FORSVARET

GPS

Global Positioning System

Agenda

- What is GPS?
  - Basic consept
  - History
- GPS receivers
  - How they work
- Comunication
  - Message format
  - Satellite frequencies
  - Sources of GPS signal errors

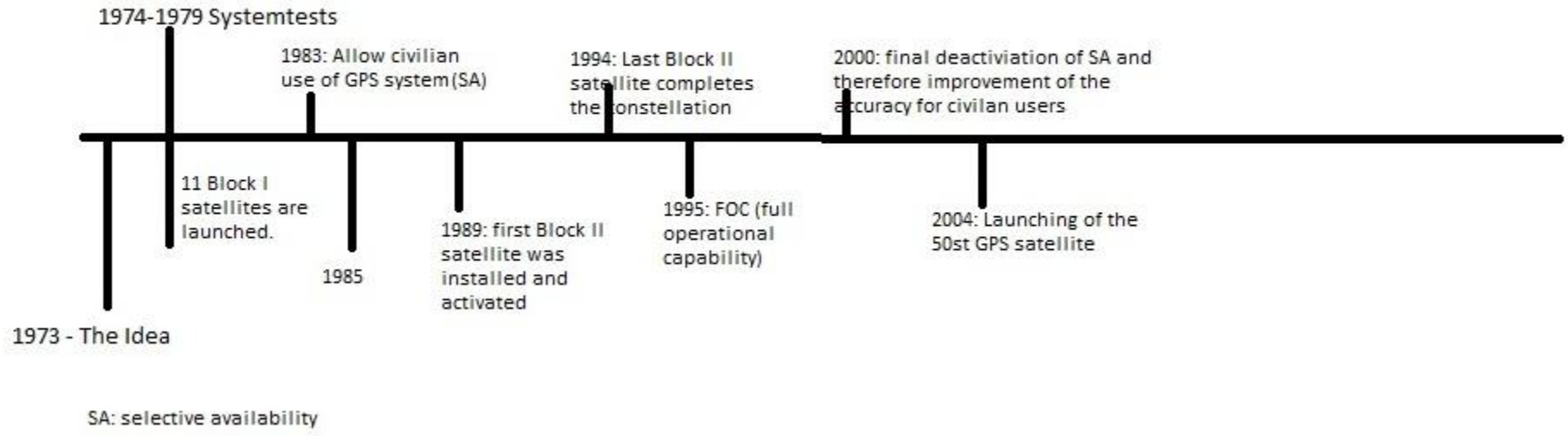
What is GPS

- Global Positioning System
  - Satellite-based navigation system
  - Used in aviation, nautical navigation and for the orientation ashore.
  - Can be used by any person with a GPS receiver.
  - 32 satellites in orbit, 20180 km above us
    - 6 different orbital planes
      - Each satellite orbits the Earth in 12 hours
      - At least 4 satellites are in radio comms with any point on earth
    - Powered by solar energy
    - Backup batteries to keep them running in the event of solar eclipse
    - Small rocket boosters – keep them flying in correct path
    - 4 atomic clocks onboard
  - Orginally intended for military applications

