SAPOS®

. . . moves you into position!

Satellite *Positioning Service* of the German State Survey

Working Committee of the Surveying Authorities
of the States of the Federal Republic of Germany (AdV)

SA*POS*® Reference Stations

Copyright: Landesbetrieb Geoinformation und Vermessung Hamburg

Legend

- reference station in operation with location
- national border crossing networking with AGNES reference stations of Switzerland
- national border crossing networking with 06-GPS reference stations of the Netherlands
- national border crossing networking with BEV (Bundesamt für Eich- und Vermessungswesen) and ÖAW (Österreichische Akademie der Wissenschaften) reference stations of Austria
- continental real-time networking
- coastal real-time networking

Contents

SAPOS®

Satellitenpositionierungsdienst der deutschen Landesvermessung

Echtzeit-Vernetzung

Zeichenerklärung:

- Referenzstation in Betrieb mit Ortsbezeichnung

Länderübergreifende Vernetzungen mit den Referenzstationen der folgenden Institutionen sind realisiert:

- GPSnet.dk (Dänemark)
- 06-GPS, LNR Globalcom (Niederlande)
- WALCORS Verkehrsministerium der Region Wallonien (Belgien)
- TERIA (Frankreich)
- AGNES (Schweiz)
- Bundesamt für Eich- und Vermessungswesen (BEV), Österreichische Akademie der Wissenschaften (ÖAW), (Österreich)
- Aktywna Siec Geodezyjna ASG-EUPOS (Polen)
- CZEPOS Zeměměřický Úřad (Tschechien)

Vernetzungsgebiete in den Bundesländern

Vernetzungsgebiete in den Küstenregionen

Stand: Februar 2010

SA*POS*® Products

The Satellite Positioning Service SA*POS*® is a joined project of the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (AdV). SA*POS*® is based on the techniques of the Global Positioning System (GPS) and consists of a network of more than 250 permanently observing reference stations with national expanse.

Within differential GPS measurements, the user will be provided with SA*POS*® data on different accuracy levels in order to increase the position accuracy. The received data is adapted to the individual requirements of the user. SA*POS*® data can be used for real-time as well as for postprocessing approaches.

SA*POS*® provides the following fields of service with different features:

- **SA*POS*®-HEPS**
  High Precision Real Time Positioning Service

The network-based RTK service SA*POS*® HEPS enables a real-time positioning with an accuracy of 1–2 centimeter (horizontal) respectively 2–6 centimeter (vertical). The correction data is derived from carrier phase measurements and is broadcasted with a data rate of 1 second by mobile radio (GSM) or 2m band radio using the standardized RTCM format.
Distance dependent errors can be considerably minimized by means of a networking process of the SA*POS*® reference stations. Thus, an increased accuracy and reliability of the positioning will be achieved.

Possible fields of application:

Engineering surveying, Geo-Information Systems (GIS) with higher accuracy requirements, real estate cadastre, supply and disposal, register of utility services, ...

- **SA*POS*®-EPS**
  Real Time Positioning Service

SA*POS*® EPS provides real-time positioning at an accuracy level of about 0,5 to 3 meter. Code corrections are transmitted nationally via VHF (RASANT) and long wave stations (ALF). Additionally, SA*POS*® EPS can be used with a data rate of 1 second via mobile radio (GSM) or 2m band radio using the standardized RTCM format.

Possible fields of application:

Vehicle navigation, fleet management, authorities and organizations with security duties (BOS), Geo-Information Systems (GIS), maritime shipping, hydrography, ...

- **SA*POS*®-GPPS/GHPS**
  Geodetic Precision/High Precision Positioning Service

Postprocessing analysis is necessary for the highest accuracy requirements. The SA*POS*® GPPS and SA*POS*® GHPS services enable a both horizontal and vertical positioning with an accuracy at the 1 centimeter or even millimeter level. The data is provided for the user in the standardized RINEX format via e-mail, internet (ftp-download) or on data carriers.
The SA*POS*® GPPS service additionally allows the processing of a "near-online" solution, retrieving the RINEX data in the field.
The SA*POS*®data with a data rate of 1 second is stored at least for 30 days. The SA*POS*® data with a data rate of 15 seconds is stored permanently on data carrier. If required, a data rate below 1 second can be provided on request.

Possible fields of application:

Aerial photogrammetry, laserscanning, fundamental geodetic survey, reference systems of the German State Survey, analysis of geodynamic processes, ...

Method	Service	Broadcasting Medium	Accuracy	Equipment
Real-time	HEPS	mobile radio (GSM, Germany-wide) 2m band radio (optional) internet (NTRIP, intended)	1 to 2 cm (horizontal) 2 to 6 cm (vertical)	RTK capable geodetic GPS receiver, modem for data communication
Real-time	EPS	VHF (RASANT, Germany-wide) long wave (ALF, Germany-wide) mobile radio (GSM, optional) 2m band radio (optional) internet (NTRIP, intended)	0,5 to 3 m	DGPS capable single frequency receiver, modem for data communication
Postprocessing	GPPS GHPS	Internet, e-mail, data carrier	1 cm < 1 cm	geodetic GPS receiver, internet access

Service	Data Rate	Unit	Utilization Fee	Data Format
HEPS	1 second	1 minute	0,10 €	RTCM 2.3
EPS	3–5 seconds 1 second	not applied 1 year	single fee with purchase of equipment (ALF, RASANT) 150,- € (GSM, 2m band radio)	RTCM 2.0
GPPS / GHPS	≥ 1 second < 1 second	1 minute 1 minute	0,20 € 0,80 €	RINEX 2.1

SAPOS® National

Within the framework of its legal brief, the official surveying and mapping stipulates the nationwide official spatial reference system with the SAPOS® reference stations of the states using satellite techniques. It's a fundamental part of a basic maintenance of the state's infrastructure. Already today, a nationwide provision of data to third parties is required.

