The Global Positioning System

"That'll be the new navigation system I warned your Dad about."

GPS system

1. 24 NAVSTAR (Navigation Satellite Time And Range), at height of about 20.000 km.
   - They are doing two rotations around the Earth every day
   - They are equipped with One transmitter, one receiver and four atomic clocks.
   - They weight about 1500 –2000 kg
   - They send one signal per second

- $12 billion investment

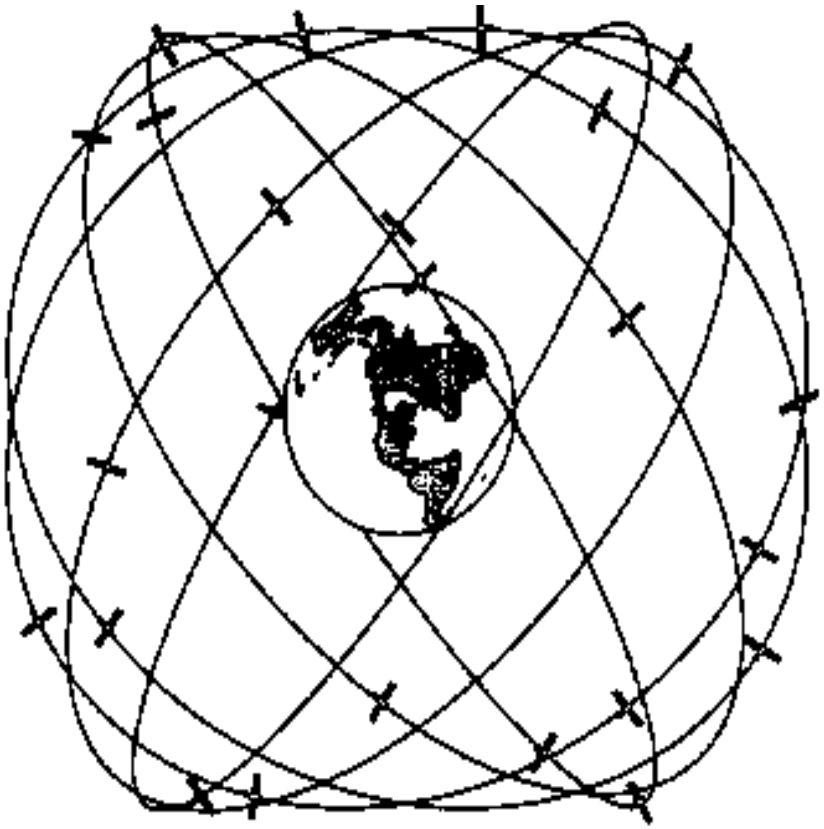
GPS system

2. Earth Stations are used for verification of the satellite position and correction of data

   Satellites orbits are known with accuracy but there are changes from different reasons.
3. User parts

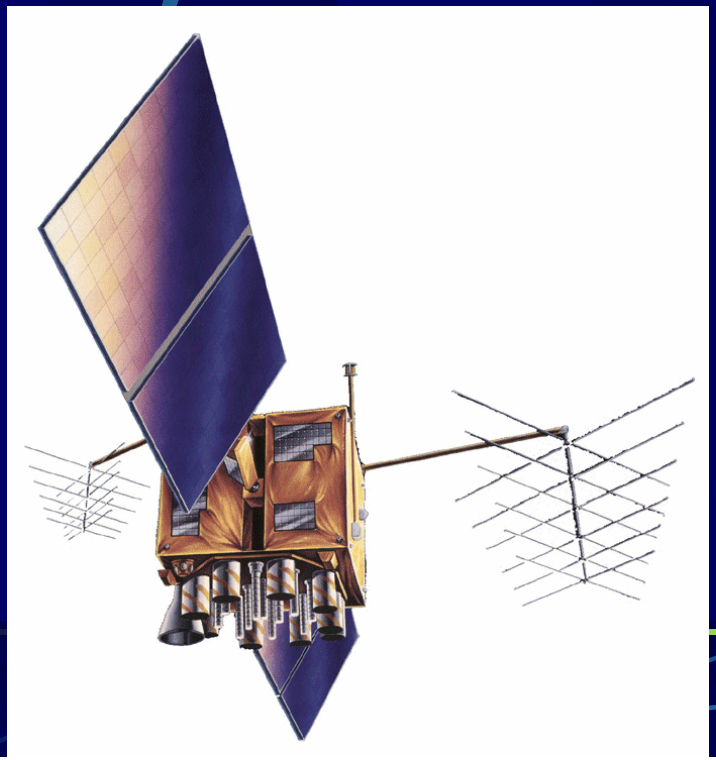
GPS system

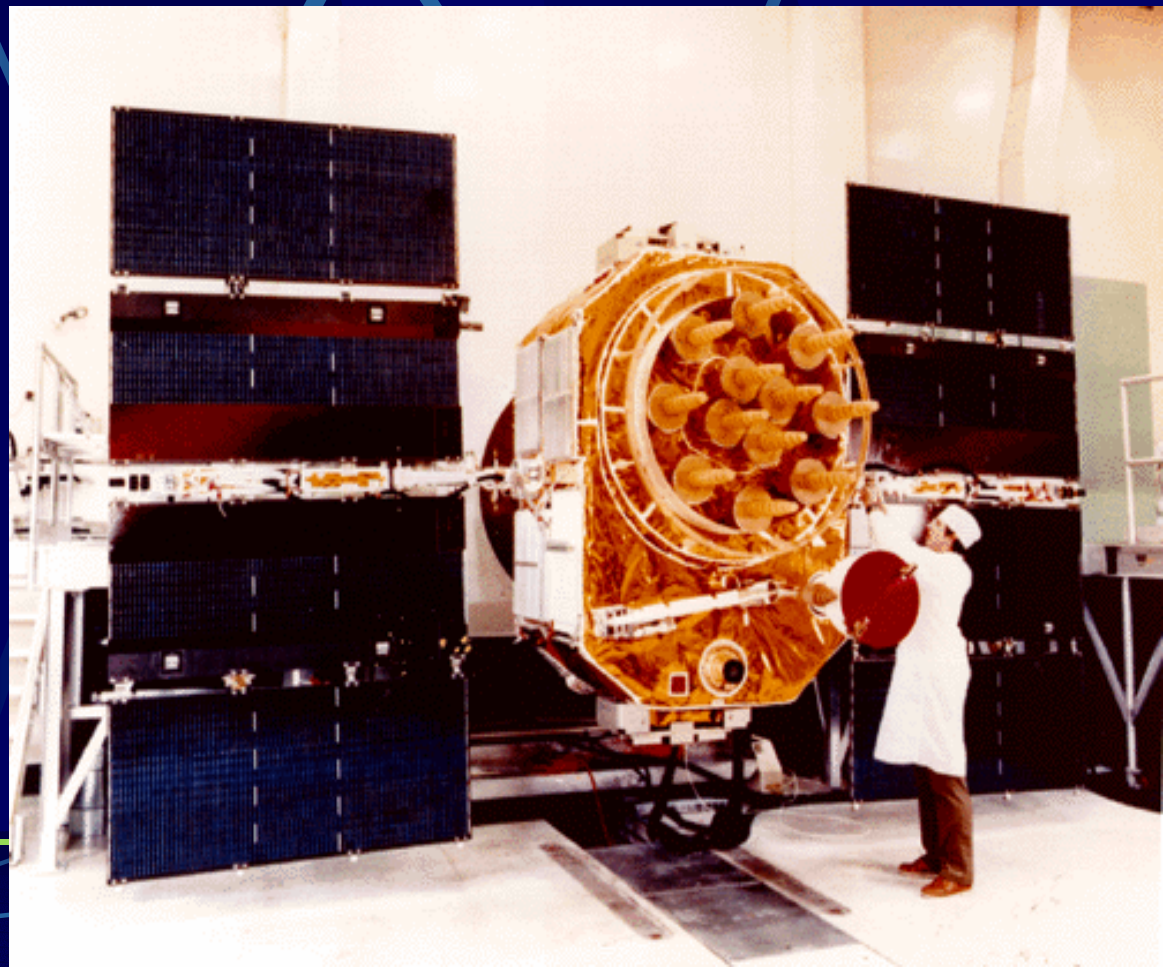
- Space segment
  - US military
  - 24 orbiting satellites
- Ground segment
  - US military
  - Controlling the satellites
- User segment
  - Civilian
  - The equipment we use to receive find our position



