EUROCONTROL
Terrain and Obstacle Data Manual

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EUROPEAN ORGANISATION
FOR THE SAFETY OF AIR NAVIGATION

EUROCONTROL

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Draft 1.2	November 2010	Second draft release for IFG review.	All
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EXECUTIVE SUMMARY

This Manual is intended to be used by those bodies involved in the origination, processing and provision of electronic terrain and obstacle data, from the point at which the need for origination is identified, through to the point when the State makes it available in accordance with the requirements of ICAO Annex 15.

This document provides assistance to those tasked with implementing electronic terrain and obstacle data. It seeks to provide the necessary guidance for a range of stakeholders: from those defining the project and undertaking budgetary costing, to those who are responsible for the capture of the data.

It sets out to provide general guidance and to highlight considerations and areas of particular concern that must be borne in mind during implementation.

1. INTRODUCTION

1.1 Background

The introduction of Standards and Recommended Practices (SARPs) by the International Civil Aviation Organisation (ICAO) into Annex 15 "Aeronautical Information Services" (AIS), related to the provision of electronic terrain and obstacle data, led to significant challenges for States in achieving compliance.

These challenges are wide reaching in scope and relate to technical, institutional and implementation aspects. In order to facilitate their implementation, the Member States (the States) of the European Organisation for the Safety of Air Navigation (EUROCONTROL) asked that support and guidance be provided to identify and address these issues. EUROCONTROL formed the Terrain and Obstacle Data Working Group (TOD WG) of the Aeronautical Information Team to address this request. Some of the TOD WG's tasks were to help resolve the ambiguities in the ICAO SARPs, ensure that their implementation was cost-effective and provide guidance on their interpretation and implementation. This Manual has been prepared by the EUROCONTROL TOD WG in response to this task.

Whilst primarily intended to support European Civil Aviation Conference (ECAC) Member States in their implementation of terrain and obstacle data, the document has also been prepared with the aim of being globally applicable.

1.2 Purpose of Document

This document provides assistance to those tasked with implementing electronic terrain and obstacle data. It seeks to provide the necessary guidance for a range of stakeholders: from those defining the project and undertaking budgetary costing, to those who are responsible for the capture of the data.

It sets out to provide general guidance and to highlight considerations and areas of particular concern that must be borne in mind during implementation.

It is not possible to address every question likely to arise during implementation, as to do so would result in a document so vast as to be impracticable to use. Rather, it aims to provide sufficient understanding that the reader, and the organisation that he/she represents, can make an informed decision as to how they should proceed. The document also, as far as is practicable, aims to bring about harmonisation in implementation between States across ECAC.

It is expected that this will be a living document, updated as experience grows during implementation. As a result, in order to ensure that this document can continue to meet stakeholder needs, it is important that comments on the document and any issues identified as not being adequately addressed, are brought to the attention of EUROCONTROL.

1.3 Scope

This Manual is intended to be used by those bodies involved in the origination, processing and provision of electronic terrain and obstacle data, from the point at which the need for origination is identified, through to the point when the State makes it available in accordance with the requirements of ICAO Annex 15.

Out of scope activities include, but are not limited to:

- Non-aviation management of facilities;
- Use of data.

1.4 Background to SARPs

It has been a requirement for States to publish obstacle data within their Aeronautical Information Publication (AIP) for many years. However, the requirement was to provide this information in a simple, textual form, classified in one of three ways:

- Impacting the en-route phase of flight;
- At the aerodrome and impacting the circling area;
- At the aerodrome and impacting the approach / take-off phases of flight.

Information relating to terrain has only been required in a very limited form, for runways for which Category (CAT) II/III operations are approved. This terrain information is provided graphically by way of the Precision Approach Terrain Chart (PATC), specified by ICAO Annex 4.

Whilst this provided sufficient information for the navigation techniques in use when these requirements were first developed, the advent of modern technology, improved navigation techniques and the availability of more sophisticated tools have led to a desire for States to make available more extensive terrain and obstacle data sets in a digital form.

This digital data provides a means of allowing a number of advances in technology and the operating environment. For example, the information may be automatically ingested within procedure design tools, allowing better validation that the procedures designed maintain the required clearances in relation to both terrain and obstacles.

1.4.1 Amendment 33 to ICAO Annex 15

The need for digital data sets was expressed to ICAO by industry and, as a consequence, was included within Amendment 33 to ICAO Annex 15 which was adopted in February 2004 and became effective in July of that year. It was acknowledged by ICAO, however, that the introduction of SARPs related to the provision of terrain and obstacle data was a challenge and, consequently, the applicable dates for this data were deferred. Area 1 (The State) and Area 4 (CATII/III Operations Area) became effective on 20th November 2008. The remaining areas, Area 2 (The Terminal Area) and Area 3 (The Aerodrome/Heliport Area) were to become effective on 18th November 2010.

1.4.2 Amendment 36 to ICAO Annex 15

The work of the TOD WG and its Technical Focus Group in resolving the ambiguities with Amendment 33 to ICAO Annex 15 was provided to ICAO and formed the basis of Amendment 36 to ICAO Annex 15. This Amendment was formally issued on the 1st April 2010 and was effective from 12th July 2010, becoming applicable on 18th November 2010.

This Amendment, although containing a number of ambiguities, offers significant cost savings over the original requirements introduced by Amendment 33. Work is, however, still needed from the TOD WG to determine exactly how compliance can be achieved and, where ambiguities exist, how a harmonised approach can be established.

1.4.3 Amendment 37 to ICAO Annex 15

Amendment 37 was adopted by the ICAO Council on the 1st March 2013 and on 15st July 2013 it was effective. This Amendment became applicable on 14st November 2013.

Amendment 37 introduces a set of definitions such as: aeronautical information management (AIM), aerodrome mapping data (AMD), aerodrome mapping database (AMDB) and confidence level. It puts forward a new integrity classification concept that removes integrity level values. The requirement for terrain and obstacle data collected within Area 2 is split into two different requirements for terrain and obstacles and some updates are made to the collection surfaces in Area 1, 2 and 4. A new mandatory attribute Data source identifier is introduced.

1.5 Application of Terrain and Obstacle Data

It is important that those who provide terrain and obstacle data are aware of the applications in which digital sets of terrain and obstacle data may be utilised as these determine the data quality requirements.

This section, therefore, provides an overview of those applications specified in the introduction to ICAO Annex 15 Chapter 10 which will make use of terrain and obstacle data, and explains their purpose. The requirements of these applications for data are explained in section 1.6. Whilst this leads to a degree of duplication, this structure was requested by the TOD WG in order to gain as clear a picture as possible of the possible uses of terrain and obstacle data.

1.5.1 Terrain Warning Systems

Ground Proximity Warning System (GPWS) technology issues warnings and alerts based upon the use of height above terrain using the Radio Altimeter (RADALT) and the rate of change in the aircraft's barometric altitude.

The logic employed utilises the aircraft altitude and descent/climb rate information to give alerts to the pilot of potential impact with the ground. However, as the RADALT is only able to provide height above the ground directly beneath the aircraft, the system is unable to warn of any rising terrain ahead. As a result, this provides the pilot with a very restricted time to recover in the event of a potential conflict.

The latest GPWS technology, Enhanced-GPWS (EGPWS), makes use of terrain data and Global Navigation Satellite System (GNSS) position data to provide the flight crew with information regarding impending hazardous terrain or obstacles. This provides early alerts and, therefore, more time for the pilot to take corrective action.

For EGPWS, the currently certified terrain warning systems use digitised data that is only for advisory use.

It is stated that electronic sets of terrain and obstacle data could support new cockpit Controlled Flight into Terrain (CFIT) prevention applications, including two-, three- and four-dimensional predictive CFIT protection. It is believed that the provision of quality-assured data sets may also lead to a reduction in approach and landing accidents, in addition to CFIT accidents.

1.5.2 Procedure Design

1.5.2.1 Instrument Flight including Circling Procedures

Instrument flight procedure design, undertaken using ICAO 8168 Procedures for Air Navigation Services - Aircraft Operations (PANS-OPS), addresses operations on arrival and departure, the interconnection (transitions) to and from the en-route structure, and approach procedures, including missed approaches. Data relating to terrain and obstacles are used by the procedure designers who then apply obstacle clearance criteria to calculate minimum safe altitudes, and minimum descent altitude/height or decision altitude/height according to the approach procedure type. The minimum altitudes ensure that aircraft flown in instrument flight conditions do not impact the ground or obstacles.

No explicit benefits of terrain and obstacle data are provided for this application in ICAO draft Doc 9881 or the European Organisation for Civil Aviation Equipment's (EUROCAE) ED-98A / RTCA DO-276A. However, the lack of quality controlled terrain and obstacle data will result in the need for more robust flight validation of the procedures if the quality control requirements being introduced into ICAO Doc 8168 are to be achieved.

1.5.2.2 Contingency Procedures

PANS-OPS (ICAO Doc 8168) provides the material needed to develop procedures for departure. However, PANS-OPS assume that the aircraft is fully operational, for example, all engines are operational. It is not considered practicable to develop public procedures that cater for all contingencies and that would suit all aircraft types. As a result, it is incumbent upon the aircraft operators to develop such contingency procedures which are normally co-ordinated with the Air Navigation Service Providers (ANSPs).

To develop these procedures, the aircraft operators must perform take-off analysis, to ensure the safe operation of each aircraft type in their fleet in the event of contingencies. The Aircraft Flight Manual provided by the aircraft manufacturer contains the performance data needed to calculate the contingency performance.

Take-off analysis is performed to establish if the State-published procedure can be flown with one-engine inoperable. Where this is not possible, an alternative procedure is developed which requires an understanding of the terrain and obstacle data around the aerodrome.

Currently, aircraft operators use ICAO Type A, B and, where available, C charts, in addition to topographic maps, for the terrain and obstacle data for the aerodrome. These will eventually be replaced by electronic products (e.g. the new Aerodrome Terrain and Obstacle Chart – ICAO (Electronic)) and it is foreseen that contingency procedure analysis and determination will be significantly improved through the use of electronic products. It is anticipated that take-off weights can also be maximised by using data in this form. EUROCAE ED-98A / RTCA DO-276A also states (Appendix C, paragraph C.10) that by having digital and standardised data sets "*confusion caused by different co-ordinate systems*[1]*, measurement units and language translation issues may be eliminated*".

1.5.3 Drift-Down Procedures

Whilst multi-engine aircraft are able to safely operate with the loss of an engine, they may, however, need to slowly descend (drift-down) to a lower flight level to continue to operate safely.

Drift-down procedures document how the pilot should ensure that the aircraft reaches a safe cruising altitude despite a loss of power.

ICAO draft Doc 9881 states that for some light, twin-engine aircraft, the one-engine inoperative cruise flight performance may not be feasible and the aircraft may not be able to sustain flight above the Minimum Obstacle Clearance Height. As a result of this, pilots need to be able to quickly and accurately calculate their best "escape" route.

With Area Navigation (RNAV), more direct routing will be applied, resulting in the need to know the terrain beneath and in front of the aircraft over the whole of the territory of the State to ensure the pilot has the data necessary to manage this contingency.

[1] The issue of different co-ordinate reference systems should have been addressed by the global adoption of WGS-84.

1.5.4 Emergency En-route Landing

ICAO draft Doc 9881 stresses the importance of selecting an acceptable emergency landing site, particularly for general aviation aircraft. The risks are particularly great at night or when over unfamiliar territory. Further, it states that during instrument flight conditions, the problem becomes more severe as the pilot has no visual references. Most benefit would be brought about under these circumstances, and also during climb-out, en-route, and under the Instrument Meteorological Conditions (IMC). ICAO draft Doc 9881 also states that the World Aeronautical Chart – ICAO (1:1,000,000) and the Aeronautical Chart – ICAO (1:500,000) are of limited use in these circumstances. It believes that a high-resolution, digital image, overlaid onto a terrain and obstacle database could assist pilots in identifying the safest location for an emergency landing. It cites the benefits of colour rendering of vegetation cover to aid the selection of a suitable landing site. Enhancements to continuously re-calculate the aircraft's "drift-down" performance, glide path and minimum landing field requirements, and display this graphically, with the vegetation and landing site image, would provide the pilot with continuous, current information on the availability of forced landing sites. Using modern imagery, distinctions can be made between the different classes of land cover although information regarding vertical heights and densities of the cover are not provided.

1.5.5 Advanced Surface Movement Guidance and Control System

Advanced Surface Movement Guidance & Control System (A-SMGCS) is a system providing routing, guidance and surveillance for the control of aircraft and vehicles in order to maintain the declared surface movement rate under all weather conditions within the aerodrome visibility operational level while maintaining the required level of safety.

A-SMGCS is a modular system consisting of different functionalities to support the safe, orderly and expeditious movement of aircraft and vehicles on aerodromes under all circumstances with respect to traffic density and complexity of aerodrome layout, taking into account the demanded capacity under various visibility conditions. It includes complementary procedures that at the lower levels of implementation aims to deliver improved situational awareness to controllers. Higher levels of implementation deliver safety nets, conflict detection and resolution as well as planning and guidance information for pilots and controllers.

The A-SMGCS would require the aerodrome mapping data (AMD) together with the terrain and obstacle datasets for Area 3 to display to the users the position related to the airport layout and fixed obstacles in all visibility conditions.

ICAO Annex 15 recommends that aerodrome mapping data should be supported by electronic terrain and obstacle data for Area 3 in order to ensure consistency and quality of all geographical data related to the aerodrome. Therefore, the provision of terrain and obstacle data for Area 3 for the A-SMGCS serves no purpose if aerodrome mapping data is not provided, as the view resulting from the Area 3 data set will comprise "islands" of data with no reference point to place the data in context, i.e. a digital representation of the movement surfaces.

1.5.6 Aeronautical Chart Production and On-board Databases

1.5.6.1 Aeronautical Chart Production

Whilst cartography was traditionally a manual process, in recent years, the use of databases and Geographic Information Systems (GIS) to support the automated and semi-automated preparation of charts has become more prevalent.

These applications use digital information to portray a representation of the necessary information on a chart which may be either displayed electronically or printed to paper, as with traditional maps.

1.5.6.2 On-board Databases

Whilst digital data has been required to support Flight Management Systems for many years, there is an increasing trend today to make digital information available in the cockpit to serve other functions.

These cockpit applications rely upon good quality information to allow the user (be it a person or a system) to interpret the information correctly to aid decision-making, for example.

1.5.7 Aerodrome/Heliport Obstacle Restriction and Removal

Restrictions are placed on the location of objects in the operational[2] area of an aerodrome. Only approved equipment and installations may be located in this area and these must be of minimum possible mass and height, and designed to be frangible so as not to pose a hazard to aircraft. The objects in these areas are considered in determining the approach and take-off surfaces for the aerodrome.

This area must be monitored by the aerodrome operator and any possible infringements to the area dealt with in order to minimise the erection of new objects, for example. This often involves liaising with planning authorities and construction companies. If a new obstacle is proposed, including temporary or mobile obstacles, it must be assessed to determine any impact on the instrument flight procedures and the obstacle limitation surfaces. In addition, obstacles outside the obstacle restriction area must be monitored for non-precision runways. To aid this assessment, the instrument flight procedures and information on the dominant obstacles (which may be spot elevation height, including an allowance for vegetation) need to be provided.

Aerodrome operators follow procedures for monitoring the obstacle limitation surfaces. The aerodrome operator must be notified of any change in status of the critical obstacles or of the erection of any obstacle higher than the already existing critical (dominant) obstacle.

The main benefits of having a set of digital obstacle data would be to aid the aerodrome operator in the monitoring of obstacles. As the safety and efficiency of the aerodrome can be seriously impacted by the presence of obstacles close to the take-off or approach areas, the process of assessment can be made more efficient by the use of electronic data, in turn, helping to improve the efficiency of the aerodrome operations.

1.5.8 Radio Altimeter Height Determination

During the final approach phase of landings made under CAT II/III conditions, the aircraft makes use of its RADALT to determine its precise height above ground. In order to be able to accurately determine whether an automatic approach is being carried out correctly, the aircraft flight systems must have a precise description of the surface below the aircraft in this final approach phase. This surface must include the terrain and any objects which may affect the measurements received from the RADALT.

1.5.9 Synthetic Vision

ICAO draft Doc 9881 states that, at the time of writing, the quality requirements needed to support synthetic vision, in terms of resolution, accuracy, integrity and timeliness, had not been determined. However, the document considers that with the combination of terrain and obstacle data (of the “to be determined” quality), flight operations down to a CAT IIIb landing minima may be achievable.

Synthetic vision creates a virtual visual environment. This is composed of three components: an enhanced intuitive view of the flight environment, hazardous terrain and obstacle detection and display, and precision navigation guidance. The display consists of terrain background images with information superimposed / integrated over them. The display needs to be intuitive and easy to comprehend, rather than cluttered. Features that need to be displayed include terrain, vegetation

[2] The operational area is defined within ICAO Annex 14.

and both temporary and permanent obstacles, including “mobile” obstacles. The pilot will then be able to choose the layers he/she wishes to display.

Reduced visibility is often cited as a major reason for the use of synthetic vision. It is anticipated that synthetic vision could almost eliminate reduced visibility as a significant factor in flight operations. It is stated that synthetic vision systems are expected to emulate daytime visual flight operations both at night and in limited visibility conditions. Displays of this capability will require access to very high-resolution terrain and obstacle data, including the texture information necessary to enable the construction of realistic images.

Such systems will have both a safety and operational benefit. The support of the user community is needed early in the development and implementation process. The RTCA stresses the importance of timely private sector participation in this emerging technology and cite the benefits as being enhanced airport terminal area operations, including reduced arrival and departure minima, and the use of additional multi-runway operations.

Synthetic vision systems are, however, limited in commercial aviation today. When they become more widely available, systems are likely to have a limited initial application in regions where many airports have precision landing aids or GNSS-based Approach Procedures with Vertical Guidance (APV).

1.5.10 Flight Simulators

No thorough assessment of the user needs for this application has been made, at the request of EUROCONTROL. The reason for this decision is that flight simulators are typically used to train pilots for planned operations, including actions to be taken in contingency situations. To this end, no additional data items over and above those needed for actual flight operations should be necessary.

However, the amount, resolution and detail of data required for each data item can vary significantly and, as such, definitive requirements are difficult to establish. The situation here is broadly similar to that discussed above for synthetic vision and presented in section 1.5.9, above.

1.6 Requirements for Data

1.6.1 Terrain Warning Systems

In order for an aircraft to be able to provide warnings concerning the close proximity of the aircraft to the terrain, two approaches may be taken:

- The system operates using only a series of Minimum Safe Altitudes which have been provided for geographical areas, i.e. for a defined region, a lowest safe altitude is set that applies across that region, irrespective of the undulating terrain that actually exists;
- The system is provided with a terrain profile that may be used at any point to assess the exact vertical distance between the aircraft and the terrain profile, both below and in advance of the aircraft.

The former approach helps to provide a level of awareness whilst not relying on high-definition data and is, therefore, useful where there is a limited scope of data accessible by the cockpit systems, either as a result of the availability of data or as a result of constraints in the amount of data that may be held on-board.

The latter approach allows a much more comprehensive facility to be provided but requires a larger amount of data to be held within the on-board aircraft systems.

With regards to the accuracy and resolution of the data needed, this has proven difficult to establish with absolute certainty. This is because the defined safe minima are established on the basis of a number of factors which include the accuracy of the terrain and obstacle data available, as well as the accuracy of the aircraft’s capacity to determine its height.

1.6.2 Procedure Design

1.6.2.1 Instrument Approach including Circling Procedures

Data about the terrain and obstacles in the approach and missed approach areas are required to support an assessment of Instrument Approach Procedures (IAP) against the approach and missed approach obstacle assessment surfaces. Some parts of these surfaces do not permit penetration by obstacles, whilst other areas do allow some penetration to occur. The surfaces depend upon the approach type being flown and are defined within ICAO Annex 14 and ICAO Doc 8168.

These surfaces tend to be aligned along the extended centreline of the runways and around the aerodrome in the circling area. A full description may be found in the paper "ICAO SARPs and TOD Gap Analysis", which was developed under the work of the TOD WG[3].

Today, procedure designers operate with a small subset of the obstacles which exist. Quite simply, within defined regions, procedure design is mainly interested in the highest obstacle, normally referred to as the dominant obstacle.

1.6.2.2 Contingency Procedures

The data requirements for the design of contingency procedures are no different from those for IAP design. However, whilst the published IAPs will have been configured to provide paths between the airport and the en-route airspace in a manner that maximises airspace capacity, the main criteria for the contingency procedure is to maximise the safety of the aircraft concerned, whilst giving consideration to the failure that has resulted in the need for contingency. For this reason, the climb angle requirements would normally be reduced and the procedure is therefore likely to follow a different route to that of the published IAP. The need to have already provided the necessary obstacles to support the design of non-precision approach procedures means that all obstacles, irrespective of whether they penetrate the defined assessment surfaces, or not, are needed in the approach and take-off areas. As a result, the requirements for obstacle data to support contingency procedures should also be met.

1.6.3 Drift-Down Procedures

In order to allow the airline operators and the pilot executing a flight to both plan for and perform emergency actions in the event of engine failure, a basic understanding of the underlying terrain and the obstacles that exist upon it, is required. Whilst in an ideal world the data provided would represent reality precisely, this is considered unachievable and, instead, the data available will be provided within specific tolerances (horizontal and vertical), and the calculations performed for drift-down will take these possible measurement uncertainties into account.

1.6.4 Emergency En-route Landing

The data required to execute an emergency en-route landing is broadly similar to that required for the execution of drift-down procedures: a basic understanding of the underlying terrain and the obstacles that exist upon it, is required.

The provision of this data to the pilot allows him/her to attempt to safely navigate towards a selected aerodrome, at which a landing may be made. The landing itself will usually be made either visually or in accordance with the prescribed landing procedures.

1.6.5 Advanced Surface Movement Guidance and Control System

A-SMGCS require a digital representation of the terrain and obstacles located at the aerodrome which may impact operations. Whilst A-SMGCS for aircraft will require this information to be limited to the movement surfaces intended for aircraft movement, the control of road vehicles would require information for any surface, paved or otherwise, over which a road vehicle could operate.

[3] This paper has not been amended in line with the revised SARPs introduced by Amendment 36 to ICAO Annex 15. Nonetheless, the descriptions of the Annex 14 surfaces remain valid.

The data provided must, therefore, allow the safe navigation of vehicles over terrain, around obstacles and avoiding other potential hazards, such as culverts.

1.6.6 Aeronautical Chart Production and On-board Databases

Aeronautical charts and on-board databases must contain the information needed to support flight operations.

As such, the aviation-specific data required for these applications is foreseen to be a composite data set of the information required for all other applications which are directly utilised in flight planning and execution. In addition, other, non-aviation data, such as roads, rivers etc. may be needed. This is considered to be out of scope for this Manual.

There is, however, a large range of possible charts and on-board systems and it is expected that there will be a move away from paper charts to electronic flight bags in the coming years. Therefore, it is not possible to fully define the data needed for these in the absence of detailed charting and electronic data requirements.

1.6.7 Aerodrome/Heliport Obstacle Restriction and Removal

In order to support the management functions of aerodrome/heliport obstacle restriction and removal, aerodrome authorities require access to data for all obstacles which may have an impact on these. It should be noted that this may mean that objects which do not penetrate an assessment surface, and are not strictly obstacles, are of interest. Furthermore, it is likely that information required for the management of each obstacle will be needed and this may mean a larger obstacle data set, with additional attributes / metadata.

1.6.8 Radio Altimeter Height Determination

During an approach conducted under CAT II or CAT III conditions, where the aircraft avionics are navigating the aircraft to the landing point, the aircraft does not rely solely on pressure to determine its height above ground level. Instead, as the aircraft approaches the ground, a RADALT is used to accurately measure the aircraft's height above ground.

In an automatic approach, if the height determined by the RADALT does not match that expected at the distance from the runway threshold that the aircraft is at (within a certain tolerance), this is an indication that the aircraft is not located where it should be. In such circumstances, the pilot will take mitigating action which may include initiating a "go around".

Today, the terrain profile and any objects which may affect height determination in advance of the runway threshold are obtained manually from the PATC by cross-referencing the distance from the threshold to obtain the anticipated RADALT reading. The provision of a digitised set of terrain and obstacle data for the area in advance of runway thresholds, for all runways at which CAT II/III operations are permitted, will bring significant benefit and remove the need to utilise the PATC, a manual process which is prone to error.

1.6.9 Synthetic Vision

It is believed that the requirements for terrain and obstacle data for the applications listed above also provide the data needed to support synthetic vision, i.e. the provision of information needed to support the data applications needed for flight operations. This statement is supported by the following evidence:

- Synthetic vision is used to provide a computer generated representation of what a pilot would see in Visual Meteorological Conditions (VMC);
- The data needed to support the flight operations outlined in 1.5.1 to 1.5.8 above are sufficiently well defined to allow Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) operations.

However, the manner in which the objects are collected and recorded is unlikely to provide sufficient information to allow a successful implementation of synthetic vision. To elaborate, in order to correctly portray a building in a synthetic vision system, information relating to its precise profile and colouring (even down to that needed to correctly show windows etc.) is needed. The information prescribed by ICAO Annex 15 does not extend to this level of detail.

1.6.10 Flight Simulators

No thorough assessment of the user needs for this application has been made, at the request of EUROCONTROL. The reason for this decision is that flight simulators are typically used to train pilots for planned operations, including actions to be taken in contingency situations. To this end, no additional data items, over and above those needed for actual flight operations, should be necessary.

However, the amount, resolution and detail of data required for each data item can vary significantly and, as such, definitive requirements are difficult to establish. The situation here is broadly similar to that discussed above for synthetic vision and presented in sections 1.5.9 / 1.6.9 above.

1.7 Uses of Data – The Benefits

1.7.1 General

As has been seen, there are a number of instances where the digital data required will support existing and future applications. The true benefits will only be seen over time, as applications are modified to make use of the available data. For example, today's procedure design tools typically make use of a limited obstacle set (defined only as points and elevations) which includes terrain spot heights. In the future, tools are likely to make use of both a detailed terrain profile and a more complex representation of the obstacle situation.

Even before these aviation-specific tools are available, the widespread use of GIS tools will allow better visualisation of the aeronautical data and will, even in the short-term, promote a better understanding of the power of data in open and interoperable forms.

Furthermore, as the ICAO requirements include metadata to fully describe the information provided, a measure of quality may be more easily assessed. In some cases, this may mean that the reliance on costly validation / verification methods, such as the confirmation of instrument flight procedures by physical flights, may be minimised.

1.7.2 Support to Aeronautical Information Management (AIM)

The requirements for the provision of terrain and obstacle data in an electronic form are part of the move from traditional AIS to Aeronautical Information Management (AIM) defined by ICAO as the dynamic, integrated management of aeronautical information through the provision and exchange of quality-assured digital aeronautical data in collaboration with all parties. It is anticipated that the provision of data, rather than the traditional paper products that have always been required in the past, will increase over time.

Therefore, terrain and obstacle data bring about a change in the culture and philosophy with regards to aeronautical information provision.

2. BASIC CONCEPTS

2.1 Digital Terrain Models

A Digital Height Model (DHM) is simply a mathematical representation of the continuous surface of the ground based on a (large) number of points defined in terms of X, Y and Z co-ordinates. The more points provided for a given area, the better the terrain relief can be modelled. For many years, the most common DHM described the *bare earth* and this resulted in the term Digital Terrain Model (DTM) being established. The expression *bare earth* is typically understood to mean that the elevation points included in the model describe the visible surface of the earth which is permanently visible. This includes mountains, ridges, bodies of water, glaciers and permanent snow.

In recent years, the point densities for DTM have increased dramatically due to the use of new sensors and digital processing capabilities, and often reach 1 point per square metre.

It is evident that such high-resolution models can represent not only the DTM but also the outer profile (normally referred to as the convex hull) of the visible surface (e.g. buildings, towers and vegetation), and these models are referred to as Digital Surface Models (DSM). Figure 1 demonstrates the difference between a DSM and a DTM. The DSM is shown on the left, the DTM on the right.

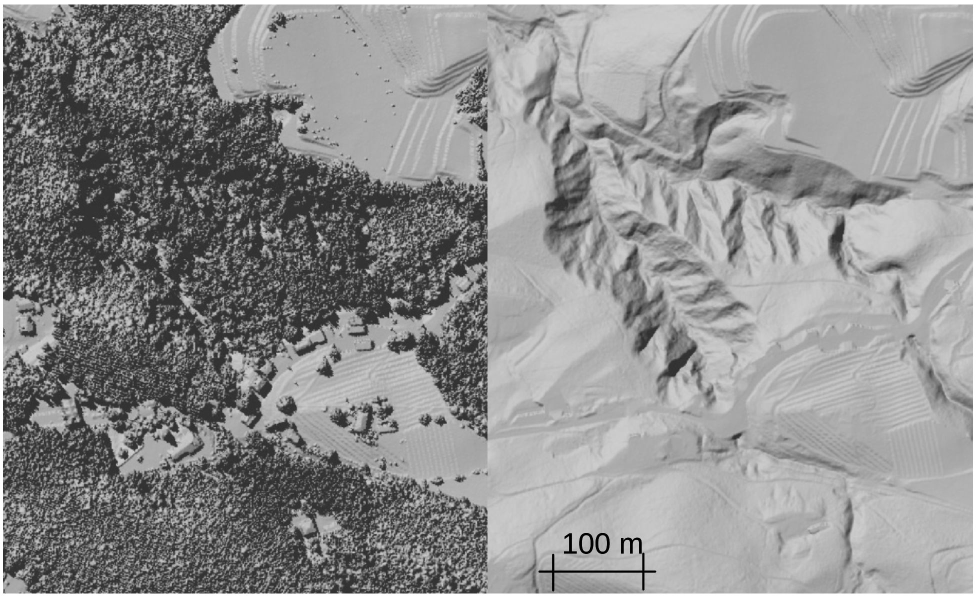

Figure 1: DSM v DTM at the Same Location [4]

Another widespread term is Digital Elevation Model (DEM). As for the DHM, a DEM does not usually describe the bare earth but an imprecise elevation above the bare earth. This is often the case when an active sensor partially penetrates the canopy; ICAO Annex 15 refers to this as “something in-between”. Another common term is “intermediate reflective surface”.

[4] Source Swissphoto AG, Switzerland.

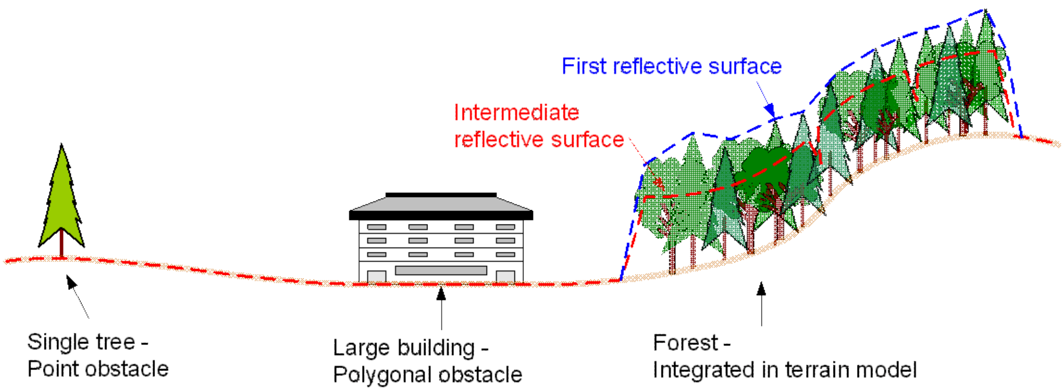

Figure 2: Intermediate Reflective Surface

2.2 Obstacles

During the development of this Manual, and in undertaking the activities assigned to the TOD WG, it became apparent that the meaning of the term "obstacle" was not entirely clear. Significant confusion arose and alternative terms, such as "object", have been proposed to be used in certain circumstances.

Existing applications of the term "obstacle" go some way to identify the problem of providing a single, all inclusive, definition:

1. ICAO Annex 15

ICAO Annex 15's Chapter 1 definition of an obstacle is:

"*All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that:*

a) are located on an area intended for the surface movement of aircraft; or

b) extend above a defined surface intended to protect aircraft in flight; or

c) stand outside those defined surfaces and that have been assessed as being a hazard to air navigation."

This definition is based around the need to protect aircraft and air navigation, i.e. an obstacle is an object which can potentially affect aircraft operations.

2. ICAO Doc 8168

ICAO Doc 8168 does not provide a definition of what constitutes an obstacle, rather it defines a series of surfaces that must either not be penetrated or, if an object does penetrate the surface, must be recorded as an obstacle. Adequate clearance between an aircraft and terrain and obstacles must be provided for through flight procedure design.

3. Obstacle Management

As addressed in section 1.5.7 of this Manual, the purpose of obstacle management is to confirm that structures do not impact aircraft operations. This is achieved by establishing processes to ensure that obstacles have not penetrated the defined surface, are not constructed in the first place, are mitigated for in flight procedure design, or that their demolition is known.

As may be seen from these three points of view, there is no single definition of what an obstacle is, with it differing depending upon the perspective of the user and application.

It has, therefore, been necessary to define what is meant by "obstacle" in the context of both this Manual and the wider AIM context. The following definition has been derived:

"*All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that penetrate the identified obstacle assessment surfaces or whose height above ground level exceeds a defined minima.*"

2.3 Data Modelling

2.3.1 Introduction

An overview of spatial data modelling is given in this section, such that the reader may understand the meaning and purpose of terms related to data and its modelling.

Spatial data modelling describes the processes of abstracting the universe of discourse into an application schema. The universe of discourse is the view of the real or hypothetical world that includes everything of interest. Obviously the interest may be different depending on the application (business case) in which the data will be used[5]. The abstraction encompasses the selection, generalisation, simplification and structuring of elements that exist in the real world, within the relevant domain. Therefore, an application schema is one specific view on the real world.

Data modelling from the perspective of terrain and obstacles is addressed in the following two sections. Metadata, which applies to both, is then addressed.

2.3.2 Digital Terrain Models

Digital Terrain Models, and variations thereof (DEM, DHM and DSM), can be regarded as a continuous data set or "coverage", to use the term of the International Organisation for Standardisation's (ISO) standards. Coverage types are (Quadrilateral) grid, Triangulated Irregular Network (TIN) and Thiessen polygon. Common to all types of coverage is the limitation that, for each location, only one elevation can be stored, i.e. they support 2.5 Dimensions. A TIN-based terrain model provides a close representation of the surveyed objects because points, (break-) lines and even voids (an area with no data) can be used as input for the triangulation. With the growing number of mass points, as a result of using modern sensors, the importance of break-lines has been reduced, whilst the computing time has been massively increased due to the complexity of the algorithm (n*log n) used. To improve the performance of a TIN calculation, a point cloud can be thinned out with very limited impact on the accuracy.

High-resolution data acquisition results in up to 10,000 points per hectare[6]. However, a football field can be modelled using only the four corner points as it is flat. With similar thinning, the number of points can be reduced to a reasonable amount which still allows for accurate triangulation.

Grid coverage are built upon a lattice with regular cell size which means that, for their creation, the surveyed points need to be interpolated so that, for each cell, one value is given. There are several interpolation methods, each with strengths and weaknesses. Compared to a TIN-based terrain model, the grids are much simpler to handle since only a corner co-ordinate, the cell length and width, and the cell values must be stored. This results in less disk usage and faster processing times. A drawback of the grid-based terrain model is the close relationship to the co-ordinate system in which the grid is generated. If a local map projection is used for the interpolation and the raster is then transformed to an international reference frame (ellipsoidal co-ordinates), the raster is distorted and information can be lost. One must also be aware that for areas not close to the equator, a cell which is a square in a local map projection (such as 90m by 90m or 3 by 3 arc-seconds) becomes a near rectangle in ellipsoidal co-ordinates because of reduced West-East distances (3 by 6 arc-seconds at 60 degree latitude).

Hence, the input points should first be transformed and then the grid coverage interpolated.

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[5] The phenomenon "street" may have the following meanings, depending on the application:

- For a car navigation system: transportation networks axes (including rules);
- For noise abatement: area with structure of surface, noise cancellation factor;
- For flood modelling: area with slopes of surface, location of gullies.

[6] 1 Hectare = 10,000 square metres.

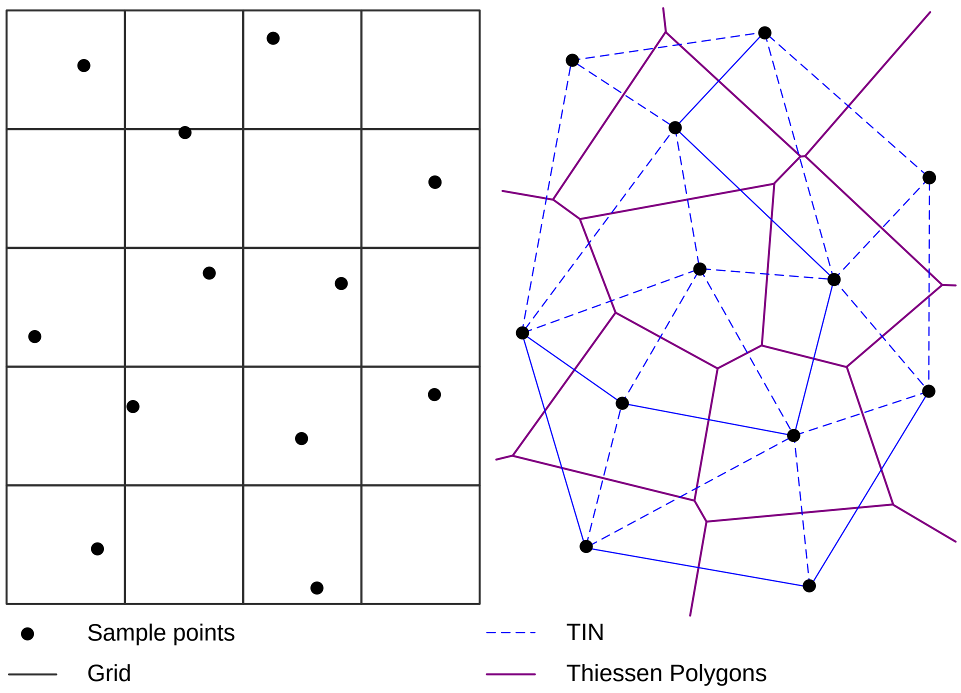


Figure 3: Terrain Representations through Grid (left) and Vectors (right)

The TOD WG was not able to identify an existing, suitable exchange model to fully meet the requirements of ICAO Annex 15. The provision of the required metadata was noted as a particular issue with existing models. As a result, EUROCONTROL has developed a new model, the Terrain Information Exchange Model (TIXM), to support the exchange of terrain data.

2.3.3 Obstacles

Data models for obstacles must correctly reflect the position, shape[7] and temporality of an obstacle, as well as providing sufficient information about the obstacle, such as its type, markings and lighting.

A basic obstacle model would allow for a simple shape to be defined, with more complex approaches allowing a number of "parts" to be described. This latter approach is desirable where obstacles are made up of distinct parts which together form a whole. An example would be a building which is basically rectangular in shape but which has an aerial on the roof that increases the overall height. Whilst a "bounding" box could be described which encompasses the building and aerial, this may adversely impact operations, as it restricts operations in an area larger than that actually occupied by the building. A compound shape comprising these two elements would more closely reflect reality.

Such segmentation will typically be more beneficial where planned aircraft operations are closer to obstacles and, therefore, in Area 2 and Area 1 in mountainous regions. More details of approaches for segmentation may be found in section B.2.1 and B.2.2.

Whilst terrain is predominantly static, obstacles are relatively dynamic, with temporary obstacles, such as cranes, being commonplace. It is, therefore, essential that the ability to define the temporality and status of an obstacle is provided for. The latter is needed as obstacles are typically planned, under construction, existing, planned for removal, being removed and removed. In some cases, flight operations are adjusted based on the status of the obstacle.

No new model has been developed by EUROCONTROL for the sole purpose of meeting the requirements of obstacle data. Rather, and in order to maintain a more homogenous approach, the

7 To the degree needed to support the appropriate applications.

obstacle element of the existing Aeronautical Information Exchange Model (AIXM) has been enhanced to provide full coverage of the attributes needed.

2.3.4 Metadata

Metadata provides information describing a number of attributes concerning a real data set. One of the objectives of publishing metadata is to permit a user to determine the fitness for use of the data set with respect to the requirements of a specific application, without having to evaluate the data set itself.

Within the metadata, one can distinguish between overview information which is valid for the entire data set (such as distribution information), overview information which is usually generated from the content (such as extent information) and metadata per feature (such as data quality information). Sometimes the same metadata can also be linked to an individual feature or to the data set, for example, reference system information. The metadata models in AIXM and TIXM, which are based on the ISO 19115 standard, provide this flexibility. More information on metadata can be found in section 7.7 of this Manual.

2.4 Reference Systems[8]

2.4.1 Horizontal Reference Systems

2.4.1.1 Definitions

2.4.1.1.1 Reference System

A reference system provides a definition of a co-ordinate system in terms of the position of an origin in space, the orientation of an orthogonal set of Cartesian axes, and a scale. A terrestrial reference system defines a spatial reference system in which positions of points anchored on the Earth's solid surface have co-ordinates.

Examples: World Geodetic System 1984 (WGS-84), International/European Terrestrial Reference System (ITRS/ETRS) and national reference systems.

2.4.1.1.2 Reference Frame

A reference frame is a realisation of a reference system through a consistent set of 3-dimensional (3D) station co-ordinates, taking into account the continental drifts.

Examples: European Terrestrial Reference Frame (ETRF) 89 (valid as of January 1st 1989), ETRF90, ETRF91, etc.

2.4.1.1.3 WGS-84

WGS-84 defines a global terrestrial reference system (geodetic datum) and a geocentric reference ellipsoid[9]. It was developed by the United States Department of Defence, together with scientists of other countries and institutions. WGS-84 is currently the reference system ICAO requires for georeferencing aeronautical information.

2.4.1.1.4 The International Terrestrial Reference System

As was seen with WGS-84, the ITRS is a global terrestrial reference system. The ITRS is maintained by the International Earth Rotation and Reference Systems Service (IERS) and the realisation of the ITRS is the International Terrestrial Reference Frame (ITRF).

Plate tectonic movement has been incorporated in the ITRS co-ordinate system using the results of recent measurements and a global geophysical model. Thus, it is a model with changing co-ordinates due to the movement of the tectonic plates on which the ground stations are located. However, ITRS provides the fundamental position of the Earth to within 10cm and the orientation of

[8] For a more sophisticated explanation of horizontal and vertical reference systems and their use in the origination of aeronautical data, please see the EUROCONTROL Specification for Aeronautical Data Origination.

[9] More information can be found here:http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html.

the axes to correspondingly high accuracies. Since 1988, the IERS has defined the mean spin axis, the IERS Reference Pole, the zero meridian and the IERS Reference Meridian.

Whilst WGS-84 is not a dynamic model, the maintenance of a datum at a higher level of accuracy as for the ITRS requires constant monitoring of the rotation of the Earth, the motion of the pole and the movement of the plates of the crust of the Earth, on which the ground stations are located. Whilst WGS-84 is defined by only 13 reference stations globally, ITRS is defined by a network of many reference stations. The continuous measurement from these stations is used to determine the dynamic variables of the ITRS.

2.4.1.1.5 European Terrestrial Reference System 1989 (ETRS89)

ETRS89 is a reference system based on the ITRS. Like ITRS, it uses the Geodetic Reference System 1980 (GRS80) reference ellipsoid which is slightly different to the WGS-84 reference ellipsoid.

For its realisation (ETRF89), the positions of the ITRS stations in and around Europe, at the beginning of 1989, were used as a reference. Only stations on the stable part of the Eurasian plate were used as these are considered to be consistent. Due to the continental drift of the Eurasian plate, ITRF and ETRF89 co-ordinates differed by about 25cm in the year 2000, a difference which is increasing by about 2.5cm per year.

2.4.1.1.6 Relationship between WGS-84, ITRS and ETRS89

The theoretical principles of both the WGS-84 and ETRS89 systems are the same. For WGS-84, the position of the reference ellipsoid was initially calculated on the basis of available data and modelled as a best fit for the whole world but with limited precision (initially 1-2 metres). ITRS2000 is the latest instantiation of WGS-84. ETRS89 was identical to ITRS at the 1989 epoch. ETRS89 is only used in Europe but the relationship between ITRS and ETRS is well known (and transformation parameters are available for the various epochs). The reference network for WGS-84 consists of only 13 stations around the world, whereas the European Reference Network (ERN) consists of over 100 stations within Europe. In practical terms, this means that Global Positioning System (GPS) surveys within Europe will need to be based on ETRS89, and converted to ITRS, as necessary[10].

2.4.1.1.7 Universal Transverse Mercator (UTM)

ETRS89 describes space in a 3D ellipsoidal co-ordinate system. To obtain 2-dimensional (2D) planar co-ordinates that are used for a wide range of applications, co-ordinates are transformed using a map projection. Co-ordinates in a planar system, such as Universal Transverse Mercator (UTM), are much easier to use and understand, and objects can be published at different scales, and on digital or analogue devices. A variety of different map projections exist, each being optimised for a certain application or region (often used in combination with a local, best fitting ellipsoid). At a global level, UTM has become very popular in recent years and many countries have started substituting the local map projection with UTM. UTM, as an isogonic projection, is suitable for aviation charting. Another advantage of UTM over many local map projections is the simplicity of the projection: x/y co-ordinates in UTM can be easily projected to ETRS89 ellipsoidal co-ordinates, and vice versa, because they are both based on the same reference ellipsoid.

2.4.2 Recent Developments in Co-ordinate Reference Frames

2.4.2.1 Reference Frame for Europe

Since national reference frames generally use locally adjusted ellipsoids which are a best fit for the earth surface of a country (such as Bessel 1841), they are not suitable for projects involving different countries. In this context, a continental system such as UTM/ETRS89, as a reference frame for Europe, is preferred because it is a general, best fit for a large area. Such a system simplifies the process of exchanging data between different countries, integrating data into global systems or using positioning services from permanent GPS networks.

[10] More information on reference systems and datum transformations is provided in EUROCONTROL Specification for Aeronautical Data Origination.

2.4.2.2 National Reference Frames

Although surveying using triangulation was considered a very accurate technique in the early 20th century, “old” national networks contain scalar and angular errors and inconsistencies. These torsions are mainly due to blunders in the measurement of reference distances (base measurements). The torsions can easily reach several metres between the most remote areas of a country.

Thus, GPS measurements are only consistent with those existing co-ordinates in the “old” national co-ordinate system which are at a very close distance to their reference station. The reference station must be established on a point whose co-ordinates are known in the old national co-ordinate system.

For this reason, many countries started the development of new national reference frames based on GPS measurements. In Europe, these frames are linked to ETRS89 but adjusted for local purposes. Therefore, they are often based on a different ellipsoid to that which is used by ETRS89 (GRS80), such as Bessel or Clarke.

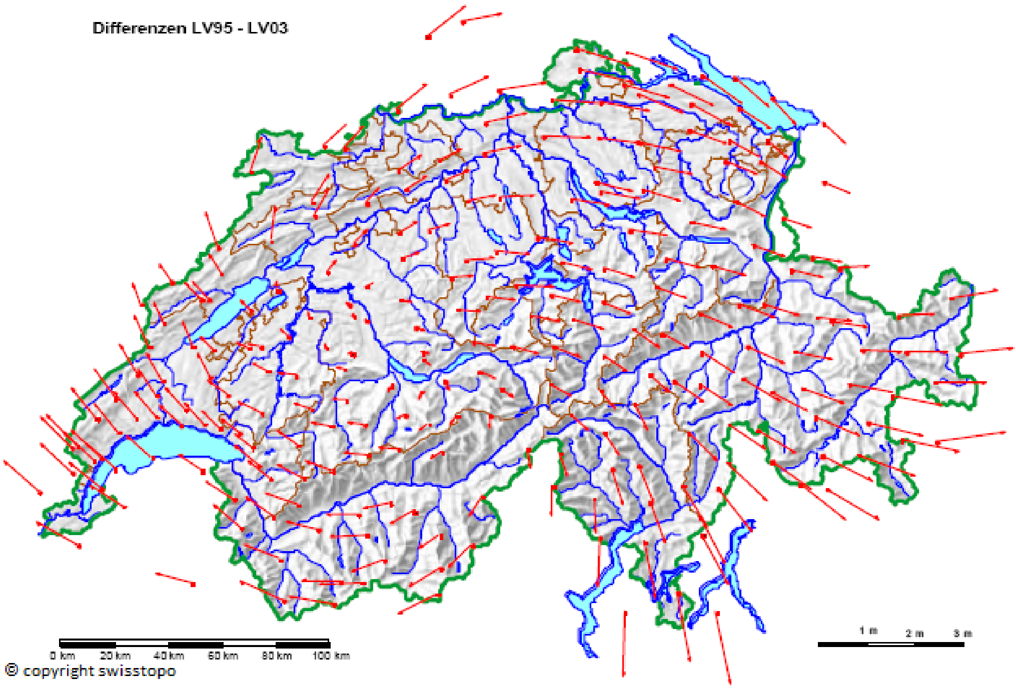


Figure 4: Deviation between Old and New Horizontal Reference Frames[11]

2.4.3 Vertical Reference Systems

2.4.3.1 Definitions

2.4.3.1.1 Vertical Reference System

A vertical (height) reference system can be defined by only two parameters: a point with a known elevation from which vertical differences are calculated, and the reference surface. The different height systems are briefly explained below.

2.4.3.1.2 Ellipsoidal Heights

The ellipsoid, which is used as part of the definition of a geodetic datum, can be used as a reference surface. The ellipsoidal height is the orthogonal distance between a point and the reference ellipsoid. Therefore, it does not take into account the Earth’s gravity field.

[11] Source: http://www.swisstopo.ch

2.4.3.1.3 Geoid

The geoid is the equipotential surface of the earth's gravity field, chosen at a certain level (approximately Mean Sea Level (MSL)) which serves as the reference surface for height measurements. Globally, the difference in elevation between the geoid and the geocentric ellipsoid is between ± 100m.

Global and local geoids differ in their origin: global geoids consider only the long-wave and middle-wave part of the earth's gravity field, whilst local geoids, in addition, also consider the short-wave part of the gravity field, resulting in higher resolution and, hence, better local accuracy.

Global geoids are used when consistent, orthometric heights, over long distances (continent or earth surveying), are required. Currently, the world's best global geoid model is the Earth Gravitational Model (EGM) 2008[12]. It was determined using satellite tracking, gravity anomalies and satellite altimetry. Its accuracy is in the range of ± 0.05m (oceans) and ± 0.5m (on land). This accuracy is higher in flat regions than in topographically mountainous terrain, such as the Alps. In aviation, elevation values have long been referenced to MSL; ICAO Annex 15 requires that EGM-96 is used as the global gravity model as EGM-2008 was not available when the requirements for a global gravity model requirement were introduced through Amendment 33 in 2004. The accuracy of EGM-96 is sufficient for terrain and obstacle elevations. This is because it meets the accuracy requirements of aviation and because height information is primarily used in context.

For local engineering applications and cadastre-surveying, global geoids are not as accurate as needed. For such applications, local geoid models are calculated, developed using local field measurements. They offer centimetre accuracy over several hundred kilometres, with a high resolution. Local geoids are not suitable for height comparison over large distances since they are based on different origins and reference heights (different equipotential levels).

2.4.3.1.4 Orthometric Heights

The orthometric height is the distance (H) along a line of force from a given point (P) on the physical surface of the earth to the geoid (the line is perpendicular to the equipotential surfaces at different levels).

2.4.3.1.5 Normal Heights

The normal height (H*) of a point is computed from its geopotential difference to that of sea level. It takes into account normal gravity, computed along the plumb line of the point (height difference of a point to the quasi-geoid). The difference between the normal height and the ellipsoidal height is called height-anomaly or quasi-geoid-height.

[12] http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/index.html.

2.4.3.1.6 Graphical Representation of Different Reference Surfaces

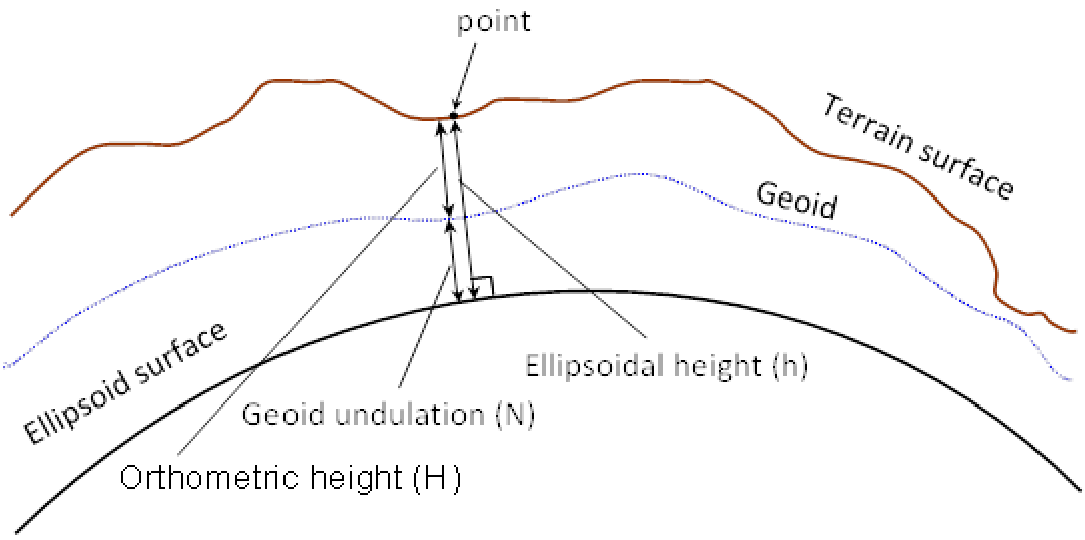


Figure 5: Different Reference Surfaces

2.4.3.2 Recent Developments in Vertical Reference Systems

2.4.3.2.1 European Vertical Reference System

The European Vertical Reference System (EVRS) has been built to reflect the globalisation of GIS applications and the need for continental-wide, consistent height information. EVRS is a gravity-related height reference system, i.e. the height values provided are normal heights. The EVRS is a tidal zero system. The EVRS is realised in the European Vertical Reference Frame (EVRF) by the geopotential numbers and normal heights of nodal points of the United European Levelling Network 95/98, extended for Estonia, Latvia, Lithuania and Romania, in relation to the Normaal Amsterdams Peils (NAP). The geopotential number at NAP is zero[13].

2.4.3.2.2 Modernised National Vertical Reference Frames

Heights in old national frames were usually determined using levelling. The heights are not strictly orthometric heights since the so-called orthometric correction was not taken into account. Whereas this correction will only be very small (millimetres) in flat areas, it can be several centimetres in mountainous terrain (10-30cm per 100km levelling). The orthometric correction can be determined using gravity measurements.

To eliminate inaccuracies, as well as torsion in the vertical reference, national geodetic agencies have started, often in combination with new horizontal reference frames, to rebuild the vertical reference frame, taking into account very accurate geoid or quasi-geoid models. The results are strict orthometric or normal heights which provide the base for a new national height reference frame. This allows the simple combination of GPS measurements (ellipsoidal heights) and levelling since the geoid undulation is precisely known for each horizontal co-ordinate.

[13] For more information on EVRS/EVRF, see http://www.bkg.bund.de/geodIS/EVRS/EN/Home/homepage__node.html__nnn=true

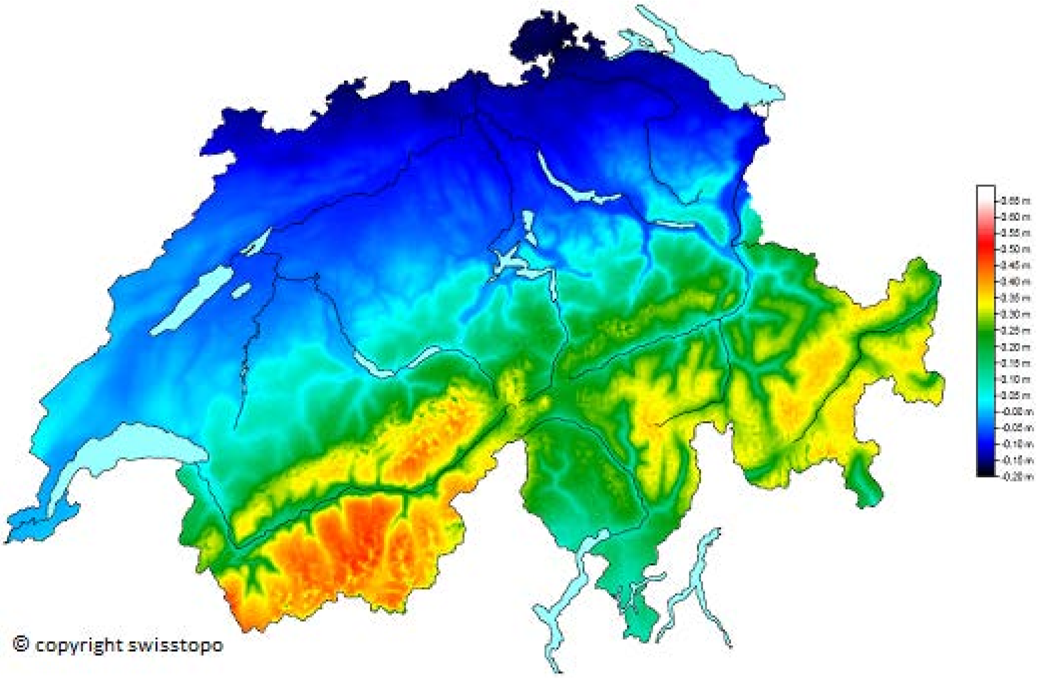


Figure 6: Difference between Old and New Vertical Reference Frames[14]

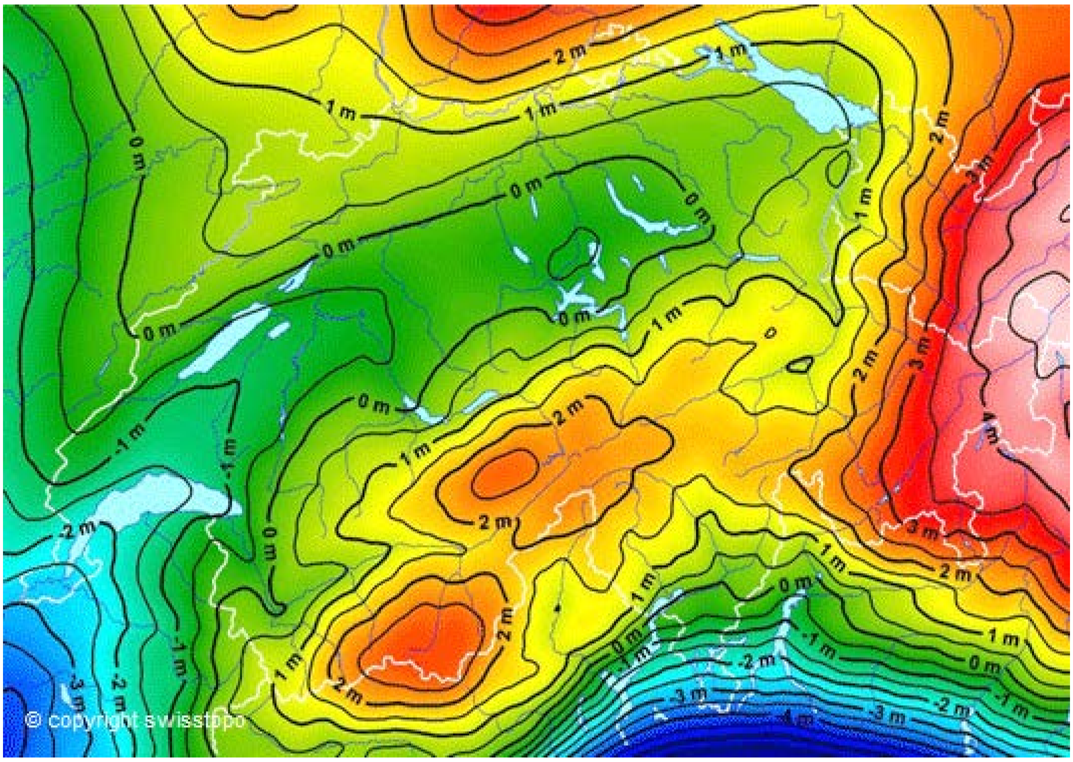


Figure 7: Swiss Geoid Model (Geoid Undulations Relative to the Local Reference Ellipsoid)[15]

2.4.4 Reference Points

Throughout this Manual, a range of reference documents are referred to. The terminology normally used within the survey domain is not used in an identical manner in this Manual. Therefore, the following list should be regarded as the definitions of the terms as they are used within this Manual.

[14] Source http://www.swisstopo.ch

[15] Source: http://www.swisstopo.ch

Reference Point: *The reference points establish a set of well-defined points in the real world which are used to instantiate a mathematical definition of a co-ordinate system to become a frame (see 2.4.1.1.1 and 2.4.1.1.2). Example 1: the ETRS is a set of abstract definitions of a co-ordinate system which must be combined through a numbers of points (theoretically only three but for practical reasons and for better accuracy and stability, many more) to become ETRF. Example 2: Points which are known in different co-ordinate systems can be used to determine the transformation parameters between the two systems.*

Benchmark Point: *Benchmark points (other common term is survey point) are points in the real world which are marked by some kind of disk and whose co-ordinates (2D, 3D or height only) are determined very accurately. There are different orders of benchmark points, depending on their relative importance in traditional survey networks. Example: Benchmark points can be used to establish a direct geodetic connection between a sensor and the co-ordinate system.*

Ground Control Point: *Ground Control Points (GCP) are usually highly accurate points, but less long-lasting than reference or benchmark points, used for establishing a direct geodetic connection. Often GCP are determined ad-hoc using GNSS. Example 1: GCP for the geo-referencing of imagery. Example 2: Set of points which are used for independent validation of the accuracy of orthophoto or a DHM.*

2.4.5 Temporal Reference Systems

2.4.5.1 Introduction

Temporal reference systems are used for items of aeronautical information that are time-related. In this context, time is used to mean both a point during a year and a point during the day, i.e., to specifically identify a unique point at which an occurrence takes place. A temporal reference system comprises a calendar and time system.

ICAO Annex 15, section 1.2.3.1, requires that "*For international civil aviation, the Gregorian calendar and Coordinated Universal Time (UTC) shall be used as the temporal reference system*". Consequently, it is the recommendation of this Manual that all temporal aspects for terrain and obstacle data are published using the Gregorian calendar and Coordinated Universal Time (UTC).

