GPS Basics

History excerpt

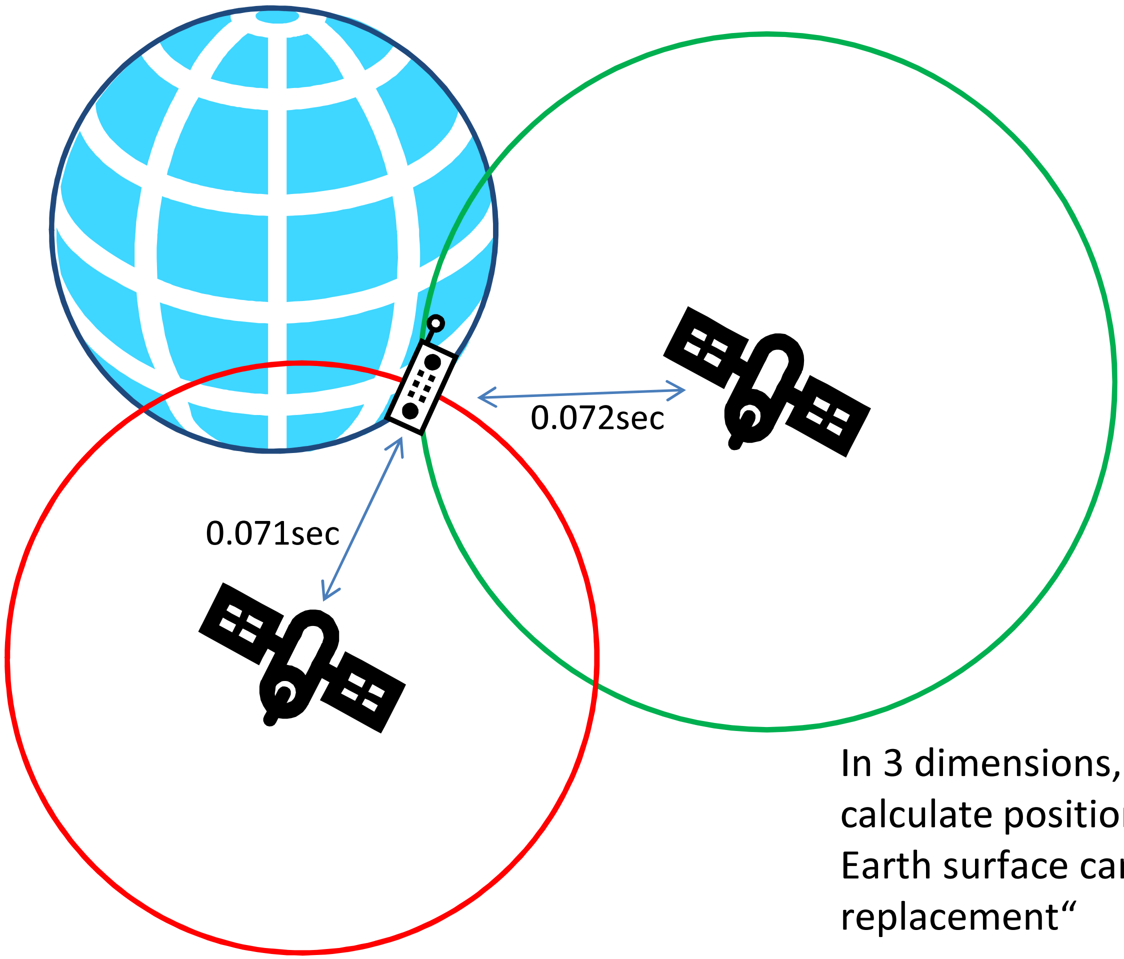
- 1940s: First ground based navigation developed (Loran, Decca)
- 1960s: First tests of a satellite based system (Transit)
- 1973: Decision the create an unified satellite navigation system (Navstar, later simply referred to as „GPS“)
- 1983: directive by Ronald Reagan to make GPS freely available for civilian use
- 2000: directive by Bill Clinton to turn of „selective availablity“ increasing accuracy of civilian GPS from 300m down to 2m
- 2004: first successful tests of assisted GPS for mobile phones by Qualcomm

Basic Idea of GPS (I)

- Distance = time ∗ speed
- E.g. sound of thunder → ~340m/s → 3 sec. Time between flash & sound means 1km distance to thunderstorm

Basic Idea of GPS (II)

Message sent by a GPS satellite consists of sat number, sat position and sat time.
The GPS receiver checks against the local time to calculate delay of signal.



