INSPIRE
Infrastructure for Spatial Information in Europe

D2.8.I.1 Specifications on Coordinate Reference Systems Draft Guidelines

Title	D2.8.I.1 Specifications On Coordinate Reference Systems – Draft Guidelines
Creator	INSPIRE Thematic Working Group on Reference Systems
Date	2008-12-19
Subject	INSPIRE Data Specifications: *Coordinate reference systems*
Status	n/a
Publisher	INSPIRE Reference Systems Thematic Working Group
Type	Text
Description	This document describes the requirements for the Implementing Rules.
Contributor	Members of the INSPIRE Reference Systems Thematic Working Group
Format	MS Word 95/2000 (doc)
Source	
Rights	Public
Identifier	INSPIRE_Specification_CRS_v2.0.pdf
Language	En
Relation	Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)
Coverage	Project duration

These are Dublin Core metadata elements. See for more details and examples http://www.dublincore.org/.

Foreword
How to read the document?

This document describes the INSPIRE data specification on *Coordinate Reference Systems* presented by the Thematic Working Group.

This document includes two executive summaries that provide a quick overview of the INSPIRE data specification process in general, and the content of the specification on *Coordinate Referenced System* in particular. We highly recommend that managers, decision makers, and all those new to the INSPIRE process and/or information modelling should read these executive summaries in the first place.

In order to distinguish the INSPIRE spatial data themes from the spatial object types, the INSPIRE spatial data themes are written in *italics* and with capital letter, like *Coordinate reference systems.*

Spatial Data Interest Communities and Legally Mandated Organisations are invited to comment on the proposed structure and content of the forthcoming Implementing Rule on Interoperability of Spatial Data Sets and Services. In order to do so we recommend that they read this draft data specification and the questions of the consultation document in parallel.

The document will be publicly available as a ‘non-paper’. It does not represent an official position of the European Commission, and as such can not be invoked in the context of legal procedures.

Interoperability of Spatial Data Sets and Services
General Executive Summary

The challenges regarding the lack of availability, quality, organisation, accessibility, and sharing of spatial information are common to a large number of policies and activities and are experienced across the various levels of public authority in Europe. In order to solve these problems it is necessary to take measures of coordination between the users and providers of spatial information. The Directive 2007/2/EC of the European Parliament and of the Council adopted on 14 March 2007 aims at establishing an Infrastructure for Spatial Information in the European Community (INSPIRE) for environmental policies, or policies and activities that have an impact on the environment.

INSPIRE will be based on the infrastructures for spatial information that are created and maintained by the Member States. To support the establishment of a European infrastructure, Implementing Rules addressing the following components of the infrastructure are being specified: metadata, interoperability of spatial data themes (as described in Annexes I, II, III of the Directive) and spatial data services, network services and technologies, data and service sharing, and monitoring and reporting procedures.

INSPIRE does not require collection of new data. However, after the period specified in the Directive[1] Member States have to make their data available according to the Implementing Rules.

Interoperability in INSPIRE means the possibility to combine spatial data and services from different sources across the European Community in a consistent way without involving specific efforts of humans or machines. It is important to note that “interoperability” is understood as providing access to spatial data sets through network services, typically via Internet. Interoperability may be achieved by either changing (harmonising) and storing existing data sets or transforming them via services for publication in the INSPIRE infrastructure. It is expected that users will spend less time and efforts on understanding and integrating data when they build their applications based on data delivered within INSPIRE.

In order to benefit from the endeavours of international standardisation bodies and organisations established under international law their standards and technical means have been referenced, whenever possible.

To facilitate the implementation of INSPIRE, it is important that all stakeholders have the opportunity to participate its specification and development. For this reason, the Commission has put in place a consensus building process involving data users, and providers together with representatives of industry, research and government. These stakeholders, organised through Spatial Data Interest Communities (SDIC) and Legally Mandated Organisations (LMO)[2], have provided reference materials, participated in the user requirement and technical[3] surveys, proposed experts for the Data Specification Drafting Team[4] and Thematic Working Groups[5], expressed their views on the drafts of the technical documents of the data specification development framework[6] and are invited to comment the draft Implementing Rule on Interoperability of Spatial Data Sets and Services.

