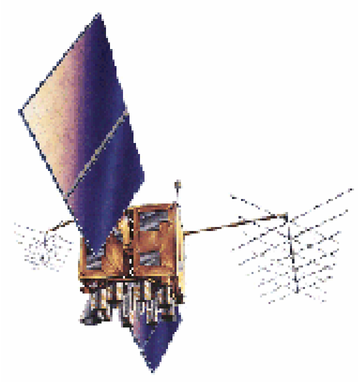
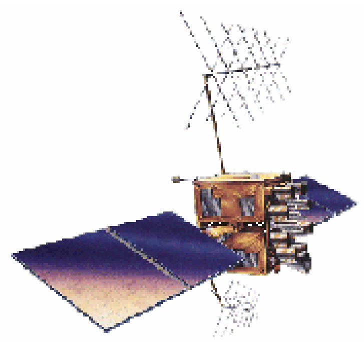
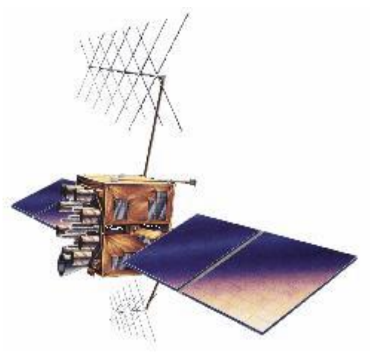
GPS use in Amanat Survey

GPS Concept & Theory







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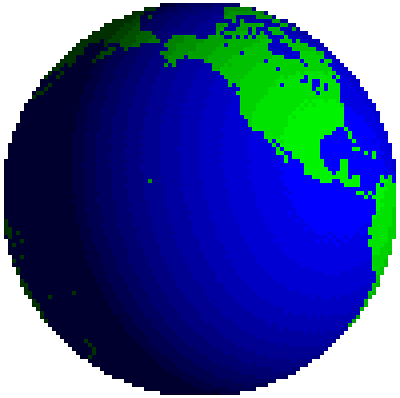


What is Navigation?

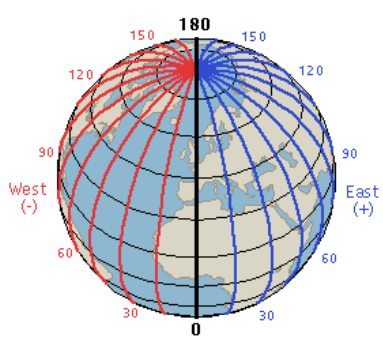
The act, activity or process of finding the way to get to a place when you are travelling in a ship, airplane or car etc.

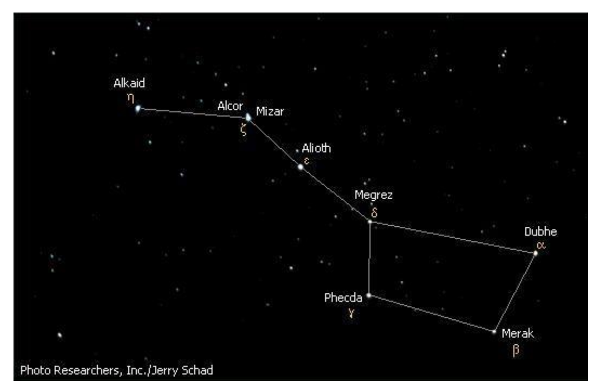
Traditional Navigational Tools

- ✓ Landmarks
- ✓ Sun, Moon or Star
- ✓ Maps
- ✓ Compass, Sextant

Navigation remained the greatest challenge

- ✓ Columbus and his ships were misdirected
- ✓ Amelia Earhart disappeared and never found due to poor navigation.
- ✓ Many space ships missed then destination.





GPS: The Magic

- ✓ Type an address into your phone and up will pop a step by step route from **where you are to where you want to be**.
- ✓ This is in its way magic , magic that has at this point been rubbed and polished into a simple fact of life.
- ✓ The ease with which we machine carrying human make our way through the world, through is quite new and it's the product of long, painstaking history: of people plotting a course getting lost and finally finding their way.
- ✓ So it is a very new complex and meaningful system in our life.

What is GPS ?

- ✓ The satellite based radio navigation and positioning system, Global Positioning System (GPS) launched by US Department od Defense has revolutionized the field of survey and mapping.

- ✓ With unprecedented accuracy, economy, efficiency and ease of operation offered by the GPS this unique space geodetic techniques has found numerous applications in virtually every engineering, scientific and resource management field.

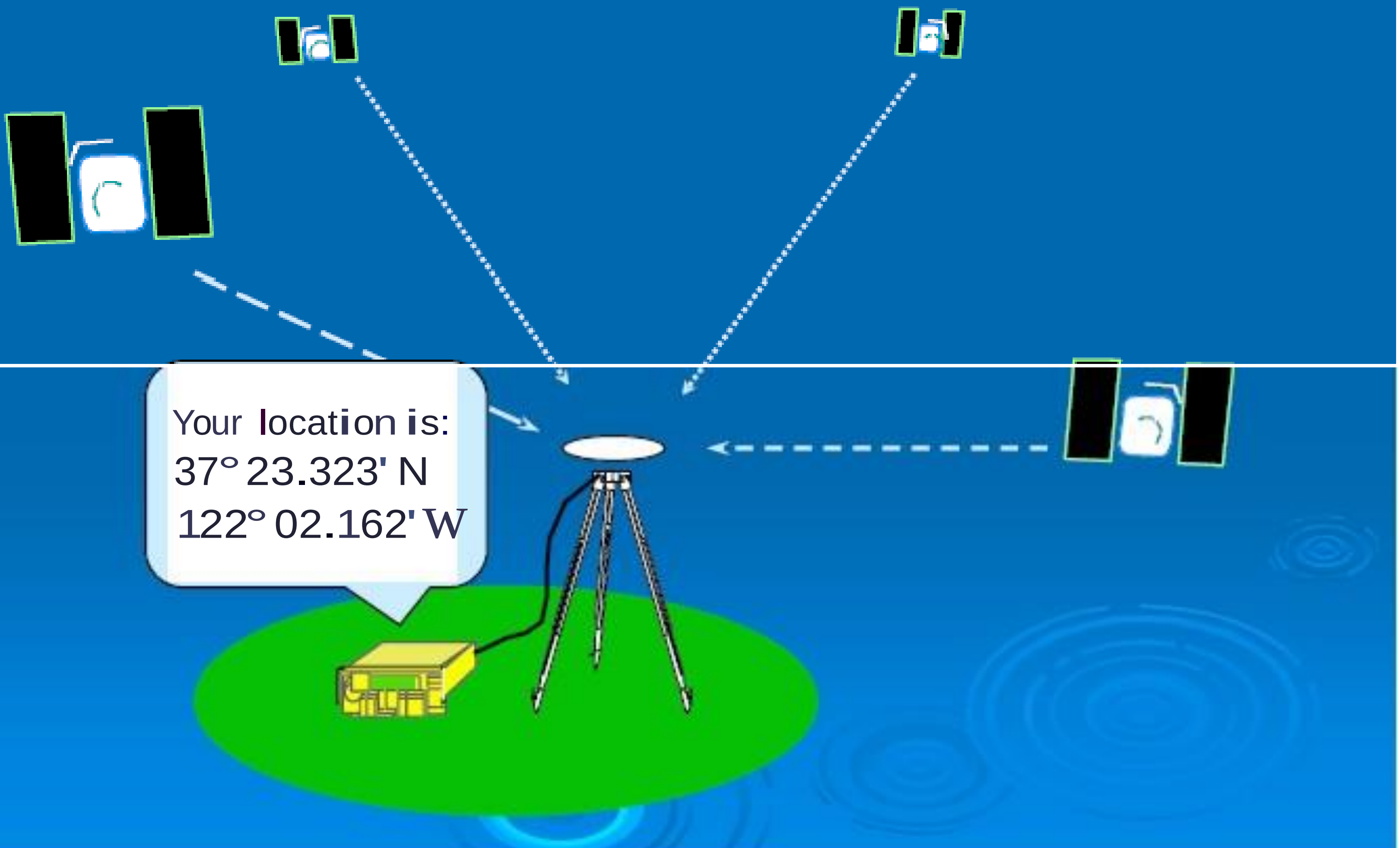
- ✓ It provides positions of stationary as well as moving objects.

What is GPS?

- It is a Satellite based radio-navigation system which is used to determine the position, time and velocity
- anytime, anywhere in the world
- weather independent
- Developed by US DoD (Department of Defens
  - NAVSTAR GPS; United State System (Navigation Satellite Timing and Ranging)
  - Global Navigation Satellite System (GNSS)
  - Galileo (Consortium of European Governments)
  - IRNSS (Indian satellite Navigation System)

What it gives?

Position, Time & Velocity



History of GPS

- ✓ 1958: Transit Nevi navigational system (NNSS) by US Navy

(Five Satellite at 1075 Km Altitude).

- ✓ 1964: it became operational
- ✓ 1967: Available to civilian users
- ✓ 1969: Defense Navigation Satellite System (DNSS) formed
- ✓ 1972 joint service programmed of US Air force, Navy, Army, Mariners and Defense mapping Agency.
- ✓ 1973: NAVSTAR (Navigational Satellite Timing and Ranging) Global Positioning System developed
- ✓ 1978: first 4 satellites launched
- ✓ 1993: 24th satellite launched: initial operational capability
- ✓ 1995: full operational capability
- ✓ May 2000 Military accuracy available to all users.

- ✓ The Russian Global Navigation Satellite System (GLONASS) was developed contemporaneously with GPS, but suffered from incomplete coverage of the globe until the mid-2000s.
- ✓ China's BeiDou Navigation Satellite System began global services in 2018, with full deployment scheduled for 2020.
- ✓ European Union Galileo positioning system.
- ✓ Japan's Quasi-Zenith Satellite System (QZSS) is a GPS satellite-based augmentation system to enhance GPS's accuracy in Asia-Oceania, with satellite navigation independent of GPS scheduled for 2023

What is GPS

The global Positioning System (GPS) is a U.S owned utility that provides users with positioning, navigation and timing (PNT) services. That system consists of three segments: the space segment, control segment, and the user segment. The U.S. Air force develops, maintains and operates the space and control segments.

Levels of Accuracy in GPS

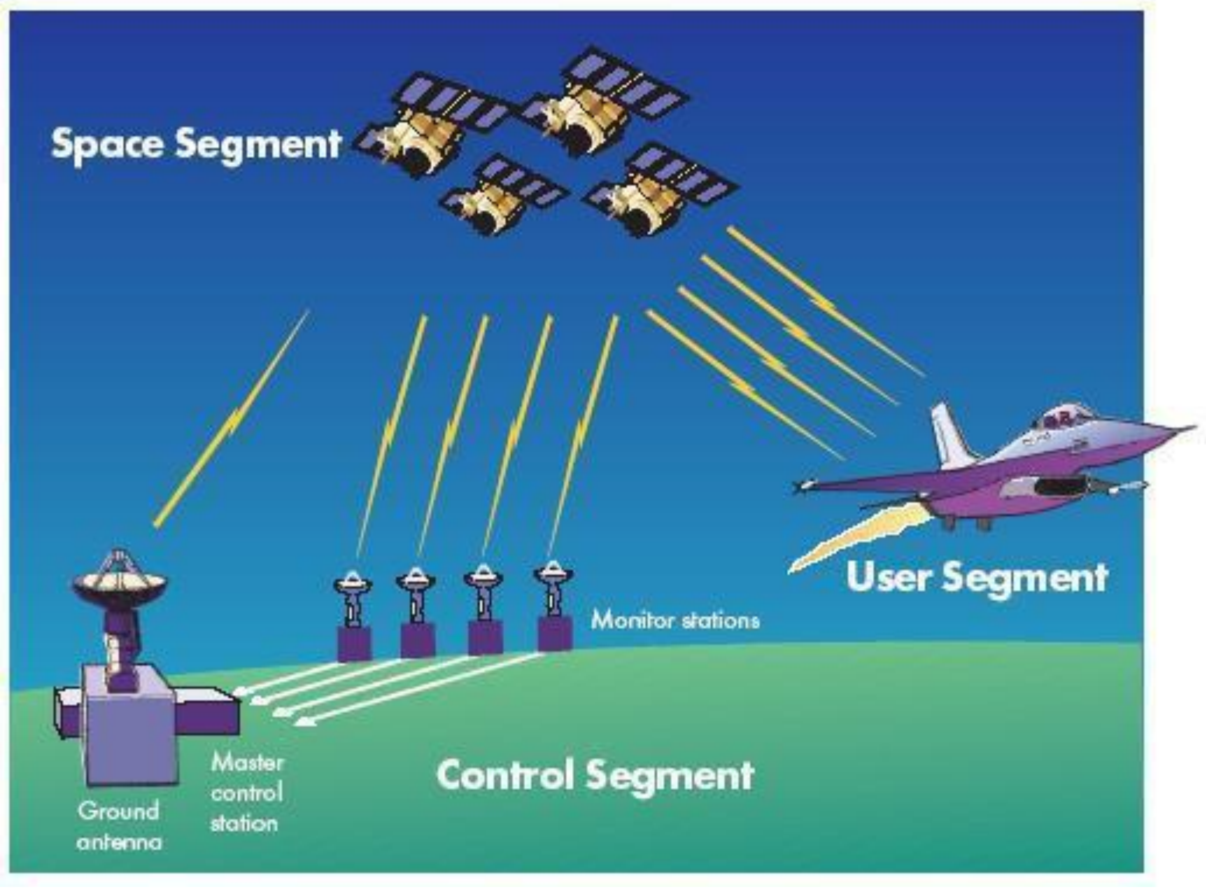
- ❑ Navigation : 100 m
- ❑ Mapping : 1m
- ❑ Geodetic Positioning : Millimeter

- ✓ The accuracy of the GPS signal in space is actually the same for both the civilian GPS service (Slandered Positioning Service SPS) and the military GPS service (Précises Poisoning Service PPS).
- ✓ However SPS broadcasts on one frequency. While PPS uses two frequency.
- ✓ This means military users can performs ionospheric correction, a techniques that reduces radio degradation caused by the earth's atmosphere with less degradation, PPS provides batter accuracy that the basic SPS.

So how does it operate?

Three segments of GPS satellite

Relies on 3 separate components, all operating together



- 1. Space
- 2. Control
- 3. User

Space Segment in GPS

- ✓ The GPS segments consists of a constellation of satellites transmitting radio signals to users, the united sates is committed to maintaining the availability of at least operational GPS satellites, 95% of time. To ensure this commitment , the Air Force has been flying 31 operational GPS satellites for past few years As of June 15th 2016, there were 31 operational satellites in the GPS constellation.

- ✓ 24 satellite vehicles.

- ✓ Six orbital planes.

- Inclined 55 degree with respect to equator
- Orbits separated by degree

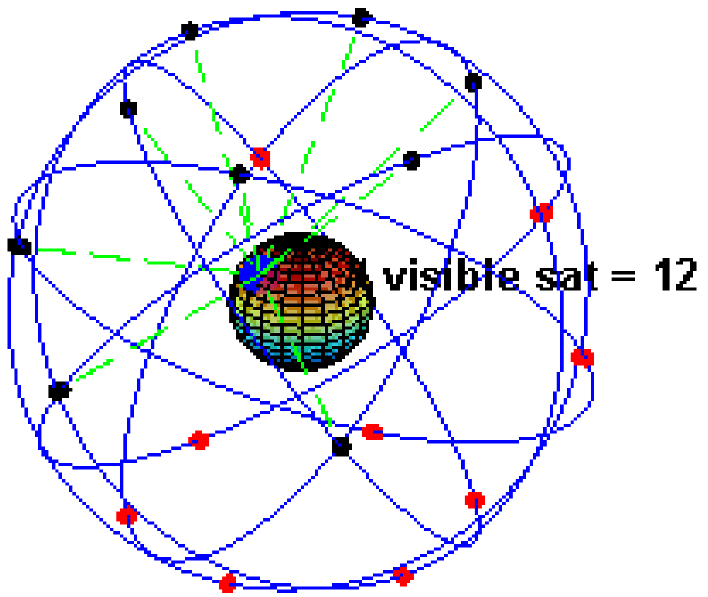
- ✓ 20,200 Km elevation above earth.