In 3 dimensions, 4 satellites are needed to calculate position through trilateration. Earth surface can be used as a „satellite replacement“

GPS problems

- GPS can never provide exact position information - only probability (which may improve over time)
- Accuracy depends on many factors including atmospheric problems
- Accuracy can vary over time on the same location

Precision Measurements

- GDOP – geometric dilation of precision:
  Over all precision in 3D-space and time differences
- PDOP – positional dilation of precision:
  Positioning precision in 3D-space
- HDOP – horizontal dilation of precision:
  Positioning precision on 2D surface
- VDOP – vertical dilation of precision
- TDOP – time dilation of precision

Don‘t mess precision with truth and accuracy: precise numbers don‘t have to be true. Only high precision and truth will provide high accuracy. A GPS receiver can not always tell you if the calculated position is true and therefore accurate (only by aquiring enough redundant information)!

DOP Value	Rating
1	Ideal
1-2	Excellent
2-5	Good
5-10	Moderate
10-20	Fair
>20	Poor

Source: http://en.wikipedia.org/wiki/PDOP

System-inherent error sources

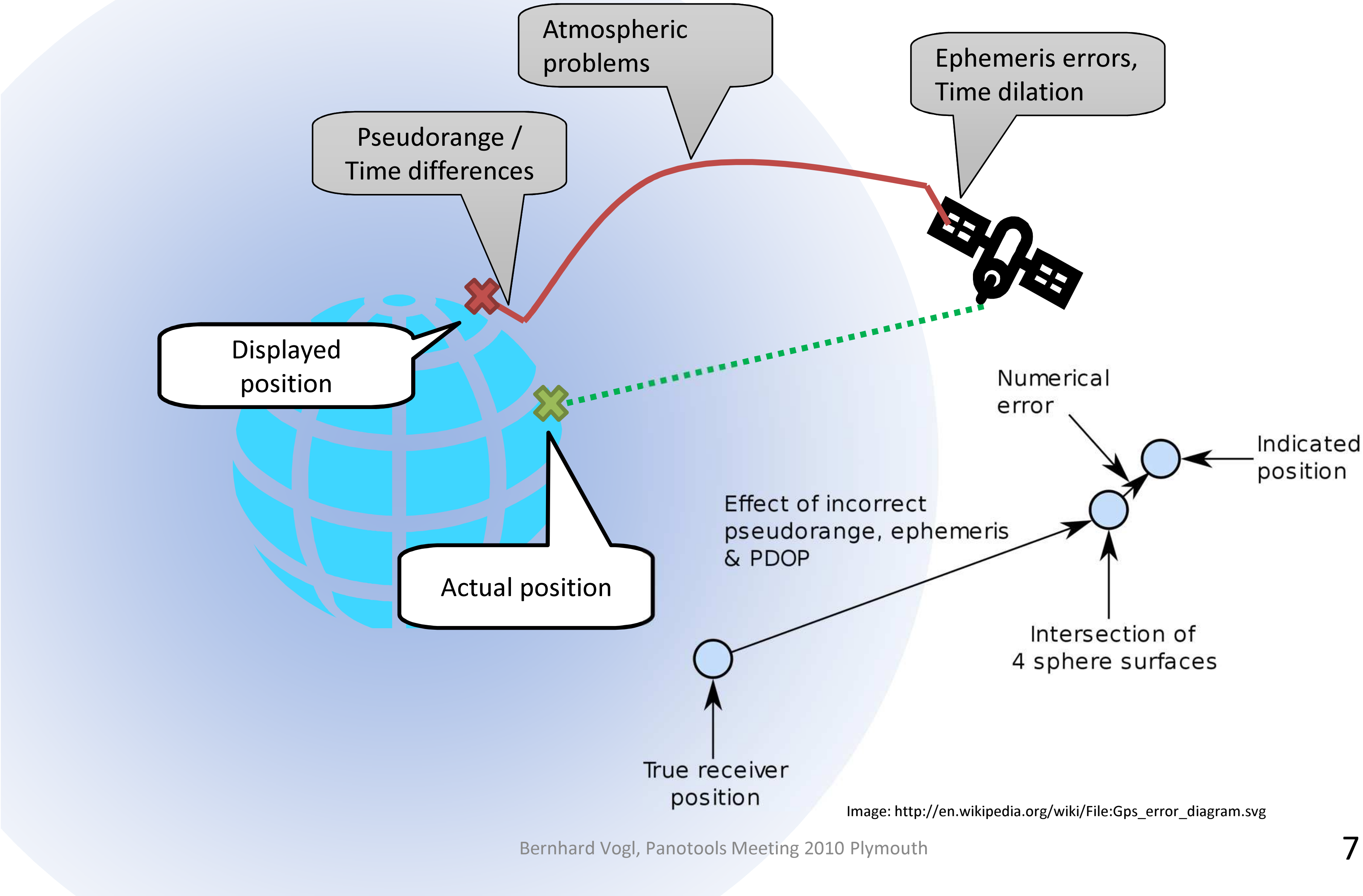


Image: http://en.wikipedia.org/wiki/File:Gps_error_diagram.svg

Oh, all these strange words!

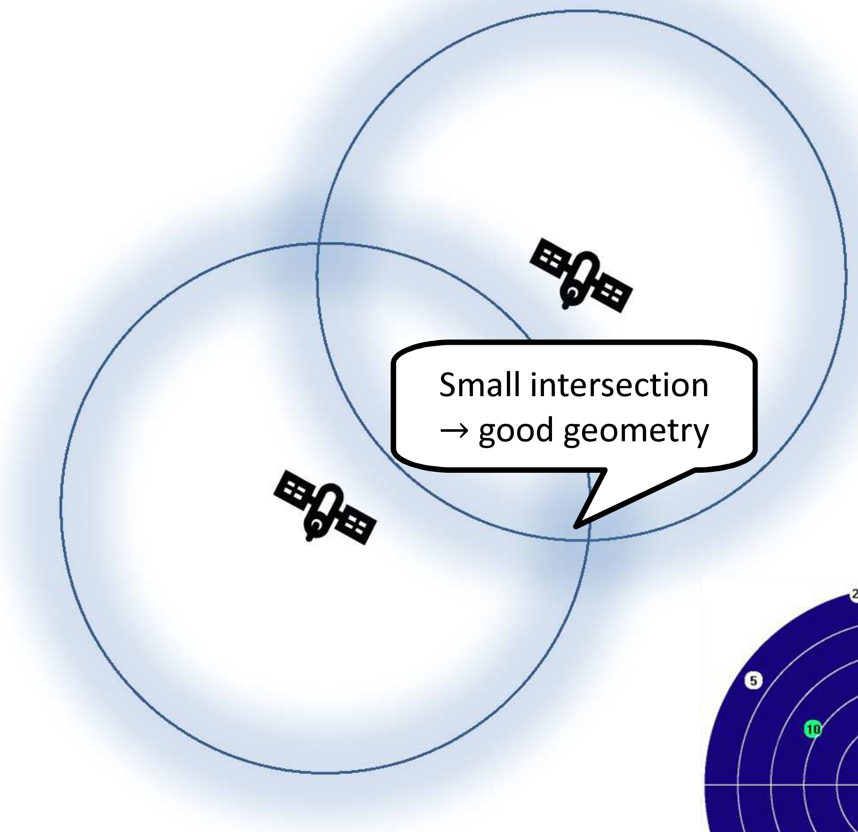
- An ephemeris (plural: ephemerides) is a table of values that gives the positions of astronomical objects in the sky at a given time or times. In GPS vocabulary, the ephemeris describes the position of the satellite orbit at a given time.
- Time dilation can arise from
  - relative velocity of motion between the observers, and
  - the difference in their distance from gravitational mass.