What is GPS

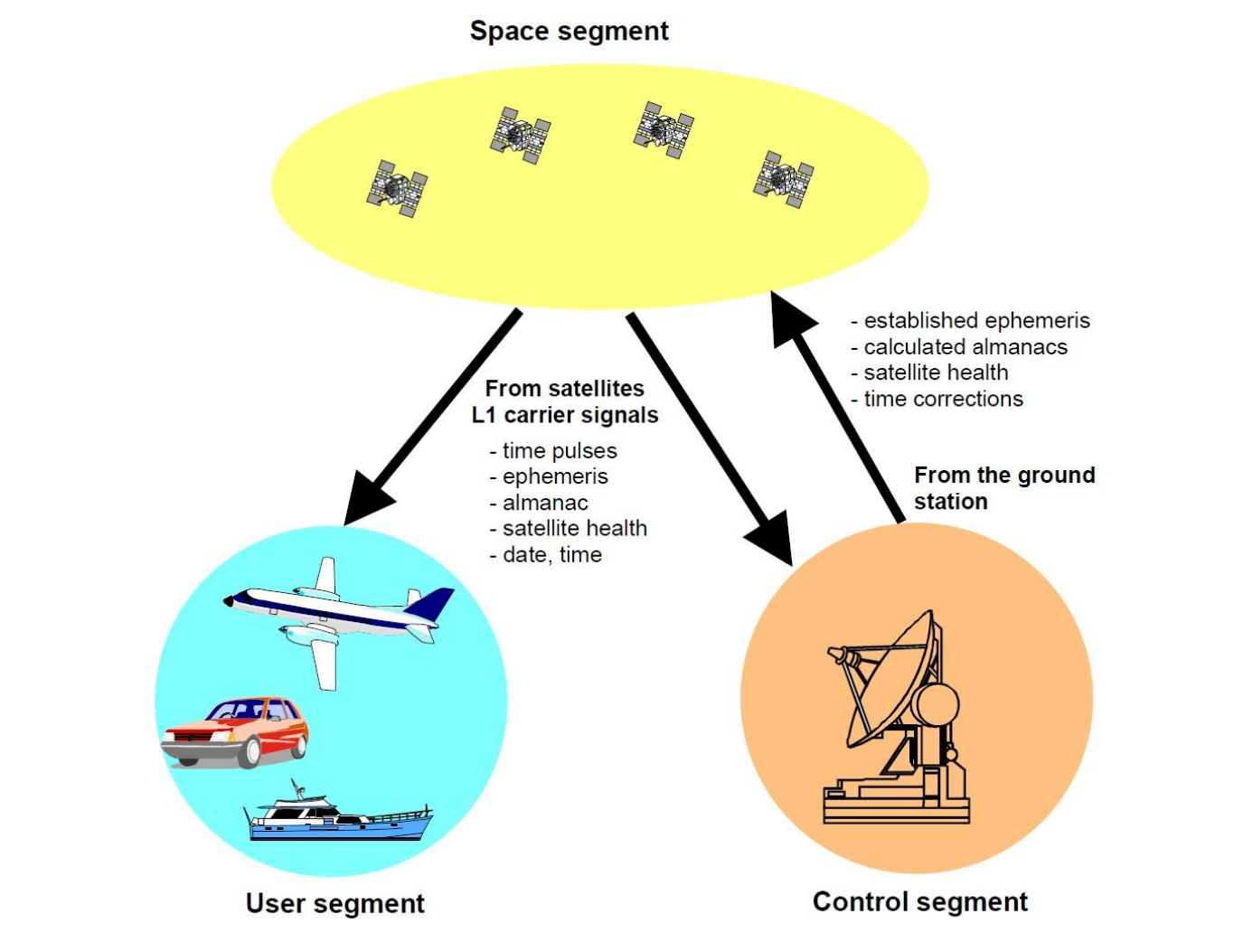
History

- American Department of Defence (DOD)
- NAVSTAR-GPS
- One of 4 different Global Navigation Satellite Systems (GNSS)