In order to provide a national closed appearance of the SAPOS® service to the SAPOS® users with standardized interfaces and formats, the AdV Plenum passed the following resolutions:

• SAPOS® as official task of the German State Survey; use and further processing of SAPOS® data by other public and also private institutions

SAPOS® is prerequisite for the fulfilment of the official tasks of the survey and cadastre administrations of the states. Therefore, it's an exclusive part of the legal remit of the federal states to deploy and operate the SAPOS® reference stations including the processing of official SAPOS® data. SAPOS® data is the data, that is received on the SAPOS® reference stations in form of satellite signals. Together with descriptive data of the reference stations, this data will be provided to the SAPOS® users in an especially prepared form using different formats. SAPOS® data can comprise networking information or can be generated within a networking process.

Beside the provision of SAPOS® data for direct positioning applications, SAPOS® data can also be provided to other public and private institutions for their own SAPOS®-based services.

In case of a provider with self-processed positioning data and derivative products on the basis of SAPOS® data, these products do not belong to the SAPOS® data and thus are not official data.

• Standardization of SAPOS® – Germany

Fundamental Principles for SAPOS® HEPS

It's necessary to establish a concept for a nationally stipulated standardization of networked SAPOS® HEPS. Within this concept there are no specific alternatives within for the single federal states. The supply of standardized parts of SAPOS® should comprise a great variaty. In the course of this, compulsory standards for the SAPOS® provider (SAPOS® Standard Obligation) and so-called optional "add on" components (SAPOS® Standard Option) will be stipulated. SAPOS® HEPS is build up multifunctionally.

Broadcasting Medium

The mobile radio is employed as a medium for the data transfer from the service provider to the user, in order to facilitate an extensive deployment. SAPOS® Standard Obligation means the transmission of correction data via GSM. SAPOS® Standard Option comprises the broadcasting using 2m band radio.

Data Format

Standardized data format for the user interface is RTCM 2.3. SAPOS® Standard Obligation means the message types 20/21 (not encrypted and not compressed).
SAPOS® Standard Options are RTCM-AdV (encrypted and compressed), as well as RTCM 2.3, message types 18/19 (not encrypted and not compressed).

Implementation of the Networking

SAPOS® Standard Obligation is the networking of SAPOS® reference stations. This serves an increasing reliability and accuracy of SAPOS® HEPS and has to be guaranteed across the borders of the single federal states. Thus, extrapolation problems are avoidable. The networking results are provided to the SAPOS® user as Area Correction Parameters ("Flächenkorrekturparameter" FKP) or Virtual Reference Station (VRS).

SAPOS® Standard Obligation is the transmission of FKP.
SAPOS® Standard Option is the calculation of a VRS.

• Agreement about the Central Bureau SAPOS® of the federal states for the provision of satellite positioning data (Zentrale Stelle SAPOS®)

On demand of many SAPOS® customers the Central Bureau SAPOS® has been established at the LGN in Hannover on October, 1st 2003. As a authorized contact person and negotiating partner the Central Bureau SAPOS® is responsible for all customers who intend to use SAPOS® in more than one state. After the introduction of uniform SAPOS® standards this is another step in view of providing a Germany-wide uniform SAPOS® service.

The Central Bureau SAPOS® carries out the following tasks:

- Nationwide provision of SAPOS® data and responsibility for the issue of usufructs including the affiliated fees according to AdV resolutions
- Marketing of SAPOS® data to nationwide users
- Support of the AdV with the coordination of nationwide activities
- Nationwide integration of SAPOS® data
- Technical support for the cross national (Germany-wide) networking on request

• Public Private Partnership (PPP)

In terms of an opened geodata market, the AdV would like to engage increasingly in partnerships of sale with private service providers. These PPP co-operations are requested by the politics, since, speaking of national economy, it's useful and desirable, that the investments of the public sector for SAPOS® are applied by as many users as possible. With regard to this aim, in May, 2002 the AdV and the Ruhrgas AG signed a Memorandum of Understanding (MoU) about strategic goals as well as about conjoint basic positions concerning the nationwide use and marketing of SAPOS® data by the Ruhrgas AG (positioning service ascos).

In the meanwhile, this wanted partnership has been formally sealed through the signing of a contract between the Ruhrgas AG and the AdV at the Hannover fair on April, 8th 2003.

GNSS – Global Navigation Satellite Systems

The development of the today available two global navigation satellite systems (GNSS) NAVSTAR-GPS and GLONASS in the USA and the former UdSSR started in the early 1970's. Both systems were developed originally for military navigation purposes, in order to provide a real-time positioning service and ensure accurate time transfer possibilities. Whereas the Russian GLONASS do not employ any restrictions for civil use, the USA implemented an intentional accuracy deterioration for non-military or non-authorized users by means of Selective Availability (suspended on May, 2nd 2000) and Anti-Spoofing.

Basically, there exist only small differences in the techniques and functionalities of both GNSS. Each consists of three segments, the space segment (satellites), the control segment (control and monitor stations, ground-based transmission stations), and the user segment (receiving equipment). Using the high-precision atomic clock's frequency standard of the GNSS satellites, codes, navigation messages and system status information, all modulated on two carrier frequencies, are transmitted. The control segment is responsible for maintaining the operation of the satellites, e.g. by calculating the broadcast ephemeris (satellite orbits) and generating the GPS-time.

