European Spatial Reference Systems
- Frames for Geoinformation Systems -

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Abstract

The European initiative for a common spatial reference including the standardization activities will be described. Activities of EUREF and CERCO will define a common vertical European datum and establish an information system of national CRS and their relationship to ETRS89.

1. Introduction

One of the basics of geoinformation systems is to guarantee an unambiguous spatial reference of the stored information. The spatial reference can be given by coordinates or by geographic identifiers. Coordinates are unambiguous when the reference system to which those coordinates are related has been fully described. The standardisation activities since the nineties in the frame of the European standardisation organisation CEN and of the international standardisation organisation ISO for geographic information systems included the spatial reference aspect as a central topic. The realization of geoinformation systems needs conventions for the use of geodetic reference systems. On behalf of the European Commission (EC) at the end of 1999 a Spatial Reference Workshop was organized by MEGRIN to recommend common European reference systems for geoinformation systems and data of the EC and for the member states. The IAG Subcommission for Europe (EUREF) works for over 10 years actively and continuously together with the national mapping agencies for the realization of the ETRS89 and since 1995 on the United European Levelling Network. Therefore, EUREF was well prepared and able to answer the requests. EUREF and the Work Group VIII of the Comité Européen des Responsables de la Cartographie Officielle (CERCO) were asked to prepare relevant information describing the systems and the transformation from the national reference frames to the European one.

2. European initiative for common spatial reference

The Spatial Reference Workshop, 29-30 November 1999 in Marne-La-Vallée was organised by MEGRIN on a request of the Joint Research Centre on behalf of the EC. Due to the participation of relevant geodesy and standardisation experts as well as institutional cross-border GI users the workshop was successful.
It was recognised that the ETRS89 is accepted by the National Mapping Agencies (NMAs) and the scientific community as the most appropriate European geodetic datum for continental spatial referencing tasks. The geodetic datum ETRS89 derived from GPS campaigns and the European GPS Permanent Network (EPN) are part of the geodetic basic networks of EU member states. The Spatial Reference Workshop recommended that the European Commission:

- Adopts ETRS89 as the geodetic datum for the geo-referenced coordinates of its own data;
- Includes ETRS89 in the future specifications of the products to be delivered to the EC, within projects, contracts, etc;
- Promotes the wider use of ETRS89 within all member states, by appropriate means (recommendations, official statements, …).
- The coordinates for expressing positions related to ETRS89 datum will normally be ellipsoidal (geodetic latitude, geodetic longitude, and if appropriate ellipsoidal height).

The Workshop defined its various needs for map projections and to obtain further expert advice to determine the appropriate projections.

It was recognized that the European Vertical Network (EUVN) and the United European Levelling Network (UELN) projects form the basis for a vertical reference in Europe. The workshop recommended that the EC:

- Adopts the results of the EUVN/UELN initiatives when available, as definitions of vertical datum and gravity-related heights;
- Includes the EUVN reference system so defined for the specifications of the products to be delivered to the EC, within projects, contracts, etc;
- Future promotes the wider use of the European vertical reference system within all member states, by appropriate means (recommendations, official statements, …).

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Both the ETRS89 and the current national coordinate reference systems for spatial reference and both a European vertical datum and the current national height systems for height reference will continue for many years in parallel. From this point of view the workshop recommends to the NMAs that transformation parameters and algorithms to and from ETRS89 providing coordinates of an accuracy level of 1 - 2 m should be placed in the public domain.

This paper gives an overview about the standardisation approach and the status of the action following the spatial reference workshop.

3. Standardisation Activities

The European standardisation activities in the field of geographic information systems started in 1993 with its technical committee CEN/TC 287 Geographic information with 5 Working Groups (WG). The Working Group 4 *Position* was chaired by H. Seeger and accompanied by various active members of the EUREF community. The work was finished in 1999 with 8 European pre norms (ENV) and 4 reports (R): Overview (R), Definition (R), Query and update (R), Rules for application schema (ENV), Position (ENV), Geographic identifiers (ENV), Transfer (ENV), Metadata (ENV), Quality (ENV), Spatial schema (ENV), Reference model (ENV), Conceptional schema language (R).

