EUROCONTROL
Working together to deliver the Single European Sky

Terrain and Obstacle Data Working Group

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EUROCONTROL Headquarters, Brussels
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ACTION PAPER
TODWG16/AP3
10/04/2013

AGENDA ITEM 4.1: TERRAIN FORMATS

Submitted by: TOD WG secretariat

EXECUTIVE SUMMARY

The paper provides the outcome of the consultation on the most frequently used formats for terrain data.

RECOMMENDATIONS

The members of the TOD WG are invited to

a) note the outcome of TOF WG consultation on preferred terrain formats;

b) develop a recommendation for preferred terrain formats;

c) approve the inclusion of the developed material in the TOD Manual.

1 INTRODUCTION

1.1 At TOD WG/14 in May 2012 the meeting acknowledged that there were not detailed specifications for the format of terrain data in both ICAO and EUROCONTROL material on eTOD. Therefore the Members of the TOD WG agreed to create a group of volunteers among the WG to identify, document and recommend the most frequently used formats for terrain data, including their detailed technical specifications and their interoperability, for inclusion in the TOD Manual.

1.2 The outcome of this work was provided at TOD WG/15 in November 2012 and the meeting agreed to review the proposal and to provide comments to the TOD secretary for presentation and approval at TOD WG/16.

2 DISCUSSION

2.1 The tables in the Annexes include the outcome of the consultation[1] with the TOD WG covering the following actions:

TODWG/15 ACT/3	Clarify the use of “certified tools / certification” for the next version of the paper
TODWG/15 ACT/4	Comment on AP03 and provide comments to TOD Secretary
TODWG/15 ACT/5	Secretary: Collect comments and prepare an updated version for presentation and approval at next meeting
TODWG/15 ACT/6	Collect user preferences for terrain formats from other data integrators (e.g. LH Systems, Navtech)
TODWG/15 ACT/7	Liaise with the national terrain data providers on their preferred terrain formats and provide these to the TOD Secretary.

2.2 With regard to ACT/7, Lufthansa Systems has provided their opinion on the existing terrain formats and their preference for GeoTIFF (see last Annex)

3 RECOMMENDATIONS

The members of the TOD WG are invited to

a) note the outcome of TOF WG consultation on preferred terrain formats;

b) develop a recommendation for preferred terrain formats;

c) approve the inclusion of the developed material in the TOD Manual.

[1] received comments are in green

Annex 1

Requirements for Terrain Data Formats based on ICAO Annex 15, Chapter 10
AMTD 36, July 2010

Para-graph	Text	Requirements in regard to terrain data formats
10.2 Terrain data set — content, numerical specification and structure		
10.2.1.	A terrain data set shall contain digital sets of data representing terrain surface in the form of continuous **elevation values** at all **intersections (points) of a defined grid**, **referenced to common datum**. A **terrain grid shall be angular or linear and shall be of regular or irregular shape**. Note.— In regions of higher latitudes, latitude grid spacing may be adjusted to maintain a constant linear density of measurement points.	provide elevation values intersections (points) of a defined grid ==> position referenced to a common datum terrain grid: - angular or linar - regular or irregular shape
10.2.2.	Sets of electronic terrain data shall include spatial (position and elevation), thematic and temporal aspects for the surface of the Earth containing naturally occurring features such as mountains, hills, ridges, valleys, bodies of water, permanent ice and snow, and excluding obstacles. In practical terms, depending on the acquisition method used, this shall represent the continuous surface that exists at the bare Earth, the top of the canopy or something in-between, also known as “first reflective surface”.	-
10.2.3.	In terrain data sets, **only one feature type, i.e. terrain**, shall be provided. **Feature attributes** describing terrain shall be those listed in Table A8-3. The **terrain feature attributes listed in Table A8-3** represent the minimum set of terrain attributes, and those annotated as mandatory shall be recorded in the terrain data set.	attributes according Table A8-3: (M = Mandatory) Area of coverage (M) Data originator identifier (M) Acquisition method (M) Post spacing (M) Horizontal reference system (M) Horizontal resolution (M) Horizontal accuracy (M) Horizontal confidence level (M) Horizontal position (M) Elevation (M) Elevation reference (M) Vertical reference system (M) Vertical resolution (M) Vertical accuracy (M) Vertical confidence level (M) Surface type - Optional Recorded surface (M) Penetration level - Optional Known variations - Optional Integrity (M) Date and time stamp (M) Unit of measurement used (M) ---------- *ICAO Annex 15 makes no requirement to have attribute/meta data on every point in the terrain data set and so reference in the conclusions column to this is not necessary.*
10.2.4.	Electronic terrain data for each area shall conform to the applicable **numerical requirements in Appendix 8, Table A8-1**.	Numerical requirements according Table A8-1 ==> for data formats: vertical resolution Area 1: 1m Area 2: 0.1m Area 3: 0.01m Area 4: 0.1m (==> see supported data types in Annexes 2 and 3)
10.4 Terrain and obstacle data product specifications		
10.4.1.	To allow and support the interchange and use of sets of electronic terrain and obstacle data among different data providers and data users, the **ISO 19100 series of standards for geographic information** shall be used as a general data modelling framework.	ISO 19100 series of standards for geographic information
10.4.2.	A comprehensive statement of available electronic terrain and obstacle data sets shall be provided in the form of terrain data product specifications as well as obstacle data product specifications on which basis air navigation users will be able to evaluate the products and determine whether they fulfil the requirements for their intended use (application). Note.— ISO Standard 19131 specifies the requirements and outline of data product specifications for geographic information.	-
10.4.3.	Each terrain data product specification shall include an overview, a specification scope, data product identification, data content and structure, reference system, data quality, data capture, data maintenance, data portrayal, data product delivery, additional information, and metadata.	-

