INSPIRE
Infrastructure for Spatial Information in Europe

D2.8.I.2 Specifications on Geographical Grid Systems Draft Guidelines

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Foreword
How to read the document?

This document describes the INSPIRE draft data specification on *Administrative units* as developed by the Thematic Working Group using both natural and conceptual schema language.

This document includes two executive summaries that provide a quick overview of the INSPIRE data specification process in general, and the content of the data specification on *Administrative units* 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.

The UML diagrams given in 5.1.1 offer a rapid way to see the main elements of the specifications and their relationships. The definition of the spatial objects, attributes, and relationships are included in the Feature Catalogue in 5.1.2. People having thematic expertise but not familiar with UML can fully understand the content of the data model focusing on the Feature Catalogue. Users might also find the Feature Catalogue especially useful to check if it contains the data necessary for the applications that they run. The technical details are expected to be of prime interest to those organisations that are/will be responsible for implementing INSPIRE within the field of *Administrative units.*

The technical provisions and the underlying concepts are often illustrated by examples. Smaller examples are within the text of the specification, while longer explanatory examples are attached in the annexes.

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 *Administrative units.*

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

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.

recommendations to achieve interoperability. The pillars of the framework are four technical documents:

- 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.

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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)

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.

Geographical grid systems
Executive summary

Geographical grid 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 *Geographical grid 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 *Coordinate reference systems* and G*eographical grid systems*, the specifications of both themes were developed by one Thematic Working Group.

Geographical grid systems (hereafter: *Grids*) play a specific role that is quite different from the other themes in the Directive's annexes. Contrary to the other themes the *Grids* specification does not concern a downloadable or viewable thematic data set. Rather, it presents 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 *Geographical grid systems* theme therefore consists in taking the right decisions on the choice of one (or a limited number of) grid systems that will ensure a common basis for the geographical harmonisation between all the other themes defined in the Annexes of the Directive.

This document represents the result of the specification of the *Geographical grid systems* theme, which contains 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 Rules.

The cornerstone of the specification development was the definition of the Directive on *Geographical grid systems* as being "Harmonised multi-resolution grid with a common point of origin and standardised location and size of grid cells". The requirements and recommendations of this theme are based on the results from the "European Reference Grids" workshop[13].

The scope of the theme "Geographical grid systems" covers quadrilateral grids used for indirect geo-referencing of themes with typically coarse resolution and wide (pan-European) geographical extent. The grid is two-dimensional and mainly used for spatial analysis or reporting. A geographical grid is associated with predefined resolutions and a coding system for identifying individual cells.

The grid – proposed as the multipurpose Pan-European standard – is based on the ETRS89 Lambert Azimuthal Equal Area coordinate reference system with the centre of the projection at the point 52o N, 10o E and false easting: x_0 = 4321000 m, false northing: y_0 = 3210000 m

[13] http://sdi.jrc.ec.europa.eu/presentations-and-publications/publications/

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1. Symbols and abbreviations

CRS	Coordinate reference system
EC	European Commission
ETRS89-LAEA	Projection Lambert Azimuthal Equal Area
Grid_ETRS89-LAEA5210	Pan-European Grid
GCM	Generic Conceptual Model
EEA	European Environmental Agency
EIONET	Environmental Information and Observation Network
TWG	Thematic Working Group

2. Scope

2.1. Introduction

One method of storing spatial information with indirect position is by using geographical grids. Grids omit direct spatial reference and average the qualitative properties of the subject. This makes them powerful tools for harmonisation and reduction of the complexity of spatial datasets. Geographical grids are also effective communication means for reporting spatial variability of features.

Technically, grids for geographical data are predefined spatial reference structures composed of cells regular in shape or area. Cells are usually squares based on a given coordinate reference system but, in rare cases, they can be shaped differently, e.g. as hexagons.