CEN/TC 287 decides to continue its activity with the following objectives:

- to provide a technical body for reaching consensus on revision of ENVs and reports, and adoption of IS when becoming available;
- to review requirements for European standards leading possibly and eventually to the definition of a new work programme;
- to provide a forum for discussion of issues of common concern.

The ISO/TC 211 Geographic Information started with its works in the field of standardization of digital geographic information in 1994 (1st plenary Nov. 1994, Oslo) and has now 5 WGs and more than 20 work items (WI).

This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations.

This work shall link to appropriate standards for information technology and data where possible, and provide a framework for the development of sector-specific applications using geographic data.

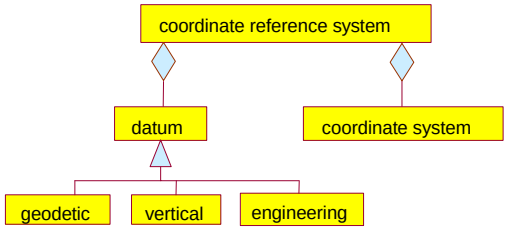
The ISO/TC 211, WI 11 - Spatial referencing by coordinates (ISO 19111) standard - was not made for geodetic experts, it was made for producers and users of GIS. Therefore the structure shall be clear and easy - but correct on a common level of abstraction.

WI 11 (Chairman H. Seeger, Editor J. Ihde) describes the conceptual schema and defines the description for a minimum data to two cases for which 1-, 2- and 3-dimensional coordinate reference system information shall be given:

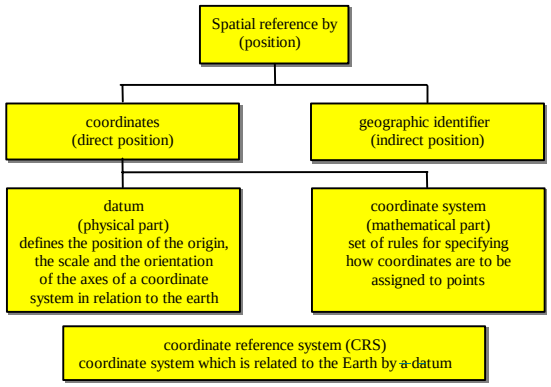
- Case A:
  A coordinate reference system to which a set of coordinates is related;
- Case B:
  A coordinate operation (coordinate transformation, coordinate conversion, concatenated coordinate operation) to change coordinate values from one coordinate reference system to another.

Coordinate Reference Systems

The coordinate reference system (CRS) is an aggregate class with the component classes datum and coordinate system, geodetic datum, vertical datum and engineering datum are subclasses to the datum:



The following schema contains the definitions of CRS, datum and coordinate system:

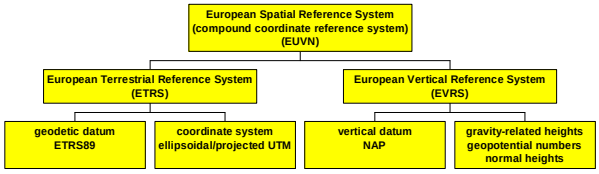


Annex 1 contains the schema with the elements describing a CRS (example: ETRS89/Cartesian coordinates).

The horizontal and vertical components of the description of a position in the space may sometimes come form different CRS. This shall be handled through a compound coordinate reference system (CCRS). The

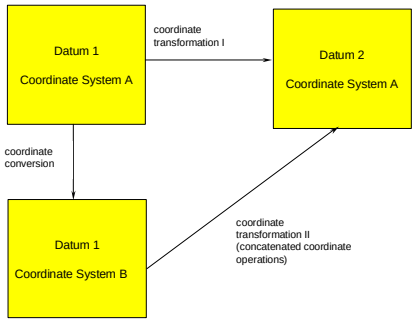
CCRS describes the position through two independent coordinate reference systems.