NAVigation Satellite Timing And Ranging - Global Positioning System (NAVSTAR-GPS)

The GPS space segment currently consists of 29 satellites. Due to the constellation, it's always possible to receive at least 4 up to 12 satellites simultaneously on all locations on the earth's surface. The satellites are orbiting the earth with an altitude of about 20.230 km in six orbital planes, each with an inclination of 55°. The ascending nodes of the orbits are separated by 60°. The period of one revolution of the satellites is about 11 hours and 58 minutes. A repeated satellite constellation can be found on the observing sites after one mean sidereal day, thus each day about 4 minutes earlier.

GPS satellite

The GPS position accuracy for civil users increased from 100 m to ≤ 13 m (95% probability) with the suspension of Selective Availability (US DoD, 2001). Sustainable improvements can be expected within the GPS modernization in the future (e.g. third carrier frequency, C/A code on L2).

GLObal NAvigation Satellite System (GLONASS)

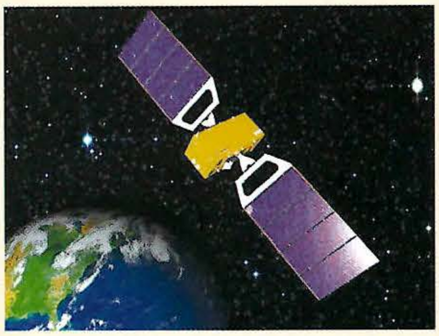
The GLONASS space segment had been completed with 24 satellites in the late 1990's. Actually, there are only 10 satellites available due to technical failures without appropriate replacements. The satellites are orbiting the earth in an approximate altitude of 19.100 km in three orbital planes with an inclination of 64,8°. The ascending nodes of the orbits are seperated by 120°. The period of one revolution of the satellites is about 11 hours and 16 minutes.

GLONASS satellite

The potential accuracy level of GLONASS for civil users is comparable to that of GPS without Selective Availability. Presently, GLONASS is only partly usable.

Galileo

The European Union (EU) and the European Space Agency (ESA) are currently working on the deployment of Galileo, an independent civil GNSS. Overall costs of about 3,2 billion € are estimated. Beside the official sector, also the private industry should have a share in these costs. The Galileo space segment will consist of 30 satellites in an altitude of about 23.616 km in three orbital planes with an inclination of 56°. The satellite's period of one revolution will be approximately 14,4 hours.



Galileo satellite Photo: EADS Astrium

In terms of accuracy, availability, and integrity, Galileo will be superior to GPS. Furthermore, the interoperability of Galileo and GPS will optimize satellite positioning. Through this also the quality of SA*POS*® will be enhanced continuously. Probably, the Galileo system will be put into service in 2008.

Basic Principles of differential GNSS and Networking

- **Real Time**

Differential GNSS (using one single reference station)

Within the process of differential real-time positioning, corrections are estimated by the comparison between measured pseudo-ranges and geometric ranges which are calculated from known coordinates. Thus, the effect of systematic errors will be minimized. The corrections for the mobile receiver are provided in a standardized form using a suitable communication medium.

Mobile receivers can eliminate or greatly reduce distance dependent errors using the correction data, since it can be assumed that one finds comparable errors in the near surrounding of a reference station. Unfortunately, the errors considerably deviate between the mobile and the reference station.

The reference station observations can represent the errors of the mobile station only with reduced accuracy, getting worse with increasing distance. Here, one speaks about a distance dependence of the error effects.

The possible distance between mobile and reference station should be chosen according to the wanted position accuracy. With mean accuracy requirements in the order of 0.5 to 3 meter (code positioning), the possible distance can reach several hundred kilometers. The distance is mainly limited due to ionospheric effects for the highest accuracy demands in the order of 1 to 2 centimeters (carrier phase positioning). In case of low ionospheric activity, a distance up to 20 kilometers to the reference station is possible. In case of high ionospheric activity, the maximum distance to the reference station is limited to less than 5 kilometers. These values are strongly dependent of the quality of the used equipment (single or dual frequency receiver, antenna, data processing, etc.) and of the satellite geometry. Further distance dependent errors arise with an insufficient modeling of orbits and tropospheric delays.

Networking of reference stations

Distance dependent errors can be greatly reduced within a common processing of the observation data of a reference station network. This approach is commonly described as "networking". Here, the spatial alterations of the error components are calculated from the observations of a set of homogenously distributed reference stations with highly precise known coordinates. It's necessary and prerequisite for this approach to resolve the carrier phase ambiguities for the reference stations. A comparison of the measured pseudo-ranges between the reference stations and GNSS satellites with the calculated ranges using their known coordinates enables the determination of ionospheric and geometric (troposphere and satellite orbits) residuals. These serve as base points for the calculation of linear planes (polynomial parametrization). Using this networking principle, even highest accuracy requirements in the order of 1 to 2 centimeters can be met with distances between 30 and 50 kilometers between mobile and the nearest located reference station. Thus, SA*POS*® users can obtain considerable economic profits.

The results of the networking are currently provided as Area Correction Parameters ("Flächenkorrekturparameter" FKP) or Virtual Reference Station (VRS) correction data. Both methods can represent the results of the networking process taking distance dependent errors into account.

Aside from the original single station corrections for each satellite, the FKP approach additionally provides linear FKP planes (polynomial parametrization) valid for a certain regional area. The mobile receiver (rover) has to read this network information and the single station corrections for a common processing (FKP individualization). Almost all modern geodetic receivers are capable to work up these parameters.

The VRS approach generates and transmits correction data referring to a non-existing and therefore virtual reference station located directly aside the rover station. In a first step, the rover has to broadcast its approximate coordinates resulting from a single station adjustment to the network central office. Afterwards, the VRS correction data can be received, which is corrected for distance dependent errors to the greatest possible extent.