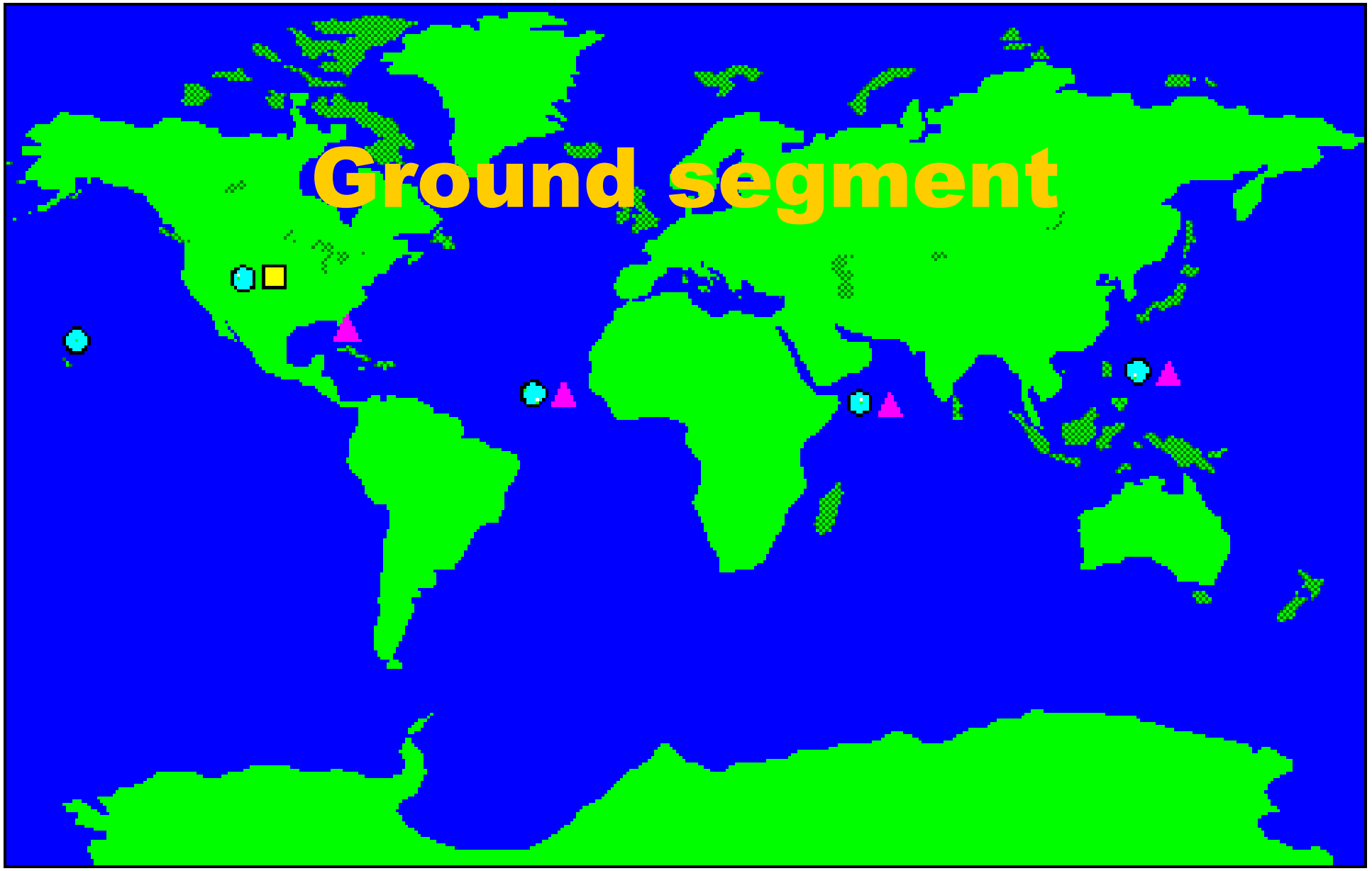
Satellites

- Transmitting microwave timing signals only
  - no cameras!
- Atomic clock





Ground segment



- MASTER CONTROL STATION
  - SATELLITE CONTROL
  - SYSTEM OPERATIONS

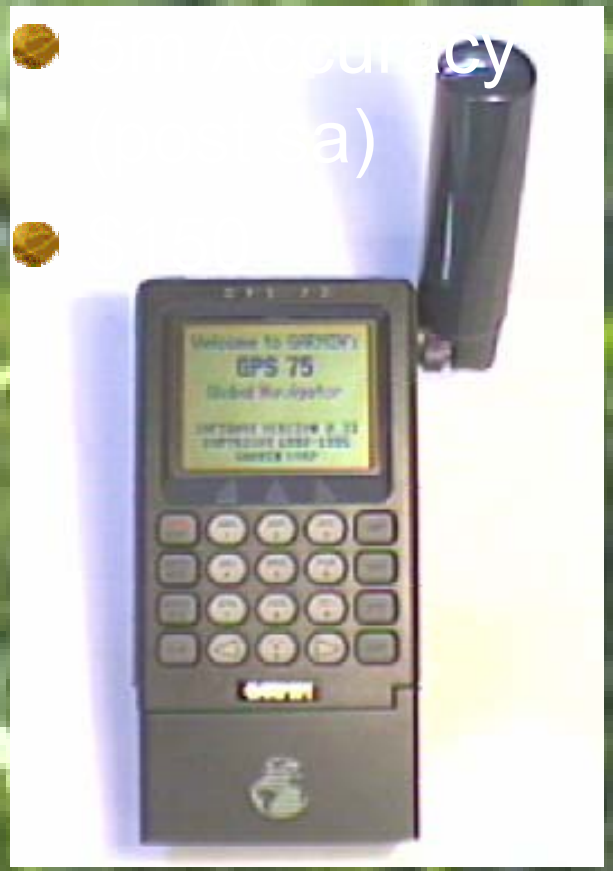
- MONITOR STATION
  - MONITOR NAVIGATION
  - COLLECT RANGE DATA

- GROUND ANTENNA
  - TRANSMIT DATA/COMMANDS
  - COLLECT TELEMETRY

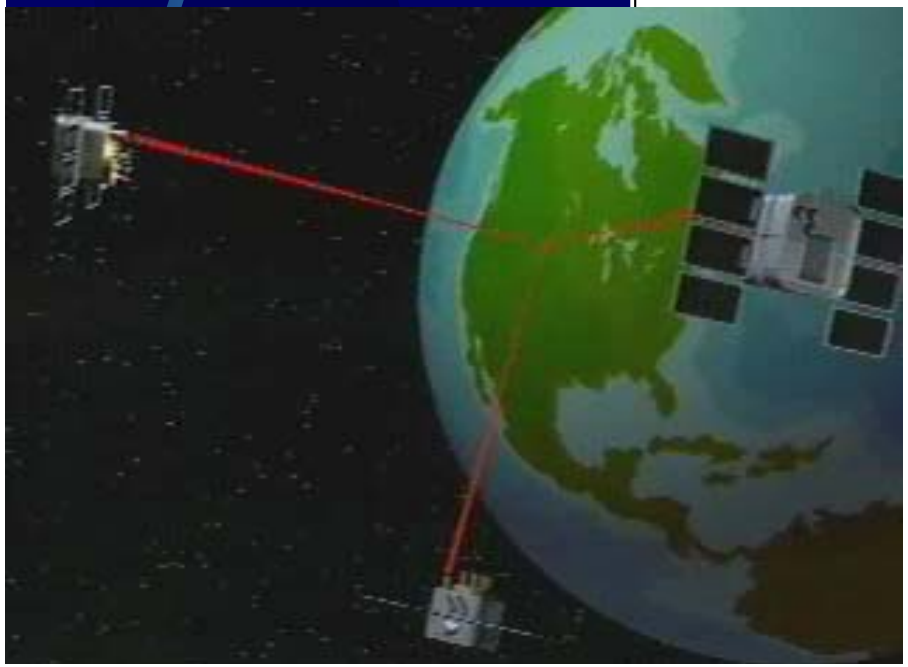
User segment

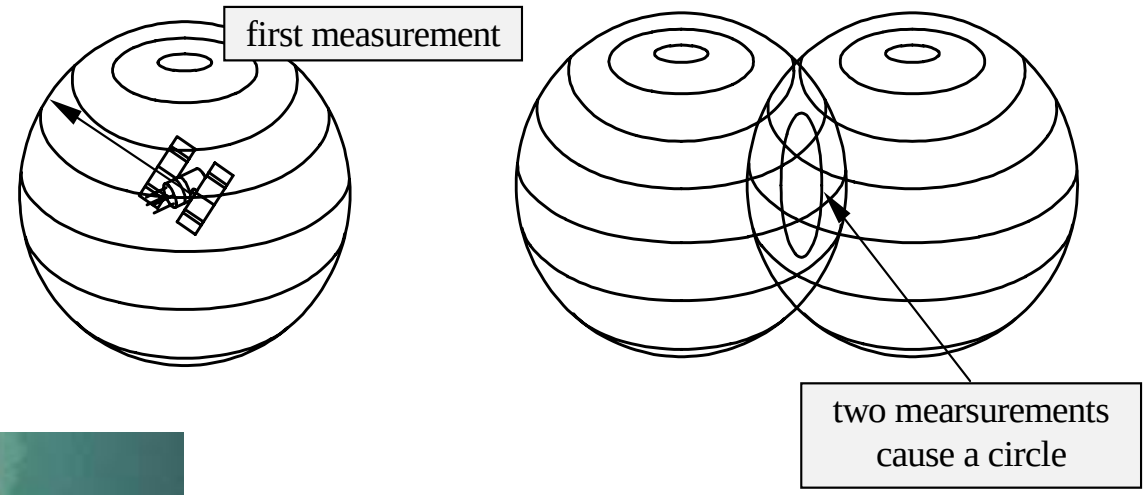
- GPS
- Differential GPS
  - Own base station
  - Beacon
  - Geostationary satellite broadcast
  - Wide Area Augmentation System
- Carrier phase DGPS
- Real-Time Kinematic (RTK) GPS
- Timing

