Satellite-based positioning

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Application fields

- Surveying
- Military operations
- Engineering
- Vehicle tracking
- Flight navigation
- Car navigation
- Ship navigation
- Agriculture
- Mapping

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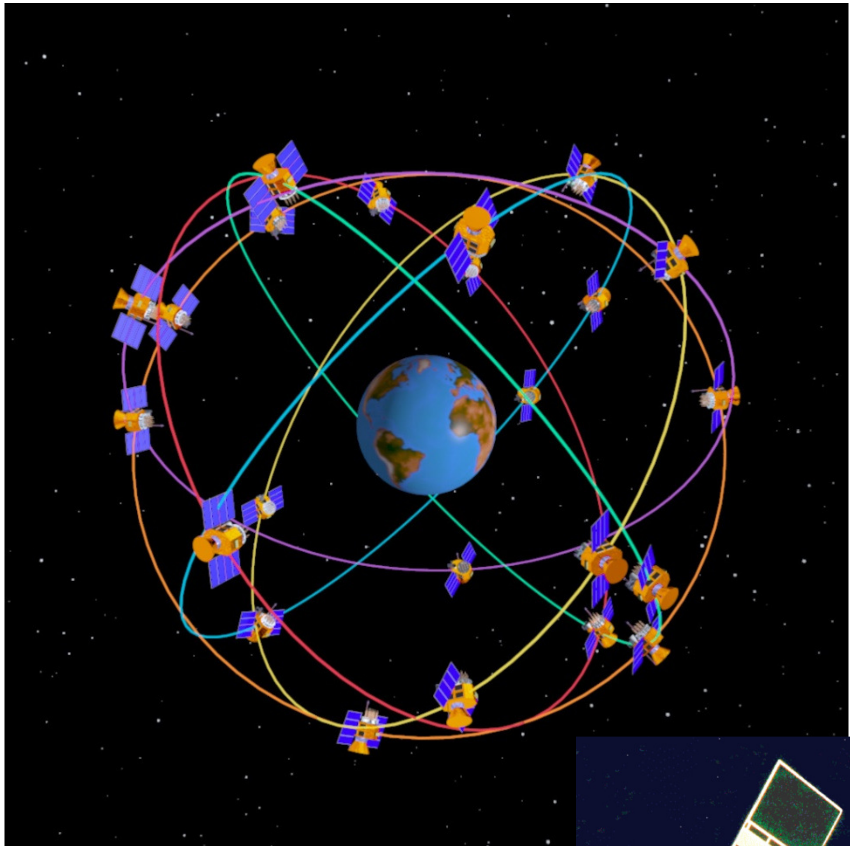
Topics for discussion

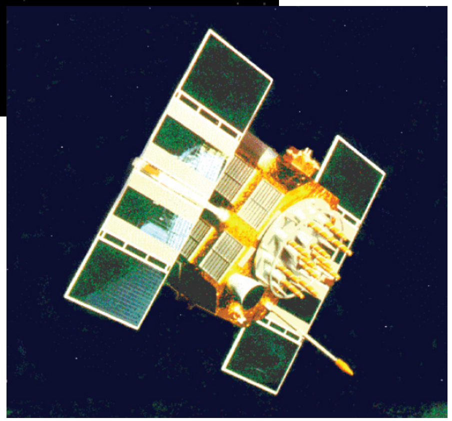
- The segments of a satellite-based positioning system
- GPS, GLONASS and Galileo
- Principle of positioning
- Errors and their sources
- Positional accuracies
- Relative (differential) positioning

Three segments

- Space segment: the satellites that orbit the Earth, and the radio signals that they emit.
- Control segment: the ground stations that monitor and maintain the space segment components.
- User segment: the users with their hard- and software to conduct positioning.

Space segment of GPS system





NAVSTAR GPS
Satellite

The space segment of GPS consists of 24 satellites on 6 orbits (approx. 22,000 km from the centre of the Earth):

- Each satellite carries a clock.
- Each satellite completes 2 orbits/day.
- 24 hour complete GPS coverage anywhere on the Earth.
- Accuracy: 21 meters 95% of time

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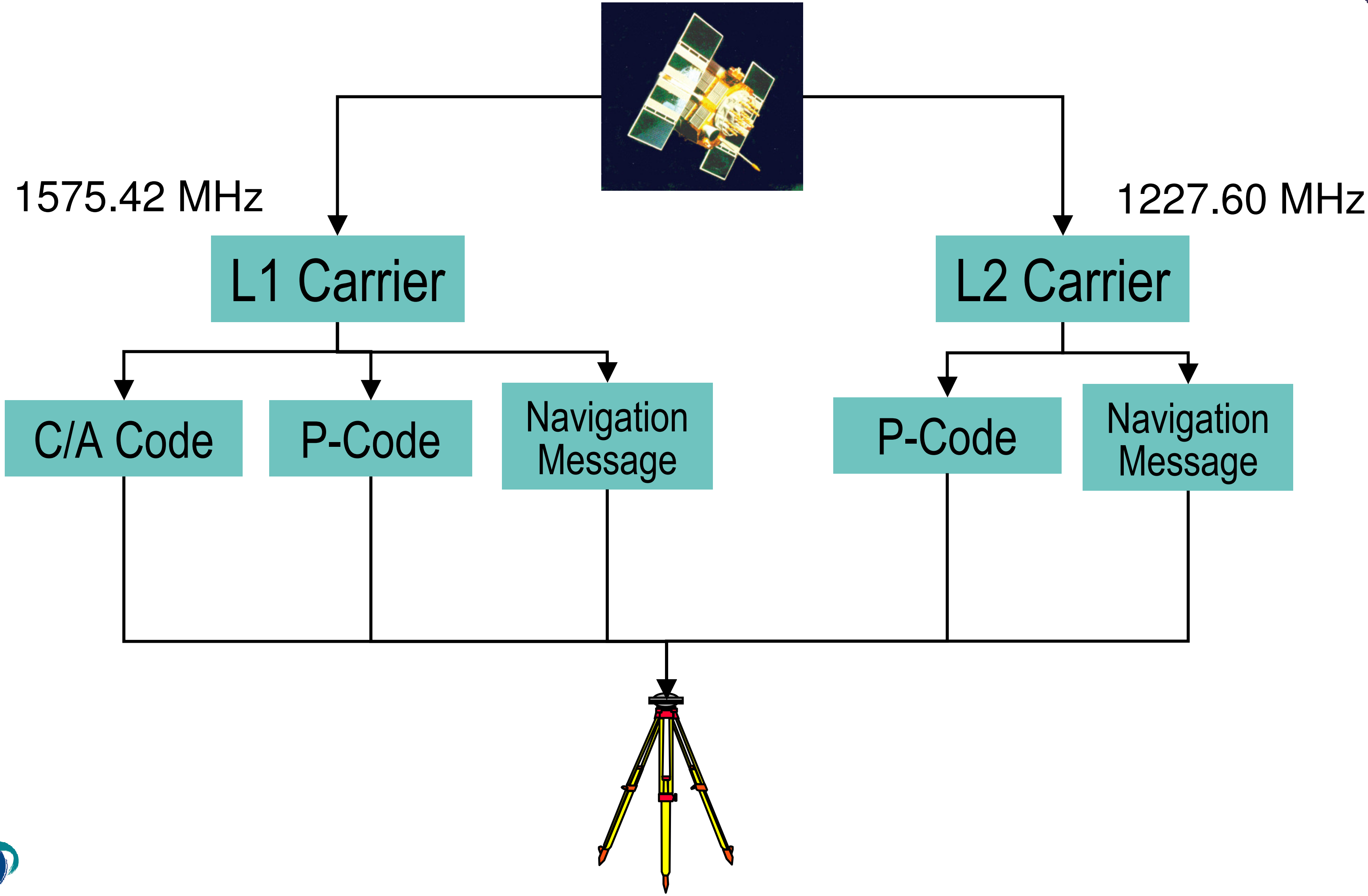
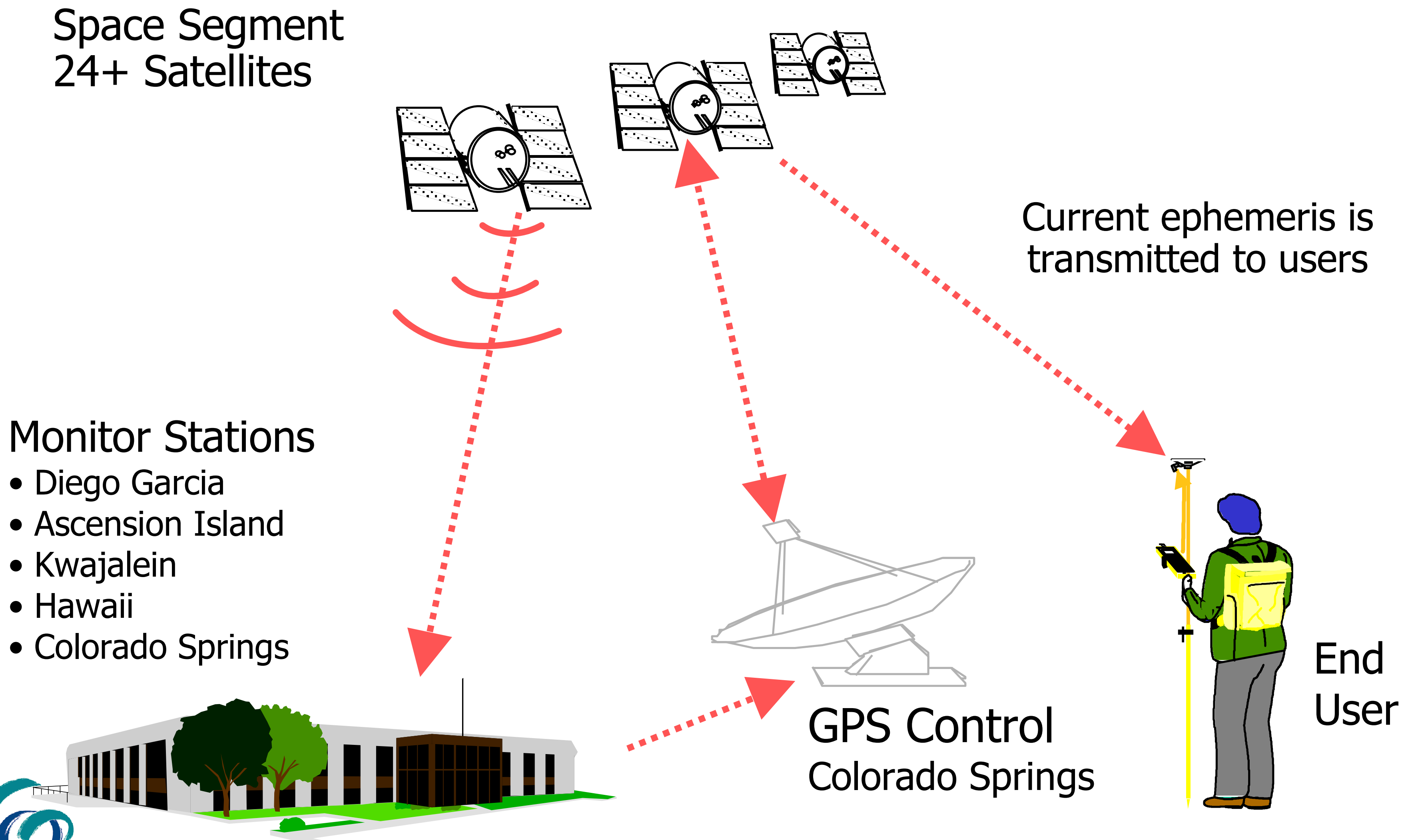
GPS Signal Structure



