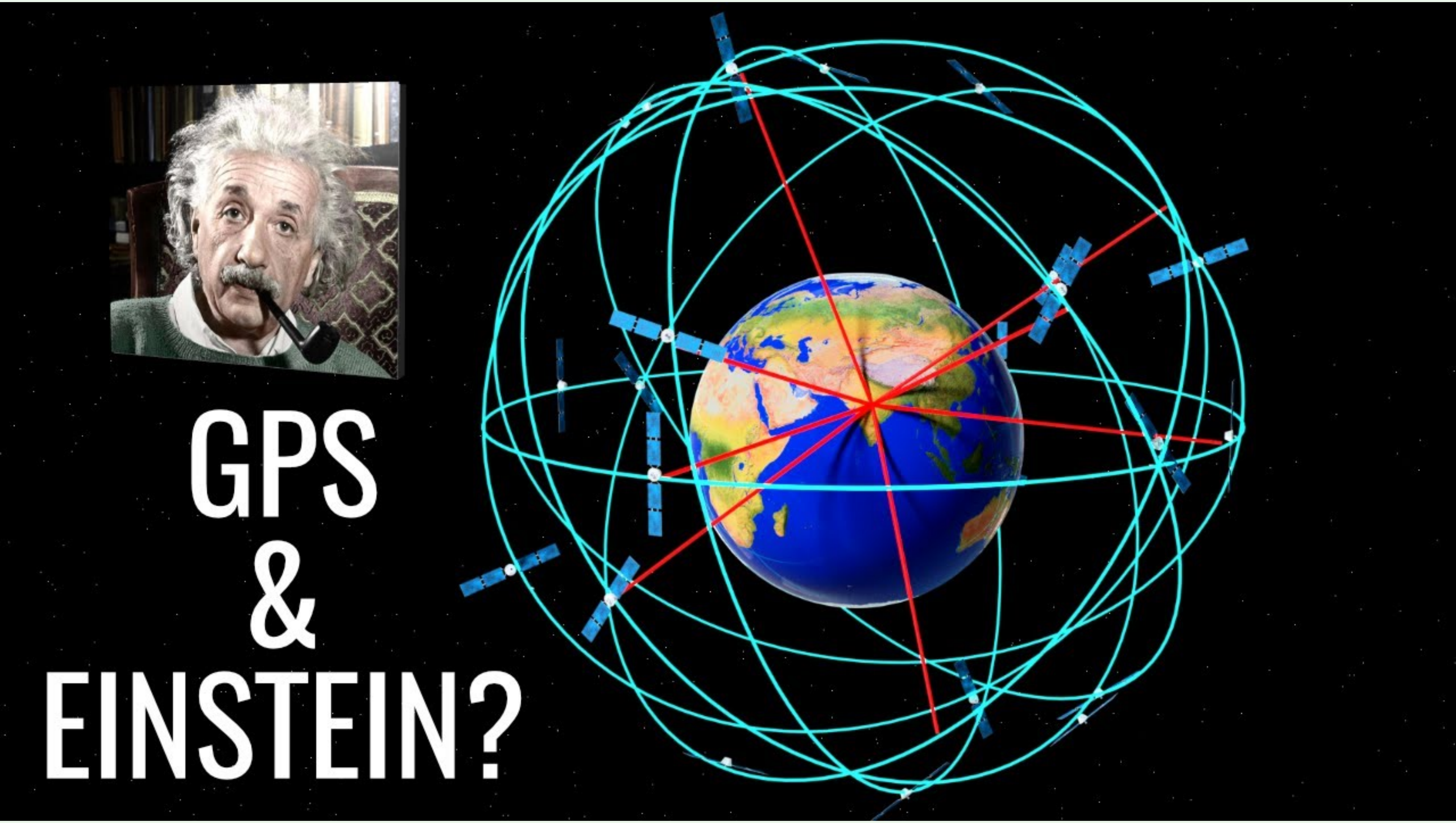
- Traditional ground survey
- Remote sensing
- Satellite positioning



# Satellite positioning technology

- A ***technology*** using radio signals broadcast from satellites for navigation and position determination on Earth

- Global navigation satellite systems (GNSS)
  - Systems implemented the technology


GPS
&
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# Satellite Positioning Technology and Implementations

- GNSS (global navigation satellite system)
  - An overall term refers to the systems that use signals from satellites to find locations on Earth's surface
- GPS = NAVSTAR GPS
  - Navigation Satellite Timing and Ranging System (NAVSTAR)
  - U.S. version of GNSS
  - The first of its kind
- Other versions/implementations of GNSS
  - GLONASS (Russia)
  - Beidou (China)
  - Galileo (European Union)

# A Brief History

- GPS (or NAVSTAR GPS)
  - DoD began the study in 1973
  - Prototype satellites were launched in 1974 and 1977
  - Ten NATO countries began participation in 1978
  - Full operation started in 1993
  - GPS is a dual-use system for the military and civil communities
- Other similar systems
  - Russia—GLONASS, deployed in 1976, global coverage in 2009
  - China—Beidou, operational in 2011
  - European Union—Galileo, operational in 2013

# GNSS or GPS

- GPS (Global Positioning System) is sometimes used synonymously for GNSS
- GPS more specifically refers to the U.S. developed GNSS

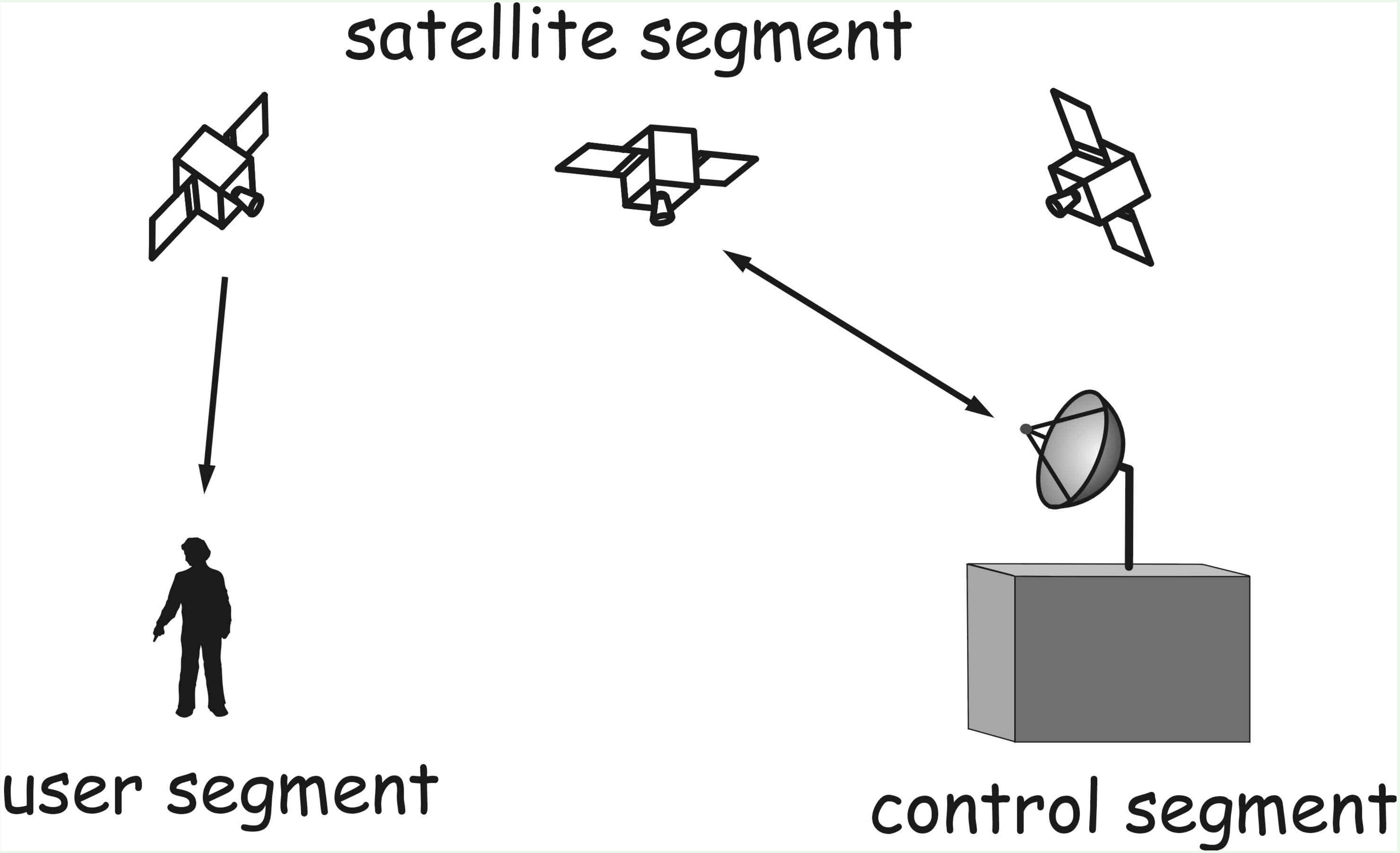
# What can be determined by GNSS?

- **Position**
- **Time**
- **Velocity**

# What are the unique features of GNNS?

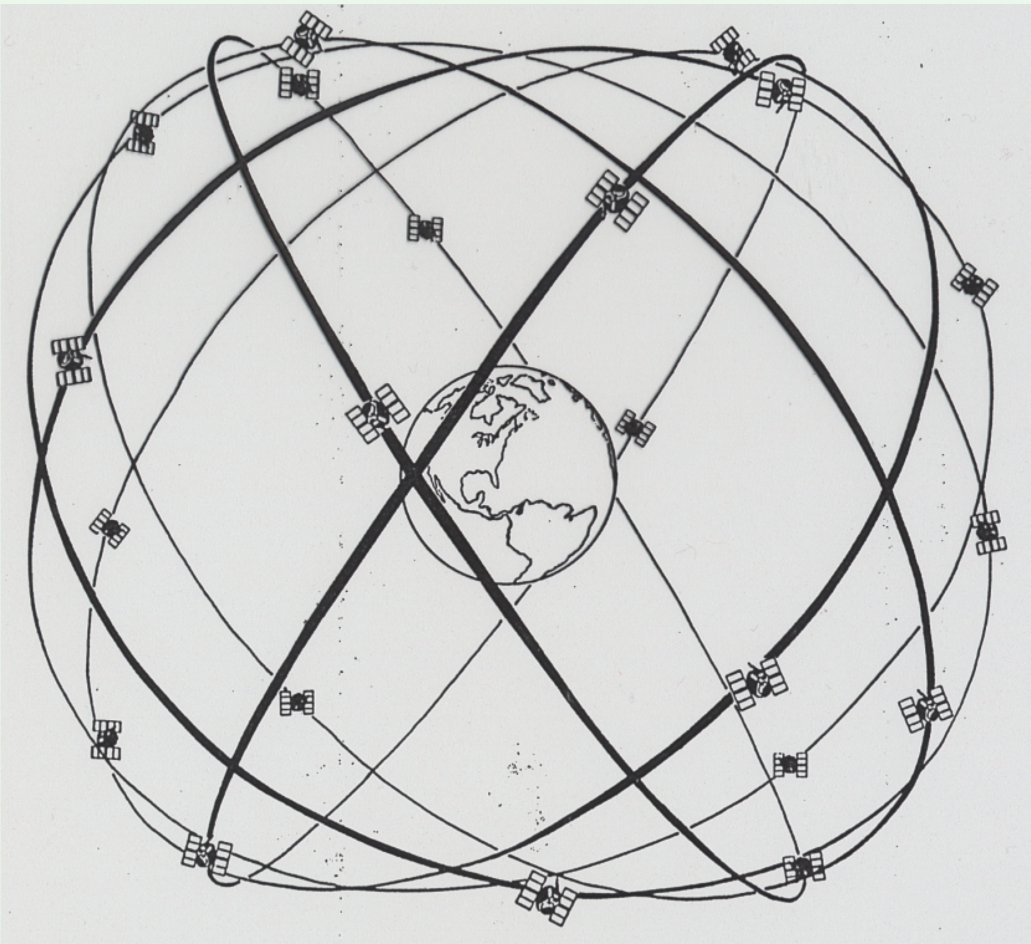
- Very accurate (varies from about 10 meters to several centimeters)
- Very small antenna requirement
- Global coverage
- Any time (day & night)
- Any weather
- Easy to use
- Free to the user community

