Global Navigation Satellite Systems (GNSS): GPS, GLONASS, GALILEO

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National Culture High School, 13 November 2012, Gorna Bania, Bulgaria

Global Navigation Satellite Systems (GNSS)

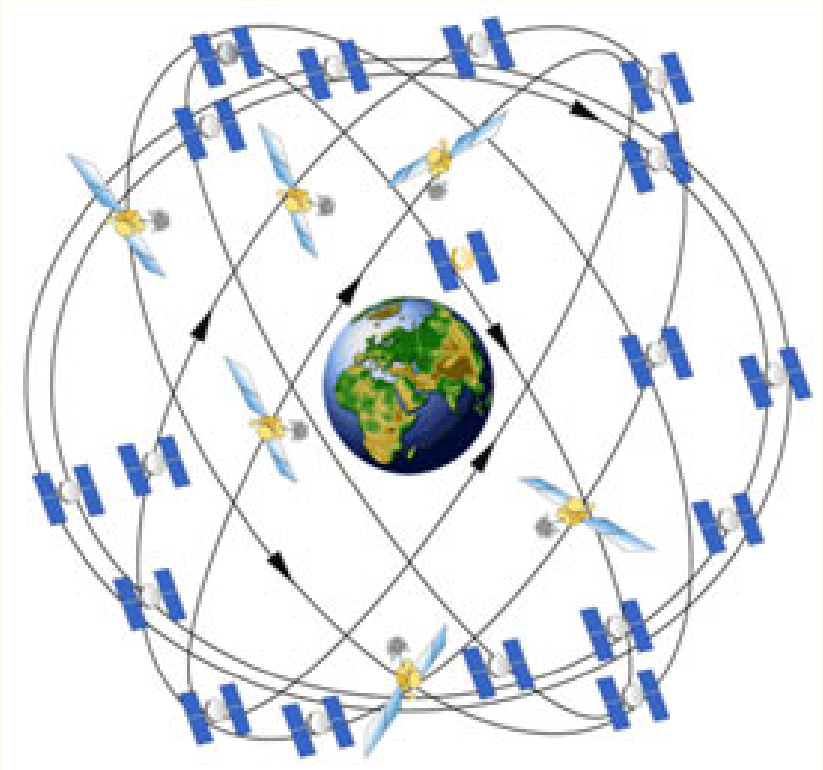
параметри	GPS	ГЛОНАСС	GALILEO	COMPASS
години	1971/1993	1976/1995	1994/2020	2000/2020
спътници	24	24	27	35
орбити	6, елипт.	3, кръгови	3, кръгови	>10
височина	20200 км	19100 км	23 222 км	21 155 км
инклинация	55°	64,8°	56°	55,5°
основни сигнали	1,58 GHz 1,23 GHz	1,61 GHz 1,25 GHz	1,57 GHz 1,28 GHz	1,56 GHz 1,20 GHz

source: Tzvetan Simeonov's BSc thesis: "GNSS meteorology in Bulgaria" July 2011

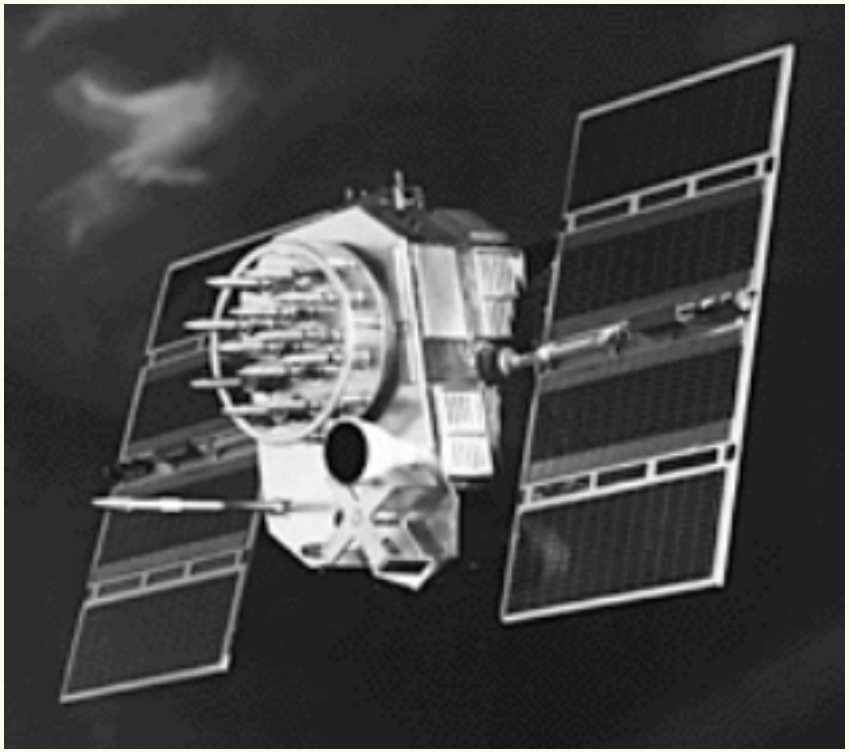
USA: Global Positioning System (GPS)

- Why Global Positioning System (GPS) was created
  - Need of high-accuracy, real-time position, velocity and time on variety of platforms
  - Worldwide, all weather operation - military and civilian users
- What is GPS
  - NAVSTAR GPS satellites - 24 active satellites - 6 orbital planes
    - altitude - 20 200 km
    - inclination - 55° (with respect to the Equator)
    - orbit periods - 11h 58 min
  - Ground based reference receivers
    - Europe - 1700
    - Japan - 1000
    - Bulgaria - 120
  - Control segment
    - worldwide monitor and control stations
    - maintain the satellites orbits
    - maintains health and status of the satellite constellation

