ICAO RBIS TOD PROJECT

TERRAIN AND OBSTACLES DATA

TERMS OF REFERENCE (TORs) TEMPLATE FOR TERRAIN DATA ACQUISITION

Doc No. : AFI_AIM_RBIS_TOD_ToR Terrain_TMP

Statement of Requirements

For

terrain data acquisition for [aerodromes]

0. DOCUMENT ADMINISTRATION

0.1. APPROVAL PAGE

	Position	Name and Signature	Date
Prepared by			
Reviewed by			
Approved by			

0.2. LIST OF EFFECTIVE PAGES

List of Effective Pages	
Page Number	Revision Date

0.3. RECORD OF AMENDMENTS AND CORRIGENDA

Record of amendments			
Ed.	**Rev.**	**Date of the amendments**	**Reason for the amendments**

Record of corrigenda			
Ed	**Rev**	**Date of the corrigenda**	**Reason for the corrigenda**

0.4. DOCUMENTS REFERENCES

- ICAO Annex 4: Aeronautical Charts;
- ICAO Annex 14 - Aerodromes, Volume l: Aerodrome Design and Operations;
- ICAO Annex 15: Aeronautical Information Services;
- ICAO Document 9881 - Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information;
- ICAO Document 9674 - World Geodetic System 1984 (WGS-84) Manual v11. Standards related to electronic terrain and obstacle data collection;
- ICAO Doc 10066 PANS AIM.

0.5. CONTENTS

1 INTRODUCTION

The need for digital data sets and digitized aerodrome maps 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, however, acknowledged by ICAO that the introduction of electronic terrain and obstacle data (TOD) was a challenge and, consequently, the applicable dates for this data were deferred. Area 1 (The State) and Area 4 (CAT II/III Operations Area) became effective on 20th November 2008. The remaining areas, Area 2 (The Terminal Area) and Area 3 (The Aerodrome) became effective on 12th November 2015.

It is because of the above mentioned reasons that **[Organization name]** has budgeted and allocated funds for the acquisition of terrain data for **[list each specific coverage areas]** for **[list of aerodromes]**.

The primary objective of this project is to achieve the following national and international regulations related to terrain data for **[list of aerodromes]**.

Digital data covering an area within the radius of 45km centered around the aerodrome Reference Point (ARP) of each of the following **[list of aerodromes]** and subsequent aerodrome mapping [**including extraction of DEM, DTM, DSM and generation of contours at appropriate intervals**] over the study area indicated in paragraph 2 below. It is intended that the data collected will be used to generate spatial and non-spatial data/ information of **[list of aerodromes]** to be used for aerodrome mapping, terrain modelling and obstacle mapping for the safe operations of airports and aircraft for the specific aerodrome.

The acquired digital data/ information shall be use for the following airports and air navigation applications.

1. **For airports:**

a) Certification of airports types of operations;

b) Determination of maximum take-off weights;

c) Update of airport ground movement and control systems e.g. Advanced surface movement guidance and control system (A-SMGCS);

d) Airport planning and land use studies; and

e) Provision of geodetic control for engineering projects.

f) Review and maintenance of Approach, Departure, and Arrival flight procedures both conventional and Performance Based Navigation(PBN) types of flight procedures

2. **For air navigation applications:**

a) Setting up TOD and Aerodrome Mapping databases;

b) Ground proximity warning system with forward looking terrain avoidance function and minimum safe altitude warning system

c) Minimum flight altitude for VFR and IFR flights

d) Aeronautical chart production;

e) Update of aeronautical publications;

f) Aircraft operating limitations analysis; and

g) Update of on-board databases of the flight management systems.

2 PROJECT AREA

{For the airport(s) that data is being collected} **[list of aerodromes]** large format images are to be captured over a circular area of approximately 45km centred on the Aerodrome Reference Point (ARP) usually located midway the runway. Preliminary representations of the Areas of Interest (AOI) and tentative lines of flight if applicable alongside detailed/elaborate methodologies on capture and processing of data are to be included in the technical proposals to be provided.

a) To attain the aerodrome data requirement of the Civil Aviation Aerodromes, the project area for the work involves the survey of features or positions (navigation aids and navigation points) of importance to air and ground navigation within a fifteen (15) kilometer radius from aerodrome Reference Point (ARP) of the airports which corresponds to the Outer Horizontal surface, approach and take-off climb surfaces of the aerodrome's Obstacle Limitation Surfaces. A list of possible features or points to be surveyed are provided in the project deliverables and related appendices to this document. In general, the area to be surveyed is also under the obstacle limitation surfaces as listed in ICAO Annex 14 Volume 1.

b) To achieve the TOD requirements specified in the state regulatory requirements, the area of interest will cover an area within a radius of forty five (45) kilometers from the ARP of the above aerodromes inclusive of the area specified in a) above.

The take-off flight path area is defined in ICAO Annex 4 Paragraph 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.

