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EUROCONTROL
Terrain and Obstacle Data Manual

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Terrain and Obstacle Data Manual

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Abstract

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.

Keywords

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The following table identifies the authority who has approved the present issue of this document.

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DOCUMENT CHANGE RECORD

The following table records the complete history of the successive editions of the present document.

EDITION NUMBER	EDITION DATE	REASON FOR CHANGE	PAGES AFFECTED
Draft 1.0	June 2010	First draft release for TOD WG review.	All
Draft 1.2	November 2010	Second draft release for IFG review.	All
Release 2.0	October 2011	Issue addressing the comments from public consultation and the results of the Trial Survey	All
Release 2.1	November 2015	Updates addressing issues from TOD implementation and amendments to ICAO SARPS	All
Release 2.2	December 2019	Restructuring of TOD provisions in Amendment 40 of ICAO Annex 15 and new PANS-AIM Several updates agreed by the TOD/WG/20 and TOD/WG/21 New National Policy Template Input from TOD forum about TOD-related accidents Reference to EUROCONTROL guideline on harmonised publication Various minor improvements Changes according to Stakeholder Consultation Workshop.	Chapter 3 Sections 1.5, 2.3, 5, 7.1, 7.6 Appendix D Appendix C Chapter 4 Appendix E Section 7.5 Various All
Released Issue 3.0	04/05/2021	Procedures related to update of this document Introduction to DTM changed shortened to a definition. Additional description of DTM moved to 5.1.1 and consolidated with new content on terrain and terrain models Content (Aerodrome Terrain and Obstacle Chart (ICAO) Electronic) moved from institutional matters to applications and requirements for data More detailed explanation of terrain and obstacle attributes New chapter 4 Implementation Matters: -Merged previous chapters 4 and 5 from v2.2	1.1, 1.2 and new 1.5 and Appendix I 1.7, 5.1 2.6.4 3.5.4 and 3.6.4 Chapter 4

		-Restructured following the policy template structure in Appendix C	
		-Improvements and additional explanations	
		-Merged and new content on costs, cost recovery and charging mechanism	
		Restructured content	Chapter 5
		Totally revised content on digital terrain models including information from section 1.6.	5.1.1
		Section on reference systems deleted because of duplication with EUROCONTROL DO Specification Volume 2	*Previous 6.2 from v2.2*
		Section on spatial data quality merged into 5.5 Data Validation and Verification	*Previous 6.3 from v2.2*
		Section on GIS merged into 5.6 Data Storage	*Previous 6.4 from v2.2*
		New content on data product specification according to ISO 19131:2019	5.2
		New content on aerial sensor platforms, available terrain data, collecting data for AMD and TOD	5.4
		Restructured, merged with spatial data quality (previous 6.3) and new content on data validation and verification	5.5
		Data Storage includes section on GIS	5.6
		New content on data provision	5.7
		Table of ISO19100 standards only contains the standards applicable to TOD with an explanation of the relevance	5.9
		Reformatted; contains only entries referenced in the manual	Appendix A
		New content and examples on feature capture rules	Appendix B
		Reduced policy template in line with chapter 4	Appendix C
		List of Abbreviations deleted from the manual and replaced with a reference to the EUROCONTROL Air Navigation Inter-Site Acronym List (AIRIAL) in section 1.4	*Previous Appendix F*
		-New example of a data product specification for Donlon obstacle data set	New Appendix F
		-New example of a data product specification for Donlon terrain data set	
		Previous chapter 6.8 from v2.2	New Appendix G
		Content split between the Appendix and the accompanying Validation Tasks Table	
		List of accompanying tools and specimens	New

		- New DTM metadata sample; - New obstacle data sets examples of Donlon Area 1, 2, 3, 4; - New tool which converts AIXM 5.1(.1) obstacle data to an Excel spreadsheet; - Validation tasks table - Previous chapter 6.8 from v2.2;	Appendix H
		-References to external documents (standards, regulation etc.) have been simplified and unified in the text. Details are provided in Appendix A -Hyperlinks are used instead of footnotes or explicit links in parenthesis -Some duplications within the document removed	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 incorporation of Standards and Recommended Practices (SARPs) by the International Civil Aviation Organisation (ICAO) into Annex 15 [4], 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 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) to address this request. Some of the TOD WG's tasks were to help resolve 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 AIM Group (AIMG) in response to these tasks. Additional material was added to the Manual to reflect the experience of the States during the implementation of the TOD requirements.

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 impractical 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.

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 [4] and PANS-AIM [5].

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

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

1.4 TERMS AND ABBREVIATIONS

The reader is referred to the EUROCONTROL Air Navigation Inter-Site Acronym List (AIRIAL) for definitions of the terms and abbreviations used in this manual.

The references to regulations and external documents are made using abbreviations or the short version of the regulation or document name. The full title and detailed reference information are provided in Appendix A.

1.5 MAINTENANCE OF THIS DOCUMENT

The TOD manual was developed in line with the EUROCONTROL Standards Development Process and is maintained by EUROCONTROL. The document update procedure can be found at Appendix I. The main Stakeholder group requesting this work, AIMG, will remain the prime interface for the evolution of this document.

1.6 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, tabular 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 been required only 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 [1]. The terrain relief is depicted on procedural charts, i.e. Instrument Approach Chart (IAC), Standard Instrument Departure Chart (SID), Standard Instrument Arrival Chart (STAR), Visual Flight Rules (VFR) charts.

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 automated tools have led to a requirement for States to make more extensive terrain and obstacle data sets available 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 incorporated within procedure design tools, allowing better validation that the procedures designed maintain the required clearances in relation to both terrain and obstacles.

1.6.1 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.

1.6.2 AMENDMENT 36 TO ICAO ANNEX 15

The work of the TOD WG 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 offered significant cost savings over the original requirements introduced by Amendment 33. This Amendment also introduced the division of Area 2 into four sub-areas: Area 2a, 2b, 2c and 2d.

1.6.3 AMENDMENT 37 TO ICAO ANNEX 15

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

Amendment 37 introduced a set of definitions such as: aeronautical information management (AIM), aerodrome mapping data (AMD), aerodrome mapping database (AMDB) and confidence level. It put forward a new integrity classification concept that removed integrity level values. The requirement for terrain and obstacle data collected within Area 2 was 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, was introduced.

1.6.4 AMENDMENT 40 TO ICAO ANNEX 15

Amendment 40 was adopted by the ICAO Council on the 9th March 2018 and became applicable on 8th November 2018.

It introduced the new ICAO PANS-AIM, designed to complement the SARPs in Annex 15. With this amendment of Annex 15 and the introduction of PANS-AIM, the TOD provisions have been rearranged and are now spread across different chapters and appendices in these two documents.

Amendment 40 also introduced the Aeronautical Data Catalogue, which is a repository of all data quality requirements for aeronautical data originally provided in different appendices of different ICAO Annexes (i.e. Annex 4 Appendix 6, Annex 11 Appendix 5, Annex 14 Volume I Appendix 4 and Volume II Appendix 1, Annex 15 Appendices 7 and 8, PANS-OPS Volume II).

As such, ICAO PANS-AIM Appendix 1 “Aeronautical Data Catalogue” provides a general description of the AIM data scope and consolidates all aeronautical data and aeronautical information to be collected and maintained by an AIS.

The Aeronautical Data Catalogue is divided into nine aeronautical information sub-domains:

- Aerodrome data;
- Airspace data;
- ATS and other routes data;
- Instrument flight procedure data;
- Radio navigation aids/systems data;
- Obstacle data (see ICAO PANS-AIM Table A1-6 Obstacle data);
- Terrain data (see ICAO PANS-AIM Table A1-8 Terrain data);
- Geographic data; and
- Information about national and local regulations, services and procedures.

Each sub-domain is described through a list of “subjects”; for every subject, the Aeronautical Data Catalogue lists the data (referred to as either properties or sub-properties) that can be collected, their data types, their description, their notes and their data quality requirements.

1.7 TERRAIN

Information about the terrain is relevant to air navigation in different phases of the flight. Examples are: approach and departure procedures assuring a sufficient separation of the flight from terrain, en-route contingency procedures (one engine out or loss of cabin pressure) being based on terrain information and automated approach and landing systems relying on precise ground elevation data.

A Digital Terrain Model (DTM) or Digital Elevation Model (DEM) is a digital discrete representation of the continuous surface of the ground based on a large number of surveyed points. The more points provided for a given area, the better the terrain relief can be modelled.

1.8 OBSTACLES

Obstacles in terms of aviation are features with a vertical significance compared to the surrounding terrain or surrounding features that constitute a potential hazard to aircraft operations.

The term “obstacle” has different applications in ICAO SARPs: in Annex 4 [1] for objects to be depicted on charts; in Annex 14 [3] for the purpose of clearing, marking and lighting and in Annex 15 for information to be promulgated by means of aeronautical information products.

Accordingly, the ICAO 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.”

2. APPLICATION AND REQUIREMENTS FOR 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 they determine the data quality requirements. It is also important to understand that all these applications require ***data*** rather than information in an AIP or on a chart that has to be converted into digital form by the user or provider of the applications.

This section, therefore, provides an overview of those applications.

2.1 SAFETY NETS

Safety nets are system functions which provide an additional defence against air navigation hazards such as aircraft collision or terrain and obstacle collision. These functions are ground-based or airborne safety nets. The ground-based safety nets are usually a part of the air traffic control system issuing timely warnings to ATC. The airborne safety nets are usually part of the aircraft system (on-board system) issuing timely warnings to flight crews.

2.1.1 TERRAIN AWARENESS AND WARNING SYSTEMS

Terrain Awareness and Warning System (TAWS) is an airborne safety net which issues warnings to flight crew of aircraft proximity to terrain or obstacles. TAWS implementations currently in use include GPWS and EGPWS.

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.

The latest GPWS technology, Enhanced-GPWS (EGPWS), has the capabilities of GPWS and additionally 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 enhances terrain area awareness, 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 for advisory use only.

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 important to note that the provision of quality-assured data sets leads to a reduction in approach and landing accidents as well as in CFIT accidents.

<u>Requirements for data</u>

If an aircraft is to be able to provide warnings concerning close proximity to terrain, there is a choice between two approaches:

- The system operates using only a series of Minimum Safe Altitudes 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 limited data accessible to 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 systems.

With regard 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.

2.1.2 MINIMUM SAFE ALTITUDE WARNING

Minimum Safe Altitude Warning (MSAW) is a ground-based safety net which issues timely warnings of aircraft proximity to terrain or obstacles. Its purpose is to increase safety and it serves as a function in air traffic control systems.

The logic employed utilises the aircraft's transponder technology with the capability to report pressure altitude to the ground radar system. Then the altitude level is compared to the stored map as well as minimum safe altitudes. Warnings are issued to the ATC system if the level is lower than, or predicted to be lower than, the minimum safe altitude. The essential elements of MSAW are accurate terrain data model and appropriate forward-looking time for terrain avoidance.

Requirements for data

MSAW uses surveillance data, flight data and environment data (e.g. terrain and obstacle data) to issue warnings. Use of a terrain and obstacle model with appropriate accuracy and resolution increases the reliability of the MSAW warnings.

Guidance for MSAW and for the terrain and obstacle data used in MSAW are provided in EUROCONTROL-GUID-160 [40].

2.1.3 APPROACH PATH MONITOR

Approach Path Monitor (APM) is a ground-based safety net which issues timely warnings of aircraft proximity to terrain or obstacles during the final approach of the aircraft. Its purpose is to increase safety and it serves as a function in air traffic control systems.

The logic employed is the same as for MSAW. Since it is used only for the final approach, additional information is required. Flight plan and flight path data are necessary to determine any irregularities and deviations of the aircraft's path and in this case, to issue warnings. If both MSAW and APM are employed in an air traffic control system, then the delimitation between them needs to be considered, i.e. the point where APM needs to take over the MSAW, essentially the point where the aircraft is established on the localiser.

Requirements for data

APM uses surveillance data, flight data and environment data (e.g. terrain and obstacle data) to issue warnings. Use of a terrain and obstacle model with appropriate accuracy and resolution increases the reliability in the APM warnings.

Guidance for APM are provided in EUROCONTROL-GUID-162 [41].

2.2 PROCEDURE DESIGN

2.2.1 INSTRUMENT FLIGHT INCLUDING CIRCLING PROCEDURES

Instrument flight procedure design, carried out using ICAO PANS-OPS [6], addresses operations on arrival and departure, the connections/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.

The lack of quality-assured terrain and obstacle data will result in the need for more robust flight validation of the procedures if the quality assurance requirements being incorporated into ICAO PANS-OPS are to be achieved.

Requirements for data

Data on 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 on the approach type being flown and are defined in ICAO Annex 14 [3] and ICAO PANS-OPS.

These surfaces tend to be aligned along the extended centreline of the runways and around the aerodrome in the circling area.

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.

If the tools (e.g. CRM) used to validate the instrument flight procedures are not able to take into account digital terrain data due to its excessive size then significant terrain features (hills, peaks etc.) can be extracted from the DTM with the help of a geographic information system and inserted as pseudo obstacles into the CRM. A simple extraction method is the generation of contour lines and the creation of a polygon obstacle from every contour line layer.

2.2.2 CONTINGENCY PROCEDURES

ICAO Annex 6 [2] requires the operator to evaluate the existing obstacle data for developing procedures in the event of a critical engine failure during take-off, or other reasons, in order to clear all obstacles along the flight path by an adequate vertical or horizontal distance.

ICAO PANS-OPS [6] provides the material needed to develop procedures for departure. However, ICAO PANS-OPS assume that the aircraft is fully operational, for example all engines are operational. It is not considered feasible to develop public procedures that cater for all contingencies that would suit all aircraft types. As a result, it is incumbent upon the aircraft operators to develop such contingency procedures, which are normally coordinated with the Air Navigation Service Providers (ANSPs). For example, engine-out standard instrument departure procedures (EOSID) have to be created on the assumption that one engine fails during take-off, defining the flight path which can then be flown.

To develop these procedures, aircraft operators must perform take-off analyses 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. EOSIDs can significantly deviate from standard instrument departures and are optimized for take-off weight by avoiding limiting obstacles and terrain.

Requirements for data

Currently, aircraft operators use ICAO Aerodrome Obstacles Charts Type A, B and, where available, C, 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.

The data requirements for the design of contingency procedures are no different from those for IAP design. However, whilst the published SID 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 SID. 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.

Obstacle and terrain data is essential for EOSID during take-off. By identifying the terrain and obstacle surface, the climb trajectory is calculated for normal condition operations (gross flight path), i.e. two to four operating engines as well as for engine-out operations (net flight path). In the case of the net flight path, the climb gradients for each segment of the climb trajectory is lower compared to the gross fight path. It is important to identify the terrain and obstacle surface outside the climb trajectory (SID track) to be able to change the horizontal trajectory when performing EOSID in case obstacles cannot be overflown.

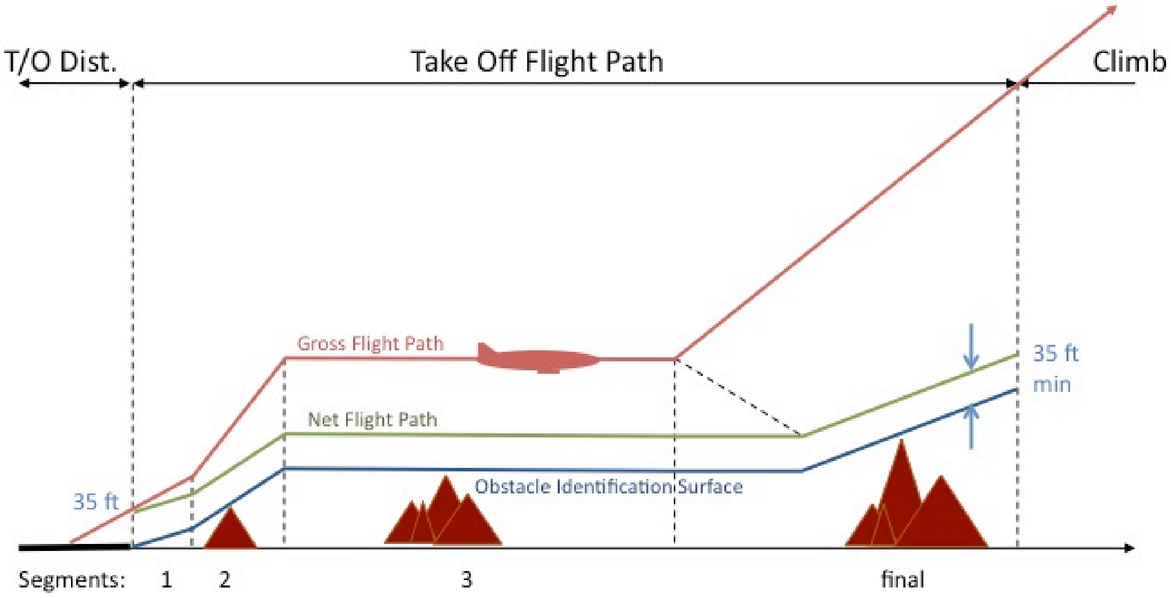

Figure 1: Take off flight path

2.3 DRIFT-DOWN PROCEDURES

Whilst multi-engine aircraft are able to operate safely 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. The method is to maintain maximum thrust of the operating engine with minimum descent rate, usually during cruise, when an aircraft is not able to maintain its altitude and clear coming terrain and obstacles.

For some light, twin-engine aircraft, 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. These routes may be flown over mountainous terrain and thus, it is important to develop and use Mountainous Terrain Escape Route procedures in case of an emergency, to avoid high terrain and maintain necessary separation.

Another requirement for this procedure is related to cabin decompression (depressurisation). In this case, the oxygen generator exhaustion needs to be taken into consideration as it imposes time limitations on this procedure. The exhaustion of oxygen generators usually happens between 12 and 20 minutes. The depressurisation route must be planned in a way to allow a safe descent to FL140 or lower where the passengers can breathe without a mask before the exhaustion happens.

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 these contingencies.

Requirements for data

In order to allow both airline operators and pilots executing a flight to plan for and perform emergency actions in the event of engine failure or cabin decompressure, 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.

Accurate and quality-assured terrain and obstacle data are important for these contingency procedures as they are key to the safety of aircraft operations in the event of emergencies.

2.4 EMERGENCY EN-ROUTE LANDING

It is believed 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 would be useful to render vegetation cover in colour in order 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.

Requirements for data

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.

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.

2.5 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, subject to the aerodrome's operational visibility limits, 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 at aerodromes under all circumstances with respect to traffic density and complexity of aerodrome layout, taking into account the capacity required under various visibility conditions. It includes complementary procedures that, at the lower levels of implementation, aim 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.

Requirements for data

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.

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

2.6 AERONAUTICAL CHART PRODUCTION AND ON-BOARD DATABASES

2.6.1 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 displayed electronically or printed on paper, as with traditional maps.

2.6.2 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.

Requirements for data

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 wide 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.

2.6.3 ELECTRONIC FLIGHT BAG

Electronic Flight Bag (EFB) is an electronic device intended for cabin use by the flight crew. This device replaces the traditional paper documentation carried on board. EFB is able to host databases and makes use of different technologies and formats. Applications include:

- data storage;
- display of documents, manuals, flight plans, meteorological information, technical logs, NOTAM and AIS briefings;
- data exchange with aircraft systems enabling aircraft performance calculations;
- displays of electronic aeronautical charts;
- internet access;
- aircraft operational communications;
- aircraft exterior surveillance cameras; and
- connection possibility to GNSS or FMS, enabling map display with GNSS position, speed vectors of other aircraft and weather information.

Requirements for data

Terrain and obstacle data is required in EFB applications for the monitoring of aircraft position and trajectory by the flight crew. Performance calculations especially require airport-specific data, i.e. terrain and obstacle data, in determining and optimising calculations during take-off, en-route, approach, landing, missed approach, go-around and power settings.

2.6.4 AERODROME TERRAIN AND OBSTACLE CHART (ICAO) ELECTRONIC

The Aerodrome Terrain and Obstacle Chart – (ICAO) Electronic was introduced in ICAO Annex 4 [1] with an applicability date of 2010.

The purpose of this chart can be summarised as follows:

- It provides a visualisation of the obstacle and terrain information in electronic form rather than as paper chart;
- It combines the existing specifications of the Aerodrome Obstacle Chart Types A, B and former Type C as well as the Precision Approach Terrain Chart with terrain and obstacle data; and
- It may be produced in lieu of the Aerodrome Obstacle Chart — ICAO Types A and B and the Precision Approach Terrain Chart — ICAO.

The chart shall be compatible with widely available desktop computer hardware, software and media and should include its own “reader” software.

Requirements for data

The availability of digital terrain data meeting the numerical requirements described in section 3.5.5 and digital obstacle data meeting the quality requirements described in section 3.6.5 is a prerequisite for the production of the Aerodrome Terrain and Obstacle Chart – (ICAO) Electronic.

2.7 AERODROME/HELIPORT OBSTACLE RESTRICTION AND REMOVAL

Restrictions are placed on the location of objects in the operational area of an aerodrome defined in ICAO Annex 14. 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, for example by minimising the erection of new objects. 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, the obstacle limitation surfaces and the aerodrome's navigation and surveillance infrastructure. 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.

Requirements for data

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 them. 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.

2.8 RADIO ALTIMETER HEIGHT DETERMINATION

Radio altimeter (RADALT) is an aircraft antenna device which measures the height of the aircraft above the terrain below it.

The logic employed utilises radar technology by transmitting a signal to the ground. Timing the return of the reflected signal to the aircraft determines the height between the aircraft and the ground below it. The delay between the timing measurement and the displayed height above ground depends on the aircraft's actual height above ground: the closer the aircraft is to the ground, the smaller the RADALT delay. It can be said that below 500ft, the delay is less than 300ms while below 100ft, the delay is less than 100ms.

This device is used in the GPWS and in the approach procedures determining the aircraft position compared to the decision height applicable.

During the final approach phase of landings made under CAT II/III conditions, 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 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 within radio altimeter operating area must include the terrain and any objects which may affect the measurements received from the RADALT. Therefore, digital terrain and obstacle data of Area 4 can be used for improved decision height information.

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”.

Requirements for data

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 benefits and remove the need to utilise the PATC, a manual process which is prone to error.

It is possible to use Area 4 terrain and obstacle data to identify and publish decision height information for CAT II/III operations. As a result, digital terrain and obstacle data can be used to improve the radio altimeter height for these operations.

2.9 SYNTHETIC VISION SYSTEM AND ENHANCED VISION SYSTEM

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 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.

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). In modern helicopters avionics the primary flight display with synthetic vision system capabilities provides a 3D representation of terrain and obstacles.

Enhanced Vision System (EVS) creates a virtual visual environment based on infrared technology of aircraft sensors and camera. It enables a real-time image of the aircraft’s path projected onto the Heads-Up Display of the aircraft. Environment information such as lights, runway, terrain, obstacles, etc. are visible on the displayed image. The pilot is thus able to fly safely in limited visibility conditions.

The new EVS II provides increased visibility, safety and situational awareness under low visibility conditions.

Requirements for data

It is believed that the requirements for terrain and obstacle data for the applications listed above also provide the data needed to support synthetic and enhanced 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 and enhanced vision are 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 above are sufficiently well-defined to allow Instrument Flight Rules (IFR) and Visual Flight Rules (VFR) operations.

Requirements for SVS data were introduced in EUROCAE ED-179B [29], however they are not yet included in ICAO SARPs. These requirements would need data on all obstacles higher than 200 ft. Terrain data require to be gridded at 30 arc seconds with 100 ft resolution within 30 NM of all airports with 3500 ft or more runway length and 15 arc seconds with 100 ft resolution within 6 NM of the closest runway.

2.10 FLIGHT SIMULATORS

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 2.9 above.

2.11 SAFETY OF ROTORCRAFT OPERATIONS

The main civil helicopter operations include:

- Emergency Medical Services (EMS) – e.g. air ambulances carrying sick or injured people as fast as possible from a known location to hospital;
- Search and Rescue (SAR) – similar to EMS, but the location of the sick or injured people is unknown and needs to be established. The EMS and SAR often operate in challenging environments such as degraded weather conditions or mountainous areas;
- private and business transportation, which operates in similar way to transportation of passengers in fixed-wing aircraft, i.e. taking people from an aerodrome, performing an en-route flight and landing at another aerodrome;
- offshore transportation, which is similar to private and business transportation but is operated from offshore locations, e.g. oil and gas platforms;
- law enforcement – use of helicopters by the police and special forces, flying very close to the ground, mostly in urban areas;
- aerial works – all works related to buildings and maintenance in locations with difficult access, e.g. mountainous areas.

In normal weather and visibility conditions, a light and medium-sized helicopter operates for transit over land or sea between 1,000 and 5,000 ft AGL and at 120-150 kts. For surveillance or SAR activities, it operates between 30 and 2000 ft AGL and at less than 80 kts.

In degraded weather or/and visibility conditions:

- when low-altitude clouds cover flat terrain or sea: helicopters need to fly below the clouds at a lower altitude;
- when low-altitude clouds cover the mountains: no fly or IFR agreement;
- when there is reduced visibility > 800m but still VMC: helicopters need to lower their altitude to maintain visual contact with the ground, i.e. between 200 and 2000 ft AGL;
- when visibility is reduced to under 800m and only IMC: if no IFR agreement, helicopters flying over land need to land as soon as possible or turn back to try to find better conditions; over sea, if there is an IFR agreement, the flight can continue following the route provided by the ATC;

- when inadvertent IMC in the mountains with frozen conditions: helicopters need to lower their altitude and/or land as soon as possible.

According to the various studies, most incidents and accidents with helicopters are due to inadequate consideration by the pilot of obstacles or terrain, or are related to the pilot´s awareness of non-detected obstacles, insufficient ground visibility, difficult terrain, or hoist/sling relation to ground obstacles. Therefore, improving helicopter pilot awareness of terrain and obstacles helps to improve safety.

Modern helicopters are equipped with an avionic suite which includes on their displays a graphical representation of various layers, such as position relative to the terrain, digital maps with topographic elevation, and obstacle depiction – which in the event of close terrain or obstacles trigger HTAWS aural and visual caution/warning alerts for pilots to change direction in order to avoid collision with the ground or obstacles.

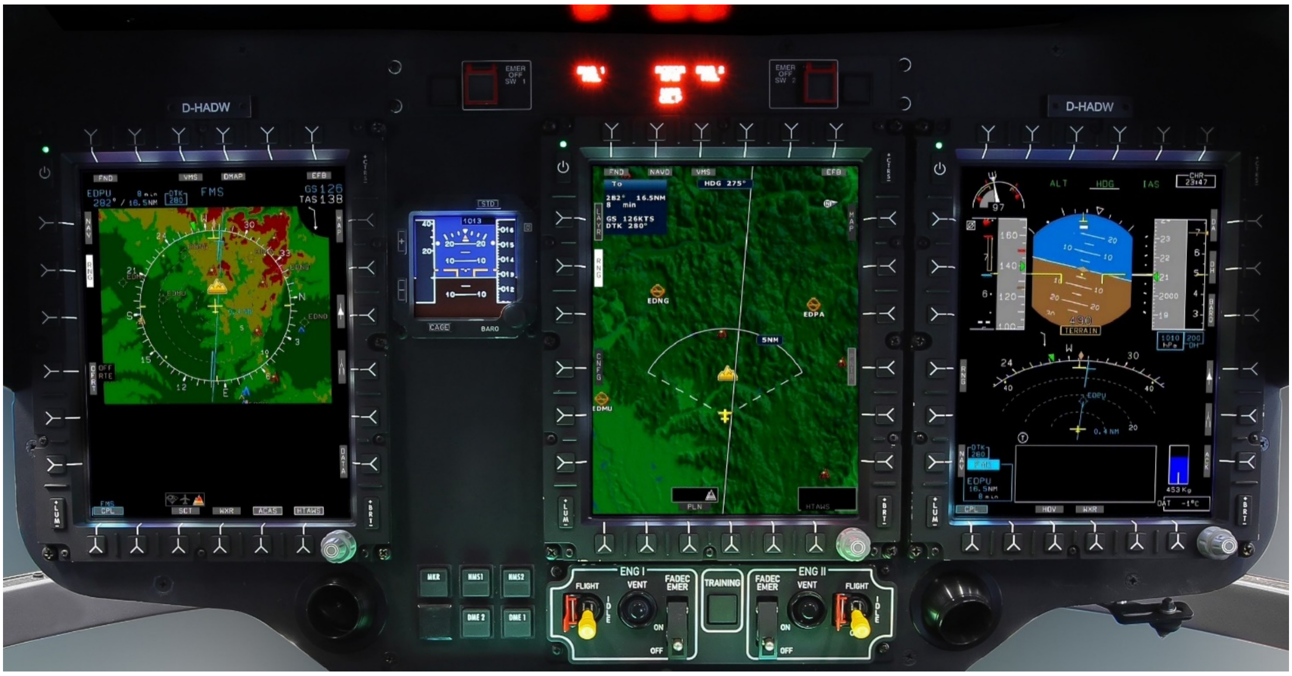

Figure 2: Example of avionic suite: Helionix for EC 145[1]

Requirements for data

The current requirements for obstacle data provision outside aerodrome areas are insufficient for helicopter operations in terms of accuracy and collection surfaces.

Based on the operational needs of helicopters and mission-function performances, they would require data on all objects higher than 60 m, with a vertical accuracy of 7 m and a horizontal accuracy of 16 m. With regard to terrain data, the helicopters' operational needs will be covered if the terrain outside aerodrome areas is provided with the same numerical requirements as aerodrome terminal areas (i.e. Area 2).

These requirements for rotorcraft were introduced in EUROCAE ED-98C [26], however they are not yet included in ICAO SARPS.

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[1] Source: Airbus Helicopters

2.12 USES OF DATA – THE BENEFITS

2.12.1 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.

2.12.2 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.

With the transition from a product-based to a data-centric environment, the AIM will be able to use the digital terrain and obstacle data from the central storage for the development and provision of various AIM products using terrain and/or obstacle data.

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

3. THE REQUIREMENT

3.1 INTRODUCTION

This section presents the text of ICAO Annex 15 [4], Chapters 5 and 6 and the text of ICAO PANS-AIM [5], Chapters 5 and 6. A full analysis of the requirement is provided and, where appropriate, links are made to additional information provided in this Manual.

To provide coherent guidance, this chapter is structured by subject rather than by the order of the provisions. Guidance on each of the provisions (Standards and recommended practice in ICAO Annex 15 and procedures in ICAO PANS-AIM) can be found in one of the following four main sections:

- TOD-relevant Areas and Surfaces
- Specific Provisions for Terrain Data Sets
- Specific Provisions for Obstacle Data Sets
- General Provisions for Digital Data Sets

A user who seeks information on a particular provision may refer directly to the relevant sub-section without reading the entire chapter. As a result, some information is repeated where the provisions contain similar text.

3.2 TERMINOLOGY

An understanding of the ICAO use of terminology is needed for this section. ICAO SARPs and procedures 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.

3.3 APPLICATIONS

An introductory note to ICAO PANS-AIM section 5.3.3.2 provides information about the intended use of the terrain and obstacle data:

“*Note.— 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 training/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.”

The applications listed together with the terrain and obstacle requirements are discussed in detail in Chapter 2 of this document.

TOD requirements cover the needs of all these applications. Flight simulator and synthetic vision systems, as mentioned in the last paragraph, will also benefit from the provision of terrain and obstacle data. These applications are, however, reliant upon more detailed information, particularly with regard to obstacle data, which includes such information as that needed to correctly render a real-life representation of the objects.

Terrain and obstacle data should be used in conjunction with other aeronautical information. The owners of the applications will be free to choose, or assemble from the multitude of data, the relevant information required for their specific use (e.g. significant obstacle for IFP design, relevant obstacles in the take-off flight path area for operating limitation analysis).

3.4 TOD-RELEVANT AREAS AND SURFACES

Different geographic areas and 3D-surfaces constitute the spatial scope of the ICAO TOD provisions. The majority of these areas and surfaces are related to airport geometry. They are defined in the following ICAO Annexes and PANS and are presented in this section:

- Annex 15 and PANS-AIM (coverage areas)
- Annex 14 [3] (obstacle limitation surfaces)
- Annex 4 [1] (take-off flight path area)

3.4.1 COVERAGE AREAS DEFINED IN ICAO ANNEX 15 AND PANS-AIM

3.4.1.1 OVERVIEW OF FOUR AREAS

With the introduction of TOD in Amendment 33 to ICAO Annex 15, ICAO has defined four coverage areas where different numerical requirements apply for terrain (see section 3.5.5.2) and obstacle data (see section 3.6.5.2):

- Area 1 The entire territory of a State
- Area 2 The vicinity of an aerodrome
- Area 3 An area bordering the movement area on an aerodrome
- Area 4 The radio altimeter area operating in front of a precision approach runway, Category II or III.

With Amendment 36 to ICAO Annex 15, Area 2 was broken down into four sub-areas.

The areas are defined in ICAO Annex 15 Para 5.3.3.1 and ICAO PANS-AIM Appendix 8 and are discussed in the following sections.

3.4.1.2 AREA 1

3.4.1.2.1 ICAO ANNEX 15 TEXT PARA 5.3.3.1 (EXTRACT)

….

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

> *— Area 1: The entire territory of a State;*
>
> *…*

Understanding of Requirement

Area 1 encompasses the entire territory of the State and those areas over the high seas for which the State is responsible for the provision of air traffic services (ATS).

3.4.1.3 AREA 2

3.4.1.3.1 ICAO ANNEX 15 TEXT PARA 5.3.3.1 (EXTRACT)

…

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

> *…*
>
> *— Area 2: Within the vicinity of an aerodrome, subdivided 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;*
>
> *…*

Understanding of Requirement

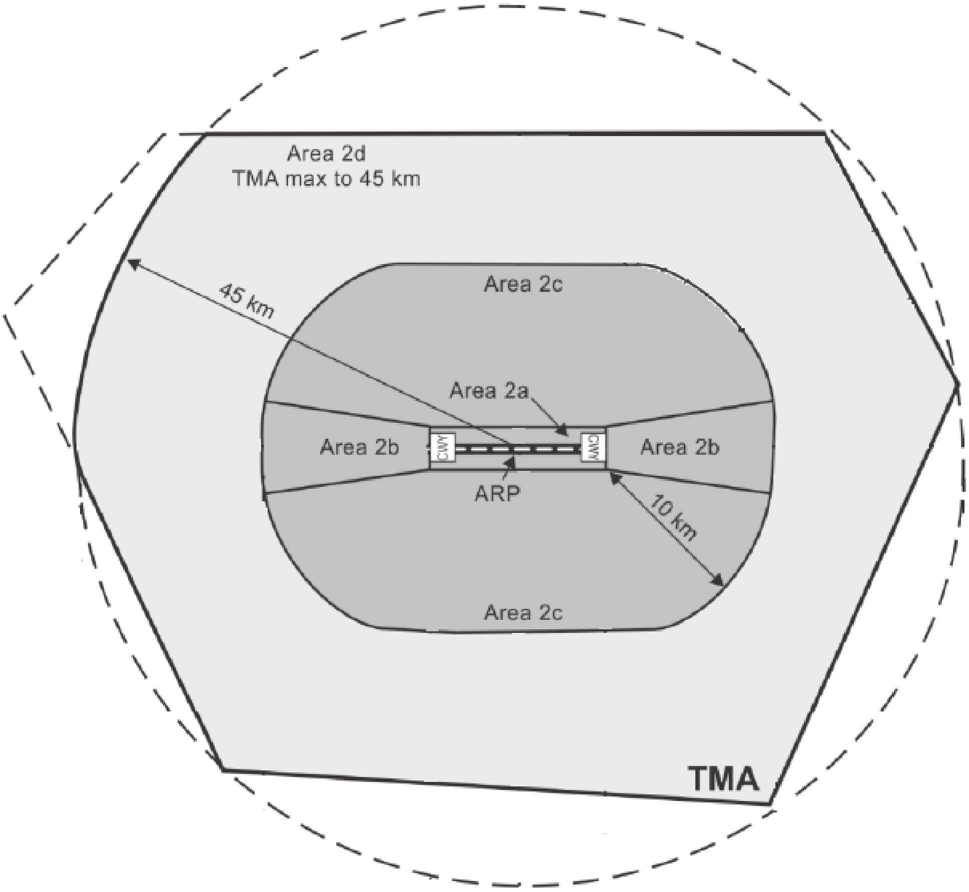


Figure 3: Area 2

Area 2a

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). Area 2a is intended to reduce the risk of damage to aircraft running off a runway and to protect aircraft flying over the strip and clearway during take-off or landing.

Area 2b

Area 2b covers an area for take-off and landing and, as described, extends from the outer ends of Area 2a, with a 15% splay to either side and a length of 10 km.

Note: The possibility of a curved Area 2b should be taken into account in appropriate cases where a straight take-off or approach path is not possible due to terrain or other (e.g. environmental) restrictions.

Area 2c

Area 2c is described as the area within 10km of the edges of Area 2a, excluding those parts identified as being Area 2b.

Area 2d

Area 2d is identified as the area extending from the outer edges of Area 2a, Area 2b and Area 2c, out to a distance of 45 km from the aerodrome reference point or the TMA boundary, whichever is the closest. Given that the TMA boundary is only mentioned with respect to Area 2d, it is assumed that should the TMA end closer to Area 2a than 10 km, Area 2b and 2c would still extend to 10 km, despite extending further than the TMA boundary.

3.4.1.4 AREA 3

3.4.1.4.1 ICAO ANNEX 15 TEXT PARA 5.3.3.1 (EXTRACT)

….

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

> *…*
>
> *— 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; and*
>
> *…*

Understanding of Requirement

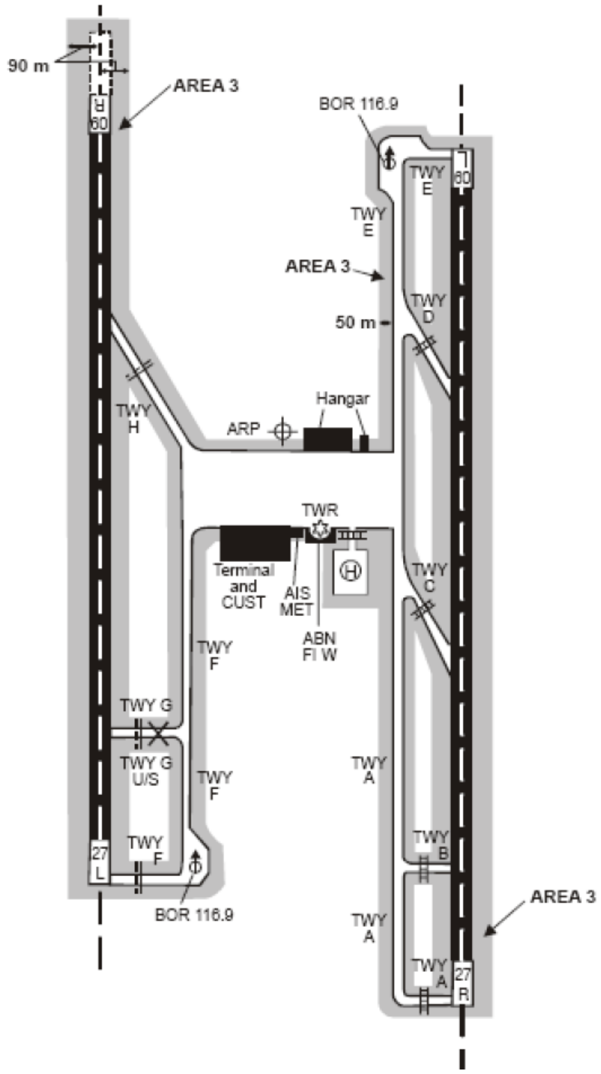


Figure 4: Area 3

Area 3 is defined as an area bordering the movement area. It extends horizontally 90 m from the runway centre line and 50 m from the edge of all other movement areas.

It should be noted that the movement area is defined as that part of an aerodrome to be used for the take-off, landing and taxiing of aircraft, consisting of the manoeuvring area and the apron(s). The taxiway shoulders are therefore not part of the movement area but part of Area 3, i.e. the 50 m bordering area starting at the edge of the taxiway and not at the edge of the taxiway shoulder.

3.4.1.5 AREA 4

3.4.1.5.1 ICAO ANNEX 15 TEXT PARA 5.3.3.1 (EXTRACT)

….

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

> *…*
>
> *— 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.*”

Understanding of Requirement

Area 4 is defined as a rectangle of 900 m by 120 m in front of a precision approach runway, Category II or III. This area corresponds to the area of the Precision Approach Terrain Chart (PATC) as defined in ICAO Annex 4. See section 3.5.2.4.2 for the representation of Area 4.

3.4.2 OBSTACLE LIMITATION SURFACES DEFINED IN ICAO ANNEX 14

ICAO Annex 14 [3] 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.*"

ICAO Annex 14 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.

The obstacle limitation surfaces comprise of:

- 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 in Table 4-1 for approach runways and Table 4-2 for runways meant for take-off.

Figure 5 provides a graphical representation of the listed obstacle limitation surfaces.

It should be noted that the obstacle limitation surfaces extend up to 15 km, which is different to Area 2b, whose extension is only 10 km.

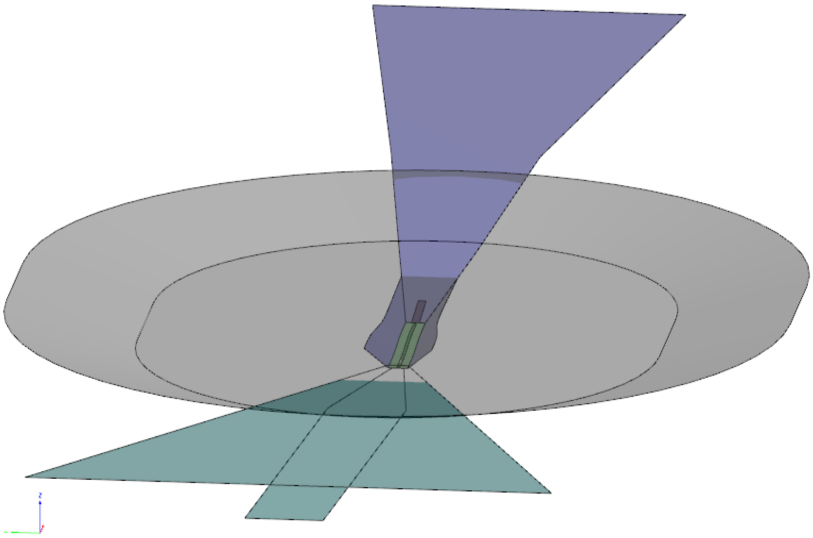


Figure 5: Graphical depiction of Para 5.3.3.4.5 requirements (Obstacle Limitation Surfaces)

3.4.3 TAKE-OFF FLIGHT PATH AREA DEFINED IN ICAO ANNEX 4

The take-off flight path area is defined in ICAO Annex 4 [1] Paragraph 3.8.2.1:

> "*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.*

Figure 6 provides a graphical representation of take-off flight path area as defined in ICAO Annex 4.

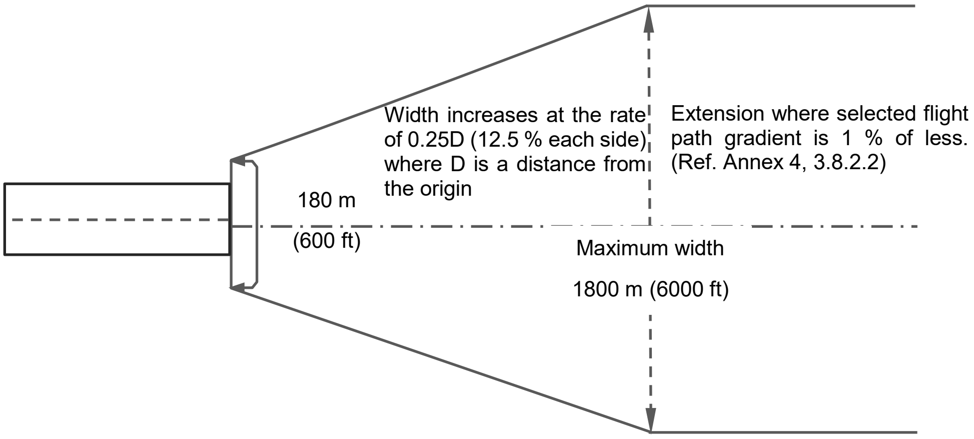

Width increases at the rate of 0.25D (12.5 % each side), where D is a distance from the origin
Extension where selected flight path gradient is 1 % of less. (Ref. Annex 4, 3.8.2.2)
180 m
(600 ft)
Maximum width
1800 m (6000 ft)

Figure 6: Graphical depiction of take-off flight path area

3.5 SPECIFIC PROVISIONS FOR TERRAIN DATA SETS

3.5.1 CONTENT

3.5.1.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.1

"*Terrain data sets shall contain digital representation of the terrain surface in the form of continuous elevation values at all intersections (points) of a defined grid, referenced to common datum.*"

3.5.1.2 ICAO PANS-AIM TEXT PARA 5.3.3.2.1.1

"*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."

Understanding of Requirement

This text provides the following requirements:

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

b) The elevation of the terrain must 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 will 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.

3.5.1.3 ICAO PANS-AIM TEXT PARA 5.3.3.2.1.2

"*Sets of electronic terrain data shall include spatial (position and elevation), thematic and temporal aspects for the surface of the Earth containing naturally occurring features such as mountains, hills, ridges, valleys, bodies of water, and permanent ice and snow, and exclude obstacles. 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".*"

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 must 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 goes on to state that the terrain modelled should reflect the surface of the earth and that, in particular, this includes areas of water and permanent 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. glaciers), this should be included in the terrain model.

It is clearly indicated by ICAO that obstacles should not be included within the terrain data set. Therefore, obstacles always have to be filtered out from a DSM.

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 5.4.3.3) over a forested area, the laser signals are reflected back from the top of the trees (top of the canopy) as well as from the ground (bare earth) and from the vegetation in between. This makes it possible to produce a digital model of the surface of the earth (Digital Surface Model DSM) including the vegetation or a digital terrain model (DTM) without vegetation. The type of recorded surface has to be provided as an attribute (see section 3.5.4.2.18) and the data product specification has to clearly indicate if the elevation model represents the true surface of the terrain or includes vegetation.

In using Interferometric Synthetic Aperture Radar (IfSAR) (see section 5.4.3.4) 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 an unknown distance before being reflected back. 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.

3.5.2 SPATIAL SCOPE

3.5.2.1 AREA 1

3.5.2.1.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.2

“*Terrain data sets shall be provided for Area 1.*”

Understanding of Requirement

This standard requires an electronic terrain data set to be provided for the entire territory of the State.

Area 1 data is mainly used for en-route applications (see Chapter 2 for details). For such applications users need data on a global or at least extensive regional scale. This requires the integration of data from different States, with additional effort on the part of data integrators as regards harmonisation and resolving consistency issues between different data sets (e.g. resolution differences, cross-border differences, different vertical references).

Electronic terrain data meeting the Area 1 numerical requirements (post spacing: 3 arc seconds, vertical accuracy: 30 m) is available today from satellites on a global scale. Even though this data is not from an authorised source and has gaps (e.g. glaciers, lakes and mountainous regions) and artefacts, it is used by the industry to produce global data sets that have been quality-assured and where the gaps and artefacts have been removed. These products are homogenous and do not require the integration effort mentioned above when using data provided by States.

For this reason, the demand for terrain data with Area 1 numerical requirement is low. On the other hand, higher quality data for the entire Area 1 is often available in the State from national geodetic services, topographic mapping agencies or other authorities. Therefore, States should if available provide Area 1 Terrain data sets with Area 2 numerical requirements as it is of interest in some applications, e.g. helicopter requirements as described in 2.11.

3.5.2.2 AREA 2

3.5.2.2.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.3

“For aerodromes regularly used by international civil aviation, 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.”

Understanding of Requirement

This standard defines the minimal required set of electronic terrain data for Area 2 to be provided for all aerodromes designated as international in the National AIP section AD 1.3 – ‘Index to aerodromes and heliports’.

See section 3.4.1.3 for more information on Area 2a, section 3.4.3 for more information on the take-off flight path area and section 3.4.2 for more information on the obstacle limitations surface areas.

It should be noted that the requirement defines only the lateral extent of the area where terrain data must be provided, independent of terrain height. Even though Figure A8-1 in ICAO PANS-AIM Annex 8 mentions that Area 1 numerical requirements are sufficient for terrain beyond 10 km of the ARP lower than 120 m above the lowest runway, all terrain data must be provided with Area 2 numerical requirements within the bounds defined in points a), b) and c) (see section 3.5.2.2.3 for a detailed explanation).

3.5.2.2.2 ICAO ANNEX 15 TEXT PARA 5.3.3.3.4

“*Recommendation.— For aerodromes regularly used by international civil aviation, additional terrain data should be provided within Area 2 as follows:*

a) In the area extending to a 10-km radius from the ARP; and

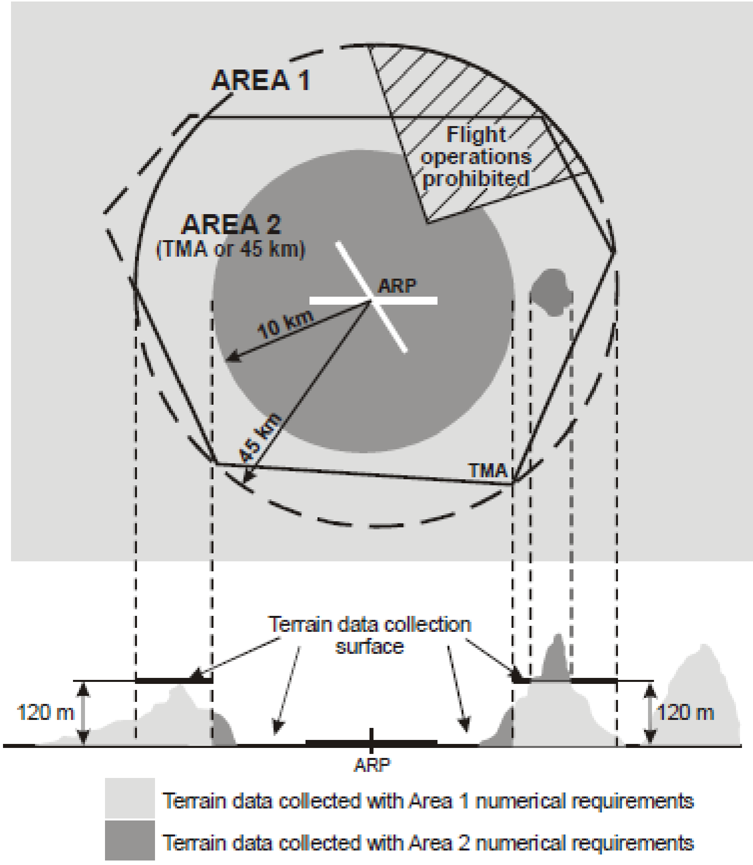
b) Within the area between 10 km and the TMA boundary or a 45-km radius (whichever is smaller), where terrain penetrates a horizontal terrain data collection surface specified as 120 m above the lowest runway elevation.”

Understanding of Requirement

ICAO recommends that, in addition to the minimal set of electronic terrain specified in Annex 15 Para 5.3.3.3.3, terrain data should be provided for all of Area 2 (see section 3.4.1.3) for all aerodromes designated as international in the National AIP section AD 1.3 – ‘Index to aerodromes and heliports’.

The recommendation is to provide all terrain data within a 10 km radius from the ARP, and beyond the 10 km radius only data for terrain that is above 120 m of the lowest runway elevation (see next section for a detailed discussion).

3.5.2.2.3 ICAO PANS-AIM FIGURE A8-1 “TERRAIN DATA COLLECTION SURFACES — AREA 1 AND AREA 2”


AREA 1
Flight operations prohibited
AREA 2
(TMA or 45 km)
ARP
10 km
45 km
TMA
Terrain data collection surface
120 m
120 m
ARP
Terrain data collected with Area 1 numerical requirements
Terrain data collected with Area 2 numerical requirements

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 Appendix 1.

Understanding of Requirement

Point 1) indicates that all terrain within 10 km of the Aerodrome Reference Point must be collected in accordance with the Area 2 numerical requirements specified in ICAO PANS-AIM Appendix 1 Table A1-8. 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 10 km from the edges of Area 2a.

Point 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 120 m above the lowest runway elevation at the aerodrome, also to be collected in accordance with the Area 2 numerical requirements specified in ICAO PANS-AIM Appendix 1 Table A1-8. Here it should be noted that the reference height is the lowest runway elevation and not that of the Aerodrome Reference Point.

Point 3) states that all other terrain in Area 2 not covered by point 1) and point 2) is to be collected in accordance with the Area 1 numerical requirements specified in ICAO PANS-AIM Appendix 1 Table A1-8. It should be noted that electronic terrain data for Area 2 with Area 1 numerical requirements is already covered by the required Area 1 data set.

Point 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 PANS-AIM Appendix 1 Table A1-8.

It should be noted that, with the recommendation to provide electronic terrain data with Area 2 numerical requirements only for terrain 120 m above the lowest runway elevation beyond 10 km of the ARP, islands of data might be created within Area 2. The Area 2 terrain data set would contain the terrain within 10 km of the ARP, the areas beyond 10 km from the ARP covered by the standard of ICAO Annex 15 paragraph 5.3.3.3.4 (e.g. obstacle limitation surfaces extending to 15 km) and the islands mentioned above.

Considering that an inhomogeneous terrain data set can be confusing for the user of the data, requires more processing effort and that digital terrain data collection techniques are most efficiently deployed for contiguous areas (see section 5.4.4 for more information on terrain collection techniques) it is recommended that, if more than the minimal required data should be provided, the whole of Area 2 is covered with data according to Area 2 numerical requirements.

3.5.2.3 AREA 3

3.5.2.3.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.7

“*Recommendation.— For aerodromes regularly used by international civil aviation, terrain data should be provided for Area 3.*”

Understanding of Requirement

The provision of terrain data for Area 3 is a recommendation and it should be provided to support aerodrome mapping data in order to ensure the consistency and quality of all geographical data related to the aerodrome.

3.5.2.4 AREA 4

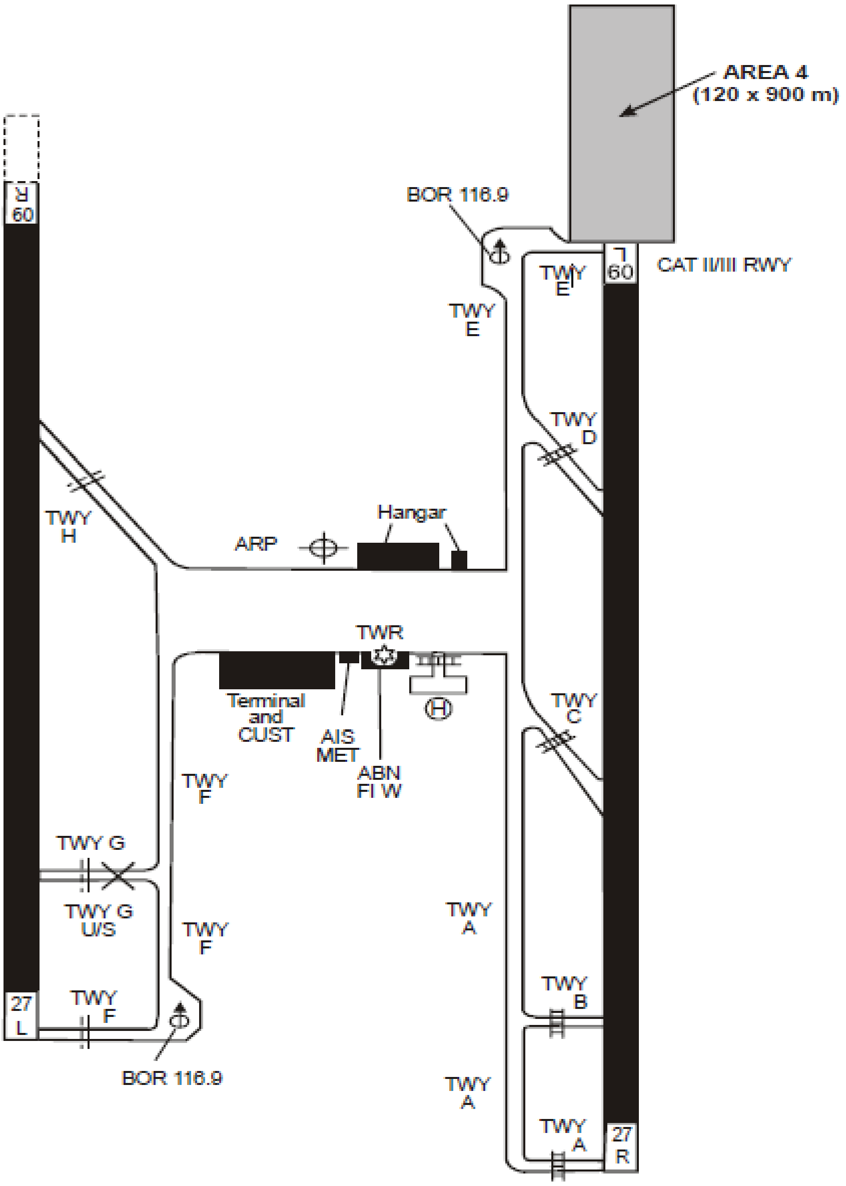
3.5.2.4.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.8

“*For aerodromes regularly used by international civil aviation, terrain data shall be provided for Area 4 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.*”

Understanding of Requirement

This standard requires that terrain data for Area 4 (see section 3.5.2.4) is made available for Cat II/III runways of all aerodromes designated as international in the National AIP section AD 1.3 – ‘Index to aerodromes and heliports’. See section 2.8 for more information on application using this data.