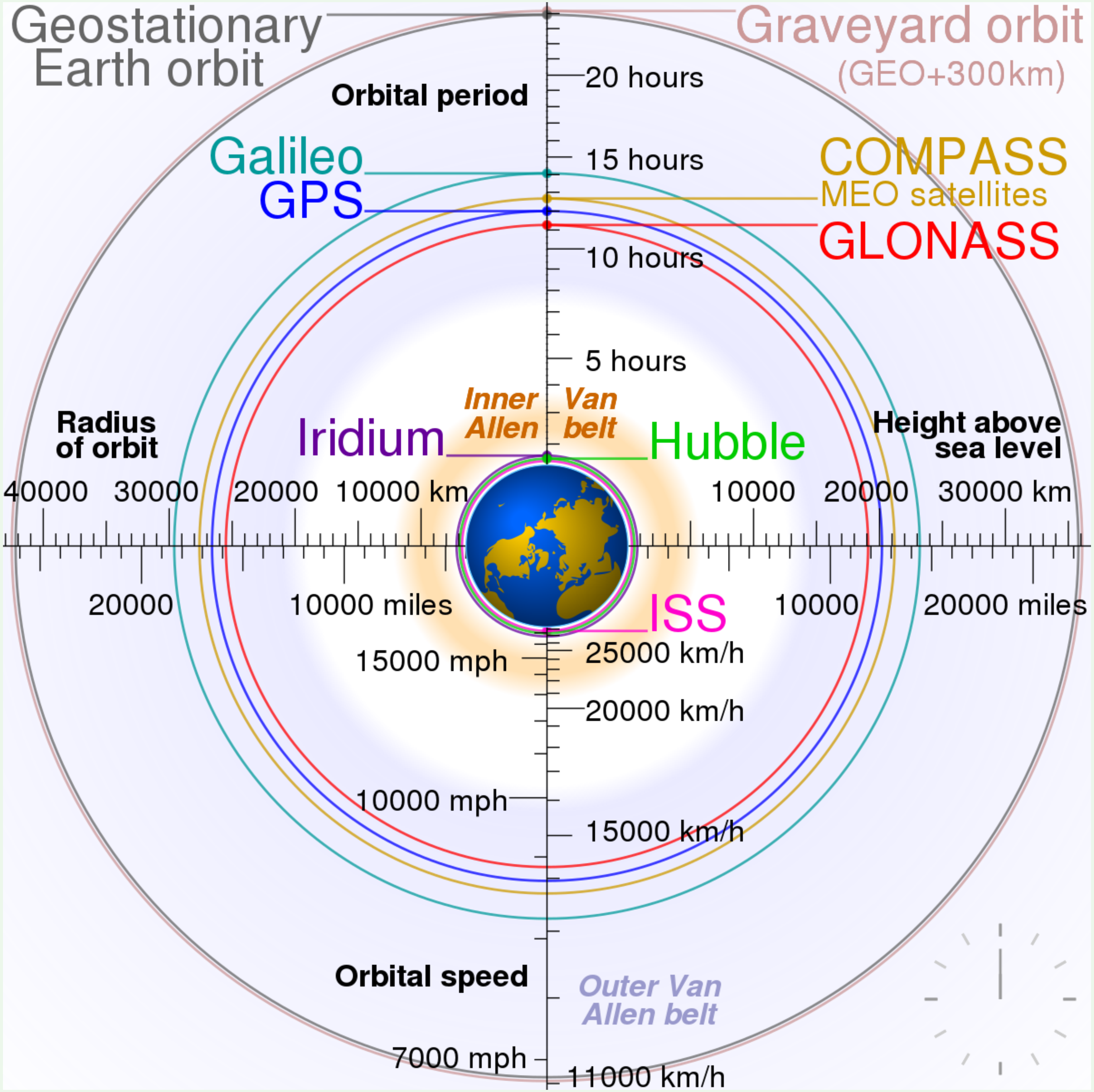
# GNSS Segments



# Satellite/Space Segment

- GPS as the example
- A constellation of 18+ satellites orbiting around the earth
- Distributed in 6 orbital planes with inclination of 55 degrees to equator
  - Four or more satellites visible at all times anywhere on earth
- Satellites are at an altitude of 20,000 km (12,500 miles)





Geostationary Earth orbit
Graveyard orbit
(GEO+300km)
Orbital period
20 hours
15 hours
10 hours
5 hours
Galileo
GPS
COMPASS
MEO satellites
GLONASS
Inner Van Allen belt
Iridium
Hubble
Radius of orbit
Height above sea level
40000
30000
20000
10000 km
10000
20000
30000 km
20000
10000 miles
10000
20000 miles
ISS
15000 mph
25000 km/h
20000 km/h
10000 mph
15000 km/h
Orbital speed
Outer Van Allen belt
7000 mph
11000 km/h

# Signal Contents / Navigation Message

- Satellite date/time, position and status
- Ephemeris
  - precise orbital information for the transmitting satellite
- Almanac
  - status and low-resolution orbital information for every satellite (for speeding up fixing position)

# Signal Contents / Navigation Message

- Ranging code
  - Music used to align signals for estimating travel time
  - C/A—coarse acquisition code, accessible by everyone
  - P—precision code, accessible by military
  - Y –encrypted P code
  - New code (M code) on newer satellites
- Carrier frequency
  - L1(broadcast at 1575.42 MHz)—carries C/A, P and Y code
  - L2 (broadcast at 1227.60 MHz)—carries P and Y code
  - New frequencies (L5) are used on newer satellites

# Control Segment

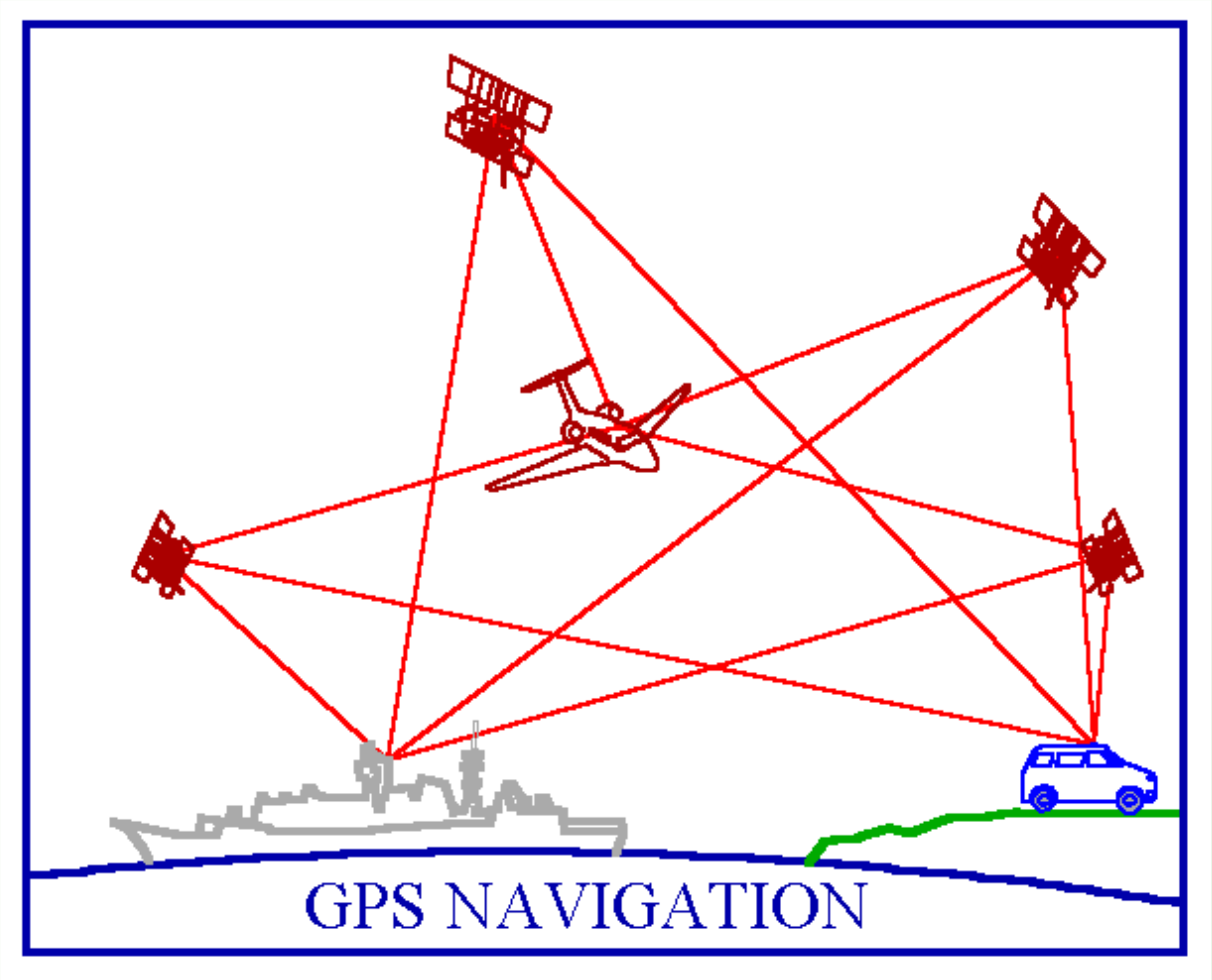
- Observe, maintain and manage the GPS satellites and system
  - Check both their operational health, exact position in space, and clocks
- Monitor stations + master station
- The master station transmits corrections back to the satellites
- Corrections made daily
- U.S. Air Force

# Monitor & Master Stations


Global Positioning System (GPS) Master Control and Monitor Station Network

# User Segment

GPS receivers use the signals from the satellites and process the data to obtain position



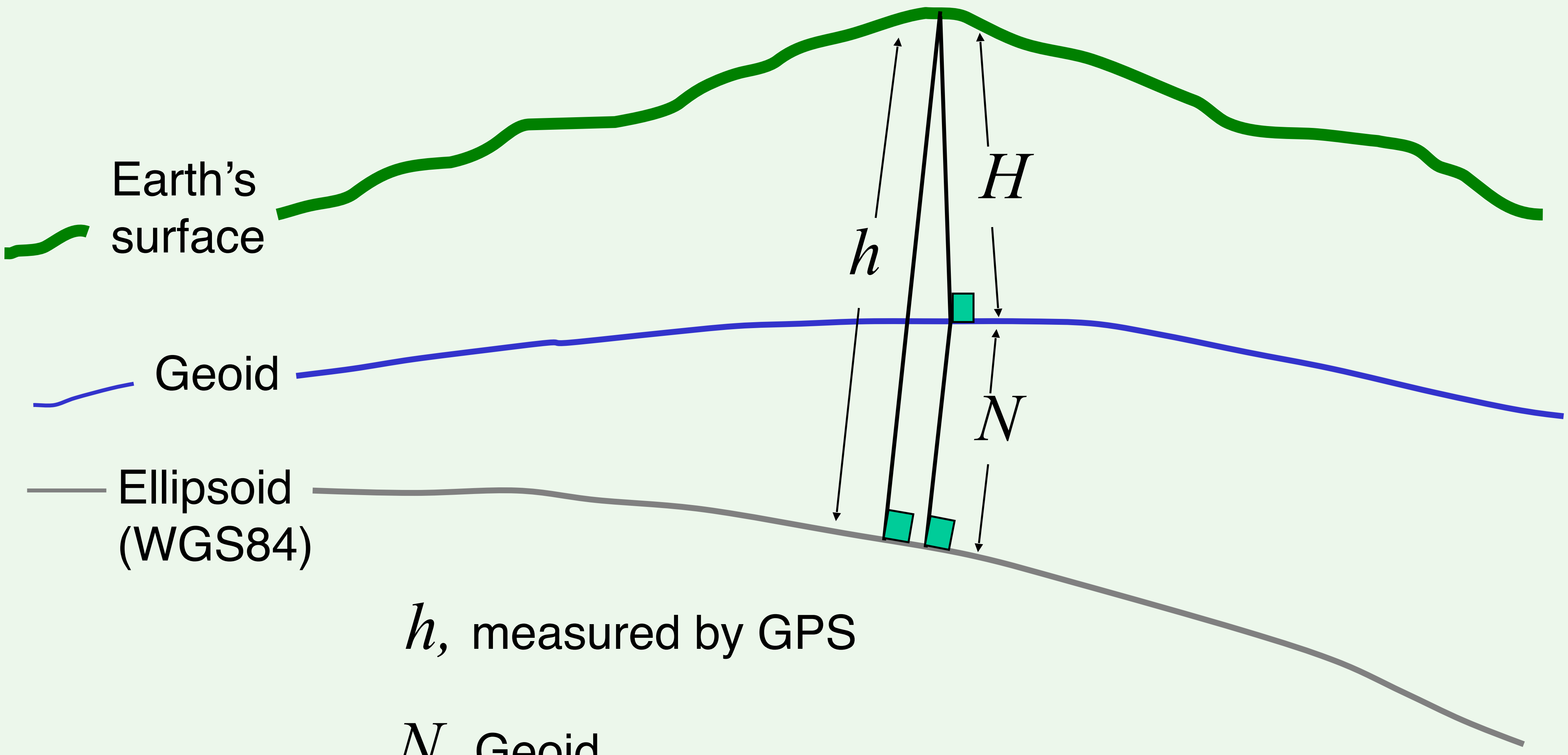
# User Segment

- A one-way ranging system
  - satellites broadcast information, and receivers use it
- GPS receiver capacity
  - Number of channels
    - The number of satellites from which the receiver can obtain signals at one time
  - Number of frequencies
    - Single frequency (L1)
    - Dual frequencies (L1 & L2)

# GPS Data Format

- Coordinates measured with a GPS receiver are commonly saved in GPX format
- A standard file format for working with GPS data collected by GPS receivers