3 PROJECT SCOPE

(It is advisable that the state follow a systematic steps in the planning process in order to achieve the required milestones)

The scope of the project shall include, but not limited to:

a) Mobilization to/from the work sites;

b) Carry out community sensitizations, whenever necessary, in the areas to be mapped;

c) Supply and positioning of sufficient ground based GPS base stations as required to achieve the specified survey accuracy. As far as practicable, the Aerodrome Reference Point (ARP) shall form part of the GPS base stations;

d) Gaining of all necessary approvals from the relevant aviation authorities, military or other authorities as may be required, for the execution of the project;

e) Capture of the required area (Area 1, 2, 3 and 4), in order to obtain the required point density; swath coverage and digital imagery to meet the product requirements;

f) Processing and formatting of the digital data in accordance with the technical specification requirements described in the referenced documents;

g) Data usage, integration and interpretation Training;

h) Load the data onto the client's databases;

i) Processing and formatting of the data in accordance with the technical specification requirements;

j) Delivery of specified products or deliverables especially the survey reports in full compliance with the data quality accuracies, digital data and reporting formats. stipulated in ICAO Doc 9674, PANS-AIM appendix 1; and

k) Setting out and Documentation of aerodrome control points (inclusive of the ARP) in compliance with ICAO Doc 9674 specifications.

Note: Survey observations to meet or exceed the accuracy and integrity requirements stated in ICAO Annex 14, Annex 15 and ICAO Doc 9674-AN/946 (WGS-84 Manual)

4 GEODETIC PARAMETERS

All results are to be provided in WGS-84 and UTM projection (bearing in mind the relevant zone). An example of which is provided in the table below.

- Horizontal Datum: World Geodetic System — 1984 (WGS-84);
- Ellipsoïdal Heights are given above the GRS-80 ellipsoid;
- Vertical Datum: EGM96 to be used as basis for Orthometric height.

Plane Coordinates are expressed in a UTM projection applicable to the relevant zone

Elevations refer to MSL as given by the EGM96 global geo-potential mode.

5 PROJECT DELIVERABLES

a) The following are project deliverables expected after the successful completion of the WGS-84 survey that are meant to address the requirements project objective :

i. Set out and monument to establish at least four (04) monumented compliant stations at the end of the project as per the specifications provided in ICAO Doc 9674 Chapter 5 Attachment A, including photographs.

ii. Description and photographs of geographical positions as per the specification provided in ICAO Document 9674 Chapter 5 Attachment B;

iii. Survey Reports, namely:

- Geodetic Connection Report - that details how the connection was made to the WGS-84 geodetic network (Refer to ICAO Doc 9674 Chapter 5 Attachment C and Appendix C);
- Aerodrome Survey Report (Refer to ICAO Doc 9674 Chapter 5 Attachment C);

Note:

- *In addition to these reports, records of actual observations must be provided in separate indexed volumes. Cross-references to observations must be made in the survey report.*
- *All survey observations may be made and recorded to the resolution and accuracy of the equipment used so that future requirements for surveys of greater precision might be met. Where surveys are undertaken using equipment or techniques that yield height data as well as horizontal position, these must be comprehensively recorded and included in the survey report.*
- *Survey observations of key points such as monuments, runway threshold, stand "T" markings etc. should be photographed to aid identification of exactly the point surveyed.*

iv. WGS-84 geographic coordinates and elevations/heights of any features that are of significance to air or ground navigation that are located within the runway or taxiway strips;

v. Digital Data delivered by the Universal Data Delivery Format (UDDF) to cater for the process of reporting surveyed data to the AIS (Refer to ICAO Doc 9674 Chapter 7 Section 7.3).

vi. Data should also be supplied in Shapefiles, CAD data format (the exact data base format to be agreed with AIM prior to tender) in addition to UDDF; and

vii. Google earth KMZ files containing all obstacles and obstacle limitation surfaces.

b) The deliverables that cater for the TOD requirements for this project are summarized in the table 2 below:

Table 1: Summarize of TOD requirements

Description	Attribute	Specification
Survey area in km^2	Km^2	
Equipment to be used (including parameters used in data processing)	All relevant equipment	e.g. Large format digital camera
Colour Imagery	Entire area	GeoTIFF, ECW
Resolution in cm	cm	10
XY - accuracy of images in cm	cm	20
Z - accuracy in cm	cm	10 - 20 in areas without vegetation
Digital Elevation Mode (DEM), Digital Terrain Model (DTM), Digital Surface Model (DSM)		ASCII & DXF, Feature, Datasets/Classes, Raster/Mosaic Datasets/Catalogs, Shapefiles, GeoTIFF, Relationship Classes, SDE Tables, ESRI file Geodatabase, DGN or DWG
Fully processed geo-referenced and ortho rectified aerial photo image files in GeoTIFF format on a hard drive or via ftp account.	For the whole area of coverage	GeoTIFF, ECW