An unambiguous European spatial reference system could be described as a CCRS:



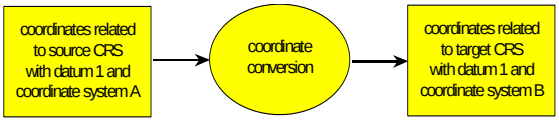
Coordinate Operations

A coordinate operation is a change of coordinates, from one coordinate reference system to another. Coordinate transformations and coordinate conversions are sub-types of coordinate operations:



Annex 2 contains the schema with the elements describing a coordinate operation in the case of coordinate transformation (example: transformation from German geodetic datum DHDN to ETRS89).

A coordinate conversion is a change of coordinates, from one coordinate system to another based on the same datum, for example between the geodetic and the cartesian coordinate systems or between geodetic coordinates and projected coordinates, or change of units such as from radians to degrees or feet to meters. A coordinate conversion uses parameters which have constant values:



A coordinate transformation is a change of coordinates from one coordinate reference system to another coordinate reference system based on a different datum:

A coordinate transformation uses parameters which may have to be derived empirically by a set of points common to both coordinate reference systems. The formula of the 7 Parameter Helmert Transformation shall be used for all coordinate transformations:

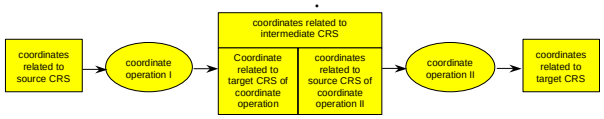
$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{(T)} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{(S)} + \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} + \begin{bmatrix} 0 & -R_3 & R_2 \\ R_3 & 0 & -R_1 \\ -R_2 & R_1 & 0 \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{(S)} + D \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{(S)}$$

$$= \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix} + \begin{bmatrix} 1+D & -R_3 & R_2 \\ R_3 & 1+D & -R_1 \\ -R_2 & R_1 & 1-D \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{(S)}$$

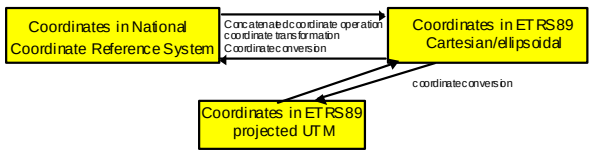
(T)	Target Datum
(S)	Source Datum
T_1, T_2, T_3	geocentric X/Y/Z translations [m]
R_1, R_2, R_3	rotations around X/Y/Z axis [radian]
D	correction of scale [ppm]

(Remark: the rotations R1, R2, R3 must be small.)

The change of coordinates from one coordinate reference system to another coordinate reference system may follow from a series of operations consisting of one or more transformations and/or one or more conversions. A concatenated operation records a change of coordinates through several transformations and/or conversions. There is no upper limit to the number of steps a concatenated operation may have. Each step is an operation described in the normal way. The figure shows a two-step concatenated operation:



The relationship between coordinates in a European coordinate reference system, a national coordinate reference system, and a European projection represents as following:



Under the head of ISO/TC 211 it is not planned to standardise a special CRS for worldwide GIS users, e. g. ITRS. A new work item with geodetic relevance "Geodetic codes and parameters" started in the year 2000 but cannot take over the function of a standard CRS. It is the task of political, technical and scientific organisations or commissions to define reference systems as defacto standards for GIS applications, as to be done by the spatial reference workshop, EUREF and CERCO with their activities.

4. Activities of EUREF and CERCO

Two EUREF activities were initiated from the urgent requests of the Spatial Reference Workshop. EUREF was asked to define a European vertical datum based on the EUVN and UELN initiatives in the year 2000 (see Ihde and Augath). Furtherance the TWG EUREF was asked together with the Work Group VIII of CERCO to manage the collection of relevant transformation data, and its publication in the year 2001.

A common letter (Annex 3) of CERCO and EUREF was send out to the NMAs of CERCO/EUREF countries in May 2000 for gathering the information of national European coordinate reference systems defined by a national datum and a coordinate system and of the relations (operations) between national and a conventional European coordinate reference system (between the datums - as coordinate transformation - and between the coordinate systems - as coordinate conversion).
The letter includes the available information about national coordinate reference systems and the information about the coordinate transformation to ETRS89. The information are stored in a relational data base regarding the conventions and tables of ISO 19111 standard. With the response of the countries the information system will be updated and more information will be added. In a public domain the information should be available through Internet.

