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СОЗДАНИЕ ГОСУДАРСТВЕННОЙ GNSS СЕТИ - БАЗОВОГО ЭЛЕМЕНТА НАЦИОНАЛЬНОЙ ГЕОГРАФИЧЕСКОЙ ИНФОРМАЦИОННОЙ СИСТЕМЫ УЗБЕКИСТАНА

Creation a state gnss network as a basic component Of the national geographic information system of uzbekistan

Макалада Өзбекстандын жаңы GNSS торун түзүүнүн маселелери каралган. Ошондой эле жаңы координат системаларын куруу жана жергиликтүү система менен геоборбордук системанын которуу параметрлери да изилденген.

Ачкыч сөздөр: *таяныч чекит, GNSS, жергиликтуу координат системасы, которуу параметрлери.*

В статье рассмотрены вопросы реализации новой GNSS сети Узбекистана. Также изучены проблемы построения новой системы координат и выбора параметров перехода между локальной и геоцентрической системами.

Ключевые слова: *опорный пункт, GNSS, локальная система координат, параметры перехода.*

The paper presents the authors views on options for, and reviews current progress towards a new GNSS network of Uzbekistan. Problems with establishing of a new datum and choosing transformation parameters were considered also.

Keywords: *reference point, GNSS, local datum, parameters transformation.*

1. Introduction

The most efficient form for complex presentation and analysis of information about territory, natural resources, their dynamics and using is a Geographic Information System (GIS). As is generally known, any object of digital map has the coordinates "tied" to coordinate basis. Besides the tasks of collection and updating of information, GNSS–technology decides another important problem of the landed cadastre - providing a reference coordinate system. The geodetic GNSS control network is essential basis of the NGIS. State Geodetic Network of Uzbekistan is fragment of Commonwealth of Independent States Geodetic Network and incorporates approximately 9400 geodetic points of 1-3 classes. When CS-42 was established, it was of high quality and accuracy for the standards of the day. However, this accuracy is now insufficient to meet modern requirements and new technologies. CS-42 suffers from a number of problems and limitations. Results of adjusting of geodetic network in territory of the former USSR have confirmed availability of significant deformations of State geodetic network in CS-42 /1/. The general regional deformations in the north and the east countries made 20-30 m, local deformations on border of blocks of up to 10 m and more have been recorded. The second-order triangulation networks were adjusted under the control of the first-order chains. The density of stations defining non-geocentric CS-42 is dependent on the technology that was used to define them.

Uzbekistan is located on the Asian continent in the basin of the great Amudarya and Syrdarya rivers, in the desert subtropical zone, taking the part of Turan Lowland in the West and mountainous highlands in the East. Natural environment of the Republic is characterized by high seismic conditions. As a result, severe earthquakes have plagued the region for thousands of years. Uzbekistan, lying across the Eurasia/India plate boundary, is subject to ground movements across the country of 3-5 cm/year, disregarding the effects of large earthquakes /2/. This amounts to 2 m in the last years since CS-42 was established. Modern satellite geodetic technologies not only allow increasing accuracy of coordinate determination by an order but also lift restrictions from geodetic point layout and working procedures imposed by classical geodesy. These drastic changes provoke developing new geodetic base that will satisfy coordinate determinations with GPS/GLONASS satellite systems in respect of precision and working procedures. These technologies are already used (still slightly) in traditional spheres: cartography, navigation, geology, agriculture, planning of construction and others, but this activity have not systematic program character. Some progress was outlined in this direction recently. Modernization program of the national geodetic network of the Republic of Uzbekistan has provided the soonest transition from the traditional methods to the building of the stationery base station networking.

2. Proposed new network configuration

With the purpose of improving the national geodetic reference frame an establishment of the new State Geodetic network (SGN), based mainly on use the GPS measurements, is now carried out in Uzbekistan under the management of the State Committee for Land Recourses, Geodesy, Cartography and State Cadastre in collaboration with the Academy of Sciences. National satellite geodetic network in its structure is formed on the principle working “from the whole to the part” /3/. In the course of improving, the national geodetic network provides for the establishment

- System of Continuously Operating Reference Stations (CORS);
- Satellite geodetic network 0th class points (SGN-0);
- Satellite geodetic network 1st class points (SGN-1)

2.1 Objectives of the GNSS CORS Network

At present CORS includes both permanently working points and passive points (figure1). The primary function of these stations will be to connect the Uzbekistan survey system to global geodetic networks (like ITRF, EUPOS), which will increasingly be used by modern survey technology. These stations will be located on secure stable rock sites and will be used as base stations for developing of geodetic networks follow classes. Station positions will be calculated and updated on a regular basis and data will be made available to the international community for use in determining GPS satellite orbits. The general definition of a GNSS CORS Network is a terrestrial infrastructure designed for delivery of a National Service of Positioning based on GNSS technology with different levels of accuracy and realization and open to multiple segments of activities. For better understanding, let us call this National Service UzPOS (Uzbekistan Positioning).