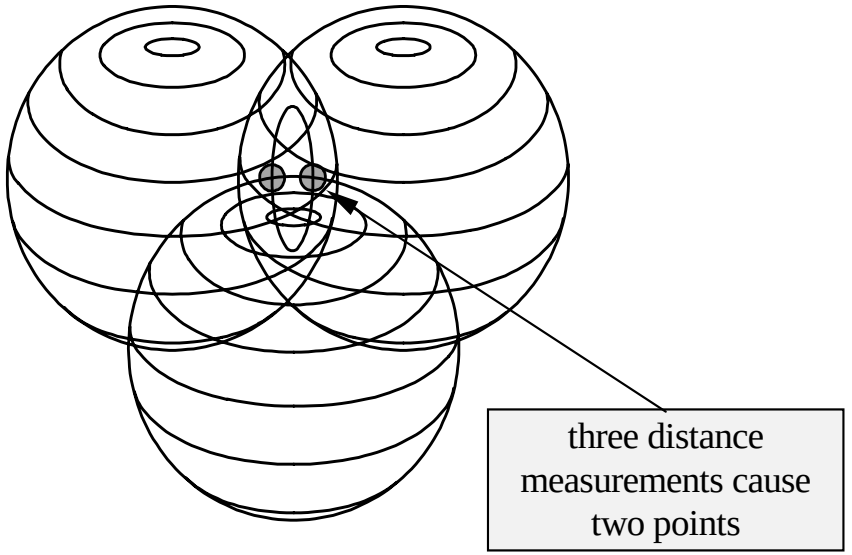
GPS



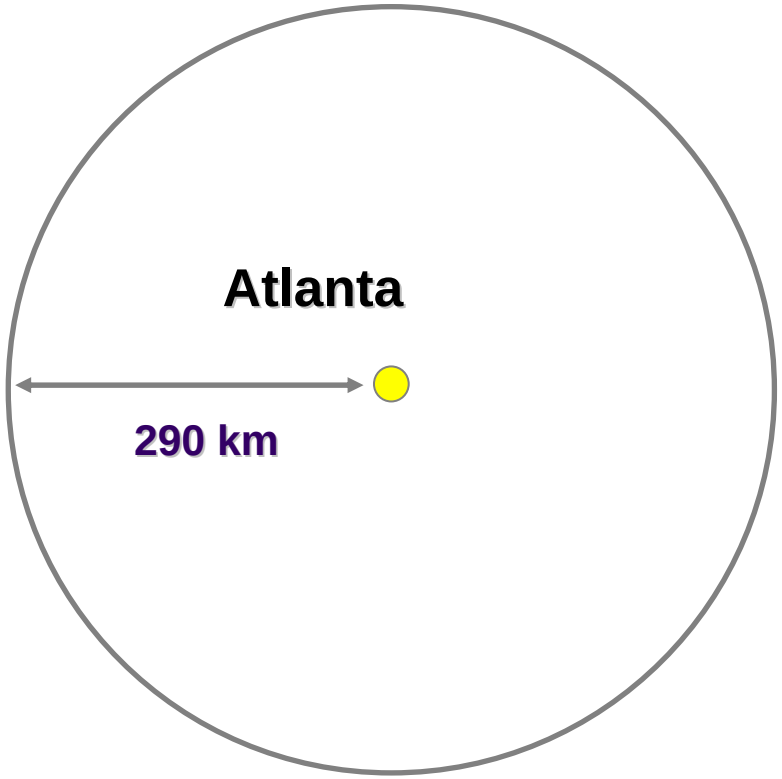
Triangulation from 3 known points



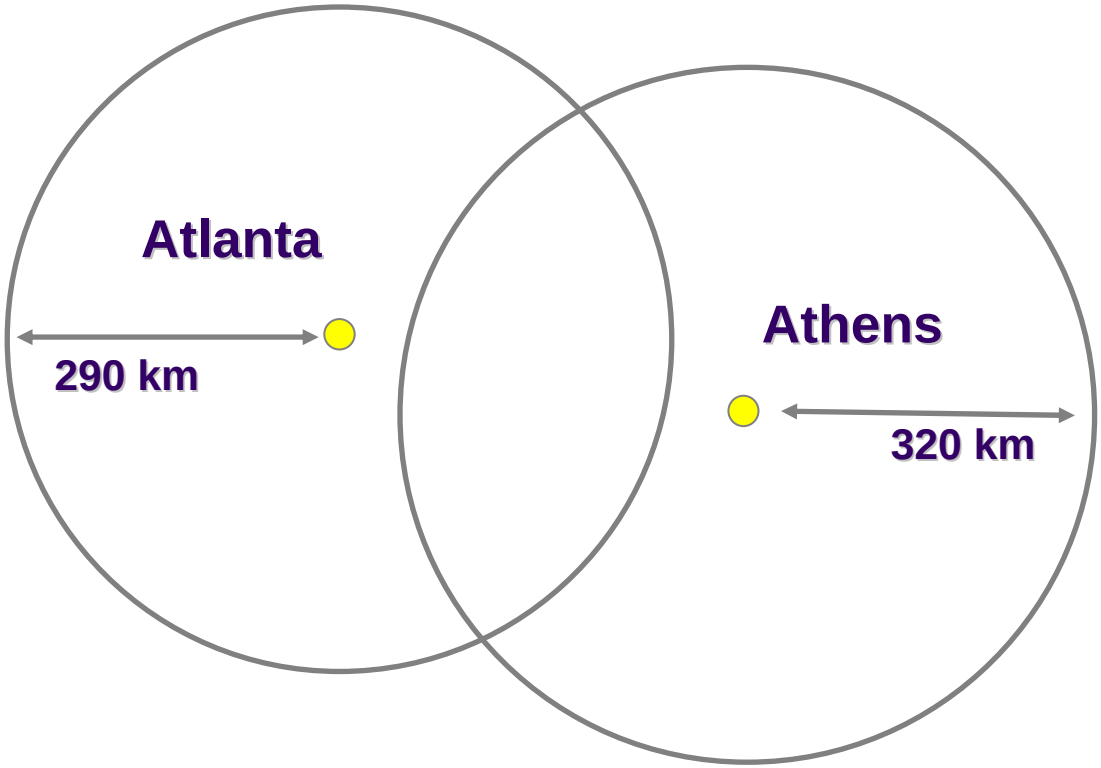




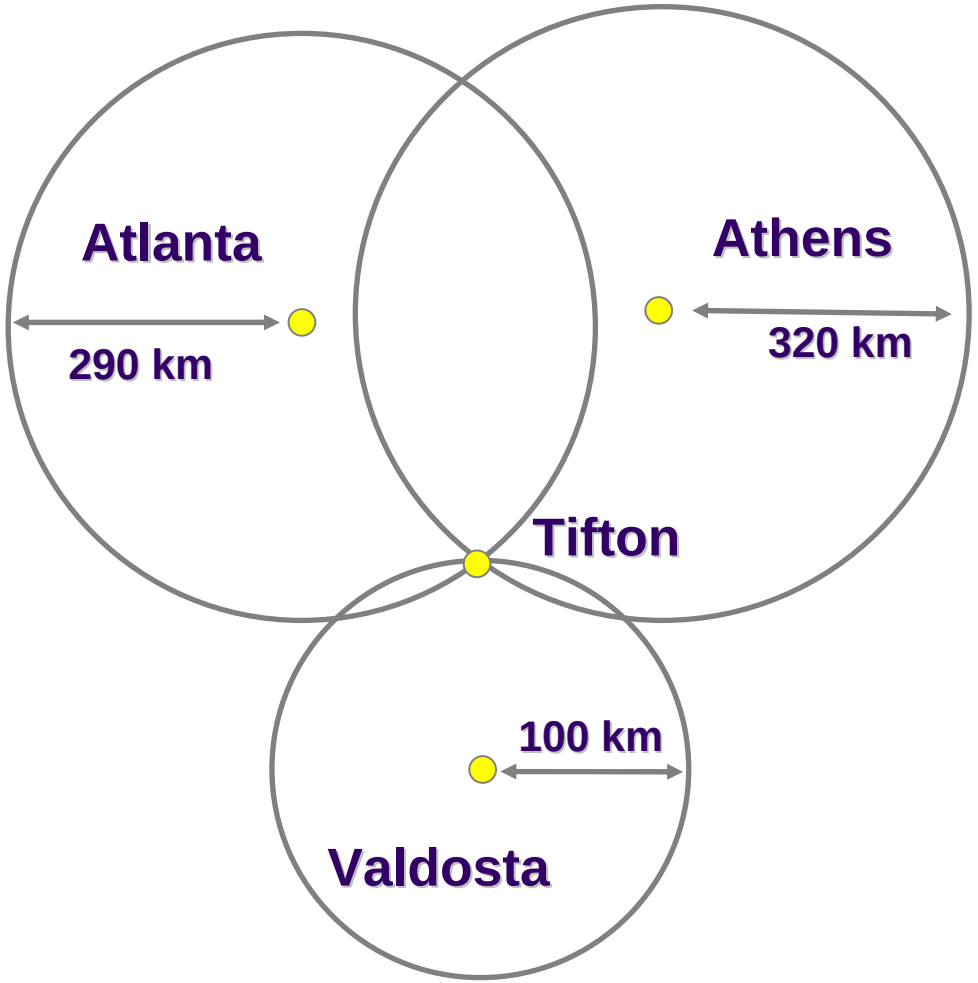
Trilateration Basics



Trilateration Basics

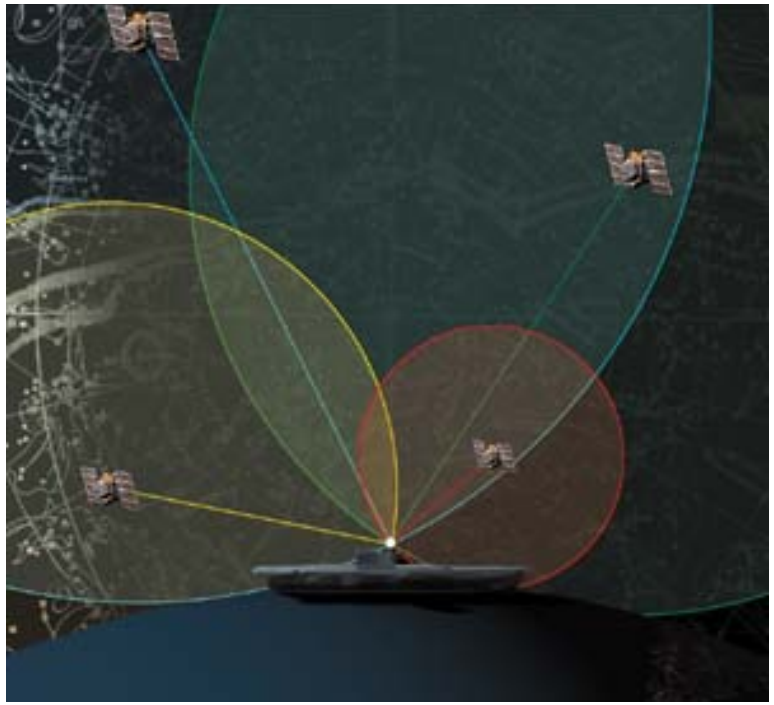


Trilateration Basics



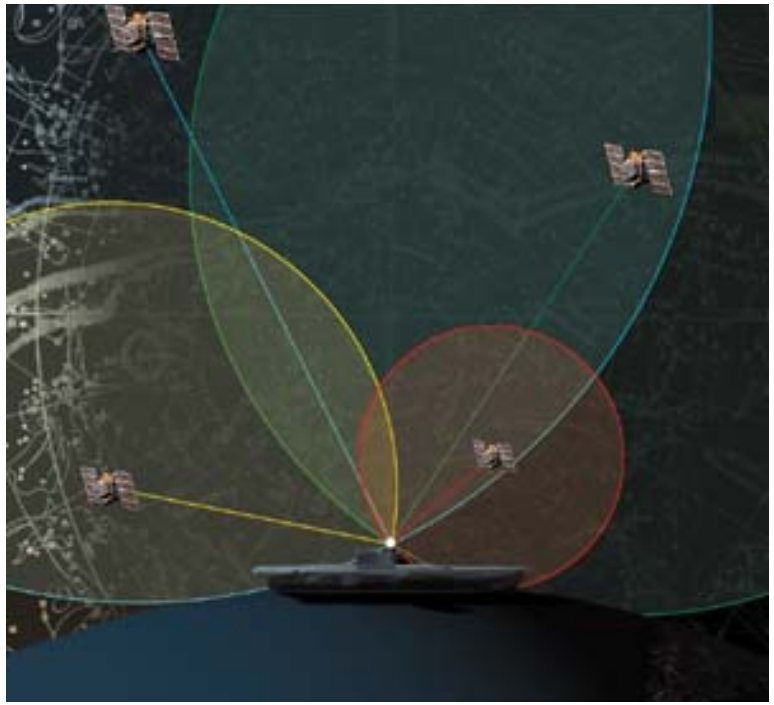
3-D Trilateration

- In 3-D space, the circles we just discussed become spheres



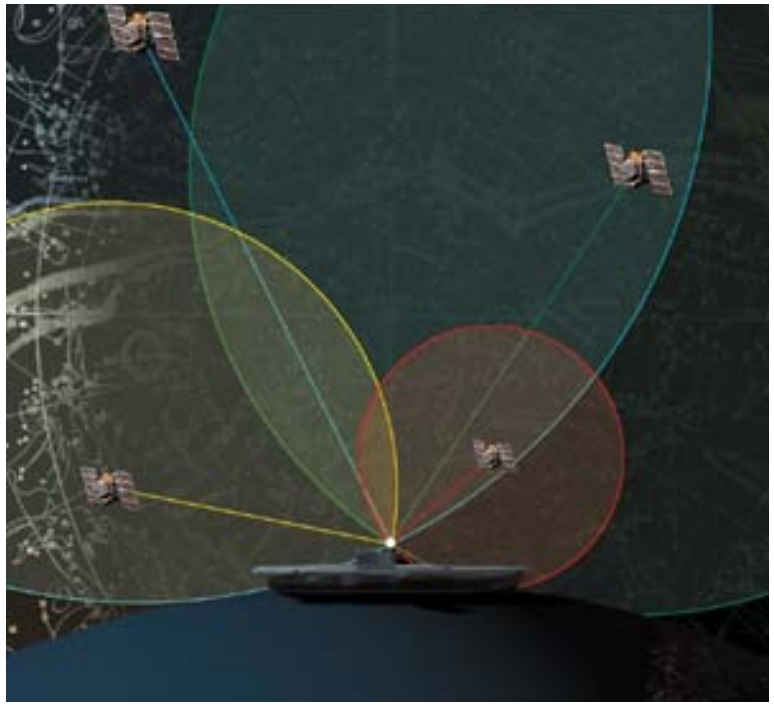
3-D Trilateration

- Example:
  - If you are 10,000 km from satellite A, you could be anywhere on a the surface of an imaginery sphere with a radius of 10,000 km.

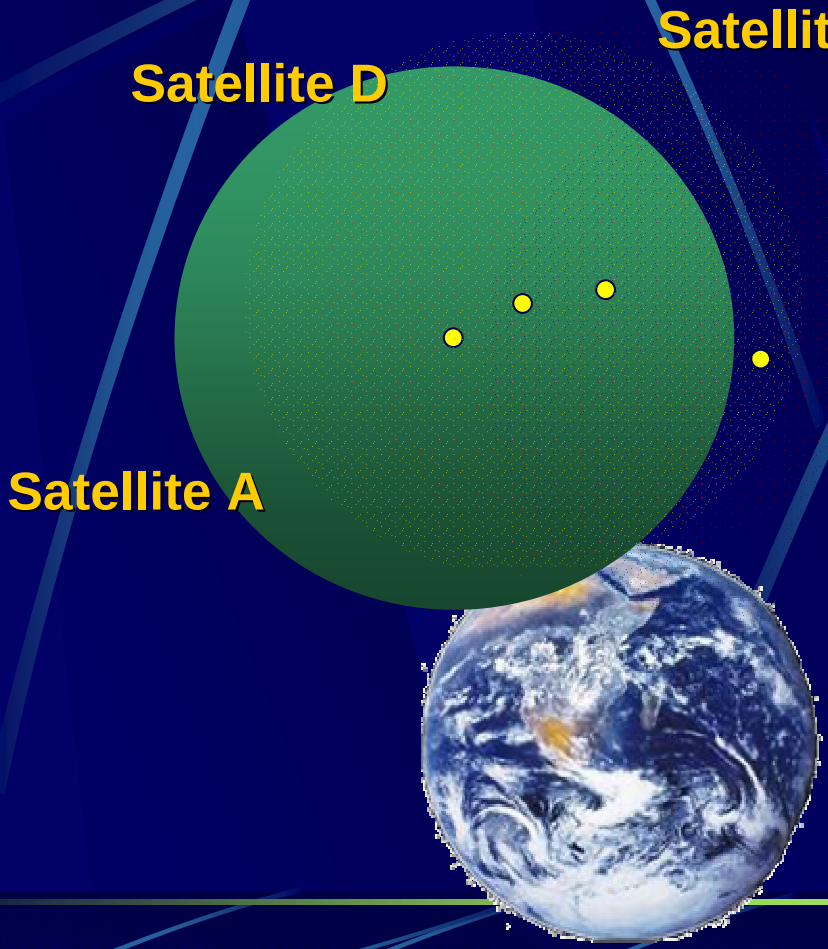


3-D Trilateration

- Example continued:
  - If you are also 9,000 km from satellite B, you are somewhere on surface created by the intersection of spheres A and B.
- What shape is that surface?



3-D Trilateration



Because of various measurement errors, at least 4 satellites are required to locate our position accurately.