# GPS Height Measurement

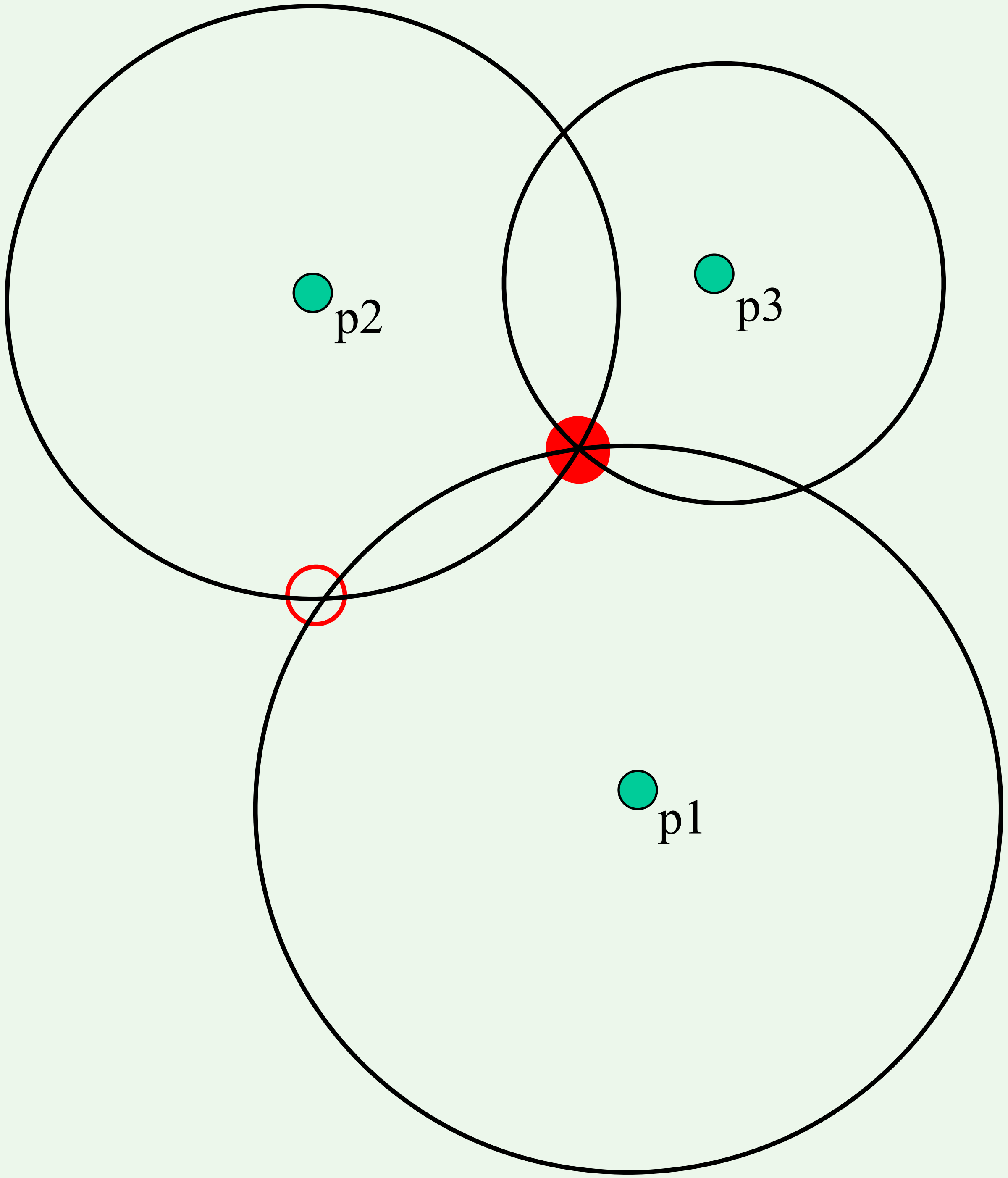



$h$, measured by GPS

$N$, Geoid

$H$, orthometric height = *h* - *N*

# How Does GPS Work in 2D?




Trilateration--finding a location in relation to three points of reference

1. **Location** of 3 reference points
2. **Distance** to 3 reference points

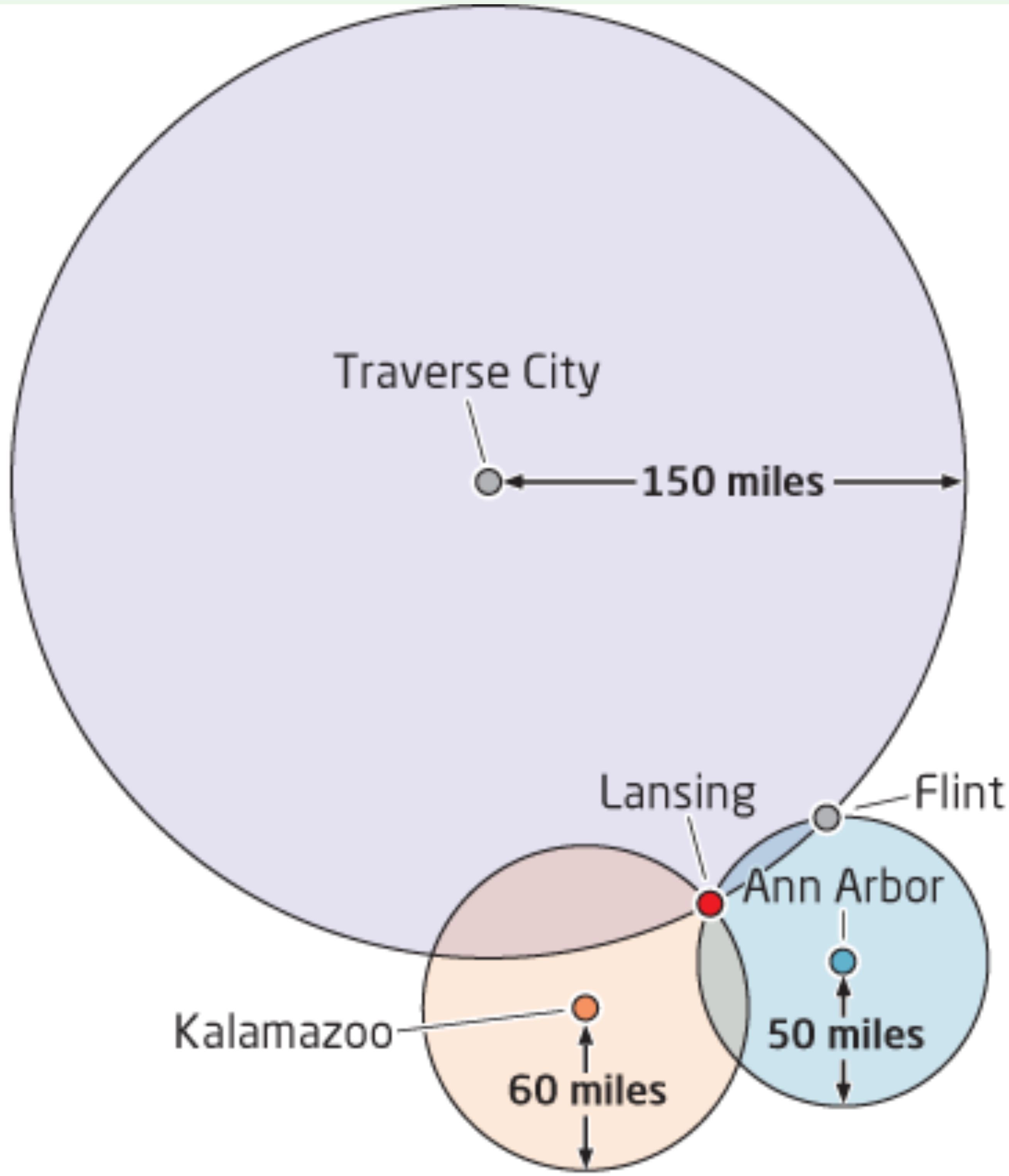
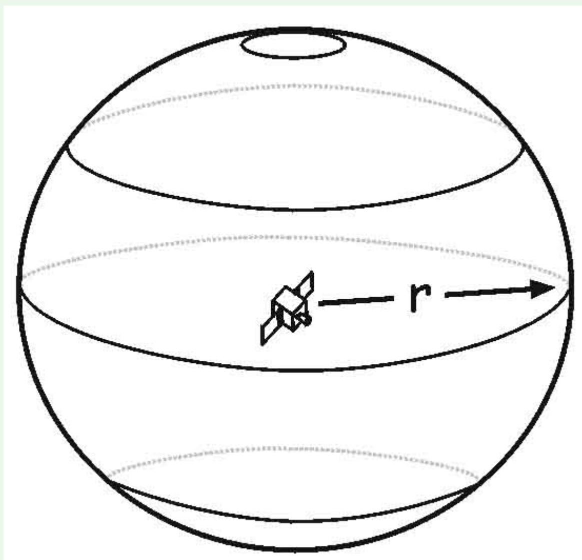
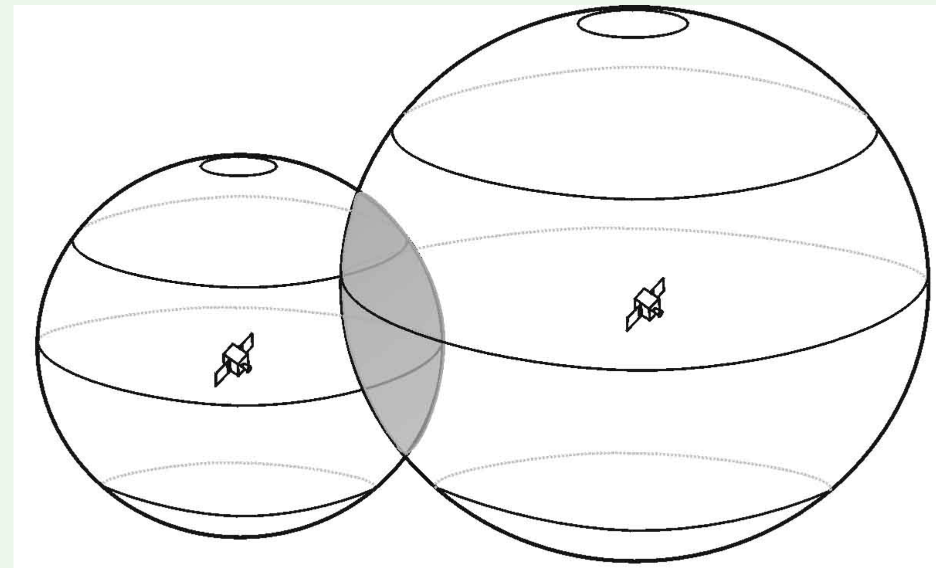
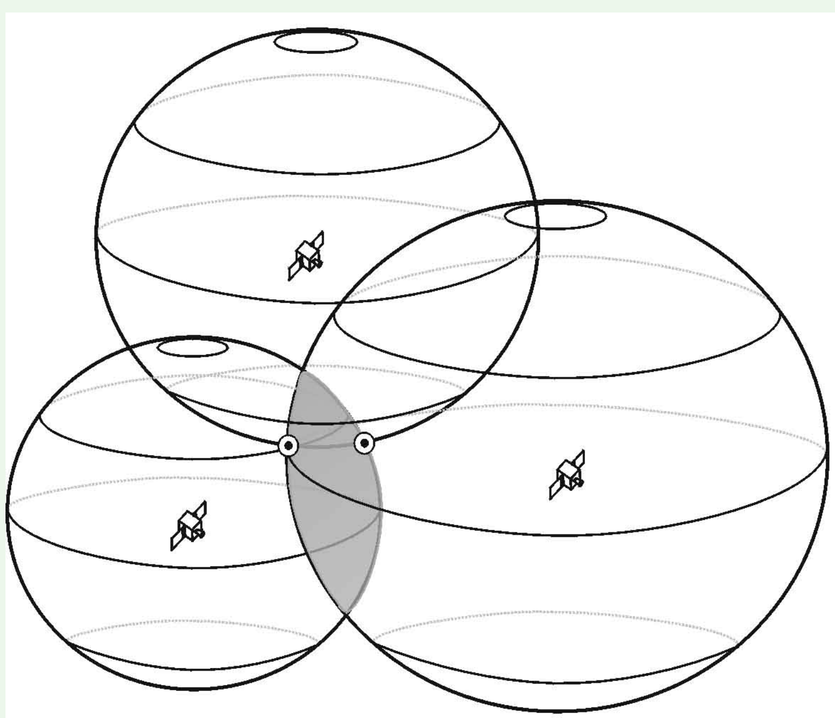