NAVSTAR GPS satellites



Satellite constellation

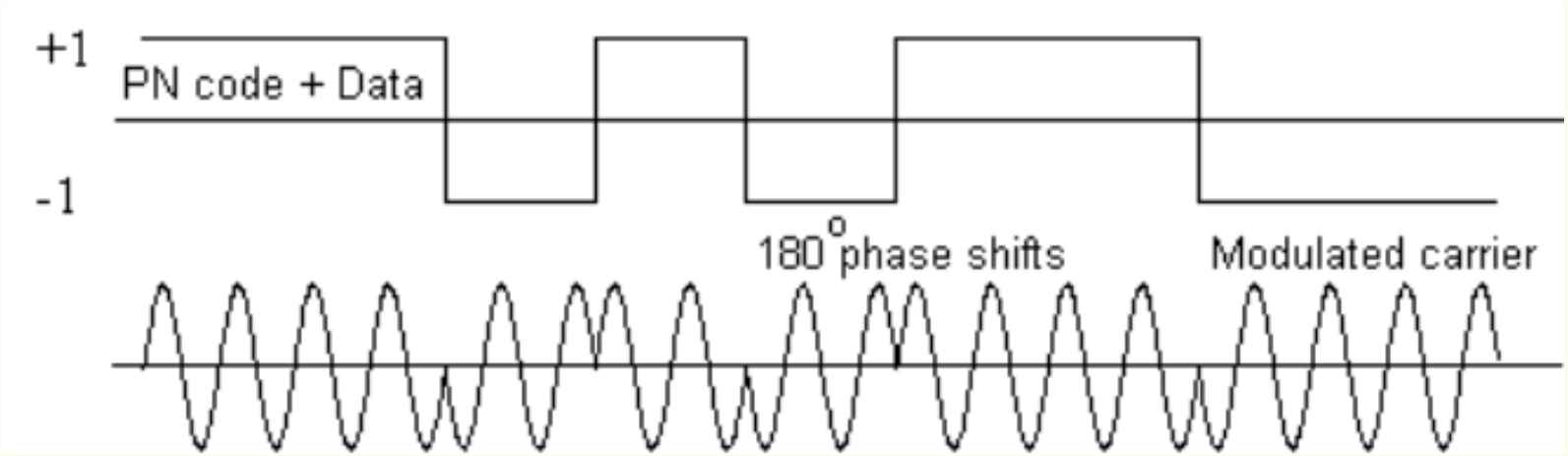


Block IIA satellite type

source: GPS.gov http://www.gps.gov/systems/gps/space/

The GPS signal

- Microwave bi-phase signal
  - Fundamental frequency f_o = 10.23 MHz
  - L1 carrying frequency with wavelength 19cm
  - L2 carrying frequency with wavelength 22.4cm
- Pseudo - Random Code structure
  - Navigation message - low frequency signal added to L1 code - 1500 bits
  - Information about: satellite clock and satellite orbit
- All satellites use the same frequencies but have different codes



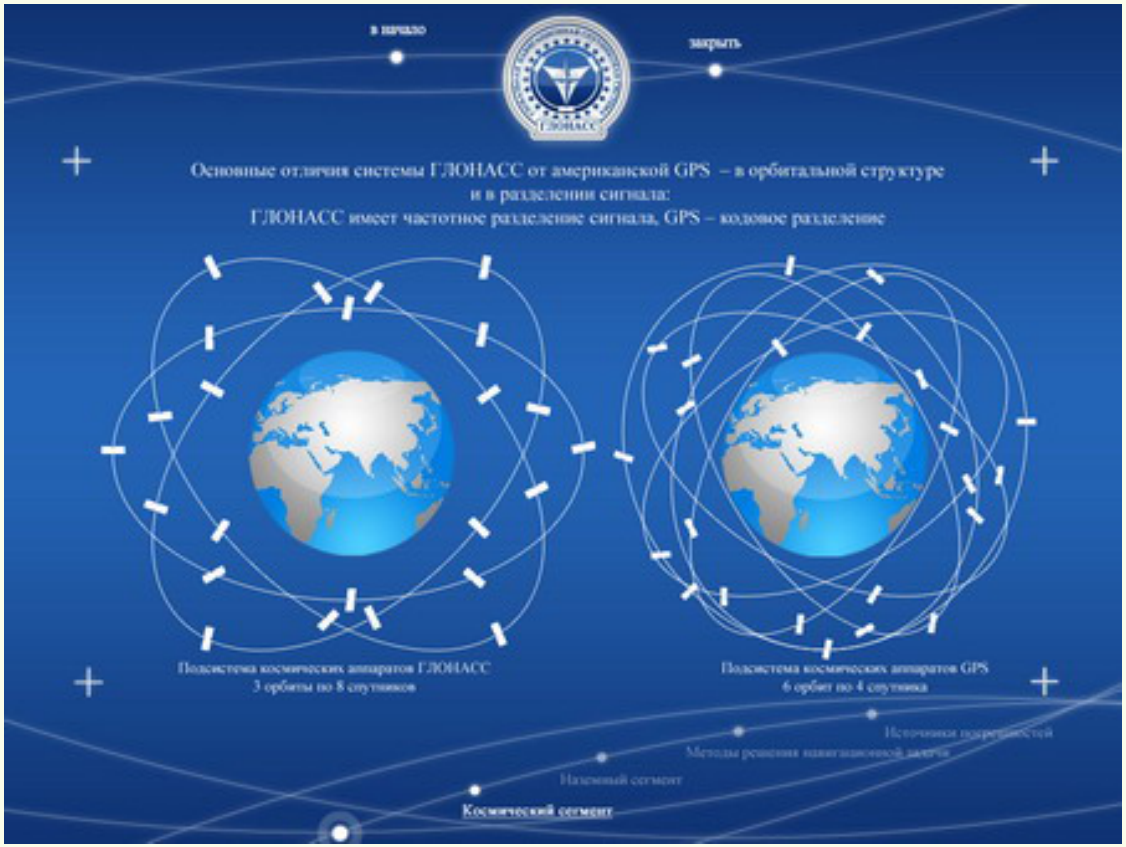
source: Global Positioning System: Theory and Applications, Volume I & II, 1996, ISBN-13: 978-1-56347-249-7

RUSSIA: GLObal NAvigation Satellite System (GLONASS)

- GLONASS satellites - 24 active satellites - 3 orbital planes
  - altitude - 19 100 km
  - inclination - 64.8° (with respect to the Equator)
  - orbit periods - 11h 15 min
- Ground based reference receivers: mostly GLONASS compatible
  - Europe - 1700
  - Japan - 1000
  - Bulgaria - 120