- **Postprocessing**

Original carrier phase observations of the GNSS-receivers are the data basis for differential positioning both in postprocessing and in real-time. Using the available software, station and distance dependent error sources are handled with to real-time comparable methods and strategies. Finally, the solution of the carrier phase ambiguities is always the key for a high precise positioning.

Generally, one differentiates the two approaches "Parameterelimination" (elimination of parameters) and "Parameterschätzung" (estimation of parameters). The first approach uses differenced carrier phase measurements as observables so that certain disturbing parameters are eliminated to the greatest possible extent. In contrast, the second method is based on non-differenced observations with the purpose of a strict state parameter estimation in order to present the reality most suitably. This approach is comparable to the networking process applied in the common analysis of reference station data in real-time.

The postprocessing method is used for positioning applications with highest accuracy requirements (e.g. state survey, geodynamic investigations) in the range of a few millimeters even over very long distances. For this purpose longer observation periods are necessary. Besides those static applications also trajectories of kinematic objects (e.g. for aerial photograph measurements) can be determined subsequently ("post-mission") with high precision.

If a user records satellite data with a GNSS receiver in a permanent reference station network (SA*POS*®), the following analysis is carried out commonly with the data of the surrounding reference stations to aim one solution. The used format is RINEX. The simultaneous use of several receivers in several sessions is practically used for analysis approaches in terms of multi station or multi session solutions. In strict consideration of existing correlations high neighborhood accuracies can be achieved. Highest accuracies, e.g. for the derivation of precise height information, are obtained with static observation periods up to 24 hours, the use of external satellite orbit information and absolute antenna calibration values.

Data Formats and Communication Media

SA*POS*® Data Formats

HEPS / EPS

The real-time services of SA*POS*® use the RTCM format definition (actual version 2.3). RTCM defines several message types for different kinds of information. Thus, the provided data contents can be adapted to the requirements at a time.
SA*POS*® HEPS may provide different message types depending to the user's requirements. All federal states agreed with a national stipulated data provision format using the RTCM message types 20 and 21 (compulsory or standard obligation including further message types) and additional networking information in form of FKP. The data has not to be encrypted and compressed, so that the receiver can directly process the information.
Over and above that, the federal states may supply other message types (standard options) which meet possible different customer's requirements. These message types comprise the RTCM message types 18 and 19, and the provision of VRS correction data. Further on, encrypted and compressed data is provided with the RTCM-AdV format.
The SA*POS*® EPS service uses pseudo-range corrections with additional information. The pseudo-range corrections are transferred using the RTCM message type 1. The RTCM message type 1 has been introduced with the RTCM version 2.0 and is used unmodified in the following versions.

GPPS / GHPS

SA*POS*® employs internationally recognized standard formats. The postprocessing procedures GPPS and GHPS use the RINEX format (actual version 2.1), which is an ASCII data format. It consists of a header and a body data section. General station information like station number and name, information about the GPS receiver and antenna, station coordinates, antenna heights etc. are given in the header. The epoch-wise observation information is written into the body section afterwards.
The Virtual Reference Station (VRS) exists within GPPS as a special kind of data. The processing of this correction data is carried out comparable to the real-time networking using the whole reference station network, but the results are stored up in a special type of RINEX format. The data files look like standard RINEX files. Nevertheless, network correction information is included, which is normally not permitted and not part of the RINEX standards. The main advantage of this approach is the possibility for a fast and easy standard postprocessing.

SA*POS*® Communication Media

HEPS

Standard broadcasting medium of SA*POS*® HEPS and actual European mobile radio standard is the GSM. This medium is used in Germany for the most positioning applications with SA*POS*® HEPS. It is almost area-wide available, cost-efficient and accepted. Optionally, HEPS data is transmitted via 2m band radio on demand.

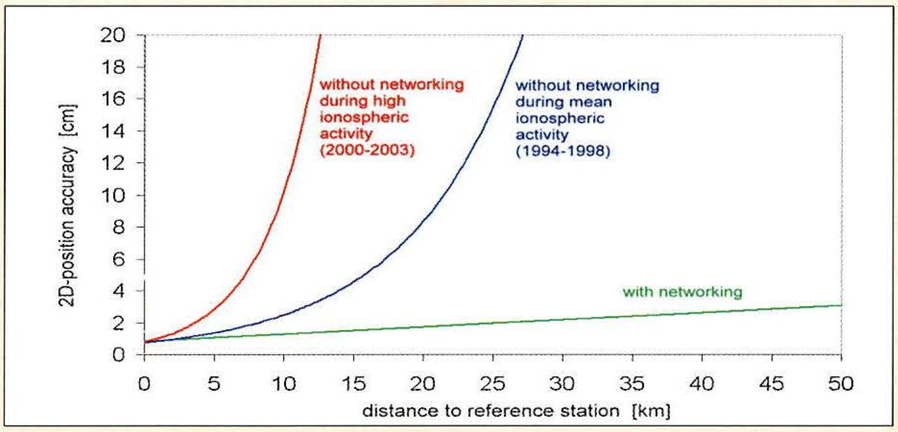
Momentarily, the introduction of a broadcasting medium based on the internet protocol (IP) is projected. Using this method SA*POS*® data can be transmitted via all IP-capable media. Today at the rover's site this is GPRS (General Packed Radio Service), in the future it will be UMTS (Universal Mobile Telecommunications System). The Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie, BKG) has worked out the protocol definition NTRIP and proposed to the RTCM Special Committee No. 104 (SC-104).

