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CONTRIBUTION OF EUPOS PERMANENT GPS NETWORK TO THE EUREF REFERENCE SYSTEM

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Abstract

EUPOS (European Position Determination System) is a new European initiative of establishment of a uniform ground based GNSS augmentation system of multifunctional permanently operating reference stations creating a satellite positioning infrastructure in Central and Eastern Europe (CEE). The Project was initiated by the Berlin Senate Department for Urban Development and European Academy of the Urban Development Berlin. The project consists in establishment of about 900 multifunctional satellite reference stations in Central and Eastern Europe. Sixteen countries (Bosnia & Herzegovina, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovakia, Slovenia and Ukraine) intend to participate in the project. One common project standard set will be observed by all countries, however the project will include the existing or developed infrastructure in participating countries. Experiences of all participating countries in establishing and operating satellite systems will also be used. The system will be compatible with the German network SAPOS and in future will use as main signal the signal of the European system Galileo. The network of reference stations will provide services for both positioning of the geodetic control points and for land, air and marine navigation. Several levels of positioning accuracy will be offered.

The participating countries decided to form a Steering Committee. Eleven working conferences of the Steering Committee were held up to now. The conferences were devoted to discussions on practical aspects of realisation of establishment of the network, the standards and possible sources of financial support for realisation of the Project.

EUPOS is a member of the International Committee on Global Navigation Satellite Systems (ICG) and the Radio Technical Commission for Maritime Services Special Committee 104 (RTCM SC 104).

The project EUPOS was also presented at many international conferences and symposia. On 12 November 2003 the representatives of the EUPOS International Steering Committee have held consultations in Brussels with Galileo Joint Undertaking and the European Commission EuropeAid Co-operate Office. The objectives of consultations were to inform the EC about the Project EUPOS, its organisation, standards and services, links to the European Project Galileo and expected benefits for all participating countries. As positive aspects there were recognised short time (2,5-3 years) of realisation of the Project and the fact that the organisational structures of the project are already available. It was advised that the attempt could be made to request for financial support from different EU Programmes: ERDF for EU member countries, ISPA – for EU candidate countries, CARDS – for West-Balkan countries and TACIS – for the Russian Federation. Since Germany has complete network of reference stations SAPOS, the financial support for this country will be used only for international co-ordination, organisation, supervising and promotion of the Project particularly by the International EUPOS Steering Committee.

1. GENERAL INFORMATION ON EUPOS PROJECT

The programme EUPOS was initiated in March 2002 by the initiative workshop/conference organised by the Berlin Senate Department for Urban Development, supported by the European Academy of the Urban Environment (EA.UE), Berlin, Germany. The participants of the Berlin workshop decided to form a founding/steering committee comprising representatives of countries expressing an interest of establishment of multifunctional DGNSS reference station system. Since that time there were held eleven conferences of the EUPOS Steering Committee devoted to discussions on practical aspects of establishment of a multi-functional network of GNSS reference stations in Central and Eastern European countries, problems of standards, organisation of the Project and financial support for realisation of the Project. As in 2007 the following countries intend to participate in the EUPOS Project: **Bosnia and Herzegovina, Bulgaria, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Macedonia, Montenegro, Poland, Romania, Russian Federation, Serbia, Slovakia, Ukraine and the German States Hamburg advisory and Berlin as chair. Slovenia has an observer status.**

The European Position Determination System EUPOS is both an international initiative and a project to establish and to provide a basis infrastructure particularly for positioning and navigation in Central and Eastern Europe (CEE) realised by ground based multifunctional DGNSS reference station systems and services in the participating countries, which use agreed uniform standards**. The EUPOS ground-based GNSS augmentation system will cover about 25% of the European Union territory and more than 60% of the area of the whole Europe (cf Fig. 1).** Taking into consideration also the Russian territory in Asia, where this infrastructure will be established, EUPOS will be realised for an area of about 10 million square kilometres.