- ✓ Orbital period of 11 hr. 55 min.

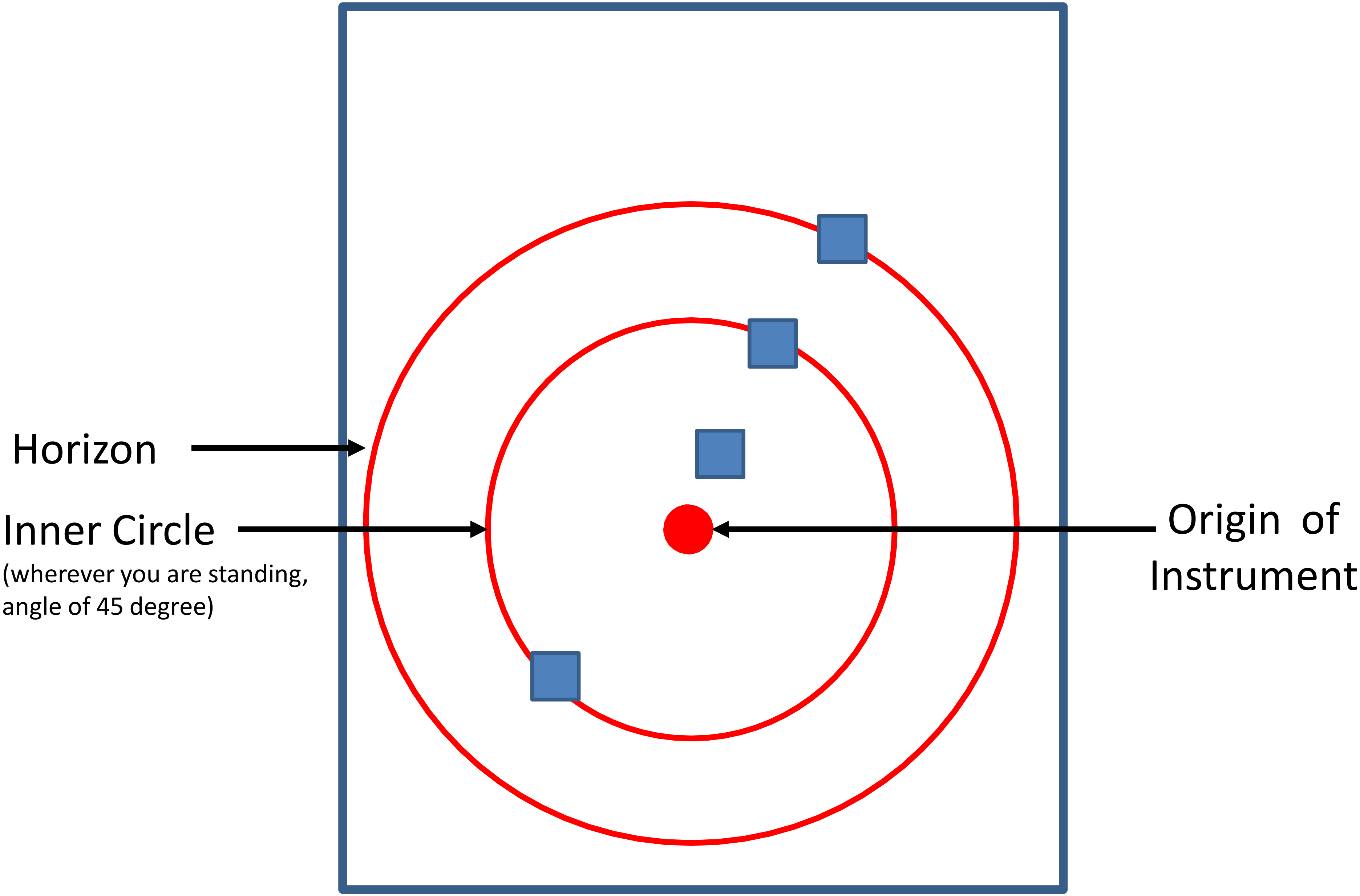
- ✓ Five to eight satellites visible form any point on earth.

1. Space segment

- 24 satellites in ~12 hour orbits about 12,500 miles above the Earth
  - This is known as the **GPS constellation**
- At any given time, at least **four of the satellites** are above the local horizon at every location on earth 24 hours a day
- Ephemeris -- provides position in space at any specific time

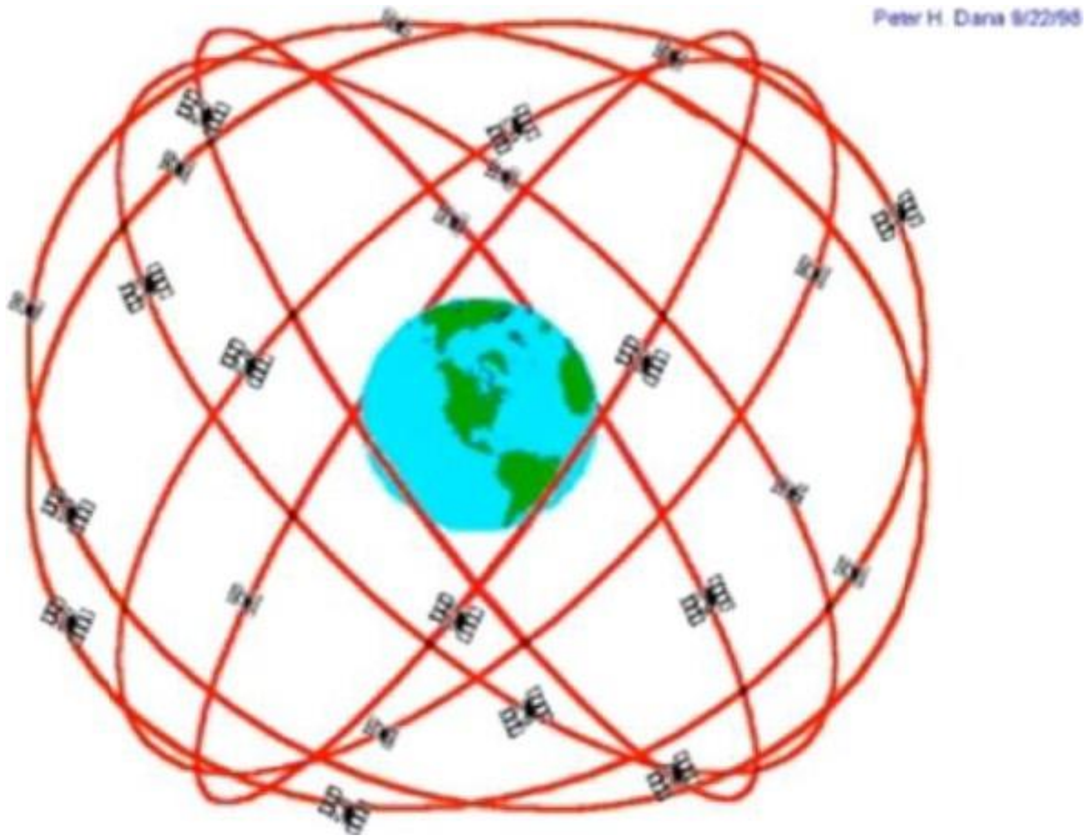


Satellite Page



For 2D minimum number of satellite required is 3 and for 3D minimum number of satellite required is 4

The GPS **Constellation**



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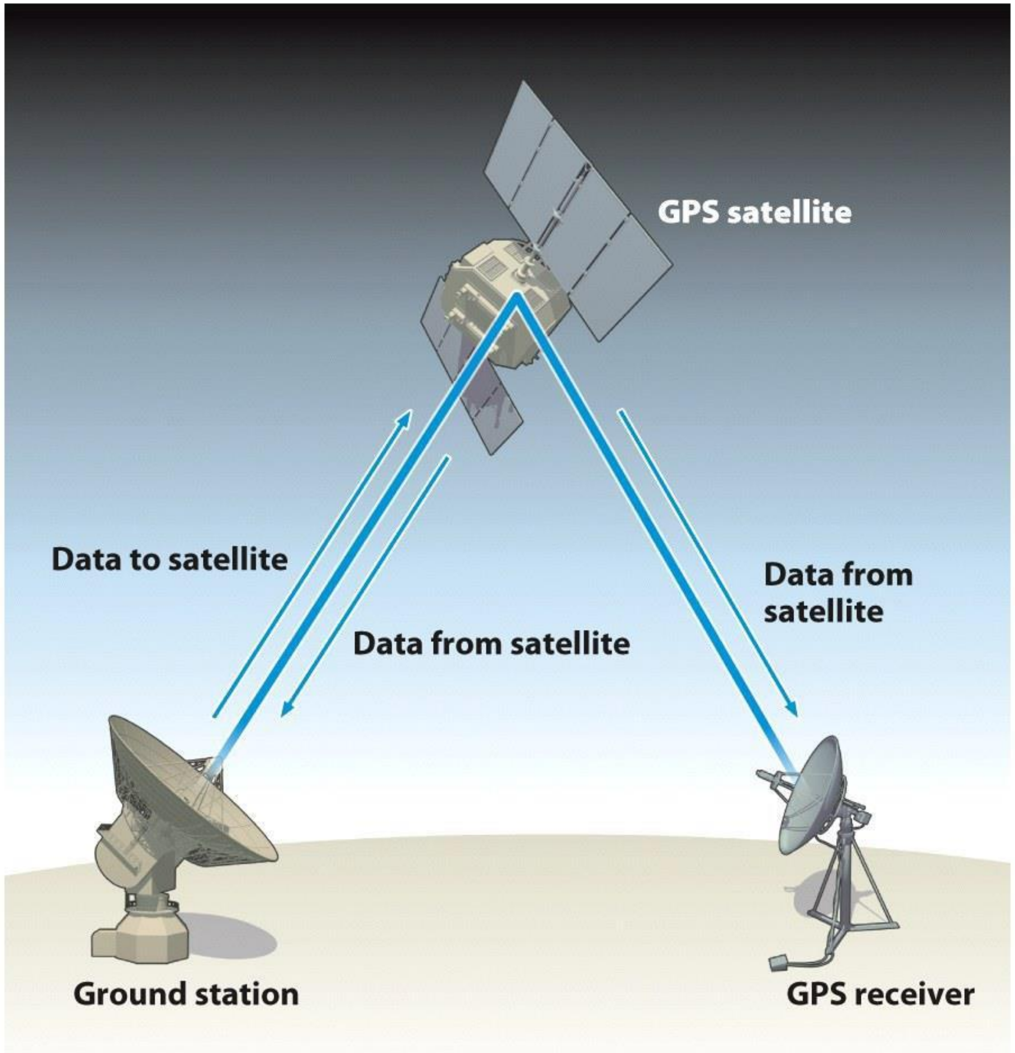
2. Control segment

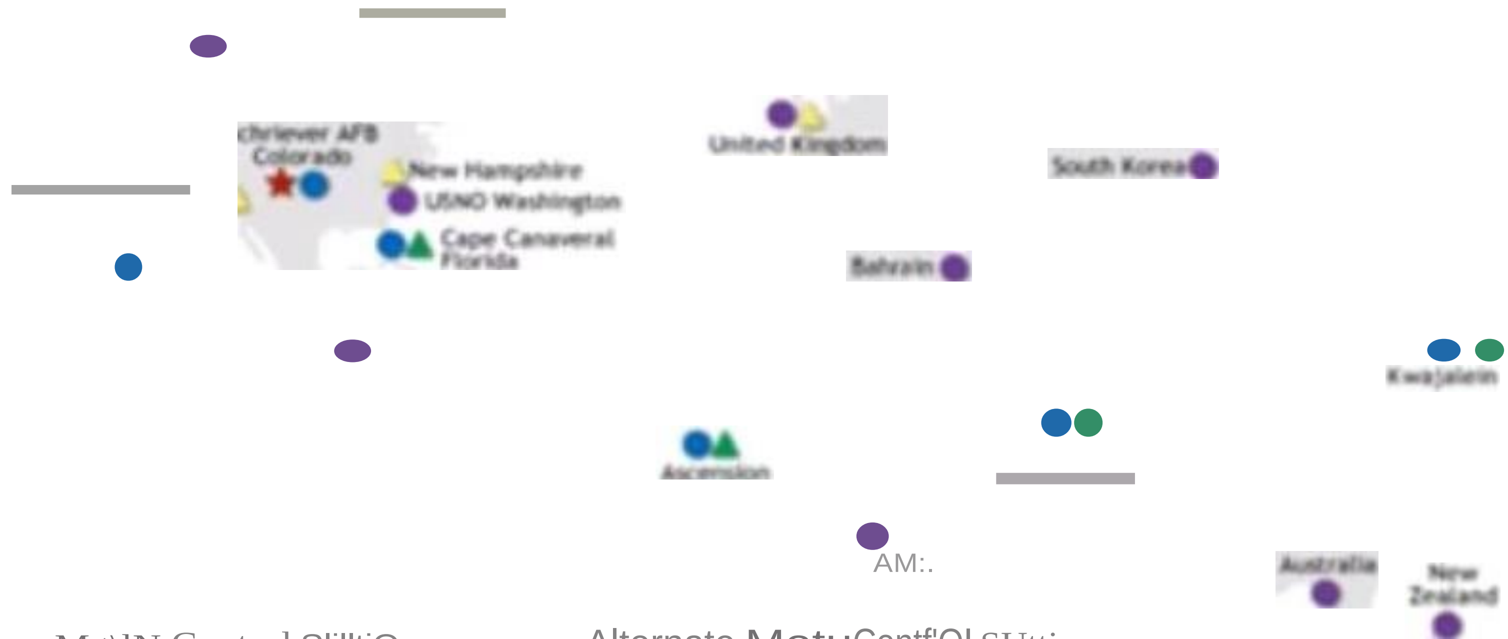


- ✓ US Air Force operates the satellite
- ✓ They update ephemeris information for the satellite
- ✓ They maintain information on the health of each satellite
- ✓ They configure the hardware on the satellite
- ✓ They check the clocks on the satellites