2.4.5.2 The Gregorian calendar

As addressed above, ICAO mandates that the Gregorian calendar is used for international civil aviation.

The Gregorian calendar is the most commonly used calendar in the world and is the standard used for most transactions which occur internationally, including trade. It was first introduced on 15th October 1582.

The Gregorian calendar is specified within ISO 8601:2004. The reader is referred to this standard for more information relating to the use of the Gregorian calendar.

2.4.5.3 UTC

The UTC reference system was established by the International Bureau of Weights and Measures and the International Earth Rotation Service. It provides a basis for standard time, the use of which is legally required in most countries.

UTC provides a means of referring to a single time reference globally, i.e. it provides a time reference which is not affected by time zones and, hence, reference to a specific time using UTC will indicate a single point in time that is the same throughout the world. UTC replaced Greenwich Mean Time (GMT) as the international time reference in 1972. It should be noted that UTC and GMT are often used interchangeably, however, this is incorrect and this practice should be avoided.

The use of UTC is specified within ISO 8601:2004. The reader is, once again, referred to this standard for more information.

It should be noted that ISO 8601:2004 (section 4.2.4) requires that whenever a time is reported in UTC, it is followed immediately by a Z. For example, midday UTC would be recorded as “1200Z”.

2.4.5.4 Local Reference Systems

Despite ICAO Annex 15 specifying the use of the Gregorian calendar and UTC, ICAO does recognise the possible need to use local systems. In particular this possibility is documented in two places within ICAO Annex 15:

> Section 1.2.3.2 states “*When a different temporal reference system is used for some applications, the feature catalogue, or the metadata associated with an application schema or a dataset, as appropriate, shall include either a description of that system or a citation for a document that describes that temporal reference system.*”
>
> Appendix 1, GEN 2.1.2 states “*Description of the temporal reference system (calendar and time system) employed, together with an indication of whether or not daylight saving hours are employed and how the temporal reference system is presented throughout the AIP.*”

The use of such systems is not, however, recommended and should be avoided wherever possible.

Where an alternative system is used, it is imperative that sufficient information is provided to allow the user to transform the date and/or time from the local reference system into the global reference systems required by ICAO.

2.4.5.5 Time/Temporality in the Context of Terrain and Obstacles

The need to report temporal aspects for terrain and obstacles is limited in scope and falls broadly into the following categories:

a) Start of Effectivity

The point in time at which the reported aeronautical information shall be considered as correct and in use. It is important to note the use of the words “*considered as being correct*”, rather than that the aeronautical information is actually correct, in reality. Why is this?

Let us take the example of a new obstacle. Typically, in a well-managed environment, the intention to erect a new obstacle whose location and size may impact aviation will have been reported. This will most likely result from a request for permission to build or modify a structure. Once this permission is granted, the planned location and the size of the structure may then be reported to the necessary authorities, including aviation.

Depending upon the management processes in place, the action of reporting that permission has been granted may occur at different times. In some cases, it may be reported even though construction may not have started and, indeed, may never start. Other processes may exist, such that the report is only made once construction commences. Either way, the reported obstacle will not fully reflect the actual status on the ground, until the structure has been completed and precisely surveyed.

The start of effectivity will be published and used to indicate the point in time at which the obstacle should be considered to exist, from an operational perspective, whether it does so or not.

b) End of Effectivity

The End of Effectivity records the last point in time when the aeronautical information shall be considered and is in use, from an operational perspective. Once again, in relation to obstacles, the actual structure may have been removed before this point in time and, therefore, as with the Start of Effectivity, the effective aeronautical information may not fully reflect reality, but is considered to be operationally correct.

c) Activation

Some attributes of aeronautical information may only apply during certain periods. For example, an obstacle may be recorded as having lighting, but this lighting may only be in use during certain periods of time.

As may be seen, these items are, in the main, related to obstacles. Terrain is typically reported in its “as is” state, i.e. effective from the point of publication. The cases where a change to terrain is planned in advance and reported as such will be very limited.

The one exception to this statement may be where terrain is known to move on a regular basis, such as in desert areas where sand dunes may form and disappear on a regular basis. In such cases, it is foreseen that the terrain will be reported as a “highest” value, providing a fail-safe system whereby it is highly unlikely, although not impossible, that the terrain will increase above the published value, despite a shift in the conditions.

2.5 Spatial Data Quality

2.5.1 Introduction

For many years, the data quality of spatial data has primarily been determined by its spatial accuracy. This is a fast and fairly simple way to determine some aspects of data quality with a quantitative measure. The quality experts within the spatial information domains have, for many years, discussed additional and alternative quality elements for a more holistic approach. In EUROCAE ED-76 and, subsequent to this, in ISO 19113, a broader set of quality elements has been published in recent years.

Compared with other fields of application, spatial accuracy plays a less significant role in the aviation domain; the degree of completeness, conceptual consistency and timeliness have a relatively more important impact on the usability of data published in the AIP.

The quality philosophy developed for terrain and obstacle data reflects the holistic approach to spatial data quality on the basis of the ISO 19100 series of geospatial standards. This section should help the reader to understand the philosophy and ensure that terrain and obstacle data sets are of the required data quality, whether they consist of already existing data or newly originated data. It provides an overview on the methodology used to achieve spatial data quality, from the design of the data set and the required data quality level (both based on the needs of a specific application), through to the measurement of the data quality (quality evaluation procedure) and the data quality reporting

The data quality philosophy consists of the following four topics:

a) Data Product Specification (DPS);
b) Spatial Data Quality Elements/Sub-elements;
c) Data Quality Evaluation Procedure;
d) Data Quality Reporting/Metadata.

2.5.2 Data Product Specification (DPS)

According to the definition in the ISO 19100 series of standards, the SARPs from ICAO Annex 15 are regarded as a DPS. Therefore, this section will describe the concept of a DPS and its relationship with the actual data sets. The usage of DPS in the context of terrain and obstacle data is described in more detail in section 7.1 of this Manual.

A DPS specifies a data product which is implemented as a data set and documented by metadata. The DPS provides important guidelines for the origination of new data. The relationship between DPS and metadata is shown in the following figure (source ISO 19131):

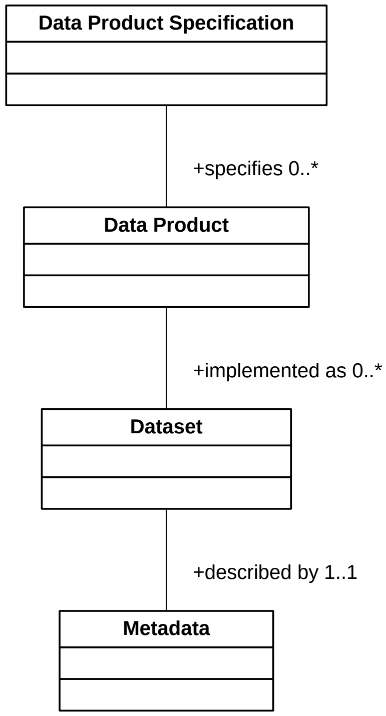


Figure 8: Hierarchy from DPS to Metadata

Surveyors are specialists in data acquisition, using different sensors and software tools for data processing which are aligned with the intended use of the resulting data. They are experienced in using their technical instruments, alongside ‘best practice’, to achieve the required results. They often, however, have little or no understanding of the data usage. Consequently, for the data originating party, it is imperative to have detailed knowledge of what level of data quality is required. Therefore, it is essential that detailed technical specifications are available before starting the data acquisition. Based on the technical specifications, the most appropriate survey technique can then be selected. This will save money and resources for all the parties involved. The development of the DPS should follow the structure specified in the ISO 19131 standard and always be driven by the end-user requirements.

In addition, it is recommended that the surveyor and the commissioning organisation agree on the methods / specifications that the surveyor should use to prove the conformance of the data with the required quality requirements. If these specifications exist, the surveyors can perform tests on the data to verify and subsequently document the conformance of the data quality with the specifications. Such tests shall be performed and reported in accordance with the ISO 19114 and ISO 19115 standards. The advantage for the commissioning organisation is that the delivered data can be validated and verified with less effort and in a shorter timeframe, which is more economical.

Where existing data sets may meet the needs of an application, the comparison between the DPS and the data sets’ metadata should document if, or under which conditions, the data set is compliant with the DPS.

2.5.3 Spatial Data Quality Elements / Sub-elements

To establish a good understanding of the influences on data quality, it must be understood that the quality of spatial data cannot be expressed by the spatial accuracy alone. Nowadays, the term quality is more comprehensive[16]. It includes the following data quality elements and data quality sub-elements[17]:

a) Accuracy:

[16] For detailed information, see ISO 19113 - Quality Principles and EUROCAE’s ED-76. Guidance for measures and samples can be found in ISO 19131 - Data Quality Measures.

[17] Unless otherwise stated, the source of an element and its definition is ISO 19113 - Quality Principles.

- Positional accuracy (x, y, z)

  For positional data, the accuracy is normally expressed in terms of a distance from a stated position, within which there is a defined confidence of the true position falling (ICAO Annex 15)[18];

- Thematic accuracy:

  Accuracy of quantitative attributes and the correctness of non-quantitative attributes, and of the classifications of features and their relationships;

- Temporal Accuracy

  The degree of confidence that the data is applicable to the period of its intended use (EUROCAE ED-76).

b) Resolution of data:

   A number of units or digits to which a measured or calculated value is expressed and used (ICAO Annex 15).

c) Integrity[19]:

   The degree of confidence that a data element is not corrupted[20] while stored or in transit (ICAO Annex 15).

d) Traceability:

   The ability to trace the history, application or location of an entity by means of recorded identifications (ICAO Annex 15).

e) Completeness (presence and absence of features, their attributes and relationships):

- Commission:

  Excess data present in a data set.

- Omission:

  Data absent from a data set.

f) Logical consistency:

- Format consistency:

  Degree to which data is stored in accordance with the physical structure of the data set.

- Conceptual consistency:

  Adherence to rules of the conceptual schema.

- Domain consistency:

  Adherence of values to the value domain.

- Topological consistency:

  Correctness of the explicitly encoded topological characteristics of a data set.

The data quality elements can be split into quantitative quality elements and non-quantitative quality elements (information about purpose, traceability or usage). It is expected that the DPS contains appropriate data quality elements, data quality evaluation procedures and the associated acceptable quality levels. The description of data quality requirements and associated test cases can be found in sections 7.1.7 and 7.3 of this Manual.

[18] Therefore, a positional accuracy statement is usually expressed together with a level of confidence (like 95 %).

[19] Also known as assurance level in other standards, for example, in ED-76.

[20] Corruption should be understood to mean that it no longer represents the value that was established. Integrity should not be understood to have any relation to the correctness of the value established.

2.5.4 Data Quality Evaluation Procedures

One data quality evaluation procedure should be provided for each data property or for a group of data properties. A data quality evaluation procedure ("test case") usually describes the methodology used to apply a data quality measure to the data items specified by a data quality scope. The data quality evaluation procedure shall also include the reporting of the methodology. In addition to the evaluation of individual data elements, the entire data set may also undergo an overall inspection, such as testing the completeness criteria or the logical consistency. Figure 9 provides a general data quality evaluation process.

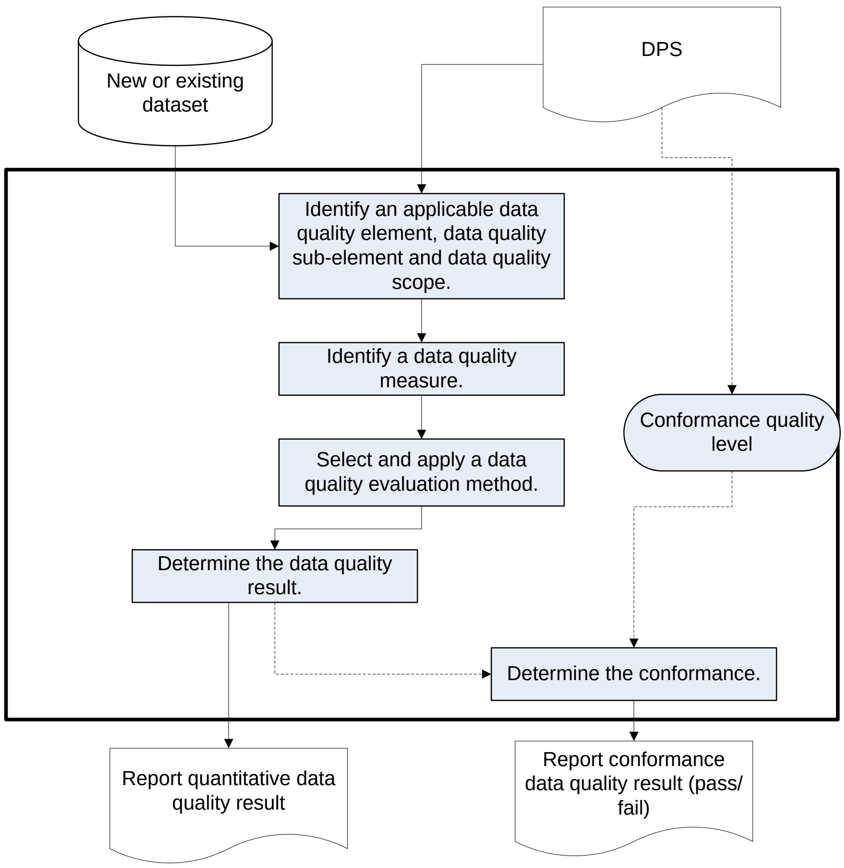


Figure 9: The Data Quality Evaluation Process (source ISO 19114)

Data quality evaluation procedures may either be direct or indirect (see Figure 10). Direct methods determine data quality through the comparison of the data with internal and/or external reference information. Indirect methods infer or estimate data quality using information on the data, such as lineage. The direct evaluation methods are further sub-classified by the source of the information needed to perform the evaluation. The validation of the *vertical accuracy* quality element of a data set is often determined by applying an *external direct evaluation method* using independent control points. As one alternative, the vertical accuracy may be estimated *indirectly* using the lineage information in the metadata, for example, "digitised from a contour map in the scale of 1:25k".

Various examples of the application of these concepts for terrain and obstacle data are found in section 7.3.

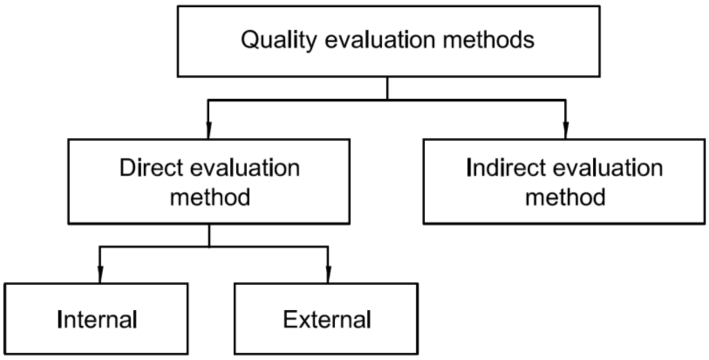


Figure 10: Classification of Data Quality Evaluation Methods (source ISO 19114)

2.5.5 Data Quality Reporting / Metadata

Reporting of the results of the data quality evaluation is strongly connected to the metadata (section DQ_DataQuality in ISO 19115). In this section, only the quantitative quality information (according to ISO 19113) is covered. The reporting of non-quantitative quality information, such as traceability, is part of the metadata section. Figure 11 shows the data model for data quality reports (source ISO 19109).

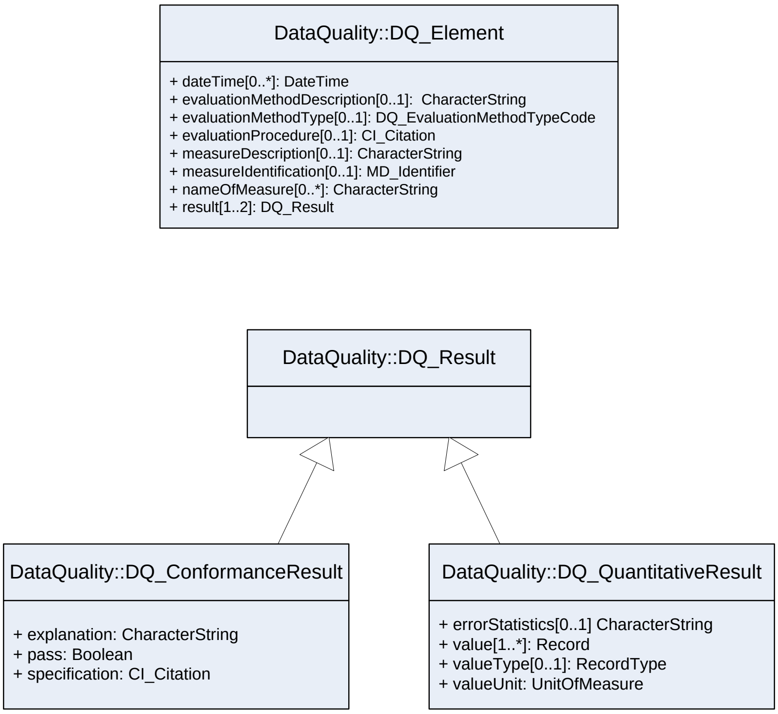


Figure 11: Data Model for Data Quality Reports

The goal of each data quality report is to provide sufficient information to allow an end-user to determine what has been tested, how it has been tested, the conformance results (are the requirements met) and the quantitative result of the quality assessment. Each data quality report consists of the following elements:

- DQ_Element: This table contains the metadata about the data quality evaluation, such as the scope and the description of the test, and the evaluation method (internal).
- DQ_ConformanceResult: Whenever a conformance quality level has been specified in the DPS, the data quality result is compared with it to determine conformance. A data quality conformance result (pass-fail) is the comparison of the quantitative data quality result with a conformance quality level. If no conformance level has been defined, then the pass attribute is

left empty.

- DQ_QuantitativeResult: A quantitative data quality result, a data quality value or set of data quality values, a data quality value unit and a date result from the application of the evaluation method.

2.6 Geographic Information Systems

The provision of terrain and obstacle data in accordance with the ISO 19100 series of standards allows the data sets delivered to be utilised by GIS. The following provides a high-level description of GIS for those who are not familiar with the term.

A GIS is the group of Information Technology (IT) components which is used to describe, in a structured form, real-world phenomena. Contrary to other information systems, a GIS emphasises the spatial property of a phenomenon. Therefore, a GIS is used to capture, maintain, store, analyse, manage and present data that is linked to a location. In a more generic sense, GIS applications are tools that allow users to create interactive queries (user created searches), analyse spatial information, edit data, and present the results of all these operations (on screen or as maps). The following figure shows, at a high level, a typical GIS architecture.

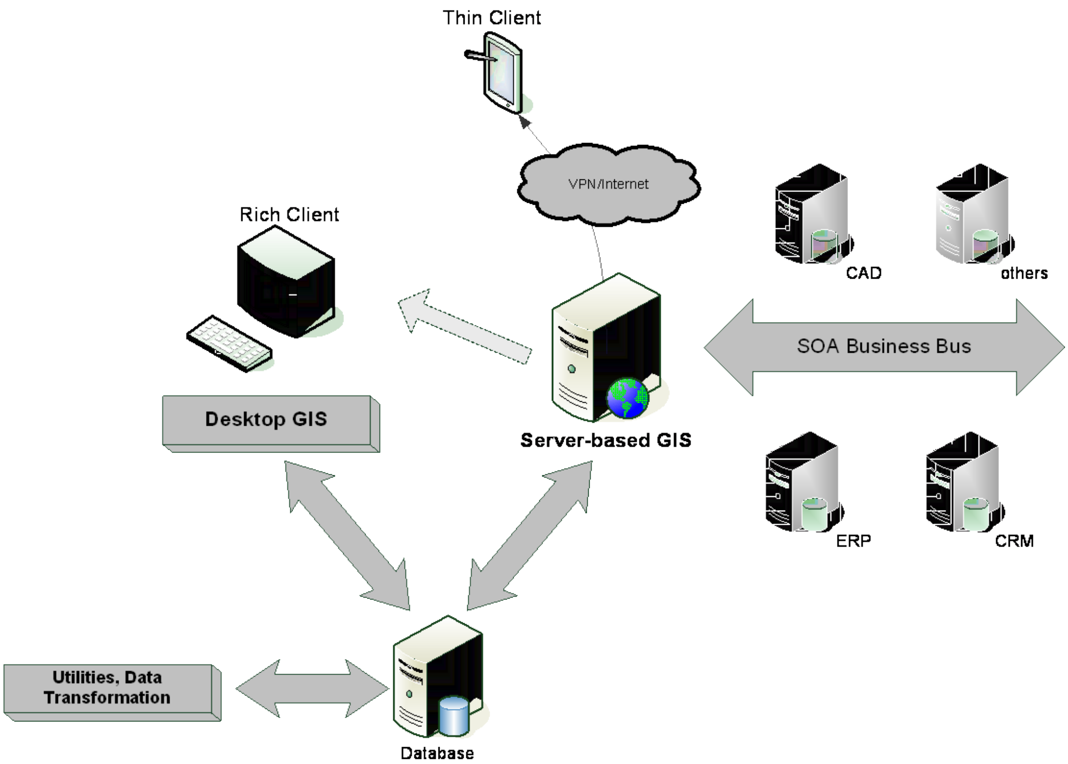


Figure 12: Typical Architecture of a GIS Environment

GIS and appropriate data sets offer vast opportunities for:

- Fast and easy access to spatial data and system resources;
- Data sharing with external organisations;
- Integrating with other information systems;
- Faster and more accurate decision making;
- Simpler data maintenance through elimination of redundancies;
- Provision of a wider range of spatial-based products.

2.7 Data Provision using Web Services

Besides the traditional means of distribution for aeronautical information, for example, the AIP and Notice to Airmen (NOTAM), there are other methods which may be used to make data available.

Alternative means of making data available are of particular relevance where digital data products are concerned. This section introduces a basic understanding of what must be provided and how web services may be used as exchange mechanisms.

More detailed descriptions of particular mechanisms by which data may be made accessible are provided in section 7.5 of this Manual.

Web services, as defined by the World Wide Web Consortium (W3C)[21], provide "*A software system designed to support interoperable machine-to-machine interaction over a network. It has an interface described in a machine-processable format (specifically Web Services Description Language WSDL). Other systems interact with the web service in a manner prescribed by its description using SOAP messages, typically conveyed using HTTP with an XML serialization in conjunction with other web-related standards.*".

Typically, these services are used to exchange data in Extensible Markup Language (XML) or Geography Markup Language (GML) and, as such, are ideally suited for the interoperable exchange of terrain and obstacle data. This is reinforced by the fact that many GIS solutions in existence today include the capability to allow the identification and exploitation of web services.

The Open Geospatial Consortium (OGC)[22] defines a series of standards to provide interoperable solutions that "geo-enable" the Web, wireless and location-based services, and mainstream IT. The standards empower technology developers to make complex spatial information and services both accessible and useful to all kinds of applications. Although developed by the OGC, these standards are typically adopted by ISO, as part of the ISO 19100 series of standards.

Four of these standards are of particular relevance to terrain and obstacle data. These are:

- Catalogue Service (CS);
- Web Feature Service (WFS);
- Web Map Service (WMS);
- Web Coverage Service (WCS).

2.7.1 Catalogue Service

The Catalogue Service (CS) defines common interfaces to discover, browse and query metadata about data, services and other potential resources. This service, therefore, provides a means of identifying possible data sources and determining their suitability for use.

With respect to terrain and obstacle data, these services may be used to identify, for example, what digital products are available, what their “*legal*” status is (for example, are they issued on behalf of the State) and the quality characteristics associated with each product.

In effect, the CS acts as a combination of a “*telephone*” directory and “*product catalogue*”. The service allows the user to look up what products are available, without necessarily knowing who offers the products, and then to assess the specification of those products that interest them.

2.7.2 Web Feature Service

The Web Feature Service (WFS) standard provides an interface for the user to make requests for geographical features, across the Internet, using platform-independent calls. Features may be best described as the information which is used to place the symbols on a map/chart.

[21] The W3C is an international community that develops standards to ensure the long-term growth of the Web. Refer to http://www.w3.org for more information.

[22] The OGC is an international industry consortium of companies, government agencies and universities participating in a consensus process to develop publicly available interface standards. Refer to http://www.opengeospatial.org for more information.

The WFS specification defines interfaces for describing data manipulation operations of geographic features. Data manipulation operations include the ability to:

- Get or query features, based on spatial and non-spatial constraints;
- Create a new feature instance;
- Delete a feature instance;
- Update a feature instance.

The basic WFS allows the query and retrieval of features, for example, is it read-only? A transactional WFS allows the creation, deletion and update of features.

A WFS describes discovery, query or data transformation operations. The client generates the request and posts it to a web feature server using Hypertext Transfer Protocol (HTTP). The web feature server then executes the request.

For terrain and obstacle data, this service would mainly be used to return data relating to obstacles as it is oriented towards data for a specific feature (hence the name). Nonetheless, services could be developed to return specific terrain features, if so desired. For example, a WFS could be used to return information about a specific terrain location, providing information such as its elevation and surface type, along with the relevant metadata.

A transactional WFS may be of use to States in their creation and management of obstacles as those originating data could use a web service to report the data digitally, supporting enhanced data quality assurance.

2.7.3 Web Map Service

A Web Map Service (WMS) is a standard protocol for serving geo-referenced map images over the Internet. These images are typically generated by a map server using data from a GIS database.

2.7.4 Web Coverage Service

The Web Coverage Service (WCS) interface standard provides an interface for requests for geographical coverages to be made, across the Internet, using platform-independent calls. The coverages are objects (or images) in a geographical area, whereas the WMS interface or online mapping portals, such as Google Maps®, only return an image, which end-users cannot edit or spatially analyse.

The basic WCS allows the query and retrieval of coverages.

A WCS describes discovery, query, or data transformation operations similar to those for the WFS. The client generates the request and posts it to a web feature server using HTTP. The web feature server then executes the request. The WCS specification uses HTTP as the distributed computing platform, although this is not a mandatory requirement.

3. THE REQUIREMENT

This section presents the text of ICAO Annex 15, Chapter 10, as amended by Amendment 37 to ICAO Annex 15. A full analysis of the requirement is provided and, where appropriate, links are made to additional information provided in this Manual.

It should be noted that this chapter is intended to provide a guide to each one of the SARPs in a standalone manner, i.e. a user who seeks information on a particular requirement may refer directly to the relevant text without reading the entire chapter. As a result, some information is repeated where the SARPs contain similar text.

3.1 Terminology

An understanding of the ICAO use of terminology is needed for this section. ICAO SARPs use one of three verbs to indicate the status of the text:

- Requirements using the operative verb “**shall**” are mandatory.
- Requirements using the operative verb “**should**” are recommended.
- Requirements using the operative verb “**may**” are optional.

3.2 ICAO Annex 15, Chapter 10 Introductory Text

ICAO Annex 15 Text:

“*Note.— Electronic terrain and obstacle data is intended to be used in the following air navigation applications:*

a) ground proximity warning system with forward looking terrain avoidance function and minimum safe altitude warning (MSAW) system;

b) determination of contingency procedures for use in the event of an emergency during a missed approach or take-off;

c) aircraft operating limitations analysis;

d) instrument procedure design (including circling procedure);

e) determination of en-route “drift-down” procedure and en-route emergency landing location;

f) advanced surface movement guidance and control system (A-SMGCS); and

g) aeronautical chart production and on-board databases.

The data may also be used in other applications such as flight simulator and synthetic vision systems, and may assist in determining the height restriction or removal of obstacles that pose a hazard to air navigation.”

3.2.1 Understanding of Requirement

This section provides information relating to the intended use of the terrain and obstacle data to be provided. When initially introduced by Amendment 33, Annex 15 stated that terrain and obstacle data were to be used in conjunction with other aeronautical information. Whilst Amendment 36 has removed the statement, it should be assumed that this intent remains.

The final part of the text introduces applications which will also gain benefit from the provision of terrain and obstacle data. These applications are, however, reliant upon more detailed information, particularly with regards to obstacle data, which includes such information as that needed to correctly render a real-life representation of the obstacle.

As will be seen, the State is required to prepare data sets in accordance with the requirements laid down in ICAO Annex 15 sections 10.2 to 10.4 and it is these requirements that should be sufficient to meet the listed applications. This introductory text is, therefore, considered as being for information only, i.e., no action needs to be taken as a result of this introductory text.

The applications listed are discussed in detail in section 1.5 of this document.

3.3 ICAO Annex 15, Section 10.1 "Coverage Areas and Requirements for Data Provision"

3.3.1 Para 10.1.1

ICAO Annex 15 Text:

"*The coverage areas for sets of electronic terrain and obstacle data shall be specified as:*

— Area 1: The entire territory of a State;

— Area 2: Within the vicinity of an aerodrome, sub-divided as follows;

— Area 2a: A rectangular area around a runway that comprises the runway strip plus any clearway that exists.

Note.— See Annex 14, Volume I, Chapter 3 for dimensions for runway strip.

— Area 2b: An area extending from the ends of Area 2a in the direction of departure, with a length of 10 km and a splay of 15% to each side;

— Area 2c: An area extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a; and

— Area 2d: An area outside the Areas 2a, 2b and 2c up to a distance of 45 km from the aerodrome reference point, or to an existing TMA boundary, whichever is nearest;

— Area 3: The area bordering an aerodrome movement area that extends horizontally from the edge of a runway to 90 m from the runway centre line and 50 m from the edge of all other parts of the aerodrome movement area.

— Area 4: The area extending 900 m prior to the runway threshold and 60 m each side of the extended runway centre line in the direction of the approach on a precision approach runway, Category II or III.

Note.— See Appendix 8 for descriptions and graphical illustrations of the coverage areas."

3.3.1.1 Understanding of Requirement

The standard establishes the four basic areas for which terrain and obstacle data is required, describing the geographical extent of each of the areas. Area 2 is, in turn, broken down into four sub-areas. The precise collection surfaces for each of these areas are not described in this text but may be found in section 3.7 of this Manual.

A note draws the reader's attention to the fact that figures are provided in Appendix 8 of ICAO Annex 15 and these provide a graphical representation of these areas.

The four areas are discussed in more detail in section 3.7 of this Manual.

3.3.2 Para 10.1.2

ICAO Annex 15 Text

"*Recommendation. — Where the terrain at a distance greater than 900 m (3 000 ft) from the runway threshold is mountainous or otherwise significant, the length of Area 4 should be extended to a distance not exceeding 2 000 m (6 500 ft) from the runway threshold.*"

3.3.2.1 Understanding of Requirement

Area 4 data is intended to provide a digital representation of the information typically provided by way of the PATC, which is required to be provided as part of the AIP and is detailed in ICAO Annex 4.

The purpose of the chart is described as follows:

"*The chart shall provide detailed terrain profile information within a defined portion of the final approach so as to enable aircraft operating agencies to assess the effect of the terrain on decision height determination by the use of radio altimeters.*"

Whilst under normal conditions the geographical extent of Area 4 matches that needed to be included on this chart, there are circumstances in which it is extended. ICAO Annex 4 paragraph 6.5.2 states:

"*Recommendation.— Where the terrain at a distance greater than 900 m (3 000 ft) from the runway threshold is mountainous or otherwise significant to users of the chart, the profile of the terrain should be shown to a distance not exceeding 2 000 m (6 500 ft) from the runway threshold.*"

The recommendation provided in paragraph 10.1.2 of ICAO Annex 15 introduces a similarly worded recommended practice to ensure that the digital representation of the terrain and obstacles in the CAT II/III operations area is consistent with the requirements for the PATC.

In all cases, and as described in 3.6.10 of this Manual, the metadata for an Area 4 data set should provide a precise description of the geographical region which is included in the data set.

3.3.3 Para 10.1.3

ICAO Annex 15 Text

"*Electronic terrain data shall be provided for Area 1. The obstacle data shall be provided for obstacles in Area 1 higher than 100 m above ground.*"

3.3.3.1 Understanding of Requirement

This standard requires that data relating to two aspects is provided: firstly terrain for the entire territory of the State and, secondly, obstacle data for all objects over 100 metres in height (above ground level).

The collection and maintenance of obstacle data is currently conducted under National level arrangements, and in some cases this may be based on informal arrangements. The capture of objects over 100 metres missing from the obstacle data base is critical to ensuring the completeness of the data base used to publish such obstacles in the AIP and to reflect these on aeronautical charts. This requirement pre-existed Amendment 33 to ICAO Annex 15 and the consequential changes to ICAO Annex 4. It is important to ensure the data base is compliant with the data quality requirements.

A national obstacle notification process should be established to enable the capture of all existing relevant obstacles. This should be incorporated as part of a national obstacle permissions process. Guidance within this document details implementation of processes to ensure the obstacle data base is managed in compliance with the current requirements.

It should be noted that not all metadata was required for Area 1 Obstacle data collection prior to the above Amendment. Therefore it is recommended that State should, in such cases, provide in interim (until all metadata is collected) the obstacle data that is available, minimum being the data published in ENR 5.4 'Air Navigation Obstacles' of the National AIP, and to inform the users of the missing metadata elements and on their responsibilities in determining the suitability of data.

Note: Section 8 'Use of Existing Data' – provides additional guidance on the provision of the data of unknown or deficient quality.

If any probability exists that not all obstacles are included in the provided Area 1 Obstacle data set, then this fact should be clearly specified and the information on the potential limitations should be provided.

Note: Section 8.1 provides an example for an appropriate statement within the national AIP.

3.3.4 Para 10.1.4

ICAO Annex 15 Text

"*From 12 November 2015, at aerodromes regularly used by international civil aviation, electronic obstacle data shall be provided for all obstacles within Area 2 that are assessed as being a hazard to air navigation.*"

3.3.4.1 Understanding of Requirement

Whilst it is traditionally accepted that the term "*a hazard to air navigation*" is used to refer those objects which penetrate defined surfaces, this does not appear to be the case with ICAO Annex 15, Chapter 10. These defined surfaces would encompass:

- The ICAO Annex 14 Obstacle Limitation Surfaces;
- The ICAO Annex 4 Take-off Flight Path Area Obstacle Identification Surfaces;
- The ICAO Annex 15 Obstacle Data Collection Surfaces (ODCS).

However, if the traditional meaning is applied in the context of paragraph 10.1.4, all penetrations of these surfaces would have to be collected and made available. This would result in paragraph 10.1.5 and 10.1.6 of ICAO Annex 15 being superfluous.

It is believed that this was not the intent of ICAO and, as a result, it is clear that a more "all-embracing" requirement, catering for future applications, was intended. However, unless there is a clearly defined user requirement, the onus of determining which obstacles are "*a hazard to air navigation*" rests with the data provider rather than with the users of the data who know best what data is necessary for their operations. As such, it is considered that this introduces a liability issue which will need to be considered as part of the implementation planning. As a result, an alternative approach to understanding the term "*a hazard to air navigation*" is needed.

One approach to this is to not provide data in relation to this SARP and to declare a non-conformance (filing a difference accordingly). Instead, compliance with the SARP presented in paragraph 10.1.5 of ICAO Annex 15 is achieved. Choosing this latter option will ensure that there is no risk of the publication of an incomplete data set, in the case where obstacles have been incorrectly assessed as being of no "*hazard to air navigation*" and, as a result, excluded from the data set. By not complying with this SARP, States will reduce the potential for litigation in the event of wrong data exclusion.

An alternative approach would be to identify <u>all</u> obstacles (i.e. anything that extends above the terrain's surface) in Area 2 as being a potential hazard to air navigation but this will result in an expensive data collection exercise and a resultant data set that contains a vast number of obstacles.

3.3.5 Para 10.1.5

ICAO Annex 15 Text:

"From 12 November 2015, at aerodromes regularly used by international civil aviation, electronic terrain data shall be provided for:

a) Area 2a;

b) the take-off flight path area; and

c) an area bounded by the lateral extent of the aerodrome obstacle limitation surfaces."

3.3.5.1 Understanding of Requirement

This standard requires that a limited set of electronic terrain data for Area 2 is made available from the specified date of 12th November 2015.

a) Area 2a:

The terrain data within the region defined as Area 2a shall be provided with the Area 2 numerical requirements defined in ICAO Annex 15 Appendix 8 Table A8-1.

ICAO Annex 15 Appendix 8 Figure A8-1 is supposed to provide the description and graphical illustration of Area 2a. Nevertheless the terrain data collection surfaces for Area 2 in this figure are based upon an integer circular area, which is in contradiction with the requirements for coverage areas of ICAO Annex 15 10.1.1. As a result, it is recommended that the description of Area 2a from 10.1.1 is used instead as follows:

Area 2a: a rectangular area around a runway that comprises the runway strip plus any clearway that exists.

Note.— See Annex 14, Volume I, Chapter 3, for dimensions for runway strip.

The area defined by runway strip is intended to reduce the risk of damage to aircraft running off a runway and to protect aircraft flying over the strip during take-off or landing. (see Figure 13)

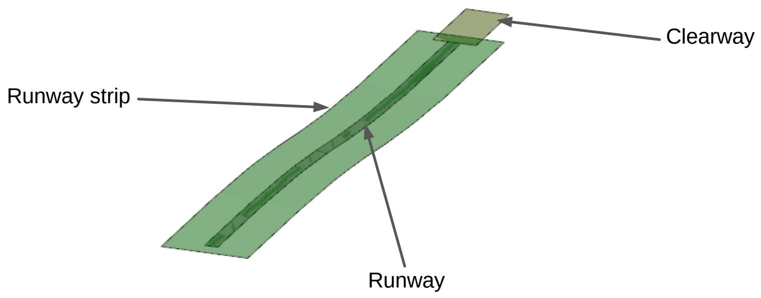


Figure 13: Graphical depiction of Area 2a

b) The take-off flight path area;

The terrain data within the region defined as the take-off flight path area shall be provided with the Area 2 numerical requirements defined in ICAO Annex 15 Appendix 8 Table A8-1.

The take-off flight path area is defined in ICAO Annex 4 Paragraph 3.8.2. Graphical representation of take-off flight path area is defined on the Figure 14.

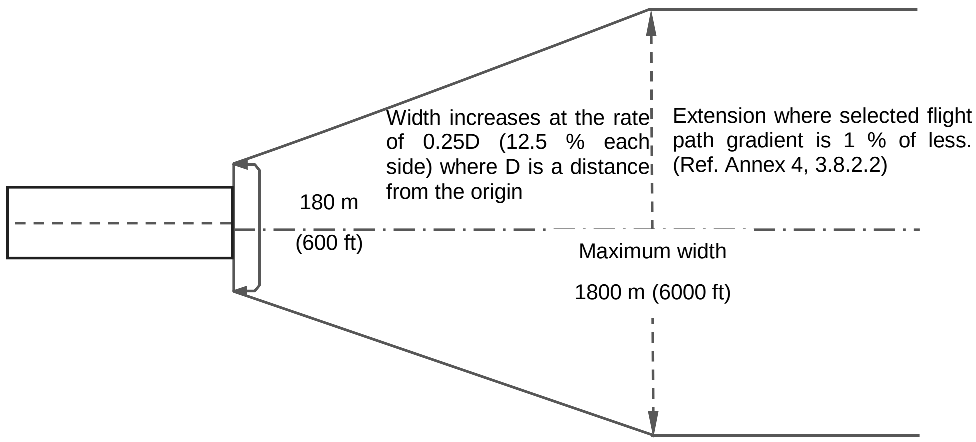


Figure 14: Graphical depiction of take-off flight path area

c) An area bounded by the lateral extent of the aerodrome obstacle limitation surfaces.

The terrain data within the area defined by the lateral extent of the aerodrome obstacle limitation surfaces shall be provided with the Area 2 numerical requirements defined in ICAO Annex 15 Appendix 8 Table A8-1. The graphical depiction of lateral extent of the aerodrome obstacle limitation surfaces represented on the Figure 15.

ICAO Annex 14 Chapter 4 defines the components which make up the obstacle limitation surfaces. The precise dimensions of each of these surfaces varies depending upon the classification of the runway in question, with the dimensions being provided by ICAO Annex 14 Volume I in Table 4-1 for approach runways and Table 4-2 for runways meant for take-off.

According to ICAO Annex 15 Appendix 8 Figure A8-1 only the area covered by a 10-km radius from the ARP shall comply with the Area 2 numerical requirements for terrain data. For the remaining portion of the area bounded by the lateral extent of the aerodrome obstacle limitation surfaces only the terrain that penetrates the horizontal plane 120 m should be provided with the Area 2 numerical requirements for terrain data, otherwise Area 1 numerical requirements should be applicable.

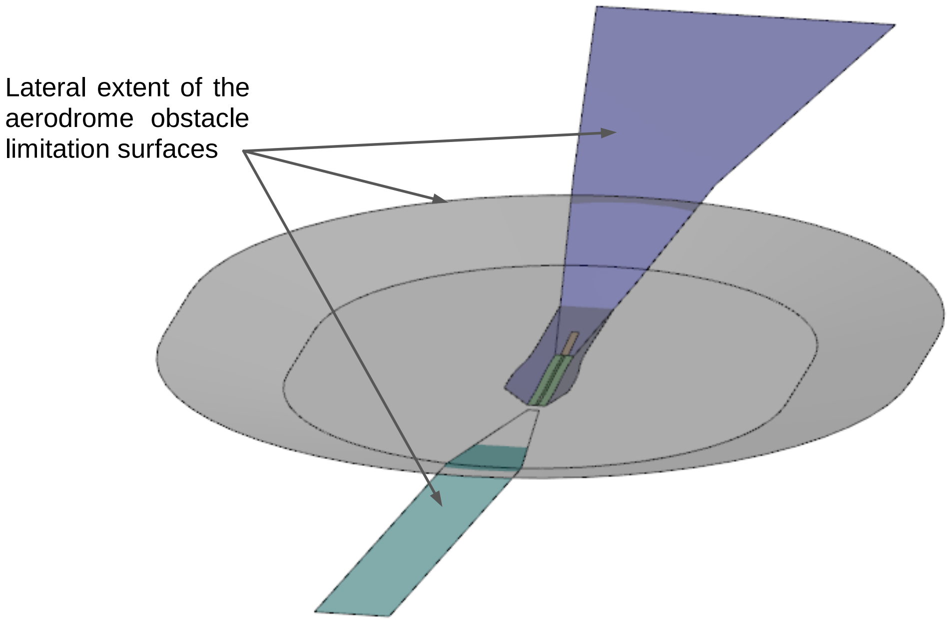


Figure 15: Graphical depiction of lateral extent of the aerodrome obstacle limitation surfaces

3.3.6 Para 10.1.6

ICAO Annex 15 Text:

"*From 12 November 2015, at aerodromes regularly used by international civil aviation electronic obstacle data shall be provided for*:

a) Area 2a, for those obstacles that penetrate the relevant obstacle data collection surface specified in Appendix 8;

b) Objects in the take-off flight path area which project above a plane surface having a 1.2 per cent slope and having a common origin with the take-off flight path area; and

c) penetrations of the aerodrome obstacle limitation surfaces.

Note.— Take-off flight path areas are specified in Annex 4, 3.8.2. Aerodrome obstacle limitation surfaces are specified in Annex 14, Volume 1, Chapter 4."

3.3.6.1 Understanding of Requirement

This standard requires that a limited set of electronic obstacle data for Area 2 is made available from the specified date of 12th November 2015.

The limitations which are applied, as a standard, are:

a) Area 2a:

All obstacles which exist within the region defined as Area 2a and that are over 3m in height when measured from the ground level are to be provided in the digital data set with the Area 2 numerical requirements defined in ICAO Annex 15 Appendix 8 Table A8-2.

b) Objects in the take-off flight path area which project above a plane surface having a 1.2 per cent slope and having a common origin with the take-off flight path area shall be made available with the Area 2 numerical requirements defined in ICAO Annex 15 Appendix 8 Table A8-2:

The take-off flight path area is defined in ICAO Annex 4 as being:

"*3.8.2.1 The take-off flight path area consists of a quadrilateral area on the surface of the earth lying directly below, and symmetrically disposed about, the take-off flight path. This area has the following characteristics:*

a) it commences at the end of the area declared suitable for take-off (i.e. at the end of the runway or clearway as appropriate);

b) its width at the point of origin is 180 m (600 ft) and this width increases at the rate of 0.25D to a maximum of 1 800 m (6 000 ft), where D is the distance from the point of origin;

c) it extends to the point beyond which no obstacles exist or to a distance of 10.0 km (5.4 NM), whichever is the lesser.

3.8.2.2 For runways serving aircraft having operating limitations which do not preclude the use of a take-off flight path gradient of less than 1.2 per cent, the extent of the take-off flight path area specified in 3.8.2.1 c) shall be increased to not less than 12.0 km (6.5 NM) and the slope of the plane surface specified in 3.8.1.1 and 3.8.1.2 shall be reduced to 1.0 per cent or less.

Note.— When a 1.0 per cent survey plane touches no obstacles, this plane may be lowered until it touches the first obstacle."

It is, therefore, only necessary to include those obstacles which must be included on the Aerodrome Obstacle Chart — ICAO Type A (Operating Limitations) in order to meet this clause.

c) Penetrations of the aerodrome obstacle limitation surfaces:

ICAO Annex 14 Chapter 4 defines a series of obstacle limitation surfaces. The chapter states in its introductory text that:

"*The objectives of the specifications in this chapter are to define the airspace around aerodromes to be maintained free from obstacles so as to permit the intended aeroplane operations at the aerodromes to be conducted safely and to prevent the aerodromes from becoming unusable by the growth of obstacles around the aerodromes. This is achieved by establishing a series of obstacle limitation surfaces that define the limits to which objects may project into the airspace.*"

Section 4.1 defines the components which make up the obstacle limitation surfaces and it is the objects which penetrate these surfaces which must be included within the obstacle data set. It should be noted that the ICAO Annex 15 text does not allow for filtering / shadowing to be applied.

The obstacle limitation surfaces comprise:

- Outer horizontal surface;
- Conical surface;
- Inner horizontal surface;
- Approach surface;
- Inner approach surface;
- Transitional surface;

- Inner transitional surface;
- Balked landing surface; and
- Take-off climb surface.

The precise dimensions of each of these surfaces varies depending upon the classification of the runway in question, with the dimensions being provided by ICAO Annex 14 Volume I in Table 4-1 for approach runways and Table 4-2 for runways meant for take-off.

Figure 16 provides a graphical representation of the limited set of electronic obstacle data for Area 2 requirements highlighted in ICAO Annex 15.

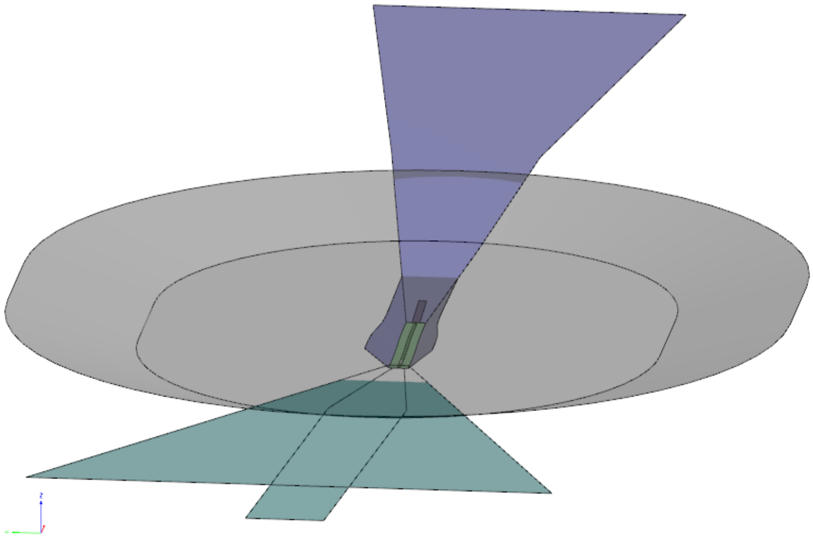


Figure 16: Graphical depiction of Para 10.1.6 requirements

3.3.7 Para 10.1.7

ICAO Annex 15 Text:

"*Recommendation.— At aerodromes regularly used by international civil aviation, electronic terrain and obstacle data should be provided for Areas 2b, 2c and 2d for obstacles and terrain that penetrate the relevant terrain and obstacle data collection surface specified in Appendix 8, except that data need not be collected for obstacles less than a height of 3m above ground in Area 2b and less than a height of 15m above ground in Area 2c.*"

3.3.7.1 Understanding of Requirement

The provision of a full Area 2 data set for all aerodromes was considered to be costly and, as a result, unlikely to be justifiable in many cases. Whilst the original intent of ICAO had been the provision of Area 2 data for all IFR aerodromes published in the AIP, feedback received from States indicated that this was not considered feasible or necessary.

Consequently, the standard for the provision of a full Area 2 data set had been revised, such that the provision of data for Areas 2b, 2c and 2d is now a Recommended Practice only.

It should be noted that only terrain which penetrates the defined Area 2b, 2c and 2d surfaces needs to be collected in accordance with this SARP. This is in contradiction with the requirements expressed in Figure A8-1 (see section 3.7.1 of this Manual). It is recommended that the terrain collection surfaces defined in Figure A8-1 are applied.

The collection of obstacle data should comply in accordance with the Area 2 numerical requirements (see section 3.7.2 of this Manual and Annex 15 Chapter 10 Table A8-2)

Further, this Recommended Practice relates only to those aerodromes "*regularly used by international civil aviation*". Guidance on the interpretation of this phrase may be found in section 5.1 of this Manual.

3.3.8 Para 10.1.8

ICAO Annex 15 Text:

"*Recommendation.— At aerodromes regularly used by international civil aviation, electronic terrain and obstacle data should be provided for Area 3 for terrain and obstacles that penetrate the relevant obstacle data collection surface specified in Appendix 8.-,Figure A8-3*"

3.3.8.1 Understanding of Requirement

As discussed in section 1.4 of this document, the original material that led to the inclusion of the terrain and obstacle data requirements in Chapter 10 of ICAO Annex 15 was developed by EUROCAE / RTCA, as ED-98A / DO-276A "User Requirements for Terrain and Obstacle Data". In this material, Area 3 was included as "Supplemental Terrain Requirements for Aerodrome Mapping". The area is introduced in ED-98A, as follows:

"*Aerodrome mapping is addressed in EUROCAE ED-99A/RTCA DO-272A "User requirements for Aerodrome Mapping Information", which establishes requirements for aerodrome databases, but does not address terrain requirements. This section describes the area and the terrain data numerical requirements for digital terrain data supporting applications described in EUROCAE ED-99A/RTCA DO-272A.*"

The Recommended Practice in ICAO Annex 15 reflects the situation described in EUROCAE ED-98A / RTCA DO-276A by specifying that Area 3 data should be provided, where there is a benefit, in order to support other data sets, such as airport maps.

According to Annex 15 Chapter 10 data collection for terrain and obstacles in Area 3 extends a half-metre (0.5 m) above the horizontal plane passing through the nearest point on the aerodrome movement area and shall comply with the numerical requirements specified in Table A8-1 and A8-2 respectively.

Aerodrome mapping data should be supported by electronic terrain and obstacle data for Area 3 in order to ensure consistency and quality of all geographical data related to the aerodrome.

3.3.9 Para 10.1.8

ICAO Annex 15 Text

"*At aerodromes regularly used by international civil aviation, electronic terrain and obstacle data shall be provided for Area 4 for terrain and obstacles that penetrate the relevant obstacle data collection surface specified in Appendix 8, for all runways where precision approach Category II or III operations have been established and where detailed terrain information is required by operators to enable them to assess, the effect of terrain on decision height determination by use of radio altimeters.*

Note.— Area 4 terrain data and Area 2 obstacle data are normally sufficient to support the production of the Precision Approach Terrain Chart — ICAO. When more detailed obstacle data is required for Area 4, this may be provided in accordance with the Area 4 obstacle data requirements specified in Appendix 8, Table A8-2. Guidance on appropriate obstacles for this chart is given in the Aeronautical Chart Manual (Doc 8697)."

3.3.9.1 Understanding of Requirement

Area 4 data will replace the need to digitise the PATC. This chart presents the general terrain profile for the area in advance of the threshold and any obstacles on it which may impact the aircraft's ability to determine its height above ground using RADALT.

As discussed in 3.3.2 of this Manual, the geographical scope of Area 4 matches that of the PATC.

This standard requires that terrain and obstacle data for this region is made available.

It should, however, be noted that the subsequent note suggests that an Area 2 data set is sufficient, in most cases, to meet the needs for obstacle data in Area 4. After analysis by navigation experts, this is not considered to be the case and the reader is recommended to disregard this note. The Area 2 obstacle data comprises those obstacles which penetrate a 1.2% assessment surface whilst, for Area 4, obstacles which do not penetrate this surface may impact the RADALT if their footprint is large enough.

For example, at 900m from the threshold, a 1.2% slope would allow obstacles of 10m to be excluded (1.2% of 900m = 10.8m), yet such an obstacle may have a significant effect on RADALT. Indeed, the requirements for the PATC give a clear indication that an obstacle of 3m height should be considered relevant. ICAO Annex 4 paragraph 6.5.1 2) states: "*an indication where the terrain or any object thereon, within the plan defined in 1) above, differs by ±3 m (10 ft) in height from the centre line profile and is likely to affect a radio altimeter*".

The situation whereby obstacles are needed for the PATC but do not exist in the Area 2 data set is demonstrated by the example[23] shown in Figure 17. As may be seen, the 1.2% assessment surface for Area 2 obstacles is highlighted in red, as are three obstacles which, although needing to be provided on the chart, have not penetrated this surface and would not, consequently, be present in the Area 2 data set.

[23] The PATC shown is for Filton airport runway 27 and is provided by the kind permission of the UK Civil Aviation Authority (CAA) whose copyright in this regard is duly noted.

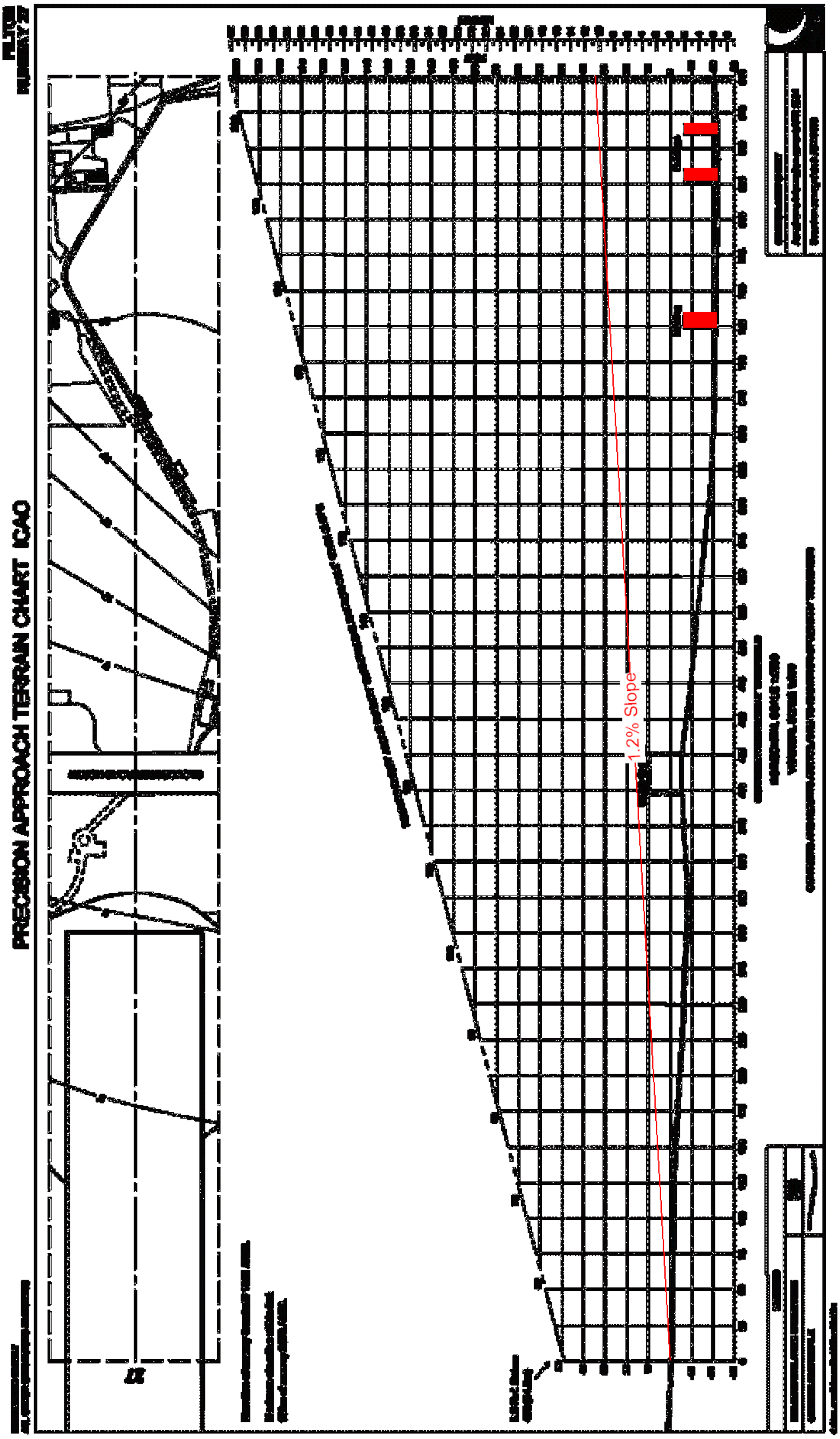


Figure 17: PATC Overlaid with 1.2% Surface Assessment Surface

3.3.10 Para 10.1.9

ICAO Annex 15 Text

"*Recommendation.— Where additional electronic obstacle or terrain data is collected to meet other aeronautical requirements, the obstacle and terrain data sets should be expanded to include these additional data.*"

3.3.10.1 Understanding of Requirement

In order to meet other needs, States may capture other electronic obstacle data which is not strictly required by the SARPs. For example, this may be for obstacle management purposes or, indeed, as a result of the survey techniques used to gather the obstacles that are needed.

In such cases, States may also wish to include these obstacles within their digital data sets, so as to provide a more complete data set. The commission of objects in the data set (i.e. objects which are not considered to be obstacles according to the definition given in the SARPs) should be declared as such in the metadata.

In should be noted that it is possible that not all metadata is present for these additional obstacles. The State should, in such cases, decide whether the obstacles should be included in the data set it makes available, or not. This decision will be based upon whether it is considered beneficial to have the obstacle data even though metadata is missing.

Where metadata is not present because it is unavailable, this should be clearly indicated in the metadata associated with the data set.

3.3.11 Para 10.1.10

ICAO Annex 15 Text

"*Recommendation.— Arrangements should be made for the coordination of providing Area 2 electronic terrain and obstacle data for adjacent aerodromes where their respective coverage Areas overlap to assure that the data for the same obstacle or terrain is correct.*"

3.3.11.1 Understanding of Requirement

In many States, and particularly around major cities, aerodromes may be located relatively close to each other, such that the Area 2 for the aerodromes overlaps. This is especially true when the full 45km is considered or a shared Terminal Area (TMA) exists for the aerodromes.

The Recommended Practice suggests that arrangements need to be established between these aerodromes to ensure that the terrain and obstacle data for these overlapping areas is "correct". It is considered important to define what is meant by "correct".

Two aerodromes could independently collect terrain and obstacle data and, in one case, the data is in fact higher than reality but within the accuracy requirements, and in the other, lower but, again, within the accuracy requirements. Similarly, the horizontal accuracies may be met in both cases but the two sets of data itself may be horizontally offset.

As the vertical accuracy for Area 2 is 3m and the horizontal accuracy is 5m, in the worst case, the two aerodromes could legitimately reflect the same obstacle with a 6m difference in height/elevation and a 10m difference in location. This is obviously not an ideal situation.

Such a situation is to be avoided wherever possible and this is the purpose of this Recommended Practice. The ideal situation would be for the aerodromes to work together to jointly procure a single survey as this would lead to a single, consistent data set. It is, however, apparent that such arrangements will not always be feasible. Where a single survey is not possible, the relevant aerodrome authorities should take steps to agree a single, harmonised representation of the terrain and obstacles in the overlapping area, whilst ensuring that the join between the overlapping and non-overlapping areas remains consistent.

3.3.12 Para 10.1.11

ICAO Annex 15 Text

"*Recommendation.— At those aerodromes located near territorial boundaries, arrangements should be made among States concerned to share Area 2 electronic terrain and obstacle data.*"

3.3.12.1 Understanding of Requirement

Many aerodromes are located very close to State boundaries and, in some cases, the TMA extends into the neighbouring State's territory. In these circumstances, there may be a need to collect data for those portions of Area 2 which are located in the neighbouring State.

Where there is a need to for the collection of the data for territory not under the direct responsibility of the State in which the aerodrome is located, there is the need for agreements to be reached for the collection of this data. This Recommended Practice proposes that in such cases, arrangements should be made between the relevant States to ensure that this terrain and obstacle data is collected in a manner which allows it to be shared and, therefore, also provides a cost-effective solution.

The issues relating to the costs of cross-border collection and responsibility for payment are addressed in Chapter 5 of this Manual.

3.4 ICAO Annex 15, Section 10.2 "Terrain Data Set — Content, Numerical Specification and Structure"

3.4.1 Para 10.2.1

ICAO Annex 15 Text

"*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."

3.4.1.1 Understanding of Requirement

This text provides the following requirements:

a) The terrain data shall be based upon a defined grid. "Defined" is understood to indicate that the spatial representation of the grid should be documented (co-ordinate reference system used, elevation reference, etc);

b) The elevation of the terrain shall be provided for each cell of the grid;

c) The elevations provided in the data set are all to be based upon a single vertical reference. Although not explicitly stated, it is assumed that a single horizontal reference shall also be used to define the grid. This is of particular relevance when terrain data is provided in multiple grids within a data set;

d) The terrain grid may be angular (meaning that it is based upon a grid which is formed by lines of latitude and longitude) or linear (meaning that the distance between the posts is fixed);

e) A regular shaped terrain data set is typically understood as a raster built by cells. Irregular terrain data sets are based on an irregular set of points (i.e. they are unevenly distributed) which are used to create a TIN.

3.4.2 Para 10.2.2

ICAO Annex 15 Text:

"*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”.*”

3.4.2.1 Understanding of Requirement

This standard provides clarification of what should be considered as terrain and, hence, captured for inclusion within the terrain data set.