On 12 November 2003 the representatives of the EUPOS International Steering Committee have held consultations in Brussels with Galileo Joint Undertaking and the European Commission EuropeAid Co-operate Office. The objectives of consultations were to inform the EC about the Project EUPOS, its organisation, standards and services, links to the European Project Galileo and expected benefits for all participating countries. As positive aspects there were recognised short time (2,5-3 years) of realisation of the Project, that the Project covers a great part of the European territory and the fact that the organisational structures of the project are already available. As negative were pointed out the high cost of the project and a fact that not all countries participating in the Project can request for financial support from one EU programme. It was recommended that the total cost of the Project should be reduced (mainly by reducing the number of planned stations) and was advised that the attempt could be made to request for financial support from different EU Programmes: ERDF - for EU member countries, ISPA – for EU candidate countries, CARDS – for West-Balkan countries, TACIS – for the Russian Federation. It is planned to build in total up to about 900 reference stations in above mentioned countries beyond Germany, where a reference station system SAPOS already exists.

EUPOS provides DGNSS correction data for real-time positioning and navigation as well as GNSS observation data for post-processing position determination. **EUPOS is able to support precise positioning and navigation with high accuracy (metre, decimetre, centimetre in real-time and centimetre and sub-centimetre in post-processing) and with guaranteed availability and quality.** EUPOS is independent of private company solutions and uses only international standards and open standards.

At last almost 900 EUPOS reference stations are planned currently: circa 500 stations by the Russian Federation and about 400 stations by the other participating countries. The progress of the EUPOS system realisation in the member countries is different since it depends on the financial facts.

The vision of such a uniform DGNSS infrastructure in CEE was born in the nineties of the last century. EUPOS itself presented this aim to a series of regional workshops and international meetings of experts on the use and applications of GNSS, which the United Nations Office for Outer Space Affairs (OOSA) has been organizing since 2001 in co-sponsorship with the Government of the United States. The International Workshops reviewed the implementation of project proposals from the series of GNSS meetings with a view to prioritizing the projects for support by the OOSA. EUPOS was identified as one of the priority projects that were provided. The OOSA noted with satisfaction that EUPOS would be the first ground-based GNSS infrastructure of its kind with regional reach and that that EUPOS significantly enhance the scope of use and applications of GNSS as well as their scientific, social and economic benefits. It was pointed out, too, that EUPOS would serve as a good model for the other regions to follow in the development of their GNSS infrastructure.

EUPOS contributes to the ICG (International Committee on Global Navigation Satellite Systems) work as an Associated Member.

Since the existing international technical standards on DGNSS do not fulfill all demands of the EUPOS community the ISC followed the requests of the international GNSS equipment industry and organized the establishment of a EUPOS working group on Technical Cooperation with the Industry (TCI). EUPOS also became member of the Radio Technical Commission for Maritime Services (RTCM) in 2006 and contributes to the Special Committee 104 (RTCM SC 104), which sets guidelines in the field of real-time DGNSS. Among other issues EUPOS is interested in an international standard for RTCM data encryption against manipulation and unauthorized use, but also for deduction of fees, especially if data are broadcasted.

Table 1. Number of planned EUPOS reference stations

No.	Country	Area [km^2]	Number of EUPOS reference stations
EU member countries			
1.	Berlin	891	4
2.	Bulgaria	110 950	23
3.	Czech Republic	78 870	26
4.	Estonia	45 220	13
5.	Hungary	93 030	36
6.	Latvia	64 600	24
7.	Lithuania	65 300	13
8.	Poland	312 680	87
9.	Romania	237 500	48
10.	Slovak Republic	49 035	21
11.	Slovenia (observer status)	20 270	15
Balkan countries			
1	Bosnia and Herzegowina	51 000	30
2	Macedonia	25 330	15
3	Serbia and Montenegro	88 360	32
1	Russian Federation	17 075 000	500
2	Ukraine	603 700	13
T o t a l			**900**