Control Segment

Master Control Station ◆ Monitor Station ▲ Ground Antenna

Control the Satellites – upload ephemeris, time information



M.t\lN Control SlilltiOn
Ground MlenM
Au F'Ofte Monitor Station

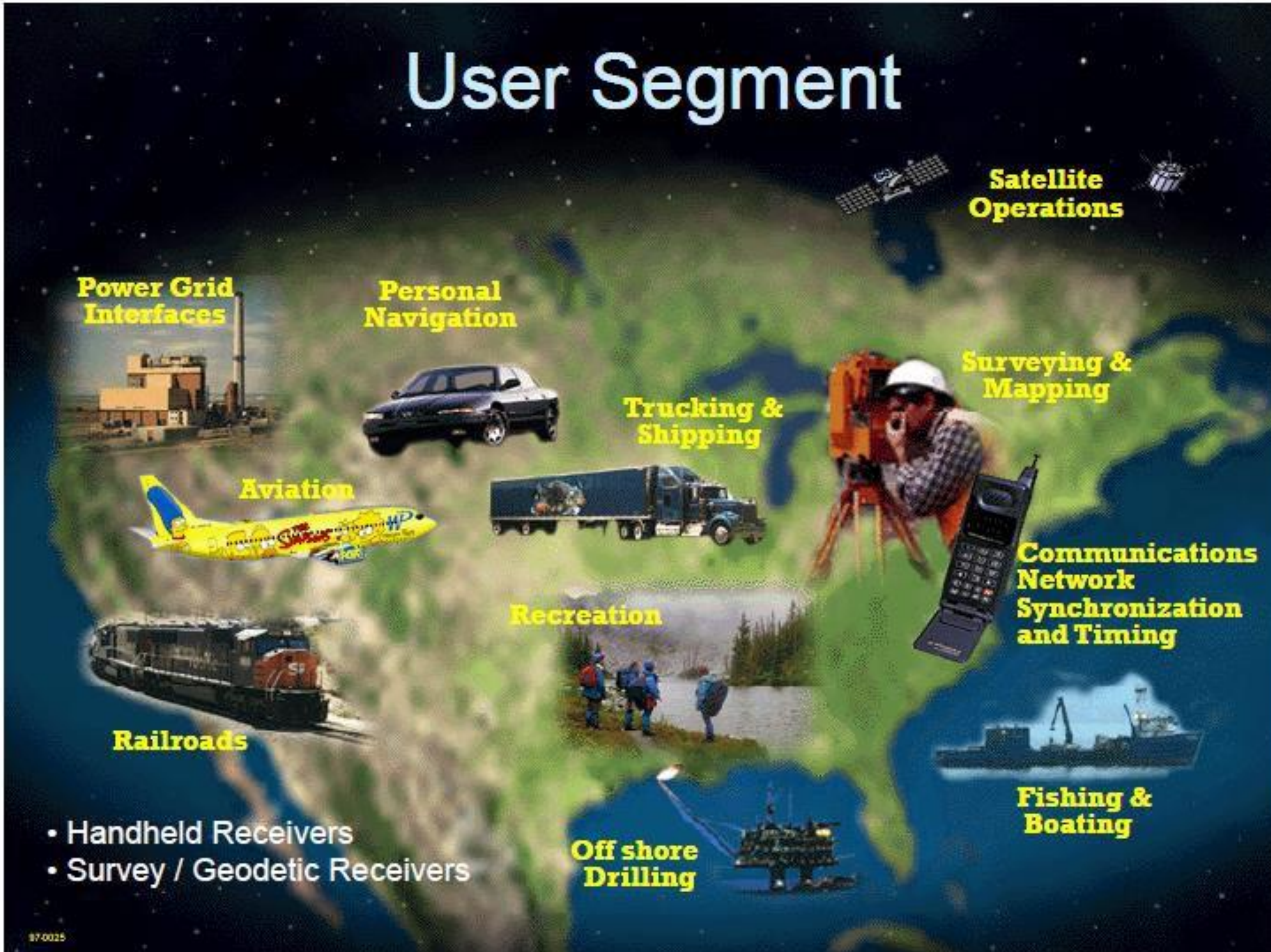
Alternate MotuContf'Ol SUttion
AFSCN Aemote Trac._lftt Station
e NGAN.onilQI Statton

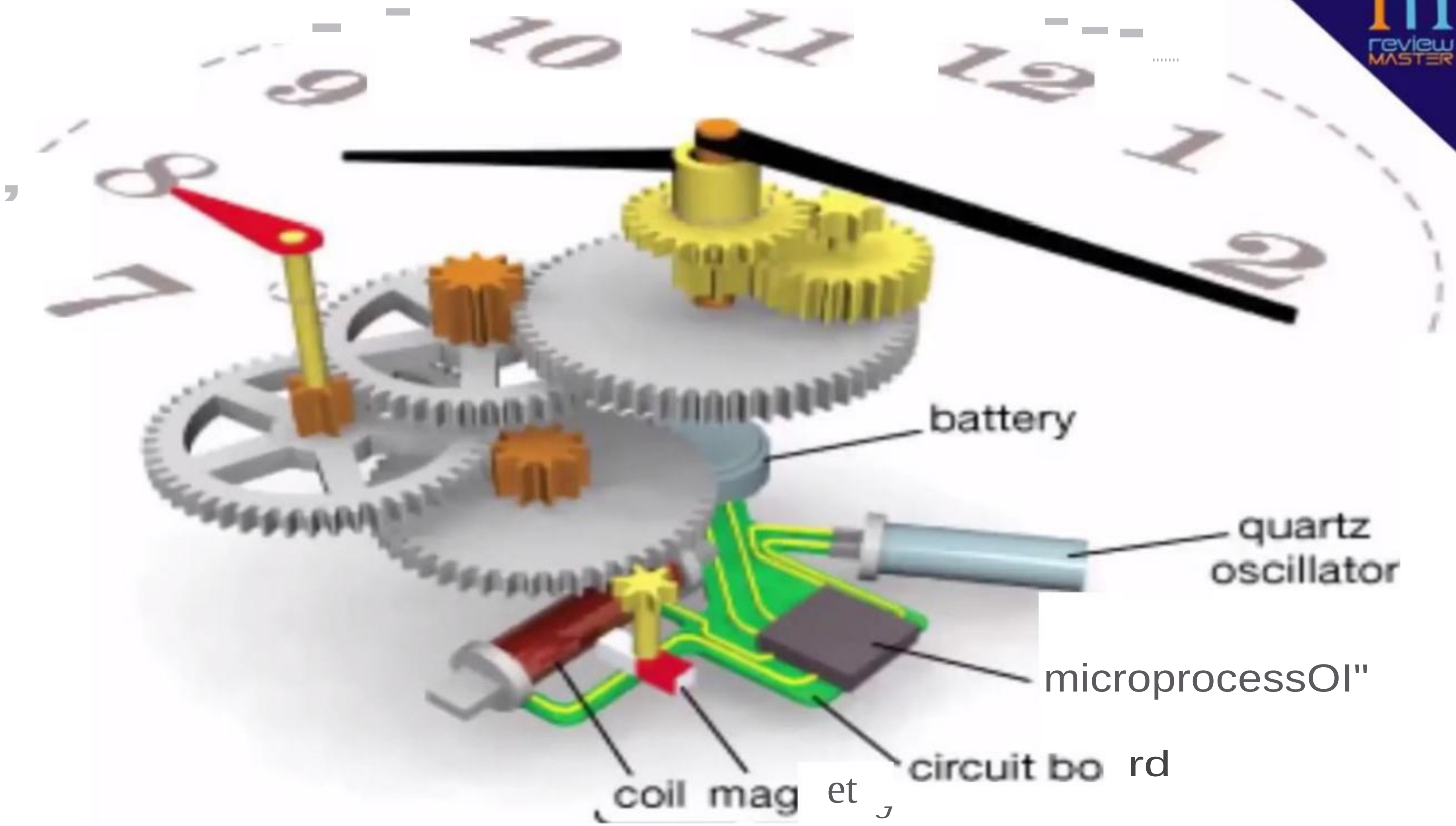
Control Segment

- ✓ The GPS control segment consists of a global network of ground facilities that track the GPS satellites, monitor their transmission, perform analysis and send commands and data to the constellation.
- ✓ The current operational control segment includes a master control station, an alternate master station at Vandenberg California, 11 command and control antennas and 15 monitoring sites.
- ✓ The locations of these facilities are shown in the map.

User Segment

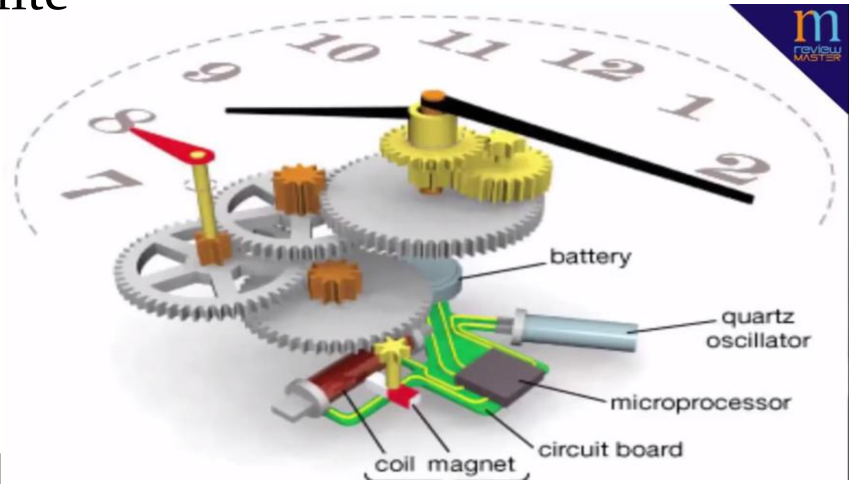
The user segment consists of the GPS receiver equipment that receives the signals from the GPS satellites and uses the transmitted information to calculate the users there dimensional position.


User Segment
Satellite Operations
Power Grid Interfaces
Personal Navigation
Surveying & Mapping
Trucking & Shipping
Aviation
Communications Network Synchronization and Timing
Recreation
Railroads
Fishing & Boating
• Handheld Receivers
• Survey / Geodetic Receivers
Off shore Drilling
97-0025


battery
quartz
oscillator
microprocessOI"
circuit bo rd
coil
mag et

Accurate clocks

- ✓ Satellites have very accurate clocks and very accurate ephemeris information
- ✓ Light speed = 186,000 mi./second
- ✓ Out of sync by 1/100th of second equals error of 1860 miles.
- ✓ Atomic clocks (4) aboard each satellite
- ✓ Three nickel cadmium batteries.
- ✓ Two solar panels
  - Battery charging
  - Power generation
  - 1136 watts



- ✓ S band antenna – for satellite control
- ✓ 12 element L band antenna – for user communication
- ✓ Block IIF satellite vehicle (forth generation)

GPS Satellite Vehicle

- ✓ Weight: 2370 Pounds
- ✓ Height: 16.25 feet
- ✓ Width: 38.025 feet including wing span
- ✓ Design life: 10 years

Components of the System

User Segment:

✓ GPS antennas & receiver/processors
✓ Position
✓ Velocity
✓ Precise Timing

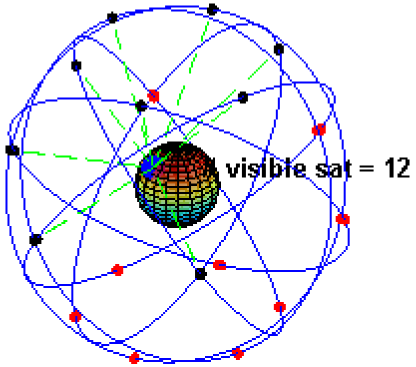
Used By

❖ Aircraft
❖ Ground Vehicles
❖ Ships
❖ Individuals

How does GPS Work?

What are the basic science has behind that?

- Triangulation
  - Based on angular measurement
- Trilateration
  - Based on time
  - (or distance)
  - GPS is based on Trilateration



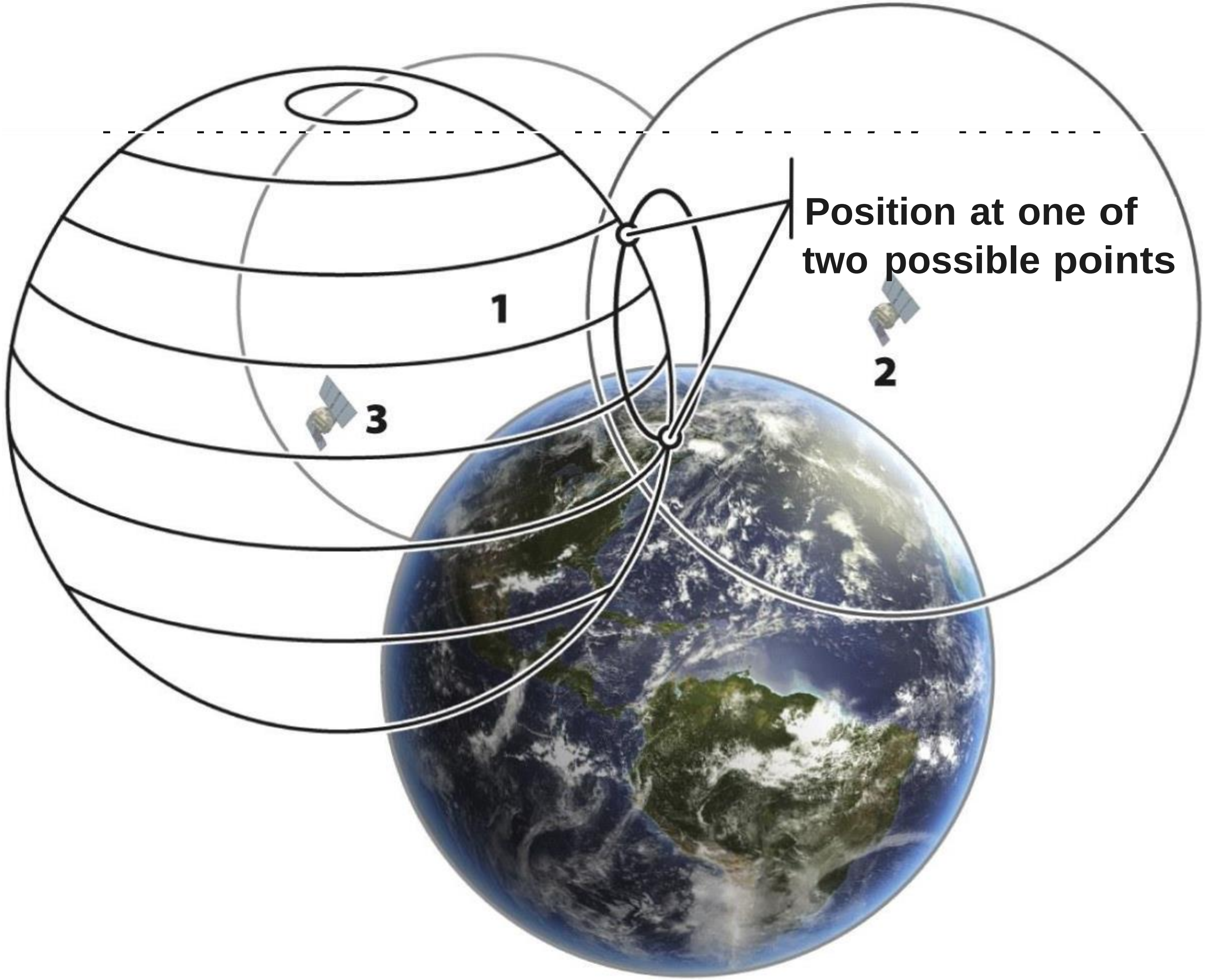
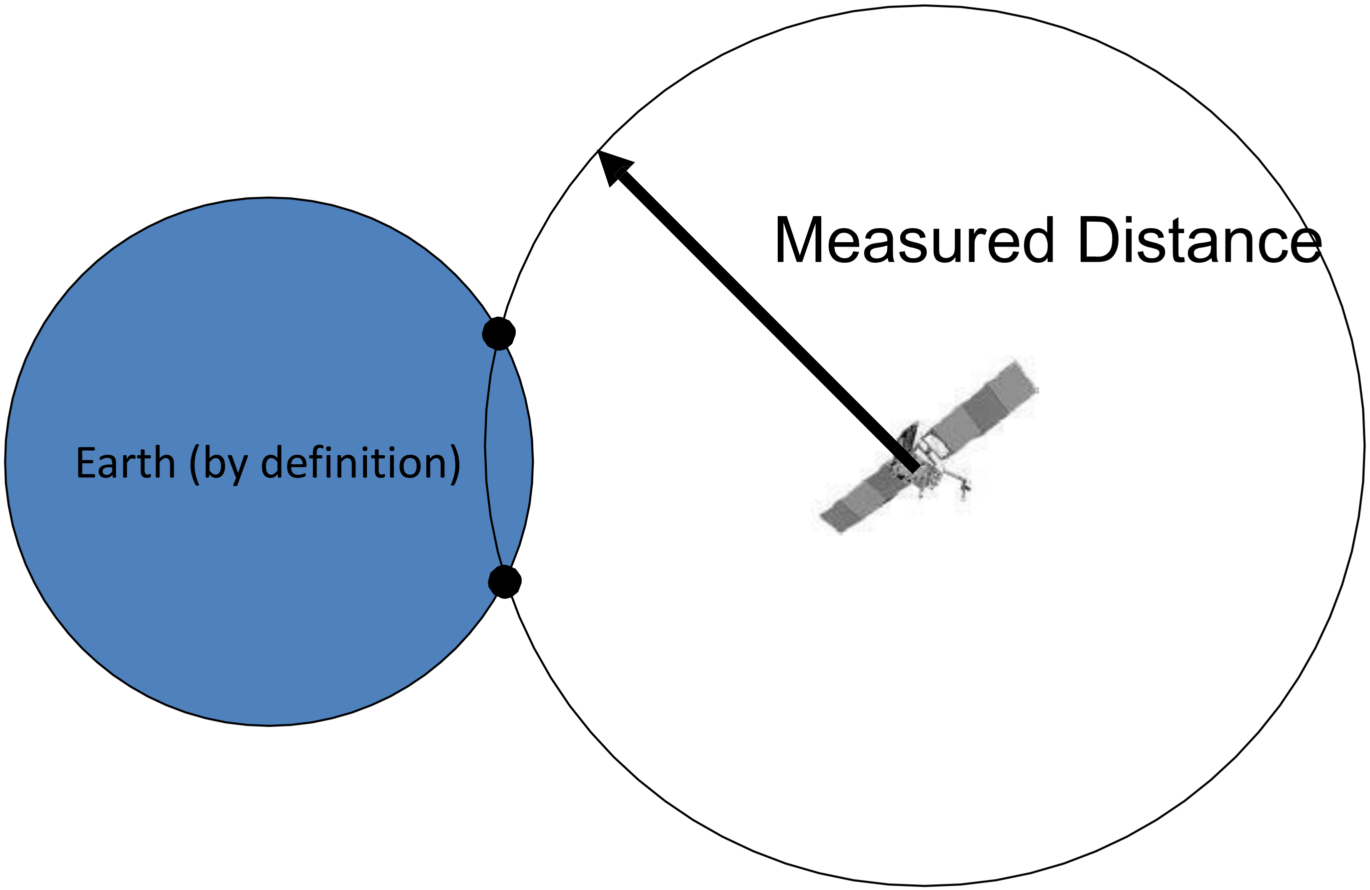