Firstly, the requirement is for the data set to include:

- Positional information – the horizontal and vertical location for the terrain elevation value provided. This is considered to be self-explanatory;
- Thematic aspects of the terrain - This means that the surface type of the terrain may be gathered because it is considered to be beneficial for the selection of en-route emergency landing locations.
- Temporal aspects indicate that information related to the date and time at which the data was captured, shall be gathered and recorded. It should be noted that a single data set may include terrain which has been captured at many different points in time.

The standard continues by defining that the terrain modelled should reflect the surface of the earth and that, in particular, this includes areas of water and <u>permanent</u> ice or snow. This indicates that the terrain model is not intended to provide information relating to the sea bed or the bottom of lakes/rivers etc. Furthermore, where snow or ice exists on a permanent basis (i.e. permafrost[24]), this should be included in the terrain model.

It is clearly indicated that obstacles should not be included within the terrain model.

Lastly, the standard acknowledges the difficulty in ascertaining the precise nature of terrain in those areas where vegetation has an impact on the data capture (survey) techniques used. For example, in using Airborne Laser Scanning (ALS) (see section 7.2.2.3 of this Manual), the radar signal may not be reflected back to the sensor from the very top of the trees, rather it may penetrate the canopy for a distance before being reflected back. This results in the sensor believing that the top of the canopy is not, in actual fact, where it really is. The point at which the signal is reflected is, as mentioned in the ICAO text, referred to as the “first reflective surface. Key in such instances is to ensure that the terrain model correctly indicates that the area includes vegetation and that, consequently, there is a likelihood that the values provided are not the true surface of the terrain. In many cases, where the type of vegetation, season and the sensor are known, the likely penetration may be estimated.

3.4.3 Para 10.2.3

ICAO Annex 15 Text:

“*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.*”

3.4.3.1 Understanding of Requirement

This standard further elaborates the content of the terrain data set, once again stating that only terrain shall be included. In specifying the attributes that should be provided in the data set, it references Table A8-3 as providing the minimum set of attributes that shall be provided. As indicated, some of these attributes are mandatory and shall be provided, whereas others are optional. As this attribute list is described as the minimum set that shall be provided, it is considered that additional attributes may be provided, where appropriate.

Table A8-3 is described in section 3.7.7 of this Manual.

[24] Permafrost means a thick subsurface layer of soil that remains below freezing point throughout the year.

3.4.4 Para 10.2.4

ICAO Annex 15 Text:

"*Electronic terrain data for each area shall conform to the applicable numerical requirements in Appendix 8, Table A8-1.*"

3.4.4.1 Understanding of Requirement

This table, which is fully explained in section 3.7.5 of this Manual, provides the numerical requirements which must be met by the terrain data set. Numerical requirements provide, for example, the post-spacing and accuracies that must be achieved.

3.5 ICAO Annex 15, Section 10.3 "Obstacle Data Set — Content, Numerical Specification and Structure"

3.5.1 Para 10.3.1

ICAO Annex 15 Text

"*Obstacle data shall comprise the digital representation of the vertical and horizontal extent of the obstacle. Obstacles shall not be included in terrain data sets. Obstacle data elements are features that shall be represented in the data sets by points, lines or polygons.*"

3.5.1.1 Understanding of Requirement

This standard defines what is meant by obstacle data, reiterating that obstacles must not be included in the terrain data set. It indicates that obstacle data should provide a representation of the horizontal and vertical extent of the obstacles, in a digital form. It further outlines that these extents may be defined as a:

- Point: A single geographical location;
- Line: A series of geographical locations, comprising a minimum of two points;
- Polygon: A series of geographical locations that shall be closed to form a complete bounding box.

No indication is provided within ICAO Annex 15 as to when each of these representations should be used. Guidance on this topic may be found in Appendix B of this Manual.

3.5.2 Para 10.3.2

ICAO Annex 15 Text

"*In an obstacle data set, all defined obstacle feature types shall be provided and each of them shall be described according to the list of mandatory attributes provided in Appendix 8, Table A8-4.*

Note.— By definition, obstacles can be fixed (permanent or temporary) or mobile. Specific attributes associated with mobile (feature operations) and temporary types of obstacles are annotated in Appendix 8, Table A8-4, as optional attributes. If these types of obstacles are to be provided in the data set, appropriate attributes describing such obstacles are also required."

3.5.2.1 Understanding of Requirement

This standard further elaborates the content of the obstacle data set. In specifying the attributes that shall be provided in the data set, it references Table A8-4 as providing the minimum set of attributes that shall be provided. As this attribute list is described as the minimum set that shall be provided, it is considered that additional attributes may be provided, where appropriate.

Table A8-4 is described in section 3.7.8 of this Manual.

3.5.3 Para 10.3.3

ICAO Annex 15 Text

"*Electronic obstacle data for each area shall conform to the applicable numerical requirements in Appendix 8, Table A8-2.*"

3.5.3.1 Understanding of Requirement

This table, which is fully explained in section 3.7.6 of this Manual, provides the numerical requirements which must be met by the obstacle data set. Numerical requirements provide, for example, the vertical and horizontal accuracies that must be achieved.

3.6 ICAO Annex 15, Section 10.4 "Terrain and Obstacle Data Product Specifications"

3.6.1 Para 10.4.1

ICAO Annex 15 Text:

"*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.*"

3.6.1.1 Understanding of Requirement

ICAO is increasingly making use of other international and industry standards in the specifications provided by the Annexes. In relation to the provision of digital sets of terrain and obstacle data, ICAO has elected to make use of the ISO 19100 series of standards.

These standards, developed by the OGC which acts as the technical committee for these standards, provide a complete framework for the provision of information relating to geo-referenced elements. Adherence to the framework should enable interoperability between actors within the same domain, as well as across domains.

Further details of these standards may be found in sections 2 and 7.9 of this Manual.

3.6.2 Para 10.4.2

ICAO Annex 15 Text:

"*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."

3.6.2.1 Understanding of Requirement

The use of DPS is mandated by this standard. DPS provide a means by which the content of a data set is precisely specified. A DPS supports the party generating a data set by providing information as to what exactly should be included within the data set. The content of the DPS is closely related to the metadata model. The users of the data may determine, by comparing their DPS with the metadata, how the data may be used in their application and what mitigations, if any, are needed as result of, for example, the quality / completeness of the data.

The use of DPS is explained in more detail in sections 2.5.2 and 7.1 of this Manual.

3.6.3 Para 10.4.3

ICAO Annex 15 Text:

"*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.*"

3.6.3.1 Understanding of Requirement

This requirement specifies a set of topics which must be addressed, as a minimum, within the DPS for terrain data sets. The content of the DPS is the same as that provided in ISO 19131, in which, in contrast to the ICAO SARPs, several elements are not mandatory. The purpose of each of these topics is discussed in section 7.1 of this Manual.

3.6.4 Para 10.4.4

ICAO Annex 15 Text:

"*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.*"

3.6.4.1 Understanding of Requirement

This requirement outlines what should be included in the "specification scope" section of the DPS. The text is considered to be self-explanatory and no further elaboration is considered necessary.

3.6.5 Para 10.4.5

ICAO Annex 15 Text:

"*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."

3.6.5.1 Understanding of Requirement

This requirement outlines what should be included in the "data content and structure" section of the DPS. The text is considered to be self-explanatory. Guidance on the data content and structure is provided in section 7.1.5 of this Manual.

3.6.6 Para 10.4.6

ICAO Annex 15 Text:

"*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."

3.6.6.1 Understanding of Requirement

This requirement outlines what should be included in the "reference system" and "data quality" sections of the DPS. The text is considered to be self-explanatory. Guidance on reference systems is provided in sections 2.4 and 7.1.6 of this Manual. The background information on data quality can be found in section 2.5 and guidance on its application in the DPS is provided in section 7.1.7 of this Manual.

3.6.7 Para 10.4.7

ICAO Annex 15 Text:

"*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.*"

3.6.7.1 Understanding of Requirement

This requirement outlines what should be included in the "data capture" and "data maintenance" sections of the DPS. The text is considered to be self-explanatory. Guidance on data capture is provided in section 7.1.8 (high level statements) and in Appendix B (suggested feature capture rules for obstacles) of this Manual. Information on data maintenance is provided in section 4.1.13 of this Manual.

3.6.8 Para 10.4.8

ICAO Annex 15 Text:

"*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."

3.6.8.1 Understanding of Requirement

This requirement outlines what should be included in the "data portrayal" and the "data product delivery" sections of the DPS. The text is considered to be self-explanatory. Portrayal specification is not considered of relevance where the requirement is only for the provision of electronic data sets[25]. No guidance on the portrayal of terrain and obstacle data is provided in this Manual at the current time. Background information on data product delivery can be found in section 2.7 and guidance on its application in the DPS is provided in section 7.1.9 of this Manual.

3.6.9 Para 10.4.9

ICAO Annex 15 Text:

"*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."

[25] Portrayal specification could be of interest when there is a requirement for the preparation and delivery of charts. This is considered to go beyond the scope of the SARPs in ICAO Annex 15 Chapter 10 and the Terms of Reference of the TOD WG.

3.6.9.1 Understanding of Requirement

This requirement outlines what should be included in the “metadata” section of the DPS. The text is considered to be self-explanatory. More information on metadata can be found in section 7.7 of this Manual.

3.6.10 Para 10.4.10

ICAO Annex 15 Text:

“*The obstacle data product specification, supported by geographical coordinates for each aerodrome included within the data set, shall describe the following areas:*

— *Areas 2a, 2b, 2c, 2d;*

— *the take-off flight path area; and*

— *the obstacle limitation surfaces.*”

3.6.10.1 Understanding of Requirement

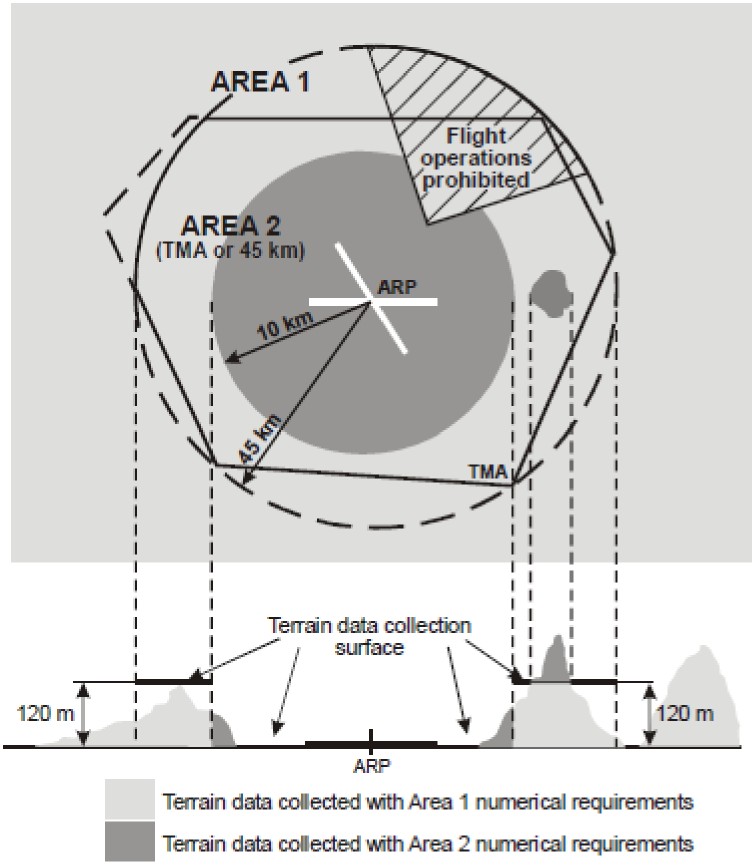
The “specification scope” section of the DPS allows differences which arise in terrain and obstacle data due to spatial or temporal extents (areas) or feature types (terrain vs. obstacle) to be described. This requirement states that such differentiation shall be made in the DPS. Although not explicitly stated, it is recommended that the “specification scope” section is used for the definition of the different areas (1, 2a, 2b, 2c, 2d, 3 and 4).

The take-off flight path area and the obstacle limitation surfaces have an impact on data capture and so it is important that these, and their impacts, are specified in the DPS. The requirement specifies that geographical co-ordinates shall be used to describe the geographical extents of these areas.

More information on the “specification scope” section of the DPS is provided in section 7.7.

3.7 ICAO Annex 15, Appendix 8 “Terrain and Obstacle Data Requirements”

3.7.1 Figure A8-1 “Terrain data collection surfaces — Area 1 and Area 2”



1. *“Within the area covered by a 10-km radius from the ARP, terrain data shall comply with the Area 2 numerical requirements.*
2. *In the area between 10 km and the TMA boundary or 45-km radius (whichever is smaller), data on terrain that penetrates the horizontal plane 120 m above the lowest runway elevation shall comply with the Area 2 numerical requirements.*
3. *In the area between 10 km and the TMA boundary or 45-km radius (whichever is smaller), data on terrain that does not penetrate the horizontal plane 120 m above the lowest runway elevation shall comply with the Area 1 numerical requirements.*
4. *In those portions of Area 2 where flight operations are prohibited due to very high terrain or other local restrictions and/or regulations, terrain data shall comply with the Area 1 numerical requirements.*

Note.— Terrain data numerical requirements for Areas 1 and 2 are specified in Table A8-1.

3.7.1.1 Understanding of Requirement

Note 1) indicates that all terrain within 10km of the Aerodrome Reference Point shall be collected in accordance with the Area 2 numerical requirements specified in ICAO Annex 15 Table A8-1. It should be noted that the Aerodrome Reference Point may not be centrally located on the airfield. Furthermore, the inner Area 2 terrain area is based upon a circular area, unlike the inner Area 2 obstacle areas (Area 2b and Area 2c) which extend 10km from the edges of Area 2a.

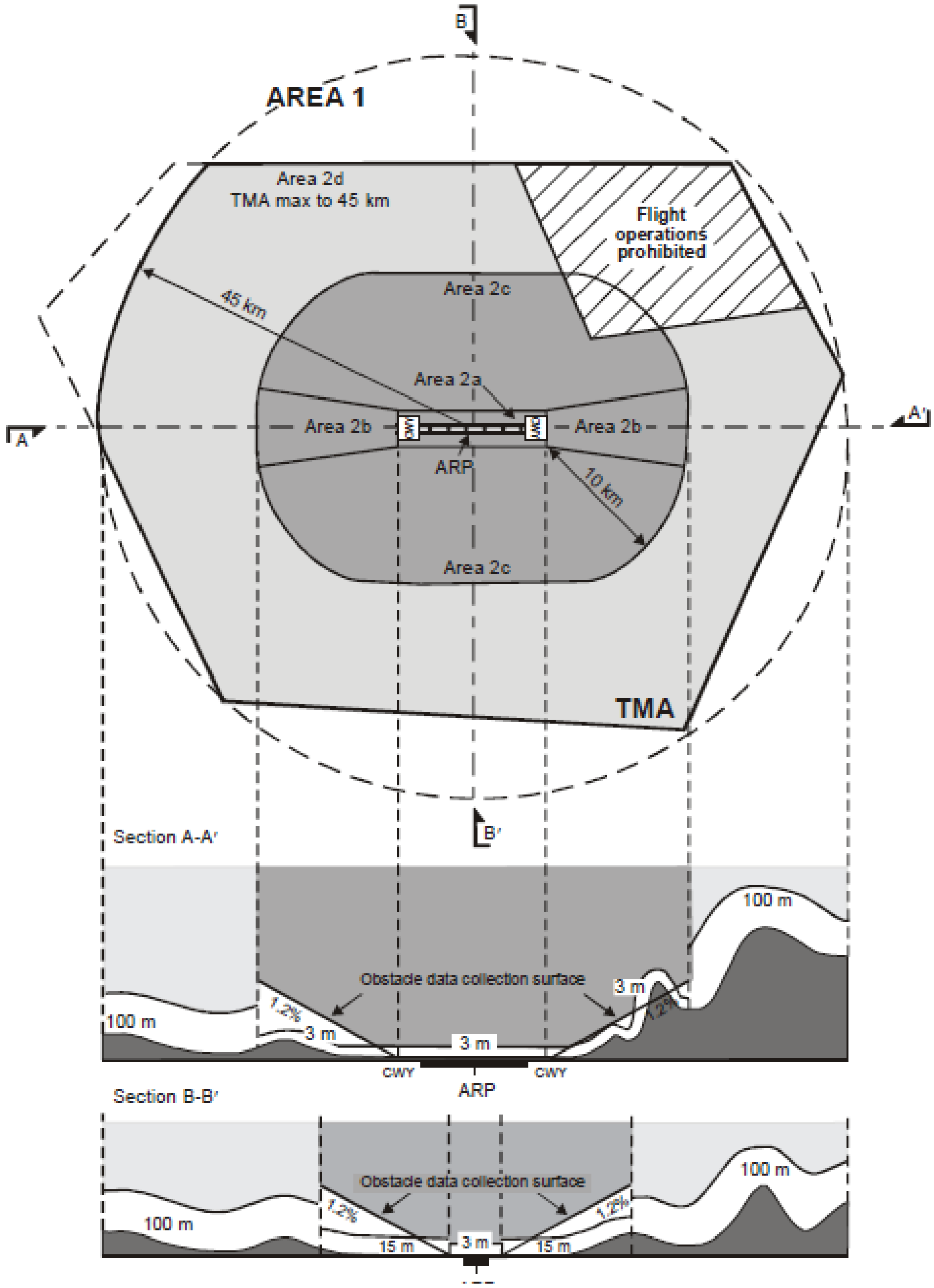
Note 2) requires any terrain located between 10km from the Aerodrome Reference Point and the outer edge of the Area 2, and which has an elevation higher than 120m above the lowest runway elevation at the aerodrome, to also be collected in accordance with the Area 2 numerical requirements specified in ICAO Annex 15 Table A8-1. Here it should be noted that the reference height is the lowest runway elevation and not that of the Aerodrome Reference Point.

Note 3) states that all other terrain in Area 2, not covered by Note 1) and Note 2), is to be collected in accordance with the Area 1 numerical requirements specified in ICAO Annex 15 Table A8-1.

Finally, Note 4) allows the exclusion of any areas in which flight operations are not permitted from the Area 2 numerical requirements. Instead, for these areas, the terrain should be captured in accordance with the Area 1 numerical requirements specified in ICAO Annex 15 Table A8-1.

It should be noted that this figure and its supporting notes provide a different set of collection surfaces for terrain to those presented in paragraphs 10.1.5 and 10.1.6 of ICAO Annex 15 (see sections 3.3.5 and 3.3.6 of this Manual). It is recommended that terrain data is collected in accordance with the surfaces defined by this figure rather than as specified in paragraphs 10.1.5 and 10.1.6 of ICAO Annex 15.

3.7.2 Figure A8-2 "Obstacle data collection surfaces — Area 1 and Area 2"



1. *"Obstacle data shall be collected and recorded in accordance with the Area 2 numerical requirements specified in Table A8-2:*

a) *Area 2a: a rectangular area around a runway that comprises the runway strip plus any clearway that exists. The Area 2a obstacle collection surface shall have height of 3 m above the nearest runway elevation measured along the runway centre line, and for those portions related to a clearway, if one exists, at the elevation of the nearest runway end;*

b) *Area 2b: an area extending from the ends of Area 2a in the direction of departure, with a length of 10 km and a splay of 15% to each side. The Area 2b obstacle collection surface has a 1.2% slope extending from the ends of Area 2a at the elevation of the runway end in the direction of departure, with a length of 10 km and a splay of 15% to each side. Obstacles less than 3 m in height above ground need not be collected;*

c) *Area 2c: an area extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a. The Area 2c obstacle collection surface has a 1.2% slope extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a. The initial elevation of Area 2c shall be the elevation of the point of Area 2a at which it commences Obstacles less than 15 m in height above ground need not be collected; and*

d) *Area 2d: an area outside the Areas 2a, 2b and 2c up to a distance of 45 km from the aerodrome reference point, or to an existing TMA boundary, whichever is nearest. The Area 2d obstacle collection surface has a height of 100 m above ground.*

2. *In those portions of Area 2 where flight operations are prohibited due to very high terrain or other local restrictions and/or regulations, obstacle data shall be collected and recorded in accordance with the Area 1 requirements.*
3. *Data on every obstacle within Area 1 whose height above the ground is 100 m or higher shall be collected and recorded in the database in accordance with the Area 1 numerical requirements specified in Table A8-2."*

3.7.2.1 Understanding of Requirement

Bullet 1. provides an explanation of the obstacle assessment surfaces for the four sub-areas of Area 2. These are explained by the sub-notes, as follows:

a) Area 2a is a rectangular area which encompasses the runway strip and any clearways that exist. To elaborate, the rectangular area will comprise the area between the runway thresholds (or runway end(s) where displaced threshold(s) exist) and beyond this to the end of any defined clearway(s).

The use of the word "comprises" has been questioned by some stakeholders as it considered imprecise and leaves room for the extension of Area 2a beyond the minimum needed. It is believed that for standardisation and harmonisation purposes, the text should be a clear statement of the minimum area for which the data shall be provided. As such, it is recommended that Area 2a should not be extended beyond the minimum specified without due consideration being given to the consequences of any extension.

The obstacle assessment surface is then defined, such that any object extending 3m or higher above the elevation of the nearest point on the extended runway centre line is captured.

b) Area 2b, as described, is a surface that extends from the outer ends of Area 2a, with a 15% splay to either side. This surface commences at the elevation of the nearest runway threshold or runway end, in case of a displaced threshold, and slopes upwards at an angle of 1.2%.

As indicated by the figure and the text provided in paragraph 10.1.6, all obstacles which penetrate this surface and whose height above ground level is 3m or greater must be collected.

c) Area 2c is described as the area within 10km of the edges of Area 2a, excluding those parts identified as being Area 2b. Once again, a 1.2% sloped assessment surface is identified.

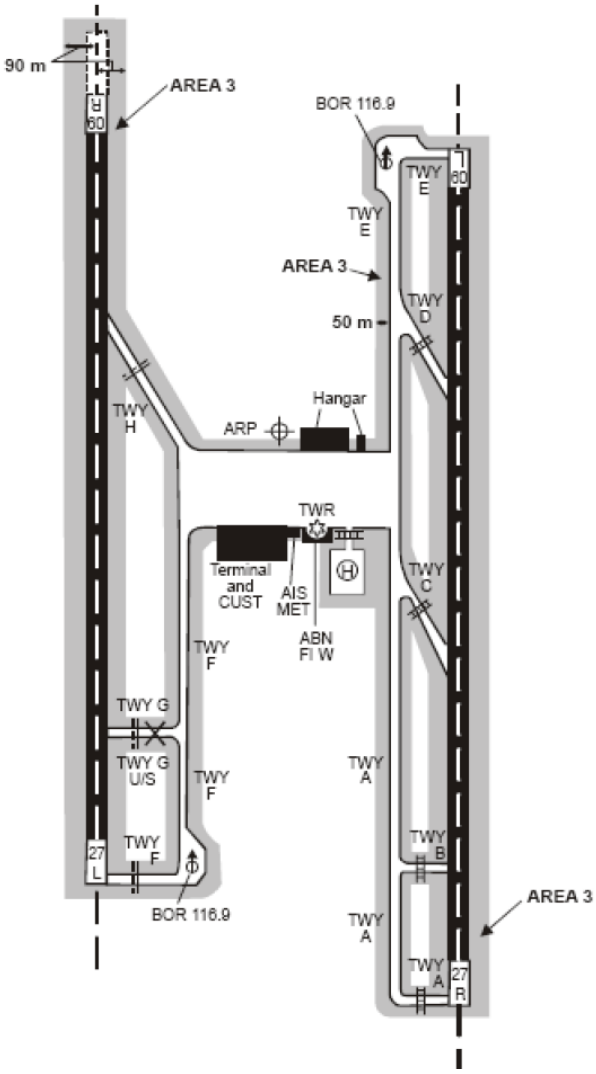
As indicated by the figure and the text provided in paragraph 10.1.6, all obstacles which penetrate this surface and whose height above ground level is 15m or greater must be collected.

d) Area 2d is identified as the area extending from the outer edges of Area 2b and Area 2c, out to a distance of 10km or the TMA boundary, whichever is the closest. Given that the TMA boundary is only mentioned in point d), it is assumed that should the TMA end closer to Area 2a than 10km, Area 2b and 2c would still extend to 10km, despite extending further than the TMA boundary.

Bullet 2. allows the exclusion of any areas in which flight operations are not permitted from the Area 2 numerical requirements. For these areas, the obstacles should be captured in accordance with the Area 1 numerical requirements specified in ICAO Annex 15 Table A8-2.

Bullet 3. states that any other obstacles that exist within the State, whose height above ground level is 100m or greater, should be collected in accordance with the Area 1 numerical requirements specified in ICAO Annex 15 Table A8-2.

3.7.3 Figure A8-3 "Terrain and obstacle data collection surface — Area 3"



1. "The data collection surface for terrain and obstacles extends a half-metre (0.5m) above the horizontal plane passing through the nearest point on the aerodrome movement area.

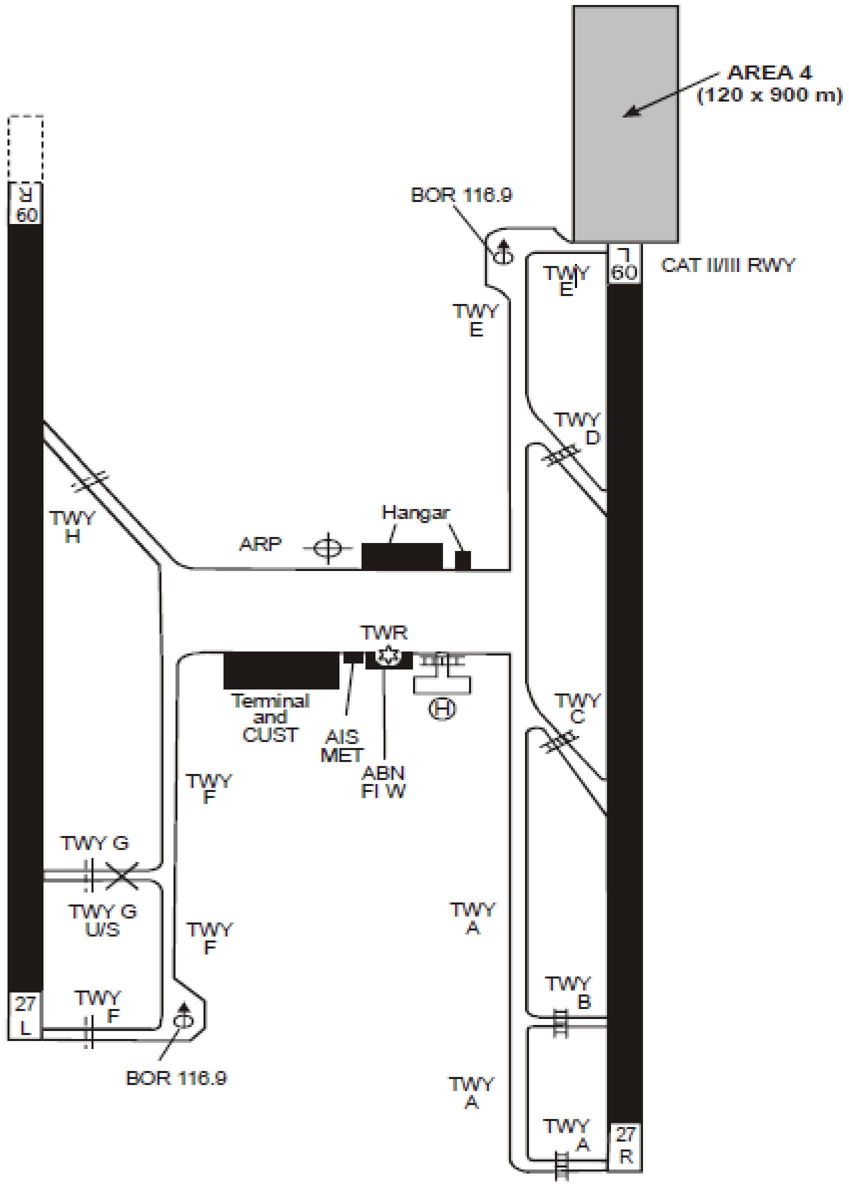
2. Terrain and obstacle data in Area 3 shall comply with the numerical requirements specified in Table A8-1 and Table A8-2, respectively."

3.7.3.1 Understanding of Requirement

Bullet 1. requires that any terrain or obstacles whose elevation is 0.5m or greater than the elevation of the nearest point on the movement area, are collected. This results in data being collected for only those "islands" where this surface has been penetrated. No data is collected within the Area 3 data set for other objects or terrain which exist below this assessment surface.

Bullet 2. simply indicates that where terrain data is collected, it should be done so in accordance with the Area 3 numerical requirements specified in ICAO Annex 15 Table A8-1 and any obstacles should be collected in accordance with the Area 3 numerical requirements specified in ICAO Annex 15 Table A8-2.

3.7.4 Figure A8-4 "Terrain and obstacle data collection surface — Area 4"



"Terrain and obstacle data in Area 4 shall comply with the numerical requirements specified in Table A8-1 and Table A8-2 respectively.

Note — Area 4 may be extended in accordance with 10.1.2."

3.7.4.1 Understanding of Requirement

The text supporting Figure A8-4 indicates that where terrain and obstacle data is collected, it should be done so in accordance with the Area 4 numerical requirements specified in ICAO Annex 15 Table A8-1 and Table A8-2 respectively.

The Note indicates that Area 4 may be increased in size, as recommended in paragraph 10.1.2 of ICAO Annex 15. See section 3.3.2 of this Manual for more information on this extension.

3.7.5 Table A8-1 "Terrain data numerical requirements"

	Area 1	*Area 2*	*Area 3*	*Area 4*
Post spacing	*3 arc seconds (approx. 90 m)*	*1 arc second (approx. 30 m)*	*0.6 arc seconds (approx. 20 m)*	*0.3 arc seconds (approx. 9 m)*
Vertical accuracy	*30 m*	*3 m*	*0.5 m*	*1 m*
Vertical resolution	*1 m*	*0.1 m*	*0.01 m*	*0.1 m*
Horizontal accuracy	*50 m*	*5 m*	*0.5 m*	*2.5 m*
Confidence level	*90%*	*90%*	*90%*	*90%*
Integrity classification	*Routine*	*Essential*	*Essential*	*Essential*
Maintenance period	*as required*	*as required*	*as required*	*as required*

3.7.5.1 Understanding of Requirement

The numerical requirements for terrain data comprise the following elements:

- Post Spacing:

  The post spacing indicates the horizontal distance between the points of the terrain elevation. As the post spacing applies in both the longitudinal and latitudinal directions, this leads to the frequently used phrase "terrain grid".

- Vertical Accuracy:

  The vertical accuracy provides the maximum permitted difference between the measured elevation and reality, which must be achieved with the corresponding level of confidence. For example, the vertical accuracy may be 3m with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum vertical deviation of 3m from the true value.

- Vertical Resolution:

  The vertical resolution indicates the number of places of units/digits to which the elevation has been determined. For example, if the resolution was stated as 0.01m and the elevation was recorded as 20.573m, it is clear that only the elevation of 20.57m should be trusted and the additional 0.003m recorded ignored. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

  It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Horizontal Accuracy:

  The horizontal accuracy provides the maximum permitted difference between a measured horizontal position and reality, which must be achieved with the corresponding level of confidence. For example, the horizontal accuracy may be 5m with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum horizontal deviation of 5m or less from the true value.

- Confidence Level:

  The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate. A required confidence level of 90% indicates that 90% of the measured points should meet their respective accuracy requirements.

- Integrity Classification:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The routine and essential data for TOD corresponds to a very low and low probability when using corrupted data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe. The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

  Based on the applicable integrity classifications, the validation and verification procedures should ensure that the corruption is avoided throughout the processing of the routine data and for essential data that corruption does not occur at any stage of the entire process and may include additional processes as needed to address potential risks in the overall system architecture to further assure data integrity at this level.

  The integrity classification is applicable to all aeronautical data and guidance on how the integrity of data may be maintained through the application of process assurance could be found in EUROCONTROL Specification for Data Assurance Levels.

- Maintenance Period:

  The maintenance period defines the frequency at which the State is expected to resurvey and/or confirm the correctness of the data issued. As this period is defined as being “as required”, the State is left to determine its own policy. Guidance on the maintenance of terrain data is provided in section 4.1.13 of this Manual.

It should be noted that there is no specification for horizontal resolution. Given the accuracy requirements, it is recommended that the following is applied:

	Area 1	***Area 2***	***Area 3***	***Area 4***
Horizontal resolution	*1 m*	*0.1 m*	*0.01 m*	*0.01 m*

3.7.6 Table A8-2 “Obstacle data numerical requirements”

	Area 1	***Area 2***	***Area 3***	***Area 4***
Vertical accuracy	*30 m*	*3 m*	*0.5 m*	*1 m*
Vertical resolution	*1 m*	*0.1 m*	*0.01 m*	*0.1 m*
Horizontal accuracy	*50 m*	*5 m*	*0.5 m*	*2.5 m*
Confidence level	*90%*	*90%*	*90%*	*90%*

Integrity classification	*Routine*	*Essential*	*Essential*	*Essential*
Maintenance period	*as required*	*as required*	*as required*	*as required*

3.7.6.1 Understanding of Requirement

The numerical requirements for obstacle data comprise the following elements:

- Vertical Accuracy:

  The vertical accuracy provides the maximum permitted difference between the measured elevation of an obstacle and reality, which must be achieved with the corresponding level of confidence. For example, the vertical accuracy may be 3m with a confidence level of 90%. This indicates that 90% of the measured elevations will have a maximum vertical deviation of 3m from the true value.

- Vertical Resolution:

  The vertical resolution indicates the number of places of units/digits to which the elevation has been determined. For example, if the resolution was stated as 0.01m and the elevation was recorded as 20.573m, it is clear that only the elevation of 20.57m should be trusted and the additional 0.003m recorded ignored. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

  It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Horizontal Accuracy:

  The horizontal accuracy provides the maximum permitted difference between a measured horizontal position and reality, which must be achieved with the corresponding level of confidence. For example, the horizontal accuracy may be 5m with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum horizontal deviation of 5m from the true value.

- Confidence Level:

  The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate. A required confidence level of 90% indicates that 90% of the measured points should meet their respective accuracy requirements.

  It should be noted that the required confidence level for obstacles published in the AIP is 95% (see ICAO Annex 15, paragraph 3.7.6) and that, if the electronic data set is to act as the source of this information, a higher confidence level than the 90% required in Table A8-2 will be needed.

- Integrity Classification:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The routine and essential data for TOD corresponds to a very low and low probability when using corrupted data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe. The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

  Based on the applicable integrity classifications, the validation and verification procedures should ensure that the corruption is avoided throughout the processing of the routine data and for essential data that corruption does not occur at any stage of the entire process and may include additional processes as needed to address potential risks in the overall system architecture to further assure data integrity at this level.

  The integrity classification is applicable to all aeronautical data and guidance on how the integrity of data may be maintained through the application of process assurance could be found in EUROCONTROL Specification for Data Assurance Levels.

- Maintenance Period:

  The maintenance period defines the frequency at which the State is expected to resurvey and/or confirm the correctness of the data issued. As this period is defined as being "as required", the State is left to determine its own policy. Guidance on the maintenance of obstacle data is provided in section 4.1.13 of this Manual.

It should be noted that there is no specification for horizontal resolution. Given the accuracy requirements, it is recommended that the following is applied:

	Area 1	**Area 2**	**Area 3**	**Area 4**
Horizontal resolution	*1 m*	*0.1 m*	*0.01 m*	*0.01 m*

3.7.7 Table A8-3 "Terrain attributes"

Terrain attribute	***Mandatory/Optional***
Area of coverage	*Mandatory*
Data originator identifier	*Mandatory*
Data source 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	*Optional*
Recorded surface	*Mandatory*
Penetration level	*Optional*
Known variations	*Optional*
Integrity	*Mandatory*
Date and time stamp	*Mandatory*
Unit of measurement used	*Mandatory*

3.7.7.1 Understanding of Requirement

In describing the application of data and metadata, it is important to understand the level at which these should be applied. The levels of digital terrain data may be described as follows:

- Data Set Level:

  A data set delivered to the user which may comprise one or more terrain areas. For example, Area 2 for an aerodrome, along with its Area 3 data and several sets of Area 4, depending upon the number of CAT II/III runways available;

- Terrain Area Level:

  Data for a single terrain area. For example, Area 2 for an aerodrome;

- Data Level:

  A number of measured “posts” which make up the data for the area.

The following provides a description of each of the attributes in Table A8-3 and their intent. Unless otherwise stated, the provision of the attributes is mandatory.

- Area of coverage:

  A description of the geographical area for which the data set provides coverage. This should be provided as a series of co-ordinates describing a bounding box.

  This metadata should relate to the entire data set and if data for more than one terrain area is provided within the data set, it should also be provided for each terrain area.

  For example, a single data set may be provided for a TMA comprising several aerodromes, each of which provides terrain data for Area 2, Area 3 and Area 4. Therefore, the geographic area of coverage should be provided for the whole data set and then for each terrain area.

- Data originator identifier:

  An indication of who the originating authority for the terrain data is. The data originator is considered to be the entity which performs measurements and represents it in the form of area of terrain. Typically for terrain this metadata should be provided at the level of the data set or at the level of the areas contained within it when the dataset comprises several areas of terrain.

  For example, a single data set may be provided for a TMA comprising several aerodromes, each of which provides Area 2, Area 3 and Area 4 terrain data.

- Data source identifier:

  An indication of the entity that provides the data set. This metadata should be provided at the level of the data set or at the level of each terrain area within the dataset. Typically, the Data source would be the entity collecting the relevant terrain data within the State, assembling the database and providing the data set for next-intended users.

- Acquisition method:

  The acquisition method relates to the means used to collect the data in the data set. As the data set often comprises information gathered through several surveys, possibly using different acquisition methods, it is recommended that the method is reported for each individual post measurement (data level).

- Post spacing:

  The term “post spacing” refers to the distance between the measured points, i.e. it gives the two lateral spaces which define the terrain model’s grid squares. It should be noted that the post spacing may be different in the latitudinal and longitudinal directions, leading to the grid squares being rectangular in shape.

  The post spacing may differ for the different areas for which data is provided for within the data set and should, therefore, be provided at the level of the area.

- Horizontal reference system:

  A record of the reference system used for each of the horizontal positions included within the data set. It is not recommended that different horizontal reference systems are used within a data set. As a result, it is recommended that this metadata is provided at the level of the data set although there is no issue if it is also provided at the level of an area or post measurement (data level).

- Horizontal resolution:

  The horizontal resolution indicates the number of places of digits/units to which the horizontal position has been determined. For example, if the horizontal resolution was provided as 1/10 second and the position included the figure, 031º55'18.61"W, it is clear that the information provided after 031º55'18.6"W should not be trusted. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

  The horizontal resolution may differ for the different areas for which data is provided within the data set and should, therefore, be provided at the level of the area.

  It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Horizontal accuracy:

  The horizontal accuracy provides the maximum permitted difference between a measured horizontal position and reality, which must be achieved with the corresponding level of confidence. For example, the horizontal accuracy may be 5m, with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum horizontal deviation of 5m from the true value.

  As the data set may contain data resulting from different surveys and the horizontal accuracy may be different depending upon the survey, this metadata should be recorded at the level of the post measurement (data level).

- Horizontal confidence level:

  The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate. As this confidence level is typically determined by the process and technique applied to gather the source data, and a data set often comprises information gathered through several surveys, it is recommended that the confidence level is reported for each individual post measurement (data level), for each area included in the data set, and also for the entire data set.

- Horizontal position:

  Terrain data primarily contains elevations representing the surface of the earth. Elevations are captured for a series of "posts" which are horizontal positions and this attribute comprises these positions (data level).

  All horizontal positions should be referenced to a single horizontal reference system.

- Elevation:

  Each post measurement has a single elevation value associated with it (data level). All elevations should be made using a single vertical reference system.

- Elevation reference:

  The elevation reference describes how elevation values in the DEM are related to the universe of discourse (see section 2.3.1 for a description of this term). The provided values may correspond to a particular corner or the centre of a DEM cell, the mean elevation value of the area covered by the cell, the maximum elevation value, etc. It is not recommended that different elevation reference systems are used within a data set. As a result, it is recommended that this metadata is provided at the level of the data set although there is no issue if it is also provided at the level of an area or post measurement (data level).

- Vertical reference system:

  A record of the reference system used for each of the vertical measurements included within the data set. It is not recommended that different vertical reference systems are used within a data set. As a result, it is recommended that this metadata is provided at the level of the data set although there is no issue if it is also provided at the level of an area or post measurement (data level).

- Vertical resolution:

  The vertical resolution indicates the number of places of units/digits to which the elevation has been determined (data level). For example, if the resolution was stated as 0.01m and the elevation was recorded as 20.573m, it is clear that only the elevation of 20.57m should be trusted and the additional 0.003m recorded ignored. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

  It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Vertical accuracy:

  The vertical accuracy provides the maximum permitted difference between the measured elevation and reality that is which must be achieved with the corresponding level of confidence. For example, the vertical accuracy may be 3m, with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum vertical deviation of 3m from the true value.

  As the data set may contain data resulting from different surveys and the vertical accuracy may be different depending upon the survey, this metadata should be recorded at the level of the post measurement (data level).

- Vertical confidence level:

  The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate

  As this confidence level is typically determined by the process and technique applied to gather the source data, and a data set often comprises information gathered through several surveys, it is recommended that the confidence level is reported for each individual post measurement (data level), for each area included in the data set and for the entire data set.

- Surface type:

  The surface type attribute should be used to indicate the type of terrain that is located at the point at which the elevation was measured. For example, this may be water, permafrost, rock, sand, etc. This metadata should be provided at the level of the post measurement (data level).

  This attribute is optional. It has been determined that the cost of providing this information is likely to be high and it is, therefore, recommended that if it is not already available that careful consideration is given as to whether it is provided, or not.

- Recorded surface:

  There are different kinds of DEMs, depending on the surface they represent. The recorded surface attribute should be used to indicate if it is the bare earth (also called DTM), a surface model (DSM) or something in between (for more information see also section 2.1 in this Manual).

  The recorded surface may differ for the different areas within the data set, depending on the survey method used, and should, therefore, be provided at the level of the collection area.

- Penetration level:

  As discussed in section 3.4.2 of this Manual, where the terrain is covered in vegetation, some data capture techniques do not result in the identification of the top of the vegetation. This attribute should provide an indication of the level of penetration into the vegetation that was likely to have resulted from the survey technique used.

  As the data set may contain data resulting from different surveys and the penetration may be different depending upon the type of vegetation and season, this metadata should be recorded at the level of regions (groups of post measurement with same penetration level), if the values deviate within the data set.

  This attribute is optional.

- Known variations:

  The attribute known variations should be used to describe predictable changes to the data e.g., seasonal elevation changes due to snow accumulations or vegetation growth. More information on this attribute is given in section 7.7. The known variation may differ for different areas of a data set and should, therefore, be provided at the level of the post measurement (data level).

  This attribute is optional.

- Integrity:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The routine and essential data for TOD corresponds to a very low and low probability when using corrupted data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe. The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

  The integrity of each obstacle should be recorded (data level), as well as indicating the lowest integrity classification level for each area and for the complete data set.

  A guidance on how the integrity of data may be maintained through the application of process assurance could be found in EUROCONTROL Specification for Data Assurance Levels.

- Date and time stamp:

  This attribute should be applied at the level of the individual post measurement (data level) and at the data set level. It shall provide the date and time at which the obstacle / data set was created or last modified.

- Unit of measurement used:

  The unit of measurement for any items provided. Depending on the way in which the vertical accuracy is recorded, this is only likely to be needed for the elevation/height and possibly for the post spacing items.

  Wherever possible, a single unit of measurement should be used within the data set, for each measurement type. For example, the use of metres or feet, not both. As a result, this attribute should normally be provided at the level of the data set. However, where a mixture of units is used, this may be applied at the level of the attribute instance.

3.7.8 Table A8-4 “Obstacle attributes”

Obstacle attribute	***Mandatory/Optional***
Area of coverage	*Mandatory*
Data originator identifier	*Mandatory*
Data source identifier	*Mandatory*

Obstacle identifier	*Mandatory*
Horizontal accuracy	*Mandatory*
Horizontal confidence level	*Mandatory*
Horizontal position	*Mandatory*
Horizontal resolution	*Mandatory*
Horizontal extent	*Mandatory*
Horizontal reference system	*Mandatory*
Elevation	*Mandatory*
Height	*Optional*
Vertical accuracy	*Mandatory*
Vertical confidence level	*Mandatory*
Vertical resolution	*Mandatory*
Vertical reference system	*Mandatory*
Obstacle type	*Mandatory*
Geometry type	*Mandatory*
Integrity	*Mandatory*
Date and time stamp	*Mandatory*
Unit of measurement used	*Mandatory*
Operations	*Optional*
Effectivity	*Optional*
Lighting	*Mandatory*
Marking	*Mandatory*

3.7.8.1 Understanding of Requirement

In describing the application of data and metadata, it is important to understand the level at which these should be applied. The levels of digital obstacle data may be described as follows:

- Data Set Level:

  A data set delivered to the user which may comprise one or more obstacle areas. For example, Area 2 for an aerodrome, along with its Area 3 data and several sets of Area 4, depending upon the number of CAT II/III runways available;

- Obstacle Area Level:

  Data for a single obstacle area. For example, Area 2 for an aerodrome;

- Data Level:

  A number of measured obstacle features which make up the data for the area.

The following provides a description of each of the attributes in Table A8-4 and their intent. Unless otherwise stated, the provision of the attributes is mandatory.

- Area of coverage:

  A description of the geographical area for which the data set provides coverage. This should be provided as a series of co-ordinates describing a bounding box.

  This metadata should relate to the entire data set and, if more than one area is provided within the data set, for each area provided. For example, a single data set may be provided for a TMA comprising several aerodromes, each of which provides Area 2, Area 3 and Area 4 data.

Therefore, the area of coverage should be provided for the whole data set and then for each area.

- Data originator identifier:

  An indication of who the originating authority for obstacle data is. The data originator is considered to be the entity which performs measurements and represents it in the form of set of obstacles. Typically this metadata should be provided for each obstacle represented.

- Data source identifier:

  An indication of the entity that provides the data set. This metadata should be provided at the level of the data set and then at the level of each obstacle area contained within the dataset. Typically, the Data source would be the entity collecting obstacle data within the State, assembling the database and providing the data set for next-intended users.

- Obstacle identifier:

  Each obstacle that has been collected should be allocated a unique identifier which will remain the primary means of identifying the obstacle throughout its life, i.e. it should not be changed as a result of a resurvey or reissue of a data set. The identifier should be independent of any data set within which it is contained, such that if it were to appear in more than one area or delivered data set, it should retain the same identifier.

  In order to achieve this, there is a need to carefully consider the application of a policy for the allocation of unique identifiers (see section 4.1.14 of this Manual) and the reconciliation of obstacles between different surveys (either resulting from overlapping surveys or resurveys) must be assured (see section 7.8of this Manual).

- Horizontal accuracy:

  The horizontal accuracy provides the maximum permitted difference between a measured horizontal position of the obstacle and reality, which must be achieved with the corresponding level of confidence. For example, the horizontal accuracy may be 5m, with a confidence level of 90%. This indicates that 90% of the measured points will have a maximum horizontal deviation of 5m from the true value.

  The horizontal accuracy should be recorded for each obstacle contained within the data set (data level).

- Horizontal confidence level:

  The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate. The confidence level is reported for each individual obstacle contained within the data set (data level).

- Horizontal position:

  The horizontal position should contain sufficient location information to describe the profile of the obstacle, either as a point, line or polygon. The determination of which of these should be used will be based upon the size of the obstacle and the areas within which it exists. Guidance on the representation of obstacles as points, lines and polygons may be found in Appendix B of this Manual. The horizontal position should be provided for each obstacle in the data set (data level).

  All horizontal positions should be referenced to a single horizontal reference system.

- Horizontal resolution:

  The horizontal resolution indicates the number of places of digits/units to which the horizontal position of the obstacle has been determined. For example, if the horizontal resolution was provided as 1/10 second and the position included the figure, 031º55’18.61”W, it is clear that the information provided after 031º55’18.6”W should not be trusted. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Horizontal extent:

The horizontal extent could be used to indicate the horizontal footprint of an obstacle (data level). Given that the geometry type already describes the profile of an obstacle, it is recommended that this attribute is only used for point or line obstacles, to indicate the level of geometric simplification (see information on feature capture rules in Appendix B).

- Horizontal reference system:

A record of the reference system used for each of the horizontal positions included within the data set. It is not recommended that different horizontal reference systems are used within a data set. As a result, it is recommended that this metadata is provided at the level of the data set although no problem is foreseen if it is also provided at the level of each obstacle (data level).

- Elevation:

Each obstacle should have the elevation of its highest point measured and recorded in the data set (data level). All elevations should be measured using a single vertical reference system.

- Height:

Whilst the elevation of an obstacle typically comprises its height above MSL, its height above ground level should also be measured (data level). It should, however, be noted that the key information is the elevation of the obstacle and that the height above ground for an obstacle may vary depending on the position at which it is measured and an uneven ground profile.

This attribute is optional.

- Vertical accuracy:

The vertical accuracy provides the maximum permitted difference between the measured elevation of an obstacle and reality which must be achieved with the corresponding level of confidence. For example, the vertical accuracy may be 3m, with a confidence level of 90%. This indicates that 90% of the measured elevations will have a maximum vertical deviation of 3m from the true value.

As obstacles may have been measured by different surveys, this metadata should be recorded at the obstacle level (data level).

- Vertical confidence level:

The probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate. As this confidence level is typically determined by the process and technique applied to gather the source data, and a data set often comprises information gathered through several surveys, the confidence level should be recorded for each individual obstacle included in the data set (data level).

- Vertical resolution:

The vertical resolution indicates the number of places of units/digits to which the elevation has been determined. For example, if the resolution was stated as 0.01m and the elevation was recorded as 20.573m, it is clear that only the elevation of 20.57m should be trusted and the additional 0.003m recorded ignored. The apparent additional information may result from the means used to store the information, for example, through the use of floating point numbers.

It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

- Vertical reference system:

  A record of the reference system used for each of the vertical measurements included within the data set. It is not recommended that different vertical reference systems are used within a data set. As a result, it is recommended that this metadata is provided at the level of the data set although there is no issue if it is also provided at the level of an area or individual obstacle (data level).

  It is unclear what the relationship between vertical reference system and elevation reference is.

- Obstacle type:

  An indication of the type of obstacle recorded. This should be assessed against a generic set of obstacle types which includes types such as tree, building, wind-turbine, etc.

  This information is linked to the obstacles recorded and should, therefore, be provided at this level (data level).

- Geometry type:

  An indication of how the obstacle is described, in respect of whether it is a point, line or polygon (data level).

- Integrity:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The routine and essential data for TOD corresponds to a very low and low probability when using corrupted data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe. The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

  The integrity of each obstacle should be recorded (data level), as well as indicating the lowest integrity classification level for each area and for the complete data set.

  A guidance on how the integrity of data may be maintained through the application of process assurance could be found in EUROCONTROL Specification for Data Assurance Levels.

- Date and time stamp:

  This attribute should be applied at the data level and the date and time at which the data set was created or last modified should also be provided.

- Unit of measurement used:

  The unit of measurement should be recorded for any numerical data item where it has not already been documented.

  Wherever possible, a single unit of measurement should be used within the data set, for each measurement type. For example, the use of metres or feet, not both. As a result, this attribute should normally be provided at the level of the data set. However, where a mixture of units is used, this may be applied at the level of the attribute instance.

- Operations:

  This attribute is used to reflect the current status of the obstacle. It may be used, for example, to indicate that the obstacle is:

  - Planned;
  - Under construction;
  - Completed;

  - Demolition planned;
  - In demolition.

  This attribute is optional.

- Effectivity[26]:

  Unlike terrain which changes slowly and tends to be already exist when it is measured, many obstacles are planned, built and, in time, removed. As a result, obstacles may need to be published which do not yet exist but which will do at a defined point in time (or at least the protection area for them must be made available to allow for their construction). Consequently, information may be made available that it is known to not be effective until a point in the future. This attribute should be used to indicate when an obstacle should be considered as being effective (i.e. impacting flight operations) and when it is no longer effective.

  The effectivity of individual obstacles should be recorded (data level) and the complete data set should have its effective period identified.

  This attribute is optional.

- Lighting:

  Any lighting which may be used for aviation purposes (i.e. that required by ICAO) which is situated on the obstacles in the data set should be recorded using this attribute. It is applicable to individual obstacles and, therefore, applies at the data level.

  The actual lighting associated with an obstacle should be confirmed. Sole reliance upon legal obligations for the owner to notify the authorities of lighting should be minimised.

- Marking:

  Any markings intended to be used for aviation purposes (i.e. those required by ICAO) which are applied to obstacles in the data set should be recorded using this attribute. It is applicable to individual obstacles and, therefore, applies at the data level.

  The actual marking associated with an obstacle should be confirmed. Sole reliance upon legal obligations for the owner to notify the authorities of marking should be minimised.

3.8 Announcement of the TOD availability in the AIP

This section sets out the harmonised approach to announcing the availability of electronic Terrain and Obstacle Data (eTOD) in the national Aeronautical Information Publications (AIP).

Terrain: Information on availability and detailed information on how to obtain the Areas 1-4 terrain datasets should be provided in GEN 3.1.6 of the AIP.

Obstacles: The list of obstacles affecting air navigation in Area 1 shall be included in ENR 5.4 and Areas 2 and 3 shall be included in AD 2.10 and/or if appropriate, there should be an indication that the list of obstacles is available in electronic form, and a reference to GEN 3.1.6. Information on availability and detailed information on how to obtain the Area 4 obstacle dataset should be provided in GEN 3.1.6 of the AIP.

Data Product Specifications: In addition to the requirements regarding the provision of details on how electronic Terrain and Obstacle Data may be obtained, GEN 3.1.6 should provide a pointer to a comprehensive statement in the form of Terrain and/or 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 1: The States may include an indication in the Aerodrome Obstacle Charts of the availability of Area 2 electronic terrain and/or obstacle datasets and a reference to GEN 3.1.6.

[26] ICAO uses the term effectivity to indicate the period for which the information should be considered in planning operations.

Note 2: The States may include an indication in the Precision Approach Terrain Chart (PATC) of the availability of Area 4 eTOD and a reference to GEN 3.1.6.

Note 3: The appropriateness of publication of the Area 1 obstacles in ENR 5.4 and Area 2 and 3 obstacles in AD 2.10, where the electronic obstacles dataset is available, should be evaluated by the States. This applies in particular to publications where the number of published obstacles would make their manual processing cumbersome or where additional metadata is available.

<table>
<tr><th>AIP Reference</th><th>Terrain dataset</th><th>Obstacles dataset</th></tr>
<tr><td>GEN 3.1.6 - Electronic Terrain and Obstacle Data</td><td colspan="2">Identification of the electronic Terrain and/or Obstacle Data that may be obtained
Area 1 - name of the country/territory for which eTOD may be obtained, if different from AIP name
Area 2 and 3 - identification of the aerodrome
Area 4 - identification of the aerodrome and designator of the runway
Details of how electronic Terrain and/or Obstacle Data for Areas 1-4 may be obtained
Pointer to location where detailed Data Product Specification for electronic Terrain and/or Obstacle Data for Areas 1-4 may be obtained</td></tr>
<tr><td>ENR 5.4 - Air Navigation Obstacles</td><td>-</td><td>An indication that the list of obstacles affecting the air navigation in Area 1 is available in electronic form, and a reference to GEN 3.1.6</td></tr>
<tr><td>AD 2.10 - Aerodrome obstacles</td><td></td><td>An indication that the electronic Obstacle Data for Area 2 and 3 is available in electronic form, and a reference to GEN 3.1.6</td></tr>
<tr><td>Aerodrome Obstacle Charts</td><td colspan="2">An indication that the eTOD for Area 2 is available in electronic form, and a reference to GEN 3.1.6.</td></tr>
<tr><td>Precision Approach Terrain Chart (PATC)</td><td colspan="2">An indication that the eTOD for Area 4 is available in electronic form, with a reference to GEN 3.1.6</td></tr>
</table>

Table 1: Announcement of the TOD availability in the AIP

4. IMPLEMENTATION PROCESS

This section outlines a recommended approach to planning and implementing terrain and obstacle data on a national basis.

4.1 Implementation Actions

4.1.1 Identification of Responsible Body

It is believed that the identification of a responsible body for the co-ordination of terrain and obstacle data implementation is an important, initial step for a successful implementation. This will help ensure that the necessary actions are taken and implementation progressed. Where no responsible body is identified, the risk is that implementation will be stalled, and if it does take place, that it may be uncoordinated.

The State body assigned with overall responsibility for meeting the ICAO SARPs should identify the body which will be delegated the responsibility for the implementation of terrain and obstacle data. This will vary from State to State. For example, in some States only certain ICAO Annex 15 functions will have been delegated (by the State) to the Aeronautical Information Services Provider (AISP), resulting in the “new” requirements for terrain and obstacle data remaining at a higher level, either with the regulator or Ministry of Transport.

Careful consideration needs to be given to who fulfils the role of responsible body. In many States, it will be the regulator, the advantage being that the regulator will have more authority to make demands on other parties than, for example, the AISP.

4.1.2 Identification of Stakeholders

It is important that all the impacted stakeholders in the State are identified so that there is full awareness of terrain and obstacle data and an efficient flow of information between the parties involved.

It is recognised that many affected parties are not aware of the requirements of ICAO. Therefore, it is important to identify all such stakeholders in order to determine the responsibilities and to develop a feasible plan for the implementation of terrain and obstacle data.

4.1.3 TOD Awareness Day

It is recommended that a national awareness day or a series of regional seminars are held to raise stakeholders’ awareness of the requirements of terrain and obstacle data. This would allow all parties, especially those that are not aware of the ICAO requirements, to be briefed on the requirements of ICAO and the pan-European approach towards the implementation of terrain and obstacle data. The attendance by personnel of the following organisations should be considered, though the list is not exhaustive:

- Ministry of Transport;
- Civil Aviation Authority (CAA);
- AISPs;
- ANSPs;
- Military;
- Aerodrome operators;
- Survey organisations – civil and military;
- Geodetic institutes;
- Airline representatives;
- Search and Rescue;

- General Aviation.

In the interests of economy, States may wish to co-host such workshops and to share their experiences and best practices associated with terrain and obstacle data for the common good.

The awareness sessions may cover the following topics:

a) The history of terrain and obstacle data;
b) The terrain and obstacle data requirements;
c) Overview of System-wide Information Management / AIM and how terrain and obstacle data support this;
d) The uses of terrain and obstacle data;
e) GIS and survey techniques;
f) Feature capture rules;
g) Institutional issues;
h) Data sources;
i) Responsibilities;
j) The way forward.

4.1.4 State Working Group

The establishment of a State Working Group for terrain and obstacle data should be considered. This has been demonstrated as a successful initiative in some States and has, therefore, been taken as an example of best practice.

A working group would allow for a co-ordinated plan for implementation, with a common understanding of what actions need to be taken. Priorities for work may be set and those involved can understand how their tasks impact the work of others and the progress of implementation.

It is expected that the State Working Group will ensure, either through their direct representation on the working group or by other means, that the needs of the following stakeholders are adequately reflected:

- The State AISP;
- The Military AISP;
- Civil procedure design authority;
- Military procedure design authority;
- The regulator;
- The Ministry of Transport;
- The State survey organisation;
- The Military survey organisation;
- The national geodetic agency;
- Aerodrome operators;
- Representation (probably at a national level) of local authorities or those with the responsibility for safeguarding and/or approving construction in the vicinity of an aerodrome;
- Authorities or organisations responsible for the authorisation or maintenance of obstacles, such as:
    - Broadcast transmission antennas;
    - Cell phone masts;
    - Electricity transmission pylons;
    - Wind turbine farms.
- In States, where aerodromes may be adjacent to ports, representatives of the Port Authority.

One of the first tasks of the group could be to establish the focal points (see 4.1.5 below) in the State.

Other tasks could include an assessment of whether the national regulation needs to change to allow terrain and obstacle data implementation to proceed, identification of costs and formulation of an implementation plan. This will ensure the necessary regulatory framework to place obligations on the relevant parties.

4.1.5 Focal Points

The following organisations should be considered establishing focal points within a State:

- Ministry of Transport;
- CAA;
- The Military;
- The ANSP;
- The State AISP;
- The Military AISP;
- Aerodrome authorities;
- National geodetic institutions.

4.1.6 State Policy with Regards to SARPs

It is advised that the State derives a policy for the implementation of terrain and obstacle data. It is important that the State determines, as a minimum, what it intends to do with regards Areas 1 and 4 as these data sets should have been made available from 20th November 2008. Should data not be available or if data that is available does not meet the data quality requirements of ICAO Annex 15 Chapter 10, it is necessary for the State to file a difference and notify ICAO. If the data made available does not meet the data quality requirements, it is important that the user is aware of this. More information on this can be found in section 8.1.

The policy should also cover the scope of Areas 2 and 3, identifying for which aerodromes Areas 2 and 3 should be implemented. It is recommended that the policy include the quality requirements for each of the areas.

The policy should also include information about who will be providing terrain and obstacle data, for each of the four areas, a timetable for provision and the means of data provision.

4.1.7 Assessment of Regulation

Existing regulation should be assessed to determine if it is sufficient to allow terrain and obstacle data to be implemented effectively. Where existing national regulation is not considered sufficient, the application of new regulation to allocate responsibilities should be considered.

4.1.8 State Policy on Aerodrome Safeguarding

It is recommended that the State policy for the safeguarding of aerodromes is assessed to consider its effectiveness, particularly in relation to the terrain and obstacle data requirements. Consideration should also be given to whether any existing data, within the scope of the current aerodrome safeguarding policy, is in compliance with the terrain and obstacle data requirements.

If a State does not have an aerodrome safeguarding policy, it is recommended that one is established.

One example of best practice that is used as a reference by many States is the CAP 738 “Safeguarding of Aerodromes” issued by the United Kingdom (UK) CAA.

4.1.9 Obstacle Permission Process

The policy on aerodrome safeguarding should form an intrinsic part of the obstacle permission process. It is recommended that the State assesses any obstacle permission process that exists to confirm that this is sufficient to ensure that the obstacles within the scope of Chapter 10 of ICAO Annex 15 are managed effectively.

If the process is deficient, it should be updated. In the case that an obstacle permission process does not exist, one should be developed. It is strongly recommended that any such obstacle permission process within the State is put in place as a legal requirement. This should incorporate mandatory obstacle reporting for significant development phases from commencement to penetration of obstacle limitation / identification surfaces and then final completion. The intended demolition of a significant obstacle should also be notified and confirmed on completion. Failure of the owner to comply should be addressed through the legislation.