Χαρακτηριστικά GPS

- Εκπέμπονται δύο σήματα σε L-Band (1000-2000 MHz):
- L1 1575,42 MHz με δύο κωδικούς τον C/A (Course/Acquisition) και το P (Precision)
- L2 στα 1227,60 MHz με μόνο ένα σήμα P που είναι κωδικοποιημένο για εξουσιοδοτημένους χρήστες (anti-proofing)

- Τα σήματα L1 και L2 μαζί δίνουν μεγάλη ακρίβεια (Precise Positioning System) και διατίθενται για στρατιωτικούς σκοπούς

  Δίνει ακρίβεια 22 μ στο γ. πλάτος και 27,7 στο μήκος
- Το L1 C/A διατίθεται για το κοινό.

  Δίνει ακρίβεια 100 μ στο γ. πλάτος και 156 στο μήκος

Προσδιορισμός των δορυφόρων

- Κάθε δορυφόρος εκπέμπει το L1 (C/A code) σήμα που αποτελείται από ένα μήνυμα που περιέχει στοιχεία για τη θέση του, τον ακριβή χρόνο και τη γενική του κατάσταση. Ο δορυφόρος πιστοποιείται είτε από τον κωδικό του οχήματος (Space Vehicle Number) ή από τον (Pseudoradom Noise PRN)
- Επί πλέον ο κάθε δορυφόρος έχει στοιχεία για τους άλλους δορυφόρους

Μέθοδοι προσδιορισμού της θέσης

- GPS με βάση την ταχύτητα του σήματος και τη διαφορά χρόνου δορυφόρου - δέκτη

  Velocity x Time = Distance

  velocity: speed of light
- Carrier phasing tracking

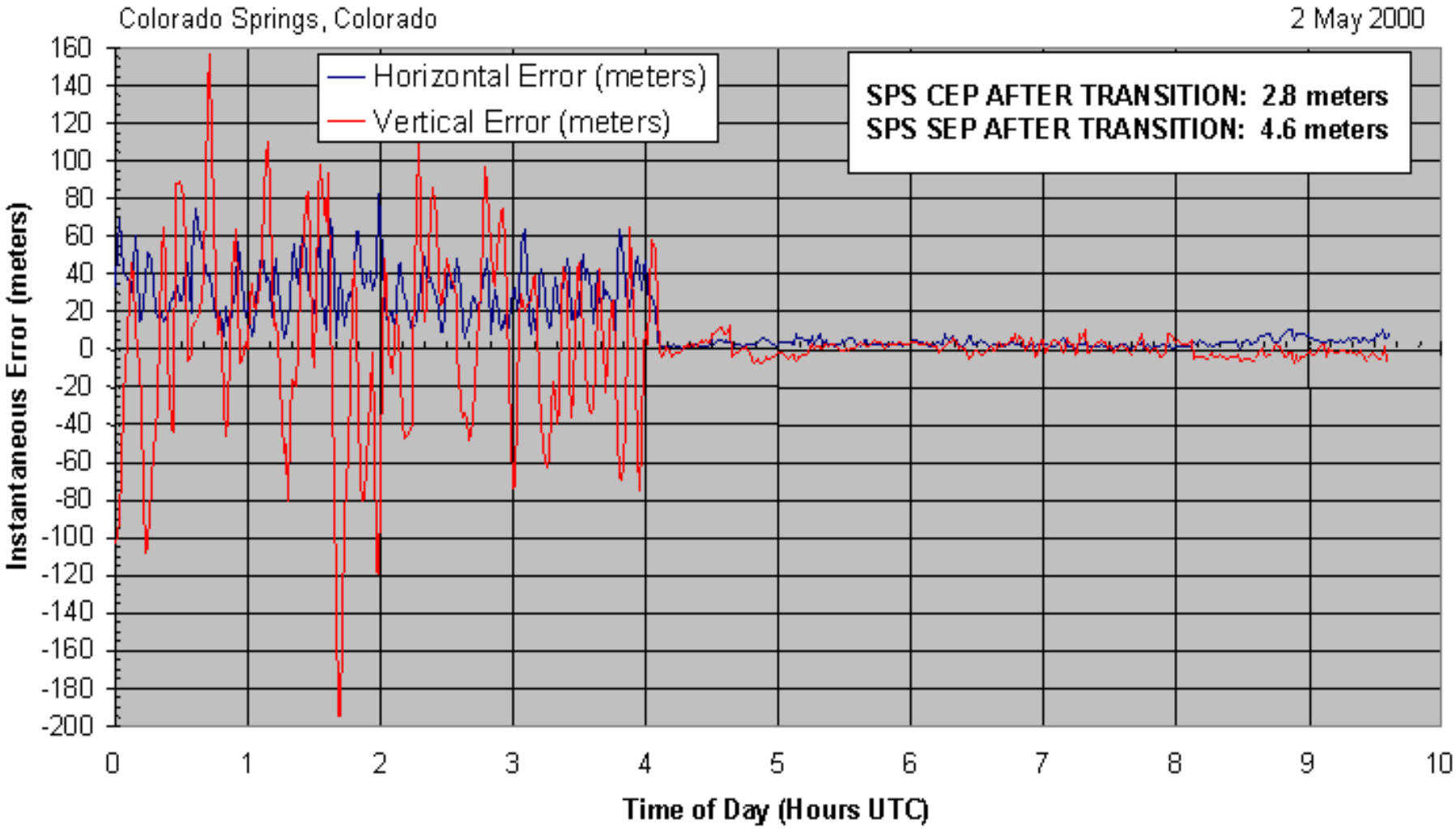
Factor affecting the accuracy

- Satellites clocks
- Satellites trajectories
- Earth atmosphere
- Deflected signals
- User receivers
- Selective availability (S/A)

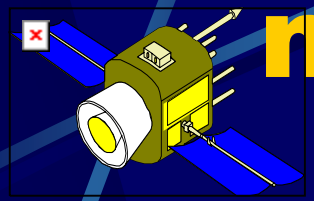
Positioning errors

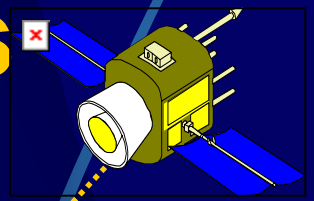
- (Selective Availability turned off 2nd May 2002)
- Obstruction, Multi-path
- Atmospheric delays
  - Troposphere
  - Ionosphere
- Clock errors