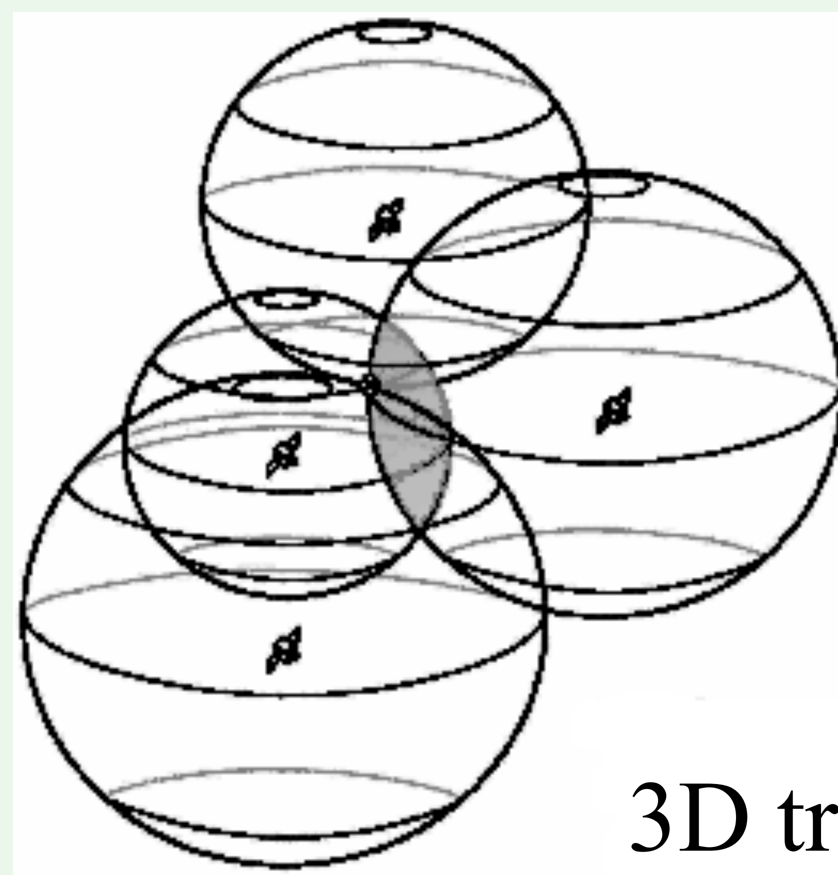

**Figure 4.5**
Shellito, *Introduction to Geospatial Technologies*, 4e,

# How Does GPS Work in 3D







3D trilateration

# Measuring Distance from GPS Satellites

- Distance is calculated by timing how long it takes for a signal sent from the satellite to arrive at a receiver.
  - Distance = Velocity * Travel Time
- GPS signals travel at the speed of light ($3 * 10^8$ m/s)
- Find travel time by matching range code

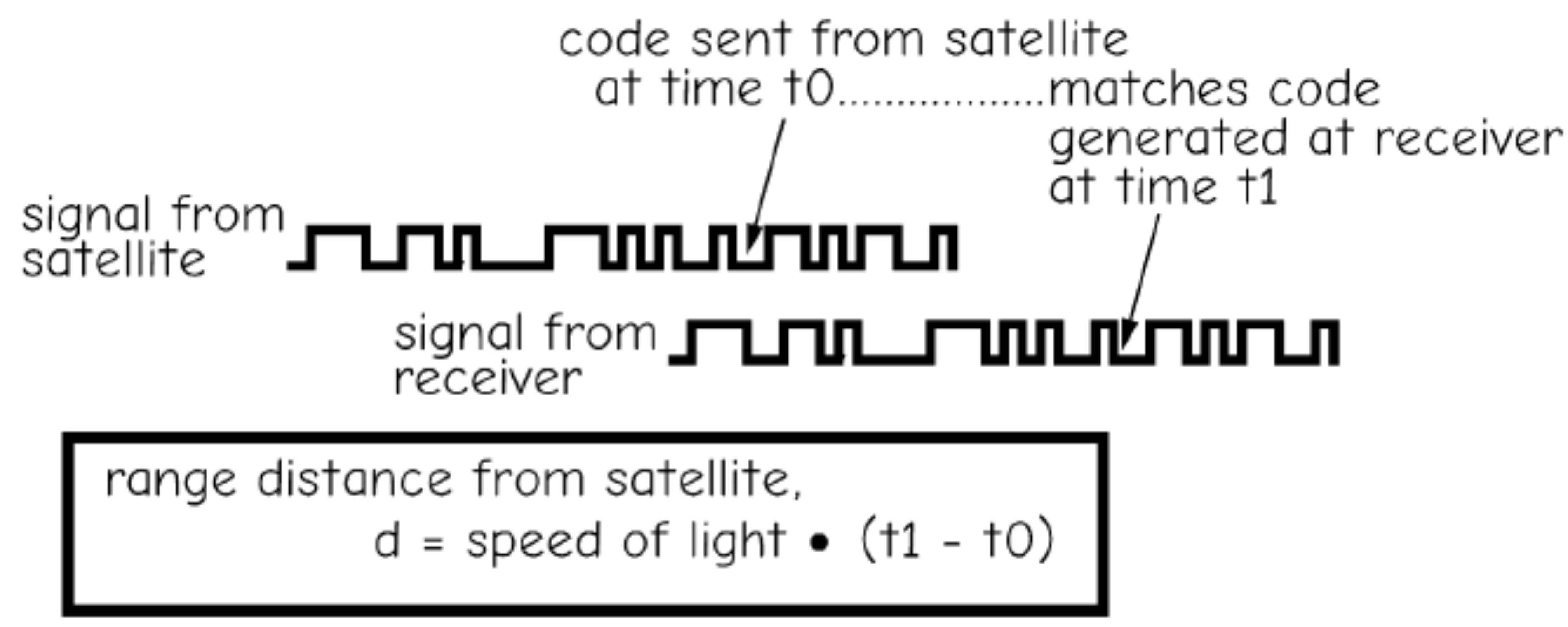


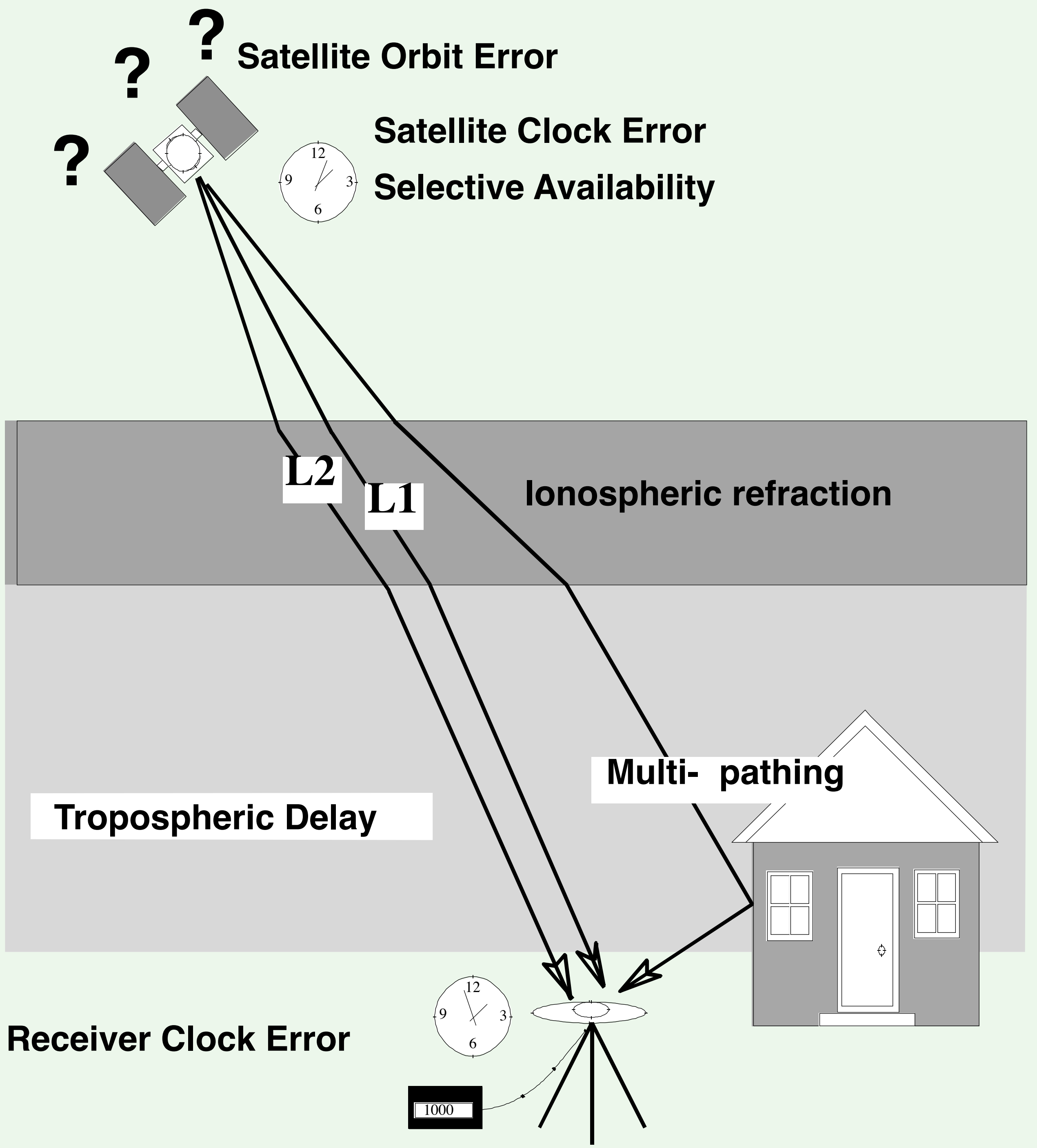

**Figure 5-6**: A decoded C/A satellite signal provides a range measurement.

# Measuring Distance from GPS Satellites

- Distance is calculated by timing how long it takes for a signal sent from the satellite to arrive at a receiver.
  - Distance = Velocity * Travel Time
- GPS signals travel at the speed of light ($3 * 10^8 m/s$)
- If a satellite were right overhead the travel time would be
  - 20,000,000 / 300,000,000 = 0.067 seconds
- Travel time is very short
- We need really precise clocks on satellites and receivers
  - An atomic clock costs about $50k to 100k

# GPS Error Sources

- Many things can interfere with the signals
- Various error sources
  - Satellite clocks and orbits
  - Atmospheric delays
  - Multipath
  - Receiver clocks
- Selective availability (SA)
  - the intentional degradation of GPS signals
  - removed on May 1, 2000



