EUROPEAN ORGANISATION FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

# Terrain Data Model Primer

## Aeronautical Information Management

AIM/



| | | |
|---|---|---|
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EUROPEAN AIR TRAFFIC MANAGEMENT

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| 0.5 | 27th February 2009 | Final release for TOD WG review. | All |

## TABLE OF CONTENTS

# GLOSSARY

| | |
|---|---|
| AIM | Aeronautical Information Management |
| AIXM | Aeronautical Information Exchange Model |
| DTED | Digital Terrain Elevation Data |
| eTOD | electronic Terrain and Obstacle Data |
| GIS | Geographic Information System(s) |
| GML | Geography Mark-Up Language |
| ICAO | International Civil Aviation Organization |
| ISO | International Organization for Standardization |
| ISO 19100 | Standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth |
| OGC | Open Geospatial Consortium |
| SARPS | Standards and Recommended Practices |
| TICM | Terrain Data Conceptual Model |
| TIXM | Terrain Data Exchange Model |
| TOD WG | Terrain and Obstacle Data Working Group |
| UML | Unified Modelling Language |
| WCS | Web Coverage Service |
| XML | Extensible Mark-Up Language |
| XSD | XML Schema Definition |
| XSL | Extensible Stylesheet Language |
| XSLT | XSL Transformations |

# REFERENCES


| | | | |
|---|---|---|---|
| 1 | ICAO Annex 15 – Aeronautical Information Services | ICAO | 12th Edition, July 2004 |
| 2 | OpenGIS Geography Markup Language (GML) Implementation Specification | Open Geospatial Consortium, Inc. | Version 3.2.1, Aug. 2007 |
| 3 | ISO 19103: Geographic Information – Conceptual Schema Language | ISO / TC 211 | Draft, July 2001 |
| 4 | ISO 19118: Geographic Information – Encoding | ISO / TC 211 | Draft, Sept. 2001 |
| 5 | ISO 19123: Geographic Information – Schema for coverage geometry and functions | ISO / TC 211 | First Edition, 2005 |
| 6 | ISO 19115 : Geographic Information – Metadata | ISO / TC 211 | First Edition, 2003 |
| 7 | ICAO Doc 9881: Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information | ICAO | Draft |

# 1. INTRODUCTION

## 1.1 Purpose

This document is a guide to the Terrain Data Conceptual Model (TICM) and the Terrain Data Exchange Model (TIXM) developed by EUROCONTROL for aviation purposes. It offers a high-level explanation of what the model is, the approach taken in its development and detailed information regarding the content of the model.

For complete understanding, this document should be read in conjunction with the model itself, as well as the related documents listed in the Glossary.

## 1.2 Overview

The TICM is a formal representation of the requirements for terrain data described in the International Civil Aviation Organization's (ICAO's) Annex 15 and is expressed as a collection of Unified Modelling Language (UML) diagrams.

The TIXM is an Extensible Mark-up Language (XML) Schema implementation of the TICM, and thereby constitutes an exchange format for terrain data. The geospatial aspects of TIXM are implemented using Geography Mark-up Language (GML) version 3.2. By conforming to Annex A of the GML Specification (Ref. 2), it is intended that TIXM datasets will be compatible with third-party GML-compliant applications, and hence enable aeronautical users to reap the benefits of open Geographic Information Systems (GIS) standards, as developed by the Open Geospatial Consortium (OGC).

As will be seen, the model is developed to allow the exchange of terrain information, with its associated metadata[1]. or to provide a means of associating metadata with existing terrain files. This latter facility is of particular use where a State wishes to utilise existing terrain data which, although it does not comply with the ICAO Standards and Recommended Practices (SARPS), provides data which is of use to aviation. The existing terrain data may be in any format, such as Digital Terrain Elevation Data (DTED) or Shape files.

A terrain dataset is a digital representation of the vertical extent of the terrain at a number of discrete points. Terrain datasets consist of either a regular or irregular distribution of sample points. Terrain may be depicted on a grid of elevations at regular intervals. Regular grids are those in which the horizontal and vertical post spacing is uniform across the grid, though the horizontal and vertical spacing does not have to be the same. Regular grids divide the area of interest into a series of rectangular cells. Irregular grids are those that do not have uniform horizontal and vertical post spacing.

Geographic phenomena fall into two broad categories – discrete and continuous. Discrete phenomena are recognisable objects that have relatively well-defined boundaries or spatial extent. Examples include buildings, streams and measurement stations. Continuous phenomena vary over space and have no specific extent. Examples include temperature, soil composition and elevation. Continuous phenomena can be represented using coverages[2]..

[1] Metadata allows a producer to describe a dataset fully so that users can understand the assumptions and limitations and evaluate the dataset's applicability for their intended use [ISO19115:2005]..

[2] A coverage is a function from a spatial, temporal or spatiotemporal domain to an attribute range. A coverage associates a position within its domain toa record of values defined data types [ISO19123:2007].

The International Organization for Standardization's (ISO) 19123 provides a definition of a coverage:

*"Coverages support mapping from a spatiotemporal domain to attribute values where attribute types are common to all geographic positions within the spatiotemporal domain. A spatiotemporal domain consists of a collection of direct positions in a coordinate space. Examples of coverages include rasters, triangulated irregular networks, point coverages, and polygon coverages. Coverages are the prevailing data structures in a number of application areas, such as remote sensing, meteorology, and bathymetric, elevation, soil, and vegetation mapping".*

Terrain datasets are coverages. Coverages are implemented in GML as features and provide a conformant implementation of the ISO 19123 coverage schema.

In order to clear up potential misunderstandings, several points need to be emphasised at this stage. Firstly, the model is not software; it is abstract formalisations of the concepts involved in terrain related to aviation. By itself, it performs no function in the software sense. The model has been created to facilitate the development and usage of cross-platform applications. Secondly, the model is not mandated in any way, nor does it make existing systems or data formats redundant. It is hoped that it will be used alongside such systems by providing a common basis for exchanging data, thus increasing interoperability.