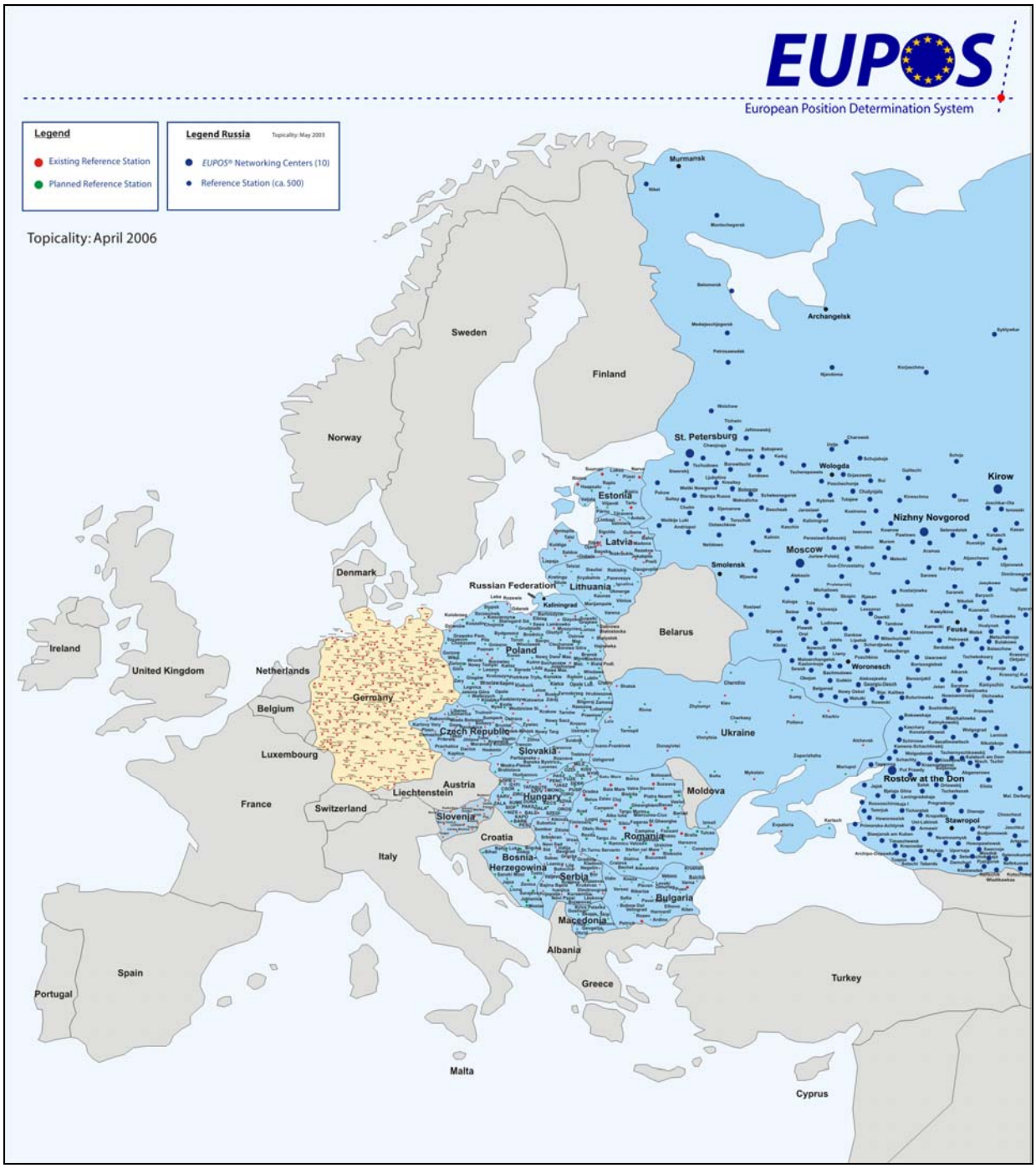

Fig. 1: Planned and existing EUPOS reference stations (Western part of the network)

Furthermore the EUPOS Working Group on System Quality, Integrity and Interference Monitoring (SQII) was established by the ISC in 2006. The SQII is responsible to ensure high quality operation and services of EUPOS on an international level, works out technical quality guidelines and standards and supervises their implementation in the national EUPOS segments, documents network and station configurations and status. Following recommendations of the UN Action Team on GNSS the SQII supports the development of methodology and software for efficient quality, interference and integrity monitoring. Such as the TCI the SQII presents its results to the ISC.

To enlarge the EUPOS activities transcending technical realisations the project EUPOS – Interregional Cooperation (EUPOS -IRC) was launched October 2006, since it is accepted as a European Union INTERREG IIIC Programme operation. Main aims of this operation are to identify, point out and enable possibilities and

benefits of the use and application of GNSS technology in the field of regional development, to establish long lasting cross-border cooperation between experts in the field of GNSS and geoinformation on the one hand and on the other hand regional policy experts and stakeholders.