The development framework elaborated by the Data Specification Drafting Team aims at keeping the data specifications of the different themes coherent. It summarises the methodology to be used for the data specifications and provides a coherent set of requirements and recommendations to achieve interoperability. The pillars of the framework are four technical documents:

1 For Annex I data: within two years of the adoption of the corresponding Implementing Rules for newly collected and extensively restructured data and within 5 years for other data in electronic format still in use

2 Number of SDICs and LMOs on 21/11/2008 was 276 and 162 respectively

3 Surveys on unique identifiers and usage of the elements of the spatial and temporal schema,

4 The Data Specification Drafting Team has been composed of experts from Austria, Belgium, Czech Republic, France, Germany, Greece, Italy, Netherlands, Norway, Poland, Switzerland, UK, and the European Environmental Agency

5 The Thematic Working Groups of Annex I themes have been composed of experts from Belgium, Czech Republic, Denmark, France, Finland, Germany, Hungary, Italy Netherland, Norway, Poland, Portugal, Slovenia, Spain, Sweden, Switzerland, UK, the European Commission, and the European Environmental Agency

6Four documents describing common principles for data specifications across all spatial data themes. See further details in the text.

- The Definition of Annex Themes and Scope[7] describes in greater detail the spatial data themes defined in the Directive, and thus provides a sound starting point for the thematic aspects of the data specification development.

- The Generic Conceptual Model[8] defines the elements necessary for interoperability and data harmonisation including cross-theme issues. It specifies requirements and recommendations with regard to data specification elements of common use, like the spatial and temporal schema, unique identifier management, object referencing, a generic network model, some common code lists, etc. Those requirements of the Generic Conceptual Model that are directly implementable will be included in the Implementing Rule on Interoperability of Spatial Data Sets and Services.

- The Methodology for the Development of Data Specifications[9] defines a repeatable methodology. It describes how to arrive from user requirements to a data specification through a number of steps including use-case development, initial specification development and analysis of analogies and gaps for further specification refinement.

- The "Guidelines for the Encoding of Spatial Data"[10] defines how geographic information can be encoded to enable transfer processes between the systems of the data providers in the Member States. Even though it does not specify a mandatory encoding rule it sets GML (ISO 19136) as the default encoding for INSPIRE.

Based on the data specification development framework, the Thematic Working Groups have created the INSPIRE data specification for each Annex I theme. The data specifications follow the structure of "ISO 19131 Geographic information - Data product specifications" standard. They include the technical documentation of the application schema, the spatial object types with their properties, and other specifics of the spatial data themes using natural language as well as a formal conceptual schema language[11].

A consolidated model repository, feature concept dictionary, and glossary are being maintained to support the consistent specification development and potential further reuse of specification elements. The consolidated model consists of the harmonised models of the relevant standards from the ISO 19100 series, the INSPIRE Generic Conceptual Model, and the application schemas[12] developed for each spatial data theme. The multilingual INSPIRE Feature Concept Dictionary contains the definition and description of the INSPIRE themes together with the definition of the spatial object types present in the specification. The INSPIRE Glossary defines all the terms (beyond the spatial object types) necessary for understanding the INSPIRE documentation including the terminology of other components (metadata, network services, data sharing, and monitoring).

By listing a number of requirements and making the necessary recommendations, the data specifications enable full system interoperability across the Member States, within the scope of the application areas targeted by the Directive. They are published as technical guidelines and provide the basis for the content of the Implementing Rule on Interoperability of Spatial Data Sets and Services for data themes included in Annex I of the Directive. The Implementing Rule will be extracted from the data specifications keeping in mind short and medium term feasibility as well as cost-benefit considerations. The Implementing Rule will be legally binding for the Member States.

In addition to providing a basis for the interoperability of spatial data in INSPIRE, the data specification development framework and the thematic data specifications can be reused in other environments at local, regional, national and global level contributing to improvements in the coherence and interoperability of data in spatial data infrastructures.

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7 http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.3_Definition_of_Annex_Themes_and_scope_v3.0.pdf

8 http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.5_v3.1.pdf

9 http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.6_v3.0.pdf

10 http://inspire.jrc.ec.europa.eu/reports/ImplementingRules/DataSpecifications/D2.7_v3.0.pdf

11 UML – Unified Modelling Language

12 Conceptual models related to specific areas (e.g. INSPIRE themes)

Coordinate Reference Systems
Executive Summary

Coordinate reference systems are included in Annex I, which means that they are considered as reference data, i.e. data that constitute the spatial frame for linking and/or pointing to other information that belong to specific thematic fields as defined in the INSPIRE Annexes II and III

The INSPIRE data specification on *Coordinate reference systems* has been prepared following the participative principle of a consensus building process. The stakeholders, based on their registration as a Spatial Data Interest Community (SDIC) or a Legally Mandated Organisation (LMO) had the opportunity to bring forward user requirements and reference materials, propose experts for the specification development, and participate in the review of the data specifications. The Thematic Working Group responsible for the specification development was composed of geodetic and mapping experts coming from Portugal, Slovenia, Finland, France, Germany, Italy and the UK, all of them for many years involved in activities aiming to establish uniform geo-referencing within Europe. Due to the close links between and the special technical nature of the two themes of C*oordinate reference systems* and *Geographical grid systems*, the specifications of both themes were developed by one thematic working group.