Control Segment of GPS



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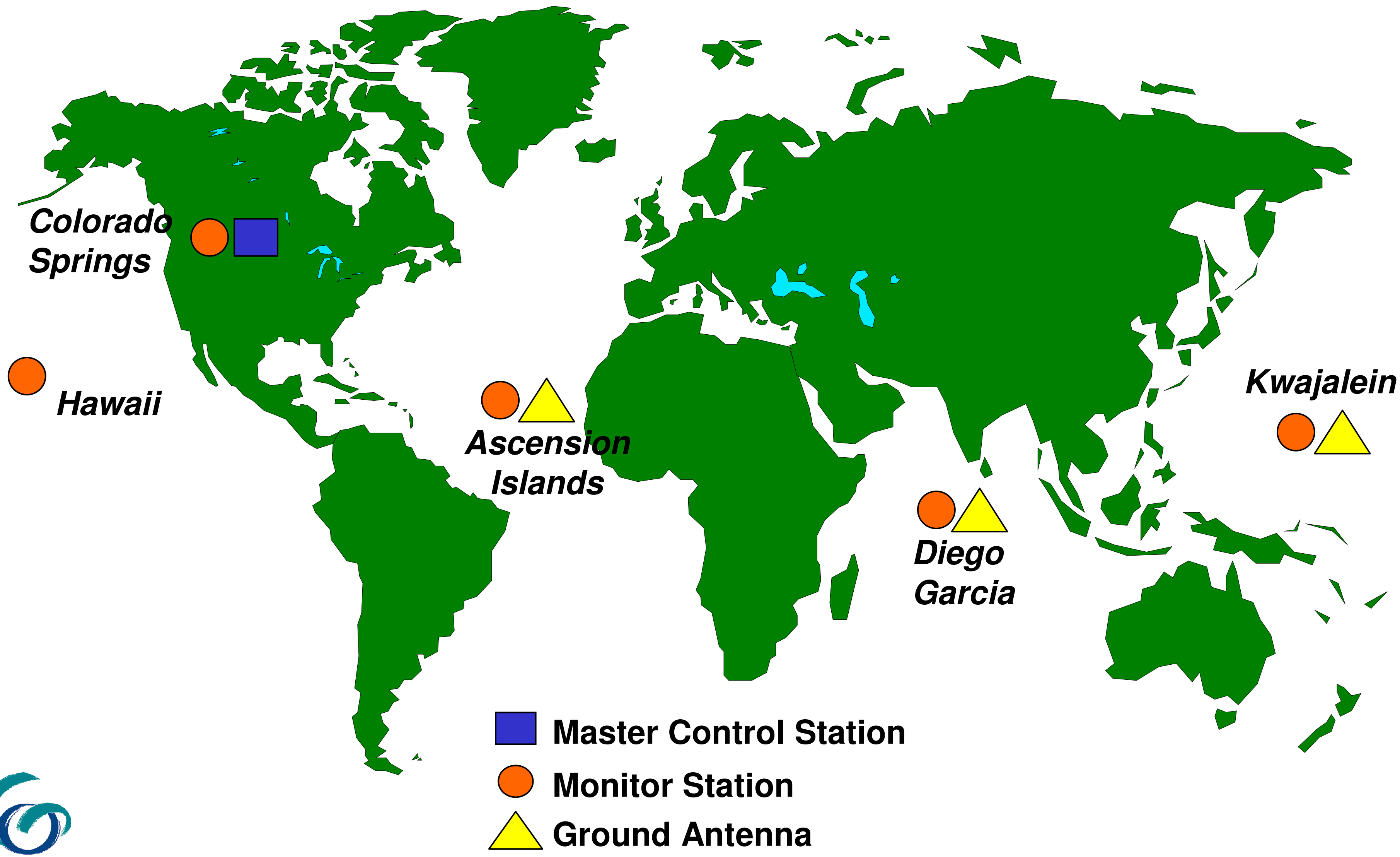
Control Segment of GPS



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User segment of GPS

GPS-Receivers

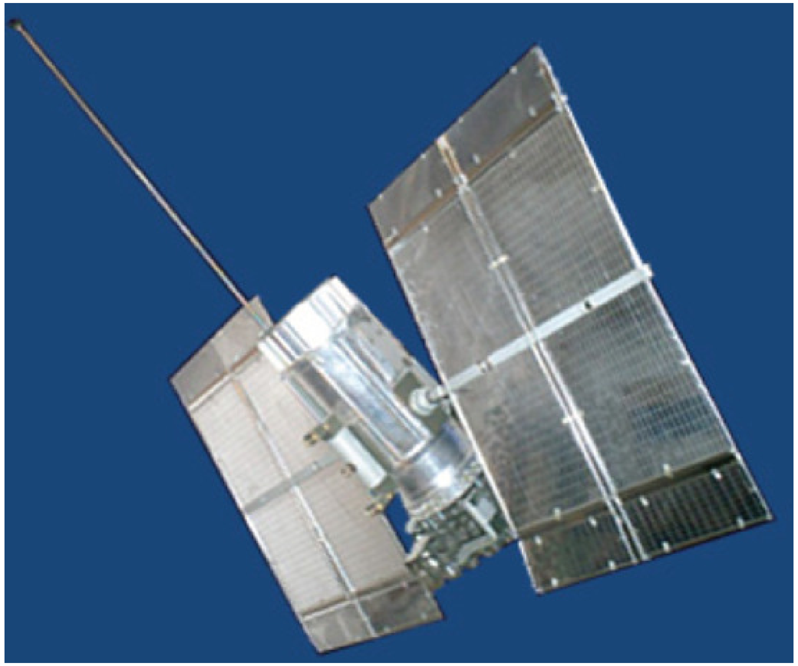
Receivers and their users:

- (Military)
- Navigation in 3D-aircrafts,
- ships, ground vehicles and hand-carried instruments
- Precise positioning - Surveying
- (Time dissemination - astronomy)
- (Research projects on atmospheric distortions)

Selection of a GPS receiver

- Application (boating, flying, driving, mapping, surveying)
- Accuracy requirements
- Power consumption requirements
- Operational environment
- Signal processing requirements
- Cost
- Data exchange standards

Space segment of GLONASS system



GLONASS Satellite

http://www.glonass-ianc.rsa.ru

Russian system
(Globalnaya Navigatsionnaya
Spunikova Sistema - GLONASS)

- 24 satellites (21 operational and 3 spare).
- Three orbital planes at 65º inclination.
- Two codes as GPS, but all satellites broadcast identical codes but using slightly different carrier frequencies for each satellite.
- The positioning principal is the same as GPS
- Accuracy: 20 m horizontal and ~30 m vertical

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Space segment of Galileo system

Galileo Satellite

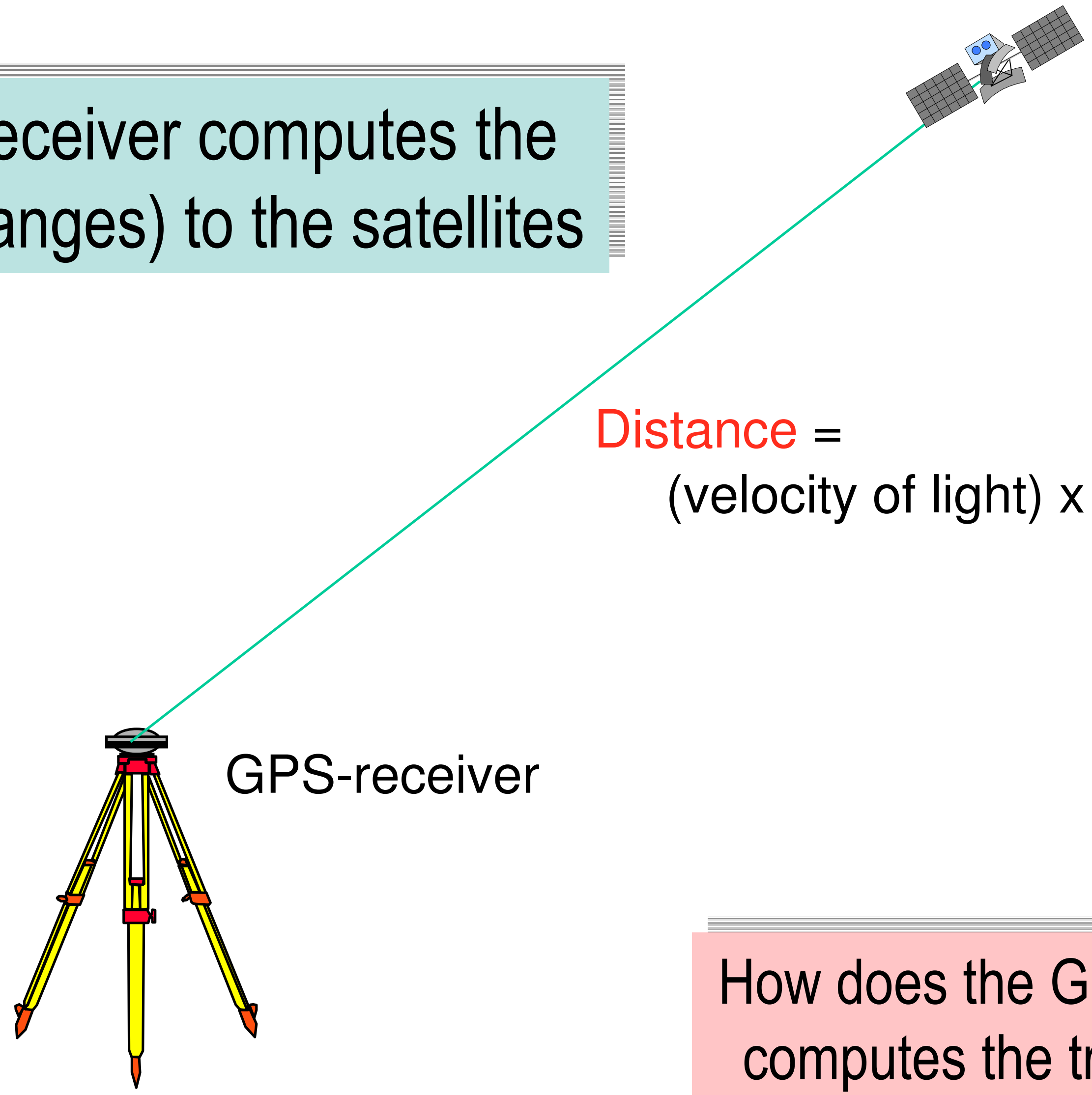
Galileo is in the implementation phase, first satellite to be launched in 2006, planned operation start 2008.

- Designed for civil purposes
- 30 satellites
- 3 orbits (23,222 km high)
- Network of ground stations, 2 control centresin Europe
- Accuracy of single receiver: around 1 m

http://www.esa.int/esaNA/SEMY02FFWOE_galileo_0.html

Principle of positioning

The GPS-receiver computes the distances (ranges) to the satellites



Distance = (velocity of light) x (travel time)

How does the GPS-receiver computes the travel time?