# 2. APPROACH

It is important that the reader understands how the data model was established and against what premise it was developed.

A data model is developed to represent something, and a set of requirements are needed to define what that something is. In the case of the TIXM, the requirements for the digital exchange of terrain data needed to be modelled. Such a high-level requirement does not, however, adequately define what exactly is needed. For example, a digital photo of a hill may well meet one group's need for the exchange of terrain data, whereas for AIS, there is a need to make available detailed and accurate information about terrain in a State. Therefore, it was essential that a more detailed set of requirements was determined.

In addressing the requirements for the terrain modelling, a number of analyses were performed.

- Firstly, the requirements laid down by ICAO Annex 15 Chapter 10 and Appendix 8 were assessed and recorded;
- Secondly, the draft guidance material (Doc 9881) issued by ICAO was analysed to determine how ICAO had foreseen that its requirements would be implemented;
- Lastly, the requirements of the electronic Terrain and Obstacle Data (eTOD) stakeholder group were determined. This latter exercise resulted in a number of optional attributes being added which support the use of the data. This analysis further allowed some domain-specific restrictions for certain attributes to be established.

Whilst this latter analysis was not strictly necessary to achieve an ICAO compliant data model, it was essential to ensure that the model meets the needs of the user community. The requirements against which the terrain model was developed are described in Appendix B.

The following sections present the data model. The eTOD Manual will be developed in due course and will provide detailed information on the application of the TIXM.

# 3. MODELLING METHODOLOGY

## 3.1 Approach

The approach taken to develop the TICM is described below.

The first step in the modelling process was to analyse and model all the requirements for terrain data in ICAO Annex 15, Amendment 33, at a conceptual level. Modelling requirements at a conceptual level subsequently allows the requirements of the exchange model to be determined. In addition to modelling the regulatory requirements, any standardisation requirements were also modelled. The requirements were modelled in UML and followed the OGC approach to modelling gridded data using coverages (for an overview of coverages, see 3.3.2 below).

The conceptual model developed has been confirmed as meeting the additional requirements for terrain data introduced by Amendment 34 to ICAO Annex 15.

This analysis led to the identification of some core components needed for a conceptual model. At the lowest level, terrain data is composed of recorded values for a given sample point. The raw terrain data points are considered to form a point cloud. The point cloud contains only the sampled data points and their associated metadata. Terrain datasets can be constructed using subsets of the point cloud, packaged with the appropriate metadata.

The use of a point cloud concept brings major advantages for use in the eTOD implementation of terrain data where there are multiple datasets, each with differing data collection requirements, but which cover the same geographic area. For example, if an Area 4 survey is performed, some of the terrain data collected may also exist within the aerodrome's Area 3 dataset, and will entirely exist within the aerodrome's Area 2 and the State's Area 1 datasets.

The eTOD requirements specify the need to exchange terrain data for the intersection points for a defined grid. Figure 1 below shows an example grid. The grid has an origin point, giving its position as well as its horizontal and vertical extent. Values are recorded for the intersection points of the grid. These values are those that exist within the point cloud.

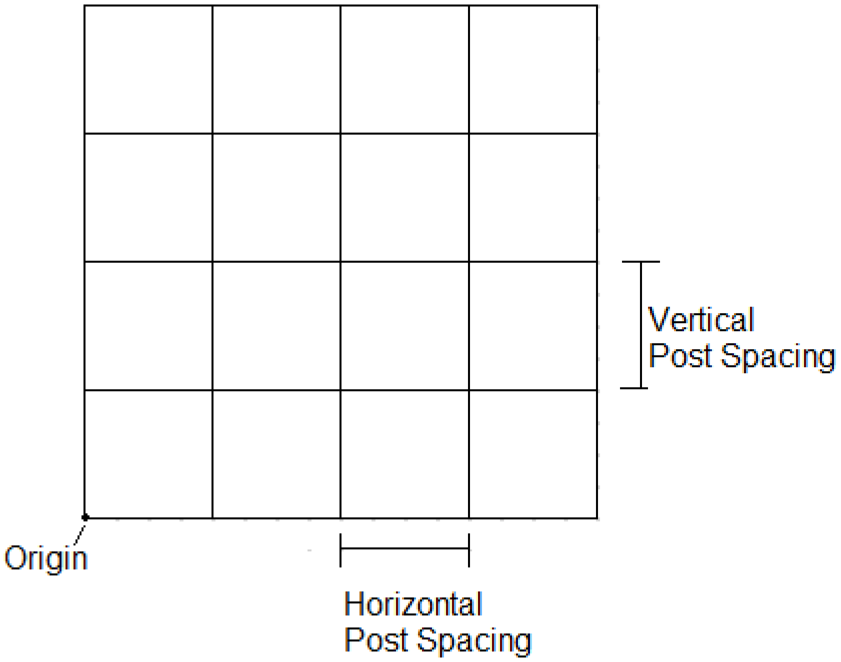



**Figure 1 - Example Grid**

The organisation of raw terrain points into a gridded structure allows location information to be removed from points and replaced by metadata defining how the point data should be evaluated.

The separation of the raw surveyed terrain data (the point cloud) and user, product-orientated, gridded data allows for ease of maintenance of both the surveyed points and grid metadata.

The point cloud concept also allows the use of partial surveys more easily within a dataset. For example, if earthworks are undertaken, only the points that relate to the affected area may be resurveyed and the resultant dataset is an amalgam of older and more recent surveys. Care must be taken, however, to ensure that data from a lower accuracy survey is not used to update a higher accuracy dataset.

Existing data formats were considered to see if any of these already met the needs of eTOD. Although a number of terrain data formats do exist, in the main, these could not be used for eTOD as no single format holds all the information mandated by ICAO. As a result, a new data exchange format was needed for the purposes of the eTOD implementation of terrain data.

As stated above, the TICM is a formal description of the terrain data defined in ICAO Annex 15. It consists of a number of related UML diagrams that define terrain. The TICM follows the principles of the EUROCONTROL Aeronautical Information Management (AIM) Concept, namely, that it should:

- Enable interoperability;
- Be open;
- Be platform independent;
- Follow global standards.