UzPOS is designed to cover the whole territory of Uzbekistan but with different levels of accuracy and realization due to the non-homogeneous infrastructure and needs from a geographical point of view:

- Accuracy may vary from mm-level up to metric level.
- Realization may differ from “real-time” mode with different level of accuracy (RTK and DGPS modes) and post-processing mode with also few different level of accuracy (PP mode).
- Positioning will be made in the National Coordinate Systems using the latest IGS08 Reference Frame or equivalent ITRF realization.
- To perform this National Service this project plans to establish and maintain for a period of 3 years a Continuously Operating Reference Station (CORS) network of 50 Reference Stations across the country.

As a summary, the UzPOS Service will be based on the GNSS technology and will be consisting of 4 segments:

- The Spatial segment composed of 4 constellations of satellites operated by different States:
- GPS operated by the US government and offering signals from 30 satellites, currently operational but in a continuous process of modernization,
- GLONASS operated by the Russian government (24 satellites), currently operational but in a process of modernization,
- Beidou operated by the Republic Popular of China and currently in implementation phase

with 14 satellites,

- Galileo operated by the European Union and currently in implementation phase with 4 satellites,
- The Ground Segment composed of 50 Continuously Operating Reference Stations (CORS) distributed across Uzbekistan following some geographical rules,
- The UzPOS Control Centre managing all national GNSS CORS, collecting GNSS measurements, processing and delivering to end-users the appropriate Positioning Service.
- The End-users connecting to UzPOS and receiving the Service they pay for with different level of accuracy and realization.