2. SOME SELECTED TECHNICAL CHARACTERISTICS OF EUPOS

The EUPOS is an international project to establish a uniform ground based GNSS augmentation system of multifunctional permanently operating reference stations creating a satellite positioning infrastructure in Central and Eastern Europe (CEE). EUPOS provides DGNSS correction information and observation data for real-time positioning and navigation and for post-processed position determination. All EUPOS data are referred to the ETRS89. The multifunctional DGNSS reference stations are permanent with a distance between the stations less than 100 km. Thus is given a guaranteed usability also by former GNSS rover systems than the newest generation as well as a measure to guarantee high system availability in agreement with the demands. Higher density might be useful in conurbations. Existing reference stations (e.g. EUREF EPN, IGS, CERGOP2) shall be connected or incorporated. A common use of reference stations in neighboring countries close to border areas is part of the concept.

Quality definition for reference station sites and technique are agreed and will be kept up to date. EUPOS uses GPS and optional GLONASS. But, as soon as GALILEO will be operable, EUPOS will use the GALILEO as main standard and both GPS and GLONASS optionally. However, it is favourable to use all available GNSS for a high number of available satellites at any time. A quality management and technical measures guarantees a minimum 99%-level of availability and integrity.

The EUPOS reference stations are linked within a network. Networking centers computes highly precise information on troposphere, ionosphere and orbits of the GNSS satellites which ensures to decrease the corresponding influences of biases dependent on the current GNSS rover position in real-time. Particularly this procedure enables the very high accuracy positioning up to centimetre in real-time .

EUPOS provides three sub-services: ‘DGNSS’ and ‘Network RTK’ for real-time applications and ‘Geodetic’ for post-processing. Standard medium to provide EUPOS data is the Internet, which could be used in the field via mobile phones. All kinds of radio etc. could be used additionally for the EUPOS data broadcast in agreement with the needs. EUPOS DGNSS supplies real-time navigation and position determination with an accuracy of 2 m up to 0.5 m for moved objects and up to 0.2 m for static positioning, dependent on the applied rover station equipment. EUPOS Network RTK realizes real-time position determination with an accuracy ≤ 2 cm. EUPOS Geodetic provides observation data for post-processed position determination with 1s-frequency.

3. RELATION LINKS OF EUPOS TO GALILEO SYSTEM AND EUREF

The Galileo signals will be the basis standard for the EUPOS stations as soon as the system Galileo is available. Systems GPS and GLONASS will be additional optional elements. Evident interrelations between the system Galileo and the EUPOS network can be noted as follows:

- Galileo gains a huge number of new users; about 900 reference stations in 15 countries will work permanently using the Galileo system;
- By EUPOS Galileo will transfer the reference system to all users in Central and Eastern Europe;
- EUPOS will offer and guarantee the services of proper accuracy as recommended by the Galileo programme;
- EUPOS stations could be integrated into Galileo programme. Some selected EUPOS stations could be incorporated to the Galileo ground control segment.

System of EUPOS stations will be related to the European EUREF Permanent Network EPN the main objectives of which is to monitor and maintain the European Terrestrial Reference Frame ETRF. In particular the following can be said:

- EUPOS reference stations will be connected to the EUREF EPN;
- The EUPOS stations will be related to the ETRF system and will transfer the ETRF to all Central and Eastern European countries;

- Some selected EUPOS Processing Centres could serve as EPN Local Analysis Centres;
- International EUPOS Steering Committee has established close cooperation links with the IAG Sub-Commission S.C.1.3a for Europe "Regional Reference Frame (EUREF)" of the IAG Commission 1".

EUREF's main tasks are the definition, establishment, maintenance and improvement of the European Reference Frame. The European Terrestrial Reference System 89 (ETRS 89) is the standard European precise GNSS coordinate system. ETRS 89 is maintained by EUREF and it is accessed by the EUREF Permanent Network (EPN). EPN consists of tracking stations, analysis and data centres. One EPN data centre (GOP, Czech Republic) and four analysis centres (GOP, Czech Republic; SGO, Hungary; SUT, Slovakia; WUT, Poland) are located in EUPOS member countries. EPN does not cover homogeneously the whole European continent, the network is very dense on the western half of Europe but information is missing from the east.