The following sections provide a generic obstacle permission process that may be used as a basis for a State's own process.

4.1.9.1 Generic Obstacle Permission Process

4.1.9.1.1 Introduction

The following generic obstacle permission process has been developed to help provide a harmonised approach to the process by which obstacles are planned, notified, surveyed and published. It is believed to be very difficult, if not impossible, to define a process which can be uniformly applied across different States as its influence extends well beyond the aviation sector and is impacted by national planning regulations and cartographic practices.

This section presents a generic process which, it is hoped, may be applied within most States, whilst still providing the degree of flexibility needed for it to be accommodated by the differing regulatory and legislative structures in existence. It is designed to consider aviation's perspective within the overall obstacle permission process within a State. For example, it allows for aviation's consideration as to the suitability of a request to build an obstacle, recognising that aviation may overrule this. Conversely, whilst aviation may be happy for an obstacle to be built, other factors, such as environmental considerations, may lead to a decision that the obstacle may not be built.

The rigor and reliability of the obstacle permission process implemented within a State will have a significant bearing on the obstacle maintenance processes that need to be established. For example, if it is known that obstacles are not built or extended without prior permission, then the need to check-survey may be reduced. See section 4.1.13.2 for more details.

The obstacle process is illustrated using a flow diagram, supported by a textual description of each of the steps and is considered to be sufficient for both temporary and permanent obstacles. The process does not identify the actors involved, with the exception of the initial responsibility for the owner to notify his/her intent to add/change an obstacle.

This assessment will, generally, be common across a State (assuming that the notification policy is not enacted at a local level). In such situations, it may be possible for the State to issue a high-level statement of policy in this regard and for each aerodrome to then tailor this to its particular situation.

The overall process is reflected in Figure 18 below. The subsequent paragraphs explain each of the steps more fully.

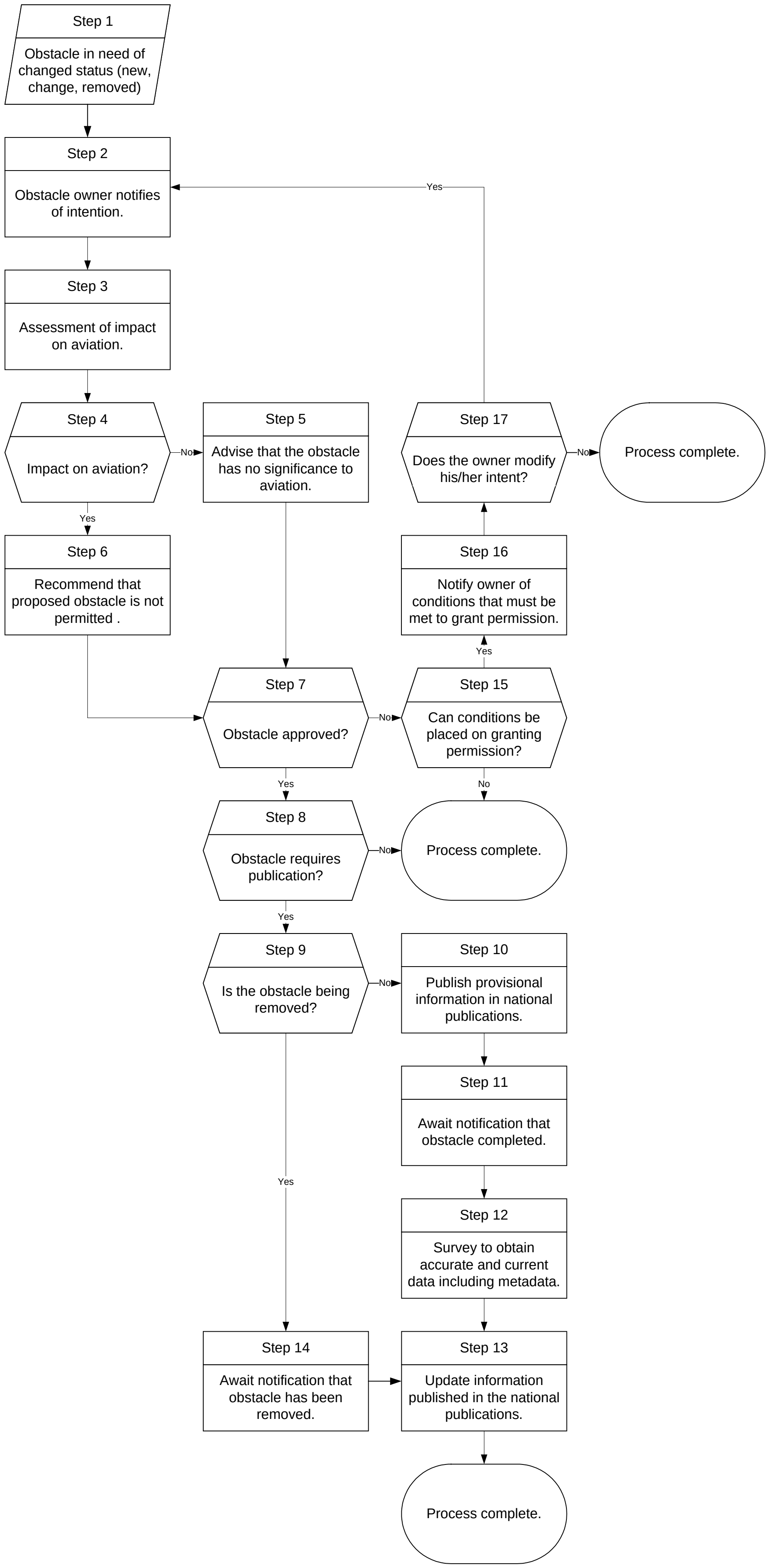


Figure 18: Obstacle Management Process

4.1.9.1.2 Step 1

The process begins with the identification, by the owner, of the wish to build a new obstacle, to change the size of an existing obstacle or to remove an existing obstacle.

It is considered that the removal of an obstacle should also be subject to a formal process as the removal may result in benefits for aircraft operations.

4.1.9.1.3 Step 2

The owner of the proposed obstacle requests the permission of the appropriate bodies to build / extend / remove a structure that will become / is an obstacle.

It is highly likely that this notification will be made to a non-aviation body, as part of the State's planning processes. Consequently, mechanisms will need to be established whereby the planning authority passes relevant information for structures in identified locations or with specific heights to the aviation authorities.

It is also important to ensure that the minimum size of obstacles that must be notified through formal national planning processes is adequate, i.e. that any obstacles that may impact aviation have to be notified.

4.1.9.1.4 Step 3

An assessment must be undertaken to determine whether the planned operation will impact aviation. The impact assessment should consider not only the penetration of obstacle limitation / identification surfaces, but also any negative impacts that may be seen on other aviation infrastructure, such as Navaid operations.

This assessment must include all relevant actors, such as regulators, aerodrome authorities and air traffic services. Consideration must also be given to the operations of any aerodromes located in neighbouring territory, if the planned obstacle is close to a national boundary.

4.1.9.1.5 Step 4

From the assessment performed, it will be determined whether a negative impact to aviation is foreseen.

If a negative impact is foreseen, go to Step 6.

4.1.9.1.6 Step 5

The planning authorities should be advised if the obstacle has no significance to aviation. The planning authority is the function within the State which is tasked with granting approval for building construction. This is typically a non-aviation function which exists at the local level, for example, a city or regional council.

As the planning process may consider other non-aviation aspects, it is possible that the changes to the obstacle will be rejected for other reasons, such as failure to conform to normal planning regulations and, despite it being of no impact to aviation, there is no guarantee that permission will be granted.

4.1.9.1.7 Step 6

The planning authorities should be advised that the obstacle has a negative impact on aviation. This should include details of the impact foreseen and the resultant effect on air traffic operations.

Despite being advised that the obstacle has an impact on aviation, in most cases, there is no guarantee that the planning authorities will reject the construction of the obstacle.

4.1.9.1.8 Step 7

The planning authorities will consider all relevant information and make a decision as to whether permission for the obstacle should be granted, or not.

If permission is not granted, go to Step 15.

4.1.9.1.9 Step 8

Given the information about the obstacle, it must be determined if the information should be included in / removed from the national publications, including the AIP and terrain and obstacle data sets. This decision will be based upon the obstacle's extent and location.

If the obstacle is not to be included in the national publications, the process ends at this step.

4.1.9.1.10 Step 9

If the obstacle is being removed, it is not appropriate to include provisional information within national publications as the removal may not, in reality, happen when planned, or at all.

If the obstacle is being removed, go to Step 14.

4.1.9.1.11 Step 10

As permission has been granted, at an appropriate point in time, construction of the obstacle will commence. At this point, the relevant information must have been published in the national publications and any other affected information, such as flight procedures, updated accordingly.

During construction, only provisional information may be published and allowance should also be made for any equipment, such as cranes, used during construction.

If the obstacle is a tall structure which is erected over a period of many months, it may be desirable to gradually increase the height data of the obstacle to reflect its growth over time. This may be particularly relevant where, upon completion, the obstacle impacts flight operations.

4.1.9.1.12 Step 11

At a given point in time, construction of the obstacle will be completed. The process for obstacle notification should require that, at this time, the aviation authorities are notified that the obstacle construction has been completed.

4.1.9.1.13 Step 12

The obstacle permission process should place a mandatory requirement on the obstacle owner to conduct a survey during which its vertical and horizontal extents are measured and all the associated metadata is captured and notified for AIRAC publication. Once again, any other related information, such as flight procedures, may need to be recalculated to take into account the actual obstacle dimensions.

4.1.9.1.14 Step 13

The provisional information contained in the national publications must be updated to reflect the information obtained through survey.

The process ends at this step.

4.1.9.1.15 Step 14

At a given point in time, the obstacle will be removed. The obstacle permissions process should place a mandatory requirement on the obstacle owner to confirm demolition is complete and that this is notified for AIRAC publication.

4.1.9.1.16 Step 15

As the planned obstacle would impact aviation, consideration should be given to whether any conditions may be stipulated which, whilst modifying the intent of the obstacle owner, would allow permission to be given without impacting aviation. It should be noted that these conditions should be supplied by the neighbouring State if its aerodrome operations are potentially affected by the obstacle.

Other non-aviation agencies involved in the assessment of the obstacle, and whose advice is considered in granting planning consent, may also stipulate similar conditions.

4.1.9.1.17 Step 16

The obstacle owner is notified of any conditions that must be met in order for the planned obstacle to be considered.

4.1.9.1.18 Step 17

The obstacle owner may wish to amend the planned obstacle in the light of the conditions that have been set. This will result in a revision to the original plans and a new notification of intent being provided. If this is the case, go to Step 2.

If the owner has not amended his/her intent, based upon the conditions set, the obstacle has not been approved and the process ends with this step.

4.1.10 Data Sources and Originators

Appropriate State representatives should assess the data sources and/or originators that currently exist within the State to assess if the data these hold could be used to meet the terrain and obstacle data requirements of ICAO Annex 15 Chapter 10. Such organisations may combine functions of sources and originators:

- Military authorities;
- ANSPs;
- Geodetic institutes;
- Mapping agencies.

Data originators organisations may include:

- Power / energy supply companies;
- Wind farm operators;
- Authority(ies) responsible for the authorisation of radio/television and other broadcast antenna;
- Cell phone operators;
- Port authorities.

It is recommended that meetings are held with these organisations. Discussion should be held regarding the feature capture rules to be applied (see Appendix B), liability of the data for data originators and costs and licensing for data sources. For the latter, consideration should be given to the type of organisation of the data source owner to determine any potential issues with regards to revenue. Clearly, if a commercial organisation already charges users for the data, it will not want to lose this revenue stream. This will make issues regarding costs and licensing more complex. If the organisation is State-owned then these issues should be less complex.

It is recommended that once appropriate data sources and/or originators have been identified and the provision of data agreed by the data source and/or originator, that formal arrangements are established between the data provider and the recipient. According to Annex 15 states shall ensure that formal arrangements are established between originators of aeronautical data and aeronautical information and the aeronautical information service in relation to the timely and complete provision of aeronautical data and aeronautical information. If the provision of data is likely to take place regularly, over a period of time, a Service Level Agreement (SLA) may be an appropriate means of formalising the data provision. For infrequent or one-off data provision, a contract may be more appropriate.

An arrangement will allow the responsibilities to be clearly defined and through the negotiations that will take place in formulating the arrangement, allow each party to understand the impact of its work on the other. Information regarding the quality requirements of the data should be documented, including timeliness, the means of provision, data formats, etc. In addition, it is important that the standards to which the data sources and/or originators should adhere to are captured in the arrangement. This could include the EUROCONTROL Specification for the Origination of Aeronautical Data, a means of compliance for many of the data origination provisions of the Commission Regulation (EU) 73/2010. Under this regulation, those requesting data in Europe have a responsibility to ensure that these provisions are adhered to. It is recommended that those undertaking surveys are able to demonstrate that they have sufficient knowledge of surveying airports.

4.1.11 Data Acquisition

At an appropriate stage of the implementation process, the survey requirements for the four areas, including resurvey intervals, should be defined, and the common survey formats to be used by surveyors and geodetic institutions should be determined for each of the areas.

The State should consider how surveyors may be monitored to ensure that they adhere to appropriate standards. The standards to be applied by the surveyors, for example, the feature capture rules, should be agreed by the State and documented.

See section 7.1, 7.2 and Appendix B for further information regarding survey and feature capture rules.

4.1.11.1 Cross-border Provision of Data

Arrangements should be made between States for the exchange, provision and receipt of terrain and obstacle data which lies in the territory of one State but which is required for a data set which needs to be provided by another State.

See section 5.6 for further details on the cross-border provision of data.

4.1.12 Data Validation and Verification

An assessment should be made to identify if any means to validate data, including metadata, already exist. Means should be identified and, if necessary, defined for the validation and verification of both new and existing data.

In addition, an assessment should be carried out to determine the suitability of existing data and how its quality can be verified and validated.

See section 7.3 for further details on data validation and verification. See Chapter 8 for further information on the use of existing data.

4.1.13 Data Maintenance

4.1.13.1 Introduction

Commission Regulation (EU) 73/2010, laying down requirements on the quality of aeronautical data and aeronautical information for the Single European Sky includes the obligation "*Survey data categorised as critical or essential data shall be subject to a full initial survey, and thereafter shall be monitored for changes on a yearly basis, as a minimum. Where changes are detected, re-survey of the relevant data shall be undertaken.*"

No terrain and obstacle data is classified as critical data. Data for Areas 2, 3 and 4 is classified as essential. Area 1 data may be considered out of scope for this provision of the regulation as it is categorised as routine.

Whilst yearly monitoring may provide a sound basis for observing changes, it may not be adequate in all cases and guidance is needed as to how and when the maintenance of terrain and obstacle data should be undertaken.

The following sections provide proposed guidance, with terrain and obstacle data addressed separately as the approach to each, whilst having some common elements, is different. In all cases, consideration should be given to any existing systems already in place within the State, for example, regular resurveys already performed by National agencies. Technical aspects of data maintenance are addressed in Section 7.8 of this Manual.

4.1.13.2 Obstacles

4.1.13.2.1 Periodicity

ICAO defines the maintenance period for obstacles as “as required” and, initially, the TOD WG requested that the frequency at which maintenance should be undertaken should be defined.

Such a task has, however, proven impossible as the need for maintenance changes on a case-by-case basis. For example, a survey could be undertaken one day and capture 100% of the existing obstacles, however, the very next day a new obstacle, for example a mobile crane, could be erected and become the new, dominant obstacle.

As such, it was believed that guidance should be developed based on the considerations which should be taken into account in the determination of a policy for obstacle maintenance. It is recommended that this guidance is applied on an individual aerodrome/heliport basis and agreed with the national regulator.

The guidance provided has been developed on the basis of providing a cost-effective and viable solution, as determining a perfect solution is not considered practicable.

In establishing a maintenance policy, the following should be considered:

- The nature of the surrounding area;
- The rigour of the obstacle notification policy;
- The impact of obstacles in a region.

There are obvious links between these. For example, if the rigour of the obstacle policy is such that small obstacles are often not reported or permission is not sought, and this is in a region where small objects, such as TV aerials, have an impact on aviation, an approach to identify these must be developed.

Note: Yearly checks can be considered to meet the requirement for “regular intervals”, as stated in the note to PANS-OPS (ICAO Doc 8168) Volume II, Part I, Section 3, Chapter 2, paragraph 2.6.2.1.

4.1.13.2.1.1 The Nature of the Surrounding Area

The area surrounding the aerodrome/heliport will have a bearing on the need to monitor and maintain obstacle data. For example, an aerodrome may be located on a headland where the majority of the area surrounding the aerodrome is water. Here, whilst obstacles are not impossible, they are highly unusual and easily identifiable. Conversely, the remaining area surrounding the aerodrome may be densely populated and, hence, be a region in which it is much harder to identify obstacles for which the recorded information is incorrect.

It is, therefore, recommended that in establishing a maintenance policy, the surrounding area is segmented to reflect the level of difficulty in identifying changes to the status of obstacles in the different areas.

4.1.13.2.1.2 The Rigour of the Obstacle Notification Policy

The obstacle permission process discussed in section 4.1.9.1 includes provisions for the notification of new, amended and removed obstacles.

For those areas in which only obstacles of a significant size penetrate the assessment surfaces, it is foreseen that planning permission will be needed for their construction / destruction and, therefore, no additional mitigation is needed (subject to check assessments - see below).

Problems exist, however, where either the current State obstacle permission policy does not require the notification of obstacles that are of interest to aviation or the policy is not sufficiently supported by enforcement, resulting in obstacles not being notified. Area 1 obstacles outside the aerodrome safeguarded area may not have previously been subject to notification and assessment for impact on flight safety.

Area 1 obstacles constitute a “hazard to air navigation” and are required to be published in ENR 5.4, therefore, an obstacle notification policy should be put in place for the mandatory notification of all Area 1 obstacles as part of the State obstacle permission policy.

An obstacle notification policy should be developed taking the following into consideration:

- Identify National agency to manage obstacle data base;
- Identify National agencies with available data for obstacles above 100m - e.g. National Geodetic Agency, MOD, Ministry of Energy, Communications, Obstacles Permissions Process, Cadastre, etc and compare with the existing data in the obstacle database to identify any missing obstacle;
- Dependent on the extent of obstacles missing from existing obstacle data base, identify owners and contact for provision of vertical and horizontal extents and all the associated metadata (further refer to section 8.3), accordingly;
- Place a legal obligation for obstacle owners to provide vertical and horizontal extent and all the associated metadata for all obstacles above 100m. Failure of the owner to comply should result in punitive measures being enforced through legislation.

4.1.13.2.1.3 The Impact of Obstacles in a Region

There is little value spending valuable time and financial resource to determine every obstacle that may have been constructed, amended or demolished in a region if, despite, strictly speaking, penetrating the assessment surface, they are significantly smaller than the surrounding obstacles. Whilst these obstacles should be identified in a full survey, if their operational impact is negligible or nil, it may be argued that, from an aviation perspective, there is no need to monitor this area for changes.

It is, therefore, proposed that the area around an aerodrome is further segmented to identify, for each area, a minimum obstacle size (most likely height only). Obstacles above this height should then be monitored. Maintenance assessments (see section 4.1.13.2.2 of this Manual) should then be carried out to determine if these minimum obstacle heights are still valid.

4.1.13.2.2 Assessment Policy

An assessment policy should be developed for each aerodrome / heliport which lays down the approach to be taken to ensure that the obstacle data is maintained in such a way as to give a sufficiently high degree of confidence that it correctly reflects the current situation.

An assessment policy should be developed and approved which outlines:

- The regions around an aerodrome / heliport to which different approaches to maintenance may be applied;
- For each region, the approach to maintenance that will be employed.

As discussed above, it may be that the policy states that, for some areas, the obstacles will not be fully maintained as their operational impact is considered to be negligible.

The approach that is taken for regions around the aerodrome / heliport may vary depending on the situation outlined in 4.1.13.2.1 above. The following provides examples of how obstacle maintenance may be established:

- No maintenance:

  It is considered that the chance of an unknown obstacle of sufficient size to impact flight operations being erected is very minimal.

- Occasional inspection:

  It is considered that the chance of an unknown obstacle of sufficient size to impact flight operations being erected is minimal and, therefore, only occasional assessment, by visual means, is sufficient.

- Frequent monitoring:

  It is considered that the chance of an unknown obstacle of sufficient size to impact flight operations being erected is significant and, therefore, assessment on a frequent[27] basis is required.

- Frequent resurvey:

  The region is known to have significant building work which is highly likely to impact operations. It is therefore considered essential that regular resurvey of this region is undertaken.

Where resurvey is undertaken, it is possible that some techniques, such as automated processes, may be used to identify possible new obstacles. For example, the raw data resulting from an ALS survey may be compared to identify differences that exceed a given tolerance. The policy could define what technique will be used for each level of maintenance but this is not considered essential.

4.1.13.3 Terrain

4.1.13.3.1 Periodicity

Once again, the ICAO requirement is for terrain data to be maintained on a “as required” basis and the same arguments that were presented for obstacles may be used to support this view, especially as, in the vast majority of cases, terrain data may be far more stable than obstacle data.

Three main categories of terrain changes may be considered:

- Terrain changes are infrequent unless, as is the case for some parts of the world, the terrain is made up of loose material, such as sand, which may be moved significantly by weather.
- Tectonic plate movement may also result in changes to terrain, particularly where an area is close to, or covers, the boundary between plates.
- Lastly, and most frequent, by far, is human intervention which changes terrain. Many earth works are carried out which significantly affect the shape of the terrain. For example, the earth embankments that are constructed for roads and bridges may be considered as terrain changes[28].

As before, it is proposed that the surrounding area is divided into regions which require different levels of monitoring. In the vast majority of cases, the entire region around an aerodrome / heliport may be considered a single region.

4.1.13.3.2 Assessment Policy

An assessment policy should be developed for each aerodrome / heliport which lays down the approach to be taken to ensure that the terrain data is maintained in such a way as to give a sufficiently high degree of confidence that it correctly reflects the current situation.

This policy may be included with the obstacle policy in a single Assessment Policy document or may be a separate document. The choice of whether to have two policies or a joint one may be dependent upon the chosen responsibilities for monitoring and surveying terrain and obstacle changes, for example.

The same four categories presented for obstacle maintenance are foreseen for terrain maintenance:

- No maintenance:

[27] It is recommended that the policy defines what the frequency of monitoring should be, for example, weekly, visual assessment and yearly resurvey.

[28] Whilst such constructions are man-made and, strictly speaking, should be considered as obstacles, it is recommended that, for simplicity, earth works are considered as terrain. In the case of bridges, for example, the bridge may be an obstacle which has elevated terrain either side of it which forms the access ramps.

It is considered that the chance of terrain changing sufficiently to impact flight operations is very minimal.

- Occasional inspection:

It is considered that the chance of terrain changing so that it impacts flight operations is minimal and, therefore, only occasional assessment, by visual means, is sufficient.

- Frequent monitoring:

It is considered that the chance of terrain changing sufficiently to impact flight operations is significant and, therefore, assessment on a frequent[29] basis is required.

- Frequent resurvey:

The region is known to experience significant changes in terrain and it is, therefore, highly likely to impact flight operations. It is, therefore, considered essential that regular resurvey of this region is undertaken.

Nonetheless, the assessment policy for terrain may well be affected, to some degree, by the obstacle policy. For example, if the decision is that frequent resurvey is needed and the chosen technology is bulk survey collection, there is a high degree of likelihood that the data capture for this survey will also detect terrain changes.

4.1.14 Obstacle Identification

As each obstacle collected needs to be assigned an identifier, it is recommended that this is a Unique Identifier (uid), such that each obstacle will be distinguishable by a single identification throughout its life and that this will not be reused[30]. There is, therefore, the need for a State-wide policy for the identification of obstacles that may be applied by all those actors who are responsible for the specification, procurement, collection, processing and publication of obstacle data.

It is recommended that this policy is established such that a series of identifiers are assigned based upon the geographic location of the obstacle. However, given that an obstacle may co-exist in the data sets of more than one aerodrome, it is recommended that this is not based upon the aerodrome area but on stable political divisions. One possible implementation is <Country-Code>-<Subdivision-Code>-<uid>[31].

The policy should be documented and made accessible to all who require access to it. It is also recommended that a register of obstacle identifiers is maintained, including to whom the obstacle identifiers have been assigned for subsequent allocation, such that concurrent survey activities do not result in the duplicated use of identifiers.

For further technical information related to obstacle identification, refer to section 7.8.1.

4.1.15 Data Provision

During the implementation process, consideration should be given to the adoption of interoperable exchange formats for terrain and obstacle data.

Additionally, the means by which terrain and obstacle data will be made available to users should be determined.

See Section 7.5 for further details about data accessibility.

[29] It is recommended that the policy defines what the frequency of monitoring should be, for example, monthly visual assessment and five-yearly resurvey. The periodicity may also be “event-driven”, for example, driven by events such as volcanic eruptions, storms impacting sand-dunes, landslides and earthquakes.

[30] At least within a defined period of time.

[31] As the basis for the country code either ICAO or ISO 3166, *Codes for the representation of names of countries and their subdivisions*, should be referred to. The subdivision code should be based on ISO 3166-2 (province/State) to avoid ambiguities.

4.1.16 Monitoring / Audit of Implementation

To be developed once the ESSIP for terrain and obstacle data is agreed. It will reflect the stakeholder lines of action.

The State regulator should:

- Determine how terrain and obstacle data implementation, management and maintenance will be monitored;
- Consider how the progress monitoring it undertakes will be able to meet regional / international oversight monitoring obligations;
- Develop a plan for auditing affected organisations.

4.1.17 Cost Recovery and Charging

The costs associated with both the initial and ongoing provision of terrain and obstacle data should be identified. Consideration should be given to:

- Increased costs for AISPs in storing, managing and making available the data;
- Increased costs for regulators in monitoring and auditing those parties involved in the implementation and provision of terrain and obstacle data;
- The indirect costs, such as the adaptation of procedures due to new / updated obstacle data.

If it is determined that a charge should be levied for data, the appropriate means/mechanisms by which the revenue can be collected also need to be determined.

See section 6.3 for further details about cost recovery and charging.

4.2 Implementation Plan Checklist

To support the activities described above, an Implementation Plan Checklist[32] has been developed and can be found at Appendix D of this Manual.

This checklist is intended to be used by either the regulator or the responsible body for the implementation of terrain and obstacle data. It is intended to help initiate implementation activities and to ensure that no area is overlooked.

The activities covered by the checklist are grouped by area of activity and any considerations related to the task are documented. The task list is by no means exhaustive and the user may choose to expand it. Similarly, not all activities will be applicable to all States.

The checklist has been implemented in Microsoft© Word, Access and Excel and is available in EUROCONTROL's OneSky Teams. This allows the user to record the following information:

- Status: for example, not applicable, not started, in progress, complete;
- Completion date;
- Any comments / further details related to the task.

4.3 Implementation Plan Template

To support the activities described above, an Implementation Plan Template has been developed and can be found at Appendix C of this Manual. This template can be used as the basis for a State Implementation Plan.

It is grouped by area of activity, guidance for each of which is included within this Manual.

Colouring is used in this template to differentiate between the different types of text. Blue is used to indicate an area that needs to be completed by the State. Green text includes guidance or considerations for completing that part of the template.

[32] It should be noted that the checklist is not intended to be a mandatory list of tasks.

The template may be extended by States to allow any other relevant issues to be covered. Similarly, not all parts of the template may be appropriate for all States and so these should be deleted, as necessary.

5. INSTITUTIONAL MATTERS

5.1 Meaning of "Regular International Civil Aviation"

In amending ICAO Annex 15 to clarify for which aerodromes it is intended that Area 2 data is provided, ICAO has introduced the following text:

"*From 12 November 2015, at aerodromes regularly used by international civil aviation, electronic obstacle data shall be provided for all obstacles within Area 2 that are assessed as being a hazard to air navigation.*"

Whilst clarification is appreciated, a precise definition of what is intended by "*regularly used by international civil aviation"* is needed, especially if harmonisation within Europe is going to be achieved, as is the intent of the Single European Sky (SES).

Uncertainty stems from the English definition of the word "regular" which has many meanings. Given that ICAO has also used the phrase "*scheduled international air traffic*", it is considered that the most relevant meanings[33], in this instance, are "*arranged in a constant or definite pattern, especially with the same space between individual instances*" and "*done or happening frequently*."

Even with these definitions, the phrase still needs clarification as, for example, there is no clear understanding of what is meant by "*happening frequently*".

Similar occurrences of this wording, in other ICAO material, have been researched but no conclusions could be made as to its precise meaning. The TOD WG, therefore, requested that guidance on the meaning of the phrase was developed and, in turn, the Institutional Focus Group (IFG) of the TOD WG addressed this subject.

The released text of Amendment 37 to ICAO Annex 15 also introduced a split in the requirements for Area 2, as follows:

"10.1.5 From 12 November 2015, at aerodromes regularly used by international civil aviation, electronic terrain data shall be provided for:

a) Area 2a;

b) the take-off flight path area; and

c) an area bounded by the lateral extent of the aerodrome obstacle limitation surfaces."

"*10.1.6 From 12 November 2015, at aerodromes regularly used by international civil aviation electronic obstacle data shall be provided for*:

a) Area 2a, for those obstacles that penetrate the relevant obstacle data collection surface specified in Appendix 8;

b) Objects in the take-off flight path area which project above a plane surface having a 1.2 per cent slope and having a common origin with the take-off flight path area; and

c) penetrations of the aerodrome obstacle limitation surfaces.

Note.— Take-off flight path areas are specified in Annex 4, 3.8.2. Aerodrome obstacle limitation surfaces are specified in Annex 14, Volume 1, Chapter 4."

"10.1.7 Recommendation.— At aerodromes regularly used by international civil aviation, electronic terrain and obstacle data should be provided for Areas 2b, 2c and 2d for obstacles and terrain that penetrate the relevant terrain and obstacle data collection surface specified in Appendix 8."

It is, therefore, apparent that there is a need to develop guidance as to which aerodromes the Standard (10.1.5) should be applied, as well as to which the Recommended Practice (10.1.6) should be applied.

[33] Definitions taken from the Oxford English Dictionary.

5.1.1 Criteria for Inclusion

5.1.1.1 General

In its discussions, the IFG considered that it was highly desirable that the guidance applied should lead to the inclusion of only those aerodromes for which the cost is deemed to be reasonable. It was appreciated that this cost basis is hard to quantify as the benefits gained vary from aerodrome to aerodrome. For example, the provision of high-resolution digital terrain and obstacle data may, in some cases, alleviate the need to undertake flight checks which can be very costly.

The IFG therefore analysed a number of possible options for determining which aerodromes may be considered as having regular international air traffic.

The following outlines possible approaches that may be used in the selection of aerodromes for the provision of Area 2 data. It does not attempt to allocate approaches to either the Standard or the Recommended Practice, at this stage; this may be found in Section 5.1.2.

The inclusion of aerodromes available for both civil and military operations was discussed and the IFG concluded that the same criteria should be applied but with only civil operations taken into consideration, i.e. for the purposes of determining aerodromes "*regularly used by international civil aviation",* all military flights should be discounted.

5.1.1.2 Flights per Year – Cost per Flight

It was considered that a restriction on aerodromes could be applied on the basis of the number of flights per year, such that the cost per flight was reasonable.

After discussion, it was established that a figure of 1,000 flights per year[34] or greater could be used to determine for which aerodromes Area 2 data should be provided.

–For example, if we assume[35] that the survey for Areas 2a, 2b and 2c is €150K per aerodrome, and taking a full resurvey period of 5 years, the costs could be amortised, as follows:

- Cost per year = €30K per year.
- Cost per flight = €30 per flight.

5.1.1.3 EC Regulation 1108/2009

The recently introduced Regulation (EC) No 1108/2009, amending Regulation (EC) No 216/2008 in the field of aerodromes, air traffic management and air navigation services and repealing Directive 2006/23/EC, extends the tasks of the European Aviation Safety Agency (EASA), with a view towards a 'total system approach'. This extension encompasses aerodrome/airport safety, as well as Air Navigation Services (ANS) and Air Traffic Management (ATM).

The regulation places a number of new essential requirements, compliance with which is required.

It is, however, obvious that the European Commission (EC) did not wish this regulation to be a burden on smaller aerodromes and, as a result, a derogation has been included to exclude smaller aerodromes.

The derogation, Article 1(3.3b), which introduces a new provision to Article 4 of EC Regulation 216/2008, states:

"*3b. By way of derogation from paragraph 3a, Member States may decide to exempt from the provisions of this Regulation an aerodrome which:*

— *handles no more than 10 000 passengers per year, and*

— *handles no more than 850 movements related to cargo operations per year.*"

To address simply the cost per passenger, once again using the –figure of €150K per aerodrome for Area 2, and taking a full resurvey period of 5 years, the costs could be amortised, as follows:

[34] It is assumed that one flight constitutes two movements.

[35] This figure is used for illustrative purposes only.

- Cost per year = €30K per year.
- Cost per passenger = €3.0 per passenger.

The cost for cargo is less easy to quantify as it is not known what 850 cargo movements would equate to in terms of freight tonnes or packages moved. What is clear, however, is that the cost of terrain an obstacle data would have to be shared between passenger and cargo flights and that, in most cases, the cost per passenger would be less than that shown above.

It was considered that the use of this same derogation to the Area 2 requirement may bring advantages, for three main reasons:

1. It is a derogation that has already been accepted and is now found within European regulation;
2. Regulation (EC) No 1108/2009 relates to safety and is, therefore, likely to be equally acceptable in the context of terrain and obstacle data;
3. Using the same derogation would aid harmonisation.

It should be noted however, that the IFG did raise some concerns at the precise wording of the derogation since an airport may handle over 10,000 passengers and no cargo could not be derogated but if it handles 9,999 passengers and 849 cargo movements it could be derogated. Nonetheless, the wording does give the responsibility for exemption to the Member State and so, in such cases, the regulator could apply common sense.

5.1.1.4 Commission Regulation (EU) 73/2010

In January 2010, Commission Regulation (EU) 73/2010 relating to the quality of aeronautical data and/or information was adopted. This regulation establishes provisions governing the origination, processing, handling, storage, transfer and publication of aeronautical data/information.

Once again, a derogation has been included relating to which aerodrome authorities the regulation applies to. Article 2(2)(b) states "*operators of those aerodromes and heliports, for which instrument flight rules (IFR) or Special-visual flight rules (VFR) procedures have been published in national aeronautical information publications*". It should, however, be noted that the full content of the AIP published by a State is applicable under Article 2(1) of the regulation and that, as a consequence, the data published in relation to VFR aerodromes remains within the scope of the regulation.

The IFG considered whether the same set of conditions could be used to determine for which aerodromes Area 2 data should be provided. Such an approach was, once again, believed to bring harmonisation with another, existing regulation. The following additional points were, however, raised in the discussion:

- It was acknowledged that this definition does not link the elected aerodromes to the traffic type/frequency;
- That the resultant set of aerodromes would, in many cases, be a significant percentage of those published in the AIP;
- That the data required for the Area 2 Standard (10.1.5), in most cases, already exists and, therefore, although the resultant set of aerodromes may be large, the cost of provision should not be onerous. The exception to this statement relates to the provision of the Aerodrome Obstacle Chart — ICAO Type A (Operating Limitations) and the fact that this is not required for all aerodromes that fall under the regulation. The IFG expressed concern that the scope of aerodromes requiring the Type A chart should not be increased as a result of a link between the definition of "*regularly used by international civil aviation*" and Commission Regulation (EU) 73/2010.

5.1.1.5 Regional Air Navigation Plan - FASID

States already list their major aerodromes within the Regional Air Navigation Plan Facilities and Services Implementation Document (FASID). The IFG discussed the possible provision of Area 2 data for only those aerodromes listed within the FASID, as this should list the "*major international aerodromes"*.

The IFG was, however, aware that there are problems with selecting only those aerodromes listed in the FASID as it is known that there can be significant differences between the aerodromes listed in the FASID and those that could reasonably be considered as being "*regularly used by international civil aviation*".

5.1.1.6 Support to APV/PBN

There is a significant move towards the introduction of APV and Performance Based Navigation (PBN). In both cases, the availability of high-resolution terrain and obstacle data, with the known quality characteristics that an Area 2 data set will provide, brings significant benefit.

ICAO, as agreed through the thirty-sixth meeting of the ICAO Assembly, has established a phased plan for the introduction of both APV and PBN, addressing the period 2010 to 2016. Whilst the IFG acknowledged that terrain and obstacle data was not essential for implementation, it considered an approach by which Area 2 data is made available for those aerodromes at which either APV or PBN is being implemented. Such an approach would allow a gradual implementation of Area 2, with effort being focussed on those aerodromes where most benefit may be gained.

5.1.2 Recommendations

In making recommendations for the provision of Area 2 for the Standard and Recommended Practices specified, the IFG has strived to ensure that the costs per flight / passenger are kept to a minimum in the full knowledge that any significant increase would be unacceptable to many stakeholders.

5.1.2.1 Standard

Given that the obstacles needed to define IFR and Special VFR (S-VFR) flight procedures already exist and that Area 2a relates to a tightly controlled area, it is recommended that the Standard:

"*10.1.5 From 12 November 2015, at aerodromes regularly used by international civil aviation electronic terrain and obstacle data shall be provided for:*

a) Area 2a , for those obstacles that penetrate the relevant obstacle data collection surface specified in Appendix 8;

c) penetrations of the aerodrome obstacle limitation surfaces."

is implemented in line with Commission Regulation (EU) 73/2010, namely for:

"*those aerodromes and heliports, for which instrument flight rules (IFR) or Special-visual flight rules (VFR) procedures have been published in national aeronautical information publications.*"

It should be noted that part b) of the Standard is not included. This is intentional to avoid a circular definition as the obstacles needed to comply with this part of the Standard are defined in Annex 4 as also being for "*aerodromes regularly used by international civil aviation*". Furthermore, there was no wish to increase the number of aerodromes for which a Type A chart should be made available.

Such an approach should have a minimal cost impact given that adherence to Commission Regulation (EU) 73/2010 will, in most cases, already require the provision of metadata, etc., and, hence, possible resurvey to gather any missing information.

5.1.2.2 Recommended Practice

For the Recommended Practice, the IFG was not able to determine a single approach. The approaches discussed in 5.1.1.2 (1,000 flights per year) and 5.1.1.3 (10,000 passengers and 850 cargo movements) are both thought to have merit.

It is therefore recommended that these two approaches are considered in establishing which aerodromes data for Areas 2b, 2c, and 2d should be provided, in order to meet:

"10.1.7 Recommendation.— At aerodromes regularly used by international civil aviation, electronic terrain and obstacle data should be provided for Areas 2b, 2c and 2d for obstacles and terrain that penetrate the relevant terrain and obstacle data collection surface specified in Appendix 8."

As highlighted in section 5.1.1.6, the introduction of APV and PBN introduces an increased need for the provision of terrain and obstacle data for those aerodromes at which these are being implemented. As a result, it is further recommended that once the list of aerodromes for which Area 2 data will be provided has been established, priority is given to those aerodromes at which the establishment of APV and PBN is planned, thus aiding implementation planning.

5.2 Aerodrome Terrain and Obstacle Chart (ICAO) Electronic

5.2.1 Background

There has been much debate about whether the Aerodrome Terrain and Obstacle Chart – ICAO (electronic) is part of the Integrated Aeronautical Information Package (IAIP) and, therefore, whether it can be charged for. A second issue has also arisen related to whether access to the data necessary to generate the chart can be restricted. It was, therefore, decided that the background to the chart should be further researched to identify the rationale for its inclusion in ICAO SARPs. It was hoped that such consideration would clarify the requirements and the intent of ICAO.

5.2.2 History of the Aerodrome Terrain and Obstacle Chart – ICAO

In 1998, the ICAO AIS / Aeronautical Charts (MAP) divisional meeting called for review of the ICAO Annex 4 requirements relating to aerodrome and obstacle charts, and the development of specifications for the use of digital terrain and obstacle data. As a result, the Air Navigation Commission (ANC) approved a task to review the obstacle chart provisions in ICAO Annex 4, in light of related requirements in ICAO Annex 6 – Operation of Aircraft, Part I. In particular, the task should:

- Examine whether any rationalisation of the number of charts would be possible;
- Develop specifications for electronic terrain and obstacle data for use in the production of those charts;
- Explore the possibility of providing the obstacle and terrain information in electronic form rather than as paper chart.

As a result of this task, and in conjunction with another ANC task, AIS-9802 – Electronic Terrain Data, a proposal to amend ICAO Annex 4 and a consequential amendment to ICAO Annex 15 were presented in October 2004 in AN-WP/7966, “Preliminary Review of a Proposal to Amend Annex 4, and a Consequential Amendment to Annex 15”**.** The extent to which ICAO Type A, B and C charts met the operating limitations in ICAO Annex 6 was presented and it was concluded that there were overlaps in the specifications for the charts. These resulted from the impracticability of showing all the required information on a single, paper chart. It was felt that these limitations could be overcome by the use of electronic charts.

It was also concluded that the requirements introduced in Amendment 33 to ICAO Annex 15 satisfied the terrain and obstacle data requirements necessary to support the production of all existing ICAO obstacle charts, as well as the PATC.

A number of advantages for electronic chart production, over paper chart production, were identified in the working paper, the most relevant to the issue of restricting the data was:

“*2.3.2. Commercially available Geographic Information System (GIS), mapping and illustration software products are obtainable internationally at a reasonable cost. Free "reader software" which allows for viewing of charts without the need to acquire the originating software is also widely available. In addition, the International Organization for Standardization (ISO) 19100 series of international standards for geographic information, together with related standardization in the GIS/mapping industry, have established conditions for the interchange, portrayal, and use of electronic chart files*”.

It is clear that the intention was for the data to be available in an open and interoperable manner in order that it may be viewed in a wide range of software products which are compliant with the ISO 19100 standards. It appears that placing any physical restrictions on accessing the data would be contrary to the benefits gained by complying with the ISO 19100 series of standards.

In summary, Appendix B of AN-WP/7966 proposes the amendment to ICAO Annex 4 which:

"*a) introduces specifications for a new Aerodrome Terrain and Obstacle Chart — ICAO (Electronic) which combines existing specifications of the Types A, B and C with terrain and obstacle data specifications contained in Annex 15. It also introduces chart data product specifications which are based on the ISO 19100 series of standards for geographic information;*

b) proposes that the Aerodrome Terrain and Obstacle Chart — ICAO (Electronic) shall replace requirements for the Aerodrome Obstacle Charts — ICAO Types B and C and may be produced in lieu of the Aerodrome Obstacle Chart — ICAO Type A;

c) requires that a suitable hard copy format of the Aerodrome Terrain and Obstacle Chart — ICAO (Electronic) be made available upon request; and

d) provides the option to include information required by the Precision Approach Terrain Chart — ICAO in the Aerodrome Terrain and Obstacle Chart — ICAO (Electronic) as an alternative to publishing a paper copy chart."

Furthermore, and most relevant to the issue of whether the chart is part of the IAIP, is the proposal for the Amendment of ICAO Annex 15 which states[36]:

"*4.1 Appendix C presents a proposal for the consequential amendment of Annex 15 which provides for the inclusion of the Aerodrome Terrain and Obstacle Chart — ICAO (Electronic) in the Aeronautical Information Publication (AIP)*".

This clearly illustrates ICAO's intentions for the chart to be made available as part of the AIP, and therefore, free of charges other than those involved in the production and distribution of the AIP. Costs incurred in data collection and compilation should be covered in the cost basis for airport and air navigation services charges, in accordance with the principles contained in ICAO Doc 9082, Policies on Charges for Airports and Air Navigation Services), as with all other AIP data.

As it seems clear that the chart is part of the IAIP, it was also considered that the requirements of ICAO Annex 4 could not be met without making the data available, for example, those associated with the scaling, etc. The chart could be made available on a website using WMS technology which would only make the resultant image available, restricting physical access to the data. However, this could not apply if the chart was placed on a Compact Disc (CD), as part of the AIP. It is felt that the one of the few practicable ways of restricting the use of the data and protecting investments is by the use of licence agreements. Further guidance on this can be found in 5.4.2 of this Manual.

5.3 Liability

The State, ANSP, aerodrome, regulator, etc. all fall under a State's liability framework. However, responsibility and liability need to be allocated by the State, as it is the State, in the first instance, that is deemed liable for the data published. The State may then delegate this to other parties. Through capturing and maintaining adequate traceability of data from its point of origination to publication, the cause of the error can be detected and, therefore, liability can be placed accordingly.

[36] The amendments were consequently issued for State consultation in January 2005 and adopted as Amendment 54 to ICAO Annex 4 and Amendment 34 to ICAO Annex 15 in March 2007.

5.4 Copyright and Intellectual Property Rights

5.4.1 Use of Existing Data

Prior to compliance with the SARPs introduced by Amendment 33 to ICAO Annex 15, data users were, in many States, able to obtain, at a cost, terrain data which met the majority of the numerical requirements specified in Appendix 8 of ICAO Annex 15.

A potential issue arises whereby this data is now provided by the aviation sector, possibly with no additional charge, and is considered to be detrimental to the business of the previous provider.

One solution for Area 1 could be that where data has been collected to a higher resolution than needed, that the data is re-sampled to prepare an Area 1 data set with a lower resolution. This could reduce the licence costs and help ensure that the data would not be of great interest to many, non-aviation users but that the data would still be compliant with the requirements of ICAO Annex 15.

This should help ensure that the current revenue streams continue to exist for these organisations.

Alternatively, those requiring Area 1 data could have to contact the organisation that has traditionally provided the data directly to make arrangements for receiving the data, for example, a national geodetic agency.

5.4.2 Commercial Exploitation of Data

Given that the aviation community will be paying for the data it makes available, in some form[37], concern has been raised about organisations outside of aviation, exploiting the data for their own purposes. This exploitation is made all the more likely given the ICAO requirement for the use of the ISO 19100 series of standards. These are specifically intended to promote the open and interoperable exchange of geospatial data.

As it is difficult to define what “aviation use” is, unauthorised use of the data is difficult to monitor. However, a number of options have been considered, some of which are used today by the providers of data in other domains.

Technical means could be used to restrict the unauthorised use of the data, such as restricting access to the data itself. This may, however, be considered to be going against the spirit of the ICAO SARPs. Other possibilities include the injection of errors/patterns into the data. These errors/patterns should not alter the accuracy of the data for aviation use but would allow an organisation that is monitoring the use of the data to detect if an unauthorised organisation has gained access to the data and is exploiting it. There are disadvantages with this approach as the effort involved in monitoring the use of the data is significant.

It is clear that preventing the commercial exploitation of the data is difficult and so, contracts/licences could be used to limit the use of the data. Where the AIS/AIM owns the data, this licence could be between it and the end-user. Where the data ownership remains with a geodetic organisation, the licence could be between this body and the end-user. Licensing is considered a practicable approach as this would provide a legal basis for restricting the use of the data, placing the responsibility for correct use on the user. Whilst it will not totally inhibit the misuse, it does provide the owner of the data with the legal basis to address any unauthorised use of the data and is one of the common mechanisms in place today, in many domains.

[37] It is clear that there will be costs associated with the implementation of terrain and obstacle data, for example, the cost of survey, licence charges, etc. These costs will need to be recovered by some means and it is likely that the aviation community will ultimately pay.

5.5 Copyright and Product Licensing

As discussed above, one way of restricting the unauthorised use of data is by placing copyright on and/or licensing the data. This method is used in many domains, for example, most commercial software available today relies on the use of a licence agreement between the owner and the user.

A similar concept could be applied to terrain and obstacle data and this would provide the means to legally challenge any misuse of the data. The wording of a licence can specifically define how the data may be used.

5.5.1 Sample Copyright Notice Text

Some example text that may be used in a copyright notice could be:

> "*All material, publications, information and data (AIS Products) published by the Aeronautical Information Services of <<State Name>> are the subject of copyright. This specifically includes all elements of the Integrated Aeronautical Information Package (IAIP).*
>
> *Unless specified otherwise, AIS Products may be used for <u>aviation purposes only</u> by the organisation to which they were issued.*
>
> *Except as permitted above, no part of the AIS Publications may be reproduced, stored in a retrieval system, transmitted, redistributed, republished or commercially exploited in any way without the prior written permission of the Aeronautical Information Services of <<State Name>>.*
>
> *If any part of the AIS Products is to be used in any way not permitted by this notice, contact the Aeronautical Information Services of <<State Name>>to obtain a licence.*"

5.5.2 Licence Agreement Considerations

Below is a list of the subjects that should be considered for inclusion in a licence agreement, established with the intention of controlling and restricting the use of terrain and obstacle data.

- Grant:
  - The type and terms of the licence granted.
- Ownership:
  - Which parties retain ownership of the data;
  - Whether modifications of the data or merging data into another program may affect the ownership of the data.
- Intellectual Property Rights (IPR):
  - To which party the IPR of the data belongs.
- Restrictions:
  - Restrictions placed on the use of the data, such as, sub-licensing, re-supplying, etc.
- Liability:
  - Details of any warranties that accompany the data;
  - Responsibilities for determining fitness for use of the data;
  - Liability taken on using the data;
  - Liability for loss or damage resulting from the use of the data;
  - Any liabilities for the accuracy of the data.
- Governing Laws:
  - The laws of the State by which the agreement is governed.

5.6 Cross-border Access to Information

5.6.1 Introduction

In many cases, Area 2 for an aerodrome will extend into the territory of another State. Furthermore, in a more limited number of cases, a State boundary may even intersect the aerodrome. In these instances, access should be permitted to the data in neighbouring States.

The main focus of this chapter is to discuss the institutional issues associated with cross-border provision of data that may arise.

5.6.2 Area 1

In order to ensure a complete, global[38] coverage of Area 1 data, with no gaps existing between States' data sets, it is proposed that each State provides an Area 1 data set that extends to the mutually agreed territorial boundary and a limited distance beyond this. As such, this principle provides a similar coverage as is commonly seen for Air Traffic Services (ATS) routes, whereby an indication of the next few route points in the neighbouring State is provided.

During initial implementation of Area 1 data by States, it has also been noted that the issue of gaps is harder to address given that Area 1 terrain data is for 3 arc-second grid squares. To address this, it is proposed that the outer edges of Area 1 terrain are divided on the basis of larger grid squares, each of which contains a number of 3 arc-second grid squares.

It is, therefore, recommended that Area 1 terrain borders are provided for 1 arc-minute grid squares (each comprising 400 3 arc-second terrain grid cells), and that the data should be provided for those 1 arc-minute grid cells through which the territorial boundary passes, extending into the neighbouring State.

This concept is shown in Figure 19, below. The green terrain squares show the extent to which it is proposed Area 1 data is provided.

The sharing of this necessary data must be addressed though cross-border letters of agreement, as discussed in section 5.6.6, below. Care must be taken to ensure that the consistency of data at the borders is addressed in this agreement and that common reference models, etc. are specified.

[38] It is appreciated that the Area 1, as defined by ICAO, will only cover the landmasses of the world and, therefore, "global coverage" is not meant to indicate that data should be available for seas and oceans.

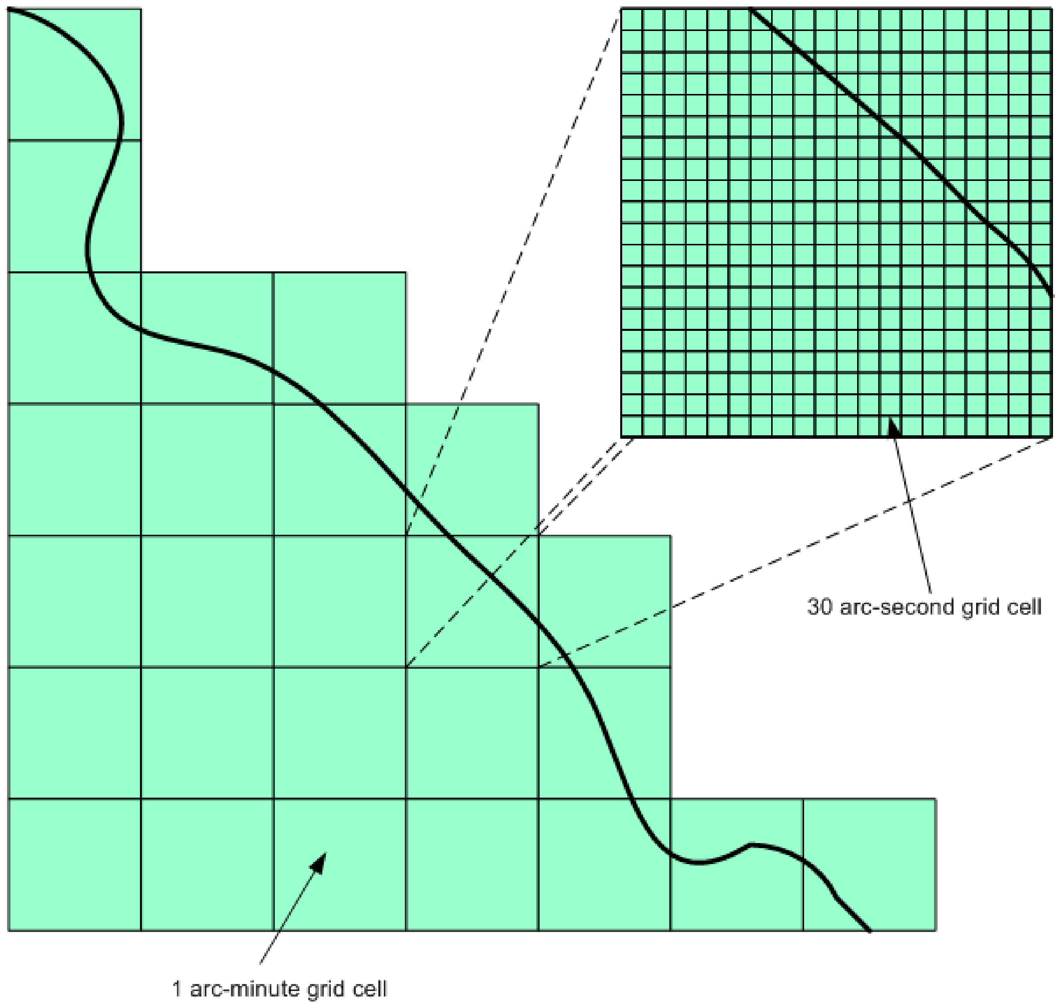


Figure 19: Area 1 Terrain Provision

5.6.3 Area 2

5.6.3.1 Request for Data

Once the regulator has determined which aerodromes fall under the requirements of Chapter 10 of ICAO Annex 15, the areas for which terrain and obstacle data needs to be provided should be clearly defined. It is recommended that this is carried out by the aerodrome operator, in close co-ordination with the regulator. This information should then be provided to the regulator. For each aerodrome, the regulator should subsequently identify the areas in the territory of other State(s) for which data is needed.

A meeting should be held between the regulator(s) of the neighbouring State(s) to discuss their needs with regards to access to data. The meeting should agree the geographical areas for which there is a need for data to be provided / exchanged.

It is recommended that the regulators then meet with the relevant authorities in their States to clarify their responsibilities with regards to the provision of data to neighbouring States.

The obligation to make the data available should rest with the State in which the aerodrome is located, as is currently the case with regards to the publication of data in the AIP. However, which State is responsible for the survey may be determined on a case-by-case basis and should, therefore, be a working level arrangement. However, it is likely that the State making the data available, i.e., that in which the aerodrome is published, should pay for the survey.

5.6.3.2 Obstacle Permission Process

Consideration should be given to how the obstacle permission processes of one State can ensure that other States are notified of the data if the obstacle affects an aerodrome in another State, and vice versa. Clearly, if an obstacle notification process is National law then it would be beneficial to include within it provisions for the notification of obstacles in another State's territory, and vice versa. Where these processes exist, it is recommended that these are modified, if necessary, to include such a provision.

5.6.3.3 Arrangements between Different State AIS/AIM

The body responsible for the data set for Area 2 may vary between States, for example, in some States, it may be the aerodrome operator, in others the ANSP and in others the State. In some cases, it may be a combination of two or more of these bodies. It is for each individual State to determine who the responsible body should be.

However, regardless of which body manages the data, it is recommended that the provision of data by the State is made to the AIS/AIM of the neighbouring State, in line with the requirements of ICAO Annex 15:

> *"2.2.1 An aeronautical information service shall ensure that aeronautical data and aeronautical information necessary for the safety, regularity or efficiency of air navigation are made available in a form suitable for the operational requirements of the ATM community, including:*
>
> *a) those involved in flight operations, including flight crews, flight planning and flight simulators; and*
>
> *b) the air traffic services unit responsible for flight information service and the services responsible for pre-flight information.*
>
> *Note.— A description of the ATM community is contained in the Global Air Traffic Management Operational Concept (Doc 9854).*
>
> *2.2.7 An aeronautical information service shall promptly make available to the aeronautical information services of other States any aeronautical data and aeronautical information necessary for the safety, regularity or efficiency of air navigation required by them, to enable them to comply with 2.2.1.*
>
> *2.3.4 Wherever practicable, direct contact between aeronautical information services shall be established in order to facilitate the international exchange of aeronautical data and aeronautical information."*

In many cases, arrangements will already be in place between AIS/AIM of neighbouring States although these may need to be expanded to encompass terrain and obstacle data, and, in some cases, to also address the issues related to obstacles outside the scope of the ICAO Annex 15 requirements. It is recommended that where arrangements do exist, and these have not been fully formalised, that these are formalised into a written agreement. A meeting should be held between the appropriate State representatives to negotiate the contents of the agreement. The inclusion of the regulator in this process is considered to be beneficial due to the authority it holds. In particular, it is advisable for the regulator to be included in the processes for conflict resolution which the agreement may document. This agreement should cover data formats and the means of data provision. In addition, it is recommended that it references standards to be used for data collection. If an aerodrome's Area 2 extends into another State and this State has collected the data, an inconsistent representation of obstacles for a single aerodrome may result if inconsistent feature capture rules are applied by the States. Considerations need to be made to the different levels of detail applied, as well as the horizontal geometry and vertical segmentation.

Within Europe, Commission Regulation (EU) 73/2010, laying down requirements on the quality of aeronautical data and aeronautical information for the SES places additional requirements on the content of formal agreements which should also be considered.

5.6.3.4 Data Collection

In some cases, it may be decided that the State does not have and does not need to collect the data for the area in question. The State may then simply grant permission for the neighbouring State to undertake a survey of this area.

In addition, it is possible that an agreement could be made to allocate survey costs and/or to use the same survey resources to survey neighbouring States. The use of the same survey resources would promote the harmonisation of data, ensuring that it is processed in the same manner to produce consistent data sets which utilise, for example, common reference systems. This would also help ensure that a survey did not have to be carried out twice, for example, to conduct a survey for Area 1 in one State, and for Area 2 in another State.

Where the same survey resources are not shared, any agreement between States should seek to harmonise survey dates as closely as possible to achieve optimum concurrent aerodrome survey data. This objective should also apply to the management of adjacent aerodrome surveys within the State.

5.6.4 Data Validation

The same data validation and verification processes should be applied to data from neighbouring States, as with any other data. However, it is appreciated that, in some cases, it may be difficult to validate the data received from another State as a result of a lack of other data sources against which the data may be validated. In such cases, the publishing State may not wish to take liability for the data it is publishing and this should be clearly stated in the DPS. It should be clear that if the data user elects to use the data, they assume liability for its use.

5.6.5 Non-Provision of Data / Data of Deficient Quality

If a State is provided with data that does not meet the ICAO quality requirements then it is recommended that it either does not publish the data or, where it chooses to publish, the DPS clearly informs the user that the data does not meet the quality requirements. If the State does not publish the data then the DPS should also document this.

If a State is not provided with the data that it needs, it is recommended that the regulator contacts the regulator in the relevant State to discuss how the issue can be resolved. It is hoped that if the discussions recommended in section 5.6.2, above, have taken place, a good working relationship will exist between the regulators, leading to a quick and successful resolution of any problems that may arise.

If this action is not successful, then a higher authority should be consulted, with regional bodies, such as the EC, and, finally, ICAO being contacted, if all other possibilities have been exhausted.

In the case that data is not provided, the DPS should clearly state which data is and is not included in the data set.

5.6.6 Letter of Agreement

The following section provides guidance on the establishment of a letter of agreement that may be used between two States as an instrument to promote harmonisation in the terrain and obstacle data that needs to be published for an aerodrome in one State, where the area of coverage extends into the territory of another State. By using it, the States will contribute to the achievement of a high-level of harmonisation in respect to the data published.

This type of agreement may be established between different levels of authority, depending on the needs of the States. For example, in some cases, the agreement may be established between State regulators, in others it may be established at the AIS level, whilst in others it may be needed on a per aerodrome basis. It is anticipated that a State level agreement would address the more general and institutional matters, whereas an AIS level agreement would contain more detailed, technical information. As such, some subjects may not be considered applicable in all cases. Therefore, the suggestions for content should not be considered as complete or mandatory and are provided as an example only.

It may be that two levels of agreement are needed, one at the level of the State, laying down the principles, and another at a lower level laying down the precise terms of an agreement with regards to a particular aerodrome. In addition, the guidance may be unable to provide for all aspects of a given institutional situation between two States.

The inclusion of the following subjects should be considered when establishing a letter of agreement.

- General:
  - Purpose of the Agreement;
  - Parties to the Agreement;
  - Conventions;
  - Definitions and Abbreviations;
  - Operational Status:
    - The need for the States to inform each other of any changes which may impact the flow of data between the States.
  - Escalation Procedures and Settlement of Disputes:
    - This may cover the rejection of data not suitable for publication and what should happen if the providing State does not take action to rectify the situation.
  - Cancellation of Agreement.
- Regulatory Environment:
  - International:
    - ICAO;
    - ISO.
  - European;
  - National;
  - Organisational.
- Areas of Common Interest / Responsibility:
  - Geographical Areas:
    - Definition of the geographical areas in each State for which one State is responsible for the provision of terrain and obstacle data to the other State, including any special areas, for example, military zones;
    - The distance beyond the territorial boundary for which Area 1 data should be provided. See section 5.6.2 for further details.
  - The obstacles that need to be exchanged for evaluation in accordance with the ICAO Annex 14 limitations, e.g., obstacle limitation surfaces;
  - Additional objects that need to be exchanged to meet the recommendations of ICAO Annex 15;
  - Obstacle Notification Processes;
  - Data Maintenance Procedures.
- DPS for Terrain and Obstacle Data:
  - Data Collection Techniques;
  - Feature Capture Rules;
  - Data Exchange Formats;
  - Data Validation and Verification Techniques;
  - Time Frames;
  - Data Delivery;
  - Data Quality Requirements (including reference systems, metadata, etc).
- Legal Liability;

- Financial Agreements;
- Letter of Agreement Lifecycle:
    - Reporting;
    - Review and Revision;
    - Change Process.
- Points of Contact.