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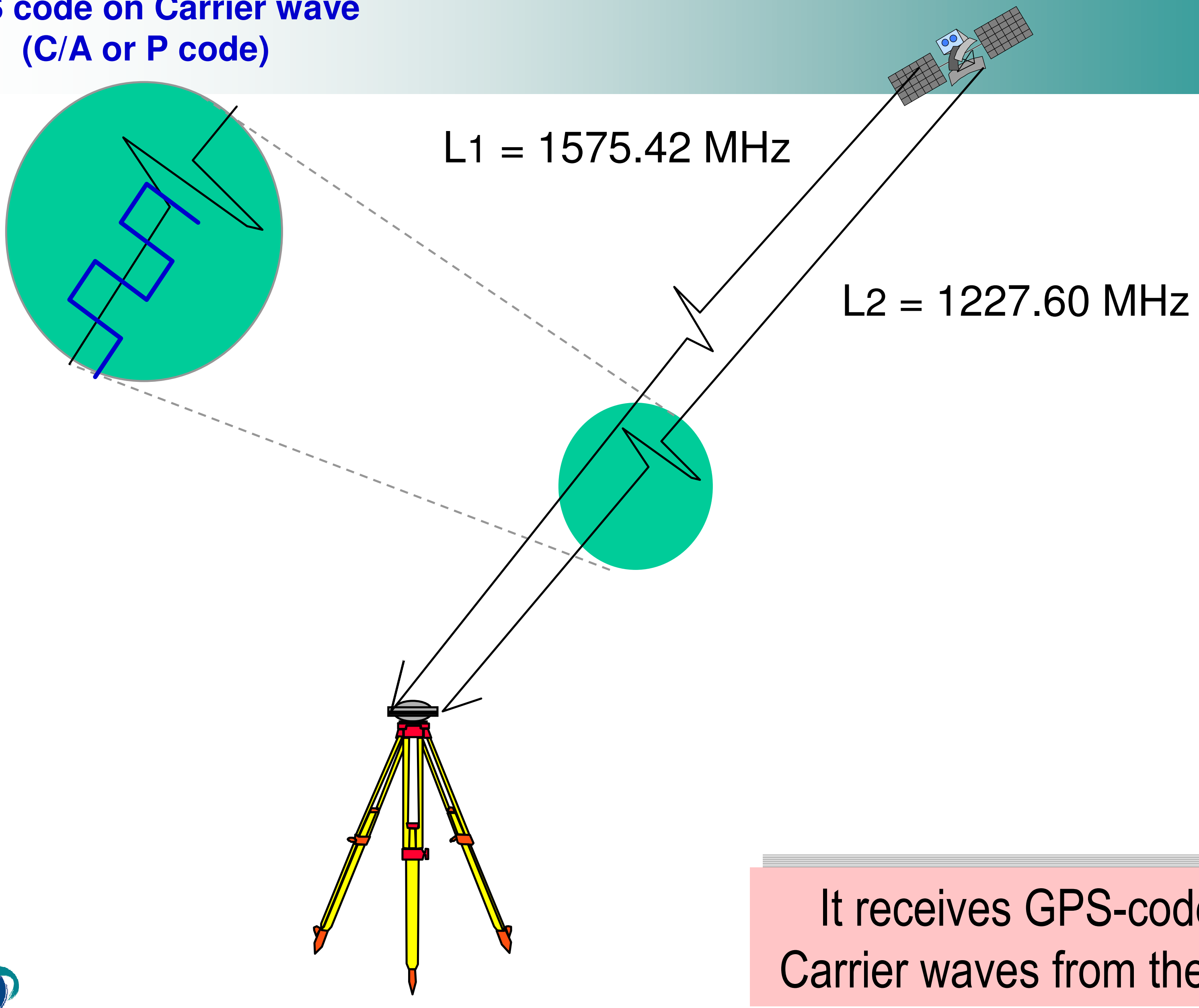
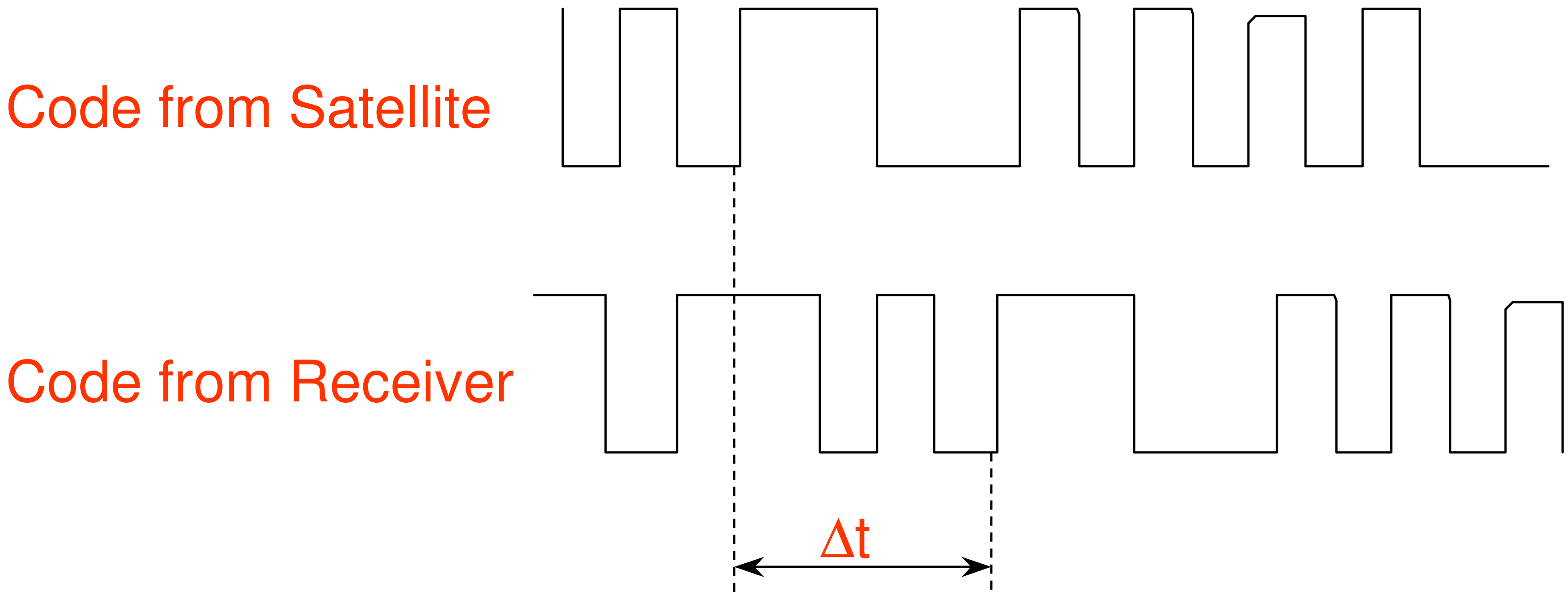
GPS code on Carrier wave (C/A or P code)



It receives GPS-codes and Carrier waves from the satellite

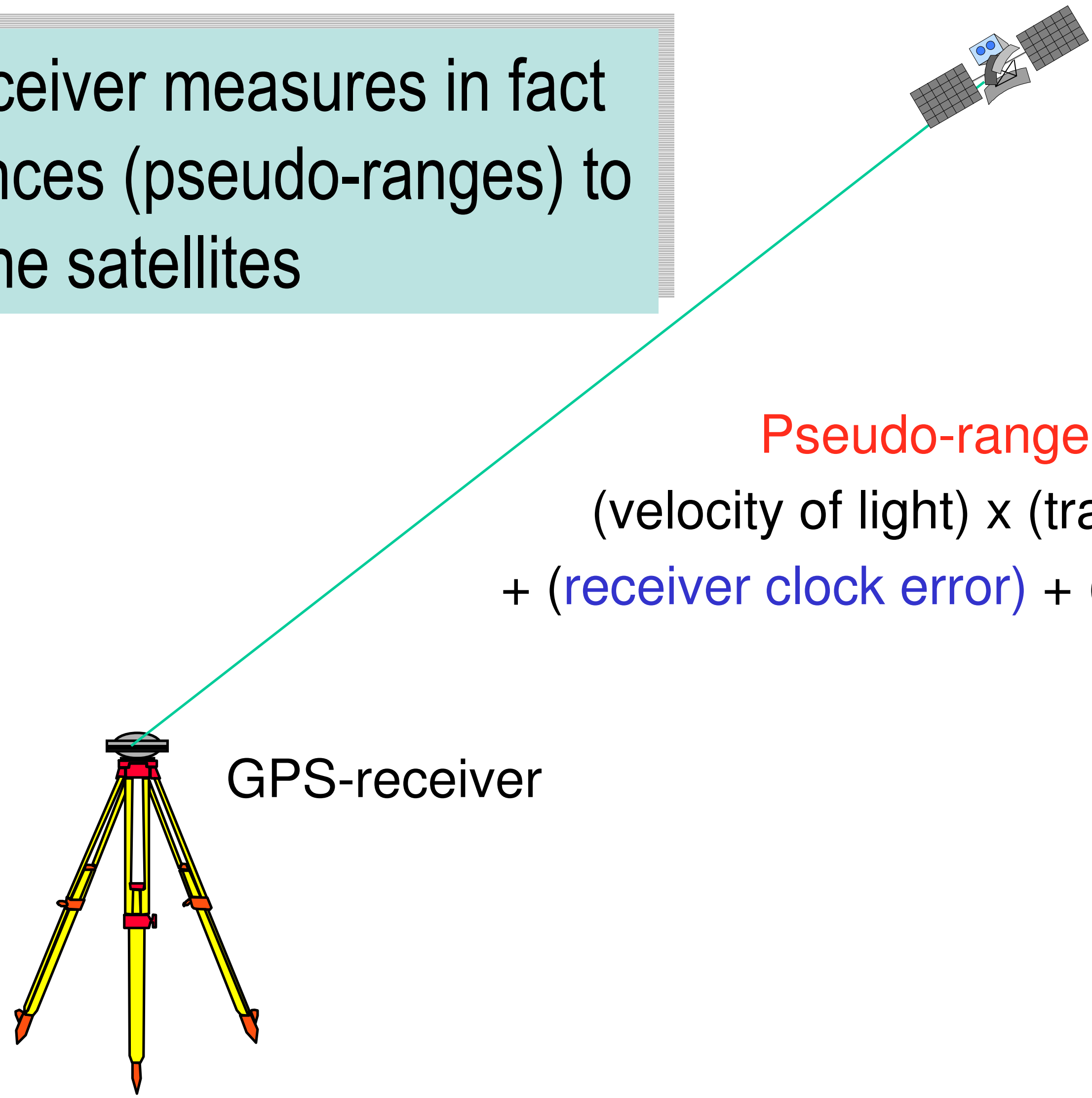
Code comparison



Time difference between Receiver and Satellite signal

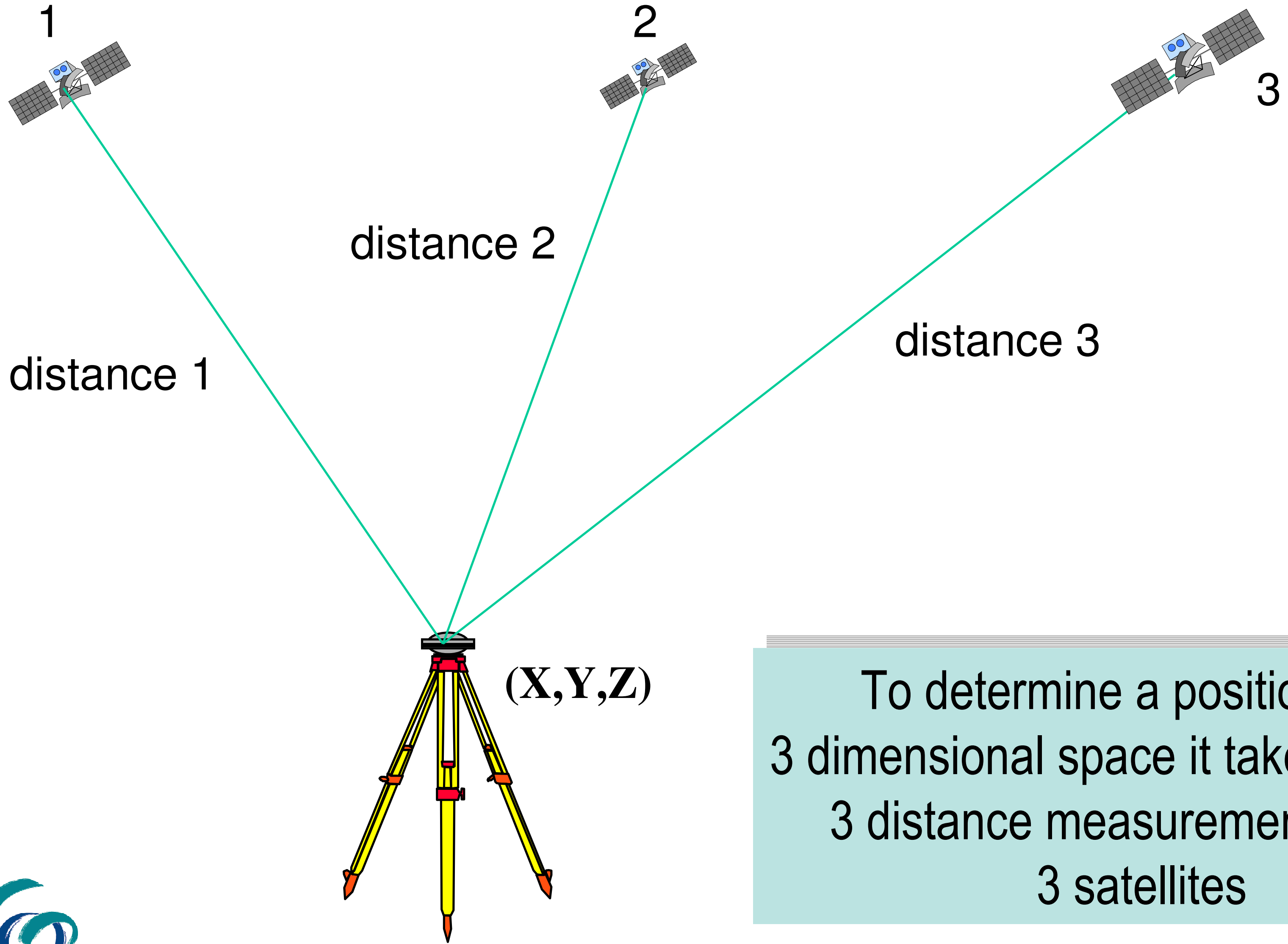
Principle of positioning

The GPS-receiver measures in fact pseudo distances (pseudo-ranges) to the satellites



Pseudo-range =
(velocity of light) x (travel time)
+ (receiver clock error) + (other errors)

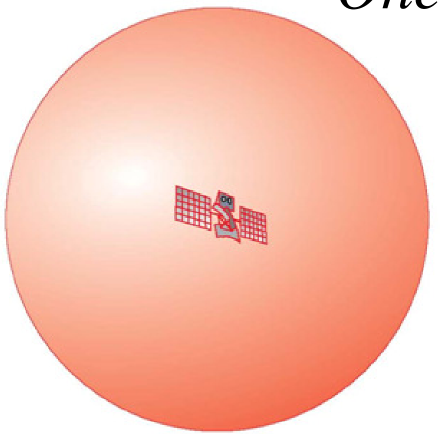
Principle of positioning

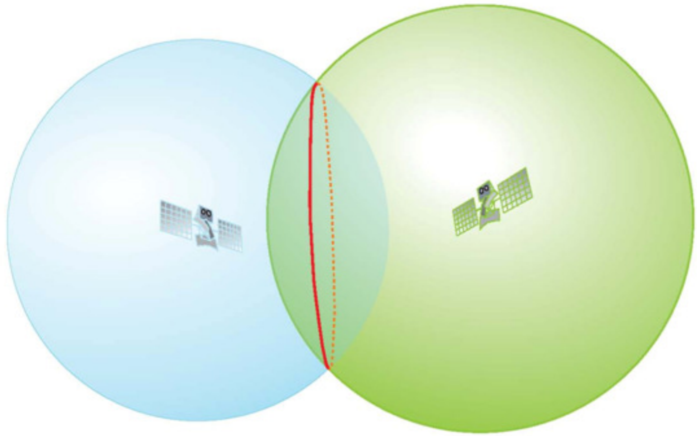


To determine a position in a
3 dimensional space it takes in theory
3 distance measurements from
3 satellites