SA Transition -- 2 May 2000



Obstruction and multipath errors



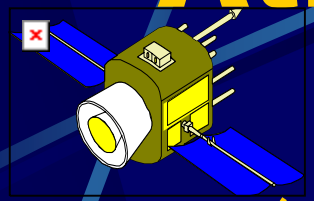


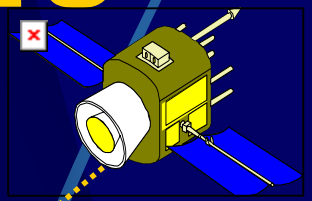
•Obstruction

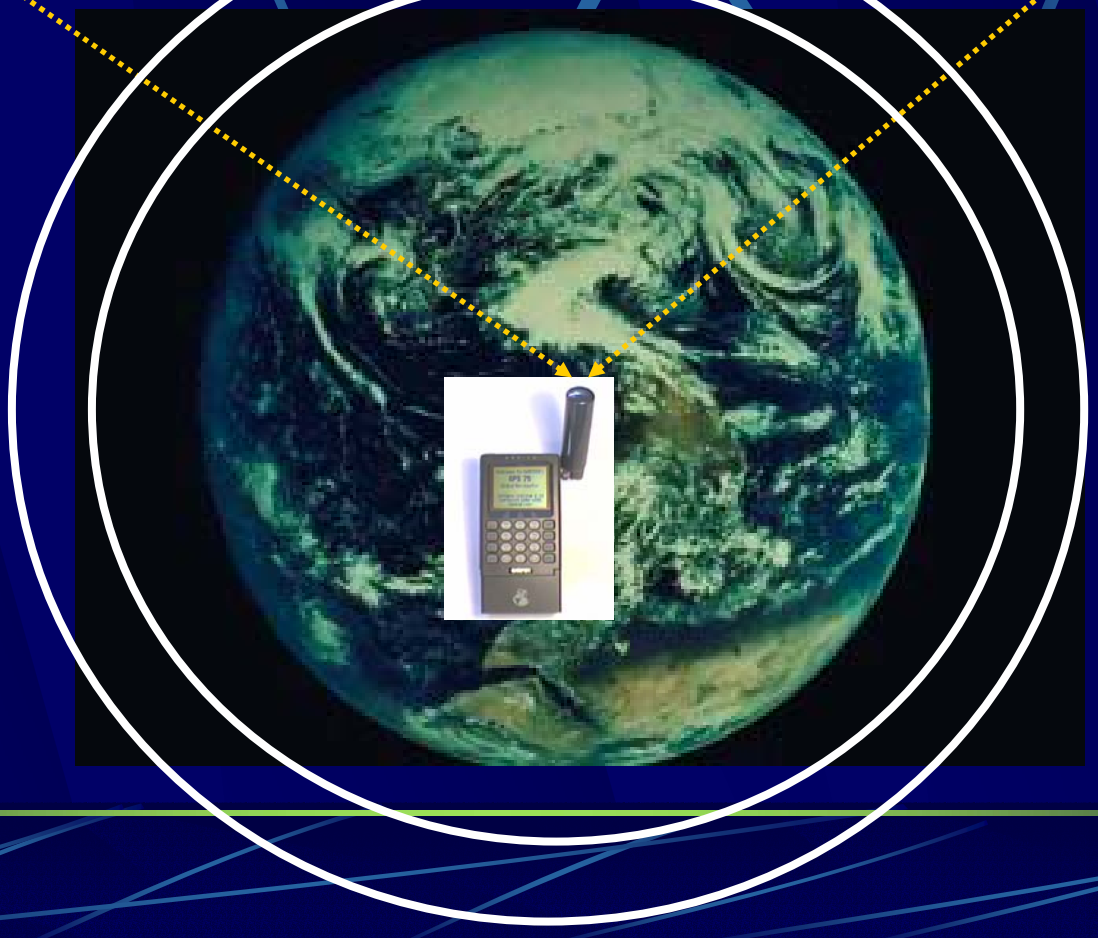
•Multipath

Atmospheric errors

- Ionosphere
- Troposphere







GPS stationary over 30 min

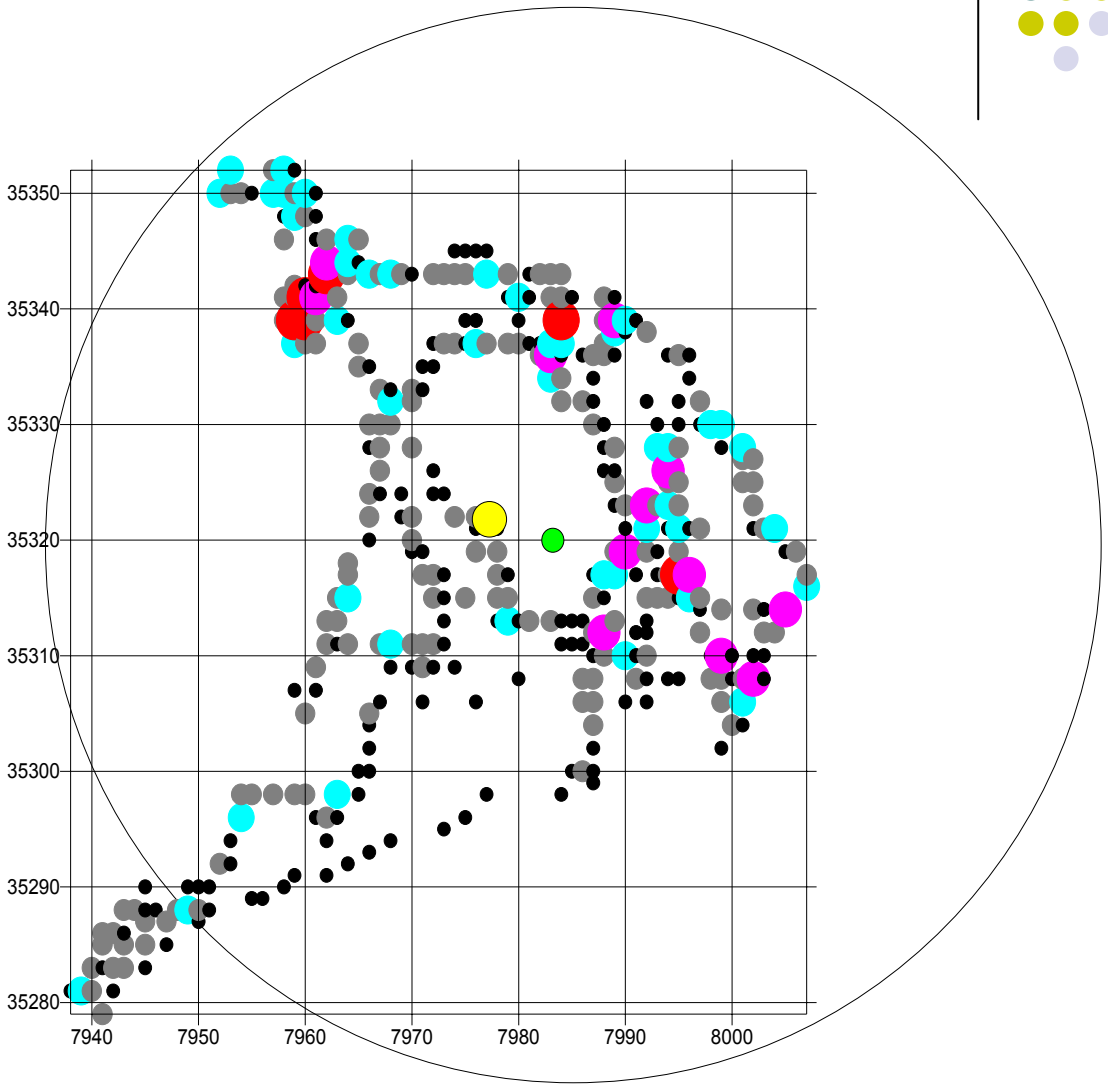
Reference Point

Mean Position

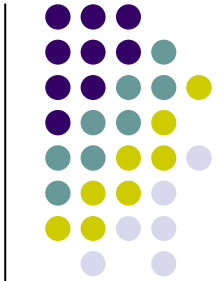
Location:	Reference Point Silsoe College
Date:	14.12.1995
Data Source:	Garmin GPS 75
Recording Interval:	2 Seconds
DOP / EPE:	1 / 24
Mean (E/N):	7977 / 35322
Ref. (E/N):	7983 / 35320
dE/dN:	-6 / 2
2DRMS:	50.4

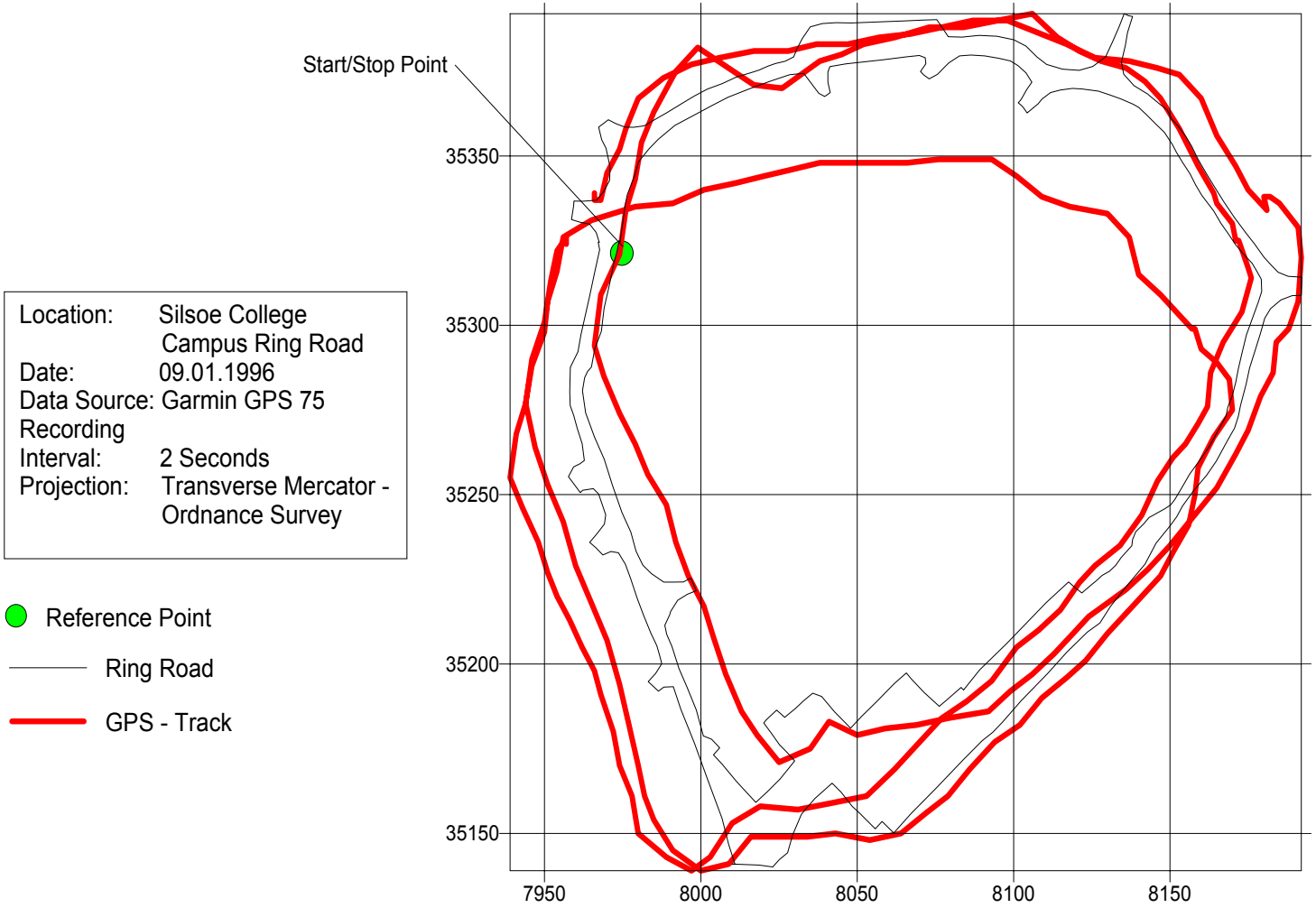
No. of Readings

- 1 to 2
- 2 to 4
- 4 to 6
- 6 to 8
- 8 to 10



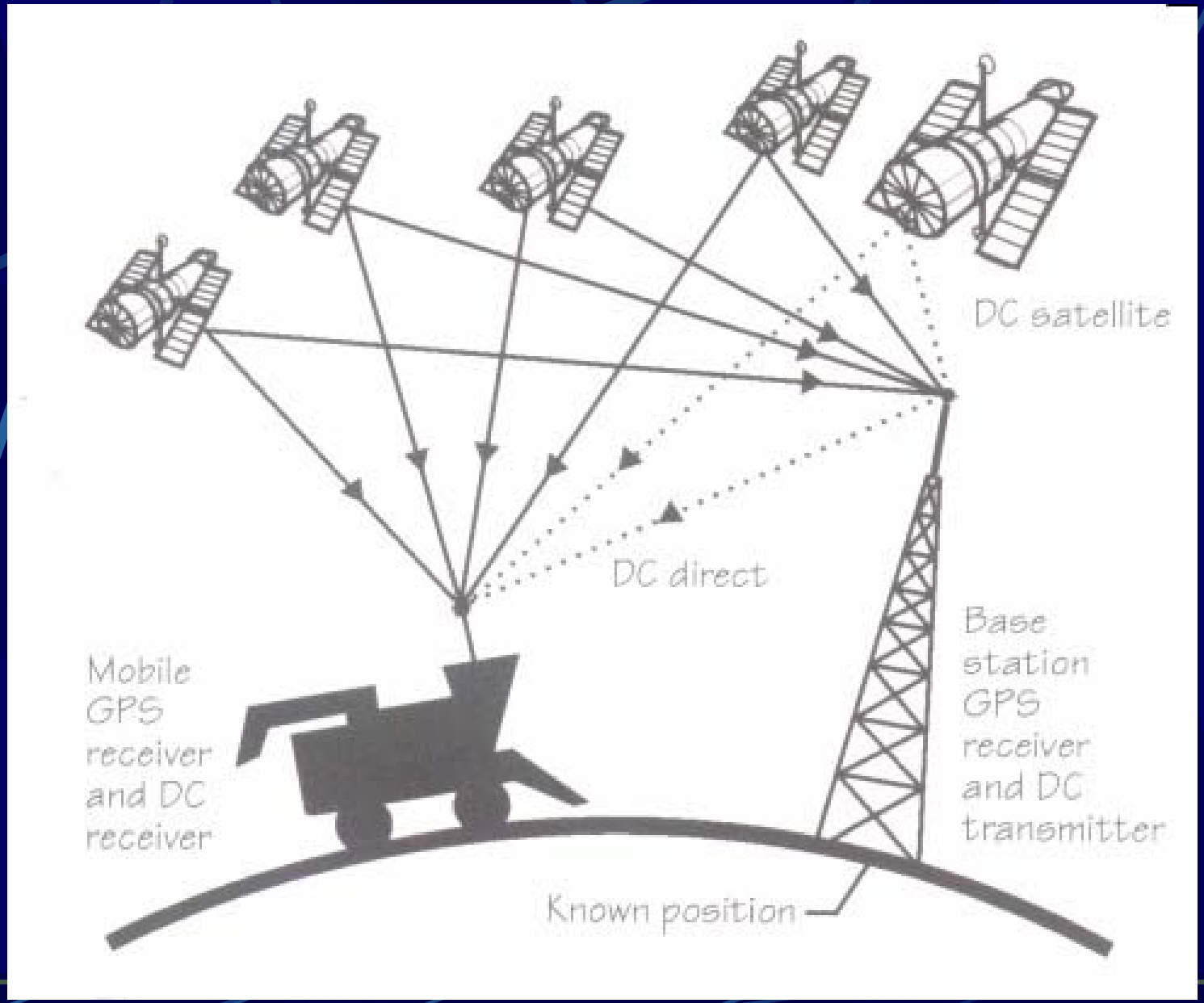
GPS mobile repetition

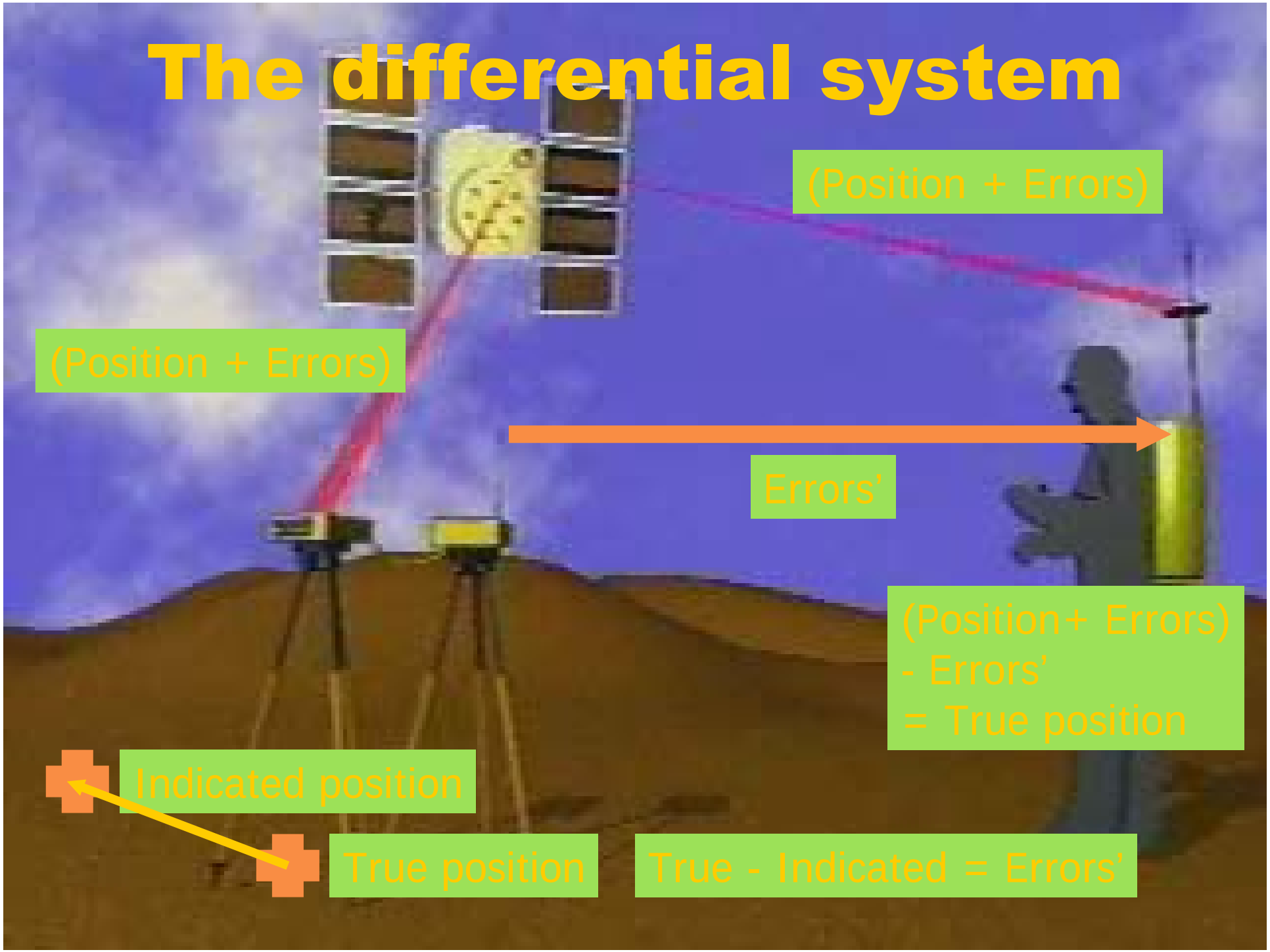




Differential GPS (DGRS)

