Aspects Concerning the Adoption of the Pan-European International Standard in the Terrestrial Measurements Activity in Romania

Gheorghe NISTOR, Ph D, Eng., Professor, "Gh.Asachi" Technical University of Iasi, Romania, ghnistor@yahoo.fr
Gheorghe SALCEANU, Ph D candidate, Eng., Iasi City Hall, Romania, gsalceanu@yahoo.com

Abstract: *Romania's admission into The European Union required the introduction and/or preparation of the technical standards and regulations needed in the process of setting up digital plans. The preparation and implementation of such plans must comply with international standards, such as ISO 19111, with respect to coding, the use of symbols, the use of reference systems, the storage of spatial data, as well as the setting up of a national GIS (Geographic Information System). This entire integrations process will facilitate the exchange of compatible data and information with the European Union in particular, and internationally as well. At the same time, this enables the creation of a National Spatial Database compatible with the European Infrastructure for Spatial Information. The paper presents several aspects related to the implementation in Romania of the pan-European international standards for terrestrial measurements.*

Keywords: *technical standards, regulations, digital plans, GIS, exchange data, pan-European international standards, terrestrial measurements.*

1. Introduction

The necessity of founding of a modern and precise reference network, achieved on the basis of the spatial satellite geodetic technical, has imposed European Union countries to adopt in 1990 the new System of Reference and Coordinates ETRS 89, which has become the European geodetic datum. This datum has been implemented on the Geodetic Reference System GRS 80, maintained and described by Euro Geographical and used as a reference system exclusively based on EUREF network. In this global reference system, the positions of the points from the physical surface of the Earth are expressed and stored up using ellipsoidal (B,L,h) and/or Cartesian (X,Y,Z) coordinates, which both refer to an ellipsoid of rotation with the same origin. The achievement of a unified geodetic system for entire Europe become applicable with the occurrence of the Global Positioning System (GPS). The dynamical evolution of satellite technologies, especially of the GPS, caused a spectacular evolution into constituent sciences of terrestrial measurements. This transformation can be compared with the transition from the two-dimensional geodesy, to the four-dimensional one, the time representing the fourth dimension, in both theoretical and practical current activities.

Romania's admission as a member with full rights into the European Union, event of historic importance, involves the adoption and/or elaboration of technical standards for the elaboration of digital cartographic outputs, which must fulfil the international standards concerning the codification, symbolism, manner of reference of data, storage of spatial information, creation and administration of a national GIS (Geographic Information System). This framework will enable the exchange between the European Community and international community and the creation of an infrastructure of National Spatial Data which will be compatible with the infrastructure for spatial information from Europe. Theses desideratum are possible and achievable by the adoption and fulfilment of the International Standard ISO 19111, adopted as a pan-European standard with the purpose of a precise and correct identification of the system of reference and of coordinates for each member country and also with the aim of establishing the compatibility of these systems with the pan-European ones.

The adoption by Romania of the European system of reference and of coordinates which will be identified by the acronym RO-ETRS 89, involve also supplementary the use of the some systems of plane coordinates, corresponding to the use of the same cartographic projection recommended by European Commission. To fully benefit of the accuracy of the obtained data by Global Navigation Satellite System technology – GNSS, is imperatively necessary that the geodetic determinations, as well as the output of plans and maps to be based upon the same geodetic network of control, determined in the European geodetic datum ETRS 89. The fact that the utilitarian geodesy do not operate with the positions of the points from the terrestrial surface expressed in the adopted reference systems but for the most times, in plane representation systems by the mediation of cartographic projections and/or by the position vector. In order to can combine them with other type of data originating from terrestrial measurements, one needs to impose the transfer of geodetic data not only between reference systems, but even between systems of cartographic projection referred to different reference systems.

If one takes into consideration either only the achievement of the general Cadastre and of the Informational Systems from different fields, it is necessary that, for the implementations of the unique Cadastral evidence in the territorial administration, to use methods, techniques and technologies which supply quality and homogeneous precision in the data reference process. The geodetic reference thus created, which can be optimized and is interactive, with remarkable possibilities of development and actualization, can be used in the various different fields. The informatics systems achieved in this manner is based on a rigorous geodetic reference system, without which one cannot speak of correct Cadastral evidence at the level of the administrative territories of the country.