EPS

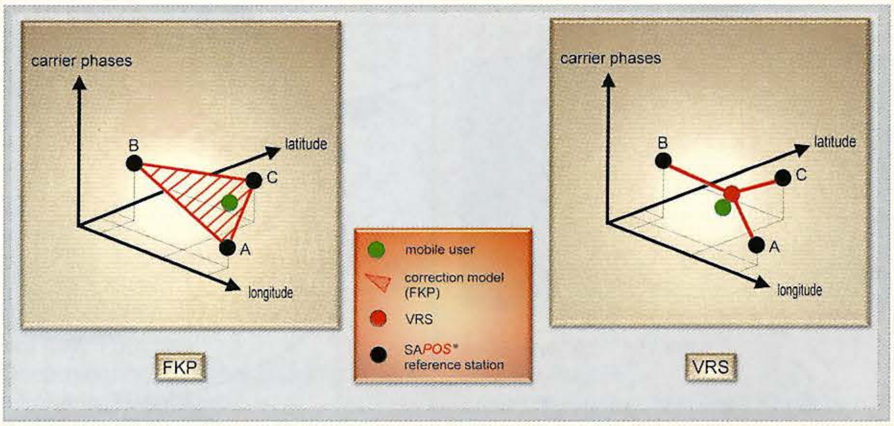
EPS data can be received Germany-wide via VHF (RASANT) and long wave stations (ALF). Optional communication media are the GSM, 2m band radio and in the future also NTRIP.

GPPS / GHPS

Normally, GPPS / GHPS data is transmitted using the internet. The user receives the data via FTP or E-mail. In addition the data is available on data carrier (e.g. CD-ROM) and partially provided via mailbox.



Achievable horizontal positioning accuracy depending on distance to reference station



The representations of the networking results by means of FKP and VRS are illustrated exemplary for a commonly at three networked reference stations observed satellite. Accordingly, these examples are transferable to a higher number of networked reference stations.

SAPOS® Quality Management

In the sense of a modern service, the quality of SAPOS® is measured as the totality of the user requests for the product SAPOS®. According to the definition DIN EN ISO 8402, quality is defined as the sum of the features and characteristics of a product or a service with regard to their suitability to meet fixed and presupposed requirements.

Fundamental quality characteristics of SAPOS® in the form of a national standardization of the service have been established by the AdV Plenum in November 2001. The rules comprise SAPOS® Standard Obligations and SAPOS® Standard Options concerning the basic principles of the SAPOS® service HEPS, the broadcast technology, the used data formats as well as the networking process of the SAPOS® reference stations. These standards correspond with accepted technical rules and will be adapted and supplied according the technological progress.

Within a modern circulation of a quality assurance model, a realization phase comes after the definition of the quality standards. The realization is particularly characterized by the specific qualities and features of the SAPOS® service. This includes for example the redundancy of the system, the alarm functions, the system validation, the user information services, but also a high accuracy, reliability and availability of the service. From a wealth of single measures for the realization of the high quality of SAPOS® two actual examples should be described here.

Diagnostic Adjustment of the SAPOS® Reference Stations

For the real-time networking process of the SAPOS® reference stations within the SAPOS® service HEPS a coordinate accuracy at the level of ± 10 mm standard deviation in the reference system ETRS89 is prerequisite. This assures optimal modeling and fast ambiguity resolution processes. An essential aspect is that the high relative accuracy has to be realized homogeneously even across the borders of the single federal states in order to meet the requirements of the SAPOS® customers if large geographical areas have to be covered.

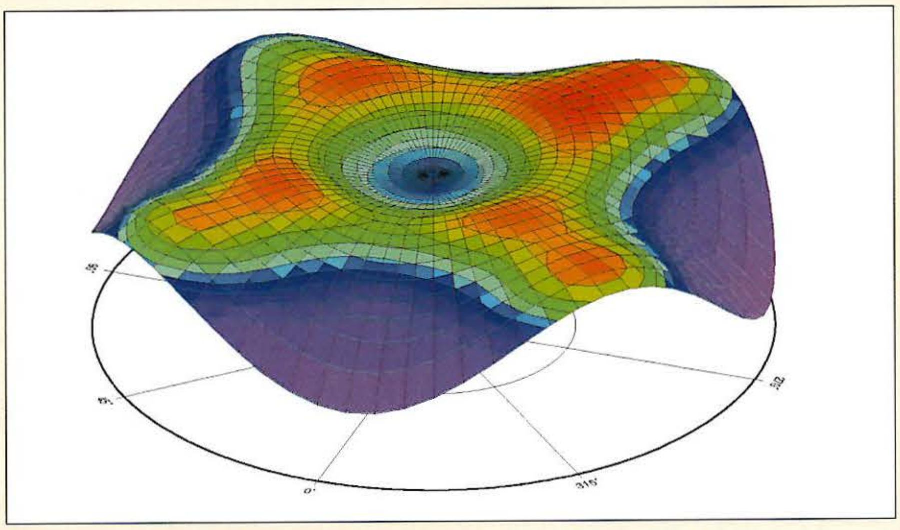
For that reason, in 2003 the Federal Agency for Cartography and Geodesy ("Bundesamt für Kartographie und Geodäsie", BKG) was commissioned by the AdV to carry out a so-called diagnostic adjustment of the entire SAPOS® reference station network. The primary objectives of this task were to analyze whether the above described accuracy requirements can be achieved and to point out possible weaknesses of the network.

The AdV Plenum decided in April 2003 to introduce the result of the diagnostic adjustment as the homogeneous, official set of coordinates for all SAPOS® reference stations.

Calibration of SAPOS® Reference Station Antennas

In accordance to a resolution of the AdV Plenum of April 2002, all of the more than 250 reference stations have to consider absolute antenna calibration data. Thus, the so-called ADVNULLANTENNA is realized within the RTCM correction data. This procedure agrees with up-to-date international technical developments and is realized by an individual antenna calibration of each single reference station. The Technical Committee SAPOS®, consisting of representatives of the GNSS industry and SAPOS®, explicitly recommends and supports this forward-looking proceeding.