- Signal correction for earth stations
- The earth station with known position defines the error and transmit it to the user.
- The error can be transmitted directly to the user (real time correction) or retained for future use (post-processing)


DC satellite
DC direct
Mobile GPS receiver and DC receiver
Base station GPS receiver and DC transmitter
Known position

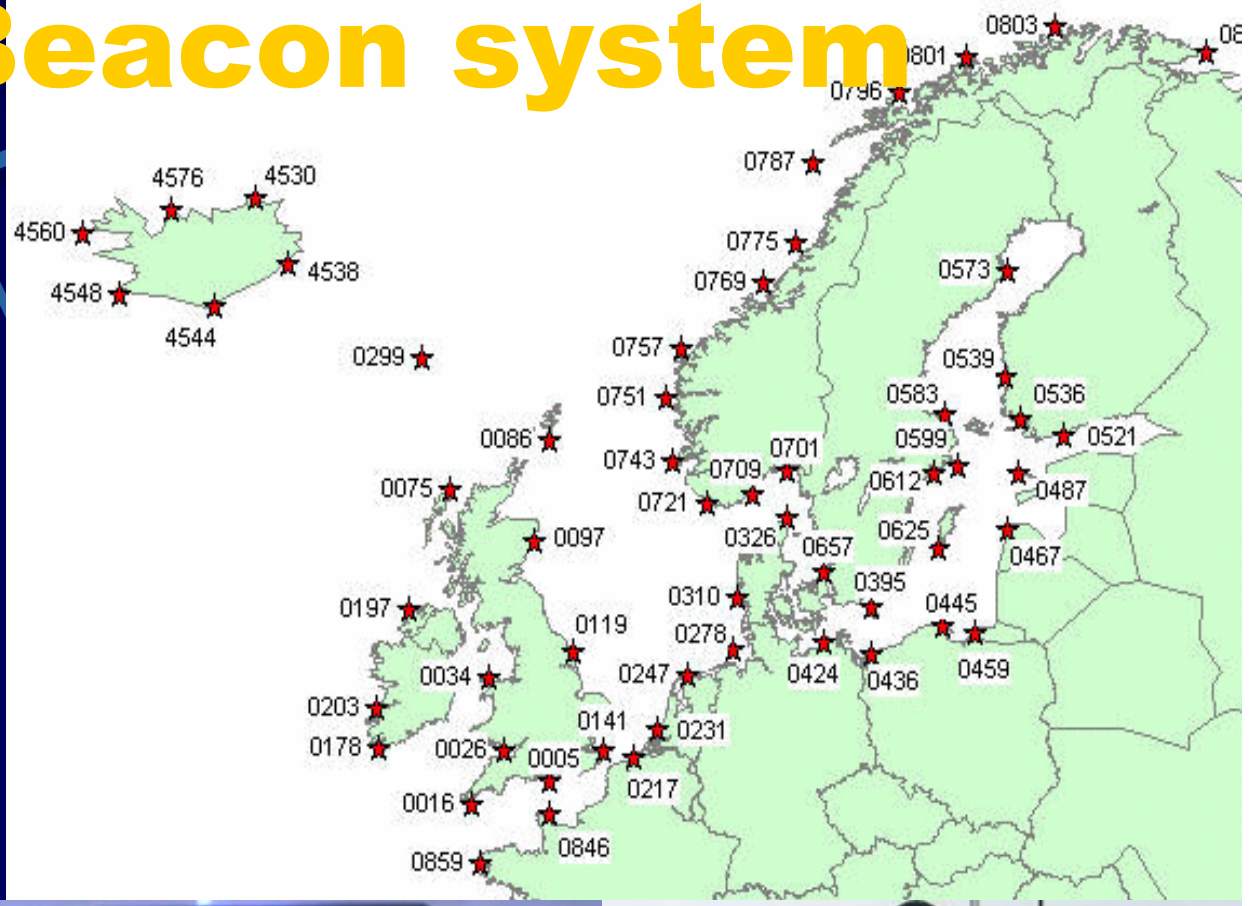

The differential system
(Position + Errors)
(Position + Errors)
Errors'
(Position+ Errors)
- Errors'
= True position
Indicated position
True position
True - Indicated = Errors'

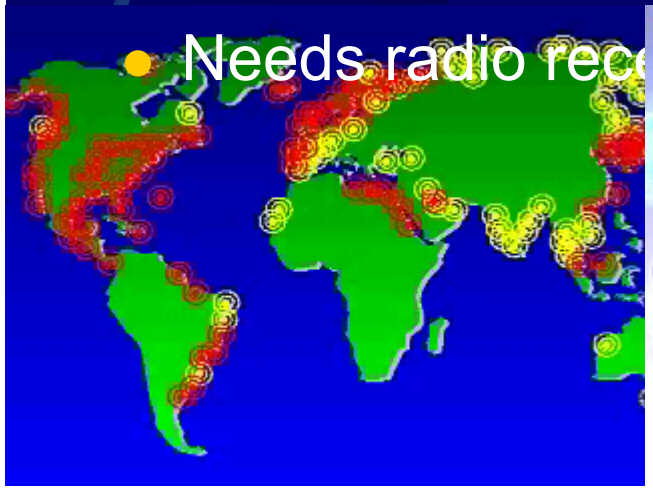
Own base station

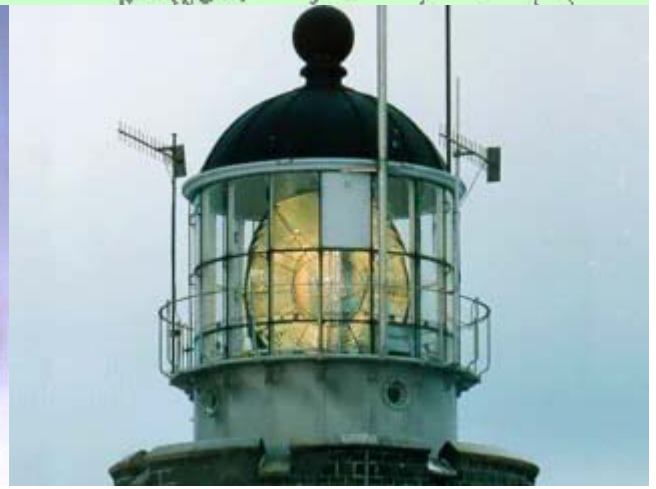
- DGPS
  - Accuracy <2m
  - Cost of second system
- Carrier phase DGPS
  - Accuracy <0.5m
    - Post processing
  - Cost of second system

The Beacon system

- Broadcast from lighthouses by national coastguards
- 2m Accuracy
- Cost
  - FREE!
  - Needs radio rec

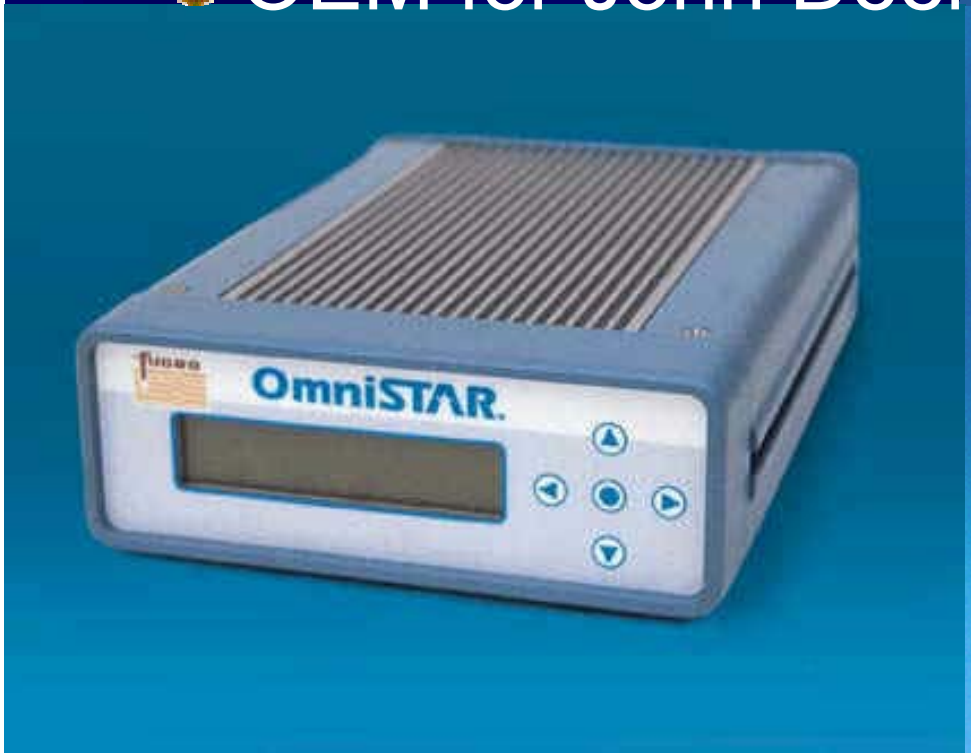






Omnistar differential service

- Subscrption service (~$1000 per year)
- <1m accuracy
- High reliability, worldwide coverage
- OEM for John Deere Greenstar

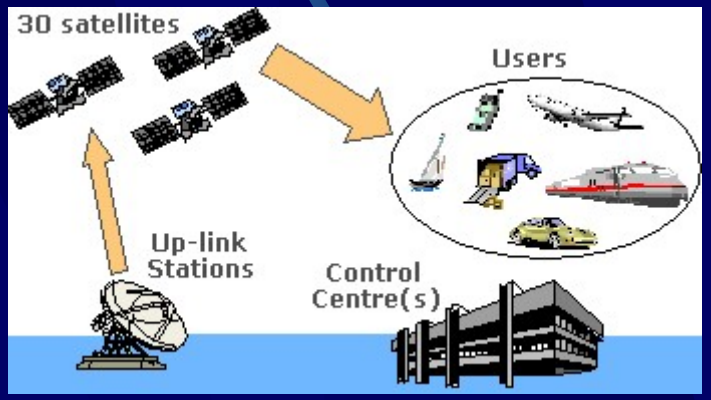


Real Time Kinematic

- Accuracy in real time
  - 1cm stationary
  - 2cm kinematic
  - 20ms latency
- Base station
- Radio link
- Rover
- ~$20000