# Effects of Atmosphere

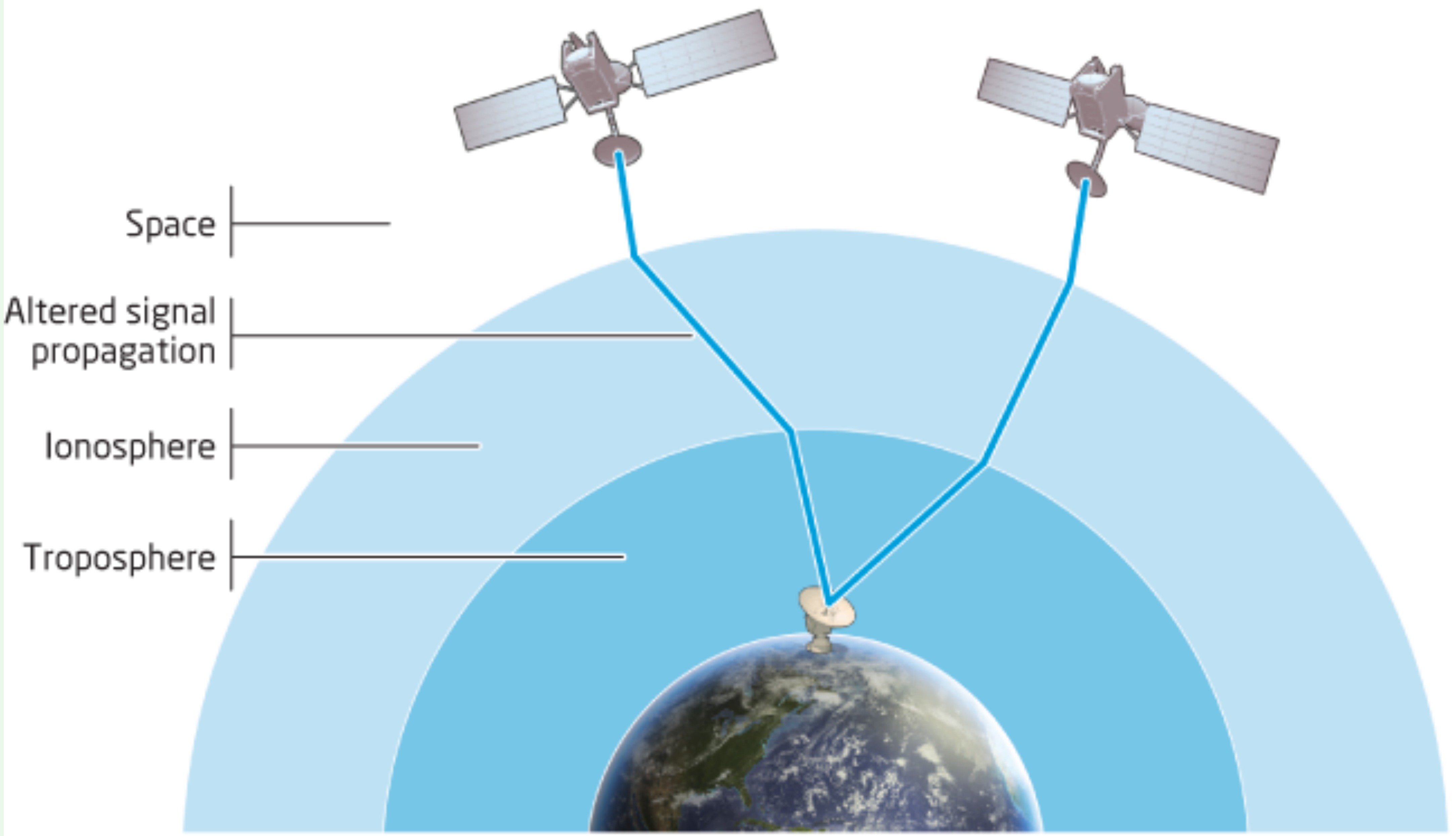
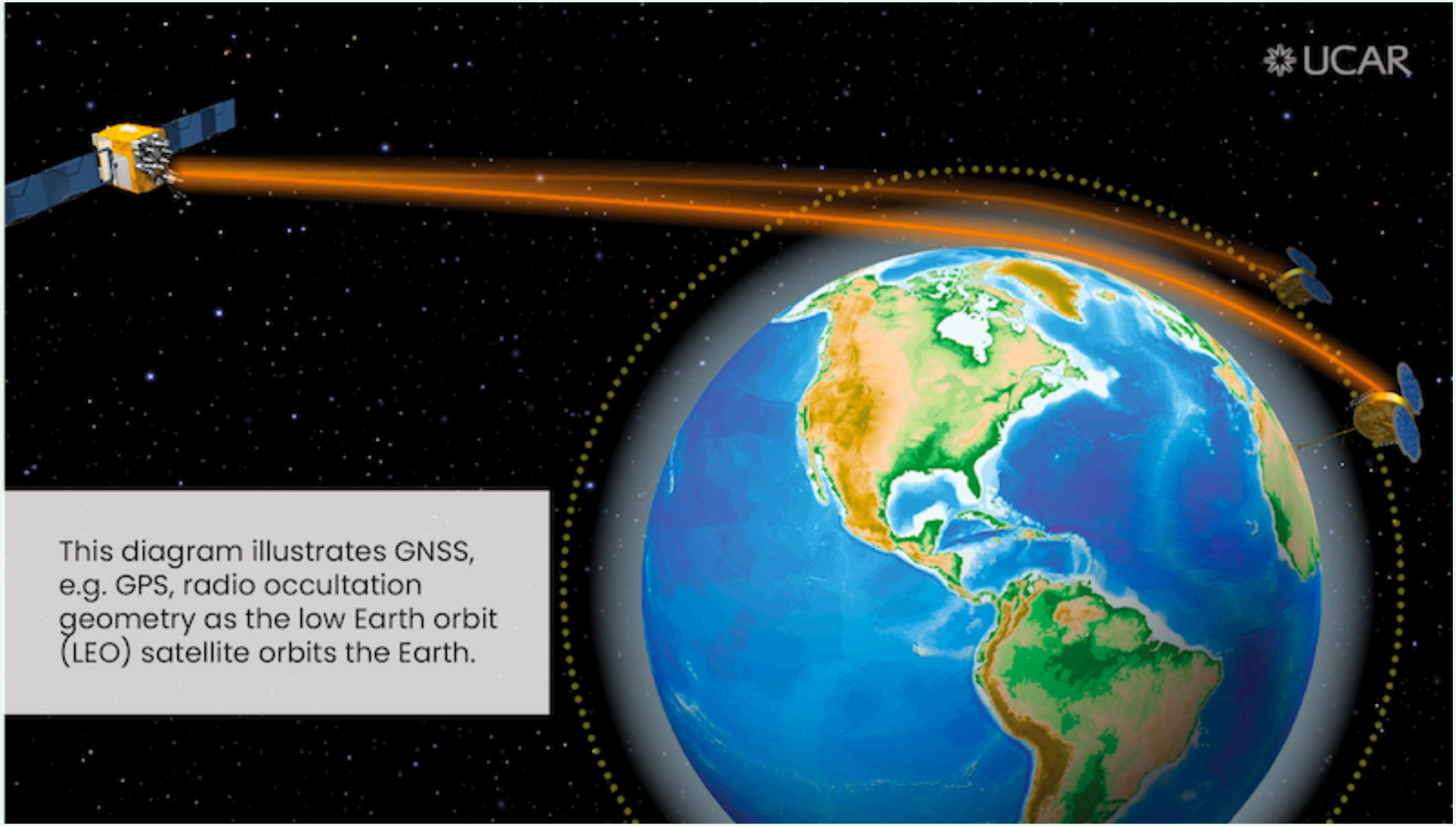
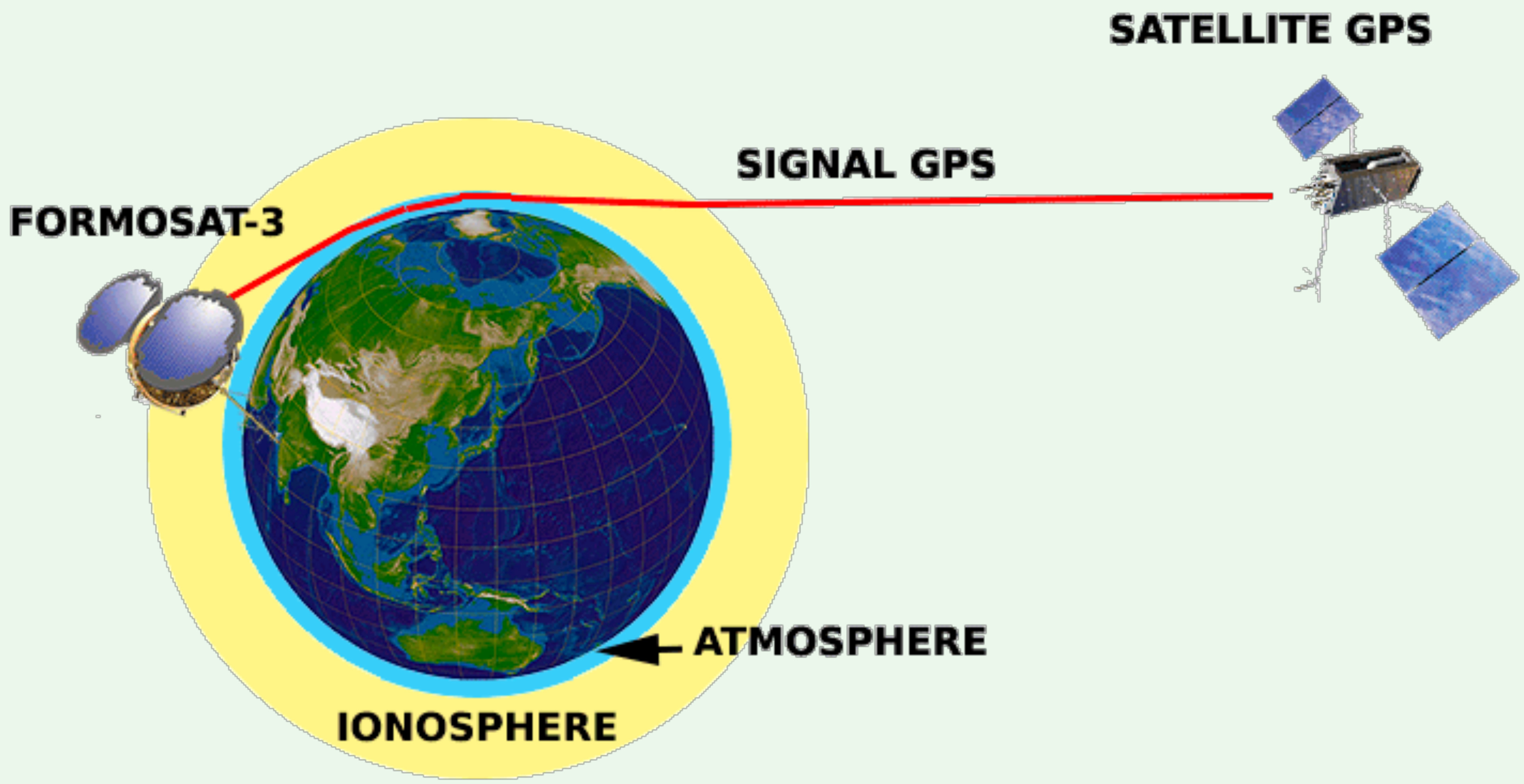



**Figure 4.7**
Shellito, *Introduction to Geospatial Technologies*, 4e, © 2018 W. H. Freeman and Company

# Radio occultation

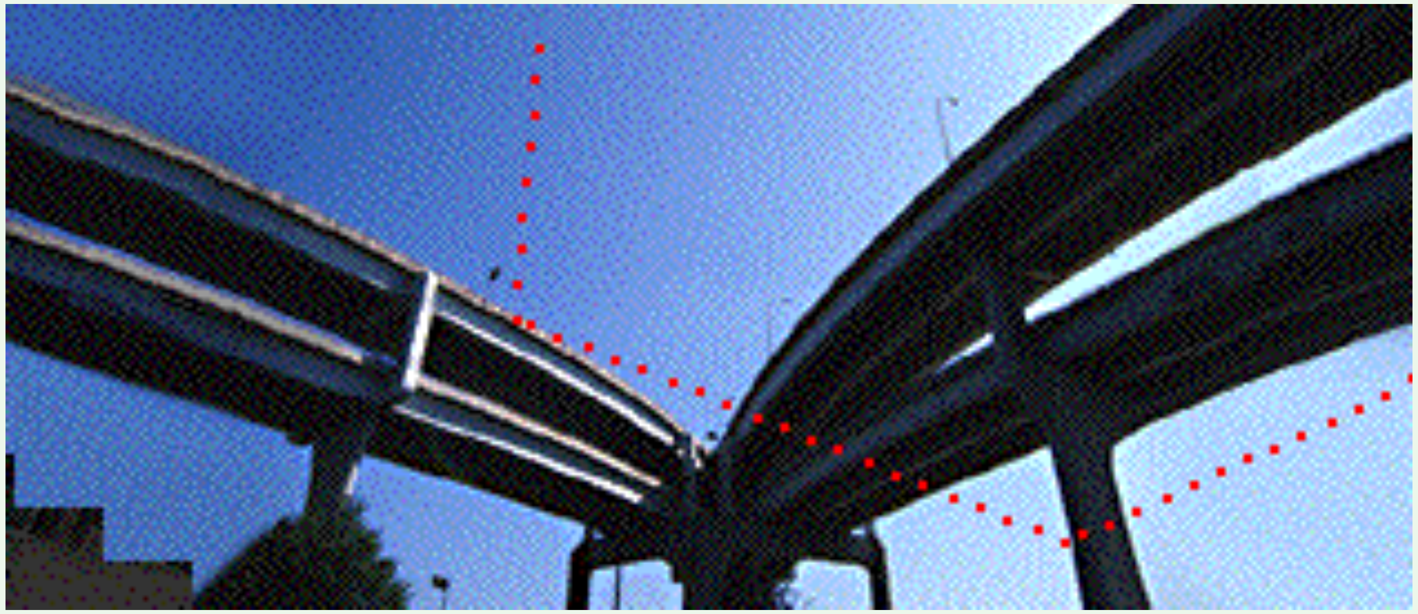


# Radio occultation



# Multi-Path Error

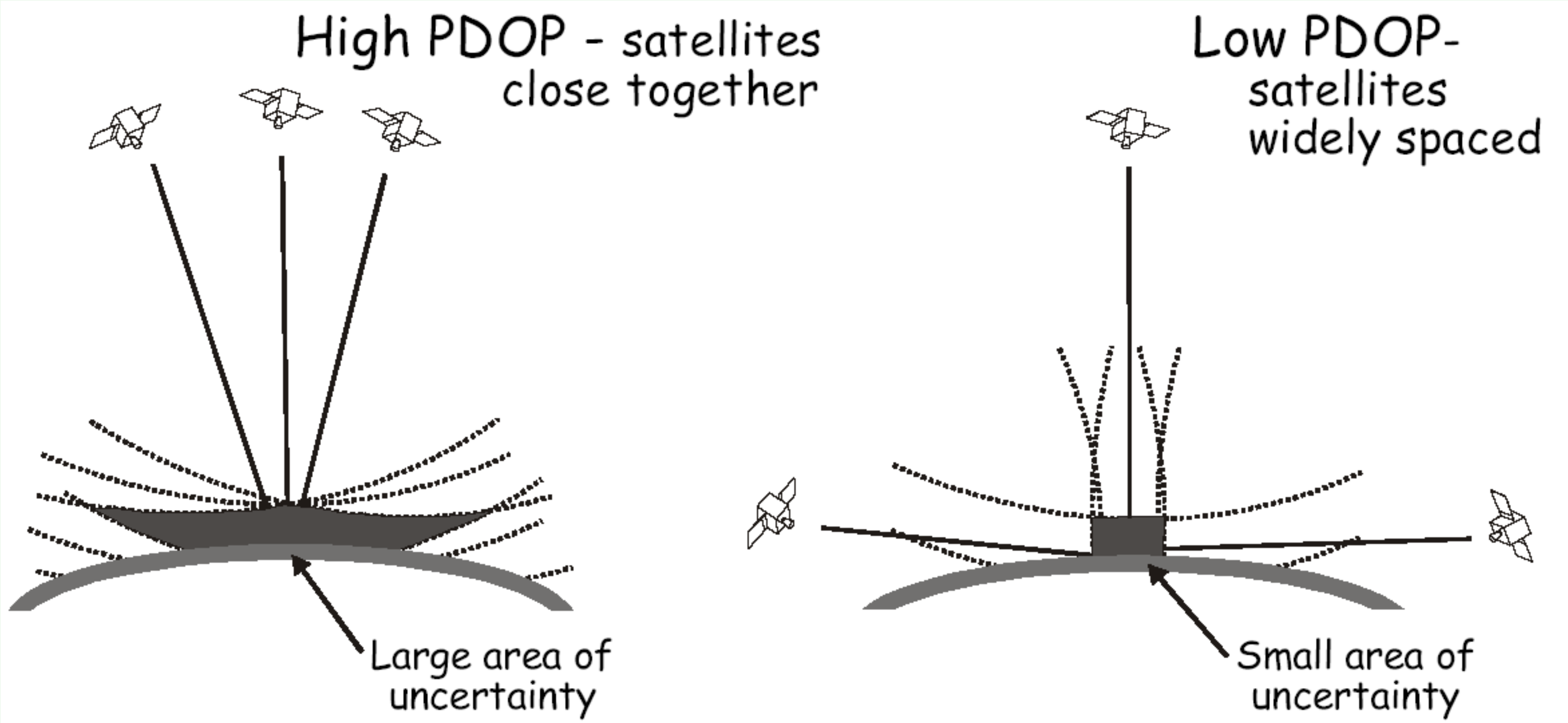
- GPS signals may not travel straight from the satellite to the receivers
- GPS signals may bounce off various local obstructions before they get to receivers