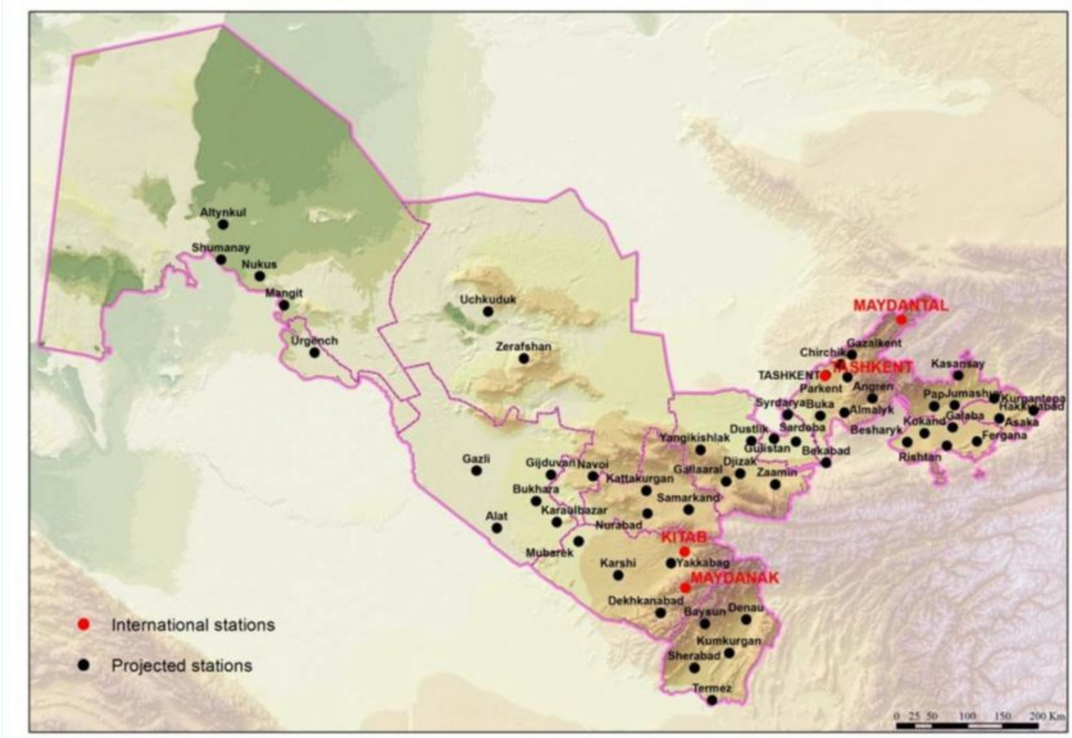

Figure 1. Present status of Uzbekistan State Geodetic Network

UzPOS Services will cover a large range of applications for any potential segment of end-users and not only for geodesists. For some technical reasons which will be developed later in this chapter, some Services will be available in “real-time”, others only in a delayed mode from 1 hour to few days – this is called “post-processing” mode (PP mode). In real-time accuracy is better than either 10cm or we talk of RTK mode or the accuracy is between 10cm and 1m: this is the domain of DGPS or DGNSS. In post-processing mode, most of the applications require accuracy from mm level down to few cm. Table 1 is listing the main Services of UzPOS representing 99% of the market needs.

2.2 Classification of Sites

Following the Segmentation of applications given above, it is possible and desirable to differentiate the design of the GNSS CORS Stations.

A Type-A Station is designed for high primary geodetic infrastructure like EPN for EUREF or IGS. These sites are designed for long-term geodetic network of zero order and to participate to international scientific programs (IGS) and geophysical studies. Monumentation is specific to highest stability (concrete pillars on bedrock), GNSS equipment will include Choke Ring Antenna and a tilt device to check long term stability. This Station will also participate to the RTK Network. Type A Stations will be distributed all along the country with spacing about 300-400km.

Type-B Station are designed for RTK Network only, mainly for RTK and quick static surveys. Sub-millimeter stability of Monumentation is not so high requirement and a solid mast on top of a roof of a secured building is acceptable. GNSS equipment with high quality Geodetic Antenna is acceptable. In order to deliver good VPPS service, spacing between Type B Station will range from 50 to 80km – depending on geographical conditions.

Table 1 - Listing the Main Services of UzPOS

GNSS CORS Network service	**Procedure/ method**	**Data transmission**	**Accuracy**	**Data format**
DPS (*) differential positioning	code measurements in real-time for GNSS rovers (DGNSS)	Mobile Internet (GPRS, 3G) with NTRIP protocol	±0.3 m to ±1 m	RTCM 2.3
VPPS (*) highly precise positioning	phase measurements in real-time for double-frequency GNSS rovers	Mobile Internet (GPRS, 3G) with NTRIP protocol UHF radio when Mobile Internet coverage not available	±2 cm (2D) ±4 cm (3D)	RTCM 3
GPPS (**) geodetic highly precise positioning	post-processing for single or double frequency GNSS rovers	internet (web, FTPore-mail)	±1 cm (2D, 3D)	RINEX 2.1 Virtual RINEX RINEX 3
ACPS (**) geodetic highly precise positioning	On-line post-processing for double frequency GNSS rovers	internet (web, e-mail)	±1 cm (2D, 3D)	Text message, or ,email

* *It is understood that this accuracy is dependent on local conditions, satellite geometry and availability.*

** *This accuracy is highly dependent on observation time.*

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Reliability and availability of raw data being the main drivers for VPPS and DPS, the quality of the telecommunication links between all sites and the control Centre are of prime importance.

It is recommended for Uzbekistan to provide at least 15 Type-A Sites for the realization of a geodetic infrastructure of zero order and consequently 35 Type-B stations.

As explained above, UzPOS is split in a 2 stages network:

- The Sparse Network composed of the Type-A Sites and mainly designed for the realization of a zero-order geodetic infrastructure and for all GPPS applications (Geophysics, Geodesy, Densification of Geodetic network, Special high accuracy applications for Surveying & engineering).
- Few regional clusters containing each between 5 and 15 GNSS CORS and integrated in the Sparse Network mixing Type-A and Type-B Sites. These clusters will focus to deliver the

best VPPS Service where Mobile Internet coverage is available (e.g. Tashkent region, Namangan region, Samarkand region).

- As explained above, some spots of VPPS and DPS Services may exist based on Type-A Stations, which are outside the clusters. In these areas, it is possible to use a limited local VPPS and DPS Services via UHF radio broadcast.

In some segments like Surveying & Engineering or Infrastructure and Road Constructions, it will become obvious that working outside the Clusters will become an issue both due to the lack of Mobile Internet coverage and close Reference Station.