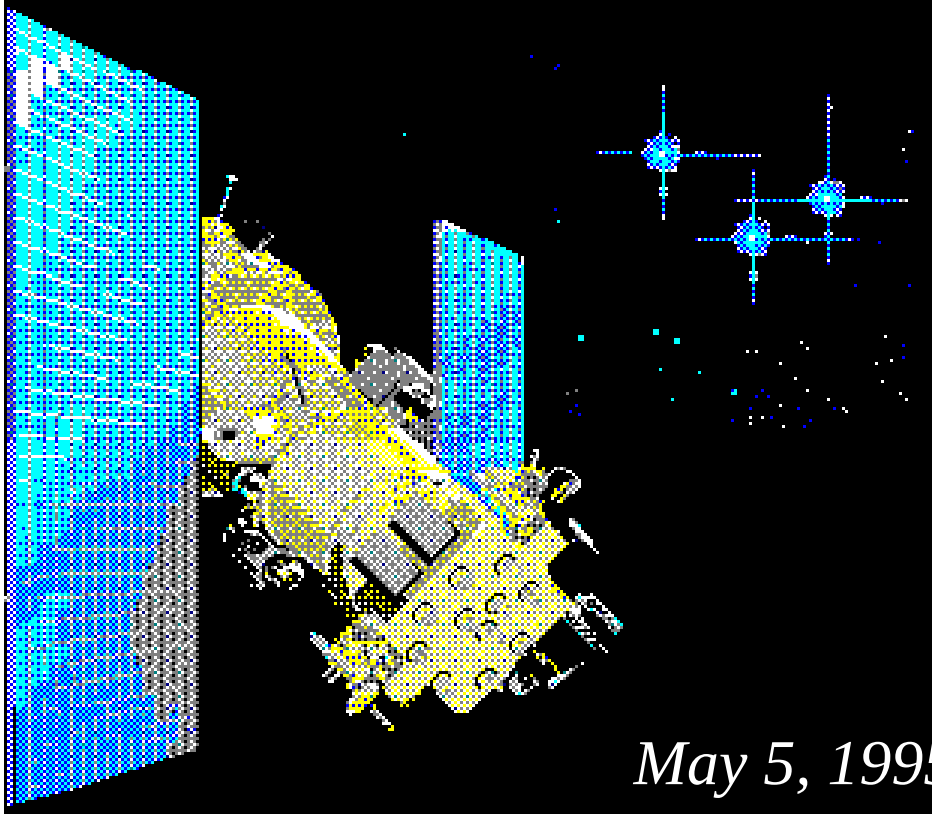
Άλλα συστήματα προσδιορισμού θέσης

- GLONASS Ρωσικό
- EGNOS (ΕΕ)
- Gallileo (ΕΕ)



http://europa.eu.int/comm/dgs/energy_transport/galileo/index_en.htm

- 24 satellites GLONASS
- 3 orbital planes
- Orbital altitude.....19100 km
- Inclination.....64,8 deg



May 5, 1995

GLONASS satellite

Global navigation satellite system GLONASS that provides precise, three-dimentional position, velocity, and time, for national military and civil users and international civil users community was formally put into operation in September 23, 1993 by the Order of the President of Russian Federation.

System Performances

- Accuracy (99,7 % probability)

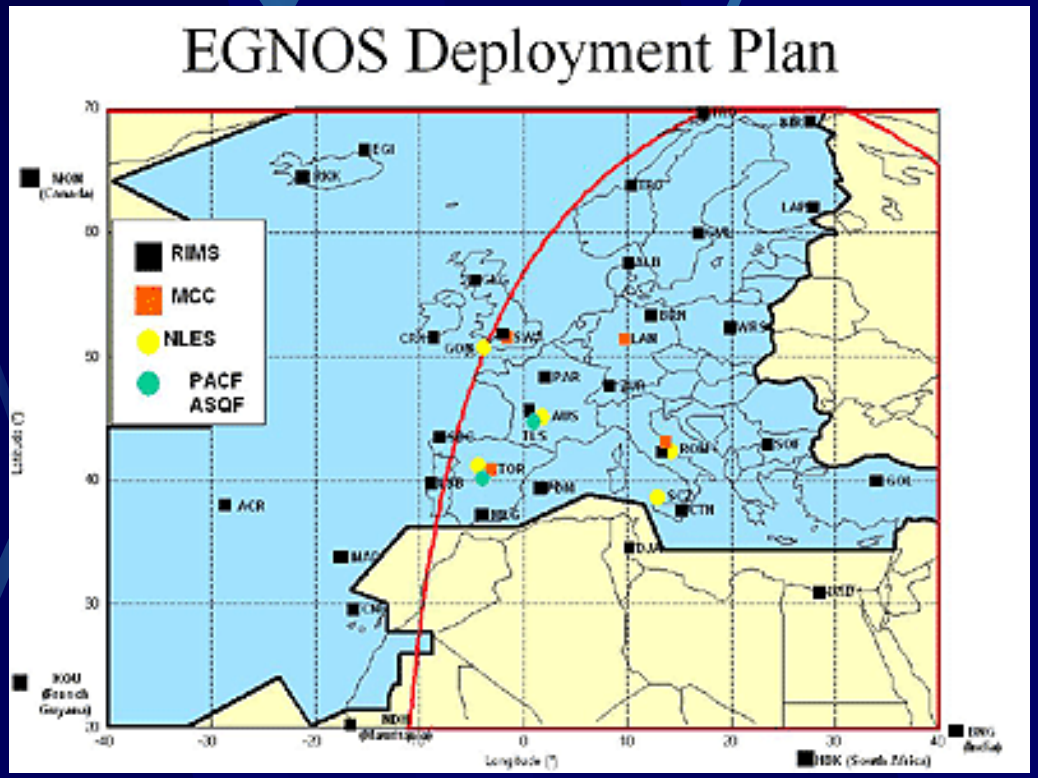
horizontal..... 50-70 m
altitude..... 70 m
velocity.....15 sm/s
time vc. UTC(CIS).....1 mks

- Time required to make
  a first detection.....1-3 min
  and then.....with 1-10 seconds interval
  (depending on navigation equipment)
- Coverage.....global
- Number of users.....unlimited
- Determination of location in real time undepending on meteorological conditions, year season and time of the day environment.

GLONASS is launched by "Proton" launch vehicle and booster "D".

EGNOS

European Geostationary Navigation Overlay Service (EGNOS) is Europe's first venture into satellite navigation. It will augment the two military satellite navigation systems now operating, the US GPS and Russian GLONASS systems, and make them suitable for safety critical applications such as flying aircraft or navigating ships through narrow channels.



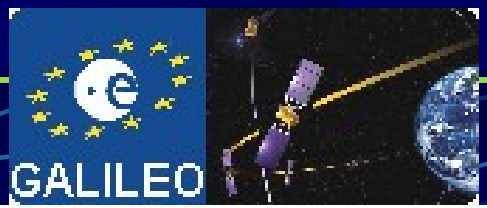
2005: Accuracy down to 2 m 3 Satellites, 30 ground stations

http://www.esa.int/esaNA/GGG63950NDC_index_0.html

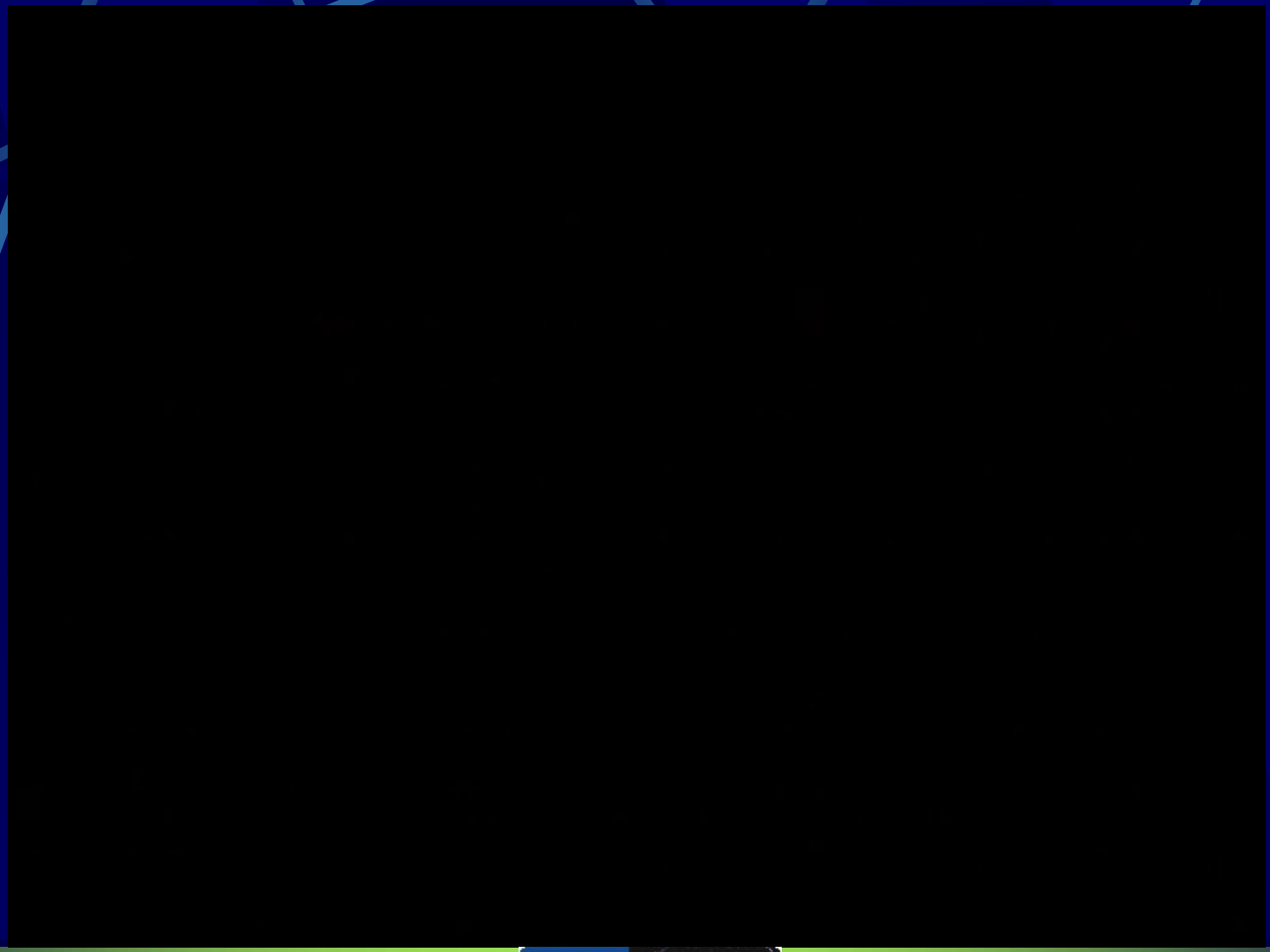
Galileo services

2006: Βάζουν τους 30 δορυφόρους σε τροχιά
2008: Ξεκινούν να λαμβάνουν σήματα στη γη.