# Arrangement of GPS Satellites

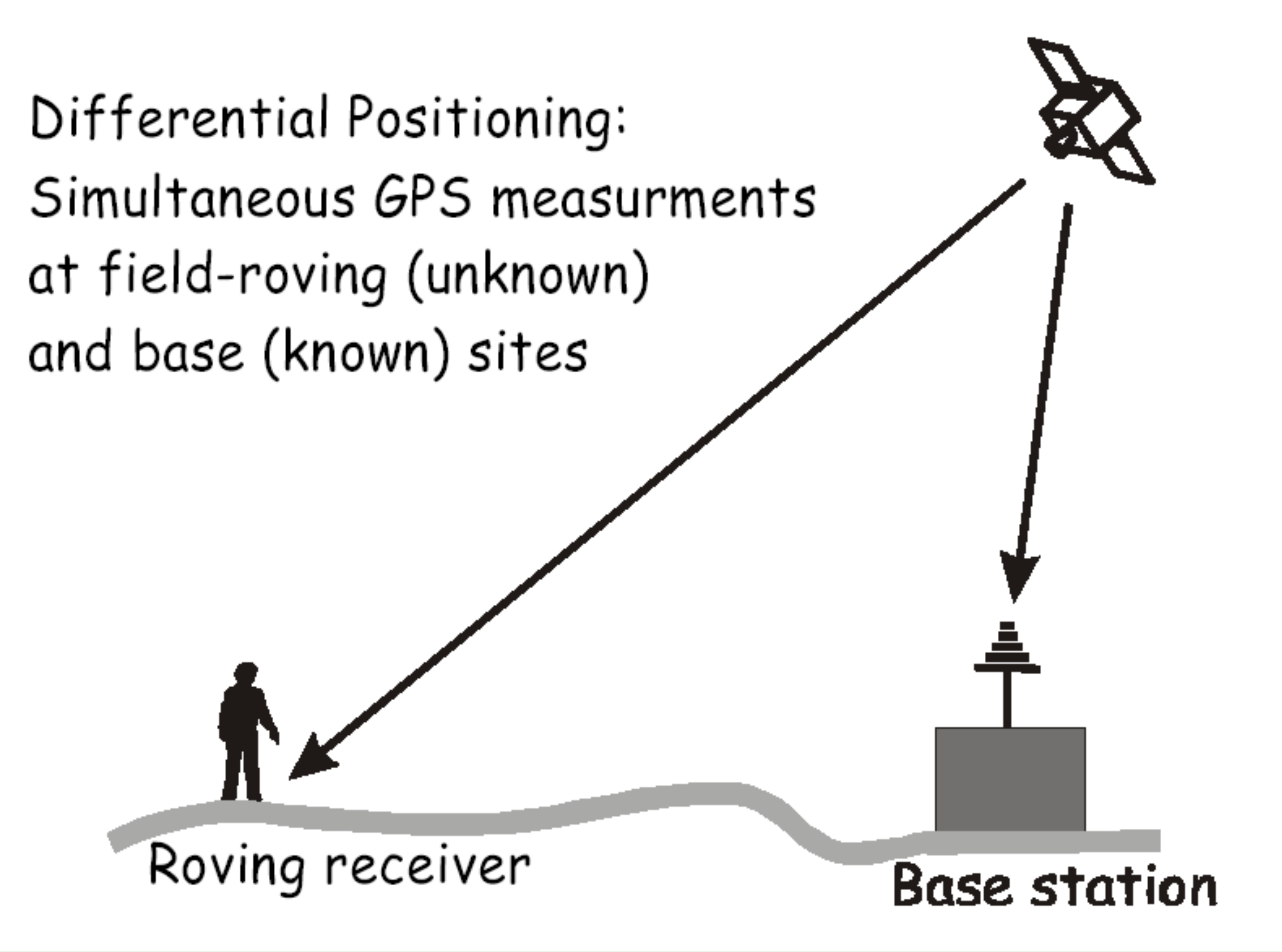
- Positional Dilution of Precision (PDOP)
  - A measure of satellite spatial configuration
  - a wider-spaced constellation is better
- Lower PDOPs represent signals from widely spaced satellites
  - Range is from 1 to 100
  - Good range is from 2 to 10
- There are usually more satellites available than a receiver needs to fix a position.
  - Good receivers use satellites that give the lowest PDOP

# GPS Satellite Geometry--PDOP

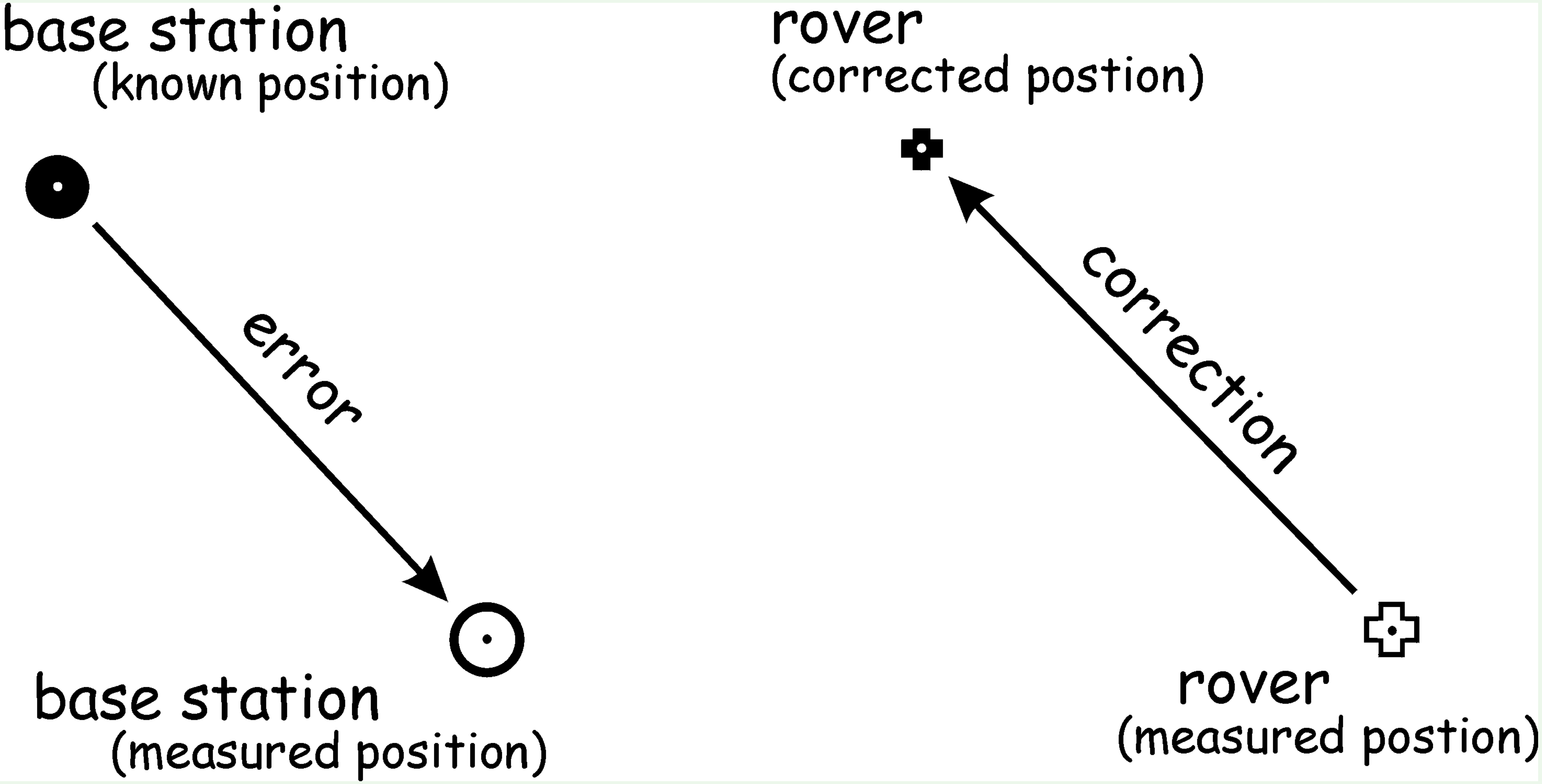


# Differential GPS

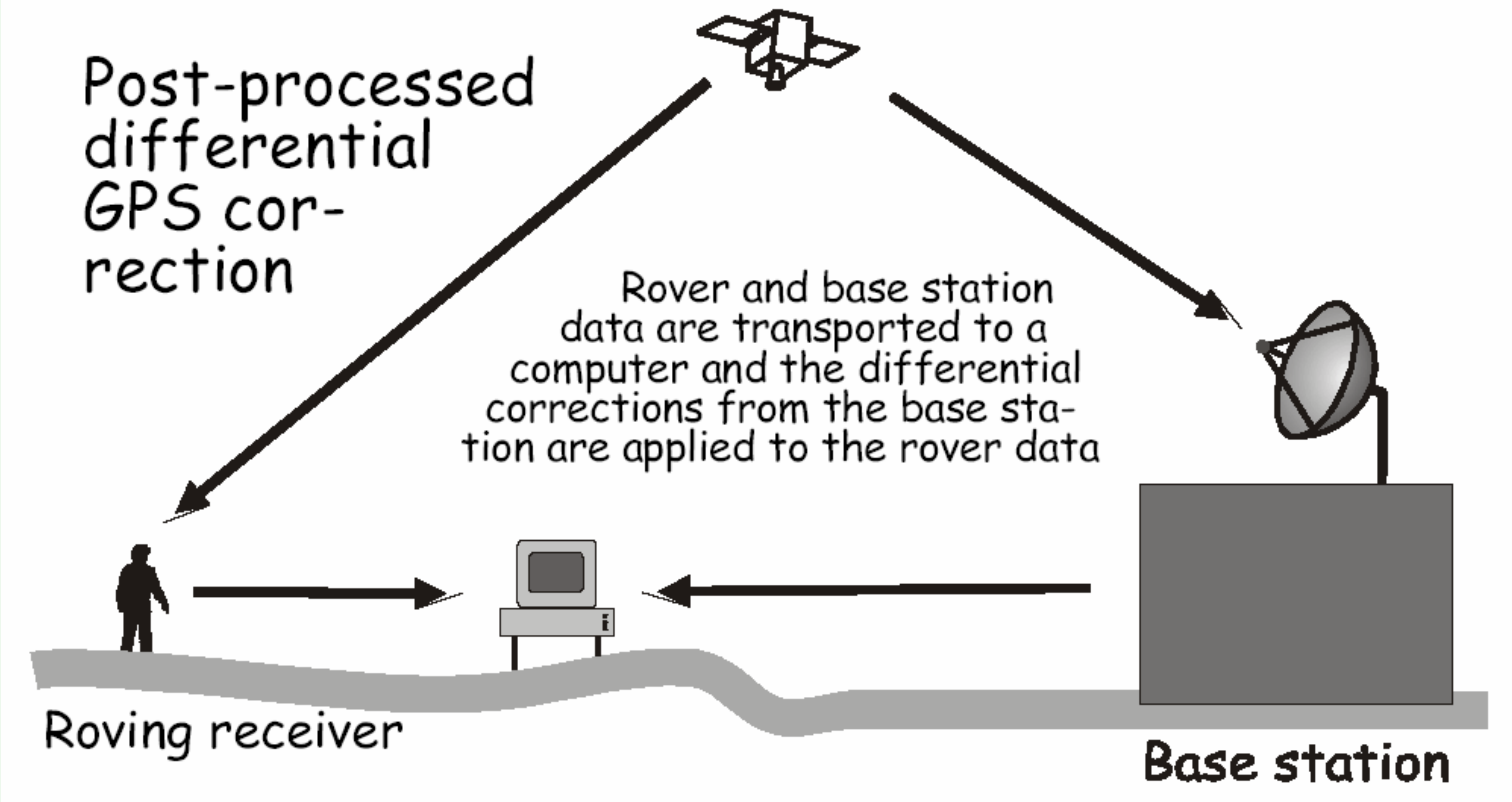
- A method of using a ground-based correction in addition to the satellite signals to improve position accuracy
- Position measurement can be often reduced to less than 1 meter