Figure4.6
Introduction to Geospatial Technologies

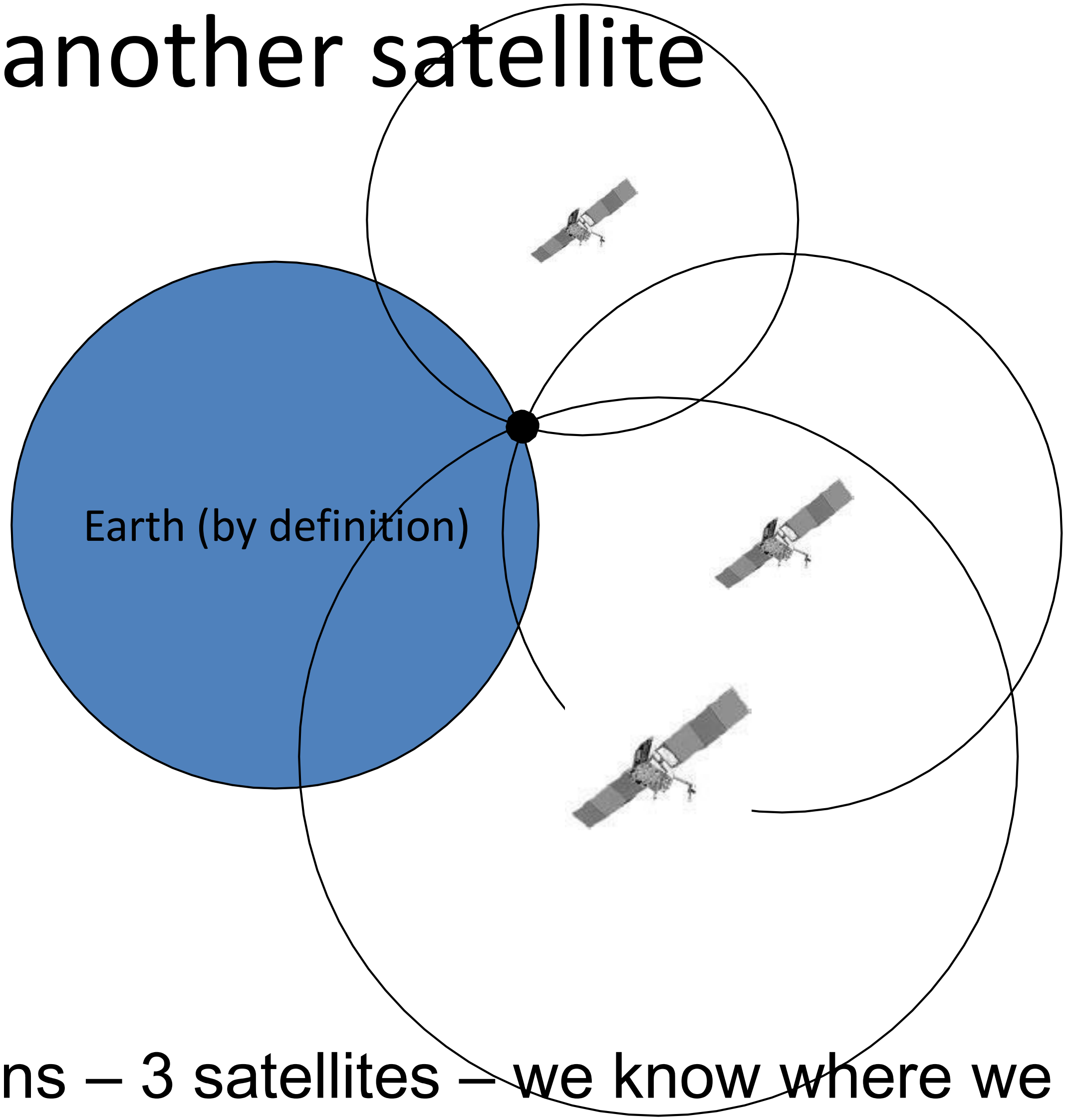
The satellite knows where it is.



We know the distance from the satellite by the code correlation.

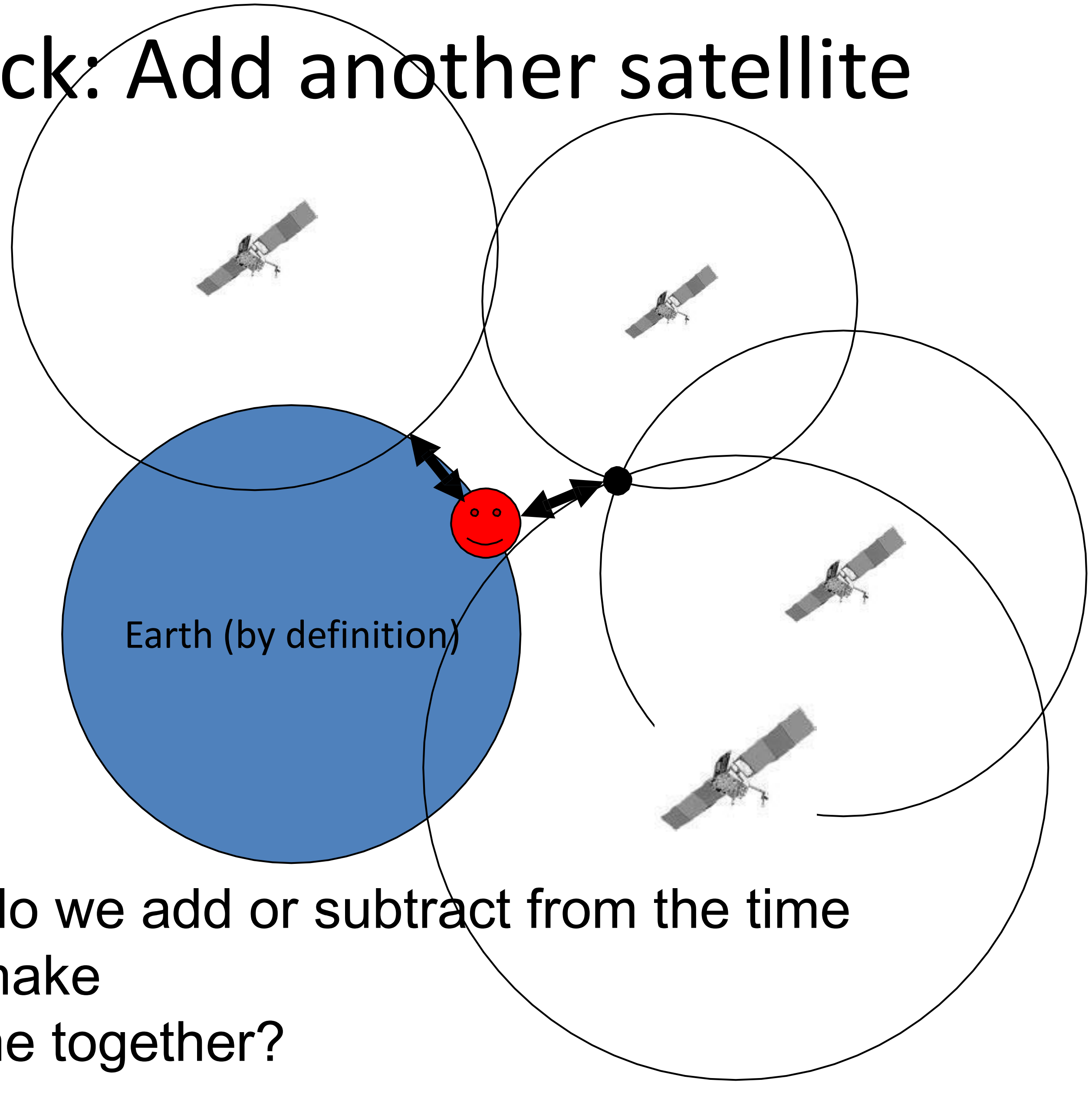
So we know where we are on a big circle (sphere) around the satellite.

Add another satellite



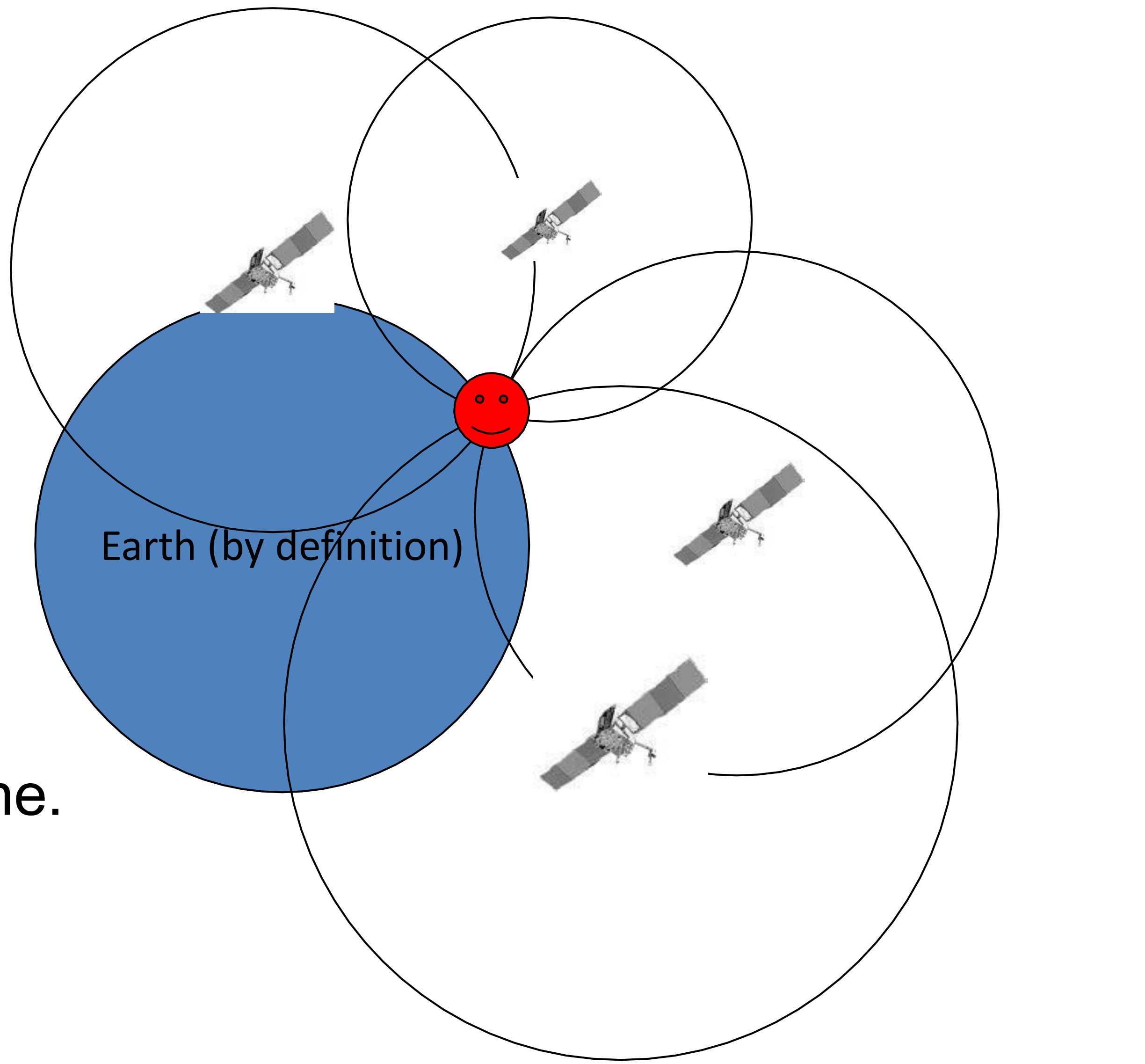
Again: Two dimensions – 3 satellites – we know where we are!

Old trick: Add another satellite



What number do we add or subtract from the time correlation to make
everything come together?

Add or subtract the time offset number



Now you got the time.

How does GPS Work?

- ➢ Satellite Ranging
- ✓ Satellite Locations
- ✓ Satellite to user distance
- ✓ Need four satellites to determine position

- ➢ Distance measurement
- ✓ Radio Signal traveling at speed of light
- ✓ Measure time from satellite to user

- ➢ Low tech Simulation

- ➢ Pseudo – Random Code
- ✓ Complex Signal
- ✓ Unique to each satellite
- ✓ All satellites use same frequency

How does GPS Work?

- ✓ Distance to a satellite is determined by measuring how long a radio signal takes to reach us from that satellite.
- ✓ To make the measurement we assume that both the satellite and our receiver are generating the same pseudo-random codes at exactly the same time.
- ✓ By comparing how late the satellite's pseudo-random code appears compared to our receiver's code. We determine how long it took to reach us.
- ✓ Multiply that travel time by the speed of light and you've got distance.

