Mobile Systeme
Grundlagen und Anwendungen standortbezogener Dienste

Location Based Services in the Context of Web 2.0

Department of Informatics - MIN Faculty - University of Hamburg
Lecture Summer Term 2007

Dr. Thilo Horstmann

CLDC

NMEA

MIDP

Google Earth

OpenGIS

SQL

KML

Bluetooth

Mash-Ups

Web 2.0

J2ME

Loxodrome

Euclidean Spaces

RDMS

GPS

PostGIS

GPX

Maps

JSR 179

Polar Coordinates

Threads

API

Today: GPS

- Introduction: Map Datums
- GPS
- Processing GPS data: NMEA

Last week ...

- the earth was a ideal sphere
- However,
  - in fact the earth is flattened at the poles
  - and more convex in the equator region
  - even worse, the earth has more dents and convexities that does not follow any particular pattern
- In addition, we saw that our calculated distance between Hamburg and New York differs from the real distance found in literature.
- Hm...

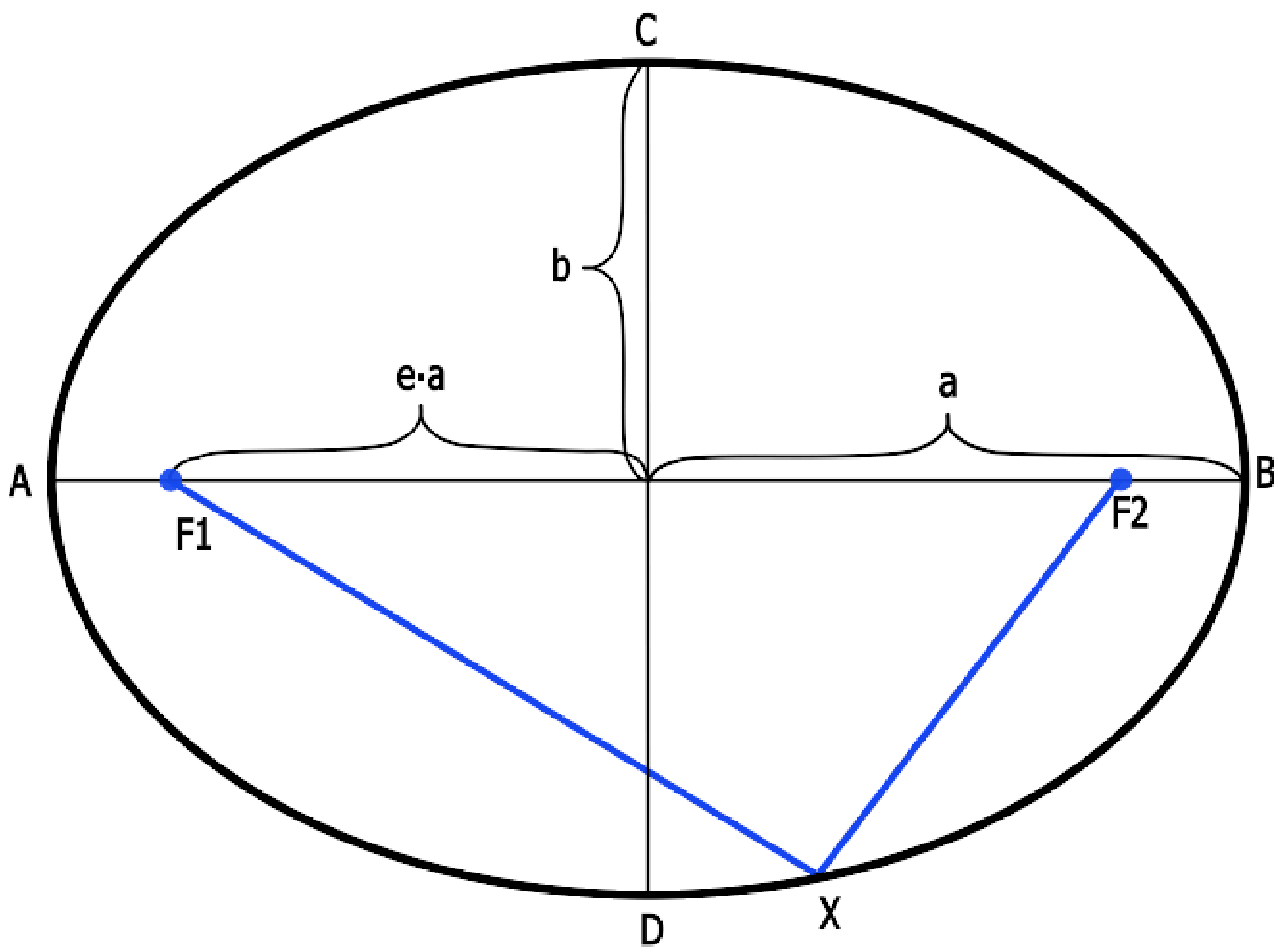
Geodetic datums

- Geodetic datums define the size and shape of the earth and the origin and orientation of the coordinate systems used to map the earth. Hundreds of different datums have been used to frame position descriptions since the first estimates of the earth's size were made by Aristotle. Datums have evolved from those describing a spherical earth to ellipsoidal models derived from years of satellite measurements.

- Modern geodetic datums range from flat-earth models used for plane surveying to complex models used for international applications which completely describe the size, shape, orientation, gravity field, and angular velocity of the earth. While cartography, surveying, navigation, and astronomy all make use of geodetic datums, the science of geodesy is the central discipline for the topic.

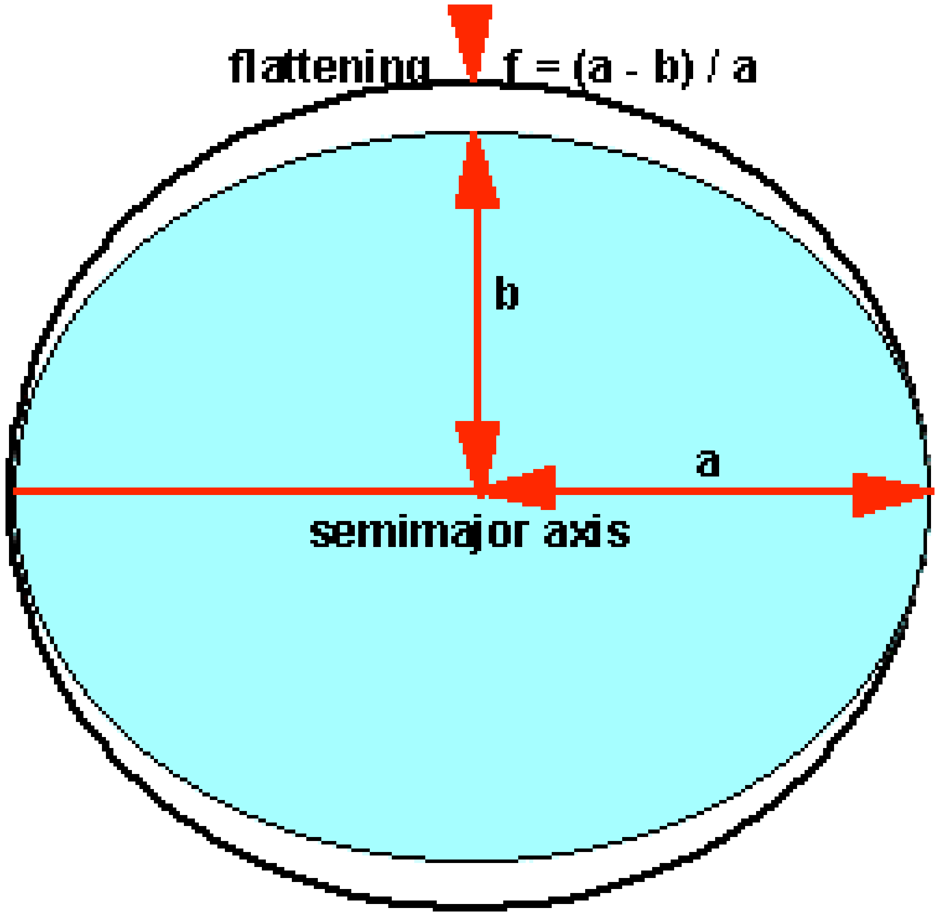
- Referencing geodetic coordinates to the wrong datum can result in position errors of hundreds of meters. Different nations and agencies use different datums as the basis for coordinate systems used to identify positions in geographic information systems, precise positioning systems, and navigation systems. The diversity of datums in use today and the technological advancements that have made possible global positioning measurements with sub-meter accuracies requires careful datum selection and careful conversion between coordinates in different datums.