Contour Interval in metres	As appropriate, e.g 0.5, 1.0, 2, 5	ASCII & DXF, Feature Datasets/Classes, Raster/Mosaic Datasets/Catalogs GeoTIFF, Relationship Classes, SDE Tables, Shapefiles, GeoTIFF, Relationship Classes, SDE Tables, ESRI Geodatabase, DGN or DWG formats.
Coordinate System	GCS-WGS- 1984 Datum: D-WGS-1984 Spheroid: WGS_1984 Geiod: EGM96	Geographical and projected, Ellipsoïdal & Orthometric heights. WGS-84 Manual (ICAO Doc 9674) refers
Monthly progress reports	Both soft & hard copies	Appropriate
Final survey reports	Both soft & hard copies	RINEX/ ASCU; ICAO Doc 9674 WGS-84 Manual report structure
All the raw survey data files and the processed data files shall be delivered to **[Organization name]** including all the processing parameters	Soft and hard copies	ASCII & DXF, Feature Datasets/Classes, Raster/Mosaic Datasets/Catalogs, GeoTIFF, Relationship Classes, SDE Tables, Shapefiles, GeoTIFF, Excel, Relationship Classes, SDE Tables, Shapefiles, ESRI Geodatabase, DGN or DWG files
Terrain data sets for areas 1, 2, 3 and 4, as described in ICAO Annex 15	Soft and hard copies	For each set of terrain data for area 1, 2, 3 and 4, provide; Overview, 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. Aeronautical Data quality requirements in the Doc 9674 and other relevant documents must be met (section 11)
Monumentation	Soft and hard copies	Tabulated WGS-84 coordinates (EGM 96)
Data usage, integration and interpretation Training	Customized hands-on training for 6 AIM personnel	Load TOD into the clients TOD databases Produce an aerodrome terrain and obstacle chart as evidence (As specified in ICAO Annex 4 and Document 8697)

		Provide instruction manuals for loading the terrain and obstacle databases, and loading updates to the data

6 PROJECT METHODOLOGY

The consultant will clearly document the project methodology step by step indicating how the project will be executed, the method to use in data capture, acquisition and implementation.

{The suitability of terrain and obstacle data collection techniques should be in respect to the purpose of the data. 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}

6.1 PROJECT IMPLEMENTATION PLAN REVIEW

The consultant's project implementation plan shall be reviewed with the client to check the work plan and deliverables. Appropriate reference shall be made to the WGS-84 Manual, (ICAO Doc 9674), Electronic terrain and obstacle and aerodrome mapping manual (ICAO Doc 9881) and all reference material indicated in section 11 of these TORs) during the implementation of the entire project.

6.2 PROCESSING OF PERMISSIONS AND CLEARANCES

Clearances from the relevant authorities are necessary for the survey teams. Clearances will be sought from the military, civil aviation authority, the ministry of lands, housing and urban development, and local authorities. To facilitate this process, letters of introduction will be required from the State.

6.3 COMMUNITY SENSITIZATIONS

Conduct community sensitization and liaison with local authorities of all project areas affected by the project.

6.4 EQUIPMENT

The equipment used should provide data that will meet the terrain data numerical requirements as specified in ICAO Doc 10066, Appendix 1, Table A1-8.

6.5 DATA CAPTURE AND ACQUISITION

The Consultant shall clearly and extensively document the method of data capture and acquisition clearly elaborating the steps in the methodology and how data will be captured.

6.6 DEFINITION OF TERRAIN AIRSPACES

The airspaces to be defined are terrain area 1, 2, 3 and 4.

6.7 FIELD CHECKS/GROUND TRUTHING

Once the draft layouts or maps are ready, the consultant shall carry out ground truthing exercise in order to identify features which are not mapped, and subsequently update the surveyed data

- Samples of the surveyed data (as specified in the section 5) will be sent to **[Organization name]** for verification and analysis at the third meeting with the consultant before the final deliverables are produced.
- The client should have a qualified staff to oversees the application of techniques mentioned in the Bidder methodology.
- Markings and colours used should be those specified in ICAO Annex 4, Appendix 3.

6.8 HANDS-ON DATA USAGE, INTEGRATION AND INTERPRETATION TRAINING

The consultant shall offer customized hands-on data Usage, Integration and Interpretation training for **AIM personnel.**

a) Load data into the clients databases, and generate aerodrome terrain and obstacle chart - ICAO, terrain dataset, and obstacle dataset

b) Develop and deliver user instructions

c) Train at least six AIM users

7 QUALIFICATIONS OF THE CONSULTANT

7.1 LEAD CONSULTANT

7.1.1 OVERALL QUALIFICATIONS

To qualify for award of the Contract, bidders shall meet the following minimum qualifying criteria:

(a) Experience as prime contractor of a similar aviation project in African region

(b) Experience as prime contractor in the provision of at least two projects of a size and nature equivalent to this over the last 5 years (to comply with this requirement;

(c) Proposals for the timely acquisition (own, lease, hire, etc.) of the essential equipment

(d) a Project Manager with five years' experience in projects of an equivalent nature and volume, including no less than three years as Manager;

Site Visit: The Bidder, at the Bidder's own responsibility and risk, is encouraged to visit and examine the sites of required services and its surroundings and obtain all information that may be necessary for

preparing the Bid and entering into a contract for the Services. The costs of visiting the Site shall be at the Bidder's own expense.

7.1.2 COMPANY REQUIREMENTS

a) The Bidder shall have a modern digital equipment, software and technology to carry out a colour digital aerial photography, data processing, aerial triangulation, digital terrain model extraction and production of the digital ortho-rectified imagery.

b) The Bidder shall have at minimum 15 years of experience working in the aerial photography and digital mapping including at minimum 10 years of experience of similar nature projects in Africa. The experience implementing aerial photography projects other Africa countries with similar environment and climate conditions, knowledge of security, requested permits and clearances procedures etc. will be considered as an advantage.

c) The Bidder should be financially strong to carry out the project of similar nature and complexity in tropical environment, infrastructure and climate conditions of the Sub-Saharan Africa and provide the documentary evidence of its financial status and stability during last five years.

d) The Bidder should provide the confirmation and documented evidence of the successful completion of similar projects in equatorial and/or desert conditions and in neighboring countries. The evidence of such project's completion during last ten (10) years in Africa will be an advantage.