Para-graph	Text	Requirements in regard to terrain data formats
10.4.4.	The overview of terrain data product specification or obstacle data product specification shall provide an informal description of the product and shall contain general information about the data product. Specification of terrain data may not be homogenous across the whole data product but may vary for different parts of the data sets. For each such subset of data, a specification scope shall be identified. Identification information concerning both terrain and obstacle data products shall include the title of the product; a brief narrative summary of the content, purpose, and spatial resolution if appropriate (a general statement about the density of spatial data); the geographic area covered by the data product; and supplemental information.	-
10.4.5.	Content information of feature-based terrain data sets or of feature-based obstacle data sets shall each be described in terms of an application schema and a feature catalogue. Application schema shall provide a formal description of the data structure and content of data sets while the feature catalogue shall provide the semantics of all feature types together with their attributes and attribute value domains, association types between feature types and feature operations, inheritance relations and constraints. Coverage is considered a subtype of a feature and can be derived from a collection of features that have common attributes. Both terrain and obstacle data product specifications shall identify clearly the coverage and/or imagery they include and shall provide a narrative description of each of them. Note 1.— ISO Standard 19109 contains rules for application schema while ISO Standard 19110 describes feature cataloguing methodology for geographic information. Note 2.— ISO Standard 19123 contains schema for coverage geometry and functions.	-
10.4.6.	Both terrain data product specifications and obstacle data product specifications shall include information that identifies the reference system used in the data product. This shall include the **spatial reference system and temporal reference system**. Additionally, both data product specifications shall identify the data quality requirements for each data product. This shall include a statement on acceptable conformance quality levels and corresponding data quality measures. This statement shall cover all the data quality elements and data quality sub-elements, even if only to state that a specific data quality element or sub-element is not applicable. Note.— ISO Standard 19113 contains quality principles for geographic information while ISO Standard 19114 covers quality evaluation procedures.	spatial reference system and temporal reference system
10.4.7.	Terrain data product specifications shall include a data capture statement which shall be a general description of the sources and of processes applied for the capture of terrain data. The principles and criteria applied in the maintenance of terrain data sets and obstacle data sets shall also be provided with the data specifications, including the frequency with which data products are updated. Of particular importance shall be the maintenance information of obstacle data sets and an indication of the principles, methods and criteria applied for obstacle data maintenance.	-
10.4.8.	Terrain data product specifications shall contain information on how data held with data sets is presented, i.e. as a graphic output, as a plot or as an image. The product specifications for both terrain and obstacles shall also contain data product delivery information which shall include delivery formats and delivery medium information. Note.— ISO Standard 19117 contains a definition of the schema describing the portrayal of geographic information including the methodology for describing symbols and mapping of the schema to an application schema.	-
10.4.9.	The core terrain and obstacle metadata elements shall be included in the data product specifications. Any additional metadata items required to be supplied shall be stated in each product specification together with the format and encoding of the metadata. Note.— ISO Standard 19115 specifies requirements for geographic information metadata.	-
10.4.10.	The obstacle data product specification, supported by geographical coordinates for each aerodrome included within the dataset, shall describe the following areas: — Areas 2a, 2b, 2c, 2d; — the take-off flight path area; and — the obstacle limitation surfaces.	-