Little Remainder: The Ellipse

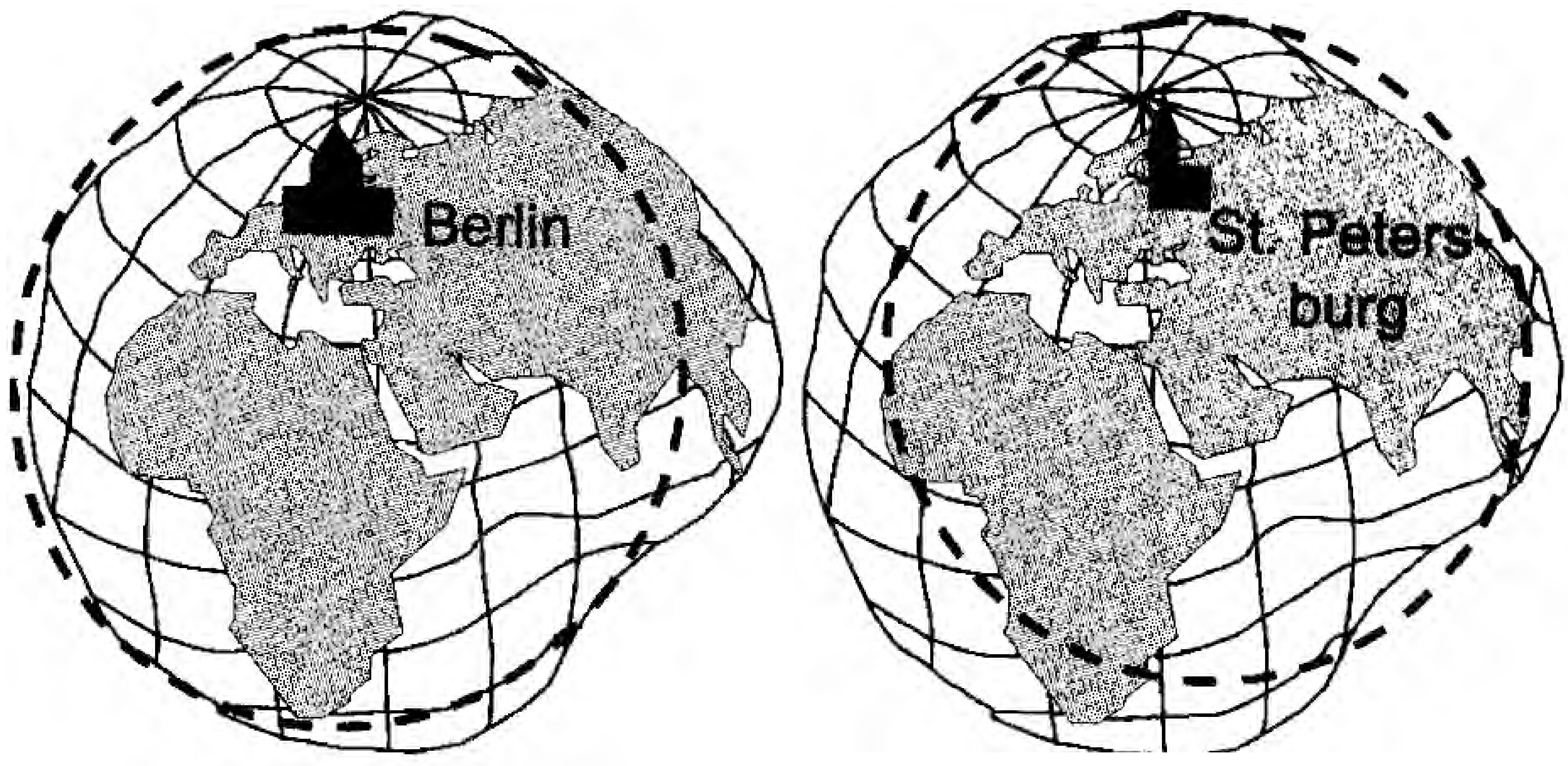


The earth as an ellipsoid

- An ellipsiod is determined by revolving a ellipse about an axis
  - Axis b is called semiminor or polar axis
  - Axis a is called semimajor or equatorial axis
- The flattening f is defined as f=(a-b)/a
- An earth reference ellipsoid is determined by revolving the ellipse about the polar axis b. Since f is about 21 km it is common practice to describe an earth reference ellipsoid using a and the inverse flattening 1/f.

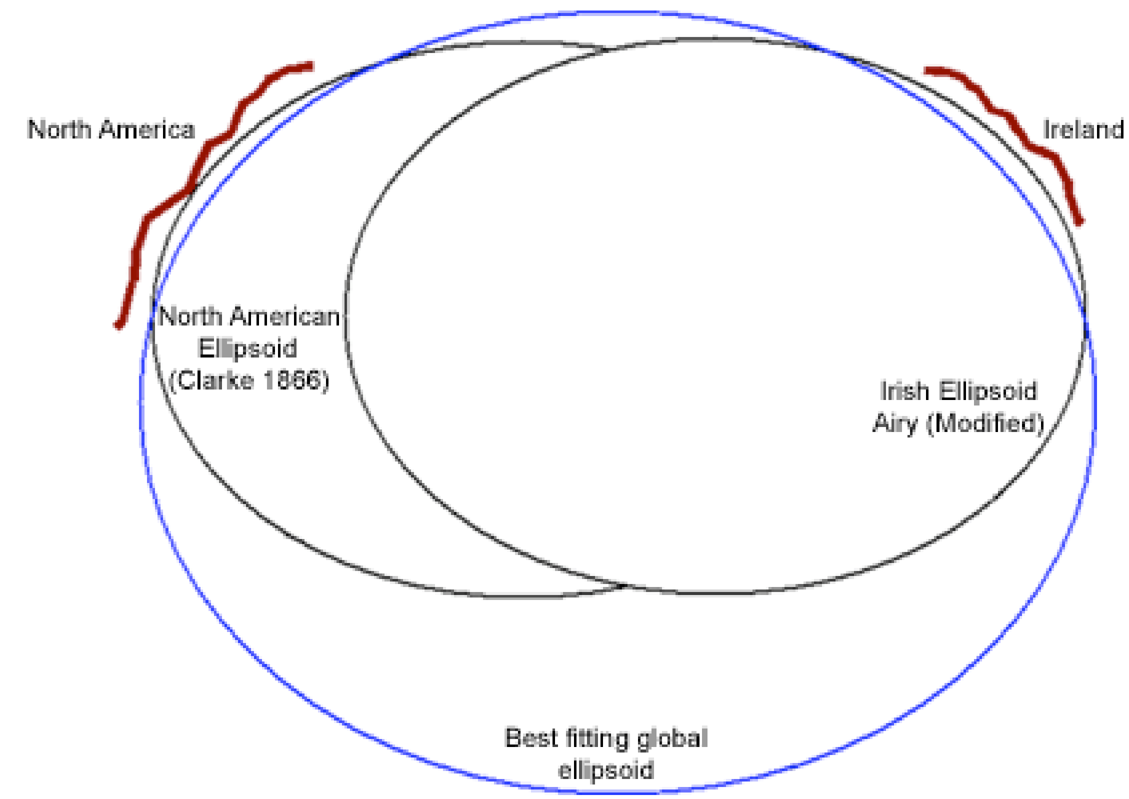


Which reference ellipsoid is best?