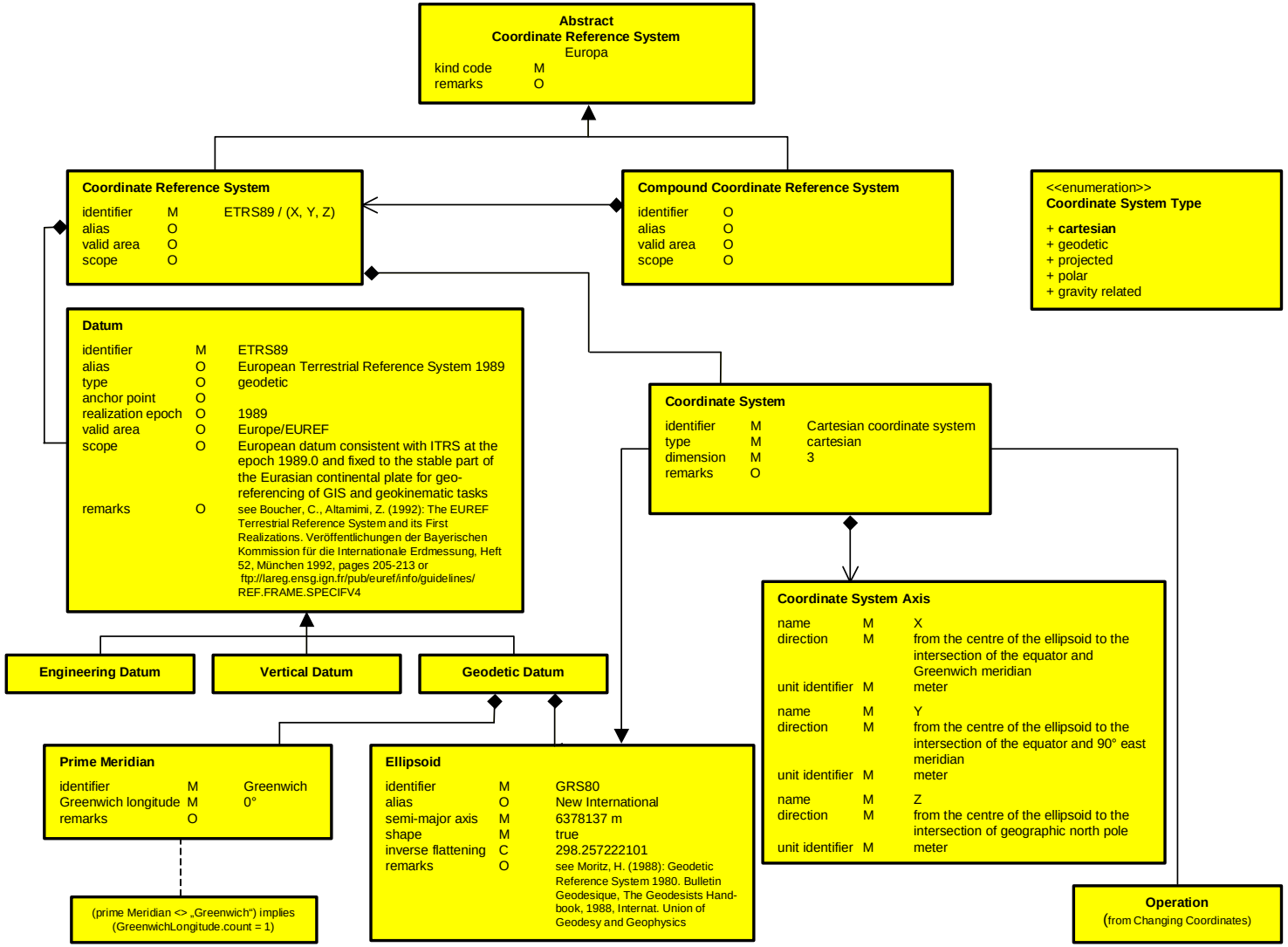
References

Annoni A., Luzet C. (Editors; 2000): Spatial Reference Systems for Europe, Proceedings & Recommendations of Workshop, Marne – La Vallee, 29-30 Nov. '99, In: www.ec-gis.org