After the definition and realization of the SAPOS® quality, the continuous circulation of the quality assurance model is closed by a third phase. Here within the daily tasks of a quality management system, the quality will be measured, controlled and adapted. Thus, in close co-operation to its users and to the equipment manufacturers SAPOS® will be adapted to the requirements and improved permanently.



GPS-antenna L1-PCV depending on azimuth and elevation of the received satellite signal

Selected SAPOS® Applications

Surveying and Cadastre

State Survey
Real Estate Cadastre
Land Consolidation

Engineering Surveying

Road Construction
Marking out Constructions
Register of Utility Services
Geoinformation Systems (GIS)

Hydrography

Maritime Surveying
Depths Profiling
Wreck Search

Transport Sector

Photo: Berliner Verkehrsbetriebe (BVG)

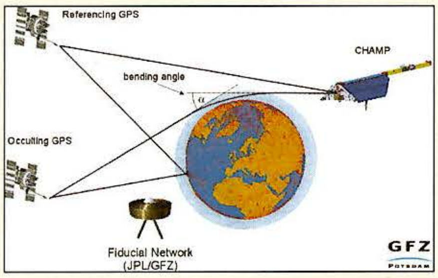
Vehicle Navigation
Fleet Management
Telematics in Traffic
Traffic Guidance Systems

Authrities and Organizations with Security Duties

Photo: Berliner Polizei

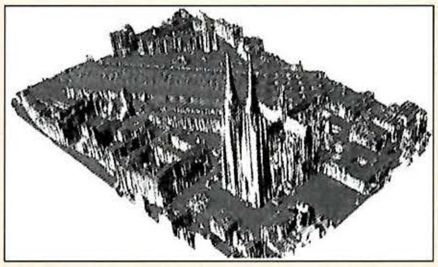
Emergency Guidance Systems:
Police, Fire Brigade, Rescue Services
State Visits
Cash Transports

Weather Services



Climatic Research
Weather Forecast
Determination of Tropospheric and Stratospheric Parameters

Laserscanning and Aerial Photogrammetry



Digital Terrain Models (DGM)
Digital Surface Models (DOM)
3D City Models
Protection from Flooding

Deformation Measurements

Construction Survey (e.g. Bridges, Dams)
Scientific and Geodynamic Investigations

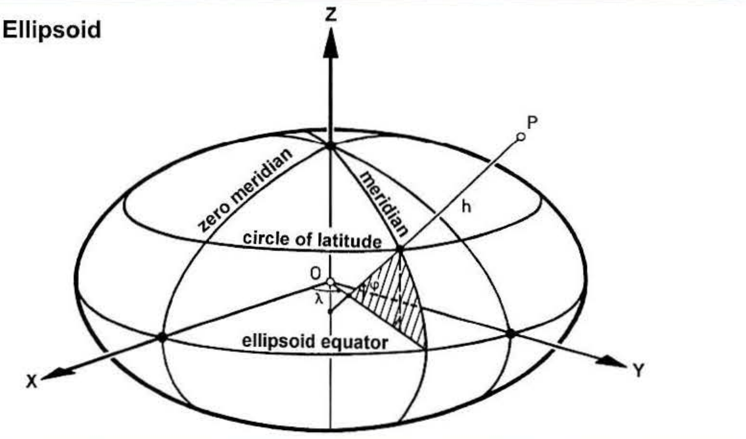
Agriculture and Forestry

Area-specific Farming
Precise Farming
Land Valuation (Capitalized Value of Potential Yield)
Documentation of Soiled Areas
Tree Cadastre

Geodetic Reference Systems

By using satellite positioning systems one yields three-dimensional Cartesian coordinates X,Y,Z referring to a global geocentric coordinate system. The X-axis points towards the intersection of the equator with the zero meridian (Greenwich). The Z-axis coincides with the mean rotational axis of the earth. The Y-axis is perpendicular to the X- and Z-axis completing a right-handed system. The XY-plane is formed by the mean equatorial plane. The XZ-plane is represented by the mean meridian plane with the longitude of Greenwich.

In a first approximation, the earth has a spherical shape. It can be described more precisely by a rotational ellipsoid. Beside a mathematical also a physical approach is necessary for a fundamental description of the figure of the earth in order to take the effects of gravity into consideration. The surface of fluid masses is always normal to the plumb line direction and forms a part of a level or equipotential surface. C.F. Gauss defined the geoid as the equipotential surface of the earth's gravity field coinciding with a mean sea level of the oceans, which may be regarded as being extended under the continents. Due to the extension inside the earth and the irregularities of deeper located masses with abrupt density changes, its curvature shows discontinuities. Geoid heights above the ellipsoid (geoid undulations) can be modeled using the recordings of gravimeters. This level surface serves as a reference for the height and not for the horizontal coordinate components. Formerly, horizontal and vertical coordinates have been derived independently. Both, satellite geodesy and precise geoid determination now enable a complete three-dimensional concept of geodesy.



• **Ellipsoid**

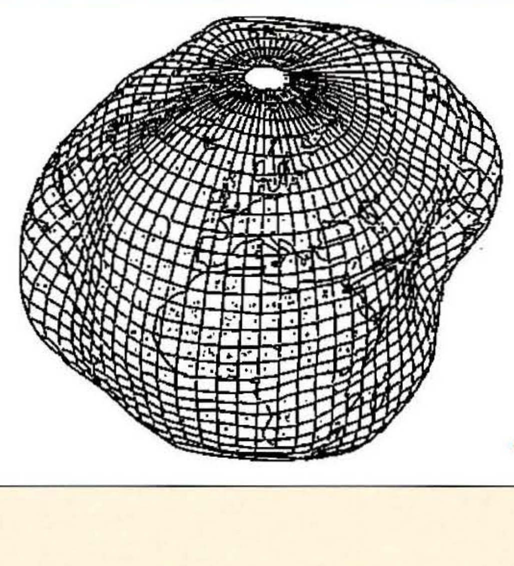
In order to give a mathematical description of the earth's figure, an ellipsoidal earth model has been introduced representing a best-fitting approximation of the earth's surface. A three-dimensional position is described by ellipsoidal coordinates (latitude φ, longitude λ, height h) on this reference ellipsoid.