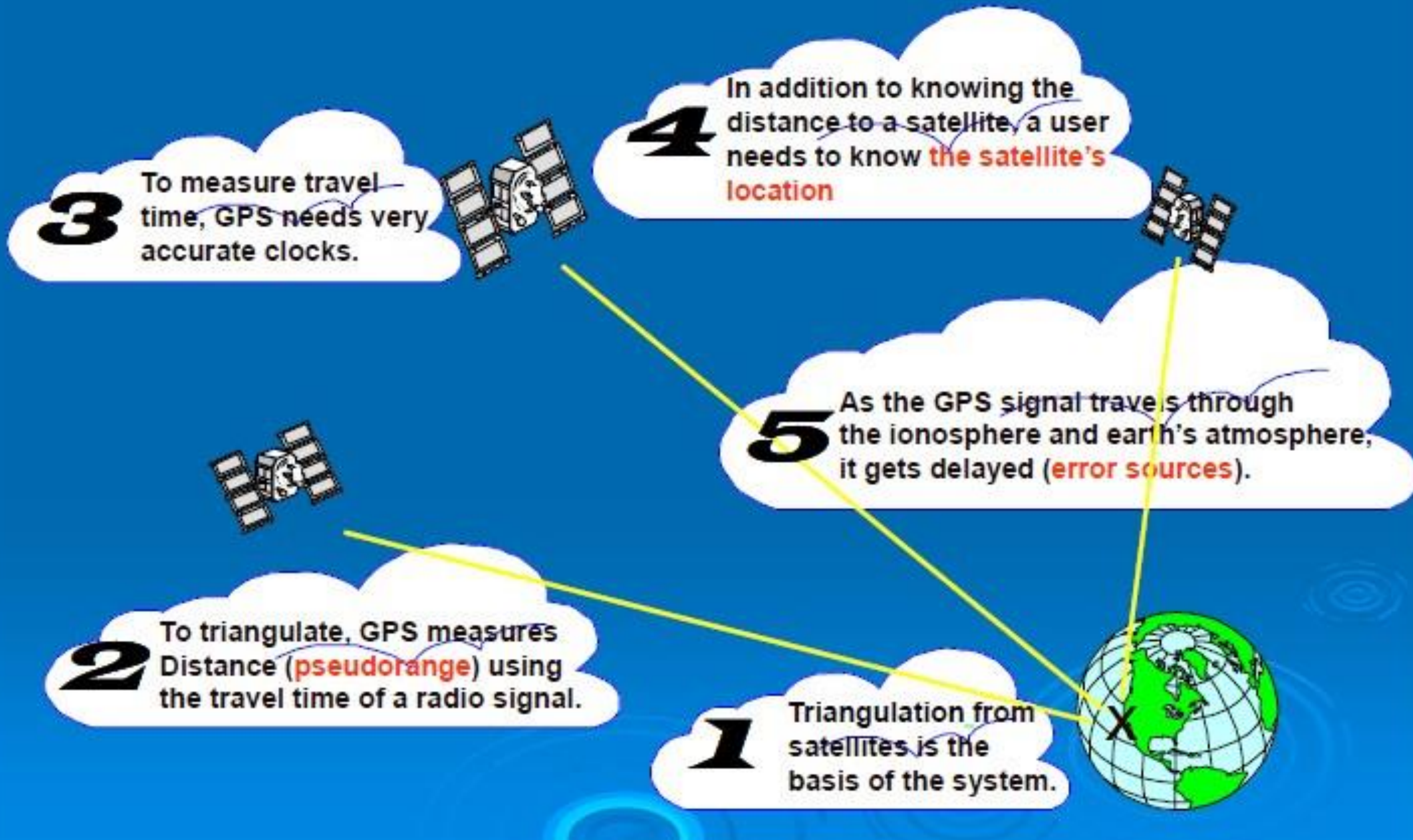
How does GPS Work?

- ✓ Accurate timing is the key to measuring distance to satellites.
- ✓ Satellites are accurate because they have four atomic clocks($100,000 each) on broad.
- ✓ Receiver clocks don’t have to be too accurate because an extra satellite range measurement can remove errors.

How does GPS Work?

- ✓ To use the satellites as references for range measurements we need to know exactly where they are.
- ✓ GPS satellites are so high up their orbit are very predictable.
- ✓ All GPS receivers have an almanac programmed into their computers that tells them where in the sky each satellite is, moment by moment.
- ✓ Minor variation in their orbit are measured by the department of defense.
- ✓ The error information is sent to the satellites, to be transmitted along with the timing signals.

How GPS works ?



System Performance

Standard positioning System

- ✓ 100 meters horizontal accuracy
- ✓ 156 meters vertical accuracy
- ✓ Designed for civilian use
- ✓ No user fee or restrictions

Precise Positioning System

- ✓ 22 meters horizontal accuracy
- ✓ 27.7 meters vertical accuracy
- ✓ Designed for military use

System Performance

Selective Availability

- ✓ International degradation of signal
- ✓ Controls availability of system's full capabilities
- ✓ Set to zero on may 2, 2000 : US President Bill Clinton asked DoD make GPS open access to civilians with higher precision and accuracy.

✓ Reasons

- Enhanced 911 service (public safety answering point PSAP)
- Car navigation

Application of GPS technology

- ✓ **Location:** Determining a basic position
- ✓ **Navigation:** Getting from one location to another
- ✓ **Tracking:** Monitoring the movement of people and things
- ✓ **Mapping:** creating maps of the world
- ✓ **Timing:** Bringing precise timing to the world

Applications

GP technology is now in e\·erything from '"dl phon s and wri ·twatchc to bulJ<.l .>/(. 'h pp1 1¹ l.O 1ta1 \. ..no \ l \1 s.

GP boosts productivity across a wide swath of the economy. to include tamung. constntcti n mmu1g. survcytng. pack:tge d I!\'CI) and .ogtstlcJl -upply chain managemt:nt. lajor comrnu-,=e:nion-. nC't :'lrk' an - ing \ ,tem::.-.. tin:m ·ial markeb and ·l:r _rid, depend hea\ ily on GP for precise time synchronization. Some wireless ser\'ice cannot operate without it.

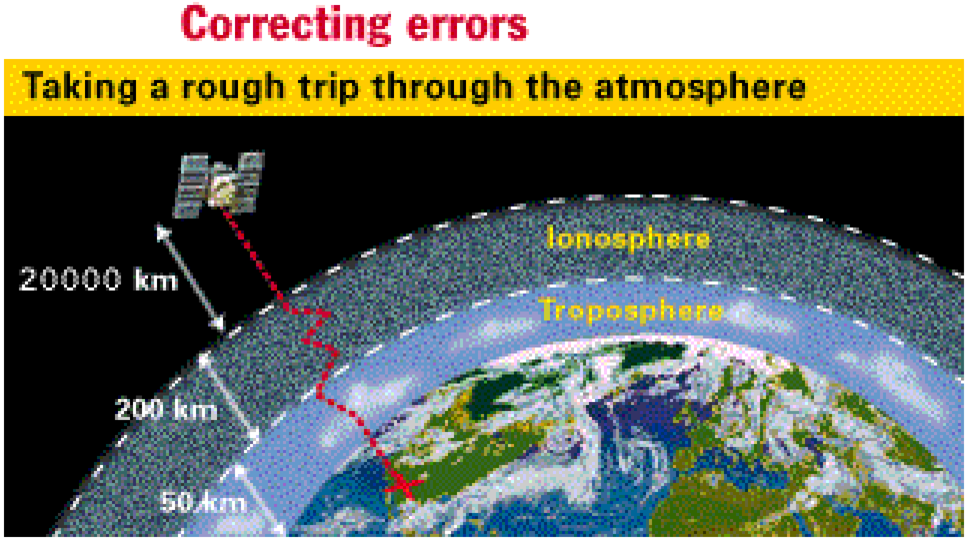
GP saves li,es by pre,'enting tran pmilation accidents. .. iding search and n.: <.t.a .- d1orh 1<.1 .; ,;din_ the.. Jdh c..f\ of ml:nH ncY s ..:r·ic\,;.. nd di aster rdic[GP is vital to the Next Generation Air Transportation ystem • cxtGcn) that wiU enhance flight safety while increasing airspace capacity. GP al o advances cientific aim uch as weather forecasting. earthquake monitoring. and environmental protection.

Sources of Errors in GPS

- Satellite Clock Error
- Orbit Error
- Ionospheric Error
- Tropospheric Error
- Receiver Noise
- Multipath
- Receiver Clock Error

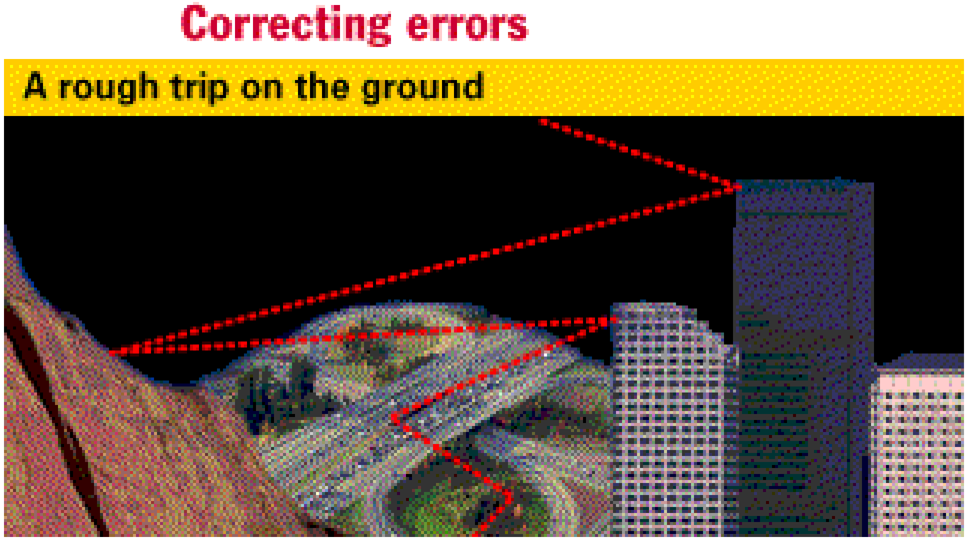
Ionospheric and Atmospheric Delays

- Speed of light = 186,000 miles/second in a vacuum
- Earth's atmosphere is heterogeneous
  - Can cause signals to slow down or speed up
- Eliminated by 'dual frequency' receivers
  - Low and high frequency
  - Low frequency affected more than high frequency
  - Receiver evaluates signal and corrects for error



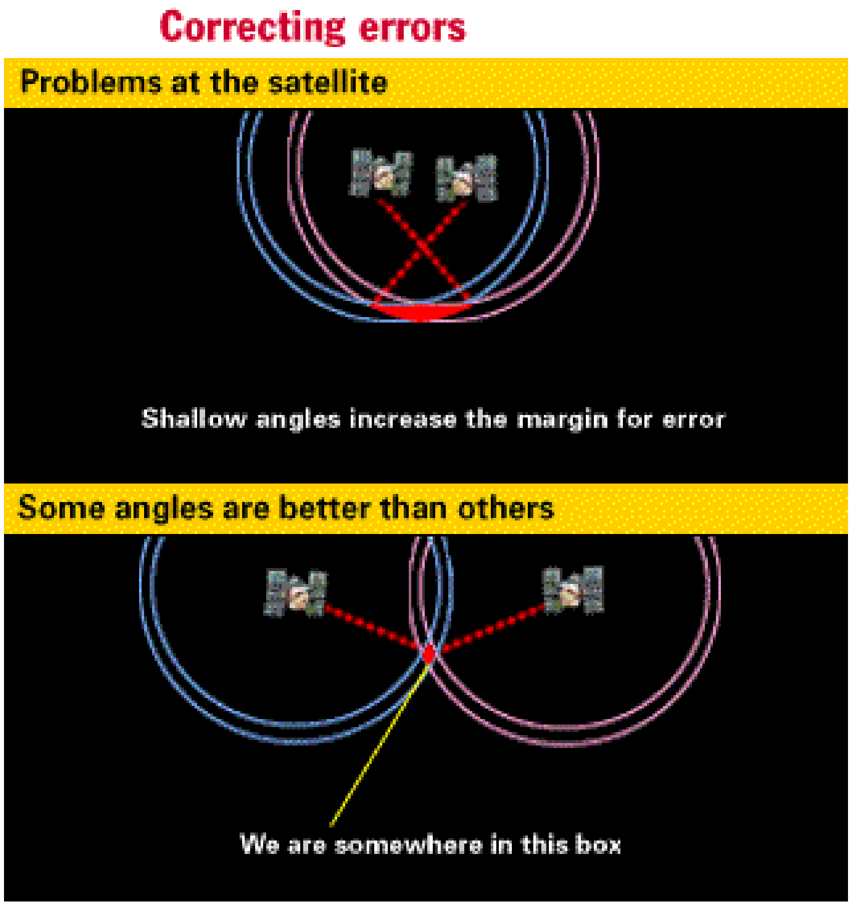
GPS Erros: 2. Multipath Error

- The signal may bounce off various local obstructions before it gets to your receiver.
- Good receivers use sophisticated **signal rejection techniques** to minimize this problem.



GPS Errors: 3. Geometric Dilution of Precision

- Basic geometry itself can magnify these other errors
- A principle called Geometric Dilution of Precision or GDOP.
- Good receivers determine which satellites will give the **lowest GDOP**



Satellite geometry

- ✓ *If a receiver sees 4 satellites and all are arranged for example in the north-west, this leads to a "bad" geometry.*

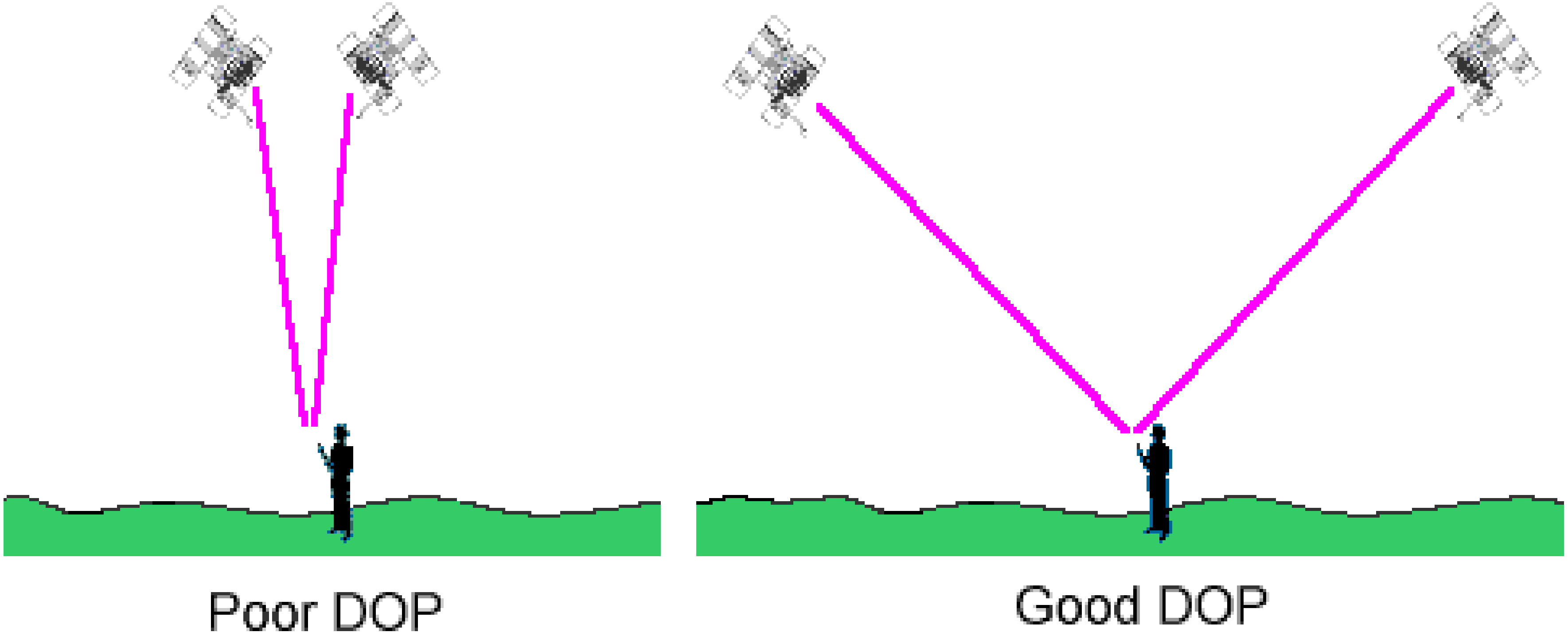
- ✓ *In the worst case, no position determination is possible at all, when all distance determinations point to the same direction.*

- ✓ *Even if a position is determined, the error of the positions may be up to 100 – 150 m. If, on the other hand, the 4 satellites are well distributed over the whole firmament the determined position will be much more accurate.*

- ✓ *Let's assume the satellites are positioned in the north, east, south and west in 90° steps. Distances can then be measured in four different directions, reflecting a „good" satellite geometry.*