7.1.3 MINIMUM EQUIPMENT REQUIREMENTS

The Bidder shall provide document evidence confirming that it has the minimum equipment as follows:

- A minimum of two (2) Specialized Aircrafts for aerial photography that comply with the requirements;
- At least Two (2) medium - large format Digital Aerial Cameras with the calibration certificates that expire not earlier than estimated end of aerial photography works;
- Industry standard navigation and flight management system such as for each set of aerial cameras as per requirements of;
- GPS and other equipment certified for the aerial photography - a minimum of two sets of equipment as per requirements of the project.
- Software and Equipment for Aerial Triangulation as per requirements and specifications of the project.
- Software, Equipment for the Digital Terrain Model and Digital Ortho-rectified Imagery production and human capacity to complete such production within the time specified in the Project Schedule and as per requirements and specifications of project.
- GPS equipment (dual frequency receivers) for surveying of the GCPs and additional control points as well as reference stations for the aerial photography according to the specifications

and requirements of the project work in the quantities necessary for the completion of the project blacks as per requirements of the Project Implementation Schedule.

- The Bidder shall present the registration documentation, recent maintenance certificates for the aircrafts and recent camera calibrations certificates.
- The Software for the Aerial Triangulation, Digital Terrain Model and Digital Ortho-rectified Imagery should be of internationally recognized providers.
- The Bidder shall provide the documented evidence confirming the capability to replace deployed aircraft or equipment in the case of failure within not more than 3 weeks to ensure the completion of aerial photography in time.
- The Bidder shall demonstrate that it has established appropriate Quality Assurance and Quality Control System and provide the Company (QA/QC) Plan together with the Bid Proposal. The QA/QC Plan should be prepared in accordance with the requirements of the ISO 10005: 1995 Quality management - Guidelines for quality standard. The ISO Quality Certificates provided will be considered as an advantage.
- The documented evidence confirming the compliance with the requirements above should be presented in the Bid Proposal. The failure to comply with this requirements will lead to the disqualification of the Bidder from this bid.

7.2 CONSULTANT'S STAFF

7.2.1 BIDDER PERSONNEL REQUIREMENTS

The Bidder shall assign highly qualified personnel in adequate numbers to complete the project in time. The number of the technical personnel required for data processing and production of the deliverables as per requirements of the project works is the responsibility of the Bidder but it must ensure and that the Project will be completed according to the Estimated Project Schedule agreed upon in the contract.

In addition to the technical personnel that will carry out the works the Bidder shall provide a full time Project Manager that should be permanently available on needs basis during the project time, for the project management, organisation and control of the project results and deliverables.

The Bidder shall also provide a part time Training Expert that will be the requirements for project management, key experts and personnel:

- Project Manager should have a Master's degree (or equivalent) in photogrammetry, Geomatics or related fields and a minimum of 10 years of experience of similar projects management including a minimum of 5 years in Africa or developing countries in equatorial conditions; good management and reporting skills; language proficiency - must be fluent in English/French;
- Specialized Technicians/ Key staff - should have a minimum of 5 years of experience in data capture, processing and production of data outputs like databases, charts and maps as well as necessary professional licenses. Experience for similar projects in similar environments and airports in Africa, practical experience of similar projects from east Africa will be an advantage; language proficiency - must be fluent in English (or local official language);

- QA/QC Expert - should have masters or equivalent degree in Photogrammetry or similar disciplines, good practical and theoretical experience in the relevant fields and a minimum of 5 years of practical work and project management with similar assignments; good analytic skills and quality management practices providing the necessary check through policies and procedures; language proficiency - must be fluent in English (respectively in French for francophone states).

Requirements of technical personnel that will carry out data processing and production of required products and deliverables:

i) Degree/Diploma in relevant fields such as aerial photography, photogrammetry, spatial data management etc.;

ii) A minimum of 3 years of practical experience in the production of similar products for similar terrain conditions.

7.3 SUBMISSION OF CURRICULUM VITAE

Detailed Curriculum vitae of all relevant technical and administrative staff involved shall be submitted in the bidder's proposal.

8 REPORTS

The Service Provider will provide detailed **monthly progress reports** (including the inception report, and final report) on the status of the project, which will include, at the appropriate stages of the project:

(a). One Draft digital copy of each aerodrome's map AutoCAD 2010 (aerodromes), compatible with other software such as Arc Info and ArcView GIS. This will be checked by the client for accuracy and to ascertain that no features which were left out.

(b). One final digital map of each aerodrome [list of aerodrome] in AutoCAD 2010

(c). Aerial photos of the aerodromes covering the total area to be digitized at an appropriate scale as will be proposed by the service provider and accepted by the client

(d). A set of hard copies of the digitized maps ie 10 copies of A_o sealed in plastic and 05 copies of A_1, sealed in plastic;

(e). Raw survey data files in excel format;

(f). Traverse and levelling computations;

(g). Project reports (monumentation report, data capture report including the methodology and photographs, image development report, sensitization report and WGS-84 survey report). These will be appended to the main final report.