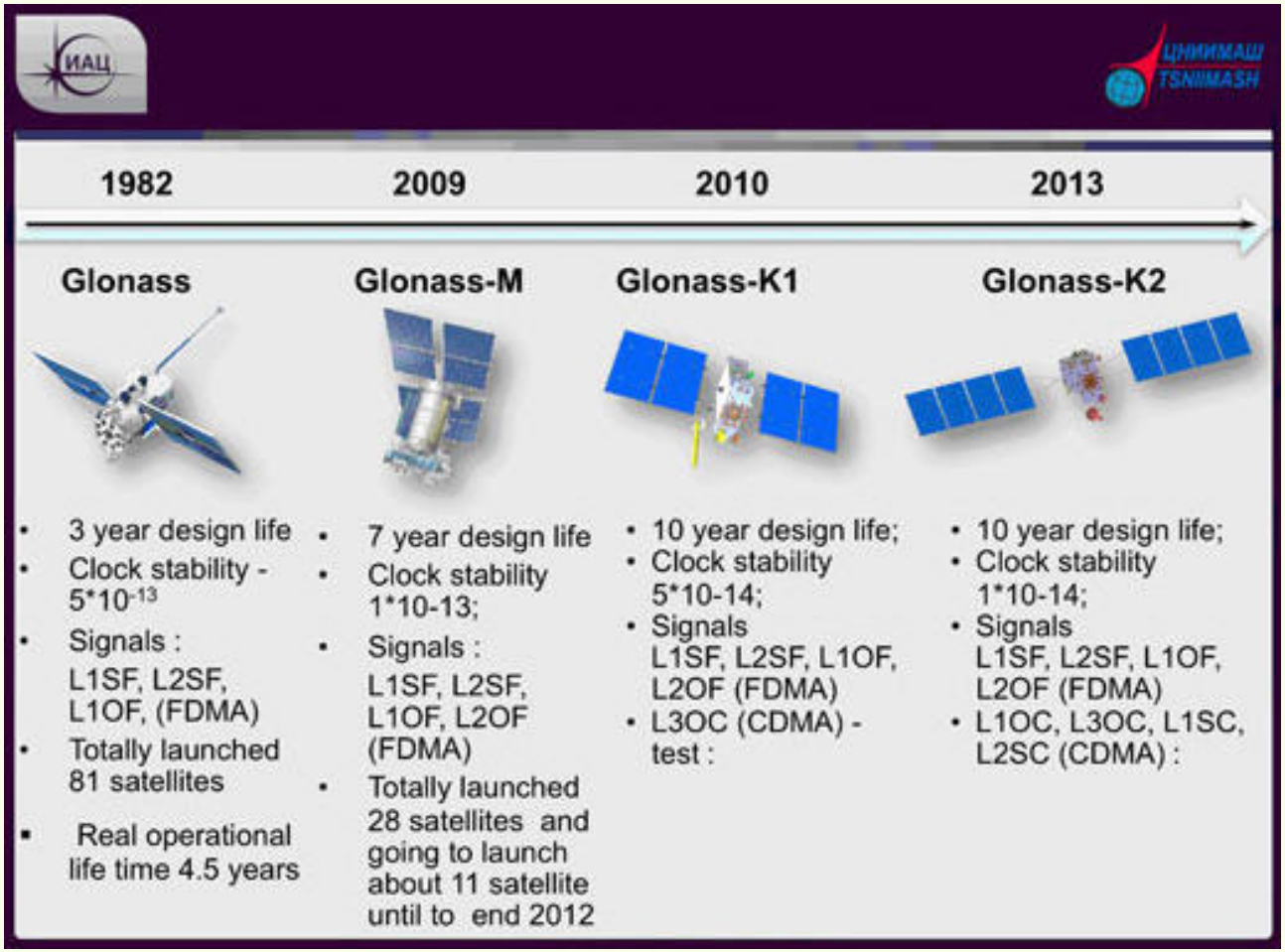
source: http://www.glonassgsm.ru/information.html

GLONASS constellation



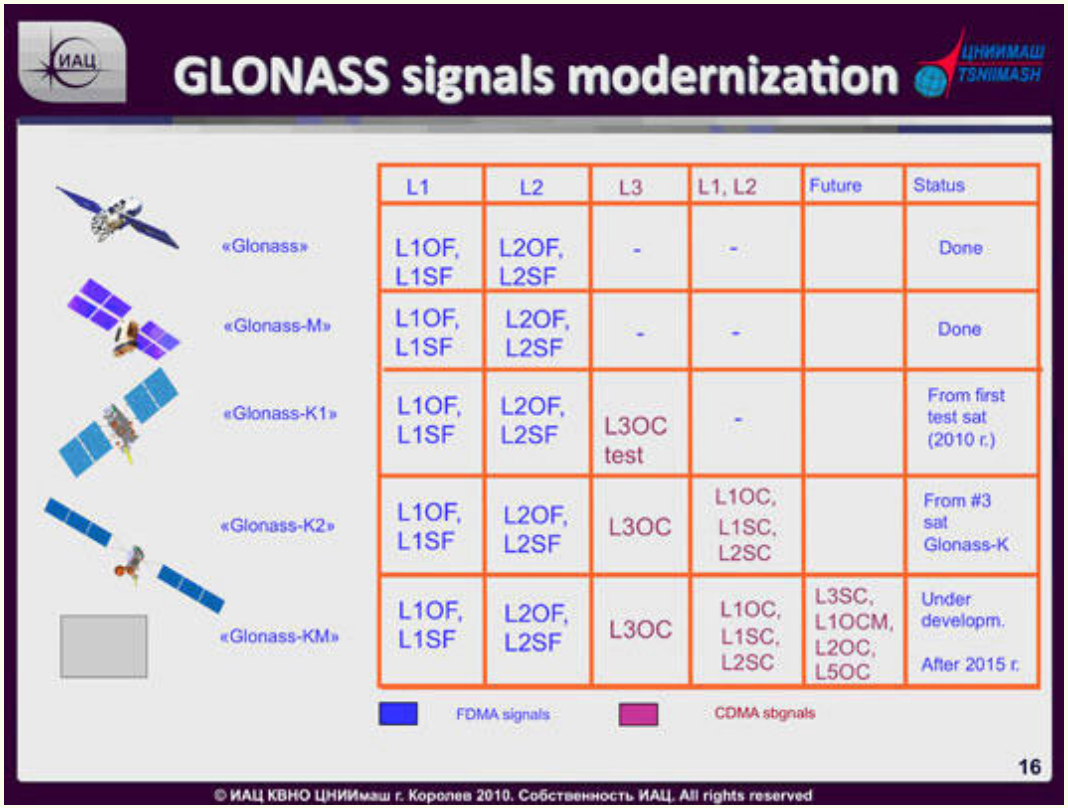
GLONASS/GPS constellation

GLONASS satellites



GLONASS signal

- Each satellite has its own frequencies
- All satellites have the same code
  - Fundamental frequency f_o = 5 MHz
  - L1 band range: 1602.5625 MHz to 1615.5 MHz
  - L2 band range: 1240 MHz to 1260 MHz