The European Terrestrial Reference System 1989 (ETRS89) has been introduced as geodetic reference system in Europe. Basically, ETRS89 coordinates refer to a three-dimensional Cartesian coordinate system or alternatively to an ellipsoidal coordinate system. The associated reference ellipsoid is the GRS80 (Geodetic Reference System 1980).

Subsequently, these three-dimensional ellipsoidal coordinates will be projected into the mapping plane. In 1991/95, the AdV decided to introduce ETRS89 as a uniform geodetic reference system and to use the UTM coordinate projection as a uniform two-dimensional mapping for all points of the state survey and the real estate cadastre. In1996, the federal state Brandenburg realized these decisions. Some federal states are presently in the realization phase; the other ones will follow in the next years. Actually, the Bessel reference ellipsoid is used within the old federal states. Partly, the Krassowski or the Bessel reference ellipsoid is still used within the new federal states. Most states are currently still working with the Gauss-Krüger coordinate projection.

The transfer of ellipsoidal position coordinates into another reference system, e.g. the "Deutsches Hauptdreiecksnetz 1990" (DHDN90) or another geodetic reference system, has to be carried out by means of a transformation / conversion process, since the systems differ in their reference ellipsoids.

The quasigeoid became the official reference system with the introduction of the uniform height reference system "Deutsches Haupthöhennetz 1992" (DHHN92). The vertical datum is defined by the geopotential number of the nodal point Wallenhorst near Osnabrück taken from the European leveling network. The rule to use normal heights as official heights enables an optimized combination with heights resulting from satellite measurements, e.g. SAPOS®. The ellipsoidal heights of ETRS89 can be transformed into the official heights above "Normalhöhennull" (NHN) in the DHHN92 using quasigeoid models.


• **Geoid**

SA*POS*® Glossary

AdV: The Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany is assigned to the Standing Conference of Ministers and Senators of the Interior. Conference members are the Surveying Authorities of the federal states and the Federal Ministries of Transport, Building and Housing, the Interior and Defense.

ALF, Accurate Positioning by Low Frequency: Service for a Germany-wide long wave broadcasting of DGPS correction data (123,7 kHz).

Antenna Phase Center Variations (PCV): The center of a GNSS antenna varies in dependence of the received satellite signal's direction. The PCV describe the deviations of the actual wave front from a mean spherical wave front with its origin in the mean phase center (> Phase Center Offset). The PCV have to be taken into account for precise differential GNSS measurements (SA*POS*®-HEPS, -GPPS, -GHPS), particularly while using different GNSS antenna types simultaneously (> Nullantenna). As a rule, for the antenna of a mobile station a type calibration is sufficient, whereas the antennas of the SA*POS*® reference stations have to be calibrated individually.

Area Correction Parameters ("Flächenkorrekturparameter" FKP): Representation method (Transfer) of the networking results. The FKP are transmitted using the SA*POS*® defined >RTCM message type 59.

Ascending Node: The point of the elliptical orbital plane at which a satellite ascends the equatorial plane from south to north.

DREF91, German Reference Network 1991: Three-dimensional reference network observed with GPS in 1991 and finally adjusted in 1994, based on the European Reference Frame EUREF93 (>EUREF89).

ETRF89, European Terrestrial Reference Frame 1989: The ETRF89 is based on the > ITRF89 and can be considered as a densification of European stations of the International Earth Rotation Service (IERS). The first realization of the >ETRS89 is formed by the station coordinates of the measurement epoch 1989.0. ETRF89 was condensed by subsequent networks of > EUREF, > DREF and other densifications within the federal states in the following period.

ETRS89, European Terrestrial Reference System 1989: The ETRS89 is the European part of the >ITRS with respect to the reference epoch 1989.0 and the solid part of the Eurasian plate. The > AdV decided 1991 to introduce the ETRS89 as the national reference system.

EUREF89, European Reference Frame 1989: Term for the European GPS campaign in May 1989, which is the origin of the European reference network. The absolute datum of the network is defined by the coordinates of the fundamental stations of the > ETRF89 including local ties. The solutions of subsequent GPS campaigns - carried out for the expansion or improvement of the network - will always be transformed to the reference epoch 1989.0. Thus, the continental drift of the European plate is taken into account in a standardized way, as it was done for example with the results of the GPS campaign EUREF93 for the calculation of > DREF91.

Gauß-Krüger Coordinates: Plane and right-angled coordinates used by the German State Survey. The coordinates result from a conformal mapping (preservation of angles) of ellipsoidal coordinates into the projection plane (Reference Ellipsoid: old federal states BESSEL, new federal states partially KRASSOWSKI). The linear scale factor for the central meridian is m=1.0 (Transverse Mercator Projection). Each projection zone covers 3 degrees of longitude in the old federal states or 3/6 degrees in the new federal states.

Geoid: A physical model of the figure of the earth considering the irregularities of the interior mass distribution. In contrast to the real earth's relief the geoid is a closed and continuous surface with a normal plumb line in each point. It's defined as the equipotential surface of the earth's gravity field coinciding with or best fitting the mean sea level of the oceans. The geoid serves as a height reference surface or as the representation of the gravity field, whereas geodetic calculations are normally carried out on a > Reference Ellipsoid.