3.5.2.4.2 ICAO PANS-AIM 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 Appendix 1.”

Understanding of Requirement

The text supporting Figure A8-4 indicates that terrain data must be collected in accordance with the Area 4 numerical requirements specified in ICAO PANS-AIM Appendix 1 Table A1-8 (see section 3.5.5.2).

3.5.2.4.3 ICAO ANNEX 15 TEXT PARA 5.3.3.2

“*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.*”

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 5.3.3.3.8 of ICAO Annex 15 introduces a similarly worded recommended practice to ensure that the digital representation of the terrain in the CAT II/III operations area is consistent with the requirements for the PATC.

In all cases, and as described in 3.7.1 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.

3.5.2.5 ADDITIONAL TERRAIN DATA

3.5.2.5.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.9

"*Recommendation.— Where additional terrain data is collected to meet other aeronautical requirements, the terrain data sets should be expanded to include this additional data.*"

Understanding of Requirement

In order to meet other needs, States may capture other electronic terrain data which is not strictly required by the SARPs. For example, a non-standard departure/arrival procedure could require additional terrain data outside the lateral limits of OLS.

3.5.3 COORDINATION

3.5.3.1 ICAO ANNEX 15 TEXT PARA 5.3.3.3.5

"*Recommendation.— Arrangements should be made for coordinating the provision of terrain data for adjacent aerodromes where their respective coverage areas overlap to assure that the data for the same terrain is correct.*"

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 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.

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.

3.5.3.2 ICAO ANNEX 15 TEXT PARA 5.3.3.3.6

"*Recommendation.— For those aerodromes located near territorial boundaries, arrangements should be made among States concerned to share terrain data.*"

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 for the collection of data for territory not under the direct responsibility of the State in which the aerodrome is located, agreements need 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 data is collected in a manner which allows it to be shared and, therefore, also provides a cost-effective solution.

Cross-border coordination issues are addressed in section 4.4.11 of this Manual and in section 4.2.1 regarding the National TOD policy.

3.5.4 ATTRIBUTES

3.5.4.1 ICAO PANS-AIM TEXT PARA 5.3.3.2.1.3

"*In terrain data sets, only one feature type, i.e. terrain, shall be provided. Feature attributes describing terrain shall be those listed in Appendix 6, Table A6-1. The terrain feature attributes listed in Appendix 6, Table A6-1 represent the minimum set of terrain attributes, and those annotated as mandatory shall be recorded in the terrain data set.*"

3.5.4.2 ICAO PANS-AIM APPENDIX 6 TABLE A6-1. 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*

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 ICAO PANS-AIM Appendix 6 Table A6-1 as providing the minimum set of attributes that must be provided. As indicated, some of these attributes are mandatory and have to be provided, whereas others are optional. As this attribute list is described as the minimum set that must be provided, it is considered that additional attributes may be provided, where appropriate. The attributes can be provided either as metadata (e.g. horizontal and vertical reference system) or as data (e.g. elevation, surface type).

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 on the number of CAT II/III runways available;

- Terrain Area Level:

  Data for a single terrain area. For example, Area 2 for an aerodrome or a particular take-off flight path area or a runway;

- 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 ICAO PANS-AIM Appendix 6 Table A6-1 and their intent. Unless otherwise stated, provision of the attributes is mandatory.

3.5.4.2.1 AREA OF COVERAGE

A description of the geographical area for which the data set provides coverage. This metadata can be provided as a:

- Geographic description:

  A description clearly identifying the area of coverage: e.g. Belgium, TMA of airport EEAD.

  “Area 2”, “Area 3” or “Area 4” should not be used as geographic description because they are not explicitly specifying the area of coverage.

- Geographic bounding box:

  Minimum latitude / longitude and maximum latitude / longitude describing a bounding box of the area of coverage. See Figure 12.

- Bounding polygon:

  A series of coordinates describing the boundary of the area of coverage.

3.5.4.2.2 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 data from different originators.

3.5.4.2.3 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. 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 the next-intended users.

3.5.4.2.4 ACQUISITION METHOD

The acquisition method relates to the means used to collect the data in the data set. If the data set 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). There are different methods to provide this information on the data level: in raster form as a second file with a code for the acquisition method, as cell values or as polygons with the acquisition method as attribute.

3.5.4.2.5 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 is provided in the header of the data set in prevalent raster data formats like GeoTIFF or ASCII grid (see Appendix D for terrain data set formats).

3.5.4.2.6 HORIZONTAL REFERENCE SYSTEM

A record of the reference system of the horizontal position information must be included in the data set (e.g. GeoTIFF) or the metadata if the data set format does not provide for reference system information (e.g. ASCII Grid). It is not recommended to use different horizontal reference systems within a data set.

3.5.4.2.7 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.

ICAO Annex 15 para 3.2.2 requires the order of resolution of aeronautical data to be commensurate with the actual data accuracy. The resolution of the data contained in the database may be the same as or finer than the publication resolution.

3.5.4.2.8 HORIZONTAL ACCURACY

The specific horizontal accuracy achieved with the applied surveying method should be recorded as metadata. 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 post measurement (data level). There are different methods to provide this information on data level: in raster form as a second file with the accuracy as cell values or as polygons with the accuracy as attribute. See section 3.5.5 for additional guidance.

3.5.4.2.9 HORIZONTAL CONFIDENCE LEVEL

Usually the accuracies are provided with the same level of confidence for horizontal position information in the data set. Therefore, the confidence level is provided as metadata on the data set level. See section 3.5.5 for additional guidance.

3.5.4.2.10 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). When providing terrain data as a raster grid, the positional information is coded in the header of the raster file (e.g. GeoTIFF) or as metadata (see section 5.1.2.4 for more details).

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

3.5.4.2.11 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.

3.5.4.2.12 ELEVATION REFERENCE

The elevation reference describes how elevation values in the DEM are related to the universe of discourse (see section 5.1.1 for a description of this term). The values provided 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 to use different elevation references within a single data set. Therefore, it is recommended to provide this metadata at the level of the data set.

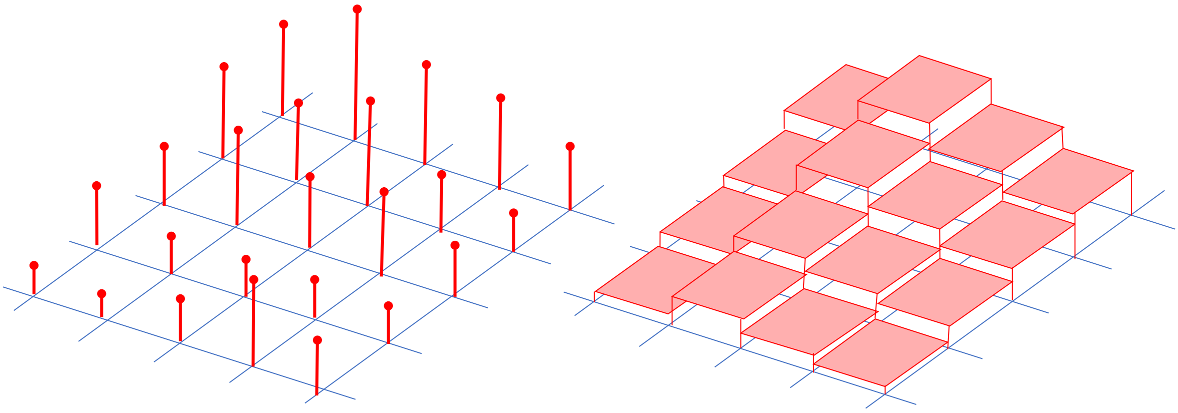


Figure 7: Elevation reference: Left: Point, Right: Area

3.5.4.2.13 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 to use different vertical reference systems within a single data set. Therefore, it is recommended to provide this metadata at the level of the data set.

3.5.4.2.14 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.

ICAO Annex 15 para 3.2.2 requires the order of resolution of aeronautical data to be commensurate with the actual data accuracy. The resolution of the data contained in the database may be the same as or finer than the publication resolution.

3.5.4.2.15 VERTICAL ACCURACY

Similar to horizontal accuracy, the specific vertical accuracy achieved with the applied surveying method should be recorded. See section 3.5.5 for additional guidance.

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 post measurement (data level). There are different methods to provide this information: in raster form as a second file with the accuracy as cell values or as polygons with the accuracy as attribute.

3.5.4.2.16 VERTICAL CONFIDENCE LEVEL

Similar to the horizontal confidence level, the accuracies are usually provided with the same level of confidence for all post measurements in the data set. Therefore, the confidence level is provided as metadata on the data set level. See section 3.5.5 for additional guidance.

3.5.4.2.17 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, ice, rock, sand, etc. This data should be provided at the level of post measurement (data level).

There are different methods to provide this information: in raster form as a second file with a code for the surface type as cell values or as polygons with the surface type as attribute.

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, careful consideration be given to whether or not to provided it.

3.5.4.2.18 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) representing the first reflective surface or something in between (for more information see also section 5.1.2 in this Manual).

Usually the recorded surface is the same for all parts of the data set. Therefore, this metadata should be provided at the level of the data set.

3.5.4.2.19 PENETRATION LEVEL

As discussed in section 3.5.1.3 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. There are different methods to provide this information on data level: in raster form as a second file with a code for the penetration level as cell values or as polygons with the penetration level as attribute.

This attribute is optional and only applicable if the data is surveyed with IfSAR (see sections 5.4.4.4 and 5.4.5.4).

3.5.4.2.20 KNOWN VARIATIONS

The known variations attribute 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 5.3. The known variation may differ for different areas of a data set and should therefore be provided at the level of post measurement (data level).

This attribute is optional.

3.5.4.2.21 INTEGRITY

The integrity of terrain data is determined by the processing chain, especially the validation and verification procedures applied to avoid corruption of the data.

Guidance on how the integrity of data may be maintained through the application of process assurance can be found in EUROCONTROL-SPEC-148 [35] and in EUROCAE ED-76A [25].

The integrity classification of the data set is usually maintained by the entity maintaining the data within the State but is not provided to the next intended user. If the terrain data does not meet the integrity specification then this has to be described in the metadata.

3.5.4.2.22 DATE AND TIME STAMP

This attribute should be applied at the level of individual post measurement (data level) and at data set level. At data level it must provide the date and time at which the terrain was surveyed and at the data set level when the data set was created or last modified.

There are different methods to provide this information at data level: in raster form as a second file with survey date as cell values or as polygons with the survey date as attribute.

3.5.4.2.23 UNIT OF MEASUREMENT USED

This is the unit of the elevation measurements provided. A single unit of measurement must be used within the data set for each elevation value. For example, the use of metres or feet, not both. This attribute should be provided in the metadata of the data set.

The post spacing will often have a different unit of measurement (e.g. decimal degrees if the horizontal positions are provided in WGS-84) and is usually specified in the header of the data file (see 5.1.2.5).

3.5.5 NUMERICAL REQUIREMENTS

3.5.5.1 ICAO PANS-AIM TEXT PARA 5.3.3.2.1.4

“*Terrain data for each area shall conform to the applicable numerical requirements in Appendix 1.*”

3.5.5.2 ICAO PANS-AIM APPENDIX 1 TABLE A1-8 TERRAIN DATA

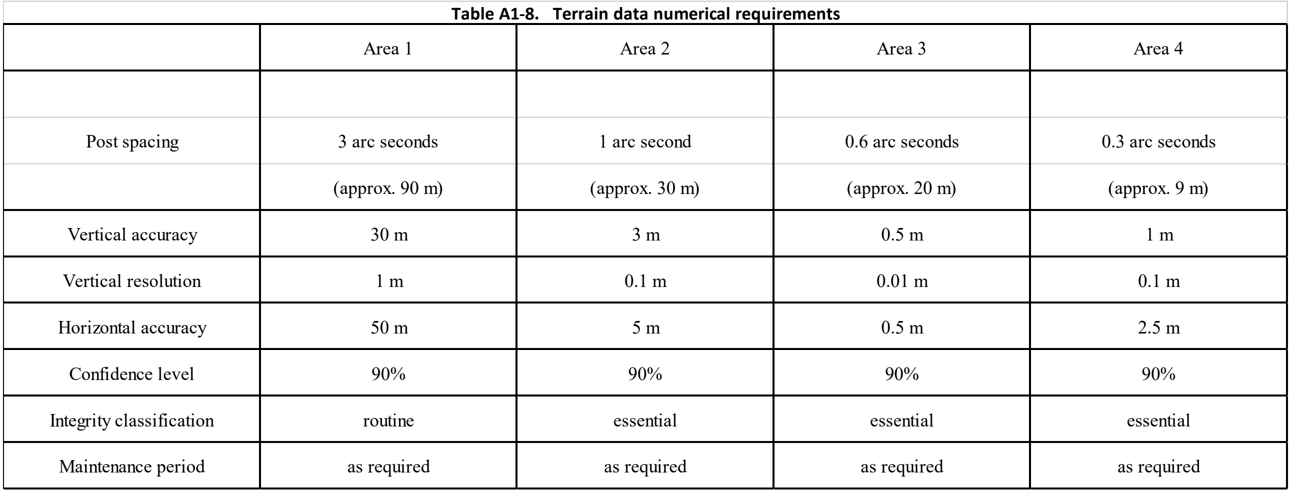


Table A1-8. Terrain data numerical requirements

	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

Understanding of Requirement

Table A1-8 of the Appendix 1 provides the numerical requirements which must be met by the terrain data set. It is organised in a different way to the other data catalogue entries. Digital terrain data has continuous elevation values at intersections of a defined grid. Therefore, the catalogue entries define the post spacing of the grid and the data quality requirements.

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 difference permitted 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.

  ICAO Annex 15 para 3.2.2 requires the order of resolution of aeronautical data to be commensurate with actual data accuracy. The resolution of the data contained in the database may be the same as 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.

- Integrity Classification:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The terrain data corresponds to routine (Area 1) and essential (Area 2, 3, 4) integrity classification, which is defined as 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.

- 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 4.4.9 of this Manual.

3.6 SPECIFIC PROVISIONS FOR OBSTACLE DATA SETS

3.6.1 CONTENT

3.6.1.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.1

"*Obstacle data sets shall contain the digital representation of the vertical and horizontal extent of the obstacles.*"

3.6.1.2 ICAO ANNEX 15 TEXT PARA 5.3.3.4.2

"*Obstacles data shall not be included in terrain data sets.*"

3.6.1.3 ICAO PANS-AIM TEXT PARA 5.3.3.2.2.1

"*Obstacle data elements are features that shall be represented in the data sets by points, lines or polygons.*"

Understanding of Requirement

These provisions define what is meant by obstacle data, reiterating that obstacles must not be included in the terrain data set. They indicate that obstacle data should provide a representation of the horizontal and vertical extent of the obstacles, in a digital form and outline 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 must be closed to form a complete bounding box.

No indication is provided within ICAO Annex 15 and PANS-AIM as to when each of these representations should be used. Guidance on feature capture rules may be found in Appendix B of this Manual and in EUROCAE ED-98C [26].

3.6.2 SPATIAL SCOPE

3.6.2.1 AREA 1

3.6.2.1.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.3

"*Obstacle data shall be provided for obstacles in Area 1 whose height is 100 m or higher above ground.*"

Understanding of Requirement

This standard requires that data relating to obstacle must be provided for all objects over 100 metres in height (above ground level).

As indicated in section 2.11 the helicopters' operational needs go beyond the ICAO requirements for Area 1 obstacle data. Rotorcraft operations would require data on all obstacles higher than 60 m. These requirements were introduced in EUROCAE ED-98C [26]. As indicated in section 2.9 SVS' operational needs also go beyond the ICAO requirements by requiring data on all obstacles higher than 200 ft. These requirements were introduced in EUROCAE ED-179B [29].

3.6.2.2 AREA 2

3.6.2.2.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.4

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

Understanding of Requirement

The text "*aerodromes regularly used by international civil aviation*" means all aerodromes designated as international in the National AIP section AD 1.3 - Index to aerodromes and heliports.

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 5. These defined surfaces are described in section 3.4 and obstacles would encompass:

- The Obstacle Limitation Surfaces defined in ICAO Annex 14;
- The surface having a 1.2 per cent slope over the Take-off Flight Path Areas defined in ICAO Annex 4; and
- Areas 2a, 2b, 2c and 2d defined in ICAO Annex 15.

However, if the traditional meaning is applied in the context of paragraph 5.3.3.4.4, all penetrations of these surfaces would have to be collected and made available. This would result in paragraph 5.3.3.3.3 and 5.3.3.4.5 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 obligation 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.

State authorities can refer to 5.3.3.4.4 in their policy for any other objects that do not penetrate the surfaces defined in 5.3.3.4.5 and 5.3.3.4.6 and are identified as a hazard for air navigation (e.g. objects near a helipad).

3.6.2.2.2 ICAO ANNEX 15 TEXT PARA 5.3.3.4.5

"*For aerodromes regularly used by international civil aviation, obstacle data shall be provided for*:

a) Area 2a for those obstacles that penetrate an obstacle data collection surface outlined by a rectangular area around a runway that comprises the runway strip plus any clearway that exists. The Area 2a obstacle collection surface shall have a 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) 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."

Understanding of Requirement

This standard defines the minimal required set of electronic obstacle data for Area 2 to be provided for all aerodromes designated as international in the National AIP section AD 1.3 – 'Index to aerodromes and heliports'.

a) Area 2a:

All obstacles which exist within the region defined as Area 2a (see section 3.4.1.3) and that intersect a horizontal plane 3m above the nearest point on the runway centreline are to be provided in the digital data set with the Area 2 numerical requirements defined in ICAO PANS-AIM Appendix 1 Table A1-6.

It should be noted that the obstacle collection surface can have a different elevation at each point along the runway according to the longitudinal profile of the runway centre line (see Figure 8). Therefore, the minimum height of an obstacle in Area 2a depends on the elevation of the nearest point on the centreline and the terrain elevation.

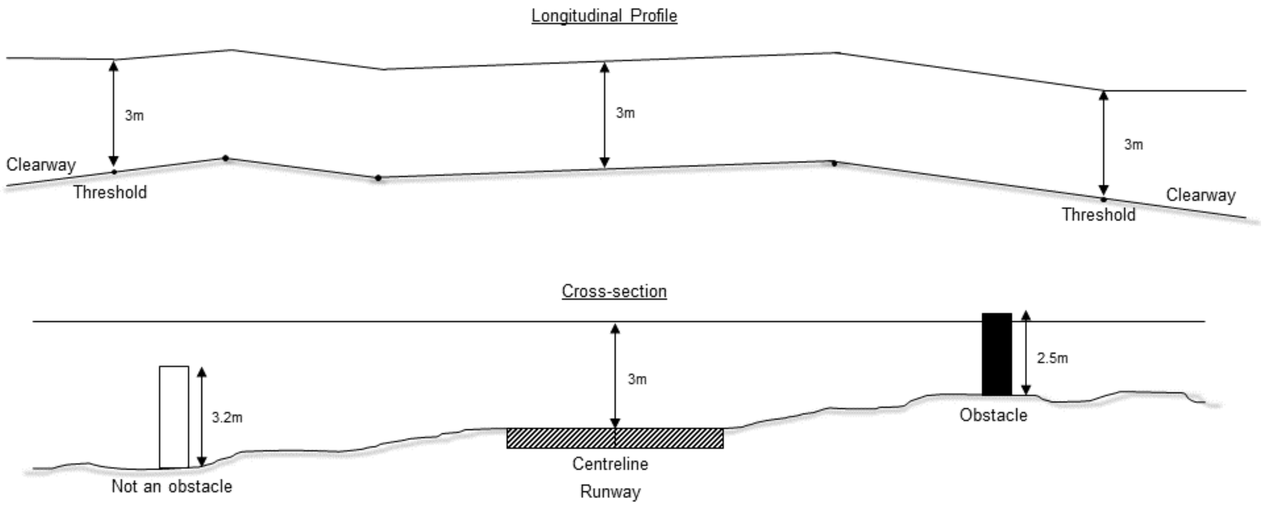


Figure 8: Obstacles in Area 2a

b) Objects in the take-off flight path area

Objects in the take-off flight path area (see section 3.4.3) 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 (i.e. at the end of the runway or clearway as appropriate) must be made available with the Area 2 numerical requirements defined in ICAO PANS-AIM Appendix 1 Table A1-6:

It is, therefore, 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.

It should be noted that according to the requirements in ICAO Annex 4 not all obstacles penetrating the 1.2% surface are shown on the Aerodrome Obstacle Chart — ICAO Type A: obstacles lying wholly below the shadow of other obstacles need not to be shown. This is not the case for the Area 2 obstacle data set. All obstacles penetrating the 1.2% surface in the take-off flight path area have to be included in the data set.

It should also be noted that according to ICAO Annex 4 para. 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 recommended that in the case of applying this provision for the production of the Aerodrome Obstacle Chart — ICAO Type A (Operating Limitations) then also the obstacle data set should be based on a surface with the same reduced slope of 1.0% or less. It should be noted that in the case of a 1.0% or lesser slope the take-off flight path are extends beyond the 10 km extension of Area 2b.

c) Penetrations of the aerodrome obstacle limitation surfaces:

Objects penetrating the aerodrome obstacle limitation surfaces (see section 3.4.2) must be provided with the Area 2 numerical requirements defined in ICAO PANS-AIM Appendix 1 Table A1-6.

3.6.2.2.3 ICAO ANNEX 15 TEXT PARA 5.3.3.4.6

"*Recommendation.— For aerodromes regularly used by international civil aviation, obstacle data should be provided for Areas 2b, 2c and 2d for obstacles that penetrate the relevant obstacle data collection surface specified as follows:*

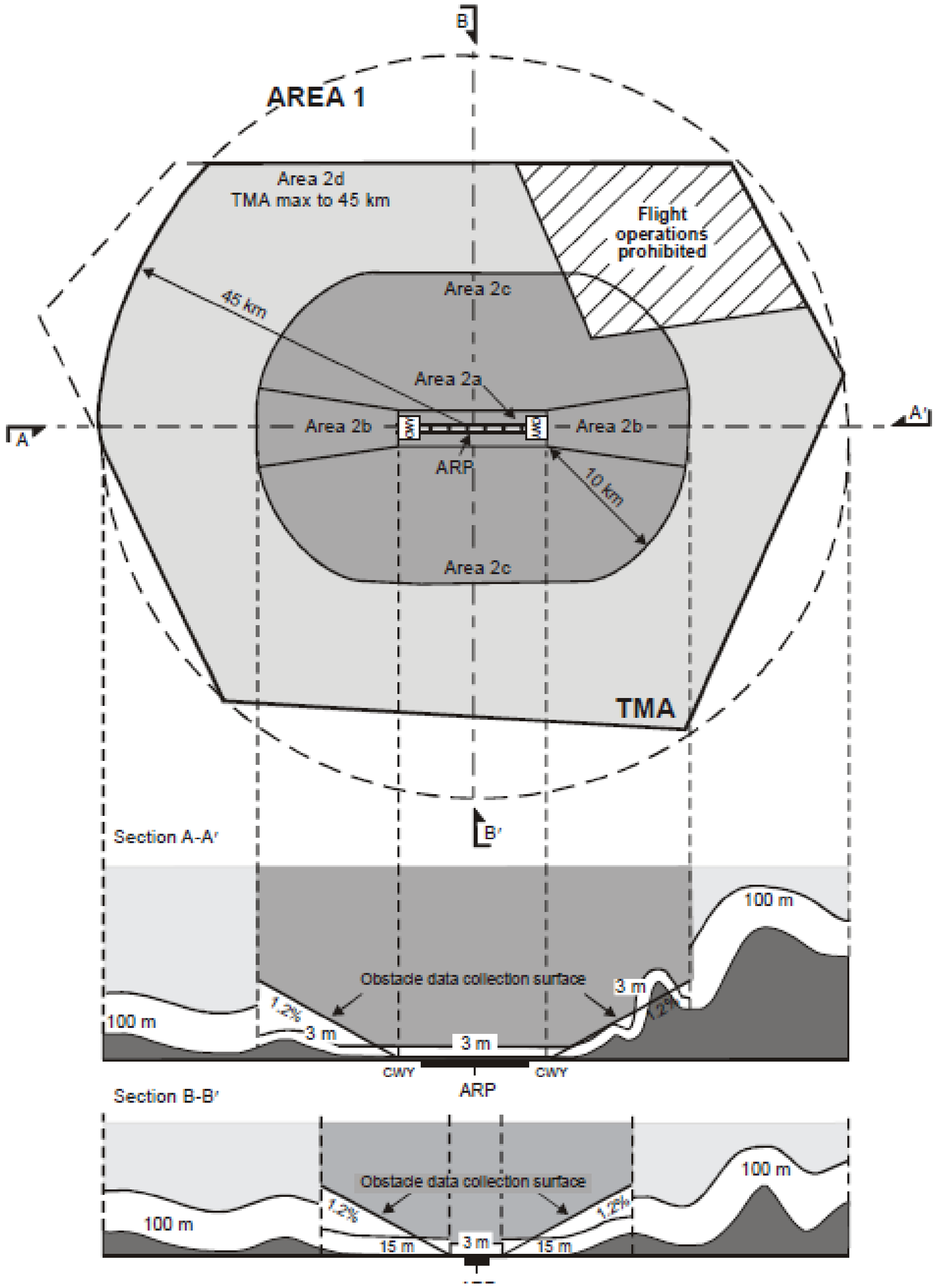
a) Area 2b: an area extending from the ends of Area 2a in the direction of departure, with a length of 10 km and a splay of 15 per cent to each side. The Area 2b obstacle collection surface has a 1.2 per cent slope extending from the ends of Area 2a at the elevation of the runway end in the direction of departure, with a length of 10 km and a splay of 15 per cent to each side;

b) 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 per cent 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 has the elevation of the point of Area 2a at which it commences; and

c) Area 2d: an area outside 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;

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."

3.6.2.2.4 ICAO PANS-AIM 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 Appendix 1.*
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 Appendix 1.”*

Understanding of Requirement

The collection of obstacle data should comply in accordance with the Area 2 numerical requirements (see also ICAO PANS-AIM Appendix 1 Table A1-6):

a) 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 5.3.3.4.6, all obstacles which penetrate this surface and whose height above ground level is 3m or greater must be collected.

b) 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 5.3.3.4.6, all obstacles which penetrate this surface and whose height above ground level is 15m or greater must be collected.

c) Area 2d is identified as the area extending from the outer edges of Area 2a, Area 2b and Area 2c, out to a distance of 45km or the TMA boundary, whichever is the closest. Given that the TMA boundary is only mentioned in this point and in ICAO PANS-AIM Appendix 8 Figure A8-1, 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.

It should be noted that there are certain areas (see Figure 9) where the Area 2 surfaces with the 1.2% slope are situated above the obstacle limitation surfaces and therefore less restrictive for obstacle data collection. Nevertheless, **all obstacles penetrating an OLS** must be included in the Area 2 obstacle data set even if a State is following the recommendation of ICAO Annex 15 Para. 5.3.3.4.6.

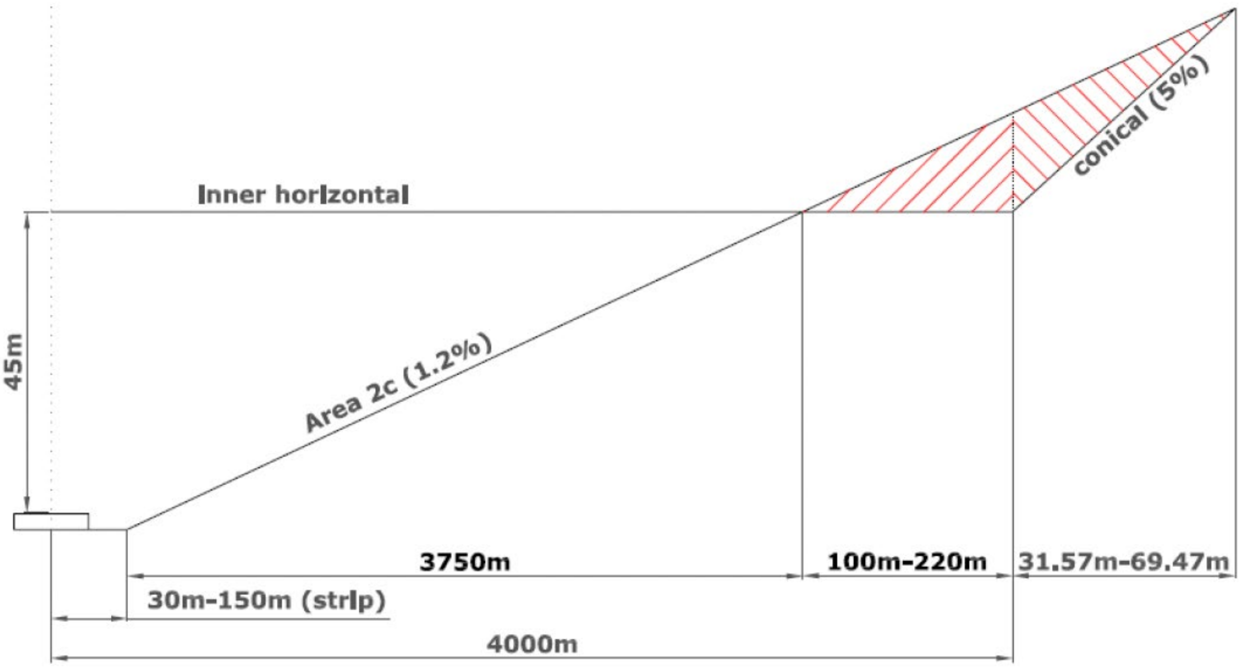


Figure 9: Gaps between Area2c 1.2% Surface and Obstacle Limitation Surfaces

3.6.2.3 ICAO PANS-AIM TEXT PARA 5.3.3.2.2.4

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

a) Areas 2a, 2b, 2c, 2d;

b) the take-off flight path area; and

c) the obstacle limitation surfaces.

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 are required for Area 4, these may be provided in accordance with the Area 4 obstacle data requirements specified in Appendix 6, Table A6-2. Guidance on appropriate obstacles for this chart is given in the Aeronautical Chart Manual (Doc 8697)."

Understanding of Requirement

The "specification scope" section of the DPS allows to differentiate the specification of obstacle data based on spatial or temporal extents (areas) or feature types (terrain vs. obstacle). 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 coordinates shall be used to describe the geographical extents of these areas.

See section 3.6.2.6 for a discussion of the Note.

3.6.2.4 AREA 3

3.6.2.4.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.9

"*Recommendation.— For aerodromes regularly used by international civil aviation, obstacle data should be provided for Area 3 for obstacles that penetrate the relevant obstacle data collection surface extending a half-metre (0.5 m) above the horizontal plane passing through the nearest point on the aerodrome movement area.*"

Understanding of Requirement

The provision of obstacle data for Area 3 is a recommendation and the data should be provided to support aerodrome mapping data in order to ensure consistency and quality of all geographical data related to the aerodrome. Therefore, the provision of this data 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, e.g. a digital representation of the movement surfaces.

Data collection for 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. It should be noted that this is not a requirement for the minimal height of obstacles. As illustrated in Figure 10, depending on the terrain, obstacles with a height of less than 0.5 m can penetrate this surface and objects higher than 0.5 m can remain below the collection surface.

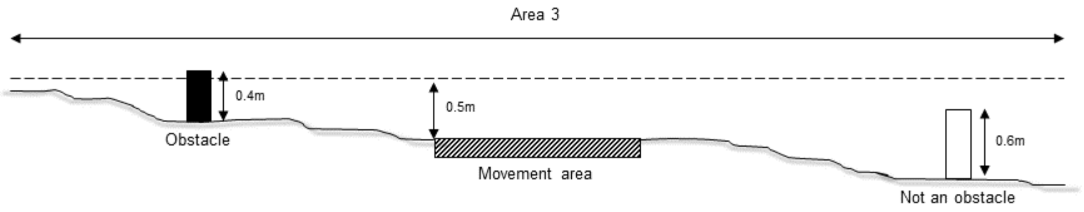


Figure 10: Obstacles in Area 3

3.6.2.5 AREA 4

3.6.2.5.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.10

"*For aerodromes regularly used by international civil aviation, obstacle data shall be provided for Area 4 for all runways where precision approach Category II or III operations have been established.*"

3.6.2.5.2 ICAO PANS-AIM FIGURE A8-4 “TERRAIN AND OBSTACLE DATA COLLECTION SURFACE — AREA 4”

See section 3.5.2.4.2 for the text and figure of requirement.

Understanding of Requirement

This standard requires that obstacle data for Area 4 (see section 3.4.1.5) is made available. See section 2.8 for more information on application using this data.

The text supporting Figure A8-4 indicates that where obstacle data is collected, it should be done so in accordance with the Area 4 numerical requirements specified in ICAO PANS-AIM Appendix 1 Table A1-6 (see section 3.6.5.2).

The ICAO requirement does not specify the minimum obstacle collection surface for Area 4. However, since the vertical accuracy for Area 4 is 1 m, it is recommended that obstacle data for all objects over 1 metre in height (above ground level) be provided.

3.6.2.6 ICAO PANS-AIM NOTE TO PARA 5.3.3.2.2.4

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 are required for Area 4, these may be provided in accordance with the Area 4 obstacle data requirements specified in Appendix 6, Table A6-2. Guidance on appropriate obstacles for this chart is given in the Aeronautical Chart Manual (Doc 8697).”

Understanding of Requirement

This note, which used to be and still should be a note to the ICAO Annex 15 requirement for Area 4 obstacle data (Para 5.3.3.4.10 of ICAO Annex 15) has erroneously been moved to ICAO PANS-AIM section on data product specifications with Amendment 40 of Annex 15.

The 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.

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[2] shown in Figure 11. 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.

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[2] 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.

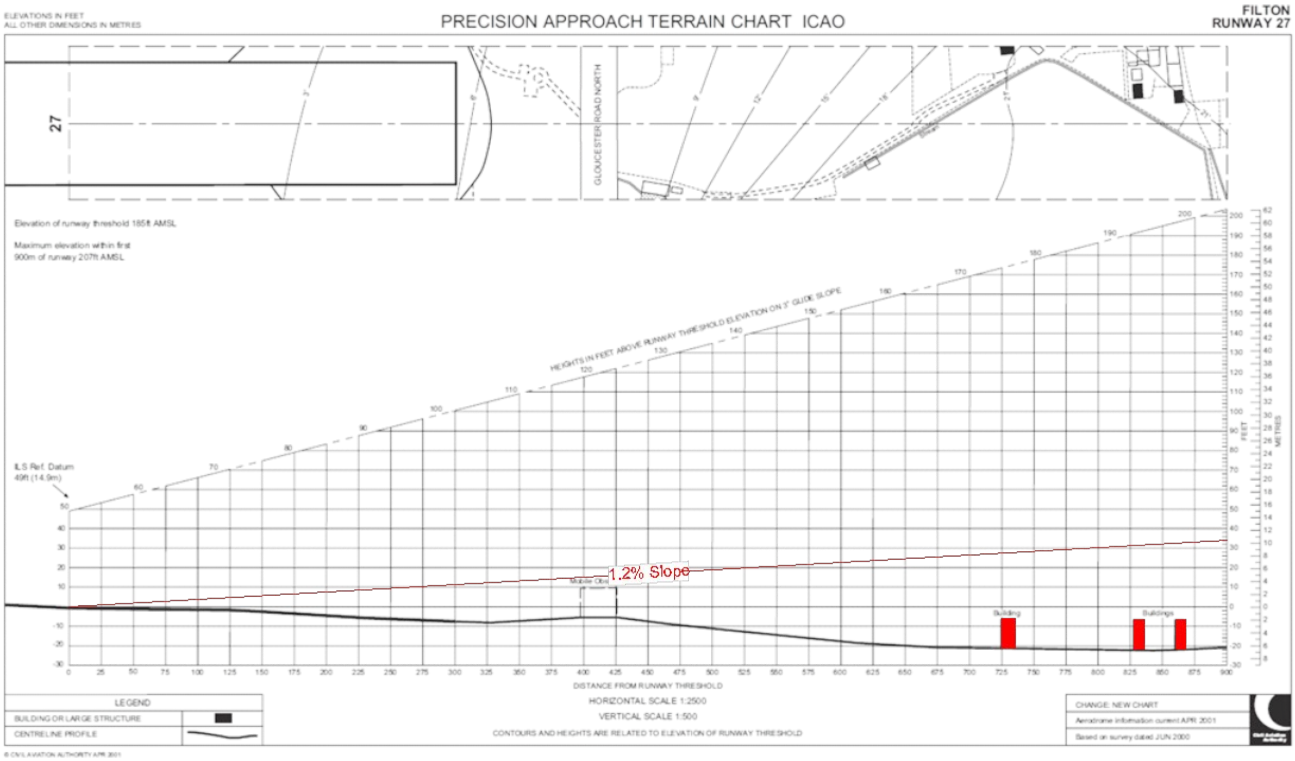
ELEVATIONS IN FEET
ALL OTHER DIMENSIONS IN METRES
PRECISION APPROACH TERRAIN CHART ICAO
FILTON
RUNWAY 27
27
GLOUCESTER ROAD NORTH
Elevation of runway threshold 185ft AMSL
Maximum elevation within first
900m of runway 207ft AMSL
HEIGHTS IN FEET ABOVE RUNWAY THRESHOLD ELEVATION ON 3° GUIDE SLOPE
ILS Ref. Datum
49ft (14.9m)
1.2% Slope
Mobile Obs
Building
Buildings
FEET
METRES
DISTANCE FROM RUNWAY THRESHOLD
HORIZONTAL SCALE 1:2500
VERTICAL SCALE 1:500
CONTOURS AND HEIGHTS ARE RELATED TO ELEVATION OF RUNWAY THRESHOLD
LEGEND
BUILDING OR LARGE STRUCTURE
CENTRELINE PROFILE
CHANGE: NEW CHART
Aerodrome information current APR 2001
Based on survey dated JUN 2000
© CIVIL AVIATION AUTHORITY APR 2001

Figure 11: PATC Overlaid with 1.2% Surface Assessment Surface

3.6.2.7 ADDITIONAL OBSTACLES

3.6.2.7.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.11

"*Recommendation.— Where additional obstacle data is collected to meet other aeronautical requirements, the obstacle data sets should be expanded to include this additional data.*"

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 to satisfy the needs of SVS application and rotocraft operations (see sections 2.9 and 2.11).

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.

3.6.3 COORDINATION

3.6.3.1 ICAO ANNEX 15 TEXT PARA 5.3.3.4.7

"*Recommendation.— Arrangements should be made for coordinating the provision of obstacle data for adjacent aerodromes where their respective coverage areas overlap to assure that the data for the same obstacle is correct.*"

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 obstacle data for these overlapping areas is “correct”. It is considered important to define what is meant by “correct”.

Two aerodromes could independently collect 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 obstacles in the overlapping area, whilst ensuring that the join between the overlapping and non-overlapping areas remains consistent.

3.6.3.2 ICAO ANNEX 15 TEXT PARA 5.3.3.4.8

“*Recommendation.— For those aerodromes located near territorial boundaries, arrangements should be made among States concerned to share obstacle data.*”

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 (e.g. LFSB Bâle-Mulhouse or LOWS Salzburg).

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.

Cross-border coordination issues are addressed in section 4.4.11 of this Manual and in section 4.2.1 regarding the National TOD policy.

3.6.4 ATTRIBUTES

3.6.4.1 ICAO PANS-AIM TEXT PARA 5.3.3.2.2.2

“*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 6, Table A6-2.*

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 6, Table A6-2 as optional attributes. If these types of obstacles are to be provided in the data set, appropriate attributes describing such obstacles are also required.”

3.6.4.2 ICAO PANS-AIM APPENDIX 6 TABLE A6-2. 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[3]	*Mandatory*

Understanding of Requirement

This provision defines the content of the obstacle data set by specifying the attributes that must be provided in the data set.

These obstacle attributes can be provided either as metadata or as data (properties of the obstacle features).

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 or part thereof. For example, Area 2 for an aerodrome; or take-off flight path area.

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[3] The attribute "Marking" was erroneously omitted in ICAO PANS-AIM Table A6-2 when transferring the table from the previous edition of ICAO Annex 15 Appendix 8.

- 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 ICAO PANS-AIM Appendix 6 Table A6-2 and their intent. Unless otherwise stated, the provision of the attributes is mandatory. Guidance on coding of obstacle attributes can be found in the AIXM coding guidelines for obstacle data sets.

3.6.4.2.1 AREA OF COVERAGE

A description of the geographical area for which the data set provides coverage.

For a user of the obstacle data set the coverage area is important metadata. Obstacle data sets can exist in different configurations: one obstacle data set may contain obstacles for a TMA comprising several aerodromes, each providing Area 2, Area 3 and Area 4 data whereas another obstacle data set contains obstacles for the Area 2A, the obstacle limitations surfaces and the take-off flight path area of one airport. For the user the coverage area is a required piece of information to correctly interpret the absence of obstacles at a location of interest: Only if the location of interest is inside the coverage area can the user be assured that there is no obstacle at this location.

The area of coverage can be provided as a:

- Geographic description:

  A description clearly identifying the area of coverage: e.g. Belgium, TMA of airport EEAD.

  “Area 2”, “Area 3” or “Area 4” should not be used as geographic description because they are not explicitly specifying the area of coverage.

- Geographic bounding box:

  Minimum latitude / longitude and maximum latitude / longitude describing a bounding box of the area of coverage.

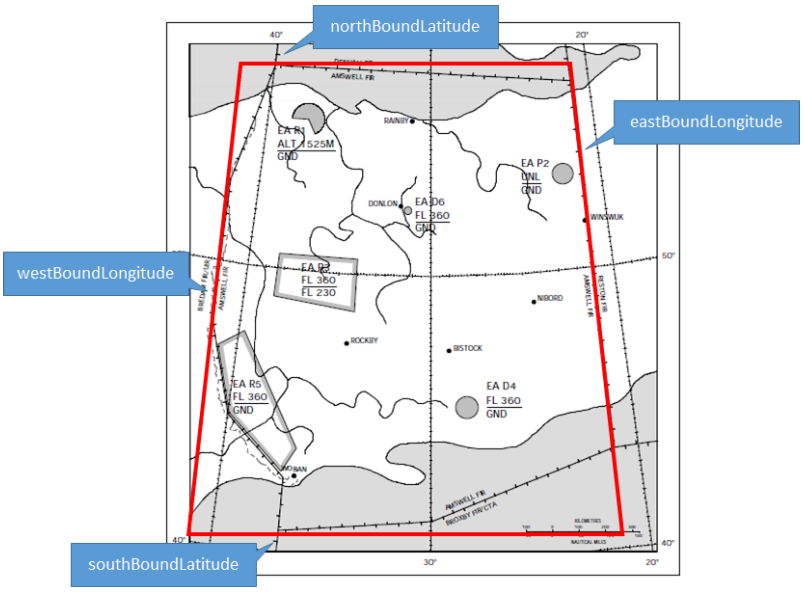

Figure 12: Bounding Box of Donlon FIR

  The geographic bounding box should only be used if the area of coverage consists of different areas (for example Area 2A, area of OLS and take-off flight path area) that are defined with polygons in the data set.

- Bounding polygon:

  A series of coordinates describing the boundary of the area of coverage.

The bounding polygon should, if available, be provided for each area, if data for more than one area is provided within one data set. For example, a single data set may contain obstacles of Area 2, Area 3 and Area 4 of one airport.

3.6.4.2.2 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 collected for each obstacle represented.

The originator identifier is usually maintained by the entity storing obstacle data within the State but is not provided to the next intended user in the obstacle data set.

3.6.4.2.3 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. 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.

3.6.4.2.4 OBSTACLE IDENTIFIER

Each obstacle that has been collected should be allocated a unique identifier which will remain the primary means of identifying the obstacle by all parties dealing with it (obstacle owner/operator, surveyor, approval authority, etc.) throughout its life, i.e. it should not be changed as a result of a resurvey or reissue of a data set (see section 5.8). 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.

There are two different types of identifiers that serve different purposes:

- *Administrative identifiers* are assigned to the obstacle by an authority applying a policy for the allocation of unique identifiers (see section 4.3.3.3 of this Manual). Administrative identifiers are the means for users to identify an obstacle and therefore published in the AIP and provided in the data set.
- Each obstacle as any other feature provided in AIXM must also have a *universally unique identifier* (UUID) assigned to it. The UUID is a 128-bit number used to identify the data related to the obstacle feature in computer systems, i.e. the data set and data base applications. The UUID is generated by the computer system of the first party that creates a data record of the obstacle and is usually hidden from the user. The UUID is used by systems to identify an obstacle and will not change when data is exchanged between different systems.

3.6.4.2.5 HORIZONTAL ACCURACY

The specific horizontal accuracy achieved with the applied surveying method should be recorded for each obstacle contained within the data set (data level). See section 3.6.5 for additional guidance.

3.6.4.2.6 HORIZONTAL CONFIDENCE LEVEL

Usually the accuracies are provided with the same level of confidence for all obstacles in the data set[4]. Therefore, the confidence level is provided on the data set level. See section 3.6.5 for additional guidance.

3.6.4.2.7 HORIZONTAL POSITION

The horizontal position should contain sufficient location information to describe the footprint 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 (see section 3.6.4.2.18). Rules on the representation of obstacles as points, lines and polygons may be found in EUROCAE ED-98C [26] and further guidance and examples in Appendix B of this Manual. The horizontal position should be provided for each obstacle in the data set (data level).

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[4] Accuracy values referring to different confidence levels can be converted to a confidence level of 90% assuming normal (Gaussian) distribution of errors.

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

3.6.4.2.8 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 coordinate, 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.

ICAO Annex 15 para 3.2.2 requires the order of resolution of aeronautical data to be commensurate with the actual data accuracy. The resolution of the data contained in the database may be the same as or finer than the publication resolution.

3.6.4.2.9 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 to use this attribute only for point or line obstacles, to indicate the level of geometric simplification (see information on feature capture rules in Appendix B).

Note that in AIXM 5.1 the horizontal extent should be coded as Radius or if relevant, as Width and Length of a VerticalStructure (see AIXM coding guidelines for obstacle data sets).

3.6.4.2.10 HORIZONTAL REFERENCE SYSTEM

This is a record of the reference system used for each of the horizontal positions included within the data set. It is not recommended to use different horizontal reference systems within a data set. As a result, it is recommended to provide this metadata 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[5]).

3.6.4.2.11 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.

3.6.4.2.12 HEIGHT

This attribute is optional in ICAO SARPs, however it is declared mandatory in EUROCAE ED-98C [26].

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, with an uneven ground profile. According to EUROCAE ED-98C the height is the maximum vertical distance of an obstacle, measured from its base (ground level) to the top.

3.6.4.2.13 VERTICAL ACCURACY

The specific vertical accuracy achieved with the applied surveying method should be recorded for each obstacle contained within the data set (data level). See section 3.6.5 for additional guidance.

3.6.4.2.14 VERTICAL CONFIDENCE LEVEL

Usually the accuracies are provided with the same level of confidence for all obstacles in the data set[6]. Therefore, the confidence level is provided on the data set level. See section 3.6.5 for additional guidance.

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[5] AIXM coding specifications require the reference system at data level.

[6] Accuracy values referring to different confidence levels can be converted to a confidence level of 90% assuming normal (Gaussian) distribution of errors.

3.6.4.2.15 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.

ICAO Annex 15 para 3.2.2 requires the order of resolution of aeronautical data to be commensurate with the actual data accuracy. The resolution of the data contained in the database may be the same as or finer than the publication resolution.

3.6.4.2.16 VERTICAL REFERENCE SYSTEM

This is a record of the reference system used for each of the vertical measurements included within the data set. It is not recommended to use different vertical reference systems within a data set. As a result, it is recommended to provide this metadata 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[5]).

3.6.4.2.17 OBSTACLE TYPE

This is an indication of the type of obstacle recorded. This should be assessed against a generic set of obstacle types defined in AIXM Class – CodeVerticalStructureBaseType, which includes types such as TREE, BUILDING, CRANE, etc. When no appropriate obstacle type exists in the list, then obstacle type ‘OTHER’ should be used, followed by a colon separated proper type of the obstacle. For example: ‘OTHER:CHIMNEY’.

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

3.6.4.2.18 GEOMETRY TYPE

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

ICAO does not provide explicit specifications when and what geometry type should be used, however EUROCAE ED-98C [26] Appendix G provides guidance on the geometric representation (point, line or polygon) of an obstacle based on the width and lengths of its footprint.

3.6.4.2.19 INTEGRITY

The integrity of an obstacle is determined by the processing chain, especially the validation and verification procedures applied to avoid corruption of the data.

The integrity of each obstacle should be recorded at data level. The integrity classification is usually maintained by the entity storing obstacle data within the State but is not provided to the next intended user in the obstacle data set. In case that obstacles of a data set do not meet the integrity requirement, this should be noted in the metadata.

Guidance on how the integrity of data may be maintained through the application of process assurance can be found in EUROCONTROL-SPEC-148 [35] and in EUROCAE ED-76A [25].

3.6.4.2.20 DATE AND TIME STAMP

This attribute should be applied at data and data set level. At data level it must provide the date and time at which the obstacle was created and at data set level when the data set was created or last modified.

3.6.4.2.21 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.

3.6.4.2.22 OPERATIONS

According to ICAO PANS-AIM this optional attribute is only required for mobile obstacles. It is an attribute on data level defining feature operations that a mobile obstacle may perform. Examples of feature operations are: a mobile bridge or a mobile crane raising or a ship passing by.

3.6.4.2.23 EFFECTIVITY[7]

Effectivity is an optional attribute on data level required for mobile and temporary obstacles. It defines the time period when the obstacle is in effect (e.g. a mobile bridge is risen, a temporary crane is mounted, a ship is present).

It should be noted that in EUROCAE ED-98C [26] the term *Effectivity* comprises three different attributes: validity (period when a feature state is effective), interpretation (how the feature state is to be interpreted) and feature lifetime (period during which the feature exists).

3.6.4.2.24 LIGHTING

Any lighting which may be used for aviation purposes (i.e. those 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 data level. The requirements for obstacle lighting are described in ICAO PANS-Aerodromes [7] and Annex 14 [3].

The obstacle lighting information should not be based solely on legal obligations (e.g. all obstacles higher than 60 m need to be lit). There should be a verification process in place to ensure that the lighting information reflects reality. Usually this is assured by the organisation responsible for obstacle assessment and permission (see section 4.3.3.2) requiring evidence (e.g. a photograph) at the regular intervals from the obstacle owner that the lighting requirement has been met.

3.6.4.2.25 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 data level. The requirements for obstacle marking are described in ICAO PANS-Aerodromes and Annex 14.

The obstacle marking information should not be based solely on legal obligations (e.g. all obstacles higher than 60 m need to be marked). There should be a verification process in place to ensure that the marking information reflects reality. Usually this is assured by the organisation responsible for obstacle assessment and permission (see section 4.3.3.2) requiring evidence (e.g. a photograph) from the obstacle owner that the marking requirement has been met.

3.6.4.2.26 STATUS

Unlike terrain which changes slowly and tends to already exist when it is measured 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 can be made available when the obstacle is still in planning or construction status. ICAO provisions do not require information about the status of an obstacle but it should be noted that in EUROCAE ED-98C [26] defines an attribute *Status* that provides the following indications: “planned”, “under constructions” or “completed”. In AIXM 5.1.1 the attribute constructionStatus of the class VerticalStructurePart can have the following values: IN_CONSTRUCTION, COMPLETED, DEMOLITION_PLANNED, IN_DEMOLITION and OTHER.

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

3.6.5 NUMERICAL REQUIREMENTS

3.6.5.1 ICAO PANS-AIM TEXT PARA 5.3.3.2.2.3

"*Obstacle data for each area shall conform to the applicable numerical requirements contained in Appendix 1.*"

3.6.5.2 ICAO PANS-AIM APPENDIX 1 TABLE A1-6 OBSTACLE DATA

Table A1-6 Obstacle data

Subject	Property	Sub-	Type	Description	Note	Accuracy	Integrity	Orig Type	Pub. Res.	Chart Res.
Obstacle				All fixed (whether temporary or permanent) and mobile obstacles or parts thereof.						
	Obstacle identifier		Text	Unique identifier of obstacle						
	Operator / Owner		Text	Name and Contact information of obstacle operator or owner						
	Geometry type		Code list	An indication whether the obstacle is a point, line or polygon.						
	Horizontal position		Point Line Polygon	Horizontal position of obstacle		See Note 1)				
	Horizontal extent		Distance	Hoizontal extent of the obstacle						
	Elevation		Elevation	Elevation of the highest point of the obstacle.		See Note 2)				
	Height		Height	Height of the obstacle above ground						
	Type		Text	Type of obstacle						
	Date and time stamp		Date	Date and time the obstacle was created						
	Operations		Text	Feature operations of mobile obstacles						
	Effectivity		Text	Effectivity of temporary types of obstacles						
	Lighting									
		Type	Text	Type of lighting						
		Colour	Text	Colour of the obstacle lighting						
	Marking		Text	Type of marking of obstacle						
	Material		Text	Predominant surface material of the obstacle						
			Note 1)	Obstacles in Area 1		50 m	routine	surveyed	1 sec	as plotted
				Obstacles in Area 2 (including 2a, 2b, 2c, 2d, take-off flight path area and obstacle limitation surfaces)		5 m	essential	surveyed	1/10 sec	1/10 sec
				Obstacles in Area 3		0.5 m	essential	surveyed	1/10 sec	1/10 sec
				Obstacles in Area 4		2.5 m	essential	surveyed		
			Note 2)	Obstacles in Area 1		30 m	routine	surveyed	1 m or 1 ft	3 m (10 ft)
				Obstacles in Area 2 (including 2a, 2b, 2c, 2d, take-off flight path area and obstacle limitation surfaces)		3 m	essential	surveyed	1 m or 1 ft	1 m or 1 ft
				Obstacles in Area 3		0.5 m	essential	surveyed	0.1 m or 0.1 ft0.01 m	1m or 1 ft
				Obstacles in Area 4		1 m	essential	surveyed	0.1 m	

Understanding of Requirement

Table A1-6 of the Aeronautical Data Catalogue provides the numerical requirements which must be met by the obstacle data set. The obstacle numerical requirements are presented in the tables containing Note 1) and Note 2).

The numerical requirements for obstacle data comprise the following elements:

- Accuracy:

  The accuracy provides the maximum difference permitted between the measured elevation of an obstacle or horizontal position and reality, which must be achieved with the corresponding level of confidence.

