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The Civil Aviation Authority of Thailand

Guidelines for Electronic Terrain and Obstacle Data

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Approved By

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Director General of

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PART 0. ADMINISTRATION

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2. LIST OF EFFECTIVE PAGES

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3. RECORD OF REVISION

The valid pages of this Manual are listed in the List of Effective Pages distributed with every revision.

The table below describes the dates and reason for the different revisions of the current issue of this manual.

Issue	Rev	Date	Rev by	Reason
01	00	31/May/2020	Chai K.	Initial Issue

4. AMENDMENT TRANSMITTAL PAGE

To: All holders of Guidelines for Electronic Terrain and Obstacle Data

Subject: Manual Transmission

The table below lists pages to insert and remove from the previous version of the manual.

When doing so, users should ensure not to throw away pages that have not been replaced.

Using the List of Effective Pages can help determine the correct content of the manual.

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I attest that the Hard copy in my possession has been updated according to the instructions above

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ANS Manager

5. DISTRIBUTION LIST

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6. DEFINITIONS & ACRONYMS

6.1 Definitions

For the purpose of this guidelines, the definitions as contained in the ICAO annex and ICAO document, as amended from time to time, shall apply unless as otherwise indicated in AIP or as follow:

Definition	Meaning
Accuracy	A degree of conformance between the estimated or measured value and the true value.
Aerodrome	A defined area on land or water (including any buildings, installations and equipment) intended to be used either wholly or in part for the arrival, departure and surface movement of aircraft.
Aerodrome elevation	The elevation of the highest point of the landing area.
Aerodrome mapping database (AMDB)	One or more files containing information in a digital form that represent selected aerodrome features. This data includes geo-spatial data and metadata over a defined area. The files have a defined structure to permit an AMDB management system and other applications to make revisions that include additions, deletions, or modifications.
Aerodrome reference point (ARP)	The designated geographical location of an aerodrome.
Aerodrome surface movement area	That part of an aerodrome that is to be used for the take-off, landing, and taxiing of aircraft. This includes runways, taxiways, and apron areas.
Aeronautical data	A representation of aeronautical facts, concepts or instructions in a formalized manner suitable for communication, interpretation or processing.
Aeronautical database	Any data that is stored electronically in a system that supports airborne or ground based aeronautical applications. An aeronautical database may be updated at regular intervals.

Definition	Meaning
Aeronautical data preparation agency	An agency, public or private, other than an originator and/or publisher of government source documents, who compiles official government document information into charts or electronic formats for computer-based systems.
Aeronautical Information Publication (AIP)	A publication issued by or with the authority of a State and containing aeronautical information of a lasting character essential to air navigation.
Aeronautical information regulation and control (AIRAC)	A system aimed at advance notification based on common effective dates, of circumstances that necessitate significant changes in operating practices.
Aeronautical information service (AIS)	A service established within the defined area of coverage responsible for the provision of aeronautical information/data necessary for the safety, regularity and efficiency of air navigation.
Altitude	The vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL).
Application schema	Conceptual schema for data required by one or more applications.
Arresting gear location	Location of the arresting gear cable across the runway.
Assemble	A process of merging data from multiple sources into a database and establishing a baseline for subsequent processing. Note.— The assemble phase includes checking the data and ensuring that detected errors and omissions are rectified.
Bare earth	Surface of the Earth including bodies of water and permanent ice and snow, and excluding vegetation and man-made objects.
Blunder errors	From the statistical point of view, blunders or mistakes are observations that cannot be considered as belonging to the same sample from the distribution in question. They should not be used with other observations. They should be located and eliminated.
Canopy	Bare earth supplemented by vegetation height.

Definition	Meaning
Circular error probability (CEP)	CEP refers to the radius of a circle within which a stated percentage of measurements for a given point will fall. For example, if the horizontal accuracy of a surveyed point is stated as 1 m with 90% CEP, then 90% of measurements of this point will fall within a circle of 1 m radius. The true position is then estimated to lie at the center of this circle.
Completeness	The primary quality parameter describing the degree of conformance of a subset of data compared to its nominal ground with respect to the presence of objects, associations instances, and property instances.
Computer-based systems	Systems operating from pre-assembled aeronautical databases. Systems include, but are not limited to, area navigation systems, flight management systems, flight planning systems, flight simulators, computer modelling and design systems.
Conceptual model	Model that defines the concepts of a universe of discourse.
Conceptual schema	Formal description of a conceptual model.
Conceptual schema language	Formal language based on a conceptual formalism for the purpose of representing conceptual schemas.
Confidence	Meta-quality element describing the correctness of quality information. Confidence level.
Coordinate reference system	Coordinate system that is related to the real world by a datum.
Coordinate system	Set of mathematical rules for specifying how coordinates are to be assigned to points.
Correct data	Data meeting stated quality requirements
Corruption	A change to previously correct data introduced during processing, storage, or transmission, which causes the data to no longer be correct.

Definition	Meaning
Coverage	A feature that acts as a function to return one or more feature attribute values for any direct position within its spatiotemporal domain.
Coverage geometry	Configuration of the spatiotemporal domain of a coverage described in terms of coordinates.
Cultural features	Manmade morphological formations that include transportation systems (roads and trails; railroads and pipelines; runways; transmission lines), and other manmade structures, (buildings, houses, schools, churches, hospitals).
Culture	All man-made features constructed on the surface of the Earth, such as cities, railways and canals.
Cyclic redundancy check (CRC)	A mathematical algorithm applied to the digital expression of data that provides a level of assurance against loss or alteration of data.
Database	One or more files of data so structured that appropriate applications may draw from the files and update them. Note. — This primarily refers to data stored electronically and accessed by computer rather than in files of physical records.
Data element	A term used to describe any component of an AMDB. For example: a feature, an attribute, an object, an entity, or a value.
Data integrator	The part of an organization, which takes data from one or more sources to produce a terrain or obstacle database that satisfies a particular specification.
Data originator	The part of an organization which performs measurements by a particular means and which then groups those measurements to represent an area of terrain or a set of obstacles.
Data product	Data set or data set series that conforms to a data product specification.

Definition	Meaning
Data product specification	Detailed description of a data set or data set series together with additional information that will enable it to be created, supplied to and used by another party.
Data quality	A degree or level of confidence that the data provided meet the requirements of the data user in terms of accuracy, resolution and integrity.
Data set	Identifiable collection of data.
Data set series	Collection data sets sharing the same product specification.
Data type	Specification of the legal value domain and legal operations allowed on values in this domain.
Datum	Any quantity or set of quantities that may serve as a reference or basis for the calculation of other quantities.
Deficiency	The aeronautical data process is not adequate to ensure that data quality requirements are satisfied.
Digital Elevation Model (DEM)	The representation of terrain surface by continuous elevation values at all intersections of a defined grid, referenced to common datum. Note. — Digital Terrain Model (DTM) is sometimes referred to as DEM.
Digital ortho-rectified imagery	Digital aerial photography or satellite imagery that has been matched, or registered, to a surveyed ground control coordinate system and to spatially corresponding elevation data. Directions, angles, and distances are all to scale. A digital ortho-rectified image, therefore, is one whose coordinates have been adjusted to match its corresponding ground position, including adjustment for the effects of terrain undulations.
Digital surface model	Digital model of the topographic surface, including vegetation and man-made structures.

Definition	Meaning
Distribution (paper)	The process of disseminating documents containing formatted aeronautical data in various media, including the shipping and loading of a database into the target system for application.
Distribution (data)	The process of duplication of formatted aeronautical data into a database and the shipping and loading of the database into the target system for application. Distribution is usually achieved by transferring the data from one medium to another, with each transfer being verified.
Domain	Well-defined set.
Draping	Digital overlaying of one spatial data set onto another, where both data sets have been georectified (digitally matched) to the same coordinate system and map projection. Particularly useful in 3D visualizations of spatial data. Example: draping a satellite image over terrain data and creating a fly-through visualization in motion.
Elevation	The vertical distance of a point or a level, on or affixed to the surface of the earth, measured from mean sea level.
Ellipsoid height (Geodetic height)	The height related to the reference ellipsoid, measured along the ellipsoidal outer normal through the point in question.
End-user	An ultimate source and/or consumer of information.
Enterprise data	Common data used by multiple users but stored at a single location.
Error	Defective or degraded data elements or lost or misplaced data elements or data elements not meeting stated quality requirements.
Feature	Abstraction of real-world phenomena.
Feature association	Relationship between features.
Feature attribute	Characteristic of a feature.

Definition	Meaning
Feature catalogueue	Catalogueue containing definitions and descriptions of the feature types, feature attributes, and feature relationships occurring in one or more sets of geographic data, together with any feature operations that may be applied.
Format	The process of translating, arranging, packing, and compressing a selected set of data for distribution to a specific target system.
Frequency area	Designated part of a surface movement area where a specific frequency is required by air traffic control or ground control.
Geodetic datum	A minimum set of parameters required to define location and orientation of the local reference system with respect to the global reference system/frame.
Geodetic distance	The shortest distance between any two points on a mathematically defined ellipsoidal surface.
Geographic coordinates	The values of latitude, longitude, and height that define the position of a point on the surface of the Earth with respect to a reference datum.
Geographic data	Data with implicit or explicit reference to a location relative to the Earth.
Geoid	The equipotential surface in the gravity field of the Earth, which coincides with the undisturbed mean sea level (MSL) extended continuously through the continents.
Geoid undulation	The distance of the geoid above (positive) or below (negative) the mathematical reference ellipsoid.
Global navigation satellite system (GNSS)	A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation.

