สำนักงานการบินพลเรือนแห่งประเทศไทย
The Civil Aviation Authority of Thailand

WGS-84 Survey Manual for Air Navigation Service Providers and Aerodrome Operators

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Approved By

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Director General

The Civil Aviation Authority of Thailand

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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.

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0	13/MAY/2019	IC/ANS	Initial Issue

4. AMENDMENT TRANSMITTAL PAGE

To: All holders of WGS-84 Survey Manual
for Air Navigation Service Providers and Aerodrome Operators

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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This page shall be returned signed to Quality Assurance Department.

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Manager of ANS

5. DISTRIBUTION LIST

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Table 1: Distribution List

6. DEFINITIONS & ACRONYMS

6.1 DEFINITIONS

Term	Definition
aerodrome elevation	the elevation of the highest point of the landing area
aerodrome mapping data (AMD)	data collected for the purpose of compiling aerodrome mapping information for aeronautical uses
aerodrome mapping database (AMDB).	a collection of aerodrome mapping data organized and arranged as a structured data set
aeronautical data	a representation of aeronautical facts, concepts or instructions in a formalized manner suitable for communication, interpretation or processing
aeronautical information	information resulting from the assembly, analysis and formatting of aeronautical data
aeronautical information product	aeronautical data and aeronautical information provided either as digital data sets or as a standardized presentation in paper or electronic media. Aeronautical information products include: aeronautical Information Publication (AIP), including amendments and supplements; aeronautical Information circulars (AIC); aeronautical charts; NOTAM; and digital data sets. *Note.- Aeronautical information products are intended primarily to satisfy international requirements for the exchange of aeronautical information*
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.*
altitude	the vertical distance of a level, a point or an object considered as a point, measured from mean sea level (MSL)
ArcGIS	a proprietary geographic information system

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
circular error probability (CEP)	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 centre of this circle. *Note.— For GPS, CEP is usually stated at 50%*
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, including, but 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	the probability that the true value of a parameter is within a certain interval around the estimate of its value. The interval is usually referred to as the accuracy of the estimate.
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
corruption	a change to previously correct data introduced during processing, storage, or transmission, which causes the data to no longer be correct.
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
data accuracy	a degree of conformance between the estimated or measured value and the true value
data completeness	the degree of confidence that all of the data needed to support the intended use is provided.
data format	a structure of data elements, records and files arranged to meet standards, specifications or data quality requirements

data integrity (assurance level)	a degree of assurance that an aeronautical data and its value has not been lost or altered since the origination or authorized amendment
data product	data set or data set series that conforms to a data product specification (ISO 19131*)
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 (ISO 19131*).
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 resolution	number of units or digits to which a measured or calculated value is expressed and used
data set	identifiable collection of data (ISO 19101*).
data set series	collection of data sets sharing the same product specification (ISO 19115*).
data timeliness	the degree of confidence that the data is applicable to the period of its intended use
data traceability	the degree that a system or a data product can provide a record of the changes made to that product and thereby enable an audit trail to be followed from the end-user to the originator
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.
DGN	a 2D/3D drawing created by various construction CAD software, such as MicroStation and Intergraph Interactive Graphics Design System. It may be saved in one of two formats, either the Intergraph Standard File Format (ISFF) or the r V8 DGN standard. DGN files are typically used to save designs for construction projects

digital elevation model	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 Elevation Model (DEM)	the representation of terrain surface by continuous elevation values at all intersections of a defined grid, referenced to common datum.
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.
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.
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.
domain	well-defined set. *Note.- Well-defined means that the definition is both necessary and sufficient, as everything that satisfies the definition is in the set and everything that does not satisfy the definition is necessarily outside the 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.

DWG (file)	a database of 2D or 3D drawings created with AutoCAD, a professional CAD program. It contains vector image data and metadata that describes the contents of the file. DWG files are related to .DXF files, which are ASCII versions of DWG files
DXF (file)	data file saved in a format developed by Autodesk and used for CAD (computer-aided design) vector image files, such as AutoCAD documents. DXF files are similar to .DWG files, but are more compatible with other programs since they are ASCII (text) based.
ECW (file)	Enhanced Compressed Wavelet (Image compression format created by Earth Resource Mapping)
elevation	the vertical distance of a point or level on, or affixed to, the surface of the earth measured from mean sea level
ellipsoid 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.
epoch	the "epoch date" is the date associated with the coordinates of a control station. An epoch date is a necessary part of a complete datum or reference frame name, because coordinates can change with time (i.e., they often have non-zero velocities relative to some chosen, stable coordinate reference).
Error	Defective or degraded data elements or lost or misplaced data elements or data elements not meeting stated quality requirements.
ESRI	A corporate entity providing GIS
feature	abstraction of real-world phenomena.
feature association	relationship between features. *Note 1.- A feature association may occur as a type or an instance. Feature association type or feature association instance is used when only one is meant. Note 2.- Feature associations include aggregations of features*

