International GNSS Symposium 2008
November 11.–14. 2008
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SAPOS®
Spatial references and network
Examples
What is SAPOS®?

Satellite Positioning Service of the German National Survey
Concept of SAPOS®

- Full 24-hour DGNSS and PDGNSS-service
- Use of GPS, GLONASS and Galileo
- Real time and post-processing service
- Replacement of the necessary second RTK-GNSS receiver in the classical use of RTK
- Use of a high accurate international reference frame (ETRS89)
- Broadcasting of data via various communication media
- Real time processing of the RTK-network and actual data exchange
- Elimination of distance dependent errors
- Initialization times of 15-45 seconds over distances of more than 20 km
• Reference Stations in Lower Saxony
• Real time data transmission from each reference station to the central control
• Processing of the whole network in a permanent real time adjustment
• Estimation of distance dependent errors in a regional model
• Transmission of observations and model parameters to the user
• Estimation of the users coordinates relative to the next reference station
<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1994</td>
<td>Establishment of an expert group on reference stations</td>
</tr>
<tr>
<td>1996</td>
<td>Decision, to build up an “Satellite Positioning Service of the German surveying authorities“</td>
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<tr>
<td>1998</td>
<td>1st SAPOS symposium, Hamburg</td>
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<td>1999</td>
<td>Foundation of Technical Committee SAPOS</td>
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<tr>
<td>2002</td>
<td>Introduction of nationwide compulsory SAPOS-HEPS standards, e.g. network RTK, absolute antenna calibration</td>
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<tr>
<td>2003</td>
<td>250 operational SAPOS reference stations</td>
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<tr>
<td>2003</td>
<td>Establishment of Central Bureau SAPOS</td>
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<td>2003</td>
<td>1st PPP contract with Ruhrgas AG (ascos)</td>
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<tr>
<td>2005</td>
<td>Installation of ntrip caster (internet interface)</td>
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<tr>
<td>2006</td>
<td>Framework paper on the future of SAPOS</td>
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<tr>
<td>2007</td>
<td>270 operational SAPOS reference stations</td>
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</tbody>
</table>
SAPOS® - Reference Stations in Germany, Mai 2007

- 270 stations
- mean station distances between 25 - 60 km
- dual frequency receivers
- in the responsibility of the 16 State Survey Offices
SAPOS® - Reference Stations

AERIAL IMAGE OF GPS-REFERENZSTATION HANNOVER

ANTENNA SET UP
SAPOS® - Reference Stations

Different variations of reference stations

Borkum

Yellowstone, 1999

Swisstopo, 2006
### SAPOS®-Services

<table>
<thead>
<tr>
<th>Real time</th>
<th>Post Processing</th>
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<tbody>
<tr>
<td><strong>EPS</strong></td>
<td><strong>HEPS</strong></td>
</tr>
<tr>
<td>1-3 m</td>
<td>1-2/ cm</td>
</tr>
<tr>
<td>FM radio</td>
<td>mobile phone,</td>
</tr>
<tr>
<td>RTCM 2.0, 2.3</td>
<td>Internet</td>
</tr>
<tr>
<td></td>
<td>RTCM 2.3,</td>
</tr>
<tr>
<td></td>
<td>3.0/3.1</td>
</tr>
<tr>
<td></td>
<td>Network RTK</td>
</tr>
<tr>
<td></td>
<td>(FKP,VRS,MAC)</td>
</tr>
</tbody>
</table>

**EPS**: Real Time Positioning Service  
**HEPS**: High Precision Real Time Positioning Service  
**GPPS**: Geodetic Precision Positioning Service
## SAPOS®-Fees

<table>
<thead>
<tr>
<th>Service</th>
<th>Data Rate</th>
<th>Fee¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPS</td>
<td>1 s</td>
<td>150,00 € / year²</td>
</tr>
<tr>
<td>HEPS</td>
<td>1 s</td>
<td>0,10 € / min</td>
</tr>
<tr>
<td>GPPS</td>
<td>&gt; 1 s</td>
<td>0,20 € / min</td>
</tr>
<tr>
<td></td>
<td>&lt; 1 s</td>
<td>0,80 € / min</td>
</tr>
</tbody>
</table>

1) Fees principally depending on used amount of data
2) Single fee with purchase of equipment
Application of SAPOS®

State survey:
- Provision of reference frame
- Geodetic control measurements
- Height transfer