Definition	Meaning
Gregorian calendar	Calendar in general use; first introduced in 1582 to define a year that more closely approximates the tropical year than the Julian calendar.
Height	The vertical distance of a level, a point, or an object considered as a point, measured from a specified datum.
Imagery	The product of photography or advanced imaging sensors. Can be produced via either aerial or satellite fly-overs.
Integrity (aeronautical data)	A degree of assurance that an aeronautical data and its value has not been lost or altered since the data origination or authorized amendment.
Line	A connected sequence of points.
Linear Error Probability (LEP)	A linear magnitude within which a stated percentage of measurements for a given point will fall. For example, if the vertical accuracy of a surveyed point is stated as 1 m with 90% LEP, then 90% of measurements of the height of this point will fall along a vertical line of length 1 m. The true position is then estimated to lie at the center of this vertical line.
Mean sea level (MSL)	The average location of the interface between the ocean and the atmosphere, over a period of time sufficiently long so that all random and periodic variations of short duration average to zero.
Metadata	Data about data.
Model	Abstraction of some aspects of reality.
Multi-ring polygon	One or more polygons located inside another polygon that excludes the area of the inner polygons (e.g. doughnut, figure eight).
NOTAM	A notice distributed by means of telecommunication containing information concerning the establishment, condition, or change in any aeronautical facility, service, procedure, or hazard, the timely

Definition	Meaning
	knowledge of which is essential to personnel concerned with flight operations.
Obstacle	All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that are located on an area intended for the surface movement of aircraft or that extend above a defined surface intended to protect aircraft in flight.
Obstacle/terrain data collection surface	A defined surface intended for the purpose of collecting obstacle/terrain data.
Originate	The process of creating a data item or amending the value of an existing data item.
Originator (data)	The first organization in the aeronautical data chain that accepts responsibility for the data.
Orthometric height	Height of a point related to the geoid, generally presented as an MSL elevation.
Point	The smallest unit of geometry which has no spatial extent. Points are described by two dimensional (2D) or three-dimensional (3D) coordinates.
Polygon	A surface or area described by a closed line.
Portrayal	Presentation of information to humans.
Position (geographical)	Set of coordinates (latitude and longitude) referenced to the mathematical reference ellipsoid that define the position of a point on the surface of the Earth.
Post spacing	Angular or linear distance between two adjacent elevation points.
Precision	The smallest difference that can be reliably distinguished by a measurement process.
Quality	Degree to which a set of inherent characteristics fulfils requirements.

Definition	Meaning
Quality assurance	Part of quality management focused on providing confidence that quality requirements will be fulfilled.
Radiometric resolution	The capability of a sensor to discriminate levels or intensity of spectral radiance. In the analogue systems such as photography, the radiometric resolution is measured based on the number of grey levels that can be obtained. In opto-electronic systems, the radiance is recorded in an array of cells. A digit is assigned to each cell proportional to the received level of energy. This is done by an analog to digital converter in the platform. Generally, in modern sensors the range is between zero radiance into the sensor and 255 at saturation response of the detector.
Random errors	Random errors of observations refer to the basic inherent property that estimates of a random variable do not agree, in general, with its expectation.
Reference Ellipsoid	A geometric figure comprising one component of a geodetic datum, usually determined by rotating an ellipse about its shorter (polar) axis, and used as a surface of reference for geodetic surveys. The reference ellipsoid closely approximates the dimensions of the geoid, with certain ellipsoids fitting the geoid more closely for various areas of the earth. Elevations derived directly from satellite observations are relative to the ellipsoid and are called ellipsoid
Repeatability	The closeness with which a measurement upon a given, invariant sample can be reproduced in short-term repetitions of the measurement with no intervening instrument adjustment.
Required navigation performance (RNP)	A statement of the navigation performance necessary for operation within a defined airspace.
Resolution	A number of units or digits to which a measured or calculated value is expressed and used.

Definition	Meaning
Runway	A defined rectangular area on a land aerodrome prepared for the landing and take-off of aircraft.
Schema	Formal description of a model.
Situational awareness	The perception of elements in the environment, the comprehension of their meaning, and the projection of their status into the near future. [Endsley, 1990] For example, for pilots, the elements of the environment include, but are not limited to, the crew, passengers, aircraft systems, time, position, weather, traffic, and ATC constraints.
Spatial resolution	The capacity of the system (lens, sensor, emulsion, electronic components, etc.) to define the smallest possible object in the image. Historically, this has been measured as the number of lines pair per millimetre that can be resolved in a photograph of a bar chart. This is the so-called analogue resolution. For the modern photogrammetric cameras equipped with forward motion compensation (FMC) devices and photogrammetric panchromatic black and white emulsions, the resolution could (depending on contrast) be 40 to 80 lp/mm (line pairs per millimetre).
Specification	Document which establishes the requirements the product or service should be compliant with.
Spectral resolution	The capability of a sensor to discriminate the detected radiance in different intervals of wavelengths of the electromagnetic spectrum. Hence, the spectral resolution is determined by the number of bands that a particular sensor is capable to capture and by the corresponding spectral bandwidth.
State	An internationally recognized geographic entity that provides aeronautical information service.
Survey control point	A monumented survey control point.
Systematic errors	Systematic errors affect all repeated observations in the same way. Systematic errors are often referred to as bias errors. These effects

Definition	Meaning
	can be minimized via instrument calibration and/or the use of the appropriate math model.
Temporal resolution	The periodicity through which a sensor can acquire a new image of the same spot of the Earth's surface.
Terrain	The surface of the Earth containing naturally occurring features such as mountains, hills, ridges, valleys, bodies of water, permanent ice and snow, excluding obstacles.
Traceability	Ability to trace the history, application or location of that which is under consideration.
Universe of discourse	View of the real or hypothetical world that includes everything of interest.
User of aeronautical data	The group or organization using the system that contains the delivered aeronautical data on an operational basis, such as the airline operator.
Validation	Confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled.
Verification	Confirmation, through the provision of objective evidence that, specified requirements have been fulfilled. Note 1.— The term "verified" is used to designate the corresponding status. Note 2.— Confirmation can comprise activities such as — performing alternative calculations, — comparing a new design specification with a similar proven design specification, — undertaking tests and demonstrations, and — reviewing documents prior to use.
Vertex	A point that defines a line structure, curvature, or shape.

Definition	Meaning
Vertical line structure	Line structure of a defined vertical extend that is located within an area that extends from the edge(s) of the runway(s) to 90 m from the runway centerline(s) and for all other parts of the aerodrome movement area(s), 50 m from the edge(s) of the defined area(s).
Vertical object	An object with vertical extent that is within the designated buffer area.
Vertical point structure	Point structure of a defined vertical extend that is located within an area that extends from the edge(s) of the runway(s) to 90 m from the runway centerline(s) and for all other parts of the aerodrome movement area(s), 50 m from the edge(s) of the defined area(s).
Vertical polygonal structure	Polygonal structure of a defined vertical extend that is located within an area that extends from the edge(s) of the runway(s) to 90 m from the runway centerline(s) and for all other parts of the aerodrome movement area(s), 50 m from the edge(s) of the defined area(s).

6.2 Abbreviations and Acronyms

For the purpose of this guidelines, the abbreviations as contained in the ICAO annex and ICAO document, as amended from time to time, shall apply unless as otherwise indicated in AIP or as follow:

Definition	Meaning
ACARS	Aircraft Communications Addressing and Reporting System
ACR	Avionics Computer Resource
ADS-B	Automatic Dependent Surveillance - Broadcast
AFM	Aeroplane Flight Manual
AGL	Above Ground Level
AIP	Aeronautical Information Publication
AIRAC	Aeronautical Information Regulation and Control
AIS	Aeronautical Information Service
AIXM	Aeronautical Information Exchange Model
ARINC	Aeronautical Radio Inc
ARP	Aerodrome Reference Point
ASCII	American Standard Code for Information Interchange
ATC	Air Traffic Control
ATM	Air Traffic Management
BITE	Built-In Test Equipment
CAA	Civil Aviation Authority
CAD	Computer-Aided Design
CCD	Charge Coupled Device
CEP	Circular Error Probability

Definition	Meaning
CNG	Change
CNL	Cancel
CRC	Cyclic Redundancy Check
DEM	Digital Elevation Model
DEP	Departure
DLA	Delay
DORI	Digital Ortho-Rectified Imager
DPS	Data Product Specification
DSM	Digital Surface Model
DTM	Digital Terrain Model
ED	EUROCAE Document
EGM-96	Earth Gravitational Model 1996
EPSG	European Petroleum Survey Group
ETRF	European Terrestrial Reference Frame
EUROCAE	European Organization for Civil Aviation Equipment
EUROCONTROL	European organization for safety of air navigation
FAA	Federal Aviation Administration
FAR	FAA Aviation Regulation
FHA	Functional Hazard Analysis
FPL	Filed Flight Plan
FMC	Forward Motion Compensation
GIS	Geographic Information System

Definition	Meaning
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
ICAO	International Civil Aviation Organization
IERS	International Earth Reference System
IFSAR	Interferometric Synthetic Aperture Radar
IMC	Instrument Meteorological Conditions
INS	Inertial Navigation System
ISO	International organization for standardization
JAA	Joint Aviation Authority
LEP	Linear Error Probability
LIDAR	Light Detection and Ranging
MEF	Maximum Elevation Figures
MSA	Minimum Sector Altitude
MSAW	Minimum Safe Altitude Warning
MSL	Mean Sea Level
MVA	Minimum Vector Altitude
N/A	Not Applicable
NAD-83	North American Datum 1983
NGA	National Geospatial-Intelligence Agency
NM	Nautical mile
NOAA	National Oceanographic and Atmospheric Administration
NOTAM	Notice to Airmen

Definition	Meaning
NS	Not specified
OIS	Obstacle Identification Surface
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PDF	Probability Density Function
PMC	Program Management Committee
SAE	Society of Automotive Engineers
SAR	Synthetic Aperture Radar
SARPs	Standards and Recommended Practices
SC	Special Committee
STAR	Standard Terminal Arrival Route
SUA	Special Use of Airspace
SVS	Synthetic Vision System
TAWS	Terrain Awareness Alerting System
TCP/IP	Transmission Control Protocol/Internet Protocol
TERPS	US standard for Terminal Instrument Procedures
TIN	Triangular Irregular Network
TMA	Terminal Area
TSO	Technical Standard Order
UDDF	Universal Data Distribution Format
UID	Unique object Identifier
UML	Unified Modelling Language
USGS	United States Geological Survey

Definition	Meaning
UTC	Universal coordinated time
UTM	Universal Transverse Mercator
UUID	Universal Unique Identifier
VMC	Visual Meteorological Conditions
WG	Working Group
W3C	World Wide Web Consortium
WGS-84	World Geodetic System - 1984
XML	Extensible Mark-up Language

PART 1. INTRODUCTION

1.1 Electronic Terrain and Obstacle Data

Significant safety benefits for international civil aviation will be provided by in-flight and ground-based applications that rely on quality electronic terrain and obstacle data. The increasing worldwide equipage of aircraft and air traffic control units with systems that make use of electronic terrain data requires standardization in the provision of supporting data. Furthermore, as terrain information is increasingly finding its primary usage in the cockpit, many other personnel involved with operations will also benefit from the use of quality terrain and obstacle data. The performance of these applications that often make use of multiple data sources, however, may be degraded by data with inconsistent or inappropriate specifications for quality.