By adhering to these principles, the models should be more easily compatible with existing systems and services, as well as well-established data formats.

## 3.2 Terminology

Table 1 below describes the association types used in the UML diagrams that follow.

| | |
|---|---|
|  | Bi-directional (standard) association<br><br>A relationship between 2 classes in which classes at each end are aware of each other and their relationship. |
|  | Uni-directional association<br><br>A relationship between 2 classes in which only one of the classes is aware of the other and the relationship. |
|  | Basic aggregation<br><br>A relationship between 2 classes in which one class is a part of another class. In basic aggregation, the child class can exist without a parent class. |
|  | Composition aggregation<br><br>A relationship between 2 classes in which one class is a part of another class. In composition aggregation, the child class cannot exist without a parent class. |

**Table 1 - UML Association Types**

Associations can also have a defined multiplicity, showing how many classes can exist at each end of the association. Table 2 below describes the meaning of some common values.

| **Indicator** | **Meaning** |
|---|---|
| 0..1 | Zero or one |
| 1 | One only |
| 0..* | Zero or more |
| 1..* | One or more |
| n | Only *n* (where *n* > 1) |

**Table 2 - UML Association Multiplicity**

Associations may also be labelled with either the name of the association or each end may be labelled with the role the target class plays.

## 3.3 Model Components

### 3.3.1 Packages

The TICM is divided into three packages, as follows:

a) TICM: top-level container for the TICM packages;

b) TI_DataTypes: terrain domain restrictions for object properties;

c) TI_Terrain: terrain classes.

Figure 2 shows how the TICM packages relate to one another.

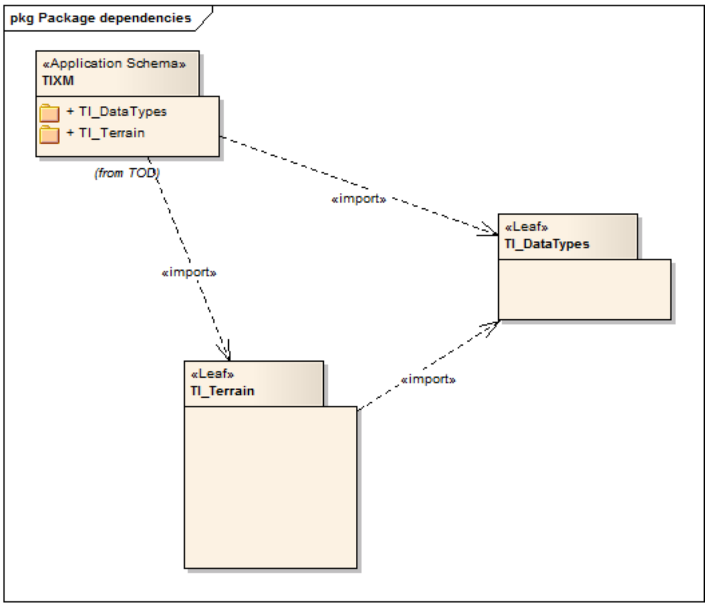
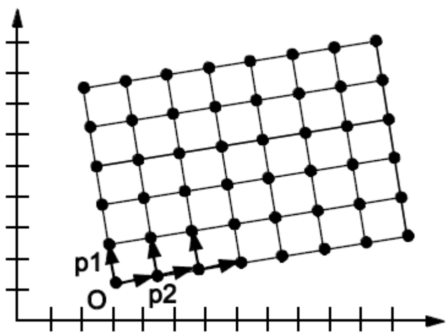



**Figure 2 - TICM Package Dependencies**

### 3.3.2 Classes

The model has been developed to use concepts that exist in GML. The TerrainSet class is defined to be of type coverage.

The TerrainSet coverage maps between a domain, which in this case is a rectified grid, as shown in Figure 3, and a range set containing ElevatedPoints.




**Key**

O origin

p1, p2 offset vectors

**Figure 3 - Rectified Grid**

The TerrainSet also contains the metadata for the defined grid.

An optional association to a set of GridCells is defined in line with the definition of a grid given in ISO 19123. GridCells provide an additional evaluation structure for the elevated points that comprise the terrain dataset. Each GridCell has an association to a number of ElevatedPoints that comprise the corners of the cell.

Figure 4 shows the TICM:

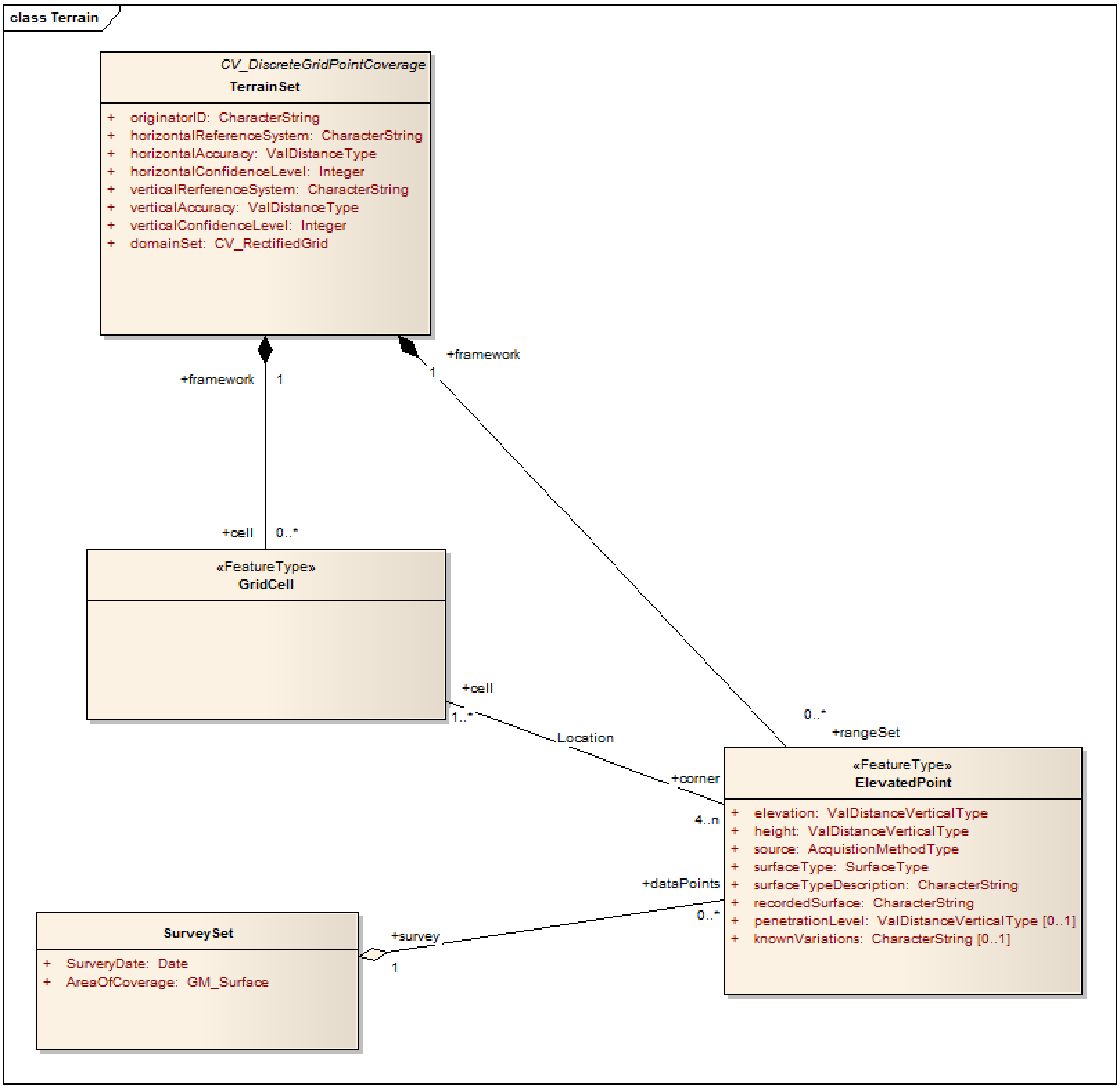



**Figure 4 - Terrain Data Conceptual Model (TICM)**

ElevatedPoints contain the metadata relating to the physical properties for that intersection point of the grid, including surface type and penetration level.

The TICM has been defined to separate the gridded dataset with associated metadata, from the underlying raw terrain data points. This allows a single dataset to contain multiple gridded sets without duplication of terrain data points, and for irregular grids to be defined.

The OGC standard allows the ElevatedPoints to be contained within the same file as the TerrainSet or stored in separate files and referenced. External files of different formats may be referenced in this way and the TIXM file would serve as a metadata wrapper. For example, a GeoTIFF binary file could be referenced.

Using this approach, the model is compatible with other OGC specifications including the Web Coverage Service (WCS) which specifies an interface for accessing coverage data over the web.

### 3.3.3 Data Types

ICAO Annex 15 defines several "domains" – legal ranges for a value which is common to one or more attributes. Generally, these were implemented as restrictions of an XML Schema simple type. Other simple types, corresponding to feature properties, were then derived from these domain types. Where appropriate, TIXM uses data types already defined in the Aeronautical Information Exchange Model (AIXM). An example is shown below in Figure 5.

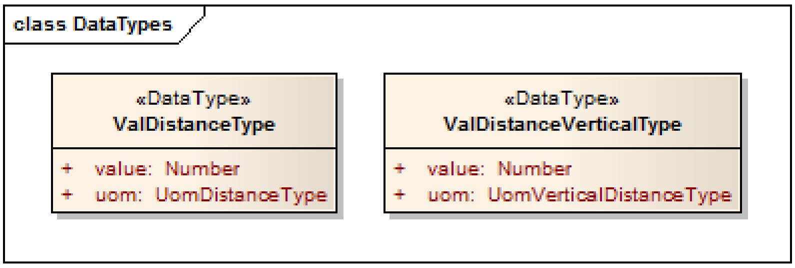



**Figure 5 - Data Types**

### 3.3.4 Enumerations

There are several enumerations used in the definition of vertical structures. An enumeration is a fixed list of values that can be used to restrict the value of an attribute. These were stereotyped as <<enumeration>>, which provides a direct translation to the XML Schema Definition (XSD) equivalent. An example is given below in Figure 6.