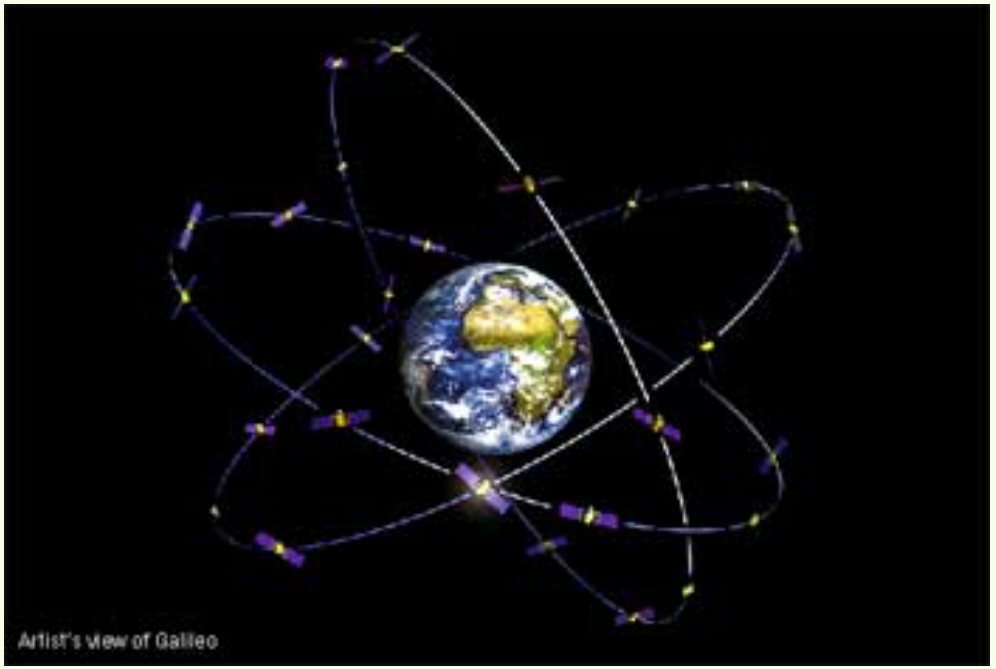


EUROPE: GALILEO

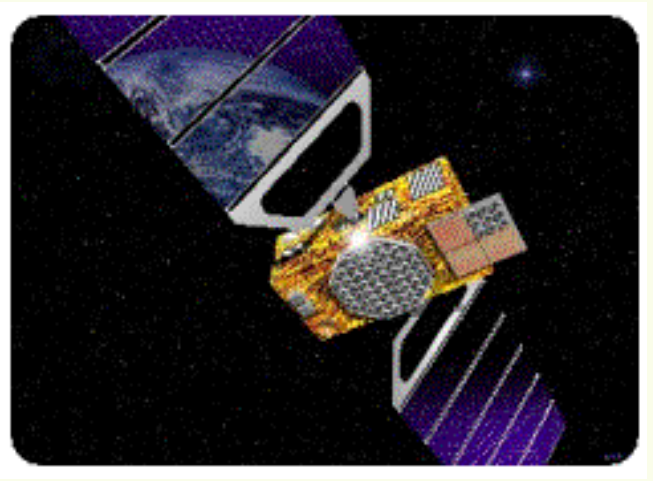
- Why GALILEO was created
  - Need of high-accuracy, real-time position, velocity and time on variety of platforms
  - Worldwide, all weather operation - civilian only
  - Galileo will provide a global Search and Rescue (SAR) function
- What is GALILEO
  - satellites - 30 active satellites - 3 orbital planes
    - altitude - 23 222 km
    - inclination - 56° (with respect to the Equator)
    - orbit periods - 14h 07 min repeat every 10 days
  - Ground based reference receivers: GALILEO compatible
    - Europe - 1700
    - Japan - 1000
    - Bulgaria - 120

source: GALILEO at ESA
http://multimedia.esa.int/Videos/2012/10/Galileo-In-Orbit-Validation-Phase

GALILEO satellites



GALILEO constellation



GALILEO satellite

GALILEO signal

- Microwave signal
  - Fundamental frequency f_o = 10.23 MHz
  - E1 carrying frequency: 1575.42 MHz
  - E5 carrying frequency: 1191.795 MHz
  - E6 carrying frequency: 1278.75 MHz

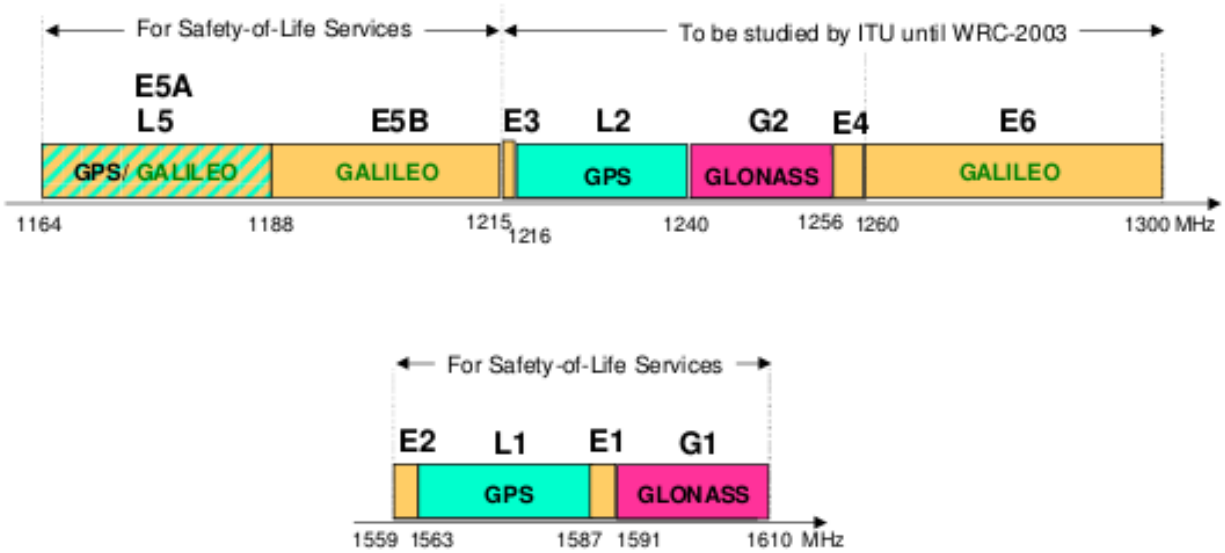


Figure 1. Galileo, GLONASS and GPS Frequency Bands

EUREF permanent GNSS station Sofia (SOFI)