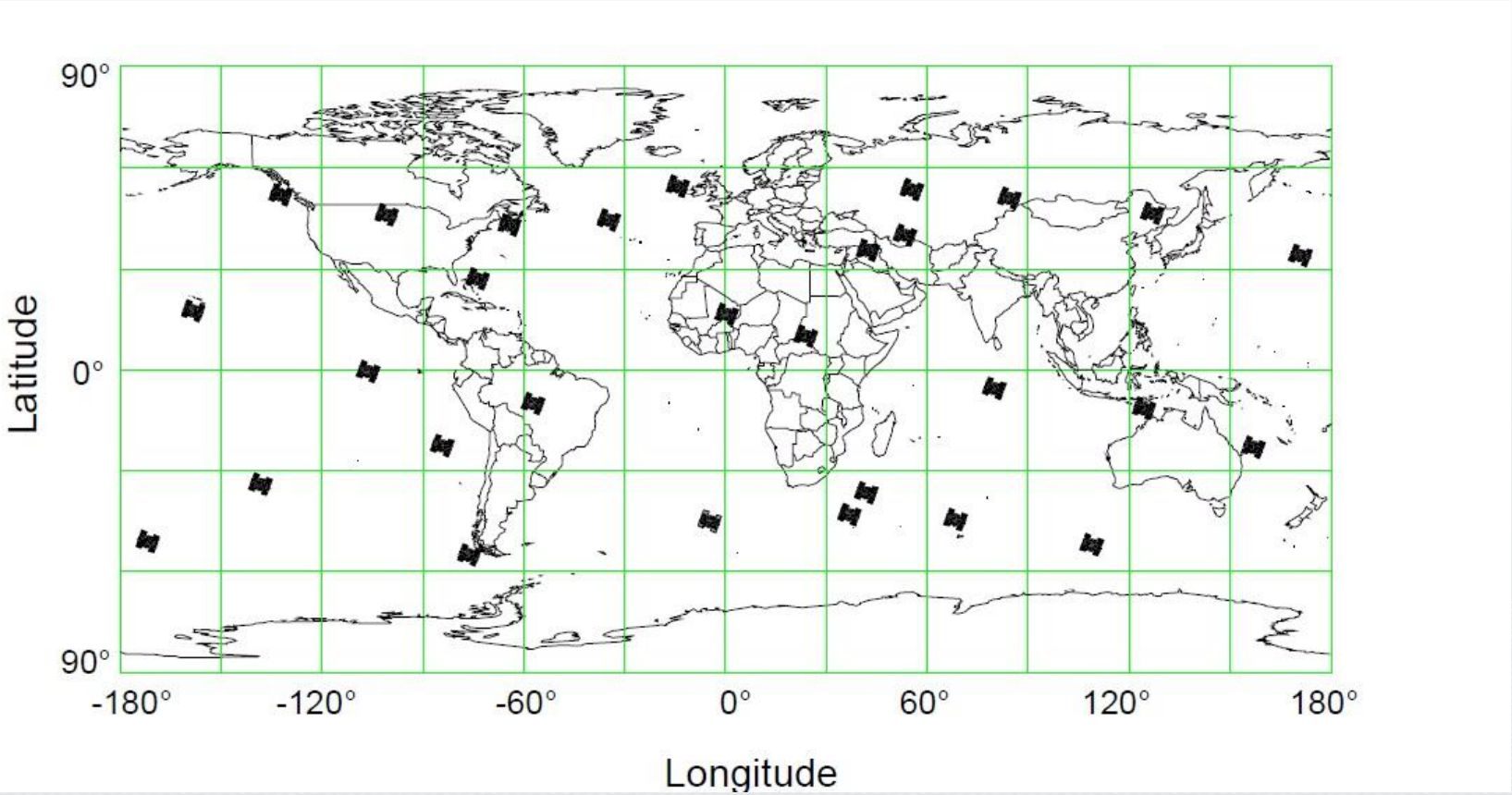
What is GPS

Basic Consept of satellite navigation



What is GPS

Basic Consept of satellite navigation

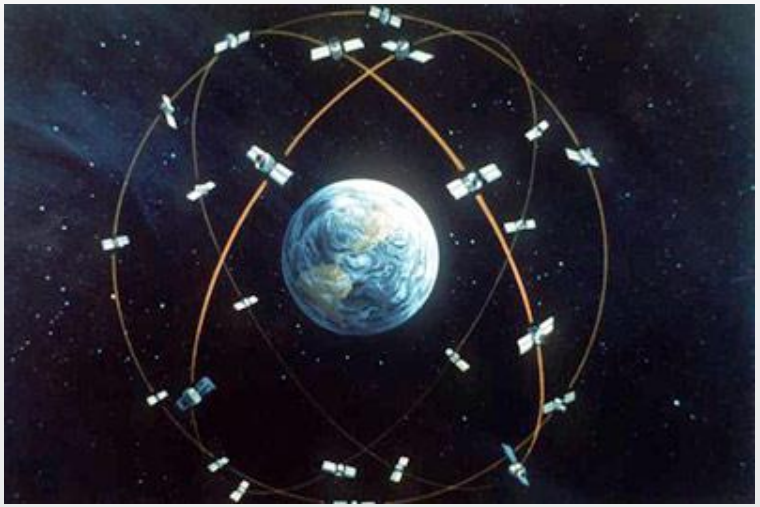


Position of the GPS satellites at 12:00 hrs UTC on 14th April 2001

What is GPS

Basic Consept of satellite navigation

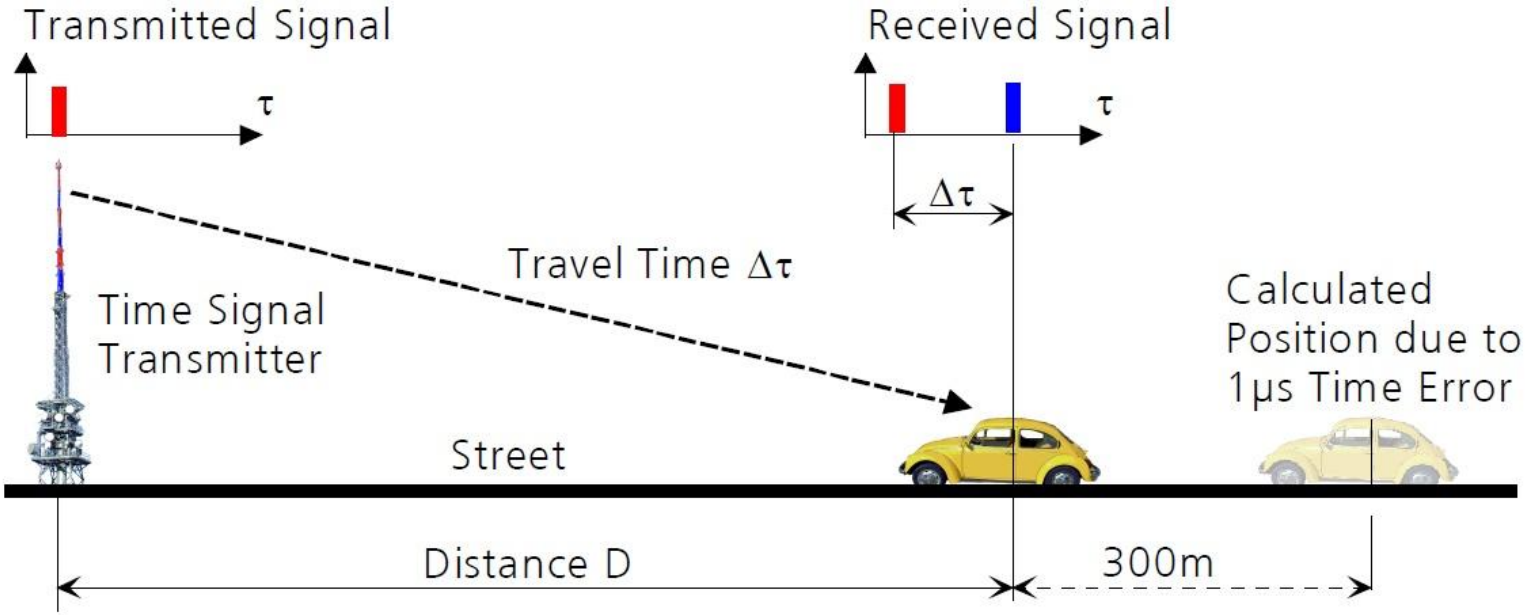
- GPS receivers use triangulation to calculate the users exact location.
  - Compares transmit time – received time
    - Satellites with a known position transmit a regular time signal.
    - Based on the measured travel time of the radio waves (electromagnetic signals travel through space at the speed of light) the position of the receiver is calculated
    - 3 satellites:2D(lat/long) track movement
    - 4 or more satellites: 3D (lat/long/altitude)
  - GPS unit can calculate:
    - Speed, bearing, track, distance to destination etc.