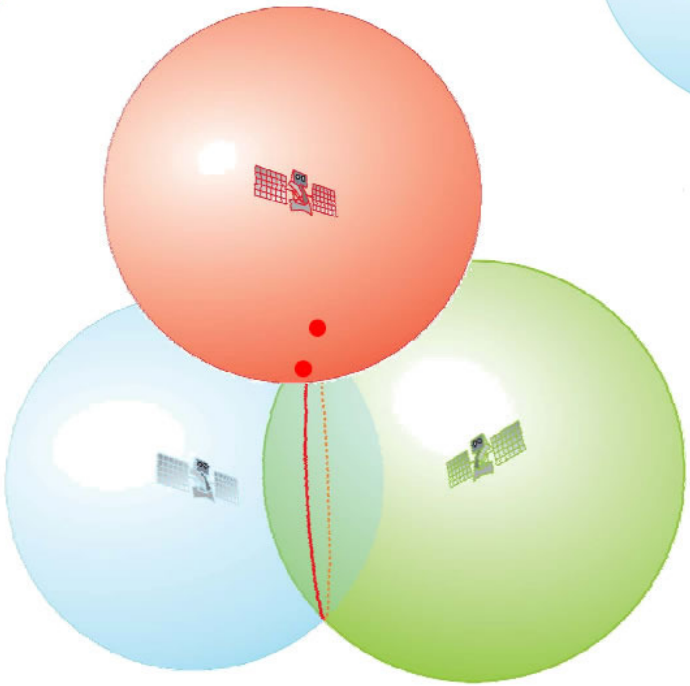
Pseudorange positioning

One-satellite fix position





Two-satellite fix position



Three-satellite fix position (trilateration)

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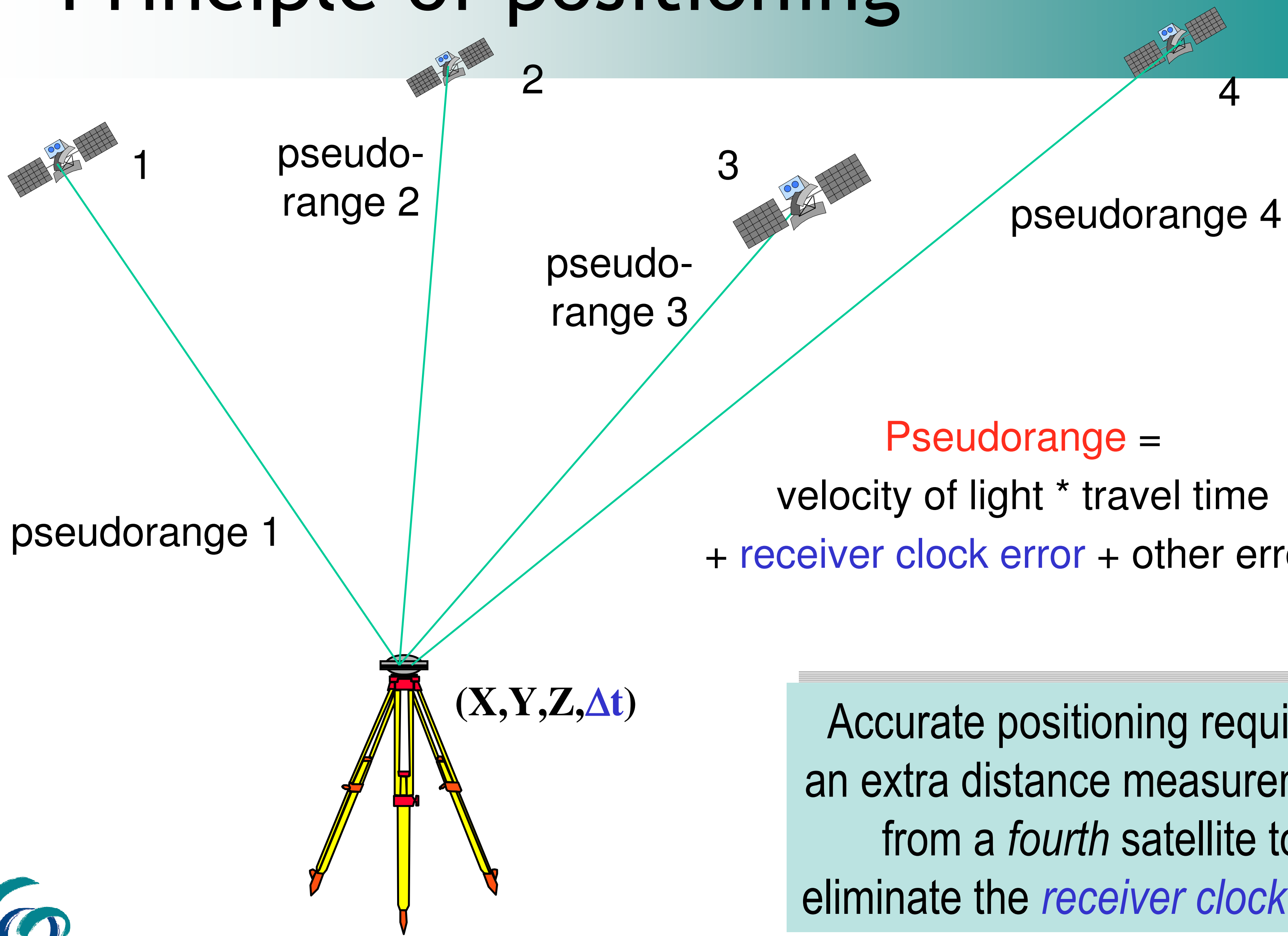
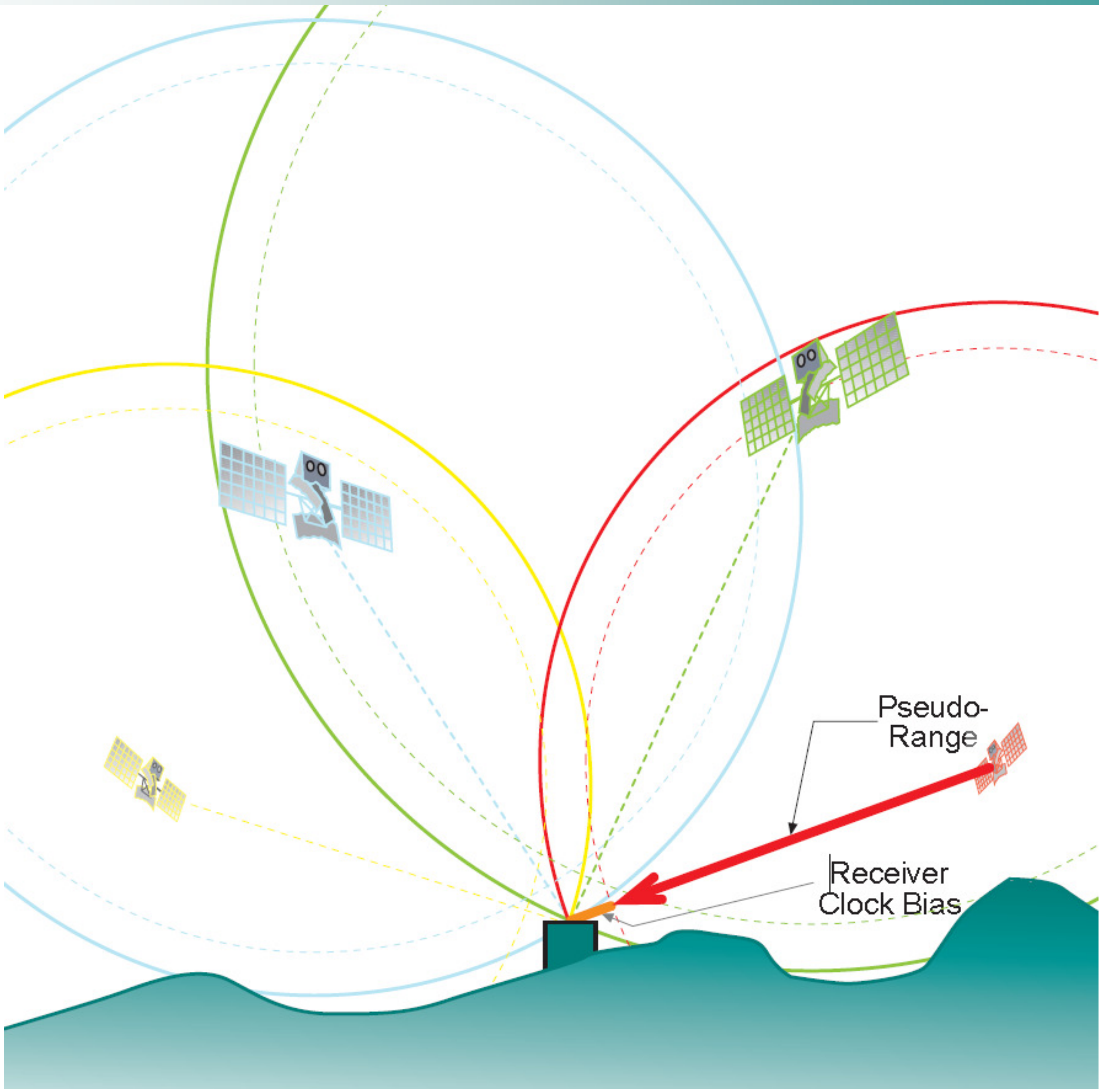
Principle of positioning



Pseudorange =
velocity of light * travel time
+ receiver clock error + other errors

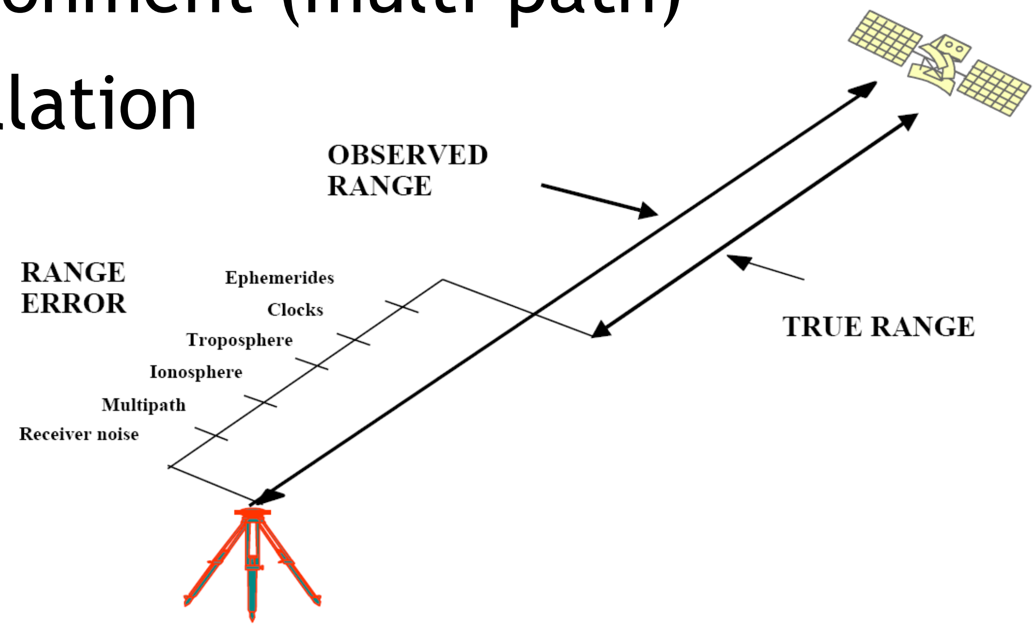
Accurate positioning requires an extra distance measurement from a *fourth* satellite to eliminate the *receiver clock error*