6. FINANCIAL MATTERS

The implementation, provision and on-going maintenance of terrain and obstacle data is a costly exercise and needs careful consideration. This section outlines the financial matters that a State needs to address.

6.1 Allocations

To support the determination of appropriate funding and cost recovery for a State, it is recommended that the Table 2 is completed. This allows the State to determine the beneficiaries of the data, the owner of the data and the allocation of costs to recovery mechanisms. Allowance is also made for the indication of extant material relating to the cost recovery mechanism proposed, for example, the ICAO Doc 9161 Manual on Air Navigation Services Economics.

The following describes the columns of the table.

- Responsible:

  Indicates the body responsible for the initial payment for the collection of the terrain and obstacle data. This may be, for example, the owner of the obstacle or the State.

- Beneficiary:

  Indicates what functions are likely to benefit from the data. For example, Area 4 data is of benefit to IFR approaches operating CAT II/III. Area 2 data is of benefit to flight procedure design. It is likely that, in most cases, the data will be of use to many different functions and providing as complete a list as possible can help with the allocation of costs.

- Allocation:

  This indicates what percentage of the cost will be allocated to particular cost recovery mechanisms. Such mechanisms can include, but not be limited to, State funding, aerodrome terminal charges, en-route charges, etc.

- Reference:

  A reference to any material used to described or establish the cost recovery mechanisms referred to.

		Responsible	Beneficiary	Allocation	References
Area 1	Obstacle				
	DTM				
Area 2	Obstacle				
	DTM				
Area 3	Obstacle				
	DTM				
Area 4	Obstacle				
	DTM				

Table 2: Cost Allocation

6.2 Anticipated Costs

It had been hoped to identify, in this section, estimates of the likely costs to be incurred in making terrain and obstacle data available. However, early implementations have demonstrated that the costs vary significantly between implementations.

These variations are due to a number of reasons, including:

1. The tasks which are taken into account in recording the cost.
2. The division of responsibility and the costing methods adopted. For example, some States undertake much of the data processing “in-house” and do not attribute specific additional costs to this as it is already covered in the normal operating costs of the service.
3. The variation of the cost-index of the States. The significant differences in the cost of living, and hence wage costs, across Europe will affect implementation costs.
4. The technologies employed and their availability locally will significantly affect costs. The selection of a particular survey technique has often been based upon the local availability of survey teams and their experience, as well as the local availability of bulk survey equipment. The cost of acquiring access to an aircraft for the bulk survey collection recommended in this Manual may be significant if there is no local access to such facilities. Thus, an analysis will be necessary to identify the most cost-effective means by which a specific implementation may be best undertaken.
5. The reliance that can be made on existing data will have a significant impact. For example, in some States, the national geodetic organisation will have some of the data required. In such cases, implementation costs will depend upon the cost recovery policy of that organisation and the remaining surveys that need to be undertaken.
6. As a result of other developments within the European Union relating to data availability, there has been a possibility of sharing costs with other organisations. As a result, the overall cost for aviation can be reduced.

To assist in financial planning, the reader is advised to consider these factors and to determine their own situation. The range of costs seen to date has varied from around €30K per aerodrome to €150K.

6.3 Cost Recovery and Charging

6.3.1 Introduction

Whilst the anticipated costs of implementing terrain and obstacle data have been significantly reduced by the changes introduced by Amendment 36 to ICAO Annex, there is still an increase in the total costs foreseen for the provision of obstacle data. Furthermore, the need to provide terrain data is, in the main, new, with the only requirement existing prior to Amendment 33 to ICAO Annex 15 being that needed to support the preparation of the PATC.

Whilst the increases in cost are considered to be modest, the economic situation within aviation, and wider, is such that even small increases must be justified and will be unpopular with some stakeholders.

The desire of the TOD WG had been to determine a single approach for cost recovery that may be applied across Europe. Such a common approach would bring many benefits and ensure that both aerodromes and ANSPs, both of which are increasingly commercial entities, compete on a level playing field in terms of the charges levied for the implementation of terrain and obstacle data.

Discussions within both the TOD WG and the IFG to determine such a single approach have, however, demonstrated that the approaches that States are electing to take are varied and are determined by factors such as whether the collection of data is considered as an aviation task only or one that brings wider benefits for the entire State.

As such, it has been concluded that to make a recommendation as to the approach that should be taken in Europe would be controversial and that any selected approach would be unacceptable to some States. Consequently, this Manual makes no recommendation of the charging mechanism to be implemented. Rather, it presents the approaches that exist within the charging framework in place today. These mechanisms include those established by ICAO, the European Union and EUROCONTROL.

States are encouraged to read this chapter and determine the approach or approaches that best suit their individual circumstances.

6.3.2 Existing Charging Mechanisms

6.3.2.1 General

The following sections introduce the various documents and regulations which cover charging mechanisms and highlight the relevant text within these.

6.3.2.2 ICAO Doc 7300

ICAO Doc 7300 is the "*ICAO Convention on International Civil Aviation*" which is more commonly known as "*The Chicago Convention*". This document comprises the commitments with which a State must comply to be a member of ICAO. These are reflected as Articles.

With respect to charging, Article 15 is of relevance as this addresses "*Airport and similar charges*".

The text of this article states:

"*Charges imposed for the use of airports and air navigation facilities shall not be higher*

a) As to aircraft not engaged in schedule international air services, than those that would be paid by its national aircraft of the same class engaged in similar operations, and

b) As to aircraft engaged in scheduled international air services, than those that would be paid by its national aircraft engaged in similar international air services."

In essence, ICAO Doc 7300, in respect to aerodrome charges, has the following principles:

- Uniform conditions shall apply to the use of airports and air navigation services in a contracting State, by aircraft of all other contracting States; and
- The charges imposed by a contracting State for the use of such airports or air navigation services shall not be higher for aircraft of other contracting States than those paid by its national aircraft engaged in international operations.

It is also stated that no charges are to be imposed by any contracting State solely for the right of transit over or entry into or exit from its territory of any aircraft of a contracting State or persons or property thereon.

From a terrain and obstacle data perspective, it is considered that nothing in ICAO Doc 7300 prohibits the allocation of terrain and obstacle data costs to the use of an airport. Likewise, there is no indication that the charging of terrain and obstacle data costs to the users of the airport is prohibited.

6.3.2.3 ICAO Doc 9082

ICAO Doc 9082 is the "*ICAO's Policies on Charges for Airports and Air Navigation Services*". As recorded by ICAO, this document provides *"…the recommendations and conclusions of the Council resulting from ICAO's continuing study of charges in relation to the economic situation of airports and air navigation services provided for international civil aviation. The policies, which are intended for the guidance of Contracting States, are mainly based on the recommendations made in this field by the various conferences on the economics of airports and air navigation services which are held regularly by ICAO. The last such conference took place in Montreal from 15 to 20 September 2008 (Doc 9908 — Report of the Conference on the Economics of Airports and Air Navigation Services (CEANS) refers).*"

In its introductory text, the council recommends that States:

1. Permit the imposition of charges only for services and functions which are provided for, directly related to, or ultimately beneficial for, civil aviation operations; and
2. Refrain from imposing charges which discriminate against international civil aviation in relation to other modes of international transport.

It also expresses concern regarding the *"…proliferation of charges on air traffic and notes that the imposition of charges in one jurisdiction can lead to the introduction of charges in another jurisdiction*."

Given the apparent lack of business case for some data and the repeated statements that the terrain and obstacle data is of no use to some of the parties which were identified as being its users, care must be taken in allocating costs if heed is to be taken of the recommendation that costs are charged on the basis that they are "*provided for, directly related to, or ultimately beneficial for, civil aviation operations*".

ICAO Doc 9082 then addresses specific charges for airports and ANS which are addressed below.

6.3.2.3.1 The Cost Basis for Airport Charges

ICAO Doc 9082 introduces the cost basis for aerodromes, as follows:

"*The Council considers that as a general principle it is desirable, where an airport is provided for international use, that the users shall ultimately bear their full and fair share of the cost of providing the airport. It is therefore important that airports maintain accounts that provide information adequate for the needs of both airports and users and that the facilities and services related to airport charges be identified as precisely as possible. In determining and allocating the total cost to be met by charges on international air services, the list in Appendix 1 may serve as a general guide to the facilities and services to be taken into account. Airports should maintain accounts that provide a satisfactory basis for determining and allocating the costs to be recovered, should publish their financial statements on a regular basis and should provide appropriate financial information to users in consultations. Moreover, the Council recommends that States consider the application, where appropriate, of internationally accepted accounting standards for airports.*"

It then lays down the principles that should be applied in establishing airport charges:

i. "*The cost to be shared is the full cost of providing the airport and its essential ancillary services, including appropriate amounts for cost of capital and depreciation of assets, as well as the costs of maintenance, operation, management and administration, but allowing for all aeronautical revenues, plus contributions from non-aeronautical revenues accruing from the operation of the airport to its operators.*

ii. *In general, aircraft operators and other airport users should not be charged for facilities and services they do not use, other than those provided for and implemented under the Regional Air Navigation Plan.*

iii. *Only the cost of those facilities and services in general use by international air services should be included, and the cost of facilities or premises exclusively leased or occupied, and charged for separately, should be excluded.*

iv. *While airports should maintain cost data in sufficient detail to facilitate consultation, transparency and economic oversight, it may be beneficial to develop more aggregated cost bases in certain circumstances for the purpose of setting charges. However, the aggregation should be done in a logical and transparent manner, accompanied by safeguards, as appropriate, regarding consultation and, where possible, agreements with users to avoid discrimination among users.*

v. *An allocation of costs should be considered in respect of space or facilities utilized by government authorities.*

vi. *The proportion of costs allocable to various categories of users, including State aircraft, should be determined on an equitable basis, so that no users shall be burdened with costs not properly allocable to them according to sound accounting principles.*

vii. *Costs related to the provision of approach and aerodrome control should be separately identified.*

viii. *Airports may produce sufficient revenues to exceed all direct and indirect operating costs (including general administration, etc.) and so provide for a reasonable return on assets, at a sufficient level to secure financing on favourable terms in capital markets, for the purpose of investing in new or expanded airport infrastructure and, where relevant, to remunerate adequately holders of airport equity.*

ix. *The capacity of users to pay should not be taken into account until all costs are fully assessed and distributed on an objective basis. At that stage, the contributing capability of States and communities concerned should be taken into consideration, it being understood that any State or charging authority may recover less than its full costs in recognition of local, regional or national benefits received.*"

As may be seen, the allocation of the benefit of terrain and obstacle data to applications and user categories will assist when applying these principles. However, these benefits will differ between aerodromes, as will the categories of user involved. For example, if APV and PBN are to be introduced at an airport, terrain and obstacle data will bring benefit for these applications.

It should be noted that bullet ix., above, does allow for the case that a State does not wish to recover all the costs of provision through charges, as it considers the aerodrome to be providing economic benefit.

Appendix 1 to ICAO Doc 9082 lists the facilities which should be taken into account when establishing the airport costs. These are provided below. It should be noted that only those which are considered to have a bearing on the possible allocation of terrain and obstacle data costs are expanded.

- Approach, landing and take-off facilities and services:
  - Landing area with cleared approaches and taxiways with necessary drainage, fencing, etc. Also, lights for approach, landing, taxiing and take-off, as well as communications and other special aids for approach, landing and take-off;
  - Approach and aerodrome Air Traffic Control (ATC) for approach, landing and take-off with necessary communication, navigation and surveillance supporting services (sometimes partly or wholly provided by other than the airport operator);
  - Meteorological service;
  - Fire and ambulance service in attendance.
- Terminals, aircraft parking space, hangars and other facilities and services provided for aircraft operators;
- Security measures, equipment, facilities and personnel;
- Accommodation for other than aircraft operators;
- Noise alleviation and prevention;
- Mitigation and prevention of emission affecting local air quality.

Whilst it is clear that terrain and obstacle data are not included in this list, the provision of this data forms an inherent part of the provision of some facilities listed. For example, approach aids will need to be planned, installed and commissioned, and knowledge of the terrain and obstacles present will have a bearing on the introduction of the facility. Likewise, approach and departure control will, in many cases, require the establishment of flight procedures which, once again, benefit from the provision of terrain and obstacle data.

It may, therefore, be considered that a portion of the costs of providing terrain and obstacle data may be attributable to the availability of these facilities.

6.3.2.3.2 The Cost Basis for Air Navigation Services

ICAO Doc 9082 introduces the cost basis for air navigation services, as follows:

"*The Council considers that as a general principle, where air navigation services are provided for international use, the ANSPs may require the users to pay their share of the related costs; at the* *same time international civil aviation should not be asked to meet costs which are not properly allocable to it. The Council therefore encourages States to maintain accounts for the air navigation services they provide in a manner that ensures that air navigation services charges levied on international civil aviation are properly cost based.*

The Council considers that an equitable cost recovery system could proceed from an accounting of total air navigation services costs incurred on behalf of aeronautical users, to an allocation of these costs among categories of users, and finally to the development of a charging or pricing policy system. In determining the total costs to be paid for by charges on international air services, the list in Appendix 2 may serve as a general guide to the facilities and services to be taken into account. Moreover, the Council specifically recommends that States consider the application, where appropriate, of internationally accepted accounting standards for ANSPs."

It then lays down the principles that should be applied in establishing air navigation service charges:

"*i) The cost to be shared is the full cost of providing the air navigation services, including appropriate amounts for cost of capital and depreciation of assets, as well as the costs of maintenance, operation, management and administration.*

ii) The costs to be taken into account should be those assessed in relation to the facilities and services, including satellite services, provided for and implemented under the ICAO Regional Air Navigation Plan(s), supplemented where necessary pursuant to recommendations made by the relevant ICAO Regional Air Navigation Meeting, as approved by the Council. Any other facilities and services, unless provided at the request of operators, should be excluded, as should the cost of facilities or services provided on contract or by the carriers themselves, as well as any excessive construction, operation or maintenance expenditures.

iii) The costs of air navigation services provided during the approach and aerodrome phase of aircraft operations should be identified separately, as should the costs of providing aeronautical meteorological service, when possible.

iv) Costs for certain security measures of a preventive nature for the provision of air navigation services, which are specifically related to civil aviation and performed on a routine basis, may be included in the cost basis for air navigation services charges, to the extent that they have not already been considered in the context of safety-related measures. Civil aviation should not be charged for any costs that would be incurred for more general security functions performed by States, such as general policing, intelligence gathering and national security. Further, costs associated with airport security should not be combined with security costs incurred with regard to air navigation facilities or services.

v) Air navigation services may produce sufficient revenues to exceed all direct and indirect operating costs and so provide for a reasonable return on assets (before tax and cost of capital) to contribute towards necessary capital improvements."

Key within these recommendations is that the full cost of the service is to be shared amongst the users of the service. As the provision of some terrain and obstacle data is of benefit to services (most particularly in the case of Area 1 data), this is a clear indication that this cost should be included in the ANS costs.

Reference is also made to the facilities and services which are identified within the Regional Air Navigation Plan. Given that not all aerodromes within a State's AIP typically appear within the Regional Air Navigation Plan, this may be considered as indicative of which aerodromes the costs should be included for.

The document continues by laying down recommendations as to how the costs of services should be allocated to the users of the service.

"*The Council recommends that the allocation of the costs of air navigation services among aeronautical users be carried out in a manner equitable to all users. The proportions of cost attributable to international civil aviation and other utilization of the facilities and services (including domestic civil aviation, State or other exempted aircraft, and non-aeronautical users) should be determined in such a way as to ensure that no users are burdened with costs not properly* *allocable to them according to sound accounting principles. The Council also recommends that States acquire basic utilization data in respect of air navigation services, including the number of flights by category of user (i.e. air transport, general aviation, and other) in both domestic and international operations, and other data such as the distance flown and aircraft type or weight, where such information is relevant to the allocation of costs and the cost recovery system.*"

As may be seen, the two key points which may be brought out from this statement are:

- That the allocation of costs must be equitable to all users;
- That it should be ensured that no users are burdened with costs which cannot be properly allocated using sound accounting principles.

Once again, the benefits to users and the categorisation of users is mentioned and, more specifically, the use of services by domestic operations. Whilst ICAO is predominantly interested in international flights, there is recognition that the costs of services (presumably including terrain and obstacle data) must also be met by domestic services.

Appendix 2 of ICAO Doc 9082 lists the facilities which should be taken into account when establishing the costs of providing the ANS. These are provided below. It should be noted that only those which are considered to have a bearing on the possible allocation of terrain and obstacle data costs are expanded.

- Air Traffic Management:
    - The dynamic, integrated management of air traffic and airspace, including ATS, airspace management and air traffic flow management (ATFM) — safely, economically and efficiently — through the provision of facilities and seamless services, in collaboration with all parties and involving airborne and ground-based functions.
- Communication, navigation and surveillance systems;
- Meteorological services;
- Other ancillary aviation services:
    - Any permanent civil establishment of equipment and personnel maintained for the purpose of providing such services as search and rescue, accident investigation, aeronautical charts and information services.

Given that the provision of an ATM service requires the establishment of, for example, routes, procedures and minimum safe altitudes, and that terrain and obstacle data will assist with the establishment of these facilities, it may be considered that a portion of the terrain and obstacle data costs may be allocated to these facilities.

It may clearly be seen that the cost of the provision of AIS is included in this list, as is the preparation of charts. However, as has been discussed before, whether this is intended to mean purely the costs of preparing and distributing the products, or the costs of collecting the necessary data, is not entirely clear.

6.3.2.4 ICAO Doc 9161

ICAO Doc 9161 is the "*Manual on Air Navigation Services Economics*", the objective of which is to provide practical guidance to States, ANS managing and operating entities, and designated charging and regulatory authorities, to assist in the efficient management of ANS and in implementing ICAO's Doc 9082, Policies on Charges for Airports and Air Navigation Services.

With regards to AIS, the manual indicates that the AIS comprises the *"…staff, facilities and equipment employed to collect, collate, edit, publish and distribute aeronautical information concerning the entire territory of a State as well as any other areas for which it has undertaken to provide air navigation services*" this service is to include "*the preparation and dissemination of Aeronautical Information Publications (AIPs), Notices to Airmen (NOTAM) and Aeronautical Information Circulars (AICs) and the provision of plain-language pre-flight information bulletins to flight crews as part of the pre-flight information service.*"

It should be noted that it is unclear whether the use of the word "collect" is meant to indicate the act of survey or the gathering of information from data providers.

It is acknowledged that there are services which are provided purely to service aviation, such as ATS, and those which also serve other communities, such as Meteorology. Furthermore, some aviation services are shared between en-route and airports, and costs should be met by a combination of en-route and airport charges. ICAO Doc 9161 recommends that the costs should be shared between the different beneficiaries of these shared services, on an equitable basis.

It is undeniable that terrain and obstacle data is of interest to a wider community that just aviation, however, the sourcing and any license agreements in place may constrain possible users. Consequently, whether terrain and obstacle data are designated as an aviation service only or as part of a more widely used service, will depend upon the decision of individual States.

Costs should be attributable to route utilisation and airport utilisation, and allocated among the different categories of users. Of particular relevance is State traffic, including Military traffic which may often be exempt from charges. ICAO Doc 9161 uses the following figure to categorise users.

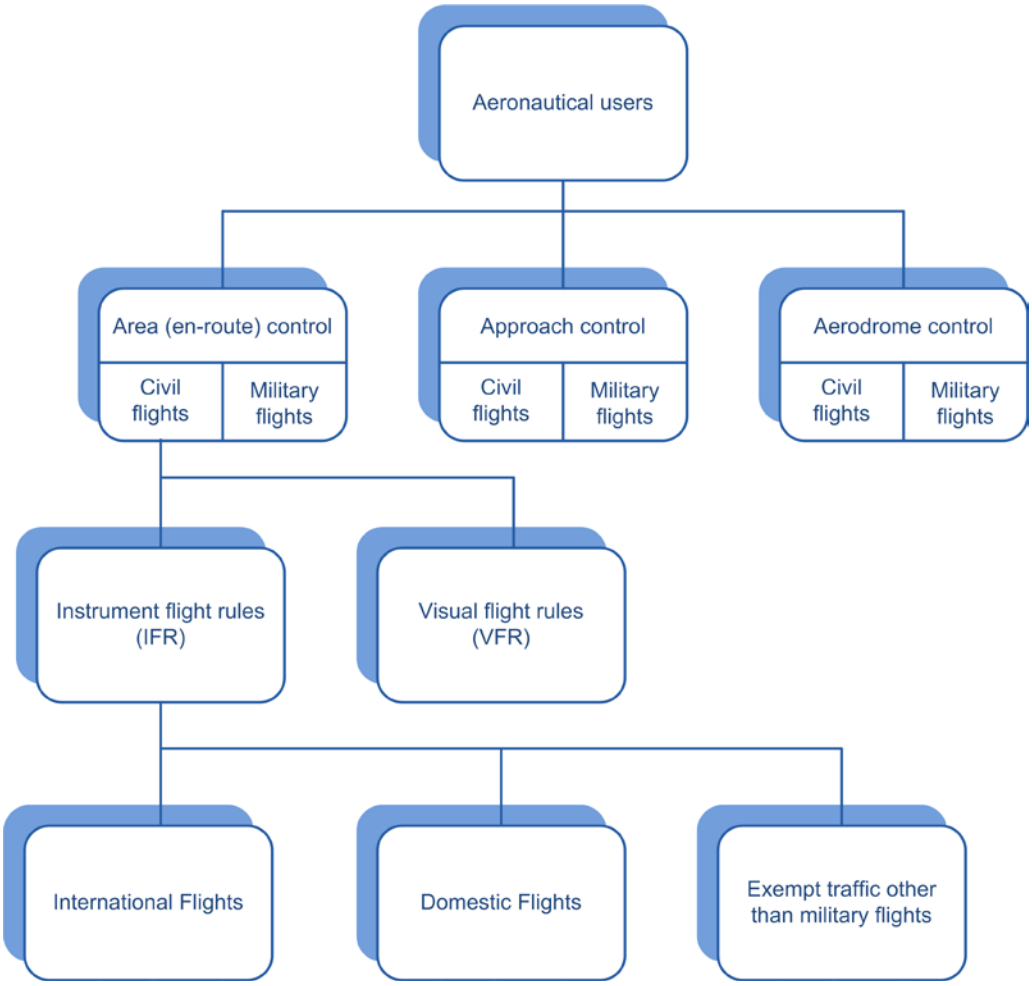


Figure 20: Categorisation of Users

Once again, ICAO Doc 9161 does not provide any clear recommendation which may be applied to terrain and obstacle data; rather it elaborates principles already identified in ICAO Doc 9082. Key to the application of these recommendations is the allocation of terrain and obstacle data costs to aviation/non-aviation services, and the allocation of those costs attributable to aviation, to categories of user. As discussed before, this allocation and attribution will be affected by each individual State's particular situation.

6.3.2.5 Commission Regulation (EC) No 1794/2006

Commission Regulation (EC) No 1794/2006 lays down a common charging scheme for air navigation services within the scope of the Single European Sky. The scheme required is consistent with the EUROCONTROL Route Charges System (see below). As a regulation, its application is mandatory by those parties identified within its scope. These are:

- Air traffic service providers designated in accordance with Regulation (EC) 550/2004, the Service Provision Regulation;
- Providers of meteorological services for general air traffic within the ICAO European (EUR) and Africa-Indian Ocean (AFI) regions, if the provider has been designated in accordance with Article 9(1) of Regulation (EC) 550/2004.

The provision of terrain and obstacle data by an AIS falls under the first category.

The regulation imposes the following key principles in establishing a common charging scheme for ANS:

- Reflect the costs incurred either directly or indirectly;
- Costs for en-route services shall be financed by en-route charges;
- Costs for terminal services shall be financed by means of terminal charges and/or other revenues.

The charging scheme adopted is required to provide transparency, with the service providers involved publishing financial reports and being subject to independent audits.

Services, facilities and activities which are considered to be eligible for inclusion under the charging scheme are:

- Cost incurred in the provision of ANS in relation to the facilities and services provided for and implemented under the ICAO Regional Air Navigation Plan, European Region;
- Administrative overheads, training, studies, test and trials, as well as research and development allocated to these services;
- Cost incurred by the relevant national authorities and recognised organisations, and cost stemming from international agreements.

The regulation determines that the terminal service costs shall be comprised of:

- Aerodrome control services, aerodrome flight information services, including air traffic advisory services, and alerting services;
- Air traffic services related to the approach and departure of aircraft within a certain distance of an airport, on the basis of operational requirements;
- An appropriate allocation of all other ANS components, reflecting a proportionate attribution between en-route and terminal services.

Consequently, the en-route costs comprise all other eligible costs that are not attributed to the terminal services.

The cost of terrain and obstacle data may, under this scheme, reasonably fall under both the terminal service costs (cost incurred in the provision of ANS) and those for en-route, with the State needing to identify a fair and transparent allocation. Once again, no specific requirements are found relating either to terrain and obstacle data itself or the collection and publication of such data.

6.3.2.6 EUROCONTROL Doc 10.60.01

EUROCONTROL Doc 10.60.01 is the "*Principles for Establishing the Cost-Base for En Route Charges and the Calculation of the Unit Rates*", issued by the Central Route Charges Office (CRCO).

It lays down common principles which the "*contracting States to the multilateral agreement relating to route charges*" have agreed to adopt. These principles are "*…principles are based on those described in the "ICAO's Policies on Charges for Airports and Air Navigation Services" as contained in ICAO Document 9082 and in the "Manual on Air Navigation Services Economics" as contained in ICAO Document 9161, subject to any modification made in order to take account of* *other methods specific to the EUROCONTROL route charges system*." The principles are also consistent with Commission Regulation (EC) 1794/2006.

The focus of the document, as its title indicates, is en-route charges and, therefore, terminal costs are not addressed. Recognition is, however, given to the fact that some services are shared between terminal and en-route services. In this regard, the document identifies that facilities and services serving both en-route and terminal costs should be allocated based on one or more of the following criteria, as appropriate:

- In proportion to the number of dedicated controller positions;
- In proportion to the number of dedicated sectors;
- In proportion to the number of flights;
- In proportion to the estimated time of use of the equipment;
- In proportion to the personnel;
- In proportion to the square footage of accommodation;
- In proportion to the number of radio channels;
- In proportion to the average distance flown or the time spent;
- In accordance with the organisational structure of ATS provision.

In relation to AIS costs, it is stated that "*AIS costs should either be charged to en route services or apportioned between en route services and other services, the latter according to national practice*."

The issue here, once again, is whether or not the costs of terrain and obstacle data are considered to be an AIS cost. No specific mention is made of the cost in originating information needed to support the provision of ANS.

6.3.3 Conclusions

As it may be seen, a number of mechanisms exist which may be used to recover the cost of the provision of terrain and obstacle data. There is no clear indication as to a single mechanism which should be used and, indeed, this does not appear to be the desire of many States. That said, the main principles outlined within the existing charging frameworks are broadly similar, with the main points being:

- Transparency;
- Fair allocation of shared costs to the users/services affected;
- Cost burden to be shared amongst all users, with no party having an unreasonable share;
- Recognition of support costs.

The inclusion of the requirements within ICAO Annex 15 has somewhat blurred the boundary between the origination of data (which is normally within the scope of the SARPs contained in other ICAO Annexes) and the publication of information, as is normally the remit of an AIS. This leads to uncertainty as to whether or not the cost of collecting and providing terrain and obstacle data may reasonably be classified as an AIS cost.

7. TECHNICAL MATTERS

7.1 Product Specification

For the specification of a terrain and obstacle data set, the DPS should be based on the structure given by ISO 19131 and should cover the following topics (*mandatory items, according to ISO 19131, are shown in italic*):

- *overview*:

  Informal description of the product and general information about the creation of the DPS;

- *specification scope*:

  For each subset of a homogenous data set, the scope (intended use or coverage) should be provided. Multiple scopes can be used to distinguish between the four areas;

- *data product identification*:

  Title of the product, a brief summary of the content, purpose and expected spatial resolution; geographical area covered by the data product; supplementary information, such as legal constraints;

- *data content and structure*:

  Application schema (formal description of the data structure and content of data sets) and feature catalogue (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);

- *reference system*:

  Spatial and temporal reference system;

- *data quality*:

  Acceptable conformance quality levels and corresponding data quality measures. Data quality elements and sub-elements;

- data capture:

  General description of the sources of the data and the processes applied for the capture of data;

- data maintenance:

  Principles and criteria applied, including the frequency of updates;

- portrayal:

  Information on how data held within the data sets is presented (graphic output (plot/image));

- *data product delivery*:

  Delivery formats and delivery medium information;

- additional information;
- *metadata*:

  The metadata catalogue is based on ISO 19115 and should be adapted according to application needs. See section 7.7 of this Manual for more information.

In the following sections, the attributes of the requirements which shall be used to specify the product in more detail, are described[39]. For each attribute, its name (in blue), a brief description (in

[39] The entire schema can also be found on the ISO TC211 homepage: http://www.isotc211.org/hmmg/HTML/root.html.

italic) and the recommended values (if feasible) are provided. This section can therefore be consulted when preparing a request for terrain and obstacle data origination. For general aspects on data origination in aviation, refer to the EUROCONTROL Specification for Aeronautical Data Origination.

Since a DPS defines the requirement for a data product, it may be used both in the creation/origination of the data set in the upstream process and downstream by users to understand the product's requirements.

7.1.1 Overview

Note: The overview section is not modelled using the Unified Modelling Language (UML) but as human-readable, free text. The elements listed hereafter are based on the recommendation given by ISO 19113.

a) DPS metadata

〉 **Data set title**

The title of the data set. This may need to be aligned with a national spatial data infrastructure.

terrain and obstacle data, according to ICAO Annex 15, for <country>.

〉 **Data set reference date**

Date when the DPS was published.

2009-09-30.

〉 **Data set responsible party**

The party which is responsible for the creation of the DPS.

EUROCONTROL Headquarters

Rue de la Fusée 96

B-1130 Brussels, Belgium

Tel: +32 2 729 90 11

Fax: +32 2 729 90 44

URL: http://www.eurocontrol.int.

〉 **Data set language**

The language in which the DPS and the data set are published.

English.

〉 **Data set topic category**

A classification of the data set, in accordance with the enumeration list given in MD_TopicCategoryCode of ISO 19115, optionally enhanced by the domain.

018 – transportation (Aviation).

b) Terms and Definitions

〉 **Terms and Definitions**

Important terms used in the DPS can be described in this section. The target audience of the DPS should be considered when compiling the list of terms (for example, there is no need to explain a geoid to surveyors).

Examples: Integrity, Obstacle, ODCS, Terrain Data Set, Traceability.

c) Abbreviations

〉 **Abbreviations**

All abbreviations used in the DPS shall be described in this section.

Examples: AIP, AIXM, Cyclic Redundancy Check (CRC), ICAO

7.1.2 Informal Description of the Product

Due to the importance of differentiating between the four terrain and obstacle data areas, the extent of the geographical area should be described in a more detailed manner than that proposed by the DPS data content contained within the ISO 19131 model. Therefore, it is expected that the terrain and obstacle data profile will expand the *Data content* section of the ISO standard. It is recommended that the figures and text provided in this Manual, in sections 3.7.1, 3.7.2, 3.7.3 and 3.7.4, are used for a general description of the four terrain and obstacle data areas. This can be enhanced by the country-specific definition, such as the list of airports for which Area 2, Area 3 or Area 4 data is made available.

7.1.3 Specification Scope

The DPS may specify the partitioning of the product data content, based on one or more criteria (for example, feature type, spatial extent, etc.). Such partitioning may differ for parts of the DPS. Each such part of the data content shall be described by a specification scope that may inherit or override the general scope specification. In the following sections, examples of the scope definitions are given. However, it is important that more scope definitions are defined to allow for a complete and unambiguous set of scopes to exist.

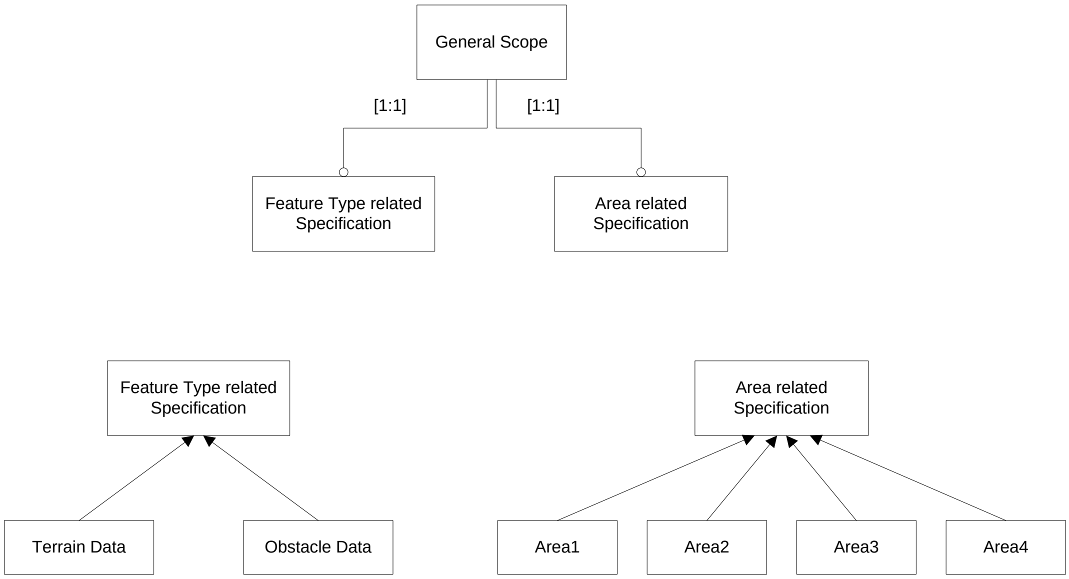


Figure 21: Specification Scopes and their Dependencies

7.1.3.1 Scope “General Scope”

The “general scope” is used to describe requirements which are common to both data sets (terrain and obstacles) and to all terrain and obstacle data areas. In this section, the properties of the scope packages are described and an example of the content is given.

- **DPS_ScopeInformation.scopeIdentification:**
  The identification of the scope which is used as a reference.
  General Scope.

- **DPS_ScopeInformation.level**
  The code identifying the hierarchical level of the data. It uses the MD_ScopeCode enumeration from ISO 19115. For the general scope, it is assumed that it refers to the series level. Other levels which may be useful, in the context of terrain and obstacle data, are data set (Area 1 obstacle) and feature type (terrain data).
  006 – series.

- **DPS_ScopeInformation.levelName**
  Name of the hierarchy level of the data specified by the scope.
  General scope of terrain and obstacle data for <country>.

- **DPS_ScopeInformation.Extent**
  In this section, information about the spatial, vertical and temporal extent of the data specified by the scope can be given. For terrain and obstacle data, only the horizontal extent shall be given. A simple description can be provided.
  The area of <country> and adjacent areas, if needed, for the complete coverage of Area 2.

- **DPS_ScopeInformation.levelDescription**
  Detailed description about the level of the data specified by the scope.
  The general scope is the root level of the scope level hierarchy. Specifications which refer to the general scope are valid for all data sets and all features of terrain and obstacle data, according to ICAO Annex 15, unless they are rendered more precise in a lower level scope.

7.1.3.2 Scope “Obstacle Scope”

The scope level “obstacle scope” provides an example of how the “general scope” can be refined to provide valid specifications for specific cases, for example, in this case, obstacles.

- **DPS_ScopeInformation.scopeIdentification**
  Obstacle scope.

- **DPS_ScopeInformation.level**
  006 – series.

- **DPS_ScopeInformation.levelName**
  Detail specifications valid for all obstacles, according to ICAO Annex 15.

- **DPS_ScopeInformation.Extent**
  The area of <country> and adjacent areas, if needed, for the complete coverage of Area 2.

- **DPS_ScopeInformation.levelDescription**
  The scope level “Obstacle scope” defines the requirements which are specifically for obstacles and which therefore deviate from the “general scope”.

- **DPS_ScopeInformation.superScope**
  The superScope is the reference to the parental scope.
  General scope.

7.1.3.3 Scope “Obstacle Area1”

The scope level “Obstacle Area1” gives an example how the “General scope” and the “Obstacle scope” can be refined for obstacles in Area 1[40].

- **DPS_ScopeInformation.scopeIdentification**
  Obstacle Area1.

- **DPS_ScopeInformation.level**
  005 – data set.

- **DPS_ScopeInformation.levelName**
  Detail specifications valid for obstacles in Area 1.

- **DPS_ScopeInformation.Extent**
  The entire area of <country> which defines Area 1.

[40] The scope of the other areas is developed in the same way. It is recommended that a geographical outline of the individual scopes is provided to allow an unambiguous description of the area of interest.

〉 **DPS_ScopeInformation.levelDescription**
The scope level "Obstacle Area 1" defines the requirements which are specifically for obstacles in Area 1 and which, therefore, deviate from the "General scope" and the "Obstacle scope".

〉 **DPS_ScopeInformation.superScope**
Obstacle scope.

7.1.3.4 Scope "Terrain Scope"

The scope level "terrain scope" provides an example of how the "general scope" can be refined to provide valid specifications for specific cases, for example, in this case, terrain data.

〉 **DPS_ScopeInformation.scopeIdentification**
Terrain scope.

〉 **DPS_ScopeInformation.level**
006 – series.

〉 **DPS_ScopeInformation.levelName**
Detail specifications valid for terrain data, according to ICAO Annex 15.

〉 **DPS_ScopeInformation.Extent**
The area of <country> and adjacent areas, if needed, for the complete coverage of Area 2.

〉 **DPS_ScopeInformation.levelDescription**
The scope level "Terrain scope" defines the requirements which are specifically for terrain data and which therefore deviate from the "general scope".

〉 **DPS_ScopeInformation.superScope**
The superScope is the reference to the parental scope.

General scope.

7.1.4 Data Product Identification

The samples given for the product identification are independent from the area definitions. For each data origination request which goes beyond surveying single obstacles, the geographical extent shall be documented in this section. Since certain definitions may only be valid for a portion of the entire data set, it is proposed that more than one product identification is defined. The sample provided below relates to all terrain data.

- Overview elements

〉 **DPS_IdentificationInformation.title**
The title of the data product.

Terrain data for <country> according to ICAO Annex 15.

〉 **DPS_IdentificationInformation.abstract**
A brief narrative summary of the content of the data product.

The product contains a terrain data set which is compliant with the requirements laid down in ICAO Annex 15 (Amendment 36).

〉 **DPS_IdentificationInformation.purpose**
A summary of the possible applications and uses for which the data product is developed.

The purpose of the data product is given in the introductory text to ICAO Annex 15, Chapter 10 which provides possible uses of the data. It is the responsibility of the user to determine if the data product meets their needs.

- Category

〉 **DPS_IdentificationInformation.topicCategory (MD_TopicCategoryCode)**
Specifies to which main themes the data product belongs.

006 – Elevation

018 – Transportation.

- Spatial information

〉 **DPS_IdentificationInformation.spatialRepresentationType (MD_SpatialRepresentationTypeCode)**
Form of spatial representation.
002 – grid.

〉 **DPS_IdentificationInformation.geographicDescription**
Description of the geographical area for which data is made available. The DPS allows the geographical extent to be defined in a number of ways, such as bounding polygon (as GML), bounding box or by a geographic identifier (which could be an ISO country code).
SI – Slovenia.

〉 **DPS_IdentificationInformation.geographicDescription>EX_BoundingBox.polygon**
The bounding box can be expressed as a polygon, coded in GML.

```
<gml:PolygonsrsName="EPSG:4326">
        <gml:LinearRing>
            <gml:coordinates decimal="." cs="," ts="">
                119.593002319336,-31.6695003509522
                119.595306396484, 31.6650276184082
                119.600944519043,-31.6658897399902
                119.603385925293,-31.669527053833
                119.60050201416,-31.6739158630371
                119.595664978027,-31.6728610992432
                119.593002319336, 31.6695003509522
            </gml:coordinates>
        </gml:LinearRing>
</gml:Polygon>
```

- Scope

〉 **DPS_ScopeInformation.superScope**
General scope.

7.1.5 Data Content and Structure

7.1.5.1 Terrain

In this section, the data model for terrain data which is required to fulfil the SARPs is depicted. The Terrain Information Conceptual Model (TICM) is a formal representation of the requirements for terrain data described in ICAO Annex 15 and is expressed as a collection of UML diagrams. Terrain data is modelled using the concept of coverages and TICM provides a conformant implementation of the ISO 19123 coverage schema. The requirements for the terrain data model attributes are provided and explained in detail in section 3.7.7. The conceptual model and the exchange schema can be found in section 7.6.1.

〉 **DPS_CoverageInformation.narrativeDescription**
The data model for terrain data follows the model defined in TIXM.

〉 **DPS_CoverageInformation.contentScope (DPS_ScopeInformation.scopeIdentification)**
Terrain scope.

- **DPS_CoverageInformation.coverageDescription**

  The TerrainSet coverage entity describes the domain over which elevation data is provided.

  The ElevatedPoint entity has attributes for elevation information, as well as metadata for items, such as known variations.

  The SurveySet entity allows survey information applicable to multiple ElevatedPoints to be specified once and referenced.

- **DPS_CoverageInformation.coverageType**

  Elevated Points.

- **DPS_CoverageInformation.specification**

  Figure 22 shows the data model for terrain data.

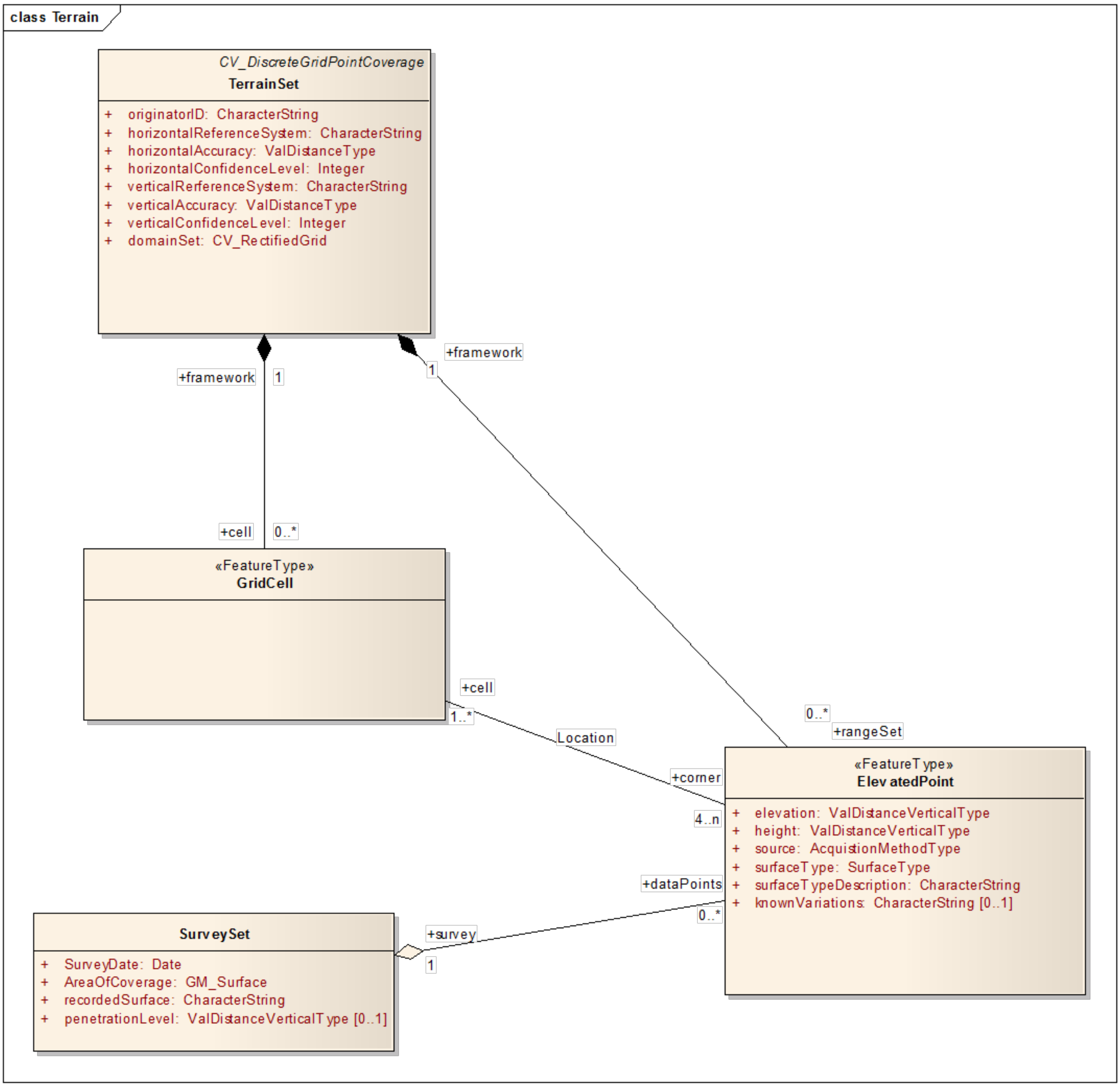


Figure 22: Terrain Data Model

7.1.5.2 Obstacles

The requirements for the obstacle data model attributes are provided and explained in details in section 3.7.8, the conceptual model and the exchange schema can be found in section 7.6.2.

- **DPS_FeatureBasedDataInformation.narrativeDescription**
  The data model for obstacle data follows the model defined in AIXM 5.1.
- **DPS_FeatureBasedDataInformation.contentScope (DPS_ScopeInformation.scopeIdentification)**
  Obstacle scope.

a) Application schema

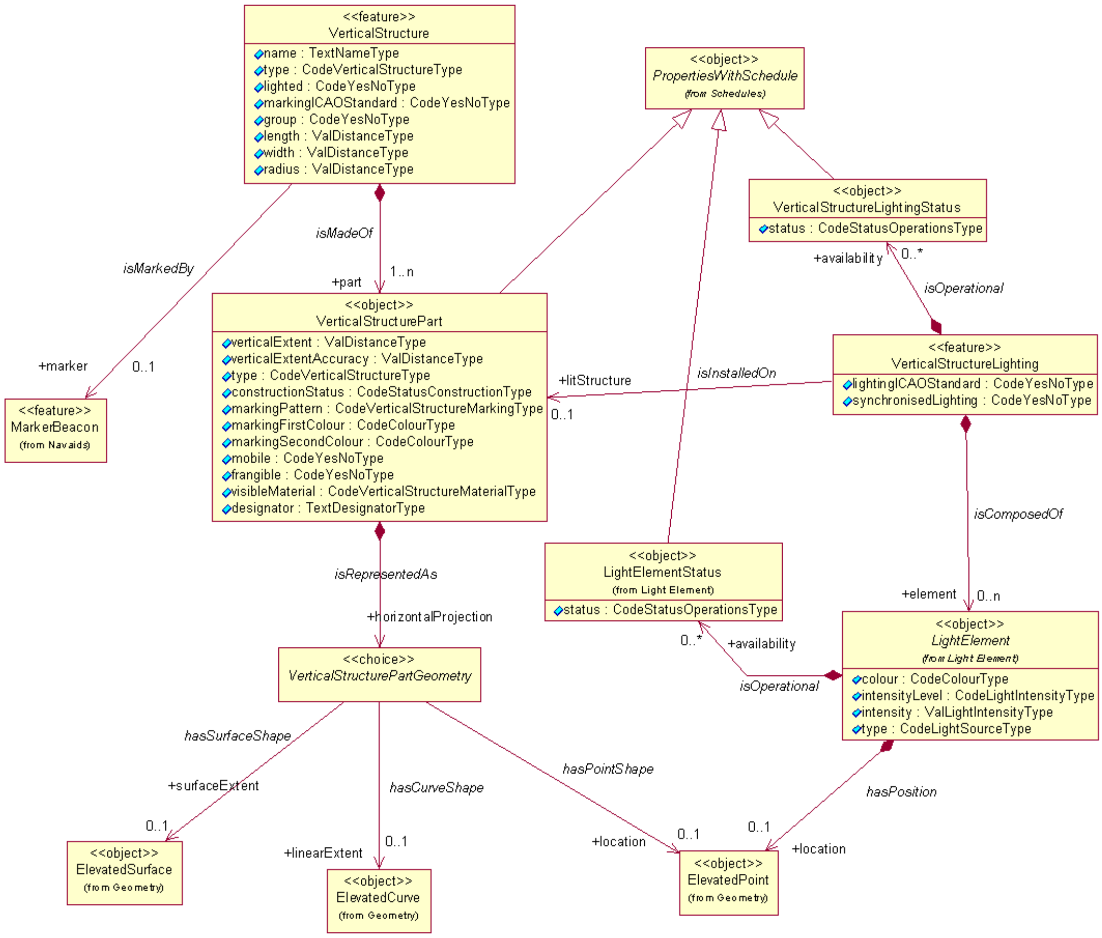


Figure 23: Application Schema

b) Feature Catalogue

All necessary definitions are given in AIXM. Here is an example of the additional attribute “BottomHeight”, in the feature class VerticalStructurePart:

- **DPS_FeatureBasedDataInformation.featureCatalogue (FC_FeatureCatalogue.functionalLanguage)**
  The language in which the Feature catalogue is described.
  English.
- **DPS_FeatureBasedDataInformation.featureCatalogue (FC_FeatureCatalogue.producer>CI_Citation)**
  The producer of the feature catalogue.
  EUROCONTROL / Federal Aviation Administration (FAA).
- **DPS_FeatureBasedDataInformation.featureCatalogue (FC_FeatureType.typeName)**
  Name of the feature type.
  VerticalStructurePart.

- **DPS_FeatureBasedDataInformation.featureCatalogue (FC_FeatureType.definition)**
  The definition of the feature type.
  A part of the vertical structure that can be represented as a point, line or polygon, with vertical extent.

- **DPS_FeatureBasedDataInformation.featureAttribute (FC_FeatureAttribute.code)**
  The numeric or alphanumeric code that uniquely identifies the feature attribute within the feature catalogue.
  BottomHeight.

- **DPS_FeatureBasedDataInformation.featureAttribute (FC_FeatureAttribute.valueMeasurementUnits)**
  Unit of measurement used for this feature attribute.
  See also AIXM.DataTypes.ValDistanceType. UomDistanceVerticalType.

- **DPS_FeatureBasedDataInformation.featureAttribute (FC_FeatureAttribute.valueType)**
  Value type used for this feature attribute.
  See also AIXM.DataTypes.ValDistanceVerticalType.

7.1.6 Reference Systems

The catalogue given by ISO 19131 has the ability to have only one spatial reference system and, therefore, either a horizontal or vertical reference system. The model is, therefore, extended to include two spatial reference systems:

a) General

- **DPS_ReferenceSystemInformation (DPS_ScopeInformation.scopeIdentification)**
  General Scope

b) Horizontal reference system

- **DPS_ReferenceSystemInformation.spatialReferenceSystem (MD_ReferenceSystem.referenceSystemIdentifier>RS_Identifier.codeSpace)**
  The reference system identifier shall be stated if the projection, ellipsoid and datum are not documented. The code space is an identifier within which one or more codes are defined. This code space is often defined by an appropriate authority, where one authority may define multiple code spaces.
  WGS-84 – World Geodetic System[41].

- **DPS_ReferenceSystemInformation.spatialReferenceSystem (MD_ReferenceSystem.referenceSystemIdentifier>RS_Identifier.Version)**
  Identifier of the version of the associated codeSpace or code, as specified by the codeSpace or code authority.
  Epoch G1150.

c) Vertical reference system

- **DPS_ReferenceSystemInformation.spatialReferenceSystem (MD_ReferenceSystem.referenceSystemIdentifier>RS_Identifier.codeSpace)**
  MSL based on EGM.

- **DPS_ReferenceSystemInformation.spatialReferenceSystem (MD_ReferenceSystem.referenceSystemIdentifier>RS_Identifier.Version)**
  EGM-96[42].

[41] For an upstream specification, the use of regional horizontal reference systems, such as ETRS, should be considered. For terrain data origination, the use of a map projection may be beneficial. If more than one horizontal reference system is used, the scope must be defined accordingly.

[42] For an upstream specification, the use of a regional vertical reference system, like EVRS, should be considered. If more than one

d) Temporal reference system

〉 **DPS_ReferenceSystemInformation.temporalReferenceSystem (TM_ReferenceSystem.name)**
The name of the temporal reference system (calendar).
Gregorian calendar.

7.1.7 Data Quality Requirements

The ISO 19131 terrain and obstacle data model allows the definition of several data quality requirements. Each requirement can be associated with a scope, ensuring a precise description of the quality requirements for each feature type, in each terrain and obstacle data area. In the following section, two samples of data quality DPS are given. More information on data validation and verification is given in section 7.3, where a more comprehensive set of test cases for different attributes is provided.

7.1.7.1 Data Quality Requirements for Obstacles in Area 1: Example Horizontal Accuracy

a) Scope

〉 **DPS_DataQualityInformation.qualityScope (DPS_ScopeInformation.scopeIdentification)**
Obstacle Area 1.

b) Name of measure

〉 **DPS_DataQualityInformation.dataQuality (DQ_AbsoluteExternalPositionalAccuracy.nameOfMeasure)**
Name of the test which shall be applied to the data.
Absolute horizontal accuracy.

〉 **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.measureDescription)**
The description of the measure.
The absolute horizontal accuracy of the obstacles in Area 1 is determined by a control survey.

c) Quantitative quality requirements

〉 **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.valueUnit.UnitOfMeasure.uomName)**
The means by which the value represented in the data is described.
Metre.

〉 **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.valueUnit.UnitOfMeasure.errorStatistics)**
The statistical method used to determine the value.
Standard deviation at 90% level (ap. 1.65 σ).

〉 **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.value)**
The quantitative value content to be determined by the evaluation procedure used.
50 – The horizontal accuracy of obstacles in Area 1 must be better than 50m, at a 90% confidence level.

d) Evaluation method requirement

〉 **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.evaluationMethodType)**
The type of method used to evaluate the quality of the data set, selected from the list provided in DQ_EvaluationMethodTypeCode.
002 – directExternal.

vertical reference system is used, the scope must be defined accordingly.

- **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.evaluationMethodDescription)**
  Description of the evaluation method. It is recommended that the evaluation method is defined as precisely as possible (e.g., accuracy of the control survey, redundancy, lot size).
  The horizontal accuracy is determined by independent control surveys using conventional terrestrial survey. The surveyor has to provide evidence that the control survey is at least three times better than the accuracy requirement (i.e. better than 16m in the case of Area 1). The control points shall be such that they reflect the “final” geometry of the obstacle, as recorded in the data set (i.e. taking into account the generalisation). The lot size shall be no less than 100 objects or 5% (whichever is smaller).

7.1.7.2 Traceability

a) Scope

- **DPS_DataQualityInformation.qualityScope (DPS_ScopeInformation.scopeIdentification)**
  General scope.

b) Name of measure

- **DPS_DataQualityInformation.dataQuality (DQ_AbsoluteExternalPositionalAccuracy.nameOfMeasure)**
  Determination of traceability.

- **DPS_DataQualityInformation.dataQuality (DQ_ AbsoluteExternalPositionalAccuracy.measureDescription)**
  The traceability requirement specifies that the origination and transformation of obstacles are recorded so that the history of an entity can be traced.

c) Non-Quantitative quality requirements

- **DPS_DataQualityInformation.dataQuality (LI_processStep.statement)**
  The origination and transformation of feature instances shall be documented in the metadata so that all relevant process steps can be made available to the requesting party. For at least the following activities, the process steps shall be documented:
    - Raw data acquisition: conventional terrestrial survey, operation of reference stations, survey flights;
    - Transformation: geodetic transformation (horizontal and vertical), aerotriangulation, strip adjustment;
    - Automated or manual feature extraction/origination;
    - Data deliveries.

For all of these activities, the following information shall be captured:

- **DPS_DataQualityInformation.dataQuality (LI_ProcessStep.description)**
  Description of the activity.

- **DPS_DataQualityInformation.dataQuality (LI_ProcessStep.rationale)**
  The requirement and rationale for this activity.

- **DPS_DataQualityInformation.dataQuality (LI_ProcessStep.dateTime)**
  Date and time or period in which the activity was performed.

- **DPS_DataQualityInformation.dataQuality (processor >CI_ResponsibleParty)**
  Organisation(s) responsible for the activity (including their roles).

7.1.8 Data Capture Requirements

7.1.8.1 Terrain

〉 **DPS_DataCaptureInformation.captureScope (DPS_ScopeInformation.scopeIdentification)**
Terrain scope.

〉 **DPS_DataCaptureInformation.dataCaptureStatement**
General description of the process for the capture of the data.

The terrain model for <country> shall be based on a so-called bare earth model, i.e. the model shall describe the continuous surface of the ground without any man-made objects[43]. Vegetation obstacles which cannot, due to their size, be modelled as point or line features shall be added on top of the bare earth. In such cases, it should be ensured that the vegetated area is collected as a first reflective surface. Where this is not achievable, due to sensor constraints, the penetration level must be stated, based on control surveys.

The point spacing for airborne data acquisition should be planned to allow an average of 1.5 points per cell. In a conventional terrestrial survey, the density of the survey points and break lines shall follow the topography and the accuracy requirement.

Where the data origination is based on a map projection, evidence must be given that the transformation from the planar co-ordinate system to the geographical co-ordinates in WGS-84 does not lead to a loss of quality and resolution.

The construction of a gridded data set shall be based on a maximum elevation calculation: if more than one height value is located in a cell, the highest value is taken into account. Data voids up to nine cells can be filled by a spline interpolation[44]. Spline interpolation must occur before the construction of a gridded data set and interpolating in a map projection is recommended to avoid unequal cell size with growing latitude. Interpolated points shall be marked as such (traceability). The grid construction shall be the last process step.

Data voids exceeding three times the required ground sampling distance (equals nine cells), must be reported. Data voids exceeding 36 cells are not acceptable.

In hilly regions of Area 2, the minimum point spacing requirement given in the SARPS may not correspond with the vertical accuracy requirement. For such cases, a TIN-based terrain model should be considered since it is more suitable than a gridded data set.

7.1.8.2 Obstacles

The feature capture rules unambiguously define which real-world features should be captured as obstacles and in which geometry (point, line, polygon), depending on the terrain and obstacle area in which they are located. A proposal for feature capture rules can be found in Appendix B of this Manual.

7.1.9 Data Product Delivery

It can be assumed that the means of delivery differ between obstacle and terrain data sets, not only due to different exchange formats, but also due to the different data sizes.

7.1.9.1 Data Product Delivery for "Terrain scope"

a) Scope

〉 **DPS_DeliveryInformation.deliveryScope (DPS_ScopeInformation.scopeIdentification)**
Terrain scope.

b) Delivery medium information

〉 **DPS_DeliveryInformation.deliveryMedium (DPS_DeliveryMedium.mediumName)**
Name of the data medium.
File Transfer Protocol (FTP) to <server>.

---

[43] See also DTM definition in section 2.1.

[44] Spline interpolation is most suitable for estimating missing mountain peaks, which are of high interest to aviation applications.

- **DPS_DeliveryInformation.deliveryMedium (unitsOfDelivery)**
  Description of the units of delivery, such as tiles, layers, geographic areas.
  File extensions: following naming convention is mandatory: Elevation data: .tif, metadata: .mtd, Integrity information: crc additional file extensions must be described in a README.txt file.

  Area 1: For terrain data in Area 1, the data must be structured in tiles of size 1 by 1 degree. All files for a tile must be packaged in one data folder. The data folder is named by the lower left corner of the tile (i.e. E018N55). Each file associated with the tile shall also include the tile name. For tiles at the State boundary, it shall be ensured that at least a one-by-one arc minute block is always provided[45].

- **DPS_DeliveryInformation.deliveryMedium (otherDeliveryInformation)**
  Other information about the delivery. Can be used to specify special arrangements for data delivery, such as providing a Cyclic Redundancy Check (CRC).
  For example, the results from the CRC may be delivered in printed form.

c) Data Format

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.formatName)**
  Name of the data format.
  TIXM and TIFF (for elevation information).

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.version)**
  Version of the format.
  TIXM: Version 1.0 / 2010.

  TIFF: Version 6.0 / 1992.

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.specification)**
  Name of a subset, profile or product specification of the format.
  TIFF: http://partners.adobe.com/public/developer/tiff/index.html.

  TIXM: Terrain Data Model Primer, source www.eurocontrol.int / OneSky Teams.

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.language)**
  Language(s) used within the data set.
  English.

- **DPS_DeliveryInformation.deliveryFormat> (DPS_DeliveryFormat.characterSet>MD_CharacterSetCode)**
  Full name of the character coding standard used for the data set. The MD_CharacterSetCode lists the most common character sets.
  006 – ISO8859-1.

7.1.9.2 Data Product Delivery for “Obstacle scope”

a) Scope

- **DPS_DeliveryInformation.deliveryScope (DPS_ScopeInformation.scopeIdentification)**
  Obstacle scope.

b) Delivery medium information

- **DPS_DeliveryInformation.deliveryMedium (DPS_DeliveryMedium.mediumName)**
  Name of the data medium.
  File transfer protocol (FTP) to <server>.

- **DPS_DeliveryInformation.deliveryMedium (unitsOfDelivery)**
  Description of the units of delivery, such as tiles, layers, geographic areas.

[45] For more details, see the recommendations given in section 5.6.2.

File extensions: following naming convention is mandatory: Obstacle data: .xml, metadata: .mtd, Integrity information: crc additional file extensions must be described in a README.txt file.

Area 1: For obstacle data in Area 1, all data must be packaged in one exchange file which must be packaged together with the metadata and the CRC information in one folder.
All other areas: For obstacle data in Areas 2, 3 and 4, all data should be packaged per aerodrome except where the outlines of different Area 2 polygons overlap. In such situations, the delivery of Area 2 data should be organised per combined aerodrome region.

- **DPS_DeliveryInformation.deliveryMedium (otherDeliveryInformation)**
  Other information about the delivery. Can be used to specify special arrangements for data delivery, such as providing a Cyclic Redundancy Check (CRC).
  For example, the results from the CRC may be delivered in printed form.

c) Data Format

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.formatName)**
  Name of the data format.
  AIXM for downstream data provision, simplified XML (or similar) for upstream deliveries from data origination / surveyor.

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.version)**
  Version of the format.
  AIXM: Version 5.1 / 2010.

  (or as agreed, if deviates from AIXM).