The EUPOS community could help EUREF increase the coverage area and improve the quality of EPN by building hundreds of state-of-the-art GNSS permanent stations across Central and Eastern Europe, fixed in the ETRS89 system (the official terrestrial reference system of EUPOS is ETRS 89). With this work the number of stations contributing to EPN can be significantly increased, especially in countries, where the number of EPN stations was very low before EUPOS started its coordinated actions (e.g., Bulgaria, Estonia, Latvia, Lithuania, Romania, Russia, Serbia, Ukraine, etc.)

The new permanent stations will strengthen the geometry of EPN in eastern direction, enabling EPN to launch special projects to generate higher quality GNSS data-based products. European precise orbit determination or near real-time tropospheric zenith delay estimation projects would clearly benefit from new Central and Eastern European EPN stations. Meteorological applications such as numerical weather prediction and climate change modelling require hourly and daily raw GNSS observation files in RINEX format. Such files are produced by the EUPOS networking centres on a routine basis with low latency and high data rate. EUPOS could provide such files to EPN for scientific purposes free of charge.

EUPOS countries also support the EUREF-IP initiative by streaming carrier phase GNSS data of their growing number of EPN stations through the Internet via Ntrip (Networked Transport of RTCM via Internet Protocol). Ntrip was originally a EUREF-IP Pilot Project. The primary objective of EUREF-IP was to disseminate RTCM corrections via Ntrip for precise positioning and navigation purposes. This aim coincides very well with the main goal of EUPOS, i.e. to provide homogeneous real-time DGNSS corrections for a large part of Europe in a standard format. Ntrip in the meantime became an RTCM recommended standard for DGNSS data distribution and it is also the basic standard of EUPOS for real-time DGNSS and Network RTK data distribution.

EUPOS countries exchange raw GNSS data across the borders using also Ntrip technology. According to the EUPOS technical standards it is preferred to use UDP (User Datagram Protocol) over TCP/IP (Transmission Control Protocol/Internet Protocol), which is currently adopted by the Ntrip standard version 1.0. EUREF is also investigating the potential benefits of the UDP protocol and plans to revise the Ntrip standards. In case EUREF-IP will come up with a revised Ntrip version including UDP, EUPOS would be ready to quickly adapt to the changes.

The coordinate time series analysis of all Hungarian EUPOS stations (not only EPN stations) is carried out on a routine basis using the same approach as EPN. The EUPOS International Steering Committee (ISC) encourages other EUPOS member countries to monitor the coordinate changes of their permanent stations based on the same process. Hungary is also monitoring the quality of its reference station data (based on RINEX files), an extended quality analysis is carried out on a daily basis, which contains additional processes (e.g. signal strength analysis) above routine EPN data checking. EPN could improve its quality control system based on the Hungarian example. Regular radio interference monitoring of EUPOS stations is recommended by the System Quality, Integrity and Interference Monitoring (SQII) working group of EUPOS. Hungary has several years of experience in monitoring the GNSS frequency bands for interfering signals at permanent or campaign stations. The applied technology and the resulting database could be of EPN's interest.

The EUREF Technical Working Group (TWG) is responsible among other things for the coordination and development of EPN. The International EUPOS Steering Committee ISC has established several personal contact links with EUREF. Jaroslav Šimek from the Czech Republic works in the EUREF TWG and is also a member of the EUPOS International Steering Committee. Hermann Seeger is a technical advisor of EUPOS ISC and a permanent guest at EUREF TWG meetings. Ambrus Kenyeres is the Hungarian member of the EUREF

TWG who is deeply involved in the coordinate time series analysis of EPN stations and also carries out similar analyses for non-EPN EUPOS reference stations in Hungary.

EUPOS cooperates with EUREF and observers of both the ISC and the EUREF Technical Working Group participate in the conferences and meetings of the other organizations. We do hope that the cooperation between EUPOS ISC and EUREF TWG will give fruitful, concrete and encouraging results from scientific and practical points of view.

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Further details on the project EUPOS are available in the Web Pages

www.eupos.org