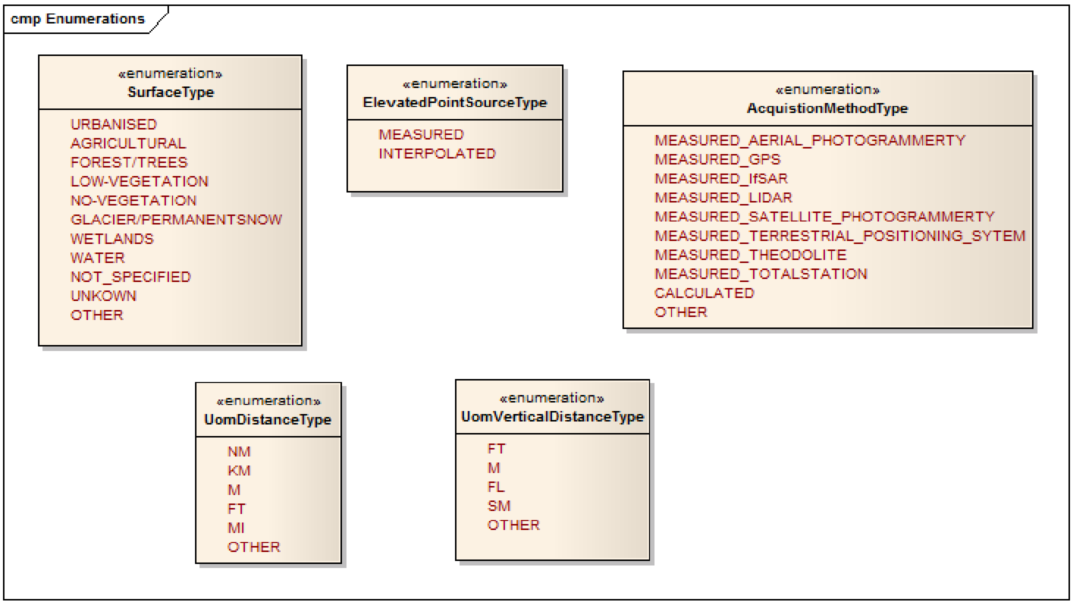



**Figure 6 - Enumerations**

### 3.3.5 Metadata

The model contains attributes defined by ICAO that could be considered as metadata. In addition, there is currently a separate activity underway to produce a metadata profile that is specific to aviation. When this activity is complete, the model shall be updated to include further elements from this profile.

## 3.4 Exchange Schema

The XML Schemas that make up the exchange model were derived programmatically from the UML. The Solid Earth and Environment GRID have defined a process for transforming a UML model into a GML Application schema. This process uses Extensible Stylesheet Language (XSL) Transformations (XSLT) scripts in combination with some proprietary third-party software (ShapeChange).

The files that make up the exchange schema are included in Appendix A.

### 3.4.1 Examples

Through the use of the GML coverage features, the exchange schemas support various configurations of exchange files and some examples are shown below. The examples have been included to show how the exchange packages can be structured and do not include full size datasets.

Note: The examples have not yet been populated with actual data.

### 3.4.2 Inline XML Data

This example shows a single XML file containing terrain data included as marked up XML.

```xml
<?xml version="1.0" encoding="UTF-8"?>
<tixm:TerrainSet gml:id="tixm_example"
xsi:schemaLocation="http://www.eurocontrol.int/tixm TIXM.xsd"
xmlns:tixm="http://www.eurocontrol.int/tixm" xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
	<gml:boundedBy>
		<gml:Envelope srsName="urn:x-ogc:def:crs:EPSG:6.6:EPSG:4326">
			<gml:lowerCorner>x y</gml:lowerCorner>
			<gml:upperCorner>x y</gml:upperCorner>
		</gml:Envelope>
	</gml:boundedBy>
	<gml:domainSet>
		<gml:RectifiedGrid gml:id="examplegrid" dimension="2">
			<gml:limits>
				<gml:GridEnvelope>
					<gml:low>x y</gml:low>
					<gml:high>x y</gml:high>
				</gml:GridEnvelope>
			</gml:limits>
			<gml:axisLabels>u v</gml:axisLabels>
			<gml:origin>
				<gml:Point gml:id="exampleorigin" srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
					<gml:pos>x y</gml:pos>
				</gml:Point>
			</gml:origin>
			<gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
				x y
```

```
                        </gml:offsetVector>
                        <gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                                x y
                        </gml:offsetVector>
                </gml:RectifiedGrid>
        </gml:domainSet>
        <gml:rangeSet>
                <gml:ValueArray gml:id="exampledata">
                                <gml:valueComponents>
                                        <tixm:ElevatedPoint>
                                                <tixm:elevation>

        <tixm:ValDistanceVerticalType>

        <tixm:value>3</tixm:value>

        <tixm:uom>M</tixm:uom>

        </tixm:ValDistanceVerticalType>
                                                </tixm:elevation>
                                                <tixm:height>

        <tixm:ValDistanceVerticalType>

        <tixm:value>4</tixm:value>

        <tixm:uom>M</tixm:uom>

        </tixm:ValDistanceVerticalType>
                                                </tixm:height>

        <tixm:source>MEASURED_GPS</tixm:source>

        <tixm:surfaceType>AGRICULTURAL</tixm:surfaceType>
                                                <tixm:surfaceTypeDescription>Corn
field</tixm:surfaceTypeDescription>

        <tixm:recordedSurface></tixm:recordedSurface>
                                                <tixm:survey></tixm:survey>
                                        </tixm:ElevatedPoint>
                                </gml:valueComponents>
                </gml:ValueArray>
        </gml:rangeSet>
        <tixm:originatorID/>
        <tixm:horizontalReferenceSystem/>
        <tixm:horizontalAccuracy>
                <tixm:ValDistanceType>
                        <tixm:value>1</tixm:value>
                        <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
        </tixm:horizontalAccuracy>
```

```
        <tixm:horizontalConfidenceLevel>90</tixm:horizontalConfidenceLevel>
        <tixm:verticalRerferenceSystem/>
        <tixm:verticalAccuracy>
                <tixm:ValDistanceType>
                        <tixm:value>1</tixm:value>
                        <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
        </tixm:verticalAccuracy>
        <tixm:verticalConfidenceLevel>90</tixm:verticalConfidenceLevel>
</tixm:TerrainSet>
```

