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Geodetic Reference Systems and Map Projections in Bulgaria: Historical Context and Modern Applications

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"Concepts are the nodal points of our knowledge."
Acad. Vladimir Hristov

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Abstract:

The significant advancements in modern geodetic technologies over recent decades necessitate a reassessment of geodetic coordinate systems. These systems should enhance 3D positioning accuracy, provide direct access to the national reference geodetic coordinate system for a wide range of users, and effectively leverage geospatial information for various applications that rely on a geodetic foundation. Many countries around the world have modernized their Geodetic Reference Systems (GRS) and networks, implementing them in practice using advanced geodetic satellite and ground-based systems, as well as measurement, information, and communication technologies and tools (e.g., Yovev, 2007; 2008).

This document presents a brief historical overview of the coordinate, height, and map projection systems used in Bulgaria since the late 19th Century. From the beginning of the 20th Century to the present, several geodetic reference systems and related height and gravity systems have been implemented, with practical application taking anywhere from several years to a decade. The astronomical-geodetic, leveling, and gravimetric networks developed over the years serve as the infrastructure through which the corresponding coordinate, height, and gravimetric systems are established and disseminated over specific territories. Historically, Bulgaria's mapping efforts began at the end of the 19th Century with the Russian triangulation in the Walbeck 1875 system (Kovács and Timár, 2009). Subsequently, geodetic science and practice in Bulgaria followed global trends in its development, adopting and introducing contemporary geodetic reference coordinate and elevation systems and cartographic projections. The Hayford ellipsoid, the Baltic height system, and the Gauss-Krüger coordinates for a three-stripe map projection were adopted in the 1930s (Yovev, 2003).

In the mid-20th Century, the Karsovski ellipsoid and the 1950 system were introduced, along with a Gauss-Krüger map projection with 3- and 6-degree stripes and the Black Sea height system. For civil purposes, the 1970 coordinate system was adopted in the late 1960s and early 1970s by order of the State Defense Committee in 1969. This system is a type of projection coordinate system from the class of conic projections. Despite Bulgaria's relatively small territory, four Lambert map zones were defined, and geodetic and cartographic products prepared in this system are still utilized today. Additionally, local geodetic projections were used to map major cities, such as Sofia and Plovdiv, to minimize image distortions. Following the alignment of the Unified Astronomical and Geodetic Network of the Eastern European socialist countries, a system from 1942/1983 was also introduced. This system used the Krasovski ellipsoid and the Baltic height system with normal heights, with mapping conducted in 3- and 6-degree Gaussian stripes using the Gauss-Krüger map projection (Yovev, 2003).

The National Geodetic Reference System comprises geodetic datums, reference frames, and physical realizations (such as networks of survey monuments, continuously operating GNSS stations, and gravity measurements) that define the position (latitude, longitude, height), gravity, and orientation of points on, above, or below the Earth's surface across national territory. The transitions between different reference, coordinate, and height systems have been scientifically justified and thoroughly prepared. Global and European practices in modernizing geodetic systems have prompted changes in the structure and functions of high-precision state geodetic networks, aligning with international standards. By the end of the 1990s, Bulgarian geodetic theory and practice had amassed considerable experience in establishing continental and national geodetic networks and their respective reference systems. Bulgaria's state geodetic networks have been created, maintained, and updated using the latest methods, technologies, and instruments.

Following the democratic changes in 1989, the geodetic community organized a special conference in Bulgaria in 1994, during which extensive discussions took place on the introduction of new geodetic reference and height systems.

Decisions were made to implement these systems. Over the past three decades, Bulgarian scientific teams have participated in numerous European and international projects, including EUPOS (http://monitoringeupos.gku.sk/), CERGOP 1/2, CEGRN (http://sgo.fomi.hu/cegrn/), WEGENER-MEDLAS, and INCO-COPERNICUS. Similar research and application projects have been initiated by the International Association of Geodesy (IAG), various international organizations and unions, as well as consortia that include private companies.

Several years after the 1994 conference, the Bulgarian Geodetic System BGS'2000 was introduced by Decree No. 154 of the Council of Ministers of the Republic of Bulgaria on June 4, 2001. This decree defined the parameters and characteristics for global and European geodetic reference and coordinate systems, such as GRS80, EUREF, and ETRF89, as well as for European leveling and gravimetric networks, including UELN and UNIGRACE. The Lambert projection was designated for all civil applications, and a world layout of map sheets, including those at a scale of 1:2000, was incorporated. However, BGS'2000 has never been implemented. During the process of introducing a new Geodetic Reference System in the country from 1995 to 2016, several regulatory documents were created and published, including instructions, ordinances, and training manuals.

After some years, the Council of Ministers introduced the Bulgarian Geodetic System 2005 (BGS 2005) through Decree № 153 on July 29, 2010, and Ordinance № 2 on July 30, 2010. This new system replaced GRS'2000 and maintained the same basic geodetic parameters. The BGS 2005 includes three reference systems: 1. Coordinate System 2005: Based on the 2005.0 epoch of ETRS89, it uses GRS80 parameters and relies on the State GPS network connected to the EPN; 2. Vertical Reference System 2005: Established using the First Order State Leveling Network and points from the EUNV-DA project, linking to EVRF2007 with data from IGSN71; 3. Gravimetric Reference System IGSN71: Defined by the UNIGRACE project (2005) and realized through the National Gravimetric Network. The primary cartographic projection for Bulgaria is the Universal Transverse Mercator (UTM) projection, divided into zones 34N and 35N. The second zone covers most of the country, as per Instruction № RD-02-20-12 on August 3, 2012. Deformations increase progressively beyond ±30 from the central meridian, with a scale factor of m = 0.9996. Due to the UTM projection's limitations for practical applications, the "Cadastral Coordinate System 2005" was implemented through Ordinance No. RD-02-20-5 on December 15, 2016. This system utilizes a Lambert Conformal Conic projection designed to minimize distortion across Bulgaria. The GCCA offers a free program, BGSTrans 4.6 (AGCC; https://www.cadastre.bg/), for converting between geodetic coordinate systems. Additionally, information on Bulgaria's official geodetic systems has been added to the Information System for European Coordinate Reference Systems (CRS-EU) (https://www.crs-geo.eu/) and the EPSG public registry (https://epsg.io/?q=Bulgaria), allowing for coordinate transformations with an accuracy of ±1 m.

When introducing a new geodetic reference and coordinate system, selecting an appropriate map projection is crucial to minimizing distortion within the state's territory. For large areas mapped on small scales, Universal Transverse Mercator (UTM) and Lambert Conformal Conic projections are recommended. Parameters of the chosen projection, including the central meridian, the latitude of the origin, and the scale factor, must be aligned to ensure an optimal depiction with minimal deformation. It is also important to use official transformation parameters in geodetic software or GIS tools, such as QGIS or ArcGIS, to achieve accuracy. GRS provides accurate, interoperable positioning for diverse users, from smartphone navigation to advanced Earth monitoring. These systems should be regularly maintained and updated in line with advancements in geodetic science (UN-GGCE, 2025).

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