  The confidence level for the accuracy requirement of obstacles is defined in the introductory Note 7 of Appendix 1:

  "(7) Accuracy requirements for aeronautical data are based on a 95 per cent confidence level. For those fixes and points that are serving a dual purpose, e.g. holding point and missed approach point, the higher accuracy applies. Accuracy requirements for obstacle and terrain data are based on a 90 per cent confidence level."

  This corresponding level of confidence represents 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.

  For example, the elevation accuracy for an obstacle in Area 2 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 another example, the horizontal position accuracy for an obstacle in Area 2 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.

- Integrity Classification:

  The integrity classification for aeronautical data is based upon the potential risk resulting from the use of corrupted data. The obstacle data corresponds to routine (Area 1) and essential (Area 2, 3, 4) integrity classification, which is defined as 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 disaster. The integrity of aeronautical data must 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 corruption is avoided throughout the processing of routine data and that corruption does not occur at any stage of the entire process for essential data. Additional processes as needed to address potential risks in the overall system architecture to further assure data integrity at this level.

- Origination Type:

  The obstacle data is identified as surveyed.

- Publication and Chart Resolution:

  Publication and chart resolution are specified for the Horizontal Position, Elevation and Height properties. Publication resolution is used for representation in AIP, while chart resolution is used in representing numerical values on aeronautical charts.

  For example, the elevation resolution indicates the number of places of units/digits to which the elevation has been determined. 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.

  ICAO Annex 15 para 2.5.5 requires the order of resolution of aeronautical data to be commensurate with the actual data accuracy. The resolution of the data contained in the database may be the same as or finer than the publication resolution.

3.7 GENERAL PROVISIONS FOR DIGITAL DATA SETS

3.7.1 METADATA

3.7.1.1 ICAO ANNEX 15 TEXT PARA 5.3.1.2

“Each data set shall be provided to the next intended user together with at least the minimum set of metadata that ensures traceability.

Note.— Detailed specifications concerning metadata are contained in the PANS-AIM (Doc 10066).”

3.7.1.2 ICAO PANS-AIM TEXT SECTION 5.3.2

“*Each data set shall include the following minimum set of metadata:*

a) the names of the organization or entities providing the data set;

b) the date and time when the data set was provided;

c) period of validity of the data set; and

d) any limitations with regard to the use of the data set.

Note.— ISO Standard 19115 specifies requirements for geographic information metadata.”

Understanding of Requirement

This requirement outlines the purpose of “metadata” as well as what should be included in the “metadata” for each data set to ensure the traceability of the data sets. More information on metadata for TOD can be found in section 5.3 of this Manual.

3.7.2 CHECKLIST

3.7.2.1 ICAO ANNEX 15 TEXT PARA 5.3.1.3

“*A checklist of valid data sets shall be regularly provided.*”

3.7.2.2 ICAO PANS-AIM TEXT PARA 5.4.1.3

“*A checklist of the available data sets, including their effective and publication dates, shall be made available to allow the users to ensure that current data is being used.*”

Understanding of Requirement

This requirement outlines the regular provision of valid data sets. As a new requirement for data sets, the form of such a checklist has not been provided by ICAO. As an open item with no clear indication on the form, it is for States to decide. However, it may be helpful to present such a checklist in a manner similar to that of a checklist and lists of valid NOTAMs.

3.7.3 DATA PRODUCT SPECIFICATION

3.7.3.1 ICAO PANS-AIM TEXT PARA 5.3.1.1

“*To facilitate and support the use of exchange of digital data sets between data providers and data users, the ISO 19100 series of standards for geographic information should be used as a reference framework.*

Note.— Guidance material concerning the use of the ISO 19100 series of standards is contained in Doc 8126.”

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 section 5.9 of this Manual.

3.7.3.2 ICAO PANS-AIM TEXT PARA 5.3.1.2

“*A description of available digital data sets shall be provided in the form of 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 outlines the specifications for geographic data products. This may 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.”

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 note specifies a set of topics which must be addressed, as a minimum, within the DPS for terrain and obstacle data sets. The content of the DPS is the same as that provided in ISO 19131 [21]. The use of DPS and the purpose of each of the topics are discussed in section 5.2 of this Manual.

3.7.3.3 ICAO PANS-AIM TEXT PARA 5.3.1.3

"*The content and structure of digital data sets shall be defined in terms of an application schema and a feature catalogue.*

Note. — ISO Standard 19109 contains rules for application schema while ISO Standard 19110 describes the feature cataloguing methodology for geographic information."

Understanding of Requirement

This provision requires the content and structure of digital data set to be documented with an application schema and a feature catalogue. It applies to obstacle and terrain data sets. ISO 19109 [16] defines an application schema as a "conceptual schema for data required by one or more applications." The conceptual model of AIXM 5.1 is an information model (see section 3.7.4) providing an application schema for aeronautical information including obstacles whereas terrain data is defined as coverage outside the context of AIXM. Guidance on the data content and structure is provided in section 5.1 of this Manual.

3.7.4 AERONAUTICAL INFORMATION MODEL

3.7.4.1 ICAO PANS-AIM TEXT PARA 5.3.1.4

"The aeronautical information model used should encompass the aeronautical data and aeronautical information to be exchanged."

3.7.4.2 ICAO PANS-AIM TEXT PARA 5.3.1.5

"The aeronautical information model used should:

a) use Unified Modelling Language (UML) to describe the aeronautical information features and their properties, associations and data types;

b) include data value constraints and data verification rules;

c) include provisions for metadata as specified in 4.2.1 and 5.3.2; and

d) include a temporality model to enable capturing the evolution of the properties of an aeronautical information feature during its life cycle."

Understanding of Requirement

An aeronautical information model is an abstract, formal representation of entity types, including their properties and relationships. The entity types in the model are real-world objects, such as obstacles, or they may themselves be abstract, such as organisations or services.

AIXM 5.1 with its different components (UML, business rules, and temporality concept) is an aeronautical information model fulfilling the provisions specified in 5.3.1.5 a) – d). Details can be found on the AIXM Website www.aixm.aero.

3.7.5 AERONAUTICAL DATA EXCHANGE MODEL

3.7.5.1 ICAO ANNEX 15 TEXT PARA 2.3.10

"Globally interoperable aeronautical data and aeronautical information exchange models shall be used for the provision of data sets.

Note 1.— Specifications concerning globally interoperable aeronautical data and aeronautical information exchange models are contained in the Procedures for Air Navigation Services — Aeronautical Information Management (PANS-AIM, Doc 10066).

Note 2.— Guidance material on globally interoperable aeronautical data and aeronautical information exchange models is contained in Doc 8126."

3.7.5.2 ICAO PANS-AIM TEXT PARA 5.3.1.6

"The aeronautical data exchange model used should:

a) apply a commonly used data encoding format;

b) cover all the classes, attributes, data types and associations of the aeronautical information model detailed in 5.3.1.5; and

c) provide an extension mechanism by which groups of users can extend the properties of existing features and add new features which do not adversely affect global standardization.

Note 1.— The intent of using a commonly used data encoding format is to ensure interoperability of aeronautical data exchange between agencies and organizations involved in the data processing chain.

Note 2.— Examples of commonly used data encoding formats include Extensible Markup Language (XML), Geography Markup Language (GML) and JavaScript Object Notation (JSON)."

Understanding of Requirement

AIXM 5.1 fulfils these provisions: XML/GML is used as data encoding format, the XML schema is automatically derived from the UML, therefore covering all classes, attributes and associations of the information model and AIXM provides an extension mechanism.

Therefore, the preferred data exchange model for obstacle data is AIXM 5.1. Not all States are able to provide obstacle data AIXM 5.1 data sets. Alternative formats used are CSV files or proprietary but documented GIS-formats such as ESRI® Shapefile.

As already mentioned before, AIXM 5.1 does not encompass terrain data. Commonly used terrain data exchange formats are listed in Appendix D. See section 5.1.2 for more information on terrain information and exchange models.

3.7.6 DATA SET UPDATES

3.7.6.1 ICAO ANNEX 15 TEXT PARA 6.3.3.1

"Data sets shall be amended or reissued at such regular intervals as may be necessary to keep them up to date."

Understanding of Requirement

ICAO Annex 15 requirement to amend or reissue data sets at "regular intervals as may be necessary to keep them up to date" is kept very general and does not specify an update frequency for terrain or obstacle data. The State is left to determine its own policy.

The interval at which an obstacle or terrain data set has to be amended or reissued depends on the frequency at which the data changes. The obstacle situation may change daily with every obstacle that is raised or torn down whereas changes of the terrain are less frequent. As data sets cannot be reissued with every new obstacle, intermediate changes must be announced to the users by NOTAM.

The availability of up-to-date obstacle data is especially relevant in the vicinity of aerodromes, since operational take-off performance calculations fully depend on proper obstacle information reflecting the current reality. Section 4.4.9 provides guidance on the maintenance of obstacle and terrain data.

3.7.6.2 ICAO PANS-AIM TEXT PARA 6.1.5.1

"The update interval for the digital data sets shall be specified in the data product specification."

Understanding of Requirement

The requirement to specify the update interval for obstacle and terrain data sets in the DPS (see section 5.2) is considered to be self-explanatory.

3.7.6.3 ICAO ANNEX 15 TEXT PARA 6.3.3.3

"Recommendation.— When made available as a completely reissued data set, the differences from the previously issued complete data set should be indicated."

Understanding of Requirement

Guidance is found in the Obstacle Data Set Coding guidelines on the AIXM Confluence website, under Common Interoperability Rules.

3.7.6.4 ICAO PANS-AIM TEXT PARA 6.1.5.2

"Data sets that have been made available in advance (according to the AIRAC cycle) shall be updated with the non-AIRAC changes that occur between the publication and the effective date."

Understanding of Requirement

Information concerning terrain and obstacles is not in the list of information in ICAO Annex 15 that must be distributed under the AIRAC system. Although this provision is not relevant for terrain and obstacle data sets, it is preferable to follow AIRAC as much as possible. Due consideration is needed for obstacle owners as it is not entirely possible to follow AIRAC, which does therefore have an effect on the updates of data sets.

3.7.7 REMOVAL OF OBSTACLE TABLES FROM THE AIP

3.7.7.1 ICAO PANS-AIM TEXT PARA 5.2.1.1.4

"When the Obstacle Data Set (as specified in 5.3.3.2.2) is provided, the following sections of the AIP may be left blank and a reference to the data set availability shall be provided:

a) ENR 5.4 Air navigation obstacles;

*b) ****AD 2.10 Aerodrome obstacles; and*

*c) ****AD 3.10 Heliport obstacles."*

Understanding of Requirement

The appropriateness of removing the obstacle tables in ENR 5.4 and in AD 2.10/AD 3.10 from the AIP 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. It should also be considered that there might be users who are not (yet) able to decode digital data sets and rely on the AIP publications. It is therefore suggested that all AIP subscribers be consulted in a survey if they agree with the removal of certain tables.

3.7.8 ANNOUNCEMENT OF THE TOD AVAILABILITY IN THE CONTENTS OF THE AIP

According to ICAO PANS-AIM Appendix 2 "Contents of the Aeronautical Information Publication (AIP)" the availability of terrain and obstacle data sets has to be announced in the national AIP in section GEN 3.1.6:

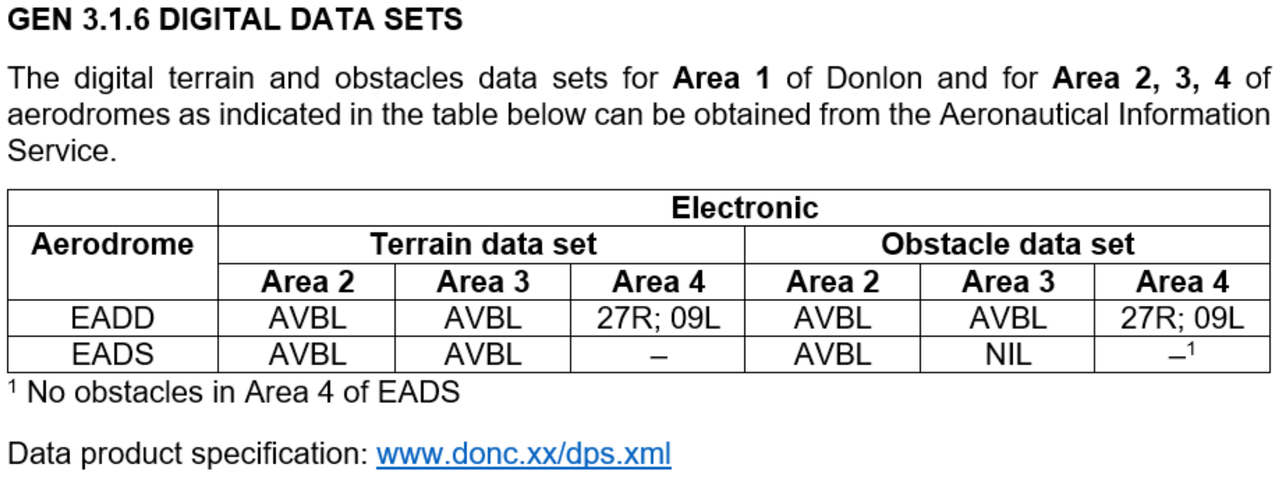
*"**GEN 3.1.6 Digital data sets***

Description of the available data sets, including:

1) *data set title;*
2) *short description;*
3) *data subjects included;*
4) *geographical scope; and*
5) *if applicable, limitations related to its usage.*
6) *Contact details of how data sets may be obtained, containing:*
    a) *name of the individual, service or organization responsible;*
    b) *street address and e-mail address of the individual, service or organization responsible;*
    c) *telefax number of the individual, service or organization responsible;*
    d) *contact telephone number of the individual, service or organization responsible;*
    e) *hours of service (time period including time zone when contact can be made);*
    f) *online information that can be used to contact the individual, service or organization; and*
    g) *supplemental information, if necessary, on how and when to contact the individual, service or organization."*

The description according to items 1) to 6) is considered insufficient for users to understand the full content of an available dataset. Therefore it is recommended that in addition to the items specified in ICAO PANS-AIM Appendix 2, GEN 3.1.6 should also provide a link to the Data Product Specifications (see section 5.2) 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). GEN 3.1.6 can also provide a link direct to the dataset or an online platform hosting the dataset (if available) in point 6(g).

An example for the announcement of TOD datasets in GEN 3.1.6 is presented below:



GEN 3.1.6 DIGITAL DATA SETS

The digital terrain and obstacles data sets for **Area 1** of Donlon and for **Area 2, 3, 4** of aerodromes as indicated in the table below can be obtained from the Aeronautical Information Service.

Aerodrome	**Electronic**					
	Terrain data set			**Obstacle data set**		
	Area 2	**Area 3**	**Area 4**	**Area 2**	**Area 3**	**Area 4**
EADD	AVBL	AVBL	27R; 09L	AVBL	AVBL	27R; 09L
EADS	AVBL	AVBL	–	AVBL	NIL	–[1]

[1] No obstacles in Area 4 of EADS

Data product specification: www.donc.xx/dps.xml

Figure 13: Example of Announcement of TOD Availability in AIP

In addition to the announcement on the availability of TOD data sets in GEN 3.1.6, States may include:

- An indication in ENR 5.4 that a list of obstacles affecting air navigation in Area 1 is available in electronic form, and a reference to GEN 3.1.6 (mandatory if the obstacle tables are omitted).
- An indication in ***AD 2.10 and ***AD 3.10 that Obstacle Data for Area 2 and 3 is available in electronic form, and a reference to GEN 3.1.6 (mandatory if the obstacle tables are omitted).
- 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.
- An indication in the Precision Approach Terrain Chart (PATC) of the availability of Area 4 eTOD and a reference to GEN 3.1.6.

4. IMPLEMENTATION MATTERS

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

4.1 ATM MASTERPLAN LEVEL 3 OBJECTIVE INF07 ETOD

The ECAC States agreed to set up ATM Master Plan Level 3 implementation objective INF07 Electronic Terrain and Obstacle Data (TOD) to aid the States in establishing a robust framework that will ensure the timely provision of the eTOD.

Accordingly, the States need to assess existing national regulations and policies, including the safeguarding of aerodromes and obstacle permission processes, in order to evaluate their suitability in relation to the electronic terrain and obstacle data requirements of ICAO Annex 15 [4], and to allocate responsibilities.

In addition, States will need to create capabilities for the origination, collection, exchange, management and distribution of the digital terrain and obstacle information in the form of digital data sets. This implies the establishment of efficient and reliable processes (e.g. data acquisition, cross-border provision, data validation and verification, data maintenance, data storage, data transmission, and oversight, etc.), ensuring the provision of up-to-date data which meets the operational requirements in support of an enhanced overall situational awareness and separation assurance and at the same time complies with the requirements of ICAO SARPs and relevant EU regulations [42].

The objective consists of several Stakeholder Lines of Action (SloA) for State regulators (REG), ANS Providers (ASP) and Aerodrome Operators (APO). The cornerstone of this objective is the establishment by the State regulator of National TOD policy in close coordination with the main TOD stakeholders identified at national level, e.g. National Geodetic Authority, Aerodrome Operators, Air Navigations Services Provider, etc.

During development of the National TOD Policy, agreeing on certain points, the REG, ASP and APO can already begin the planning and implementation of the activities required by the policy, without the need to wait for the State regulator to enforce it through the regulatory framework, because in some cases this can take up to 3 years. However, the agreement in the National TOD Policy serves as a guarantee that the agreed roles and responsibilities will become part of the regulatory framework in due course.

4.2 TOD POLICY PROCESS

4.2.1 NATIONAL TOD POLICY

The National TOD policy is not a regulation, but a course, plan or principle of action for TOD implementation at national level agreed by all parties concerned (regulators, ANS providers, aerodrome operators, national geodetic authorities, etc.).

The main objective of the National TOD Policy is to ensure that the State regulator, in coordination with all affected TOD stakeholders, agrees to the respective roles and responsibilities, as well as the necessary actions for implementation.

For each specific dataset and TOD coverage area concerned, the National TOD Policy should cover the following main topics:

Scope:

- National, international and industry quality/numerical requirements for TOD collection (e.g. surfaces) and provision that will be applicable in the State. It should set out whether existing data is compliant with these requirements, highlighting any existing differences.
- Aerodromes involved (except Area 1)
- Stakeholders involved

Definition of roles and responsibilities for TOD stakeholders with regard to:

- Collection
  - Data sources (provider, liability, cost model, licensing, formal arrangements)
  - Regulation of data sources (survey formats, requirements, contracts, vetting)
- Validation and verification of new data and assessment of existing data
- Repository
- Maintenance (including periodicity)
- Provision (data exchange formats, means/media, cross-border provision issues, where appropriate)
- Oversight mechanism (progress monitoring and audit)

Cost-recovery and charging mechanisms:

- Cost recovery, including initial and ongoing costs
- Charging mechanisms

The National TOD Policy will also set out the milestones and tasks of TOD stakeholders and an implementation timeline.

To support the activities described above, a National TOD Policy Template has been developed and can be found at Appendix C to this Manual. It is grouped by type of data, subdivided into sections defining the scope, roles and responsibilities, cost-recovery and charging mechanisms. This chapter follows the structure of the policy template and provides guidance for the different sections.

It is important to note that the contents of the National TOD Policy template are not intended to be mandatory or exhaustive. A State may choose to modify and/or include whichever sections and information it deems appropriate.

4.2.2 IDENTIFICATION OF STAKEHOLDERS AND AWARENESS

It is important that all the stakeholders impacted 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 responsibilities and develop a feasible plan for the implementation of terrain and obstacle data.

It is recommended to hold a national awareness day or a series of regional seminars to raise stakeholder 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. Attendance by staff from the following organisations should be considered, although 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 to share experiences and best practices associated with terrain and obstacle data for the common good.

The awareness sessions may cover the following topics:

- The history of terrain and obstacle data;
- The terrain and obstacle data requirements;
- An overview of System-Wide Information Management/AIM and how terrain and obstacle data support this;
- The uses of terrain and obstacle data;
- GIS and survey techniques;
- Feature capture rules;
- Institutional issues;
- Data sources;
- Responsibilities;
- The way forward.

4.2.3 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 coordinated 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 civil and military AISP;
- The civil and military ANSP;
- Civil and military procedure design authority;
- The regulator;
- The Ministry of Transport;
- The State civil and military survey organisations;
- 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 in the State such as:

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

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.

4.2.4 MONITORING/AUDIT OF IMPLEMENTATION

The State Supervisory Authority should:

- *Verify the regulatory compliance of TOD implementation:* The verification of compliance with the regulatory TOD requirements through oversight and acceptance of TOD implementation for data origination, collection, verification and validation, management and provision based on the international TOD requirements and the State TOD regulatory framework;
- *Establish oversight of TOD implementation:* considering how monitoring its progress can meet regional/international oversight monitoring obligations (e.g. ICAO Regional Air Navigation Plan [15]) and developing a plan for auditing the organisations concerned.

The following lines of action are to be monitored for the TOD stakeholders concerned:

<u>Actions by State Authorities:</u>

- *Establish the TOD regulatory framework:* based on the agreed State policy by drafting or updating national rules and regulations affecting the provision of TOD (e.g. the suitability of the existing national safeguarding policy for obstacle development in all four areas in relation to electronic obstacle data requirements or origination responsibilities and processes).
- Where appropriate, State laws should be amended to ensure timely implementation.

<u>Actions by ANS Providers and Aerodrome Operators:</u>

- *Plan the activities required for the collection, management and provision of TOD in accordance with national TOD policy:* in close coordination with the State authorities and related TOD stakeholders, analyse the current environment and develop a plan/roadmap demonstrating the feasibility of achieving the necessary steps to enable the collection (where applicable), management and provision of electronic terrain and obstacle data in accordance with the State TOD policy. Implementation planning should cover the following topics, as applicable:
  - System change;

  - Change management;
  - Process development;
  - Migration of processes and data;
  - Data validation and verification;
  - Financial and human resources;
  - Performance monitoring;
  - Risk management;
  - Compliance management;
  - Training.
- *Implement the collection, management and provision of TOD in accordance with the national TOD policy and regulatory framework*: adjust the related operational system (i.e. people, equipment and procedures) to ensure the collection (where applicable), management and provision of TOD in accordance with the State TOD policy and regulatory framework.

4.3 TOD POLICY SCOPE

4.3.1 SCOPE

The scope should be documented in relation to the collection, processing and provision of electronic terrain and obstacle data. As such, the following should be mentioned:

- Area 1 coverage, including more information if it covers only part of the territory
- Area 2 coverage, including the subdivisions of terrain and obstacle data sets, if applicable, e.g. provision of Area 2a, 2b, 2c and 2d or only Area 2a, the take-off flight path area, an area bounded by the lateral extent of the aerodrome obstacle limitation surfaces and aerodrome obstacle limitation surfaces
- Area 3 coverage, including any statement related to the provision of TOD for this area
- Area 4 coverage

Moreover, the obstacle collection surfaces for each specific coverage area should be described. These collection surfaces could differ from the ICAO requirements to cover additional specific applications (see Chapter 2) or different requirements. For example, Switzerland requires that all structures higher than 25 m outside built-up area or more than 60 m inside a built-up area to be submitted to the civil aviation authority.

It is important to note that 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 for all aerodromes designated as international in the National AIP section AD 1.3 – ‘Index to aerodromes and heliports’ is now a Recommended Practice and only the part of Area 2 specified in para 5.3.3.4 is required minimal standard.

It should be noted that the text of ICAO Annex 15 on obstacle data sets in Chapter 5.4.3 leaves it to the States to decide to which aerodromes the Standards (5.3.3.4.5) should be applied, and to which the Recommended Practice (5.3.3.4.6) should be applied.

In the light of the ICAO plans for the move towards the introduction of APV and Performance Based Navigation (PBN) and an increased need for the provision of terrain and obstacle data for those aerodromes where these are being implemented, it is recommended that priority for implementation of 10.1.7 be given to those aerodromes where the establishment of APV and PBN is planned. Such an approach would allow a gradual implementation of Area 2, with effort being focussed on those aerodromes where the greatest benefits could be gained

4.3.2 QUALITY AND NUMERICAL REQUIREMENTS FOR TOD

The quality and numerical requirements for electronic terrain and obstacle data should be documented based on the applicable national and international regulations. If applicable, additional requirements (e.g. resulting from specific applications requirements – see Chapter 2) should be documented as well as statements about the (non) compliance of the provided/available sets of electronic terrain and obstacle data.

4.3.3 APPLICABLE REGULATIONS

The applicable regulations should be documented and assessed, i.e. ICAO, European Community and other existing international and national regulations applicable to electronic terrain and obstacle data in the State. Additional references to other standard-making organisations' requirements, e.g. EUROCAE, should be stated.

Where existing national regulation is not considered sufficient, the application of new regulation to allocate responsibilities should be considered.

4.3.3.1 STATE POLICY ON AERODROME SAFEGUARDING

It is recommended that the State policy for the safeguarding of aerodromes (requirements from ICAO Annex 14 [3]) 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 be established.

Examples of best practice that are used as references by many States are UK CAA's CAP 738 [47] and CAP 1732 [48].

4.3.3.2 STATE POLICY ON OBSTACLE PERMISSION PROCESS

The policy on aerodrome safeguarding should form an intrinsic part of the obstacle permission process as there is the possibility of different data flow processes considering the area of coverage for both terrain and obstacle data. For example, an Area 1 originator (e.g. a building owner) may deliver data to the local planning authority for obstacle assessment, while an Area 2 originator (e.g. an aerodrome) may deliver to the aerodrome safeguarding authority for obstacle assessment.

The main objective of the obstacle permission process is to evaluate the effect of a structure construction or alteration of an obstacle on operational procedures and determination of the possible hazardous effect on air navigation. It is recommended that States assess any obstacle permission process that exists to confirm that it is sufficient to ensure that the obstacles within the scope of ICAO Annex 15 and PANS-AIM are managed effectively.

If the process is deficient, it should be updated. If there is no obstacle permission process, one should be developed. It is strongly recommended that any such obstacle permission process be introduced within the State as a legal requirement.

The objective of an obstacle permission process in the State is to evaluate the effect of the construction/alteration on operational procedures, to determine the possible hazardous effects on air navigation. The process may include an aeronautical study and should result in a decision and/or recommendation for marking and lighting or other measures to support the continued safety of air navigation. 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 legal channels.

Besides the obstacle permission process, the State should consider a process on reporting existing obstacles which were not included in the national database or reflected in aeronautical information products.

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

4.3.3.2.1 GENERIC OBSTACLE PERMISION PROCESS

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 provided. It is difficult, if not impossible, to define a process which can be applied uniformly 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 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 provides the means for aviation to assess the suitability of a request to build an obstacle, recognising that aviation may decline permission. 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 rigour 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 cannot be built or extended without prior permission, then the need for a check-survey may be reduced.

The obstacle permission process is illustrated in Figure 14 below 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 below does not identify the actors involved, with the exception of the owner with initial responsibility for notifying an intention to construct/change/remove a structure. However, the actors involved in the process usually consist of local planning authority, the civil aviation authority, the air navigation service provider, the aerodrome authority, the military authority, etc.

Such assessments will generally be the same across a given 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 it to its particular situation.

An example of best practice is the Federal Regulation Title 14 Part 77, issued by the US Federal Aviation Administration (FAA) that establishes standards and notification requirements for objects affecting navigable airspace.

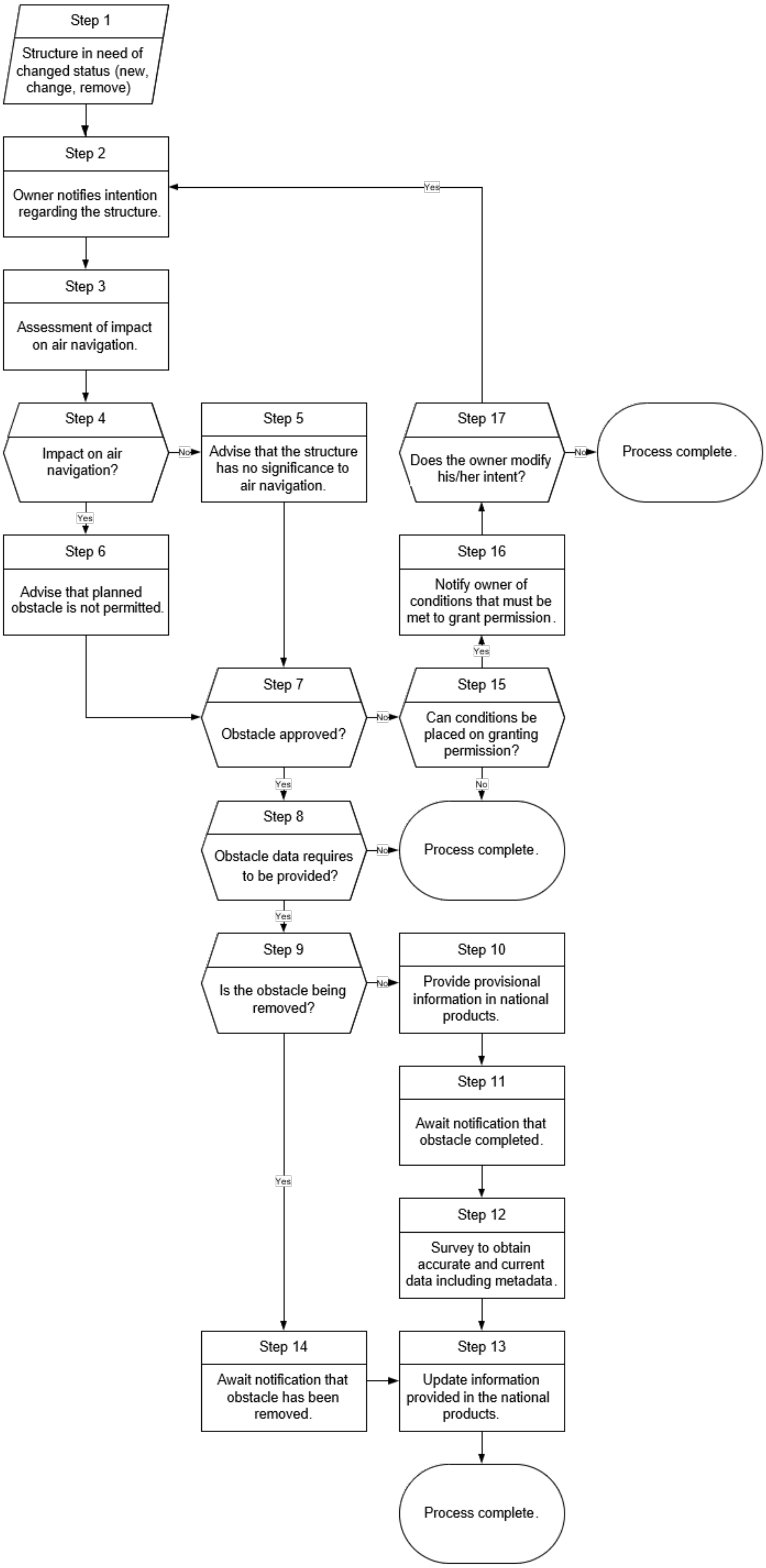

Step 1
Structure in need of changed status (new, change, remove)
Step 2
Owner notifies intention regarding the structure.
Step 3
Assessment of impact on air navigation.
Step 4
Impact on air navigation?
No
Step 5
Advise that the structure has no significance to air navigation.
Yes
Step 6
Advise that planned obstacle is not permitted.
Step 7
Obstacle approved?
No
Step 15
Can conditions be placed on granting permission?
Yes
Step 16
Notify owner of conditions that must be met to grant permission.
Step 17
Does the owner modify his/her intent?
Yes
No
Process complete.
No
Process complete.
Yes
Step 8
Obstacle data requires to be provided?
No
Process complete.
Yes
Step 9
Is the obstacle being removed?
No
Step 10
Provide provisional information in national products.
Step 11
Await notification that obstacle completed.
Step 12
Survey to obtain accurate and current data including metadata.
Yes
Step 14
Await notification that obstacle has been removed.
Step 13
Update information provided in the national products.
Process complete.

Figure 14: Obstacle Permission Process

4.3.3.2.2 STEP 1

The process begins with identification by the owner to change a structure's status, e.g. build a new structure, change the size of an existing obstacle or 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.

4.3.3.2.3 STEP 2

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

It is highly likely that such notifications will be made to a non-aviation body, i.e. the appropriate local planning authority, as part of the State's planning processes. The planning authority is the function within the State which is tasked with granting approval for building construction. Typically, it exists at a local level, e.g. a city or regional council.

Consequently, mechanisms will need to be established whereby the planning authority passes relevant information to the civil aviation or military authority for structures in identified locations or with specific heights to the aviation authorities. For example, a State may require that all planned constructions equal to or more than 100 m AGL are to be submitted to the civil aviation authority.

Such structures that may impact air navigation have to be notified accordingly by the planning authority or owner.

4.3.3.2.4 STEP 3

An assessment must be undertaken to determine whether the planned operation will impact air navigation. This assessment must include all relevant actors, such as regulators, aerodrome authorities ANSP and neighbouring States.

An important aspect is the location of the structure, i.e. if it is penetrating an OLS. If the structure penetrates the OLS, then the structure is considered an obstacle and the assessment is performed by the aviation authority in charge; otherwise, not. However, there are cases when the structure outside the OLS is eventually a hazard to air traffic safety and impacting air navigation (e.g. power line lower 100 m AGL on a mountain ridge.). Then the assessment may be performed by the aviation authority.

The impact assessment should consider not only the penetration of OLS, but also any negative impacts that may be seen on other relevant actors and their aviation infrastructure and operations, such as CNS on ILS, navigation and surveillance infrastructure and operations, ICAO PANS-OPS on flight procedures, aerodrome operator on safeguarding, etc. 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 (see section 4.4.11).

4.3.3.2.5 STEP 4

The assessment conducted should determine whether there might be a negative impact on air navigation.

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

4.3.3.2.6 STEP 5

The planning authorities should be advised if the structure has no significance for air navigation.

4.3.3.2.7 STEP 6

The planning authorities should be advised that the structure has a negative impact on air navigation and thus, it is considered to be an obstacle. This should include details of the impact foreseen and the resultant effect on air navigation.

4.3.3.2.8 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. The decision of the aviation authority(ies) on the obstacle assessment should have an influence in the permission by the local planning authority. Also, the same relevant authority(ies) should decide if there are any obligations or conditions regarding the structure such as requiring lighting and/or marking.

Despite being advised that the structure has an impact on air navigation, there is no guarantee that the planning authorities will reject the construction of the structure.

If permission is not granted, go to Step 15.

4.3.3.2.9 STEP 8

Given the information about the obstacle, it must be determined if the information should be included in/removed from the appropriate national aeronautical information products. This decision will be based upon the extent and location of the obstacle as assessed in Step 3.

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

4.3.3.2.10 STEP 9

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

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

4.3.3.2.11 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 should be provided in the appropriate national aeronautical information products and any other affected information, such as flight procedures, updated accordingly.

Special consideration should be given to obstacle constructions. For example, a crane is often set up higher than the final height of the construction. The height of the crane also needs to be taken into consideration when assessing the negative impact on air navigation in Step 3.

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.

It is recognized that the obstacle permission process is not entirely able to follow AIRAC dates. However, it is preferable, where possible, that the provision of the obstacle information in the aeronautical information products is planned in accordance with the AIRAC system at the earliest possible phase (e.g. at Step 7).

For that reason, the obstacle start of effectivity may be used to indicate in the appropriate aeronautical information products (i.e. data sets, AIP, charts) the point in time at which the obstacle should be considered to exist, from an operational perspective, whether it does so or not.

If the planning according to the AIRAC system is not possible, NOTAM should be used to reflect the stage of the obstacle. For example, the construction of high-rise buildings might take many months. Thus, it would be inefficient to provide the final height of such an obstacle in the beginning of the constructions. In this case the owner needs to report on the different stages of advancement of the obstacle construction.

4.3.3.2.12 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 construction of the obstacle has been completed.

4.3.3.2.13 STEP 12

The obstacle permission process should place a mandatory requirement after completion of the construction/removal/alteration for a survey during which its vertical and horizontal extents are measured and all the associated metadata is captured. Once again, any other related information, such as flight procedures, may need to be checked/recalculated to take into account the actual obstacle dimensions.

4.3.3.2.14 STEP 13

The provisional information as provided in Step 10 must be updated to reflect the information obtained through survey after completion of the change and then, notified for AIRAC publication.

The obstacle is provided in the aeronautical information products. The process ends at this step.

4.3.3.2.15 STEP 14

At a given point in time, the obstacle will be removed. The obstacle end of effectivity may be used to indicate the last point in time when the aeronautical information is valid from an operational perspective. The actual structure may have been removed before the effective end and therefore, as with the effective start, the aeronautical information may not fully reflect reality, but it is considered to be operationally correct.

For that reason, the obstacle permissions process should place a mandatory requirement on the obstacle owner to confirm demolition is complete and that this is notified for updates of the aeronautical information products.

4.3.3.2.16 STEP 15

As the planned obstacle would impact air navigation, consideration should be given to whether any special conditions may be stipulated which modify the intent of the obstacle owner and remove said impact, thus allowing permission to be given. Such measures may consist of limitations of height, location, etc.

If there are no conditions to be placed on the planned structure which will allow construction without impacting air navigation, then the permission is not granted and the process ends with this step.

4.3.3.2.17 STEP 16

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

4.3.3.2.18 STEP 17

The obstacle owner may wish to amend the planned structure 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.

4.3.3.3 STATE POLICY ON OBSTACLE IDENTIFICATION

As each obstacle collected needs to be assigned an identifier, it is recommended that this is a unique identifier, such that each obstacle will be distinguishable by a single identification throughout its life cycle and that this will not be reused. The identifier can be alphabetical, numerical or alphanumerical.

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. The policy should be documented in a national regulation for allocation of obstacle identifiers, made accessible to all who require access to it and applied consistently.

It is also recommended that a register of obstacle identifiers be 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 5.8.1.

4.3.4 AERODROMES REQUIRED TO PROVIDE TOD

The TOD policy should identify the aerodromes that should provide TOD. It should include as a minimum, the aerodromes publishing Aerodrome Obstacle Charts Types A/B in national AIPs as well as all aerodrome runways with CAT II/III operations. The list could be supplemented with information if the aerodrome is to provide Area 2a, 2b, 2c and 2d or Area 2a, the take-off flight path area, an area bounded by the lateral extent of the aerodrome obstacle limitation surfaces.

It should also include those aerodromes where the provision of electronic terrain and obstacle data for Area 3 is considered useful in conjunction with the provision of aerodrome mapping data.

4.4 TOD FUNCTIONS AND RESPONSIBILITIES

4.4.1 IDENTIFICATION OF RESPONSIBLE BODY

It is believed that the identification of a responsible body for the coordination of terrain and obstacle data implementation is an important, initial step for successful implementation. This will help ensure that the necessary actions are taken and implementation is progressed. Where no responsible body is identified, the risk is that implementation will stall, and if it does go ahead, 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 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 parties other than, for example, the AISP.

4.4.2 LIABILITY

Similarly, as for aeronautical data, the parties involved in TOD process, 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. By capturing and maintaining adequate traceability of data from its point of origination to publication, the cause of the error can be detected and liability can therefore be attributed accordingly.

4.4.3 OVERVIEW OF TOD FUNCTIONS

There are different parties performing different functions in the TOD process. The following two diagrams show an overview of these functions for the obstacle and terrain data process.

In this chapter, the data flow processes in a State are presented at a generic level focussing on roles, functions and entities. Therefore, adaptation considering the national framework and structure is essential. Further guidance on each function can be found in this guidance material.

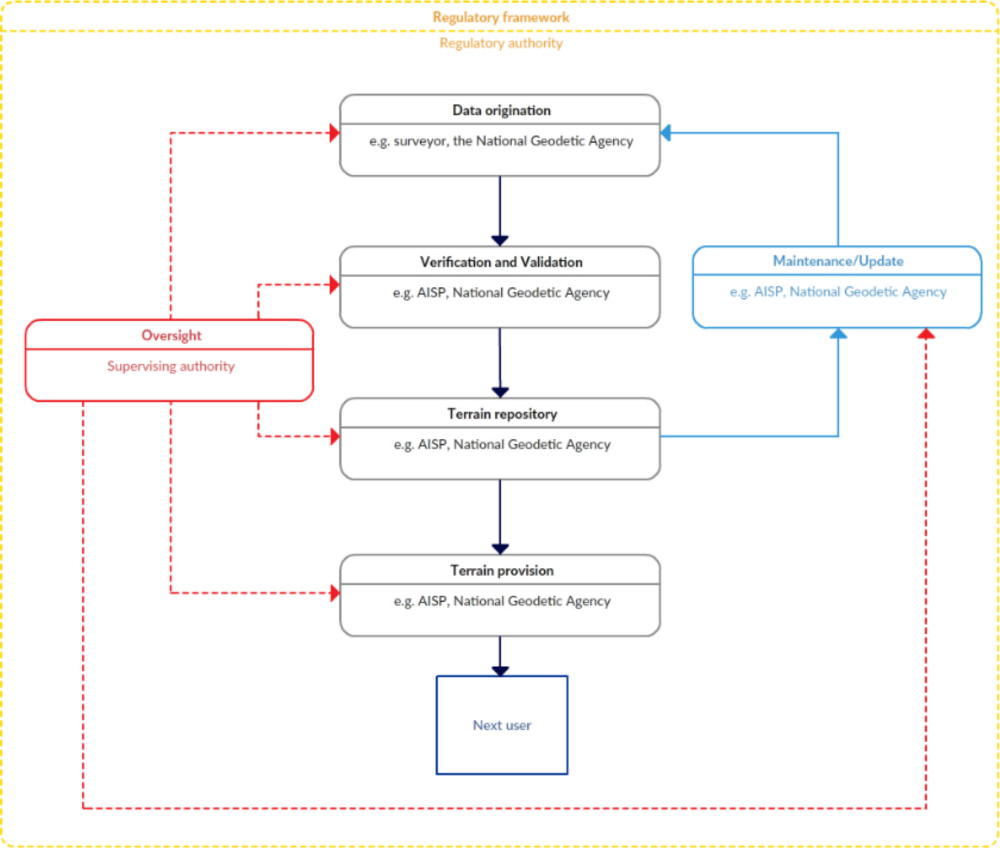

Regulatory framework
Regulatory authority
Data origination
e.g. surveyor, the National Geodetic Agency
Verification and Validation
e.g. AISP, National Geodetic Agency
Maintenance/Update
e.g. AISP, National Geodetic Agency
Oversight
Supervising authority
Terrain repository
e.g. AISP, National Geodetic Agency
Terrain provision
e.g. AISP, National Geodetic Agency
Next user

Figure 15: Functions for the Terrain Data Process

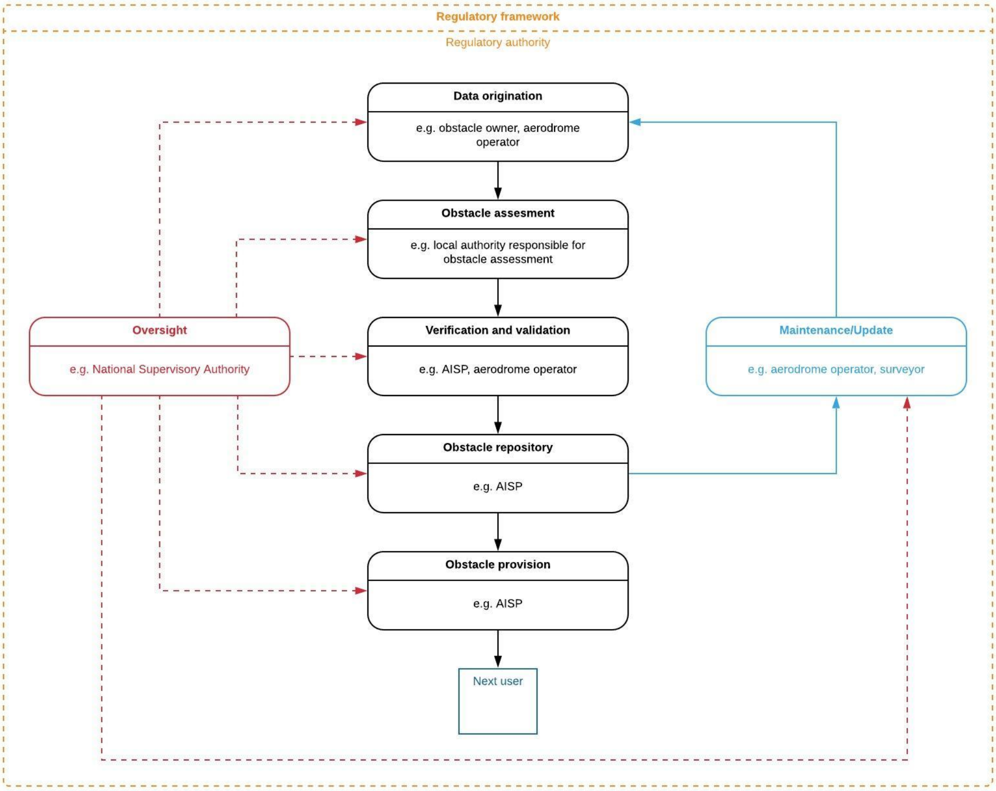
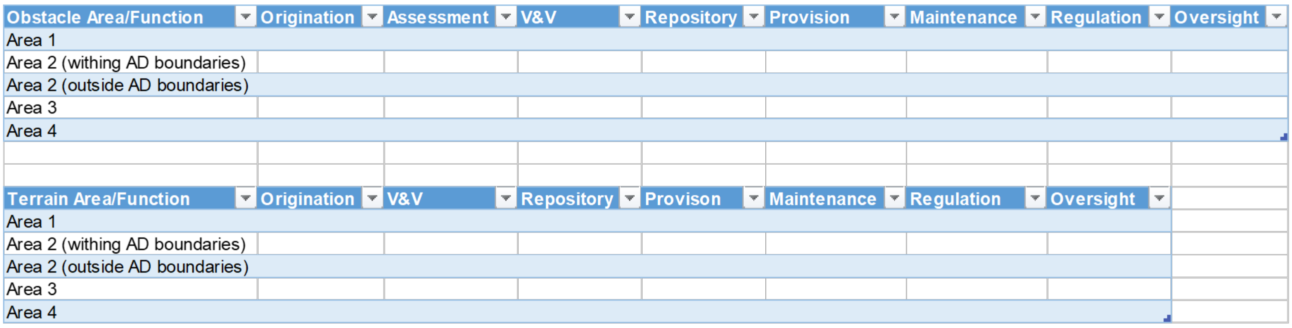

Regulatory framework
Regulatory authority
Data origination
e.g. obstacle owner, aerodrome operator
Obstacle assesment
e.g. local authority responsible for obstacle assessment
Oversight
e.g. National Supervisory Authority
Verification and validation
e.g. AISP, aerodrome operator
Maintenance/Update
e.g. aerodrome operator, surveyor
Obstacle repository
e.g. AISP
Obstacle provision
e.g. AISP
Next user

Figure 16: Functions for the Obstacle Data Process

It is beneficial for the sake of clarity to provide a list of the functions and roles required for terrain and obstacle data in the State in the national policy, as in the figure below. For each area, functions for the collection, processing and provision of data need to be determined by naming the responsible entity.



Obstacle Area/Function	Origination	Assessment	V&V	Repository	Provision	Maintenance	Regulation	Oversight
Area 1								
Area 2 (withing AD boundaries)								
Area 2 (outside AD boundaries)								
Area 3								
Area 4								

Terrain Area/Function	Origination	V&V	Repository	Provison	Maintenance	Regulation	Oversight
Area 1							
Area 2 (withing AD boundaries)							
Area 2 (outside AD boundaries)							
Area 3							
Area 4							

Figure 17: List of Functions and Roles for Terrain and Obstacle Data

4.4.4 REGULATION

The organisation responsible for the development of national civil aviation regulatory framework for terrain and obstacle data, e.g. Civil Aviation Authority, should be identified and mandated.

4.4.5 DATA ORIGINATION

The State’s approach to electronic terrain and obstacle data origination should be documented as follows:

- For terrain data: the organisation responsible for the survey of terrain and provision of quality-assured data, e.g. surveyor, aerodrome operator, National Geodetic Agency
- For obstacle data: the organisation responsible for or owning objects in accordance with the national obstacle permission process and organisation responsible for the survey of obstacles and provision of quality-assured data
    - The data origination entity in the data process is considered to be the organisation responsible for the obstacle in the national obstacle permission process. Different organisations may be responsible for obstacle data, for example:
        - Area 1: obstacle owner;
        - Area 2: aerodrome operator, obstacle owner, ANSP;
        - Area 3, 4: aerodrome operator.
    - The actual origination of the obstacle is done by surveying the obstacles and providing quality-assured data to the responsible organisation.

4.4.5.1 DATA SOURCES

Appropriate State representatives should assess the data sources and/or originators that currently exist within the State to assess if the data could be used to meet the terrain and obstacle data requirements of ICAO Annex 15 and PANS-AIM. 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 be held with these organisations. Discussions should take place on the feature capture rules to be applied (see Appendix B for guidance), data liability 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 regard 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 be established between the data provider and the recipient. According to ICAO Annex 15, States must 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. National regulations may include the appropriate requirements for data provision in the State.

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, data source provider information, survey requirements, liability etc. In addition, it is important that the standards which the data sources and/or originators should adhere to are captured in the arrangement. This could include EUROCONTROL-SPEC-154 [33], a means of compliance to ensure that these provisions are adhered to and that the originators have sufficient knowledge of surveying airports.

4.4.5.2 FORMAL ARRANGEMENTS

The formal arrangements in place should be documented as they are related to the provision of electronic terrain and obstacle data established between the data source providers and the receiving body.

4.4.5.3 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. EUROCONTROL-SPEC-154 [33] is also applicable for TOD surveys.

The standards to be applied by the surveyors, for example the feature capture rules, should be agreed and defined by the State and documented. 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.

See section 5.1, 5.3 and Appendix B for further information regarding survey and feature capture rules.

An example of best practice of national survey requirements is the UK CAA CAP 1732 [48].

4.4.6 OBSTACLE ASSESSMENT

The organisation(s) responsible for the obstacle assessment should be identified and mandated. This organisation(s) should assess the effects of erected objects on aviation infrastructure which should be taken into consideration in the obstacle permission process, e.g. local planning authority, aerodrome safeguarding authority, CNS infrastructure authority, ICAO PANS-OPS. The obstacle assessment is part of the obstacle permission process (refer to Chapter 4.4.6).

4.4.7 DATA VALIDATION AND VERIFICATION

The organisation responsible for the validation and verification of data should be identified and mandated, e.g. AISP, National Geodetic Agency, aerodrome operator.

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. See section 5.5 for further details on data validation and verification.

In addition, an assessment should be carried out to determine the suitability of existing data and how its quality can be verified and validated. It is highly likely, especially where a State elects to initially use legacy data, that full compliance with the requirements of ICAO will not be achieved. The following chapters give considerations to this subject.

4.4.7.1 LEGACY OBSTACLE DATA

Obstacles that were published before the introduction of TOD requirements often lack information about data quality, associated metadata, etc. Possible methods of obtaining the missing information consist of seeking the required information from:

- The owners or operators of the obstacles (e.g. utility companies for wind turbines and power lines, telecom for transmission towers): They usually have documentation about their constructions.
- The national or local authorities in charge of the obstacle permission process: they might have records of the approval act documenting the obstacle.

The quality of the obstacle data can then be validated by means of this information and documented with metadata. See section 5.5.8 for quality assessment of existing TOD.

If the required information does not exist, then the existing obstacle data should be annotated or explicitly identified as not meeting the quality requirements. A resurvey should be envisaged if the quality of relevant obstacles remains questionable.

When using data of obstacles that were published before the introduction of the TOD requirements it is important to note that sometimes AIP ENR 5.4 does not list all Area 1 obstacles. The sources mentioned in 4.4.5.1should be used to receive data of missing obstacles. Data from remote sensing satellites or from national survey campaigns can also be used to identify missing obstacles.

Once an obstacle data base is established, a tight obstacle permission and notification process, which is sufficiently enforced, should allow to keep it up-to-date. A notification system for pilots to report encountered obstacles missing on their charts or moving map displays will allow to further improve the completeness of the obstacle data base. See example of such a system in which pilots can report on missing, incomplete obstacles or markings and lightings.

4.4.7.2 USE OF DATA OF UNKNOWN OR DEFICIENT QUALITY

It is appreciated that, in some cases, it may be difficult to validate already available data as a result of a lack of other data sources against which the data may be validated (see section 5.5.8 for more details on quality assessment of existing obstacle data). 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, then they accept liability for its use.

If it is known that data does not fully meet the ICAO quality requirements, it is necessary for the State to file a difference and notify ICAO. Then the State should publish 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 (including product description and data quality reporting) and the DPS that the data does not fully meet the quality requirements, indicating where gaps exist between the SARPs and the data set provided. 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, not all the specifications of ICAO PANS-AIM Appendix 1 Table A1-6 and Table A6-2 are 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. "

Where information about the quality and traceability of all or parts of the data is not present because it is unavailable, this should be clearly indicated in the metadata associated with the data set.

4.4.8 DATA REPOSITORY

The organisation responsible for data storage should be identified and mandated, e.g. AISP, National Geodetic Agency, aerodrome operator.

4.4.9 DATA MAINTENANCE

The organisation responsible for data consistency (maintenance and update) with the evolution of the terrain and obstacle should be identified and mandated, e.g. surveyor, aerodrome operator, National Geodetic Agency, etc.

4.4.9.1 INTRODUCTION

ICAO defines the maintenance period for digital data sets as "at such regular intervals as may be necessary to keep them up to date". Yearly checks can be considered to meet the requirement for "regular intervals", as stated in the note to ICAO PANS-OPS [6] Part I, Section 3, Chapter 2, paragraph 2.6.2.1.

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 5.8 of this Manual.

4.4.9.2 PERIODICITY

4.4.9.2.1 OBSTACLES

The frequency of obstacle data maintenance has proven impossible to determine as the need for maintenance changes on a case-by-case basis. For example, a survey could be conducted 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, the following considerations below should be taken into account when establishing a maintenance and monitoring policy:

- **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.

Thus, when establishing a maintenance and monitoring policy, the surrounding area should be segmented to reflect the level of difficulty in identifying changes to the status of obstacles in the different areas.

- **The rigour of the obstacle notification policy**

  The obstacle permission process discussed in section 4.3.3.2 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.

  Problems arise, 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 air navigation.

  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.

- **The impact of obstacles in a region**

  There is little benefit in spending valuable time and financial resources on determining every obstacle that may have been constructed, amended or demolished in a region if, despite 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 to further segment the area around an aerodrome in order to identify, for each area, a minimum obstacle size (most likely height only). Obstacles above this height should then be monitored. Monitoring should then be carried out to determine if these minimum obstacle heights are still valid.

There are obvious links between these elements. 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 air navigation, an approach must be developed to identify such obstacles.

4.4.9.2.2 TERRAIN

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 movements 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 constructed for roads and bridges may be considered as terrain

changes[8].

It is proposed that the surrounding area be 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.

4.4.9.3 MONITORING POLICY

A monitoring policy should be developed for each aerodrome/heliport which lays down the approach to be taken to ensure that the terrain and obstacle data is maintained in such a way as to give a sufficiently high degree of confidence that it correctly reflects the current situation. It is recommended that this monitoring policy be applied on an individual aerodrome/heliport basis and agreed with the national regulator.

It should outline:

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

This policy may be included with the obstacle permission policy or the aerodrome safeguarding policy in a single 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 as well as on the periodicity situation outlined above.

The following provides examples of how terrain and obstacle maintenance and monitoring may be established:

- No maintenance:

  It is considered that the chances of terrain changing sufficiently and/or of an unknown obstacle of sufficient size to impact flight operations being erected are very minimal.

- Occasional inspection:

  It is considered that the chances of terrain changing sufficiently and/or of an unknown obstacle of sufficient size to impact flight operations being erected are minimal and, therefore, only occasional assessment, by visual means, is sufficient.