As the two first themes mentioned in Annex I of the INSPIRE Directive, the coordinate reference systems (hereafter: CRS) play a specific role that is quite different from the other themes in the Directive's annexes. Contrary to the other themes, the CRS specification does not concern the specification of a downloadable or viewable thematic data set. Rather CRS provide a basic functionality allowing the harmonised and interoperable geographic localisation of spatial objects defined by the other INSPIRE thematic data specifications. Therefore, the methodology developed by the Drafting Team on Data Specifications is only partly applicable to the work of this thematic working group.

The specific task of the definition of the CRS therefore consists in taking the right decisions on the choice of one (or a limited number of) coordinate reference systems and geographical projections that will ensure a common basis for the geographical harmonisation between all the other themes defined in the Annexes of the Directive. There are however themes for which in addition to linear systems (that are usually used for the horizontal component) parametric, or on non-length-based systems[13] are used for the vertical component.

There are also themes that may require temporal references. The referencing by parameters and temporal reference systems are out of scope of the theme CRS because the parametric systems do not provide unique and unambiguous referencing in space.

The document provides the result of the specification of the CRS contain elements that will be proposed as part of the draft Implementing Rule on interoperability of spatial data sets and services. These elements are clearly indicated in the document as "requirements". The other parts of the documents give clarification, background information and examples and are intended as part of the technical guidance documents accompanying the Implementing Rule.

The cornerstone of the specification development was the definition of the Directive on Coordinate Reference Systems as being "Systems for uniquely referencing spatial information in space as a set of coordinates (X, Y, Z) and/or latitude and longitude and height, based on a geodetic horizontal and vertical datum". The requirements and recommendations are based on the results from the "Map Projections for Europe" workshop[14].

For the horizontal component, INSPIRE will mandate the use of the European Terrestrial Reference System 1989 (ETRS89) for the areas within the geographical scope of ETRS89. The International Terrestrial Reference System (ITRS) or other geodetic coordinate reference systems compliant with

[13] like barometric, or other systems
[14] The workshop took place on 15/12/2000. See proceedings on http://sdi.jrc.ec.europa.eu/presentations-and-publications/publications/

ITRS shall be used in areas that are outside the geographical scope of ETRS89. Compliant with the ITRS means that the system definition is based on the definition of the ITRS and there is a well established and described relationship between both systems, according to ISO 19111:2007 Geographic Information – Spatial referencing by coordinates.

For the height component, INSPIRE will mandate the use of the European Vertical Reference System (EVRS) for the areas within the geographic scope of EVRS. Other vertical reference systems may be used in areas that are outside the geographical scope of EVRS.

Map projections: For the representation of data in plane coordinates in general applications, the projections recommended by the “European Reference Grids” workshop and by the “Map Projections for Europe” workshop are mandated. These are:

- Lambert Azimuthal Equal Area (ETRS-LAEA) for spatial analysis and display;
- Lambert Conformal Conic (ETRS-LCC) for conformal pan-European mapping at scales smaller or equal to 1:500,000;
- Transverse Mercator (ETRS-TMzn) for conformal pan-European mapping at scales larger than 1:500,000.

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1 Symbols and abbreviations

CRS	Coordinate reference system
EC	European Commission
ETRS89	European Terrestrial Reference System 1989
ETRS89/EVRS	Compound coordinate reference system ETRS89/EVRS
ETRS89-LAEA	Projection Lambert Azimuthal Equal Area
ETRS89-LCC	Projection Lambert Conformal Conic
ETRS89-TMzn	Projection Transverse Mercator
EUREF	Reference Frame Sub-commission for Europe of the IAG
EVRS	European Vertical Reference System
GCM	Generic Conceptual Model
GRS80	Geodetic Reference System 1980
IAG	International Association of Geodesy
IERS	International Earth Rotation and Reference Systems Service
ITRS	International Terrestrial Reference System
JRC	Joint Research Centre
TWG	Thematic Working Group

2 Scope

2.1 Definition of the theme in the Inspire Directive

Systems for uniquely referencing spatial information in space as a set of coordinates (X, Y, Z) and/or latitude and longitude and height, based on a geodetic horizontal and vertical datum.

2.2 Description

The INSPIRE theme Coordinate Reference Systems (CRS) provides a harmonised specification for uniquely referencing spatial information.