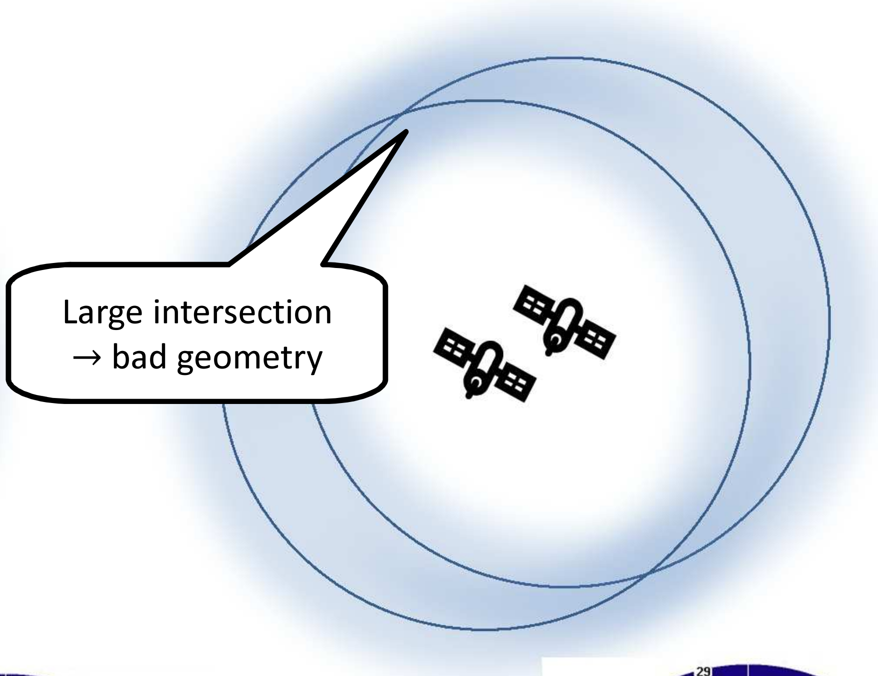
  For GPS navigation, time has to be exact down to 20 Nanoseconds.
  GPS satellites orbit at a speed of 3874 m/s and a distance of 20200 km. Time dilation sum up to a difference of 38 Microseconds/day resulting in a position error of 10 km per day. So the satellite's atomic clocks run slightly slower to compensate for this effect.
  More at http://www.kowoma.de/gps/Fehlerquellen.htm and http://homepage.univie.ac.at/Franz.Embacher/rel.html (all German)
- Pseudo range: To determine its position, a satellite navigation receiver will determine the ranges to (at least) four satellites as well as their positions at time of transmitting. Knowing the satellites' orbital parameters, these positions can be calculated for any point in time. The pseudoranges of each satellite are obtained by multiplying the speed of light by the time the signal has taken from the satellite to the receiver. As there are accuracy errors in the time measured, the term pseudo-ranges is used rather than ranges for such distances (receiver clock offset).