The new provisions in Annex 15 on the subject of electronic terrain and obstacle data are based on work done by ICAO together with EUROCAE WG 44 and RTCA SC 193 and comments received from States during the Annex 15 amendment process. These new Annex 15 provisions deal with the electronic terrain and obstacle data function, coverage, terrain and obstacle numerical requirements, content and structure of terrain and obstacle databases, data product specifications for terrain and obstacle data and their availability. In addition, applications for which quality terrain and obstacle data, used in conjunction with aeronautical data, are required, have also been identified.

To satisfy identified user requirements for electronic terrain and obstacle data, while taking into account cost-effectiveness, acquisition methods and data availability, the data are to be provided according to four basic coverage areas;

<u>Area 1</u>: the entire territory of a State;

<u>Area 2</u>: 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 strips.

— 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: 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 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;

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

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.

For each of the four areas, numerical requirements for terrain and obstacle data have been defined;

The provisions in Annex 15, concerning terrain database and obstacle database contents and structures are defined as two separate databases. There are several reasons for this division which include, different acquisition methods and established maintenance periods of data. It is recognized that depending on the acquisition method, the description of the terrain contained in the database could be the bare earth, the top of vegetation (canopy) or something in between.

Paragraph 10.5.2 of Annex 15 contains details regarding the provision of terrain and obstacle data product specifications on the basis of the ISO 19131 standard. Terrain and obstacle data product specifications are comprehensive statements regarding available electronic and obstacle data sets on which basis air navigation users will be able to evaluate the products and determine if any of them satisfy the requirements for their intended use in a particular application. Data product specification is intended to support information interchange between interested parties by providing feature types, feature attributes, geometry and attribute encoding rules, maintenance, quality requirements and metadata.

Successful interchange of data sets implies delivery, receipt and interpretation of data among the communicating parties and this interchange could be achieved through data set transfer. One interchange process is based upon a common application schema known to both suppliers and users of data. Data sets are transformed into the common transfer format based upon an encoding process that is defined by mapping between an application schema of a supplier and the common application schema. In a similar manner, decoding by the user of a common transfer data set format would generate data for the user. The above represents the fundamental principle for data interchange that would be applied to terrain and obstacle data interchange and onward use of data for different applications. On the basis of this principle, more complex and fully automated data interchange mechanisms may be built using a network to communicate messages requesting data on which basis corresponding delivery of requested data will be made. This type of interaction-based process represents an extension of the fundamental interchange principle and would lead to a dynamic (real-time) interchange of terrain and obstacle data. Therefore, the Standards in Annex 15 for terrain and obstacle data interchange represent a conceptual step towards networked interoperability aimed at an XML-based implementation of the data set transfer model.

1.2 Application of this Guidelines

Any terrain and obstacle data to be used to support aeronautical applications must meet the requirements defined in Annex 15 and detailed in this document. The aim of this document is to provide guidelines regarding the requirements that should be applied along data chain in order to obtain a database commensurate with the criticality of the final application of the data. The data requirements provided in this document will not affect existing standards being used for data acquisition, however, in some cases because of stringent accuracy and integrity requirements, traditional validation procedures may require modifications to accommodate quality requirements.

As a first step, **it is beyond the scope of this document to mandate requirements on the originators of such data (derived from topographic survey, satellite imagery, etc.) as it is understood that they already follow clearly identified professional standards, specific requirements and methodologies.** Nevertheless, it is recognized that quality requirements derived from the system designer or the end user specifications may be equally applicable to the data originator.

Once originated, data may exist in different formats and have different quality characteristics and these data are transmitted to the data integrators, who then merge the data received. The data will then be passed to the system designer for integration into the end-user system.

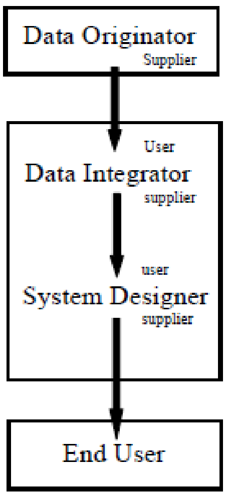

Figure 1-1: Data flow from supplier to user

1. **Data originators**, collect the terrain or obstacle data using aerial photography, laser scanning, satellite information, topographical surveys, etc. Certain existing data may have to

be modified (e.g. resurveyed) to satisfy stringent accuracy and integrity requirements. The data from data originators are supplied to data integrators.

2. **Data integrators**, use the data sets supplied by the originators, manipulate to integrate the data sets to ensure full data (terrain, obstacle) coverage in accordance with the required accuracy and integrity. The data sets are supplied to the system designers.

3. **System designers**, (e.g. avionics manufacturers) use and if necessary, merge specific data sets provided by multiple data integrators to meet the requirements of a specific application. Some of these requirements are also defined in this document. The data set are then supplied to the end users.

4. **End users**, which consist of Aircraft Operators, Aerodrome Authorities, Aircraft/ Avionics manufacturers etc, use and validate the data sets as applicable.

At each of the above steps of the process, it is the responsibility of the user to ensure that the data received meets the requirements for its intended application.

1.3 Reference System

World Geodetic System – 1984 (WGS-84) is the adopted aviation standard for horizontal reference system while Mean Sea Level (MSL) is the adopted vertical reference system. MSL elevations can be derived using an appropriate geoid model. **The Earth Gravitational Model (EGM-96)** is the adopted global geoid model. Gregorian calendar and **Coordinated Universal Time (UTC)** are adopted as temporal reference system.

1.4 Digital Data

1.4.1 General Provision

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.

A description of available digital data sets shall be provided in the form of **data product specifications (DPS)** on which basis air navigation users will be able to evaluate the products and determine whether they fulfil the requirements for their intended use.

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

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

1. use Unified Modelling Language (UML) to describe the aeronautical information features and their properties, associations and data types;
2. include data value constraints and data verification rules;
3. include provisions for metadata and
4. include a temporality model to enable capturing the evolution of the properties of an aeronautical information feature during its life cycle.

The aeronautical data exchange model used should:

1. apply a commonly used data encoding format;
2. cover all the classes, attributes, data types and associations of the aeronautical information model and
3. 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.

1.4.2 Metadata

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

1. the name of the organisations or entities providing the data set;
2. the date and time when the data set was provided;
3. validity of the data set; and
4. any limitations with regard to the use of the data set.

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

PART 2. TERRAIN AND OBSTACLE DATA REQUIREMENTS

2.1 Terrain and Obstacle Data Quality Requirements

1. Within the area covered by a 10-km radius from the aerodrome reference point (ARP), terrain data shall comply with the Area 2 numerical requirements.
2. In the area between 10 km and the terminal control area (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.
5. Obstacle data shall be collected and recorded in accordance with the Area 2 numerical requirements
6. 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.
7. 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.
8. Terrain and obstacle data in Area 3 shall comply with the numerical requirements.
9. Terrain and obstacle data in Area 4 shall comply with the 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

Table 2-1: Terrain numerical requirements

		Accuracy	Integrity	Orig Type	Pub. Res.	Chart Res.
Horizontal Position	Area 1	50 m	routine	surveyed	1 sec	as plotted
	Area 2	5 m	essential	surveyed	1/10 sec	1/10 sec
	Area 3	0.5 m	essential	surveyed	1/10 sec	1/10 sec
	Area 4	2.5 m	essential	surveyed	-	-
Vertical Position	Area 1	30 m	routine	surveyed	1 m or 1 ft	3 m (10 ft)
	Area 2	3 m	essential	surveyed	1 m or 1 ft	1 m or 1 ft
	Area 3	0.5 m	essential	surveyed	0.1 m or 0.1 ft	1m or 1 ft
	Area 4	1 m	essential	surveyed	0.1 m	-