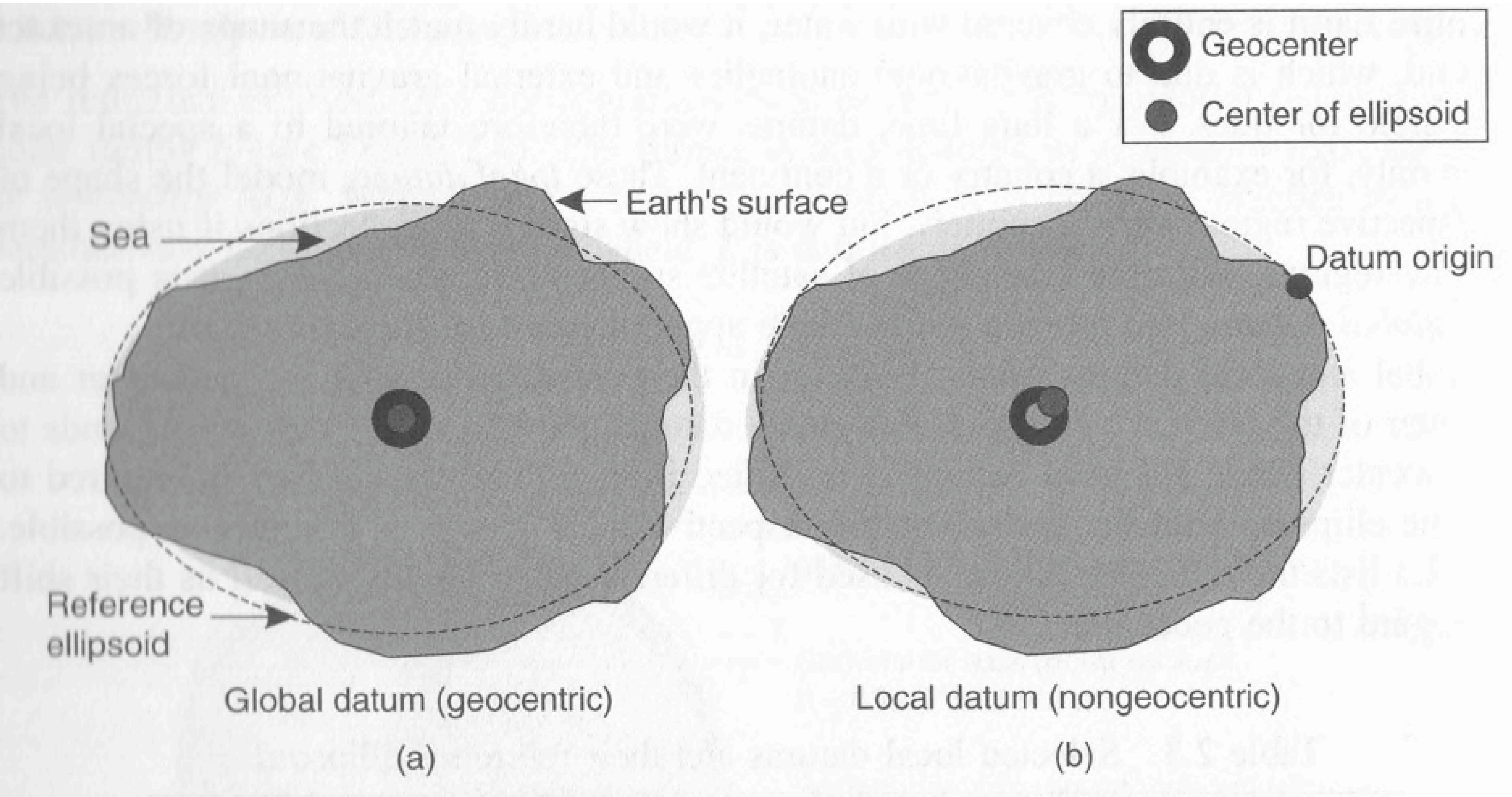
There is no best ellipsoid

- Since there is no ellipsoid which perfectly matches all regions on earth, the different countries have defined different reference ellipsoids over the last centuries



- These local ellipsoids model certain regions of the world quite closely but are not suitable for global use („***local datum***“)
- The other way around global reference ellipsoids may be inaccurate in certain areas of the world („***global datum***“)

Global and local datums



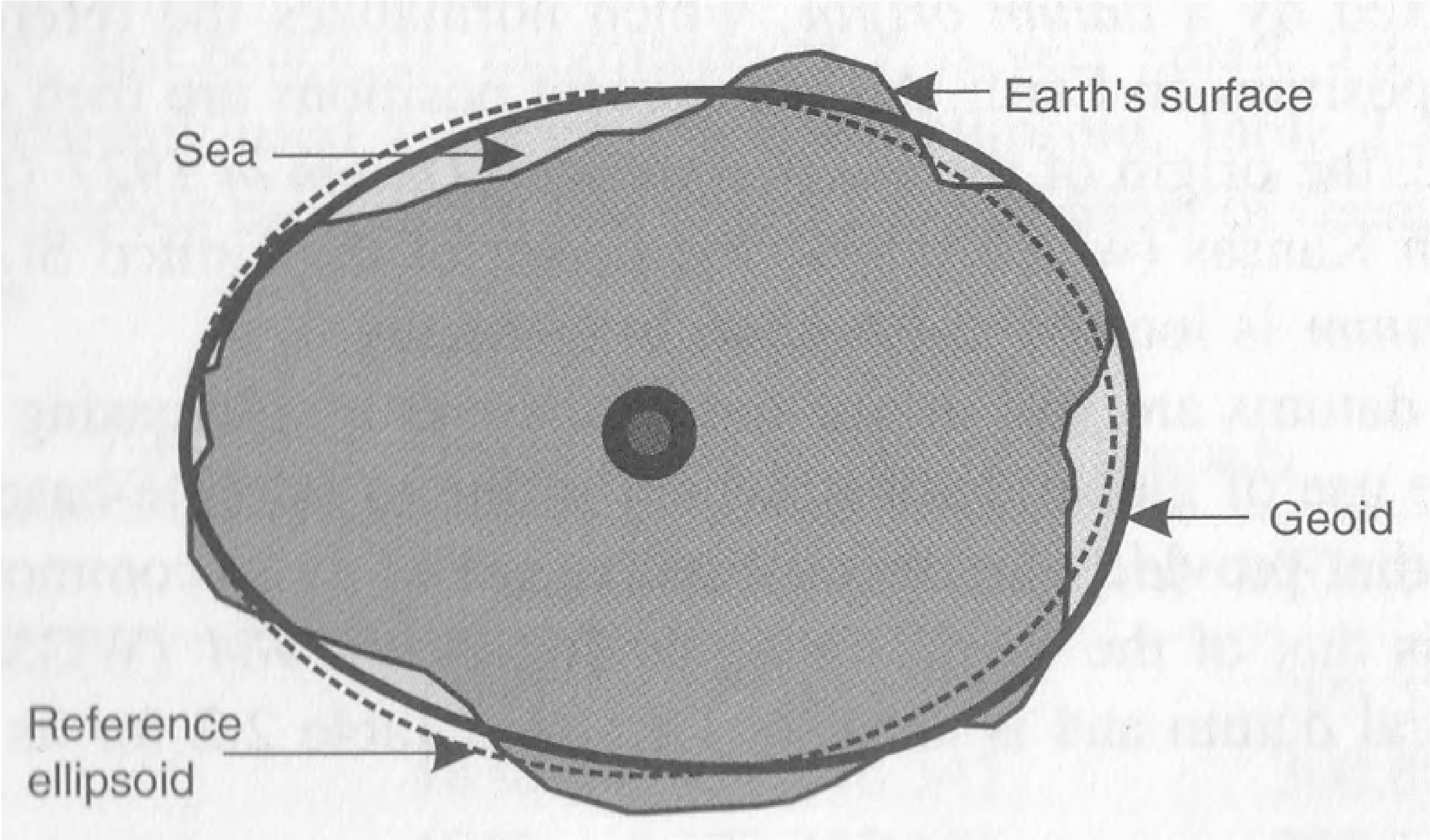
Example reference ellipsoids

Ellipsoid and Year	Semi-major axis (meters)	1/f
Airy 1830	6,377,563	299.33
Everest 1830	6,377,276.3	300.80
Bessel 1841	6,377,397.2	299.15
Clarke 1866	6,378,206.4	294.98
Clarke 1880	6,378,249.2	293.47
International 1924	6,378,388	297
Krasovsky 1940	6,378,245	298.3
International Astronomical Union 1968	6,378,160	298.25
WGS 72 (1972)	6,378,135	298.26
GRS 80 (1980)	6,378,137	298.26
WGS 84 (1984)	6,378,137	298.25722