- Frequent monitoring:

  It is considered that the chances of terrain changing sufficiently and/or of an unknown obstacle of sufficient size to impact flight operations being erected is significant and, therefore, assessment on a frequent[9][10] basis is required.

- Frequent resurvey:

  The region is known to experience significant changes in terrain and/or to have significant building work which is highly likely to impact operations. A regular resurvey of this region is therefore considered essential.

Where resurveys are conducted, 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. Also, future

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[8] Whilst such constructions are man-made and, strictly speaking, should be considered as obstacles, the recommendation is that, for the sake of simplicity, earth works should be 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.

[9] The policy should define the frequency of monitoring, for example, weekly, visual assessment and yearly resurvey.

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

techniques and methods could better detect changes, e.g. machine learning techniques used on satellite images to automatically identify changes on land use, infrastructure, etc.

The policy could define what technique will be used for each level of maintenance, but this is not considered essential.

4.4.10 DATA PROVISION

The organisation responsible for the provision of data to next intended users should be identified and mandated, e.g. AISP, National Geodetic Agency, aerodrome operator. This organisation is in charge of the provision to the next-intended users, including the formats to be used and the means and media whereby the electronic terrain and obstacle data could be made available.

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 5.7 for further details about data accessibility.

4.4.11 CROSS-BORDER PROVISION OF DATA

The arrangements (to be put) in place with adjacent States for the exchange, provision and receipt of electronic terrain and obstacle data should be documented. They might affect the civil aviation infrastructure, e.g. aerodromes located close to the border with obstacle limitation surfaces extending into the adjacent State, wind farms or other obstacles close to the border. Arrangements could include sharing the survey costs or use of the same survey company, all with the intention of reducing the cost of data acquisition.

4.4.11.1 INTRODUCTION

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.

In some cases, Area 2 for an aerodrome can extend into the territory of another State (Figure 18 shows the Area 2 of Euroairport Basel-Mulhouse extending into France, Switzerland and Germany). 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.

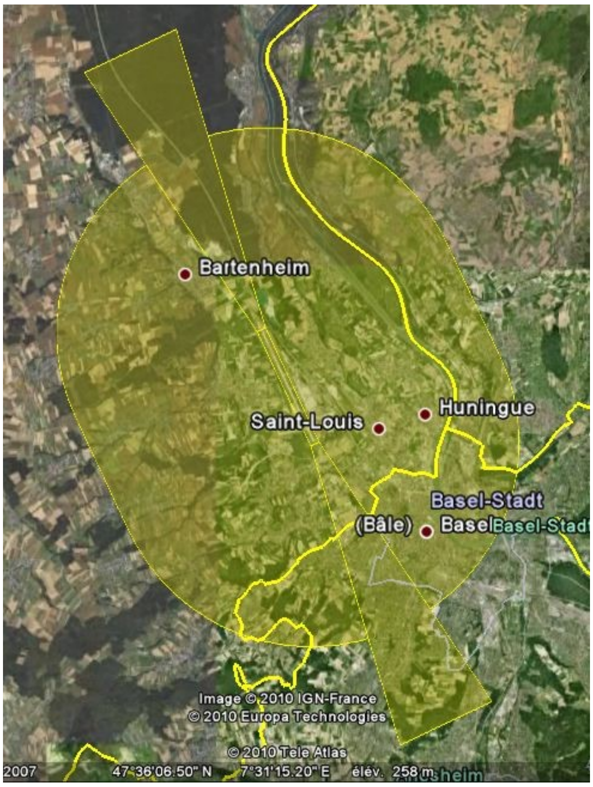

Figure 18: Area 2 of Airport Basel-Muhouse

The main focus of this chapter is to discuss the institutional issues associated with any cross-border provision of data that may arise.

4.4.11.2 AREA 1

In order to ensure complete, global coverage of Area 1 terrain data, with no gaps between State data sets, it is proposed that each State should provide an Area 1 data set that extends to the mutually agreed territorial boundary and a limited distance beyond this, as determined in the formal arrangements between the neighbouring States and/or AISPs.

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 includes a buffer beyond the State border of more than just one 3 arc second grid cell (500 m to 1 km buffer is common practice).

The sharing of this necessary data must be addressed though cross-border letters of agreement, as discussed in section 4.4.11.6, 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. The use of a global DTM allows for consistent data across State borders.

4.4.11.3 AREA 2

4.4.11.3.1 REQUEST FOR DATA

Once the regulator has determined which aerodromes the TOD requirements of ICAO Annex 15 apply to, the areas for which terrain and obstacle data needs to be provided should be clearly defined. It is recommended that this be carried out by the aerodrome operator, in close coordination 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 regard to access to data. The meeting should agree on 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 regard 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 for the publication of data in the AIP. However, the State responsible for the survey may be determined on a case-by-case basis and should therefore be a working-level arrangement.

4.4.11.3.2 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 enshrined in 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 such processes exist, they should be amended, if necessary, to include such a provision.

4.4.11.3.3 ARRANGEMENTS BETWEEN DIFFERENT STATE AIS/AIM

The body responsible for the data set provision for Area 2 may vary between States, for example in some States it may be the aerodrome operator and in others the ANSP or even 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 States should provide data to the AIS/AIM of the neighbouring State, in line with the provisions of ICAO Annex 15 and PANS-AIM (see ICAO Annex 15 paragraphs 2.2.1, 2.2.7 and 2.3.5).

In many cases, arrangements will already be in place between the AIS/AIM of neighbouring States, although these may need to be expanded to encompass terrain and obstacle data and in some cases also to address issues related to obstacles outside the scope of the ICAO Annex 15 requirements. It is recommended that where arrangements do exist but have not been fully formalised, they should be formalised in the form of 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 means of data provision. In addition, it is recommended that it should reference 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. Consideration needs to be given to the different levels of detail applied, as well as the horizontal geometry and vertical segmentation.

Within Europe, EU Regulation 2017/373 [43], 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.

4.4.11.3.4 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 to the neighbouring State to survey this area.

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.

4.4.11.4 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.

4.4.11.5 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 either that it should not publish the data or, where it chooses to publish, the DPS should clearly inform 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 should contact the regulator in the relevant State to discuss how the issue can be resolved. It is hoped that if the discussions recommended in section 4.4.11.2 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 ICAO Regional Office, being contacted if all other possibilities have been exhausted.

If data is not provided, the DPS should clearly state which data is and is not included in the data set.

4.4.11.6 LETTER OF AGREEMENT

The following section provides guidance on the drafting of a letter of agreement that may be used between two States as an instrument to harmonise 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. States will thereby help achieve a high-level of harmonisation of 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 drawn up between State regulators, in others it may be drawn up at 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 complete or mandatory; they are provided solely by way of an example.

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 regard to a particular aerodrome. In addition, the guidance may be unable to cover 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 4.4.11.6 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.

4.4.12 OVERSIGHT

The organisation responsible for the oversight of national provisions with regard to terrain and obstacle data should be identified and mandated, e.g. National Supervisory Authority.

4.5 COSTS, COST RECOVERY AND CHARGING MECHANISMS

4.5.1 INTRODUCTION

The financial matters should be documented as a State should determine costs and cost recovery mechanisms when deciding on TOD functions, and responsibilities.

The initial inclusion of the TOD requirements solely 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, 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. The origination, provision and ongoing maintenance of terrain and obstacle data is a costly exercise and needs careful consideration.

The total cost for TOD can be divided in three different parts:

- **Data origination costs** include the survey cost of terrain and/or obstacles. The survey can be an area survey covering the origination of terrain and/or all obstacles in a certain area (e.g. Area 2 or 2a, 2b and 2c) or the survey of an individual newly built obstacle.
- The **data management costs** that include data verification and validation, maintaining a terrain and/or obstacle data base and the preparation of the terrain and/or obstacle data product.
- **Data provision costs** include the cost of the delivery service (e.g. Web infrastructure) or postal delivery. In case that specific products or formats are required for a specific user or a group of users/applications then the production of these user specific products can also be allocated to the data provision cost.

There is an additional cost arising in the obstacle lifecycle: Before a structure that represents a potential obstacle can be built an assessment/approval of the project is required (see section 4.3.3.2). There are different costs involved: cost of the evaluation and approval process itself but also cost for preparing documentation required for the obstacle assessment like aeronautical studies, electromagnetic studies etc. This cost that can be covered by either the obstacle owner/operator, the State Authority or the ANSP is not further discussed in this Manual because it is not a cost directly related to the obstacle data.

The principle for cost recovery of the data management and data provision costs is the same as for all other AIM data and it follows the well-established ICAO Doc 9082 [9]. Guidance can be found in ICAO Doc 9562 [11] and ICAO Doc 9161[10]. EU Regulation 2019/317 [45] lays down a performance and charging scheme in the Single European Sky.

However, the data origination costs for terrain and obstacles are significantly higher than the costs for other aeronautical data due to large amount of data to be captured and managed. The high level of the origination cost and the fact that the data origination cost is incurred by non-aviation organisations (e.g. obstacle owners/operators) requires a closer analysis of the responsibility for data origination (and thus incurring the cost) and cost recovery from the users of the data.

4.5.2 RESPONSIBILITY FOR DATA ORIGINATION

The ICAO TOD provisions do not cover the allocation of responsibilities for data origination of obstacle and terrain data in the different areas. The only clear designation for data origination in the EU regulations is the responsibility of an aerodrome for terrain and obstacle data capture found in an AMC to the EU Regulation 139/2014 [44]:

AMC1 ADR.OPS.A.005 Aerodrome data:

(b) The aerodrome operator should measure and report to the aeronautical information services obstacles and terrain data in Area 3, and in Area 2 (the part within the aerodrome boundary) in

degrees, minutes, seconds and tenths of seconds. In addition, the top elevation, type, marking and lighting (if any) of obstacles should be reported to the aeronautical information services

…

(f) The aerodrome operator should establish arrangements with the Air Traffic Services providers and the Competent Authority for the provision of obstacles and terrain data outside of the aerodrome boundary

The responsibilities for data origination for Area 1, and Area 2 and 4 outside the aerodrome boundary have to be defined in the State policy (see section 4.2.1). The manual makes no recommendation regarding the assignment of responsibilities. Rather, it presents various approaches used in States today and encourages the States to consider those that best suit their individual circumstances:

1. The responsibility is with the State: The responsible organisation can be the national mapping / cadastre organisation or the military. This case if often seen for the origination of Area 1 obstacles and it is quite common for the origination of terrain data for Area 1 and 2. The cost is either covered by the general State budget or recovered from the users (see next section).

   It has become preferred practice for several national mapping agencies in Europe to provide DTM suitable for Area 1 and Area 2 free of charge under the open government data initiative.

2. The obstacle owner is responsible to survey a newly constructed obstacle at his own cost. In this case the State has to establish the legal basis obligating the owner who wants to build an object that is considered a risk for air navigation (= an obstacle) to survey the construction after it is built and to submit the data to the organisation responsible for collecting and publishing obstacle data.
3. The area of responsibility of the aerodrome operator can be extended to cover the complete Area 2 and Area 4.
4. The responsibility for obstacle data origination can be assigned to the ANSP (e.g. for all obstacles in Area 2 beyond the airport boundary).
5. A combination of 3. and 4: ANSP and aerodrome sharing the cost.

4.5.3 COST RECOVERY AND CHARGING MECHANISMS

States should establish a transparent policy for recovering the data origination cost from the users/services affected with no party obliged to carry an unreasonable share.

The question arises if specific applications are likely to benefit from the data, so that the costs could be directly recovered from specific applications using this data. For example, Area 4 data is of benefit to IFR approaches operating CAT II/III. But Area 2 data is of benefit to flight procedure design, aircraft performance calculation and VFR traffic in and out of an airport. It is likely that, in most cases, the TOD will be of use for many different applications and it will be difficult to identify single beneficiaries. Therefore, a cost recovery and charging scheme solely based on benefit for specific application is not practical.

The manual makes no recommendation regarding the cost recovery or charging mechanism to be implemented. Rather, it presents the following approaches that exist within the charging framework in place today. States are encouraged to select the approach or approaches that best suit their individual circumstances.

- Cost recovery through the subscription fee for aeronautical information product

  The cost is recovered by including it in the subscription fee for aeronautical information product (e.g. AIP and amendment service). With this model all users of specific national AIP are contributing.

- Assigning a price tag to the obstacle and/or terrain data sets

The cost is recovered by including it in the fee for obstacle and/or terrain data sets. With this model only the users of the obstacle and/or terrain data sets are contributing

- Recovery of cost by means of airport or air navigation charges

  The inclusion of costs to the different type of charges follows the policies and rules mentioned in the General Principles (section 4.5.2 above).

4.5.4 ASPECTS AFFECTING COSTS

It is not practical to provide actual cost estimates for implementing the TOD requirements because cost can vary significantly from one airport to another and between different States. 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 carry out 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. Another example is the division of responsibility between neighbouring States. In this case, 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.
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 carried out. Also increasing the cost, some complementary field surveys may be required to verify and/or collect the mandatory Marking and Lighting attributes as well as inspect and/or survey very thin objects.
5. The impact of the complexity of the obstacle geometry on the survey 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 setup 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
6. Reliance on data which already exists 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 conducted.
7. As a result of other developments within the European Union relating to data availability, there has been potential for collaboration and sharing costs with other organisations. As a result, the overall cost for aviation can be reduced.
8. For Area 2 TOD survey, the environment around the aerodrome is affecting the production cost. Producing TOD for an aerodrome close to the sea or where the terrain remains flat or where it is located far from dense urban areas will be cheaper compared to an aerodrome surrounded by relief or close to a dense urban area or forests. Also, the number of runways (and the combination of their orientations) will increase the price for Area 2b (or take-off flight path area) due to stronger requirements.

Cooperation with national or regional mapping agencies and topographic services can significantly reduce the cost of obstacle and terrain surveys. Common requirements for topographic mapping and obstacle surveys will allow to share cost for LIDAR (Light Detection and Ranging) or photogrammetric data capture.

DTM products from satellite remote sensing data might be lower-priced alternatives to new surveys if no better data is available.

To assist in financial planning, the reader is advised to consider these factors and to determine their own situation.

4.6 COPYRIGHT AND PRODUCT LICENSING

Given that the aviation community will be paying for the data it makes available in some form[11], concern has been raised about organisations outside the aviation sector exploiting the data for their own purposes. Such exploitation is made all the more likely by the ICAO requirement to use 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 unauthorised use of the data, such as restricting access to the data itself. This may, however, be considered to be 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 commercial exploitation of the data is difficult and 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 feasible approach as this would provide a legal basis for restricting use of the data, placing responsibility for proper use on the user. 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. Whilst this will not prevent misuse totally, it will provide the data owner with a legal basis to address any unauthorised use of the data, and is one of the common mechanisms in place today across many domains.

4.6.1.1 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 aeronautical information products.*
>
> *Unless specified otherwise, AIS Products may be used for aviation purposes only 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."*

4.6.1.2 LICENCE AGREEMENT CONSIDERATIONS

Below is a list of the subjects that should be considered for inclusion in a licence agreement, drawn up with the intention of controlling and restricting the use of terrain and obstacle data.

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[11] It is clear that there will be costs associated with the implementation of terrain and obstacle data, for example survey costs, licence charges, etc. These costs will need to be recovered by some means and it is likely that the aviation community will ultimately pay.

- Grant:
  - The type and terms of the licence granted.
- Ownership:
  - Which parties have 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):
  - Which party the IPR of the data belongs to.
- Restrictions:
  - Restrictions placed on 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 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. TECHNICAL MATTERS

5.1 TERRAIN AND OBSTACLE DATA MODELS

5.1.1 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 involved in 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[12]. 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 of the real world.

ICAO Annex 15 [4] calls for terrain and obstacle data to be provided as digital data sets and ICAO PANS-AIM prescribes the manner in which these data sets should be modelled, stating "*To facilitate and support the use of exchange of digital data sets between data providers and data users, the ISO 19100 series of standards for geographic information should be used as a reference framework.*".

The following two sections describe the recommended data models for terrain and obstacle data which, if used, will increase harmonisation and interoperability and, from a European perspective, aid compliance with the EU Regulations [42].

5.1.2 DIGITAL TERRAIN MODELS

5.1.2.1 TERMINOLOGY

Different terms are in use for digital models describing the surface of the earth. There is no consistent usage of these terms in scientific literature. In this Manual the terms are used as follows.

- Digital Elevation Model (DEM) is the general term for a digital model of the topographic surface. DEM is defined by ICAO as: The representation of terrain surface by *continuous elevation values at all intersections of a defined grid, referenced to common datum.*

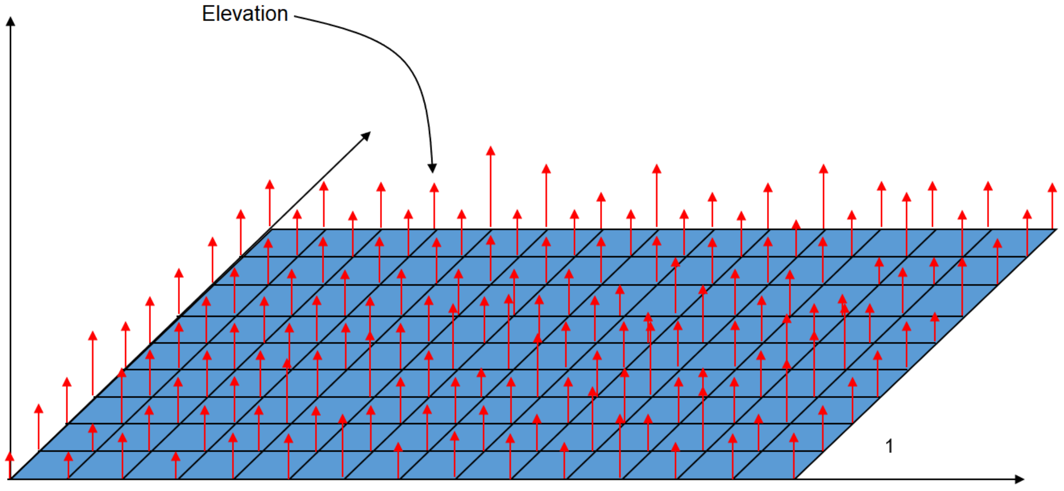

Figure 19: DEM Representation

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[12] 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.

- Digital Terrain Model (DTM) is a DEM that represents the bare surface of the earth without man-made objects or vegetation.
- Digital Surface Model (DSM) is a DEM that represents the outer profile (normally referred to as the convex hull) of the visible surface (e.g. buildings, towers and vegetation).

Figure 20 demonstrates the difference between a DSM and a DTM. The DSM is shown on the left, the DTM on the right.

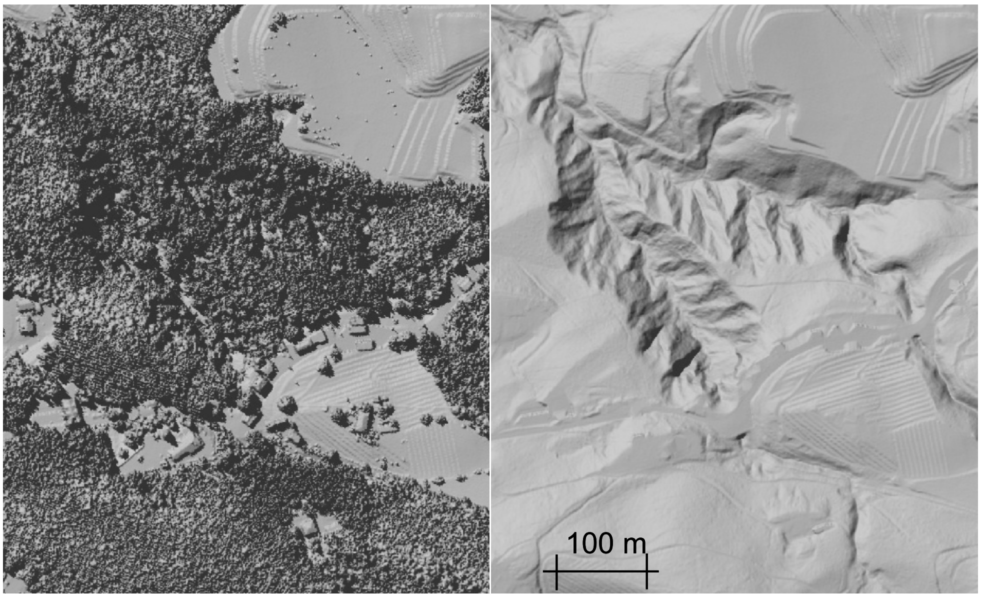

Figure 20: DSM v DTM at the same location[13]

A DEM does not usually describe the bare earth or the top surface 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”.

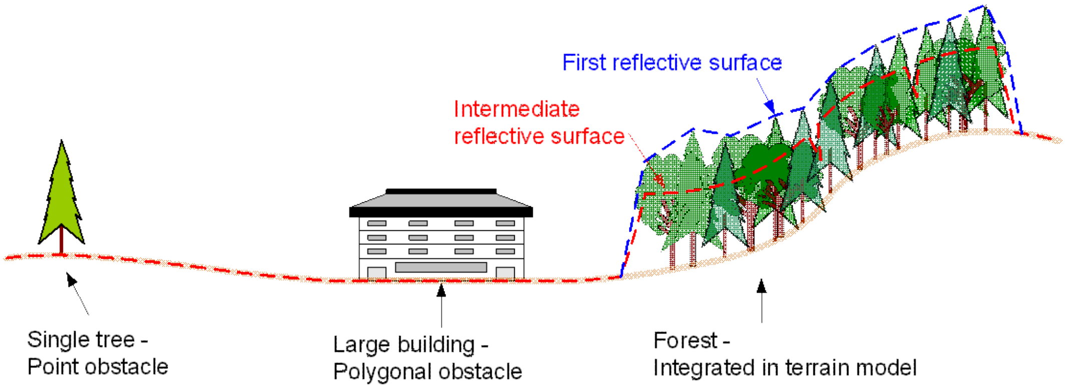
First reflective surface
Intermediate reflective surface
Single tree - Point obstacle
Large building - Polygonal obstacle
Forest - Integrated in terrain model

Figure 21: Intermediate reflective surface

5.1.2.2 TERRAIN REPRESENTATION

At the lowest level, terrain data is composed of values recorded 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.

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[13] Source Swissphoto AG, Switzerland.

Digital Elevation Models, 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 (also known as Voronoi polygons). 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 accuracy.

High-resolution data acquisition results in up to 10,000 points per hectare[14]. 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 is 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, grids are much simpler to handle since only a corner coordinate, 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 coordinate 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 coordinates), 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 coordinates 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.

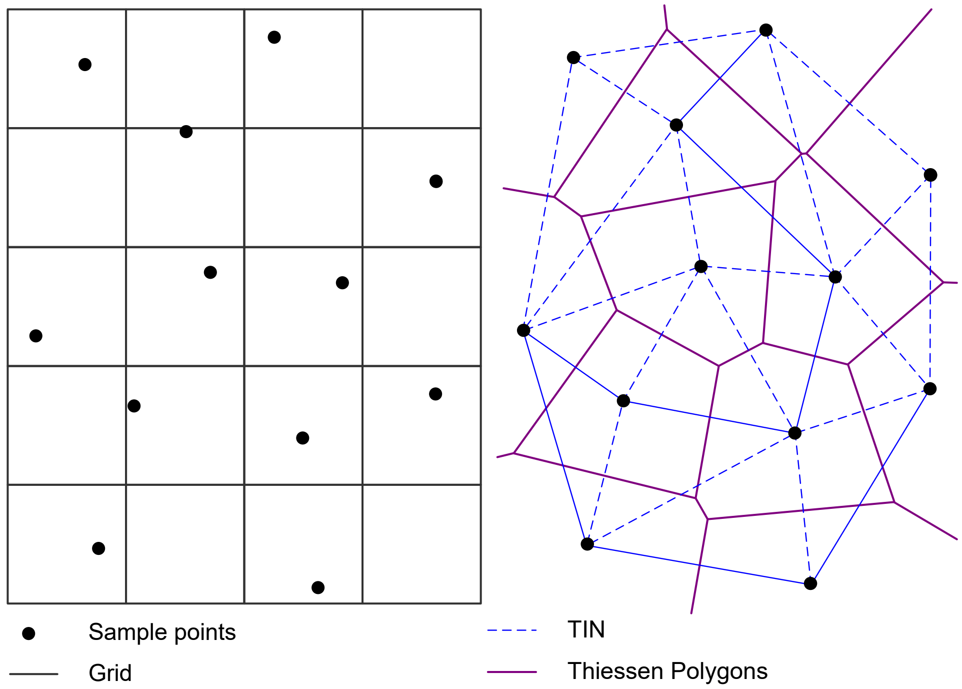

Figure 22: Terrain Representations through Grid (left) and Vectors (right)

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[14] 1 Hectare = 10,000 square metres.

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.

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.

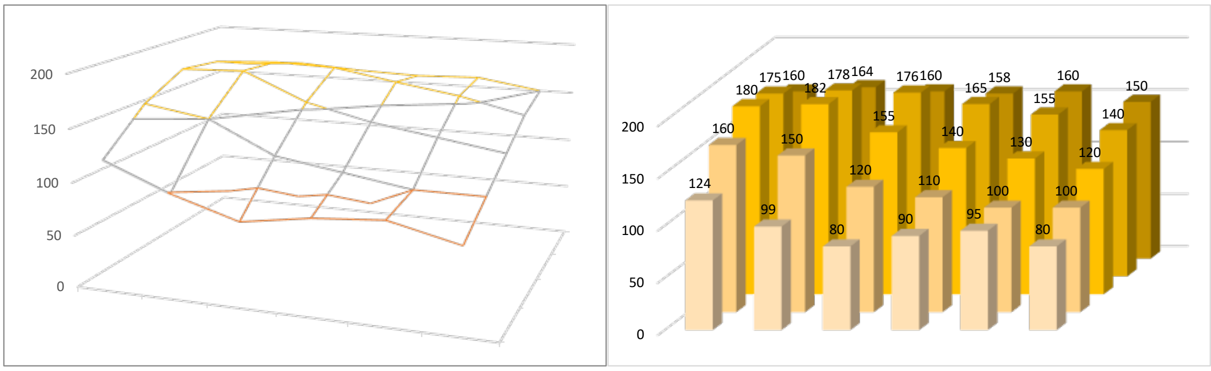
When interpolating data from different surveys into a grid or merging data from different sources, attention must be paid to the safety aspects of aviation. Therefore, the elevation value in a resulting grid cell should represent the highest value of all source values and not an average or weighted mean value.

5.1.2.3 APPLICATION SCHEMA

The application schema for terrain data provided in Chapter 2 Terrain Data Product specification requirements of EUROCAE ED-119C [28] 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.

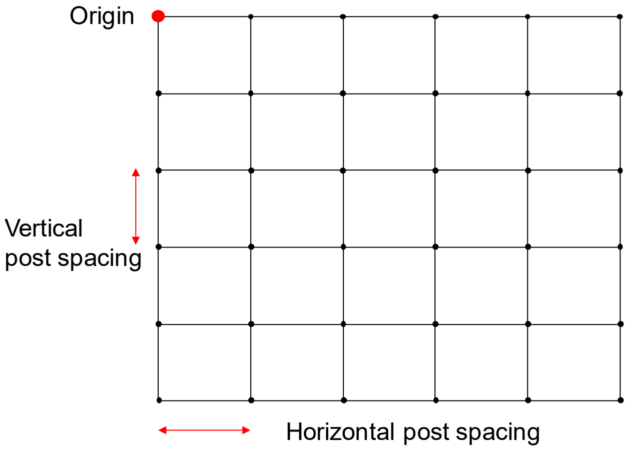
5.1.2.4 CONCEPTUAL EXCHANGE MODEL

The terrain and obstacle data requirements specify the need to exchange terrain data for the intersection points for a defined grid.



a) Terrain surface

b) Discrete elevation values of grid points



160	164	160	158	160	150
175	178	176	165	155	140
180	182	155	140	130	120
160	150	120	110	100	100
124	99	80	90	95	80

c) Grid definition

d) Recorded elevation values

Figure 23: Grid representation of digital terrain data

Figure 23 shows an example terrain surface (a) that can be represented with discrete elevations at grid points (b). The grid is defined by origin point and the vertical and horizontal post spacing (c). Elevation values are recorded for each grid square (d).

The organisation of raw terrain points into a gridded structure allows location information to be removed from points because they can be calculated if the origin, the orientation and post spacing of the grid are known. Therefore, a DTM in a grid structure consists of two parts:

- **Geo reference information** defining the transformation from grid space to real world space. The transformation can either be defined by a set of transformation parameters or by a set of points with coordinates in grid and real-world space. If the grid is parallel to the real-world coordinate system then real-world coordinates of the grid origin and the post spacing are sufficient.
  Example: Origin: 47° 23' 00" N 8° 12' 00" E, Vertical post spacing: 3", Horizontal post spacing: 3"
- **Elevation information** consisting of a list of n x m[15] elevation values without location information.
  Example: 160 164 160 158 160 150 175 178 176 165 155 140 180 182 155 140 130 120 160 150 120 110 100 100 124 99 80 90 95 80

5.1.2.5 EXCHANGE FORMATS

The TOD stakeholders have identified, documented and recommended a list of most-used formats for terrain data, including their detailed technical specifications and their interoperability (see Appendix D). This list was documented due to the absence of any requirements in ICAO SARPs for terrain data formats to be used for provision and exchange. Furthermore, it consulted the main next intended users of terrain data (i.e. navigation data providers) to establish their preferences as regards terrain formats. The outcome of this survey, using samples of terrain data, shows a strong preference from the main users for GeoTIFF and shape formats with metadata.

The format of the georeferencing information depends on the file format and are shown for two of the most common file formats.

5.1.2.5.1 GEOTIFF

GeoTIFF is an extension to the Tagged Image File Format (TIFF), the well-known format for raster images. The OGC GeoTIFF standard[16] defines how the geo-reference information is encoded in the header of a TIFF file. GeoTIFF supports a wide variety of grid definitions (rotated grids, different post spacing in x and y direction, tie points, etc.) including geodetic reference system information. Figure 24 below shows an extract of the GeoTIFF tags for a digital terrain data set with its origin at 47.869374736°N 5.833735249°E in WGS-84 coordinate system, a post spacing of 1 arc second (0.000083°) and elevations expressed in meters.

---

[15] n and m are denoting the number of rows and columns

[16] See the OGC GeoTIFF Standard Version 1.1 for details

```
   Version: 1
   Key_Revision: 1.0
   Tagged_Information:
      ModelTiepointTag (2,3):
         0                 0                 0
         5.833735249       47.869374736      0
      ModelPixelScaleTag (1,3):
         8.3e-05           8.3e-05           0
      End_Of_Tags.
   Keyed_Information:
      GTModelTypeGeoKey (Short,1): ModelTypeGeographic
      GTRasterTypeGeoKey (Short,1): RasterPixelIsArea
      GeographicTypeGeoKey (Short,1): GCS_WGS_84
      GeogCitationGeoKey (Ascii,7): "WGS 84"
      GeogAngularUnitsGeoKey (Short,1): Angular_Degree
      GeogSemiMajorAxisGeoKey (Double,1): 6378137
      GeogInvFlatteningGeoKey (Double,1): 298.257223563
      End_Of_Keys.
   End_Of_Geotiff.

GCS: 4326/WGS 84
Datum: 6326/World Geodetic System 1984
Ellipsoid: 7030/WGS 84 (6378137.00,6356752.31)
Prime Meridian: 8901/Greenwich (0.000000/  0d 0' 0.00"E)
Projection Linear Units: User-Defined (1.000000m)

Corner Coordinates:
Upper Left    (  5d50' 1.45"E, 47d52' 9.75"N)
Lower Left    (  5d50' 1.45"E, 45d39'27.03"N)
Upper Right   ( 10d58'42.86"E, 47d52' 9.75"N)
Lower Right   ( 10d58'42.86"E, 45d39'27.03"N)
Center        (  8d24'22.16"E, 46d45'48.39"N)
```

Figure 24: Extract of GeoTIFF tags for a digital terrain data set

The dimension of the grid (number of rows and columns) and the coding of cells with no data are included in the standard TIFF tags.

5.1.2.5.2 ESRI ASCII GRID

ASCII Grid is a simple format originally defined by the GIS-Vendor ESRI[17]. It supports only minimal geo-reference information: number of columns and rows of the grid, real world coordinates of the lower left (!) corner of the grid and a uniform post spacing in x and y direction. Rotated grids are not supported and reference system and unit of measurements information have to be provided in additional metadata. Figure 25 below shows the header of an ESRI ASCII Grid file with 1926x1201 elevation values, a lower left (south-west) corner at the coordinate 479900 / 61900 and a uniform post spacing of 200. A value of -9999. of a grid cell means that no elevation is provided for the specific cell.

```
NCOLS 1926
NROWS 1201
XLLCORNER 479900.
YLLCORNER 61900.
CELLSIZE 200.
NODATA_VALUE -9999.
```

Figure 25: Header of ESRI ASCII Grid file

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[17] See the ESRI documentation for details

Coordinate reference system and units of measurements for the elevations have to be provided in the metadata of an ASCII Grid file.

5.1.2.6 PACKAGING OF DTM DATA SETS

For large Areas (Area 1 of States with a large geographic extent or regional/global data sets) the coverage area is too big for providing the digital terrain data set in one file. In such cases it is common practice to divide the data into subsets of equal size (tiles). The tile size depends on the grid spacing of the data set. Examples:

Post spacing	Size of a tile	Number of Grid Points per tile	Approx. file size (GeoTIFF)
3 arc seconds	1° x 1°	1'440'000	5 MB
1 arc second	30' x 30'	3'240'000	13 MB

Digital terrain data sets for Airports are usually packaged according to coverage areas. There are different possibilities depending on the size of the area and the post spacing. Post spacing must be uniform in a terrain data set. Possible arrangements are:

Packaging	Comment
One data set covering the complete Area 2 including Area 3	Feasible if data meeting Area 3 requirements is available for the complete Area 2. For a large Area 2 tiling might be recommended to keep the files at reasonable size.
Separate data sets for each Area 2, Area 3 and Area 4	This is the recommended practice if data of each area meets different numerical requirements (post spacing etc.).
Separate data sets for each part of Area 2 (Area 2a, take-off-flight-path-area, area comprising the obstacle limitation surfaces) and Area 4 for each runway / runway direction	The partitioning of Area 2 into single files has an advantage for a user with an application for a specific runway who might need only one file but penalises the user who needs the data of the whole Area 2 and has to assemble all parts.

5.1.3 OBSTACLES

5.1.3.1 GENERAL ASPECTS

Data models for obstacles must correctly reflect the position, shape[18] 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 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.

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[18] To the degree needed to support the appropriate applications.

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 to segmentation may be found in Appendix B.

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

5.1.3.2 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.

No new model has been developed for the sole purpose of meeting the requirements of obstacle data. Rather, in order to maintain a more homogenous approach, the obstacle element of the Aeronautical Information Exchange Model (AIXM) from version 5.1 onwards provides full coverage of the attributes needed.

Consequently, it is recommended that users refer to the AIXM documentation on www.aixm.aero for a full description of the model. Nonetheless, the obstacle elements are described here to provide a high-level overview.

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 be represented using the VerticalStructure entity. Only those vertical structures located in an area intended for the surface movement of aircraft or extending 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.

5.1.3.3 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 only of 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.

5.1.3.4 EXCHANGE SCHEMA

The exchange schemas are generated automatically from the UML model and can be found on the AIXM website.

5.1.3.5 CODING GUIDELINES AND SPECIMEN OBSTACLE DATA SETS

Obstacle data set coding guidelines are available on the AIXM confluence website and in the accompanying specimen obstacle data sets.

5.2 DATA PRODUCT SPECIFICATION

A description of available obstacle and terrain data sets must be provided in the form of data product specifications (DPS).

With a DPS, air navigation users will be able to evaluate a data product and determine if it is fit for their purpose.

ISO 19131[21][19] outlines the specifications for geographic data products.

The term data product refers to a data set or to a data set series that conform to a data product specification.

A data product specification according to ISO 19131 is divided into sections. Each section covers and specifies an aspect of the data product:

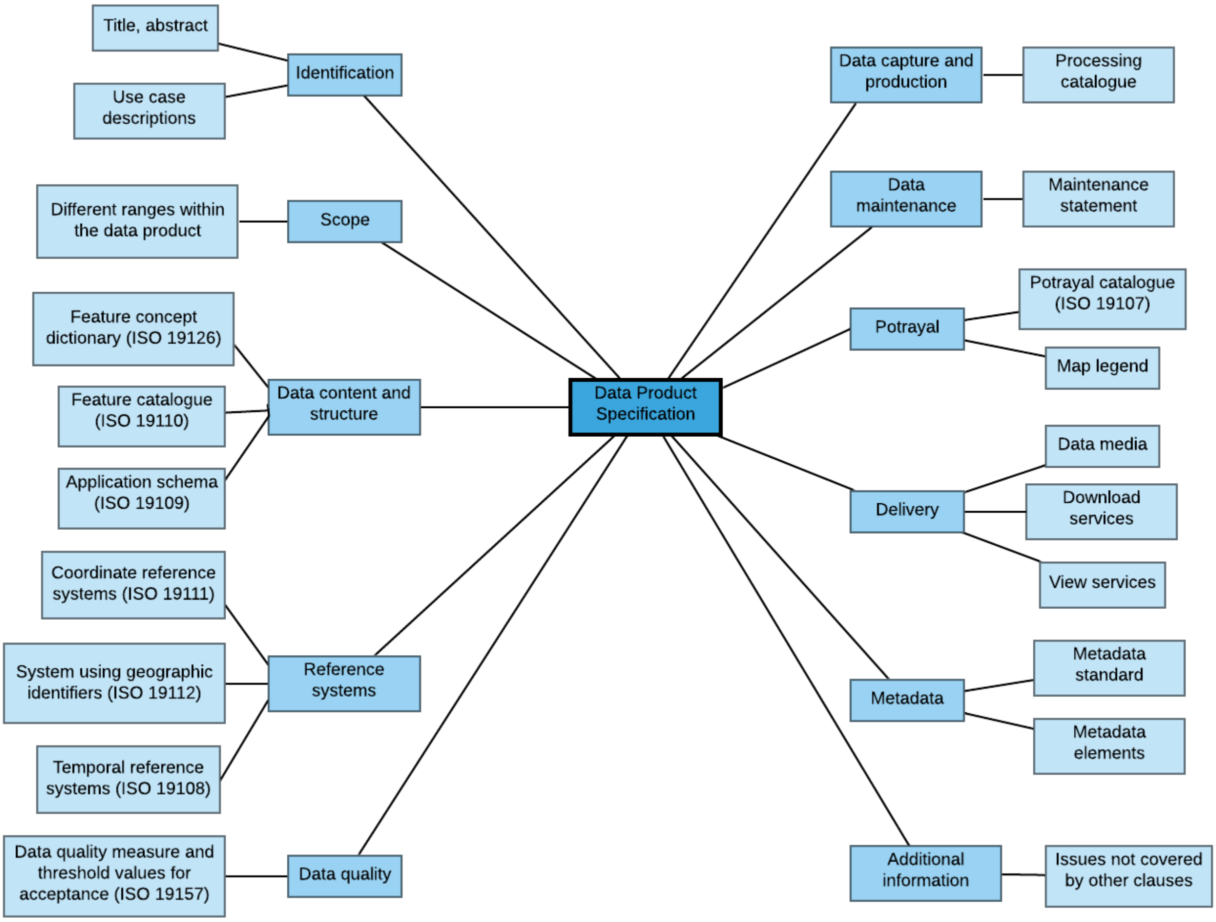
Title, abstract
Use case descriptions
Identification
Different ranges within the data product
Scope
Feature concept dictionary (ISO 19126)
Feature catalogue (ISO 19110)
Application schema (ISO 19109)
Data content and structure
Coordinate reference systems (ISO 19111)
System using geographic identifiers (ISO 19112)
Temporal reference systems (ISO 19108)
Reference systems
Data quality measure and threshold values for acceptance (ISO 19157)
Data quality
Data Product Specification
Data capture and production
Processing catalogue
Data maintenance
Maintenance statement
Potrayal
Potrayal catalogue (ISO 19107)
Map legend
Delivery
Data media
Download services
View services
Metadata
Metadata standard
Metadata elements
Additional information
Issues not covered by other clauses

Figure 26: DPS Sections

All sections should always be included in the data product specification, even when there is no content. This provides a stable and recognizable structure across different DPSs.

Sections or sub-section with no content should be marked with ‘*Not applicable’*.

A specification overview placed in the beginning of a DPS should provide a short introduction to the data product and allow the reader a better understanding of the data product specification. It has the form of a human-readable, narrative description of the data product and the data product specification. It may be regarded as a summary of other parts of the data product specification. The content of the overview is described in section 5.2.1.

ISO 19131 specifies both an XML encoding and a layout of a DPS where human readability is prioritized. Appendix F presents a specimen DPS for an obstacle data set according to the layout specified in ISO 19131.

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[19] The guidance material provided in this section is based on the Draft International Standard ISO/DIS 19131:2019(E) that is going to replace ISO 19131:2007

An XML encoding of a DPS is not addressed in this guidance given that the DPS will usually be read by users before accessing the data set and will most probably not have to be processed by computer systems. Metadata describing a specific data set should be provided in machine readable XML encoding together with or as part of the data set.

The following chapters contain a description of the information that has to be provided in the different sections of the DPS.

5.2.1 OVERVIEW

The following information should be included in the specification overview and reflect corresponding structured information when such information is present:

- Title of the DPS
- Dates for significant events in the life cycle of the DPS (creation, changes, approval and publication)
- Contact details of the party responsible for the DPS
- Language that is used in the DPS.
- Topic category, which is a code for a theme[20] applicable to the data product. The topic category for all aeronautical data products is *transportation*.
- Terms and definitions used in the DPS. The target audience of the DPS should be considered when compiling a list of terms (for example, there is no need to explain a navigation aid to a user of aeronautical data and information).
- Abbreviations used in the DPS
- Name (title) of the data product
- Informal description (abstract) of the data product including the data sources, production process and maintenance of the data
- Information regarding the DPS such as web location, format, maintenance and restrictions

5.2.2 DATA PRODUCT IDENTIFICATION

The purpose of the identification section is to provide information for identification, search, discovery and first evaluation of data products. The identification section has the following attributes:

Official title	Official designation of the data product.
Alternative title	Other designations or names under which the data product is also known should be indicated as alternative titles.
ID	A unique identifier of the data product. The file name of the data product can be used as identifier.
Abstract	A brief narrative summary of the content of the data product.
Purpose	A summary of the possible applications and uses for which the data product is developed.
Topic categories	Topic category is a code for a theme applicable to the data product (see footnote 20). The topic category for all aeronautical data products is *transportation*.
Spatial representation	The spatial representation of the data product. The spatial representation of Obstacle data sets is *vector* and of a

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[20] The topic category codes for geographic datasets are in accordance with the enumeration list set out in MD_TopicCategoryCode of ISO 19115