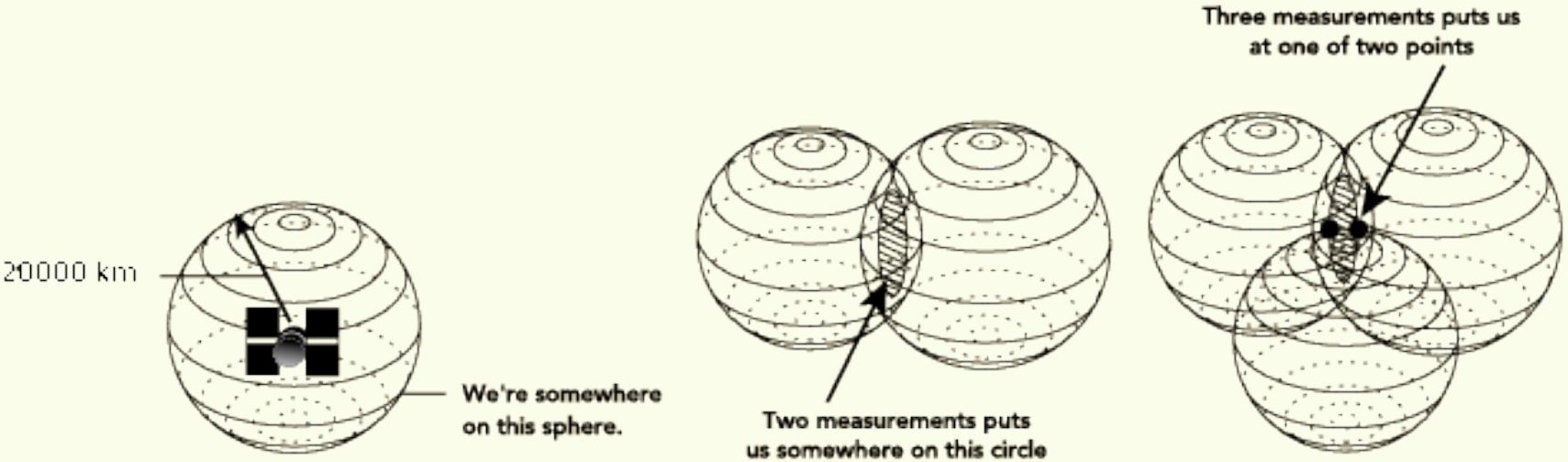
GNSS antenna

GNSS receiver

source: EUREF http://www.epncb.oma.be/_trackingnetwork/pictures/_large/sofi013.jpg

Measuring distances - how it works

- Measuring distances - satellite as a reference point
  - three satellites on view