Table 2-2: Obstacle numerical requirements

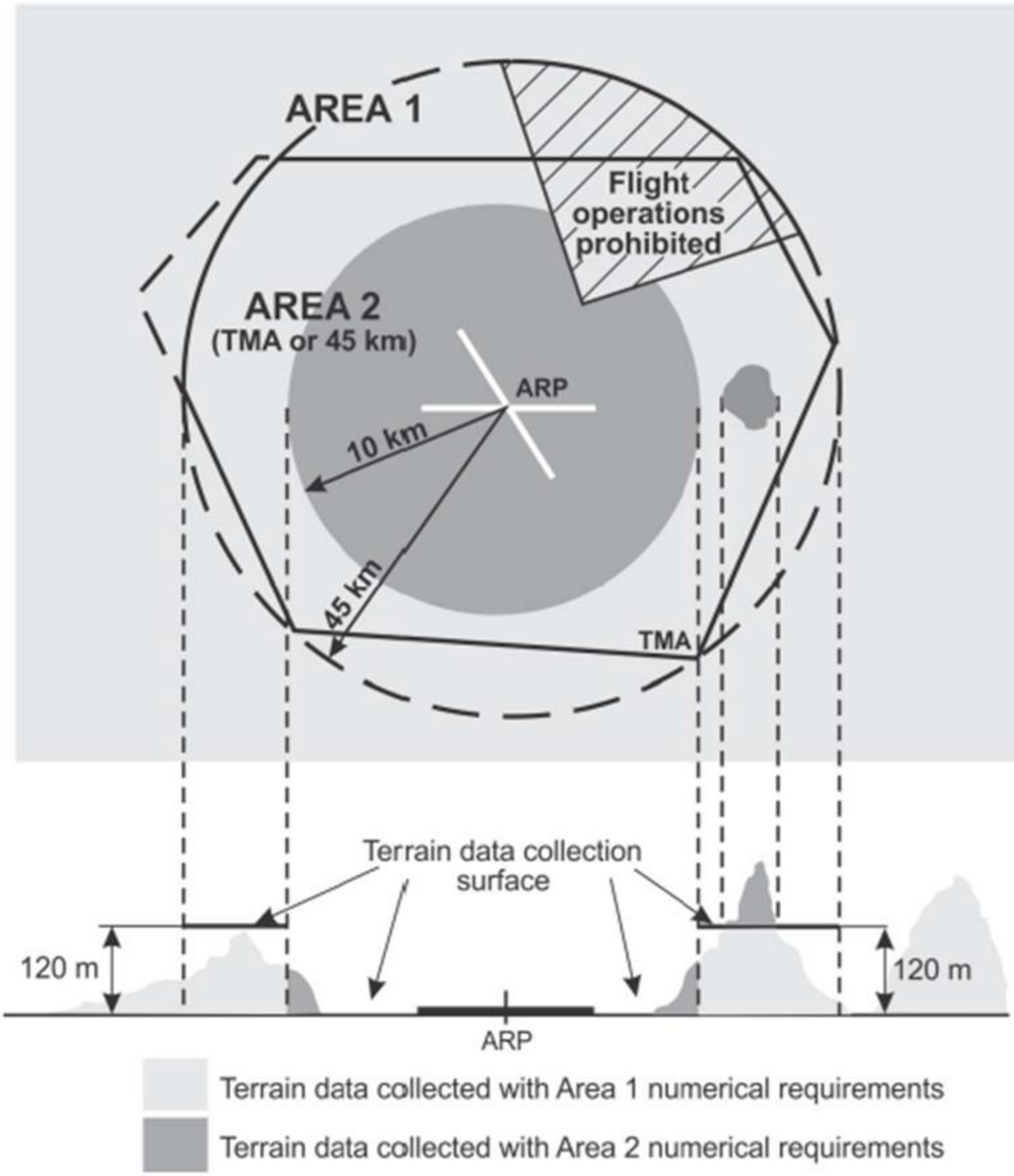

Figure 2-1: Terrain data collection surface – Area 1 and 2

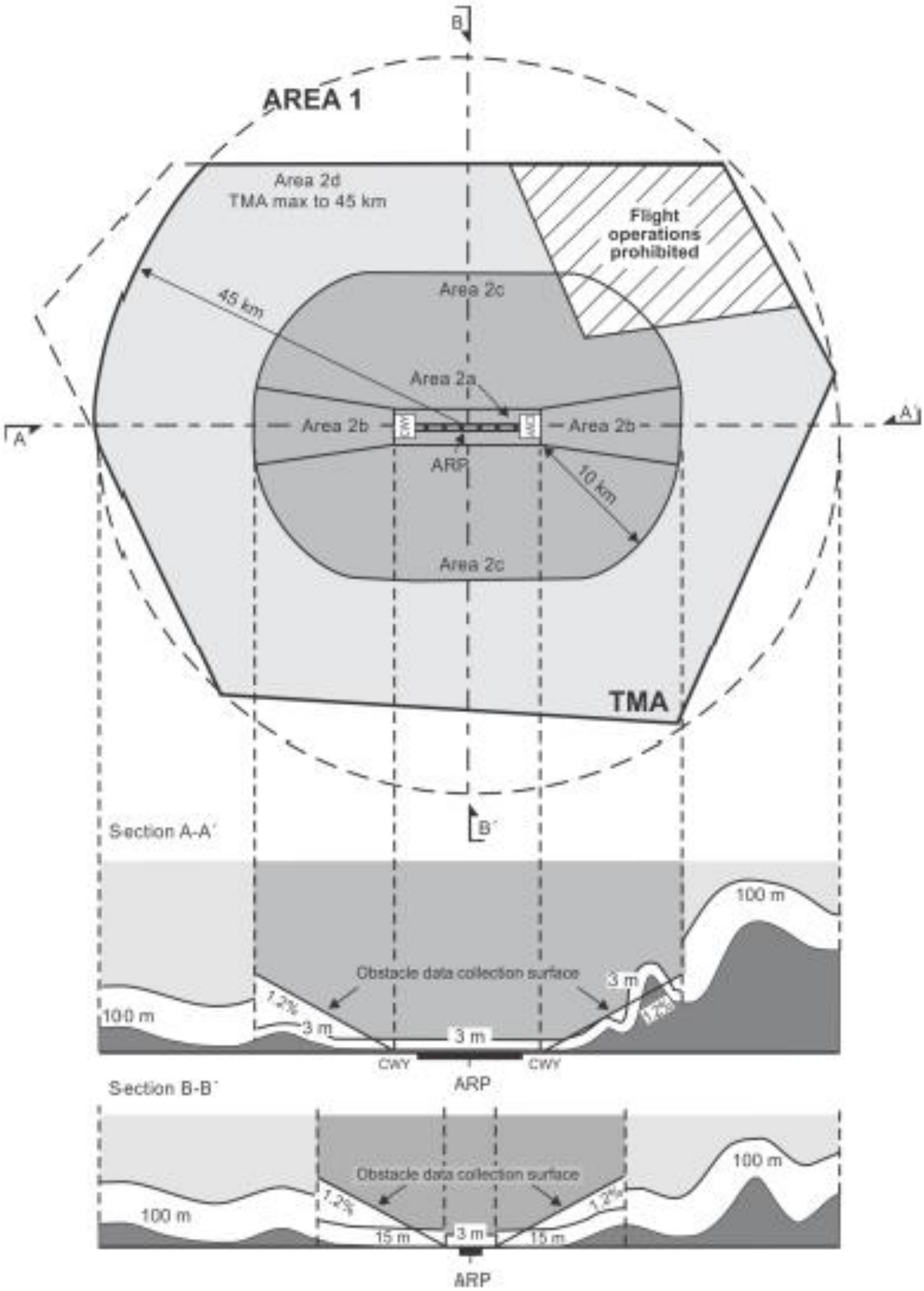

Figure 2-2: Obstacle data collection surface – Area 1 and 2

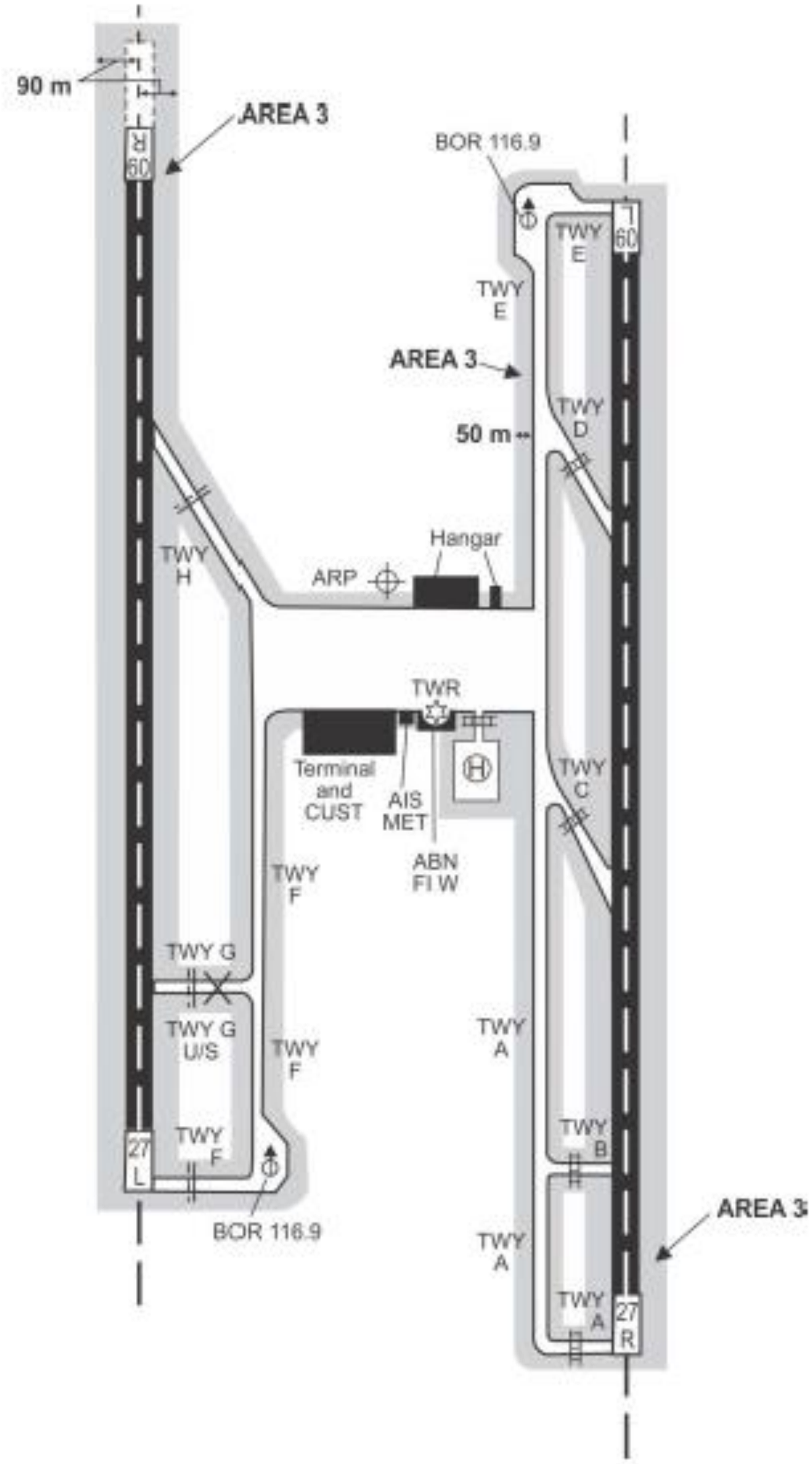

Figure 2-3: Terrain and Obstacle data collection surface – Area 3

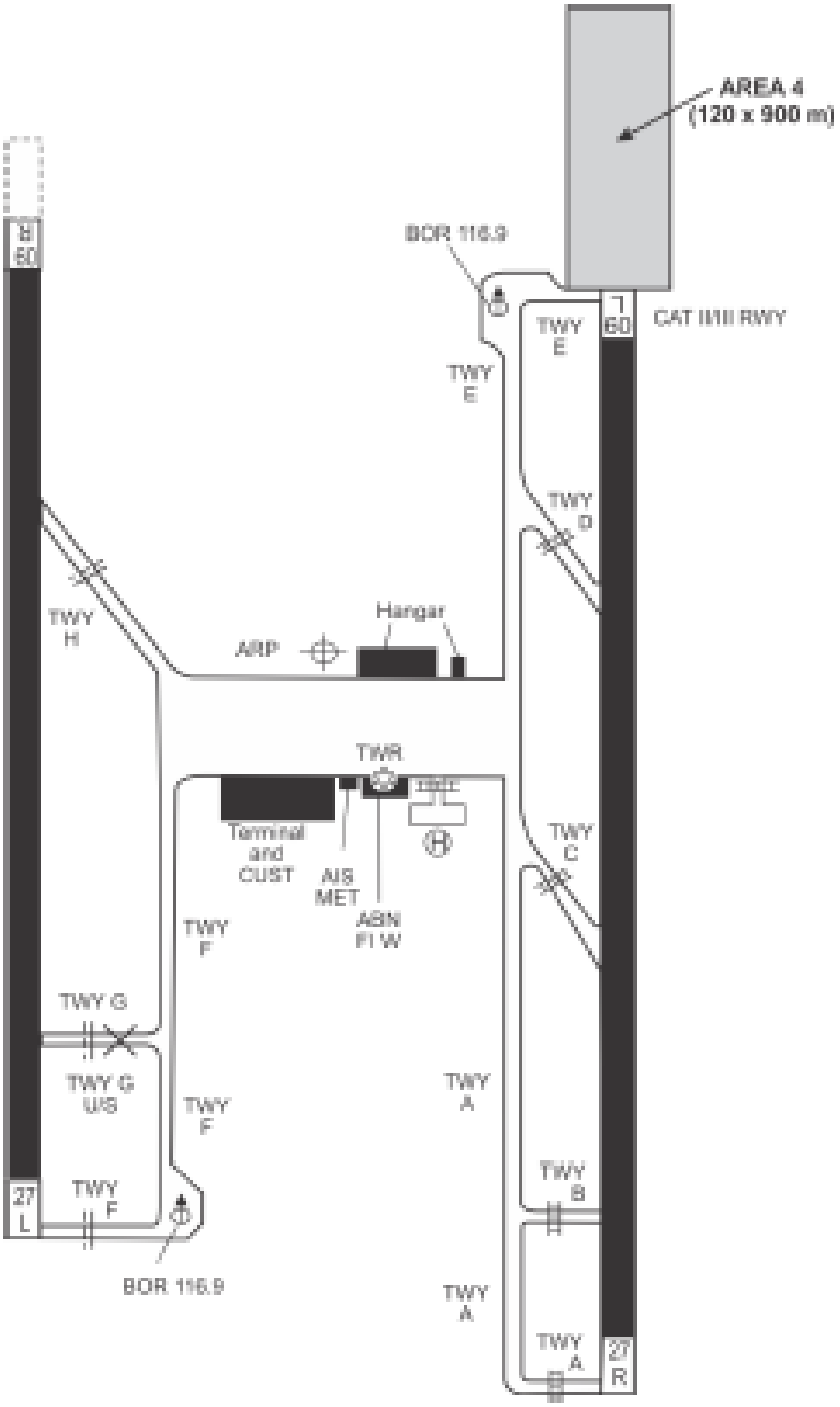

Figure 2-4: Terrain and Obstacle data collection surface – Area 4

2.2 Terrain and Obstacle Data Sets Requirements

Terrain and obstacle data are 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 integrity, accuracy, and resolution requirements specified in this document and the completeness of resulting data sets are not necessarily sufficient for primary means of navigation. The numerical values shown are not to be construed as system level or application specific requirements. System level or application specific requirements are dependent on a safety analysis of the entire system, of which the database is only one part.

2.2.1 Terrain data sets

1. A terrain database is a digital representation of the vertical extent (elevation) of the terrain at a number of discrete points. Terrain databases are also referred to as digital elevation models (DEMs), digital terrain models (DTMs), and digital surface models (DSMs).

2. A terrain grid shall be angular or linear and shall be of regular or irregular shape.

3. Sets of 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".

4. In terrain data sets, only one feature type, i.e. terrain, shall be provided. Feature attributes describing terrain shall be those listed in Table 2-3. The terrain feature attributes listed in Table 2-3 represent the minimum set of terrain attributes, and those annotated as mandatory shall be recorded in the terrain data set.

5. Terrain data for each area shall conform to the applicable numerical requirements.

6. Terrain Data Product Specification (DPS) shall follow **ICAO Document 9881** Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information Chapter 2 Terrain Data, 2.3 Data Product Specification.

Attribute	Mandatory/Optional
Area of Coverage	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 Data	Mandatory
Elevation	Mandatory
Database Units	Mandatory
Elevation Reference	Mandatory
Vertical Reference System	Mandatory
Vertical Resolution	Mandatory
Vertical Accuracy	Mandatory
Vertical Confidence Level	Mandatory
Surface Type	Mandatory
Recorded Surface	Mandatory
Penetration level	Optional
Known Variations	Optional
Integrity	Mandatory
Date and Time Stamp	Mandatory

Table 2-3: Terrain attributes

Area of coverage is a descriptor used to identify the boundary of the terrain data. The intent of this attribute is to help the user identify in general terms the area under consideration.

Data source identifier uniquely identifies the data originator. Sufficient information must be provided to distinguish among multiple data originators. A permanent record of the originator must be kept to establish an audit trail.

The **acquisition method** used to obtain the data must be defined.

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

Terrain database post spacing numerical requirements are presented in both angular and linear units to provide general guidance about the required density of measurement points. The linear measure is an approximation of the angular requirement near the equator. Angular increments may be adjusted when referencing high latitude regions to maintain a constant linear density of measurement points. When linear and angular post-spacing requirements differ, the linear requirement must take precedence.

The horizontal reference system is the datum to which the positions of the elevations are referenced. SARPs require that coordinates used for air navigation must be expressed in the WGS-84 reference system.

Horizontal resolution can have two components:

1. The units used in the measurements. Position recorded in one-arc second increments has a higher resolution than that taken in one-arc minute increments.

2. The number of decimal places for the recording of the position. Use of more decimal places can provide for higher resolution.

It is important to note that resolution and post spacing are not synonymous and can be confused with each other.

Horizontal accuracy must be stated in the same units as used for the elevation. The statistical derivation of the horizontal accuracy must be stated. Bias and standard deviation should be provided.

The **Horizontal Confidence Level** is the probability that errors in a database are within the limits specified. The confidence level of the position must be stated.

Horizontal position data are defined by geodetic latitude and longitude. The geodetic latitude of a point is defined as the angle between the normal to the ellipsoid at that point, and the equatorial plane. The geodetic longitude of a point is the angle between its geodetic meridian plane and the IRM (IERS Reference Meridian). However, it is recognized that some terrain databases use projection-based coordinates (e.g. Universal Transverse Mercator (UTM) Eastings and Northings). These terrain databases must include a projection type attribute.

Elevation is the vertical distance of a point or a level, on or affixed to the surface of the Earth measured from mean sea level. Elevation must be expressed in linear units that are consistent with the accuracy and resolution specifications.

Database Unit: For every attribute that requires it, the units used must be stated and the units must be consistent within the database.