3. Options for a new datum

Now, WGS84 datum /4/ is widely used all over the world. Therefore, the coordinates of State Geodetic Network points obtained after joint adjustment will realize WGS-84 system of geodetic coordinates in this datum. A common problem faced by most countries is the estimation of precise transformation parameters between their national geodetic datum, and the World Geodetic System 1984 (WGS84) global datum, used by the Global Positioning System (GPS). There can be considerable difference in positions of the local ellipsoidal datum and the global datum, sometimes up to several hundred meters.

In Uzbekistan, many transformation parameter sets are available for Krasovsky and GPS datum. At present there are several published transformation parameter sets are being used for transformation of GPS acquired coordinates to local CK42 datum and vice versa (Table 2) used by different programs. Map users and makers are facing many problems due to this non-standardization of the transformation parameters. Definition of exact transformation sets for this region is the most important task at present. How much parameters of transformation are "universal" for concrete network is important aspect of this question also.

Ideally, global datum positions should be determined for the local datum origin points and after re-computation, every point in the survey network would be a "common point". Unfortunately, points in local datum is not accessible for common use yet. From another side many measurements were lost. An alternative strategy would be to obtain sample common points at suitable existing survey network sites. It is wise to obtain far more than the minimum number of common point we have used published maps from /5/ and extract necessary original values coordinates in CS42 for investigated network points.

The order of introduction of world coordinate geocentric system on the territory of the Republic of Uzbekistan will be determined by standard way. The coordinates (WGS-84) have been transformed to the local system (CS-42) by using Helmert method /6/ at the published parameters of transformation (Table 2):

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{CK-42} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} + \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix} + \begin{bmatrix} m & \omega_Z & -\omega_Y \\ -\omega_Z & m & \omega_X \\ \omega_Y & -\omega_X & m \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{WGS-84} \quad (1)$$

where, T_X, T_y, T_z – translation along X, Y,Z –axis's respectively,

ω_X, ω_Y, ω_Z - rotation about the X,Y,Z-axis's and m - scale factor

For preliminary estimation of transformation parameters, we used measurements data of 4 (KIT3, TASH, MADK, MTAL) international stations on territory Republic. Since the 1990s station of International Latitude Service in Kitab hosted the GPS/GNSS Reference Station (KIT3, included in IGS) and ground based beacon of DORIS (KIUB) satellite tracking systems, providing IERS data center with precise coordinates at subdaily frequency.

Table2 - Published transformation parameters sets WGS84 to CK42 /7/

	Shift vector, (m)			Scale	Rotation angles (")			Source
	T_X	T_Y	T_Z	m	ω_X	ω_Y	ω_Z	
1	23.92	-141.27	-80.9	$-0.12*10^{-6}$	0	0.35	0.82	GOST 51794-2001 and EPSG::1267
2	27	-135	-84.5	$2.263*10^{-7}$	0	0	$-2.686*10^{-6}$	ERDAS IMAGINE Pulkovo 1942
3	24	-123	-94	$1.1*10^{-6}$	$-9.69*10^{-7}$	$1.212*10^{-6}$	$6.3*10^{-7}$	ERDAS IMAGINE System 42/83 (Pulkovo)
4	25	-141	-78.5	0	0	-0.35	-0.736	EPSG::15865
5	24	-123	-94	$1.1*10^{-6}$	-0.02	0.25	0.13	Mapinfo 1001 NB

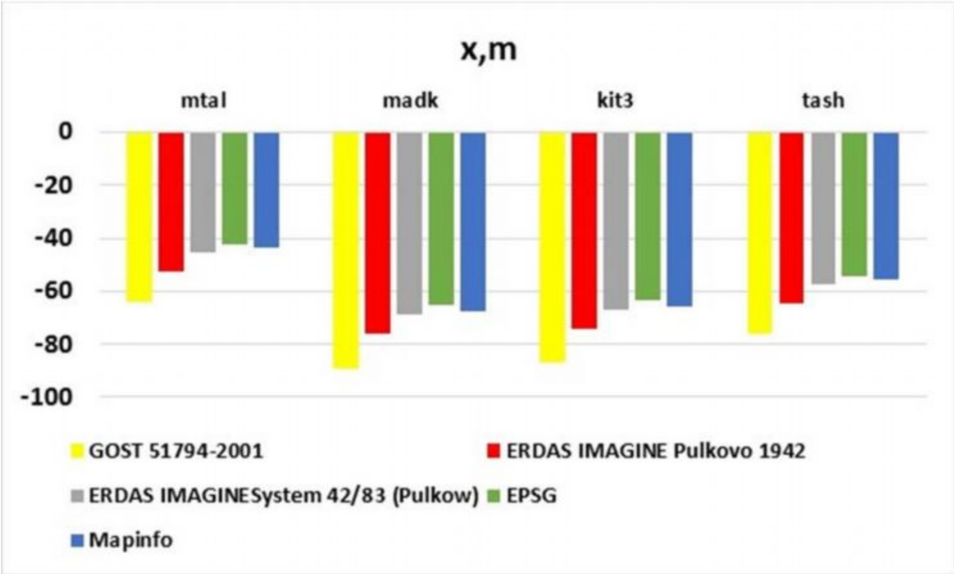
Table 3 - WGS-84 geodetic coordinates of international reference stations