2. Geodetic datum

The constitution of the cartographic database involves the definition of the space points by respect to the selected reference system. It results that the achievement of the plans and digital maps is based on the representation, in numerical format, of some graphic entities integrated into a spatial reference system. This system constitutes the geodetic datum, which consists of a set of parameters which serve as a base reference for the calculation of other parameters. This determines the position of origin, orientation of the axes of coordinate system and scale.

The geodetic datum (the reference system) defines an ellipsoid which serves as support in positioning a system of coordinates with respect to the Earth. Every reference ellipsoid has a unique system of axes of coordinates which cannot be associated to any other ellipsoid without a preliminary transformation (translation). In the current geo-topographic activity, one of the problems which appear is the transition of the coordinates from one datum to another one by the so-called datum transformation which is in fact a transformation of datum/geodetic coordinates.

There are two kinds of geodetic datum (Fig.1):

- **local/regional geodetic datum**, for which the chosen ellipsoid is tangent to the geoid with the purpose of approximating a region in the neighborhood of a fundamental point;
- **global/geocentric geodetic datum**, for which the centre of the ellipsoid is set to be the centre of gravity of the Earth.

In the **local datum** case, the centre of the ellipsoid is different from that of the geoid because of the datum orientation by a single astronomic station, what means that in this fundamental point the deviation of the vertical and the wave are set arbitrarily to zero. This approximation affects the positions of the other points from the geodetic network interior. Without going into details, the calculation of the coordinates of the points refer to a certain geodetic datum/ellipsoid will be different of those calculated with respect to another datum the ellipsoids and their orientation with respect to the centre of gravity of the Earth are different. The relative rotation of the reference systems and the differences of scale make impossible the calculation/transition from an ellipsoid to another one. Since 1951 Romania used the geodetic datum given by the Krasovski ellipsoid 42, which is a local datum.

Apart from the local geodetic datum, **the global/geocentric** one, characterized by a reference ellipsoid, is chosen so that the geoid, as a whole, to be approximated in optimal conditions (Fig.1).

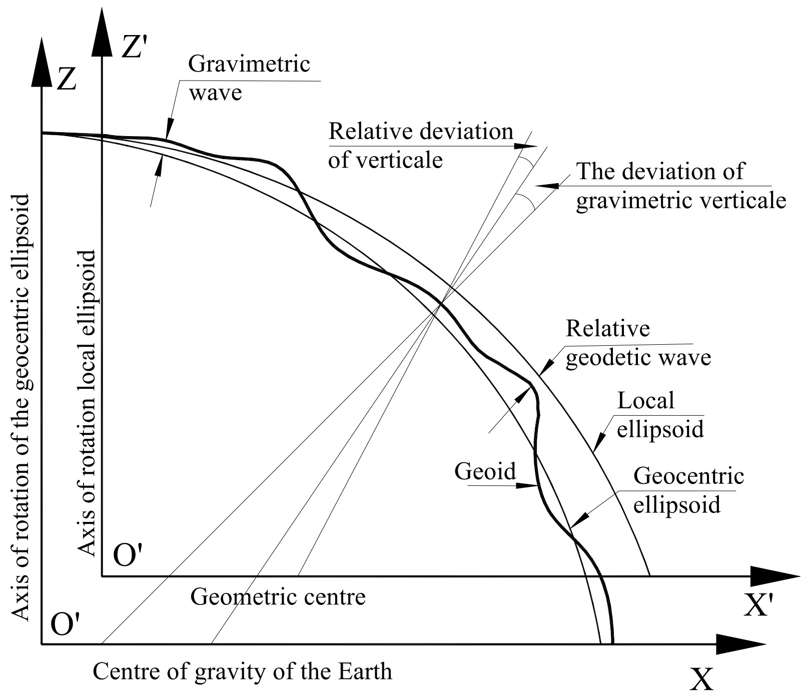

Fig. 1 Geocentric / global and local geodetic datum.