Ihde J., Augath W.: The Vertical Reference System for Europe. Presented at the EUREF Symposium, Tromsø, June, 22-24, 2000. In: Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung. München, 2001, Heft Nr. 61, S. <xxx>

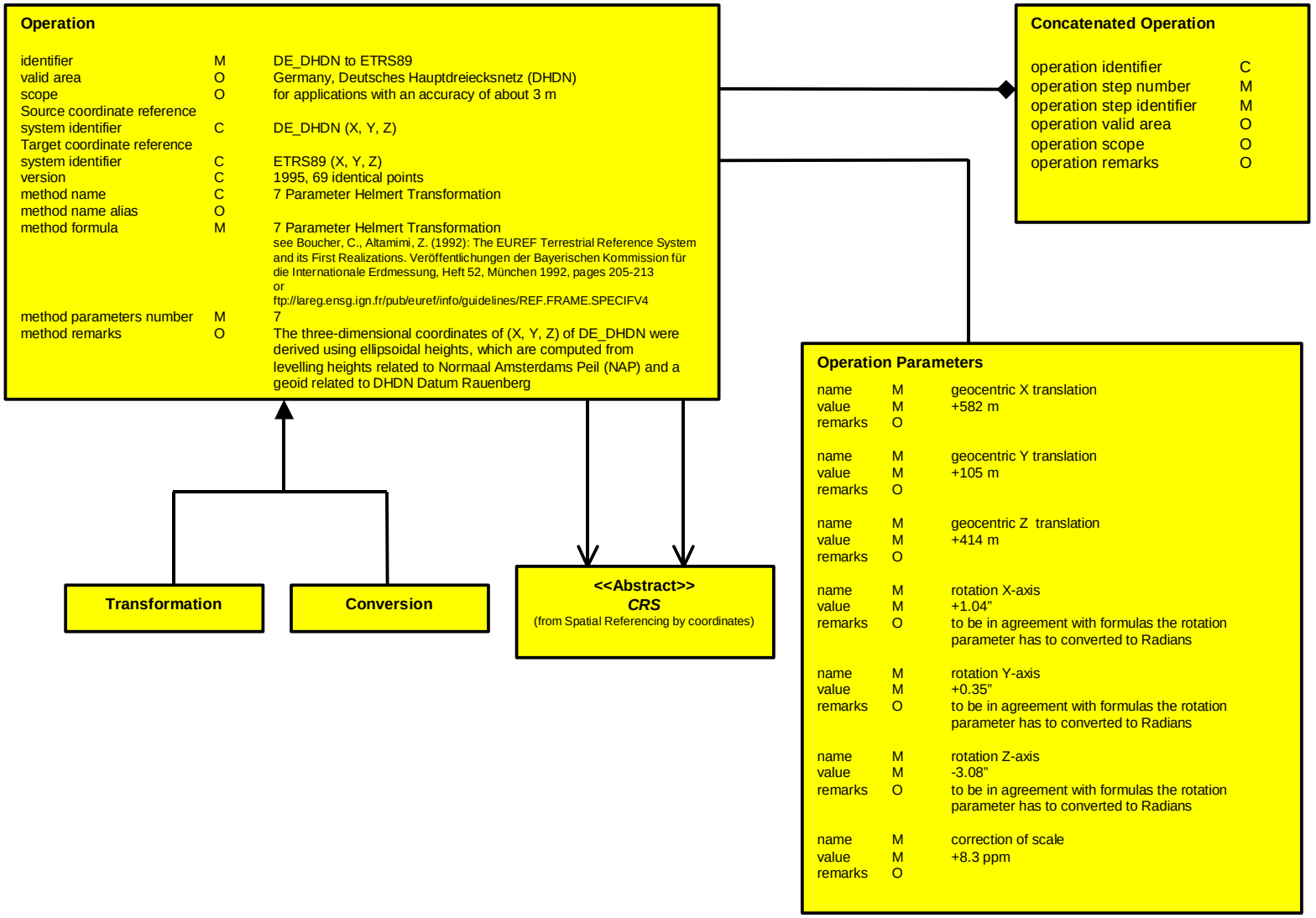
European Vertical Reference System (EVRS), International Association of Geodesy, Section I – Positioning, Commission X – Global and Regional Networks, Subcommission for Europe (EUREF). Presented at the EUREF Symposium, Tromsø, June, 22-24, 2000. In: Veröffentlichungen der Bayerischen Kommission für die Internationale Erdmessung. München, 2001, Heft Nr. 61, S. <xxx>