feature attribute	characteristic of a feature. *Note.- A feature attribute has a name, a data type and a value domain associated with it.*
feature catalogue	catalogue 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.
geodesic distance	the shortest distance between any two points on a mathematically defined ellipsoidal surface
geographic information system GIS)	a framework for gathering, managing, and analyzing data. Rooted in the science of geography, GIS integrates many types of data. It analyzes spatial location and organizes layers of information into visualizations using maps and 3D scenes
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. *Note: The geoid is irregular in shape because of local gravitational disturbances (wind tides, salinity, current, etc.) and the direction of gravity is perpendicular to the geoid at every point*
geoid undulation	the distance of the geoid above (positive) or below (negative) the mathematical reference ellipsoid
GeoTIFF (File)	GeoTIFF is format extension for storing georeference and geocoding information in a TIFF 6.0 compliant raster file by tying a raster image to a known model space or map projection
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.

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. *Note.- In the Gregorian calendar, common years have 365 days and leap years 366 days divided into twelve sequential months*
height	the vertical distance of a level, a point or an object considered as a point, measured from a specified datum
integrity (aeronautical data)	a degree of assurance that an aeronautical data and its value has not been lost nor altered since the data origination or authorized amendment
integrity classification (aeronautical data)	classification based upon the potential risk resulting from the use of corrupted data. Aeronautical data is classified as: a) routine data: there is a very low probability when using corrupted routine data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe; b) essential data: there is a low probability when using corrupted essential data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe; and c) critical data: there is a high probability when using corrupted critical data that the continued safe flight and landing of an aircraft would be severely at risk with the potential for catastrophe
KMZ (file)	Keyhole Markup language Zipped: a file that stores map locations viewable in Google Earth, a global mapping program. It contains placemarks that may include a custom name and the latitudinal and longitudinal coordinates of the location.
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 centre of this vertical line. *Note.- LEP is the one-dimensional form of CEP*

metadata	data about data (ISO 19115*). Note.— A structured description of the content, quality, condition or other characteristics of data
model	abstraction of some aspects of reality.
next intended user	the entity that receives the aeronautical data or information from the Aeronautical Information Service.
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.
origination (aeronautical data or aeronautical information)	the creation of the value associated with new data or information or the modification of the value of existing data or information
originator (aeronautical data or aeronautical information)	an entity that is accountable for data or information origination and/or from which the AIS organization receives aeronautical data and aeronautical information
orthometric height	height of a point related to the geoid, generally presented as a mean sea level (MSL) elevation
performance-based navigation (PBN)	area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace.
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. *Note.- In reference to geodetic surveys, precision is a degree of refinement in performance of an operation or a degree of perfection in the instruments and methods used when making measurements.*
quality	degree to which a set of inherent characteristics fulfils requirements. *Note 1.- The term "quality" can be used with adjectives such as poor, good or excellent. Note 2.- "Inherent", as opposed to "assigned", means existing in something, especially as a permanent characteristic.*
quality assurance	part of quality management focused on providing confidence that quality requirements will be fulfilled (ISO 9000*)
quality control	part of quality management focused on fulfilling quality requirements (ISO 9000*)
quality management	coordinated activities to direct and control an organization with regard to quality (ISO 9000*).
quality system	the organizational structure, procedures, processes and resources needed to implement quality management
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 analogue 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 heights.
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. *Note.- Navigation performance and requirements are defined for a particular RNP type and/or application.*
resolution	a number of units or digits to which a measured or calculated value is expressed and used.
RINEX	Receiver Independent Exchange Format: an ASCII standard developed for the easy exchange of GPS data from different types of GPS receivers
SDE table	a command that administers business tables, the data within them, their indexes, and views
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.
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 can be minimized via instrument calibration and/or the use of the appropriate math model.
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. *Note.— In practical terms depending on the method of data collection, terrain represents the continuous surface that exists between the bare Earth and the top of the canopy (or something in between also known as "first reflective surface").*
traceability	ability to trace the history, application or location of that which is under consideration. *Note - When considering product, traceability can relate to: - the origin of materials and parts, - the processing history, - the distribution and location of the product after delivery.*
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. *Note.- The user may also be referred to as the "end user".*
validation	confirmation, through the provision of objective evidence, that the requirements for a specific intended use or application have been fulfilled. *Note 1.- The term "validated" is used to designate the corresponding status. Note 2.- The use conditions for validation can be real or simulated.*

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.
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 centreline(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 centreline(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 centreline(s) and for all other parts of the aerodrome movement area(s), 50 m from the edge(s) of the defined area(s).
World Geodetic System (WGS-84)	published geographical coordinates indicating latitude and longitude shall be expressed in terms of the World Geodetic System - 1984 (WGS-84) geodetic reference datum