The origin of the system of axes is taken in the centre of the Earth; the OZ axis is directed towards the North pole, which corresponds to the BIH direction of the Conventional Terrestrial Pole at 1984 epoch; the OX axis is the intersection of the meridian plane of reference with the Equatorial plane of reference passing through origin, O, and which is perpendicular to the OZ axis; the OY axis is orientated to the right in the equatorial plane of reference, being perpendicular on OX axis.

Such a geocentric datum is the geodetic model of the Earth known by the acronym WGS 84, which has been determined using specific data, technical and satellite technologies. The origin and orientation of the axes of coordinates are defined using the (X,Y,Z) coordinates of five monitoring stations. At the definition of the system WGS 84 as a complex model of datum, besides the form and dimensions of the ellipsoid, one needs to add a number of physical parameters which, together with those geometrical ones, constitute the set of the main parameters of the global geocentric reference system: the great semi-axis, geometrical flattening, the gravitational constant of the Earth, and the angular velocity of the Earth. For the same WGS 84 system, the secondary parameters are the geometrical and physical constants coming from the main parameters and defining the model of the gravitational field of the Earth. The WGS 84 ellipsoid is defined as the equipotential geocentric ellipsoid on whose surface, the value of the potential gravitation is the same at every place. For this reason, it is useful not only as reference for the horizontal and vertical surfaces or for the determination of the geometrical figure of the Earth, but it also establishes the reference surface for the normal gravity of the Earth. In this manner, the geoid is a particular equipotential surface of the gravitational field of the Earth, which is connected by the mean surface of the seas and oceans. The GPS determination is performed in the global datum defined by WGS 84 ellipsoid. The parameters which define the spatial geocentric datum are represented by three constants of the position of the origin of the system of coordinates, by three spatial orientations of the axes, by a scale factor, and by the two parameters which define the form and the dimension of the ellipsoid. These parameters represent the base of the achievement of the Terrestrial Reference Frame – TRF, which contains all the reference points, necessary to supply data and includes the possibility to determine the coordinates in datum of other points of unknown coordinates and which contain errors. The practical achievement of ITRF 89 was achieved in 1989 (Fig.2).

Considering the need to achieve the European Geodetic Reference System – EUREF, as a high precision system for the terrestrial and cartographic measurements, it was decided that EUREF be based on the ITRS 89 networks. A number of 35 European positions have been selected, apart from the ITRF 89 solution, as a set of fundamental coordinates which define EUREF. Because the number of stations in different countries was insufficient, the use of the differential GPS satellite technical was decided, in order to obtain solutions by interpolating from the base stations and in order to thicken the European Network ETRF 89. The European Network uses the GRS-80 ellipsoid, identical with WGS-84, with an accuracy of millimeters.

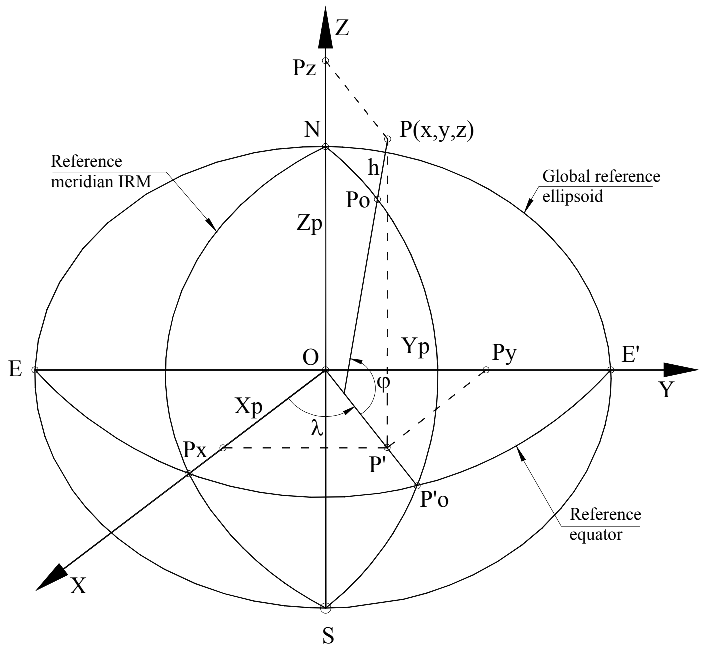

Fig. 2 The system of the special coordinates ellipsoidal (φ,λ,h) and cartesian (X,Y,Z).