### 3.4.3 Inline Tuple List

This example shows a single XML file containing terrain data as a simple list of values.

```
<?xml version="1.0" encoding="UTF-8"?>
<tixm:TerrainSet gml:id="tixm_example"
xsi:schemaLocation="http://www.eurocontrol.int/tixm TIXM.xsd"
xmlns:tixm="http://www.eurocontrol.int/tixm"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
        <gml:boundedBy>
                <gml:Envelope srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                        <gml:lowerCorner>x y</gml:lowerCorner>
                        <gml:upperCorner>x y</gml:upperCorner>
                </gml:Envelope>
        </gml:boundedBy>
        <gml:domainSet>
                <gml:RectifiedGrid gml:id="examplegrid" dimension="2">
                        <gml:limits>
                                <gml:GridEnvelope>
                                        <gml:low>x y</gml:low>
                                        <gml:high>x y</gml:high>
                                </gml:GridEnvelope>
                        </gml:limits>
                        <gml:axisLabels>u v</gml:axisLabels>
                        <gml:origin>
                                <gml:Point gml:id="exampleorigin"
srsName="urn:x-ogc:def:crs:EPSG:6.6:EPSG:4326">
                                        <gml:pos>x y</gml:pos>
                                </gml:Point>
                        </gml:origin>
                        <gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                                x y
                        </gml:offsetVector>
                        <gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                                x y
                        </gml:offsetVector>
                </gml:RectifiedGrid>
```

```
        </gml:domainSet>
        <gml:rangeSet>
                <gml:DataBlock>
                        <gml:rangeParameters/>
                        <gml:tupleList>Data List</gml:tupleList>
                </gml:DataBlock>
        </gml:rangeSet>
        <tixm:originatorID/>
        <tixm:horizontalReferenceSystem/>
        <tixm:horizontalAccuracy>
                <tixm:ValDistanceType>
                        <tixm:value>1</tixm:value>
                        <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
        </tixm:horizontalAccuracy>
        <tixm:horizontalConfidenceLevel>90</tixm:horizontalConfidenceLevel>
        <tixm:verticalRerferenceSystem/>
        <tixm:verticalAccuracy>
                <tixm:ValDistanceType>
                        <tixm:value>1</tixm:value>
                        <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
        </tixm:verticalAccuracy>
        <tixm:verticalConfidenceLevel>90</tixm:verticalConfidenceLevel>
</tixm:TerrainSet>
```

### 3.4.4 External Binary File

This example shows how an external file containing terrain data can be referenced from a master TIXM xml file. The TIXM file contains the required eTOD metadata about the gridded dataset but the raw terrain data points are contained within an external file with a known format. This example demonstrates how existing terrain data formats could be utilised. However, care must be taken to ensure that the spatial reference systems in the TIXM metadata wrapper match those in the terrain data file.

```
<?xml version="1.0" encoding="UTF-8"?>
<tixm:TerrainSet gml:id="tixm_example"
xsi:schemaLocation="http://www.eurocontrol.int/tixm TIXM.xsd"
xmlns:tixm="http://www.eurocontrol.int/tixm"
xmlns:gml="http://www.opengis.net/gml/3.2"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance">
        <gml:boundedBy>
                <gml:Envelope srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                        <gml:lowerCorner>x y</gml:lowerCorner>
                        <gml:upperCorner>x y</gml:upperCorner>
                </gml:Envelope>
        </gml:boundedBy>
        <gml:domainSet>
                <gml:RectifiedGrid gml:id="examplegrid" dimension="2">
                        <gml:limits>
```

```
                        <gml:GridEnvelope>
                            <gml:low>x y</gml:low>
                            <gml:high>x y</gml:high>
                        </gml:GridEnvelope>
                    </gml:limits>
                    <gml:axisLabels>u v</gml:axisLabels>
                    <gml:origin>
                        <gml:Point gml:id="exampleorigin"
srsName="urn:x-ogc:def:crs:EPSG:6.6:EPSG:4326">
                            <gml:pos>x y</gml:pos>
                        </gml:Point>
                    </gml:origin>
                    <gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                        x y
                    </gml:offsetVector>
                    <gml:offsetVector srsName="urn:x-
ogc:def:crs:EPSG:6.6:EPSG:4326">
                        x y
                    </gml:offsetVector>
                </gml:RectifiedGrid>
            </gml:domainSet>
            <gml:rangeSet>

            <gml:fileName>http://www.somedata.org/terrain.dat</gml:fileName>
<gml:fileStructure>Record Interleaved</gml:fileStructure>
            </gml:rangeSet>
            <tixm:originatorID/>
            <tixm:horizontalReferenceSystem/>
            <tixm:horizontalAccuracy>
                <tixm:ValDistanceType>
                    <tixm:value>1</tixm:value>
                    <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
            </tixm:horizontalAccuracy>
            <tixm:horizontalConfidenceLevel>90</tixm:horizontalConfidenceLevel>
            <tixm:verticalRerferenceSystem/>
            <tixm:verticalAccuracy>
                <tixm:ValDistanceType>
                    <tixm:value>1</tixm:value>
                    <tixm:uom>M</tixm:uom>
                </tixm:ValDistanceType>
            </tixm:verticalAccuracy>
            <tixm:verticalConfidenceLevel>90</tixm:verticalConfidenceLevel>
</tixm:TerrainSet>
```

# APPENDIX A EXCHANGE SCHEMA

**TIXM.xsd**

```
<?xml version="1.0" encoding="UTF-8"?>
<!--
Project:        Terrain Data Exchange Model
Owner:          EUROCONTROL, Rue de la Fusee, 96, B-1130 Brussels, Belgium
Summary:        This XSD file constitutes part of the EUROCONTROL Terrain Exchange
Schema.

Copyright: EUROCONTROL.

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"as seen / as is" basis, and is intended for testing purposes only.  The EUROCONTROL
Agency provides no express or limited warranty of any kind, including but not limited to
those of merchantability, fitness for a particular purpose and accepts no liability whatsoever
for or in connection with the use of the data.
-->
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:tixm="http://www.eurocontrol.int/tixm"
targetNamespace="http://www.eurocontrol.int/tixm" elementFormDefault="qualified"
version="1.0">
	<annotation>
		<documentation>EUROCONTROL Terrain Model</documentation>
	</annotation>
	<include schemaLocation="TIXM_Features.xsd"/>
	<include schemaLocation="TIXM_DataTypes.xsd"/>
</schema>
```