This document also provides the specification for the map projections to be used for geo-referencing the spatial information in plane coordinates.

The mandated CRS is used for any kind of information/resolution/accuracy; the resolution and accuracy of data are out of scope of the theme CRS.

The accuracy of the data sets resulting from transformations and conversion formulas are out of scope of the theme CRS. The accuracy of the data sets must be documented by the data set provider according to all the aspects that contribute to it, namely the original accuracy and the accuracy of the conversions, transformations and handling of data.

There are themes for which data are expressed in linear systems for the horizontal component or on non-length-based vertical systems like pressure, density, for the vertical component. There are also themes that may require temporal references. This kind of referencing is parametric.

The referencing by parameters and temporal reference systems are out of scope of the theme CRS because the parametric systems do not provide unique and unambiguous referencing in space. The parameters shall be associated with the specific data according to ISO 19111 (Part 2: Extension for parametric values). If there is a need to assign time series (array of values) to data, the ISO 19123 shall be used.

The theme CRS uses the conceptual schema within ISO19111 supplemented by specifications of ISO 19113 (quality principles), ISO 19114 (quality evaluation procedures), ISO 19115 (metadata) and ISO 19127 (geodetic codes and parameters).

3 Coordinate Reference Systems

3.1 General description

Coordinate Reference Systems (CRS) define the constants and parameters needed for Geodetic Datums, and are required for uniquely referencing spatial information in space as a set of coordinates (x, y, z) and/or latitude and longitude and height.

CRS explicitly uses the definitions given in ISO 19111:

- A coordinate system specifies how coordinates are to be assigned to points by means of mathematical rules.
- A coordinate reference system is a coordinate system related to an object by a datum.
- A datum is a parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system.

This is achieved by defining a horizontal geodetic datum to express latitude and longitude (horizontal component) and a vertical geodetic datum to express the height (height component).

Latitude and longitude are equivalent to plane coordinates using suitable cartographic projections.

The coordinate reference systems used for the horizontal component in the majority of Europe area are linked to the Eurasian tectonic plate. Since Directive 2007/2/EC affects areas that are not on the stable part of the Eurasian tectonic plate, it is necessary that the rules concerning coordinate reference systems distinguish between areas that are considered to be on the Eurasian tectonic plate, and areas that are not.

For the height component a similar rule applies, since not all the vertical datums in use can be connected to the European vertical datum.

This kind of situation occurs, for example, in the European countries' overseas territories.

3.2 Requirements for Coordinate Reference Systems

For the horizontal component, INSPIRE will mandate the use of the European Terrestrial Reference System 1989 (ETRS89) for the areas within the geographical scope of ETRS89. The International Terrestrial Reference System (ITRS) or other geodetic coordinate reference systems compliant with ITRS shall be used in areas that are outside the geographical scope of ETRS89. Compliant with the ITRS means that the system definition is based on the definition of the ITRS and there is a well established and described relationship between both systems, according to ISO 19111.

The parameters of the GRS80 ellipsoid shall be used for the computation of latitude and longitude and for the computation of plane coordinates using a suitable map projection.

Requirement 1	For the horizontal component, INSPIRE will mandate for the areas within the geographical scope of ETRS89 the use of the European Terrestrial Reference System 1989 (ETRS89).

Requirement 2	The International Terrestrial Reference System (ITRS) or other geodetic coordinate reference systems compliant with ITRS shall be used in areas that are outside the geographical scope of ETRS89.

Requirement 3	The parameters of the GRS80 ellipsoid shall be used for the computation of latitude and longitude and for the computation of plane coordinates using a suitable mapping projection.

For the height component, INSPIRE will mandate the use of the European Vertical Reference System (EVRS) for the areas within the geographic scope of EVRS. Other vertical reference systems may be used in areas that are outside the geographical scope of EVRS.

Requirement 4	For the vertical component, INSPIRE will mandate for the areas within the geographical scope of EVRS the use of the European Vertical Reference System (EVRS).

When using both ETRS89 and EVRS the CRS used is a compound one (ISO19111) and shall be designated as ETRS89/EVRS. It allows unambiguous 3D geo-referencing, as requested by INSPIRE.

Since Member States shall ensure that any data or information needed for the purposes of achieving interoperability are available on conditions that do not restrict their use for that purpose, Member States shall make available information as to which coordinate reference system they use, for both the horizontal and height components, as well as the corresponding geodetic codes and parameters to make transformations possible. These geodetic codes and parameters shall be documented according to ISO 19111 and ISO 19127.

4 Map Projections

4.1 General description

Map projections are used for geo-referencing the spatial information in plane coordinates.