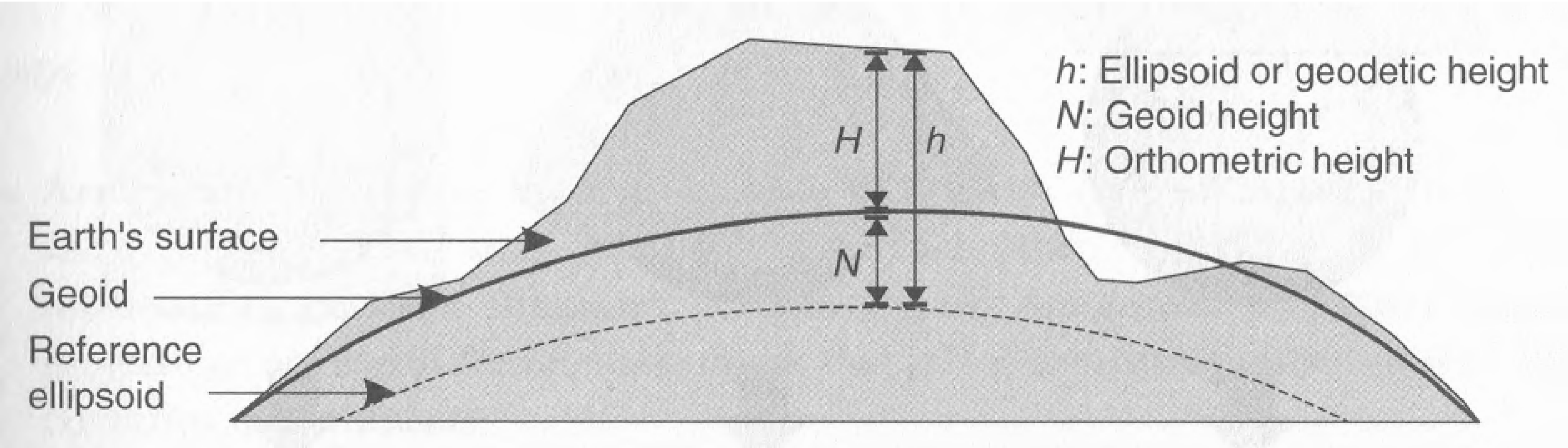
Horizontal and Vertical Datum

- Another description of the earth is a geoid. The geoid is a representation of the earth's gravity field.
- A geoid is the equipotential surface of the earth's gravity field which best fits, in a least squares sense, global mean sea level (NGS,2000 Geoid).
- Essentially this is a representation of the surface of the earth in terms of sea level for every position on earth, in a more complex manner than an ellipsoid.
- WGS-84 defines both, a reference ellipsoid and a geoid, i.e. it defines geoid heights for the entire earth.

Difference between reference ellipsoid and geoid



Classes of heights



- Orthometric height: Height of position to geoid
- Geodetic (Ellipsoid) height: Height of position and reference ellipsoid
- Geoid height: Height of position and geoid

Global Positioning System (GPS)

GPS: Brief History

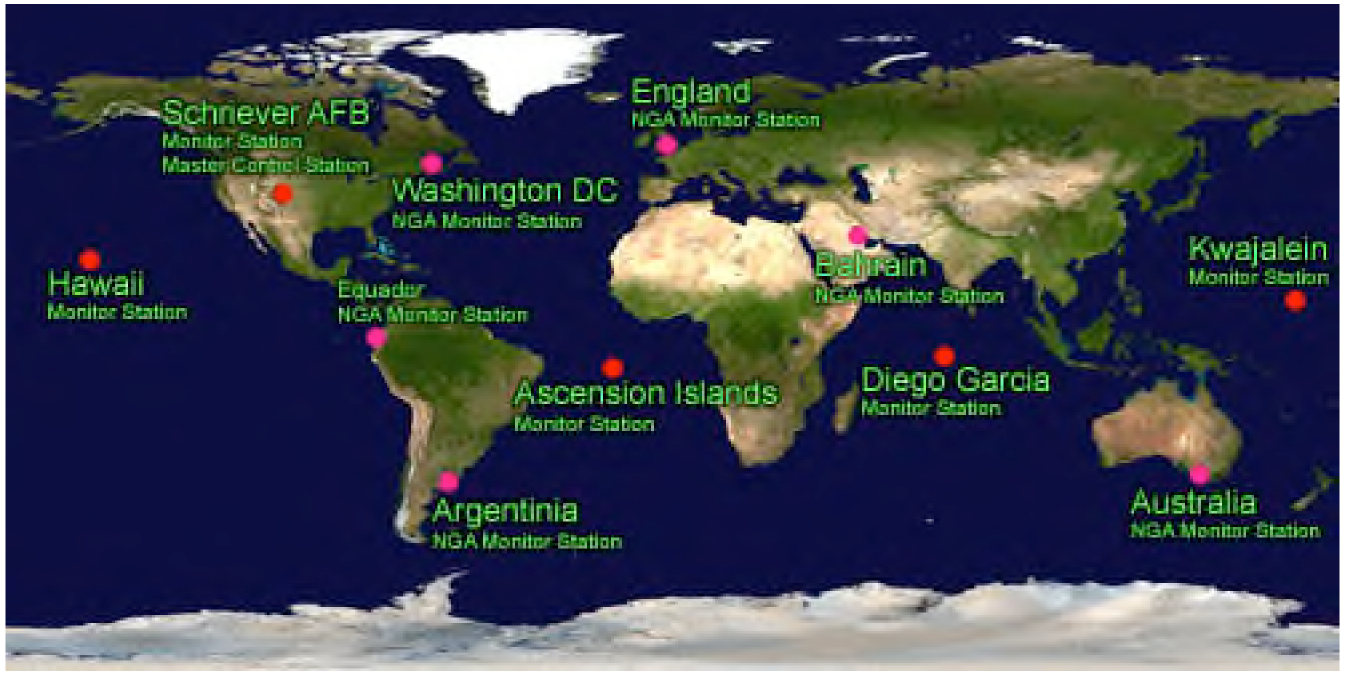
- In 1978 the first experimental Block-I GPS satellite was launched.
- On February 14, 1989, the first modern Block-II satellite was launched.
- By January 17, 1994 a complete constellation of 24 satellites was in orbit.
- Full Operational Capability was declared by NAVSTAR in April 1995.
- In 1996, recognizing the importance of GPS to civilian users as well as military users, U.S. President Bill Clinton issued a policy directive[28] declaring GPS to be a dual-use system and establishing an Interagency GPS Executive Board to manage it as a national asset.
- In 1998, U.S. Vice President Al Gore announced plans to upgrade GPS with two new civilian signals for enhanced user accuracy and reliability, particularly with respect to aviation safety.
- On May 2, 2000 "Selective Availability" was discontinued as a result of the 1996 executive order, allowing users to receive a non-degraded signal globally.
- In 2004, the United States Government signed a historic agreement with the European Community establishing cooperation related to GPS and Europe's planned Galileo system.
- In 2005, the first modernized GPS satellite was launched and began transmitting a second civilian signal (L2C) for enhanced user performance.
- The most recent launch was on 17 November 2006. The oldest GPS satellite still in operation was launched in August 1991.

GPS Segments: The Space Segment

- GPS has three parts: the space segment, the user segment, and the control segment.
- The space segment consists of a constellation of 24 satellites (and about six "spares"), each in its own orbit 11,000 nautical miles above Earth. A satellite takes appr. 12 hours to circuit (cross the same meridian) the earth once.
- Satellites are circulating in 6 orbits equally spaced apart from each other. An orbit has an inclination angle of 55 degrees so that at least 5 satellites are visible at any point on earth.