Annex 2

List of most used raster formats

Abbreviation (Name)	Description	Pros (regarding usage and requirements for TOD according to ICAO Annex 15)	Cons (regarding usage and requirements for TOD according to ICAO Annex 15)	File extension	Supported data types (e.g. integer, floating point,…)	References	Remarks
GeoTIFF	GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file. The GeoTIFF format is fully compliant with TIFF 6.0, so software incapable of reading and interpreting the specialized metadata will still be able to open a GeoTIFF format file. (source: http://en.wikipedia.org/wiki/Geotiff)	- well-known image format, supported by many GIS and image processing software ------ *completely open, public domain, non-proprietary*	- is not ISO 19100 compliant - cannot store metadata on pixel level.	*.tiff *.tif	1-bit unsigned integer 4-bit unsigned integer 8-bit unsigned integer 8-bit signed integer 16-bit unsigned integer 16-bit signed integer 32-bit unsigned integer 32-bit signed integer 32-bit floating Point (source: ***)	http://www.remotesensing.org/geotiff/spec/geotiffhome.html http://trac.osgeo.org/geotiff/	The draft guidelines for the European INSPIRE directive on elevation data use GeoTIFF as the encoding of grid coverages. -------- *If it is acknowledged by the TOD WG that INSPIRE is applicable to TOD data, then the INSPIRE guidelines on elevation specification should be applied.*
DTED (Digital Terrain Elevation Data)	A simple, regularly spaced grid of elevation points based on 1 degree latitude and longitude extents. Created by the NGA. (source: **)		- is not ISO 19100 compliant - cannot store metadata on pixel level. --------- *The DTED format has different levels of detail, and different zones over the globe where different longitude spacing's (widths of a "pixel") are used. The spacing's and levels of detail are fixed (so you cannot provide a 10m grid of elevations in DTED, for example)*	*.dt0 *.dt1 *.dt2	16-bit signed integer (source: ***)	Geospatial Standards and Specifications: http://earth-info.nga.mil/publications/specs/	Originally designed for use by the US military.
USGS DEM (United States Geological Survey Digital elevation model)	This format consists of a raster grid of regularly spaced elevation values derived from the USGS topographic map series. In their native format, they are written as ANSI-standard ASCII characters in fixed-block format. (source: **)		- is not ISO 19100 compliant - cannot store metadata on pixel level.	*.dem	16-bit signed integer (source: ***)	http://nationalmap.gov/standards/pdf/1DEM0897.PDF	
ESRI Grid	A proprietary ESRI format that supports 32-bit integer and 32-bit floating point raster grids. (source:**)	- native support by ESRI ArcGIS	- propretiary binary format - is not ISO 19100 compliant - cannot store metadata on pixel level	made up of serveral different files	32-bit signed integer 32-bit floating point (source: ***)	http://support.esri.com/en/knowledgebase/techarticles/detail/30616	Proprietary raster format
ASCII Grid	ESRI ArcInfo Grid exchange file (source: **)	- native support by ESRI ArcGIS - textual structure allows creating easy parsers for reading data	- is much slower on reading than binary formats - is not ISO 19100 compliant - cannot store metadata on pixel level ---------- *ASCII grid files contain very little metadata, so things such as the coordinate reference system, the height datum, and any quality information would have to go in a separate file.*	*.asc	16-bit signed integer 32-bit floating point (source: ***)	http://en.wikipedia.org/wiki/Esri_grid	This is often called an "ESRI GRID ASCII" format, but it is used by many applications as a simple way to import and export grid data. -------- *this is an old format in which datas are stored as text so it is both easily understandable and light after being zipped*

Raw Binary				*.bil *.bip *.bsq			BIL=Band interleaved by line / BIP=band interleaved by pixel / BSQ= band sequential ---------- *same format as before but datas are stored as binaries*
ASCII XYZ				*.xyz			
TICM/TIXM							*ECTL were developing TICM and TIXM to model and exchange terrain, it is presumed this was not completed but there must be lessons learnt from that exercise which would inform any final decision on appropriate formats.*

** ESRI Support Homepage: Supported raster dataset file formats: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#//009t0000000g000000

***ESRI Support Homepage: Technical Specs of raster dataset formats: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Technical_specifications_for_raster_dataset_formats/009t0000000r000000/

Annex 3

List of further terrain formats

Abbreviation (Name)	Description	Pros (regarding usage and requirements for TOD according to ICAO Annex 15)	Cons (regarding usage and requirements for TOD according to ICAO Annex 15)	File extension	Supported data types (e.g. integer, floating point,...)	References	Remarks
(City) GML	CityGML is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML provides a standard model and mechanism for describing 3D objects with respect to their geometry, topology, semantics and appearance, and defines five different levels of detail. (source: http://www.citygml.org/index.php?id=1523)	- ISO 19100 compliant, - easily read by existing GML parsers, - standard XML, - can store metadata information on pixel level	- will be very slow on reading than binary formats, - most of the existing GIS software does not have native support.	*.gml *.xml		http://www.opengeospatial.org/standards/gml http://www.opengeospatial.org/standards/citygml http://www.citygml.org/	
Shape Files	A shapefile is a simple, nontopological format for storing the geometric location and attribute information of geographic features. Geographic features in a shapefile can be represented by points, lines, or polygons (areas). (source: ****)			Required: *.shp *.shx *.dbf Additional Information, optional files: *.sbn and *.sbx *.fbn and *.fbx *.ain and *.aih *.atx *.ixs *.mxs *.prj *.xml *.cpg			Points, Contourlines -------- *Shape files are not actively promoted by ESRI any more - file geodatabases are recommended instead. It should also be noted that shapefiles are an ESRI proprietary format*
TIN (Triangular or traingulated Irregular Network)	A TIN is a vector-based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (x, y, and z) that are arranged in a network of nonoverlapping triangles. (source: http://en.wikipedia.org/wiki/Triangulated_irregular_network)	- "adjustable" resolution: nodes can be placed irregularly over the land surface, which allows to present more details if desired.					*"TIN" is not a format – it is more of a data model. TINS are stored in different ways by different software packages (e.g. SOCET SET and ARC). In INSPIRE, the recommended format for TINs is in a GML file.*