The spatial positioning of the points is achieved by a Cartesian system of rectangular coordinates, defined by the origin of the system of axes and directions of the axes of coordinates X,Y,Z. All these are referenced to the surface of the adopted ellipsoid.

Each adopted ellipsoid used as reference has a unique set of axes of coordinates and a proper system of Cartesian coordinates which cannot be associated to another ellipsoid without prior transformation, using precise relations of correspondence. Thus, the transition from the geodetic system of ellipsoidal coordinates (B,L,h) to the geocentric Cartesian system (X,Y,Z) and inversely is assured.

A reference system establishes the connection between the system of coordinates and the Earth so that each point or subject situated on the terrestrial surface, air or water is uniquely positioned by their coordinates.

The vertical/altimetric datum is defined by a single point, represented by a leveling mark placed at sea level. This datum is used in order to create an elevation/altitude system. The transformation of this system consists in adding of a constant value to all points. **The vertical**

datum describes the connection between the elevation of the points referred to the gravity and the Earth. One must note that the elevation of points with respect to the reference ellipsoid is treated as they are referred to the ellipsoidal three-dimensional system from the geodetic datum.

In Romania, the vertical datum is defined by the elevations of the points determined with respect to the surface of the geoid taken as reference, in comparison with a reference mark set on the Black Sea shore.

Recognizing the potential of the spatial geodetic technical, in particular that of the Global Navigation Satellite System GNSS in setting up of a modern and precise network of continental reference in Europe, the European Terrestrial Reference System, ETRS 89, was implemented. To maintain ETRS 89, the permanent network EUREF which covers the European continent with permanent stations well distributed territorially was created. The above mentioned stations are integrated into EPN (EUREF Permanent Network), ensuring thus the permanent and precise measurements using GNSS receivers, warranting the efficiency and quality through data colleted over a long period of time. In addition, these stations contribute to the thickening of GNSS network and to the achievement of the International Terrestrial Reference System used to monitor the tectonic deformations.

As mentioned before, **the European Terrestrial Reference System ETRS 89** coincides with **the International Terrestrial Reference System ITRS** at the 1989 epoch in which O is fixed on the stable part of the Euro-Asian continental plate for GIS geo-reference and for geo-cinematic determinations.

The European Vertical Reference System EVRS 2000 represents a reference system, static on height. ETRS 89 ensures a three-dimensional geocentric positioning with a precision at the level of millimeters and is a unique and homogeneous reference system for the entire Europe, while EVRS 2000 ensures the same thing for the vertical positioning. Bath systems have been recommended as basis for geo-reference in Europe by the European Commission for spatial planning of integration politics and the evaluation of the states which will adhere as are already integrated into European Union (Romania's current situation).

3. Aspects concerning the adoption of the new Reference and Coordinates System ETRS 89 in Romania

At present, considering Romania's admission into the European Union, inter-governmental organizations in Romania which include representatives of Cadastre Agency, the topographic services of the Army, spatial agencies, have made remarkable efforts towards checking the results on the chart working on the basis of a single national system. These efforts involve significant and close collaboration with international organizations in the field: EUREF, Euro Geographic, etc. The reasons for these efforts are bounded by **the adoption by Romania of the Reference System and of Coordinates ETRS 89 and of the European Vertical Reference System EVRS 2000**. The differences exist at present and create an incompatibility situation of data which can hardly be solved from a technical point of view.

The replacement of the **Krasovski 42 geodetic datum**, used in Romania since 1951 by **the Reference System and of Coordinates ETRS 89**, under **the name RO-ETRS 89,** is supported by the following reasons:

- The of Krasovski 42 geodetic datum is a local datum distorted with respect to the global European geodetic datum ETRS 89 due to the fact that the position and orientation of the reference ellipsoid differ from those of the geoid.
- The present datum is a local/regional datum. Consequently, the centre of the ellipsoid is different from that of the geoid, the ellipsoid being tangent to the geoid in the point established as the origin (Pulkovo). Also, the orientation of the datum is obtained with

reference to a single astronomic station, with negative consequences on the precision of the determination of the geodetic points.