Synchronization bias of the receiver clock

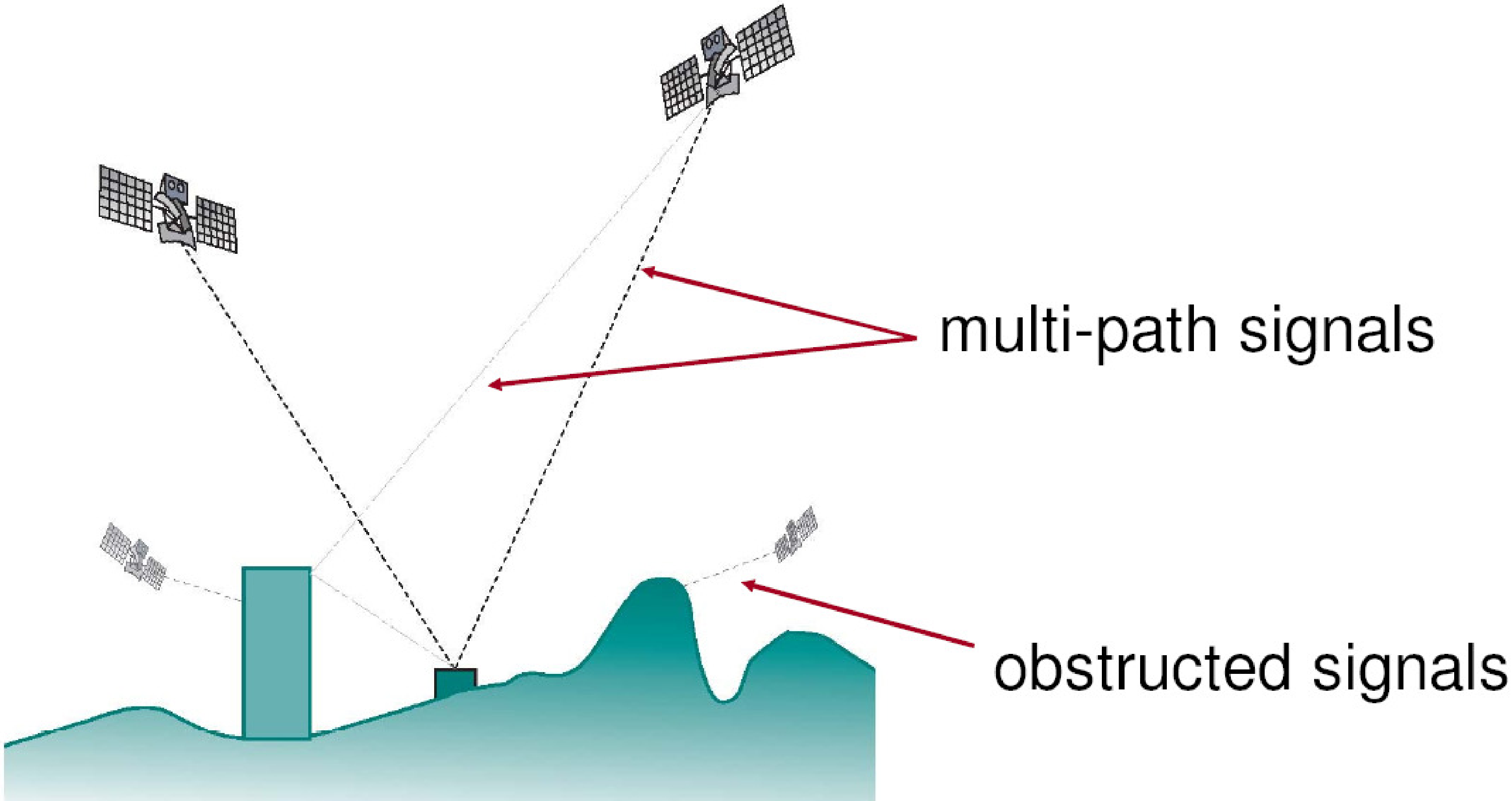


Error sources in absolute positioning

- ~~Selective availability~~
- Satellite clock and orbit errors
- Ionospheric and tropospheric delays
- Receiver's environment (multi-path)
- Satellite constellation



Receiver's environment errors



Magnitude of the error sources*

satellite clock	2 m
satellite position	2.5 m
ionospheric delay	5 m
tropospheric delay	0.5 m
receiver noise	0.3 m
multi-path	0.5 m
Total RMSE Range error: $\sqrt{2^2 + 2.5^2 + 5^2 + 0.5^2 + 0.3^2 + 0.5^2} =$	5.97 m

* Absolute, single-point positioning based on code measurements

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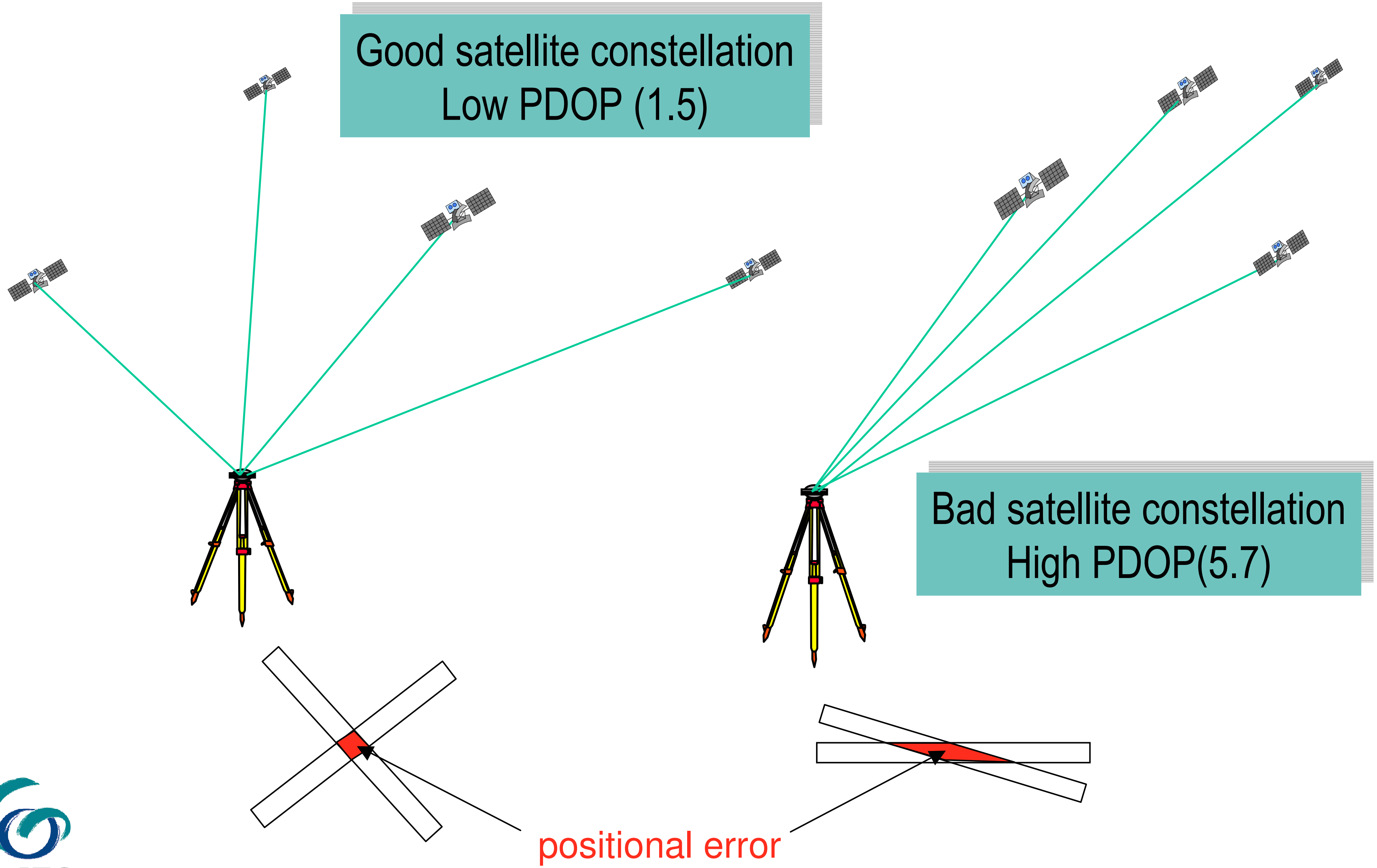
Satellite constellation



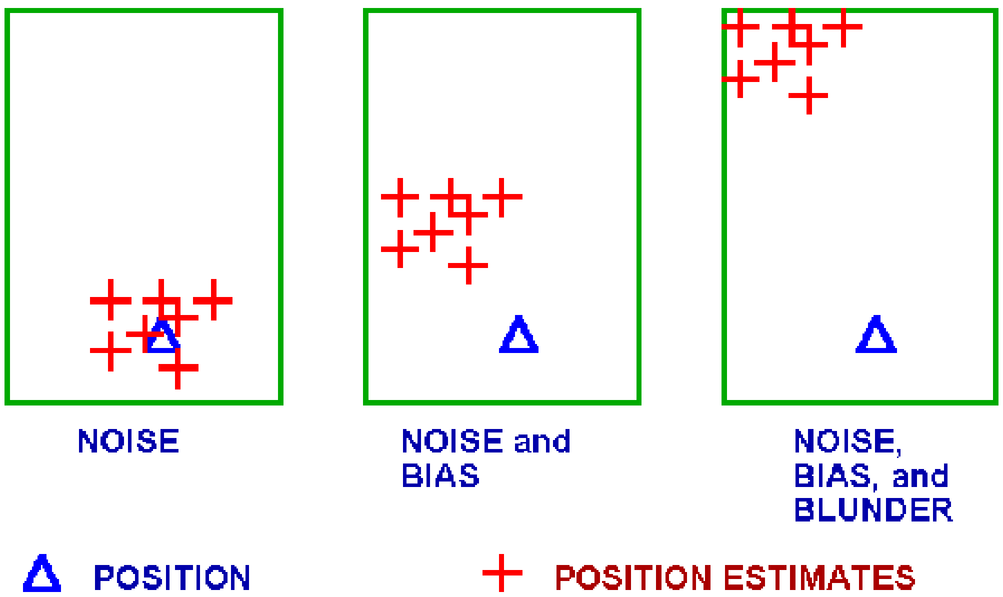
Positional accuracy in absolute positioning

Absolute, single-point positioning based on code measurements:

Typical error: **5-10 m** (horizontal accuracy)

Typical error: **2-5 m** (horizontal accuracy) when using a dual-frequency receiver or the encrypted military signals (P-code)

Location errors: noise, bias and blunder



- **Noise (random) errors:** noise in code and noise in receiver, multi-path.
- **Bias (systematic) errors:** clock, satellite position, ionosphere, troposphere, GDOP effects.
- **Blunder:** incorrect geodetic datum, software failures, hardware problems etc.

Systematic errors (bias) removal is essential to improve the positional accuracy!

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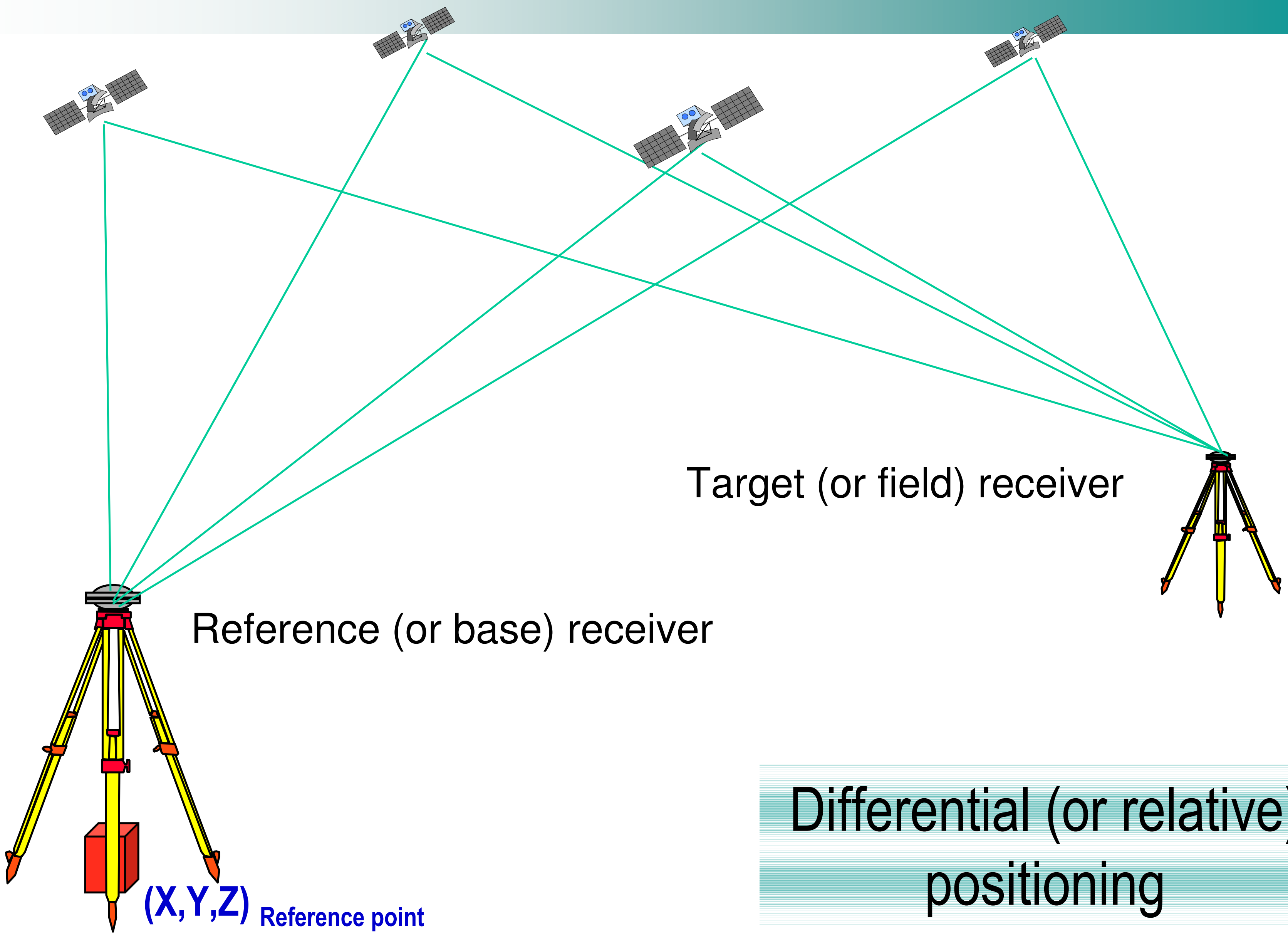
Relative positioning