Satellite geometry

Quantified by DOP: Dilution of Precision



The effect and correction of time error

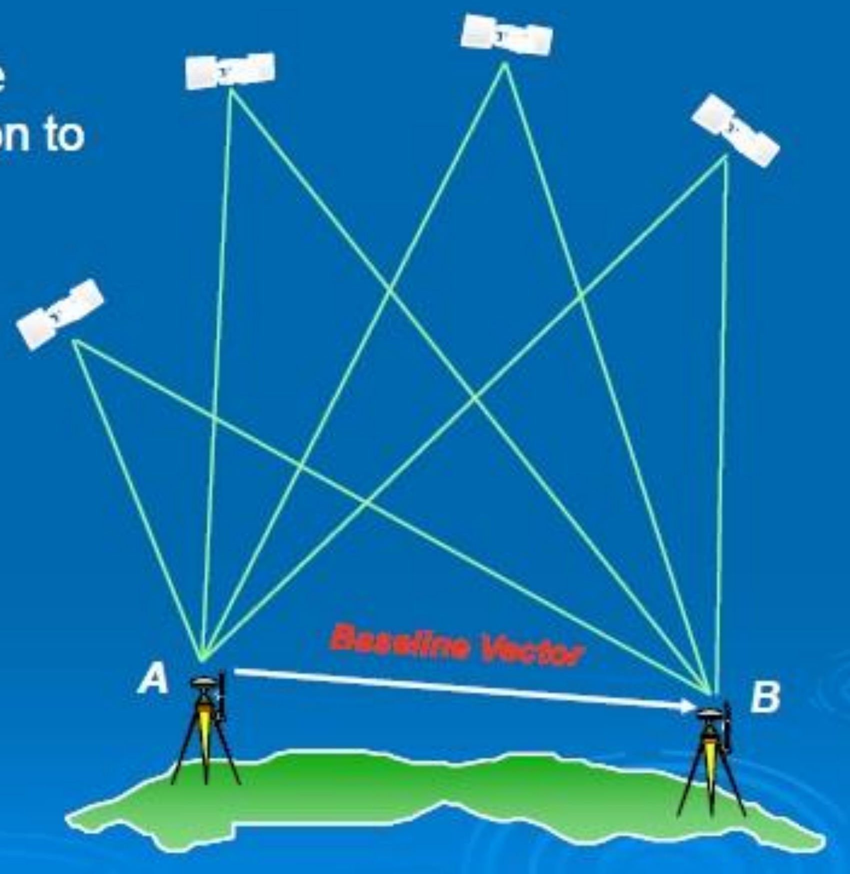
- ✓ We have been assuming up until now that it has been possible to measure signal transit time precisely.
- ✓ However, this is not the case. For the receiver to measure time precisely a highly accurate, synchronised clock is needed.
- ✓ If the transit time is out by just 1 µs this produces a positional error of 300m.
- ✓ As the clocks on board all three satellites are synchronised, the transit time in the case of all three measurements is inaccurate by the same amount.
- ✓ Mathematics is the only thing that can help us now.
- ✓ We are reminded when producing calculations that if N variables are unknown, we need N independent equations.
- ✓ If the time measurement is accompanied by a constant unknown error, we will have four unknown variables in

How the Sources of Errors in GPS Minimized / Reduced

- Satellite Clock Error- Single Difference
- Orbit Error- Precise Ephemeris
- Ionospheric Error- Dual frequency Receivers
- Tropospheric Error- Modeling
- Receiver Noise- Good quality
- Multipath- Good site selection
- Receiver Clock Error – Double Differencing

Differential Positioning

- It is possible to determine the position of Rover 'B' in relation to Reference 'A' provided
  - The coordinates of the Reference Station (A) are known
  - Satellites are tracked simultaneously
  - eliminates errors in the sat. and receiver clocks
  - minimizes atmospheric delays
  - Accuracy 0.5 cm - 5 m



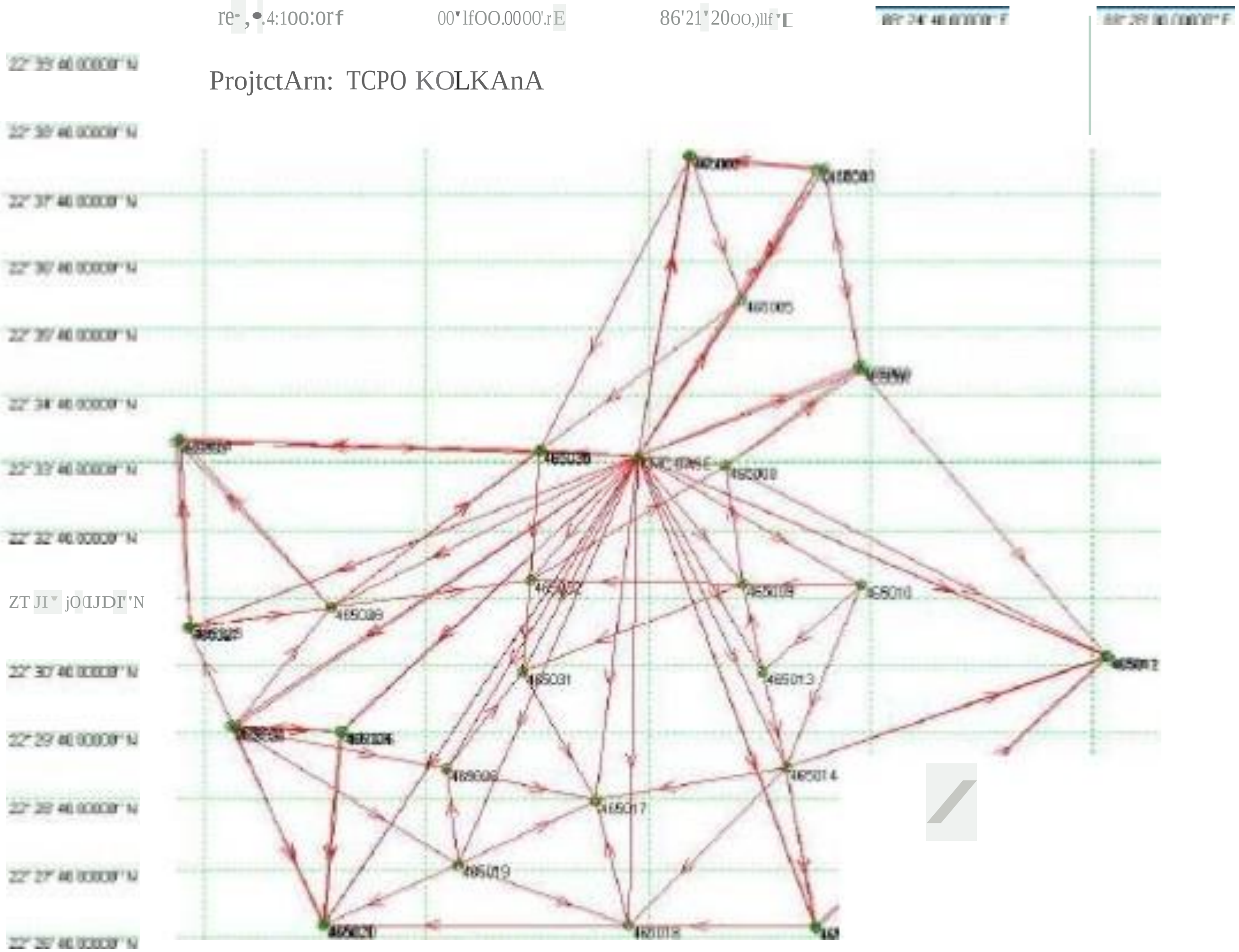
GPS Applications in Remote Sensing

- Ground Control Point
- Platform position: Aerial, Satelltie
- Aircraft Navigation
- Exposure Station Coordinates
- GIS/GPS Integration

Ground Control Point (GCP)

- Point whose position is known in object space coordinate system i.e Ground Coordinate System.
- Whose images can be positively identified on the photographs or images.
- Two types of control
  - Horizontal
  - Vertical
- Conventionally, theodolites, levels, total stations are used.
- Presently GPS is used- faster, easier and accurate measurements.

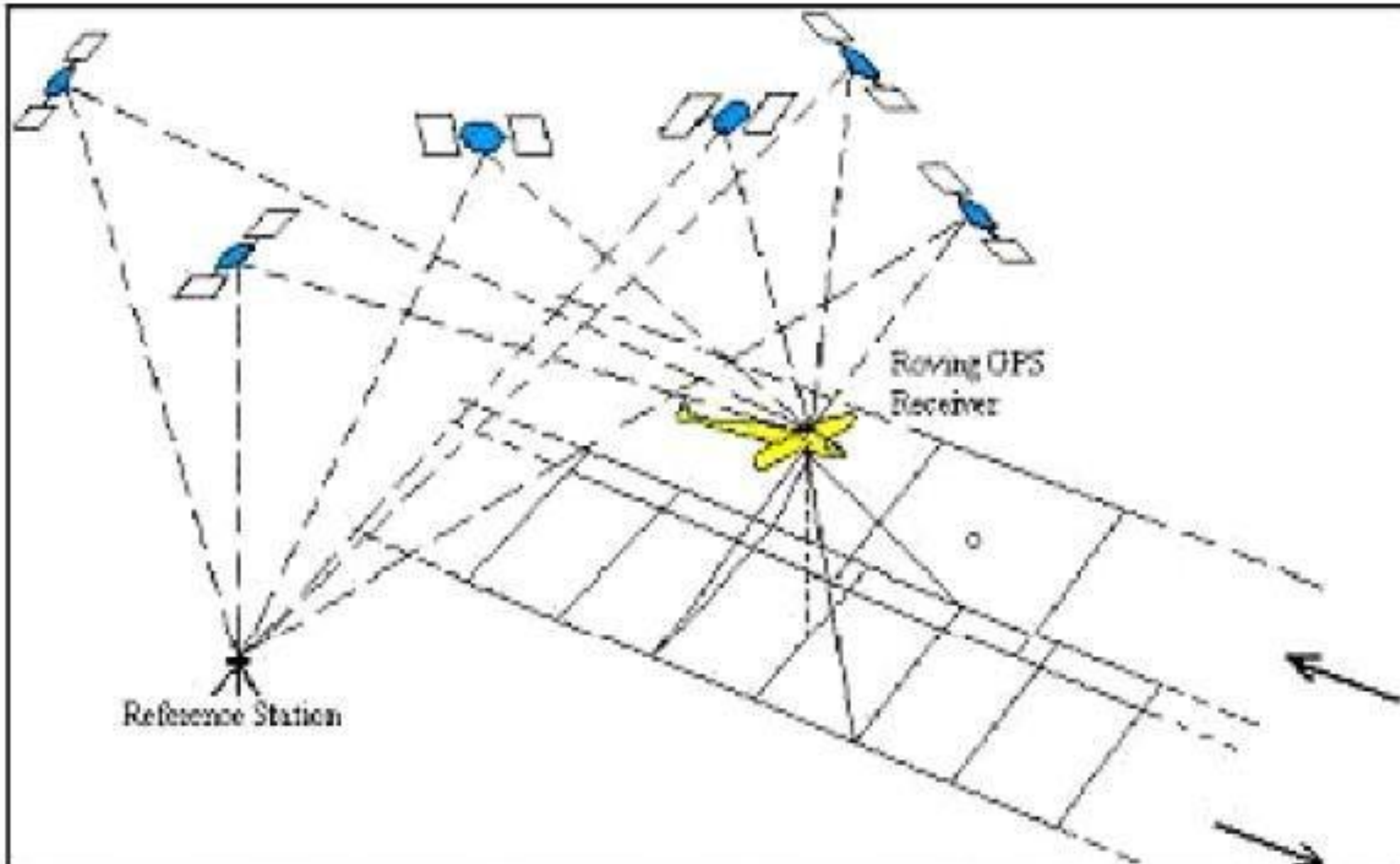
GPS CONTROL SURVEY



Duration of Survey: 18th Apr To 24 Apr 2004

Total No. of Points: 37 nos. with 8 base

CONCEPT OF AIRBORNE KINEMATIC GPS - PHOTOGRAMMETRY



Addressing Security Jssues

Handheld GPS to GPS Dots (a mmiature GPS tracking devtce)

How to befool GPS?

Wave bubble: RF Jamming Device

GPS spoofer:

Define your role:

Innovate and develop more and more applications of GPS.

Ensure to record the changes in locations/ emergence of new features using GPS after regular interval of time.

Our regional navigation capability be given a global navigation status.

Space segment: Distance from satellite

- Radio waves = speed of light
  - Receivers have nanosecond accuracy (0.000000001 second)
- All satellites transmit same signal “string” at same time
  - Difference in time from satellite to time received gives distance from satellite
- The whole thing boils down to those "velocity times travel time" math problems we did in high school!!
- "If a car goes 70 miles per hour for two hours, how far does it travel?"
- Velocity (70 mph) x Time (2 hours) = Distance (140 miles)

GPS **Satellite Vehicle**

- Weight
  - 2370 pounds
- Height
  - 16.25 feet
- Width
  - 38.025 feet including wing span
- Design life – 10 years

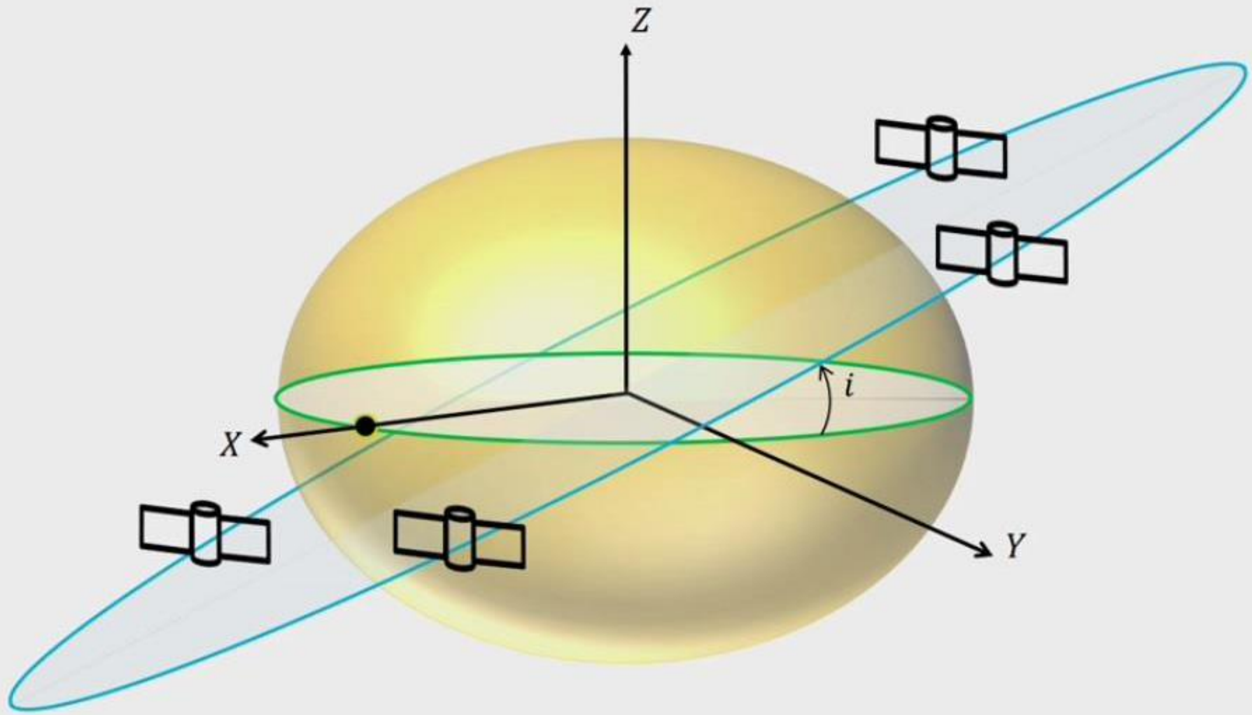
Components of the System

User segment

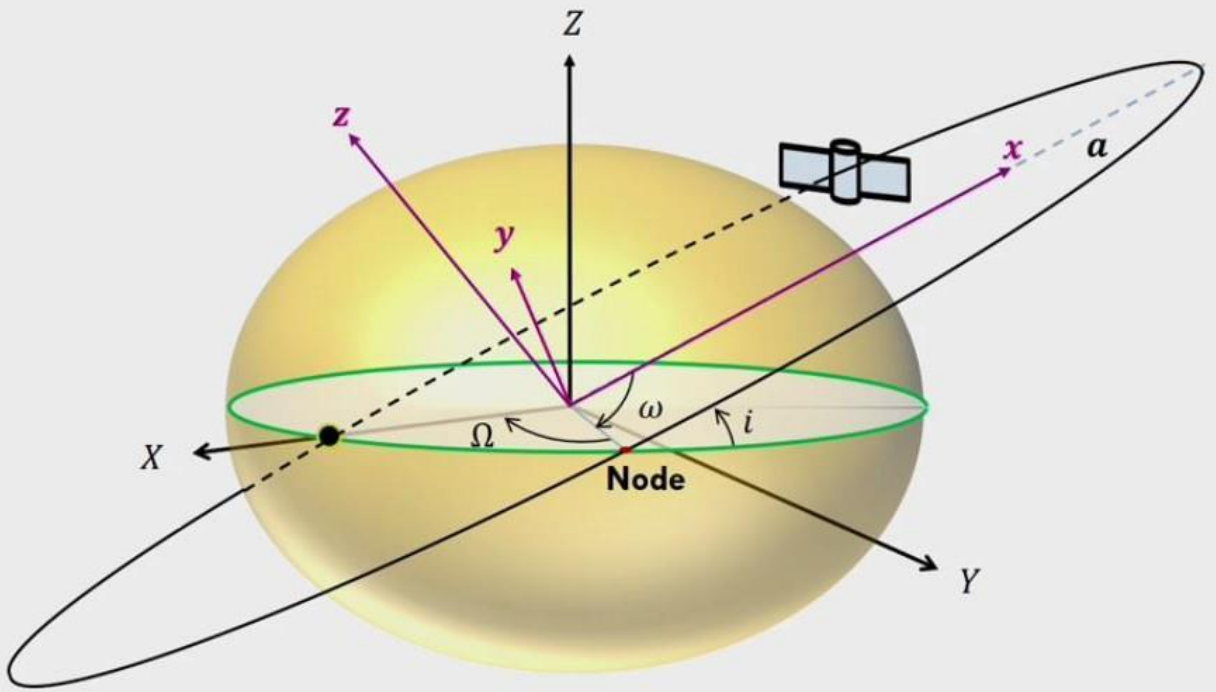
- GPS antennas & receiver/processors
- Position
- Velocity
- Precise timing
- Used by
  - -Aircraft
  - – Ground vehicles
  - -Ships
  - – Individuals