GPS receivers

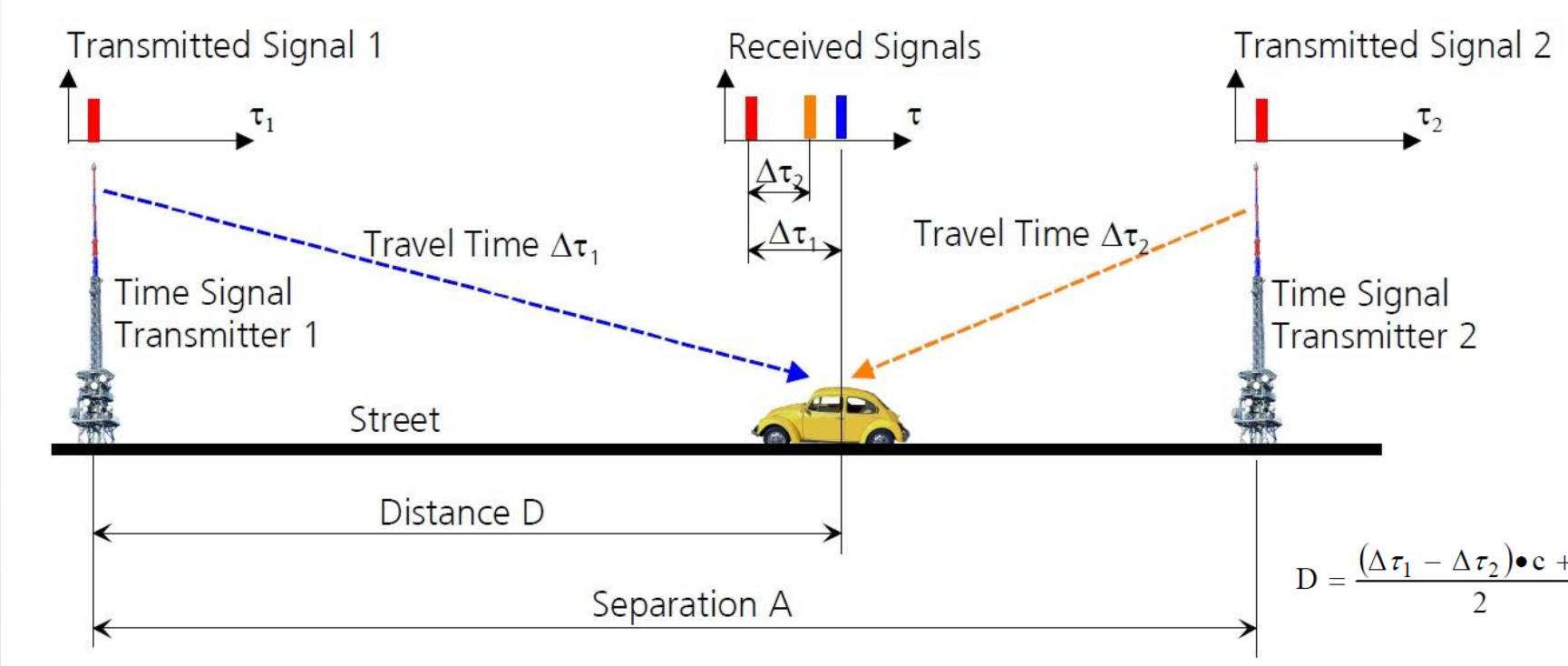
How they work

- In the simplest case distance is determined by measuring the travel time
- Speed of light: c = 300’000km/s
- The distance D is calculated by multiplying the travel time by the velocity of light c.
  - D = Travel Time • c



GPS receivers

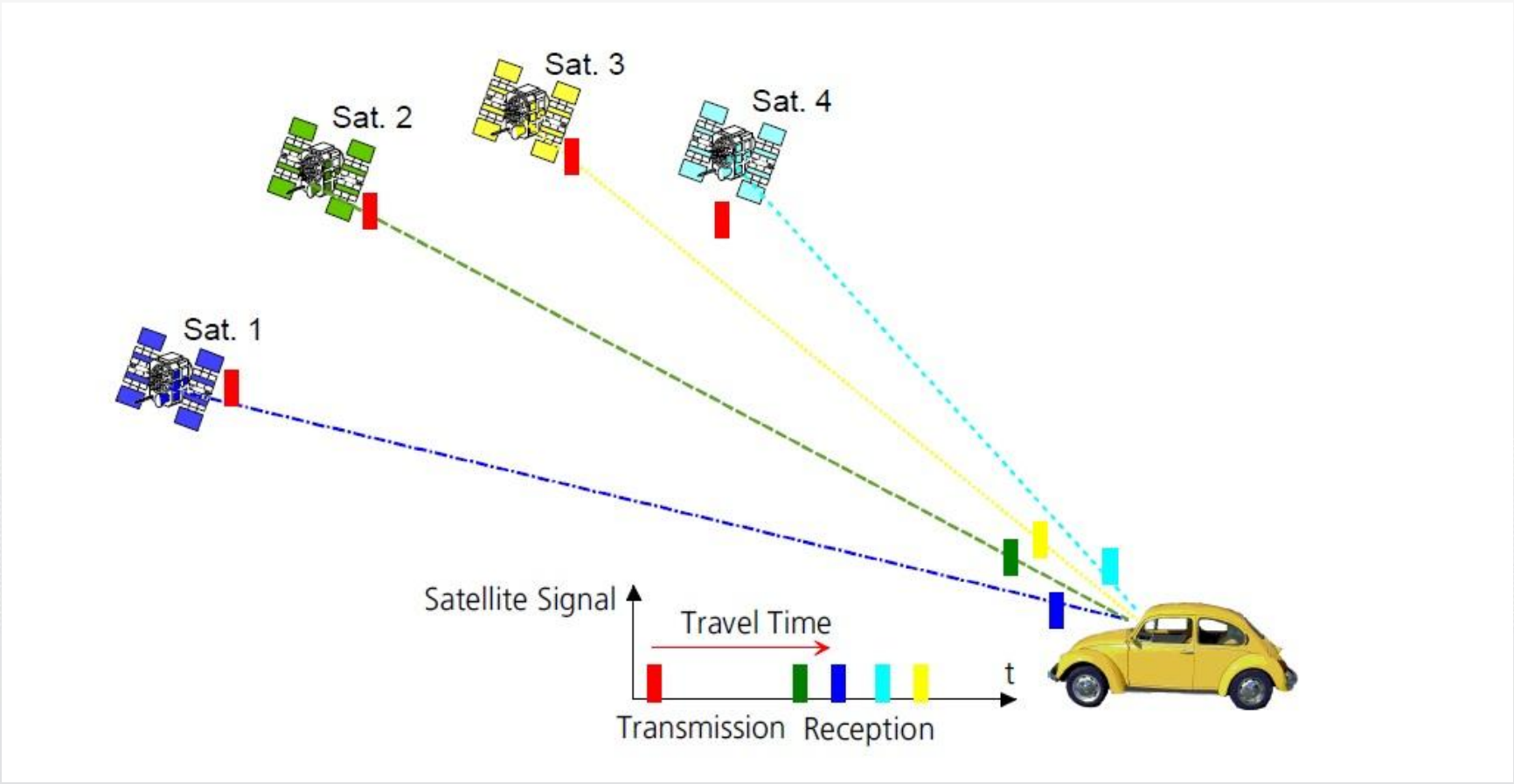
•With two transmitters it is possible to calculate the exact position despite time errors.
•It is necessary that the number of time signal transmitters exceed the number of unknown dimensions by a value of one.