Source: Wikipedia

Ground-based reception problems

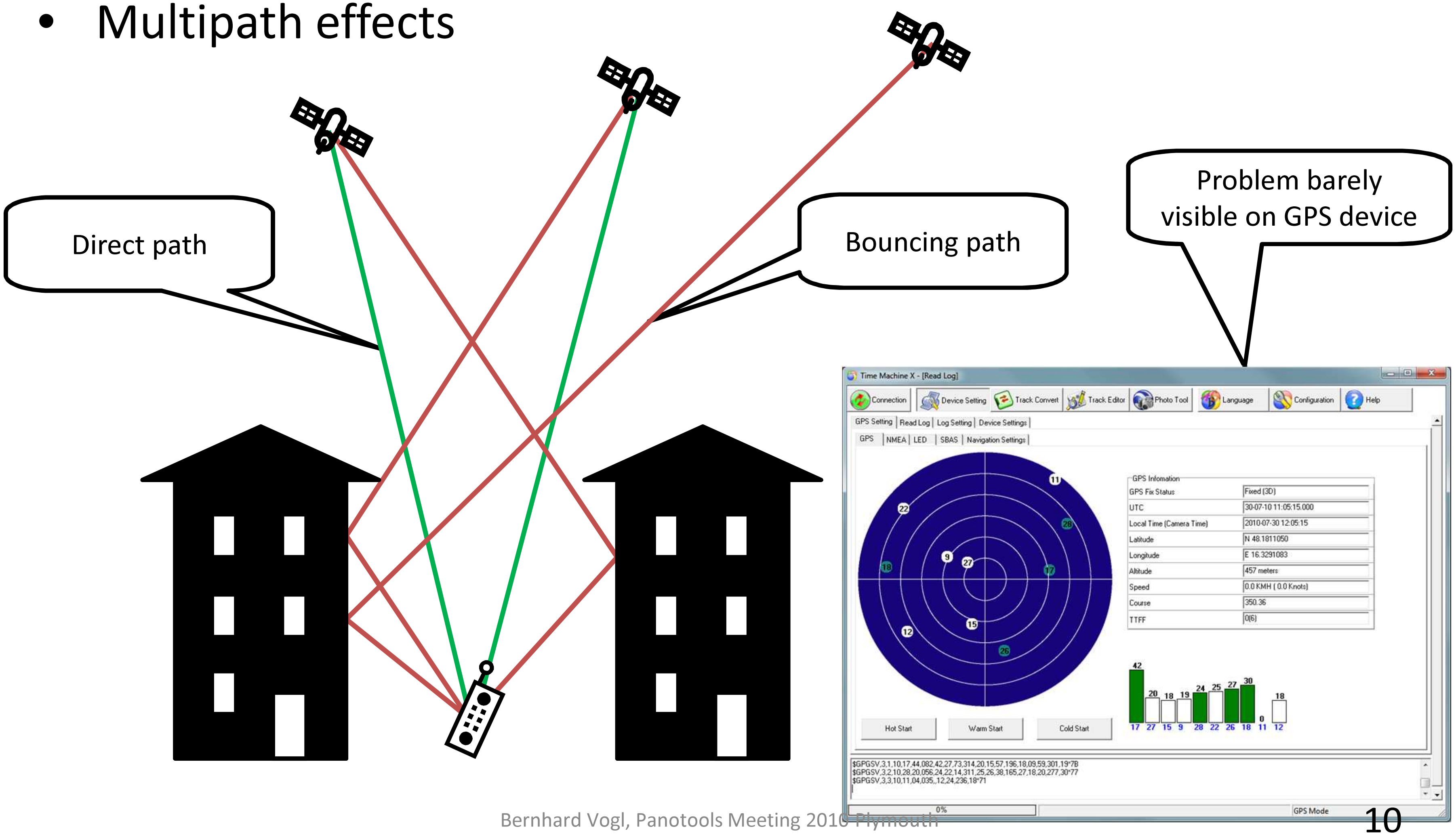
- Satellite „geometry“





Ground-based reception problems

- Multipath effects



Error dimensions and correction

Error source	Inaccuracy	Fix
Atmospheric effects	± 5.5 meters	SBAS, DGPS
Shifts in the satellite orbits	± 2.5 meters	DGPS, ~Almanac (ephemeris data)
Clock errors of the satellites' clocks	± 2 meters	GPS (RAIM), ~Almanac
Multipath effect	± 1 meter	
Calculation and rounding errors	± 1 meter	

Source: http://en.wikipedia.org/wiki/GPS

Increasing GPS performance: The almanac

Consists of…

…coarse orbit and status information for each satellite in the constellation (ephemerides)

…an ionospheric model

…information to relate GPS derived time to Coordinated Universal Time (UTC)

Provided via A-GPS or encoded within satellite signal (Transfer time per satellite 12.5 min). Parts of the almanac can be pre-calculated by the GPS receiver (don’t remove batteries!)