GPS Segments: The Control Segment

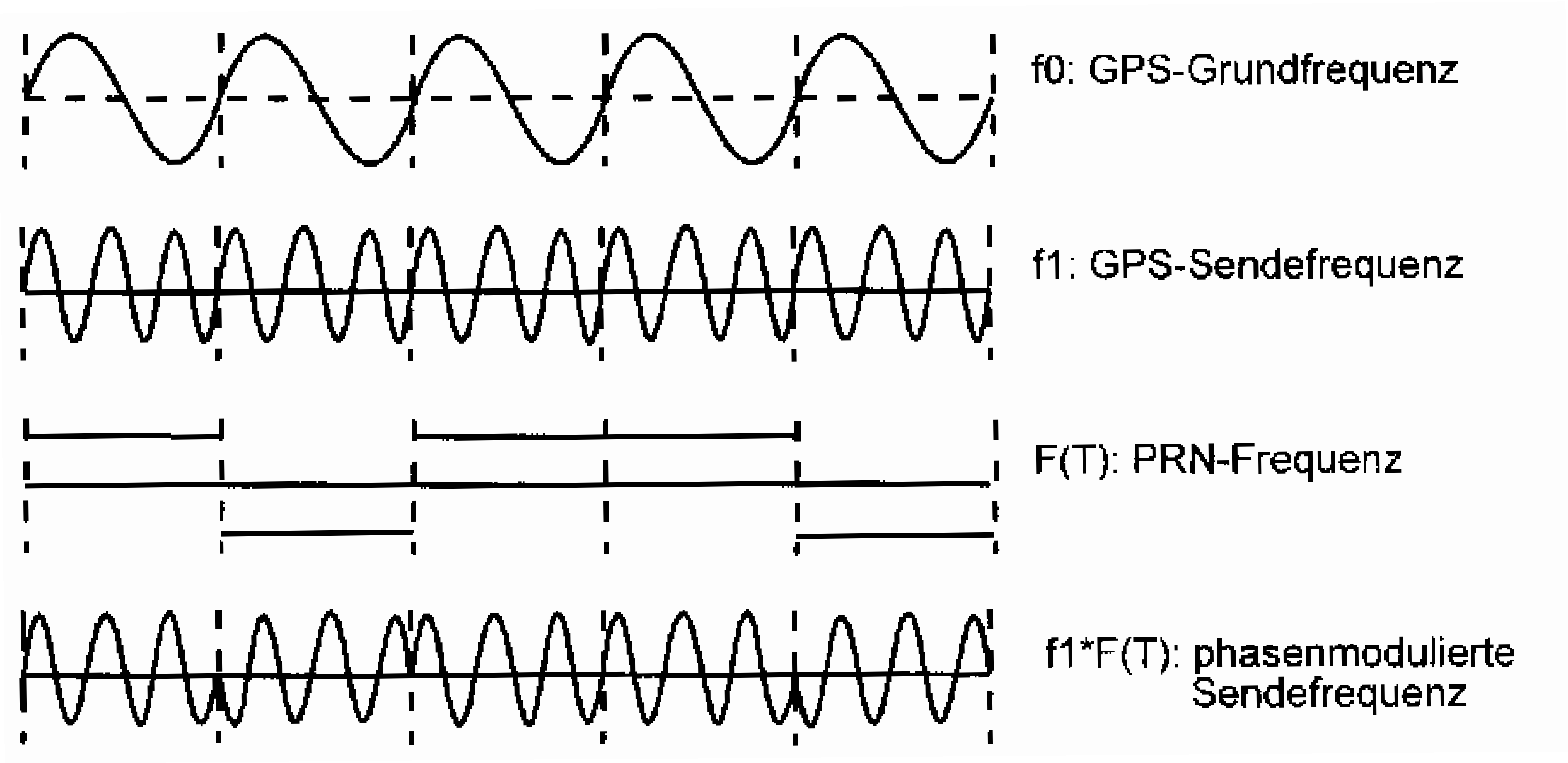
- The GPS control segment consists of several ground stations located around the world.
- A master control station at Schriever Air Force Base in Colorado, Six unstaffed monitoring stations: Hawaii and Kwajalein in the Pacific Ocean; Diego Garcia in the Indian Ocean; Ascension Island in the Atlantic Ocean; Cape Canaveral, Florida and Colorado Springs, Colorado
- Four large ground-antenna stations that send commands and data up to the satellites and collect telemetry back from them.



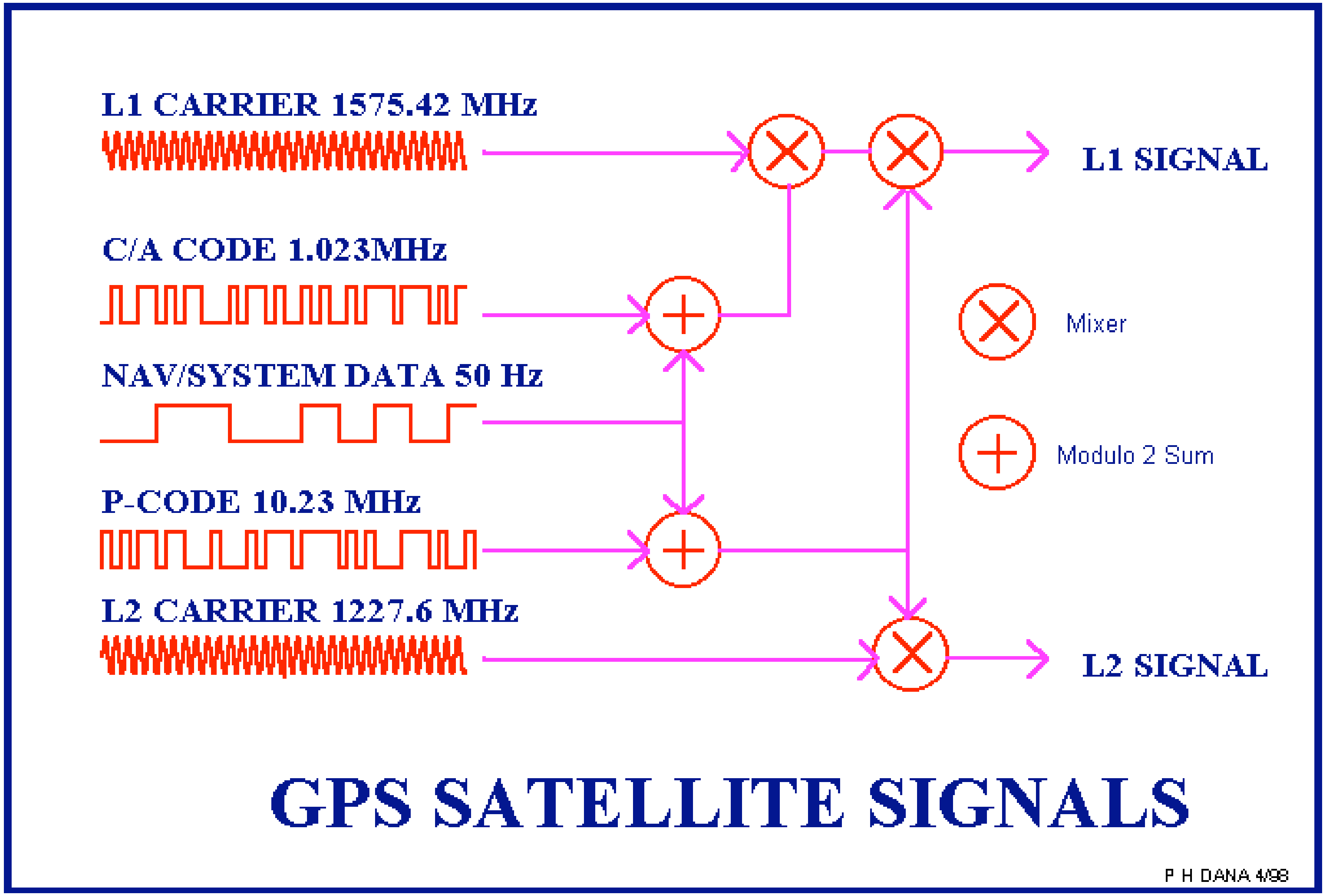
GPS Segments: The User Segment

- This component consists of the GPS receivers and the user community.
- GPS receivers convert Space Vehicle (*) signals into position, velocity and time estimates. This process requires four satellites to compute the four dimension of X, Y, Z (position) and time. With this ability, GPS has three main functions; navigation (for aircraft, ships, etc), precise positioning (for surveying, plate tectonics, etc,) and time and frequency dissemination (for astronomical observatories, telecommunications facilities, etc.)
- (*) „Space Vehicle“ (SV) is the official term for a GPS satellite. They are sequentially numbered. No 50 was launched in 2004.