$$D = \frac{(\Delta\tau_1 - \Delta\tau_2) \bullet c + A}{2}$$

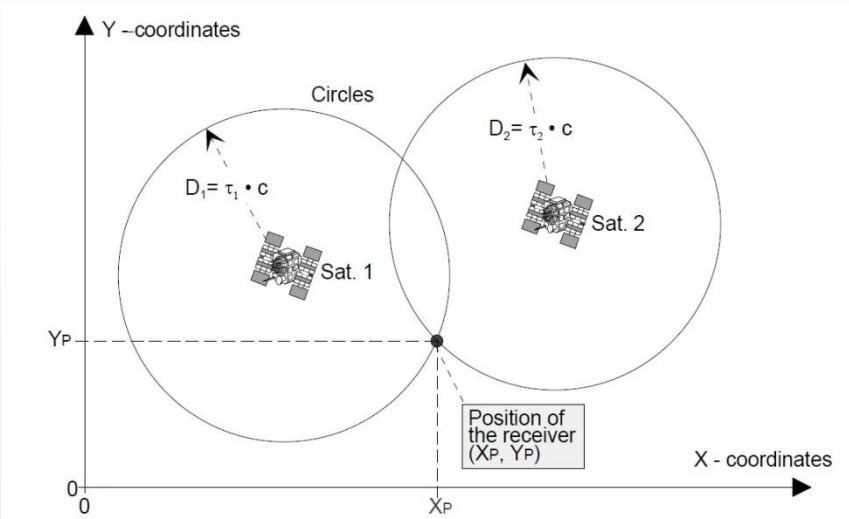
GPS receivers

•Four satellites are needed to determine longitude, latitude, altitude and time



GPS

Determining position



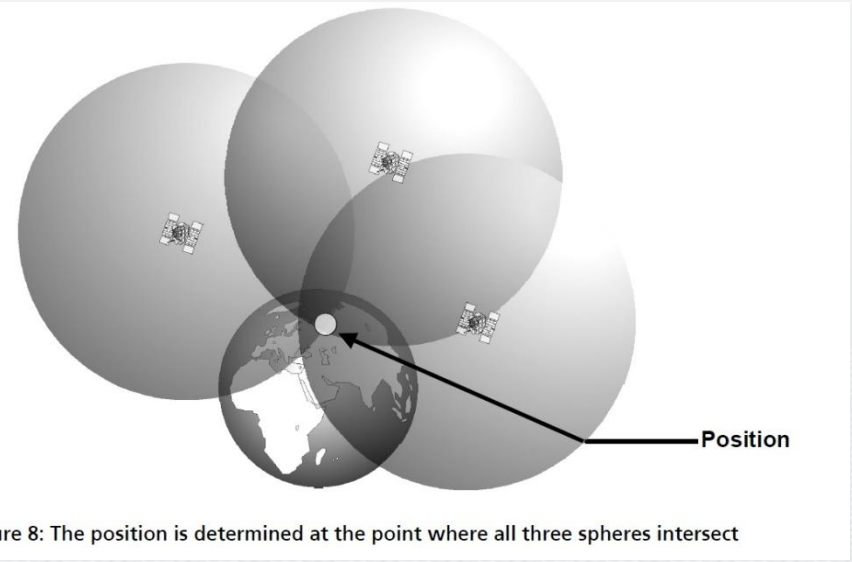


Figure 8: The position is determined at the point where all three spheres intersect