Differential (or relative) positioning

Positional accuracy in relative positioning

Relative, single-point positioning based on code measurements:

Typical error: **0.5 - 5m** (horizontal accuracy)

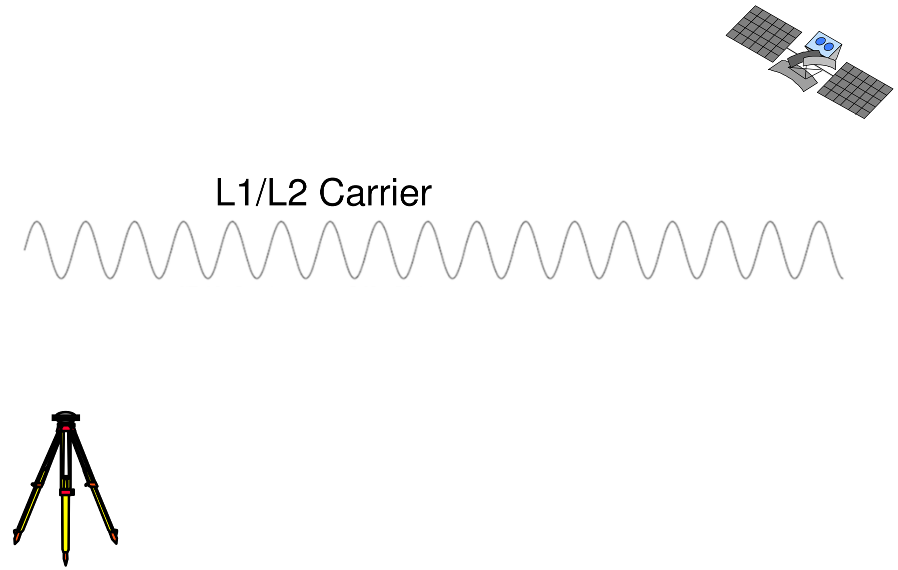
Positional accuracy in relative positioning

Relative, single-point positioning based on carrier phase measurements:

Typical error: **2mm – 2cm** (horizontal accuracy)

Carrier phase measurements

Carrier phase measurement is a technique to measure the range (distance) of a satellite by determine the number of cycles of the (sine-shaped) radio signal between sender and receiver.



The number of cycles is determined in a long observation session from the change in carrier phase (Phase Shift Keying). This change happens because the satellite is orbiting itself.

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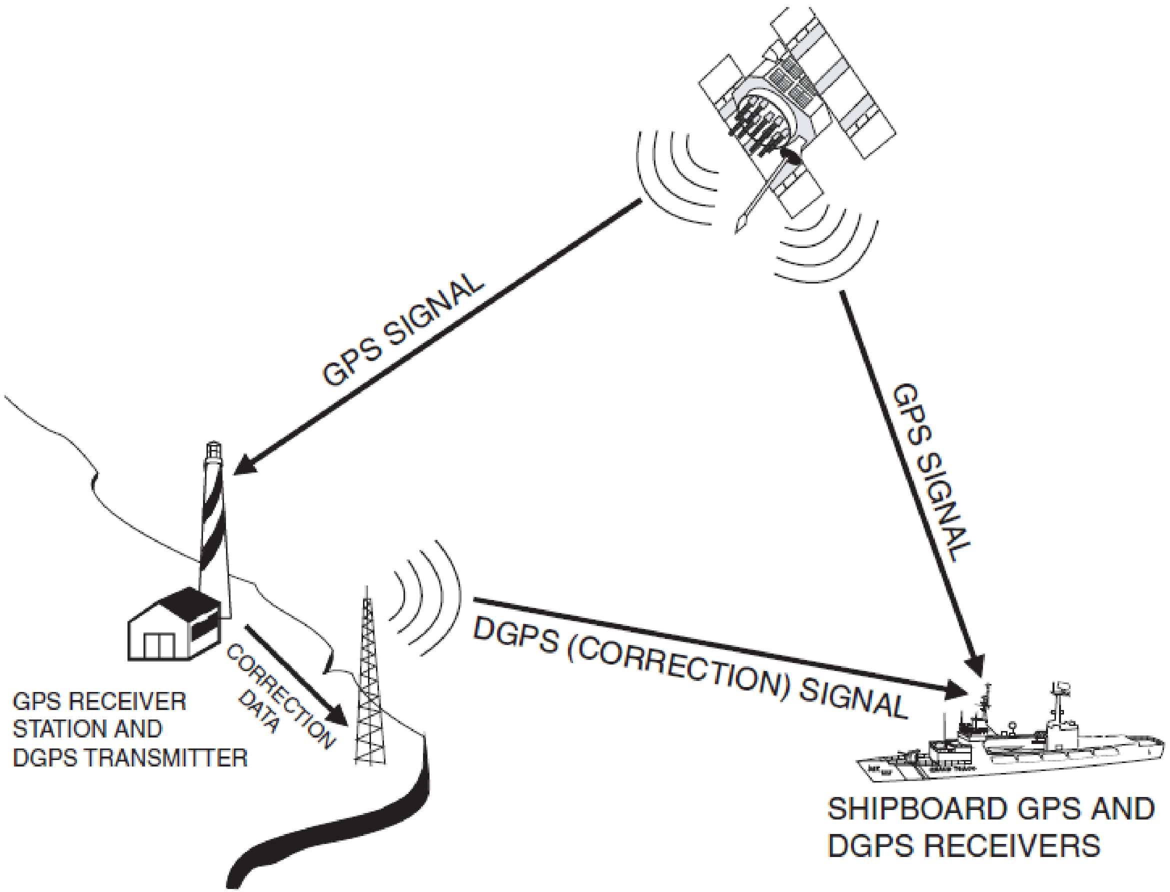
Relative (differential) survey techniques using carrier phase measurements

- Static
- Stop and go kinematic
- Pseudo-kinematic
- Kinematic
- Rapid static
- On-the-fly (OTF)/real-time kinematic (RTK)

Real-time kinematic positioning

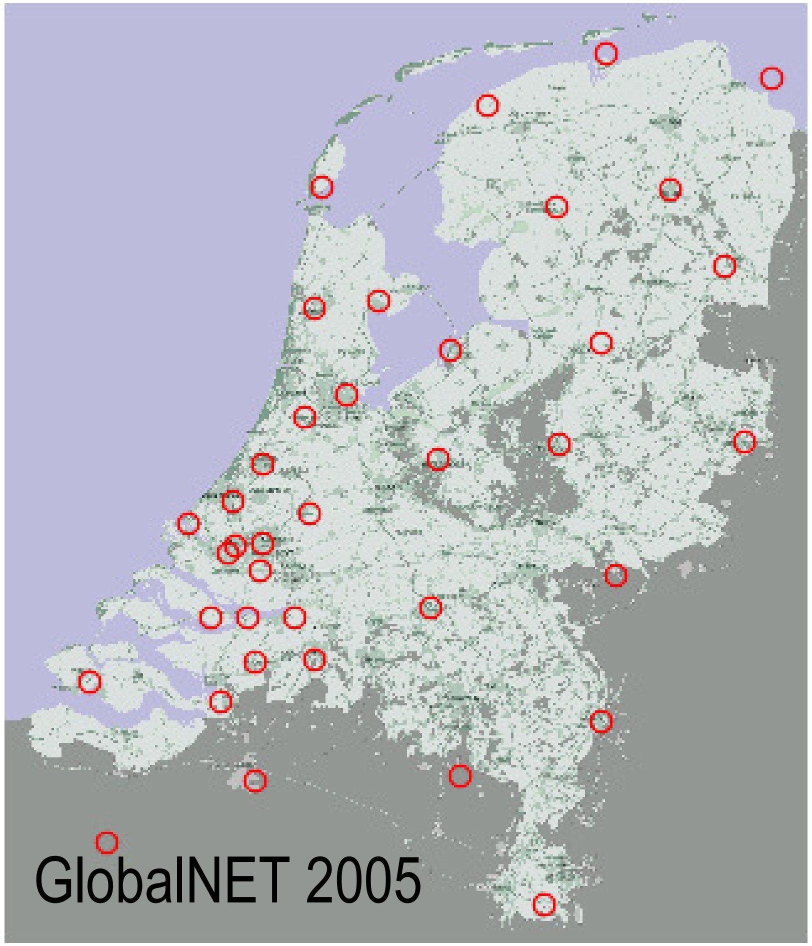


Network positioning

Network positioning

Relative positioning using a network of reference stations

LNR Globalnet



NLR Globalcom

http://www.lnrglobalcom.nl

Network positioning

GlobalNET 2005: Reference Station at ITC

GPS Referentie Stations

GPS Referentie Stations

Enschede

Station ID
0550

Position and Height
52 13'25" N
6 53'10" E
108.05 m

Location
This station is located on the roof of the International Institute for Geo-Information Science and Earth Observation (ITC) in the centre of Enschede.

This station is sending RTCM 18/19 RTK data and storing static data 24 hours a day.