Cadastral survey

Additional applications:
- Hydrography
- Engineering surveys
- Aerial photogrammetry
- Airborne / terrestrial laser scanning
- Geodynamic research
- Weather service
- Time transfer
- All kinds of navigation
Conveyance of Cruise Liners from the shipyard Papenburg to the Northsee using SAPOS-EPS
Monitoring within the RTK network

- Postprocessing of daily and weekly coordinates of reference stations
- Real time processing within the RTK network processing
- Continuous estimation of rover-coordinates for a representative user
Quality of Network-RTK
SAPOS®

Spatial references and network

Examples
Basic tasks for Spatial Reference

- Based on the laws of 16 German Federal States
- State survey authorities are responsible for providing
  - a uniform,
  - homogenous
  - spatial reference system,
- 2D/3D positions, physical heights, and gravity,
- employing monumented geodetic control networks (GCN)
Standardized Spatial Reference in Germany (AdV 2004)

Federal standardised and uniform network of control stations

- **Geodetic land network points (GGP)**
  - 3D
  - (in discussion: DHHN 2011, ...)

- **Height geodetic control points (HFP)**
  - 1D
  - DHHN 92
  - (DHHN 2011)

- **Gravity geodetic control stations (SFP)**
  - 1D
  - DSGN 94
  - DHSN 96

- **Reference station points (RS)**
  - 3D
  - SAPOS®
European Vertical Reference System (UELN)

German Primary Levelling Net (DHHN 1992)

Network graph
History of observation accuracy

Accuracy of German Levelling Networks

Accuracy of German Levelling Networks

\[ s_0 \text{ from net adjustment} = \begin{cases} 
0.5 & \text{mm/km for 1860-1880} \\
1 & \text{mm/km for 1880-1900} \\
1.5 & \text{mm/km for 1900-1920} \\
2 & \text{mm/km for 1920-1940} \\
2.5 & \text{mm/km for 1940-1960} \\
0 & \text{mm/km for 1960-2020} 
\end{cases} \]

Year

1860 1880 1900 1920 1940 1960 1980 2000 2020

DHNN 2006-2011 (Genauigk. unb.)

RHN = DHNN 12
Niv-Netz 60
NKN I – Küste
NKN I – Grundnetz
NKN II – Küste
NKN II – Grundnetz
SNN 56
SNN 76
DHHN 85 = NKN III
DHHN 92

AMTLICHES DEUTSCHES VERMESSUNGWESEN
- Levelling lines (~ 20000 km)
- 250 GNSS points
- 100 Absolute gravity points
- 250 SAPOS reference stations
- IGS, EPN, GREF
- with $s_h \leq 5$ mm in mind
- ITRF 2005 / IGS05
All sorts of activities:
• Levelling
• GNSS field measurements
• Absolut gravity measurements
SAPOS®
Spatial references and network
Examples
development of an integrated approach to altitude determination and monitoring in coastal regions

- Measurements made by different height sensors (levelling, gravity, GPS and water-level) will be gathered and combined into an integrated kinematic approach under consideration of the accuracies of the different height sensors.

- Research project by the German Coastal Engineering Research Council

- Runtime: 10.2005 – 09.2008 (3 years)

IKÜS A) coordination GNSS, gravity
IKÜS B) water-level, alignment
IKÜS C) algorithm, software, combination
IKÜS D) data of LGN, levelling, Database
Monitoring of SAPOS® reference stations

Height component

15 [mm]
0
-15 [mm]

1998 → 2006

Reference: TU Dresden
Earthquake „Rotenburg (Wümme) 2004

October 2004 - Magnitude 4,5
Salt domes and caverns

Map scale: 20 km
Ground level subsidence and displacement

- Cavern „Wilhelmshaven“
  - 1.200 - 1.400 m deep
  - about 12 Mio. m³ oil resources
- horizontal displacement (10 cm)
- vertical subsidence (20 cm)

► as a consequence of fill and deplete procedures!
Salt mine „Wunstorf Kolenfeld“

differences: 10 cm
Long time series of monthly mean sea level

- water-level observations (tide gauge) are relative!
- seemingly subsidence from postglacial uplift!

Reference: Dr. Liebsch, BKG
• **SAPOS** is actually a part of a geosensor network
• The service provides real time and post processing data for all accuracies and for a lot of applications
• **SAPOS** is a part of the new federal standardised uniform network
• The combination of all parts of the new federal network in an common mathematical model can be lead to an integrated geosensor network