Increasing GPS performance: Auxiliary technologies

- RAIM (Receiver Autonomous Integrity Monitoring)
  Modern GPS receivers can detect faults within redundant satellite signals. Various implementations exist, needs 6 satellites to detect positioning failure
- A-GPS (Assisted GPS): improves startup performance
  Can provide: Almanach (orbital data) of satellites, precise time, rough position through mobile phone cell position
- DGPS (Differential GPS): improves precision
  Uses ground based transmitters to broadcast its exact position and/or atmospheric correction data
- SBAS (Satellite based augmentation system): improves precision, primary for air navigation
  U.S.=WAAS, Europe=EGNOS, Japan=MSAS, India=GAGAN
  Augments GPS through ground based stations and provides correction data through special satellites. Each system should only be used in its respective location!

Increasing GPS performance: best practises

- Never trust your GPS!
- Use a modern GPS device with high sensitivity
- Provide clear sight to satellites
- Assist your GPS
  Some devices allow manual entry of new location
  non A-GPS devices: allow almanach retrieval (~15 minutes)
- Give device enough time to get initial fix
  Do not move device until position is fixed
- Use more samples for higher accuracy
  Stay at the same place for some time to improve data

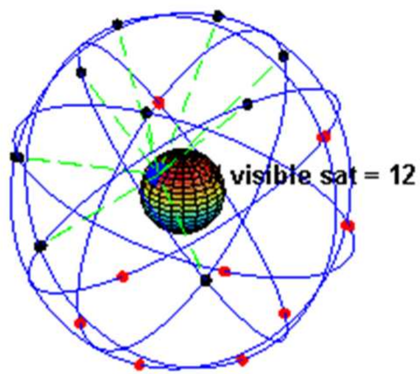
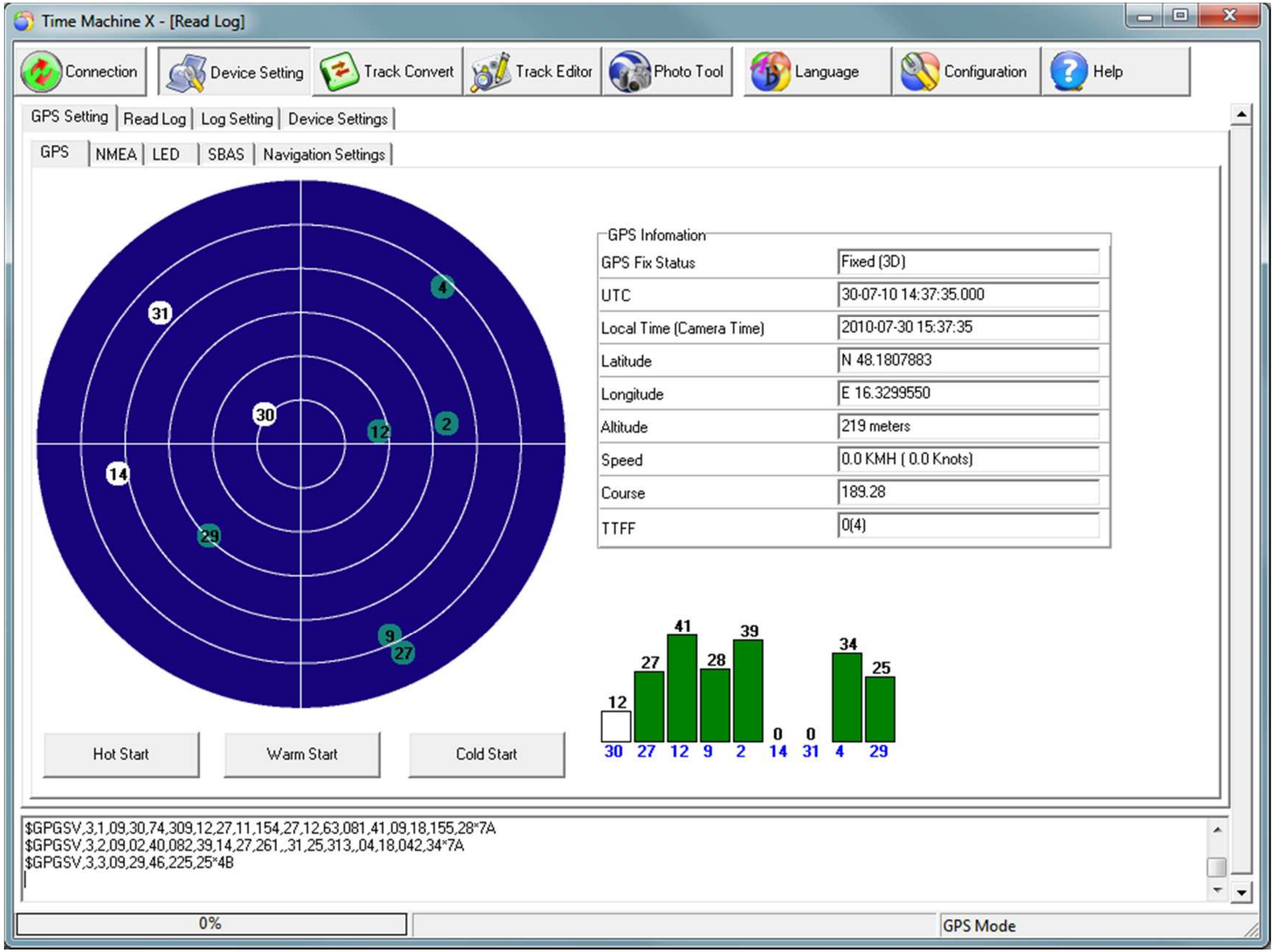
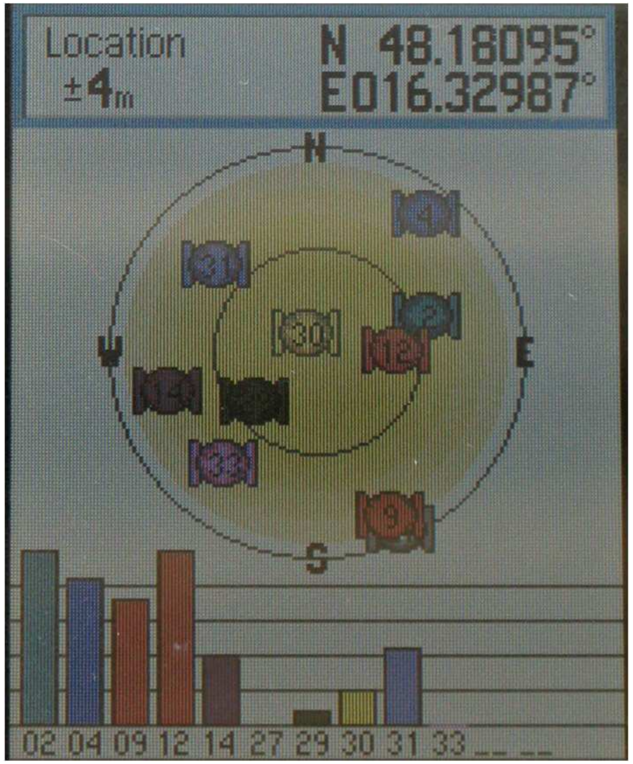


Image: http://en.wikipedia.org/wiki/File:ConstellationGPS.gif

Reading GPS information



Understanding Precision on Garmin Devices



Precision is displayed as CEP (circular error probability)

$\pm$ 4m means: out of all measured positions…

- 50% of values are inside a 4 m radius
- 95% are inside the 2x (=8 m) radius
- 98.9 % are inside the 2.55x (=10.2 m) radius

Despite the GPS saying „4m accuracy“, a single position measurement could well be somewhere within a 10m radius!

Source: http://www.kowoma.de/en/gps/accuracy.htm

GPS device types

GPS data logger

Handheld

Mobile

Phone

Compass

Why do you need a compass?

GPS is basically direction-unaware. Directions can only be calculated during movement.

However - some GPS devices have a compass included.

Use the compass at some distance to the camera!
Most cameras emit magnetic fields during operation.