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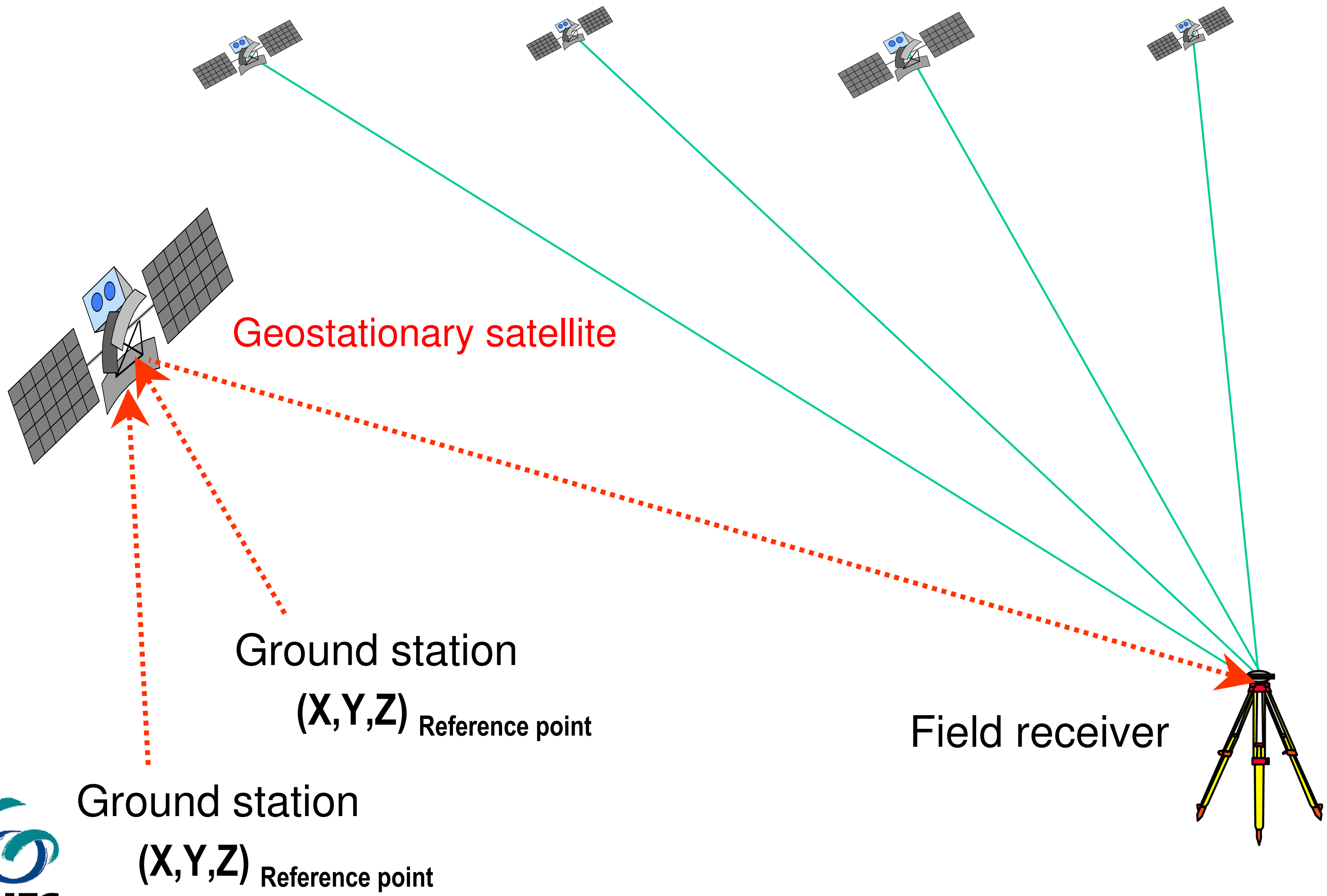
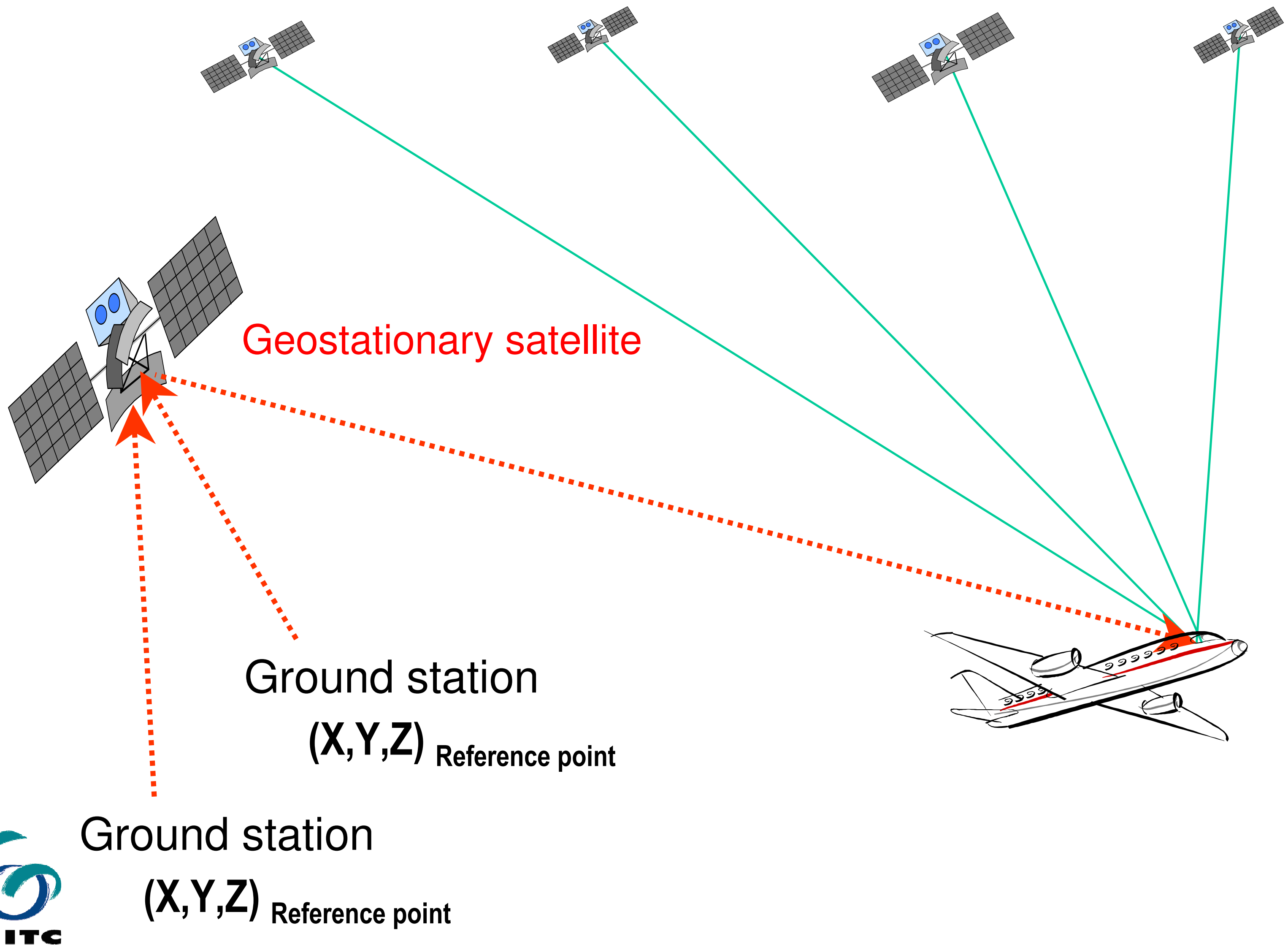
Satellite-Based Augmentation Systems (SBAS)

Satellite-based Augmentation Systems



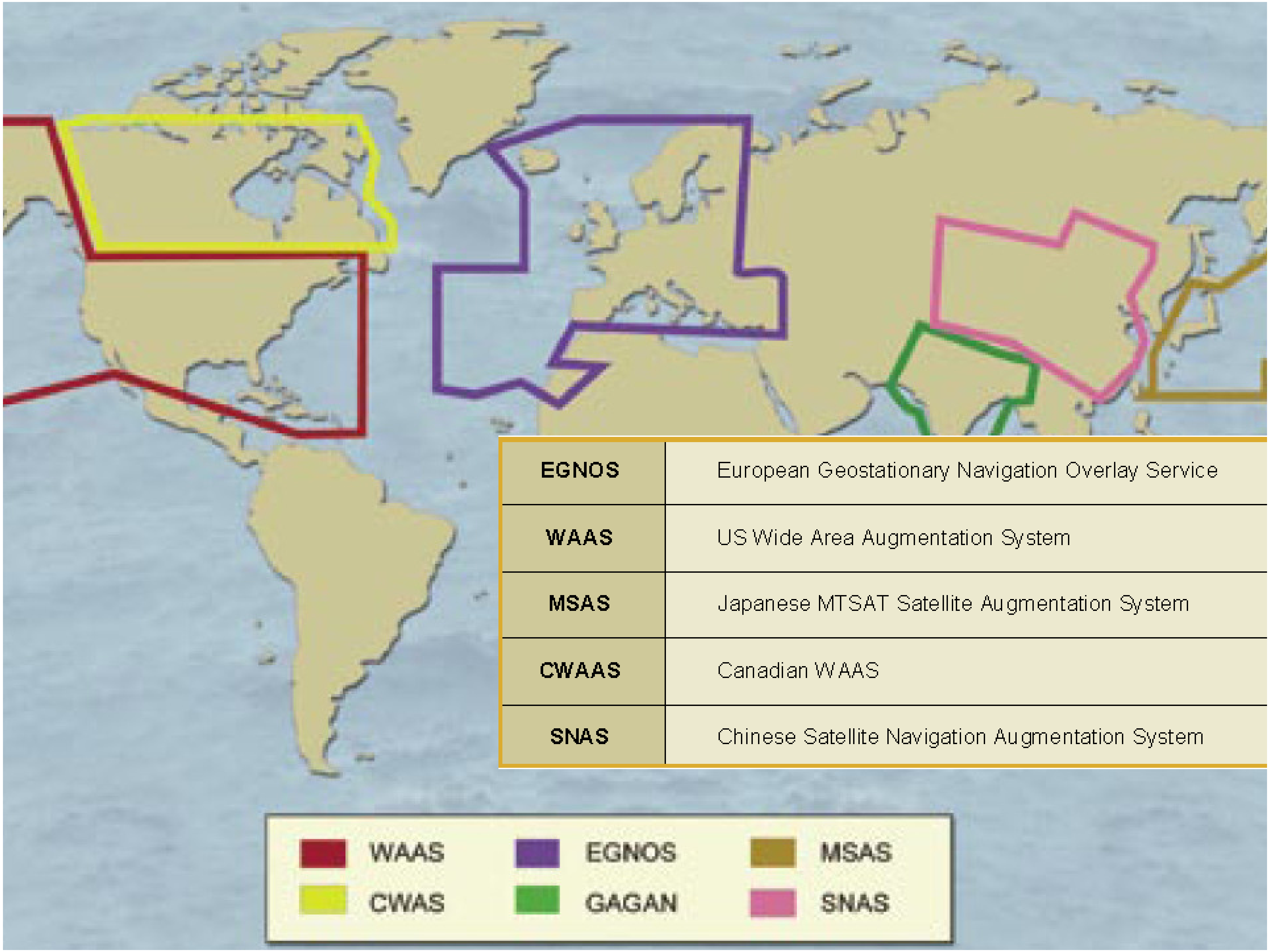
Satellite-based Augmentation Systems



Operational systems

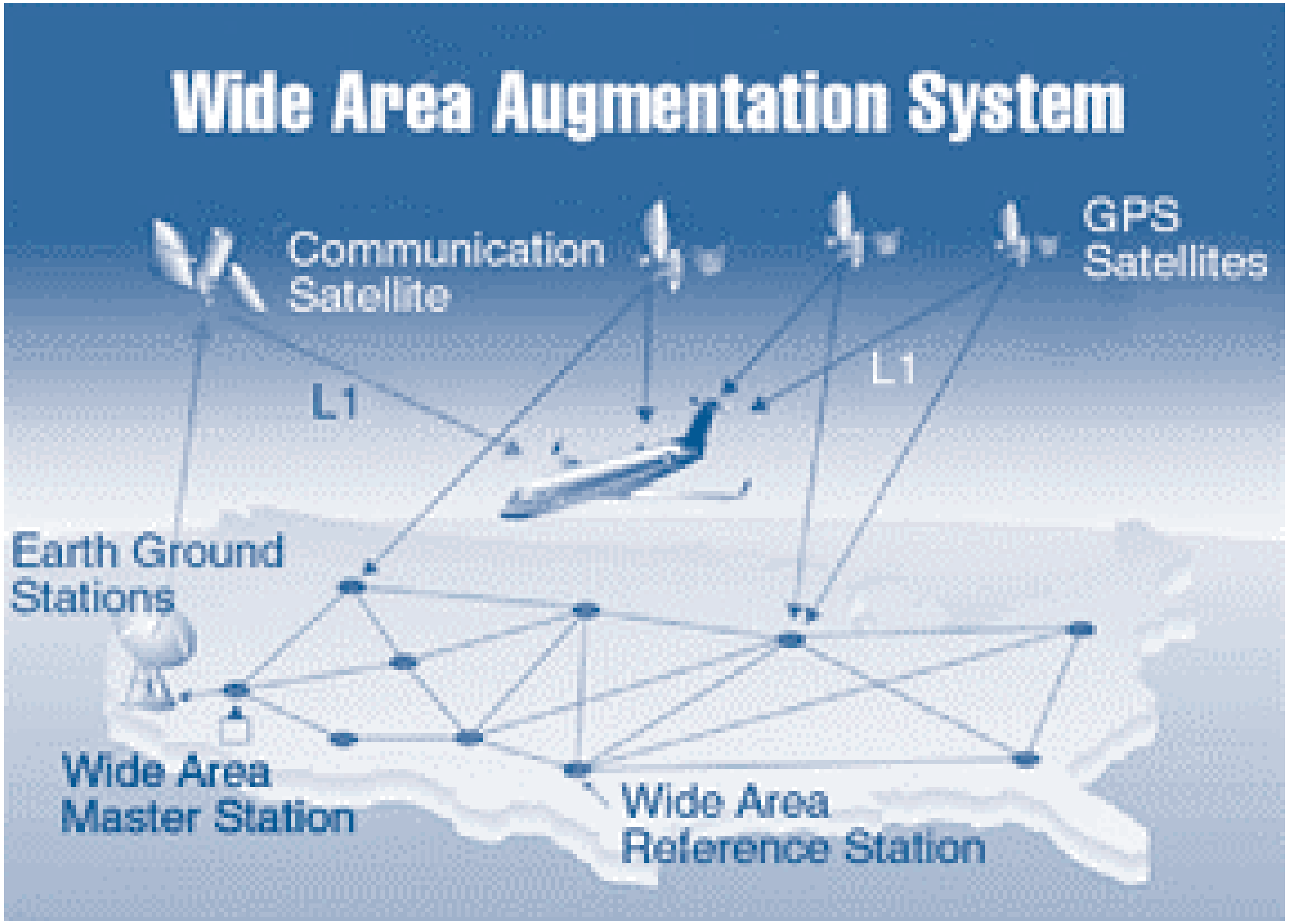
- WAAS (Wide-Area Augmentation System) for North America
- EGNOS (European Geostationary Navigation Overlay Service) for Europe
- MSAS (Multi-functional Satellite Augmentation System) for eastern Asia