# Differential Correction



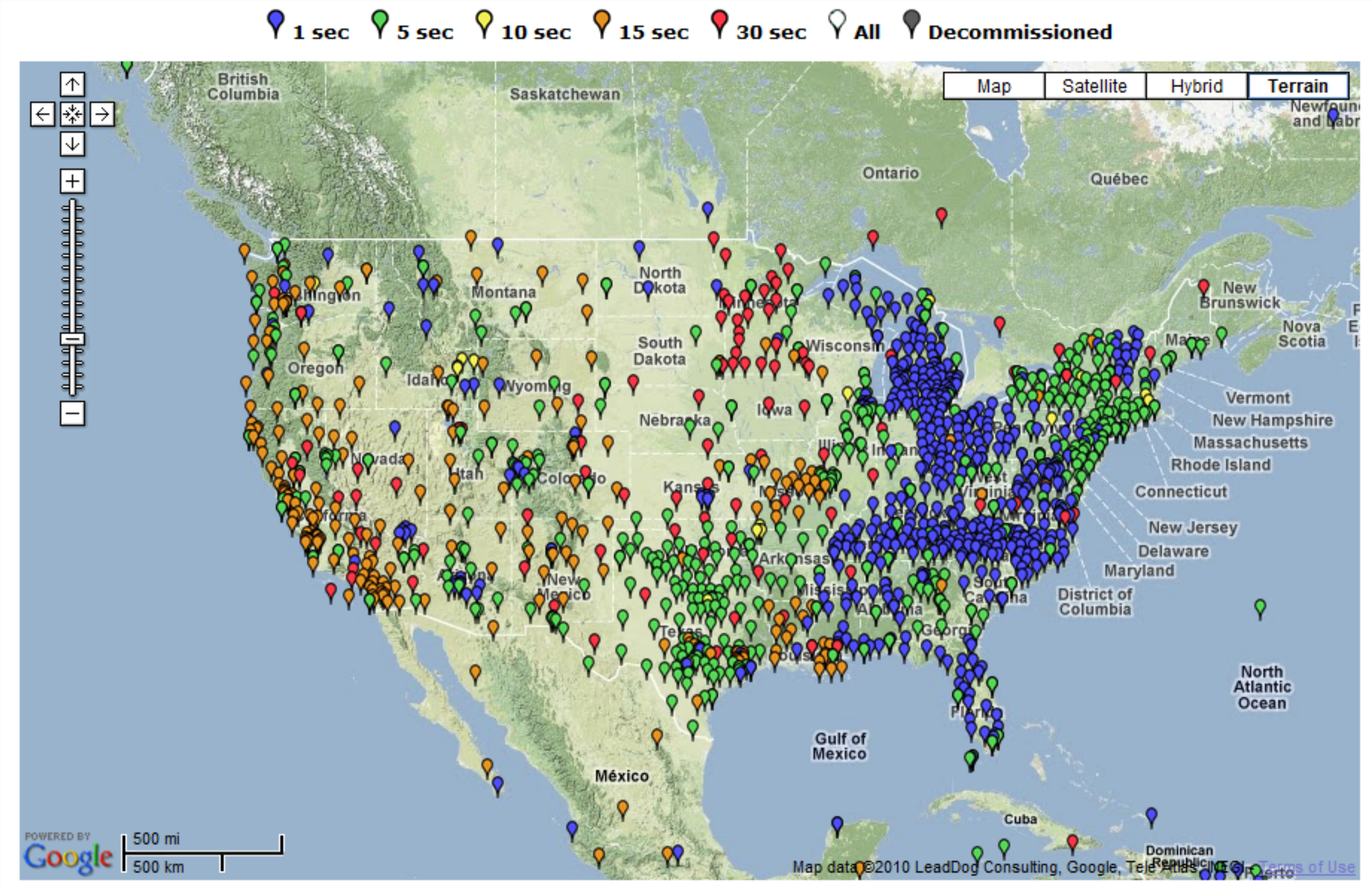
# Post-processed DGPS



# Post-Processing DGPS

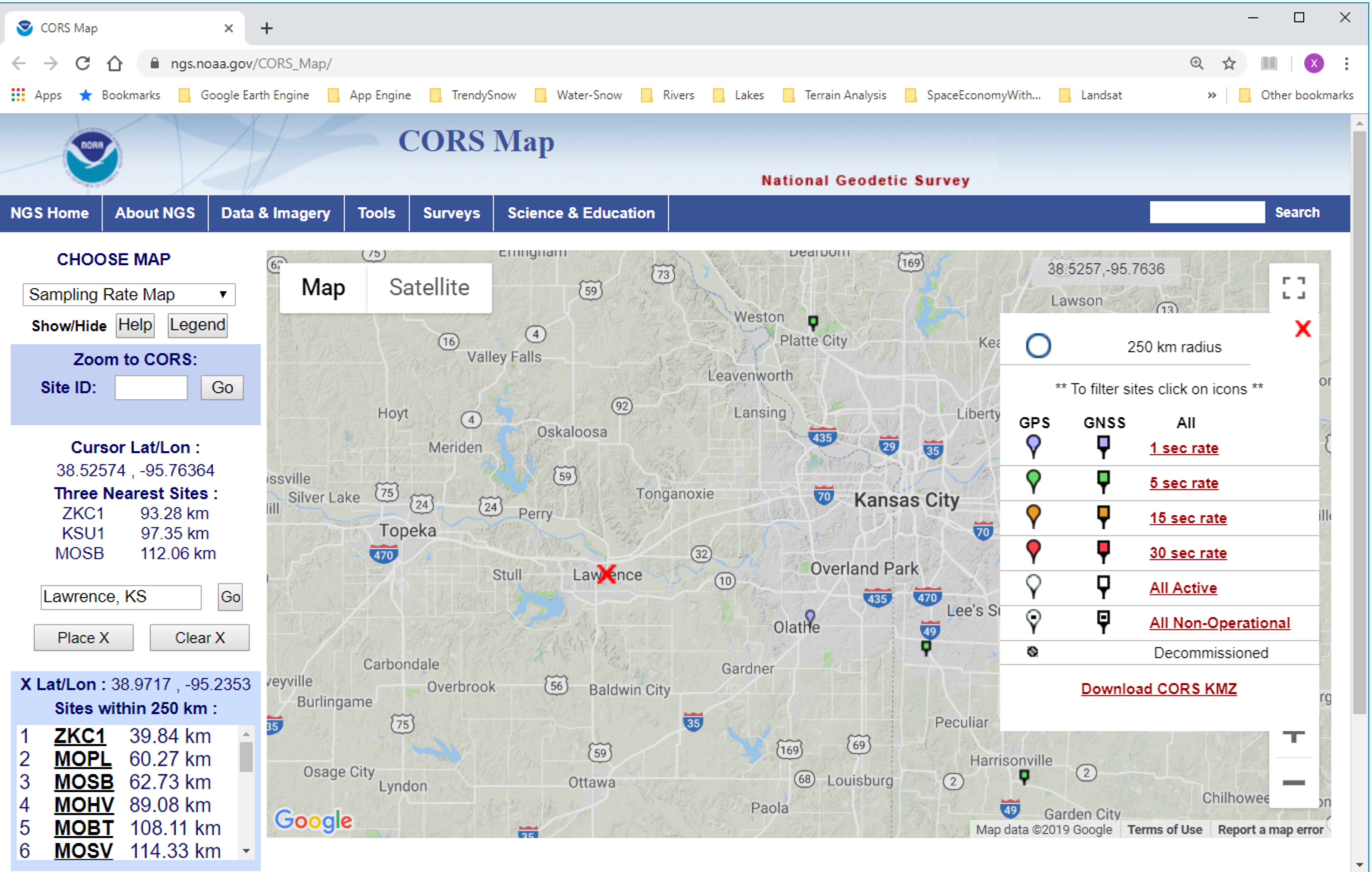
- National Geodetic Survey maintains the Continuously Operating Reference Station (CORS)
- Consists of numerous base stations located across the United States and throughout the world
- CORS data is free and can be used for Post-processing