**TIXM_Features.xsd**

```
<?xml version="1.0" encoding="UTF-8"?>
<!--
Project:        Terrain Data Exchange Model
Owner:          EUROCONTROL, Rue de la Fusee, 96, B-1130 Brussels, Belgium
Summary:        This XSD file constitutes part of the EUROCONTROL Terrain Exchange
Schema.

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those of merchantability, fitness for a particular purpose and accepts no liability whatsoever
for or in connection with the use of the data.
-->
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:tixm="http://www.eurocontrol.int/tixm"
targetNamespace="http://www.eurocontrol.int/tixm" elementFormDefault="qualified"
version="1.0">
	<annotation>
		<documentation>
			Package contain core TIXM classes and features
		</documentation>
```

```
	</annotation>
	<import namespace="http://www.opengis.net/gml/3.2"
schemaLocation="./OGC/gml/3.2.1/gml.xsd"/>
	<include schemaLocation="./TIXM_DataTypes.xsd"/>
	<element name="ElevatedPoint" type="tixm:ElevatedPointType"/>
	<complexType name="ElevatedPointType">
				<sequence>
					<element name="elevation"
type="tixm:ValDistanceVerticalTypePropertyType"/>
					<element name="height"
type="tixm:ValDistanceVerticalTypePropertyType"/>
					<element name="source"
type="tixm:AcquistionMethodType"/>
					<element name="surfaceType"
type="tixm:SurfaceType"/>
					<element name="surfaceTypeDescription"
type="string"/>
					<element name="recordedSurface"
type="string"/>
					<element name="penetrationLevel"
type="tixm:ValDistanceVerticalTypePropertyType" minOccurs="0"/>
					<element name="knownVariations" type="string"
minOccurs="0"/>
					<element name="maximumHeight"
type="tixm:ValDistanceVerticalTypePropertyType" minOccurs="0"/>
					<element name="survey"
type="tixm:SurveySetPropertyType"/>
				</sequence>
	</complexType>
	<complexType name="ElevatedPointPropertyType">
		<sequence minOccurs="0">
			<element ref="tixm:ElevatedPoint"/>
		</sequence>
		<attributeGroup ref="gml:AssociationAttributeGroup"/>
	</complexType>
	<element name="TerrainSet" type="tixm:TerrainSetType"
substitutionGroup="gml:RectifiedGridCoverage"/>
	<complexType name="TerrainSetType">
		<complexContent>
			<extension base="gml:DiscreteCoverageType">
				<sequence>
					<element name="originatorID" type="string"/>
					<element name="horizontalReferenceSystem"
type="string"/>
					<element name="horizontalAccuracy"
type="tixm:ValDistanceTypePropertyType"/>
					<element name="horizontalConfidenceLevel"
type="integer"/>
					<element name="verticalRerferenceSystem"
type="string"/>
					<element name="verticalAccuracy"
type="tixm:ValDistanceTypePropertyType"/>
```

```
                                                <element name="verticalConfidenceLevel"
type="integer"/>
                                                <element name="rangeSet" minOccurs="0"
maxOccurs="unbounded">
                                                        <complexType>
                                                                <sequence>
                                                                        <element
ref="tixm:ElevatedPoint"/>
                                                                </sequence>
                                                        </complexType>
                                                </element>
                                                <element name="cell" minOccurs="0"
maxOccurs="unbounded">
                                                        <complexType>
                                                                <sequence>
                                                                        <element
ref="tixm:GridCell"/>
                                                                </sequence>
                                                        </complexType>
                                                </element>
                                        </sequence>
                                </extension>
                        </complexContent>
                </complexType>
                <complexType name="TerrainSetPropertyType">
                        <sequence minOccurs="0">
                                <element ref="tixm:TerrainSet"/>
                        </sequence>
                        <attributeGroup ref="gml:AssociationAttributeGroup"/>
                </complexType>
                <element name="GridCell" type="tixm:GridCellType"
substitutionGroup="gml:AbstractFeature"/>
                <complexType name="GridCellType">
                        <complexContent>
                                <extension base="gml:AbstractFeatureType">
                                        <sequence>
                                                <element name="corner"
type="tixm:ElevatedPointPropertyType" minOccurs="4" maxOccurs="unbounded"/>
                                        </sequence>
                                </extension>
                        </complexContent>
                </complexType>
                <complexType name="GridCellPropertyType">
                        <sequence minOccurs="0">
                                <element ref="tixm:GridCell"/>
                        </sequence>
                        <attributeGroup ref="gml:AssociationAttributeGroup"/>
                </complexType>
                <element name="SurveySet" type="tixm:SurveySetType"
substitutionGroup="gml:AbstractFeature"/>
                <complexType name="SurveySetType">
                        <complexContent>
```

```
					<extension base="gml:AbstractFeatureType">
						<sequence>
							<element name="SurveryDate" type="date"/>
							<element name="AreaOfCoverage"
type="gml:SurfacePropertyType"/>
						</sequence>
					</extension>
				</complexContent>
			</complexType>
			<complexType name="SurveySetPropertyType">
				<sequence minOccurs="0">
					<element ref="tixm:SurveySet"/>
				</sequence>
				<attributeGroup ref="gml:AssociationAttributeGroup"/>
			</complexType>
</schema>
```