**** ESRI Support Homepage: Shapefile
http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/What_is_a_shapefile/005600000002000000/

Annex 4

List of open source tools for data transformation

Name	Reference	Certified by	Remarks
GDAL - Geospatial Data Abstraction Library	http://www.gdal.org/	Open Source Geospatial Foundation (OSGeo, www.osgeo.org). For licensing see: http://svn.osgeo.org/gdal/trunk/gdal/LICENSE.TXT	OSGeo was created to support the collaborative development of open source geospatial software, and promote its widespread use.

Annex 5

Providers preferred terrain formats

State	Preference	Remarks
Croatia	DTED, GRID, SRTM3	
France	For ordinary DEM, DTM or DSM : GeoTIFF, ESRI ASCii grid, ESRI BIL grid For point cloud achieved from LIDAR : LAS (binary) and XZY coordinates (simple text)	
Ireland	ASCII, XYZ	
Lithuania	GeoTIFF	
Norway	USGS DEM	We can, by using FME-software, convert the USGS DEM file format into other formats, such as GeoTIFF, DTED, etc.
Portugal	ascii, xyz, SCOP, DTM, LAS, Grd, TIFF, Shapefile	
Serbia	Civil: TIFF, MrSID and ECW Military: dxf,ASCII, GRID, TIN and TIFF	
Spain	GeoTIFF Shape Files	AIS Spain is currently using these formats for terrain data interexchange and consequently considers the most important formats
Turkey	DTED and ASCII	
United Kingdom	GML 3.2 & ASCII Grid & ESRI shapefile (.shp)	Ordnance Survey has previously made height data products available in DXF, NTF and ASC II Grid formats. A number of these formats are now somewhat obsolete and with the imminent launch of a range of new height data products, OS Terrain 5 and OS Terrain 50 the OS have taken the opportunity to review the formats the data is made available in. OS have engaged with the user community and have opted to make these products available in the following formats: OS Terrain 5 and OS Terrain 50 Grid – GML 3.2 & ASCII Grid OS Terrain 5 and OS Terrain 50 Contours – GML 3.2 and ESRI shapefile (.shp) This range of formats ensures ease of use within a range of GIS packages and that user product migrations will be a straightforward exercise.

Lufthansa Systems

Area1 and 4 data review

22. January 2013
Martin Gernss – Lufthansa Systems

General requirements Area 1 / 4 data Format:

- Efficient exchange
- No/little post processing (i.e. resampling)
- Projection/coordinate system easily adjustable
- No "overhead" storage of irrelevant information
- Consistency (resolution, coordinate system/origin)
- Zip compression preferred instead of .rar
- Software independent format (non proprietary)
- Possibility to deliver Metadata within the same file

Advantages/Disadvantages of some proposed formats:

Format	+	-
GeoTIFF	+ Common, widely used standard to store georeferenced raster files supported by many tools + High flexibility + All information in a single file + New format BigTIFF will even overcome the 4 GB limitation	– Resolution cannot be varied within one data set (No landscape dependent storing of terrain information => File size "overhead")
Shape File	+ Many open source libraries and tools that are able to view and work with shape files (even if it's originally a proprietary format). + Additional attributes can be stored + Metadata storable	– Only vector data (DEM usually used as raster data, but conversion is a common and easy task) – Always at least 3 files (missing overview) – No topological information – Max 2 GB – Probably Geodatabases would be even better
DTED		– Resolution not flexible enough (i.e. DTED0: extent usually at least 1 degree even if extent for relevant terrain data is way smaller)
GML	+ High flexibility (xml based) + Highly standardized and well documented	– Missing support in many standard tools
ESRI Grid		– Proprietary
ArcInfo ASCII Grid	+ Non proprietary, but no advantages compared to GeoTIFF	–
TIN	+ Resolution can be varied in dependence of terrain	– More complex data structure than regular raster – Only for smaller areas
Spreadsheets		– Conversion usually more work intense – Metadata has to be delivered in a additional spread sheet / file

Conclusion

- GeoTiff highly preferred