The **elevation reference** corresponds to the method used to determine the elevation value recorded for each cell of the data set. The elevation reference must be explicitly defined. Considerations about elevation reference include the following:

1. The provided values may correspond to a particular corner or the centre of a DEM cell, the mean elevation value of the cell, the maximum elevation value, etc;

2. In a regularly distributed grid (i.e., square, rectangular) the first data point of the set is the reference point with a known recorded planimetric position, to which the other data points are referenced;

When the data represent the terrain elevation at specific latitude/longitude points, then the terrain elevation between the database sample points may be higher or lower than the database values.

The **vertical reference system** is the datum to which the elevation values are referenced. Mean Sea Level (MSL) is the required vertical reference system. The Earth Gravitational Model (EGM-96) must be used as the global gravity model. If a geoid model other than the EGM-96 model is used, a description of the model used, including the parameters required for height transformation between the model and EGM-96 must be provided.

Vertical resolution may have two components:

1. The units used in the measurements. For example, elevation recorded in one-foot increments has a higher resolution than that taken in one-meter increments;

2. The number of decimal places for the recording of the elevation. Use of more decimal places can provide for higher resolution.

Vertical accuracy must be stated in the same units as used for the elevation. The statistical derivation of the horizontal accuracy must be stated. Bias and standard deviation should be provided.

The **Vertical Confidence Level** is the probability that errors in a database are within the limits specified. The confidence level of the position must be stated.

Surface type is a classification of the recorded surface, e.g., marshland, water, permanent ice, etc.

Recorded surface identifies the surface that the elevation data represent. Some examples of surfaces that may be recorded by available technologies are:

1. The bare earth recorded by land survey or by remote sensing techniques when vegetation or snow/ice is not present.

2. The reflective surface recorded by either an active or a passive remote sensing sensor. The sensor equipment manufacturer or the service provider must identify the surface that has been recorded.

Penetration Level: The Recorded Surface attribute identifies the surface the elevation data represent. When the position of this surface, between the bare earth and top of the canopy or the surface of snow or ice is known, it should be recorded in the attribute “Penetration Level”.

Nevertheless, when recorded by either active or passive remote sensors, it is recognized that the degree of penetration of the sensor signal is frequently impossible to determine precisely. The estimated penetration will be expressed as a unit of measurement e.g. meters or feet.

Known variations specify predictable changes to the data e.g., seasonal elevation changes due to snow accumulations or vegetation growth.

Integrity of data is the degree of assurance that the data and its value have not been lost nor altered since the data origination or authorized amendment. The integrity of the data set must be expressed, indicating the probability of any single data element having been changed inadvertently since the creation of the data set.

Date and time stamps are information about the origination or modification date and time of the data. Time stamps must refer to Universal Coordinated Time (UTC) and date stamps must refer to the Gregorian calendar.

2.2.2 Obstacle data sets

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

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 Table 2-4.

3. Obstacle data for each area shall conform to the applicable numerical requirements.

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.

5. Obstacle Data Product Specification (DPS) shall follow **ICAO Document 9881** Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information Chapter 3 Obstacle Data, 3.3 Data Product Specification.

Attribute	Mandatory/ Optional	Type of attribute
Area of Coverage	Mandatory	Metadata
Data Originator Identifier	Mandatory	Feature Attribute
Horizontal Position Data	Mandatory	Feature Attribute
Horizontal Reference System	Mandatory	Metadata
Horizontal Resolution	Mandatory	Metadata
Horizontal Extent	Mandatory	Feature Attribute
Horizontal Accuracy	Mandatory	Feature Attribute
Horizontal Confidence Level	Mandatory	Feature Attribute
Elevation	Mandatory	Feature Attribute
Height	Mandatory	Feature Attribute
Database Units	Mandatory	Metadata
Vertical Reference System	Mandatory	Metadata
Vertical Resolution	Mandatory	Metadata
Vertical Accuracy	Mandatory	Feature Attribute
Vertical Confidence Level	Mandatory	Feature Attribute
Obstacle Type	Mandatory	Feature Attribute
Integrity	Mandatory	Feature Attribute
Date and Time Stamps	Mandatory	Feature Attribute
Effectivity	Optional	Feature Attribute
Status	Mandatory	Feature Attribute
Lighting	Mandatory	Feature Attribute
Marking	Mandatory	Feature Attribute
Geometry	Mandatory	Feature Attribute

Table 2-4: Obstacle attributes

Area of coverage is a description used to identify the boundary of obstacle data. This should be used to help the user identify in general terms the area under consideration.