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.specification)**
  Name of a subset, profile or product specification of the format.
  AIXM: Aeronautical Information Exchange Model – Key Concepts – Standards, source http://www.aixm.aero.

- **DPS_DeliveryInformation.deliveryFormat (DPS_DeliveryFormat.language)**
  Language(s) used within the data set.
  English.

- **DPS_DeliveryInformation.deliveryFormat>
  (DPS_DeliveryFormat.characterSet>MD_CharacterSetCode)**
  Full name of the character coding standard used for the data set. The MD_CharacterSetCode lists the most common character sets.
  006 – ISO8859-1.

7.1.10 Data Maintenance

7.1.10.1 Data Maintenance for "Terrain scope"

a) Scope

- **DPS_DeliveryInformation.deliveryScope (DPS_ScopeInformation.scopeIdentification)**
  Terrain scope.

b) Data maintenance information

- **DPS_DataMaintenanceInformation
  (DPS_MaintenanceInformation.maintenanceAndUpdateFrequency)**
  Statement on the frequency at which the data is maintained and an update is provided[46].
  It is considered that the chance of terrain changing sufficiently to impact flight operations is minimal. The terrain data is only updated when deemed necessary.

[46] Guidance on the maintenance period for terrain data can be found in section 4.1.13.3 of this Manual.

7.1.10.2 Data Maintenance for “Obstacle Area1 scope”

a) Scope

- **DPS_DeliveryInformation.deliveryScope (DPS_ScopeInformation.scopeIdentification)**
  Obstacle Area1 scope.

b) Data maintenance information

- **DPS_DataMaintenanceInformation (DPS_MaintenanceInformation.maintenanceAndUpdateFrequency)**[47]
  The data set for Obstacle Area 1 needs to be updated upon notification, i.e. when a new building is erected or when the filter criteria change.

7.1.11 Metadata

A profile of ISO 19115 is used for terrain and obstacle data which contains all relevant information to ensure compliance with the Commission Regulation (EU) 73/2010.

The proposed metadata schema for terrain and obstacle data is based on the ISO 19115 standard and AIXM 5.1. Some extensions are necessary to comply with the requirements of ICAO Annex 15. Additional extensions are proposed to accommodate the metadata necessary for AIXM conformity. As the AIXM metadata schema is also based on ISO 19115, this allows the concepts from the AIXM metadata schema to be easily adopted[48]. Detailed information on metadata can be found in section 7.7 of this Manual.

7.2 Data Collection

7.2.1 Introduction

This section addresses the most widely used survey techniques for terrain and obstacle data. Whilst in the first part (section 7.2.2 and 7.2.3) the sensors and their processes are presented, the sections that follow this place the focus on the applicability of each sensor for terrain data collection (section 7.2.4) and obstacle data collection (section 7.2.5).

Although the suitability of the techniques are compared with respect to their type and the terrain and obstacle area that they may most appropriately be used for, it should also be considered that a combination of techniques or a combination of existing data with some data collection, may be the optimal solution under certain circumstances.

Data collection should never be regarded as a standalone process but one that needs to be integrated in the complete process of data request – collection – validation and verification – integration and eventual publication. This holistic process for data origination is covered in the EUROCONTROL Specification for Aeronautical Data Origination.

7.2.2 Techniques Available

7.2.2.1 Conventional Terrestrial Survey

Terrestrial Survey is still the most wide-spread technique for data acquisition. Compared to other surveying technologies, the investment in sensors and processing software for conventional terrestrial surveying is quite low. On the other hand, the human resources needed to perform the survey in the field are higher, when compared with any other technique. Consequently, this method of survey, although not limited to, is usually used for localised tasks. For the data capture of extended areas, it is often more economical to use an airborne mapping technique. Nevertheless, airborne survey techniques are not completely independent from terrestrial survey, e.g. benchmark surveying - the survey of highly accurate ground control points.

[47] Guidance on the maintenance period for obstacle data can be found in section 4.1.13.2 of this Manual.

[48] Details of the extensions of the metadata model, as given in ISO 19115 and AIXM 5.1, to cover the needs of terrain and obstacle data, can be found in section 7.7.

Conventional terrestrial survey uses the following instruments:

- GPS receiver;
- Theodolites or Total Stations (Theodolite combined with [reflectorless] distance measuring);
- Terrestrial positioning system (Total Station combined with a GPS receiver).

With regards to terrain and obstacle data, conventional terrestrial survey methods would be suitable for the following tasks:

- Obstacle acquisition and maintenance;
- Terrain acquisition;
- Surveying of benchmarks for airborne mapping techniques;
- Validation of data acquired by an airborne sensor system.

7.2.2.2 Aerial Photogrammetry

Aerial Photogrammetry is a survey technique which has been used for a number of years. The latest development in this field is mainly in regard to digital cameras and scanners. The pixel size (either of the digital camera or the scanner) is the dominating factor in selecting the flight parameters, to ensure that the technical requirements are fulfilled.

The most restrictive requirement for obstacle acquisition by photogrammetry is the minimum size of the obstacles which have to be captured. To capture very thin objects (e.g. antennae, street lamps, etc.), the image scale[49] has to be bigger than with traditional survey flights. This requires a lower flight height. With a lower flight level, the resulting spatial accuracy (x, y, z) will be much higher than requested. Obviously, the costs for data acquisition for terrain and obstacle data are higher than for traditional applications.

Today, analogue and digital cameras are used for photogrammetry. The only difference between the processes, for analogue and digital cameras, is that the film of the analogue camera has to be scanned. As soon as the images are digitally available, the process is the same for both cameras.

With regards to terrain and obstacle data, photogrammetry can be used for the following tasks:

- Terrain mapping;
- Obstacle mapping;
- Validation of ALS data.

7.2.2.3 Airborne Laser Scanning

Within the last few years, Airborne Laser Scanning (ALS), also known as Light Detection and Ranging (LiDAR), has progressed significantly and is now a more established technique. One of the biggest advantages of ALS, compared to conventional surveying methods, is the high-level of automation offered through a completely digital data chain. Although ALS is a mature technique with respect to the quality of data collection, improvements would be beneficial with respect to data post-processing (i.e. feature detection and extraction). The more automated the processes become, the more economical the data extraction will become. One other significant advantage compared to conventional surveying methods is the homogenous data acquisition over the whole area. The main drawbacks of the technique are the high investment costs and the low number of operators that have sensors capable of obstacle mapping.

As for photogrammetry, the minimum size of the obstacle which needs to be captured is the predominant factor for the planning of the ALS flight. If all small antennae on top of buildings have to be captured, the flight and laser parameters have to be adjusted accordingly, to fulfil the technical requirements.

ALS includes the following:

[49] Image scale = flight height / focal length, e.g. camera lens with 15cm focal length and a flight height of 1,200m above ground level will lead to an image scale of 1:8,000. With these parameters, a spatial accuracy of 15cm vertically and 5cm horizontally can be achieved.

- Laser scanner (measures the scan angle and time of flight for each laser pulse);
- Positioning and orientation system consisting of:
  - o GPS receiver on the aeroplane and reference station on the ground (differential GPS (DGPS));
  - o Inertial Measurement Unit (IMU) to measure roll, pitch and heading of the scanner system.

With regards to terrain and obstacle data, ALS methods can be used for the following tasks:

- Terrain mapping;
- Obstacle mapping.

7.2.2.4 Interferometric Synthetic Aperture Radar

Among the different radar measuring devices, Interferometric Synthetic Aperture Radar (IfSAR) is the most common one. IfSAR is an active sensor system using microwave (wavelength between 2 and 100 cm) and recording the signals reflected from the terrain. Each emitted pulse illuminates a relatively large area and the reflected signal is continuously digitised. The sampling allows a finer resolution of the illuminated area. By repeatedly emitting pulses, each object is illuminated several times. By combining the subsequent signals, the Doppler frequency can be resolved which is then used to determine the location of a point with respect to its location along the flight path and its range. By combining two spatially separated viewing positions (for which their separation must be very accurately known), the resulting interferometric image allows the precise measurement of the parallax of a common point in both images. This stereoscopic measurement (as in photogrammetry) allows the determination of the third co-ordinate. The workflow is very similar to aerial photogrammetry.

IfSAR systems consist of:

- Two Synthetic Aperture Radar (SAR) systems;
- Positioning and orientation system consisting of:
  - o GPS receiver on the aeroplane and reference station on the ground (DGPS);
  - o IMU to measure roll, pitch and heading of the scanner system.

With regard to terrain and obstacle data, IfSAR methods can be used for the following tasks:

- Terrain mapping[50].

7.2.2.5 Sensor Fusion

Since every sensor system has its strengths and weaknesses, the combination of two sensors for data acquisition can be considered. For terrain and obstacle data, it is expected that a combination of a tilted ALS sensor and a digital photogrammetric camera offers many benefits in terms of quality (completeness of data acquisition, visual validation) and efficiency (degree of automation), for large area surveys.

7.2.3 Data Processing

Depending on the data collection technique, different processing steps must be applied. The workflow for each technique is discussed in general, with particular focus on how Commission Regulation (EU) 73/2010 impacts traditional data processing (for example, collecting metadata, data validation and documentation). This section also outlines the transformation of data between different reference systems.

7.2.3.1 Conventional Terrestrial Survey

Figure 24 describes the typical workflow for conventional terrestrial survey. This method and the workflow shown below have been included in this Manual as they are most suitable for obstacle

[50] There are ongoing academic research projects where IfSAR systems are used to also detect obstacles. So far, no evidence has been provided that this data meets the quality requirements.

acquisition in large areas. For terrain data acquisition, the process can be simplified because GPS equipment alone, run in Real-Time Kinematic (RTK) mode, described later in this section, is suitable for mass data collection[51].

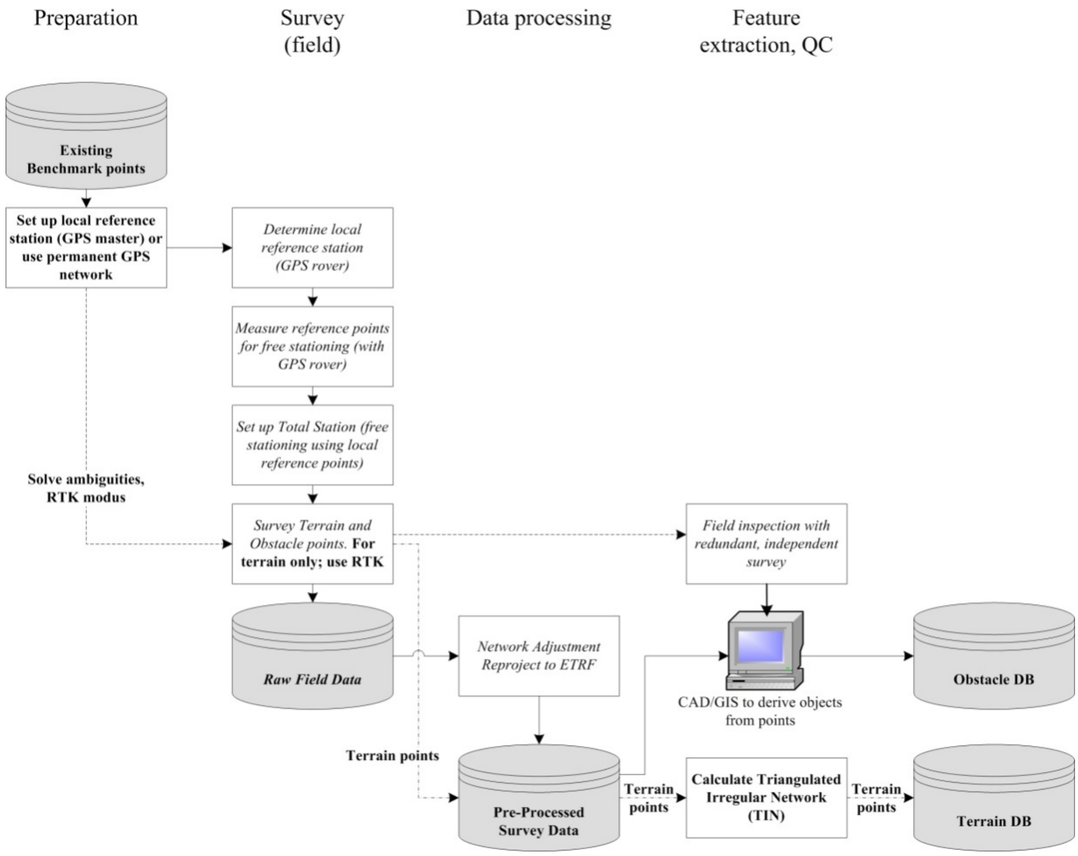


Figure 24: Workflow of Conventional Terrestrial Survey[52]

The following *preconditions* have to be fulfilled for Total Stations type survey:

- Reference station operated on points with known co-ordinates or derived by free stationing;
- Monument control stations in a local network build the base for the terrestrial survey;
- Local co-ordinate system:
    - Measurements with a theodolite are performed in a local planar co-ordinate system (e.g. UTM). The heights are measured above the (quasi-)geoid, based on the published heights of the reference points. Typically, such height values are labelled as MSL.
- Transformation parameters from local to WGS-84 co-ordinate system[53]:
    - For the transformation of the surveyed points between the local co-ordinate system and WGS-84, transformation parameters are needed. In order to obtain heights in a different system (such as ellipsoidal heights or heights above EGM-96), the local geoid must be known to a high accuracy. For a limited area, the transformation parameters can be derived with a set of reference points, with known 3D co-ordinates in both reference systems.

Preconditions for a GPS type survey:

[51] More details about data origination using conventional terrestrial surveying can be found in the ICAO Doc 9674 - WGS-84 Manual.

[52] Processes in italics indicate data in local co-ordinate system. Simplified process for terrain survey by means of GPS-RTK in bold.

[53] Benchmark points are usually available in a local co-ordinate frame as they have originally been measured using traditional survey techniques (levelling, theodolite) and form part of a national geodetic network.

- Reference station(s) for DGPS:
    - o The definition of measured GPS points is based on well-defined reference stations. For the resolution of the ambiguities, at least one additional GPS station will be used in DGPS. To improve the precision of the resulting co-ordinates, measurements with short baselines are preferred. National and international permanent GPS networks[54], which are often operated by the national survey agency, allow the surveyors to use more than one single, additional station to define the reference stations with higher precision and reliability. Where permanent or reference GPS stations transmit the correction signal by radio waves, the receiver is capable of operating in RTK mode. Thus, the co-ordinates of the measurement points are available without post-processing. With GPS, the survey is performed in a world-wide geodetic system. Transformations between WGS-84 and a local geodetic datum or co-ordinate system are therefore obsolete when the co-ordinates of the reference stations are known in WGS-84.

7.2.3.2 Aerial Photogrammetry

Figure 25 describes the workflow of aerial photogrammetry:

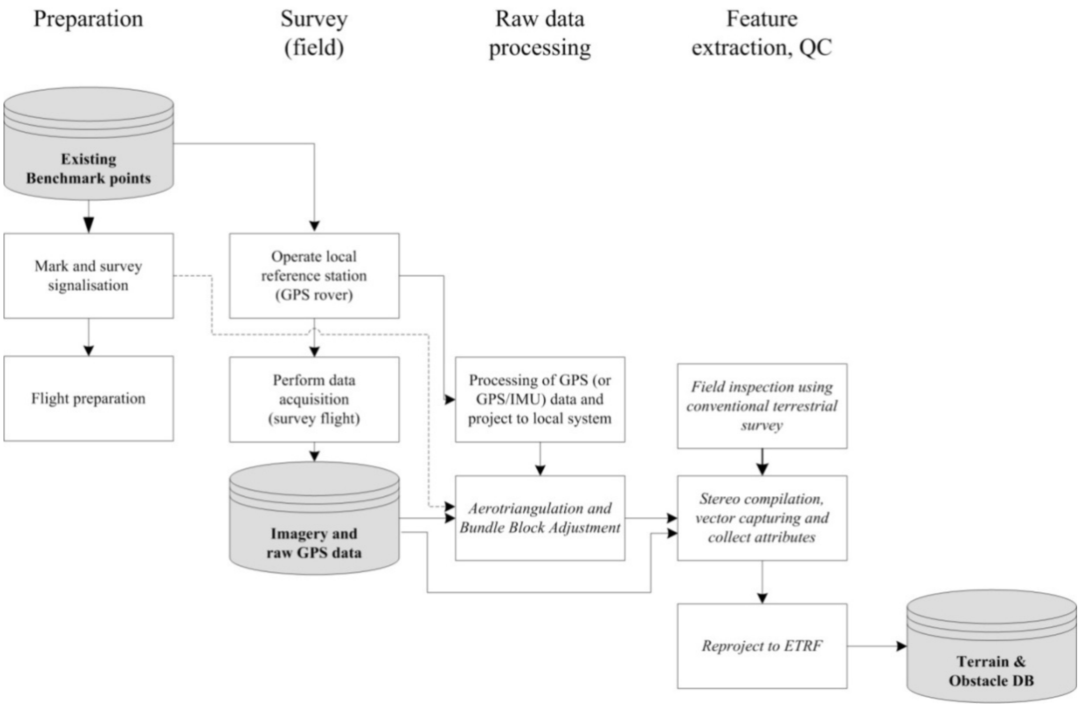


Figure 25: Workflow of Aerial Photogrammetry

The following preconditions have to be fulfilled:

- Benchmarks have to be marked (signalisation) and their co-ordinates determined using terrestrial survey;
- Flight plan based on:
    - o Focal length;
    - o Spatial accuracy requirements;
    - o Flight restrictions;
    - o Resolution requirements.

[54] An example: Online GPS Processing Service by the Australian Government http://www.ga.gov.au/bin/gps.pl.

7.2.3.3 Airborne Laser Scanning

Figure 26 describes the workflow for ALS:

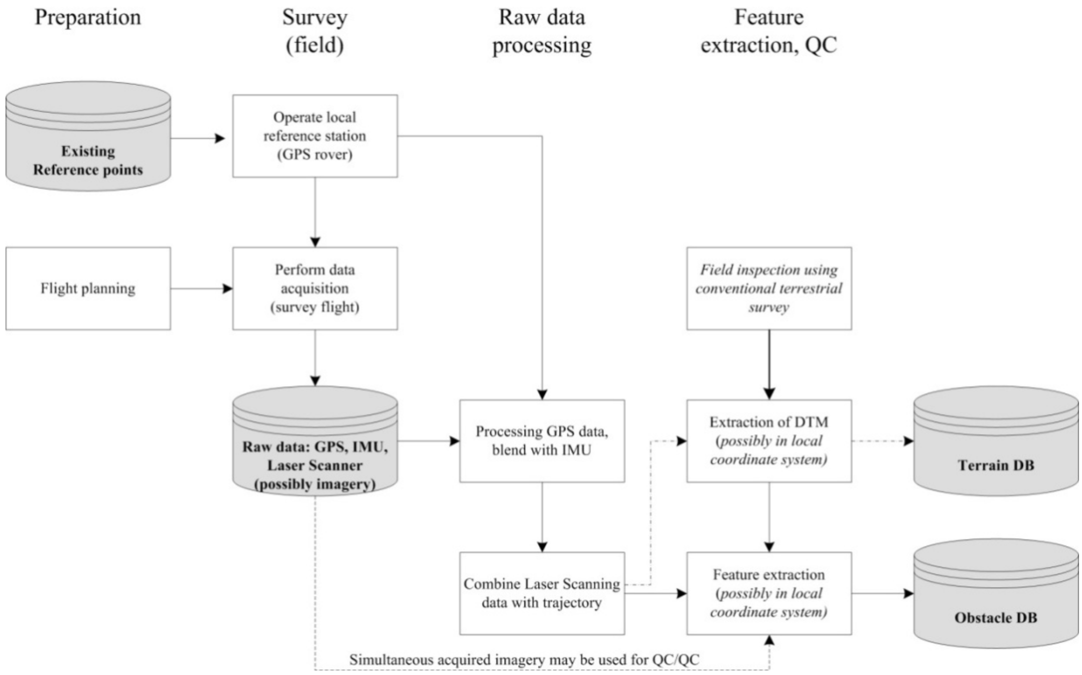


Figure 26: Workflow of ALS

The following preconditions have to be fulfilled:

- Flight plan with:
  - o Flight lines;
  - o Scan angle;
  - o Scan rate;
  - o Pulse repetition frequency.

These parameters influence the flight height but, additionally, the flight restrictions and topography may also impact the flight planning. The most appropriate system settings are selected based on the topography and the technical specifications:

- Calibration flight:

  A calibration flight is performed after the mounting of the system. Periodical re-calibration is recommended to compensate for drifts and changes in climate;

- Well-defined monument reference station for master GPS or provision of permanent GPS reference network with post-processing capabilities.

The above mentioned preconditions have to be fulfilled before the ALS surveying flight is performed.

As with any airborne survey technique, it is recommended that terrestrial survey is performed to measure specific points which are used as control points for data validation[55]. These measurements can be performed before, during or after the flight is carried out. To improve the quality, it is recommended that the field survey is performed after the post-processing. In this way, open issues, which are detected during the post-processing, can be checked in the field. This will ultimately result in higher data quality.

[55] Existing benchmark points can also be used for the validation, on condition that they are located on a solid surface and can be transformed easily to WGS-84/EGM-96.

7.2.3.4 Interferometric Synthetic Aperture Radar

Figure 27 describes the workflow for IfSAR:

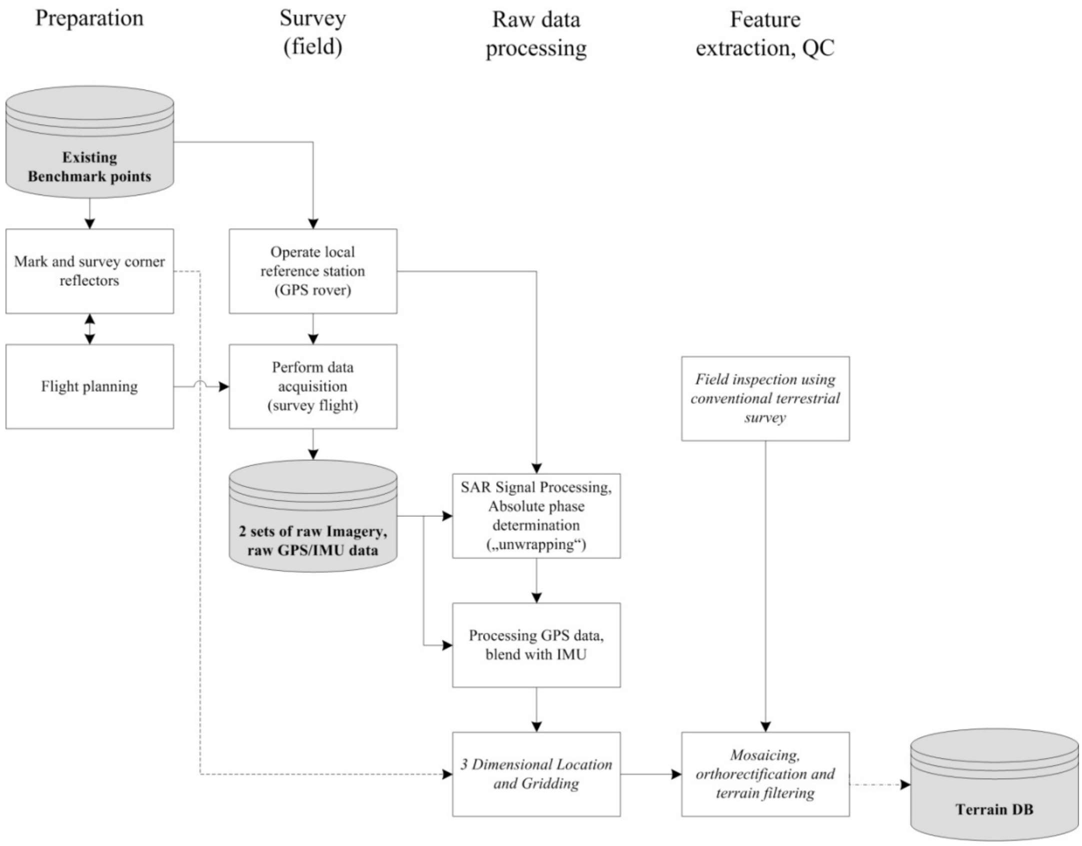


Figure 27: Workflow of IfSAR

The following preconditions have to be fulfilled:

- Benchmarks have to be marked (corner points) and their co-ordinates determined using terrestrial survey;
- Flight plan based on:
  - System characteristics (pulse rate, range, etc);
  - Spatial accuracy requirements;
  - Flight restrictions;
  - Resolution requirements.

7.2.4 Data Collection Techniques for Terrain

The utilisation of specific techniques for the collection and processing of terrain data will be outlined in this section.

7.2.4.1 Terrestrial Survey

Compared to obstacle mapping, conventional terrestrial surveying is much more efficient for terrain data acquisition. Although the number of acquired points per work day is still much lower than any aerial mapping technique, terrestrial survey has the advantage that the uneven distribution of points, with the focus on breaklines and spot elevations, significantly reduces the amount of data collected. The terrain model can then be derived from the surveyed points and breaklines, by building up a TIN.

In various studies, the possibility of mounting a GPS antenna on a car (operated in RTK mode) to increase the survey efficiency has been examined. Even though the results are promising, with respect to the achieved accuracy, this method does not meet the needs of aviation data because the highest points are only randomly accessible by car.

In forested and urban areas with tall buildings, terrain data cannot be collected very efficiently with GPS due to limited satellite visibility and signal strength.

7.2.4.2 Airborne Laser Scanning

During data acquisition with ALS, ground and non-ground objects are not distinguished between. Filtering, i.e. the removal of terrain points, is an important processing step in obstacle data extraction. Therefore, the terrain data for Areas 1, 2, 3 and 4 can be derived from ALS-based data acquisition, for very little additional cost. In the point cloud remaining after the filtering of terrain points, trees / vegetation can be detected by using the multi-return capability of ALS. The remaining points describe man-made objects which can, therefore, for a large part, be automatically extracted (see also section 2.1).

7.2.4.3 Aerial Photogrammetry

As described for ALS, the imagery collected with aerial photogrammetry for obstacle mapping allows the extraction of a DTM. If a DSM is generated using image correlation techniques, the terrain extraction process is the same as for ALS. However, the reduced penetration in vegetated areas results in fewer points on the ground which makes it difficult to achieve a “clean” DTM. If vegetation and forests need to be extracted, less information is available for automated detection in a DSM based on aerial photogrammetry than in a DSM based on ALS[56].

7.2.4.4 Interferometric Synthetic Aperture Radar

IfSAR provides the highest data acquisition rates from all currently available survey techniques. The offered products also fulfil the quality requirements for Areas 1, 2 and 3.

The main drawbacks of the technique are the complex methods used in the signal processing which reduces the number of companies able to provide IfSAR mapping services. On the technical side, the inability to achieve good interferometric phase measurements for all locations is still a major problem. The deviation of the field of view from nadir (sideward looking sensor) causes portions of the terrain to not be captured because they are obscured by other parts of the terrain or other objects. This shadow effect is typically exhibited in mountainous areas, whereas in regions with flat terrain it only occurs in urban areas. Depending on the wavelength, the signal is reflected from the topmost target (shorter wavelength, X- or C-band) or tends to penetrate the vegetation canopy or ground (long wavelength, L- or P-band). With soft ground, such as sand deserts, glaciers or snow, radar signals are absorbed rather than reflected, also leading to data voids.

7.2.4.5 Comparison and Recommendation

In Figure 28, all four surveying techniques presented are compared using different criteria. This comparison will provide recommendations as to which methods are most suitable, under which circumstances, for an organisation. The most important factors to consider are:

- ALS:
    - Has very high capital costs and is, therefore, less widely available;
    - A DTM can be extracted almost entirely automatically. Algorithms have been commercially available for many years (allowing separation between data acquisition and feature extraction);
    - Terrain data acquisition is performed almost at no extra cost when combined with obstacle mapping.
- IfSAR:
    - There are only a few providers available due to the highest capital costs and proprietary processing software of all the techniques;
    - The efficiency of data acquisition is high, but is influenced by the need for marked and surveyed corner points;
    - For raw measurements, the penetration level is unclear which impacts the quality in

[56] Auxiliary information for vegetation detection can be provided with today’s digital cameras, where infrared information is included in the imagery as a separate channel.

forested areas.

- Photogrammetry:
    - o Is the most efficient technique for data acquisition;
    - o The degree of automation is smaller, when compared to ALS, but the algorithms are still evolving;
    - o The imagery can be used as a base for many other applications.
- Terrestrial survey:
    - o Has the lowest capital costs but is very labour intensive;
    - o Results in a well-structured terrain model (points, breaklines), with a minimum of objects;
    - o Is ideal for data validation.

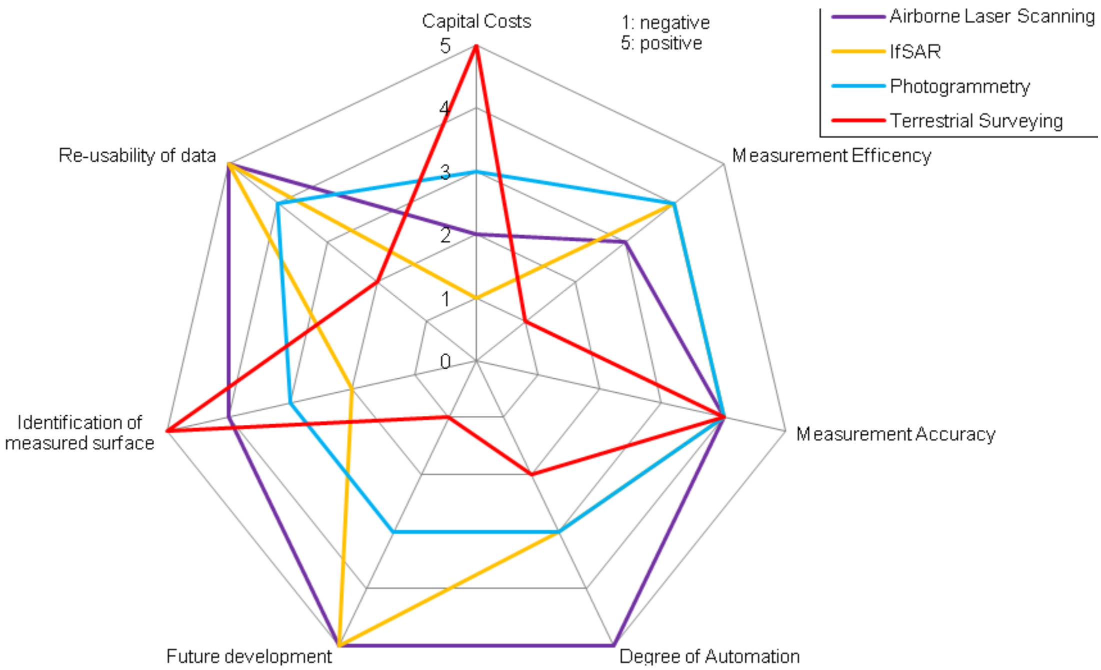


Figure 28: Comparison of Different Sensor Techniques for Terrain Mapping

In the following table, recommendations on the survey methods for terrain are provided. The symbols should be interpreted as follows:

‘++’ very suitable technically and very cost efficient;

‘+’ very suitable technically but not the most cost efficient;

‘o‘ suitable technically but very poor cost/benefit ratio;

‘- ‘ not meeting technical requirements and very poor cost/benefit ratio.

	ALS	IfSAR	Photo-grammetry	Terrestrial Survey
Area 1	+	++	+	o
Area 2	++	++	++	o
Area 3[57]	+/++	-	+/++	+
Area 4	+/++	-	+/++	++

Table 3: Recommendation on Survey Methods for Terrain

7.2.5 Data Collection Techniques for Obstacles

7.2.5.1 Terrestrial Survey

Using conventional terrestrial survey for data acquisition is often inefficient because of the limited visibility from one stand point (either due to obstructions in urban areas or due to limited measurement range in the open field). For example, there is a risk of not obtaining reflection from the targeted (thin) obstacle, but from the one behind it. It is difficult to detect such erroneous measurements during data acquisition as no additional data is used for real-time validation.

GPS/RTK measurements are not suitable for obstacle data acquisition due to the need to access each obstacle to be surveyed.

7.2.5.2 ALS

Several points should be considered when using ALS for obstacle mapping:

- To increase the probability that a thin object, like an antenna is captured, it is recommended that the sensor is tilted[58] and the radiometric resolution of the sensor is calibrated.
- Environmental conditions: The humidity can have a strong impact on the strength of the returned signal (local loss of signal). Strong winds or turbulence increase the possibility that the gathered points are distributed unevenly. Therefore, meteorological restrictions must be carefully observed during data collection.
- Obstacle detection: After pre-processing the different data streams (GPS, IMU, laser scanner) and combining them, a digital point cloud is available for further process steps. To detect obstacles, the points are separated into ground and non-ground points[59]. The non-ground points can then be compared with an ODCS and the points describing obstacles can be easily detected. With a tilted sensor, it is expected that, for each object, there are multiple pulses with almost identical x/y but different z co-ordinates registered. Algorithms can help to determine the reliability of these identified objects. Where only a single echo is registered, certain plausibility tests can help to determine if such an object may or may not be an obstacle (for example, the reflection from a bird). In certain cases, control survey with conventional terrestrial survey, is recommended.
- Feature extraction: Once points describing an obstacle are selected, they must be combined and converted to some form of GIS object, i.e. point, line and polygon. The degree of automation of such a process strongly depends on the quality requirements (i.e. target applications) of the geometry. For further information, see Airborne Laser Scanning for Airport Terrain and Obstacle Mapping (A Limited Feasibility Study).
- All processing steps can theoretically be performed by an organisation, independent of the data acquisition provider. For practical reasons, it is recommended that data acquisition and pre-processing are combined into one work package so that the first deliverable is the geo-

[57] ALS and aerial photogrammetry are only very cost efficient when Areas 3 and 4 are surveyed in one survey campaign.

[58] A limited feasibility study 'Airborne Laser Scanning for Airport Terrain and Obstacle Mapping' by Skyguide, ITV Geomatik AG and Swissphoto AG showed that the completeness of obstacle data could be increased if the laser is tilted by 20°.

[59] Mature algorithms are available to extract a DTM from the point cloud. Since accuracy requirements are relatively low compared with the high number of points registered, processing is almost completely automated, with only a few exceptions.

referenced point cloud. Feature extraction does not require ALS capabilities and so, again, it can be performed by a different organisation.

7.2.5.3 Terrain Warning Systems

Several points should be considered when using aerial photogrammetry for obstacle mapping:

- A DSM can be generated using an image correlation process. This allows similar post-processing steps to those described for ALS in section 7.2.3.3. But the image correlation is, in some circumstances (low texture), not reliable and the DSM is 2.5D[60], not true 3D, as with ALS.
- The manual interpretation of what has to be considered as an obstacle is labour intensive for photogrammetric data, but, at present, much more reliable than image correlation. As the operator has to define which objects are to be considered obstacles, human interpretation may impact the data homogeneity and data quality.
- Systems are available which support the operator by automatically generating the ODCS, based on the ODCS specifications and the actual runway data. The ODCS is shown in the system so that the differentiation of objects penetrating the ODCS, from other objects, is facilitated.

In contrast to the feature extraction in ALS, the human interaction in photogrammetric data processing allows the combination of both the obstacle detection and feature extraction steps, resulting in high-quality, true 3D vectors.

7.2.5.4 IfSAR

Obstacle detection from IfSAR data suffers from low reliability since the reconnaissance largely depends on the incident angle. Power lines, for example, are clearly visible in SAR imagery, if running parallel to the flight direction, but are not detectable if running across the flight direction. The reason for this problem is the “layover” effect, whereby points appear to be reversed in the imagery, e.g. where point A is in front of point B, the imagery reverses them so that point B appears to be in front. Layover causes a loss of useful signal and, therefore, precludes the determination of elevation in layover regions.

7.2.5.5 Comparison and Recommendations

In Figure 29, the surveying techniques appropriate for obstacle mapping are compared using different criteria. This comparison will provide recommendations as to which methods are most suitable, under which circumstances, for an organisation. The most important factors to consider are:

- ALS:
  - Has the highest capital costs and, therefore, is less widely available;
  - It already offers the highest degree of automation but further development is expected;
  - Has the lowest risk of missing an obstacle during data acquisition.
- Photogrammetry:
  - Is the most efficient technique for data acquisition;
  - The degree of automation is smaller, when compared to ALS, but the algorithms are still evolving;
  - The risk of missing an obstacle is higher, when compared to ALS, but due to manual interaction, the quality of the resulting obstacle is expected to be higher than all other techniques.
- Terrestrial survey:
  - Has the lowest capital costs but is very labour intensive;
  - Is a mature technique but not much further improvement is expected;
  - The risk that an obstacle is missed is higher than with the other techniques and, therefore,

[60] i.e. for each x/y co-ordinate, there is exactly one height.

the level of effort needed for validation is high;
  - o Is ideal for data validation.
- IfSAR:
  - o Obstacle detection suffers from low reliability. At the time of writing this Manual, the technique not suitable for obstacle data collection.

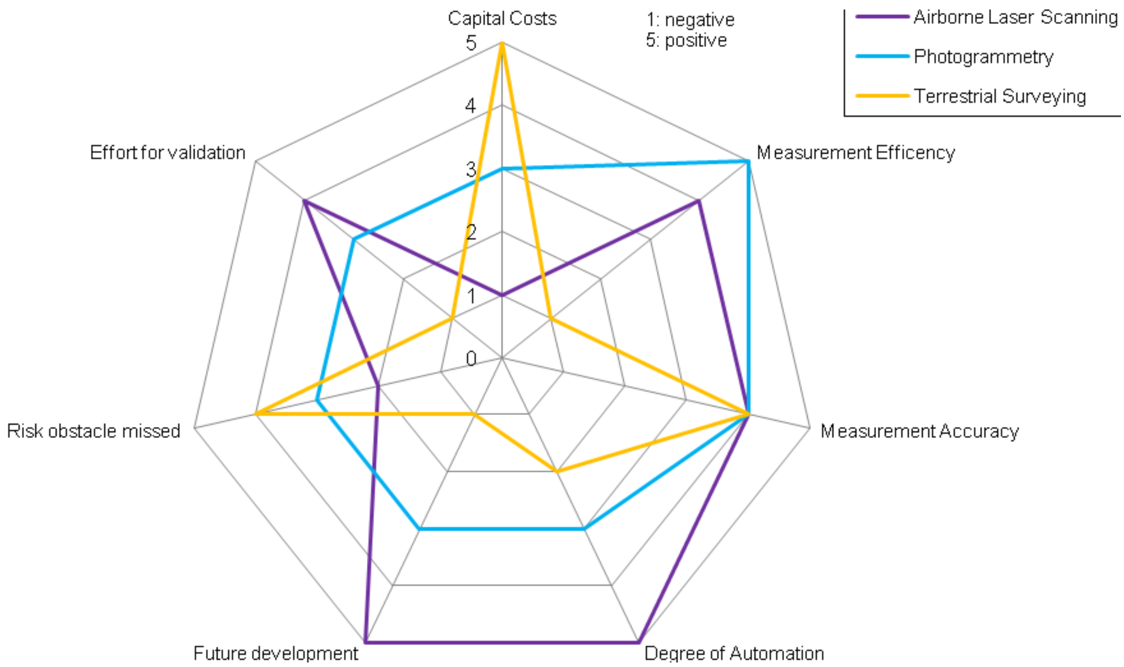


Figure 29: Comparison of Different Surveying Techniques for Obstacle Mapping

In the following table, recommendations on the survey methods for obstacles are provided. The symbols should be interpreted as follows:

'++' very suitable technically and very cost efficient;

'+' very suitable technically well suited but not the most cost efficient;

'o' suitable technically but very poor cost/benefit ratio;

'- ' not meeting technical requirements and very poor cost/benefit ratio.

	ALS	IfSAR	Photo-grammetry	Terrestrial Survey
Area 1[61]	o/+	-	o/+	++
Area 2[62]	++	-	+	o
Area 3	++	-	+	+
Area 4	+	-	+	++

Table 4: Recommendation on Survey Methods for Obstacles

[61] Cost/benefit ratio for ALS and photogrammetry is better when obstacles and terrain are surveyed in one campaign (if terrain data is not already available).

[62] If only very few obstacles are present in Area 2, terrestrial survey becomes more cost-effective and ALS/aerial photogrammetry less so.

7.2.6 Co-ordinate Transformation between Different Reference Frames

7.2.6.1 Transformation between “Old” Local Co-ordinates and WGS-84

Transforming "old" local co-ordinates into WGS-84 is often not possible using a strict mathematical transformation only. The irregular blunders in the old, local co-ordinate systems and the differences between the underlying ellipsoids must be considered. Such transformations rely on a large number of benchmark points which are known in both systems. Locally adjusted transformation parameters can be derived from those reference points, taking into account local irregularities in the reference network. Where new national reference frames have been determined, national geodetic agencies provide software packages or libraries which can be used to transform local co-ordinates from old to new national reference frames.

Obviously, new reference frames, like UTM (based on ETRS89), simplify the process of transforming co-ordinates into WGS-84, or vice versa, since there are strict mathematical relationships between the two.

7.2.6.2 Transformation from “Old” National to Ellipsoidal Heights

To convert heights from reference points available in an old national reference frame and in national map co-ordinates, to ellipsoidal heights, firstly the orthometric or normal heights above a well-known (quais-)geoid are calculated, based on transformation points in both systems. Then the heights are converted to heights above the reference ellipsoid using a local, high resolution geoid (applying the geoidal undulation) or gravity measurements respectively. The horizontal co-ordinates in the national projection system are converted to ellipsoidal co-ordinates, as described above. Finally, the ellipsoidal heights, based on the local reference ellipsoid, are transformed to a global one using a datum transformation.

7.3 Data Validation and Verification

For the validation of selected feature properties, test cases are proposed[63]. Where the SARPs do not provide the quality levels necessary for conformance, these are suggested in the following sections. The conformance quality level describes the quantitative threshold as to whether a data set is compliant with the specifications or not. In this sense, the conformance quality level could be regarded as part of an enhanced DPS.

Tests related to logical consistency, format consistency and conceptual consistency are not provided in the test cases here because the data exchange mechanisms of AIXM and TIXM are designed to validate a data set against an application schema. Background information on data validation based on the ISO 19113 and ISO 19114 standards is provided in Quality Philosophy – Approach to ISO 19113, ISO 19114 and ISO 19131.

7.3.1 New Terrain Data

7.3.1.1 Area of Coverage

Area of coverage is a descriptor used to identify the geographical extent of the terrain data. The intent of this attribute is to help the user identify, in general terms, the area under consideration. The shape of the coverage should be a polygon (e.g., Lat 30N to Lat 40N, Long 80W to Long 90W).

7.3.1.1.1 Proposed Measurement:

Logical Consistency (Topological consistency) – internal – full inspection: Check whether all items are inside the area of coverage.

7.3.1.1.2 Proposed Conformance Level:

100%: If any entry is outside the area of coverage, the data set cannot be accepted.

[63] The detailed description of the meaning of all attributes is provided in sections 3.7.7 and 3.7.8.

7.3.1.2 Data Originator Identifier

Sufficient information shall be provided to distinguish between multiple data originators[64]. A permanent record of the originator shall be kept so that it may be included in the audit trail.

7.3.1.2.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the data originator provided is the correct one. For all process steps (see 7.1.7.2 of this Manual) before the data is published by the body responsible for publication, the data originator must be provided and be correct.

7.3.1.2.2 Proposed Conformance Level:

The correct data originator shall be provided otherwise the data set cannot be accepted (traceability).

7.3.1.3 Data Source Identifier

Information shall be provided about the entity responsible for provision of the dataset.

7.3.1.3.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the data source identifier provided is the correct one.

7.3.1.3.2 Proposed Conformance Level:

The correct data source identifier shall be provided.

7.3.1.4 Acquisition Method

The acquisition method used to obtain the data shall be defined.

7.3.1.4.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the acquisition method provided is the correct one.

7.3.1.4.2 Proposed Conformance Level:

The correct acquisition method shall be provided (traceability).

7.3.1.5 Post Spacing

Post spacing is the distance (angular or linear) between two adjacent elevation points. It should be noted that the latitude post-spacing may be different from the longitude post spacing. DTM post spacing is presented in both angular and linear units, in order 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 regions of higher latitude, in order to maintain a constant linear density of measurement points.

7.3.1.5.1 Proposed Measurement:

Positional Accuracy (Gridded data position accuracy) – internal – full inspection: Measure the distance between each post and its nearest neighbouring post. Count the number of distances which deviate from the values defined by ICAO Annex 15, Table A8-1 and given in the following table[65]:

[64] The same test can also be applied to the traceability (lineage) information.

[65] The table may be adjusted for regions of higher latitude or when terrain data is provided as TIN. In both cases, the requirements shall be adjusted accordingly.

Area 1	Area 2	Area 3	Area 4
3 arc seconds	1 arc second	0.6 arc second	0.3 arc second

Table 5: Terrain – Post Spacing Requirements

7.3.1.5.2 Proposed Conformance Level:

No distances shall exceed the values defined in Table 5 above, otherwise the data set cannot be accepted. A higher resolution is acceptable.

7.3.1.6 Horizontal Reference System

The horizontal reference system is the datum to which the positions of the data points are referenced.

- ICAO Annex 15 SARPs require that co-ordinates used for air navigation are expressed in the WGS-84 reference system.
- If the horizontal reference system is not WGS-84, the reference system and transformation parameters to WGS-84 shall be specified.

7.3.1.6.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – full inspection: Check if the horizontal reference system equals "WGS-84" or if the transformation parameters from the given reference system to WGS-84 are provided[66].

7.3.1.6.2 Proposed Conformance Level:

If the horizontal reference system is not WGS-84 or the transformation parameters from the provided reference system to WGS-84 are not provided, the data set cannot be accepted.

7.3.1.7 Horizontal Resolution

Horizontal resolution is the degree of separation with which the measurements are taken. Horizontal resolution can have two components, as follows:

- The units used in the measurements. A position recorded in one-arc second increments has a higher resolution than that taken in one-arc minute increments.
- The number of decimal places for the recording of the position. Use of more decimal places can provide for a higher resolution.

It is important to note that resolution and post-spacing are not synonymous and can be confused with each other. Horizontal resolution is the number of decimal places in the measurement of the measured position (post), e.g. 0.1 arc second.

It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

7.3.1.7.1 Proposed Measurement:

Logical Consistency (Domain Consistency, Format Consistency) – internal – full inspection: Check whether all items have a horizontal resolution value which is at least as precise as the ones provided in the following table:

Area 1	Area 2	Area 3	Area 4
1.0m	0.1m	0.01m	0.1m

Table 6: Terrain – Horizontal Resolution Requirements

[66] An internal inspection using ground control points is quite costly and differences between certain systems are difficult to detect. A high-level assessment can be made by checking the value domain of the horizontal co-ordinates.

Note: This table was defined (based on ICAO Annex 15, Table A8-1) on the assumption that the metric system is used. Otherwise, the horizontal resolution must be adjusted to provide for the same level of detail.

7.3.1.7.2 Proposed Conformance Level:

No items shall exceed the values defined in Table 6, above, otherwise, the data set cannot be accepted. A higher resolution is acceptable.

7.3.1.8 Horizontal Position

Horizontal position data are defined by geodetic latitude and longitude. The geodetic latitude of a point is defined as the angle between the normal to the ellipsoid at that point, and the equatorial plane. The geodetic longitude of a point is the angle between its geodetic meridian plane and the International Reference Meridian.

The quality of the horizontal position is expressed by the positional (horizontal) accuracy. The confidence level is the statement of what proportion of the data set the positional accuracy statement is valid for: 5m at 90% means that there is a 90% probability that a particular co-ordinate value is within 5m of the true position.

Horizontal accuracy specifies the degree of closeness of the positional values of the data points to their true position.

- Horizontal accuracy shall be stated in the same units as those used for the elevation;
- The statistical derivation of the horizontal accuracy shall be stated;
- The conformance level should be provided.

7.3.1.8.1 Proposed Measurement:

Positional Accuracy (absolute or external accuracy) – external – sampling: Measure the distance between the absolute co-ordinate values of the terrain nodes/grid cells and those in the universe of discourse, using ground control points or well-defined terrain structures (ridges, mountain peaks), from a different data set[67]. Count the number of items with a distance error which exceeds the value defined in following table (from ICAO Annex 15, Table A8-1), divide by the number of control items, multiply by 100 and subtract from 100.

Area 1	Area 2	Area 3	Area 4
50m	5m	0.5m	2.5m

Table 7: Terrain – Horizontal Position Requirements

7.3.1.8.2 Proposed Conformance Level:

Conformance level as defined by ICAO Annex 15, Table A8-1: 90%.

Data sets with a lower accuracy cannot be accepted.

7.3.1.9 Elevation

Elevation is the vertical distance of a point or a level, on or affixed to the surface of the Earth, measured from MSL.

- Elevation shall be expressed in linear units that are consistent with the accuracy and resolution specifications.

  The quality of the elevation is expressed by the positional (vertical) accuracy. The vertical accuracy specifies the degree of closeness of the recorded elevation values to the true elevation.
- Elevation shall be stated in the same units as those used for the vertical accuracy;

[67] As a rule of thumb, it can be stated that a data set used for external evaluation should have at least a three times higher accuracy than the data set under evaluation; reference data for Area 2 shall have a horizontal accuracy of 1.65m or better (at 90% confidence level).

- If resampling is applied to produce the correct cell size, the validation of the data shall be performed on the original data, not on the resampled data;
- If the accuracy requirement cannot be fulfilled in a gridded data set because of the cell size (point spacing), the creation of a TIN-based model should be considered (see also section 7.1.8.1);
- The statistical derivation of the vertical accuracy shall be stated.

7.3.1.9.1 Proposed Measurement:

Positional Accuracy (absolute or external accuracy) – external – sampling: Error distance between the absolute elevation values of the terrain nodes/grid cells and those in the universe of discourse, using ground control points. Count the number of items with an error distance which exceeds the value defined by ICAO Annex 15, Table A8-1 and given in the following table, divide by the number of control items, multiply by 100 and subtract from 100:

Area 1	Area 2	Area 3	Area 4
30m	3m	0.5m	1m

Table 8: Terrain – Elevation Requirements

7.3.1.9.2 Proposed Conformance Level:

Conformance level as defined by ICAO Annex 15, Table A8-1: 90%.

Data sets with a lower accuracy cannot be accepted.

7.3.1.10 Elevation Reference

Elevation reference describes how elevation values are related to the universe of discourse: The provided values may correspond to a particular corner or the centre of a DTM cell, the mean elevation value of the area covered by the cell, the maximum elevation value, etc.

7.3.1.10.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the elevation reference provided is the correct one.

7.3.1.10.2 Proposed Conformance Level:

The correct elevation reference shall be provided.

7.3.1.11 Vertical Reference System

The vertical reference system is the datum to which the elevation values are referenced:

- MSL is the required vertical reference system. EGM-96 shall be used as the global gravity model;
- The WGS-84 ellipsoid shall be used, in accordance with ICAO Annex 15;
- If a geoid model other than the EGM-96 model is used, a description of the model used, including the parameters required for height transformation between the model and EGM-96, shall be provided.

7.3.1.11.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – full inspection: Check whether height and elevation values are indicated using MSL as the vertical reference system, based on EGM-96 as the gravitational model or, if another geoid model is used, its description is provided, including the parameters required for height transformation to EGM-96.

7.3.1.11.2 Proposed Conformance Level:

If MSL with EGM-96 is not used and a description and parameters of the model used are not provided, the data set cannot be accepted.

7.3.1.12 Vertical Resolution

Vertical resolution is, during data origination, the degree of separation with which the measurements are recorded. For data storage and exchange, the vertical resolution is defined as the number of decimal places to which the elevation is stored e.g. 0.1m. Use of more decimal places can provide for a higher resolution.

It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

7.3.1.12.1 Proposed Measurement:

Logical Consistency (Domain Consistency) – internal – full inspection: Check whether all items have a vertical resolution which fulfils or exceeds the requirements defined by ICAO Annex 15, Table A8-1 and given in the following table (i.e. the resolution values are equal to or lower than those given in the table):

Area 1	Area 2	Area 3	Area 4
1m	0.1m	0.01m	0.1m

Table 9: Terrain – Vertical Resolution Requirements

7.3.1.12.2 Proposed Conformance Level:

The resolution of items shall not be lower than the values defined in the Table 9, above, otherwise, the data set cannot be accepted. A higher resolution is acceptable.

7.3.1.13 Recorded Surface

Recorded surface identifies the surface that the elevation data represents. Some examples of surfaces that may be recorded by available technologies are:

- The bare earth, recorded by land survey or by remote sensing techniques, when vegetation or snow/ice is not present;
- The reflective surface, recorded by either an active or a passive remote sensing sensor.

7.3.1.13.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling[68]: The service provider shall identify the recorded surface. The quality evaluation of the elevation values may indicate a difference between what has been declared as the recorded surface and the actual measured surface, if control points have been captured on surfaces like trees and buildings.

7.3.1.13.2 Proposed Conformance Level:

If the recorded surface is provided, it shall be the correct one.

7.3.1.14 Penetration Level

The recorded surface attribute identifies the surface the elevation data represents. When the position of this surface is between the bare earth and top of the canopy or the surface is of snow or ice, the penetration level should be recorded in the attribute “Penetration Level”. Nevertheless, when recorded by either active or passive remote sensors, it is recognised that the degree of penetration of the sensor signal is frequently impossible to determine precisely and depends on the surface characteristics. The estimated penetration will be expressed as a unit of measurement e.g. metre or feet.

[68] The evaluation of the three items, recorded surface, penetration level and known variations, is defined here as thematic accuracy (non-quantitative attribute correctness) although from the evaluation, a statistical interpretation could be made and could, therefore, impact the vertical accuracy statement. It is assumed that the vertical accuracy statement covers deviations due to wrong surfaces types, erroneous penetration levels or incorrect variations anyway. Finally, the attributes may not be provided at all.

7.3.1.14.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: The service provider shall identify the recorded surface. The quality evaluation of the elevation values may indicate a difference between what has been declared as the penetration level and the actual measured surface, if, for the control points, a surface type of sandy soil, vegetation or permanent ice, etc., has been captured.

7.3.1.14.2 Proposed Conformance Level:

The correct penetration level should be provided if the recorded surface is not the top of the canopy.

7.3.1.15 Known Variations

Known variations specify predictable changes to the data e.g., seasonal elevation changes due to snow accumulations or vegetation growth.

7.3.1.15.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Use external information, such as that used to identify the surface type of the land, in combination with vegetation growth rates or meteorological information on average snow heights to evaluate the correctness of the given values. Differences (i.e. if the given values are lower than those in the external information) exceeding the vertical accuracy requirements should be reported.

7.3.1.15.2 Proposed Conformance Level:

Where known variations are expected, the correct variations should be provided.

7.3.1.16 Integrity

The integrity of data is the degree of assurance that the data and its value have not been lost or altered since its origination or last authorised amendment.

The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

Based on the applicable integrity classifications, the validation and verification procedures should ensure that the corruption is avoided throughout the processing of the routine data and for essential data that corruption does not occur at any stage of the entire process and may include additional processes as needed to address potential risks in the overall system architecture to further assure data integrity at this level.

The integrity of data is normally assured through the processes employed in originating, handling, processing, transferring and publishing the data which could be found in EUROCONTROL Specification for Data Assurance Levels.

7.3.1.16.1 Proposed Measurement:

Thematic Accuracy (classification correctness) – internal – full inspection: The integrity classification defined by ICAO Annex 15, Table A8-1 and given in the following table:

Area 1	Area 2	Area 3	Area 4
Routine	Essential	Essential	Essential

Table 10: Terrain – Integrity Requirements

7.3.1.16.2 Proposed Conformance Level:

The data will not be accepted, if it does not correspond to integrity classification given above.

7.3.2 New Obstacle Data

7.3.2.1 Completeness

Usually the quality evaluations refer to attribute values. The completeness element may consider the presence/absence of attributes but, for obstacles in the aviation domain, the completeness of the features is one of the main quality characteristics. Whilst it is acceptable that there is excess data in the data set[69], obstacles missing from the data set is unacceptable.

7.3.2.1.1 Proposed Measurement (1):

Completeness (omission and commission) – external – sample: Select a representative sample area and compare the features which are present in the data set with the universe of discourse.

7.3.2.1.2 Proposed Conformance Level (1):

Omission: If any feature in the universe of discourse is missing in the data set, the data set cannot be accepted.

Commission: 2.5%

Note: it is expected that few obstacles have been removed between the time of the survey and the quality evaluation. Although no conformance level is specified in ICAO Annex 15, this value should not, under regular circumstances, be exceeded.

7.3.2.1.3 Proposed Measurement (2):

Completeness (commission) – external – full: Validate the data set against the appropriate ODCS, as given in ICAO Annex 15.

Note: There is no proposed conformance level because an excess of data, in this case (i.e. objects not actually being an obstacle), has no negative impact.

7.3.2.1.4 Proposed Conformance Level (2):

None, but features not penetrating the ODCS should be marked as such.

7.3.2.2 Horizontal Position

Horizontal position data shall be expressed for a point, or points defining a line or a polygon. Horizontal position data shall be expressed in geographical co-ordinates e.g., by latitude and longitude.

The quality of the horizontal position is expressed by the positional (horizontal) accuracy.

7.3.2.2.1 Proposed Measurement:

Positional Accuracy (absolute or external accuracy) – external – sampling: Error distance between the absolute co-ordinate values of the obstacles in the data set and those in the universe of discourse. Count the number of items with a distance error which exceeds the value defined by ICAO Annex 15, Table A8-1 and given in the table below, divide by the number of control items, multiply by 100 and subtract from 100.

Area 1	Area 2	Area 3	Area 4
50m	5m	0.5m	2.5m

Table 11: Obstacle – Horizontal Position Requirements

7.3.2.2.2 Proposed Conformance Level:

Conformance level as defined by ICAO Annex 15, Table A8-2: 90%.

Data sets with a lower accuracy cannot be accepted.

[69] As long as the data meets the quality requirements and is valid for the time period of the data set.

7.3.2.3 Data Originator Identifier[70]

Sufficient information shall be provided to distinguish between multiple data originators. A permanent record of the data originator shall be kept to provide an audit trail.

7.3.2.3.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the data originator provided is the correct one. For all process steps (see 7.1.7.2) before the data is published by the body responsible for publication, the data originator must be provided and be correct.

7.3.2.3.2 Proposed Conformance Level:

The data originator shall be provided and be the correct one, otherwise, the data set cannot be accepted.

7.3.2.4 Data Source Identifier

Information shall be provided about the entity responsible for provision of the dataset.

7.3.2.4.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Check if the data source identifier provided is the correct one.

7.3.2.4.2 Proposed Conformance Level:

The correct data source identifier shall be provided.

7.3.2.5 Horizontal Reference System

The horizontal reference system is the datum to which the positions of the data points are referenced.

- ICAO Annex 15 SARPs require that co-ordinates used for air navigation are expressed in the WGS-84 reference system.
- If the horizontal reference system is not WGS-84, the reference system used and transformation parameters to WGS-84 shall be specified.

7.3.2.5.1 Proposed Measurement:

Thematic Accuracy – external – full inspection: Check if the horizontal reference system equals "WGS-84" or if the transformation parameters from the given reference system to WGS-84 are provided[71].

7.3.2.5.2 Proposed Conformance Level:

If the horizontal reference system is not WGS-84 or if no transformation parameters from the utilised reference system to WGS-84 are provided, the data set cannot be accepted.

7.3.2.6 Area of Coverage

Area of coverage is a descriptor used to identify the geographical extent of the obstacle data. This should be used to help the user identify, in general terms, the area under consideration (e.g., cell phone towers, Navaids at a particular airport).

7.3.2.6.1 Proposed Measurement:

Logical Consistency (Topological consistency) – internal – full inspection: Check whether all items are inside the area of coverage.

7.3.2.6.2 Proposed Conformance Level:

100%: If any entry is outside the area of coverage, the data set cannot be accepted.

[70] The same test can also be applied for the traceability (lineage) information.

[71] An internal inspection using ground control points is quite costly and differences between certain systems are difficult to detect. A high-level assessment can be made by checking the value domain of the horizontal co-ordinates.

7.3.2.7 Elevation

Elevation is the vertical distance of a point or a level, on or affixed to the surface of the Earth, measured from MSL.

- Elevation shall be expressed in linear units that are consistent with the accuracy and resolution specifications;
- The quality of the elevation is expressed by the positional (vertical) accuracy. The vertical accuracy specifies the degree of closeness of the recorded elevation values to the true elevation.

Vertical accuracy shall be stated in the same units as those used for the elevation.

The statistical derivation of the vertical accuracy shall be stated.

7.3.2.7.1 Proposed Measurement:

Positional Accuracy (absolute or external accuracy) – external – sampling: Error distance between absolute elevation values of the obstacles in the data set and those in the universe of discourse using ground control points. Count the number of items with a distance error which exceeds the value defined by ICAO Annex 15, Table A8-2 and given in the following table, divide by the number of control items, multiply by 100 and subtract from 100:

Area 1	Area 2	Area 3	Area 4
30m	3m	0.5m	1m

Table 12: Obstacle – Elevation Requirements

7.3.2.7.2 Proposed Conformance Level:

Conformance level as defined by ICAO Annex 15, Table A8-2: 90%.

Data sets with lower accuracy cannot be accepted.

7.3.2.8 Vertical Reference System

The vertical reference system is the datum to which the elevation values are referenced.

- MSL is the required vertical reference system. EGM-96 shall be used as the global gravity model.
- The WGS-84 ellipsoid shall be used, in accordance with ICAO Annex 15.
- If a geoid model other than the EGM-96 model is used, a description of the model used, including the parameters required for height transformation between the model and EGM-96, shall be provided.

7.3.2.8.1 Proposed Measurement:

Thematic Accuracy – external – full inspection: Check whether the height and elevation values are indicated using MSL as the vertical reference system based on EGM-96 as the gravitational model or, if another geoid model is used, its description is provided, including the parameters required for height transformation to EGM-96.

7.3.2.8.2 Proposed Conformance Level:

If MSL with EGM-96 is not used, and a description/parameters of the model used are not provided, the data set cannot be accepted.

7.3.2.9 Vertical Resolution

Vertical resolution is, during data origination, the degree of separation with which the measurements are recorded. For data storage and exchange, the vertical resolution is defined as the number of decimal places to which the elevation is stored e.g. 0.1m. Use of more decimal places can provide higher resolution.

It is recommended that the resolution of the data features contained in the database should be commensurate with the data accuracy requirements and may be the same or finer than the publication resolution.