9 MEETINGS WITH [ORGANISATION] STAFF

There shall be three meetings at the clients' premises in **[location]:**

(a). The first one will be at the inception of the project;

(b). The second one will be at the time of presentation of the drafts by the consultant;

(c). The last meeting will take place at the handover of satisfactorily complete documents by the consultant to the client.

The Service provider shall formerly present the inception report and final report to the Client in a meeting at the Client's premises in **[location].**

10 TIME SCHEDULE

10.1 COMMENCEMENT

The Consultant will commence work within the timeframe that will be specified in the Contract.

10.2 ASSIGNMENT PERIOD

The consultant shall determine the duration of the project assignment allocated as follows:

(a). Physical inspection and survey of the scoped area -;

(b). Production of a draft digital plan -;

(c). Production of the final digital map, hardcopies, and other deliverables -.

(Note: The proposed time schedule of the project should be reasonable)

10.3 PROJECT DELAYS

Measures are to be put in place by both **[organisation]** and the successful contractor to as realistically as possible avoid and where found to be inevitable mitigate any delays that may arise during the execution of the project.

11 RISK PLAN

The consultant shall submit a risk register indicating clearly all the anticipated risks and proposed mitigation measures to address such risks.

12 FINANCIAL PROPOSAL

(a). The financial proposal shall list all costs associated with the assignment broadly categorized as follows:

i. Fees (remuneration);

ii. Project execution costs;

iii. Reimbursable.

(b). The total proposal price shall be broken down into the following cost components using the appropriate forms:

i. Summary of Proposal Price (Breakdown of Lump Sum);

ii. Breakdown of Fees (remuneration);

iii. Breakdown of Project execution costs for the various project activities including; Community sensitization, Ground surveying, 3D Line mapping, TOD airspaces mapping, Ground Truthing, Map Compilation and Printing for all aerodromes within the area of coverage, Data loading, hands on Training on data usage, integration and interpretation, among other activities;

iv. Breakdown of Reimbursable expenditure, for staff (foreign and national in the field and at headquarters), such as transportation (international and local), communication, printing etc.

(c). The total proposal price shall be broken down into the separate activities indicated in the Statement of Requirements with the cost elements expressed for each activity;

(d). The total proposal price shall be subjected to a withholding tax of 15%;

(e). The completed financial proposal forms will be used to compile the Breakdown of Contract Price in any resulting Agreement as adjusted if necessary during evaluation or negotiation. The Breakdown of Contract Price will determine prices for any additional Services or costs;

(f). A form has been attached for use to prepare the financial proposal; and

(g). All proposal prices shall be in Uganda Shillings.

13 DATA AND INFORMATION TO BE PROVIDED BY THE Client

The Client will provide the following information:

a. Physical location of the scoped areas;

b. Existing digital map;

c. Existing Aerial photos.

d. Explain the State requirements for work permits to their personnel's in case of the sub-contracting foreign firm.

e. The Aerodrome operator's requirements on airside access pass for both personnel, equipment and the vehicle.

f. Disclose all charges and fees to be encountered e.g. Security pass to access airside, Airside driving permit among others.

14 ASSIGNMENT MANAGEMENT AND ADMINISTRATION

The Client will coordinate and manage this task through/ under the auspices of the Projects Manager nominated by **[organisation]** who will coordinate the Consultant's activities as well as issuing the necessary approvals to the Consultant on behalf of the Client.

If the nominated Projects Manager does not justify enough experience on WGS-84 and geospatial constraints, technical project Manager should be nominated along with the Projects Manager

15 EVALAUTION

Develop an evaluation of submitted bid criteria {see Appendices 1 Sample evaluation criteria}

16 REFERENCES

The consultant shall make reference to the latest relevant documentation including but not limited to:

- ICAO Annex 4: Aeronautical Charts;
- ICAO Annex 14 - Aerodromes, Volume l: Aerodrome Design and Operations;
- ICAO Annex 15: Aeronautical Information Services;
- ICAO Document 8697 -Aeronautical Chart Manual;
- ICAO Document 9881 - Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information;
- ICAO Document 9674 - World Geodetic System 1984 (WGS-84) Manual v11. Standards related to electronic terrain and obstacle data collection;
- ISO 8601 - Data elements and interchange formats -- Information interchange -- Representation of dates and times;
- ISO 19109 - Geographic information -- Rules for application schema Body Title Edition;
- ISO 19110-Geographic information -- Methodology for feature cataloguing;
- ISO 19113 - Geographic information -- Quality principles;
- ISO 19114 - Geographic information -- Quality evaluation procedures;
- ISO 191 15 – Metadata;
- ISO 19117 - Geographic information =Portrayal;
- ISO 19123 - Geographic information -- Schema for coverage geometry and Functions xvi. ISO 19131 - Geographic information -- Data product specifications;
- ICAO Annex 10 Vol. 1 and 4: Aeronautical Telecommunications;
- ICAO Doc 9981 PANS Aerodromes;
- ICAO Doc 8168 Vol. 2: PANS Aircraft Operations;

- ICAO Doc 9137: Aerodrome Services Manual Part 6: Obstacles;
- European Aviation Safety Agency (EASA) - Easy Access Rules for Aerodromes (Regulation (EU) No 139/2014) (January 2018);
- ICAO Doc 10066 PANS AIM.