# National Geodetic Survey
# Continuously Operating Reference Stations (CORS)

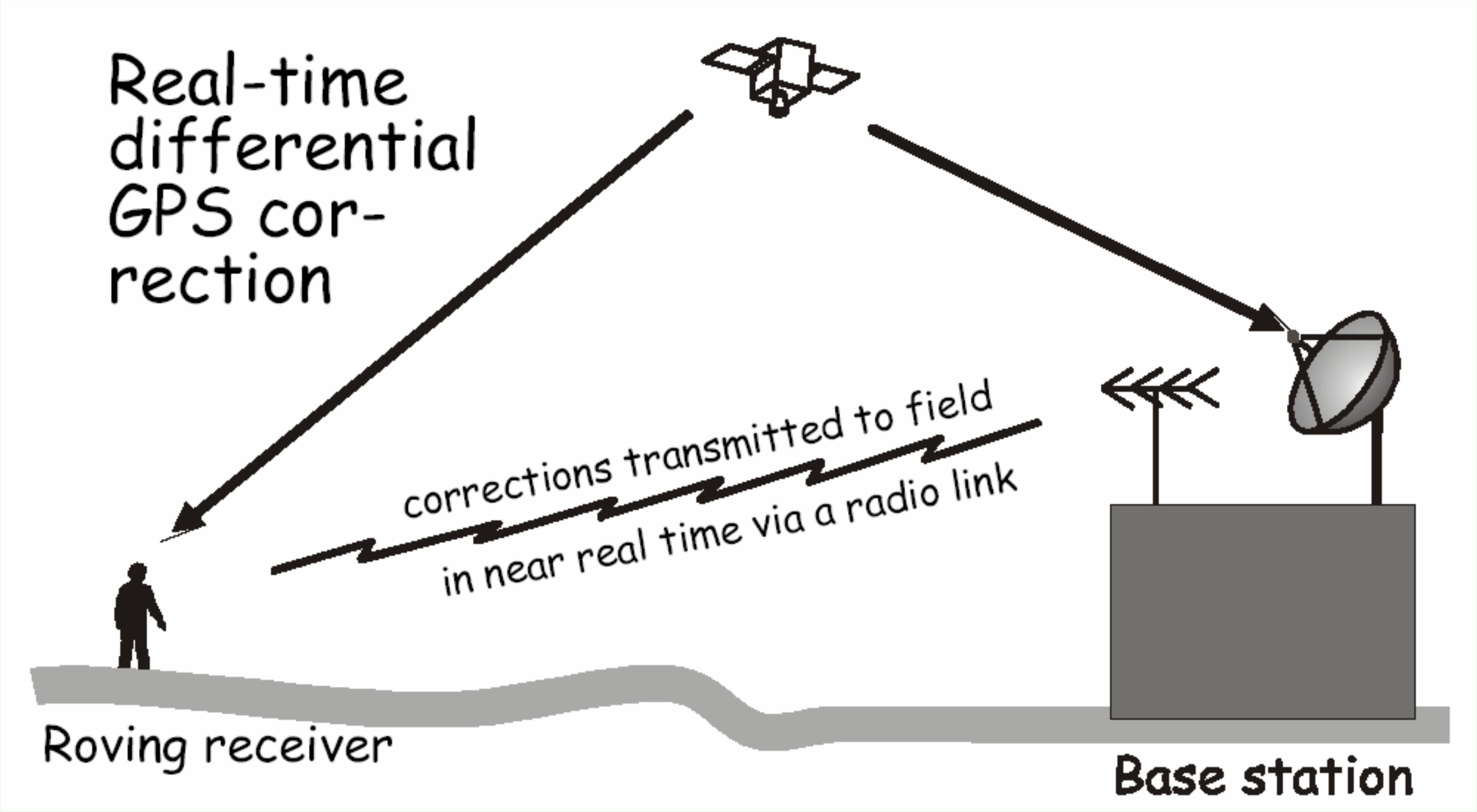



http://www.ngs.noaa.gov/CORS/cors-data.html

# CORS Stations Near Lawrence, KS



# Real-time DGPS



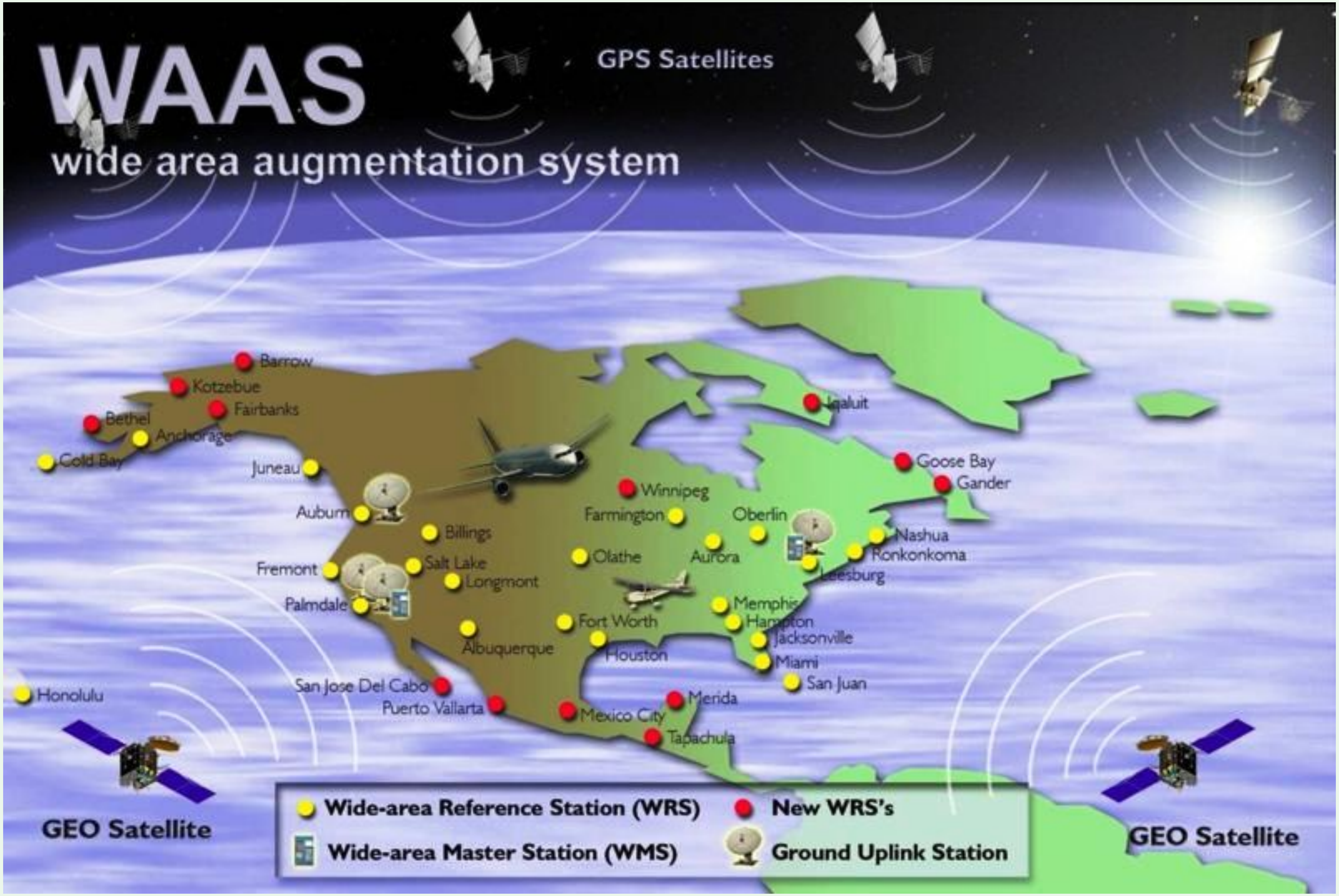
# Real-time DGPS

- Real-time link between base station and receivers
  - Base station radio
  - Satellite
  - Internet
- Nationwide Differential Global Positioning System (NDGPS)
  - Shutdown inland stations in 2015 and only 46 stations in the maritime and coastal regions
- Satellite-based augmentation systems (SBAS)
  - Correction is sent from a satellite
  - Wide Area Augmentation System (WAAS)
  - Quasi-Zenith Satellite System (QZSS)
- The Networked Transport of RTCM via Internet Protocol (NTRIP)

# Wide Area Augmentation System (WAAS)

- Developed and administered by FAA for providing accurate and dependable aircraft navigation.
- Correction is calculated and transmitted to satellites.
- Real-time accurate fixes within 3 m or less.
- Network of ground reference stations (25) scattered in North America (for calculating correction)
- The correction signal is broadcasted to **a WAAS compatible receiver**

# WAAS DGPS

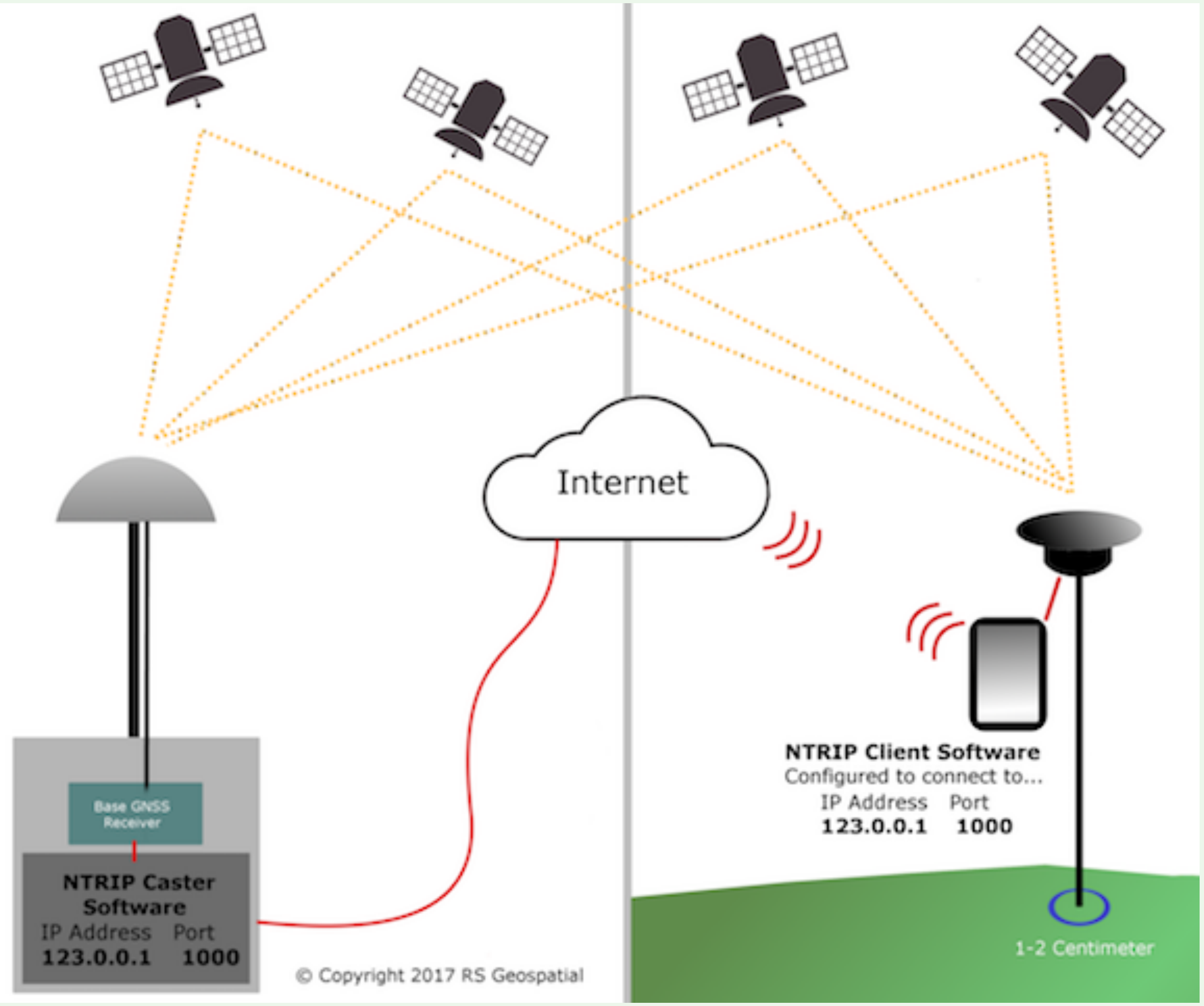

WAAS
wide area augmentation system
GPS Satellites
Barrow
Kotzebue
Fairbanks
Bethel
Anchorage
Cold Bay
Juneau
Auburn
Billings
Fremont
Salt Lake
Longmont
Palmdale
Albuquerque
Winnipeg
Farmington
Oberlin
Olathe
Aurora
Fort Worth
Houston
Memphis
Hampton
Jacksonville
Miami
San Juan
Iqaluit
Goose Bay
Gander
Nashua
Ronkonkoma
Leesburg
Honolulu
San Jose Del Cabo
Puerto Vallarta
Mexico City
Merida
Tapachula
GEO Satellite
Wide-area Reference Station (WRS)
New WRS's
Wide-area Master Station (WMS)
Ground Uplink Station
GEO Satellite

# QZSS

- Use GPS
- Similar to WAAS but maintained by Japan and covers the Asia-Oceania regions

# DGPS Using the Internet

- Sending and receiving base data over the internet
- Internet connection (cell phone)



# NTRIP

- The Networked Transport of RTCM via Internet Protocol (NTRIP)
- A protocol for streaming differential GPS (DGPS) data over the Internet in accordance with specification published by RTCM (Radio Technical Commission for Maritime Services)

# Positional Accuracy

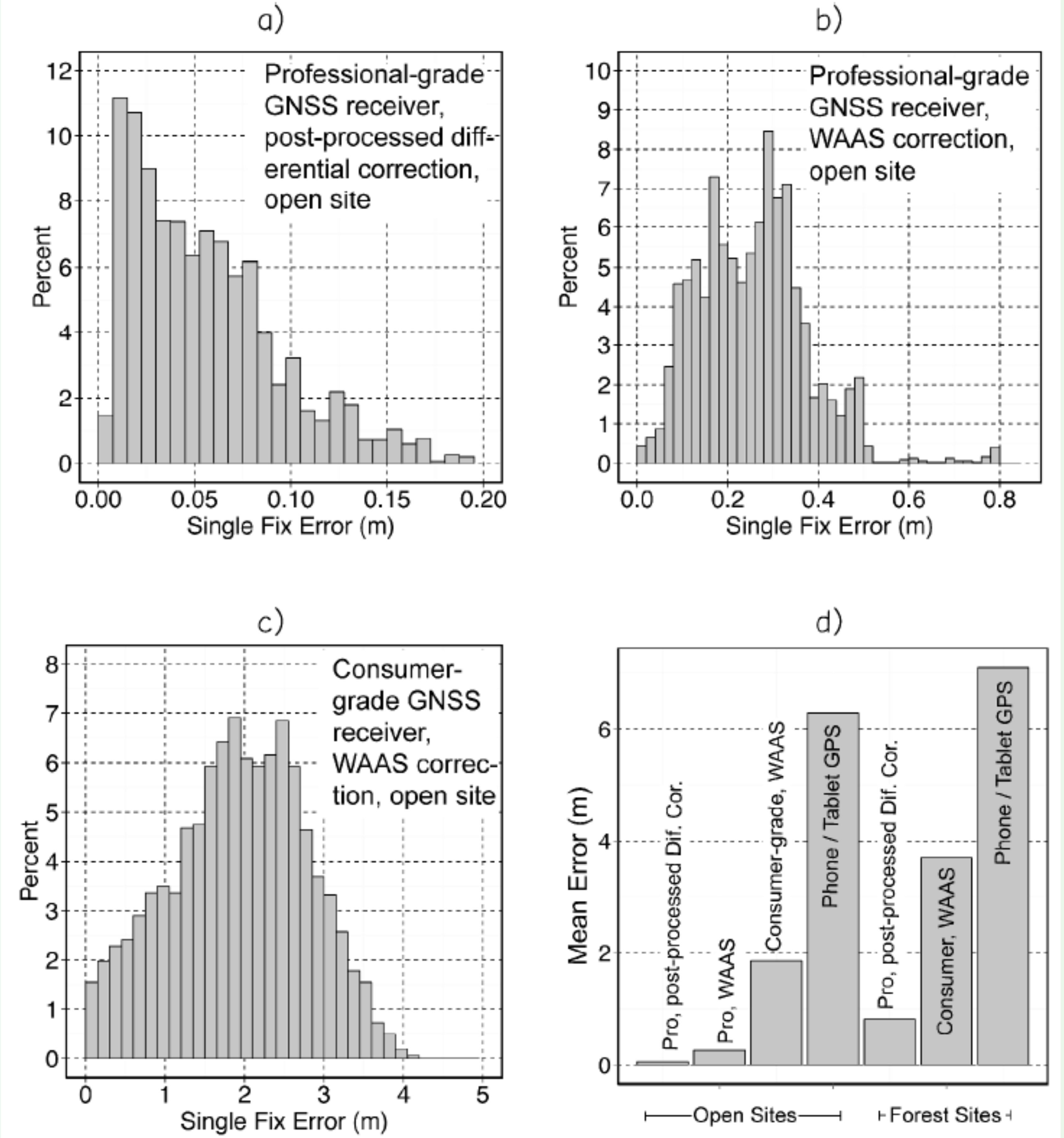



**Figure 5-12**. Observed GPS error distributions for various receivers under open sky conditions (a through c) and mean error under open sky and dense deciduous forest canopy (d). Results show highest

# GPS Applications

- Emergency response
- Farming
- Forensics
- Public utilities
- Transportation
- Wildlife management
- Personal recreation

# Field Digitization

**Figure 5-27**: Line features may be field digitized via GPS, as in this example of a GIS/GPS system mounted in a tractor. Data display and digitizing software are used to record coordinates collected by a GPS receiver (above). An antenna placed on a pole or rack (right) reduces obstruction (courtesy Jake Leguee, left, and G. Johnson, Ducks Unlimited, right).

# Movement Tracking