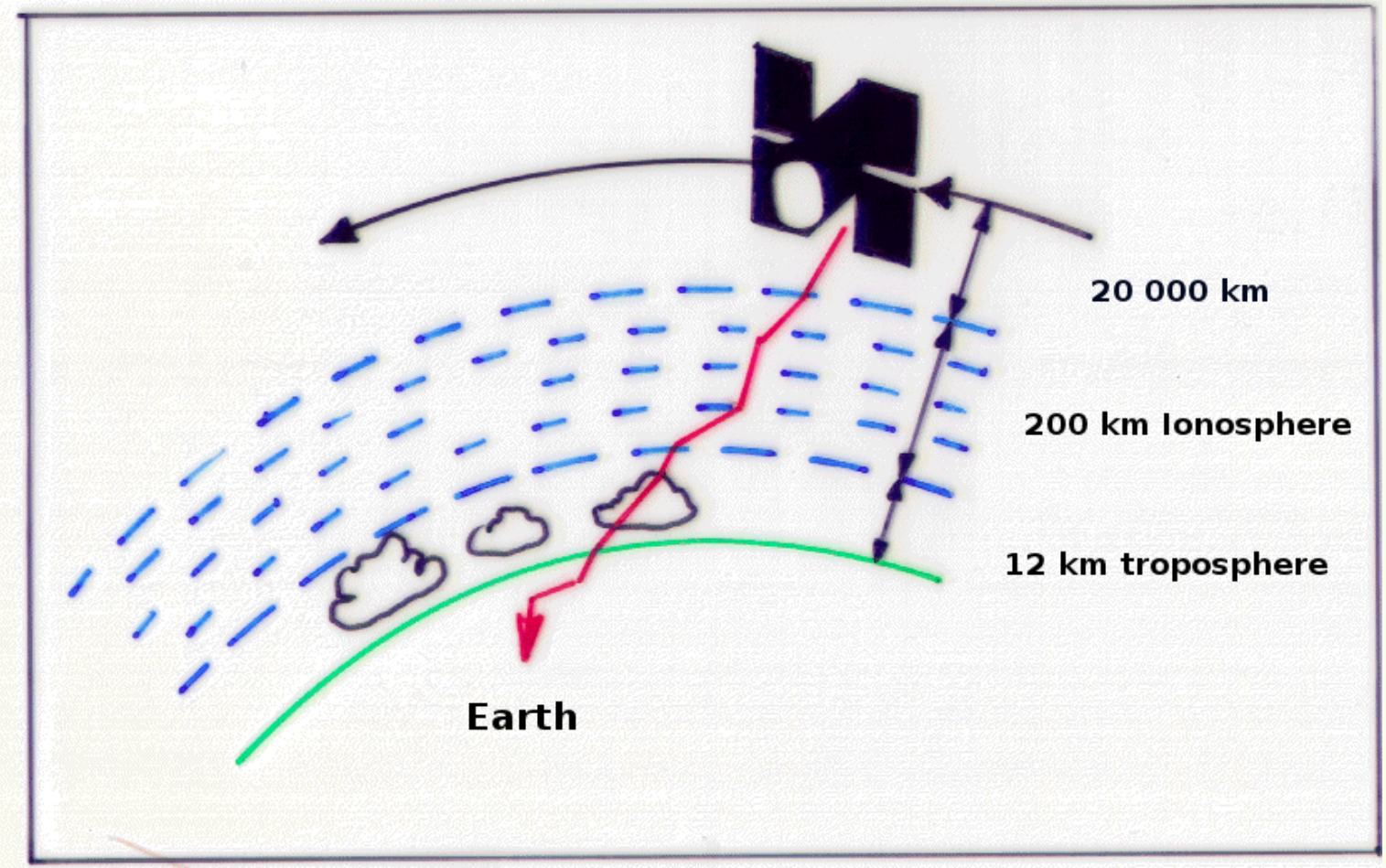


  - signal travel time $\sim$ 0.06s
  - speed of light S = V t

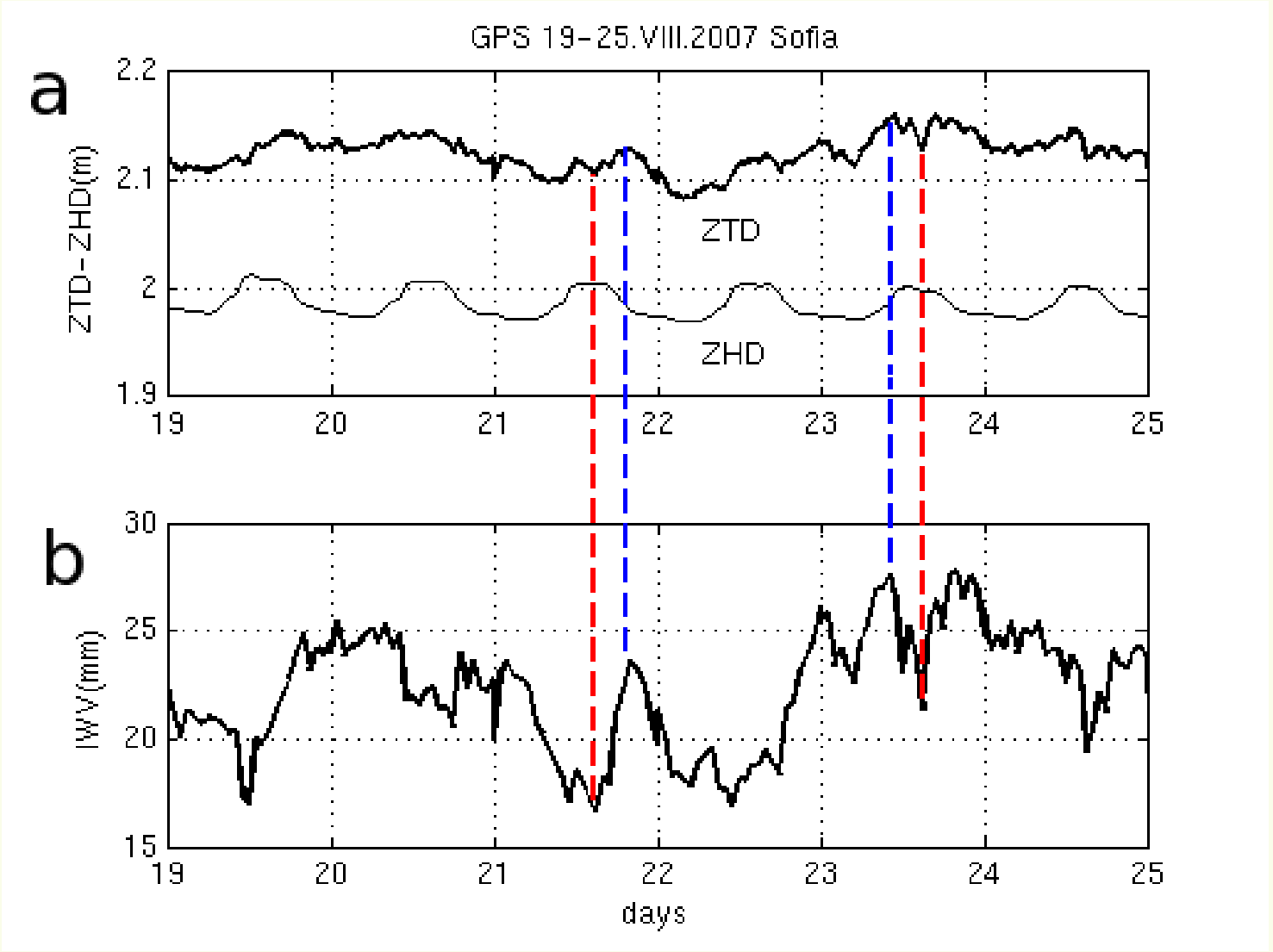
source: Trible tutorial http://www.trimble.com/gps/howgps.shtml

Science Applications: atmosphere

- Propagation errors in GNSS
  - ionosphere: delay in the range of 30 m
  - troposphere: 2 m delay at zenith, up to 20 m at low elevation