**TIXM_Datatypes.xsd**

```
<?xml version="1.0" encoding="UTF-8"?>
<!--
Project:		Terrain Data Exchange Model
Owner:		EUROCONTROL, Rue de la Fusee, 96, B-1130 Brussels, Belgium
Summary:		This XSD file constitutes part of the EUROCONTROL Terrain Exchange
Schema.

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Agency provides no express or limited warranty of any kind, including but not limited to
those of merchantability, fitness for a particular purpose and accepts no liability whatsoever
for or in connection with the use of the data.
-->
<schema xmlns="http://www.w3.org/2001/XMLSchema"
xmlns:tixm="http://www.eurocontrol.int/tixm"
targetNamespace="http://www.eurocontrol.int/tixm" elementFormDefault="qualified"
version="1.0">
	<annotation>
		<documentation>Package containing TIXM data types and enumerations
</documentation>
	</annotation>
	<simpleType name="SurfaceType">
		<restriction base="string">
			<enumeration value="URBANISED"/>
			<enumeration value="AGRICULTURAL"/>
			<enumeration value="FOREST/TREES"/>
			<enumeration value="LOW-VEGETATION"/>
			<enumeration value="NO-VEGETATION"/>
			<enumeration value="GLACIER/PERMANENTSNOW"/>
			<enumeration value="WETLANDS"/>
			<enumeration value="WATER"/>
```

```
                    <enumeration value="NOT_SPECIFIED"/>
                    <enumeration value="UNKOWN"/>
                    <enumeration value="OTHER"/>
               </restriction>
          </simpleType>
          <element name="ValDistanceType" type="tixm:ValDistanceType"/>
          <complexType name="ValDistanceType">
               <sequence>
                    <element name="value" type="double"/>
                    <element name="uom" type="tixm:UomDistanceType"/>
               </sequence>
          </complexType>
          <complexType name="ValDistanceTypePropertyType">
               <sequence>
                    <element ref="tixm:ValDistanceType"/>
               </sequence>
          </complexType>
          <simpleType name="ElevatedPointSourceType">
               <restriction base="string">
                    <enumeration value="MEASURED"/>
                    <enumeration value="INTERPOLATED"/>
               </restriction>
          </simpleType>
          <simpleType name="AcquistionMethodType">
               <restriction base="string">
                    <enumeration
value="MEASURED_AERIAL_PHOTOGRAMMERTY"/>
                    <enumeration value="MEASURED_GPS"/>
                    <enumeration value="MEASURED_IfSAR"/>
                    <enumeration value="MEASURED_LIDAR"/>
                    <enumeration
value="MEASURED_SATELLITE_PHOTOGRAMMERTY"/>
                    <enumeration
value="MEASURED_TERRESTRIAL_POSITIONING_SYTEM"/>
                    <enumeration value="MEASURED_THEODOLITE"/>
                    <enumeration value="MEASURED_TOTALSTATION"/>
                    <enumeration value="CALCULATED"/>
                    <enumeration value="OTHER"/>
               </restriction>
          </simpleType>
          <element name="ValDistanceVerticalType"
type="tixm:ValDistanceVerticalTypeType"/>
          <complexType name="ValDistanceVerticalTypeType">
               <sequence>
                    <element name="value" type="double"/>
                    <element name="uom" type="tixm:UomVerticalDistanceType"/>
               </sequence>
          </complexType>
          <complexType name="ValDistanceVerticalTypePropertyType">
               <sequence>
                    <element ref="tixm:ValDistanceVerticalType"/>
               </sequence>
```

```
        </complexType>
        <simpleType name="UomDistanceType">
                <restriction base="string">
                        <enumeration value="NM"/>
                        <enumeration value="KM"/>
                        <enumeration value="M"/>
                        <enumeration value="FT"/>
                        <enumeration value="MI"/>
                        <enumeration value="OTHER"/>
                </restriction>
        </simpleType>
        <simpleType name="UomVerticalDistanceType">
                <restriction base="string">
                        <enumeration value="FT"/>
                        <enumeration value="M"/>
                        <enumeration value="FL"/>
                        <enumeration value="SM"/>
                        <enumeration value="OTHER"/>
                </restriction>
        </simpleType>
</schema>
```

# APPENDIX B eTOD REQUIREMENTS

## B.1 Introduction

This appendix contains the requirements that have led to the development of the TICM and its exchange schema.

## B.2 ICAO Annex 15

The following requirements have been extracted from ICAO Annex 15, Chapter 10, “Electronic Terrain and Obstacle Data”.

*10.3.1 A terrain database 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.*

*10.3.2 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”.*

*10.3.3 Terrain data shall be collected according to the areas specified in 10.2, terrain data collection surfaces and criteria specified in Appendix 8, Figure A8-1, and in accordance with the terrain data numerical requirements provided in Table A8-1 of Appendix 8. In terrain databases, only one feature type, i.e. terrain, shall be recorded. Feature attributes describing terrain shall be those listed in Appendix 8, 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 database.*

*10.5.5 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.*

The following terrain attributes are defined in ICAO Annex 15, Appendix 8.

Table A8-3. Terrain attributes

| Terrain attribute | Mandatory/Optional |
|---|---|
| Area of coverage | Mandatory |
| Data originator identifier | Mandatory |
| Acquisition method | Mandatory |
| Post spacing | Mandatory |
| Horizontal reference system | Mandatory |
| Horizontal resolution | Mandatory |
| Horizontal accuracy | Mandatory |
| Horizontal confidence level | Mandatory |
| Horizontal position | Mandatory |
| Elevation | Mandatory |
| Elevation reference | Mandatory |
| Vertical reference system | Mandatory |
| Vertical resolution | Mandatory |
| Vertical accuracy | Mandatory |
| Vertical confidence level | Mandatory |
| Surface type | Mandatory[3] |
| Recorded surface | Mandatory |
| Penetration level | Optional |
| Known variations | Optional |
| Integrity | Mandatory |
| Date and time stamp | Mandatory |
| Unit of measurement used | Mandatory |

## B.3 ICAO Doc 9981

ICAO Doc 9881 introduced the following requirements:

2.1.4 Terrain Data Attributes

| Terrain attribute | Mandatory/Optional |
|---|---|
| Database Units | Mandatory |

### *2.1.4.4 Post Spacing*

*Post spacing is the distance (angular or linear) between two adjacent elevation points. It should be noted that the latitude post spacing might be different from the longitude post spacing.*

*Terrain database post spacing numerical requirements are presented in both angular and linear units to provide general guidance about the required density of measurement points. The linear measure is an approximation of the angular requirement near the equator.*

*Angular increments may be adjusted when referencing high latitude regions to maintain a constant linear density of measurement points.*

*When linear and angular post-spacing requirements differ, the linear requirement must take precedence.*

[3] It has been proposed to ICAO that this attribute be amended to optional.

## B.4 EUROCONTROL Stakeholders

Requirements were gathered from EUROCONTROL stakeholders through the Terrain and Obstacle Data Working Group (TOD WG). These requirements are included below:

*Types of terrain:*

- ◊ Water
- ◊ Bare Earth
- ◊ Wooded areas:
  - ♦ Type of trees
  - ♦ Growth rate of tree
- ◊ Perma-frost
- ◊ Sand
  - ♦ Maximum recorded height

*Recorded points:*

*Have the four corners and an optional point for the highest point in the grid.*