GPS Signal Modulation



GPS Satellite-Signals

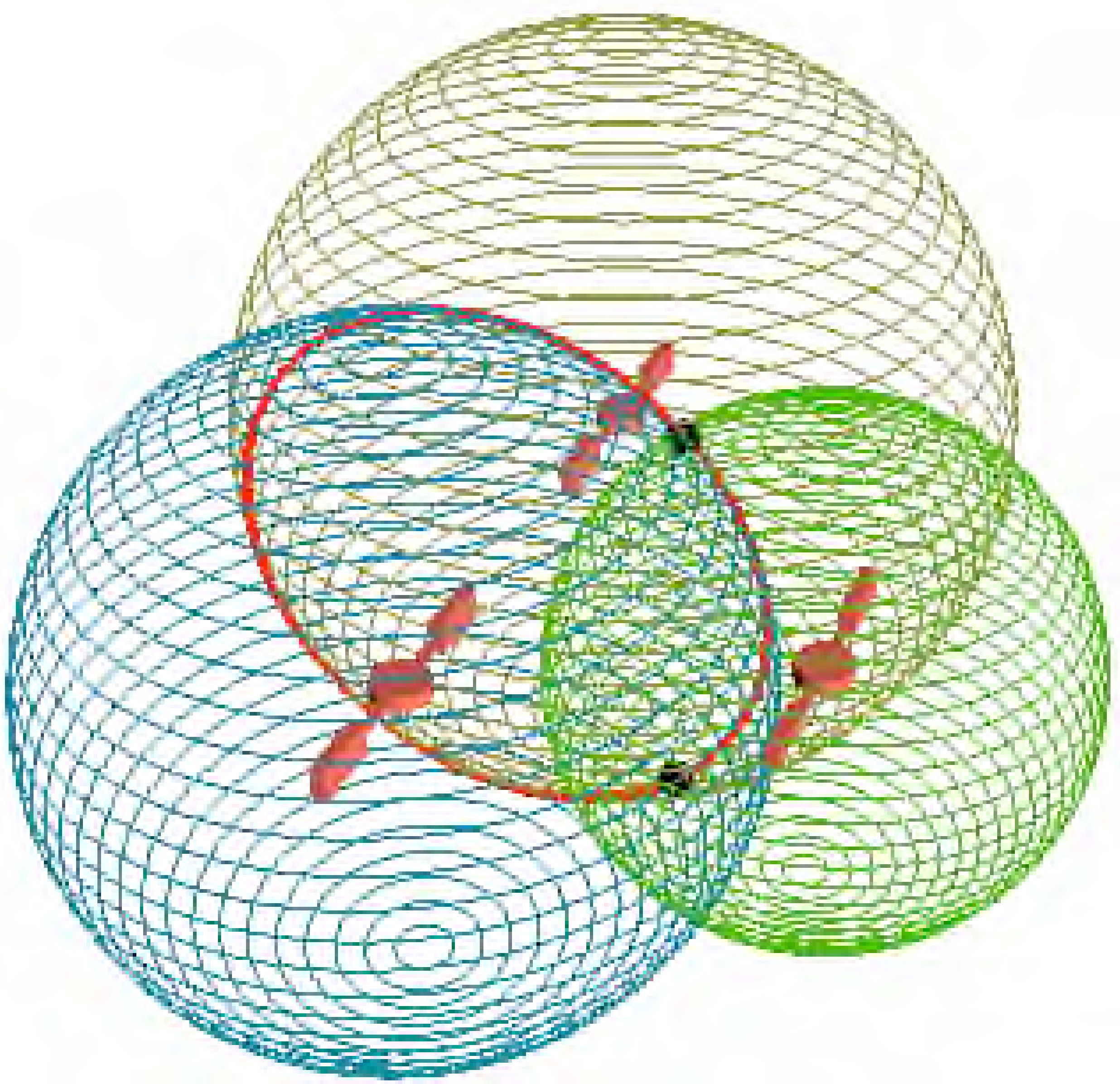


Two codes with different accuracies

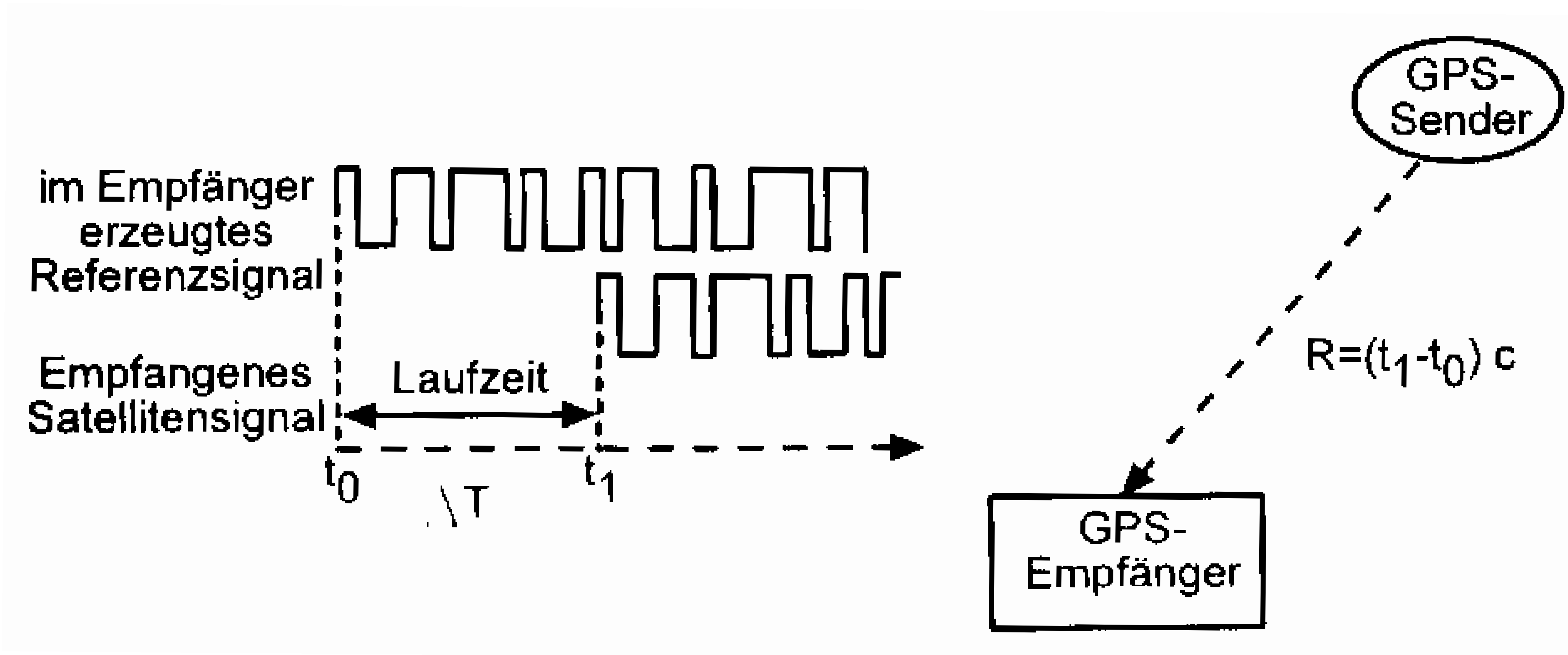
- the Coarse / Acquisition (C/A) code, which is freely available to the public
- Precise (P) code, which is usually encrypted and reserved for military applications.
- The C/A code is a 1,023 chip pseudo-random (PRN) code at 1.023 million chips/sec so that it repeats every millisecond. Each satellite has its own C/A code so that it can be uniquely identified and received separately from the other satellites transmitting on the same frequency.
- The P-code is a 10.23 megachip/sec PRN code that repeats only every week. When the "anti-spoofing" mode is on, as it is in normal operation, the P code is encrypted by the Y-code to produce the P(Y) code, which can only be decrypted by units with a valid decryption key. Both the C/A and P(Y) codes impart the precise time-of-day to the user.

Position calculation: How many satellites do we need?

Intersection	Equivalent	Result
2 Spheres	Circle	Circle
3 Spheres	Circle ∩ Sphere	2 Points
4 Spheres	2 Point ∩ Sphere	1 Point