- Because in the point of tangency the deviation of the vertical and the wave of the geoid are arbitrarily considered to be zero, the position of the other points of the geodetic network are negatively affected. The geodetic geographic coordinates on the ellipsoid of the points will be different from the astronomic coordinates on the geoid, and these differences are also extended to the Cartesian coordinates.
- The astronomic geodetic orientation has a significant disadvantage, namely the fact that the deviations of the vertical are relative, depending on the position of the ellipsoid with respect to the geoid. Therefore, the astronomic-geodetic deviations of the vertical depend on the specific geodetic datum and on the use of the geodetic data which are limited to relatively small areas.
- The particular position of the ellipsoid with respect to the geoid, constraints that the decrease of the angles and distances to the ellipsoid to be dependent on this position.
- Due to the above mentioned two remarks, the calculation of the coordinates of the points with respect to a geodetic datum will be different from that determined using another geodetic datum.
- Irrespective of the precision of the individual datums, there is no possibility to exactly calculate the distance and azimuth between two different reference systems and coordinates.
- Without going into details, data obtained in a local geodetic datum (e.g. Krasovski 42) are incompatible with the correspondent data from a geocentric datum (e.g. ETRS 89), because of the initial orientations of the two datum. One can assert that the transformation of the data obtained with the Global Navigation Satellite System (GNSS) will results with a high precision in the European System ETRS 89, but will be distorted with respect to the data obtained within the local datum Krasovski 42. For this reason, the geodetic determinations and the output of the plans and maps must be based on the same control network, determined in the European geodetic datum.
- The new Reference and Coordinates System (which will be adopted in Romania) will be identified by the acronym RO-ETRS 89. This one will consist of the geocentric geodetic datum ETRS 89 based on the ellipsoid GRS 80 and the system of ellipsoidal/geodetic coordinates. Its description is made according to the international standard ISO 19111.

At present, **Romania uses the Stereographic Projection 1970** for the geodetic plans and maps used in the national economy. According to the International Standard, this one can be defined as the Stereographic Reference System of coordinates 1970, formed by the Krasovski 42 geodetic datum (based on Krasovski 40 ellipsoid) and the stereographic system of plane coordinates 1970. The **adoption of the European System ETRS 89, and named RO-ETRS 89**, requires the transformation of coordinates of geodetic points from the local datum into the pan-European global datum. A certain amount of differences representing the distortions between the datums exists between the two sets of coordinates. The guarantee of the compatibility between the two systems can be achieved by adopting a model of transformation of the coordinates, which will include a data distortion model corresponding to the relatively small size of the Romanian territory.

4. The integration of the new Reference and Coordinates System in Romania: RO-ETRS 89

Romania achieved an important step in the rehabilitation, modernization and integration of its National Geodetic Network into the European Reference Network – EUREF, creating thus the possibility of adopting the new system RO-ETRS 89. In this respect, a number of five stations from the National Network of Permanent GPS Stations RN-SGP, and light other stations from the

Reference European Network – EUREF have been integrated. These 13 stations from National Geodetic Network of Permanent GPS Stations – also known as the National Geodetic Network of class A, are determined with ±1cm accuracy on the three spatial components. Also, the network of class B, composed of 306 points, was achieved. Of these points, 86 are common points within the classical network of triangulation, while the other 220 are new points, with ±2cm precision. The common points in the two geodetic datums, Krasovski 42 and ETRS 89, uniformly distributed on entire surface of the country, ensure the operation of transformation of the coordinates from the Reference and Coordinates System Stereographic 70 to the new system RO-ETRS 89, ensuring thus the change of spatial data between Romania and other European Union countries. The network of class B ensures a density of 1 point per 720 km2. At present, work is performed on the network of class C with ±3 cm precision, which is planned to include 4750 points in order to ensure a density of 1 point per 50 km^2.