Station	Abbr.	Latitude, B	Longitude, L	Elevation, H (м)
Kitab	KIT3	39° 08′ 05.16″	66° 53′ 07.61″	622.49
Maidanak	MADK	38 °40′ 25.57″	66° 53 ′48.71″	2551.33
Tashkent	TASH	41° 19 ′40.98″	69 °17′ 44.05″	439.70
Maidantal	MTAL	41° 59 ′ 47.65″	70 °38′ 18.03″	1445.68

The Tashkent Astronomical Observatory (Ulugbek Astronomical Institute of the Uzbek Academy of Sciences since 1966) was involved to the International Latitude Service (ILS) in 1899-1919 /8/. At present there is permanent station of IGS is providing limited satellite data corrections to GNSS users. It should be noted, except these permanent stations in Kitab and Tashkent as a result successful international (Germany, France) cooperation of Astronomical Institute with GFZ became MADK, MTAL stations (CAWa project, 2012-2015) /9/. In 2016, Kitab station will be equipped by new additional GNSS receiver for the REGINA project (CNES, France) for improvement of station precision characteristics also.

All the available transformation parameters from different sources are used to transform the positions of common known points from WGS84 datum to CS42 datum. Transformed CS42 coordinates are then compared with the original one. The difference between transformed and original coordinates was calculated and evaluated (Fig.2).

Most of the transformation parameters were transforming one of the coordinates accurately but giving error in other coordinates (Fig.2). Perhaps, if they were applied to particular zone (for example, only mountain or valley region), accurate transformation could be obtained. In future we plan, investigate these features on new network data.



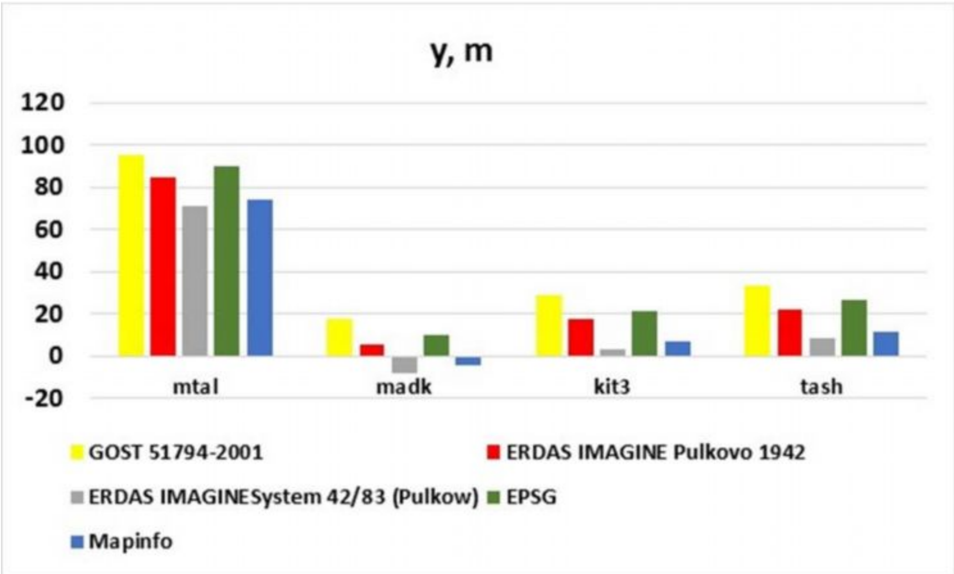


Figure 2: Difference between transformed and original coordinates

4. Conclusions

An Uzbek geodetic service is progressing towards the implementation of a new modern network before the year 2017. It will provide an accurate spatial survey infrastructure across Republic that will meet user needs, be of a suitable accuracy, and will be flexible.

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