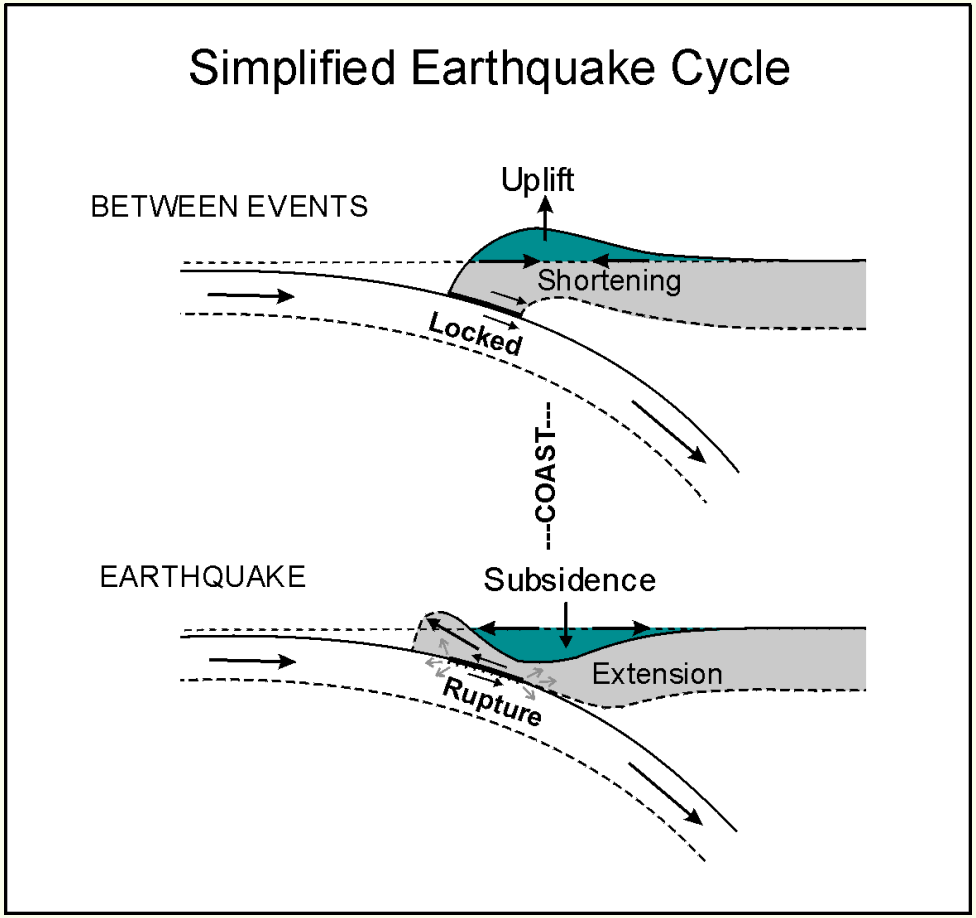
Science Applications: GNSS meteorology



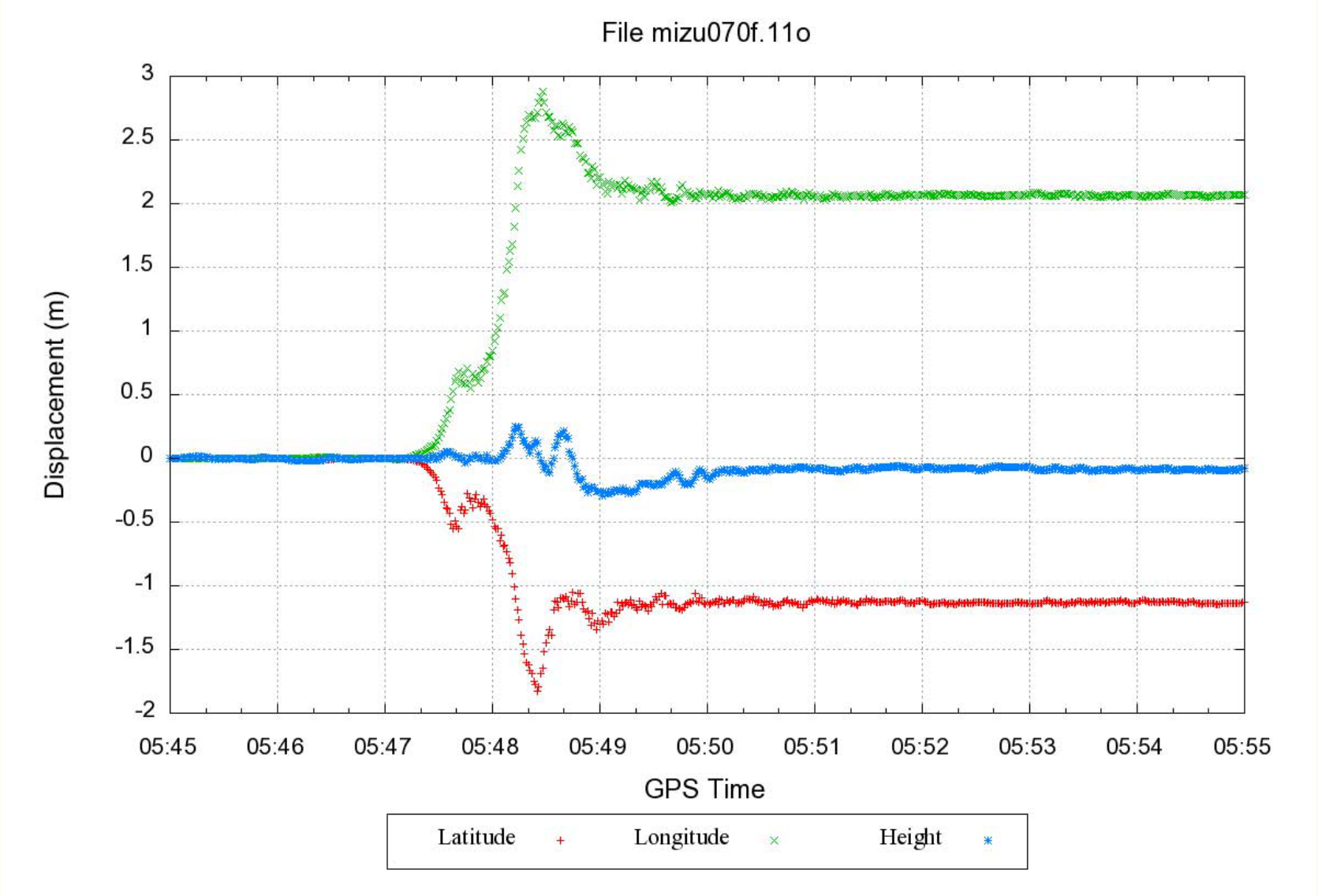
source: Tzvetan Simeonov's BSc thesis: "GNSS meteorology in Bulgaria" July 2011

Science Applications: earthquake I

- Solid Earth Studies
  - crustal deformation (with support of M. Schmidt, GS Canada)
  - uplifting phenomena - Sweden



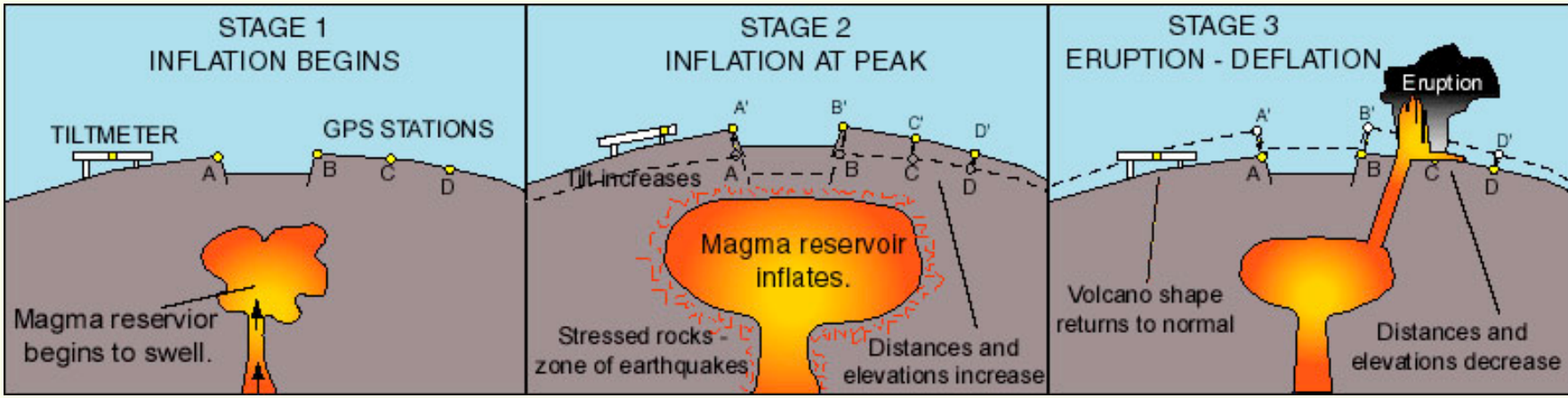
Science Applications: Japan 11 March 2011



source: Prof. Richard Langley's group at the University of New Brunswick, Canada
available from: http://gge.unb.ca/News/2011/2011.html#JapanGPS