Satellite Orbits

- Low Earth Orbit (LEO) satellites
  - Satellites that can be viewed with naked eyes
  - Spy satellites, weather satellites
- Medium Earth Orbit (MEO) satellites
  - Around 22,000 km above Earth surface
  - Most of GNSS satellites orbit in MEO
  - Orbit the Earth in an inclined plane
  - Orbital period defined in sidereal day(s)
- Geosynchronous Earth Orbit (GSO) and Geostationary Earth Orbit (GEO)
  - 35,000-36,000 km above Earth
  - Geostationary satellites: communication satellites, TV satellites
  - Some of GNSS satellites are placed
  - Orbit in equatorial plane (GEO) or inclined plane (GSO) in one sidereal day


Z
X
i
Y

Satellite Coordinates in WGS84

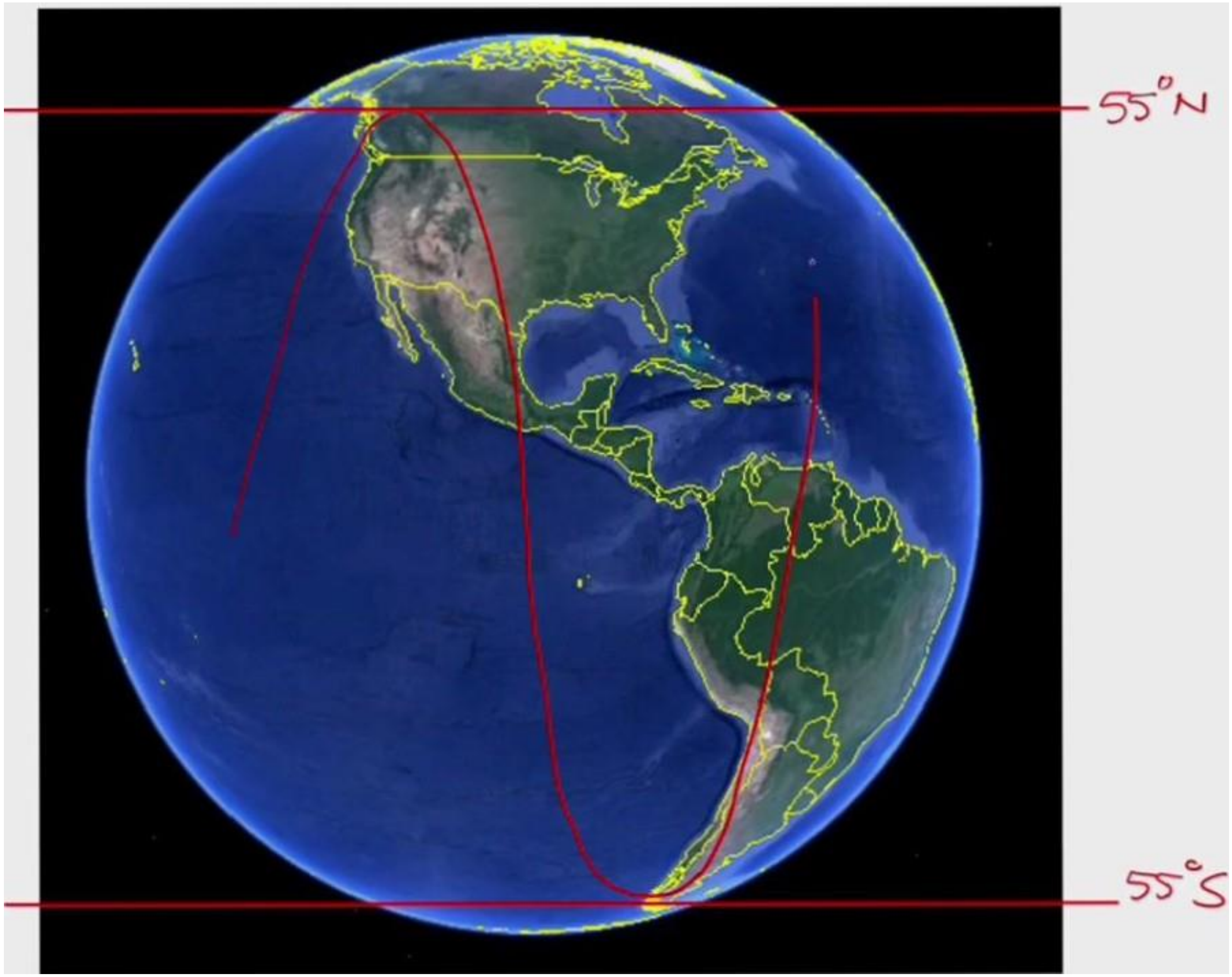


Brief Overview of GNSS

- Global Navigation Satellite System (GNSS)
- Satellite constellations
  - NAVSTAR (GPS)- NAVigation SaTellite And Ranging (USA)
  - GLONASS- GLObal NAvigation Satellite System (Russia)
  - Galileo (European Union)
  - IRNSS- Indian Regional Navigation Satellite System (India)
  - QZSS- Quassi Zenith Satellite System (Japan)
  - BeiDou or Compass (China)

NAVSTAR (GPS)

- Minimum 24 satellites
- Generally available: 30 satellites these days
- Orbits: 6 orbits, each at height 20,200 km and inclined at $5S^{o}$
- Number of satellites in a orbit: 5
- Orbital period: half sidereal day
- Foot print of satellite: vertical S shape
- Frequencies: L1 (1575.42 MHz), L2 (1227.6 MHz), L5 (1176.45 MHz)
- Code: C/A code, P code
- Combinations of code and frequencies: L1-C/A, L2-C/A, L2-P, L5-N



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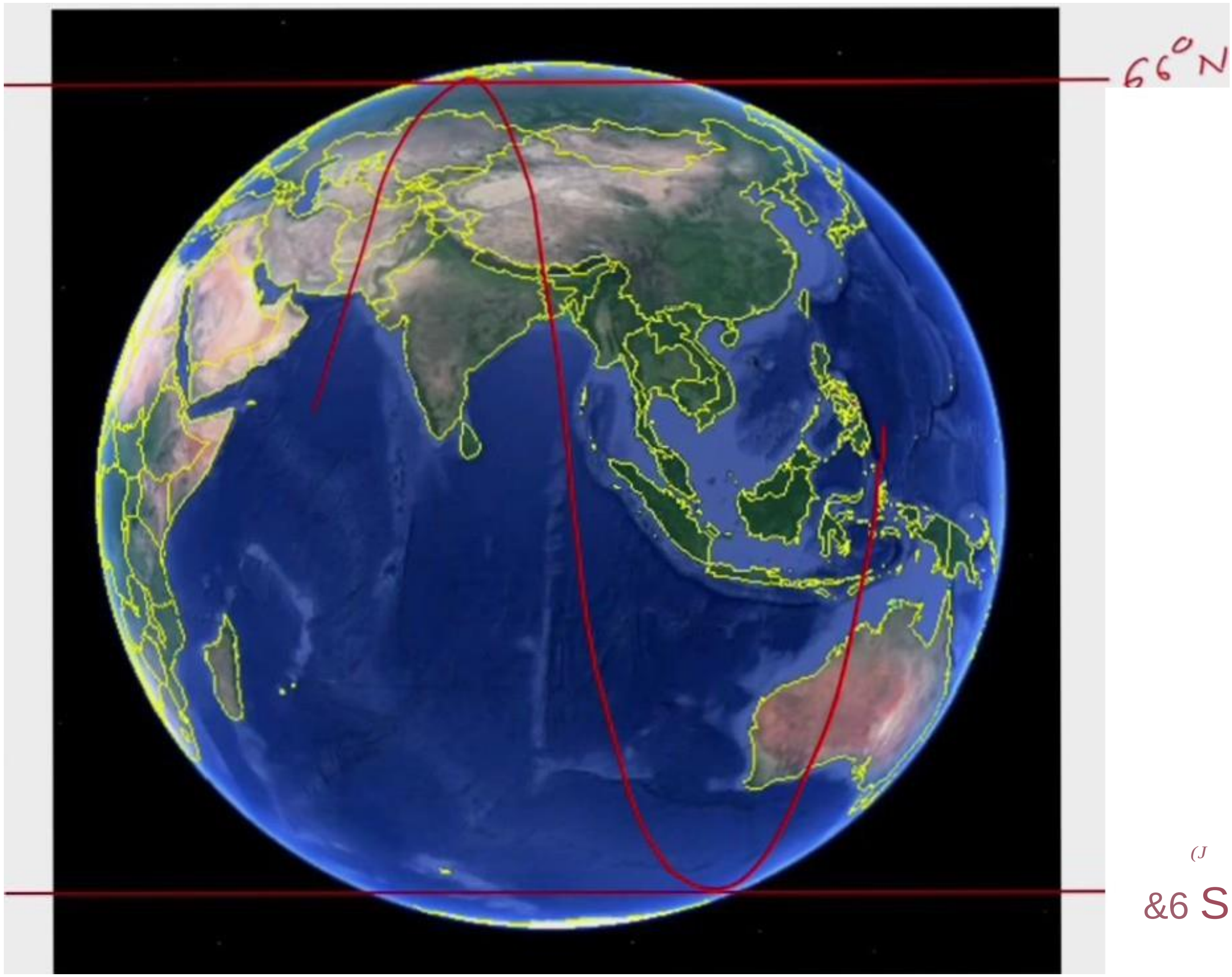
Galileo

- Total 30 satellites
- Orbits: 3 orbits, each at height 23,200 km, and inclined at 56°
- Number of satellites in a orbit: 10
- Orbital period: (10/1) sidereal day = 10 orbits in 1 sidereal day
- Foot print of satellite: vertical S shape
- Frequencies: 3; E1 (L1), E5a (L5), E6 (1278 MHz)
- Signals do not interfere with GPS signals

GLONASS

- Total 24 satellites
- Orbits: 3 orbits, each at 19,100 km height and inclined at 66°
- Number of satellites in a orbit: 8
- Orbital period: (8/17) sidereal day = 17 orbits in 8 sidereal days
- Frequencies: 14 different frequencies for 24 satellites
- Opposite satellites across Earth use same frequency
- Code: only one PRN code



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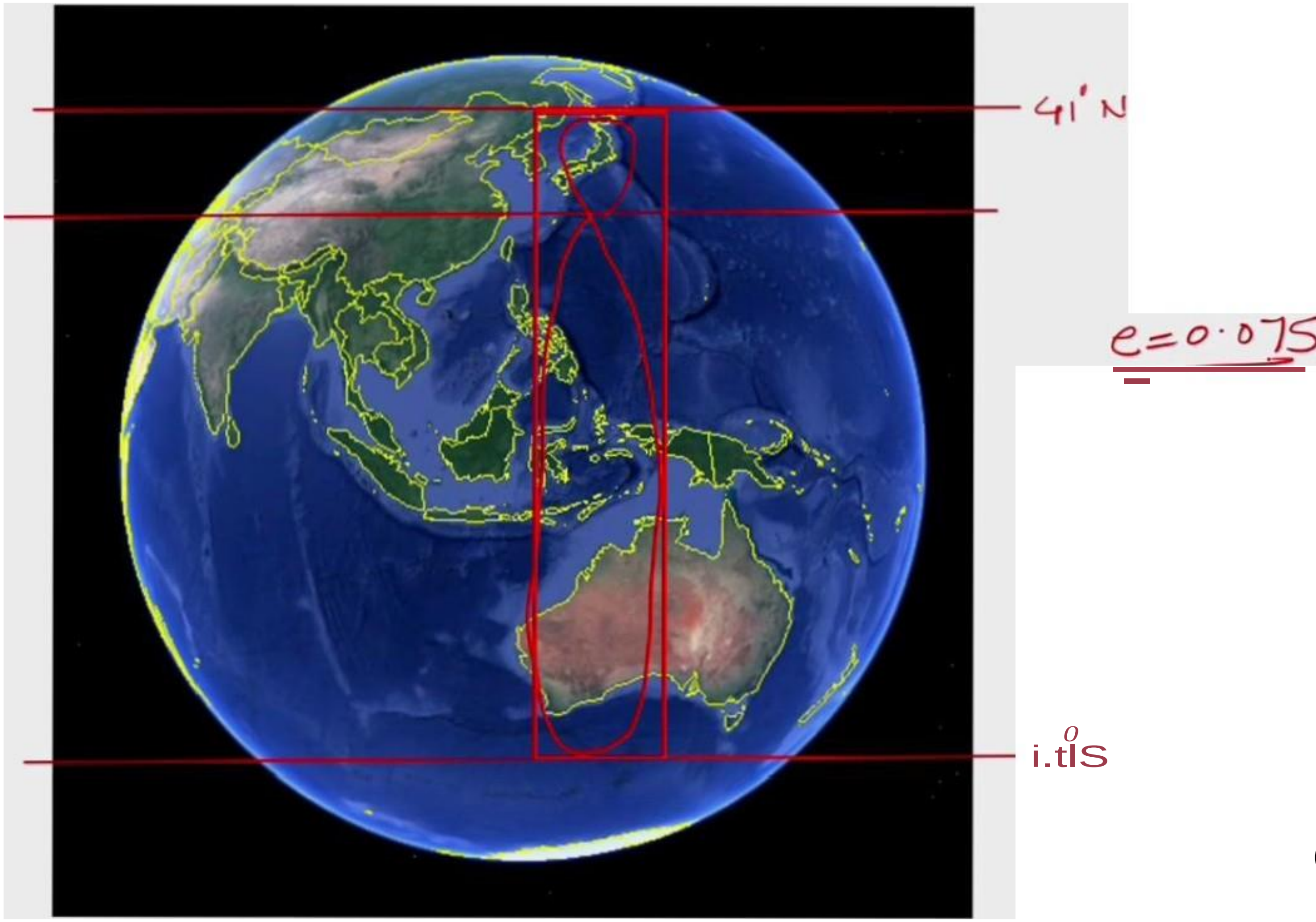
uassi Zenith Satellite System