	terrain data set is *grid.*
Spatial resolution	The spatial resolution of digital terrain data. For other data sets the spatial resolution is *not applicable*.
Supplemental information	Any other descriptive information about the data product.
Restrictions	Any legal constraints (copyright, usage restrictions etc.) or security classifications of the data products.
Extent	The temporal and spatial extent of the data set. The temporal extent is part of the data set as metadata and not defined in the DPS. The spatial extent can be defined as: • A geographic description (e.g. Donlon) • A bounding box (with minimum and maximum latitude and longitude): • A polygon encompassing the data (e.g. encoded 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> )
```

5.2.3 SPECIFICATION SCOPE

When, within a section of the DPS, distinct specifications are applicable for different parts of the data, the section should contain one separate specification scope for each distinct part. In this way, the separate specification scope can be refined against and related to a general scope to provide valid specifications for distinct cases.

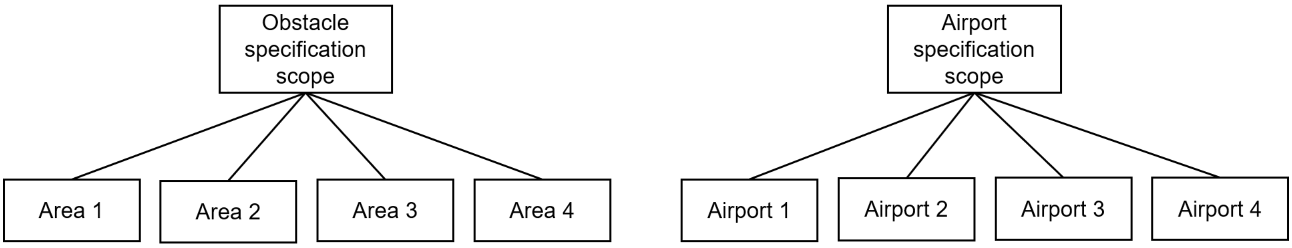

Figure 27: Examples of Specification Scopes

The specification scope is used to define the specific parts and consists of the following attributes:

Scope id	The designation of the scope. The scope id is used to identify the scope in the specification section.
Level	A code identifying the hierarchical level of the data. Possible

	codes are defined in ISO 19115 [20][21]. Meaningful level codes for the specification scope are as follows: dataset — Specification applies to a data set series — Specification applies to a data set series
Level name	The name of the specific level of the data. If there are more than one scopes of the same level (e.g. dataset) then the level name must be defined.
Level Description	A detailed description of the level of the data.
Extent	The spatial, vertical and/or temporal extent of the data
Coverage	The coverages to which the specification applies

5.2.4 DATA CONTENT AND STRUCTURE

The purpose of the data content and structure section is to provide information that specifies the data structure and content of the data product.

Narrative description	An overview description of the application schema and/or feature catalogue for the specified specification scope
Application schema	An application schema provides the formal description of the data structure and content of the data product. It is a conceptual model described using a conceptual schema language such as UML.
Feature catalogue	A feature catalogue is a repository which provides the semantics of all feature types, together with their attributes and attribute value domains, association types between feature types, and feature operations required for describing the data structure and content of the data product. If there is an application schema, the feature catalogue describes all the elements of the application schema. Also, coverages may be regarded as features but may alternatively be specified using coverage descriptions.

5.2.5 REFERENCE SYSTEMS

The reference system section provides information about the spatial, and optionally the temporal, reference system used for a certain specification scope:

Spatial reference system	The horizontal and vertical reference system must be specified. The reference system should be identified by reference to a register (the reference is made to the register and to the reference system's unique identifier in that register). EPSG[22] is such a register of geodetic reference systems maintained by the International Organisation of Oil & Gas Producers. Example: The EPSG code for WGS-84 coordinate system is

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[21] The complete list of codes identifying the hierarchical level of the data can is defined in MD_ScopeCode enumeration in ISO 19115.

[22] The EPSG Geodetic Parameter Dataset is a structured dataset of Coordinate Reference Systems and Coordinate Transformations, accessible through this online registry (www.epsg-registry.org) or, as a downloadable zip files, through IOGP's EPSG home page at www.epsg.org. The geographic coverage of the data is worldwide, but it is stressed that the dataset does not and cannot record all possible geodetic parameters in use around the world. The EPSG Geodetic Parameter Dataset is maintained by the Geodesy Subcommittee of IOGP's Geomatics Committee.

	EPSG: 4326
Temporal reference system	The temporal reference system should be specified.

5.2.6 DATA QUALITY

The data quality section provides information about the conformance of the data product with the quality requirements. This can be specified by a threshold value for a certain data quality measure or by a descriptive statement about a data quality element.

Data quality element	Name of the quality element (Accuracy, traceability etc.).
Data quality measure	Specification of the quality measure or alternatively a descriptive statement, including the threshold value for the conformance with the quality measure.

5.2.7 DATA CAPTURE AND PRODUCTION

The purpose of the data capture and production section is to provide instructions, requirements and/or descriptions of the data capture and production. This may include details referring to specific methods and/or processing steps. When data sources are specified, they may be described in detail, including specific conformance quality levels required.

Description	A narrative, free text description of the process for the capture and production of the data.
Guide	A reference to a document describing the capture of features and attributes from source information.
Inclusion criteria	A logical rule defining when and how features and attributes are to be included in the data.
Data acquisition and processing	Information about the source and/or production process used in producing the data product.

5.2.8 DATA MAINTENANCE

The purpose of the maintenance section is to provide descriptions, principles and/or criteria for how the data is maintained once it has been captured. This includes frequency with which changes and additions are made to the data product.

Description	A narrative, free text description of the process for the maintenance of the data
Frequency	The frequency with which changes and additions are made to the data product. It should be coded with MD_MaintenanceFrequencyCode[23]. Meaningful codes could be:

---

[23] The complete list of codes defining the maintenance frequency is defined in MD_MaintenanceFrequencyCode enumeration in ISO 19115.

- continual
- weekly
- monthly
- quarterly
- asNeeded
- irregular
- notPlanned
- unknown
- periodic

User defined	The period of time with which changes and additions are made to the data product. This attribute should only be used if none of the predefined codes in MD_MaintenanceFrequencyCode can be used.

5.2.9 PORTRAYAL

The purpose of the portrayal section is to specify how to portray the feature types for human interpretation, usually by means of a portrayal catalogue.

Portrayal rules	A description of the portrayal rules or a reference to a portrayal specification. The portrayal rules are usually not applicable for TOD.

5.2.10 DATA DELIVERY

The purpose of the data delivery section is to provide descriptions of data delivery format and means for physical delivery or for data delivery using download services or web services.

Format name	The name of the format in which the data product is delivered
Format version	Version number or date of the format
Format specification	A description or reference of the format specification
File structure	The structure of a delivery file
Language	A code for each language that is used within the dataset. The codes shall be according to ISO 639-2.
Character set	The full name of the character coding standard used for the dataset.
Units of delivery	The unit of delivery (e.g. airports for obstacle data sets, geographic areas or tiles for DTM).
Transfer size	An estimated size of a unit in the specified format, expressed in Mbytes.
Medium name	Name of the physical storage media. “Not applicable” if the delivery method is a service.
Other delivery	Any other information about the delivery method.
Service property	If the specified data product is delivered via SWIM services, then this field shall provide information where the service overview can be found.

5.2.11 METADATA

The purpose of the metadata section is to provide a description of the metadata provided with a dataset.

Specification	The standard, a standard profile or other specification to be used as a base for the metadata.
Encoding	The format and/or encoding used for the metadata
Metadata elements	A specification of the metadata elements that are provided in/with the data set.

5.2.12 ADDITIONAL INFORMATION

The purpose of the section is to provide additional information about the data product.

Additional information	Additional information about the data product not covered in other sections.

5.3 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 terrain or obstacle 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 proposed metadata schema for terrain and obstacle data is based on ISO 19115 [20]. Some extensions are defined to comply with the requirements of ICAO Annex 15. Additional extensions are proposed to accommodate metadata necessary for obstacle data sets.

Where an “entity” is cited in the text (like EX_BoundingPolygon), the source reference is always ISO 19115.

Guidance on minimal metadata requirements can be found in the common interoperability rules and the obstacle data set interoperability rules on the AIXM confluence website.

5.3.1 METADATA REQUIREMENTS OF ICAO ANNEX 15 AND PANS-AIM

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 1 - Table 3) list the elements specified in ICAO PANS-AIM, together with the corresponding naming in ISO 19115. Attributes not listed in Table 1, Table 2 and Table 3 are regarded as feature properties, not metadata.

New elements are described in more detail in section 5.3.2.

5.3.1.1 METADATA FOR TERRAIN DATA SETS

The following table sets out the metadata elements for a terrain data set. If a metadata element (e.g. acquisition method) is not homogeneous in the data set but has different values in different regions then it is best practice to provide this information as polygons with the metadata element as attribute.

A sample metadata file for a terrain data set is accompanying this Manual. .

Element Name	**Metadata Element in ISO 19115**
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	LI_ProcessStep, description = “Acquisition Method: …”
Horizontal reference system	MD_ReferenceSystem.referenceSystemIdentifier
Horizontal resolution	DQ_DomainConsistency
Horizontal accuracy	DQ_PositionalAccuracy
Horizontal confidence level	*New Element;*DQ_PositionalAccuracy, description “Confidence Level”[24]
Vertical reference system	MD_ReferenceSystem.referenceSystemIdentifier
Vertical resolution	DQ_DomainConsistency
Vertical accuracy	DQ_PositionalAccuracy
Vertical confidence level	*New Element;* DQ_PositionalAccuracy, description “Confidence Level”
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

Table 1: Terrain – Data Set Metadata

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[24] 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.

5.3.1.2 METADATA FOR OBSTACLE FEATURES

The following table sets out the metadata elements for an obstacle feature:

Element Name	Metadata Element in ISO 19115
Acquisition method	LI_ProcessStep, description = ”Acquisition Method: …”
Data originator identifier	MD_Usage.userContactInfo, role=CI_RoleCode.originator
Horizontal resolution	DQ_DomainConsistency
Vertical resolution	DQ_DomainConsistency
Integrity	New Element: LI_Lineage. integrity

Table 2: Obstacle – Feature Metadata

5.3.1.3 METADATA FOR OBSTACLE DATA SETS

The following table sets out the metadata elements for an obstacle data set:

Element Name	Metadata Element in ISO 19115
Area of coverage	MD_DataIdentification.extent
Data source identifier	MD_Usage.userContactInfo, role=CI_RoleCode.publisher
Horizontal confidence level	New Element; DQ_PositionalAccuracy, description “Confidence Level”
Vertical confidence level	New Element; DQ_PositionalAccuracy, description “Confidence Level”
Integrity	New Element: LI_Lineage.integrity
Date and Time stamp	EX_TemporalExtent

Table 3: Obstacle – Data Set Metadata

5.3.2 EXTENSION FOR THE ISO 19115 DATA MODEL

5.3.2.1 NEW METADATA ABOUT A DATA SET

ISO 19115 [20] 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 data set level (for terrain data only).
elevationRepresentation[25]	The function is applied to the cell area to provide the representational value (e.g. minimum, maximum, mean, etc.) (for terrain data only).

Table 4: New Metadata at Data Set Level, Extending ISO 19115

Some extracts from the UML diagram are set out below, showing the new elements:

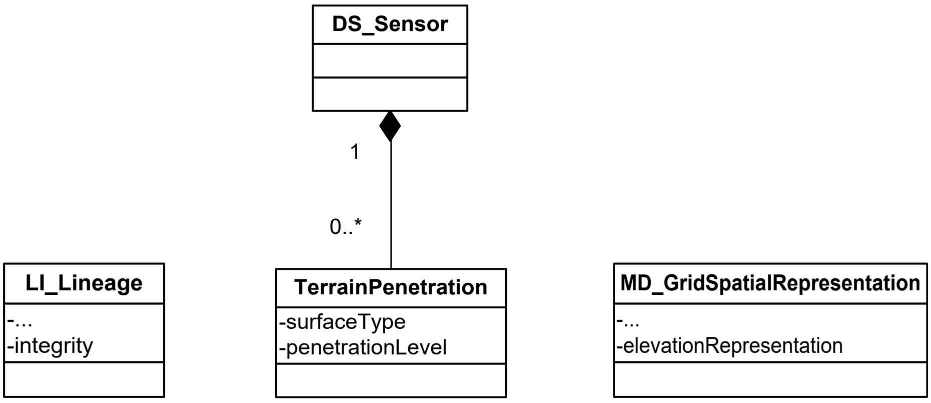

Figure 28: UML Model of New Metadata at Data Set Level

5.3.2.2 NEW METADATA ABOUT A FEATURE

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 data quality reporting and, when taken with horizontal accuracy, can provide a quick means of testing fitness for use.
verticalConfidenceLevel	The probability that the positional values are within the stated vertical accuracy of the true elevation.

---

[25] 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.

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.
knownVariations	Predictable changes to the data, e.g. seasonal elevation changes due to snow accumulations or vegetation growth (for terrain data only).

Table 5: New Metadata at Feature Level, Extending ISO 19115

All information about a feature is stored in “FeatureTimeSlice” entities and most metadata about a feature is therefore 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.

5.3.2.3 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.

5.3.3 RECOMMENDATIONS FOR METADATA COLLECTION

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 taken. The date and time of the operation, the person involved and the action taken should be recorded, as a minimum.

Operations include not only those actions that alter the aeronautical data, but also 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.

Detailed guidance on the collection and exchange of metadata between the data originators and the ANSP is provided in EUROCONTROL-GUID-177 [39].

The provision of a complete history of the data set for downstream users is not required as some of the processing procedures must be considered as the intellectual property of the processing party. Before provision, 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 there are restrictions on the data sets, it is important that such information is always passed on in full to the next intended user.

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 validation of metadata must form part of the standard production processes.

5.4 DATA COLLECTION

5.4.1 INTRODUCTION

This section addresses the most widely used surveying techniques for terrain and obstacle data. Whilst in the first part (section 5.4.3) the techniques (platforms and sensors) and their processes are presented, the following sections place the focus on the applicability of each technique for terrain data collection (section 5.4.4) and obstacle data collection (section 5.4.5).

Although the suitability of the techniques is compared with respect to their type and the terrain and obstacle area that they may most appropriately be used for, it should also be borne in mind 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 stand-alone process but one that needs to be integrated into the complete process of data request – collection – validation and verification – integration and eventual provision. This holistic process for data origination is covered in the EUROCONTROL-SPEC-154 [33].

5.4.2 GEODETIC REFERENCE SYSTEM

The World Geodetic System — 1984 (WGS-84) is the horizontal reference system and mean sea level (MSL) datum based on the Earth Gravitational Model — 1996 (EGM-96) the vertical reference system for international air navigation and therefore, applicable to the provision of TOD.

Extensive guidance on geodetic reference systems and their use in the origination of aeronautical data can be found in EUROCONTROL-SPEC-154 [33].

5.4.3 TECHNIQUES AVAILABLE

Depending on the data collection technique, different processing steps must be applied. The specifics of the different collection techniques and the corresponding processing workflows are discussed in general, with particular focus on how EU Regulations 73/2010 [42] and 2017/373 [43] impacts traditional data processing (for example, collecting metadata, data validation and documentation). This section also outlines the transformation of data between different reference systems.

5.4.3.1 TERRESTRIAL SURVEY

The terrestrial survey is still the most widespread technique for data acquisition. Compared to other surveying technologies, the investment in sensors and processing software for 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 and could be submitted to restriction access. This method is therefore mainly used for localised tasks. For the data capture of extended areas, it is often more economical to use an airborne or satellite mapping technique. Nevertheless, airborne and satellite survey techniques are not completely independent from terrestrial surveying, e.g. the surveying of highly accurate ground control points.

The terrestrial survey uses the following instruments:

- GNSS receiver;
- Total Stations (Theodolite combined with [reflector-less] distance measuring) often combined with a GNSS receiver;
- Terrestrial laser scanning.

With regard 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 or satellite mapping techniques;
- Validation of data acquired by an airborne or satellite sensor system;
- Completing airborne or satellite survey (e.g. for very thin objects).

Figure 29 describes the typical workflow for terrestrial survey. This method and the workflow shown below have been included in this Manual as they are most suitable for obstacle acquisition in large areas. For terrain data acquisition, the process can be simplified because GNSS equipment alone, run in Real-Time Kinematic (RTK) mode, described later in this section, is suitable for mass data collection[26].

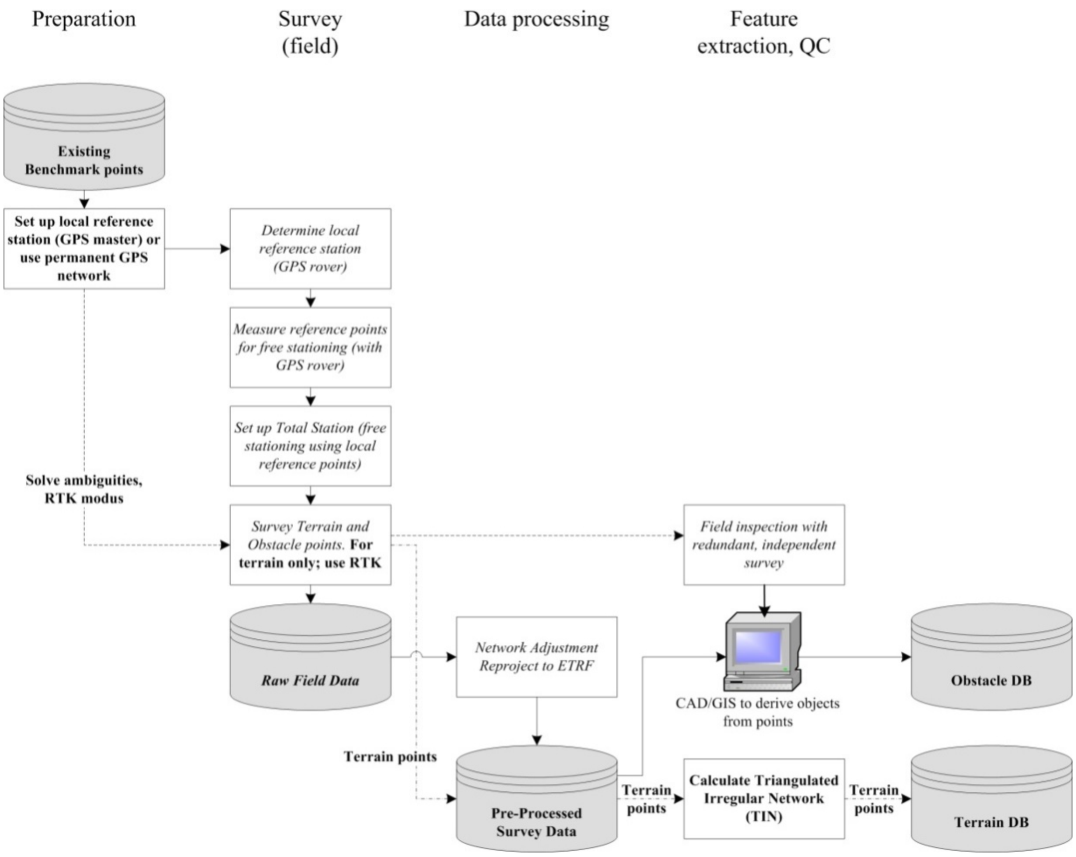
Preparation
Survey (field)
Data processing
Feature extraction, QC
Existing Benchmark points
Set up local reference station (GPS master) or use permanent GPS network
Determine local reference station (GPS rover)
Measure reference points for free stationing (with GPS rover)
Set up Total Station (free stationing using local reference points)
Solve ambiguities, RTK modus
Survey Terrain and Obstacle points. For terrain only; use RTK
Field inspection with redundant, independent survey
Raw Field Data
Network Adjustment Reproject to ETRF
CAD/GIS to derive objects from points
Obstacle DB
Terrain points
Pre-Processed Survey Data
Terrain points
Calculate Triangulated Irregular Network (TIN)
Terrain points
Terrain DB

Figure 29: Workflow of Terrestrial Survey[27]

The following *preconditions* have to be fulfilled for Total Stations type surveys:

- The reference station is operated on points with known coordinates or derived by free stationing;
- Monument control stations in a local network serve as the basis for the terrestrial survey;
- Local coordinate system:
    - Measurements with a Total Station are performed in a local planar coordinate 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 coordinate system[28]:
    - For the transformation of the surveyed points between the local coordinate 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 degree of accuracy. For a limited area, the transformation parameters can be derived with a set of reference points, with known 3D coordinates in both reference systems.

Preconditions for a GNSS type survey:

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[26] More details about data origination using conventional terrestrial surveying can be found in the ICAO Doc 9674 [12].

[27] Processes in italics indicate data in local coordinate system. Simplified process for terrain survey by means of GNSS-RTK in bold.

[28] Geodetic control points are usually available in a local coordinate frame as they have originally been measured using traditional surveying techniques (levelling, theodolite) and form part of a national geodetic network.

- Reference station(s) for DGNSS:
    - The definition of measured GNSS points is based on well-defined reference stations. For the resolution of ambiguities, at least one additional GNSS station will be used in DGNSS. To improve the precision of the resulting coordinates, measurements with short baselines are preferred. National and international permanent GNSS networks[29], which are often operated by the national survey agency, allow the surveyors to use more than one additional station to define the reference stations with higher precision and reliability. Where permanent or reference GNSS stations transmit the correction signal by radio waves, the receiver is capable of operating in RTK mode. Thus, the coordinates of the measurement points are available without post-processing. With GNSS, the survey is performed in a world-wide geodetic system. Transformations between WGS-84 and a local geodetic datum or coordinate system are therefore obsolete when the coordinates of the reference stations are known in WGS-84.

5.4.3.2 PHOTOGRAMMETRY

Aerial Photogrammetry is a mature survey technique which has been used for a number of years. Today the air borne system combines an imaging sensor with a positioning and orientation system (see 5.4.3.3). The latest development in this field is mainly in regard to digital sensors and miniaturisation. The pixel size of the sensor is the dominating factor in selecting the flight parameters, to ensure that the technical requirements are fulfilled. With the constant development of the photogrammetry systems the real challenging components remain all the environmental factors that are invariant of any technical parameter or technology utilised.

Apart from aerial photogrammetry earth observation from space is an established remote sensing technique for several years. Nowadays, civil earth observation satellites using optical sensors offer a high level of details improving small feature detection. The VHR satellites (Very High Resolution) acquire digital images of the Earth at a resolution of 30cm and covering a large area for each single image (~200 km²) with capacity of millions of km² per day. The last generation of satellites provide images with an absolute native horizontal accuracy better than 5m (at 90% confidence level) without any external ground reference.

Subject to good weather conditions (no clouds), Satellites can collect homogeneous images worldwide.

With regard to terrain and obstacle data, photogrammetry can be used for the following tasks:

- Terrain mapping (see section 5.4.4.3);
- Obstacle mapping (see section 5.4.5.3);
- Validation of ALS data, especially obstacle type classification.

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[29] An example: Online GNSS Processing Service by the Australian Government.

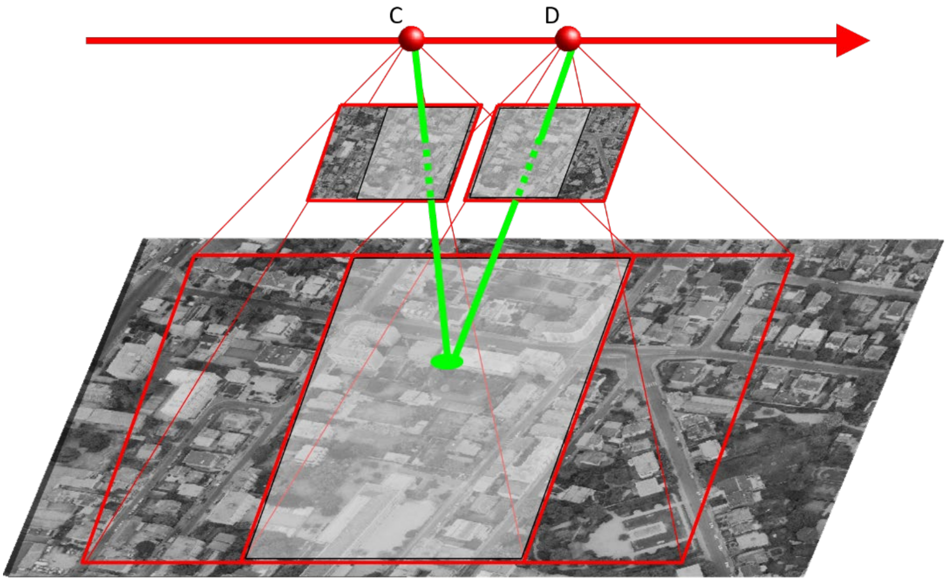


Figure 30: Stereoscopic Principle

Figure 31 describes the workflow of photogrammetry:

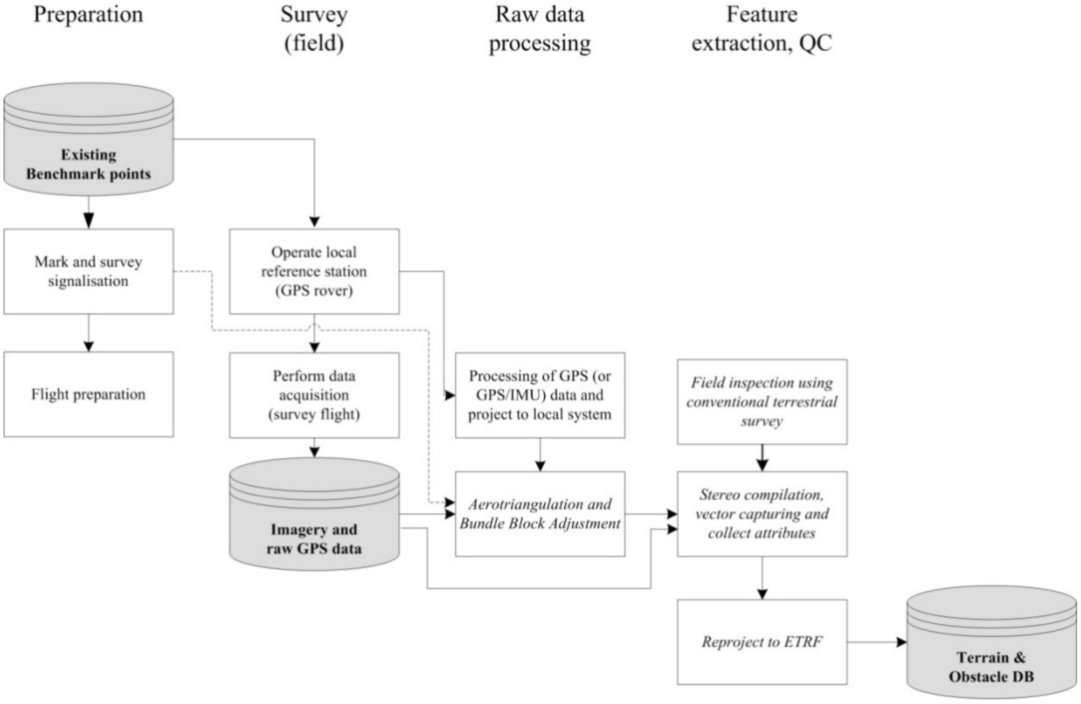

Preparation
Survey (field)
Raw data processing
Feature extraction, QC
Existing Benchmark points
Mark and survey signalisation
Operate local reference station (GPS rover)
Flight preparation
Perform data acquisition (survey flight)
Processing of GPS (or GPS/IMU) data and project to local system
Field inspection using conventional terrestrial survey
Imagery and raw GPS data
Aerotriangulation and Bundle Block Adjustment
Stereo compilation, vector capturing and collect attributes
Reproject to ETRF
Terrain & Obstacle DB

Figure 31: Workflow of Photogrammetry

The following pre-conditions have to be fulfilled:

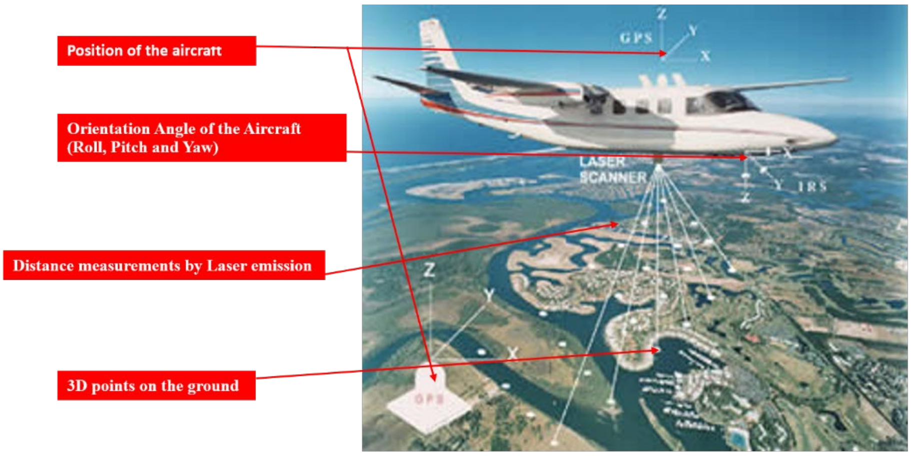
- Where not enough natural features are available as benchmarks/ground control points, the points must be marked/signalized and their coordinates determined by terrestrial survey;
- Flight plan based on:
  - Focal length;
  - Spatial accuracy requirements;
  - Flight restrictions;
  - Resolution requirements.

5.4.3.3 AIRBORNE LASER SCANNING (ALS)

Airborne Laser Scanning (ALS) also known as Light Detection and Ranging (LIDAR) is an established technique to capture terrain and surface information and derive bare-earth and obstacle data sets.

ALS is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the earth. These light pulses, combined with position and orientation data recorded by the airborne system, generate precise, three-dimensional information about the shape of the earth and its surface characteristics. An ALS system includes the following components:

- Laser scanner (measures the scan angle and time of flight for each laser pulse);
- Positioning and orientation system consisting of:
    - GNSS receiver on the aeroplane and reference station on the ground (differential GNSS (DGNSS));
    - Inertial Measurement Unit (IMU) to measure the orientation angle (roll, pitch and yaw) of the scanner system.


Position of the aircraft
Orientation Angle of the Aircraft (Roll, Pitch and Yaw)
Distance measurements by Laser emission
3D points on the ground
GPS
Z
Y
X
LASER SCANNER
IRS
GPS

4

Figure 32: ALS 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, a big development focus lies on improvements 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 homogenous data acquisition over the whole area. The main drawbacks of the technique are the high investment costs and the small number of operators that have sensors capable of obstacle mapping. While becoming more widespread and accessible, ALS is still a relatively complex and expensive - but very efficient - technique. It is therefore best suited for larger areas and repeat surveys

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 may need to be adjusted accordingly in certain technologies, to fulfil the technical requirements.

With regard to terrain and obstacle data, ALS methods can be used for the following tasks:

- Terrain mapping (see section 5.4.4.2);
- Obstacle mapping (see section 5.4.5.2).

Figure 33 describes the workflow for ALS:

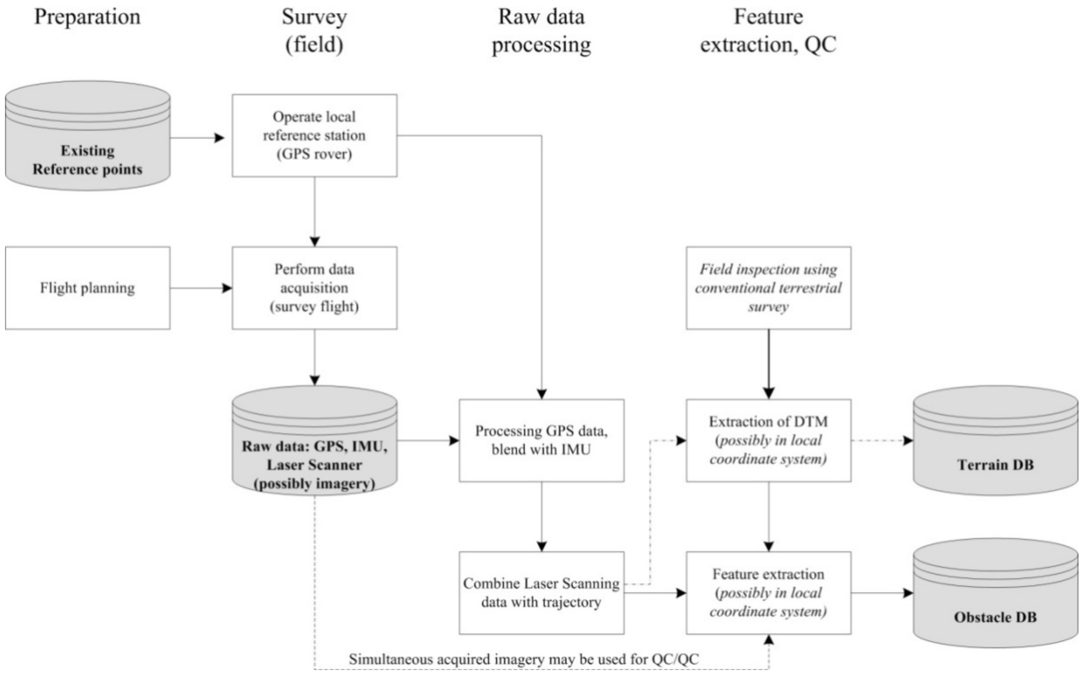

Preparation
Survey (field)
Raw data processing
Feature extraction, QC
Existing Reference points
Operate local reference station (GPS rover)
Flight planning
Perform data acquisition (survey flight)
Field inspection using conventional terrestrial survey
Raw data: GPS, IMU, Laser Scanner (possibly imagery)
Processing GPS data, blend with IMU
Extraction of DTM (possibly in local coordinate system)
Terrain DB
Combine Laser Scanning data with trajectory
Feature extraction (possibly in local coordinate system)
Obstacle DB
Simultaneous acquired imagery may be used for QC/QC

Figure 33: Workflow of ALS

The following pre-conditions have to be fulfilled:

- Flight plan with:
  - Flight lines;
  - Scan angle;
  - Scan rate;
  - Pulse repetition frequency.

These parameters influence flight height but, additionally, flight restrictions and topography may also impact flight planning. The most appropriate system settings are selected on the basis of the topography and 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;

- A well-defined monument reference station for master GNSS or the provision of a permanent GNSS reference network with post-processing capabilities.

The above-mentioned pre-conditions have to be fulfilled before the ALS surveying flight is performed.

As with any airborne survey technique, it is recommended that terrestrial survey should be performed to measure specific points, used as control points for data validation[30]. These measurements can be made before, during or after the flight is carried out. To maximise quality, the field survey should be conducted after post-processing. In this way, any open issues detected during post-processing can be checked in the field. In addition, terrestrial survey can also be performed to check and complete the TOD product derived from any remote sensing technique.

5.4.3.4 SYNTHETIC APERTURE RADAR (SAR)

Of the different radar measuring devices, Interferometric Synthetic Aperture Radar (IfSAR) is the most common. IfSAR is an active sensor system using microwave (wavelength between 2 and 100

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[30] Existing geodetic control 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.

cm) and recording the signals reflected from the terrain. Each pulse emitted illuminates a relatively large area and the reflected signal is continuously digitised. The sampling allows a finer resolution of the area illuminated. By repeatedly emitting pulses, each object is illuminated several times. By combining the subsequent signals, a 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 (where the separation is known very precisely), 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 third coordinate to be determined. The workflow is very similar to aerial photogrammetry.

IfSAR systems consist of:

- Two Synthetic Aperture Radar (SAR) systems;
- A positioning and orientation system consisting of:
    - GNSS receiver on the aeroplane;
    - Availability of GNSS reference data, e.g. from national CORS stations, global corrections services or dedicated ground reference stations; and
    - IMU to measure roll, pitch and yaw of the scanner system.

As for airborne systems, satellite SAR interferometry is a well-known technique used for several years now to accurately compute elevation models of the Earth’s surface. It requires phase information of the reflected signal (and not image intensity) from two coherent SAR images.

With regard to terrain and obstacle data, SAR methods can be used for the following tasks:

- Terrain mapping (see section 5.4.4.4),
- Obstacle mapping[31] (see section 5.4.5.4).

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[31] There are ongoing academic research projects where IfSAR systems are also used to detect obstacles. So far, no evidence has been provided that this data meets the quality requirements.

Figure 34 describes the workflow for IfSAR:

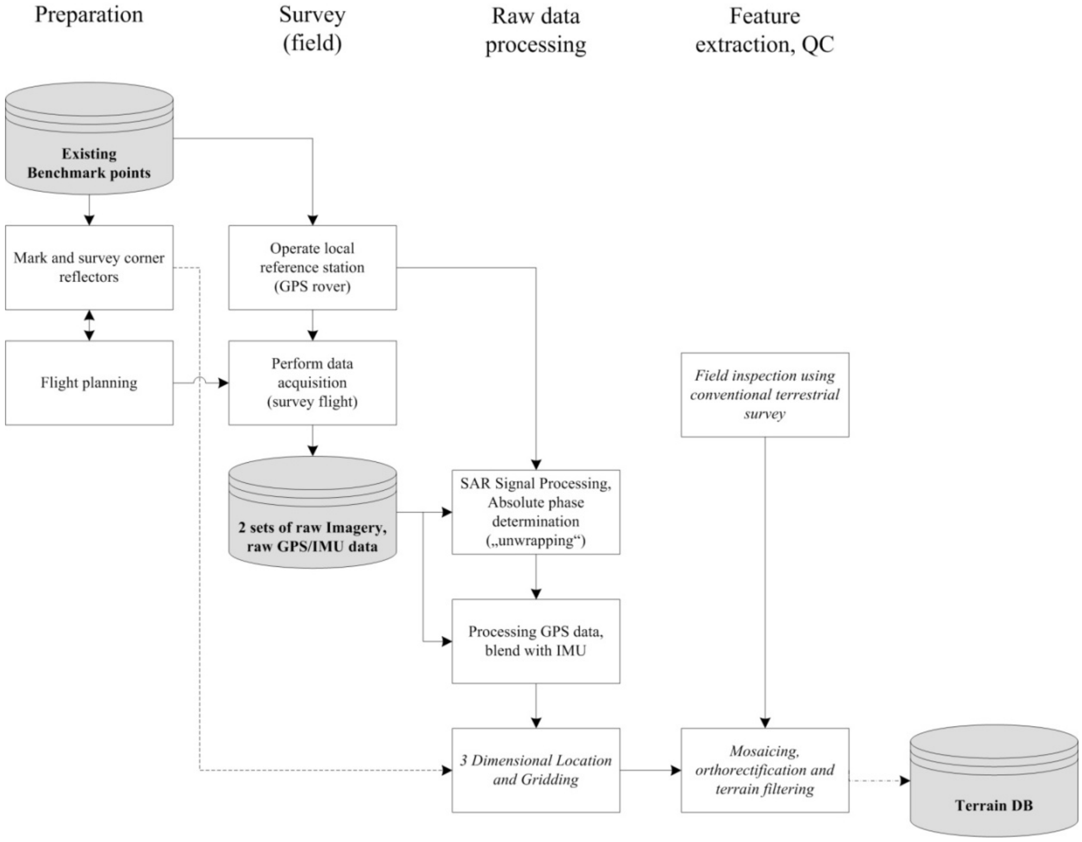
Preparation
Survey (field)
Raw data processing
Feature extraction, QC
Existing Benchmark points
Mark and survey corner reflectors
Operate local reference station (GPS rover)
Flight planning
Perform data acquisition (survey flight)
Field inspection using conventional terrestrial survey
2 sets of raw Imagery, raw GPS/IMU data
SAR Signal Processing, Absolute phase determination („unwrapping“)
Processing GPS data, blend with IMU
3 Dimensional Location and Gridding
Mosaicing, orthorectification and terrain filtering
Terrain DB

Figure 34: Workflow of IfSAR

The following pre-conditions have to be fulfilled:

- Benchmarks have to be marked (corner points) and their coordinates determined using terrestrial survey;
- Flight plan based on:
  - System characteristics (pulse rate, range, etc.);
  - Spatial accuracy requirements;
  - Flight restrictions;
  - Resolution requirements.

5.4.3.5 SENSOR PLATFORMS

Different vehicles are utilized to transport the sensors used in the aerial and space born surveying techniques (i.e. aerial and satellite photogrammetry, ALS and aerial and satellite SAR). Platform capabilities are compared using different criteria and considering important factors as follows:

- Unmanned Aircraft Vehicle (UAV):
  - Has a limited payload for simple sensors on the lower end of the spectrum.
  - Operates in a limited range due to endurance limitations, but with high flexibility.
  - The operating altitude is typically 50 m – 300 m AGL.
  - The data acquisition can be performed on a low infrastructure cost, especially if using a camera (photogrammetry).
  - Licensing and permission processes are vastly different between countries and are evolving quickly.

  - Coordination and ATC approval is required, especially when operated near airports (e.g. Area 2 and 3 obstacle surveys).
- Helicopter:
  - Enough payload capacity to carry today’s high-end survey sensors (camera, LIDAR, IfSAR).
  - Can operate in flexible flight patterns and at low speeds. This can be an advantage when operating in close proximity to arriving and departing traffic around aerodromes.
  - The operating altitude for survey operations is typically 100 m – 500 m AGL.
  - Temporary mounting of the larger sensors is possible but requires STC certification.
  - Operations are clearly regulated and integrated into today’s airspace infrastructure.
- Airplane:
  - Enough payload capacity to carry today’s high-end survey sensors (camera, LIDAR, IfSAR).
  - Most efficiently operated in regular flight patterns over a large area
  - The operating altitude for survey operations is typically 500 m – 2000 m AGL and up to 7000 m AGL with new high-resolution LIDAR technology.
  - The installation of the sensors requires a dedicated survey aircraft with STC certified sensor hatches or external pod.
  - The data acquisition is performed at a high cost. Therefore, for an efficient operation, the high cost requires a high usage rate of the aerial sensor platform.
- Satellite:
  - Satellite systems require an extremely high-cost infrastructure. There are only a few organisations operating remote sensing systems.
  - Satellites operate all over the Earth, now as constellations, without any restriction (excepting cloud coverage for optical sensors) and by definition without any air traffic disruption around aerodromes
  - Satellites operate with fixed orbit parameters allowing only limited configuration flexibility but worldwide coverage and have the ability to regularly provide data of the same area, offering a way for monitoring activity and detect changes around airports.
  - The operating altitude of most Earth observation VHR satellites is typically 400 km - 700 km AGL.
  - Satellites provide a long-term based solution as once in orbit their mission lifetime is more than 10 years. They are continuously orbiting the Earth collecting data for many type of applications creating a large catalog of archive images.

The following table shows a comparison of the different sensor platforms in regards to the coverage areas. 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.

	UAV (ALS, Photogrammetry)	Helicopter (ALS, Photogrammetry)	Airplane (ALS, Photogrammetry, IfSAR)	Satellite (Photogrammetry, SAR)
Area 1	-	o	+	++
Area 2	o	+	++	++
Area 3[32]	++	++	+	-
Area 4	++	+	o	-

Table 6: Comparison regarding Different Sensor Platforms

5.4.3.6 SENSOR FUSION

Since every sensor system has its strengths and weaknesses, a 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.

5.4.4 TERRAIN DATA COLLECTION

The application of specific techniques (described in 5.4.3) for the collection and processing of terrain data will be outlined in this section.

5.4.4.1 TERRESTRIAL SURVEY

Compared to obstacle mapping, conventional terrestrial surveying is much more efficient for terrain data acquisition. Although the number of points acquired per working day is still much lower than any aerial or satellite mapping technique, terrestrial survey has the advantage that the uneven distribution of points, with the focus on break lines and spot elevations, significantly reduces the amount of data collected. The terrain model can then be derived from the surveyed points and break lines, by building up a TIN.

In various studies, consideration has been given to the possibility of mounting a GNSS antenna on a car (operated in RTK mode) to increase surveying efficiency. A dynamic approach using vehicle-based Mobile Laser Scanning is available for more efficient data capture. However, this technique is restricted to the immediate surroundings of the mobile system's track (usually roads).

In forested and urban areas with tall buildings, terrain data with GNSS can encounter limitations and difficulties due to limited satellite visibility and signal strength.

5.4.4.2 ALS

During data acquisition with ALS, no distinction is drawn between ground and non-ground objects. Filtering, i.e. the classification of terrain and obstacle points, is an important processing step in TOD 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 5.1).

5.4.4.3 PHOTOGRAMMETRY

As described for ALS, the imagery collected with aerial photogrammetry for obstacle mapping allows the extraction of a DTM by either interactive stereo restitution of break lines and mass points or via

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[32] ALS and aerial photogrammetry are only very cost-efficient when Areas 3 and 4 are surveyed in one survey campaign.

a DSM generated using image correlation techniques. From this dense DSM point cloud, the terrain extraction process is similar 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[33].

The generation of a DTM with satellite photogrammetry is comparable to aerial photogrammetry:

Earth observation satellites allow capturing simultaneous stereopairs (even tri-stereo if required) so that a same area is covered by two different images acquired with two different incidence angles. For good quality and accuracy result, the base on height ratio (B/H) is a very important criteria being controlled during the acquisition process.

After the spatio-triangulation step allowing perfect matches and georeferencing of the stereopairs, an automatic image correlation process will generate a Digital Surface Model (DSM). This is the first raw surface generated, containing both ground and above-ground elevations, that will require a semi-automatic filtering process to clean all existing artefacts (spikes & wells), filling voids (interpolation, stereo-edition or exogenous data integration depending the size of the void), flatten water bodies to a constant elevation…

Then, additional filtering process will be necessary to remove all above-ground information (buildings, vegetation…) and obtain a Digital Terrain Model (DTM).

As for aerial photogrammetry, the accurate representation of the terrain below a dense forest with relief may be difficult in some cases. Satellite optical sensors collect information in infrared channel to support vegetation detection.

Also, instead of generating a DTM through an initial image correlation step, another process can be used based on stereo restitution (break lines and mass points) but which becomes very time consuming for large areas as it is a manual process.

5.4.4.4 SAR

Interferometric SAR (IfSAR) provides one of the highest data acquisition rates from all currently available surveying techniques. The products offered 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) prevents portions of the terrain from being 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 occurs only 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.

Digital Elevation Models (DEMs) from spaceborne SAR systems can be generated by interferometry (IfSAR) or radargrammetry techniques from different positions of SAR images.

Radar imaging systems record both the phase (or time) and the intensity information of the backscattered signals. Interferometry uses the phase information of the images to extract useful geodetic information, such as the height of the terrain. In comparison, radargrammetry uses the intensity information in a stereopair of radar images. This is similar to stereo photogrammetry which is a classic method for relief reconstruction using airborne or spaceborne optical images.

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[33] 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. This helps to identify vegetated vs non-vegetated area but doesn't help to estimate the ground elevation below trees or vegetation height

Interferometry is the most accurate and radargrammetry is the most robust method.

Interferometry requires observing an area from slightly different look angles. This can be done either simultaneously (with two radars mounted on the same platform or bistatic formation like with TanDEM-X mission) or at different times exploiting repeated orbits.

The distance between the two satellites in space (or instruments) in the plane perpendicular to the orbit is called the interferometer baseline. Based on this two slightly different image acquisition positions, the interferometric phase difference can be calculated which can be transferred into terrain height. The radar wavelength used impacts the level of penetration into the vegetation. Most of SAR interferometers are using X-band (wavelength of approximately 3 cm) and radar signals are essentially reflected at the surface of the vegetation. This allows the generation of a Digital Surface Model.

Radargrammetry is a method to determine the position of radar targets in a three-dimensional space from two SAR (amplitude) images. It is similar to stereo photogrammetry but based upon radar. The target is imaged by the SAR sensor at two different orbit positions, separated by a baseline (i.e. including a parallax). Matching algorithms are employed to obtain the range and azimuth positions of the same target point in both images.

The quality of radargrammetry DEM depends strongly on the base to height ratio (B/H) or intersection angle of the radargrammetry pair. To acquire good geometry for radargrammetry pairs, the intersection angle between the two SAR images should be enough for the observed parallax which is used to determine the terrain elevation. However, in order to have good stereo-matching, nearly identical images are necessary with small intersection images. Thus, a compromise has to be reached between a better stereo-viewing and more accurate elevation computation.

5.4.4.5 COMPARISON AND RECOMMENDATION

All surveying techniques presented in the previous sections 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.
- SAR:
    - 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 quality in forested areas;
    - SAR is independent from day/night and can collect through clouds;
    - Global data sets are available.
- Aerial 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 imagery can be used as a basis for many other applications.
- Satellite Photogrammetry:

  - Same aspects as for aerial photogrammetry plus
  - Very useful for large areas.
- Terrestrial survey:
  - Has the lowest capital costs but is very labour-intensive;
  - Results in a well-structured terrain model (points, breaklines), with a minimum of objects;
  - Is ideal for data validation.

The following table sets out recommendations regarding the various surveying methods for terrain. 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	SAR	Satellite Photogrammetry	Aerial Photo-grammetry	Terrestrial Survey
Area 1	+	++	++	+	o
Area 2	++	++	++	++	o
Area 3[34]	+/++	-	-	+/++	+
Area 4	+/++	-	-	+/++	++

Table 7: Recommendation regarding Survey Methods for Terrain

5.4.5 OBSTACLE DATA COLLECTION

The application of specific techniques (described in 5.4.3) for the collection and processing of obstacle data will be outlined in this section.

5.4.5.1 TERRESTRIAL SURVEY

Single obstacles can be measured with high accuracy and reliability by terrestrial survey if best-practice methods are observed. On-site survey is the most reliable way to verify completeness of a TOD dataset and determine all required obstacle feature attributes (e.g. type, marking and lighting). Even using state-of-the-art sensors, terrestrial survey is limited in its efficiency by the limited visibility from ground-based standpoints. This is less impactful for small areas with few, well-defined obstacles (e.g. Area 3), but especially inefficient for large areas with high numbers of obstacles.

GNSS/RTK measurements are not suitable for obstacle data acquisition due to the need to access each obstacle to be surveyed.

5.4.5.2 ALS

Several points should be considered when using ALS for obstacle mapping:

- To increase the probability of capturing a thin object, like an antenna, the sensor should be tilted[35] and the radiometric resolution of the sensor should be calibrated. It is very important to adjust the density of ALS to the size of objects that have to be detected.
- Environmental conditions: humidity and dust can have a major impact on the strength of the signal returned (local loss of signal). Meteorological restrictions must therefore be carefully

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[34] ALS and aerial photogrammetry are only very cost-efficient when Areas 3 and 4 are surveyed in one survey campaign.

[35] EUROCONTROL ALS Feasibility Study [31] showed that the completeness of obstacle data could be increased if the laser is tilted by 20°.

observed during data collection.

- Obstacle detection: After pre-processing the different data streams (GNSS, 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[36]. The non-ground points can then be compared with an ODCS and the points describing obstacles can be easily detected. With a tilted sensor, multiple pulses are expected for each object, with almost identical x/y but different z coordinates 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 (e.g. the reflection from a bird). As with all remote sensing techniques, control surveys in the form of terrestrial surveys are 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 greatly depends on the quality requirements (i.e. target applications) of the geometry. For further information, see EUROCONTROL ALS Feasibility Study [31].
- 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-referenced point cloud. Feature extraction does not require ALS capabilities and so, again, it can be performed by a different organisation.

5.4.5.3 PHOTOGRAMMETRY

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 the section above. But the image correlation is, in some circumstances (low texture), not reliable and the DSM is 2.5D[37], 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 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, thus facilitating the differentiation of objects penetrating the ODCS from other objects. A DSM can help to quickly identify hot spot areas where the terrain penetrates or is very close to ODCS so as to focus more carefully on those areas during the manual capture or the quality control.

Human interaction in photogrammetric data processing allows a combination of both the obstacle detection and feature extraction steps, resulting in high-quality, true 3D vectors.

The most restrictive requirement for obstacle acquisition by aerial 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[38] 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. However, with the mission requirements differing from the regular practice, the cost of data acquisition may be higher when using traditional approach to data gathering. This may be mitigated with a use of more capable equipment or unmanned systems.

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[36] 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.

[37] i.e. for each x/y coordinate, there is exactly one height.

[38] 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.

Satellite imagery resolution (30cm) will be a limiting factor (compared to aerial or LIDAR) when it comes to detect and measure accurately very thin or very small obstacles (antenna, mast, aerials etc.) from earth observation satellite data. But satellite photogrammetry allows to capture efficiently a very large set of objects and over a large area. To ensure higher completeness, this method must be completed by complementary ground survey or based on drone.

Also, machine learning techniques can be applied to satellite imagery due to the massive volume of images available for one single place and in perpetual growth. It can help to automatically identify specific object pattern (e.g. wind turbine) or tallest objects (e.g. for Area 1 over countrywide areas).

Last but not least, due to the permanent revisit of satellites, spaceborne method becomes very useful for the Obstacles database maintenance. An area can be regularly monitored and changes automatically detected without sending surveyors on the field or contracting a new aerial survey.

5.4.5.4 SAR

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, precluding the determination of elevation in layover regions. The signal can also be disturbed by atmospheric perturbations.

5.4.5.5 COMPARISON AND RECOMMENDATIONS

A comparison of the different obstacle surveying techniques shows advantages and disadvantages of each technique. This comparison should support organisations responsible for the survey in selecting the most suitable method. The most important factors to consider are:

- ALS:
  - Has the highest capital costs and is therefore less widely available;
  - Already offers the highest degree of automation but further development is expected;
  - Has a low risk of missing an obstacle during data acquisition.
- Aerial Photogrammetry:
  - Is the most efficient technique for data acquisition;
  - Incorporates less automation compared to ALS, but the algorithms are still evolving;
  - Involves a higher risk of missing an obstacle compared to ALS, but due to manual interaction the quality of the resulting obstacle is expected to be higher than all other techniques.
- Satellite Photogrammetry:
  - Same aspects as for aerial photogrammetry plus
  - Very useful for large areas.
- Terrestrial survey:
  - Has the lowest capital costs but is very labour-intensive;
  - Is a mature technique, but little further improvement is expected;
  - Is ideal for data validation.
- SAR:
  - Obstacle extraction from SAR generated digital surface models suffers from low reliability.

The following table sets out recommendations regarding surveying methods for obstacles. 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/or very poor cost/benefit ratio.

	ALS	SAR	Satellite Photo-grammetry	Aerial Photo-grammetry	Terrestrial Survey
Area 1[39]	+	-	+	+	-
Area 2	++	-	+	+	o
Area 3	+/++[40]	-	-	+/++[40]	+
Area 4	+/++[40]	-	-	+/++[40]	++
Single or small group of Obstacles	o/+[40]	-	-	o/+[40]	++

Table 8: Recommendation regarding Survey Methods for Obstacles

5.4.6 COORDINATE TRANSFORMATION BETWEEN DIFFERENT REFERENCE FRAMES

5.4.6.1 TRANSFORMATION BETWEEN "OLD" LOCAL COORDINATES AND WGS-84

Transforming "old" local coordinates into WGS-84 is often impossible using a strict mathematical transformation only. Errors in the old, local coordinate systems and the differences between the underlying ellipsoids must be considered. Such transformations rely on a large number of reference 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 coordinates from old to new national reference frames.

5.4.6.2 TRANSFORMATION FROM "OLD" NATIONAL TO ELLIPSOIDAL HEIGHTS

To convert heights from reference points available in an old national reference frame and in national map coordinates, to ellipsoidal heights, firstly the orthometric or normal heights above a well-known (quasi-)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 coordinates in the national projection system are converted to ellipsoidal coordinates, as described above. Finally, the ellipsoidal heights, based on the local reference ellipsoid, are converted to a global one using a datum transformation.

5.4.7 COLLECTING DATA FOR AERODROME MAPPING AND TOD

5.4.7.1 ICAO REQUIREMENTS

ICAO Annex 15 recommends that

Aerodrome mapping data sets should be made available for aerodromes regularly used by international civil aviation.

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[39] 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).

[40] This surveying method is cost efficient when the sensor is operated from a drone or Area 3/4 collection is combined with Area 2 collection

ICAO PANS-AIM describes the content and organisation of an aerodrome mapping data set:

Note 2.— Aerodrome mapping data is organized and arranged in aerodrome mapping databases (AMDBs) for ease of electronic storage and usage by appropriate applications.

Note 3.— The content of the aerodrome mapping data sets is defined in Radio Technical Commission for Aeronautics (RTCA) Document DO 272D / European Organization for Civil Aviation Equipment (EUROCAE) Document ED 99 — User requirement for Aerodrome Mapping Information

Furthermore, ICAO PANS-AIM explains the relationship between TOD and Aerodrome mapping data:

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.

This chapter presents some considerations to take into account when obstacle and aerodrome mapping data are collected in a single survey.

5.4.7.2 AERODROME MAPPING DATA

Aerodrome mapping data (AMD) contains geographic information of an aerodrome with the purpose of supporting ground navigation. Applications using AMD improve situational awareness, facilitate digital NOTAM displays and aerodrome surface routing. An example application is A-SMGCS (see section 2.5) which makes use of both aerodrome mapping data and terrain and obstacle data for maximum benefits.

Relevant for TOD is the detailed list of attributes and capture rules for vertical structures specified in section 4.1.5 of EUROCAE ED-99D [27]:

“Vertical structures include point, line, and polygon structures. Point structures have a radius indicating any associated structures such as guywires.”

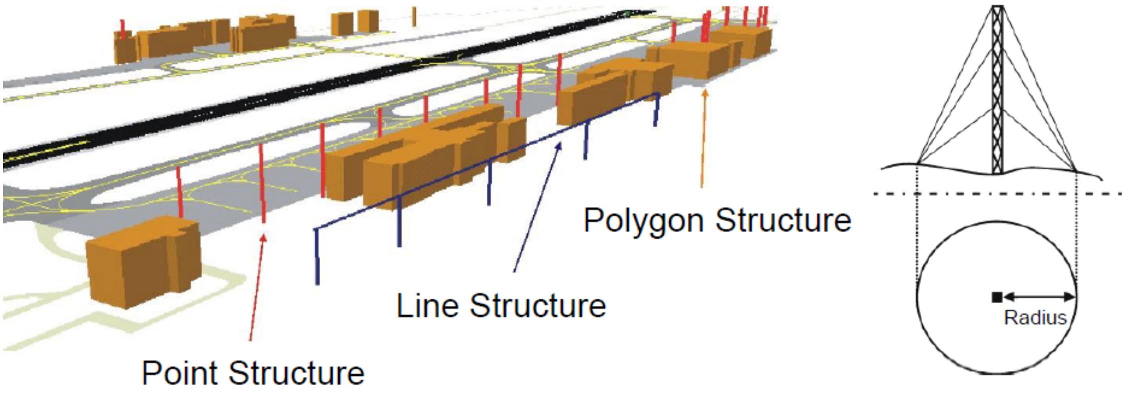

Figure 35: Vertical Structures as defined in EUROCAE ED-99D 4.1.5

EUROCAE ED-99D [27] specifies three different quality categories (*Fine*, *Medium* and *Coarse*) for accuracy and integrity of the data elements. These requirements for vertical structures are similar but not identical to the ICAO requirements for obstacle. Only the *Fine* category is identical to the ICAO Area 3 requirements. For an AMD data set of *Medium* quality, the vertical structures could be captured according to ICAO Area 2 quality requirements. An AMD of *Coarse* quality is only 2D and the requirements for vertical structure horizontal data match those defined for ICAO Area 1 obstacles.

5.4.7.3 COMMON DATA COLLECTION

TOD and AMD can be originated using common data collection techniques (as described in the sections above) and managed in a single GIS.

Aerodrome obstacles on the aerodrome and AMD vertical structure are digital representations of the same real-world objects. However, there are differences between the TOD and AMD requirements regarding collection and depiction of the objects. The most significant differences are as follows:

a) TOD Area 3 covers a limited data of the aerodrome, i.e. 50 m from taxiway boundary, 90 m from the runway centreline (see section 3.4.1.4 for details). AMD covers the whole aerodrome and its structures, i.e. any vertical structure on the aerodrome surface, e.g. aerodrome terminals, towers, hangars.

b) TOD and AMD apply different footprints of the objects. For TOD, the relevant footprint is defined at the intersection of the obstacle with the obstacle collection surface. For AMD vertical structures the footprint on the ground is considered. For most of the Area 3 obstacles where the obstacle collection surface is 0.5 m above ground level this difference is not relevant but for aerodrome buildings that intersect with an OLS transitional surface, which represents a collection surface for Area 2, the relevant footprint for TOD can substantially differ from the AMD footprint.

c) AMD vertical structures located in Area 3 must to be captured in *Fine* quality to be used in an obstacle data set meeting the ICAO requirements.

If aerodrome mapping and obstacle data sets are to be provided for an airport, then a combined survey including Area 3 obstacles and AMD features is beneficial for both purposes. However, it is important to be aware of the different processing needs of the data for the production of the obstacle and the aerodrome mapping data sets.