Science Applications: volcano monitoring

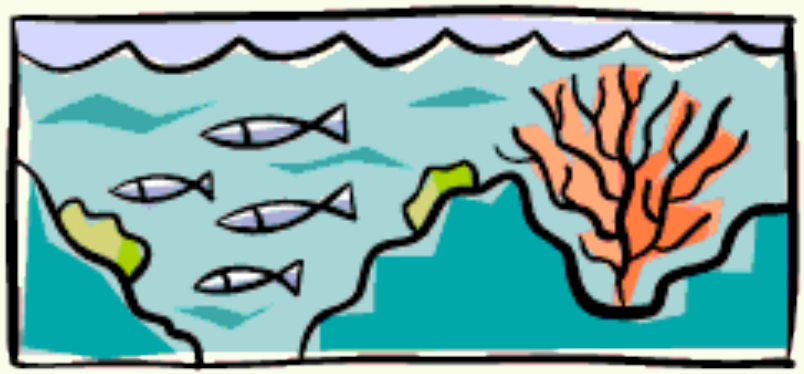
- Solid Earth Studies
  - monitoring volcanic activities



Day to day applications

Scientist, sportsmen, farmers, soldiers, pilots, surveyors, hikers, sailors, dispatchers, lumberjacks, fire-fighters ...

- Location and mapping (Where I am?)
  - measuring height of Mount Everest (8 850 $\pm$ 2m) Khumbu glecier moves towards Everest's Base camp
- Navigation and tracking (Where I am going?)
  - high - tech fishing (orange fish - underwater sea mounts)
  - landing plane in the middle of a mountain (Juneau Airport Alaska)
  - taking the top of the world
  - vessels and vehicle tracking - police, emergency services (Chicago 911)



Conclusions

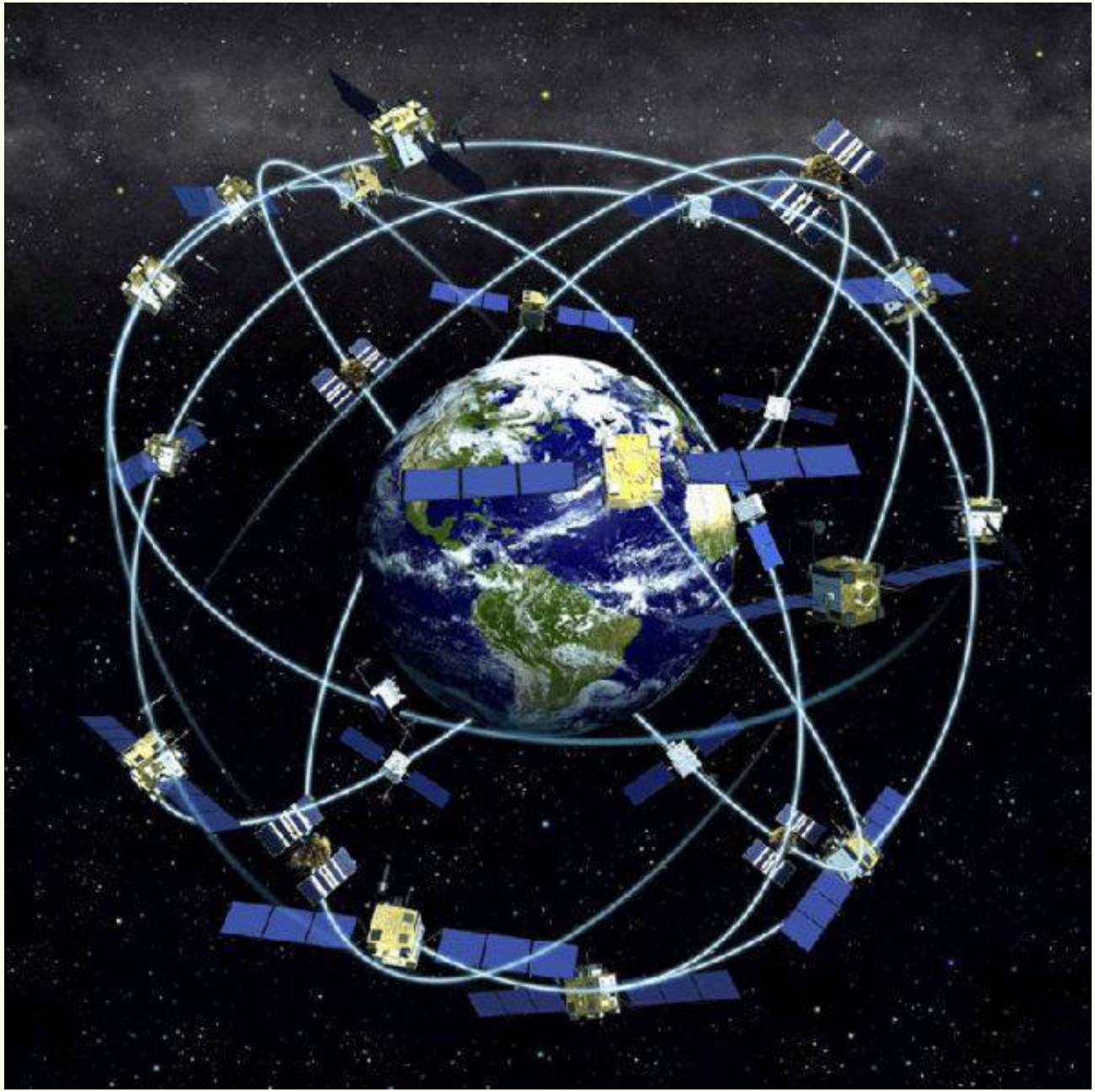
- all weather operation
- cost effective
- global coverage
- extremely accurate ($\sim$cm) for public users
- very compact

Prospective:

- Further integration in businesses - cellular phones, computer networks, agriculture, car industry
- Public safety services (decreasing costs, improving service efficiency)
- Replacement of conventional measuring techniques
- Improving weather prediction, helping to monitor earthquake activities, climate change and hazardous phenomena

Soon everything will be tracked and mapped from elephants to ...

Future constellation



Future constellation