6.2 ABBREVIATIONS AND ACRONYMS

Abbreviation or Acronym	Meaning
AIXM	Aeronautical Information Exchange Model
AMD	aerodrome mapping data
AMDB	aerodrome mapping database
amsl	above mean sea level (elevation)
ARP	aerodrome reference point
ASCII	American Standard Code for Information Interchange
A-SMGCS	Advanced Surface Movement Guidance and Control System
DEM	digital elevation model
DORI	Digital Ortho-Rectified Imagery
DPS	Data Product Specification
DSM	Digital Surface Model
DTM	Digital Terrain Model
ED	EUROCAE Document
EGM	Earth Gravitational Model
EGM-96	Earth Gravitational Model - 1996
ELEV	elevation
EPSG	European Petroleum Survey Group
eTOD	electronic terrain and obstacle data
ETRF	European Terrestrial Reference Frame
EUROCAE	European Organization for Civil Aviation Equipment

GIS	geographic information system
GNSS	global navigation satellite system
GPS	Global positioning system
GUND	geoid undulation
ICAO	International Civil Aviation Organization
IERS	International Earth Reference System
INS	inertial navigation system
ITRF	International Earth Rotation Service Terrestrial Reference Frame
ITRS	International Earth Rotation Service Terrestrial Reference System (ITRS)
LEP	Linear Error Probability
LiDAR	Light Detection and Ranging
MEF	Maximum Elevation Figures
MSL	mean sea level
NAVAID	aid to air navigation
NGA	National Geospatial-Intelligence Agency
NOAA	National Oceanographic and Atmospheric Administration
PBN	performance-based navigation
QA	quality assurance
QC	quality control
QM	quality management
QMS	quality management system

RNP	required navigation performance
SAE	Society of Automotive Engineers
SDO	Static Data Operations
RINEX	Receiver Independent Exchange Format
TAWS	Terrain Awareness Alerting System
TCP/IP	Transmission Control Protocol/Internet Protocol
TIN	Triangular Irregular Network
TSO	Technical Standard Order
UDDF	Universal Data Distribution Format
UID	Unique object Identifier
UML	Unified Modelling Language
USGS	United States Geological Survey
UTC	universal coordinated time
UTM	Universal Transverse Mercator
UUID	Universal Unique Identifier
WGS	World Geodetic System
WGS-84	World Geodetic System - 1984 (WGS-84) geodetic reference datum

PART 1. INTRODUCTION

1. HISTORY

As aids to aircraft navigation have progressed over the years from land based aids to include satellite based navigation, and the accuracy of that navigation has also improved, it has become essential for aerodromes operators and air navigation service providers to be able to publish the location and elevation of their facilities accurately to an international framework. Both aircraft and satellites over Asia need to use only one navigation reference, rather than the impractical concept of a separate reference for each country. Such separate mapping or navigational references were found to induce errors, as illustrated below.

The International Civil Aviation Organisation (ICAO) adopted the World Geodetic Survey 1984 (WGS-84) as the common geodetic reference frame for the collection and/or determination of the geographical locations of obstacles, terrain, visual and instrument navigation aids, and associated infrastructure that are required for the safety and efficiency of air navigation. This adoption ensures worldwide uniformity of the coordinates used for air navigation purposes, in particular where an aircraft may use different navigation aids across State borders simultaneously, as shown below.

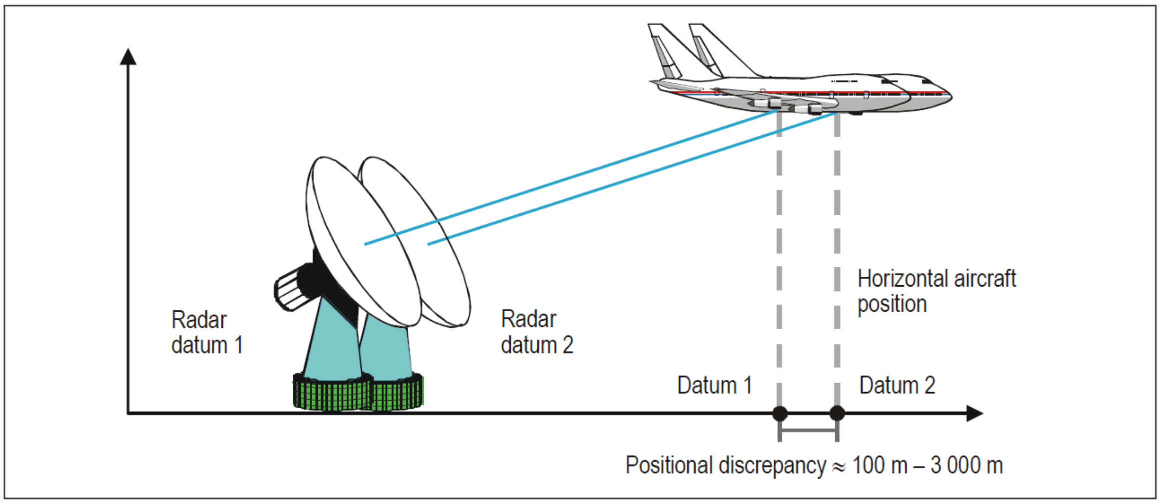


Figure 1: position error from radar sites in different countries to different datum