5.5 DATA VALIDATION AND VERIFICATION

5.5.1 CONTEXT

Data validation and verification for terrain and obstacle data are important tasks in data processing which aim to check and maintain data quality.

The terrain and obstacle data processing model is mostly similar to the aeronautical data processing model described in the ICAO AIS Manual Volume II [8]. Within the TOD context each participant in the data chain receives data from the previous participant, verifies the correct reception and each processing step and validates the data quality before passing the data to the next participant in the data chain.

The data validation and verification methods of aeronautical data are addressed in detail in EUROCAE ED-76A [25]. The definitions and guidance on terrain and obstacle data validation and verification in this document are based on this EUROCAE standard and for verification and validation methods and criteria, concepts from ISO 19113 [18], ISO 19114 [19], ISO 19157 [24], ISO 19138 [22] are used.

In TOD context, verification methods consist of digital error detection (e.g. CRC), feedback, independent redundancy and update comparison. Validation methods consist of data consistency (e.g. logical or semantic consistency) and completeness check.

The verification procedures follow the spatial data quality principles described in the next section.

5.5.2 SPATIAL DATA QUALITY

5.5.2.1 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-76A [25] and, subsequent to this, in ISO 19113 [18], 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 provided as aeronautical information products.

The quality philosophy [34] 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 measurement of the data quality (quality evaluation procedure) and the data quality reporting

The data quality philosophy consists of the following three topics:

a) Spatial Data Quality Elements/Sub-elements;
b) Data Quality Evaluation Procedure;
c) Data Quality Reporting/Metadata.

5.5.2.2 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[41]. It includes the following data quality elements and data quality sub-elements[42]:

a) Accuracy:

  - Positional accuracy (x, y, z)

    For positional data, the accuracy is normally expressed in terms of a distance from the estimated (or measured) position, within which there is a defined confidence of the true position falling (ICAO Annex 15)[43];

  - 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-76A [25]).

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[44]:

   The degree of confidence that a data element is not corrupted[45] while stored or in transit (ICAO Annex 15).

d) Traceability:

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[41] For detailed information, see ISO 19113 and EUROCAE ED-76A. Guidance for measures and samples can be found in ISO 19131.

[42] Unless otherwise stated, the source of an element and its definition is ISO 19113.

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

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

[45] 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.

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 the 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 Chapter 2 and this section of this Manual.

5.5.2.3 DATA QUALITY EVALUATION PROCEDURES

In validation and verification, data quality evaluation procedures 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 must 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 36 provides a general data quality evaluation process.

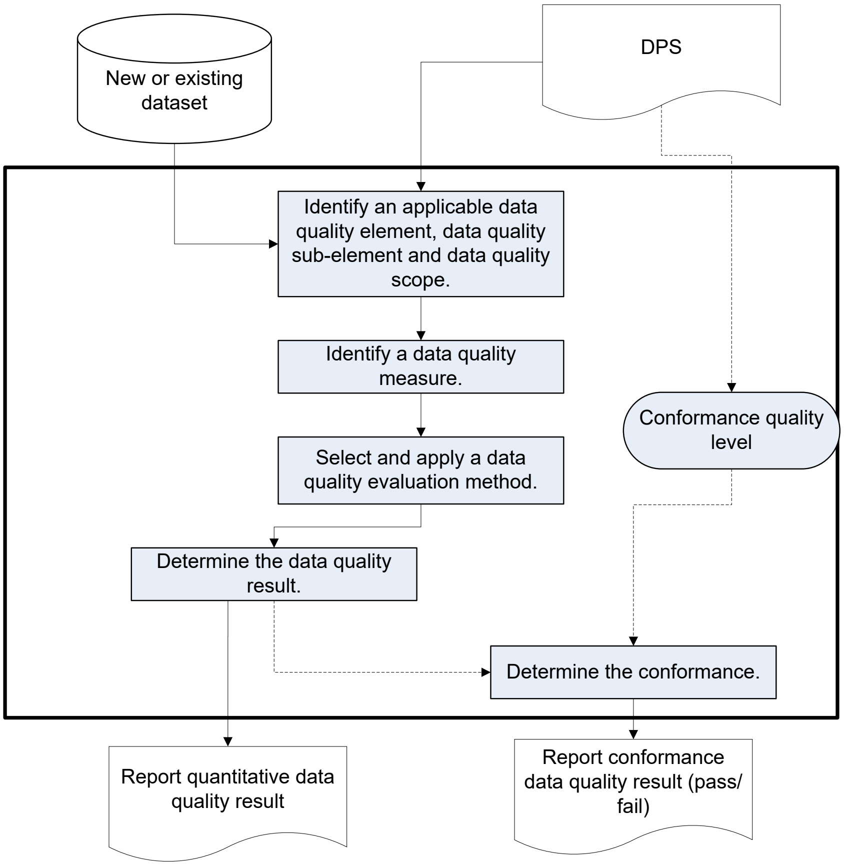
New or existing dataset
DPS
Identify an applicable data quality element, data quality sub-element and data quality scope.
Identify a data quality measure.
Select and apply a data quality evaluation method.
Conformance quality level
Determine the data quality result.
Determine the conformance.
Report quantitative data quality result
Report conformance data quality result (pass/ fail)

Figure 36: The Data Quality Evaluation Process (source ISO 19114)

Data quality evaluation procedures may either be direct or indirect (see Figure 37). Direct methods determine data quality through 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”.

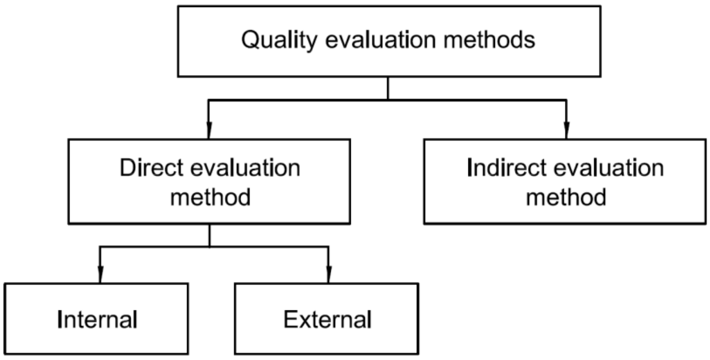

Figure 37: Classification of Data Quality Evaluation Methods (source ISO 19114)

Background information on data quality based on the ISO 19113 [18] and ISO 19114 [19] standards is provided in EUROCONTROL Quality Philosophy [34].

5.5.2.4 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 [20]). 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 38 shows the data model for data quality reports (source ISO 19109 [16]).

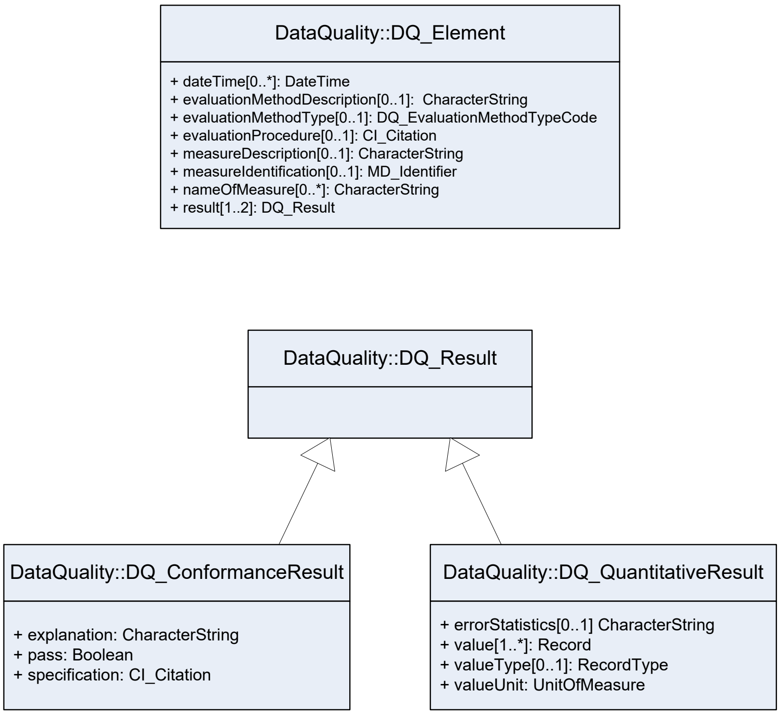
DataQuality::DQ_Element
+ dateTime[0..*]: DateTime
+ evaluationMethodDescription[0..1]: CharacterString
+ evaluationMethodType[0..1]: DQ_EvaluationMethodTypeCode
+ evaluationProcedure[0..1]: CI_Citation
+ measureDescription[0..1]: CharacterString
+ measureIdentification[0..1]: MD_Identifier
+ nameOfMeasure[0..*]: CharacterString
+ result[1..2]: DQ_Result
DataQuality::DQ_Result
DataQuality::DQ_ConformanceResult
+ explanation: CharacterString
+ pass: Boolean
+ specification: CI_Citation
DataQuality::DQ_QuantitativeResult
+ errorStatistics[0..1] CharacterString
+ value[1..*]: Record
+ valueType[0..1]: RecordType
+ valueUnit: UnitOfMeasure

Figure 38: Data Model for Data Quality Reports

The goal of each data quality report is to provide sufficient information 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.

5.5.3 VERIFICATION

EUROCAE ED-76A [25] defines Verification as *"The evaluation of the outputs of a process to ensure correctness and consistency with respect to the inputs and standards provided to that process.".*

In the TOD context, the following verification techniques can be applied:

- Data integrity checks
- Feedback

- Independent redundancy
- Update comparison

Verification task is directly linked to the data processing model and it mainly aims to check and maintain data integrity.

5.5.3.1 DATA INTEGRITY CHECKS

Data is generally well protected when stored in a database (e.g. an AIS/AIM system). As soon as data is transferred there is a heightened 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 digital error detection mechanism like hash functions or cyclic redundancy checks (CRC) can be helpful. These are simple mechanisms that support the detection of unauthorised modifications and ensures the data integrity during transmission and/or storage.

Hash function and CRC are algorithms applied to the data that provides a level of assurance against loss, modification or corruption of data.

After any data transmission or before any use of the data, the integrity check should be performed.

Note that properties of a hash function or CRC are lost when the data is translated. It has two consequences:

- After each data translation, a new hash value or CRC has to be generated;
- Digital error detection is not a tool that can check if translation interfered with data integrity. Other verification techniques have to be implemented as described below.

5.5.3.2 FEEDBACK AND INDEPENDENT REDUNDANCY CHECKS

Feedback and independent redundancy checks can be used to verify correct execution of a data translation process (e.g. coordinate transformation or data extraction).

EUROCAE ED-76A defines Feedback testing as *“the comparison of a data set between its output and input state (see Figure 39). A common method of feedback is manual confirmation, whereby data is copied to a new location and confirmed to be correct.”.*

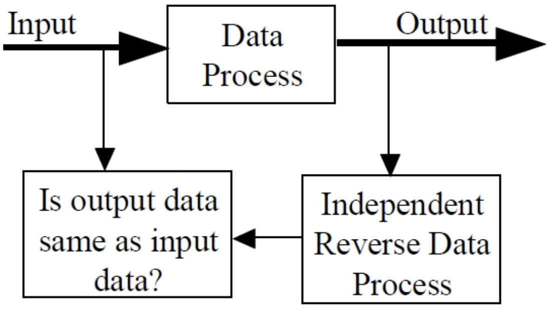
Input
Data Process
Output
Is output data same as input data?
Independent Reverse Data Process

Figure 39: Feedback

EUROCAE ED-76A defines Independent Redundancy as follows*: “Independent redundancy testing involves processing the same data through two or more independent processes and comparing the data output of each process (see Figure 40).”*

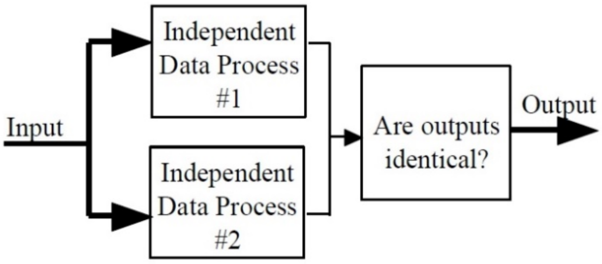

Figure 40: Independent redundancy

Usually data translation processes are performed by automated tools or such tools are used to check manual data processes (e.g. manual data entry). To ensure that data integrity is not interfered by the tool it should be verified using the techniques defined above:

- To develop two independent translation tools (development processes must be totally independent)

  Proceed data through the two processes, get the two different translated data sets and check if they are fully consistent – if they are not, the translation is not correct

  This is a strategy based on independent redundancy
- To develop another translation tool which is able to perform the reverse translation (again, development process of this tool must be totally independent from the two previous tools)

  Proceed translated data through this process and check if the reverse translated data set is consistent with the original one – if they are not, the translation is not correct

  This is a strategy based on feedback

For every translation step, those methods should be implemented to ensure data integrity.

As an alternative, tool qualification[46] can be applied to ensure that the tool complies with its requirements and does not introduce errors or fail to detect errors.

5.5.3.3 UPDATE COMPARISON

EUROCAE ED-76A defines Update Comparison as follows: *“Updated data can be compared to its previous version. This comparison can identify all data elements that have changed. The list of changed elements can then be compared to a similar list generated by the supplier. A problem can be detected if an element is identified as changed on one list and not the other.”*

Update comparison is a verification method which gives the opportunity to reduce the scope of validation tasks. It is obvious about TOD, that a huge amount of data will not be changed by an update. The idea then is to check that all the data that have not been changed are consistent with the former ones. Then, only the part of data set that has been actually updated has to be validated.

The rest can be considered as validated since it is consistent with data that has been validated before. In such situation full inspection will be reduced to inspection of data which was identified as updated.

5.5.4 VALIDATION

The purpose of validation is to ensure that the data meets the requirements or in other words that the data is fit for its intended use. The validation procedures are linked to the application of the concept of quality evaluation procedures, explained in section 5.5.2.3.

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[46] Tool qualification is the process by which assurance is achieved that tools employed will neither introduce errors into the data nor fail to detect an error. When required, tool qualification shall be performed within the context of the tool’s intended use, using EUROCAE ED-215 [30] with adaptations provided in EUROCAE ED-76A, Appendix D.

EUROCAE ED-76A defines Validation as *“The activity whereby a data element is checked as having a value that is fully applicable to the identity given to the data element, or a set of data elements is checked as being acceptable for their intended use.”*

Data should be validated as early as possible in the data chain. The earlier non-compliances with the data product specification or the data quality requirements are discovered, the cheaper it is to correct the deficiencies. Therefore, the obligation for data validation is a responsibility of the actors at every stage the data chain:

- At data origination
- At data collection
- At data product preparation

5.5.4.1 VALIDATION AT DATA ORIGINATION

The data originator is the first actor in the data chain and is responsible for “creating” the data quality. The subsequent actors can only maintain the quality of the data but not increase it. Data validation at origination is therefore crucial for the quality of the data product reaching the user.

The originator of terrain or obstacle data is the only actor in the data chain who has access to the objects to be surveyed. Therefore, the data originator has to validate the measurements (coordinates, heights, extents), the object coding (recorded surface, obstacle type), other observed attributes (marking and lighting) and the completeness of the survey (have all obstacles in the area of interest being surveyed).

Test cases for validating these properties can be found in Appendix G. Sampling as described in section 5.5.6 can be applied.

5.5.4.2 VALIDATION AT DATA COLLECTION

Data collected from the data originators has to be validated before further processing. With the validation at this stage it is ensured that the collected data complies with the quality requirements specified in the formal arrangements.

The main source of information for this validation is the metadata and survey report accompanying the collected data. The following checks should be done:

Accuracy:	Is the accuracy of the data indicated and does it meet the requirements?
Resolution	Is the resolution commensurate with the accuracy? That means: is the data provided with enough digits not to jeopardise its accuracy?
Integrity:	Is there comprehensible evidence that the data has been processed according to the integrity classification (see traceability)?
Traceability:	Have all the relevant origination, translation and validation processes been documented by the data originator (Lineage information in the metadata).
Timeliness:	Is the effective period of the data elements defined?
Completeness:	Do the features (obstacles, terrain models) have all the required attributes? Does the metadata have all required information? Is there comprehensive evidence that the data originator has validated the data for completeness (e.g. that all the obstacles in the area of interest have been surveyed)?
Format:	Has the data been provided in the format specified in the formal arrangements?

Test cases for validating of these properties can be found in F.2. Many of these validation activities can be automated as described in section 5.5.5.

In addition to validating the data based on the methods described above, the following plausibility checks can be applied:

- Obstacle and terrain data can be validated by visualisation in a geographic information system.

Topographic maps, orthophotos or satellite maps serve as the geographic reference.

- Obstacle data with elevation and height (above ground) attributes can be checked against digital terrain data. The terrain elevation at the foot-point of the obstacle should be identical (within tolerance) to the obstacle elevation minus its height above ground.
- Obstacle data can also be checked against digital terrain data in a 3D-viewer. Erroneous obstacles are either sticking in the terrain or floating in the air.

5.5.4.3 VALIDATION AT DATA PRODUCT PREPARATION

Data sets generated at data collection (see section 5.5.4.2) are validated before they are provided or made available to the next intended user. Validation at this stage means checking that the data set complies with the relevant data product specification.

The validation of the data sets includes:

Completeness checks:	Are all the relevant obstacles included in the data set? Does the data set have no excessive data elements (e.g. obstacles that should not be in the data set)? Are all required feature properties part of the data set? Is all required metadata included with the data set? Test cases for the validation of selected feature properties are proposed in F.2.
Consistency checks:	Test cases related to logical consistency, format consistency and conceptual consistency are provided in F.2.

Obstacle data sets encoded in AIXM 5 are subject to an XML schema validation: the data set is checked whether it is syntactically correct (XML is well formed) and whether it follows the structure defined in the XML schema (XML is valid).

5.5.5 AUTOMATION

It is possible to apply tools to perform verification and validation tasks on any data set and produce a detailed report. Thanks to automation, there are only few verification and validation tasks which will be carried manually on samples. Indeed, most of the validation and verification tasks can be fully automated, run under full inspection and therefore don’t need sampling.

For each assessment task, it is advised to automate it if possible. Automated tools[47] may be:

- Geographic Information Systems (GIS) with spatial analysis functions
- Software tools for statistical analysis of samples
- Tools for validating digital data sets against a set of business rules

5.5.6 USE OF SAMPLING

The purpose of sampling is to select a representative sub-set of the main data set. Hence, the sample size is reduced enough to perform a validation/verification task which is impossible to fully automate. Such tasks can be:

- Ground inspection
- Additional independent survey
- Manual verification of correctness of a value by checking it in the documentation. For example, if confidence level in the data set is 95%, then check for evidence that the provider actually committed to provide the data set with this confidence level.
- Other checks

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[47] It should be noted that tools that may introduce errors or are used to detect errors in essential or critical data should be qualified using EUROCAE ED-215 [30] with adaptations provided in EUROCAE ED-76A, Appendix D.

5.5.6.1 SAMPLING FOR ACCURACY ASSESSMENT

The goal of accuracy assessment is to determine if the value of an attribute is consistent with the universe of discourse (or at least, within the tolerances).

To build a representative sample, several methods can be used. It is proposed to use a stratified method based on obstacle collection surface. It appears to be the most relevant method for TOD.

P is the percentage which defines the size of the sample. This percentage can vary from 5% to 30%[48] and it has to be adjusted according to the costs.

For each obstacle collection surface of the assessed data set, randomly choose P% of entries to create the sample. The sample will be P% of the original data set and each obstacle collection surface will be represented proportionally to its amount of entries

This sample created can now be checked considering accuracy, thanks to ground inspections (checking obstacle type, marking, lighting etc.) and/or surveys (checking the accuracy of the coordinates). Those operations shall be independent from the first acquisition.

For checking the accuracy of the coordinates, the check-survey should be considered as the true value and therefore be significantly more accurate than the accuracy requirements.

5.5.6.2 SAMPLING FOR COMPLETENESS ASSESSMENT

Completeness assessment by sampling mainly focuses on omission of obstacles in an area survey. The sample is not built from the assessed data set, instead a representative sample area has to be defined for validating the completeness.

The location and size of the sample area or areas should be chosen based on obstacle collection surfaces and take into account the density of the area. To be representative it should include 5% to 30% of the obstacles of the complete survey.

It is advisable to put emphasis on areas where the ground is the most elevated (mountains, hills, etc.). For example, it is possible to configure the random selection to give more probability for elevated areas to be chosen.

The completeness check can be done by visual field inspection of the sample area. It should focus to identify all high thin objects (each technique will have limitation with very thin obstacles) and to integrate some elevation measurements as the top elevation of those objects may not always be properly measured.

The completeness check can also be done with an independent resurvey. If the latter is chosen then the completeness check can be combined with the accuracy assessment.

5.5.7 QUALITY ASSESSMENT OF EXISTING TERRAIN DATA

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 regard to terrain data, the following issues are expected to be the most critical ones as regards 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;

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[48] As a rule of thumb, it can be stated that a good percentage for sampling is between 5% and 30% (simplification of ISO 2859-1).

  - 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 involved in data origination and processing known? If so, can they provide additional information to that already provided in the metadata? What is the date of original survey data? Is the area fully covered? How is the recorded surface (e.g. for DTM, are all vegetation or man-made features removed)? What is the representation of the elevation value in a cell (e.g. maximum, average)?
  - The licensing should allow at least a limited distribution of the terrain data for aviation purposes;
  - 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 geodetic control points. These control 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[49] 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 ensuing costs would be.

5.5.8 QUALITY ASSESSMENT OF EXISTING OBSTACLE DATA

The requirement to capture and publish information about en-route air navigation obstacles and significant aerodrome obstacles pre-existed the introduction of the TOD provisions to ICAO Annex 15 and the consequential changes to ICAO Annex 4. The collection and maintenance of obstacle data was conducted under national arrangements and obstacle data bases were maintained for airport obstacle management based on ICAO Annex 14 and for flight procedure design. It is important to ensure that this legacy data meets the data quality requirements of ICAO PANS-AIM when using it for ICAO compliant obstacle data sets.

The process for the validation of existing obstacle data is similar to that for terrain data because, to a large extent, the origination and often also the maintenance of existing obstacle data is not under the control of the civil aviation domain. It is expected that, in the near future, obstacles will be collected and published from one single data base. Therefore, it is recommended that existing obstacles data sets, based on older less stringent ICAO SARPs of “pre-TOD”-editions of ICAO Annex 4 and ICAO Annex 14 and often based on different national regulations, are migrated to “ICAO Annex 15 - requirements” 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 (existing data is mainly of type “point” or "line" even if the footprint exceeds the threshold and requires polygon obstacle features);
- Spatial and thematic accuracy;
- Commission/omission of data:

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[49] It is assumed that the geodetic control points are known in the target reference system too. If no geodetic control points are available in WGS-84/EGM-96, new ground control points need to be surveyed as a basis for data quality evaluation.

  - entire features missing because of selection processes applied for cartographic purposes;
  - thematic information missing due to different application schema (more attributes to be provided according to the ICAO PANS-AIM schema);
- Different coordinate reference system.

Whilst some of the differences can be resolved at relatively low cost, it becomes more expensive to originate missing obstacles. It is recommended that the migration should be started with a careful analysis of the quality 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 inconsistencies between the different sources should be determined.

This analysis and assessment should identify the quality deficiencies of existing data, to determine which processing steps must be taken to enable the publication of obstacle data in accordance with the ICAO Annex 15 and PANS-AIM provisions or to annotate the limitation of use of the published information until resurveyed data is available.

5.6 DATA ORGANISATION

It is clear that what was considered to be a large data set a decade ago is no longer viewed as such today, now that systems are capable of handling terabytes of data.

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 and is best done with a Geographic Information System (GIS).

For example, in the aviation sector, many AIS providers and airport authorities use GIS to manage spatial data including terrain and obstacles. Often high-resolution imagery (orthophoto), with a 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.

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 used to describe, in a structured form, real-world phenomena as shown in Figure 41. 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).

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.

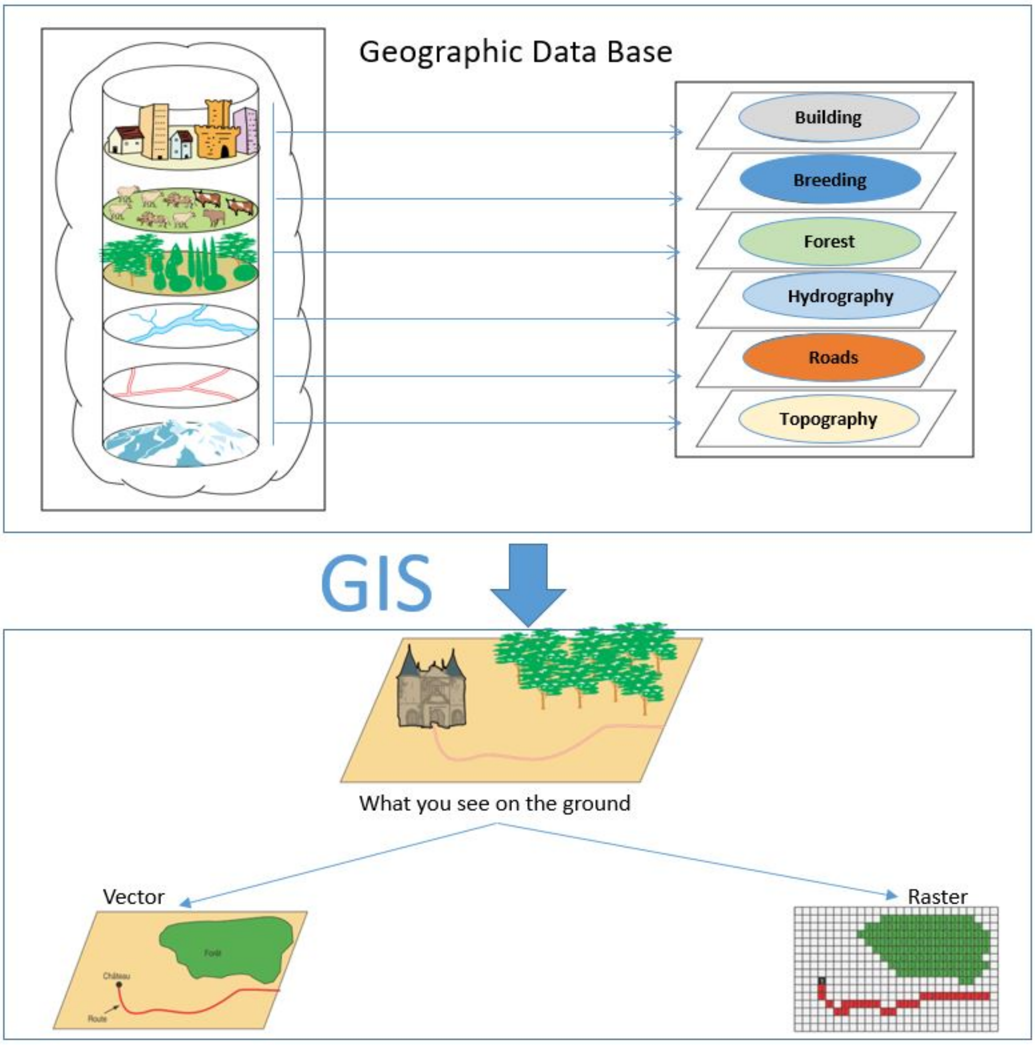

Figure 41: Modelling real world phenomena in a GIS

5.7 DATA PROVISION

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

In line with the requirements of ICAO Annex 15, States must make digital terrain and obstacle data available to users. This section sets out a number of possible solutions for making terrain and obstacle data accessible.

There are different possible methods for making this data available:

- Data is made available for the user as a SWIM compliant service;
- Data is made available for the user by other means over the Internet; and
- Data is provided to the user as a dataset on physical media.

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 user of the data. However, it does identify the capabilities, which may be offered.

Note: Guidelines for a harmonised approach for the publication of obstacles and provision of obstacle data set is provided in the EUROCONTROL-GUID-172 [32].

5.7.1 DATA PROVISION USING SWIM SERVICES

ICAO Annex 15 recommends that global communication networks such as the Internet should, whenever practicable, be employed for the provision of aeronautical information products.

System Wide Information Management (SWIM) represents a new means of managing and exchanging information. It replaces the current ground-ground point-to-point information exchange by an aviation message exchange relying on internet technologies enabling information services to be provided to the ATM community.

There are two main mechanisms by which data will flow from producers to consumers in SWIM environment:

- data which may be requested through web services as needed, and
- on-going real-time feeds of messages (notifications or actual data).

The former describes the request/reply message exchange pattern, and the latter the publish/subscribe or messaging exchange pattern. Both mechanisms will be utilised for the provision of terrain and obstacle data and are discussed in the next sections.

Further detailed guidance on the implementation of a SWIM service can be found in ICAO PANS-IM [13], ICAO Doc 10039 [14] and EUROCONTROL-SPEC-169 [38], addressing the description of information services, the definition of the exchanged information and the technical infrastructure on which the services are implemented.

5.7.1.1 AERONAUTICAL DATASET SERVICES

An Aeronautical Dataset service supports the concept of the aeronautical information product in form of digital data sets as defined by ICAO Annex 15. The provision of such digital data sets via SWIM follows the corresponding principles and requirements defined in ICAO Doc 10039 [14], ICAO AIS Manual Volume IV – Digital Products and Services [8].

A simple implementation of an Aeronautical Dataset service is the provision of pre-defined data sets, as specified in detail in ICAO PANS-AIM. “Pre-defined" means that the dataset content is specified in advance. It is not possible for the user of the service to define its own dataset. It is only possible to choose between the datasets made available. This has to be seen as a minimal digital AIS data provision service.

More advanced digital data services are also expected to be deployed by AIS, for example providing access to feature level data, for example in the form of a Web Feature Service (WFS).

5.7.1.2 DATA PROVISION WITH SWIM USING WEB SERVICES

Terrain and obstacle information exchange services will be utilised to exchange and filter data. TOD information exchanges can be quite voluminous and information exchange services can be utilised to trim down exchanged data to the exact needs of consumers. Due to the different nature of data being exchanged (gridded, imagery, and non-gridded) a specialized information exchange service is required for each.

Within the broader context of Web Services, OGC Web Services (OWS) represent an evolutionary, standards-based framework that enable seamless integration of a variety of online geoprocessing and location services. OWS allows distributed geoprocessing systems to communicate with each other across the Web using familiar technologies such as XML and HTTP.

The Open Geospatial Consortium (OGC)[50] defines a series of standards to provide interoperable solutions. These standards empower technology developers to make complex spatial information and services both accessible and useful to all kinds of applications, mainly for the Request/Reply exchange pattern.

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[50] 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.

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

- Web Feature Service (WFS)

  The WFS represents a change in the way geographic information is created, modified and exchanged on the Internet. Rather than sharing geographic information at the file level using File Transfer Protocol (FTP), for example, the WFS offers direct fine-grained access to geographic information at the feature and feature property level. This International Standard specifies discovery operations, query operations, locking operations, transaction operations and operations to manage stored, parameterised query expressions. In the context of TOD a WFS can be used to provide obstacle data.

  An example of the capabilities expected from such services is provided in the OGC Web Feature Service (WFS) Temporality Extension Discussion Paper [51].

- Web Map Service (WMS);

  The WMS provides a simple HTTP interface for requesting geo-registered map images from one or more distributed geospatial databases. A WMS request defines the geographic layer(s) and area of interest to be processed. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc) that can be displayed in a browser application. The interface also supports the ability to specify whether the returned images should be transparent so that layers from multiple servers can be combined or not. In the context of TOD a WMS is used for visualisation of terrain and obstacle data. The Aerodrome Terrain and Obstacle Chart – (ICAO) Electronic is a possible application of a WMS (see section 2.6.4).

- Web Coverage Service (WCS)

  The WCS standardizes access to large, multidimensional raster archives. A WCS request delivers the selected raster data together with detailed descriptions, allows complex inquiries and delivers the data with its original semantics, i.e. ready for further processing. In the context of TOD, a WCS can be used to provide digital terrain data.

- Web Map Tile Service (WMTS)

  The WMTS is a standard based solution to serve digital maps using predefined image tiles. WMTS intends to improve streaming access performance to large raster files that have been cut in predefined tiles. Such service is available from most recent GIS software. The WMTS provides a complementary approach to the WMS.

  WMTS can be used to access and visualize Terrain data.

5.7.1.3 DATA PROVISION WITH SWIM USING MESSAGING

While information exchange services provide advanced capabilities for accessing terrain and obstacle data, they are insufficient to address all SWIM scenarios of real-time terrain and obstacles information exchange. ICAO Doc 10039 [14] describes common messaging capabilities (the publish/subscribe messaging pattern) to be used throughout SWIM and TOD will use this capability to reliably distribute data, notifications, and status updates. Messaging is particularly useful with data that is issued at an unpredictable rate, data that must be delivered as quickly as possible, or data that represents a series of frequent and small updates. Publish/subscribe messaging technology is generally not well suited to distributing large data files/messages directly, and as such will be used in TOD SWIM for:

- notifying data consumers that data is available for access through a web service;
- pushing relatively small data files directly to consumers as they become available on the provider; and
- mission-critical service updates to data consumers, such as notifications of a web service outage, data outage, service/maintenance windows, or degraded provider capabilities.

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[51] OGC Web Feature Service (WFS) Temporality Extension, OGC 12-027r3

Of the messaging protocol standards, the Advanced Message Queuing Protocol (AMQP) is the most general-purpose, and is supported by many existing messaging broker implementations. With the AMQP Messaging it is possible to make data changes available to subscribing recipients immediately or at regular intervals while pushing the data changes to the recipient using the Publish/Subscribe Exchange pattern. Recipients do not have to poll for data changes on a regular basis and therefore unnecessary data traffic is being avoided.

5.7.1.4 SWIM REGISTRY

In line with the SWIM concept - the SWIM Registry Service aims at improving the visibility and accessibility of ATM information and services available through SWIM. This enables service providers, consumers, and regulatory authorities to share a common view on SWIM.

The SWIM Registry is the source of reference for service information in SWIM.

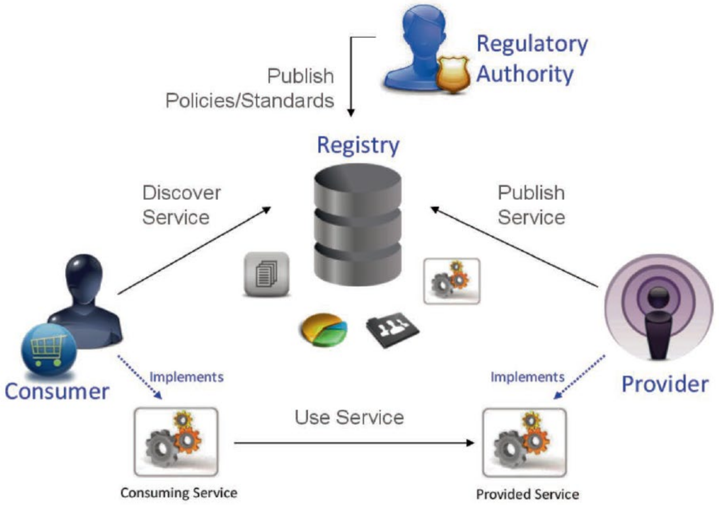
The SWIM registry provides a list of service descriptions that are in line with the EUROCONTROL-SPEC-168 [37]. It also serves as repository of available and applicable service standards, policies and additional supporting material.

By using the SWIM Registry, service providers gain visibility for their upcoming or implemented information services, on the basis of common principles. This implies that all services are duly described by metadata.

The service providers are responsible for the service description and the lifecycle management of their services included in the registry.

Service consumers use the SWIM registry to access consolidated service information so that they can identify the most suitable services for their information exchange needs.

The regulatory authority defines the registry policies (e.g. scope, service registration, access control).



5.7.2 DATA PROVISION BY CONVENTIONAL MEANS OVER THE INTERNET

In this chapter the main concepts of providing TOD data via the internet are listed and briefly described. Detailed guidance and best practices for Aeronautical Information Service Providers in distributing the State AIP on the Internet as an official/authoritative source of information can be found in the EUROCONTROL-GUID-165 [36].

5.7.2.1 FTP

File Transfer Protocol (FTP) could be used for providing the data on a server accessible by the recipient. 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.

FTP may also be used by 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.

5.7.2.2 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:

1. Only those users who have subscribed for products are able to access the download area for the data;
2. 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.

5.7.2.3 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.

5.7.3 DATA PROVISION ON PHYSICAL MEDIA

5.7.3.1 CD/DVD

The digital files could be burnt to a CD or 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 the normal postal service do not, by default, provide a proof-of-delivery although these may be available as an additional “paid-for” service.

5.7.3.2 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 portable hard disks, may be used.

5.8 DATA MAINTENANCE

Guidance on the organisational and institutional aspects of data maintenance is given in section 4.4.9. This section covers some of the technical issues which may arise during data maintenance.

5.8.1 OBSTACLE DATA

The technical aspects of obstacle maintenance do not differ greatly from those of initial data acquisition. Depending on the update process applied, the following work packages linked to data maintenance can be identified:

a) Adding, updating or deleting an obstacle as a 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 updating of the obstacle data.

As proposed in section 4.3.3.3, 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 based purely on the obstacle identifier and does not pose any implementation difficulties.

Work package b) is only of relevance when the data was first originated based on cadastral data (see also section B.3.3). 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 organisation responsible with data maintenance, leaving the handling of the identifiers to surveyors and therefore reducing the burden on the ANSP. Surveyors are likely to have the tools required for the geographic reconciliation of features.

Reconciliation by the ANSP has the advantage that it offers 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.

5.8.2 TERRAIN DATA

Data maintenance is, as stated in section 4.4.9.2.2, 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 must be integrated into the existing data by local replacement. Irrespective of the size of the replacement, enough overlap at the borders must be ensured to allow a proper transition from the old to the new data set (see also section 5.5.7).

5.9 ISO 19100 - APPLICATION

In ICAO Annex 15, several standards from the ISO 19100 series are cited as a requirement or as a recommendation. 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 users to provide evidence to their regulator that compliance has been achieved.

The following table provides a summary of those standards relevant for TOD as well as how and where within this Manual is addressed:

ISO Standard	**Relevance to TOD**
ISO 19109 [16]	The application schema proposed for obstacle data is AIXM 5.x and for terrain data the application schema from EUROCAE ED-119C [28]. Both models contain an

ISO Standard	Relevance to TOD
	application schema compliant with ISO 19109 (see section 5.2.4).
ISO 19110 [17]	The application schema proposed for obstacle data is AIXM 5.x and for terrain data, the application schema from EUROCAE ED-119C [28]. Both models use the feature cataloguing methodology laid down in ISO 19110 (see section 5.2.4).
ISO 19113 [18]	The data quality philosophy in section 5.5.2 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 [19]	In section 5.5 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 [20]	The application schema proposed for obstacle data is AIXM 5.x and for terrain data, the application schema from EUROCAE ED-119C [28]. Both models use the metadata catalogue laid down in ISO 19115 (see section 5.2.4). Some metadata elements from ICAO Annex 15 are currently missing in AIXM. These have been addressed in section 5.3.
ISO 19131 [21]	The DPS proposed to be used for terrain and obstacle data in section 5.2 strictly follows the specifications laid down in ISO 19131.

Table 9: References to the Standards of the ISO 19100 Series

Appendix A REFERENCES

The following documents are referenced within this Manual:

Ref.	Short title	Full Title	Edition
1.	ICAO Annex 4	ICAO Annex 4 – Aeronautical Charts	11th Edition, July 2009 incorporating Amendment 60
2.	ICAO Annex 6	ICAO Annex 6 – Operation of Aircraft, Part I: International Commercial Air Transport — Aeroplanes	9th Edition, July 2010
3.	ICAO Annex 14	ICAO Annex 14 – Aerodromes, Volume I: Aerodrome Design and Operations	8th Edition, July 2018
4.	ICAO Annex 15	ICAO Annex 15 – Aeronautical Information Services	16th Edition, July 2018 incorporating Amendment 40
5.	ICAO PANS-AIM	ICAO Doc 10066 – Procedures for Air Navigation Services Aeronautical Information Management (PANS-AIM)	1st Edition, 2018
6.	ICAO PANS-OPS	ICAO Doc 8168 – Aircraft Operations, Volume II (PANS-OPS)	6th Edition, 2014
7.	ICAO PANS-Aerodromes	ICAO Doc 9981 – Procedures for Air Navigation Services Aerodromes (PANS-Aerodromes)	2nd Edition, 2016
8.	ICAO AIS Manual	ICAO Doc 8126 – Aeronautical Information Services Manual Volume II — Processing Aeronautical Data Volume IV — Digital Aeronautical Information Products and Related Services	Vol II: To be released Vol IV: Under development
9.	ICAO Doc 9082	ICAO Doc 9082 – Policies on Charges for Airports and Air Navigation Services	9th Edition, 2012
10	ICAO Doc 9161	ICAO Doc 9161 – Manual on Air Navigation Services Economics	5th Edition, 2013
11	ICAO Doc 9562	ICAO Doc 9562 – Airport Economics Manual	4th Edition, 2020
12	ICAO Doc 9674	ICAO Doc 9674 – World Geodetic System 1984 (WGS-84) Manual	2nd Edition, April 2002
13	ICAO PANS-IM	ICAO Doc 100xx – Procedures for Air Navigation Services Information Management (PANS-IM) Volume I System Wide Information Management	Under development

Ref.	Short title	Full Title	Edition
14	ICAO Doc 10039	ICAO Doc 10039 – Manual on System Wide Information Management (SWIM) Concept	To be released
15	ICAO Doc 7754	ICAO Regional Air Navigation Plan - EUR Air Navigation Plan Vol II and Vol III	Regularly updated
16	ISO 19109	ISO 19109 – Geographic information – Rules for application schema	2005
17	ISO 19110	ISO 19110 – Geographic information – Methodology for feature cataloguing	2005
18	ISO 19113	ISO 19113 – Geographic information – Quality principles	2002
19	ISO 19114	ISO 19114 – Geographic information – Quality evaluation procedures	2003
20	ISO 19115	ISO 19115 – Geographic information – Metadata	2003
21	ISO 19131	ISO 19131 – Geographic information – Data product specifications	2007
22	ISO 19138	ISO 19138 – Geographic information — Data quality measures	2006
23	ISO 19139	ISO 19139 – Geographic information – Metadata – XML schema implementation	2007
24	ISO 19157	ISO 19157 – Geographic information — Data quality	2013
25	EUROCAE ED-76A	EUROCAE/RTCA ED-76A/DO-200B – Standards for processing aeronautical data	June 2015
26	EUROCAE ED-98C	EUROCAE/RTCA ED-98C/DO-276C – User requirements for terrain and obstacle data	October 2015
27	EUROCAE ED-99D	EUROCAE/RTCA ED-99D/DO-272D – User requirements for aerodrome mapping information	October 2015
28	EUROCAE ED-119C	EUROCAE/RTCA ED-119C/DO-291C – Interchange standards for terrain, obstacle and aerodrome mapping data	October 2015
29	EUROCAE ED-179B	EUROCAE/RTCA ED-179B/DO-315B – Minimum Aviation System Performance Standards (MASPS) for Enhanced Vision Systems, Synthetic Vision Systems, Combined Vision Systems and Enhanced Flight Vision Systems	September 2011

Ref.	Short title	Full Title	Edition
30	EUROCAE ED-215	EUROCAE/RTCA ED-215/DO-330 – Software Tool Qualification Considerations	January 2012
31	EUROCONTROL ALS Feasibility Study	Airborne Laser Scanning for Airport Terrain and Obstacle Mapping (A Limited Feasibility Study)	Version 1.0, May 2006
32	EUROCONTROL-GUID-172	EUROCONTROL-GUID-172 Guidelines for harmonised AIP publication and data set provision	Edition 2.0, 23 May 2019
33	EUROCONTROL-SPEC-154	EUROCONTROL-SPEC-154 Specification for the Origination of Aeronautical Data (DO)	Edition 1.0, 4 February 2013
34	EUROCONTROL Quality Philosophy	Quality Philosophy – Approach to ISO 19113, ISO 19114 and ISO 19131	TODWG9/WP4 11-12/03/09
35	EUROCONTROL-SPEC-148	EUROCONTROL-SPEC-148 Specification for Data Assurance Levels	Edition 1.1, 28 March 2018
36	EUROCONTROL-GUID-165	EUROCONTROL-GUID-165 Guidelines for Aeronautical Information Publication (AIP) distribution on the Internet	Edition 1.0, 6 October 2017
37	EUROCONTROL-SPEC-168	EUROCONTROL-SPEC-168 Specification for SWIM Service Description	Edition 1.0 1 December 2017
38	EUROCONTROL-SPEC-169	EUROCONTROL-SPEC-169 Specification for SWIM Information Definition	Edition 1.0, 1 December 2017
39	EUROCONTROL-GUID-177	EUROCONTROL-GUID-177 Guidelines for the provision of Metadata to support the Exchange of Aeronautical Data	Edition 1.0, 28 November 2019
40	EUROCONTROL-GUID-160	EUROCONTROL-GUID-160 Guidelines for minimum safe altitude warning (MSAW)	Edition 1.0, 18 January 2017
41	EUROCONTROL-GUID-162	EUROCONTROL-GUID-162 Guidelines for approach path monitor (APM)	Edition 1.0, 18 January 2017
42	EU Regulation 73/2010	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.	Short title	Full Title	Edition
43	EU Regulation 2017/373	Commission Implementing Regulation (EU) 2017/373 of 1 March 2017 laying down common requirements for providers of air traffic management/air navigation services and other air traffic management network functions and their oversight, repealing Regulation (EC) No 482/2008, Implementing Regulations (EU) No 134/2011, (EU) No 1035/2011 and (EU) 2016/1377 and amending Regulation (EU) No 677/2011.	1st March 2017
44	EU Regulation 139/2014	Commission Regulation (EU) No 139/2014 of 12 February 2014 laying down requirements and administrative procedures related to aerodromes pursuant to Regulation (EC) No 216/2008 of the European Parliament and of the Council	12th February 2014
45	EU Regulation 2019/317	Commission Implementing Regulation (EU) 2019/317 of 11 February 2019 laying down a performance and charging scheme in the single European sky and repealing Implementing Regulations (EU) No 390/2013 and (EU) No 391/2013	11th February 2019
46	OGC	OGC City Geography Markup Language (CityGML) Encoding Standard	Version 1.0.0, August 2008
47	UK CAA CAP 738	United Kingdom Civil Aviation Authority (CAA) CAP 738 Safeguarding of Aerodromes, UK Civil Aviation Authority	Second Edition, December 2006
48	UK CAA CAP 1732	United Kingdom Civil Aviation Authority (CAA) CAP 1732 Aerodrome Survey Guidance, UK Civil Aviation Authority	First Edition, December 2016

Table 10: Referenced Documents

Appendix B FEATURE CAPTURE GUIDANCE

B.1 INTRODUCTION

ICAO currently provides no specifications on the geometric properties of obstacle features. The feature capture guidance should be a deterministic, application-independent and unambiguous guidance on how a real-world object is abstracted and captured as a database feature, whilst fulfilling the quality requirements.

EUROCAE ED-98C [26] provides rules on the capture of the attributes for terrain and obstacle data. These rules include the capture of geometric properties (height, elevation, width, length and geometric type). Appendix B of the TOD manual is based on these rules and provides examples of typical use cases and additional information on how the abstraction can be handled. The approach proposed 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 level of details.

B.2 USE CASES

The following list is not an exhaustive list, but the use cases presented are considered typical and frequent by some States. The use cases are valid on the condition that the objects are penetrating the obstacle data collection surface.

It is important to note the following terminology is used, as reflected in EUROCAE ED-98C [26]:

a) The footprint is understood as the maximum footprint of the object (on the ground).

b) The relevant footprint is understood as the footprint taken at the intersection of the obstacle with the penetrated obstacle data collection surface.

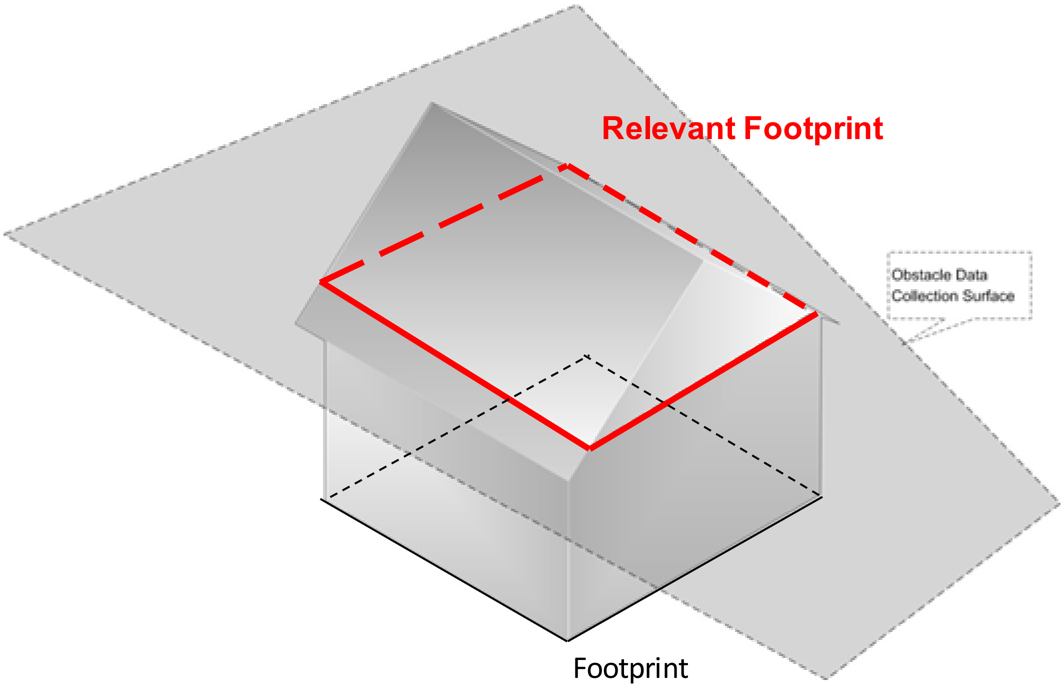


Figure 42: Relevant footprint of an obstacle penetrating an obstacle data collection surface

B.2.1 POINT OBSTACLE WITH EXTENT

An obstacle represented by a single point is the most common case in the obstacle data provided today. For obstacles with a considerable relevant footprint as opposed to antennas or poles with a neglectable horizontal extent, the knowledge of the size of this footprint is relevant for the user's operations. In these cases, the horizontal extent of the point obstacle should be captured. The following examples illustrate typical cases where a radius sufficiently describes the horizontal extent.

If the horizontal extent exceeds a certain threshold, either in width, length or both, then a polygon or a line is a better geometric representation for the obstacle than a point with a radius. See EUROCAE ED-98C Appendix G for more details.

B.2.1.1 WIND TURBINES

A wind turbine is an obstacle with moveable parts, i.e. the blades. For determining the maximum elevation (height) and horizontal extent of the obstacle, the size of the rotor blades has to be taken into account (see Figure 43).

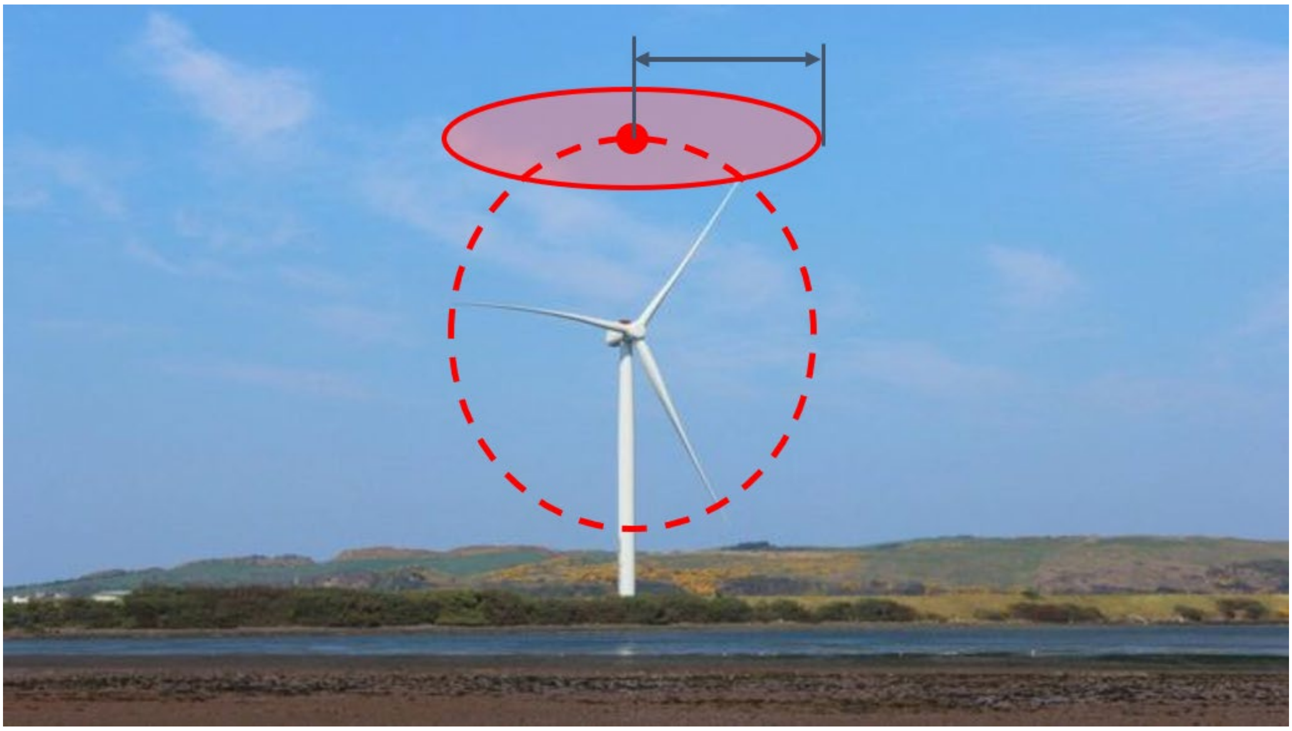


Figure 43: Capture of the relevant elevation and extent of a wind turbine

B.2.1.2 CRANES

A crane is an obstacle with a moveable part, i.e. jib. For determining the obstacle, the radius of the jib is captured as well as the maximum point of the crane. The figure below shows such an example.

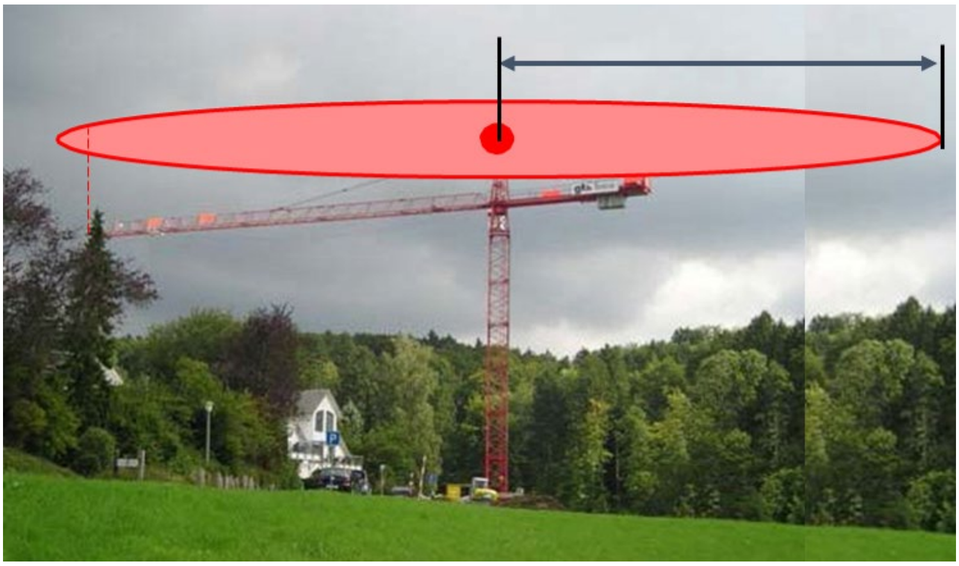


Figure 44: Capture of the relevant elevation and extent of a crane

B.2.1.3 MASTS WITH GUY WIRES

It is important to capture the horizontal extent of a mast at the relevant footprint with guy wires since the wires are not visible to a VFR pilot. Figure 45 illustrates a mast that is captured as a point with a radius. In case where the guy wires exceed the threshold value for a point obstacle for specific area a polygon obstacle would be more appropriate (see EUROCAE ED-98C [26] for details).

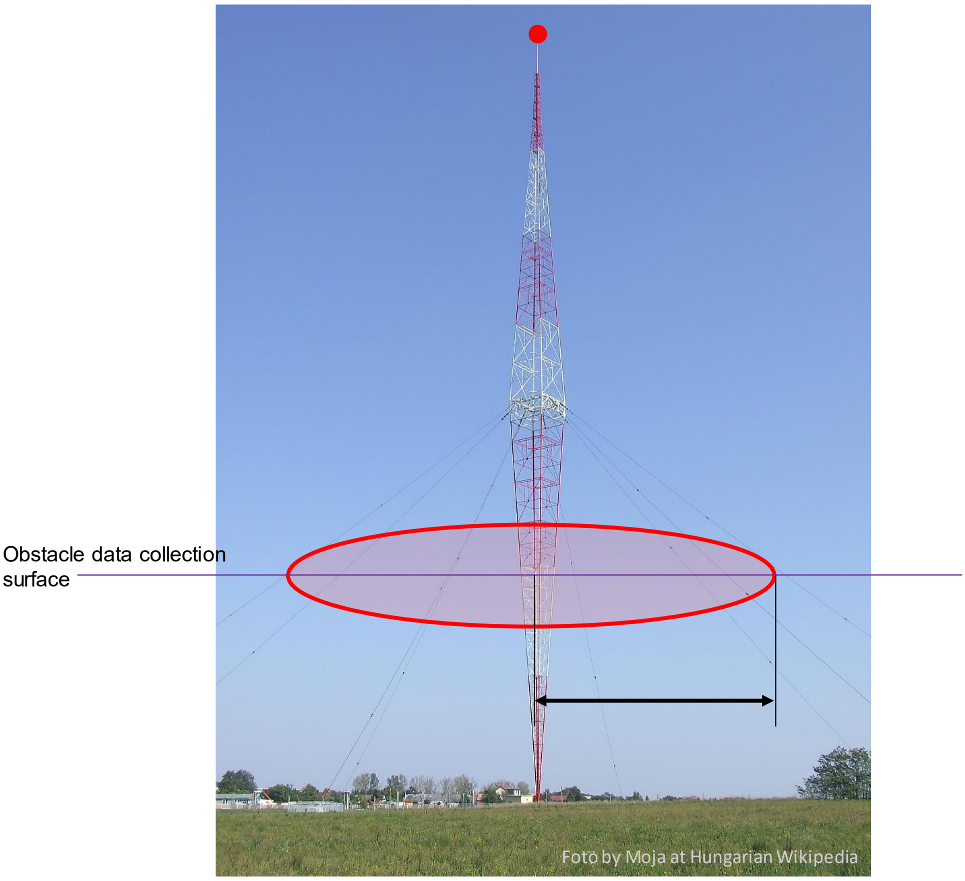

Obstacle data collection surface
Foto by Moja at Hungarian Wikipedia

Figure 45: Capture of the relevant elevation and extent of a mast with guy wires

B.2.2 GROUPING OF OBSTACLES

Adjacent point obstacles of similar height and elevation can be grouped into an obstacle of type polygon or line. The decision if the objects are captured as single obstacle or as a group depends on the operational needs e.g. if operations are planned or not between obstacles.

B.2.2.1 WIND PARKS

A wind park consisting of a group of wind turbines can be represented as a polygon, a line or a set of multiple individual obstacles as in the figures below.

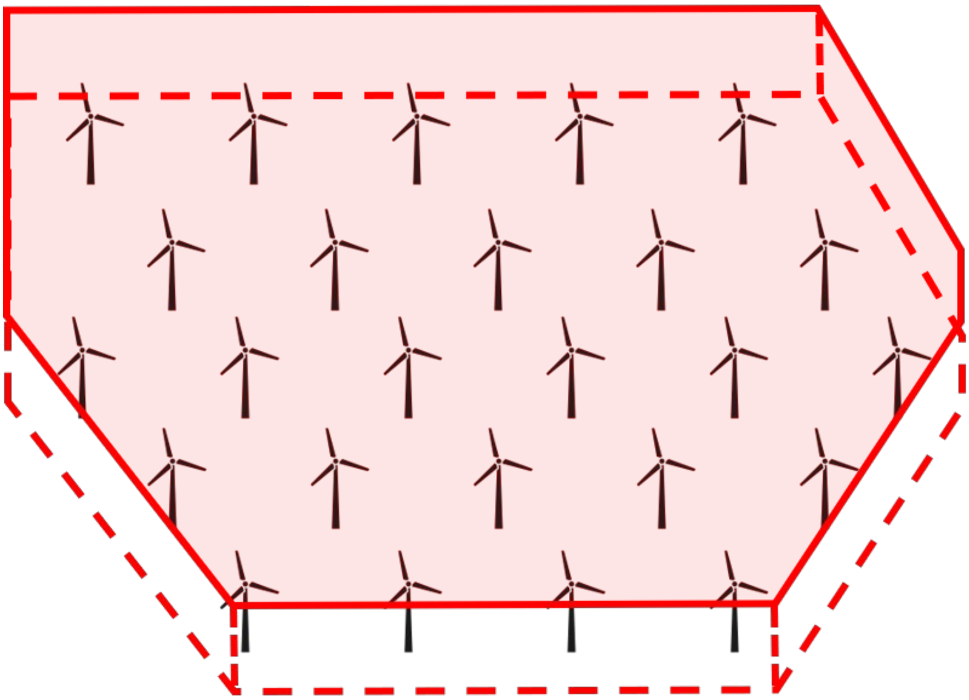


Figure 46: Capture of a wind farm as a polygon

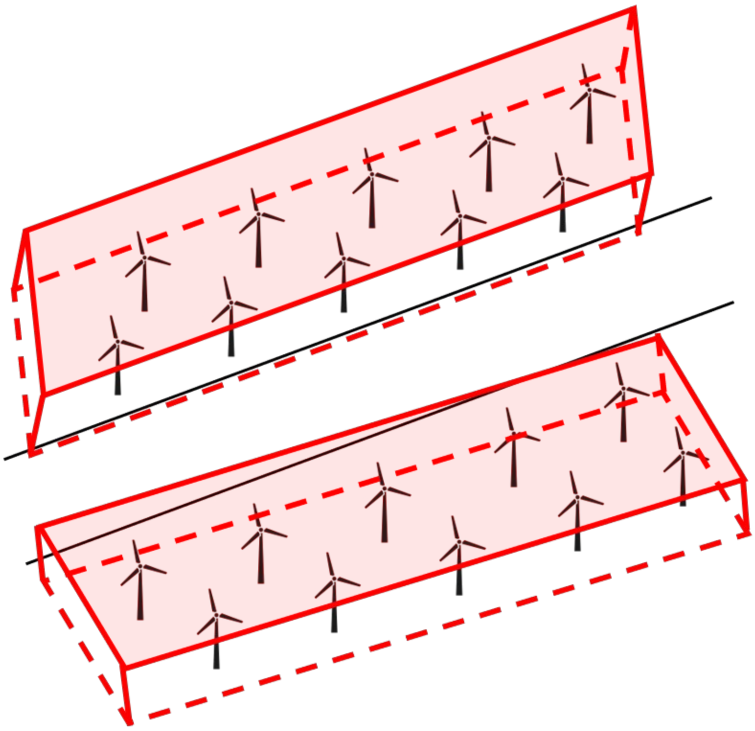


Figure 47: Capture of wind park with space for potential helicopter operations

Wind turbines positioned in a line may be collected as a line and a horizontal extent (in width) as in Figure 48 below.

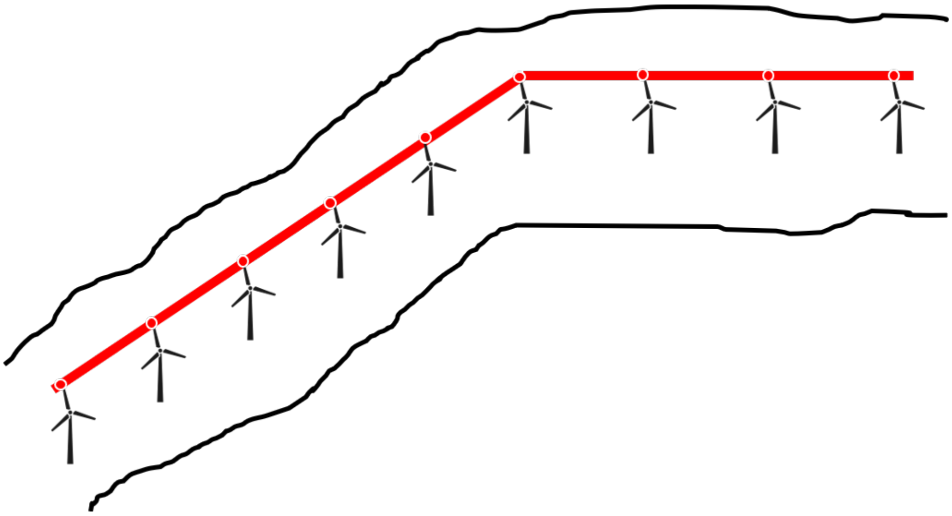


Figure 48: Capture of a wind farm as a line

There may be an operational benefit to collect and represent each individual wind turbine of a wind park as a single obstacle. For example, if flight operations can occur within a wind park (e.g. helicopter rescue operations at a crossing road), then the collection of each individual wind turbine may be the preferred method to accommodate the flight operations.

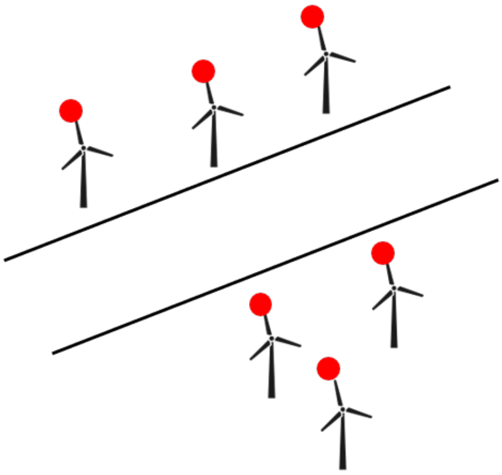


Figure 49: Capture of wind turbines as individual points

B.2.2.2 STREETS – LIGHT POLES ALONG A HIGHWAY

Light poles along a highway in the approach / take-off area can be captured as a line and a horizontal extent.

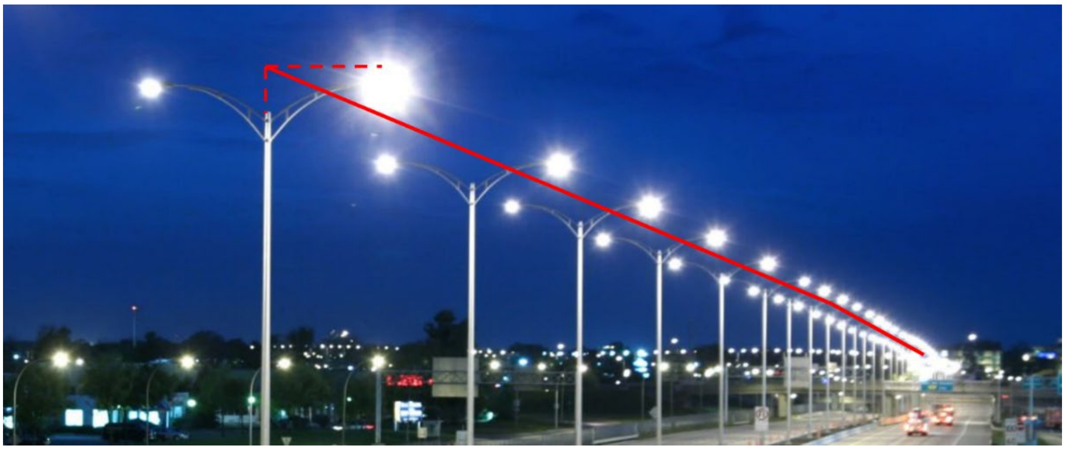


Figure 50: Capture of light poles along a highway as a line

B.2.3 OBSTACLE WITH CABLES

Obstacles with cables mounted on poles and masts like power/transmission lines, cable cars etc. are broken into parts following the principle: point – line – point – line – point and so forth, as exemplified in the figure below.

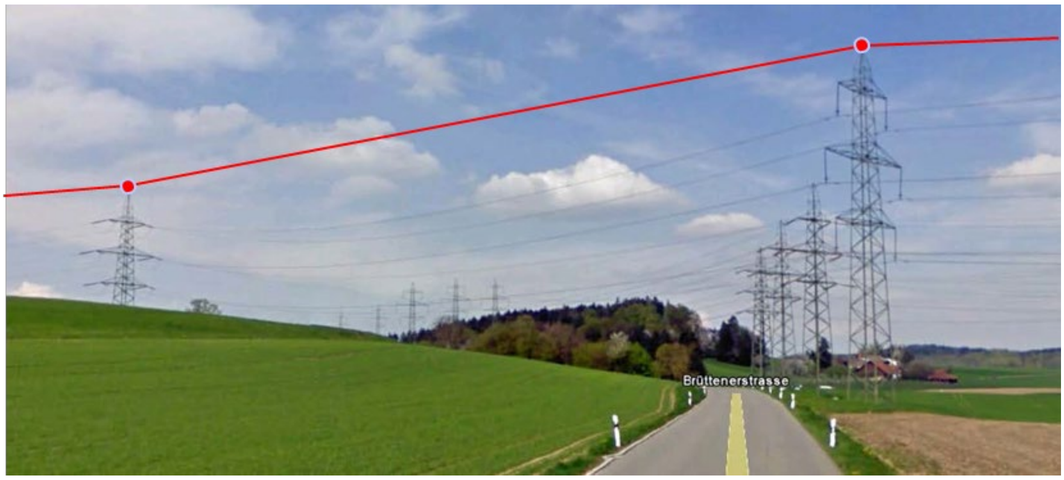


Figure 51: Principle of capturing power lines

Capture rules for the elevation of the line element between two points are specified in EUROCAE ED-98C 3.3.24.

B.2.3.1 POWER LINE NETWORKS

Power/transmission lines often form a network (see Figure 52). There are different possible ways how to structure the parts (P: poles and cables) into obstacles (O)[52]:

a) Each segment between branching or terminating nodes is a separate obstacle:

O1 = {P1, P2, P3, P4, P5}

O2 = {P5, P6, P7, P8. P9}

O3 = {P5, P10, P11, P12, P13, P14, P15}

b) All segments belong to the same obstacle:

O1 = {P1, P2, P3, P4, P5, P6, P7, P8. P9, P10, P11, P12, P13, P14, P15}

---

[52] The following considerations are based on the obstacle data model of AIXM: A VerticalStructure (= obstacle) is made up of one or several VerticalStructureParts (=Parts) that are represented as VerticalStructurePartGeometries (points, lines or polygons).

c) One main line is one obstacle; the branch is a separate obstacle:

   O1 = {P1, P2, P3, P4, P5, P6, P7, P8. P9}

   O2 = {P5, P10, P11, P12, P13, P14, P15}

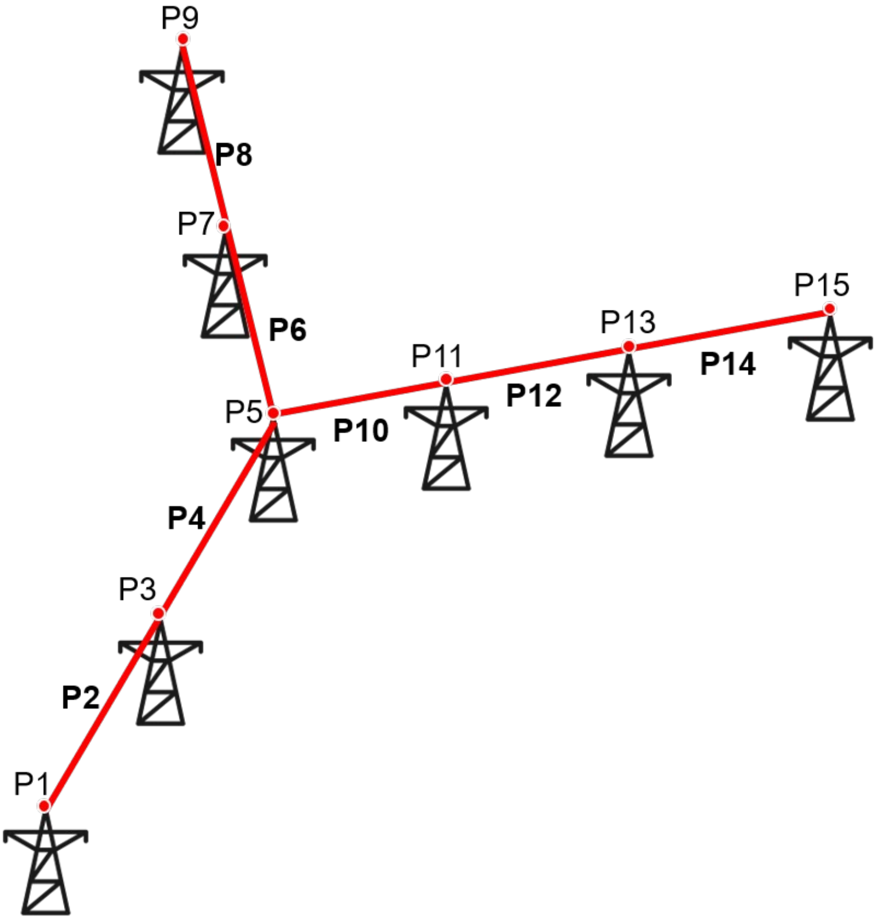


Figure 52: Capture of power line networks

B.2.3.2 POWER LINES WITH SECTIONS BELOW THE COLLECTION SURFACE

EUROCAE ED-98C [26] specifies rules how a power line / transmission line is captured if a section of the line is below the collection surface. The figure below illustrates the cases how the power lines with sections below the collection surfaces should be captured assuming an obstacle data collection surface is 100 m AGL.

Example 1) presents the capture of a power line with poles higher than the collection surface (e.g. 120m) and a section with poles below the collection surface (e.g. 45m) at the end of the line. The capture stops after the last part intersecting collection surface.

Example 2) presents the capture of a power line with a section of less than ten poles below the collection surface in the middle of the line. To preserve the continuity of the obstacle line all parts are captured regardless of their height.

Example 3) presents the case of a power line with a section of more than ten poles below the collection surface in the middle of the line. The continuity of the obstacle line is not considered and thus, the intermediate section is not captured.

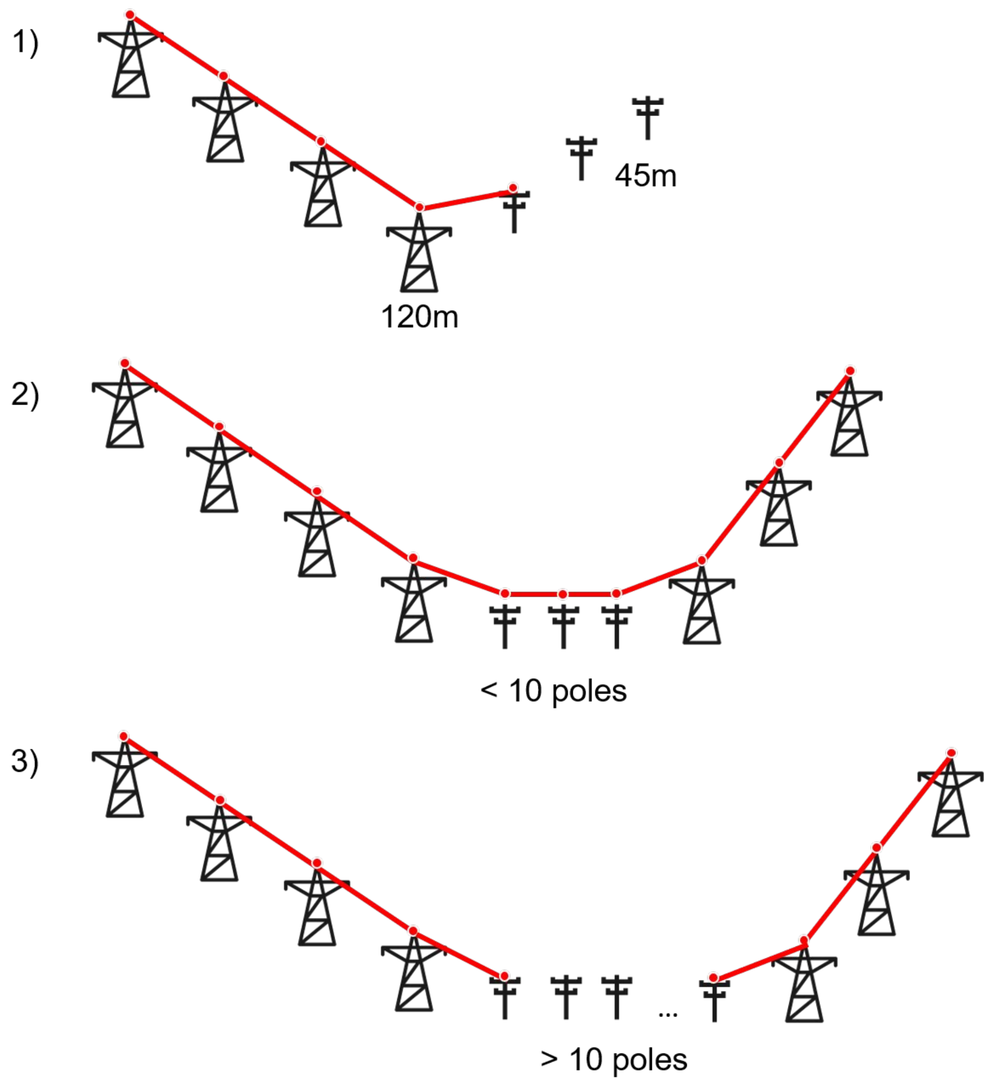


Figure 53: Capture of power lines with segments below the collection surface

B.2.4 MOBILE OBSTACLES

Mobile obstacles (objects that penetrate the obstacle collection surfaces without a fixed location) occupy a larger piece of airspace than their spatial extent. The total perimeter in which they can be located has to be taken into consideration when capturing mobile obstacles.

B.2.4.1 RAIL MOUNTED GANTRY CRANE

Rail mounted cranes such as a gantry crane (first picture below) or a container crane in a harbour can move in a limited area defined by the rails. A rail mounted gantry crane is captured considering the height and the maximum area of movement, which defines the footprint of the obstacle (second picture below). Then, the relevant footprint of the object is considered taking into account the penetration of the collection surface.

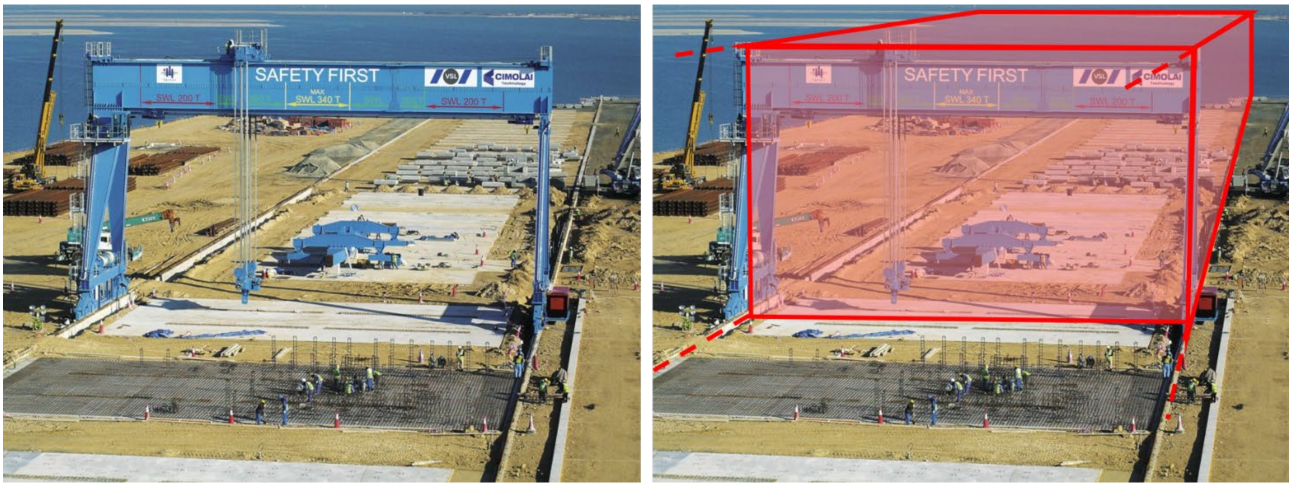
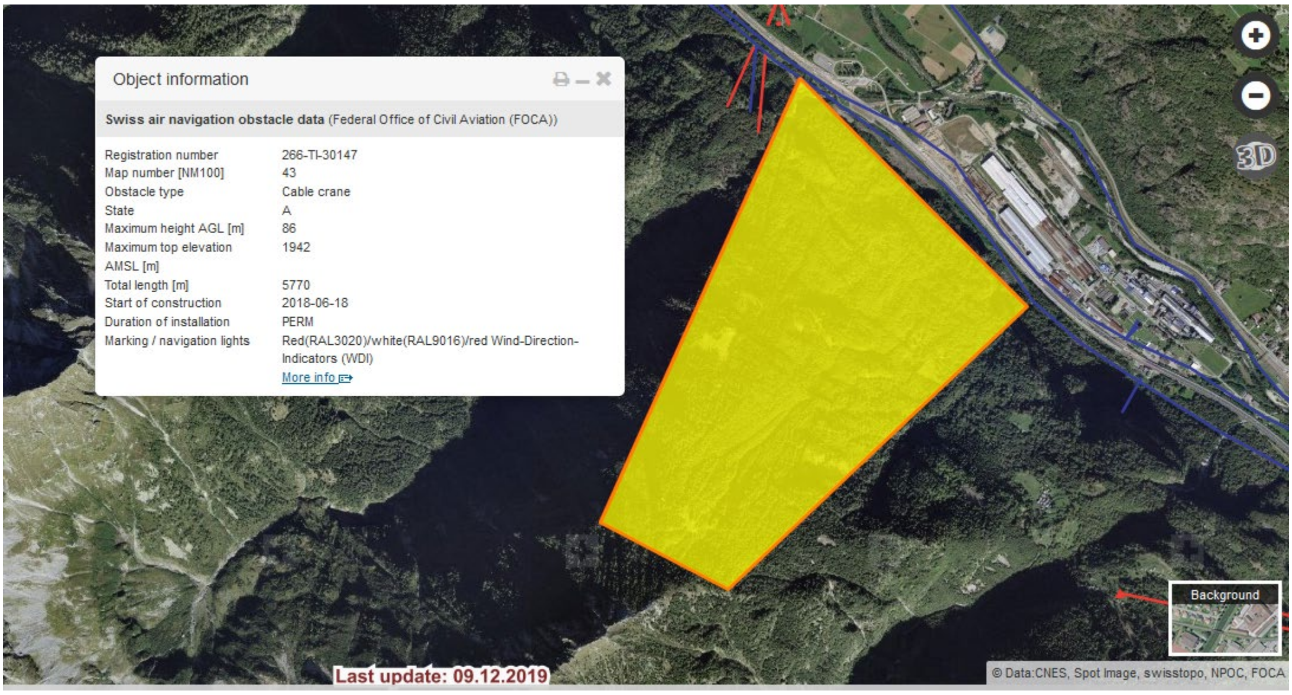


Figure 54: Capture of a rail mounted gantry crane

B.2.4.2 MOBILE CABLE CRANES

Cable cranes are mobile constructions used for logging woods in hilly forests. They are moved within a known perimeter every few days. The obstacle is captured as a polygon with an elevation of the highest possible point of the crane.



Object information

Swiss air navigation obstacle data (Federal Office of Civil Aviation (FOCA))

Registration number	266-TI-30147
Map number [NM100]	43
Obstacle type	Cable crane
State	A
Maximum height AGL [m]	86
Maximum top elevation AMSL [m]	1942
Total length [m]	5770
Start of construction	2018-06-18
Duration of installation	PERM
Marking / navigation lights	Red(RAL3020)/white(RAL9016)/red Wind-Direction-Indicators (WDI) More info

Figure 55: Mobile cable crane as a polygon obstacle

B.2.4.3 SHIPS AND ROADS

Ships and roads in the approach / take-off area of an airport can be mobile obstacles if they penetrate the obstacle limitation or collection surfaces. Such an obstacle is captured as a polygon considering the maximum height of the ships using the waterway and the boundary of the part of the waterway relevant for the operation.

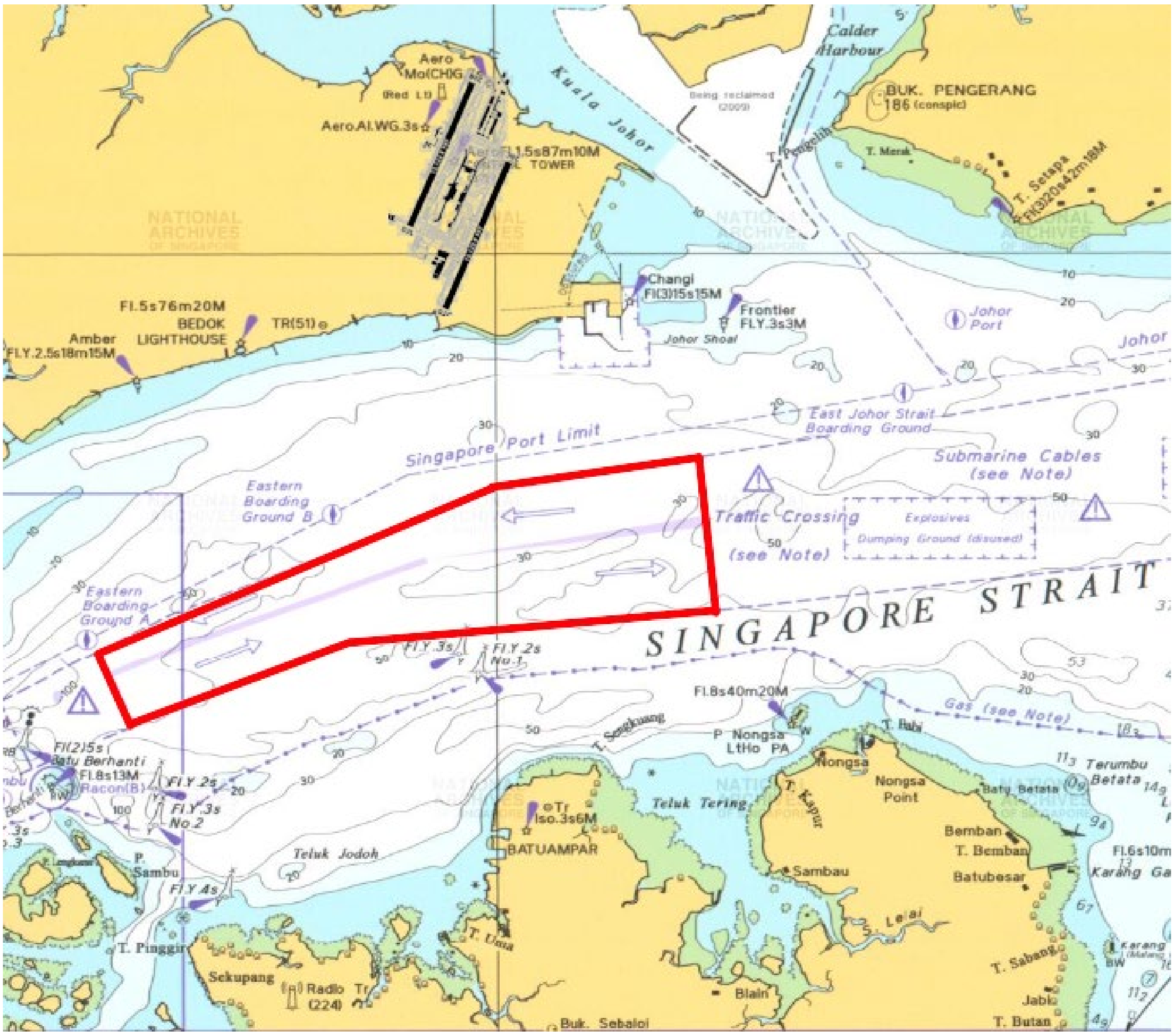


Figure 56: Ships on a waterway as mobile obstacles