7.3.2.9.1 Proposed Measurement:

Logical Consistency (Domain Consistency) – internal – full inspection: Check whether all items have a vertical resolution which fulfils or exceeds the requirements defined by ICAO Annex 15, Table A8-2 and given in Table 13 (i.e. the resolution values are equal to or lower than those given in the table):

Area 1	Area 2	Area 3	Area 4
1m	0.1m	0.01m	0.1m

Table 13: Obstacle – Vertical Resolution Requirements

7.3.2.9.2 Proposed Conformance Level:

No items shall exceed the values defined in the table above. Otherwise, the data set cannot be accepted. A higher resolution is acceptable.

7.3.2.10 Obstacle Type

Obstacle type is a description of the recorded obstacle, e.g., tower, building, tree, power lines, windmill farms, cable car, etc. Obstacles may be temporary, such as cranes, permanent, such as television transmission towers, or mobile, such as ships.

7.3.2.10.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Select a representative sample area and compare the obstacle type of the features in the data set with the universe of discourse. Count the number of incorrect types, divide by the number of controlled items, multiply by 100 and subtract from 100.

7.3.2.10.2 Proposed Conformance Level:

90%.

Note: ICAO Annex 15 does not state any conformance level for thematic accuracy. If less than 90% of obstacles are classified correctly, the reliability for this attribute is not sufficient for subsequent use.

7.3.2.11 Integrity

The integrity of data is the degree of assurance that the data and its value have not been lost or altered since its origination or last authorised amendment.

The integrity of aeronautical data shall be maintained throughout the data process from survey/origin to distribution to the next intended user.

Based on the applicable integrity classifications, the validation and verification procedures should ensure that the corruption is avoided throughout the processing of the routine data and for essential data that corruption does not occur at any stage of the entire process and may include additional processes as needed to address potential risks in the overall system architecture to further assure data integrity at this level.

The integrity of data is normally assured through the processes employed in originating, handling, processing, transferring and publishing the data which could be found in EUROCONTROL Specification for Data Assurance Levels.

7.3.2.11.1 Proposed Measurement:

Thematic Accuracy (classification correctness) – internal – full inspection: The integrity classification defined by ICAO Annex 15, Table A8-2 and given in the following table:

Area 1	Area 2	Area 3	Area 4
Routine	Essential	Essential	Essential

Table 13: Obstacle – Integrity Requirements

7.3.2.11.2 Proposed Conformance Level:

The data will not be accepted, if it does not correspond to integrity classification given above.

7.3.2.12 Effectivity

Effectivity is a description of the time and date an obstacle exists. For temporary obstacles, effectivity should be provided. Effectivity shall include:

- The time and date of construction/placement of the obstacle;
- The time and date of demolition/removal the obstacle.

7.3.2.12.1 Proposed Measurement:

Temporal Accuracy – external – sample: Select a representative sample area and compare the effectivity information of the features in the data set with the universe of discourse.

7.3.2.12.2 Proposed Conformance Level:

None.

Note: A conformance level is not proposed because the attribute is only optional and it is difficult to set a date for the construction of the obstacle (erecting it may take several months so it is difficult to identify an appropriate date). However, the quality of the effectivity information can be used to determine the overall efficiency of the notification process.

7.3.2.13 Lighting

When an obstacle has obstruction lighting, this information shall be provided.

7.3.2.13.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute correctness) – external – sampling: Select a representative sample area and compare the lighting of the features in the data set with the universe of discourse. Count the number of incorrect types, divide by the number of controlled items, multiply by 100 and subtract from 100.

7.3.2.13.2 Proposed Conformance Level

90%.

Note: ICAO Annex 15 does not state any conformance level for lighting. If less than 90% of obstacle lighting is classified correctly, the reliability for this attribute is not sufficient for subsequent use.

7.3.2.14 Geometry

Obstacles shall be described either as points, lines, or polygons.

- Point obstacles:

  The centre of the obstacle's horizontal surface shall be captured as a 2D or 3D co-ordinate. Adjacent obstacles or groups of obstacles shall be captured individually. A point obstacle may have a horizontal extent when the radius attribute is used.

- Line obstacles:

  The obstacle's horizontal surface shall be captured as a line. A line consists of a connected sequence of points. Start and end points of a line are referred to as startnodes and endnodes. Connecting points, located between the start and endnodes are referred to as vertices. Vertices are intermediate points that define the line's structure, curvature or shape. A startnode and an endnode define a line's direction. A connection between a node and a vertex or between vertices shall be a straight line.

- Polygonal obstacles:

  The polygon's outer edge shall coincide with the obstacle's projected outer edge. A polygon is a surface described by a closed line (i.e. a line whose startnode and endnode are coincident). The closed line forms the outer edge of the surface. The inside of the polygon is defined by the left side, in the order of vertices[72]. Depending on the complexity of the obstacle, one or multiple polygons may be used to model the obstacle.

7.3.2.14.1 Proposed Measurement:

Thematic Accuracy (Non-quantitative attribute consistency) – external – sample: Select a representative sample area and compare the geometry of the features in the data set with the universe of discourse and the feature capture rules. Count the number of incorrect geometry items (i.e. wrong level of detail), divide by the number of controlled items, multiply by 100 and subtract from 100.

7.3.2.14.2 Proposed Conformance Level:

90% of all validated objects should have the correct geometry type assigned.

7.4 Data Storage

Concerns have been raised regarding the likely size of the data that needs to be processed and stored in relation to terrain and obstacle data. In particular, concerns have been raised regarding terrain data.

Whereas the provision of terrain and obstacle data is, without doubt, a significant change from the data traditionally managed by the AIS, this section identifies that the volumes of data anticipated will not create the problems envisaged by some members of the community.

7.4.1 Size of Data

It is clear that what was considered to be a large data set a decade ago is significantly different to that which is considered to be a large data set today. In fact, today, systems capable of handling terabytes of data are not uncommon.

An example of the sizes of terrain and obstacle data was provided on EUROCONTROL's Terrain and Obstacle Data Forum. For an area of 49,000 km^2, the size of a file with the elevation grid is 62.8 Megabytes (MB). The size of the same data, stored as a binary database, in which every point has its geographical co-ordinates and elevation, is 657 MB.

Whilst the potential size of the data to be processed in relation to terrain and obstacle data is significantly larger than the traditional AIP data handled by AIS, managing data of this size is neither new nor unique to AIS.

For example, in the aviation sector, many AIS or airport authorities use GIS for handling spatial data. Often high-resolution imagery (orthophoto), with ground sampling distance of 25–50cm, is stored within the GIS database and used in a variety of GIS applications. The size of data in such data sets is relatively high when compared with the size of the AIP in digital form.

In the banking sector, data related to each and every transaction is stored and thousands of transactions are processed every hour of the day. Closely linked to aviation is meteorology, where large volumes of data are processed to produce displays indicating temperature, wind speed, pressure and humidity, as well as time and three spatial dimensions. In total, this equates to terabytes of data. Hydrographic offices provide another example, as they process large volumes of maritime data. In some cases, they cover large areas of the world, rather than just the territory of a single State.

[72] This rule is based on the assumption that the digitising is made counter-clockwise. If the requirement is for clockwise digitising, the inside of the polygon is defined by the right side.

7.4.2 Storage

For Area 1, there has been discussion about the different methods of storing data in files/databases and the potentially large number of records and fields that a database/file would comprise. To overcome this, a number of suggestions have been made:

- The use of two databases, the first containing the core data and the second containing the other attributes for the points in the first database.
- The use of specialised raster storage support available in databases and GIS systems to store elevation information, allowing displays and calculations to be performed quickly, or the storage of elevations in one file and the storage of other attributes in other vector files.

There has been some indication that the metadata for terrain data are common for an entire data set or at least large parts of the territory so for information other than elevation, a series of polygons could be built. The attributes could then be assigned to the polygons, allowing all the data to be stored in a single database. With regards to the formats to be used for terrain and obstacle data, databases, American Standard Code for Information Interchange (ASCII), binary Digital Terrain Elevation Data (DTED), GEOTIFF and comma-separated values (CSV) have all been considered and it is recommended that consideration is given to the data that is available and how this may be used within the applications that are likely to be used by the end-users. The development of new standards for the ISO 19100 series is also ongoing and it is further recommended that the work of the OGC, which acts as the technical committee for these standards, is monitored.

7.4.3 Systems Capacity

There have been many advances in storage technology and the costs associated with this technology have decreased in recent years.

It is acknowledged that the hardware used by AIS may have to be upgraded to be able to efficiently manage terrain and obstacle data. However, the costs associated with enhanced hardware may not be as high as first thought. For example, the AIS capability could be expanded by use of Network-attached Storage (NAS).

A NAS is a hard disk storage system which is connected to a network with the sole purpose of supplying file-based data storage services to other devices on the network. It provides the functionality of data storage, file systems, and access to files, and the management of these functionalities.

A NAS, with 10 terabytes of internal storage, can be procured for under €5,000 and such systems also utilise Redundant Array of Independent Disks (RAID) technology to provide storage which protects against hard disk failure.

If the example size provided above is taken as a basis for discussion, a NAS providing 10 terabytes of internal storage is capable of holding the entire data set for Europe many times over[73]. Area 2 data will contain nine times more information. Nonetheless, it may still be seen that this amount of storage would still be sufficient to hold the data for Europe several times over.

7.4.4 Data Backup

With regards to back-up techniques that may be employed, two main technologies could be considered for terrain and obstacle data. These are shown below, along with their relative advantages/disadvantages:

- Magnetic tape:
  - These have an improved price / capacity ratio than hard disks although this has decreased significantly in recent years;

[73] It should be noted that this figure is for Area 1 data only and does not include the metadata.

  - Access times can be poor but the rate of continuously writing or reading data can be very fast;
  - Magnetic tape is a known technology that has been used for decades;
  - Stability and reliability of a single tape has been grown continuously to around 30 years (guaranteed time that the tape is readable if adequately stored).
- Hard disk:
  - The capacity/price ratio of hard disk has been rapidly improving for many years;
  - Low access times, availability, capacity and ease of use;
  - Some systems support data de-duplication which can dramatically reduce the amount of disk storage capacity consumed by daily and weekly backup data;
  - Easily damaged;
  - Continuous power consumption;
  - Stability over periods of years is relatively unknown.

It is thought unlikely that terrain data (which accounts for the largest proportion of terrain and obstacle data) will change regularly and, therefore, backup regimes should be developed to suit the amount and frequency of data update.

7.5 Data Accessibility

This section sets out a number of possible solutions by which data may be made accessible. It was considered beneficial to use a single approach by all European States to ensure that a harmonised means is available to users[74].

Under the requirements of ICAO Annex 15, States must make digital terrain and obstacle data available to users. There are two possible methods by which this data may be made available:

- Data is sent to the user in some way, i.e. the data is “pushed” to the user;
- Data is made available for the user to collect, i.e. the data is “pulled” by the user.

The following sections outline some of the different approaches that may be used for each of these methods. It does not rank the advantages and disadvantages of each as these will depend upon the nature of the client. However, it does make statements as to what capabilities may be provided.

7.5.1 Approaches to “Push” Data

7.5.1.1 CD/DVD

The digital files could be burnt to a CD to DVD and sent using physical distribution means to the user. This may be by way of the postal services and could, as an example, be achieved as part of the distribution of an AIP Amendment.

Physical services, such as a normal postal service, do not, by default, provide a proof-of-delivery although these may be available as an additional “paid for” service.

7.5.1.2 Email

Small data files could be sent using email as a simple attachment. Delivery and read receipts can be requested to help provide some assurance of delivery, however, not all mail servers support such requests and, consequently, it may not provide a guaranteed method of ensuring delivery and, unless encryption techniques are utilised, may not be sufficiently private.

[74] To date, no agreement has been reached on a harmonised method for Europe.

7.5.1.3 FTP

File Transfer Protocol (FTP) could be used for the distributing body (e.g. AIS) to upload information to client systems. Such an approach would provide the sender with a degree of certainty that the products had been successfully distributed as they could, if they so wished, download the uploaded file to confirm that the content was identical and integrity achieved.

For such a technique, both sender and client would be required to have an FTP capability available and to have appropriate security measures in place.

7.5.1.4 Reusable Media

Where there is a close relationship between the sender and client, it is possible that arrangements could be made to make use of reusable media which, once the data has been utilised by the client, is returned to the sender. If such an approach is taken, media, such as memory sticks and portable hard disks, may be used.

7.5.2 Approaches to Allow Data to be "Pulled"

7.5.2.1 FTP

Once again, FTP may be used for pulling data, with the client having access to the sender's FTP site to retrieve data.

For such a technique, both sender and client would be required to have an FTP capability available and for appropriate security measures to be put in place.

7.5.2.2 Website

Many service providers now have a website through which the products could be made available, either for direct download, or for purchase, after which they may be downloaded.

The use of a website offers a simple solution with two contrasting capabilities:

- Only those users who have paid for products are able to access the download area for the data;
- The products may be made freely available to anybody who wishes to access them.

As with FTP, appropriate security measures would need to be put in place to ensure that the files were not manipulated or corrupted, and that cyber-attacks were resisted.

7.5.2.3 Web Services

Web services is the generic title for a series of standards developed by the Technical Committee 211 (TC211) of the ISO in collaboration with the OGC which, when implemented, provide a capability to allow system-to-system connection for identification and receipt of data products. Such products and services could provide entire data sets, such as an Area 2 data set for an aerodrome. Alternatively, it could offer services where a request for particular features, such as the dominant obstacles for a given procedure, result in a tailored data set being returned.

Many GIS tools are now web service-enabled and are, in theory, able to locate and utilise compliant products without the need for modification.

The ISO standards relating to web services are relatively new and further standards are being developed, such as those relating to security and charging.

7.6 Terrain and Obstacle Data Models

ICAO Annex 15 calls for terrain and obstacle data to be provided as digital data sets and prescribes the manner in which these data sets should be modelled, stating "*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.*".

As described in section 2.3.1, the term “Data Modelling” is used to describe the technique of describing elements in a manner which may be unambiguously understood by humans and computers alike.

The following paragraphs describe the recommended data models for terrain and obstacle data that, if used, will increase harmonisation and interoperability and, from a European Perspective, aid compliance with the Commission Regulation (EU) 73/2010.

7.6.1 Terrain

This section provides a detailed technical description of the terrain data model. For a more detailed description of the terrain data model, the TIXM Primer should be consulted.

7.6.1.1 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 data sets can be constructed using subsets of the point cloud, packaged with the appropriate metadata.

The use of a point cloud concept brings major advantages in the implementation of terrain data where there are multiple data sets, 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 in the aerodrome’s Area 3 data set, and will entirely exist within the aerodrome’s Area 2 and the State’s Area 1 data sets.

The terrain and obstacle data requirements specify the need to exchange terrain data for the intersection points for a defined grid. Figure 30, 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 each grid square (see section 2.1 of this Manual for more information). These values are those that exist within the point cloud.

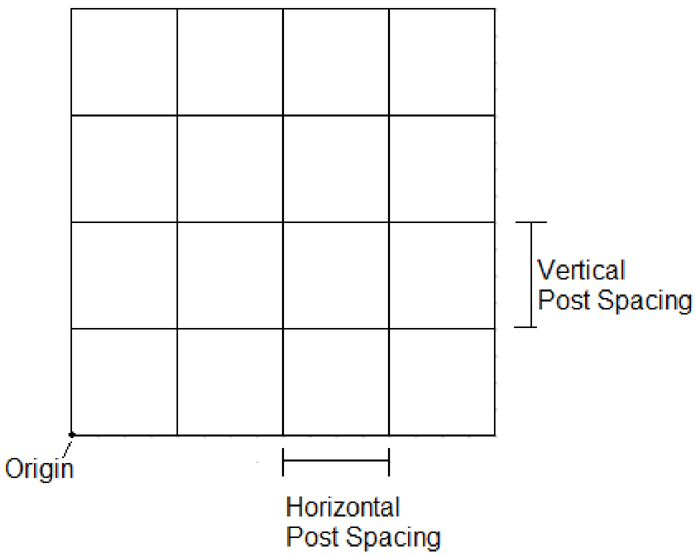


Figure 30: Example Grid

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 easier use of partial surveys within a data set. For example, if earthworks are undertaken, only the points that relate to the affected area may be resurveyed and the resultant data set 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 data set.

7.6.1.2 Exchange Model

The TIXM is a formal representation of the requirements for terrain data described in the ICAO Annex 15 and is expressed as a collection of UML diagrams. The exchange model was shown in Figure 22 and contains the concepts described in the previous section.

7.6.1.3 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 can be found in the TIXM Primer.

7.6.2 Obstacles

Whilst for terrain it was felt necessary to provide a separate model, this is not the case for obstacles. The AIXM, from version 5.0 onwards, has provided adequate coverage for obstacle data and its required metadata.

Consequently, it is recommended that users refer to the AIXM documentation for a full description of the model. Nonetheless, the obstacle elements are described here to provide a high-level overview.

7.6.2.1 Conceptual Model

This section provides an overview of the conceptual model for obstacle data which explains the principles of data modelling and the approach taken to represent the obstacle data.

The AIXM Conceptual Model contains entities necessary for the representation of obstacle data. The conceptual model is described using UML.

All objects (fixed, mobile, temporary or permanent) can by represented using the VerticalStructure entity. Only those vertical structures that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight are considered obstacles. These areas can be defined using the ObstacleArea entity, which can then be associated with the appropriate vertical structures.

7.6.2.2 Exchange Model

The AIXM exchange model builds upon the conceptual model and introduces concepts necessary for data exchange. The features defined in the conceptual model are wrapped in TimeSlice entities, allowing the exchange of only those portions that have changed.

The data originator / surveyor and the aeronautical organisation responsible for the data request may agree a less comprehensive exchange model than AIXM. However, it must be noted that not only data but also metadata have to be exchanged.

7.6.2.3 Exchange Schema

The exchange schemas are generated automatically from the UML model and can be found on the AIXM website[75].

7.7 Metadata

The proposed metadata schema for terrain and obstacle data is based on the ISO 19115 standard. Some extensions are defined to comply with the requirements of ICAO Annex 15. Additional

[75] http://www.aixm.aero.

extensions are proposed to accommodate metadata necessary for AIXM conformity. As the AIXM metadata schema is also based on ISO 19115, this allows concepts from the AIXM metadata schema to be easily adopted.

The following chapters list those modifications considered to be AIM-relevant in AIXM version 5.1, plus several other extensions that meet the requirements of ICAO Annex 15. It is recommended that the proposed modification is at least applied in the AIS/AIM system in which the data is stored although it is not yet possible to exchange such elements in standard AIXM 5.1 format. It is expected that these modifications will be incorporated in a future release of AIXM.

Where an “entity” is cited in the text (like EX_BoundingPolygon), the source reference is always ISO 19115.

7.7.1 Aggregations of Features for Raster Data Sets

ISO 19115 allows metadata to be attached to individual data sets, a series of data sets, to individual features or even individual feature properties. With raster data, in particular, it makes sense to relate metadata to a group of features (i.e. cells or pixels). When these cells form contiguous spaces, the aggregation is best described by one or several polygon(s).

A polygon can either be understood as a geographic collection of features or a geographic restriction on a data set. The polygon identifies all included features and thus can be stored as part of the identity entity (MD_DataIdentification) of the metadata. ISO 19115 already defines an entity that describes the extent (EX_BoundingPolygon) of the data as part of the metadata identity (MD_DataIdentification.extent). If a data set consists of multiple regions, multiple metadata entities are attached to it:

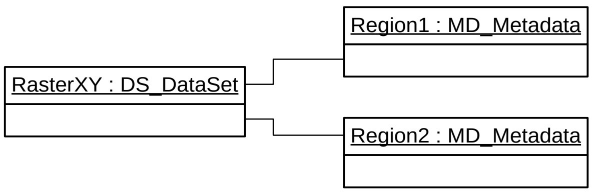


Figure 31: Regions with Dedicated Metadata Entities

When the metadata for Region1 and Region2 are very similar, there is no point in repeating the metadata information twice. In this case, it would make more sense to attach the metadata to the data set and only attach the changed metadata to specific regions:

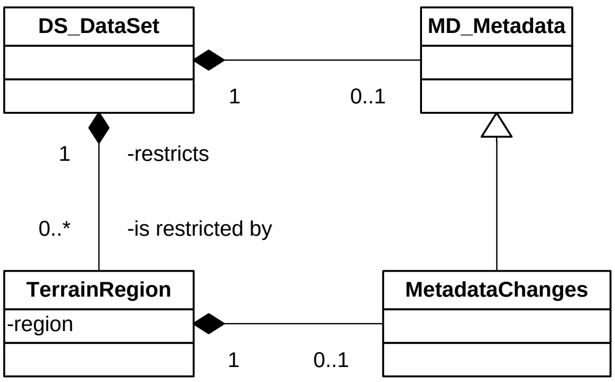


Figure 32: Regions with MetadataChanges

The entity MetadataChanges is basically identical to the entity MD_Metadata, with the difference being that all elements (also valid for all sub-elements) are optional. Only the elements that changed are listed.

When dealing with vector data, there is less need for modelling aggregations of features. Since every feature is stored in a repository as an explicit entity anyway, a metadata entity can be attached to each feature. The aggregation of features is defined implicitly by grouping features that relate to the same metadata.

7.7.2 Metadata Requirements of ICAO Annex 15

ICAO Annex 15 specifies the attributes related to terrain and obstacle data to be included as part the data made available. Some elements of this information are stored as a property of a feature; others are stored as metadata about a feature or as metadata about a data set. The following tables (Table 14 - Table 17) list the elements specified in ICAO Annex 15, together with the corresponding storage location.

New elements are described in more detail in section 7.7.3.

7.7.2.1 Metadata about a Feature (Terrain)

When dealing with raster data, a feature corresponds to a single raster cell. In most cases, it does not make sense to assign a metadata entity to every single cell of a raster. It makes more sense to group features to regions that share the same metadata (see section 7.7.1).

For the following elements, the region is used to restrict the scope of an element to a certain area. Different regions can be used for different elements and also different regions can be used for different values of the same element. Since only one element changes from one region to the other, it is not sensible to repeat the whole data set metadata. Instead, only the changed element is listed (according to Figure 32: Regions with MetadataChanges).

Element Name	Location in an AIS/AIM System[76]
Acquisition method	LI_ProcessStep, description = “Acquisition Method: …”
Horizontal accuracy	DQ_PositionalAccuracy
Horizontal confidence level	*New Element;*DQ_PositionalAccuracy, description “Confidence Level”[77]
Vertical accuracy	DQ_PositionalAccuracy
Vertical confidence level	*New Element;*DQ_PositionalAccuracy, description “Confidence Level”
Known variations	*New Entity:* KnownVariations

Table 14: Terrain – Feature Metadata

The element KnownVariations is different to all the other elements. Whilst, in general, a metadata element stores a fact about a very specific topic (defined by the element name), the element KnownVariations is not bound to a specific topic. The topic of a KnownVariations element must be provided by specifying the element name as an element itself:

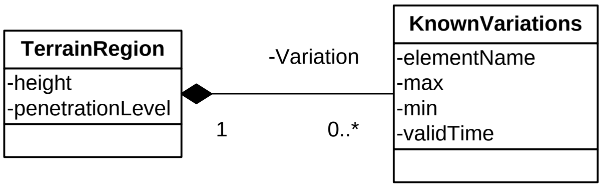


Figure 33: UML Model of New Metadata Entity KnownVariations

Here is an example:

[76] Although AIXM 5.1 does not cover all the elements, it is recommended that such elements are stored in the AIS/AIM system. All elements may be distributed using an enhanced AIXM exchange mechanism.

[77] The statements on accuracy and confidence level can be regarded as a summary of a quality report. A more comprehensive report on data quality evaluation can be stored in DQ_DataQuality.

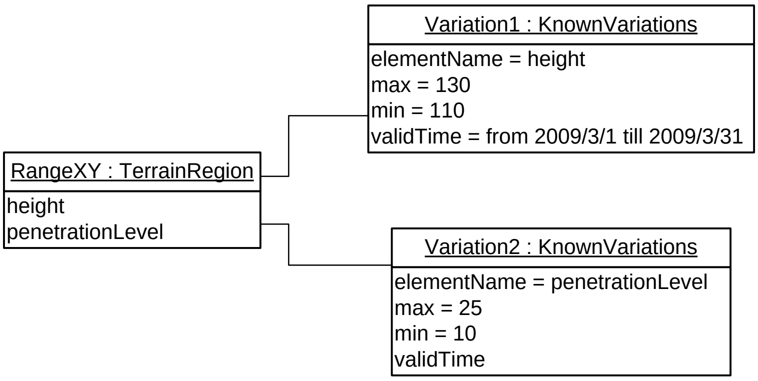


Figure 34: Sample Data for KnownVariations

By specifying the topic through the storage of the element name as a text element, the information becomes less useful. For example, it is not easy to query an AIS/AIM system with the following question: What is the minimum/maximum height of FeatureXY, as of 2009/4/1?

7.7.2.2 Metadata about a Data Set (Terrain)

In the following table, the metadata elements for a terrain data set are given:

Element Name	Location in an AIS/AIM System[78]
Area of coverage	MD_DataIdentification.extent
Data originator identifier	MD_Usage.userContactInfo, role=CI_RoleCode.originator
Data source identifier	MD_Usage.userContactInfo, role=CI_RoleCode.publisher
Acquisition method	defined as item metadata
Horizontal resolution	DQ_DomainConsistency
Elevation reference	MD_GeoRectified.pointInPixel
Elevation representation	New Element: MD_GridSpatialRepresentation.elevationRepresentation
Vertical reference system	MD_ReferenceSystem.referenceSystemIdentifier
Vertical resolution	DQ_DomainConsistency
Penetration level	New Entity & Element: DS_Sensor.TerrainPenetration.penetrationLevel
Integrity	New Element:LI_Lineage. integrity
Unit of measurement used	Z: EX_VerticalExtent.unitOfMeasure X, Y: See: Horizontal reference system
Horizontal reference system	MD_ReferenceSystem.referenceSystemIdentifier

[78] Attributes not listed in Table 13, Table 14, Table 15 or Table 16 are regarded as feature properties, not metadata.

Element Name	Location in an AIS/AIM System[78]
Post Spacing	MD_GridSpatialRepresentation.axisDimensionProperties

Table 15: Terrain – Data Set Metadata

7.7.2.3 Metadata about a Feature (Obstacle)

In the following table, the metadata elements for an obstacle feature are given:

Element Name	Location in an AIS/AIM System
Acquisition method	LI_ProcessStep, description = "Acquisition Method: …"
Horizontal accuracy	DQ_PositionalAccuracy
Horizontal confidence level	New Element; DQ_PositionalAccuracy, description "Confidence Level"
Vertical accuracy	DQ_PositionalAccuracy
Vertical confidence level	New Element; DQ_PositionalAccuracy, description "Confidence Level"
Unit of measurement used	Z: EX_VerticalExtent.unitOfMeasure X, Y: See: Horizontal reference system
Integrity	New Element: LI_Lineage. integrity
Horizontal extent	MD_DataIdentification.extent

Table 16: Obstacle – Feature Metadata

7.7.2.4 Metadata for a Data Set (Obstacle)

In the following table, the metadata elements for an obstacle data set are given:

Element Name	Location in an AIS/AIM System
Area of coverage	MD_DataIdentification.extent
Data originator identifier	MD_Usage.userContactInfo, role=CI_RoleCode.originator
Data source identifier	MD_Usage.userContactInfo, role=CI_RoleCode.publisher

Horizontal resolution	DQ_DomainConsistency
Vertical reference system	MD_ReferenceSystem.referenceSystemIdentifier
Vertical resolution	DQ_DomainConsistency
Integrity	New Element: LI_Lineage.integrity
Vertical resolution	MD_GridSpatialRepresentation.axisDimensionProperties
Unit of measurement used	Z: EX_VerticalExtent.unitOfMeasure X, Y: See: Horizontal reference system
Horizontal reference system	MD_ReferenceSystem.referenceSystemIdentifier

Table 17: Obstacle – Data Set Metadata

7.7.3 Extension for the ISO 19115 Data Model

7.7.3.1 New Metadata about a Data Set

ISO 19115 allows metadata to be attached to a data set (entity DS_Dataset). When the data set contains terrain or obstacle data, new elements are introduced to the metadata schema by extending several existing entities or adding new entities.

These elements are new:

Element Name	Description
Integrity	The degree of assurance that the data and its value have not been lost or altered since origination or authorised amendment.
penetrationLevel	The distance between the bare earth and top of the canopy of the surface. Since the penetration level depends on the sensor (and is currently only applicable to radar-based sensors), this information is placed at the data set level (for terrain data only).
elevationRepresentation[79]	The function is applied to the cell area to provide the representational value (e.g. minimum, maximum, mean etc) (for terrain data only).

Table 18: New metadata at Data Set Level, Extending ISO 19115

Below are some extracts of the UML diagram, showing the new elements:

[79] The new element elevationRepresentation contains "half" of the information from the item *elevation reference* in the terrain and obstacle data application schema. The second purpose is to reference the elevation information to the pixel (e.g., centre, lower left corner). This is stored in the entity MD_Georectified, element pointInPixel. For improved distinction, the item has been renamed.

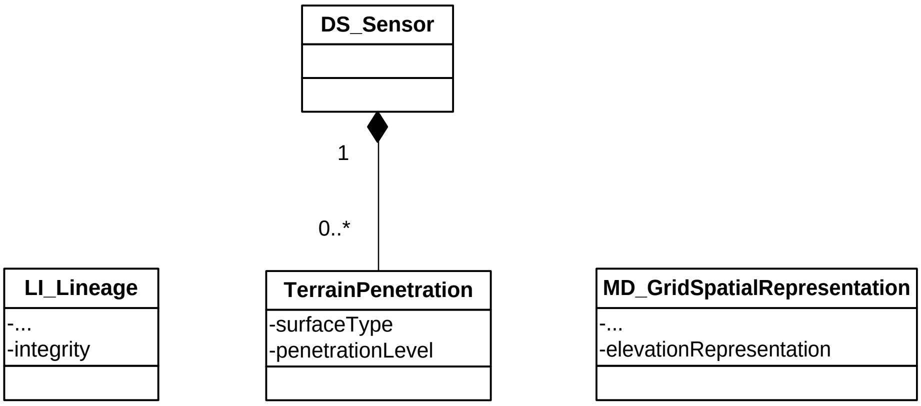


Figure 35: UML Model of New Metadata at Data Set Level

7.7.3.2 New Metadata about a Feature (or Feature TimeSlice)

An important aspect of aeronautical information is its temporal validity. Almost every piece of aeronautical information has an effectivity date attached to it. While ISO 19115 provides some means of modelling temporal extents, aeronautical information can benefit from an extended model, with strong emphasis on temporal validity. AIXM presents a model that allows for explicit modelling of temporal validity.

The AIXM temporality model defines the entity "AIXMTimeSlice" which allows all changes during a feature's lifetime to be associated with the corresponding feature. The grouping of a feature's changes allows for a complete history of the evolution of a single feature. When applying the concept of "time slices" to an AIS/AIM system, it is possible to submit queries to the AIS/AIM system, such as "show me the information about this feature as of 2008/01/02".

If the time slice concept is not implemented in an AIS/AIM system, the ability to track the changes of a single feature is lost. Depending on the update policy for the AIS/AIM database, it may or may not be possible to submit queries such as "show me a map of this extent as of 2008/01/02" to the AIS/AIM system.

Here is a UML diagram of the time slice concept:

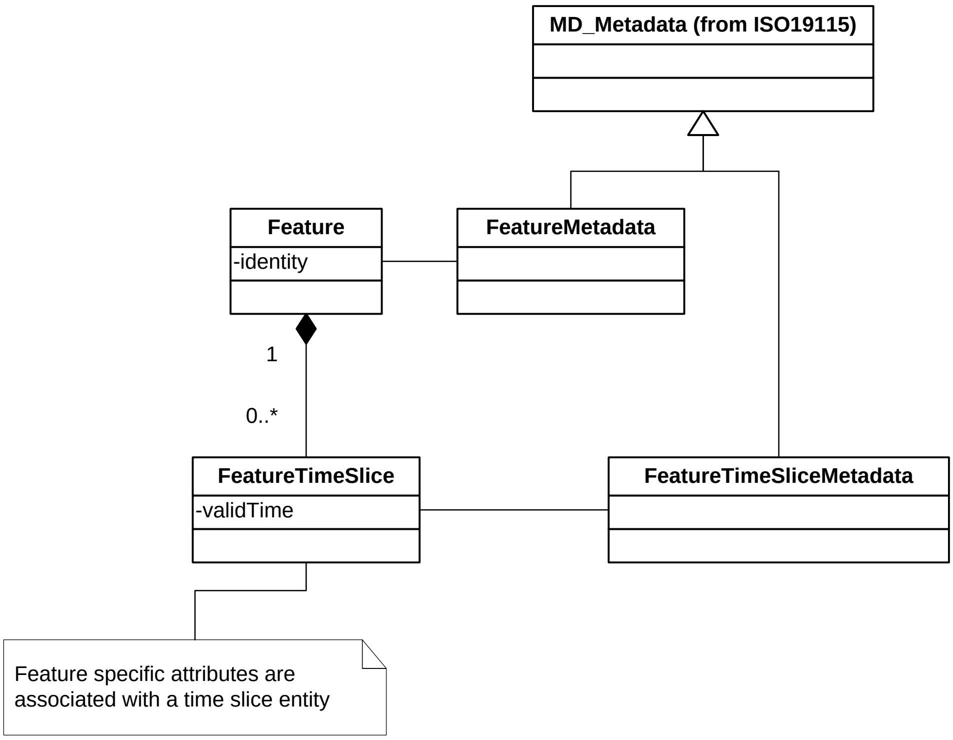


Figure 36: UML Model of the AIXM Time Slice Concept

The entities FeatureMetadata and FeatureTimeSliceMetadata are currently identical to the MD_Metadata entity and could be removed. However, future applications may want to add additional elements to these entities (see chapter 7.7.3.3). As a result, these entities have been included in the diagram for reference purposes.

The following elements are new:

Element Name	Description
horizontalConfidenceLevel	The probability that the positional values are within the stated horizontal accuracy of the true position. In general, this information is part of the data quality reporting, when taken with horizontal accuracy, and can provide a quick means of testing the fitness for use.
verticalConfidenceLevel	The probability that the positional values are within the stated vertical accuracy of the true elevation.
integrity	The degree of assurance that the data and its value have not been lost or altered since origination or authorised amendment.
knownVariations	Predictable changes to the data e.g., seasonal elevation changes due to snow accumulations or vegetation growth (for terrain data only).

Table 19: New Metadata at Feature Level, Extending ISO 19115

All information about a feature is stored in "FeatureTimeSlice" entities, and therefore, most metadata about a feature is stored in specialised "FeatureTimeSliceMetadata" entities. From this point of view, there is no need for the entity "FeatureMetadata". In future applications, this entity may become meaningful, for example, when adding CRC values to metadata elements to track unauthorised database changes. The next section provides more information about this aspect.

7.7.3.3 Consistency Checks with CRCs

Data is generally well protected whilst being stored in a database (e.g. an AIS/AIM system). As soon as data is transferred, it is much more exposed to the risk of unauthorised or accidental modification. Preventing modification is sometimes impossible or very costly. It is much simpler to allow modifications but at least be able to detect if any modifications have been made. That is where the application of CRCs can be helpful. It is a simple mechanism that supports the detection of unauthorised modifications. For this purpose, a CRC value is created for a certain data range. The CRC value is stored in the metadata, for the data range. When the data range is transferred, a CRC value is created by the receiver. When the receiver's CRC value equals the CRC value stored in the sender's database, there is a high probability there were no modifications applied to the data range during transfer.

The following metadata could be used to store CRC values:

- FeatureTimeSlice (derived from the time slice elements plus all the feature elements);
- Feature (including all FeatureTimeSlice entities).

In the case where AIXM messages are stored as well, the AIXM message metadata would also store a CRC value (derived from all the data in the message).

7.7.3.4 Unused ISO 19115 Metadata Elements

Besides the above extensions, the general ISO 19115 model is capable of holding the metadata for terrain and obstacle data. In fact, the ISO 19115 model defines entities and elements that are not needed for terrain and obstacle data. These unused entities and elements are marked as optional so there is no issue when these entities and elements are omitted. Indeed, removing such entities from the profile could lead to inconsistencies where terrain and obstacle data is part of a national spatial data infrastructure.

7.7.4 Recommendations for Metadata Collection

For the collection of metadata in the upstream data origination processes, the data model of the metadata which has to be published by the publishing organisation would ideally be used as the basis. Ideally, every party involved in the production of this could deliver an AIXM-compliant data set, including metadata, but this cannot be expected. It is, therefore, recommended that for each processing step, the required metadata items are modelled in a simplified data model and become part of the formal arrangements needed for compliance with Commission Regulation (EU) 73/2010.

One of the key benefits of metadata is the ability to support the storage of the traceability information. For each operation, the party involved must record details of the action undertaken. The date and time of the operation, the person involved and the action undertaken should be recorded, as a minimum.

Operations should be considered as not only being those actions that alter the aeronautical data, but also those that plan the data origination (like for airborne data acquisition), and those that validate and approve aeronautical data. The correct documentation of data validation procedures can simplify the comparison with the DPS to ensure that all the required procedures have been applied and the acceptable quality level is met.

The publication of a complete history of the data set for downstream users is not required as some of the processing procedures must be considered as intellectual property of the processing party. Before publication, at the latest, the history steps must be aggregated to such a level that a (surveying) specialist can judge the suitability of the processes. Where restrictions on the data sets exist, it is important that such information is always passed, in its entirety, to the next intended user.

It is expected that, at least initially, there will be several gaps between the SARPs and the implemented data sets. However, it is recommended that what is available is published and used rather than waiting until a complete, correct and accurate data set is produced. Any deviation to the DPS shall be clearly stated in the metadata for the data sets; this can also be used to document existing data sets in which gaps between the requirements and the available data set are detected (see section 8.1).

It should be borne in mind that decisions may be made based on statements in the metadata. The correctness of the metadata is, therefore, of paramount importance and the validation of metadata must be part of the standard production processes.

7.8 Data Maintenance

Guidance on the organisational and institutional aspects of data maintenance is given in section 4.1.13. This section covers some of the technical issues which may arise during data maintenance.

7.8.1 Obstacle Data

The technical aspects of obstacle maintenance do not differ greatly from those of initial data acquisition. Depending on the applied update process, the following work packages linked to data maintenance can be identified:

a) Adding, updating or deleting an obstacle as result of a notification or monitoring;
b) Monitoring changes based on updates in the cadastral base data;
c) Monitoring changes based on bulk resurvey, such as in regions where the impact of obstacles on air traffic is significant, and update of the obstacle data.

As proposed in section 4.1.13, an unambiguous identification scheme is needed and an obstacle should keep its identifier throughout its lifecycle including in the different applications in which it is used. For work package a), it is assumed that the handling of the individual obstacle can be purely based on the obstacle identifier and does not pose any difficulties in implementation.

Work package b) is only of relevance when the data was first originated based on cadastral data (see also Appendix B.2.1.5). The change detection can be based on cadastral metadata (date of last update) and/or on a feature-by-feature comparison based on the geometry. It should be noted though that a building can be expanded vertically without a change to its footprint.

In work package c), the reconciliation of existing obstacles with newly acquired ones on the basis of footprint and elevation information is of high importance. This can be performed as part of the data origination by the surveyor or as part of the data integration, by the ANSP.

Reconciliation by the surveyor has the advantage that only changes (new, changed or deleted obstacles) are forwarded to the ANSP, leaving the handling of the identifiers to surveyors and therefore reducing the burden on the ANSP. Surveyors are likely to have the required tools for geographic reconciliation of features.

Reconciliation by the ANSP has the advantage that the reconciliation provides a more reliable data validation. A surveyor may not determine the elevation of an obstacle in a resurvey when the footprint has not changed. However, a new antenna may have been erected on the roof without appropriate notification of the responsible authority. If the surveyor delivers a “new” data set without having the existing data for this area, the ANSP can validate the quality of the data during the reconciliation, by determining the difference between old and new data for obstacles which have not actually changed. If the ANSP does not have the necessary resources for data integration, the reconciliation and validation may also be provided by an independent third-party.

7.8.2 Terrain Data

Data maintenance is, as stated in section 4.1.13.3, less necessary for terrain data. Except for areas where the topography is changed by major construction or by a natural disaster, it is expected that terrain data is typically updated by means of a complete replacement. The renewal can be triggered by a bulk resurvey for obstacle data or when a State agency publishes a completely renewed terrain model to be used for Area 1. If local resurveys take place because of a change in terrain, such a section shall be integrated into the existing data by local replacement. Independent of the size of the replacement, enough overlap at the borders shall be ensured to allow a proper transition from the old to the new data set (see also section 8.2).

7.9 ISO 19100 - Application

This section includes a summary of how the requirements of ICAO Annex 15 are met by the use of the ISO 19100 series of documents, the DPS, the guidance and the data models outlined above.

This is provided in such a way as to allow a user to provide evidence to his/her regulator that compliance has been achieved.

In ICAO Annex 15, several standards from the ISO 19100 series are cited as a requirement or as a recommendation. This Manual references these standards in various sections.

The following table provides a summary of how and where within this Manual, each standard from the ISO 19100 series of standards is addressed:

ISO Standard	Summary and Reference
ISO 19101	The first standard of the ISO 19100 series of standards introduces the reference model. It describes the overall requirements for standardisation and the fundamental principles that apply in developing and using standards for geographic information.
ISO 19104	This standard provides the guidelines for the collection and maintenance of terminology used in the ISO 19100 series of standards.

ISO Standard	Summary and Reference
ISO 19108	The standard prescribes the Gregorian calendar and UTC as the primary temporal reference system for use with geographic information. No impact on the technical implementation of terrain and obstacle data is expected. Background information on temporal reference systems is given in section 2.4.4.
ISO 19109	The standard contains rules for application schemas. The application schema proposed for obstacle data is AIXM 5.x and for terrain data, TIXM. Both models contain an application schema compliant with ISO 19109 (see section 7.1.5).
ISO 19110	The standard describes a feature cataloguing methodology for geographic information. The application schema proposed for obstacle data is AIXM 5.x and for terrain data, TIXM. Both models use the feature cataloguing methodology laid down in ISO 19110 (see section 7.1.5).
ISO 19113	The standard contains quality principles for geographic information. The data quality philosophy in section 2.5 of this Manual is based on the quality principles given in ISO 19113 and extends this standard to meet the specific needs of aviation.
ISO 19114	The standard covers quality evaluation procedures. In section 7.3 of this Manual, quality evaluation procedures are proposed for both new and existing data sets. These are all based on the ISO 19114 standard.
ISO 19115	The standard specifies requirements for geographic information metadata. The application schema proposed for obstacle data is AIXM 5.x and for terrain data, TIXM. Both models use the metadata catalogue laid down in ISO 19115 (see section 7.1.5). Some metadata elements from ICAO Annex 15 are currently missing in AIXM. These have been addressed in section 7.7.
ISO 19117	The standard contains a definition of the schema describing the portrayal of geographic information. No guidance on the portrayal of terrain and obstacle data is currently provided in this Manual. Background information on data product delivery can be found in section 2.7 and guidance on its application in the DPS is provided in section 7.1.9 of this Manual.
ISO 19123	The standard contains a schema for coverage geometry and functions. Terrain data can be stored as coverage data. TIXM is compliant with the schema for coverage geometry given in ISO 19123 (see also section 7.1.5). No coverage functions are required by ICAO Annex 15.
ISO 19131	The standard specifies the requirements for geographic information and outlines DPS.

ISO Standard	**Summary and Reference**
	The DPS proposed to be used for terrain and obstacle data in section 7.1 strictly follows the specifications laid down in ISO 19131.

Table 20: References to the Standards of the ISO 19100 Series

8. USE OF EXISTING DATA

During the initial planning and implementation of terrain and obstacle data, it is highly likely that, especially where a State elects to initially use legacy data, full compliance with the requirements of ICAO may not be achieved.

This section outlines special considerations that should be given to this subject, such as:

- Responsibilities for informing users of deficiencies;
- Responsibilities of users in determining the suitability of data and steps to be taken for deficient data.

8.1 Use of Existing Data of Unknown or Deficient Quality

It is appreciated that, in some cases, it may be difficult to validate already existing data as a result of a lack of other data sources against which the data may be validated. In other cases, the difficulty in the assessment of existing data lies with the absence of metadata (e.g. integrity and traceability). In both cases, the State may elect not to take liability for the data it is publishing and this should be clearly stated in the DPS and metadata. It should be clear that if the end-user wishes to use the data, that they assume liability for its use.

If it is known that data does not fully meet the ICAO quality requirements then it is recommended that the State publishes the available data together with a statement of the limitations of the data sets. It is crucial to clearly inform the user through the metadata (to include product description and data quality reporting) and the DPS that the data does not completely meet the quality requirements and where gaps exist between the SARPs and the provided data set. If the State does not publish the data or part of the data (certain areas, certain aerodromes) then the DPS should also document this.

Note: Example of relevant statements found in National AIP GEN 1.7 Annex 15 "…as regards the digital obstacle data, all the specifications of ICAO Annex 15 Tables A8-2 and A8-4 are not complied with. The data users shall therefore carefully assess the sets of available data so as to determine whether the products are adapted to their intended use. "

8.2 Use of Existing Terrain Data for Aviation

8.2.1 Quality Assessment

There are a significant number of products available which, given a high-level assessment, may appear to offer a lower-cost and more timely solution for States than obtaining new data. However, if a State decides to consider such a product, it is encouraged to thoroughly assess the product and the approach taken in its development to ensure that it is suitable for aviation purposes.

With regards to terrain data, the following issues are expected to be the most critical ones in the use of existing data:

- Quantitative quality information:
    - The post spacing (ground sampling distance) should not be greater than required;
    - The stated horizontal and vertical accuracies should not be less than required;
    - The geodetic reference system in which the data is available should be provided and, if needed, accurate transformation parameters to WGS-84/EGM-96 to ensure no degradation of the data quality.
- Non-quantitative quality information:
    - How much information is available to support traceability? Is the lineage of the data documented? Are the parties that were involved in the data origination and processing

known? If so, can they provide additional information to that already provided in the metadata?

- o The licensing should allow at least a limited distribution of the terrain data for aviation purposes;
- o The liability of the data may not be stated in the metadata but must be evaluated.

At best, metadata will be available for the data sets and this can be used as a means of quality evaluation, without explicitly validating the data. Where metadata is not available or the quality of the metadata is questionable, sample testing should be performed. The spatial accuracy can be tested using existing benchmark points. The benchmark points should be evenly distributed over the entire data set and also reflect the different topographies in a region. Since the accuracy may be impacted by transformation and resampling, running these tests in the target reference system[80] should be considered.

This initial assessment should clarify the gap between the requirements and the currently available terrain model. This gap analysis can then be used to determine if the gap can be closed by some kind of re-processing or post-processing and what the costs involved in this are.

8.2.2 Merging of Terrain Data from Different Sources

The following provides an example of where a product may not be suitable for aviation purposes, despite initial appearances[81]:

Many terrain products are used to provide a visual representation of the terrain and combine the results of multiple surveys to generate a single, seamless product. Where the terrain surveys do not fully match at the joins, a number of techniques exist to merge the data, some of which are more visually pleasing than others. Figure 37, below demonstrates how two surveys may not match. The green dotted line reflects reality and the blue and red lines represent two surveys, each of which has small errors (both horizontal and vertical). Initially we will assume that both are considered to be within the required accuracies of ICAO Annex.

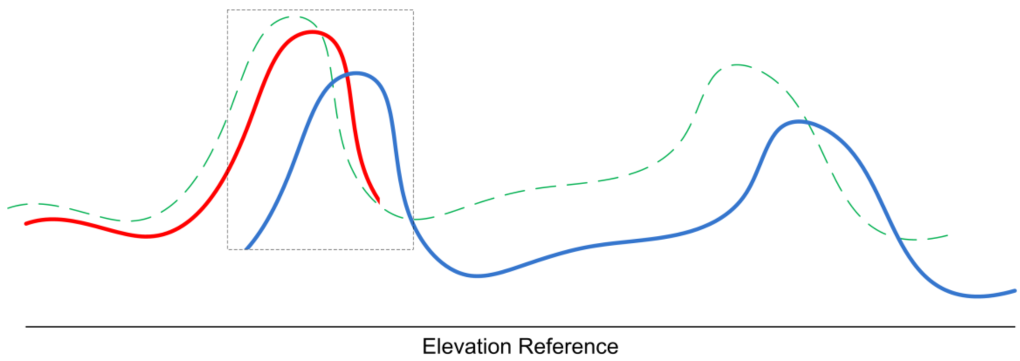


Figure 37: Terrain Data Sets

We will now look at some techniques which may be used to merge the two surveys. The area shown in the dotted box represents the “overlap” area.

One solution is to use a pure average of the two values for the overlap area which would result in the profile highlighted in yellow in Figure 38, below.

[80] It is assumed that the benchmark points are known in the target reference system too. If no benchmark points are available in WGS-84/EGM-96, new ground control points need to be collected as a base for the data quality evaluation.

[81] It should be noted that the offset between the two terrain profiles is exaggerated to graphically demonstrate the different approaches and such wide differences should not be encountered in reality.

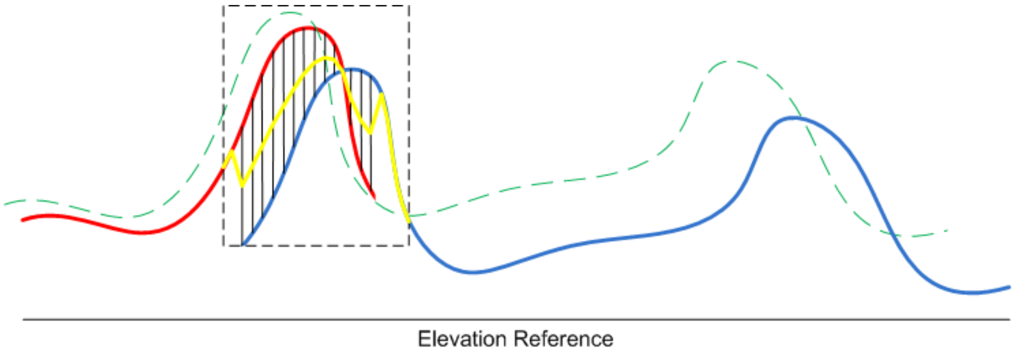


Figure 38: Merged Data Sets - Solution 1

The resultant terrain profile is statistically good, but as Figure 39 shows, is not aesthetically pleasing.

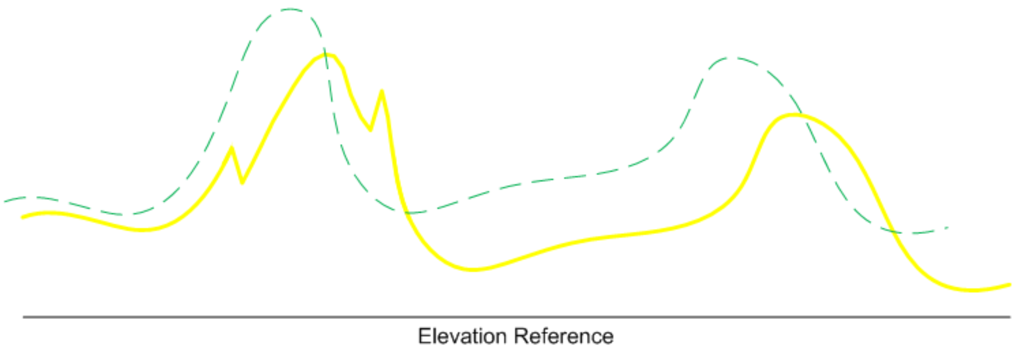


Figure 39: Resultant Terrain - Solution 1

An alternative approach is to perform a weighted average where greater importance is placed on the values for the red survey, towards the left-hand side of the overlap, than for the blue survey. On the right-hand side of the overlap, the opposite is true with the blue survey being of greater importance. This results in the solution shown in Figure 40.

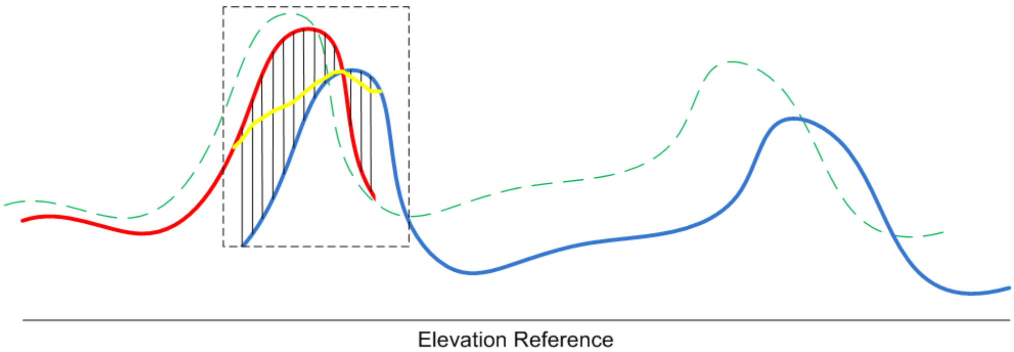


Figure 40: Merged Data Sets - Solution 2

The resultant terrain profile shown in Figure 41 is, once again, statistically sound but not aesthetically pleasing. The problem results from the large difference in the survey elevations at the edge of the coverage for each data set.

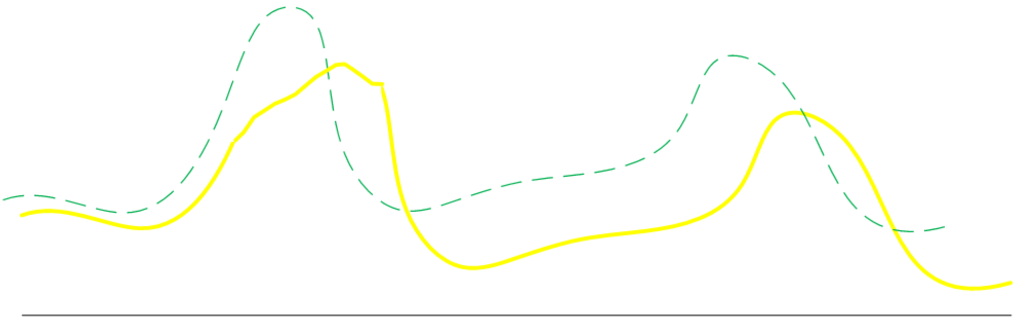


Figure 41: Resultant Terrain - Solution 2

Lastly, we consider using both the data sets and using the highest elevation recorded for each point, as shown in Figure 42.

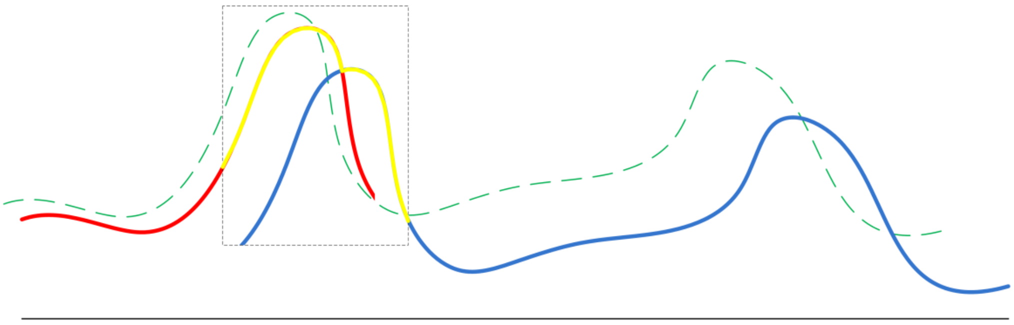


Figure 42: Merged Data Sets - Solution 3

The resultant terrain profile still does not match that of reality but does not suffer from the significant changes in "direction" seen in Figure 38 to Figure 41. A comparison of reality and the terrain model below shows that this results in a more aesthetically pleasing solution.

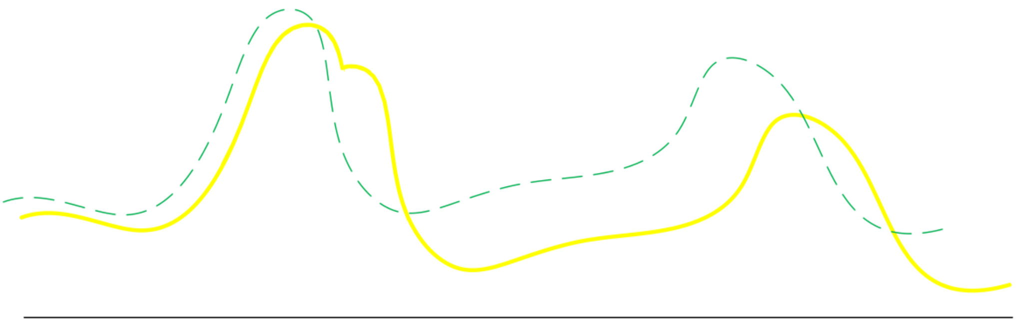


Figure 43: Resultant Terrain - Solution 3

As we made an assumption that the two terrain models met their accuracy requirements, for all of these techniques, the resultant terrain is within specification. Problems would, however, result if one of the models did not meet its requirements. In such a case, it is possible that a high degree of accuracy is reduced as a result of averaging (smoothed or not) with a data set that has a low degree of accuracy, resulting in elevation data that is outside the required accuracy requirements.

Aviation is, of course, primarily driven by safety and, in this respect, the last solution is probably the preferred option as it takes the highest value in all cases. This avoids the issue which arose with the first method which resulted in data that, although within the accuracy requirements, was further from reality than the original data set.

However, the applications that will use the terrain data need to be considered. If we were to use the data in a simulator or synthetic vision system, in each case, the pilot is presented with a data set that does not match reality. Solution 1 is probably the closest to reality but has two significant error points (large changes in terrain), whilst Solution 2 shows two “peaks” in the overlap area where, in reality, there is only one.

What is the correct way forward in such cases? Solution 3, with some smoothing applied, may result in a data set that, given the highest recorded points and a single peak, tends towards improved safety margins, whilst Solutions 1 and 2 could also be smoothed to give a visually improved data set but some recorded points may have been lowered. This lowering of points may not be acceptable for some applications and, consequently, may make these solutions unacceptable. For other applications, more aesthetically pleasing data may be necessary and a lowering of points may have no operational importance.

It is hoped that the above examples have shown that the merging of data sets is a complex issue. As has been shown, the preferred solution is, to an extent, dependent upon what the data is to be used for. As it may not be practicable to supply different data sets for different applications, careful assessment is needed. In addition, the use of already available data sets that were not developed for aviation purposes is a question that will also need careful consideration within States.

8.3 Use of Existing Obstacle Data for Annex 15 Compliant Data Set

The process for the validation of existing obstacle data is different to the one for terrain data because, to a limited extent, the origination and maintenance of existing obstacle data is already under the control of the aviation domain. It is expected that, in the near future, obstacles will be published based on one data source. Therefore, it is recommended that existing obstacles, based on the SARPs of ICAO Annex 4 and ICAO Annex 14, are migrated to “Annex 15” obstacles. The following quality issues may have to be taken into account in the data migration:

- Data inconsistencies and ambiguities between different sources (charts) or between different AIPs (cross-border in Area 2);
- Geometric footprint (mainly type “point” in existing data);
- Spatial and thematic accuracy;
- Commission/omission of data:
    - entire features missing because of applied selection processes for cartographic purposes;
    - thematic information missing due to different application schema (more attributes to be provided according to the ICAO Annex 15 schema);
- Different co-ordinate reference system.

Whilst some of the differences can be resolved at relatively low costs, it becomes more expensive to originate missing obstacles. It is recommended that the migration is started with a careful data quality analysis of a data sample. Such an analysis should provide evidence of how many obstacles and which attributes are missing. If several charts are published for the same area and especially when there are cross-border issues, it is recommended that the inconsistency between the different sources is determined.

This analysis and assessment should clarify the size of the gap between the SARPs and the existing data sets, to determine which processing steps must be taken to enable the publication of obstacle data in accordance with the ICAO Annex 15 SARPs.