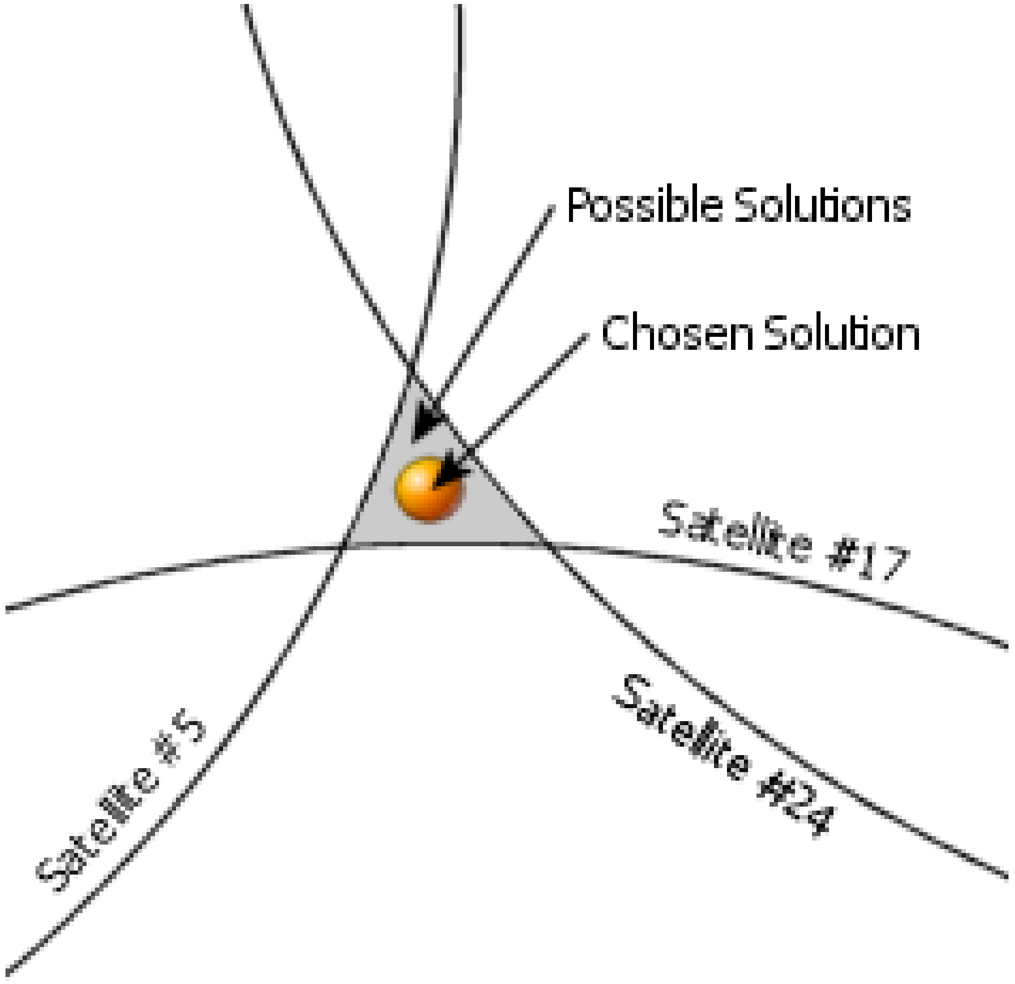


Distance measurement with GPS



Problem:

- Due to receiver‘s clock inaccuracy (in contrast to atomic clocks in satellites) the position cannot be determined precisely with 3 spheres
- since the light of speed is 300000 km/s a small a asynchronism of clocks makes a huge difference!
- Solution
  - use another satellite to eliminate the receivers clock error

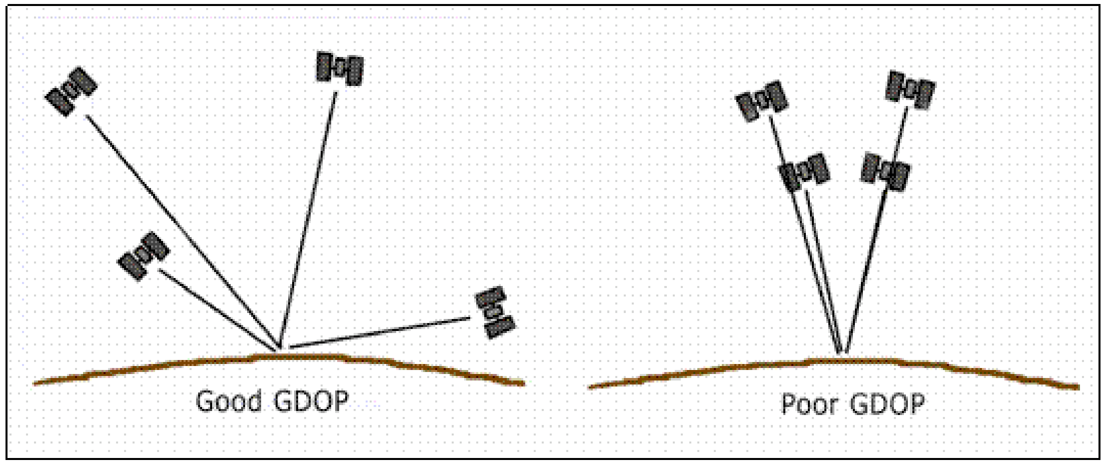


A GPS receiver can do some maths

- With R = (dT + dt) * c
  - with dT the difference of the received GPS signal
  - dt the difference of the receivers clock
  - and c light of speed
- you get a nonlinear system of equations with 4 unknown variables:
- $[(dT_i + dt) * c]^2 = (x_i - x_r)^2 + (y_i - y_r)^2 + (z_i - z_r)^2$
  - with i=1,..4. The clock of the satellites is assumed to be exact
- this can be solved using numerical methods (Newton approximation) thus eliminating dt
- With more satellites available the error can be further reduced (least squares)

We have minimized the clock problem but ...

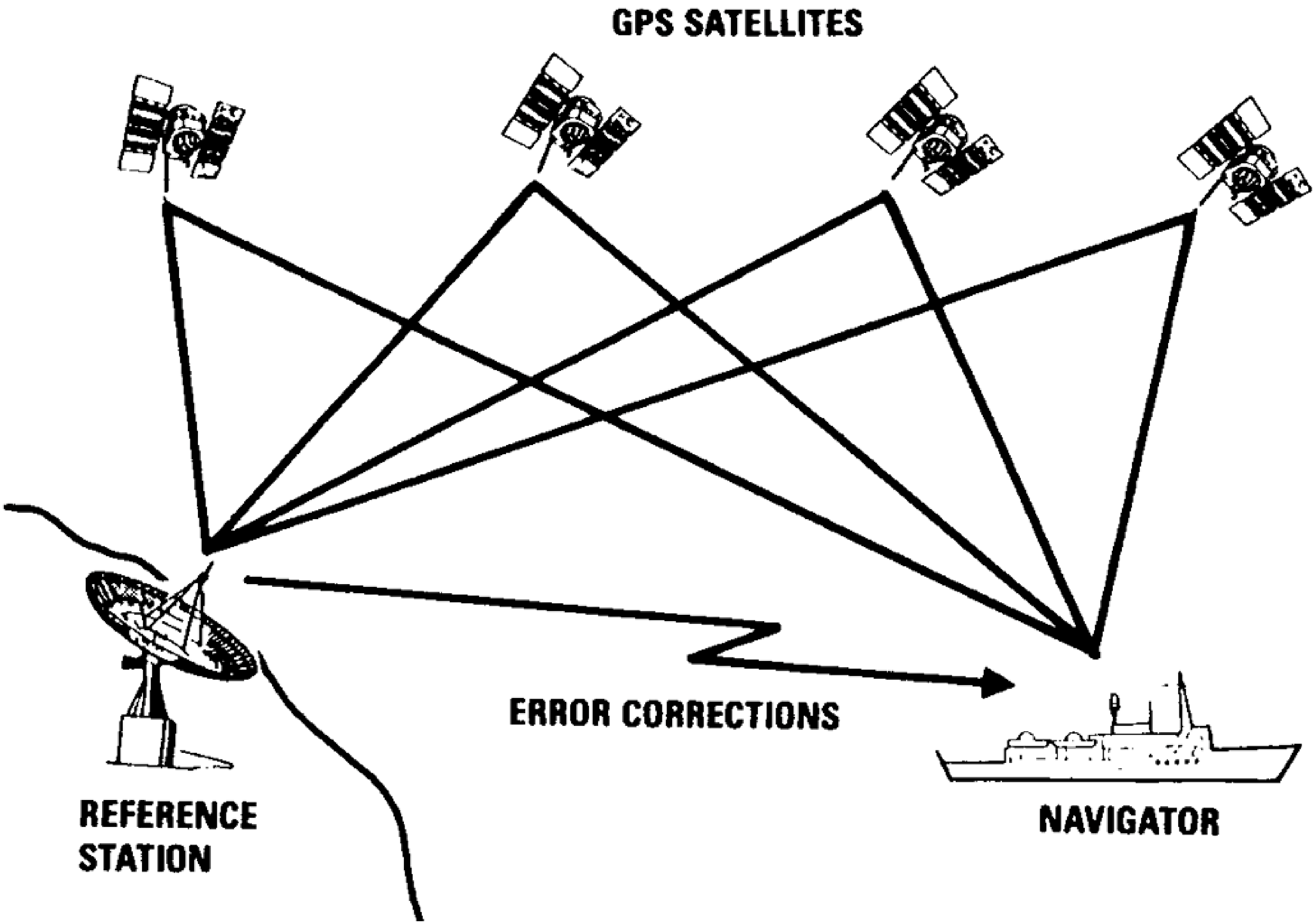
DOP = Dilution of Precision is a value of probability for the geometrical effect on GPS accuracy. Used by receiver to select satellites.