17 APPENDICES

17.1 APPENDIX 1 : SAMPLE TERRAIN DATA TABLES

17.1.1 TERRAIN DATA SETS

The terrain Information Conceptual Model (TICM) is a formal representation of the requirements for terrain data described in ICAO Annex 15 and is expressed as a collection of UML diagrams. Terrain data is modelled using the concept of coverages and TICM providing a conformant implementation of the ISO 19123 coverage schema.

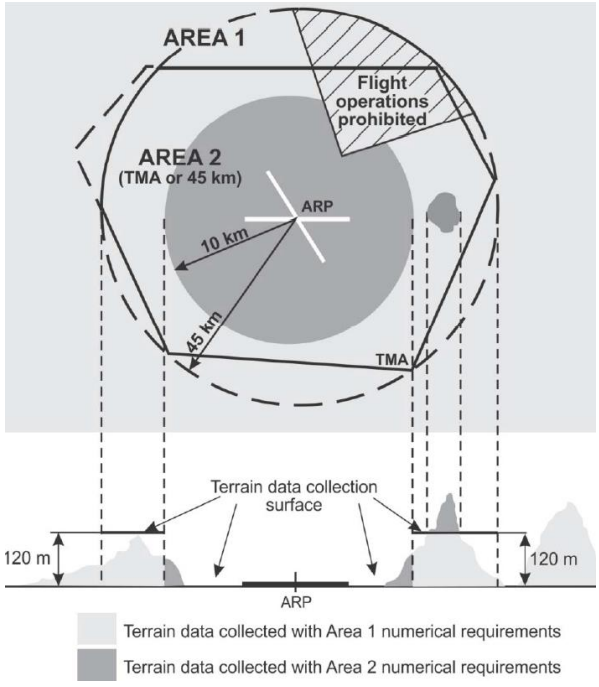
Data attribute	**data (described following ISO 19123)**	**Remarks**
Area of coverage	CoverageInformation.narrativeDescription:	the data model for terrain follows the ASCII grid model or equivalent to define
Area of coverage	CoverageInformation.contentScope	Terrain scope
Area of coverage	CoverageInformation.coverageDescription	could be specified once referenced
Area of coverage	CoverageInformation.coverageType:	Elevated points
Area of coverage	CoverageInformation.specification:	data model for terrain data

17.1.2 METADATA FOR TERRAIN DATA SETS

Metadata attribute	**Metadata (described following ISO 19115)**
Area of coverage	DataIdentification.extent
Data originator identifier	Usage.userContactInfo, role= RoleCode.originator
Data source identifier	Usage.userContactInfo, role= RoleCode.publisher

Acquisition method	ProcessStep, description = "Acquisition Method: …"
Horizontal reference system	ReferenceSystem.referenceSystemIdentifier
Horizontal resolution	DomainConsistency
Horizontal accuracy	PositionalAccuracy
Horizontal confidence level	New Element; PositionalAccuracy, description "Confidence Level"24
Vertical reference system	ReferenceSystem.referenceSystemIdentifier
Vertical resolution	DomainConsistency
Vertical accuracy	PositionalAccuracy
Vertical confidence level	New Element; DQ_PositionalAccuracy, description "Confidence Level"
Elevation reference	GeoRectified.pointInPixel
Elevation Representation	New Element: GridSpatialRepresentation.elevationRepresentation
Penetration level	New Entity & Element: Sensor.TerrainPenetration.penetrationLevel
Integrity	New Element:LI_Lineage. integrity
Unit of measurement used	VerticalExtent.unitOfMeasure X, Y: See:Horizontal reference system

17.2 APPENDIX 2: STANDARDS AND RECOMMENDED PRACTICES (SARPS) RELATED TO ELECTRONIC TERRAIN DATA



17.2.1 COVERAGE AREAS AND REQUIREMENTS FOR DATA PROVISION

(1) The coverage areas for sets of electronic terrain data shall be specified as:

a) Area 1: the entire territory of a State;

b) Area 2: within the vicinity of an aerodrome, subdivided as follows;

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

ii). the take-off flight path area; and

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

iv). in the area extending to a 10-km radius from the ARP; and

v). 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.

c) 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.

d) 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.

(2) 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 shall be extended to a distance not exceeding 2 000 m (6 500 ft) from the runway threshold.

17.2.2 TERRAIN DATA SETS

(1) Terrain data sets shall contain the 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.

(2) Terrain data shall be provided for Area 1.

(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.

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

(4) 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.

(5) Terrain data sets shall contain the 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.

(6) For aerodromes regularly used by international civil aviation, terrain data should be provided for Area 3.

(7) 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.

(8) Where additional terrain data is collected to meet other aeronautical requirements, the terrain data sets should be expanded to include this additional data.

17.3 APPENDIX 3: BASIC T E R R A I N CONCEPTS

17.3.1 DIGITAL TERRAIN MODELS

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

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

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

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

17.3.2 TERRAIN DATA SET-CONTENT, NUMERICAL SPECIFICATION AND STRUCTURE

(a). A terrain data set shall contain digital sets of data representing terrain surface in the form of continuous elevation values at all intersections (points) of a defined grid, referenced to common datum. A terrain grid shall be angular or linear and shall be of regular or irregular shape.