The higher density geodetic network representing the network of thickening of class D with ±5 cm precision and the network of elevation of class E, having ±10 cm precision, can be determined as 2D or 3D network using both the classical measuring technology and GPS technology. The thickening of the National Geodetic Network using GPS technology for the purpose of implementing and modernizing the RNG-GPS materializing on the ground the points, including also points from the old state triangulation networks, will enable the use of satellite technologies in the geodetic, photogrammetric, cadastral and cartographic works. During the transition period, these works will be also performed using the Stereographic Reference and Coordinates System 1970.

The quotation of the materialized points on the ground in the system known as Black Sea 1975 will enable the 3D transformation of the coordinates from the pan–European system ETRS 89 into the Stereographic System 70 and vice-versa. There will be a possibility to determine the waves of the geoid based on the differences between the normal and ellipsoidal quotations determined by the satellite system. In parallel, **the necessary conditions for the adoption by Romania of the new European Vertical Reference System EVRS 2000**, by thickening this one at national territory with the new gravimetric and of levelling, will be achieved.

For analogical or digital representations at mean or high scales, **Euro Geographics has adopted the Universal Transversal Projection System Marcator UTM**. The projection system used at present in Romania is STEREO 70. Therefore, if one desire the use of the referred points on cartographic outputs elaborated in Romania, he must transform the positions of these points into STEREO 70 system positions by changing the reference. If one desire the use of same cartographic information in European/international system, it w**ill be necessary to transform this information into the projection system UTM, modifying the reference ellipsoid.**

5. Conclusions

The official adoption by Romania of the pan-European Reference and Coordinates System recommended by European Commission faces legislative difficulties and problems related to the limited technical equipment, material and human resources. For this reason, the National Agency of Cadastre and Real Advertising – NACRA - proposed several steps in order to prepare the official adoption of the new ellipsoidal Reference and Coordinates System ETRS 89. As this system cannot satisfy the multiple needs of practical activity in terrestrial measurements, the supplementation of the ellipsoidal system with plane the Reference and Coordinates System has been imposed. This system comprises three kinds of cartographic projections: for the statistical analyses and visualization (ETRS-LAEA), for pan-European conformal maps at a scale less than or equal to 1:500000 (ETRS-LCC) and for maps at scales greater than 1:500000, middle and great (ETRS-TMzn).

For the transition period the following steps are taken into considerations:

- Compulsory using of a new pan-European system identified by RO-ETRS 89, in the geodetic networks belonging to the Global Navigation Satellite System GNSS also in the compact networks, by compulsion of the network of new points, the classes A,B, and C
- The thickening of the permanent stations GNSS, which will complete the present National Network of the Permanent Geodetic Stations NGN-PGS, in compliance with the European standards.
- The thickening of the National Geodetic Network GPS, at level of C class, with the purpose to ensure a suitable density. This will comprise also points of the triangulation network, which will enable the use of satellite technology in current terrestrial measurements, during the transition period, when the Krasovski datum and the projection system STEREO 70 will be used more.
- The achievement of the positioning Romania department ROMPOS in accordance with the requirement of EUROPOS, for obtaining of the specialized services.
- The achievement of the geoid model in the old vertical reference system MN 75. This will facilitate the transformation of coordinates for the 3D-points from the European system ETRS 89 to the STEREO 70 system.
- The establishing of the wave of the geoid based on the differences between the normal quotations determined by the geometric/trigonometric levelling and the ellipsoidal ones, determined in the GPS.
- Ensuring of the necessary conditions for the adoption of the new European Vertical Reference System EVRS 2000, by thickening of this system on the national territory with new gravimetric and of levelling points.

Finally, one can assert that the adoption by Romania of the new pan-European and geodetic datum represents an important stage for activities in the terrestrial measurements field such as elaborating digital cartographic outputs, which must comply with the international standards concerning the codification, symbolism, system of data, storage of the data, creation and administration of a national GIS. This will enable the exchange of data with the European and international community and the creation of an infrastructure of National Spatial Data compatible with the infrastructure for Spatial Information from Europe.

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