Annex 1 Schema for describing a coordinate reference system



Remark: The elements mandatory (M), optional (O) or conditional (C)

Annex 2 Schema of describing a coordinate operation



Remark: The elements mandatory (M), optional (O) or conditional (C)

Annex 3 Letter of CERCO and EUREF to the European National Mapping Agencies

C E R C O
Work Group VIII
Geodesy

National Mapping Agency

2000-06-05

Ladies and Gentlemen, dear colleagues,

I am writing to you in my function as President of CERCO Working Group VIII (Geodesy) and as a member of the Technical Working Group (TWG) of EUREF and I am asking for your support. As you certainly know, there is an increasing need for geographic information (GI) on an international scale for a large variety of purposes. Since all the national databases refer to national geodetic reference systems, GI from different countries cannot be combined easily.

The European Commission (EC) has asked MEGRIN to offer some support for this topic. At a Spatial Reference Workshop held near Paris in November 1999, a group of experts advised the EC to adopt the European Terrestrial Reference System ETRS89, established by the IAG Subcommission for Europe (EUREF), as the official reference system for Europe (see Appendix 6 "Short Proceedings, Conclusions & Recommendations"). In the future, all GI covering more than one country should refer to ETRS89 to make it compatible with all the other data sets. This means that there is an urgent need to perform transformations between all the national reference systems used in Europe and ETRS89. The participants of the workshop, therefore, recommended that the required information is to be made freely available with a minimum accuracy of 1 to 2 metres and that an address is published, where more accurate transformations can be performed, along with the official sources/owners of the information.

In addition to this request, MEGRIN also needs this capability for its LaClef project. Therefore, MEGRIN asked CERCO WG VIII and the EUREF Subcommission, which work closely together, to validate and make these transformations available as soon as possible. On the other hand, EUROCONTROL had collected the same information several years ago and would like to get these data checked and validated by the EUREF Subcommission as well.

On its meeting of March 20 to 21 in Brussels, the TWG decided to combine these tasks. Appendices 1 and 2 show the currently available data from different recognized sources of your country according to the standard ISO 19111 Geographic information – Spatial referencing by coordinates. We ask you to check these data thoroughly, correct false information, update phased-out data and supplement missing data and information. Appendix 3 shows examples.

To make sure that we have completely understood the information provided, we intend to perform some test computations at the Bundesamt für Kartographie und Geodäsie (BKG) and will choose a set of stations occupied in one or the other EUREF campaign for this purpose. In order to accomplish this task, we are asking you to give us the coordinates of the stations listed in Appendix 4 in your national system(s).

We intend to set up a web page containing all the available transformations with an accuracy of at least 1 to 2 metres, thus allowing easy transformations between ETRS89 and any national system, and with Appendix 5 we are officially asking you the permission to do so.

Please send the updated tables in Appendices 1 and 2 and the official permission to make the transformations publicly available (Appendix 5) not later than August 31, 2000 to Dr. J. Ihde

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Please feel free to contact either Dr. Ihde or myself if you have any questions or remarks.

Yours sincerely,

Dr. Erich Gubler
CERCO WG VIII

Appendices:

1. One (or several) Report(s): Coordinate Reference System (CRS, information currently available)
2. One (or several) Report(s): Transformation (information currently available)
3. Examples for 1. and 2.
4. List of EUREF stations intended for test transformations
5. Official permission to make transformations publicly available
6. Short Proceedings, Conclusions & Recommendations of the MEGRIN workshop