	Open Service (OS)	Commercial Service (CS)		Public Regulated Service (PRS)		Safety of Life Service (SoL)
Coverage	Global	Global	Local	Global	Local	Global
Accuracy - horizontal (h) - vertical (v)	h = 4m v = 8m (dual frequency) h = 15 m v = 35 m (mono frequency)	<1m (dual frequency)	< 10cm (locally augmented signals)	h = 6,5m v = 12m	1m (locally augmented signals)	4-6m (dual frequency)
Availability	99.8%	99.8%		99-99.9%		99.8%
Integrity	No	Value-added service		Yes		Yes

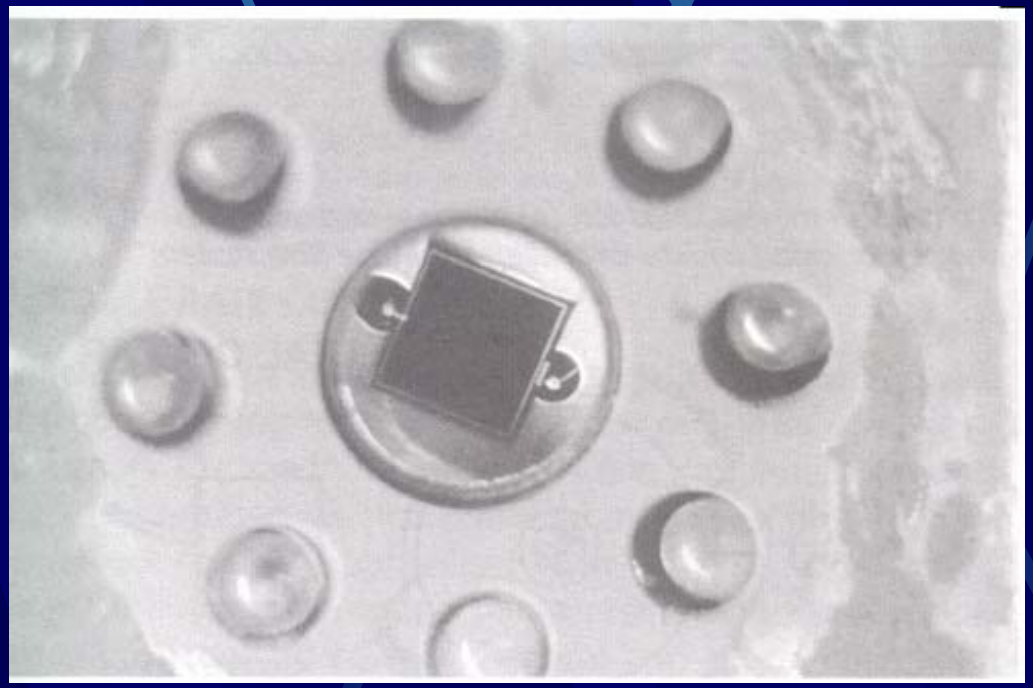


GALILEO



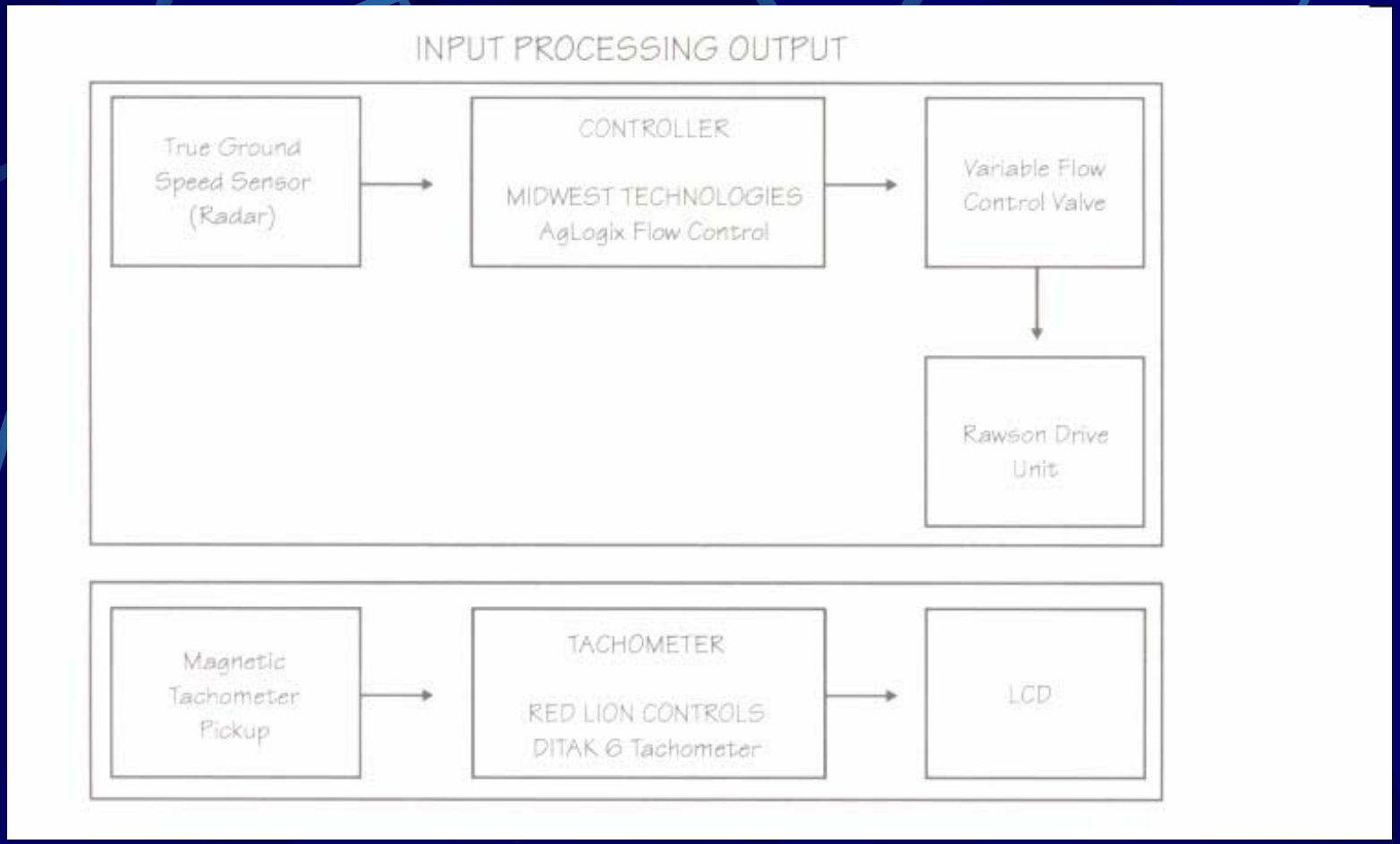
GPS, DGPS equipement

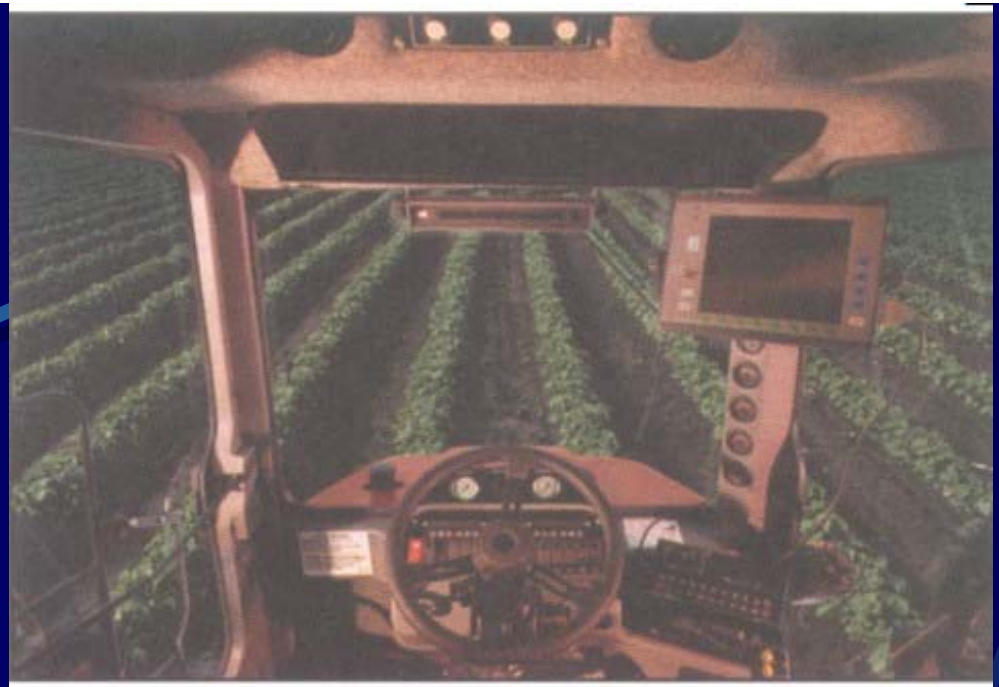
- Antena
- Receiver



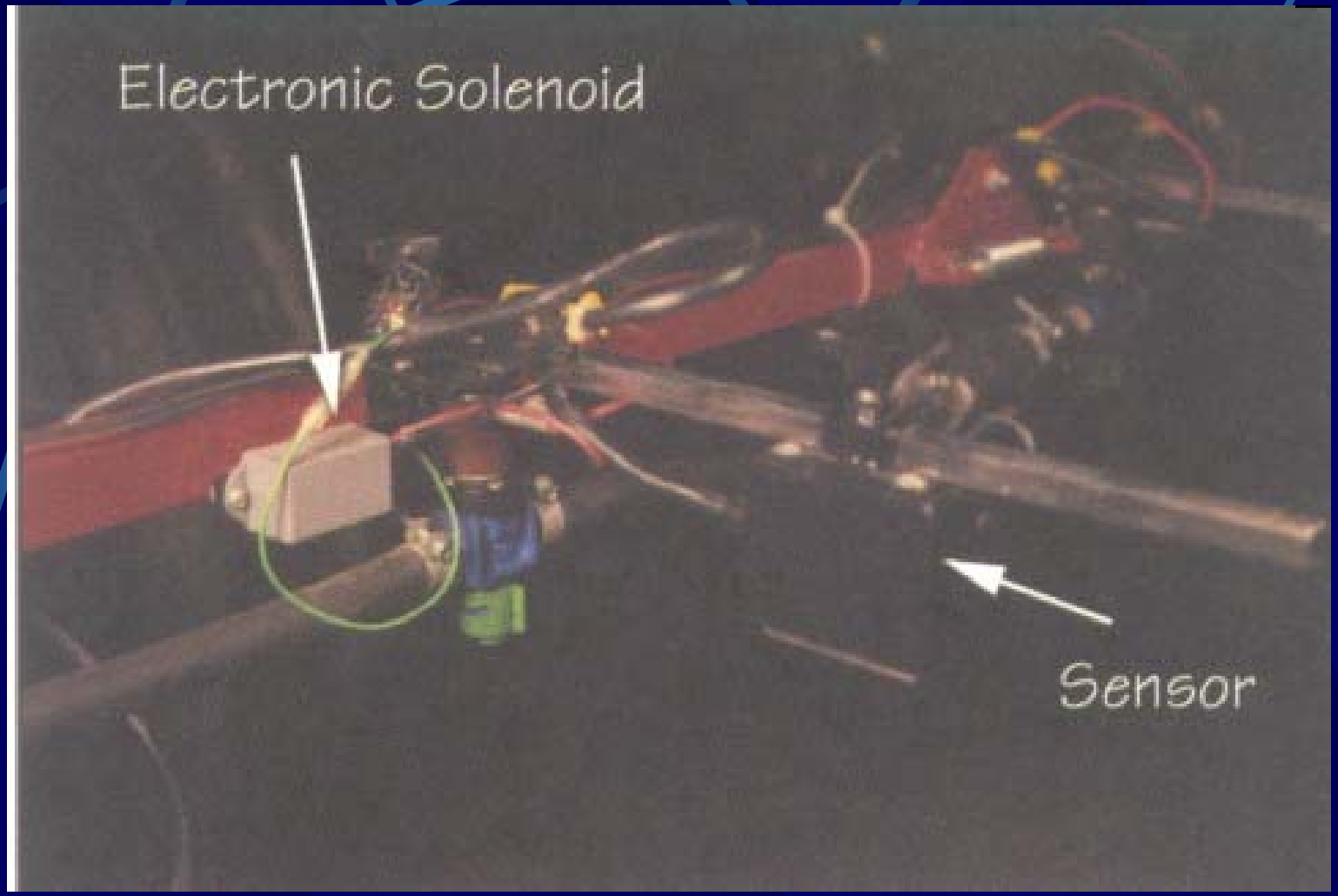
Uses of GPS

- Direction of moving vehicles, boats etc
- Direction of farm machinery in the field
- Autonomous vehicles
- Yield mapping


INPUT PROCESSING OUTPUT
True Ground Speed Sensor (Radar)
CONTROLLER
MIDWEST TECHNOLOGIES AgLogix Flow Control
Variable Flow Control Valve
Rawson Drive Unit
Magnetic Tachometer Pickup
TACHOMETER
RED LION CONTROLS DITAK 6 Tachometer
LCD




Swath
Offline Dist
1
> 1' 0"


Electronic Solenoid
Sensor

Advanced Guidance

WWW links

- Tutorial ‘How GPS works’
  - www.trimble.com