Communication

Message format

GPS message format	
Subframes	Description
1	Satellite clock, GPS time relationship
2–3	Ephemeris (precise satellite orbit)
4–5	Almanac component (satellite network synopsis, error correction)

- Basic format: 1500bit long frame
  - 5 subframes, 300 bits (6s) each
- Complete message requires 25 full frames. Total 37,500 bits long.
  - Transmission rate 50bps; 750 seconds to transmit an entire almanac message.
- Receiver must demodulate the message from each satellite it includes in its solution for 18-30 seconds.
  - Collect all transmitted almanacs the receiver must demodulate the message for 732 to 750 seconds.

Communication

Satellite frequencies

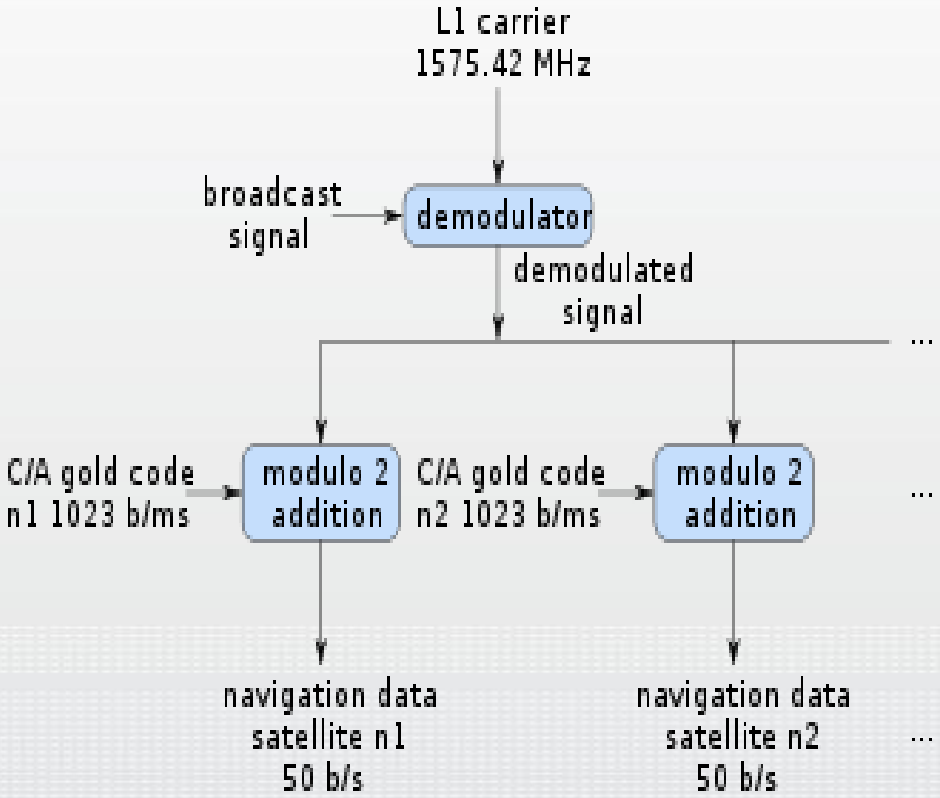
GPS frequency overview

Band	Frequency	Description
L1	1575.42 MHz	Coarse-acquisition (C/A) and encrypted precision P(Y) codes, plus the L1 civilian (L1C) and military (M) codes on future Block III satellites.
L2	1227.60 MHz	P(Y) code, plus the L2C and military codes on the Block IIR-M and newer satellites.
L3	1381.05 MHz	Used for nuclear detonation (NUDET) detection.
L4	1379.913 MHz	Being studied for additional ionospheric correction.[citation needed]
L5	1176.45 MHz	Proposed for use as a civilian safety-of-life (SoL) signal.

- CDMA
  - Unique encodings PRN (high-rate pseudo-random encoding):
    - Coarse/acquisition(C/A)
    - Precise (P) code
      - Encrypted (U.S.m)
- Two separate carrier frequencies (L1, L2) (UHF band)
  - Public
  - U.S. military
- Both the C/A and P(Y) codes impart the precise time of day to the user.