Note. - In regions of higher latitudes, latitude grid spacing may be adjusted to maintain a constant linear density of measurement points

(b). 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 excluding obstacles. In practical terms, depending on the acquisition method used, this shall represent the continuous surface that exists at the bare Earth, the top of the canopy or something in-between, also known as "first retlective surface".

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

(d). Electronic terrain data for each area shall conform to the applicable numerical requirements in PANS-AIM Appendix 1, Table A1-8.

17.4 APPENDIX 4: TERRAIN DATA MODELLING

17.4.1 INTRODUCTION

An overview of spatial data modelling is given in this section so that the reader understands the meaning and use of an application schema, Data Product Specifications (DPS), feature catalogue and metadata.

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

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

17.4.2 DIGITAL TERRAIN MODELS

Digital Terrain Models and its variations (DEM, DHM and DSM) can be regarded as a continuous data set or "coverage", to use the term of the International Organization for Standardization (ISO) standards. Coverage types are (Quadrilateral) Grid, Triangulated Irregular Network (TIN) and Thiessen Polygon. Common to all types of coverage is the limitation that, for each location, only one elevation can be stored, i.e. they support 2.5D. A TIN-based terrain mode) provides a close representation of the surveyed objects because points, (break-) lines and even voids (an area with no data) can be used as input for the

triangulation. With the growing number of mass points, as a result of using modern sensors, the importance of break-lines has been reduced whilst the computing time has been massively increased due to the complexity of the algorithm (n*log n) used. To improve the performance of a TIN calculation, a point cloud can be thinned out with very limited impact on the accuracy.

The phenomenon "street" may has 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.

High-resolution data acquisition results in up to 10,000 points per hectare. 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 coverages are built upon a lattice with regular cell size which means that, for their creation, the surveyed points need to be interpolated so that, for each cell, one value is given. There are several interpolation methods, each with strengths and weaknesses. Compared to a TIN-based terrain model, the Grids are much simpler to handle since only a corner co-ordinate, the cell length and width, and the cell values must be stored. This results in less disk usage and faster processing times. A drawback of the Grid based terrain model is the close relation to the co-ordinate system in which the Grid is generated. If a local map projection is used for the interpolation and the raster is then transformed to an international reference frame (ellipsoïdal co-ordinates), the raster is distorted and information can be lost. One must also be aware that close to the equator, a cell which is a square in a local map projection (like 90 by 90m or 3 by 3 Arc-Seconds) becomes a rectangle in ellipsoidal co-ordinates because of reduced West-East distances (3 by 6 Arc-Seconds at 60-degree latitude).

Hence, the input points should first be transformed and then the Grid coverage interpolated. The TOD WG was notable to identify an existing, suitable exchange model to meet the requirements of ICAO Annex 15. Therefore, EUROCONTROL has developed a new model, the Terrain Information Exchange Model (TIXM), to support the exchange of terrain data.

17.4.3 TERRAIN DATA PRODUCT SPECIFICATIONS

i) To allow and support the interchange and use of sets of electronic terrain data among different data providers and data users, the ISO 19100 series of standards for geo graphic information shall be used as a general data modelling framework.

ii) A comprehensive statement of available electronic terrain data sets shall be provided in the form of terrain data product specifications as well as obstacle data product specifications on which basis air navigation users will be able to evaluate the products and determine whether they fulfil the requirements for their intended use (application).

Note. - ISO Standard 19131 specifies the requirements and outline of data product specifications for geographic information.

iii) Each terrain data product specification shall include an overview, a specification scope, data product identification, data content and structure, reference system, data quality, data

capture, data maintenance, data portrayal, data product delivery, additional information, and metadata

iv) The overview of terrain data product specification or obstacle data product specification shall provide an informal description of the product and shall contain general information about the data product. Specification of terrain data may not be homogenous across the whole data product but may vary for different parts of the data sets. For each such subset of data, a specification scope shall be identified. Identification information concerning bath terrain and obstacle data products shall include the title of the product; a brief narrative summary of the content, purpose, and spatial resolution if appropriate (a general statement about the density of spatial data); the geographic area covered by the data product; and supplemental information.

v) Content information of feature-based terrain data sets or of feature-based obstacle data sets shall each be described in terms of an application schema and a feature catalogue. Application schema shall provide a formal description of the data structure and content of data sets while the feature catalogue shall provide the semantics of all feature types together with their attributes and attribute value domains, association types between feature types and feature operations, inheritance relations and constraints. Coverage is considered a subtype of a feature and eau be derived from a collection of features that have common attributes. Both terrain and obstacle data product specifications shall identify clearly the coverage and/or imagery they include and shall provide a narrative description of each of them.

Note 1.-ISO Standard 19109 contains rules for application schema white ISO Standard 19110 describes feature cataloguing methodology for geographic information.

Note 2.-ISO Standard 19123 contains schema for coverage geometry and functions.

vi) Both terrain data product specifications and obstacle data product specifications shall include information that identifies the reference system used in the data product. This shall include the spatial reference system and temporal reference system. Additionally, both data product specifications shall identify the data quality requirements for each data product. This shall include a statement on acceptable conformance quality levels and corresponding data quality measures. This statement shall cover all the data quality elements and data quality sub-elements, even if only to state that a specific data quality element or sub-element is not applicable.