GPS Data Logger

Records a GPS track, consisting of actual position every “n“ seconds

- Pro:
  - Lightweight and robust
  - Easy to handle
  - Long battery life
- Con:
  - No navigation aid
  - No data display

Handheld GPS device

Primariy aim is for hiking and pedestrian navigation. Modern devices can also record GPS tracks

- Pro:
  - Lightweight and robust
  - Easy to handle
  - Long battery life
  - Some devices have car navigation included
- Con:
  - More expensive than simple car navigation kits and data loggers

Mobile Computers

Can do anything, including GPS navigation

- Pro:
  - Universal (well, it‘s a computer)
  - Multi-tasking (navigation and data-logging)
- Con:
  - Resource (battery) hungry
  - Expensive and delicate to handle

Mobile Phones

Call and navigate, but at some cost

- Pro:
  - Modern phones includes A-GPS
- Con:
  - Most devices can only be used for either navigation or data logging – but not at the same time
  - Resource hungry – will eat your precious battery while GPS is on

Using a GPS device for (panorama) photography

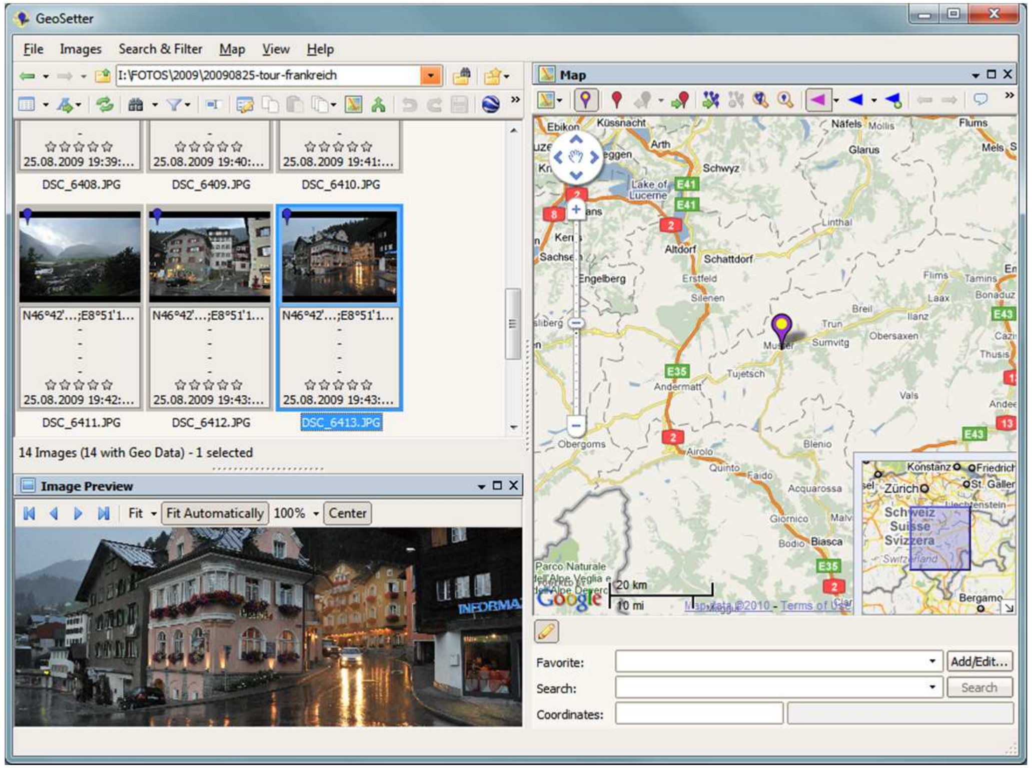
Basic Concept:

- Record a GPS track during your photography job
- Download the GPS track from your device and connect it to your images
- Update EXIF data of images

Some devices are specifically designed to connect to your camera and automatically add GPS information to EXIF data.

Connecting your GPS track to your photos

Geosetter:
http://www.geosetter.de/en/



Links

Wikipedia: http://en.wikipedia.org/wiki/Gps

GPS explained: http://www.kowoma.de/en/gps/index.htm

Additional German Link: http://www.toralf-schumann.de/html/gps_main.html