- Total 7 satellites
- 4 geosynchronous satellites and 3 geostationary satellites over Japan
- 4 satellite are placed in one geosynchronous orbit (eccentricity= 0.075)
- Asymmetric elliptical orbit creates asymmetric figure of 8 as foot print of satellite on Earth (especially on Japan)
- Orbits: 1 orbit, each at height 35,800 km, and inclined at 41^{o}
- Number of satellites in geosynchronous orbit: 4
- Number of satellite in geostationary orbit: 3
- Orbital period: (1/1) sidereal day = 1 orbit in 1 sidereal day
- Foot print of satellite: figure of 8 (small lobe over Japan)
- Signals: L1C, L1 C/A, L2C, L5, L6 or LEX (L1 experimental)
- Signals do not interfere with GPS signals



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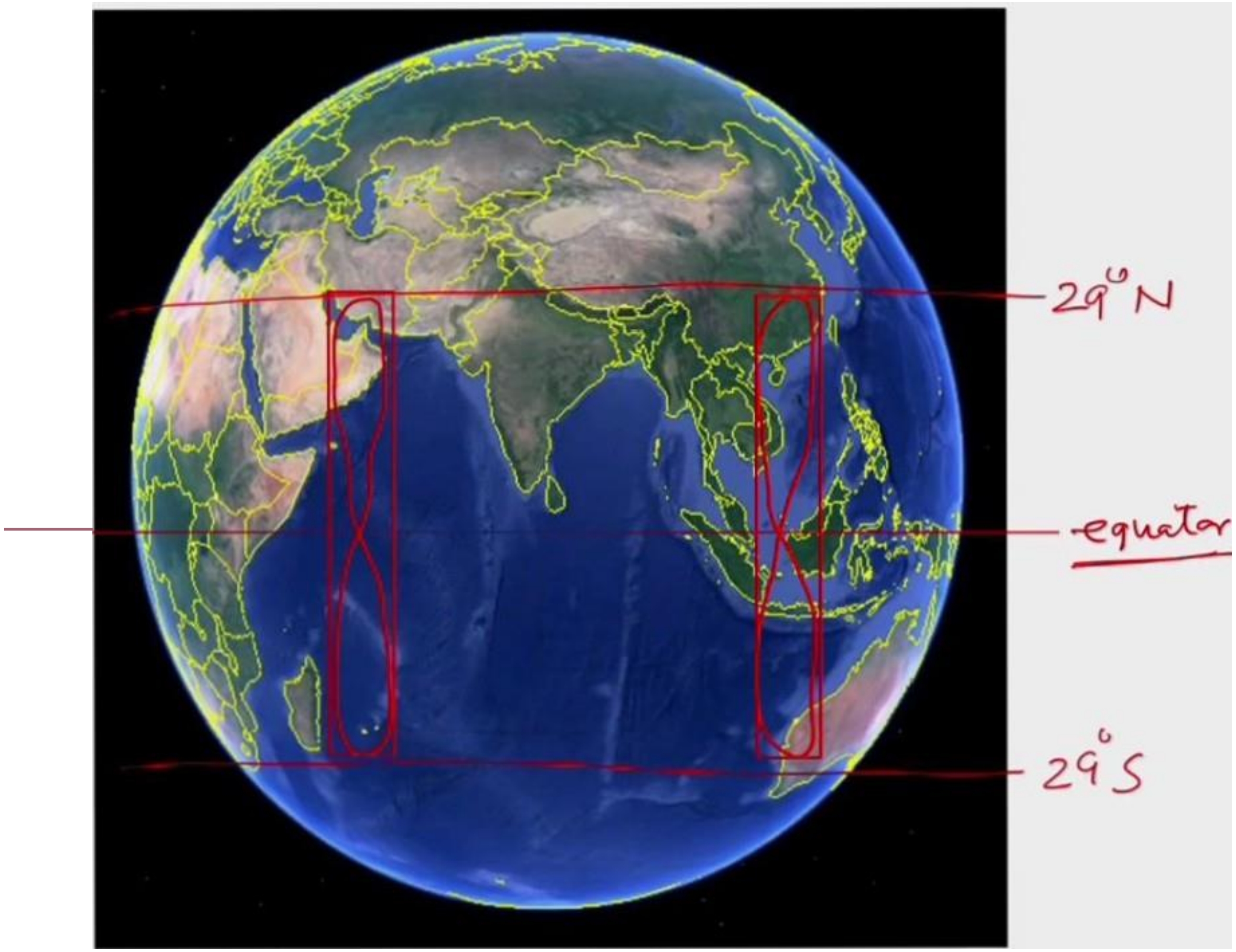
IRNSS

- Indian Regional Navigational Satellite System
- Total 8 satellites: 5 geosynchronous satellites and 3 geostationary satellites over India
- 5 satellites are placed in 2 geosynchronous orbits
- Symmetric circular orbit creates two symmetric figures of 8 as foot print of satellite on Earth (especially around India)
- Orbits: 2 orbits, at height 35,800 km, and inclined at 29°
- Number of satellites in geosynchronous orbit: 5 (IRNSS 1A, 1B, 1D, 1E, 1I)
- Number of satellites in geostationary orbit: 3 (IRNSS 1C, 1F, **1H,** 1G)
- Orbital period: (1/1) sidereal day = 1 orbit in 1 sidereal day
- GJ-;aig rd011S. 8 (2492 MHz), L5

IRNSS

- Indian Regional Navigation Satellite System
- Indigenously developed
- Space Segment
  - Seven Satellites
    - 3 Satellites in Geostationary orbit-inclination-0 deg.
    - 4 Satellites in Geosynchronous orbit-inclination-29 deg.
  - Signal – S band – 2-4 GHz, Atomic clocks
- Control Segment (in India)
  - Master Control Centre
  - Tracking stations
- User Segment
  - Position accuracy – 20m
  - Region extending 1500-2000 km from Indian territory



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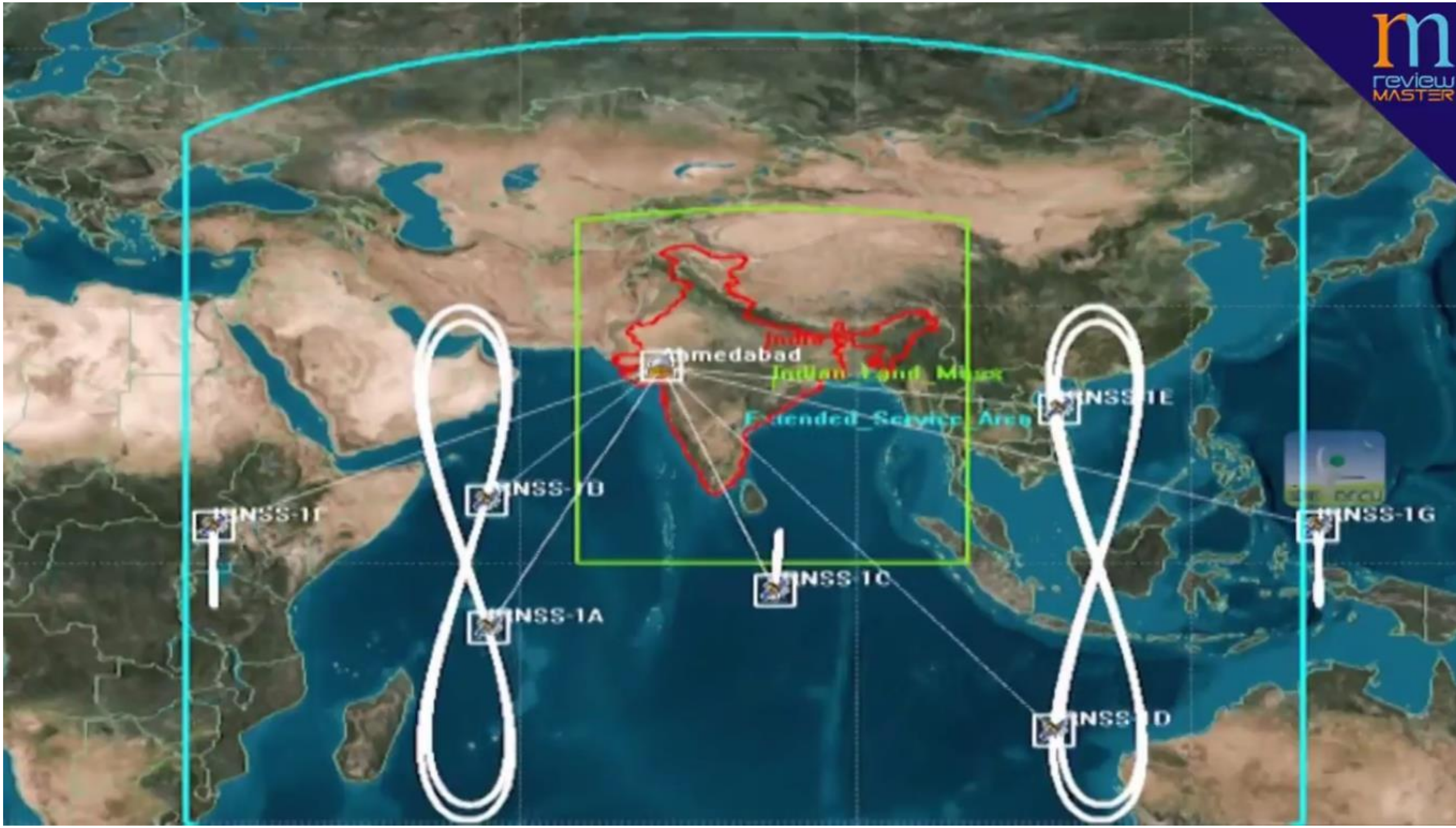
review
MASTER



medabad
NSS-1A
NSS-1C
NSS-1G

Indian Initiative

IRNSS(Indian Regional Navigational Satellite System) or NAVIC

A system with a constellation of seven satellites(IRNSS 1A- to IRNSS 1G) provides navigational support at regional level covering:

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July 2. 2013 to Apnl2 _ 20lo

BeiDou (Compass)

- **BeiDou** Navigation Satellite System **(BDS)**
- Total 35 satellites: 3 geosynchronous satellites (GSO), 5 geostationary satellites (GEO) over China, 27 MEO satellites
- 5 satellites are placed in 2 geosynchronous orbits
- Symmetric circular orbit creates one symmetric figures of 8 as foot print of satellite on Earth (over China)
- Orbits of GEO satellites: 1 orbit, at height 35,786 km, and inclined at 00, longitude range 58.75° E to 160° E
- Orbits of GSO satellites: 3 orbits, height 35,7S,6 km, and inclined at 55°
- Orbits of MEO satellites: 3 orbits, height 21,528 km, and inclined at 55°
- Orbital period: 12 hours 53 min of sidereal day
- Signals: 81, 82, 83

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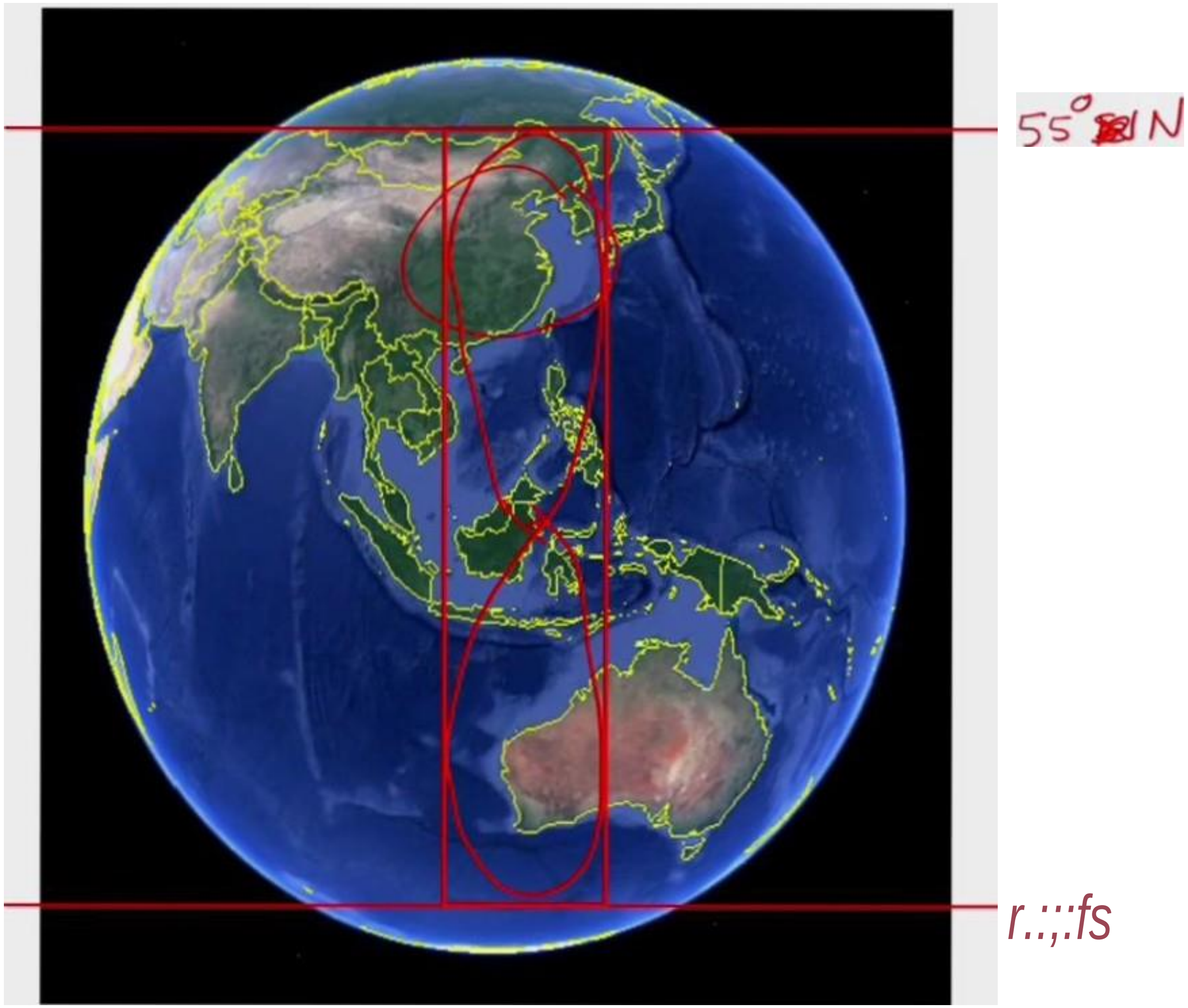

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Specifications of GPS Receivers

- Number of channels
- Position accuracy
- Data logging rate and data output rate
- Data storage (internal memory and SO card)
- Data delivery format
- Post processing
- Special features

Number of Channels

1111

[:1 Number of channels

- 120 channels
- 220-230 channels
- 440 channels
- 530-560 channels

GNSS Name	No of Satellites	Signals	Channels
GPS	30	l1 C/A, l1 C, l2C, l2P, l5	150
GLONASS	24	l1 C/A, l2C, l2P, l3, l5	120
Galileo	30	E1, E5, AltBOC, E5a, E5b, E6	180
QZSS	7	l1 C/A, l1 C, l2C, l5, l6	35
BeiDou	28	B1, B2, B3	84
IRNSS	8	Not mentioned	

Position Accuracy

- DGPS accuracy: 0.25 m + 2 ppm *(format: a+ b ppm)*
- RTK performance (accuracy)
- Static performance (accuracy)
- RMSE accuracy
  - Vertical accuracy (VA)
  - Horizontal accuracy (HA)
  - Accuracy in Geocentric Coordinate System
  - Confidence level
  - Thumb rule: VA= two times of HA

Data Acquisition and Processing

- Data logging rate and data output rate
  - Data logging rate: 1 Hz, 2 Hz, 5 Hz, ... 20 Hz
  - Data output rate
- Data storage
  - Internal memory
  - SO card
- Data delivery format
  - Propriety format
  - Universal format (RINEX format)
- Data processing
  - Data is processed through software
  - Data is processed in GPS hardware

Special Features

- Battery
  - Hot swappable
- Wire less data transfer
  - Blue tooth
  - GSM modem
- Radio modem for RTK survey
  - Internal radio modem (internal UHF)
  - External radio modem
- Tilt sensor
- Operating temperature
  - Temperature range: minimum to maximum