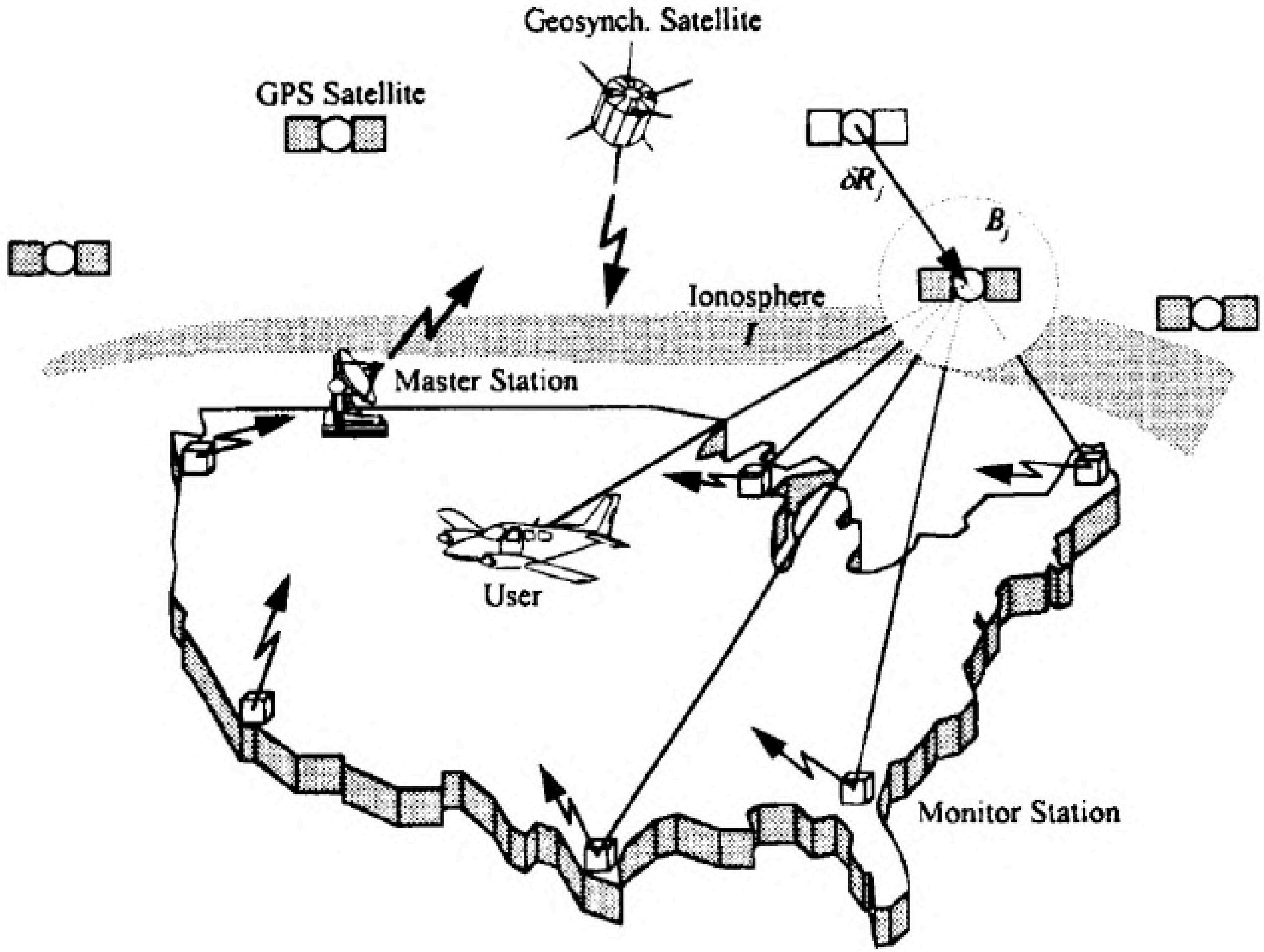
Various Error Sources

Source	Effect
Ionospheric effects	± 5 meter
Ephemeris errors	± 2.5 meter
Satellite clock errors	± 2 meter
Multipath distortion	± 1 meter
Tropospheric effects	± 0.5 meter

DGPS reduces systematical errors



WAAS, EGNOS, MSAS



GPS startup terms (Garmin)

- Search the sky
  - Time, position, almanac, and ephemeris data all unknown.
- AutoLocate
  - Time, position, and ephemeris unknown, almanac known or partially known.
- Cold Start
  - Time and position known to within some limits, almanac known, ephemeris unknown
- Warm start
  - Time and position known to within some limits, almanac known, at least 3 SVs Ephemeris are known from previous operation.

NMEA

- NMEA 0183 (or NMEA for short) is a combined electrical and data specification for communication between marine electronic devices such as depth finders, navigation instruments, and GPS receivers. It has been defined by, and is controlled by, the US based National Marine Electronics Association. It is also commonly used for GPS receivers other than on board boats.
- The NMEA 0183 standard uses a simple ASCII, serial communications protocol that defines how data is transmitted in a "sentence" from one "talker" to one or more "listeners". The standard also defines the contents of each sentence (message) type so that all listeners can parse messages accurately.
- NMEA specifies the transmission rate to be 4800 baud. That‘s only about 6 messages sentences à 100 ascii bytes per second.

NMEA example sentences (output of a standard GPS receiver)

```
$GPRMC,002454,A,3553.5295,N,13938.6570,E,0.0,43.1,180700,7.1,W,A*3F
$GPRMB,A,,,,,,,,,,,,A,A*0B
$GPGGA,002454,3553.5295,N,13938.6570,E,1,05,2.2,18.3,M,39.0,M,,*7F
$GPGSA,A,3,01,04,07,16,20,,,,,,,,3.6,2.2,2.7*35
$GPGSV,3,1,09,01,38,103,37,02,23,215,00,04,38,297,37,05,00,328,00*70
$GPGSV,3,2,09,07,77,299,47,11,07,087,00,16,74,041,47,20,38,044,43*73
$GPGSV,3,3,09,24,12,282,00*4D
$GPGLL,3553.5295,N,13938.6570,E,002454,A,A*4F
$GPBOD,,T,,M,,*47
$PGRME,8.6,M,9.6,M,12.9,M*15
$PGRMZ,51,f*30
$HCHDG,101.1,,,7.1,W*3C
$GPRTE,1,1,c,*37
$GPRMC,002456,A,3553.5295,N,13938.6570,E,0.0,43.1,180700,7.1,W,A*3D
```

GGA - essential fix data which provide 3D location and accuracy data

$GPGGA,123519,4807.038,N,01131.000,E,1,08,0.9,545.4,M,46.9,M,,*47

Where:

GGA	Global Positioning System Fix Data
123519	Fix taken at 12:35:19 UTC
4807.038,N	Latitude 48 deg 07.038' N
01131.000,E	Longitude 11 deg 31.000' E
1	Fix quality: 0 = invalid 1 = GPS fix (SPS) 2 = DGPS fix 3 = PPS fix 4 = Real Time Kinematic 5 = Float RTK 6 = estimated (dead reckoning) (2.3 feature) 7 = Manual input mode 8 = Simulation mode
08	Number of satellites being tracked
0.9	Horizontal dilution of position
545.4,M	Altitude, Meters, above mean sea level
46.9,M	Height of geoid (mean sea level) above WGS84 ellipsoid
(empty field)	time in seconds since last DGPS update
(empty field)	DGPS station ID number
*47	the checksum data, always begins with *

Homework :-)

- Write a simple NMEA parser that displays the Latitude, Longitude (in decimal degrees), Speed over Ground (SOG) and Course over Ground (COG)
- If no GPS receiver is available read GPS example data from a file stream using the GCF.

This Lecture

- Küpper, A.: Location-based Services - Fundamentals and Operation, John Wiley & Sons, 2005
  - Chapter 2, 7, (4)
- de Lange, N.: Geoinformatik in Theorie und Praxis, Springer, 2006
  - Chapter 5.4, 5.5, 6.5
- NMEA
  - http://www.gpsinformation.org/dale/nmea.htm

Thank you!

Dr. Thilo Horstmann

e-mail: thilo.horstmann@gmail.com
blog: http://www.das-zentralorgan.de