Data originator identifier uniquely identifies the obstacle data originator. Sufficient information must be provided to distinguish between multiple data originators. A permanent record of the originator must be kept to establish an audit trail.

Horizontal position must be expressed as a point, or points defining a line or a polygon. Horizontal position must be expressed in geographic coordinates by latitude and longitude.

The horizontal reference system is the datum to which the positions of the data points are referenced. Coordinates used for air navigation must be expressed in the WGS-84 reference system. If the horizontal reference system is not WGS-84, the reference system and transformation parameters to WGS-84 must be specified.

Horizontal resolution can have two components:

1. The units used in the measurements. Position recorded in one-arc second increments has higher resolution than that taken in one-arc minute increments

2. The number of decimal places for the recording of the position. Use of more decimal places provides for higher resolution.

The horizontal extent is the footprint of or the area subtended by the obstacle, e.g. area covered by mast guy wires, or weather balloon. Horizontal extend must be expressed in linear units that are consistent with the elevation specifications.

Horizontal accuracy must be stated in the same units as used for the elevation. The statistical derivation of the horizontal accuracy must also be stated. Bias and standard deviation should be provided.

Horizontal Confidence Level: The confidence level of the position must be stated as a percentage.

Elevation is the vertical distance of a point or a level, on or affixed to the surface of the Earth measured from the vertical reference system. For points obstacle, the elevation must be the elevation of the top of the obstacle. For line obstacles, the elevation must be given for each point defining the straight line. For polygon obstacles, the elevation must be given by the maximum elevation within the polygon. Elevation must be expressed in a unit that is consistent within the data set.

Height is the vertical distance of a level, point, or an object considered as a point, measured from a specific datum. Obstacle heights are normally referenced to the ground level (AGL). For point obstacles, the height must be the height of the top of the obstacle. For line obstacles, the height must be given for each point defining the straight line. For polygon obstacles, the height must be the maximum height within the polygon. Height must be expressed in a unit that is consistent within the data set.

Unit of measurement used: For every obstacle attribute that requires it, the unit used must be stated and the unit must be consistent
within the data set.

The vertical reference system is the datum to which the elevation values are referenced. Mean Sea Level (MSL) is the required vertical reference system. The Earth Gravitational Model (EGM-96) must be used as the global gravity model. If a geoid model other than the EGM-96 is used, a description of the model used, including the parameters required for height transformation between the model and EGM-96 must be provided.

Vertical resolution can have two components:

1. The units used in the measurements (elevation recorded in one-foot increment has higher resolution than that taken in one-meter increment)

2. The number of decimal places for the recording of the elevation (use of more decimal places provides for higher resolution).

Vertical accuracy must be stated in the same unit as used for the elevation. The statistical derivation of the vertical accuracy must also be stated. Bias and standard deviation should be provided.

Vertical Confidence Level: The confidence level of the elevation must be stated as a percentage.

Obstacle type is a description of the recorded obstacle, e.g., tower, building, tree, power lines, windmill farms, or cable car. Obstacles may be temporary such as cranes, permanent such as TV transmission towers, moving, such as ships.

The **integrity** of the data set must be expressed, indicating the probability of any single data element having been changed inadvertently since the creation of the data set.

Date and Time stamps are information about the origination or modification date and time of the data set. Time stamps must refer to Universal Coordinated Time (UTC) while date stamps must refer to the Gregorian calendar.

Effectivity is a description of the date/time period for which an obstacle exists. For all temporary obstacles, effectivity must be provided. Effectivity must include:

1. The time and date of building/setting up the obstacle (referenced to UTC and the Gregorian calendar)

2. The time and date of dismantling/removing the obstacle (referenced to UTC and the Gregorian calendar)

Obstacle Status: When an obstacle is still being built, an indication “under construction” must be provided.

Obstacle Lighting: When an obstacle has lighting this information must be provided.

Obstacle Marking: When an obstacle has markings, this information must be provided.

Geometry Type: Obstacles must be described either as points, lines, or polygons.

Point obstacles: the centre of the obstacle’s horizontal surface must be captured as a two-dimensional (2- D) or three-dimensional (3-D) point. Adjacent obstacles or groups of obstacles must be captured individually.

Line obstacles: the center of the obstacle’s horizontal surface must be captured as a two-dimensional (2-D) or three-dimensional (3-D) line. A line consists of a connected sequence of points. Start- and endpoints of a line are referred to as start- and end-node. Connecting points that are in between start- and end-nodes are referred to as vertices. Vertices are intermediate points that define the line structure, curvature, or shape. A start-node and an end-node define a line's directionality. A connection between a node and a vertice or between vertices must be a straight line.

Polygonal obstacles: A polygon is a surface described by a closed line (i.e. a line whose start-node and end-node are coincident). The closed line forms the outer edge of the surface. The inside of the polygon is defined by the left side in the order of vertices. Depending on the complexity of the obstacle, one or multiple polygons may be used to model the obstacle.

PART 3. TERRAIN DATABASE GENERATION PHASES

In developing a terrain database there are five phases as follows:

1. Terrain data collection
2. Mathematical transformations
3. Database assembly
4. Verification
5. Validation

3.1 Terrain Data Collection

The terrain data collection phase covers the process of recording measurements and the actions performed on those measurements to create the initial terrain data. Some examples of methods of measurement are:

1. Traditional in-situ surveys (e.g., using GPS) on the ground.
2. Photogrammetric – the process of extracting or collecting digital data from a stereo image.
3. Cartographic – a process of sampling and interpolation from lithographic hardcopy sources such as maps.
4. Radar– from either aircraft or satellite.
5. Laser Altimeter – from either aircraft or satellite.
6. Synthetic Aperture Radar (SAR) interferometer – from either aircraft or satellite.

Some of these methods involve the use of complex mathematical techniques to minimize systematic errors. For example, in photogrammetry, mathematical techniques are used to reduce the distortion in the recorded images.

It is important to realize that each measurement method has weaknesses, which might lead to poor or unreliable data. The purpose of this appendix is not to list these weaknesses but to remind suppliers and airworthiness authorities that weaknesses exist so that compensatory actions can be described, taken and traced.

Each measurement method has its own established criteria to ensure data quality. These criteria should be recorded.

Validation of the data should begin with its acquisition. Metadata should be recorded to demonstrate integrity of the database, as required.

3.2 Mathematical Transformations

Once the measurements have been collected, mathematical and spatial transformations may be required to generate a terrain elevation model.

Transformation must be made to achieve a common reference system.

The purpose of the mathematical transformations may be one or more of the following:

1. Transformation of measurement points to the appropriate post spacing: Spatial interpolation of the measurement points may not coincide with the desired reference position. Moving the horizontal location of measurements requires interpolation of the vertical elevation data.

2. Transformation of the vertical and horizontal reference systems (datum). Data sets from multiple sources such as different countries or various measurement methods may use different reference systems.

To produce a complete set of terrain data over a given area may require the combination of several data sets and the identification of any gaps that remain.

Data sets that are to be merged must be pre-processed to have common attributes.

The data sets may contain invalid measurements that can be identified by inspections or mathematical tests. Some of these methods may allow correcting the errors. The following are principles to note:

For each of these transformations, the supplier must provide justification and demonstrate the validity of any assumptions that have been made. In particular, the effect of each of the transformations on the errors in the measurements needs to be understood and documented to provide a clear audit trail. Without this complete understanding the overall quality of the database cannot be determined.

Validation of the data should begin as early as possible in the database generation processes. This can be achieved by validating data after each transformation step.

If there is insufficient quality information available from the measurement phase or subsequent transformations, then the user of the data must make due allowance to compensate for the missing information.

3.3 Database Assembly

The output of the mathematical transformation process is the set of elevations and locations that describe a region, as well as the related quality information. The next step is to organize and format the data in accordance with the requirements of the end-user. This may include filtering or systematic down-sampling of a data set.

3.4 Verification

The data to be included in a database must be verified at each stage of the origination /assembly process. Verification is defined as confirmation by examination and provision of objective evidence that specified requirements have been fulfilled (ref. Annex 15). This is necessary to ensure that the data set implementation accurately represents the developer’s specifications and that the data set has not been corrupted in the assembly process. The following verification techniques could be used:

1. Comparison of a sample of the data set points with samples from an independent measurement system. For example, GPS readings at specific points can be compared to the same points in a data set that was created by photogrammetric methods. The more samples that are checked, the higher the level of confidence in the quality of the data set.

2. Comparison of the terrain data set with other existing data sets. For this verification method, the vertical and horizontal reference datum for the data sets should be taken into account and the data sets should be independent.

3. Reasonableness checks to ensure that the terrain data set does not violate known properties of a terrain. Reasonableness checks ensure that the terrain data set does not violate known geographic extremes, such as the height of Mt Everest.

4. Comparison of the data set with independent measurements made during flight test.

3.5 Validation

It must be demonstrated that the data requirements defined by the application manufacturer have been validated. Validation is defined as the confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled.

PART 4. OBSTACLE DATABASE GENERATION PHASES

In developing a terrain database there are five phases as follows:

1. Terrain data collection
2. Mathematical transformations
3. Database assembly
4. Verification
5. Validation

4.1 Obstacle Data Collection

This phase covers the process of collecting relevant obstacle data. Obstacle data that are derived from the same source material used for terrain are subject to the same considerations.

4.2 Mathematical Transformations

The conversion of a set of measurements to an obstacle data set can be a complex process. This is especially true since the obstacle location. Extent and height measurements may have varying levels of accuracy and resolution. Reasons for obstacle data transformations on are:

1. Transformation of the reference system to align with a particular terrain database.
2. Merging of several sources to produce a complete set of obstacle data over an area may require combining several data sets.

Data sets that are to be merged must be pre-processed to have common attributes. Identification of errors: the data sets may contain invalid measurements, which can be identified by inspections or mathematical tests. Some of these methods may allow correcting the errors. Obstacle data sets are subject to the same considerations as terrain data sets mentioned above.

4.3 Database Assembly

The output of the mathematical transformation process is the set of heights, extents and locations that describe a set of obstacles, as well as the related quality information. The next step is to organize and format the data in accordance with the requirements of the end-user. This may include filtering or systematic down-sampling of a data set.

4.4 Verification

The data to be included in a database must be verified at each stage of the origination/assembly process. Verification is defined as confirmation by examination and provision of objective evidence that specified requirements have been fulfilled (ref. Annex 15). This is necessary to ensure that the data set implementation accurately represents the developer's specifications and that the data set has not been corrupted in the assembly process. The following verification techniques could be used:

1. Comparison of a sample of the data set points with samples from an independent measurement system. For example, GPS readings at specific points can be compared to the same points in a data set that was created by photogrammetric methods. The more samples that are checked, the higher the level of confidence in the quality of the data set.