GPS receiver

demodulation and decoding



- How does GPS receivers separate GPS satellite signals when signals are modulated onto the same L1 carrier frequency?
  - Signal separation:
    - Gold code
      - Unique binary sequence

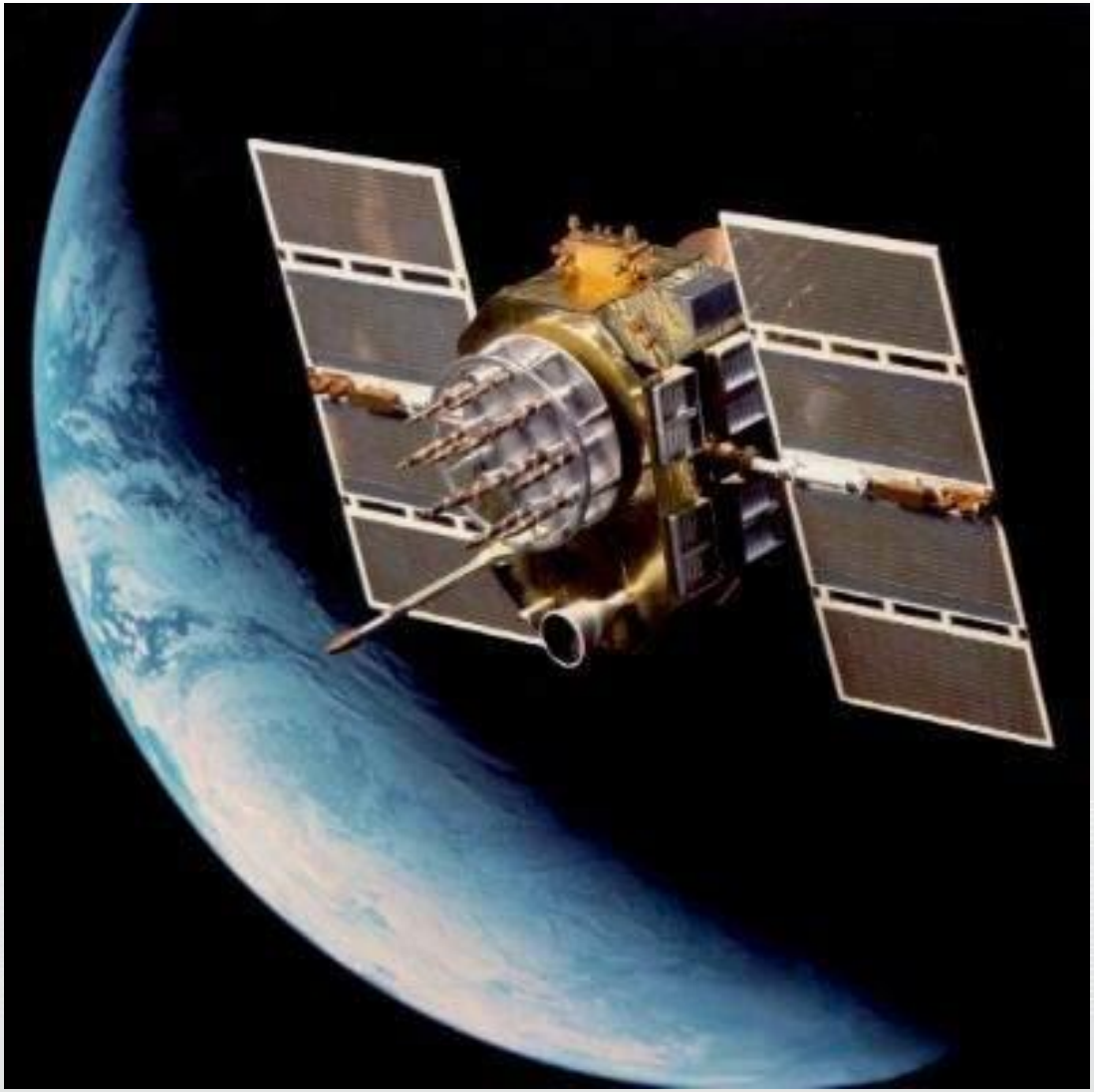
Communication

Sources of GPS signal errors

- Ionosphere and troposphere delays
- Signal multipath
- Receiver clock errors
- Orbital errors
- Satellites visibility
- Satellite geometry/shading
- Intentional degradation of the satellite signal

GPS

- Resources and further readings:
  - GPS - Essentials of Satellite Navigation
    - http://www.u-blox.com/images/downloads/Product_Docs/GPS_Compendium%28GPS-X-02007%29.pdf



Q&A