In 14-15 December 2000 was organized the “Map Projections for Europe” workshop to propose the map projections to be used for representation of data in plane coordinates in general applications. The use of the following projections was recommended:

- Lambert Azimuthal Equal Area (ETRS-LAEA) for spatial analysis and display;
- Lambert Conformal Conic (ETRS-LCC) for conformal pan-European mapping at scales smaller or equal to 1:500,000;
- Transverse Mercator (ETRS-TMzn) for conformal pan-European mapping at scales larger than 1:500,000.

These recommendations have been used by the European Commission (EC) for geo-referencing the data internally within the EC. It is a natural step to mandate these projections for the representation of data in plane coordinates in the frame of INSPIRE.

The formulas of the above mentioned map projections are published in the proceedings of the “Map Projections for Europe” workshop (Marne-La Vallee, 14-15 December 2000) and in the proceedings of the “European Reference Grids” workshop (Ispra, 27-29 October 2003).

In order to homogenize the designation of the CRS, the designations of the CRS in the projections names are changed from ETRS to ETRS89.

4.2 Requirements for Map Projections

For the representation of data in plane coordinates in general applications, the projections recommended by the “European Reference Grids” workshop and by the “Map Projections for Europe” workshop are mandated.

Requirement 5	INSPIRE will mandate the Lambert Azimuthal Equal Area (ETRS89-LAEA) for spatial analysis and display

Requirement 6	INSPIRE will mandate the Lambert Conformal Conic (ETRS89-LCC) for conformal pan-European mapping at scales smaller or equal to 1:500,000

Requirement 7	INSPIRE will mandate the Transverse Mercator (ETRS89-TMzn) for conformal pan-European mapping at scales larger than 1:500,000

There are themes that may require other types of projections to fulfil their requirements.

Specific themes may use special projections internally. In this case, these projections must be well documented to allow the conversion to geographic coordinates. The documentation shall be provided according to ISO 19111, which states how a projected coordinate reference system must be described.

5 Identifiers

The following identifiers will be used to refer the types of coordinates mandated by INSPIRE:

- ETRS89 for Cartesian coordinates in ETRS89 in space (X,Y,Z)
- ETRS89-GRS80 for geographic coordinates in ETRS89 on the GRS80 ellipsoid (Longitude, Latitude)
- EVRS for the height in EVRS (H)
- ETRS89-LAEA for ETRS89 coordinates projected into plane coordinates by the Lambert Azimuthal Equal Area projection (x, y)
- ETRS89-LCC for ETRS89 coordinates projected into plane coordinates by the Lambert Conformal Conic projection (E, N)
- ETRS89-TMzn for ETRS89 coordinates projected into plane coordinates by the Transverse Mercator projection (E,N)

6 Normative References

Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information in the European Community (INSPIRE)
ISO 19111:2007, Geographic Information – Spatial referencing by coordinates
ISO 19111-2:--[15] , Geographic Information – Spatial referencing by coordinates – Part 2: Extension for parametric values
ISO 19113, Geographic Information – Quality principles
ISO 19114 Geographic information - Quality evaluation procedures
ISO 19115 Geographic information - Metadata
ISO 19123:2007, Geographic Information – Schema for coverage geometry and functions
ISO/TS 19127:2005, Geographic information -- Geodetic codes and parameters

[15] to be published, currently in “Committee Draft” stage

7 Terms and definitions

Coordinate reference system	A coordinate reference system is a coordinate system related to an object by a datum (from: ISO 19111:2007).
Coordinate system	A coordinate system specifies how coordinates are to be assigned to points by means of mathematical rules (from: ISO 19111:2007).
Datum	A datum is a parameter or set of parameters that define the position of the origin, the scale, and the orientation of a coordinate system (from: ISO 19111:2007).
Geodetic datum	Geodetic datum is a datum describing the relationship of a two- or three-dimensional coordinate system to the Earth (from: ISO 19111:2007).

8 Bibliography and References

Map Projections for Europe - EUR Report 20120 EN. Proceedings of the “Map Projections for Europe” workshop, Marne-La Vallee, 14-15 December 2000

Spatial Reference Systems in Europe – EUR Report 19575 EN. Proceedings of the “Spatial Reference Systems in Europe” workshop, Marne-La Vallee, 29-30 November 1999

European Reference Grids - EUR Report 21494 EN. Proceedings of the “European Reference Grids” workshop, Ispra, 27-29 October 2003

www.iers.org – website for information of ERS for information on the ITRS

www.euref.eu or www.euref-iag.net – EUREF website for information on the ETRS89 and the EVRS