Note.-ISO Standard 19113 contains quality principles for geographic information white ISO Standard 19114 covers quality evaluation procedures.

vii) Terrain data product specifications shall include a data capture statement which shall be a general description of the sources and of processes applied for the capture of terrain data. The principles and criteria applied in the maintenance of terrain data sets and obstacle data sets shall also be provided with the data specifications, including the frequency with which data products are updated. Of particular importance shall be the maintenance information of obstacle data sets and an indication of the principles, methods and criteria applied for obstacle data maintenance

viii) Terrain data product specification s shall contain information on how data held with data sets is presented, i.e. as a graphic output, as a plot or as an image. The product specifications for both terrain and obstacles shall also contain data product delivery information which shall include delivery formats and delivery medium information.

Note. - ISO Standard 19117 contains a definition of the schema describing the portrayal of geographic information including the methodology for describing symbols and mapping of the schema to an application schema.

ix) The core terrain and obstacle metadata elements shall be included in the data product specifications. Any additional metadata items required to be supplied shall be stated in each product specification together with the format and encoding of the metadata.

Note.-ISO Standard 19115 specifies requirements for geographic information metadata.

17.4.4 TERRAIN DATA NUMERICAL REQUIREMENTS

Terrain data quality requirements specified in Table 3 below

	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

17.4.5 TEMPORAL REFERENCE SYSTEM

i) For international civil aviation, the Gregorian calendar and Coordinated Universal Time (UTC) shall be used as the temporal reference system.

Note 1. -A value in the time domain is a temporal position measured relative to a temporal reference system.

Note 2.-Coordinated Universal Time (UTC) is a time scale maintained by the Bureau International de l'Heure and the IERS and forms the basis of a coordinated dissemination of standard frequencies and lime signals.

Note 3.-See Attachment D of Annex 5 for guidance material relating to UTC.

Note 4.-ISO Standard 8601 specifies the use of the Gregorian calendar and 24-hour local or UTC for information interchange while ISO Standard 19108 prescribes the Gregorian calendar and UTC as the primary temporal reference system for use with geographic information.

ii) When a different temporal reference system is used for some applications, the feature catalogue, or the metadata associated with an application schema or a data set, as appropriate, shall include either a description of that system or a citation for a document that describes that temporal reference system.

Note.-1SO Standard 19108, Annex D, describes some aspects of calendars that may have to be considered in such a description.

17.4.6 METADATA

Metadata provides information describing a number of attributes concerning a real data set. One of the objectives of publishing metadata is that one can determine the fitness for use of the data set with respect to the requirements of a specific application (as described in the DPS), without having to evaluate the data set itself. There is a large overlap between the data models of the DPS and the metadata, since what is specified in the DPS should also be achieved in a real data set and, therefore, documented in the metadata of the data set.

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

i) Metadata shall be collected for aeronautical data processes and exchange points. This metadata collection shall be applied throughout the aeronautical information data chain, from survey/origin to distribution to the next intended user.

ii) The metadata to be collected shall include, as a minimum:

(a). the names of the organizations or entities performing any action of originating, transmitting or manipulating the data;

(b). the action performed or amendments made to the data;

(c). details of any validation and verification of the data that has been performed

(d). the date and time the action was performed and when the data set was provided;

(e). period of validity of the data set;

(f). for geospatial data:

— the earth reference model used,

— the coordinate system used;

(g). for numerical data:

— the statistical accuracy of the measurement or calculation technique used,

— the resolution,

— the confidence level as required by the ICAO standards;

(h). details of any functions applied if data has been subject to conversion/transformation,

(i). details of any limitations with regard to the use of the data set..

Note.- The function performed indicates any action of originating, transmitting or manipulating the data.

17.5 APPENDIX 6 TERRAIN DATA CAPTURE REQUIREMENTS

All mandatory **Attributes**, except Surface type, shall be captured and documented.

Terrain Attribute list	
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

Terrain Attribute list	
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

For airborne acquisition, an adequate resolution should be used by the supplier. The supplier should use point density to satisfy the needs of grid.

In a conventional terrestrial survey, the density of the survey points and break lines shall follow the topography and the accuracy requirement.

Where the data origination is based on a map projection, evidence must be given that the transformation from the planar co-ordinate system to the geographical co-ordinates in WGS-84 does not lead to a loss of quality and resolution.

The construction of a gridded data set shall be based on a maximum elevation calculation: if more than one height value is located in a cell, the highest value is taken into account.

Data voids up to nine cells can be filled by a spline interpolation.

Spline interpolation must occur before the construction of a gridded data set and interpolating in a map projection is recommended to avoid unequal cell size with growing latitude.

Interpolated points shall be marked as such (traceability). The grid construction shall be the last process step.

Data voids exceeding three times the required ground sampling distance (equals nine cells), must be documented.

Data voids exceeding 36 cells are not acceptable.

In mountainous regions of Area 2, the minimum point spacing requirement given in the SARPS may not correspond with the vertical accuracy requirement. For such cases, a TIN-based terrain model should be considered since it is more suitable than a gridded data set.