A similar and probably more frequent case is a highway with trucks penetrating the Area 2b (or Area 4 or the take-off flight path area) surface of an airport.

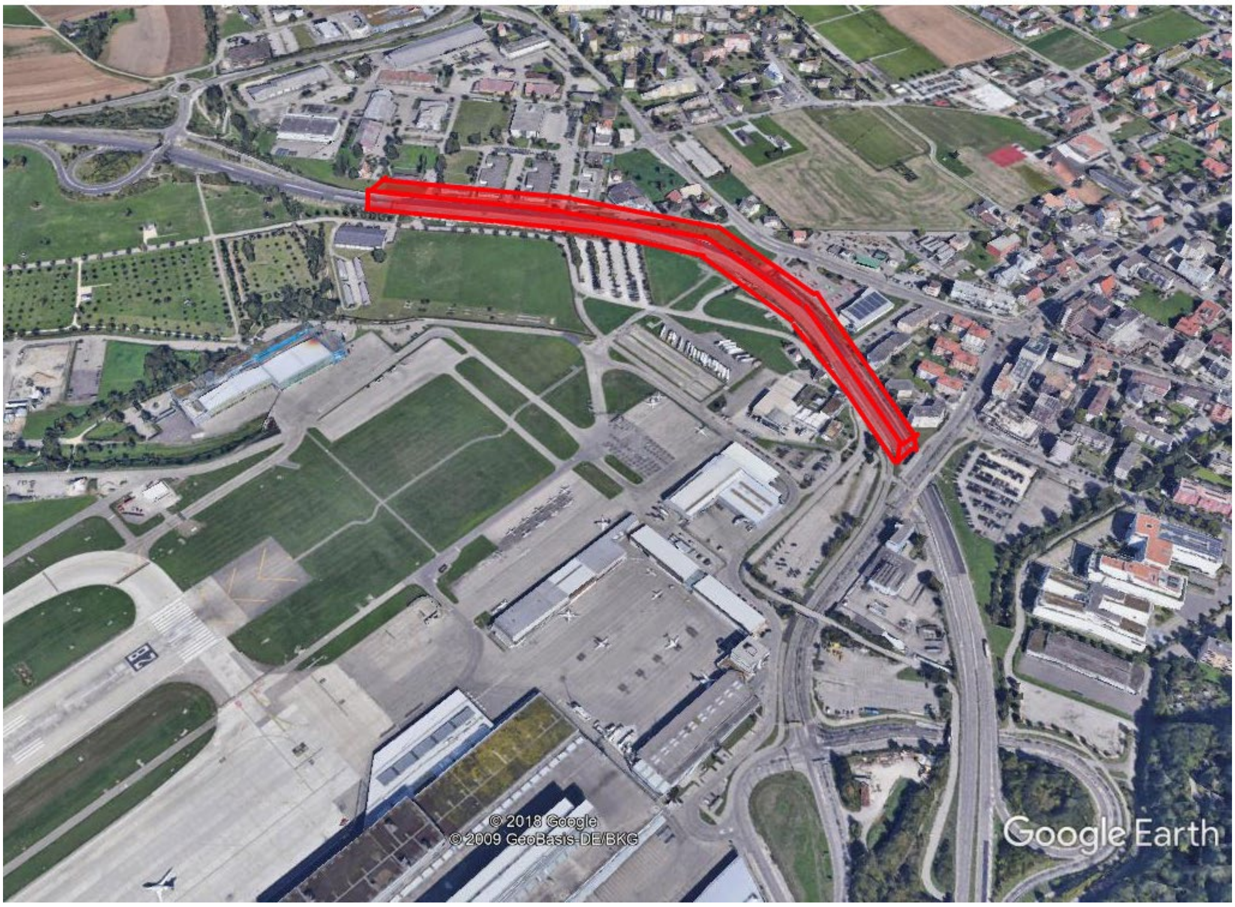


Figure 57: Trucks on a highway are mobile obstacles in the approach area of a runway

B.2.5 BUILDING WITH COMPOUND STRUCTURES

The size of the relevant footprint varies, in many cases, with growing height (trees, tilted roofs, on-top structures, nested buildings or roof mounted antennae). In several cases, the application of the footprint and the maximum height may not be favourable in cases where the object is described as much bigger than the real-world object. Such objects may impact the obstacle clearance and thus, the operational purposes.

In such cases where the description of the object is not optimal (by footprint and height/elevation), the application of vertical segmentation may provide operational benefits. The application rules of vertical segmentation can be found in EUROCAE ED-98C [26].

It should be noted that in most cases vertical segmentation is not necessary and it is suffcient to capture an object as a single point obstacle – if required with a horizontal extent (see section B.2.1). Vertical segmentation can be useful for operational gains, e.g. if the obstacle is located close to an instrument flight procedure or obstacle limitation surface and if valuable airspace can be gained by spliting the obstacle in several parts of different dimensions.

A typical example is shown in the figure below. The obstacle composed of two parts (the building P1 and with an antenna mounted on top of it P2) requires the structure to be “sliced” horizontally based on the maximum allowed footprint size for the initial geometry. This results in two segments being stacked on top of each other and therefore, segmented to avoid using the relevant footprint for the entire height of the obstacle.

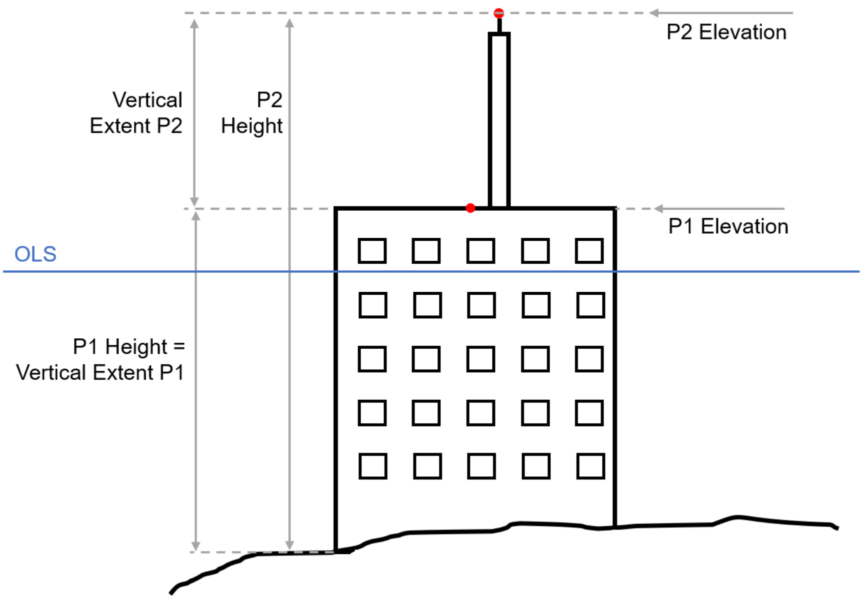


Figure 58: Example of a segmented obstacle

When obstacles are captured by airborne methods like photogrammetry, satellite imagery or LIDAR, the heights can only be derived by calculating the difference between the elevations of the obstacle and the ground or of the obstacle underneath (P1 and P2, in the example figure). The calculation of reliable heights requires the application of the same survey method (e.g. LIDAR) for the determination of the ground and obstacle elevation.

Note: There is a difference between the vertical extent of the part (vertical distance between the lowest and highest point of the part) as defined in AIXM and the height (above ground level) of the part (vertical distance between the ground and the highest point of the part) as defined in EUROCAE ED-98C [26].

AIXM does not support direct coding of obstacle height (AGL). Therefore, the attribute height has been mapped to *vertical extent*. See the coding guidelines of obstacle data sets found here for alternatives using VerticalStructurePart to code obstacle height.

B.2.6 VEGETATION

B.2.6.1 FORESTS AS PART OF A TERRAIN DATA SET

The terrain data set can be a so-called bare earth model, describing the continuous surface of the ground without any man-made objects and vegetation or include the forests or other vegetated areas (see Figure 21). Forests which cannot, due to their size, be modelled as point or line features must be added to the terrain set 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[53].

B.2.6.2 ISOLATED FORESTS AS OBSTACLES

Isolated forests are usually captured as a polygon obstacle. The construction of a forest obstacle should be based on the maximum elevation calculation. However, a single forest area with the maximum elevation is obviously too stringent especially if the forest is covering a hill. As a result, it is recommended that in addition to the polygon tree points are captured as single points with a proposed density of tree points (e.g. 1 tree per 10 ha). Density will depend on whether the terrain is flat. Local maxima could be used when data is captured by LIDAR.

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[53] Cell size corresponds to terrain model post spacing as per ICAO terrain data numerical requirements (see 3.5.5.2)

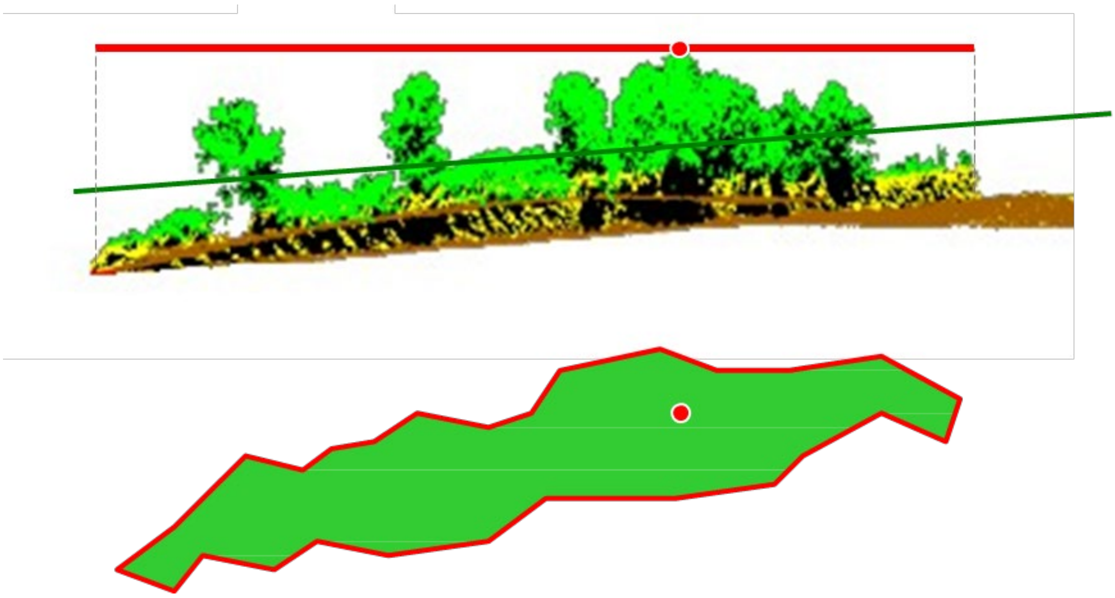

Figure 59: Capture of a forest as a polygon

B.3 CAPTURE METHODS

B.3.1 AUTOMATION

Today ALS (see section 5.4.4.2) is an established capture method for digital terrain models. The ALS sensors produce a point cloud that can be the used for the construction of a digital terrain data set as well as the base data for automated obstacle extraction.

It is expected that feature extraction (LOD1 block model[54]) 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.

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[54] Blocks model comprising prismatic buildings with flat roofs. See CityGML [46] specification document.

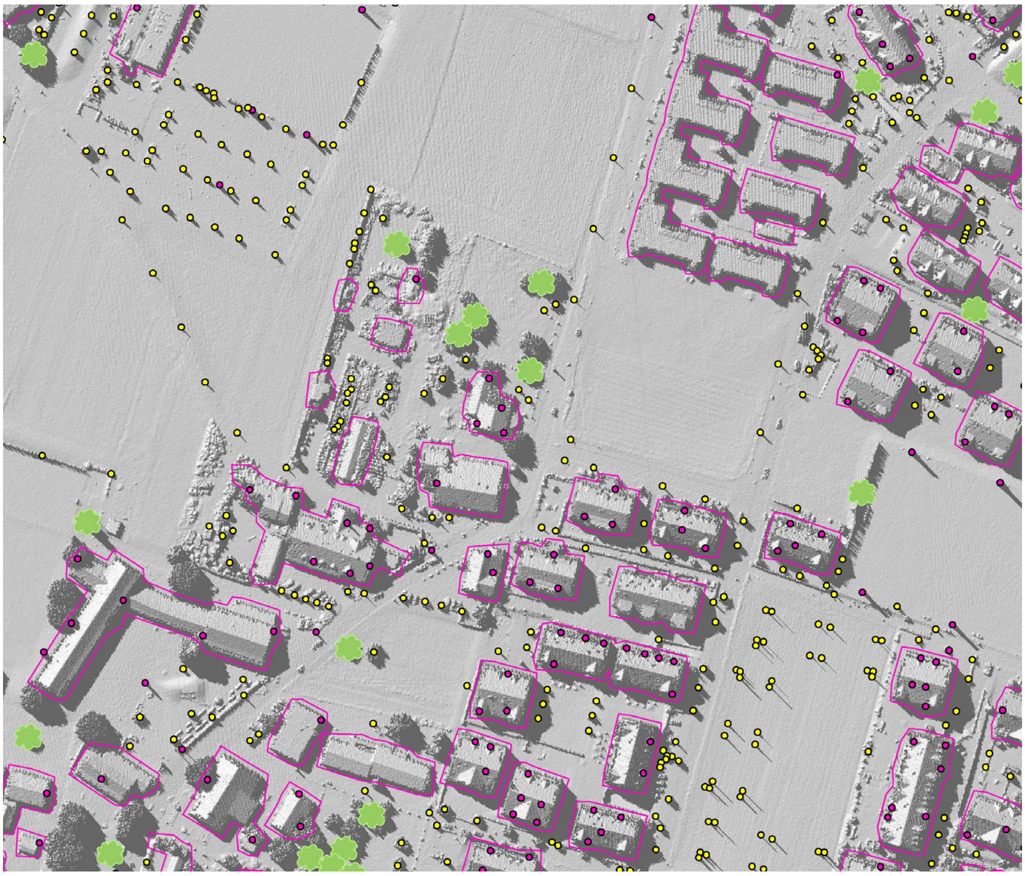

Figure 60: Fully Automated Extracted Obstacles

B.3.2 DETECTION OF THIN OBJECTS

It is important to be aware that independent of the data capture method (e.g. photogrammetry, LIDAR, satellite imagery) there will be limitations to what objects can be detected. It is possible that thin antennas and lighting rods may be missed as shown in the figure below.

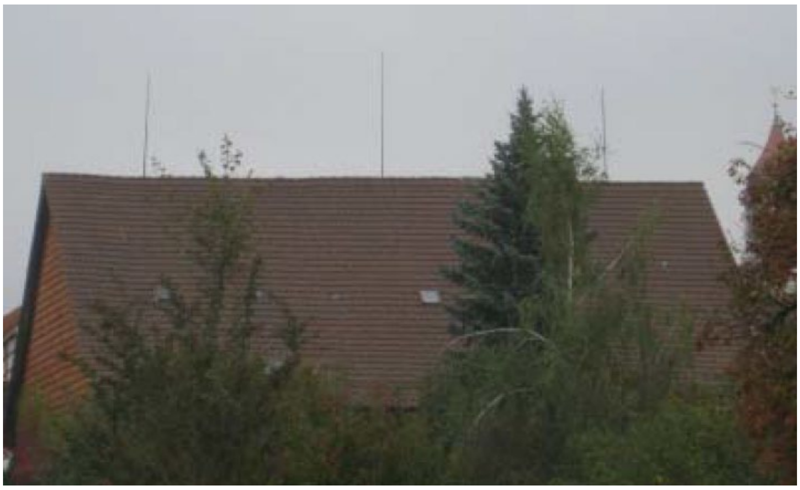

Figure 61: Example of a Missing Object

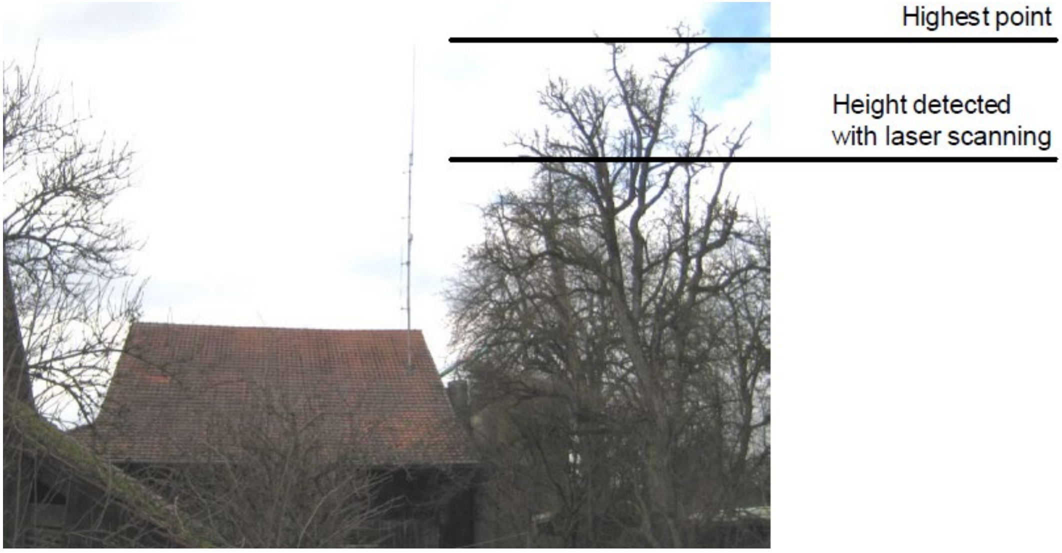

Figure 62: Example of a Thin Object not correctly detected

There are cases where such objects are important for operational reasons, e.g. near the aerodrome. Additional surveying is necessary to make sure the missing objects are captured.

B.3.3 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 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.

Existing cadastral data is of limited use if the elevation information of the cadastre feature is not available (cadastral information is often only 2D) or can't be extracted from a DSM. There can be cases where the ground footprints will not correspond to the relevant footprint at the intersection with the obstacle collection surface.

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 5.8.1), to facilitate data maintenance.

B.3.4 COST – BENEFIT

The decision how obstacles are captured – as points, lines or polygons, grouped or segmented etc. – should be based on a consideration of the capture cost versus benefit for the users.

In Area 4 and 3 the extra cost of a more detailed survey and a segmentation of an obstacle into different parts may bring a substantial operational benefit because less airspace is blocked by the segmented obstacle. Area 3 and Area 4 are relatively small. Consequently, a larger effort for capturing all details (terminal buildings, hangars, lights, etc.) will not have the same impact as a detailed capture of huge number of obstacles in Area 2.

In Area 2 the obstacle capture rules should allow for the most efficient way to capture a large number of obstacles. Simplification and grouping of obstacles can improve the cost / benefit ratio. Especially with regards to vegetation there are often too many single points captured (see Figure 63). A representation of the vegetation as point and radius or of a group of trees as a polygon will reduce the number of objects to an amount that can be handled by the users and their applications without jeopardising safety.

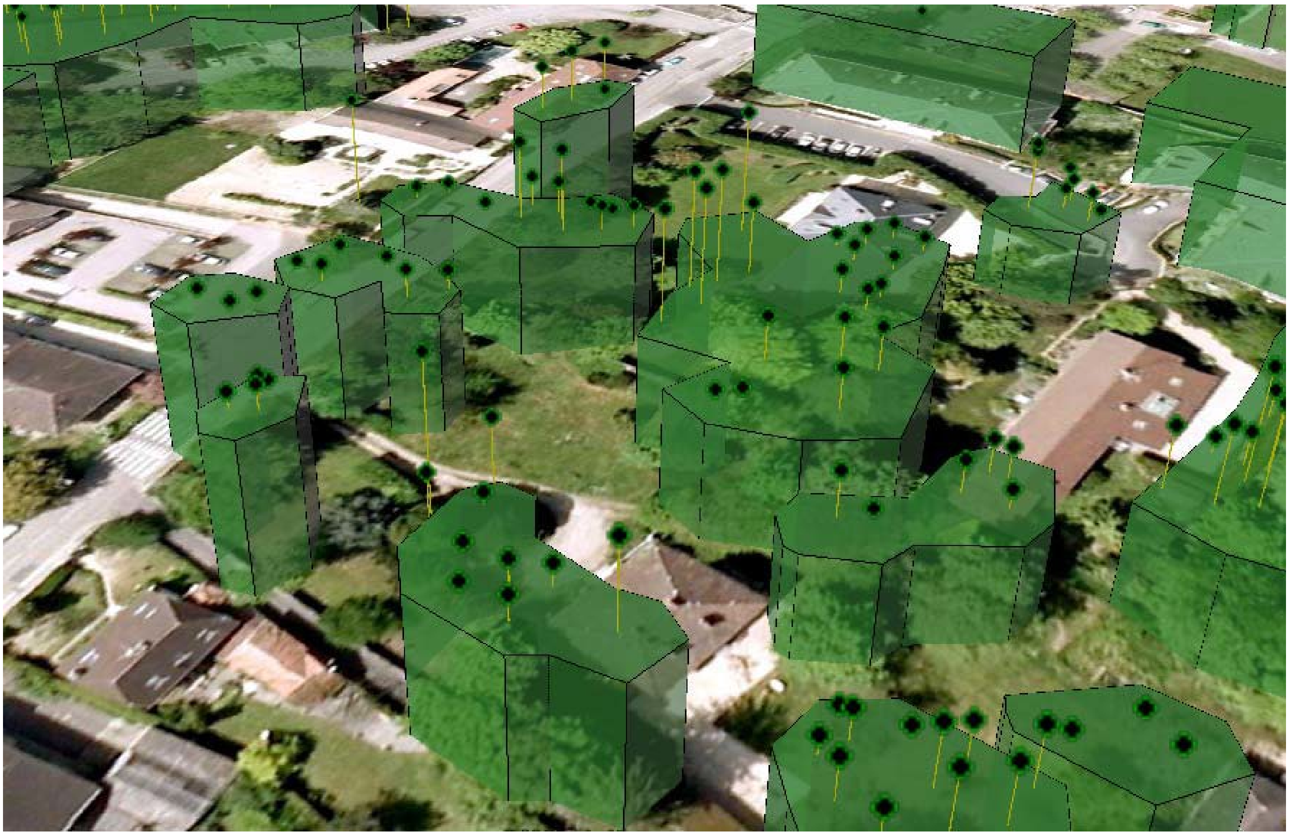

Figure 63: A bad example of capturing too many trees as single point obstacles

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, 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.

Appendix C NATIONAL TOD POLICY TEMPLATE

Text in black is a sample of the text which could be provided in the policy. Text in blue is that which needs to be replaced by the developers of the TOD policy in the State.

C.1 INTRODUCTION

C.1.1 PURPOSE AND SCOPE OF THIS DOCUMENT

This document sets out the policy for **[Name of State]** relating to the collection, processing and provision of electronic terrain and obstacle data (TOD). This document is not a regulation, but an approach, plan and set of actions adopted and agreed by the parties concerned by and included in this policy.

The main purpose of this document is to exhaustively define the policy of **[Name of State]** for TOD implementation, in order to enable **[Name of the regulatory authority of the State]** to update or develop the **[Name of State]** TOD regulatory framework and for the parties involved to develop the implementation programmes and put in place the necessary steps to enable the provision of electronic terrain and obstacle data.

C.2 ELECTRONIC TERRAIN DATA

C.2.1 DEFINITION OF SCOPE

C.2.1.1 GENERAL

This section documents the **[Name of State]** national policy relating to the collection, processing and provision of electronic terrain data for **[list each specific coverage areas]**.

- Area 1 designates the Digital Terrain Model covering the entire territory of **[Name of State]**.
- Area 2 designates the Digital Terrain Model covering the vicinity of an aerodrome **[subdivision of Area 2, if applicable]**
- Area 3 designates the Digital Terrain Model covering the vicinity of an aerodrome movement area as defined in ICAO Annex 15 and PANS-AIM.
- Area 4 designates the Digital Terrain Model covering the radio altimeter operating area for the precision approach runway, Category II or III, as defined in ICAO Annex 15 and PANS-AIM.

C.2.1.2 QUALITY/NUMERICAL REQUIREMENTS FOR ELECTRONIC TERRAIN DATA

Electronic terrain data for **[list each specific coverage areas]** in **[Name of State]** must conform to the following numerical requirements:

	Area 1	Area 2	Area 3	Area 4
Post spacing	**x** arc seconds (approx. **x** m)	**x** arc second (approx. **x** m)	**x** arc seconds (approx. **x** m)	**x** arc seconds (approx. **x** m)
Vertical accuracy	**x** m	**x** m	**x** m	**x** m
Vertical resolution	**x** m	**x** m	**x** m	**x** m

Horizontal accuracy	**x** m	**x** m	**x** m	**x** m
Confidence level	**x** %	**x** %	**x** %	**x** %
Integrity classification	routine	essential	essential	essential
Maintenance period	as required	as required	as required	as required

C.2.1.2.1 APPLICABLE REGULATIONS

The following national and international regulations govern the collection, processing and provision of electronic terrain data for **[list each specific coverage areas]** in **[Name of State].**

Ref.	Issuing body	Title and relevant sections	Edition
		[Insert applicable national regulations and policies]	

C.2.1.2.2 CURRENT COMPLIANCE

C.2.1.2.2.1 DATA

[Provide here a statement about the (non) compliance of the provided/available sets of electronic terrain data for each specific coverage area, as applicable, with the quality and numerical requirements described above]

C.2.1.2.2.2 REGULATION

[Provide here a list of the documents forming part of the national regulatory framework which need to be updated or developed, as applicable, in order to ensure compliance with the quality and numerical requirements described above]

C.2.1.3 AERODROMES REQUIRED TO PROVIDE ELECTRONIC TERRAIN DATA

[Name of State] will provide sets of electronic terrain data for Area 2 at the following aerodromes **[list of aerodromes required to provide sets of electronic terrain data for Area 2]**

[Name of State] will provide sets of electronic terrain data for Area 3 at the following aerodromes **[list of aerodromes required to provide sets of electronic terrain data for Area 3]**

[Name of State] will provide sets of electronic terrain data for Area 4 at the following aerodromes and runways **[list of aerodromes and runways required to provide sets of electronic terrain data for Area 4]**

C.2.1.4 FUNCTIONS REQUIRED FOR ELECTRONIC TERRAIN DATA

[Provide here a list of all functions and their roles within [Name of State] required for the collection, processing and provision of electronic terrain data for each specific coverage area, preferably with a diagram of the intended data flow processes]

C.2.2 DEFINITION OF RESPONSIBILITIES

This section sets out the responsibilities for the collection, processing and provision of electronic terrain data for **[list each specific coverage areas]** in **[Name of State].**

C.2.2.1 RESPONSIBILITY FOR REGULATION

The **[Name of entity]** will be responsible in **[Name of State] for** developing/updating the national civil aviation regulatory framework to ensure the collection, processing and provision of electronic terrain data for **[each specific coverage areas]**

C.2.2.2 RESPONSIBILITY FOR DATA ORIGINATION

The **[Name of entity]** will be responsible in **[Name of State]** for providing the original or updated[55] electronic terrain data for **[each specific coverage areas]**

C.2.2.2.1 DATA SOURCES

[Provide a list of data sources of electronic terrain data for [each specific coverage areas]]

C.2.2.2.2 FORMAL ARRANGEMENTS

[List here the elements of the formal arrangements which need to be put in place for the provision of electronic terrain data for [each specific coverage areas]]

C.2.2.3 RESPONSIBILITY FOR DATA VERIFICATION AND VALIDATION

The **[Name of entity]** will be responsible in **[Name of State] for** validating and verifying the electronic terrain data for **[each specific coverage areas]**

C.2.2.4 RESPONSIBILITY FOR THE ELECTRONIC TERRAIN DATA REPOSITORY

The **[Name of entity]** will be responsible in **[Name of State]** for storing the electronic terrain data for **[each specific coverage area]**

C.2.2.5 RESPONSIBILITY FOR ELECTRONIC TERRAIN DATA MAINTENANCE

The **[Name of entity]** will be responsible in **[Name of State] for** providing updates (regular maintenance) to the electronic terrain data for **[each specific coverage area]**

C.2.2.6 RESPONSIBILITY FOR ELECTRONIC TERRAIN DATA PROVISION

The **[Name of entity]** will be responsible in **[Name of State]** for providing the electronic terrain data for **[each specific coverage area]** to the next-intended users.

C.2.2.7 RESPONSIBILITY FOR CROSS-BORDER EXCHANGE OF ELECTRONIC TERRAIN DATA

[List the arrangements (to be put) in place with neighbouring States for the exchange, provision and receipt of electronic terrain data]

C.2.2.8 RESPONSIBILITY FOR THE OVERSIGHT MECHANISM

The **[Name of entity]** will be responsible in **[Name of State]** for the oversight of electronic terrain data provision for **[each specific coverage area]**.

C.2.3 COST RECOVERY AND CHARGING

[Provide here the cost recovery and charging mechanisms for each specific coverage area of the electronic terrain data]

---

[55] Updates could be covered under the responsibility for data maintenance

C.3 ELECTRONIC OBSTACLE DATA

C.3.1 DEFINITION OF SCOPE

C.3.1.1 GENERAL

This section documents the **[Name of State]'s** national policy relating to the collection, processing and provision of electronic obstacle data for **[list each specific coverage area]**.

- Area 1 covers the entire territory of **[Name of State]**.
- Area 2 covers the vicinity of an aerodrome as defined in ICAO Annex 15 and PANS-AIM **[subdivision of Area 2, if applicable]**
- Area 3 covers the vicinity of an aerodrome movement area as defined in ICAO Annex 15 and PANS-AIM.
- Area 4 covers the radio altimeter operating area for the precision approach runway, Category II or III, as defined in ICAO Annex 15 and PANS-AIM.

C.3.1.2 QUALITY/NUMERICAL REQUIREMENTS FOR ELECTRONIC OBSTACLE DATA

Electronic obstacle data for **[list each specific coverage area]** in **[Name of State]** must conform to the following numerical requirements:

	Area 1	Area 2	Area 3	Area 4
Vertical accuracy	**x** m	**x** m	**x** m	**x** m
Vertical resolution	**x** m	**x** m	**x** m	**x** m
Horizontal accuracy	**x** m	**x** m	**x** m	**x** m
Confidence level	**x** %	**x** %	**x** %	**x** %
Integrity classification	routine	essential	essential	essential
Maintenance period	as required	as required	as required	as required

C.3.1.2.1 APPLICABLE REGULATIONS

The following national and international regulations govern the collection, processing and provision of electronic obstacle data for **[list each specific coverage area]** in **[Name of State].**

Ref.	Issuing body	Title and relevant sections	Edition
		[Insert applicable national regulations and policies]	

C.3.1.2.2 CURRENT COMPLIANCE

C.3.1.2.2.1 DATA

[Provide here a statement about the (non) compliance of the provided/available sets of electronic obstacle data for each specific coverage area, as applicable, with the quality and numerical requirements described above]

C.3.1.2.2.2 REGULATION

[Provide here a list of the documents forming part of the national regulatory framework which need to be updated or developed, as applicable, in order to ensure compliance with the quality and numerical requirements described above]

C.3.1.3 AERODROMES REQUIRED TO PROVIDE ELECTRONIC OBSTACLE DATA

[Name of State] will provide sets of electronic obstacle data for Area 2 at the following aerodromes **[list of aerodromes required to provide sets of electronic obstacle data for Area 2]**

[Name of State] will provide sets of electronic obstacle data for Area 3 at the following aerodromes **[list of aerodromes required to provide sets of electronic obstacle data for Area 3]**

[Name of State] will provide sets of electronic obstacle data for Area 4 at the following aerodromes and runways **[list of aerodromes and runways required to provide sets of electronic obstacle data for Area 4]**

C.3.1.4 FUNCTIONS REQUIRED FOR ELECTRONIC OBSTACLE DATA

[Provide here a list of all functions and their roles within [Name of State] required for the collection, processing and provision of electronic obstacle data for each specific coverage area, preferably with a diagram of the intended data flow processes]

C.3.2 DEFINITION OF RESPONSIBILITIES

This section sets out the responsibilities for the collection, processing and provision of electronic obstacle data for **[list each specific coverage area]** in **[Name of State]**.

C.3.2.1 RESPONSIBILITY FOR REGULATION

The **[Name of entity]** will be responsible in **[Name of State]** for developing/updating the national civil aviation regulatory framework to ensure the collection, processing and provision of electronic obstacle data for **[each specific coverage area]**

C.3.2.2 RESPONSIBILITY FOR THE DATA SOURCE

The **[Name of entity]** will be responsible in **[Name of State]** for originating the initial, or providing updates[56] to existing, electronic obstacle data for **[each specific coverage area]**

C.3.2.2.1 DATA SOURCES

[Provide a list of data sources of electronic obstacle data for [each specific coverage area]]

C.3.2.2.2 FORMAL ARRANGEMENTS

[List here the elements of the formal arrangements which need to be put in place for the provision of electronic obstacle data for [each specific coverage area]]

C.3.2.3 RESPONSIBILITY FOR OBSTACLE ASSESSMENT

The **[Name of entity]** will be responsible in **[Name of State]** for assessing the effects of the objects penetrating the obstacle collection surfaces on the aviation infrastructure for **[each specific coverage area]** and providing advice to the obstacle authorisation process.

C.3.2.4 RESPONSIBILITY FOR VERIFICATION AND VALIDATION

The **[Name of entity]** will be responsible in **[Name of State]** for validating and verifying the electronic obstacle data for **[each specific coverage area]**

---

[56] Updates could be covered under the responsibility for data maintenance

C.3.2.5 RESPONSIBILITY FOR THE ELECTRONIC OBSTACLE DATA REPOSITORY

The **[Name of entity]** will be responsible in **[Name of State]** for storing the electronic obstacle data for **[each specific coverage area]**

C.3.2.6 RESPONSIBILITY FOR ELECTRONIC OBSTACLE DATA MAINTENANCE

The **[Name of entity]** will be responsible in **[Name of State]** for the maintenance of the electronic obstacle data for **[each specific coverage area]** in accordance with the national obstacle authorisation process.

C.3.2.7 RESPONSIBILITY FOR ELECTRONIC OBSTACLE DATA PROVISION

The **[Name of entity]** will be responsible in **[Name of State]** for providing the electronic obstacle data for **[each specific coverage area]** to the next-intended users.

C.3.2.8 RESPONSIBILITY FOR CROSS-BORDER EXCHANGE OF ELECTRONIC OBSTACLE DATA

[List the arrangements (to be put) in place with neighbouring States for the exchange, provision and receipt of electronic obstacle data]

C.3.2.9 RESPONSIBILITY FOR THE OVERSIGHT MECHANISM

The **[Name of entity]** will be responsible in **[Name of State]** for the oversight of electronic obstacle data provision for **[each specific coverage area]**.

C.3.3 COST RECOVERY AND CHARGING

[Provide here the cost recovery and charging mechanisms for each specific coverage area of the electronic obstacle data]

Appendix D LIST OF MOST USED TERRAIN FORMATS

Name	Description	Use of and requirements for TOD in accordance with ICAO Annex 15		File extension	Remarks[57]
		Pros	Cons		
List of most used raster formats					
GeoTIFF	GeoTIFF is a public domain metadata standard which allows georeferencing information to be embedded within a TIFF file. The potential additional information includes map projection, coordinate systems, ellipsoids, datums, and everything else necessary to establish the exact spatial reference for the file. The GeoTIFF format is fully compliant with TIFF 6.0, so software incapable of reading and interpreting the specialized metadata will still be able to open a GeoTIFF format file. (source)	- well-known image format, supported by many GIS and image processing software - completely open, public domain, non-proprietary - Common, widely used standard to store georeferenced raster files supported by many tools - High flexibility - All information in a single file - New format BigTIFF will even overcome the 4 GB limitation	- Not ISO 19100 compliant - Cannot store metadata on pixel level - Resolution cannot be varied within one data set (No landscape dependent storing of terrain information => File size “overhead”)	*.tiff *.tif	The draft guidelines for the European INSPIRE directive on elevation data use GeoTIFF as the encoding of grid coverage. Reference 1 Reference 2 Reference 3
DTED (Digital Terrain Elevation Data)	A simple, regularly spaced grid of elevation points based on 1-degree latitude and longitude extents. Created by the NGA. (source)		- Is not ISO 19100 compliant - Cannot store metadata on pixel level. - Has different levels of detail, and different zones over the globe where different longitude spacing’s (i.e. widths of a "pixel") are used. The spacings and levels of detail are fixed (e.g. impossible to provide a 10m grid of elevations in DTED) - Resolution not flexible enough (i.e. DTED0: extent usually at least 1 degree even if extent for relevant terrain data is way smaller)	*.dt0 *.dt1 *.dt2	Originally designed for use by the US military. Geospatial Standards and Specifications

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[57] Supported data types (e.g. integer, floating point,…) ESRI Support Homepage: Technical Specs of raster dataset formats: http://help.arcgis.com/en/arcgisdesktop/10.0/help/index.html#/Technical_specifications_for_raster_dataset_formats/009t0000000r000000/

USGS DEM (United States Geological Survey Digital elevation model)	This format consists of a raster grid of regularly spaced elevation values derived from the USGS topographic map series. In their native format, they are written as ANSI-standard ASCII characters in fixed-block format. (source)		- is not ISO 19100 compliant - cannot store metadata on pixel level.	*.dem	http://nationalmap.gov/standards/pdf/1DEM0897.PDF
ESRI Grid	A proprietary ESRI format that supports 32-bit integer and 32-bit floating point raster grids. (source)	- native support by ESRI ArcGIS	- proprietary binary format - is not ISO 19100 compliant - cannot store metadata on pixel level	made up of several different files	Proprietary raster format Reference
ASCII Grid	ESRI ArcInfo Grid exchange file (source)	- native support by ESRI ArcGIS - textual structure allows creating easy parsers for reading data - non-proprietary, but no advantages compared to GeoTIFF	- is much slower on reading than binary formats - is not ISO 19100 compliant - cannot store metadata on pixel level - contains very little metadata (e.g. coordinate reference system, the height datum, and any quality information require a separate file)	*.asc	This is often called an "ESRI GRID ASCII" format, but it is used by many applications as a simple way to import and export grid data. This is an old format where data is stored as text, being easily understandable and light after being zipped
Raw Binary				*.bil *.bip *.bsq	same format as above, but data is stored as binaries .bil-Band interleaved by line .bip-band interleaved by pixel .bsq-band sequential
ASCII XYZ				*.xyz	

List of further terrain formats					
(City) GML	CityGML is a common information model and XML-based encoding for the representation, storage, and exchange of virtual 3D city and landscape models. CityGML provides a standard model and mechanism for describing 3D objects with respect to their geometry, topology, semantics and appearance, and defines five different levels of detail. (source)	- ISO 19100 compliant, - Easily read by existing GML parsers - Can store metadata information on pixel level - High flexibility (xml based) - Highly standardized and well documented	- Will be very slow on reading than binary formats - Missing support in many standard tools	*.gml *.xml	Reference 1 Reference 2 Reference 3
Shape Files	A shapefile is a simple, non-topological format for storing the geometric location and attribute information of geographic features. Geographic features in a shapefile can be represented by points, lines, or polygons (areas). (source)	- Many open source libraries and tools that are able to view and work with shape files (even if it is originally a proprietary format). - Additional attributes can be stored - Metadata storable	- ESRI proprietary format - Only vector data (DEM usually used as raster data, but conversion is a common and easy task) - Always at least 3 files (missing overview) - No topological information - Max 2 GB - Probably Geodatabases would be even better	Required: *.shp *.shx *.dbf Additional information, optional files: *.sbn and *.sbx *.fbn and *.fbx *.ain and *.aih *.atx *.ixs *.mxs *.prj *.xml *.cpg	Points, Contourlines ESRI recommends using geodatabases files instead of shape files
TIN (Triangular or triangulated Irregular Network)	A TIN is a vector-based representation of the physical land surface or sea bottom, made up of irregularly distributed nodes and lines with three-dimensional coordinates (x, y, and z) that are arranged in a network of non-overlapping triangles. (source)	- Resolution can be varied depending on the terrain	- More complex data structure than regular raster - Only for smaller areas		"TIN" is not a format – it is more of a data model. TINs are stored in different ways by different software packages (e.g. SOCET SET and ARC). In INSPIRE, the recommended format for TINs is in a GML file.
Spreadsheets			- Conversion usually more work-intensive - Metadata has to be delivered in an additional spread sheet/file		

GPKG (Geopackage)	A GeoPackage is an open, non-proprietary, platform-independent and standards-based data format for geographic information system. It has been developed by OGC and it is now the default standard for geographic data in QGIS open GIS software.	- It can handle either raster or vector data (even both together) - It is supported by many standard GIS softwares like ESRI ArcGIS - It can handle attributes and metadata.	-	*.gpkg	

Appendix E LIST OF TOD RELATED INCIDENTS AND ACCIDENTS

1. B734, Amsterdam Netherlands, 2010

On 6 June 2010, aircraft Boeing 737-4B6 was flying from Amsterdam Schiphol Airport, Netherlands to Nador International Airport, Morocco. It collided with a flock of birds, causing serious damage to the left-hand engine. The flight crew made a right turn to return to the airport and continued in a low flight over a built-up area. The aircraft successfully passed a number of high obstacles and landed back at the airport. The investigation determined that the right turn of the flight crew had been a correct decision but that it had not been executed in accordance with the standard operational procedure in the event of engine failure.

A safety recommendation was made to ensure that aircraft in distress flying under the minimum vectoring altitude are informed about high obstacles in the Schiphol control zone.

2. C750, Frankfurt-Egelsbach, Germany, 2012

On 1 March 2012, the Cessna Citation 750 was flying from Linz, Austria to Bratislava, Slovak Republic with a planned stopover in Egelsbach, Germany. It collided with a wooded region about 4 km away from the airport and the accident resulted in five fatalities. The investigation did not determine the reason for the crash. It was found that EGPWS had issued warnings about terrain proximity.

A safety recommendation was made to ensure the clear presentation of the final approach at an angle of 4.4 degrees due to the obstacle situation. It was also recommended that the wooded region be represented as an obstacle.

3. C30J, En-route, northern Sweden 2012

On 15 March 2012, aircraft Lockheed-Martin C130J-30 Hercules operated by the air force was flying from Harstad/Narvik Airport, Norway to Kiruna, Sweden. It flew into high terrain in Sweden. The investigation determined that the aircraft had not notice shortcomings in clearances which had resulted in the flight being made at a lower altitude. Furthermore, GCAS/TWAS had not issued warnings of terrain proximity because the settings and the terrain profile used did not fulfil the criteria for GCAS/TWAS warnings. The accident resulted in five fatalities.

A safety recommendation was made to ensure that flight crew routines use the ground collision avoidance system in a safe manner.

4. A320, vicinity Lyon Saint-Exupéry, France, 2012

On 11 April 2012, aircraft A320 was flying from Ajaccio to Lyon Saint-Exupéry, France at night under IMC. At Lyon the aircraft was cleared to join ILS and descend towards terrain. Warnings from the aircraft's EGPWS and from ATC's MSAW caused the descent to be interrupted. The investigation determined that the aircraft was not correctly configured on the ILS, resulting in dangerous proximity to ground and that the normal procedures had not been properly executed due to limited experience.

This incident serves as an example of the benefits on using terrain data in EGPWS and MSAW as safety nets.

5. A109, vicinity London Heliport London UK, 2013

On 16 January 2013, helicopter A109 was flying over central London towards London Heliport. It collided with a crane at a height of 700 ft MSL in reduced meteorological visibility. The investigation determined that the helicopter was not aware of the proximity and did not see the crane, or saw it too late. The accident resulted in two fatalities: the pilot of the helicopter and a pedestrian.

Several safety recommendations were made relating to obstacle data provision, requiring an assessment of the effect of obstacles in operational procedures and implementation of a mechanism for the reporting and management of obstacle data.

6. DHC6, En route, Mount Elizabeth Antarctica, 2013

On 23 January 2013, aircraft DHC-6-300 was flying under VFR from South Pole Station to Terra Nova Bay, Antarctica. It flew into the terrain of Mount Elizabeth in extreme weather conditions. The investigation determined that the aircraft had made a turn before reaching an open region and, given the weather conditions, the crew were not aware of the proximity to terrain. The accident resulted in three fatalities.

Safety recommendations were made relating to the terrain data provision such as amending GNSS standard procedures to prevent incorrect data input and implementation of a TAWS limitation awareness programme for flights above 70th parallel North and below 70th parallel South.

7. Beechcraft Corporation 390 Premier (Premier IA), N777VG, Georgia, USA, 2013

On 20 February 2013, aircraft Premier IA was performing a go-around procedure at Thomson-McDuffie County Airport, Georgia. It collided with a utility pole, trees and terrain. The investigation determined that the pole did not respect the obstruction standards; it had not been notified and was therefore not represented on charts. The accident resulted in five fatalities.

8. JAS 39, outside Askersund, Sweden, 2013

On 11 October 2013, military aircraft JAS 39 C took off from Malmen Air Base Airport for low-level flight training. When returning to the air base the pilot passed very close to an unlit mast which was not recorded in the chart documentation used. The investigation determined that the obstacles had not been recorded in the area and lit as expected and that they constituted a hazard, especially for low-level flights. It was also found that the requirements of ADQ Regulation were not in place in Sweden.

Several safety recommendations were made regarding obstacle data provision, i.e. to clarify responsibility for the obstacle database to ensure the quality requirements of the obstacle data, to ensure the updating of the obstacle database, to take regulatory measures on the quality of obstacle data, as well as on the marking and reporting of the obstacles.

9. S-76C, HL9294, Samseong-Dong, Gangnam-Gu, Seoul, 2013

On 16 November 2013, helicopter S76C was flying under VFR from Gimpo International Airport to Jamsil Heliport, Korea. It collided with a condominium building while on approach to land under limiting weather conditions. The investigation determined that the flight crew had been unable to identify the obstacle due to fog during descent. The accident resulted in two fatalities.

A contributing factor was the fact that EGPWS did not issue a warning as the EGPWS did not contain data about high rise buildings, including the condominium.

10. Piper PA 32R-300, Highmore, SD, US, 2014

On 27 April 2014, aircraft Piper PA-32R-300 was flying from Hereford Municipal Airport, Texas to Highmore Municipal Airport, South Dakota. It collided with a wind turbine tower during deteriorating weather conditions. The investigation determined that a combination of the decision to continue at low altitude and the unlit wind turbine were the probable causes of the accidents. The accident resulted in four fatalities.

11. Sikorsky S-92A, Black Rock, Co. Mayo, Ireland, 2017

On 14 March 2017, helicopter Sikorsky S-92A was flying to County Mayo in a rescue operation for the Irish Coast Guard. The preliminary investigation determined that the helicopter touched the slopes of an island at an altitude of 200 ft when approaching to refuel and then it crashed into the sea. The terrain of the island was not available in the terrain database and it was identified by the flight crew approximately 13 seconds before impact. The accident resulted in four fatalities.

A safety recommendation was made to review all route guides of SAR helicopters and to enhance the information on obstacle heights and positions, terrain clearance, vertical profile, the positions of waypoint in relation to obstacles and EGPWS database terrain and obstacle limitations.

12. Airbus Helicopters EC 135 P2+, LN-OOI, Sollihøgda, Norway, 2014

On 14 January 2014, helicopter LN-OOI was flying from the base at Lørenskog to a traffic accident at Sollihøgda. The helicopter failed to see a power line while descending to land near the accident and after main rotor damage was sustained during unintended contact, the helicopter descended rapidly to the ground out of control. The accident resulted in two fatalities.

It is important to note that the power line was shown on the digital moving map onboard, but the height was not specified and that the map and warning system was known for being unreliable and incomplete which in turn, resulted in little faith in the warning system of the moving map.

A safety recommendation was made to improve the aviation obstacle database which was incomplete and not easily compatible with the GNSS-based warning system. The recommendation proposed the developing of the obstacle database with the aim of providing safety benefits for air ambulances as well as other aircraft operators.

13. Agusta A109S, near Porto, Portugal, 2018

On 15 December 2018, helicopter Agusta A109S was flying from the Massarelos heliport to Macedo de Cavaleiros heliport, the operational base for the aircraft with a planned technical stop for refuelling. The helicopter collided with a radio broadcasting support tower. After the main rotor blades contact with the tower and its wires, the helicopter began a continuous disintegration until crashing on a hill. None of the people onboard survived the ground impact. It is important to note the lack of night signalling on the nearest lower tower or at the intermediate level of the accidented tower, as well as the adjacent towers installed.

A safety recommendation was made to improve the legislation and to establish the conditions and responsibilities for official inspection of the operational performance of night-time beaconing of air navigation obstacles, outside of airport areas.

Appendix F DATA PRODUCT SPECIFICATIONS

F.1 DATA PRODUCT SPECIFICATION OF OBSTACLE DATA SET DONLON AIRPORT

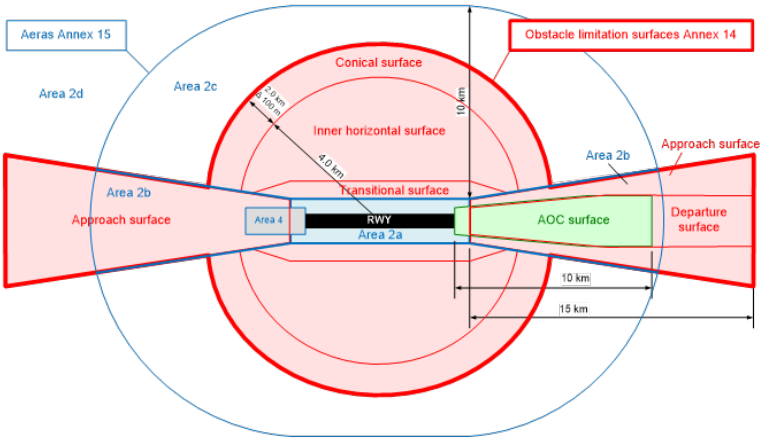
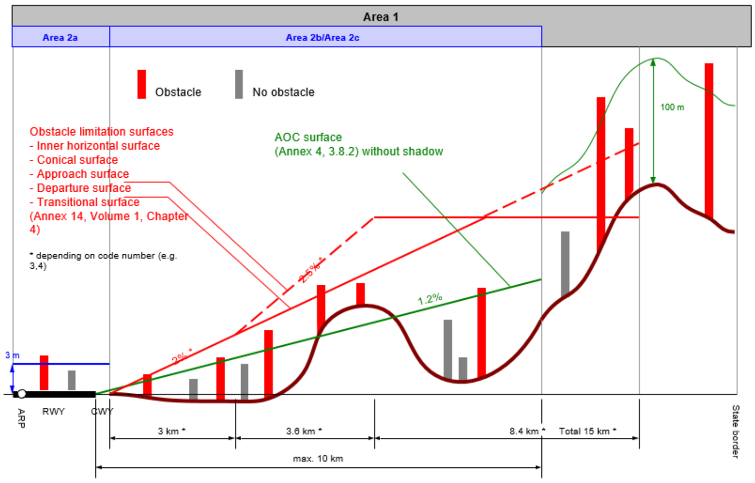
Version:	0.3
This version	http://www.aisdonlon.dl/dps.pdf
Latest version	http://www.aisdonlon.dl/
Published	2019-12-04
Language	English
Extent of the data product	Donlon Airport TMA
Topic category	Transportation
Keywords	Obstacles

Abstract of the data product
This data set is a full initial data set and it describes the obstacles in Areas 2 (2a, 2b, 2c, 2d), 3 and 4 of Donlon Airport (EADD), specifically: • EADD Area 2a for RWY 09L/27R and RWY 09R/27L; • EADD Area 2b for 09L, 27R, 09R and 27L; • EADD Area 2c for RWY 09L/27R and RWY 09R/27L; • EADD Area 2d; • EADD Area 3; and • EADD Area 4 for 27R. The descriptions and requirements of the Areas 2 (a-d), 3 and 4 obstacles can be found in ICAO Annex 15, 16th Edition and PANS-AIM (Doc 10066), 1st Edition as well as in EUROCONTROL TOD Manual, Edition 3.0. Area 2a, Area 2b, Area 2c, Area 2d and Area 3 data are collected and published according to ICAO Annex 15, 16th Edition requirements. Obstacle data are provided for Area 4 for obstacles over 1 metre in height (above ground level) for all runways where precision approach Category II or III operations have been established.

Contact Information	
Organisation	Aeronautical Information Service
Address	P.O. Box 744, 1050 State Street, Donlon
Phone / Fax	0123 697 3464 / 0123 697 3474
Email	ais@donlon.dl
Web site	http://www.aisdonlon.dl

Content

1. About the data product specification	
Title	Obstacle data set sample for EADD Area 2(a-d), Area 3 and Area 4; Initial data set
This version	http://www.aisdonlon.dl/obstacle-dps.pdf
Latest version	NIL
Published	2019-11-25
Updated	2019-12-02
Language	English
Contact	Address: P.O. Box 744, 1050 State Street, Donlon Phone / Fax: 0123 697 3464 / 0123 697 3474 Email: ais@donlon.dl Web site: http://www.aisdonlon.dl
Web location	http://www.aisdonlon.dl/obstacle-dps.pdf
Format	PDF
Maintenance	The data product specification is updated regularly and reviewed at least once every year.
Handling restrictions	*Not applicable*
Terms and definitions	See ICAO Annex 15, 16th Edition and PANS-AIM (Doc 10066), 1st Edition
Abbreviations	AIXM Aeronautical Information Exchange Model TOD Terrain and Obstacle Data For additional abbreviations, see ICAO Annex 15, 16th Edition and PANS-AIM (Doc 10066), 1st Edition
2. Identification and purpose of the data product	
Official title	Obstacle data set sample for EADD Area 2(a-d), Area 3 and Area 4 (Eff Date: 2019-12-05); Initial data set.
Alternative title	*Not applicable*
ID	EADD_OBS_DS_AREA_2A_2B_2C_2D_3_4_FULL_20191205_5.1
Abstract	Obstacle data set sample for EADD Area 2(a-d), Area 3 and Area 4 (Full initial data set). Area 2a, Area 2b, Area 2c, Area 2d and Area 3 data are collected and published according to ICAO Annex 15, 16th Edition requirements. Obstacle data are provided for Area 4 for obstacles over 1 metre in height (above ground level) for all runways where precision approach Category II or III operations have been established.
Purpose	The purpose of the data product is to provide obstacle data for air navigation applications. ICAO PANS-AIM, Chapter 5.3.3.2 provides possible uses of the data. It is the responsibility of the users to determine if the data product meets their needs.
Topic category	Transportation

Keywords	Obstacles
Spatial representation	Vector
Spatial resolution	*Not applicable*
Supplemental information	*NIL*
Restrictions	For aviation use only!
Extent	EADD Area 2 for RWY 09L/27R and RWY 09R/27L. EADD Area 3. EADD Area 4 for 27R. The Area 2 is defined as follows:  Aeras Annex 15 Obstacle limitation surfaces Annex 14 Area 2d Area 2c Conical surface 2.0 km 100 m 10 km Inner horizontal surface 4.0 km Area 2b Approach surface Transitional surface Area 2b Approach surface Area 4 RWY Area 2a AOC surface Departure surface 10 km 15 km  Area 1 Area 2a Area 2b/Area 2c Obstacle No obstacle Obstacle limitation surfaces - Inner horizontal surface - Conical surface - Approach surface - Departure surface - Transitional surface (Annex 14, Volume 1, Chapter 4) * depending on code number (e.g. 3,4) AOC surface (Annex 4, 3.8.2) without shadow 100 m 2.5% * 1.2% 2% * 3 m ARP RWY CWY 3 km * 3.6 km * 8.4 km * Total 15 km * max. 10 km State border Area 3 is defined as follows: ….. Area 4 is defined as follows: ….
3. Scopes	
General scope	
Scope id	General scope
Level	Series
Level name	General scope
Level description	The general scope is the root level of the scope level hierarchy. The general scope level defines the

	specifications which are for obstacles of EADD Areas 2 (a-d), 3 and 4 according to the requirements of ICAO Annex 15, 16th Edition.
Extent	Areas 2, 3 and 4 of EADD
Coverage	*Not applicable*
Area 2	
Scope id	Area 2
Level	Dataset
Level name	Area 2
Level description	The Area 2 scope defines the specifications which are for obstacles in Area 2 and deviate from the general scope.
Extent	Area 2 of EADD consisting of: Area 2a: The rectangular area around the runway that comprises the runway strip plus any clearway that exists. 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 per cent to each side. Area 2c: The area extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a. Area 2d: The area outside Areas 2a, 2b and 2c up to a distance of 45 km from the aerodrome reference point, or to an existing terminal control area (TMA) boundary, whichever is nearest.
Coverage	*Not applicable*
Area 3	
Scope id	Area 3
Level	Dataset
Level name	Area 3
Level description	The Area 3 scope defines the specifications which are for obstacles in Area 3 and deviate from the general scope.
Extent	Area 3 of EADD: The area bordering the 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.
Coverage	*Not applicable*
Area 4	
Scope id	Area 4
Level	Dataset
Level name	Area 4

Level description	The Area 4 scope defines the specifications which are for obstacles in Area 4 and deviate from the general scope.
Extent	Area 4 of EADD Runway 27R: 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.
Coverage	*Not applicable*
4. Data content and structure	
General scope	
Narrative description	The data model for obstacle data follows the model defined in AIXM 5.1.1
Application schema	See Annex A
Feature catalogue	See Annex B
5. Reference system	
General scope	
Spatial reference system	Horizontal reference system: WGS-84, EPSG: 4326 (Realisation: ITRF2008 Epoch 2005.0), Vertical reference system: Mean See Level using EGM-96 datum, EPSG: 5773
Temporal reference system	Gregorian Calendar, UTC
6. Data quality	
General scope	
Requirement 1	Data quality element: Assurance (Integrity) Data quality measure: The horizontal and vertical position integrity are classified as “essential”. The procedures for processing obstacles have been setup to meet the integrity requirements.
Requirement 2	Data quality element: Traceability Data quality measure: All actions over the obstacle objects are traced and saved in metadata. Metadata is available on request.
Requirement 3	Data quality element: Timeliness Data quality measure: Timeliness is assured by providing the start and end time position of all obstacles according to the temporality concept of AIXM.
Requirement 4	Data quality element: Completeness Data quality measure: All features and attributes are expressed according to the AIXM model. The content of the data set was checked by visual inspection.
Area 2	
Requirement 1	Data quality element: Horizontal accuracy

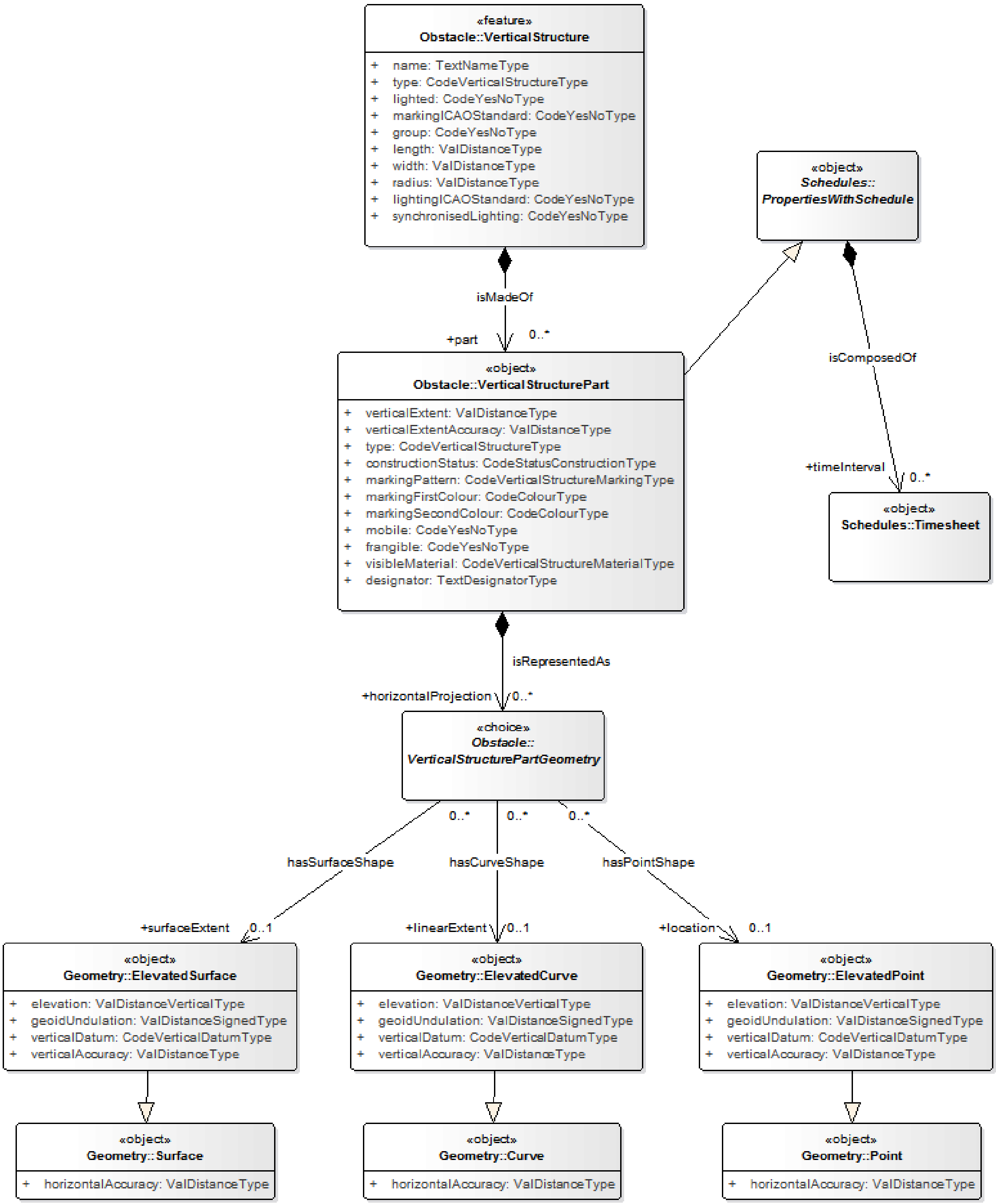
	Data quality measure: The horizontal accuracy is 5 m at 90% confidence level.
Requirement 2	Data quality element: Vertical accuracy Data quality measure: The vertical accuracy is 3 m at 90% confidence level.
Requirement 3	Data quality element: Horizontal position resolution Data quality measure: The horizontal position resolution is expressed in decimal degrees ranging from 5 to 15 decimal places, commensurate with the accuracy requirements. The resolution is sufficient to guarantee the accuracy requirements.
Requirement 4	Data quality element: Vertical position resolution Data quality measure: The vertical position resolution is 0.1 m or 1 m, commensurate with the accuracy requirements. The resolution is sufficient to guarantee the accuracy requirements.
Area 3	
Requirement 1	Data quality element: Horizontal accuracy Data quality measure: The horizontal accuracy is 0.5 m at 90% confidence level.
Requirement 2	Data quality element: Vertical accuracy Data quality measure: The vertical accuracy is 0.5 m at 90% confidence level.
Requirement 3	Data quality element: Horizontal position resolution Data quality measure: The horizontal position resolution is expressed in decimal degrees ranging from 5 to 15 decimal places, commensurate with the accuracy requirements. The resolution is sufficient to guarantee the accuracy requirements.
Requirement 4	Data quality element: Vertical position resolution Data quality measure: The vertical position resolution is 0.1m or 1 m, commensurate with the accuracy requirements. The resolution is sufficient to guarantee the accuracy requirements.
Area 4	
Requirement 1	Data quality element: Horizontal accuracy Data quality measure: The horizontal accuracy is 2.5 m at 90% confidence level.
Requirement 2	Data quality element: Vertical accuracy Data quality measure: The vertical accuracy is 1 m at 90% confidence level.
Requirement 3	Data quality element: Horizontal position resolution Data quality measure: The horizontal position resolution is expressed in decimal degrees ranging from 5 to 15 decimal places, commensurate with the accuracy

	requirements. The resolution is sufficient to guarantee the accuracy requirements.
Requirement 4	Data quality element: Vertical position resolution Data quality measure: The vertical position resolution is 0.1 m or 1 m, commensurate with the accuracy requirements. The resolution is sufficient to guarantee the accuracy requirements.
7. Data capture and production	
General scope	
Description	Obstacle data capture rules are based on EUROCAE ED-98C and Eurocontrol TOD Manual. Obstacle coverage areas have been created according to ICAO Annex 15, 16th Edition and PANS-AIM, 1st Edition.
Guide	EUROCAE ED-98C
Inclusion criteria	Obstacles must have a minimal height of 100 m above ground level to be included in an Area 1 obstacle dataset.
Data acquisition and processing	The data was captured and processed with photogrammetry and terrestrial survey.
8. Maintenance of the data	
General scope	
Description	The data set will be updated every AIRAC cycle. New obstacles erected between AIRAC dates will be announced by NOTAM.
Frequency	Continual
User defined	*Not applicable*
9. Portrayal rules	
General scope	
Portrayal rules	*Not applicable*
10. Data delivery	
General scope	
Format name	AIXM
Format version	5.1.1
Format specification	AIXM 5.1.1 Specification (source http://aixm.aero)
File structure	http://www.aixm.aero/schema/5.1.1/AIXM_Features.xsd
Language	English - eng
Character set	UTF-8
Units of delivery	Dataset
Transfer size	Various
Medium name	SWIM Dataset Service
Other delivery	*Not applicable*

Service property	An information service overview is available at http://www.aisdonlon.dl
11. Metadata	
General scope	
Specification	Title: ISO 19115:2003, Geographic information – Metadata Date: 2003
Encoding	Title: ISO 19139:2007, Geographic information – Metadata – XML schema implementation Date: 2007
Metadata elements	The metadata is included in the data set as described in ICAO Annex 15 Chapter 5.3.2. The following metadata is provided: • Title of data set • Organisation providing the data set • Abstract • Creation date • Effective date • Validity • Constraint of use
12. Additional information	
General scope	
Additional information	*Not applicable*

Annex A Application schema

The application schema is according to the AIXM 5.1.1 model (source http://aixm.aero). The overview of vertical structure is presented below.


«feature»
Obstacle::VerticalStructure
+ name: TextNameType
+ type: CodeVerticalStructureType
+ lighted: CodeYesNoType
+ markingICAOStandard: CodeYesNoType
+ group: CodeYesNoType
+ length: ValDistanceType
+ width: ValDistanceType
+ radius: ValDistanceType
+ lightingICAOStandard: CodeYesNoType
+ synchronisedLighting: CodeYesNoType
«object»
Schedules::
PropertiesWithSchedule
isMadeOf
+part
0..*
isComposedOf
«object»
Obstacle::VerticalStructurePart
+ verticalExtent: ValDistanceType
+ verticalExtentAccuracy: ValDistanceType
+ type: CodeVerticalStructureType
+ constructionStatus: CodeStatusConstructionType
+ markingPattern: CodeVerticalStructureMarkingType
+ markingFirstColour: CodeColourType
+ markingSecondColour: CodeColourType
+ mobile: CodeYesNoType
+ frangible: CodeYesNoType
+ visibleMaterial: CodeVerticalStructureMaterialType
+ designator: TextDesignatorType
+timeInterval
0..*
«object»
Schedules::Timesheet
isRepresentedAs
+horizontalProjection
0..*
«choice»
Obstacle::
VerticalStructurePartGeometry
0..*
0..*
0..*
hasSurfaceShape
hasCurveShape
hasPointShape
+surfaceExtent
0..1
+linearExtent
0..1
+location
0..1
«object»
Geometry::ElevatedSurface
+ elevation: ValDistanceVerticalType
+ geoidUndulation: ValDistanceSignedType
+ verticalDatum: CodeVerticalDatumType
+ verticalAccuracy: ValDistanceType
«object»
Geometry::ElevatedCurve
+ elevation: ValDistanceVerticalType
+ geoidUndulation: ValDistanceSignedType
+ verticalDatum: CodeVerticalDatumType
+ verticalAccuracy: ValDistanceType
«object»
Geometry::ElevatedPoint
+ elevation: ValDistanceVerticalType
+ geoidUndulation: ValDistanceSignedType
+ verticalDatum: CodeVerticalDatumType
+ verticalAccuracy: ValDistanceType
«object»
Geometry::Surface
+ horizontalAccuracy: ValDistanceType
«object»
Geometry::Curve
+ horizontalAccuracy: ValDistanceType
«object»
Geometry::Point
+ horizontalAccuracy: ValDistanceType

Annex B Feature catalogue

All necessary definitions are given in the AIXM 5.1.1 model. The full definitions as well as the mapping of all ICAO requirements to AIXM 5.1.1 can be found at http://aixm.aero.

The table below lists the obstacle attributes (as specified in ICAO PANS-AIM Appendix 1 Table A1-6) that are provided in the data set and their mapping to AIXM 5.1.1

Table A1-6 Obstacle data		AIXM 5.1.1
Property	Sub-Property	Feature
Obstacle identifier		VerticalStructurePart.designator
Operator / Owner		VerticalStrucuture.annotation.Note
Geometry type		VerticalStructurePartGeometry.surfaceExtent VerticalStructurePartGeometry.linearExtent VerticalStructurePartGeometry.location
Horizontal position		VerticalStrucurePart.location.ElevatedPoint VerticalStrucurePart.linearExtent.ElevatedCurve VerticalStrucurePart.surfaceExtent.ElevatedSurface
Horizontal extent		VerticalStructure.radius
Elevation		VerticalStrucurePart.location.ElevatedPoint.elevation VerticalStrucurePart.linearExtent.ElevatedCurve.elevation VerticalStrucurePart.surfaceExtent.ElevatedSurface.elevation
Height		VerticalStrucurePart.verticalExtent
Type		VerticalStructure.type
Date and time stamp		VerticalStructure.featureLifetime.start
Operations		VerticalStrucurePart.mobile VerticalStrucurePart.constructionStatus
Effectivity		VerticalStructure.timeSlice.VerticalStructureTimeSlice.validTime VerticalStructure.timeSlice.VerticalStructureTimeSlice.featureLifetime VerticalStructurePart.timeInterval.Timesheet
Lighting	Type	VerticalStructure.lighted VerticalStructure.lightingICAOStandard VerticalStructure.synchronisedLighting VerticalStructurePart.lighting.LightElement.type
	Colour	VerticalStructurePart.lighting.LightElement.colour
Marking		VerticalStructure.markingICAOStandard VerticalStructurePart.markingPattern VerticalStructurePart.markingFirstColour VerticalStructurePart.markingSecondColour
Material		VerticalStructurePart.visibleMaterial

F.2 SAMPLE DATA PRODUCT SPECIFICATION OF DIGITAL TERRAIN DATA SET DONLON AIRPORT

Version:	0.1
This version	http://www.aisdonlon.dl/dtm-dps.pdf
Latest version	http://www.aisdonlon.dl
Published	2020-09-30
Language	English
Extent of the data product	Donlon Airport EADD TMA
Topic category	elevation
Keywords	DTM, DEM, Terrain, Elevation

Overview of the data product
This data set contains the digital terrain data of Area 2 of Donlon Airport (EADD). The digital terrain data meets the numerical requirements defined in ICAO PANS-AIM (Doc 10066), Appendix 1, Table A1-8 for Area 2. The digital terrain model defines the bare surface of the earth and does not include any vegetation or manmade objects.

Contact Information	
Organisation	Aeronautical Information Service
Address	P.O. Box 744, 1050 State Street, Donlon
Phone / Fax	0123 697 3464 / 0123 697 3474
Email	ais@donlon.dl
Web site	http://www.aisdonlon.dl

Content

1. About the data product specification	
Title	Data Product Specification of Terrain Data Set Donlon Airport
This version	http://www.aisdonlon.dl/dtm-dps.pdf
Latest version	NIL
Published	2020-09-30
Updated	NIL
Language	English
Contact	Aeronautical Information Service Address: P.O. Box 744, 1050 State Street, Donlon Phone / Fax: 0123 697 3464 / 0123 697 3474 Email: ais@donlon.dl Web site: http://www.aisdonlon.dl
Web location	http://www.aisdonlon.dl/dtm-dps.pdf
Format	PDF
Maintenance	The data product specification is reviewed at least once every year and updated as required.
Handling restrictions	Unrestricted
Terms and definitions	See ICAO Annex 15, 16th Edition and PANS-AIM (Doc 10066), 1st Edition.
Abbreviations	See ICAO Annex 15, 16th Edition and PANS-AIM (Doc 10066), 1st Edition.
2. Identification and purpose of the data product	
Official title	DONLON Airport Area 2 terrain data set.
Alternative title	*Not applicable*
ID	EADD _DTM_DS_AREA2_20200326
Abstract	The digital terrain data set of Donlon Airport (EADD) covers Area 2 (the complete TMA). The digital terrain model defines the bare surface of the earth and does not include any vegetation or man-made objects. The digital terrain data meets the numerical requirements defined in ICAO PANS-AIM (Doc 10066), Appendix 1, Table A1-8 for Area 2.
Purpose	Digital terrain data in this data set is meant to be used for different air navigation application and systems such as: • Terrain awareness and warning systems • Minimum safe altitude warning systems • Flight procedure design, • Design of one engine out procedures • Aeronautical charting It is the responsibility of the users to determine if the data product meets their needs.
Topic category	elevation
Keywords	DTM, DEM, Terrain, Elevation

Spatial representation	grid
Spatial resolution	1 arc second (approx. 30 m)
Supplemental information	*NIL*
Restrictions	Use limitations: For aviation use only Access restrictions: Unrestricted Usage restrictions: Unrestricted Security restrictions: Unclassified
Extent	Donlon Airport EADD Area 2 The geographic description is represented by the bounding box as defined below.