There are many types of grids available for different purposes. Ideally, one grid that is useful for all purposes ought to be created but it is not possible for one grid to cover uniformly the whole of Europe. Any type of grid will always have some disadvantages that disqualify it for certain use. The following grid examples are presented to describe the difficulties in selection of a multipurpose grid.

The world geographic reference system (Georef) is made for aircraft navigation. It is also suitable for grid mapping with world coverage. Georef is based on geographical latitude and longitude. The globe is divided into 12 bands of latitude and 24 zones of longitude, each 15 degrees in extent. These 15-degree areas are further divided into one-degree units identified by 15 characters. Georef disadvantages are that the shape, area and distance of cells are distorted.

National grid systems. Most countries have defined grid systems covering their territory, based on the national plane coordinates. Belgium, Great Britain, Denmark, Finland, Ireland, Italy, the Netherlands and Sweden are examples of countries that have defined a national grid system.

The Common European chorological grid reference system (CGRS) is modified from the military grid reference system (MGRS). The MGRS itself is an alphanumeric version of a numerical UTM (Universal Transverse Mercator) or UPS (Universal Polar Stereographic) grid coordinate. MGRS has some serious disadvantages; cells do not cover the same area or have the same length of sides along latitude. This implies that cell statistics are difficult to calculate.

Equal area grids are suitable for generalising data, statistical mapping and analytical work where an equal area of cells is important. The first Workshop on European Reference Grids in Ispra, 27-29 October 2003, recommends the use of the multipurpose European grid based on Lambert Azimuthal Equal Area and ETRS89. Proceedings (1) are available from the EIONET GIS page (http://www.eionet.eu.int/gis).

2.2. Definition of the theme from the Inspire Directive

Harmonised multi-resolution grid with a common point of origin and standardised location and size of grid cells.

2.3. Theme Description

This document specifies requirements and recommendations with regards to “Geographical grid systems” theme as defined in Annex I of the INSPIRE Directive.

The document was prepared by the Inspire thematic working group "Coordinate reference systems and Geographical grid systems" composed of geodetic and mapping experts from different European countries, all of them for many years involved in activities aiming to establish uniform geo-referencing within Europe.

The scope of the theme "Geographical grid systems" covers quadrilateral grids used for indirect geo-referencing of themes with typically coarse resolution and wide (pan-European) geographical extent. The grid is two-dimensional and mainly used for Spatial Analysis or Reporting. A geographical grid is associated with predefined resolutions and a coding system for identifying individual cells.
These grids are defined by the projected coordinate reference system.

The requirements and recommendations regarding "Geographical grid systems" are harmonized with the requirements with regards to Coordinate reference systems (4).

3. Geographical grid system

3.1. General description

A grid typically uses a matrix of n x m cells spanned by 2 axes. As a result, a grid cell can be referenced by a sequence of integer values (one for each axis) that represent the position of the reference cell along each of the axes of the grid. See CV_GridCoordinate as specified in ISO 19123.

3.1.1. Pan-European grid

The grid – proposed as the multipurpose Pan-European standard – is based on the ETRS89 Lambert Azimuthal Equal Area coordinate reference system with the centre of the projection at the point 52^o N, 10^o E and false easting: x_0 = 4321000 m , false northing: y_0 = 3210000 m (CRS identifier in Inspire: ETRS89-LAEA).

The grid is designated as Grid_ETRS89-LAEA5210. For identification of an individual resolution level the name is extended by identification of cell size in metres (*example: _100K*).
The origin of Grid_ETRS89-LAEA5210 coincides with the false origin of the ETRS89-LAEA coordinate reference system (x=0, y=0).
Grid points of grids based on ETRS89-LAEA must coincide with grid points at Grid_ETRS89-LAEA5210.

The grid is defined as hierarchical one in metric coordinates in power of 10.

The resolution of the grid is 1m, 10m, 100m, 1000m, 10,000m, 100,000m.

The grid orientation is south-north, west-east.

3.1.2. Reference point

Reference point of a grid cell for grids based on ETRS89-LAEA is the lower left corner of the grid cell.