WAAS, EGNOS, MSAS

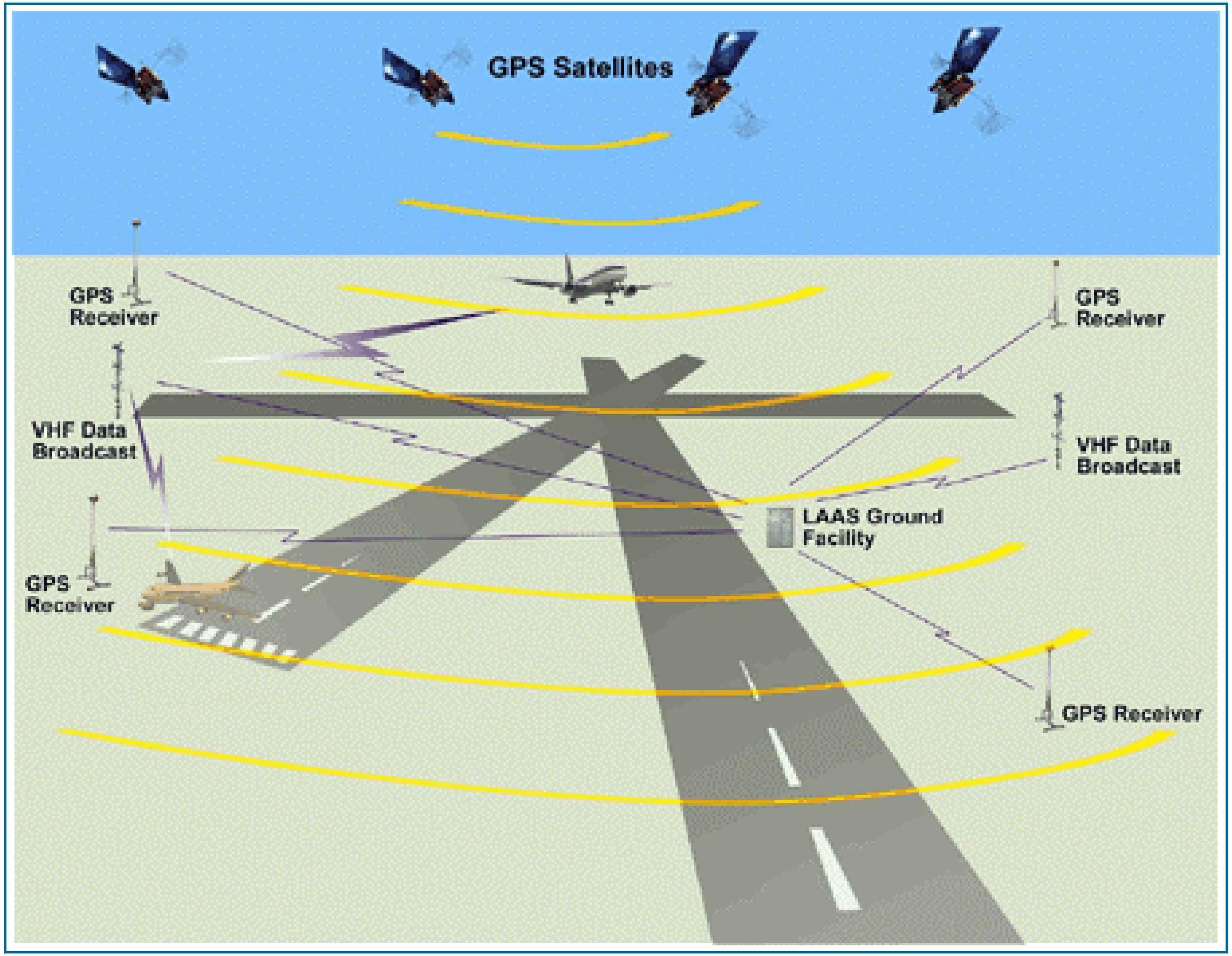


EGNOS	European Geostationary Navigation Overlay Service
WAAS	US Wide Area Augmentation System
MSAS	Japanese MTSAT Satellite Augmentation System
CWAAS	Canadian WAAS
SNAS	Chinese Satellite Navigation Augmentation System

Wide Area Augmentation System (WAAS)

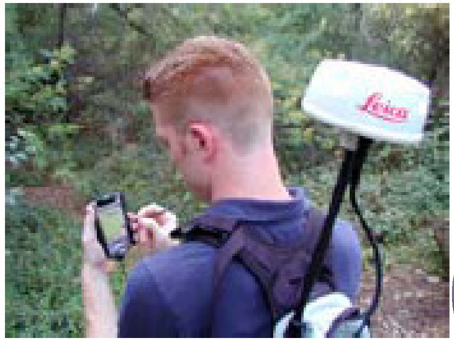


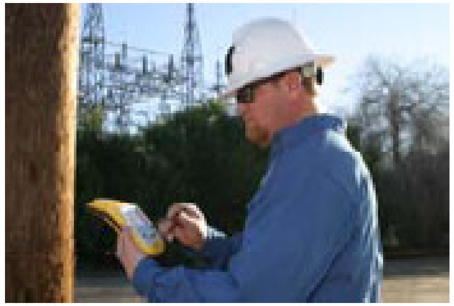
Local Area Augmentation System (LAAS)



The end !

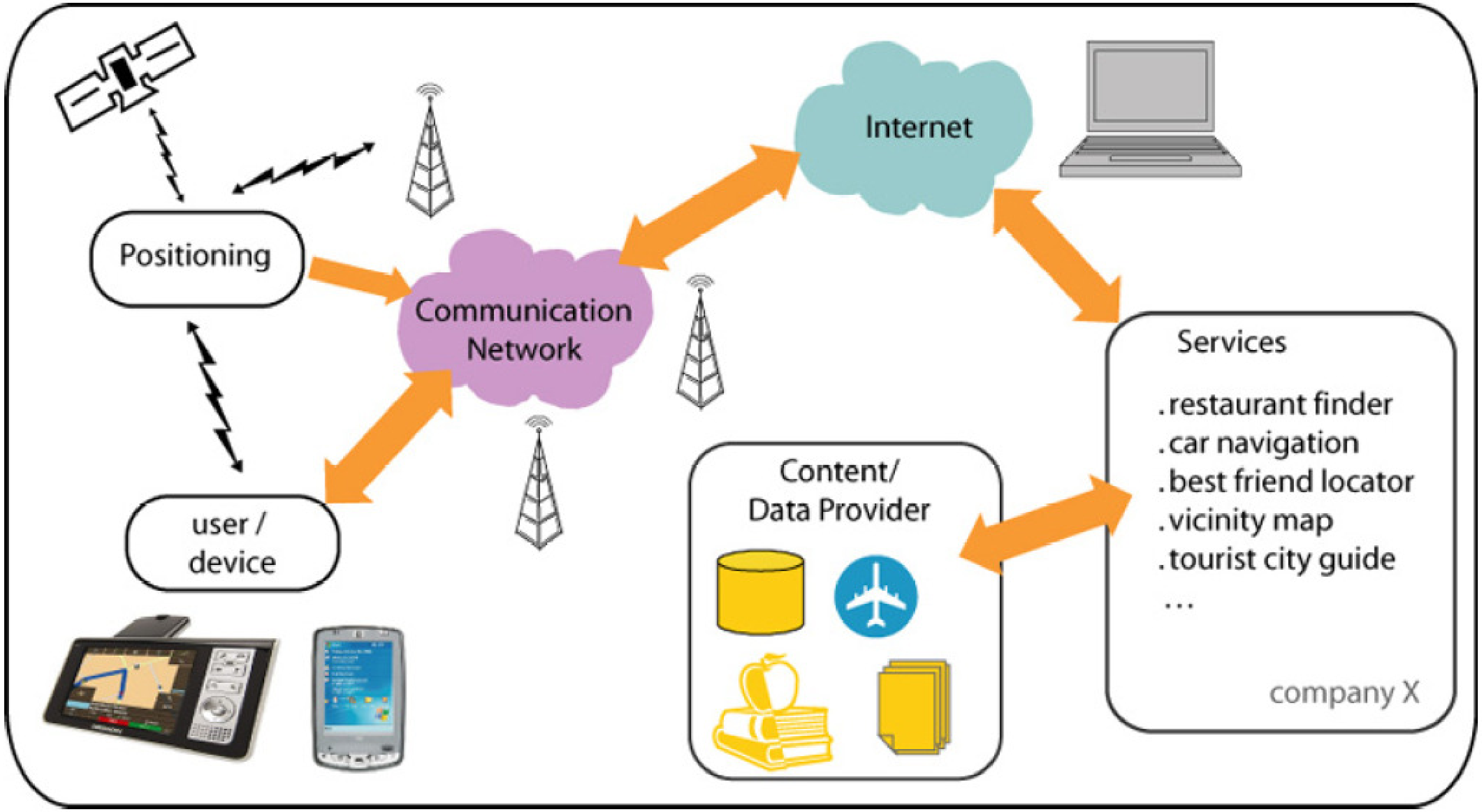
Mobile GIS applications





Data collection with a mobile computer

Location-Based Services (LBS)

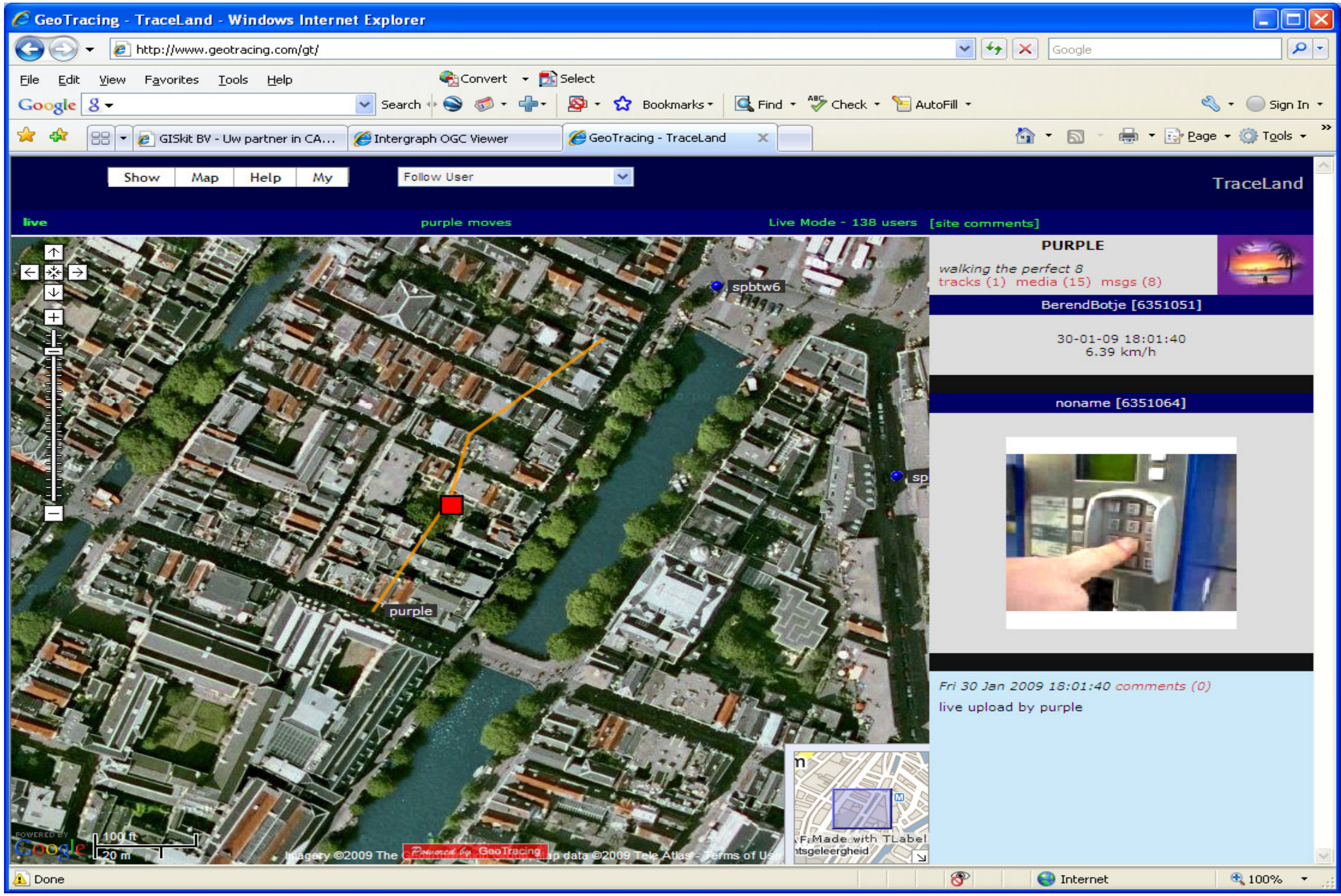


Location-Based Services on a Mobile computer or mobile phone.

Location-Based Services - Applications

1. Location based information services (e.g. search for the nearest restaurant or the nearest banking cash machine)
2. Location based emergency service (e.g. pinpoint your location on dialing 9-1-1)
3. Location based billing service (e.g. preferential billing for calling by establishing personal zones such as a home zone or work zone).
4. Fleet applications (tracking a vehicle and/or operator).

LBS application - Mobile phone tracking



http://geotracing.com/tland