```
<gmd:EX_GeographicBoundingBox>
        <gmd:westBoundLongitude>
                <gco:Decimal>-32.200547777778</gco:Decimal>
        </gmd:westBoundLongitude>
        <gmd:eastBoundLongitude>
                <gco:Decimal>-31.2910399444444</gco:Decimal>
        </gmd:eastBoundLongitude>
        <gmd:southBoundLatitude>
                <gco:Decimal>51.9631093055556</gco:Decimal>
        </gmd:southBoundLatitude>
        <gmd:northBoundLatitude>
            <gco:Decimal>-52.7764601111111 </gco:Decimal>
        </gmd:northBoundLatitude>
</gmd:EX_GeographicBoundingBox>
```

3. Scopes

General scope

Scope id	General scope
Level	Dataset
Level name	General scope
Level description	The general scope level defines the specifications which are applicable to all aeronautical data of Republic of Donlon.
Extent	Donlon Airport EADD Area 2
Coverage	*Not applicable*

4. Data content and structure

General scope

Narrative description	Digital terrain model of the bare earth surface (does not include vegetation or man-made objects)
Application schema	Raster grid with 1 arc second post spacing
Feature catalogue	Elevation

5. Reference system

General scope

Spatial reference system	Horizontal reference system: WGS-84, EPSG: 4326 (Realisation: ITRF2008 Epoch 2005.0), Vertical reference system: Mean See Level using EGM-96 datum, EPSG: 5773
Temporal reference system	Gregorian Calendar, UTC.

6. Data quality requirements

General scope	
Requirement 1	Data quality element: Assurance (Integrity) Data quality measure: The horizontal and vertical position integrity are classified as “essential”. The procedures for processing of the data have been setup to meet the integrity requirements.
Requirement 2	Data quality element: Horizontal accuracy Data quality measure: The horizontal accuracy is 5 m at 90% confidence level.
Requirement 3	Data quality element: Vertical accuracy Data quality measure: The vertical accuracy is 3 m at 90% confidence level.
Requirement 4	Data quality element: Vertical resolution Data quality measure: The vertical resolution is 0.1 m
Requirement 5	Data quality element: Traceability Data quality measure: All actions (data acquisition, verification and validation) applied to the data are traced and saved in metadata. Metadata is available on request.

7. Data capture and production

General scope	
Description	Data has been produced with a LIDAR survey.
Guide	*Not applicable*
Inclusion criteria	The data represents the bare earth surface. Vegetation and man-made objects except dams and bridges have been filtered out. The data set only covers the TMA of Donlon Airport. Grid points outside
Data acquisition and processing	LIDAR survey with a density of 2 points / m2 Data validation with a set of 25 checkpoints that were surveyed by GNSS by the national mapping authority. Postprocessing applied to raw data: 1) Filtering of vegetation and man-made objects (buildings, powerlines, antennas etc.) except bridges and dams 2) Transformation to WGS-84, EGM-96 3) Resampling to a 1 arc second grid applying a "maximum values"-filter.

8. Maintenance of the data

General scope	
Description	The data set will be updated every 5 years.
Frequency	Continually
User defined	*Not applicable*

9. Portrayal rules

General scope

Portrayal rules	*Not applicable*

10. Data delivery methods

GeoTIFF

Format name	GeoTIFF
Format version	1.1
Format specification	According OGC GeoTIFF V1.1 (see http://docs.opengeospatial.org/is/19-008r4/19-008r4.html)
File structure	GeoTIFF georeferenced raster
Language	English
Character set	UTF-8
Units of delivery	Dataset
Transfer size	*2 MB*
Medium name	*Digital file transfer*
Other delivery	*Not applicable*
Service property	An information service overview is available at http://www.aisdonlon.dl

ASCII Grid

Format name	Esri ASCII Grid
Format version	Not applicable
Format specification	See Esri ASCII Grid specification for details

File structure	A six line header indicating the reference of the grid:
	`NCOLS` `Number of cell columns`
	`NROWS` `Number of cell rows`
	`XLLCENTER or XLLCORNER` `X-coordinate of the origin (by center or lower left corner of the cell)`
	`YLLCENTER or YLLCORNER` `Y-coordinate of the origin (by center or lower left corner of the cell)`
	`CELLSIZE` `Cell size`
	`NODATA_VALUE` `The input values to be NoData in the output raster`
	followed by the values listed in "English reading order" (left-right and top-down).

Language	English
Character set	UTF-8
Units of delivery	Dataset
Transfer size	*15 MB*
Medium name	*Digital file transfer*
Other delivery	*ZIP compressed 3 MB*

Service property	An information service overview is available at http://www.aisdonlon.dl
11. Metadata	
General scope	
Specification	The metadata is provided in a separate metadata file with all metadata elements required according to ICAO Annex 15 Chapter 5.3.2 and required core elements according to ISO 19115:2003, Geographic information – Metadata. The following metadata is provided: • Title of data set • Organisation providing the data set • Abstract • Creation date • Effective date • Validity • Constraint of use • Geographic extent
Encoding	Title: ISO 19139:2007, Geographic information – Metadata – XML schema implementation Date: 2007
12. Additional information	
General scope	
Additional information	*Not applicable*

Appendix G DATA VALIDATION AND VERIFICATION RULES

G.1 INTRODUCTION

This Appendix contains guidance regarding the test cases for the validation of selected feature properties of terrain and obstacle data sets accompanying this document. The approach to data quality and quality evaluation (data validation) is based on the ISO 19113 [18] and ISO 19114.

Where SARPs do not provide the quality levels necessary for conformance, the latter are suggested in the validation table. The conformance quality level is a definition of the quantitative threshold for data sets to be compliant with the specifications. In this sense, the conformance quality level could be regarded as part of an enhanced DPS.

For many test cases, several measurements are proposed. It is advised, for each test case, to carry on tests as proposed in the validation table. Indeed, most of the time, when the first test of a test case fails then the following ones might fail as well.

G.2 DEFINITIONS

This section defines all the terms used in the validation tasks table (see section G.3).

G.2.1 VALIDATION METHODS

Coherence with specifications

Coherence with specifications consists of comparing data to its specifications. This method cannot completely validate the data as there is the possibility that the data has an error that lies within the expected specifications.

Self-coherence

Self-coherence consists of comparing data within the data set itself and identifying inconsistencies. This method cannot completely validate the data as there is the possibility that data consistent in error. For example, it is possible from some data of the data set to compute data which already exist in the data set and then compare computed data to existing data in the data set.

Coherence with exogenous data

Coherence with exogenous data consists of comparing two different data sets and identifying inconsistencies between values. This method cannot completely validate the data as there is the possibility that the different data sets include the same error. Independence of the data sets substantially improves the effectiveness of this type of validation.

G.2.2 QUALITY CRITERIA

Completeness – Omission

Entries which should be provided according to specifications are missing in the data set.

Number of missing items in the data set in relation to the number of items that should have been present.

Completeness – Excess

Entries which should not be provided according to specifications are in the data set.

Number of excess items in the data set in relation to the number of items that should have been present.

Conceptual Consistency

Compliance with the conceptual schema (all mandatory elements are provided and all constraints and all relations are respected).

Format Consistency

Compliance with the physical model of data. For TOD, it is mainly compliance of attributes with expected data types (data types can be number, geometry, etc.).

Domain Consistency

Values provided comply with the range of values defined in the specifications (the domain can be defined by a list of possible values, an interval, a construction algorithm, etc.).

Topological Consistency

Correctness of topological properties according to Open Geospatial Consortium standards and to ISO 19138 [22] (No invalid overlapping between surfaces, no undershoot, no overshoot, no invalid micro-surfaces, no auto-intersection, order of vertices, etc.).

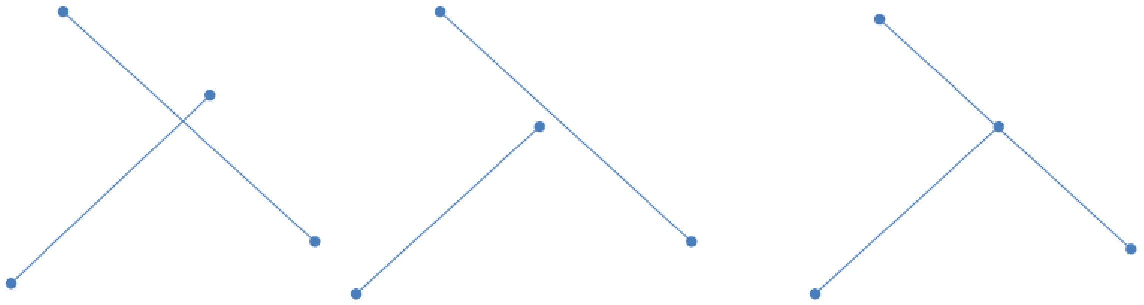


Figure 64: Overshoot, undershoot and correct connection (from left to right)

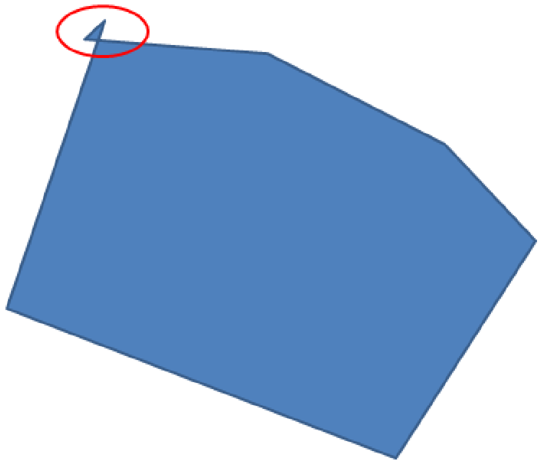


Figure 65: Auto-intersection of a surface (circled in red)

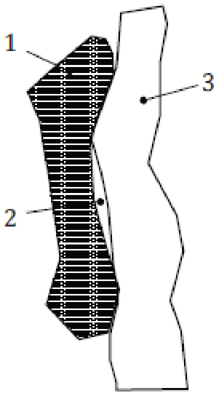


Figure 66: Incorrect micro-surface (surface 2 is incorrect as area 1 and 3 should share the same boundary)

Positional Accuracy

Proximity of positions of entities in the data set to actual positions in the universe of discourse.

Thematic Accuracy

Correctness of attribute value compared to the corresponding property in the universe of discourse and/or in reality.

Temporal Accuracy

Correctness of temporal attribute value compared to the corresponding temporal property in the universe of discourse and/or in reality.

G.2.3 SCOPE

The scope of validation operations can be:

- full inspection: the whole data set is assessed
- sampling: a representative sample of the data set is assessed to determine the data set quality using statistical analysis

Thanks to computer-based automation of validation and verification tasks, most of them can be carried out on a full inspection basis.

Those which involve ground inspections, complementary surveys or manual checking should be based on sampling methods since it is impossible to carry on such tasks for every feature of the data for cost reasons.

The verification and validation should, whenever possible, carry on full inspection rather than sampling.

G.2.4 PROPOSED IMPLEMENTATION METHOD

Implementation method can be:

- Automated (best practice, if possible)
- Manual

For each validation task, when manual task is needed, it is noted in the table (see section G.3).

G.2.5 PROPOSED MEASUREMENT

Proposed measurement details what should be assessed and why.

G.2.6 PROPOSED CONFORMANCE LEVEL

Generally, proposed conformance level is 100% except when ICAO Annex 15 states another level.

G.2.7 IMPORTANCE LEVEL

Importance level can be low, average or high. It gives an idea of the importance of the considered check.

G.3 VALIDATION TASKS TABLE

. The colour coding of the accompanying validation tasks table has the following meaning:

2	Business rule (to be developed)	Validating data set
3	Upstream validation rule	Validating data received from originator
4	Upstream and Business rule	Combination of 2 and 3
5	Data processing validation	Validating data processing

Appendix H TOD TOOLS AND SPECIMEN

The following tools and specimens accompany this document:

- Obstacle Data Converter is a tool to convert an obstacle data set encoded in AIXM 5.1 or AIXM 5.1.1 into an Excel spreadsheet.
- Fictitious obstacle data sets aligned with the current AIXM coding guidelines for Donlon Area 1 and Donlon Airport (Area 2A, 2B, 2C, 2D, 3,4)
- Specimen metadata set of a DTM. The metadata is aligned with the guidance in section 5.3 and describes an Area 1 DTM with a grid spacing of 30 arc seconds.

Appendix I DOCUMENT UPDATE PROCEDURE

It is necessary to periodically check these EUROCONTROL Guidelines document for consistency with referenced material, notably the evolution of the TOD-relevant ICAO SARPs and EU regulations [42]. The Guidance material is also expected to evolve following implementation progress and field experience.

The main objectives of a regular review are:

- to improve the quality and clarity;
- to verify that the level of detail published is adequate and up to date; and
- to make all stakeholders aware of the latest developments.

The update of the EUROCONTROL TOD Manual can be initiated by the AIM Group (AIMG) as key working arrangement. Stakeholders are advised to provide a change request (CR) through the AIMG. However, any stakeholder that wishes to request a change to these guidelines can submit a change request (CR) either directly to the identified document editor (Contact Person(s)) or via the generic email address: standardisation@eurocontrol.int .

The CR needs to provide following minimum elements:

- Originator information (name, organisation, contact details)
- Doc title, number and edition date
- Page, chapter, section/subsection, scenario/objective numbers, step numbers etc. where the issue/change appears
- Description of the issue/change and reason for change
- Specific change proposal text (incl. potential alternatives, if any).

Main steps towards a revised edition:

- AIMG secretariat will assess each CR and classify the CR impact category (major, minor or editorial).
- AIMG secretariat will then prepare resolution proposal(s) and, if needed, discuss those with the originator.
- AIMG will discuss and agree resolution proposal(s) covering at least major changes.
- Agreed changes will be integrated into a revised edition “Proposed Issue” including a summarised list of changes.
- The “Proposed Issue” will be consulted at AIMG level before release.

Note: Identified errors which may cause potential problems when implementing, may be corrected directly via separate “Corrigendum”.

– END –

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