3.1.3. Grid cells coding system

Coding system follows the recommendations from the European Environmental Agency (2).

Cell code is composed of the size of cell and the coordinates of the lower left cell corner in ETRS89-LAEA.

Cell size in metres is formatted to "m" (metre) or "km" (kilometre) depending of cell size.

Example: 10000 metres is changed to "10km".

To reduce the length of the string, values for easting and northing (in the ETRS89-LAEA they are named x and y) are divided by 10^n ("n" is number of zeros in the cell size value). With the given resolutions this means that the zeros are trimmed.

Example: Cell size is 1000 metres. Number of zeros in end is 3. Divider is 10^3 = 1000.

Example of cell code: "1kmE4695N2599 "(identifies the 1km grid cell with coordinates of the lower left corner: x=4695000m, y=2599000m).

3.2. Requirements for grids

Requirement 1	The grid – proposed as the multipurpose Pan-European standard – is based on the ETRS89 Lambert Azimuthal Equal Area coordinate reference system with the centre of the projection at the point 52° N, 10° E and false easting: x_0 = 4321000 m, false northing: y_0 = 3210000 m.

Requirement 2	Grid points of grids based on ETRS89-LAEA must coincide with grid points at Grid_ETRS89-LAEA5210.

Requirement 3	Reference point of grid cell for grids based on ETRS89-LAEA is the lower left corner of the grid cell.

4. Modelling grids

Existing standards enable different modelling of gridded data products and exchanging data in not always compatible formats. The most confusing issue seems to be the relation of grid cell and grid points in discrete surface grids. When discrete surface grids are implemented as discrete point grids, this can cause location shifts of half of cell size or unwanted cell values interpolations. When surface grids are implemented as surfaces the above mentioned problems are avoided.
Appendix 1 contains template application schema for Discrete Surface Grid Coverage (from ISO/TC 211 N 2547).

5. Manipulation with grid values

Reference grids are mainly used for exchanging discrete values assigned to individual cells. When discrete values referred to one grid (e.g. sampling results) are converted to a different grid, there is no possibility to maintain the original thematic information. "Proceedings & Recommendations" from the European Reference Grids Workshop (1) provide an exhaustive source on descriptions of the methods used when such conversion is required. A more compact source of relevant instructions is the "Guide to Geographical Data and Maps" (2). A general rule is to select the most suitable methodology, to use the original (not already derived) data, and to describe in detail the applied processing steps.
Controlling and recording resampling steps provides the needed input for calculation of expected errors.

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 19113 Geographic Information - Quality principles
ISO 19114 Geographic information - Quality evaluation procedures
ISO 19115 Geographic information - Metadata
ISO 19123 Geographic Information - Schema for coverage geometry and functions