2. Comparison of the terrain data set with other existing data sets. For this verification method, the vertical and horizontal reference datum for the data sets should be taken into account and the data sets should be independent.

3. Reasonableness checks to ensure that the terrain data set does not violate known properties of a terrain. Reasonableness checks ensure that the terrain data set does not violate known geographic extremes, such as the height of Mt Everest.

4. Comparison of the data set with independent measurements made during flight test.

4.5 Validation

It must be demonstrated that the data requirements defined by the application manufacturer have been validated. Validation is defined as the confirmation by examination and provision of objective evidence that the particular requirements for a specific intended use are fulfilled.

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APPENDIX A: REMOTE SENSING TECHNOLOGIES

A.1 Summary

The objective of this chapter is to provide basic information to the data integrator regarding remote sensing technologies for the generation of terrain databases. The main aspects outlined deal with:

1. Sensor types,
2. Characteristics of elevation models produced using stereo aerial photography, stereo pairs of satellite imagery, interferometric synthetic aperture radar and lidar,
3. Characteristics of existing and future data acquisition systems.

Note: When using high-altitude reflective sensing, the elevation values provided are a complex product of the sensor resolution area.

A.2 Sensor

There are two types of sensors:

1. Passive (or optical) sensors, which capture electromagnetic information that originated at the Sun and is reflected from the Earth's surface. These include aerial photography, scanners, push-broom and CCD array types.

2. Active sensors, which illuminate the scene and capture the reflected information from the ground surface. A typical example is a radar or lidar system.

A.3 Stereo Aerial Photography

Aerial photography is instantaneous imaging of the terrain surface. As such, the electromagnetic rays which give rise to the image have the same attitude and position in space with respect to a co-ordinate reference system. These are the so-called exterior orientation parameters of the aerial photograph. Figure A-1 illustrates the concept. The parameters that define the position and attitude of a body in space are:

1. three coordinates (X, Y, Z) define a position in space.

2. three attitude angles (Φ, Ω, K) define the attitude of the corresponding body (i.e., camera) in space with respect to a 3D co-ordinate reference system.

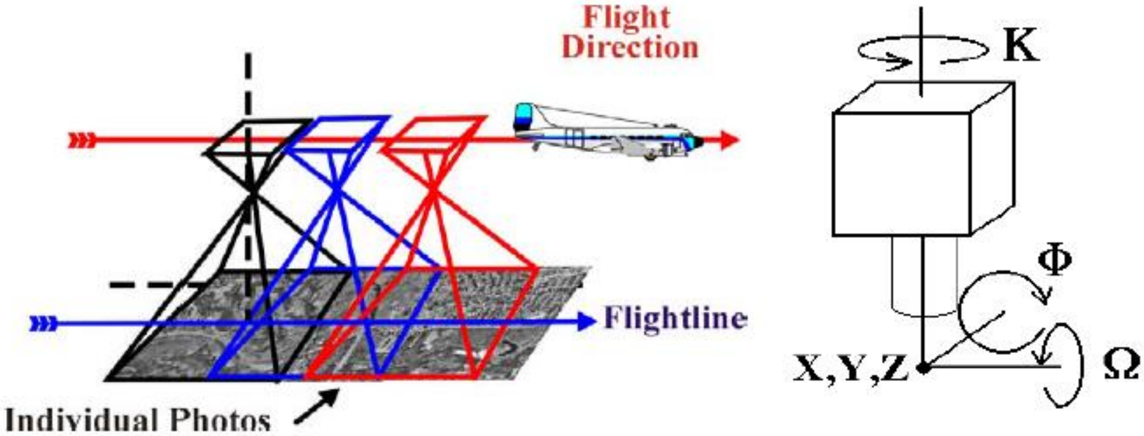

Figure A-1: Concept of stereo aerial photography

Each point of the aerial photograph has the same exterior orientation parameters and is equal to the parameters of the photogrammetric camera at the instant of exposure.

A.4 Stereo Satellite Images

A satellite image can be thought of as an image formed by a successive integration of image lines. An array of light sensitive devices captures the information (i.e., electromagnetic waves) coming from the ground. The captured light is converted to an electrical pulse that is transformed to a digital number and stored for transmission to a ground antenna.

Although a satellite image is exposed line by line in a continuous mode while the platform is moving in its orbit, a set of exterior orientation parameters are valid only for one line at a time.

The main geometrical difference between an aerial photograph and a satellite image lies in the fact that a satellite image does not have constant values for its exterior orientation parameters. They are approximately constant for one line (perpendicular to the instantaneous orbit direction), but vary from line to line. All points of an aerial photograph have the same exterior orientation parameters.

Aspects to be taken into consideration whenever satellite images are used for mapping purposes are the strong effects of Earth curvature and atmospheric refraction. The distortion of the satellite image caused by the Earth's curvature and its variation is more significant than the effect of atmospheric refraction.

A.5 Interferometric Synthetic Aperture Radar (IFSAR)

IFSAR is a technique that uses the relative phase difference between two coherent synthetic aperture radar (SAR) images, obtained by two antennae separated by an across-track baseline, to derive a measurement of the surface height. The baseline length is an important design parameter since the height error diverges as the length approaches zero. Conversely, if the baseline length is too large, the returns from the two antennae become de-correlated, increasing the phase measurement error. A block diagram of the basic process is illustrated in Figure A-2.

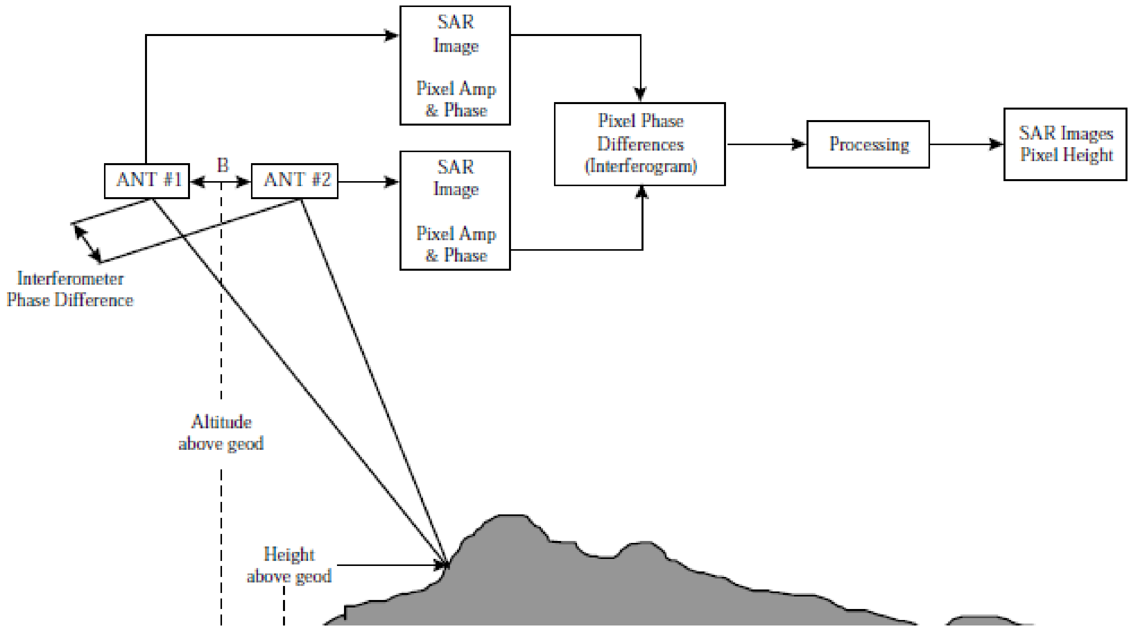

Figure A-2: Concept of stereo aerial photography

Highly accurate navigation information provided via tightly coupled differential GPS and inertial information drives this process. The first stage of the process is to form the image for each channel. This involves range compression, range curvature correction, and azimuth compression to form a slant plane image. An interferogram is created during the post-processing routine to extract accurate height information from the airborne data. The interferogram is created by combining the two complex SAR image data channels through a process of multiplying one channel by the conjugate of the other on a pixel-by-pixel basis.

To solve for the height, it is critical that the position, attitude, and length of the baseline B are known to the highest possible accuracy. For this reason, the IFSAR antennae baseline must be stable. The swath width is dependent on the height above ground. As the height above ground decreases, so too does the ground coverage. The two critical parameters for the coverage are the far incidence angle and the antenna beam width.

An IFSAR system generates two main product types:

1. Digital Elevation Models (DEM): A high resolution IFSAR system produces DEMs (see Figure A-3) with vertical accuracies ranging from 30 cm to 3 m, with post spacing from 5 m, and with horizontal accuracies of 1.25 m and 2.5 m.

2. Ortho-rectified Image (ORI): IFSAR high-resolution images (see Figure A-3) are ortho-rectified using the simultaneously generated DEM. Consequently, the radar imagery is presented with all standard radar viewing angle height distortions removed. These images are registered to a desired projection and are mosaicked into image maps. IFSAR digital images can be used to create maps at scales as large as 1:5,000.

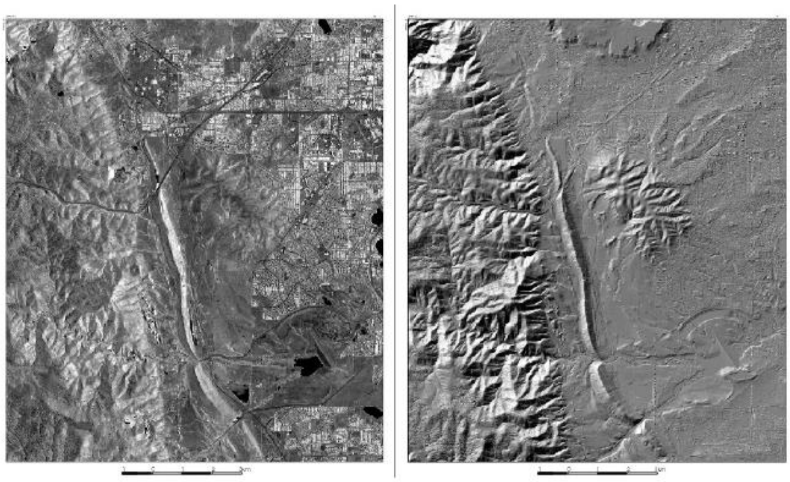

Figure A-3: IFSAR DEM and ORI products

A.6 Light Detection and Ranging

Airborne laser scanning systems, often referred to as LIDARs, are characterized by their transmission of pulses of optical radiation (usually near-IR) on either side of the aircraft nadir such that a zigzag or similar pattern of spots sample the terrain or objects upon it. The side-to-side geometry is usually effected by a rotating mirror or other scanning implementation. The forward motion of the aircraft then adds the second dimension. The back-scattered pulses are received by the LIDAR system, and through time-offlight measurement, the range or distance to each sample is determined. Sample separation and swath width is determined by the various operating parameters (pulse rate, scan frequency, maximum scan angle, aircraft altitude, velocity, etc). Typical sample spacing may range from 50 cm to 5 m while swath widths are normally several hundred meters. The spot diameter of the samples is usually about 0.1 – 1.0 m diameter, also depending on altitude.