Appendix A References

The following documents are referenced within this Manual:

Ref.	Issuing Body	Title	Edition
1.	ICAO	Annex 4 – Charting	11th Edition, July 2009
2.	ICAO	Annex 6 – Operation of Aircraft, Part I: International Commercial Air Transport — Aeroplanes	9th Edition, July 2010
3.	ICAO	Annex 14 – Aerodromes, Volume 1: Aerodrome Design and Operations	5th Edition, July 2009
4.	ICAO	Annex 15 – Aeronautical Information Services	14th Edition incorporating Amendment 37
5.	ICAO	Document 7300 – Convention on International Civil Aviation	9th Edition, 2006
6.	ICAO	Document 8168 – Aircraft Operations, Volume II	5th Edition, 2006
7.	ICAO	Document 9082 - Policies on Charges for Airports and Air Navigation Services	8th Edition, 2009
8.	ICAO	Document 9161 – Manual on Air Navigation Services Economics	4th Edition, 2007
9.	ICAO	Document 9674 – World Geodetic System 1984 (WGS-84) Manual	2nd Edition, April 2002
10.	ICAO	Document 9881 - Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information	Undated / Unreferenced
11.	ISO	ISO 8601 - Data elements and interchange formats -- Information interchange -- Representation of dates and times	2004
12.	ISO	ISO 19109 - Geographic information -- Rules for application schema	2005
13.	ISO	ISO 19110 – Geographic information -- Methodology for feature cataloguing	2005
14.	ISO	ISO 19113 - Geographic information -- Quality principles	2002
15.	ISO	ISO 19114 - Geographic information -- Quality evaluation procedures	2003
16.	ISO	ISO 19115 – Metadata	2003

Ref.	Issuing Body	Title	Edition
17.	ISO	ISO 19117 - Geographic information -- Portrayal	2005
18.	ISO	ISO 19123 - Geographic information -- Schema for coverage geometry and functions	2005
19.	ISO	ISO 19131 - Geographic information -- Data product specifications	2007
20.	ISO	ISO 3166 - Codes for the representation of names of countries and their subdivisions, Parts 1, 2 and 3	3166-1 VI-10, 9th August 2011 3166-2 II-2, 30th June 2010 3166-3, I-6, 14th March 2011
21.	EUROCAE/RTCA	ED-98A / DO276A - User requirements for terrain and obstacle data	September 2012
22.	EUROCAE/RTCA	ED-76/DO-200A – Standards for processing aeronautical data	1998
23.	EUROCONTROL	Doc 10.60.01 - Principles for Establishing the Cost-Base for En Route Charges and the Calculation of the Unit Rates	March 2010
24.	EUROCONTROL	Airborne Laser Scanning for Airport Terrain and Obstacle Mapping (A Limited Feasibility Study)	Version 1.0, May 2006
25.	EUROCONTROL	ICAO SARPs and TOD Gap Analysis	Edition 0.5, 24th January 2008
26.	EUROCONTROL	TIXM Primer	TBD
27.	EUROCONTROL	SPEC-154 - EUROCONTROL Specification for Aeronautical Data Origination	Edition 1.0 February 2013
28.	EUROCONTROL	Quality Philosophy Approach to ISO 19113, ISO 19114 and ISO 19131	TODWG9/WP4 11-12/03/09
29.	EUROCONTROL	SPEC-148 - EUROCONTROL Specification for Data Assurance Levels	Edition 1.0 March 2012
30.	EU	Commission regulation (EU) No 73/2010 of 26 January 2010 laying down requirements on the quality of aeronautical data and aeronautical information for the single European sky, as amended by Commission Implementing Regulation (EU) No 1029/2014.	27th January, 2010

Ref.	Issuing Body	Title	Edition
31.	EU	Regulation (EC) No 216/2008 of the European Parliament and of the Council of 20 February 2008 on common rules in the field of civil aviation and establishing a European Aviation Safety Agency, and repealing Council Directive 91/670/EEC, Regulation (EC) No 1592/2002 and Directive 2004/36/EC	20th February 2008
32.	EU	Regulation (EC) No 550/2004 of the European Parliament and of the Council of 10 March 2004 on the provision of air navigation services in the single European sky (the service provision Regulation)	10th March 2004
33.	EU	Regulation (EC) No 1108/2009 of the European Parliament and of the Council of 21 October 2009, amending Regulation (EC) No 216/2008 in the field of aerodromes, air traffic management and air navigation services and repealing Directive 2006/23/EC	21st October 2009
34.	EU	Commission Regulation (EC) No 1794/2006 of 6 December 2006 laying down a common charging scheme for air navigation services	6th December 2006
35.	OGC	OGC City Geography Markup Language (CityGML) Encoding Standard	Version 1.0.0, August 2008
36.	UK CAA	CAP 738 Safeguarding of Aerodromes, UK Civil Aviation Authority	Second Edition, December 2006

Table 21: Referenced Documents

Appendix B Feature capture Rules

B.1 Foundation

ICAO currently provides no specifications on the geometric properties of obstacle features. The feature capture specification should be a deterministic, application-independent and unambiguous rule set on how a real-world object is abstracted and captured as a database feature, whilst fulfilling the quality requirements (and maintaining the quality characteristics from a point-based survey). This section provides information on how the abstraction is handled in other domains and which aspects must be considered when defining the guidelines.

B.1.1 Generalisation

The domain with the longest tradition of simplifying real-world objects for scientific application is cartography. "Generalisation" is the generic term for different abstraction processes, such as:

- Selection:

  Features which are considered to be irrelevant for an application are removed to save space.

- Simplification:

  The geometrical complexity is reduced, such as removing an atrium.

- Combination:

  Adjacent features or features with a small separation which have the same property, are often combined into one, larger object.

- Smoothing:

  Reducing the complexity of objects, such as streams or roads,

- Enhancement:

  Highlighting objects to meet a specific need for the target application (such as using large symbols for obstacles on a VFR chart).

Since the cartographic generalisation of a specific object not only depends on the target application and the scale, but also on its relative position to other objects to be drawn on the map, it is believed that the cartographic generalisation rules are too fuzzy and too ambiguous for aviation applications.

B.1.2 Level of Detail

In 3D applications and virtual reality, the term Level of Detail (LOD) is used to describe how particularised an object is when it is presented to the user. It is obvious that the LOD largely depends on the application and the distance between the observer and the object. It can be stated that, especially in virtual reality applications, the LOD should always be "perfect" and any limitations are mainly driven by processing speed. However, since synthetic vision and simulators are listed as possible applications of terrain and obstacle data, it is worth taking a closer look at LOD specifications. The OGC uses the following definitions for 3D models, in the CityGML specification document[82]):

- LOD0 – a 2.5D DEM over which an aerial image may be draped (usually no vectors);
- LOD1 – blocks model comprising prismatic buildings with flat roofs;
- LOD2 – differentiated roof structures and thematically differentiated surfaces. Vegetation

[82] This document specifies a data model for 3D data sets which can be used for city models. It is a specialisation of GML which is a dialect of XML.

objects may also be represented;

- LOD3 – architectural models (outside), with detailed wall and roof structures, balconies, bays and projections;
- LOD4 – architectural models (interior).

To each LOD, an (absolute) accuracy statement and a generalisation (i.e. the minimum dimension of objects) are proposed.

	LOD0	LOD1	LOD2	LOD3
Scale description	regional, landscape	city, region	city districts, projects	architectural models (outside)
Class of accuracy	lowest	low	middle	high
Absolute 3D point accuracy (position / height)	lower than LOD1	5/5m	2/2m	0.5/0.5m
Generalisation	maximal generalisation (classification of land use)	object blocks as generalised features; > 6*6m/3m	objects as generalised features; > 4*4m/2m	object as real features; > 2*2m/1m
Building installations	-	-	-	representative exterior effects
Roof form/structure	none	flat	roof type and orientation	real object form

Table 22: Specification of LOD in CityGML

Explanation: in LOD1, buildings with a minimum footprint of 6m by 6m are represented as blocks with a flat roof. The position and height accuracy must be 5m or less (1 sigma). Purely based on the accuracy specification, it could be proposed that Area 4 obstacles should be similar to LOD1, Area 3 obstacles similar to LOD2-3 and Area ½, less stringent than LOD1[83]. With respect to the requirements for roof form modelling, the CityGML specification goes beyond the scope of both ICAO Annex 15 and the AIXM, which only allows flat surfaces.

B.1.3 Cost Benefit

The impact of the complexity of the geometry on the production costs is difficult to estimate as there are several other factors contributing to the overall costs. For conventional terrestrial survey, the driving factors in labour time are often travel and the set up of the reference station. If only 1-2 points are surveyed per building, as opposed to 3-10 points, this does not lead to survey costs being 5 times higher. For airborne data acquisition, the main cost factor is the flying time and this depends on the sensor's spatial resolution which is used to detect thin objects. It is expected that feature extraction (LOD1 block model) from a DSM produced by digital photogrammetry or ALS, can be partially automated (especially when supported by digital cadastral data). With growing particularisation, the number of additional objects increases and the degree of automation decreases and, therefore, the cost grows exponentially.

The more features are simplified (i.e. the accuracy is decreased), the bigger the buffer around each feature must be when evaluating the impact of the feature. This could lead, in the worst case,

[83] This definition is more or less consistent with a proposal made by F. Bildstein, see (http://www.ikg.uni-bonn.de/fileadmin/nextgen3dcity/pdf/NextGen3DCity2005_Bildstein.pdf).

to a reduction in operational efficiency as a result of using new data sets if the capacity of an aircraft has to be reduced in order to maintain minimum obstacle clearance.

B.1.4 Applicability

The feature capture rules should be kept as simple as possible. It must be ensured that there is little room for interpretation so that aviation and survey specialists have a common, harmonised understanding. Different rules for the terrain and obstacle data areas, as proposed above in the LOD section, could lead to extra effort when setting up a production environment.

When compiling feature capture rules, it must be kept in mind that the largest number of complex objects will be captured in Area 2. Area 3 and Area 4 are relatively small and close to the airport. Consequently, it is expected that many of the obstacles in Area 3 are already available as vectors, as part of the airport documentation (terminal buildings, hangars, lights, etc.). The features which apply as Area 4 obstacle should already be known to support the production of the PATC.

B.2 Proposal for Feature Capture Rules

B.2.1 Horizontal Geometry

B.2.1.1 Determining the Footprint and Relevant Area

For the horizontal extent of an obstacle, it is desirable that, up to a certain threshold, an object can be represented as a point. The following process is proposed:

For each feature penetrating the ODCS and exceeding the minimum obstacle height (Area 1 and Area 2[84]), only the surface above the ODCS is derived ("relevant footprint").

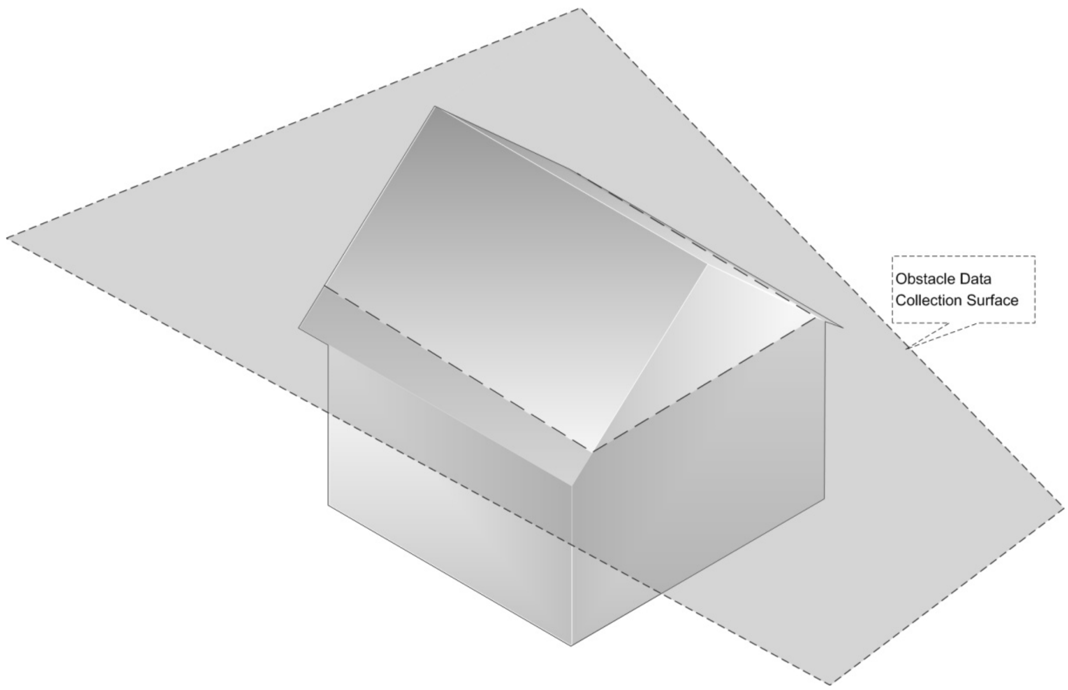


Figure 44: Intersection of a Building with the ODCS

[84] As proposed by EUROCONTROL for ICAO Annex 15 Amendment 36.

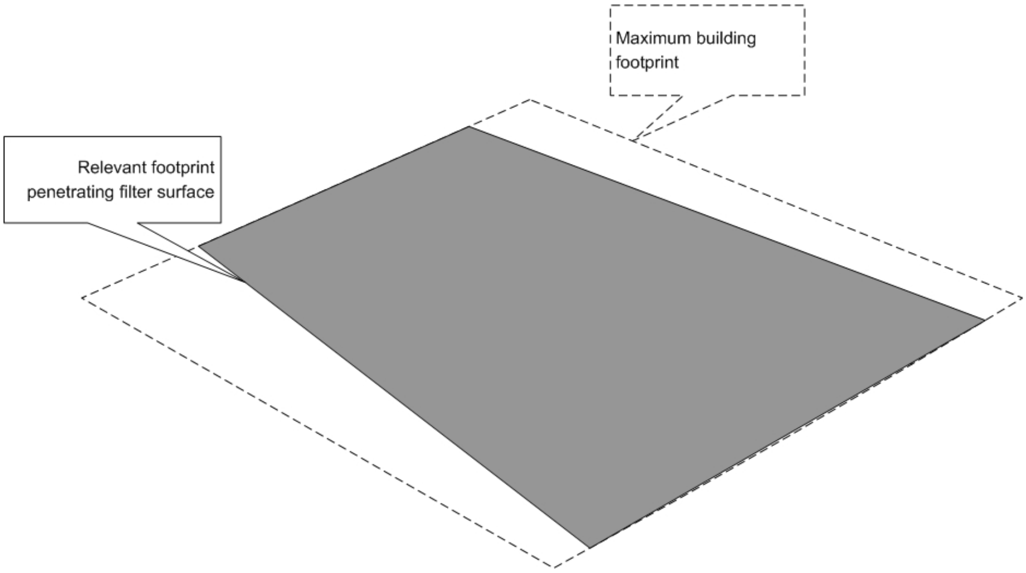


Figure 45: Relevant Footprint of Building in Figure 44

Once the relevant footprint is known, the minimum bounding box is calculated and the dimension of each axis determined (see Figure 46).

The length of the axis is compared to the threshold “footprint“ T_F. The following cases determine how the object is represented (see Figure 47):

a) If both axes exceed the threshold T_F then the object is represented as a polygon (equals the relevant surface);

b) If only one axis exceeds the threshold T_F then the object is represented as a line (centre line of relevant surface);

c) If none of the axes exceed the threshold T_F then the object is represented as a point (centroid of relevant surface).

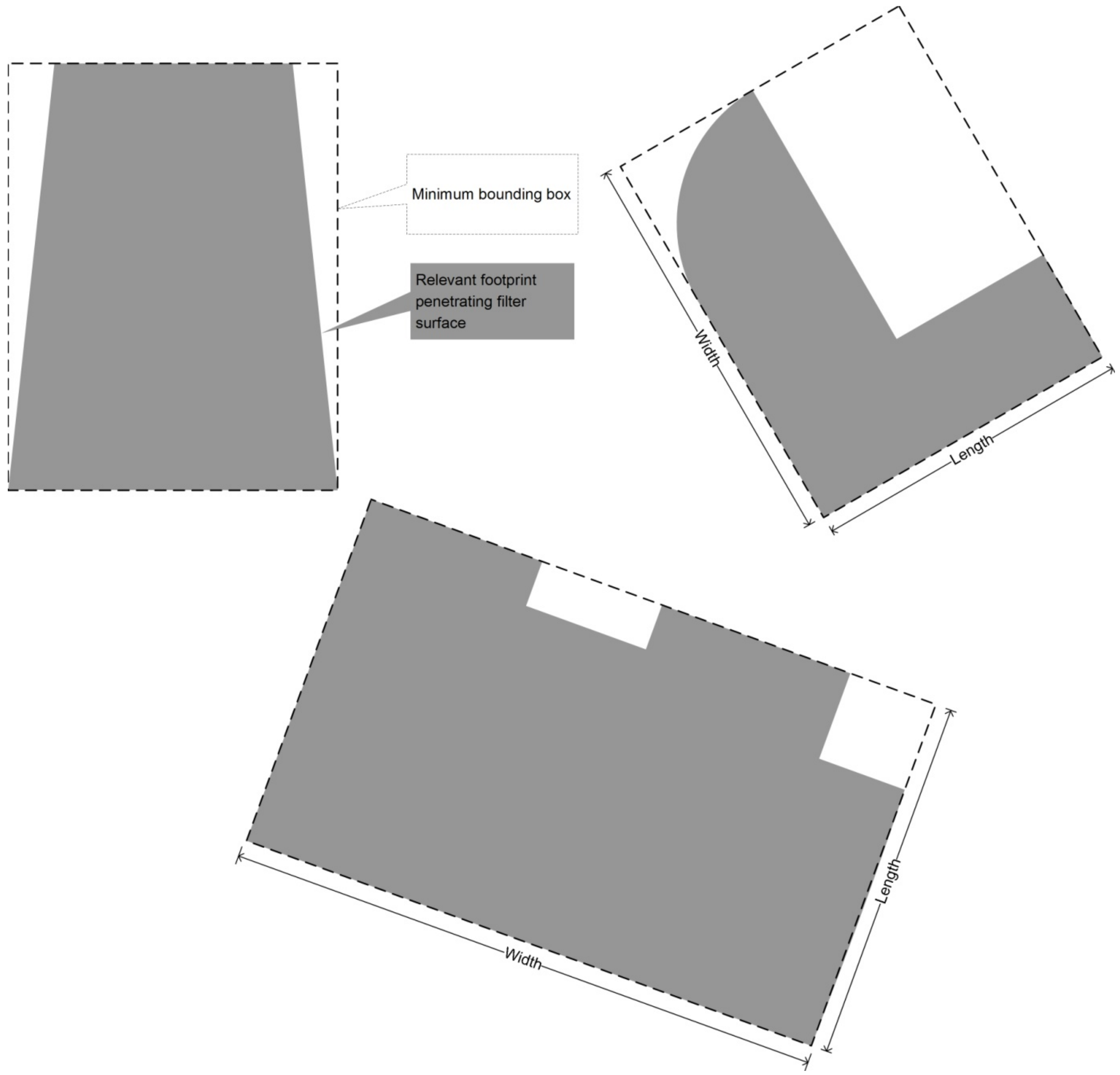


Figure 46: Samples of Minimum Bounding Box

B.2.1.2 Impact of Threshold Value on Geometrical Representation

In the following figure, the impact of the application of a minimum length threshold on spatial representation can clearly be seen:

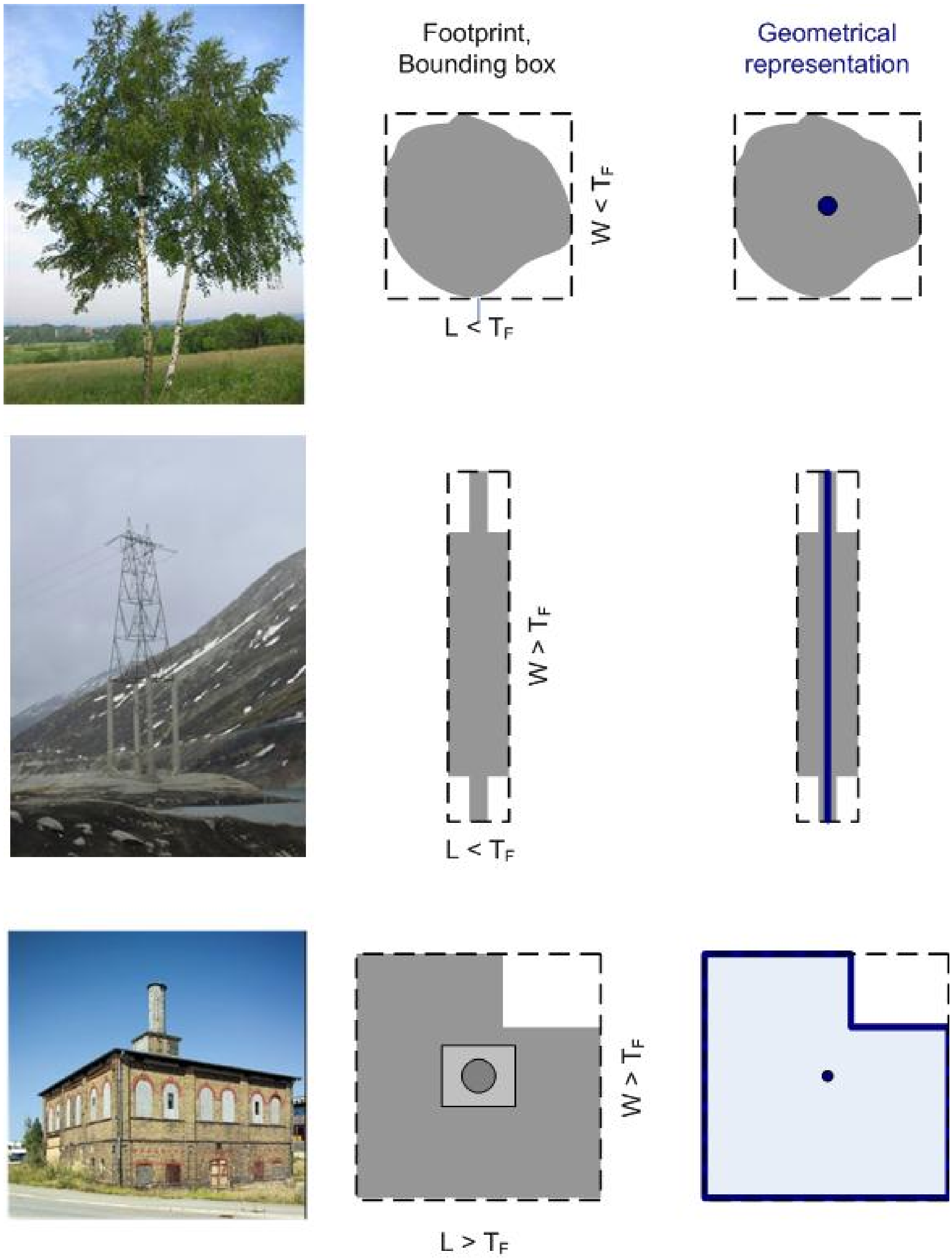


Figure 47: Impact of Generalisation Based on Bounding Box Dimension

B.2.1.3 Threshold Value T_F

For the definition of the threshold value, the use of the LOD approach and the different horizontal accuracy requirements (A_H) for Areas 1 to 4 is recommended. It is proposed that the value of the threshold $\mathbf{T_F}$ is set to $\mathbf{2*A_H}$.

Rationale:

a) The horizontal accuracy of modern survey techniques is, for most cases, better than that required by ICAO. The accuracy is expected to be between 0.3 (Area 3) and 1.0m (Area 1), which allows for generalisation;

b) It is expected that not every organisation can rely on automated feature extraction: a significant number of objects can be simplified as a point or as a line with the proposed approach;

c) The impact on payload due to a buffer being added as a result of generalisation, is expected to be negligible;

d) The ratio of A_H vs. T_F is the same as in CityGML LOD2;

e) Vegetation in Area 2 could be treated, for large parts, as points (single trees) or lines (hedges).

With the proposed threshold value, the minimum dimension of a polygonal obstacle would be:

- Area 1: 100 x 100m;
- Area 2: 10 x 10m;
- Area 3: 1.0 x 1.0m;
- Area 4: 5.0 x 5.0m.

B.2.1.4 Handling of Complex Objects

Sometimes, several objects are attached or are of linear, but curved, shape. In such circumstances, the bounding box becomes much bigger than the area of interest. It can make sense to split the objects into different segments to allow a simpler representation. The city wall in Figure 48 could, therefore, be split into three segments, where the wall may be represented as linear features and the corner tower as a polygon.

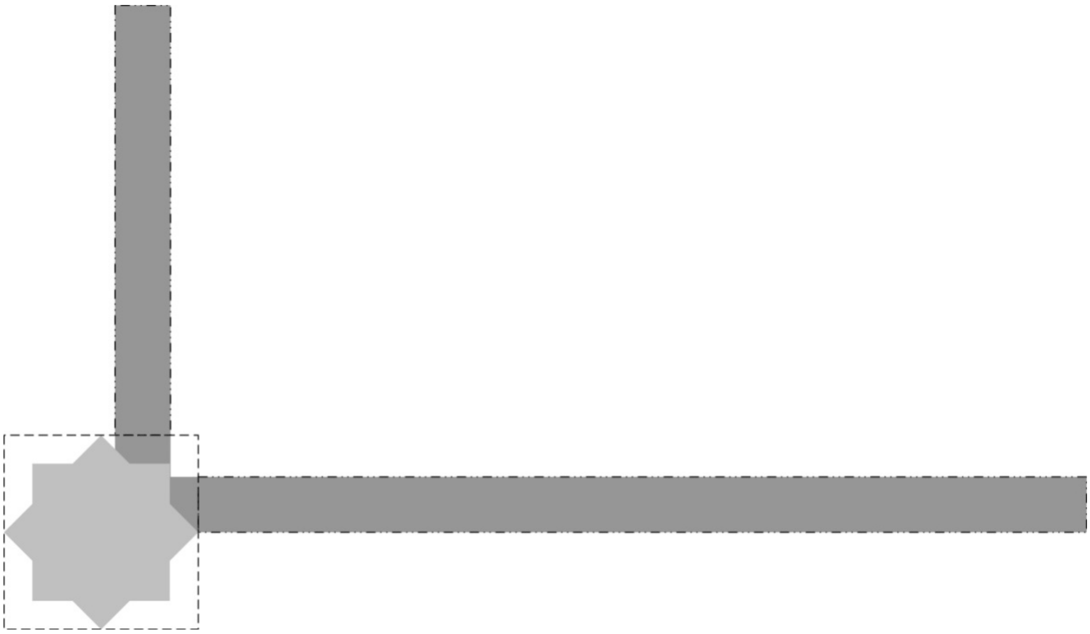


Figure 48: Sample City Wall with Tower as Segmented Bounding Boxes

Objects which can move within a limited perimeter, such as a container crane in a harbour or a wind power station, are evaluated against their maximum area of movement which defines their relevant footprint.

Where several, independent objects penetrate the ODCS at the same spatial location (layered bridges, power line over bridge), they should be captured independently.

B.2.1.5 Use of Existing Cadastral Data

In some States, the data set acquired for the cadastral data is expected to be at a very high quality (accurate, consistent, reliable and up-to-date). The use of cadastral data as the footprint for objects should therefore be considered. The advantages of using such data are a reduction in the cost of data acquisition and the consistency between different data sets (like existing aeronautical map products and newly acquired vectors).

Potential problems when using cadastral data can arise because of different semantic, “long-time” temporary objects (not captured for cadastral data although in place for some years) and “generalisation”: small cottages, light poles and similar objects are not relevant for cadastral applications. As a result, it is suggested that the completeness of cadastral data for a sample area is validated before using it in large area data collection.

If cadastral data is used as footprints, it is recommended that the object identifier from the cadastre is kept, in addition to the obstacle identifier (see also section 7.8.1), to facilitate data maintenance.

B.2.2 Vertical Segmentation

B.2.2.1 Problem Description

The size of the footprint varies, in many cases, with growing height (trees, tilted roofs, on-top structures, nested buildings or roof mounted antennae). It is expected that, in several cases, the application of the footprint and the maximum height, impact the obstacle clearance because the complex arrangement of such an object is much bigger than the real-world object.

AIXM version 5.1 does not support full 3D geometry but only allows obstacles to be built up by several “vertical structure” 2.5D elements. This flexibility can be used to minimise the complexity of describing such an object.

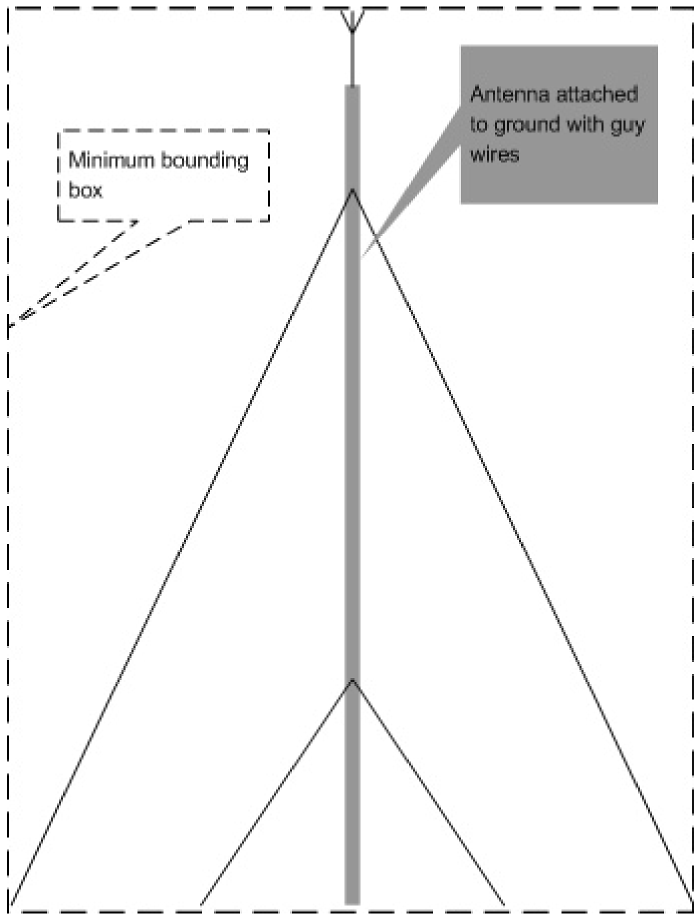


Figure 49: Complex Arrangement of a Mast and Guy Wires

The main question to answer, with respect to vertical segmentation, is therefore: “when does the simplification of the 2.5D data model have an impact on operational procedures or how tall and how big must a vertical structure be to trigger vertical segmentation”?

B.2.2.2 Feature Capture Rules

The application of vertical segmentation may offer significant benefits in some areas, where the description of an obstacle by way of a simple footprint and height/elevation may negatively impact operations. Given the additional cost of recording obstacles using vertical segmentation, careful consideration should be given to where such an approach is adopted, to ensure these costs are justified. It is, therefore, recommended that the following vertical segmentation rules are applied to obstacles:

a) Linear objects should be segmented if the vertical extension (height) exceeds the vertical accuracy significantly[85] (such as, hedges and aerial cable ways);

b) Polygonal objects – flat roofs should be separated as multipart objects if the vertical distance between two roof surfaces (e.g. main roof surface and on-top structure) exceeds the vertical accuracy significantly[86];

c) Conical objects - viewed from the top, the object is represented as a point, as long as the intersecting plane is smaller than threshold T_F. Once the feature is represented as a polygon, a new plane is defined when both the vertical accuracy requirement A_V and the footprint threshold T_F (of the extra surface) are exceeded (see Figure 50);

d) If the footprint changes with height, such that the horizontal footprint requires a different geometry, and the height of such a mounted object exceeds the vertical accuracy, segmentation should be applied. This could lead to the following situations:
   - Point on line: antenna on pole, flagpole on wall;
   - Point on surface: roof mounted antenna;
   - Line on surface: billboard on top of building.

The first two rules are quite simple to adopt because only the approximate solution needs to be compared to a surface model. The third one, for conical objects (c)), requires the structure to be “sliced” horizontally based on the maximum allowed footprint size for the initial geometry. This may result in a number of segments being stacked on top of each other (see Figure 50).

[85] It is to the task of each State to quantify the term “significantly”, prior to starting the data capture. The numerical value may depend on available data, the number of affected objects or the impact of the topography and man-made obstacles on the procedures.

[86] Consideration should be given to the inclusion of very large polygonal objects with a large elevation variation, such as forests, in the terrain data set. See also section B.2.3.

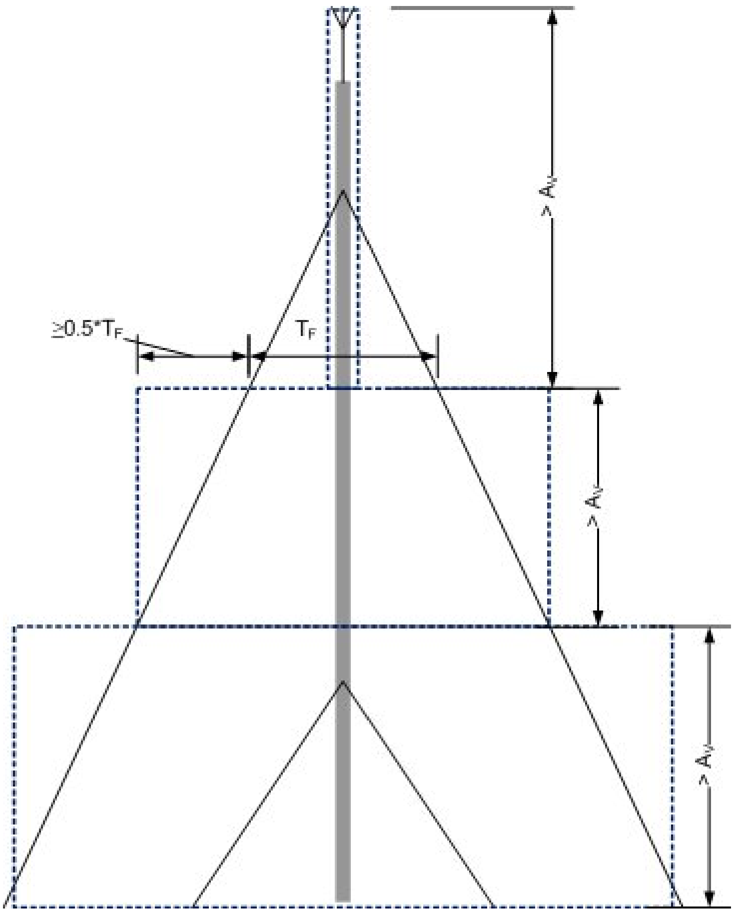


Figure 50: Vertical Segmentation of Antenna based on Footprint and Vertical Accuracy

Note: When vertical segmentation is applied, the height value of each individual structure segment shall reflect the height above ground of the structure segment, not the height above the underlying segments.

Explanation: the top of the antenna can be represented as a point, as long as the bounding box sliding towards the ground does not exceed the footprint threshold T_F. Since the footprint continues to grow, a third object is generated where the new footprint is bigger than T_F and the vertical distance to the previous obstacle part exceeds the accuracy requirement A_V.

Figure 51 below reflects the first segmentation rule, i.e., the segmentation of an aerial cable way if the vertical extension (height) exceeds the vertical accuracy.

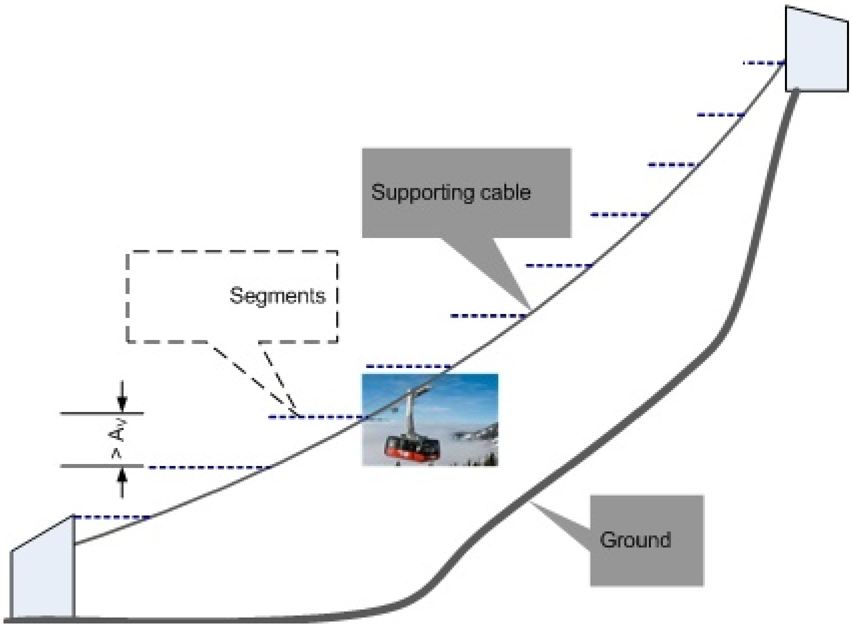


Figure 51: Vertical Segmentation Based on Vertical Accuracy

B.2.2.3 Potential Issues

Although the experience from previous (“traditional”) obstacle mapping has been incorporated in this Manual, the suitability of this should be proven by way of a pilot project and the resulting data set should be reviewed by the end-users (application specialists). Currently, it is believed that the following issues need careful evaluation:

a) What is the impact on procedure design: how many cases should be considered?

b) Can forests always be integrated in a terrain data set?

c) Is there an impact on safety due to simplification? Can the impact be quantified?

d) How important is geometrical consistency[87]? Due to the restriction to the surface above the ODCS, obstacles may not look "nice" even when they are manually captured, instead of automatically derived.

e) What are appropriate threshold values for vertical segmentation? What are the potential benefits or drawbacks when applying (or not applying segmentation)?

[87] Such as isogonic, parallel and rectangular correctness.

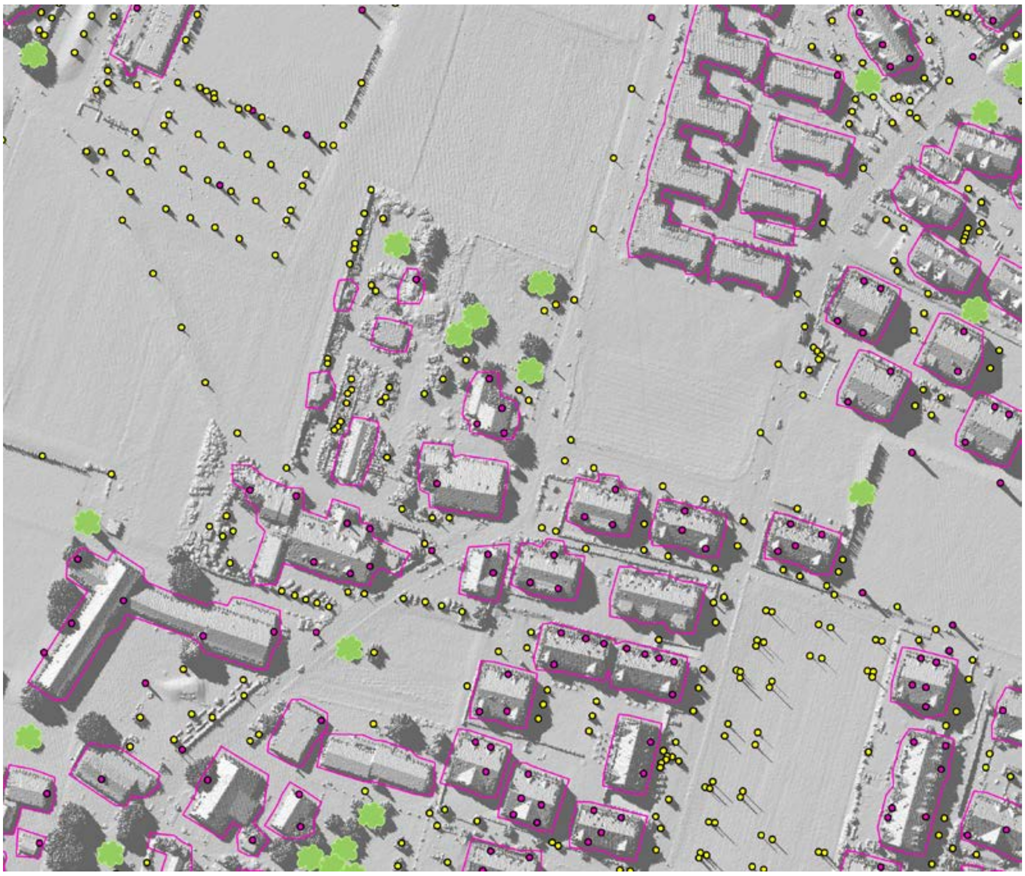


Figure 52: Fully Automated Extracted Obstacles (Source [Reference 24])

B.2.3 Capture of Terrain and Forests

The terrain model shall be based on a so-called bare earth model, i.e. the model shall describe the continuous surface of the ground without any man-made objects[88]. Vegetation obstacles which cannot, due to their size, be modelled as point or line features shall be added on top of the bare earth. In such cases, it should be ensured that the vegetated area is collected as a first reflective surface. Where this is not achievable, due to sensor constraints, the penetration level must be stated, based on control surveys.

The point spacing for airborne data acquisition should be planned to allow an average of 1.5 points per cell. In a conventional terrestrial survey, the density of the survey points and breaklines shall follow the topography and the accuracy requirement.

The construction of a gridded data set shall be based on a maximum elevation calculation: if more than one height value is located in a cell, the highest value is taken into account. Data voids exceeding three times the required ground sampling distance (equals nine cells), must be reported. Data voids exceeding 36 cells are not acceptable. Data voids up to nine cells can be filled by a spline interpolation. Spline interpolation must occur before the construction of a gridded data set and interpolating in a planar projection is recommended to avoid unequal cell size with growing latitude. Interpolated points shall be marked as such (traceability). The grid construction shall be the last process step.

B.3 Conclusion

The proposed feature capture rules address the geometrical representation of obstacles which fall within the scope of the requirements in Chapter 10 of ICAO Annex 15. The approach proposed

[88] See also definition of DTM in section 2.1.

interprets the requirements with respect to feasibility (data origination) and usability (fulfilling the needs of the end-user), taking into account the costs associated with increasing the LOD. The rules are kept simple and straightforward to assist in the development of a common understanding between surveyors and the requesting party, and to minimise costs for the development of automated feature extraction algorithms.

The proposed feature capture rules should be understood as a minimum requirement. If higher resolution data is available or required for some areas, it can, of course, be specified by the requesting party.

Appendix C TOD Implementation Plan Template

C.1 INTRODUCTION

C.1.1 Purpose and Scope

This document provides the plan for **[Name of State]** relating to the implementation of Terrain and Obstacle Data (TOD).

This covers the following activities:

- The Four Areas;
- Regulation;
- Data Sources;
- Survey;
- Cross-border Harmonisation;
- Oversight Mechanism;
- Charging and Cost Recovery;
- Data Validation and Verification;
- Data Provision and Maintenance.

[Text in blue is that which needs to be replaced by the developers of the implementation plan in the State. Text in green may be used as guidance in developing the implementation plan.

It should be noted that some sections of this template may not be applicable / appropriate for a State to include in its implementation plan. The sections are not intended to be mandatory and a State may select to include whichever sections it deems appropriate. Moreover, the issues addressed by the template are not exhaustive and States may add to the template, as required.]

C.2 THE FOUR AREAS

C.2.1 State Policy with Regard to Current SARPS

C.2.1.1 Purpose of this Section

This section documents the **[Name of State]** policy relating to the implementation of the SARPS in place on **[enter date here]**.

C.2.1.2 State Policy

[Provide the State policy here.]

C.2.1.3 Considerations

[Discussions should take place in a State with representatives of the aviation community to help define a national policy for the implementation of Chapter 10, ICAO Annex 15. The discussions should include, as a minimum, the Regulator, Military and ANSP. Mindful that any change proposals have not yet been submitted to ICAO for consideration, it is important that the State determines, as a minimum, what it intends to do with regards Areas 1 and 4 as these have an effective date of 20th November, 2008. In cases where there is data available, which meets the necessary numerical requirements, no action other than making it available needs to be taken. However, should this data not be available or data that is available does not meet the numerical requirements or the requirements of quality, including data validation, it is suggested that the State files a difference to ICAO.]

C.2.1.4 Text of ICAO Difference

[Provide the State ICAO difference text here, if applicable.]

C.2.2 State Policy for Scope of TOD for Four Areas

C.2.2.1 Purpose of this Section

This section documents the **[Name of State]** policy for the scope of data provision for Areas 1, 2, 3 and 4, and for which aerodromes Areas 2 and 3 are applicable. The policy should include the quality requirements, such as accuracy, resolution, etc.

C.2.2.2 State Policy for Area 1

[Provide the State Policy for Area 1 here.]

C.2.2.3 State Policy for Area 2

[Provide the State Policy for Area 2 here.]

C.2.2.4 State Policy for Area 3

[Provide the State Policy for Area 3 here.]

C.2.2.5 State Policy for Area 4

[Provide the State Policy for Area 4 here.]

C.2.3 State policy of how, when and by whom TOD will be made available

C.2.3.1 Purpose of this Section

This section documents the **[Name of State]** policy of how, when and by whom TOD will be made available.

C.2.3.2 State Policy

[Provide the State Policy for the availability of TOD.]

C.3 REGULATION

C.3.1 Applicable Regulation

C.3.1.1 Purpose of this Section

This section documents ICAO, European Community and other international and national regulations applicable to TOD.

C.3.1.2 International Regulation

[List international regulation for TOD here.]

C.3.1.3 National Regulation

[List any national regulation for TOD here.]

C.3.1.4 Considerations

[In addition to ICAO regulation, SES regulation, such as the SES Common Requirements and the Aeronautical Data Quality Implementing Rule should be included.

It may be determined during State discussions that some form of national Regulation may be needed to expedite the implementation of TOD and ensure that all actors accept their responsibilities. Any national Regulation related to TOD should be listed in 3.1.3.

Consideration should also be given to guidance material, such as ISO 9001, ISO 19100, OGC standards, (draft) Doc 9881, etc.]

C.3.2 State Policy on Aerodrome Safeguarding

C.3.2.1 Purpose of this Section

This section documents the **[Name of State]** policy for the safeguarding of aerodromes.

C.3.2.2 State Policy

[Provide the State policy for aerodrome safeguarding here.]

C.3.3 Obstacle Permission Process

C.3.3.1 Purpose of this Section

This section documents the obstacle permission process of **[Name of State]** and any legislation that applies.

C.3.3.2 Process

[Provide the State obstacle permission process here and list any legislation that applies.]

C.3.3.3 Considerations

[It is recommended that a State considers the development of an obstacle permission process. This may take best practice from the FAA, Germany and other States which have a declared policy. In addition, States may wish to consider the development of legislation to enforce this process on those responsible for the erection and maintenance of obstacles.]

C.3.4 Regulation of Data Sources

C.3.4.1 Purpose of this Section

This section documents the **[Name of State]** approach to regulating data sources, to ensure that the appropriate standards and processes are applied.

C.3.4.2 Regulation

[Provide the State's policy for regulating data sources.]

C.4 DATA SOURCES

C.4.1 Purpose of this Section

This section lists the organisations that have been consulted to assess if the data they originate and maintain meets the appropriate requirements of TOD. To be fully able to assess the data source, States should determine if the type of data source provider, i.e., State-owned, commercial organisation, etc, in order to be able to fully assess the impact of using its data. Where data is available and is suitable for use, this section provides information about the liability, cost/cost recovery and licence issues associated with it. Where arrangements are made for data source providers to make data available for aviation use, to the State, formal arrangements should be established between the data source providers and the receiving body. This section should list the formal arrangements in place which are related to the provision of TOD.

The use of a Service Level Agreement is one example of a formal arrangement being established.

C.4.2 Data Sources Consulted

C.4.2.1 Data Source Provider

[For each data source provider identified, provide information about its status, i.e., State-owned, commercial organisation and list any particular areas of issue that arise from this.]

C.4.2.2 Liability

[For each data source identified, provide information about where the liability for the data lies.]

C.4.2.3 Cost Model

[For each data source identified, provide information related to the costs for the data.]

C.4.2.4 Licensing

[For each data source identified, provide information related to the licensing of the data.]

C.4.2.5 Formal Arrangements

[List the formal arrangements in place for the provision of TOD.]

C.4.3 Considerations

[The owners of the following data sources or the following organisations, as an example, should be consulted:

- Geodetic institutes;
- Power / energy supply companies;
- Wind farm operators;
- Mapping agencies;
- Authority(ies) responsible for the authorisation of radio/TV and other broadcast antenna;
- Cell phone operators;
- Port authorities.

States should establish their own list of data sources which they will consult in the process of trying to identify TOD providers. Following this, it is recommended that a meeting is held with each possible data source to discuss the appropriateness and possible use of their data and where liability lies.

States should assess the cost model and licensing of the data from a data source, taking into account whether the organisation is State-owned or a commercial organisation. Clearly, commercial organisations that already provide data for a charge to its users will not be willing to loose this revenue stream, this making the cost model and licensing for these products, more complex.

Formal arrangements should be made between data source providers and the receiving party. This will clearly state the quality requirements for the data, means of provision, etc. It is recommended that where a data source provider will provide data regularly, over a period of time, a Service Level Agreement is used to capture this agreement. Where data provision is likely to be a one-off or a very infrequent occurrence, it is recommended that a contract is established between the two parties.]

C.5 SURVEY

C.5.1 Survey Formats

C.5.1.1 Purpose of this Section

This section documents the common survey formats to be used by surveyors and geodetic institutes.

C.5.1.2 Formats

[List the common survey formats to be used here.]

C.5.2 Survey Requirements

C.5.2.1 Purpose of this Section

This section documents the survey requirements for each of the four Areas.

C.5.2.2 Survey Requirements for Area 1

[Provide the survey requirements for Area 1 here.]

C.5.2.3 Survey Requirements for Area 2

[Provide the survey requirements for Area 2 here.]

C.5.2.4 Survey Requirements for Area 3

[Provide the survey requirements for Area 3 here.]

C.5.2.5 Survey Requirements for Area 4

[Provide the survey requirements for Area 4 here.]

C.5.3 Survey Contracts

C.5.3.1 Purpose of this Section

States may, if they wish, include in their implementation plans details of requirements that should be included in survey contracts. If this is the case, this section will include the requirements that should be included in survey contracts for each of the four Areas, to ensure that the data provided through the contract meets the necessary numerical and quality requirements.

C.5.3.2 Survey Contracts

[Provide the text to be used in survey contracts here.]

C.5.4 Surveyor Vetting

C.5.4.1 Purpose of this Section

This section documents how surveyors are vetted to ensure that they adhere to the correct standards and discharge their legal responsibilities in accordance with the contract.

C.5.4.2 Vetting Process

[Provide the State vetting process for surveyors here.]

C.5.4.3 Considerations

It should be noted that this section may not be relevant to every State. Responsibility for the vetting of surveyors may rest elsewhere and, therefore, this section only applies to those States that have responsibility for this.

C.6 CROSS-BORDER HARMONISATION

C.6.1 State Agreements / Arrangements

C.6.1.1 Purpose of this Section

This section documents the arrangements in place with other States for the exchange, provision and receipt of common TOD.

C.6.1.2 Arrangements

[List the arrangements in place with neighbouring States for the exchange, provision and receipt of common TOD.]

C.6.1.3 Considerations

[It is recommended that some form of harmonisation activity is undertaken with neighbouring States, perhaps through the medium of a Service Level Agreement (SLA). Further, it is recommended that, where appropriate, States could make arrangements for data within its boundary to be provided to the other State, where it is needed for the other State's aerodrome. Alternatively, arrangements could be made to share the survey costs or to use one survey company, all with the intention of lowering the cost of data acquisition.

To assist with the exchange of data between States and other users, it is recommended that a common TOD exchange format is adopted.]

C.7 OVERSIGHT MECHANISM

C.7.1 Progress Monitoring

C.7.1.1 Purpose of this Section

This section details the mechanism by which the State intends to monitor the implementation of TOD.

C.7.1.2 Monitoring Policy

[Detail how the State will monitor the implementation of TOD, including how any obligations to meet European oversight monitoring will be met.]

[List the State policy for monitoring TOD implementation.]

C.7.2 Audit

C.7.2.1 Purpose of this Section

This section details the **[Name of State]** plan for the audit of the organisations involved in the implementation and subsequent management and maintenance of TOD.

C.7.2.2 State Plan

[Provide the State's plan for the audit of organisations.]

C.8 COST RECOVERY AND CHARGING

C.8.1 Cost Recovery

C.8.1.1 Purpose of this Section

This section identifies how **[Name of State]** will finance TOD. It states from whom the finance will be obtained and the cost recovery mechanisms associated with the initial and ongoing costs for TOD, for each of the four Areas.

C.8.1.2 Initial Costs

C.8.1.2.1 Cost Recovery for Area 1

[Provide the means of cost recovery for Area 1 here.]

C.8.1.2.2 Cost Recovery for Area 2

[Provide the means of cost recovery for Area 2 here.]

C.8.1.2.3 Cost Recovery for Area 3

[Provide the means of cost recovery for Area 3 here.]

C.8.1.2.4 Cost Recovery for Area 4

[Provide the means of cost recovery for Area 4 here.]

C.8.1.3 Ongoing Costs

C.8.1.3.1 Cost Recovery for Area 1

[Provide the means of cost recovery for Area 1 here.]

C.8.1.3.2 Cost Recovery for Area 2

[Provide the means of cost recovery for Area 2 here.]

C.8.1.3.3 Cost Recovery for Area 3

[Provide the means of cost recovery for Area 3 here.]

C.8.1.3.4 Cost Recovery for Area 4

[Provide the means of cost recovery for Area 4 here.]

C.8.1.4 Considerations

[Consideration should be given to the need to recover costs not only in the initial implementation but as an ongoing activity including the:

- Increased costs for AISPs in managing the data;
- Increased costs for regulators in monitoring and auditing those associated with TOD implementation and provision;
- Indirect costs such as the adaptation of procedures due to new / updated obstacle data.]

C.8.2 Charging Mechanisms

C.8.2.1 Purpose of this Section

This section identifies the charging mechanisms in place in **[Name of State]** to recover the costs associated with the initial and ongoing provision of TOD.

C.8.2.2 Mechanisms

[Provide the charging mechanisms for TOD here.]

C.9 DATA VALIDATION AND VERIFICATION

C.9.1 Assessment of Existing Data

C.9.1.1 Purpose of this Section

This section identifies how existing data should be assessed to determine if it meets the TOD requirements.

C.9.1.2 State Policy

[Provide the State Policy for assessment of existing data here.]

C.9.1.3 Considerations

[Consideration should be given to whether means already exist in the State to validate data, including its associated metadata, to determine its appropriateness.

Consideration should be given to the following:

- Does the data meet the ICAO numerical requirements?
- Does the data have the associated metadata?
- Does the data have full traceability?

Methods for the assessment of different data types should be determined / identified.]

C.9.2 Data Validation and Verification

C.9.2.1 Purpose of this Section

This section details the approach of **[Name of State]** to the validation and verification of existing and new data.

C.9.2.2 Purpose of this Section

[Provide the State's approach to data validation and verification of existing data.]

C.9.2.3 Purpose of this Section

[Provide the State's approach to data validation and verification of new data.]

C.9.2.4 Purpose of this Section

[Consideration should be given to whether means already exist in the State to validate data, including its associated metadata.

The approach should ensure that the data has full traceability.]

C.10 DATA PROVISION AND MAINTENANCE

C.10.1 Data Exchange Formats

C.10.1.1 Purpose of this Section

This section details the data exchange formats to be used for electronic TOD (eTOD).

C.10.1.2 Data Formats

[List the exchange formats to be used for eTOD.]

C.10.2 Means / Media

C.10.2.1 Purpose of this Section

This section details the means / media by which each data set shall be made available.

C.10.2.2 Means of Provision: XXXX

[Insert explanation of how the means will be used to make the data sets available.]

C.10.2.3 Considerations

[It is intended that a subsection is provided for each means of provision, for example, Means of Provision: DVD, Means of Provision: Internet, etc.]

C.10.3 Data Maintenance

C.10.3.1 Purpose of this Section

This section details the State policy for the update / maintenance of data, including periodicity.

C.10.3.2 State Policy

[Provide the State's policy for data maintenance.]

Appendix D TOD Implementation Plan Checklist

D.1 Awareness

Task	Considerations	Status	Completion Date	Comments / Further Details
Determine the affected stakeholders in your State:	• Ministry responsible for Transportation; • Civil Aviation Authority; • AISP; • ANSP; • Military; • National Geodetic, Cadastral or State Survey organisation; • Commercial survey companies or associations such as the Royal Institute of Chartered Surveyors (UK); • Military survey organisation; • Aerodrome operator or airport association(s); • National airlines; • General Aviation; • Helicopter operators or helicopter operator associations including Air Ambulance and civil SAR; • Local authorities or those responsible for aerodrome safeguarding / construction approval in the vicinity of the aerodrome;			

Task	Considerations	Status	Completion Date	Comments / Further Details
	• Ministry responsible for local government, land planning and environment; • Power transmission companies; • Regulatory authority for radio and television broadcasts; • GSM antenna operators; • Local port authorities if ports exist within close proximity to an airport.			
From the foregoing, identify the Focal Point(s) in your State.				
Consider holding an eTOD awareness day or regional awareness days.				
Consider the establishment of a State Working Group to identify costs and determine an implementation plan.				

D.2 The four areas

Task	Considerations	Status	Completion Date	Comments / Further Details
Establish the State's policy with regard to implementing the current SARPS.				
Determine a State policy for what data will be made available for each of the four Areas, for which aerodromes and when.				
Determine a State policy for how and by whom the eTOD will be made available.				

D.3 Regulation

Task	**Considerations**	**Status**	**Completion Date**	**Comments / Further Details**
Confirm the State policy for the safeguarding of aerodromes from obstacle penetration, consider how effective the policy is and determine if available data can be demonstrated to be in compliance with eTOD requirements. In the absence of a declared or established policy, consider establishing one.				
Consider the application of National regulation to allocate responsibility for the provision of eTOD.				
Consider and map the development and implementation of an obstacle permission process.	• There are currently several commercial tools to support this process.			
Consider the nature, scope, content, time and processes associated with the development of legislation for any obstacle permission process.				
Determine which data sources should be regulated, how standards may be placed upon them and with whom responsibility for data and the data processes should rest.				

D.4 Data sources

Task	**Considerations**	**Status**	**Completion Date**	**Comments / Further Details**

Task	Considerations	Status	Completion Date	Comments / Further Details
Collate a list of possible sources of terrain and obstacle data.				
Establish a meeting to discuss the appropriateness and possible use of these data sources.				
Determine where liability for each data source resides.				

D.5 Survey

Task	Considerations	Status	Completion Date	Comments / Further Details
Determine the common survey formats to be used by surveyors and geodetic institutes.				
Determine the survey requirements for each of the four Areas, including resurvey intervals.				
Prepare example contracts for surveyors to ensure that the data provided meets the necessary numerical requirements.				
Determine the responsibilities that may be placed upon surveyors to ensure that they use the correct standards, and how this may be confirmed.				

D.6 Cross-border harmonisation

Task	Considerations	Status	Completion Date	Comments / Further Details

Task	Considerations	Status	Completion Date	Comments / Further Details
Consider how cross-border harmonisation could be organised, if applicable.				
Consider the establishment of agreements with neighbouring States to exchange and harmonise common data.				

D.7 Oversight monitoring

Task	Considerations	Status	Completion Date	Comments / Further Details
Determine a means of providing oversight management for monitoring progress.				
Determine a policy for the audit of involved organisations.				

D.8 Charging and cost recovery

Task	Considerations	Status	Completion Date	Comments / Further Details
Identify how the costs, both initial and ongoing, are to be recovered for each Area.				
If there is to be a charge levied on the use of data, identify the appropriate means / mechanisms by which the revenue can be collected.				

D.9 Data validation and verification

Task	Considerations	Status	Completion Date	Comments / Further Details
Identify if means to validate data, including metadata, already exist and, if not, determine how existing data could be assessed to determine its suitability.				
Determine what existing data may be reused and how its quality can be verified and validated.				
Determine how new data will be validated and verified.				

D.10 Data provision and maintenance

Task	Considerations	Status	Completion Date	Comments / Further Details
Consider the adoption of interoperable exchange formats for eTOD.				
Determine the means/media by which each dataset shall be made available.				
Determine a policy for data maintenance.				

Appendix E Abbreviations

The following abbreviations are used within this Manual.

Abbreviations	Meaning
2D	2-dimensional
3D	3-dimensional
AFI	Africa-Indian Ocean Region
AIM	Aeronautical Information Management
AIP	Aeronautical Information Publication
AIS	Aeronautical Information Services
AISP	Aeronautical Information Services Provider
AIXM	Aeronautical Information Exchange Model
ALS	Airborne Laser Scanning
AMD	Aerodrome Mapping data
AMDB	Aerodrome Mapping Database
ANC	Air Navigation Commission
ANS	Air Navigation Services
ANSP	Air Navigation Service Provider
APV	Approach Procedures with Vertical Guidance
ASCII	American Standard Code for Information Interchange
A-SMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATFM	Air Traffic Flow Management
ATM	Air Traffic Management
ATS	Air Traffic Services
CAA	Civil Aviation Authority
CAT	Category
CD	Compact Disc
CFIT	Controlled Flight into Terrain
CRC	Cyclic Redundancy Check
CRCO	Central Route Charges Office
CS	Catalogue Service

Abbreviations	Meaning
CSV	Comma Separated Value
DEM	Digital Elevation Model
DGPS	Differential GPS
DHM	Digital Height Model
DSM	Digital Surface Model
DTM	Digital Terrain Model
DPS	Data Product Specification
DTED	Digital Terrain Elevation Data
EASA	European Aviation Safety Agency
EC	European Commission
ECAC	European Civil Aviation Conference
EGM	Earth Gravitational Model
EGPWS	Enhanced Ground Proximity Warning System
ERN	European Reference Network
ETRF	European Terrestrial Reference Frame
ETFR89	European Terrestrial Reference Frame 1989
ETRS	European Terrestrial Reference System
EUR	European Region
EUROCAE	European Organisation for Civil Aviation Equipment
EUROCONTROL	European Organisation for the Safety of Air Navigation
EVRF	European Vertical Reference Frame
EVRS	European Vertical Reference System
FAA	Federal Aviation Administration
FASID	Facilities and Services Implementation Document
FTP	File Transfer Protocol
GCP	Ground Control Point
GIS	Geographic Information System
GML	Geography Markup Language
GMT	Greenwich Mean Time
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GPWS	Ground Proximity Warning System

Abbreviations	Meaning
GRS80	Geodetic Reference System 1980
HTTP	Hypertext Transfer Protocol
IAP	Instrument Approach Procedures
IAIP	Integrated Aeronautical Information Package
ICAO	International Civil Aviation Organisation
IERS	International Earth Rotation and Reference Systems Service
IFG	Institutional Focus Group
IFR	Instrument Flight Rules
IfSAR	Interferometric Synthetic Aperture Radar
IMC	Instrument Meteorological Conditions
IMU	Inertial Measurement Unit
IPR	Intellectual Property Rights
ISO	International Organisation for Standardisation
IT	Information Technology
ITRF	International Terrestrial Reference Frame
ITRS	International Terrestrial Reference System
LiDAR	Light Detection and Ranging
LOD	Level of Detail
MAP	Aeronautical Charts
MB	Megabytes
MSL	Mean Sea Level
NAP	Normaal Amsterdams Peils
NAS	Network Attached Storage
NOTAM	Notice to Airmen
ODCS	Obstacle Data Collection Surface
OGC	Open Geospatial Consortium
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PATC	Precision Approach Terrain Chart
PBN	Performance Based Navigation
RADALT	Radio Altimeter

Abbreviations	Meaning
RAID	Redundant Array of Independent Disks
RNAV	Area Navigation
RTK	Real-Time Kinematic (GPS survey method)
SAR	Synthetic Aperture Radar
SARPs	Standards and Recommended Practices
SES	Single European Sky
SLA	Service Level Agreement
S-VFR	Special VFR
TMA	Terminal Area
TOD WG	Terrain and Obstacle Data Working Group
TIN	Triangulated Irregular Network
TICM	Terrain Information Conceptual Model
TIXM	Terrain Information Exchange Model
UID	Unique Identifier
UK	United Kingdom
UML	Unified Modelling Language
UTC	Coordinated Universal Time
UTM	Universal Transverse Mercator
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
W3C	World Wide Web Consortium
WCS	Web Coverage Service
WFS	Web Feature Service
WMS	Web Map Service
WGS-84	World Geodetic System 1984
XML	Extensible Markup Language
XSL	Extensible Stylesheet Language
XSLT	Extensible Stylesheet Language Transformations

Table 23: Abbreviations

EUROCONTROL

www.eurocontrol.int