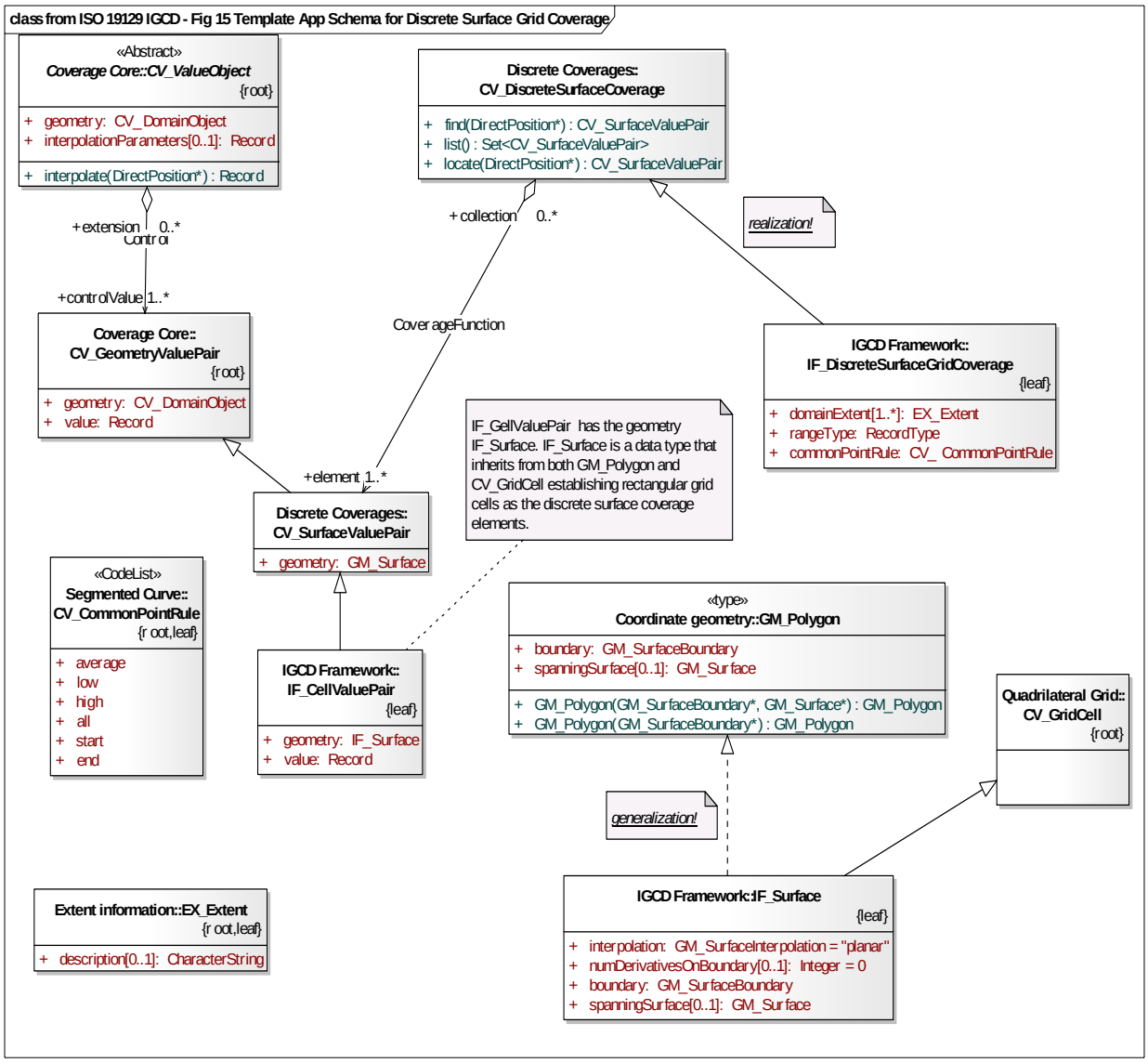
7. Terms and definitions

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).
Reference grid	Reference grid is a grid defined in the real world in order to be used for indirect geo-referencing
Grid	network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in an algorithmic way NOTE The curves partition a space into grid cells. (from: ISO 19123)
Grid point	point located at the intersection of two or more curves in a grid (from: ISO 19123)

Bibliography and References

1. European Reference Grids Workshop, Proceedings & Recommendations, EUR 21494 EN (http://sdi.jrc.ec.europa.eu/presentations-and-publications/publications/European_Reference_Grids_EUR21294.pdf)
2. Guide to geographical data and maps, version 2.0, January 2006, European Environmental Agency (http://www.eionet.europa.eu/gis/docs/EEA_GISguide_v2.doc)
3. ISO/TC 211 N 2547 (Text for ISO/TS 19129 Geographic information - Imagery, gridded and coverage data framework, as sent to the ISO Central Secretariat for publication)
4. Contribution for the INSPIRE Data Specifications V2.0 with regards to Coordinate Reference Systems

Appendix 1: Template application schema



"Fig 15 - Template Application Schema for Discrete Surface Grid Coverage" from ISO/TC 211 N 2547