GNSS, Global Navigation Satellite System: Generic term for satellite-based navigation and positioning systems. GNSS is not restricted to GPS alone, but also refers to GLONASS, to the forthcoming Galileo system as well as to other local or regional augmentation systems (e.g. EGNOS).

GSM, Global System for Mobile Communications: International mobile radio standard.

ITRF89, International Terrestrial Reference Frame 1989: The worldwide accepted, global earth-fixed reference system realized by the International Earth Rotation Service through a global set of observing sites, whose geocentric coordinates and velocities (e.g. reference epoch 1989.0) comprise the International Terrestrial Reference Frame (ITRF). The results are based on different space geodetic methods including Very Long Baseline Interferometry (VLBI), Satellite Laser Ranging (SLR), Lunar Laser Ranging (LLR), GPS as well as Doppler Orbit Determination and Radiopositioning Integrated by Satellite (DORIS).

ITRS, International Terrestrial Reference System: The ITRS is a geocentric reference system of the International Earth Rotation Service (IERS). It is established by the defined directions to a mean position of the rotation axis of the earth (Z-axis) and a defined zero point on the equator (intersection with the Greenwich meridian, X-axis).

Multipath: Multipath is the corruption of the direct GNSS signal by one or more satellite signals reflected from the local surroundings of the antenna. As a result, the received signal is a composition of direct and reflected signals. The latter are always delayed compared to the line-of-sight signals because of the longer travel paths. Multipath periods in the order of minutes up to hours arise. Multipath may affect the quality of the ambiguity resolution process and the position results. The impact is reduced for a moving antenna in kinematic applications, since the effects change rapidly because of the changing geometry between antenna and reflectors. Due to a latent possibility for the occurrence of Multipath, within all surveying applications, especially valid for short time observations, a second independent position determination with an altered satellite configuration is recommended.

Networking: The distance dependent GNSS errors are considerably reduced using the real-time correction data of the SA*POS*® interconnected reference network. These distance dependent errors, essentially the errors of ionosphere, troposphere and satellite orbits, are estimated simultaneously within a suitable model and will be transmitted to the SA*POS*® users by so-called > Area Correction Parameters ("Flächenkorrekturparameter" FKP) or the so-called > Virtual Reference Station (VRS). The networking allows higher accuracies and faster initialization times. Hence, SA*POS*® users may draw economic profits.

NTRIP, Networked Transport of RTCM via Internet Protocol: Application level protocol streaming GNSS data via internet.

Nullantenna: Generic term for a GNSS antenna, which is quasi free of errors and thus without any direction dependence of its receiving behavior. Taking the calibrated > Phase Center Offset and its associated > Antenna Phase Center Variations into account, one yields a realization of the Nullantenna with its origin in the antenna reference point.

Phase Center Offset: GNSS carrier phase measurements refer to a variable electrical phase center of the antenna. Generally, using a mean phase center coinciding with a mechanical center (antenna reference point) is not sufficient for high precise GNSS data processing. Within a first step of a calibration procedure, the Phase Center Offset as the vector link between a mechanical and a mean phase center can be determined. The associated remaining > AntennaPhase Center Variations are minimized.

Quasigeoid: The quasigeoid is a physically defined substitution model for the > Geoid. In contrast to the geoid, the quasigeoid can be determined directly from gravity measurements. It's the reference surface for the normal heights, which is close to the geoid but not a level surface. The deviations from the geoid are normally at the mm to cm-order at low elevations and can reach up to one meter in high mountains.

RASANT, Radio Aided SAtellite Navigation Technique: Transmission method of DGPS data using the radio data system of the VHF radio.

Referenz Ellipsoid: A best-fitting substitutive surface for the > Geoid. The ellipsoid's dimension and position (orientation, fundamental point etc.) have been chosen in such a way, that one yields a optimal approximation to the geoid (locally, regionally and globally fitting ellipsoids).

Reference Surface: A mathematically or physically defined surface, e.g. by using the coordinates of existing control networks, which serves as a reference for horizontal coordinates, heights or geopotential numbers (> Gravity).

RINEX, Receiver Independent Exchange Format: Receiver independent, internationally recognized ASCII data exchange format. It was developed in 1989 at the University of Berne and serves for the storage and the exchange of GNSS observation, ephemeris and weather data.

RTCM, Radio Technical Commission for Maritime Services: American organization for the development of communication standards in the marine sector. The Special Committee No. 104 (SC-104) develops and defines data formats for the real-time broadcasting of observations or corrections for GNSS navigation systems. The formats are worldwide accepted and established as a standard for real time applications.

Selective Availability: A measure implemented by the U.S. Department of Defense (DoD), which enables an accuracy deterioration for non-authorized user groups. SA simply means intentional degradation of the positioning capability. This kind of denial has been accomplished by degradation of the satellite ephemeris accuracy and "dithering" the satellite clock frequency. SA has been suspended without guaranties of the DoD on May, 2nd 2000.

State Survey: The State Survey has the responsibility to provide a standardized geodetic spatial reference (fundamental geodetic survey) as well as the topographic map books (topographic land survey). The results of the State Survey form the basis for all national geodetic surveys.

UTM coordinates, Universal Transverse Mercator Coordinates: Plane, right-angled coordinates, originating from a conformal mapping (preservation of angles) of ellipsoidal coordinates into the projection plane. Each projection zone of the UTM mapping covers 6 degrees of longitude The linear scale factor for the central meridian is m=0.9996.

Virtual Reference Station (VRS): Representation method (Transfer) of the networking results. The VRS approach generates correction data referring to a non-existing and therefore virtual reference station located directly aside the rover station.

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