The second key component of an airborne LIDAR system is its combined GPS and Inertial Measurement Unit, which allows the range samples to be converted to (X, Y, Z) coordinates. These samples are usually an irregular set of points that can be subsequently used to create either a regularly gridded DEM or a TIN.

If the reflecting surface is the bare ground, the elevation accuracy may be in the range 15 – 30 cm (RMSE) while the horizontal accuracy of the points is usually 1 – 3 m (RMSE). If the reflecting surface is vegetated, some of the pulses will scatter from the vegetation, while some may penetrate through openings to the ground. The degree of vegetation penetration depends on the vegetation characteristics as well as the LIDAR system operating parameters. These factors will therefore determine how densely sampled and how accurate the resulting bare-earth DEM will be.

A.7 Digital Ortho-Rectified Imagery

This section contains information related to Digital Ortho-Rectified Imagery (DORI). DORI is a part of photogrammetry science and has a significant role in 3D scene visualization when it’s used together with digital terrain modelling (DTM), extracted objects, textures, and metadata which can be provided for all scene layers. DORI is particularly effective when it is draped, or overlaid, onto terrain data for a photorealistic 3D image of the projected scene. The 3D scene visualization tool provides the ability to have links to obtain information about selected objects in the scene and other information such as metadata, change of date and time, and season.

Today DORI is used for revising existing maps, flight simulation software, and it is being used as source data for digitizing map features such as airport layouts. The importance of DORI has increased in recent years as its value in enhancing the display, and data capture of terrain, obstacles, and airport mapping features has been recognized. In the future, DORI is planned to be used for synthetic vision systems, in glass cockpits, particularly during all weather operations. Figure A-4 shows an example of combination between DTM, DORI, 3D objects, textures, and metadata for 3D scene visualization.

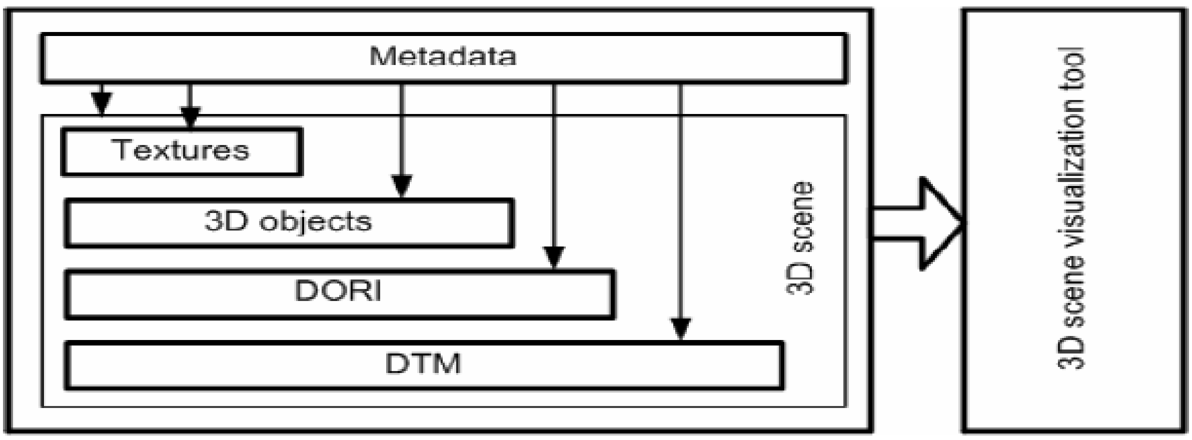

Figure A-4: DTM, DORI, 3-D objects, textures, and metadata for 3-D scene visualization

DORI is produced from aerial or satellite images by matching digital photo imagery to ground map coordinates using image processing software or GIS systems. DORI is imagery which has been georectified, or referenced to ground map coordinates, and adjusted for the effects of terrain undulation. The importance of this process is that map data can be displayed on top of its corresponding aerial image location, assuming that both map and image data have been registered to the same map coordinate system. For the DORI development process, it is necessary to specify:

1. Type of imagery survey
2. Scale of surveying
3. Control points location, and number of points
4. DTM development methodology, and DTM type
5. Output formats

In a case when DORI and 3D scenes will become aeronautical information part, DORI processing should conform to this document for tracing data quality from source to end.

Data quality requirements for DORI depend upon end-user requirements. The main consideration is the spatial resolution of the imagery, that is, the size of the smallest resolvable feature on the image. For example, an aeronautical application that views the land surface from a great height requires imagery of a coarser resolution than a ground-based visualization. An en-route application may require DORI with 10 m resolution or lower, for example, while a taxi positional awareness application may require DORI with sub-meter resolution or better.

As with any geospatial data, it is important to deliver metadata about the imagery when distributing DORI. When DORI is delivered, information that should accompany the files should include:

1. Detailed descriptions about the camera system that took the original imagery
2. The spatial resolution of the original imagery
3. The processing steps that accomplished the DORI
4. The spatial resolution of the final output imagery
5. Accuracy assessments of the final imagery

Metadata may include information about objects in the 3D scene, information about whom to contact for more information about the data or to acquire additional copies. For a full discussion of metadata, see the ISO 19115 specification.

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APPENDIX B: TOR

B.1 Summary

The objective of this chapter is to provide basic information (but not limited to) to ANSP and Airport Operator regarding TOR (Term of Reference) for eTOD data acquisition and supply services.

B.2 Scope of Services

1. eTOD data acquisition for VTBS airport that meets or exceeds the requirements of ICAO annex 15.
2. eTOD data quality control, Upload and Other Services.
   - Quality check the acquired data, and migrate to AIXM 5.1 format.
   - Upload the acquired data into the eTOD tool. (consult CAAT-AIS)
   - Documentation and training related to the above-mentioned Services.

B.3 eTOD Data Acquisition

1. Data Acquisition Requirements – ICAO Annex 15

The data supplied will meet or exceed the ICAO Annex 15 requirements for the eTOD Survey as shown 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

Table B-1: Terrain numerical requirements

		Accuracy	Integrity	Orig Type	Pub. Res.	Chart Res.
Horizontal Position	Area 1	50 m	routine	surveyed	1 sec	as plotted
	Area 2	5 m	essential	surveyed	1/10 sec	1/10 sec
	Area 3	0.5 m	essential	surveyed	1/10 sec	1/10 sec
	Area 4	2.5 m	essential	surveyed	-	-
Vertical Position	Area 1	30 m	routine	surveyed	1 m or 1 ft	3 m (10 ft)
	Area 2	3 m	essential	surveyed	1 m or 1 ft	1 m or 1 ft
	Area 3	0.5 m	essential	surveyed	0.1 m or 0.1 ft	1m or 1 ft
	Area 4	1 m	essential	surveyed	0.1 m	-

Table B-2: Obstacle numerical requirements

2. Data Acquisition Methodology

- Area 2 (including 2a & b)

Methodology: High Resolution Satellite Stereo Data Acquisition & Ground Survey. Newly Tasked High-Resolution Satellite Stereo Data will be used for the data acquisition.

- Area 2c

Methodology: High Resolution Satellite Stereo Data Acquisition & Ground Survey. Satellite Stereo Data Acquisition method will be used for the data acquisition.

- Area 2d (within 45 km TMA area)

Methodology: Medium Resolution Satellite Imagery derived DEM. Airbus SPOT 6/7 Stereo Satellite Imagery for Photogrammetric Mapping data.

3. eTOD survey area

	Area (Sq-km)			
eTOD survey area	Area 2d	Area 2a,2b	Area 2c	Area 3
VTBS	6000	45	360	5

Table B-3: eTOD Survey Area

4. eTOD Survey Data Deliverables

- The following data deliverables according to ICAO Annex 15 requirement will be provided with the data.
- Ground Control Points
    - o Survey Report – PDF format
    - o Field Verification of the Obstacles Data – PDF format
- Satellite Stereo derived Terrain Data including
    - o Digital Terrain Model (DTM) – Grid Format
    - o Digital Surface Model (DSM) – Grid Format
- Obstacles Objects – ESRI Shape File
    - o Points
    - o Polygons
    - o Attributes
    - o Geo Database
    - o Metadata
- Obstacles Data – Derived from ESRI shape file to AIXM 5.1 Format

B.4 Services

1. Quality Control

XXX will quality check the acquired eTOD data, and migrate the data to AIXM 5.1 format and ready for upload into the CAAT-AIS eTOD database.

2. eTOD data upload

XXX will upload the Quality Checked eTOD data into the eTOD tool (consult CAAT- AIS).

3. Other Services

- Documentation:
    - o User Manual for import of the data by the users
    - o User Manual for terrain data processing
    - o User Manual and guidance materials for chart preparation
- Training (*) 1 Week On-Site

  The training proposed is based on the standard training Program.
    - IT Services

IT services include setting up the internal data processing environment, installing the new configuration and updating the system as necessary.

4. Project Management

To complement the above tasks, this proposal includes Project Management services as required to support the deliveries and services.

B.5 Terms and Conditions

1. Duration of Work

1 years

2. Warranty

-

3. Liability for Aeronautical Data

XXX will allocate only qualified staff with many years of relevant experience to carry out the services offered. XXX warrants that all services will be executed with due diligence and on the basis of proven standards and processes.

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APPENDIX C: REFERENCE DOCUMENT

1. CAAT Manual of Standards: Aeronautical Information Services (CAAT-ANS-MOSAIS) Issue 02, Revision 00, Date 24 Feb 2020
2. CAAT WGS-84 Survey Manual for Air Navigation Service Providers and Aerodrome Operators
3. ICAO Annex 15 Aeronautical Information Services
4. ICAO Document 9881 - Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information
5. ICAO Document 10066 Procedures for Air Navigation Services – Aeronautical Information Management