Therefore, all surveys for aeronautical purposes, whether aerodrome, obstacle or navigation aid related, must be completed in accordance with the Requirements of CAAT,

The objectives of a survey may vary from the implementation of the WGS-84 coordinate system, through the identification and assessment of obstacles, to the collection of data for aerodrome mapping database reasons. This guidance material aims to assist the aerodrome operator in providing correct quality-controlled data and information for these different purposes. The Requirements of CAAT for aeronautical data and an aerodrome mapping database are a prerequisite for aerodrome certification.

The aeronautical and technical terms used in this guidance document are listed in Appendix 1, and a bibliography at chapter 15.

2. MAGNITUDE OF THE PROBLEM

As already outlined the datum discrepancies between one geodetic reference frame and another depend upon:

- Order of magnitude of the three origin shifts
- Magnitude of the three axial rotations
- Scale factor value
- Shape of the reference ellipsoid (if working in geographical coordinates)

The magnitude of positional differences for Europe between points expressed in different geodetic datums. The figure 2 represents the differences in seconds of arc between values in national geodetic datums and WGS-72 in five States for latitude and longitude, respectively.

WGS-72 has been used for this illustration because the transformation parametres from the national geodetic datums were known. From Figure 3, it can be deduced that the differences in position of points with respect to different national geodetic datums and WGS-72 can be in the order of a few hundred metres for a particular country.

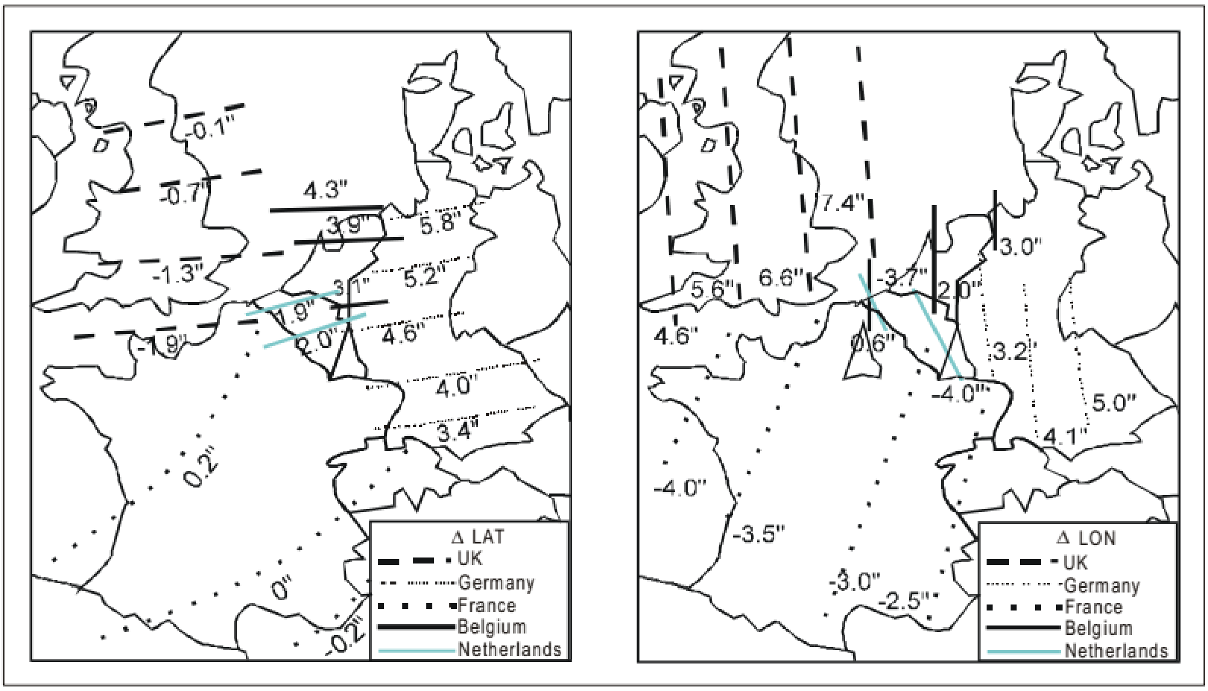


Figure 2: **Δ**LAT, **Δ**LON between local and WGS-72 (")

In Thailand, the coordinates difference between Indian75 and WGS84 are varied about hundreds of metres as shown in figure 3

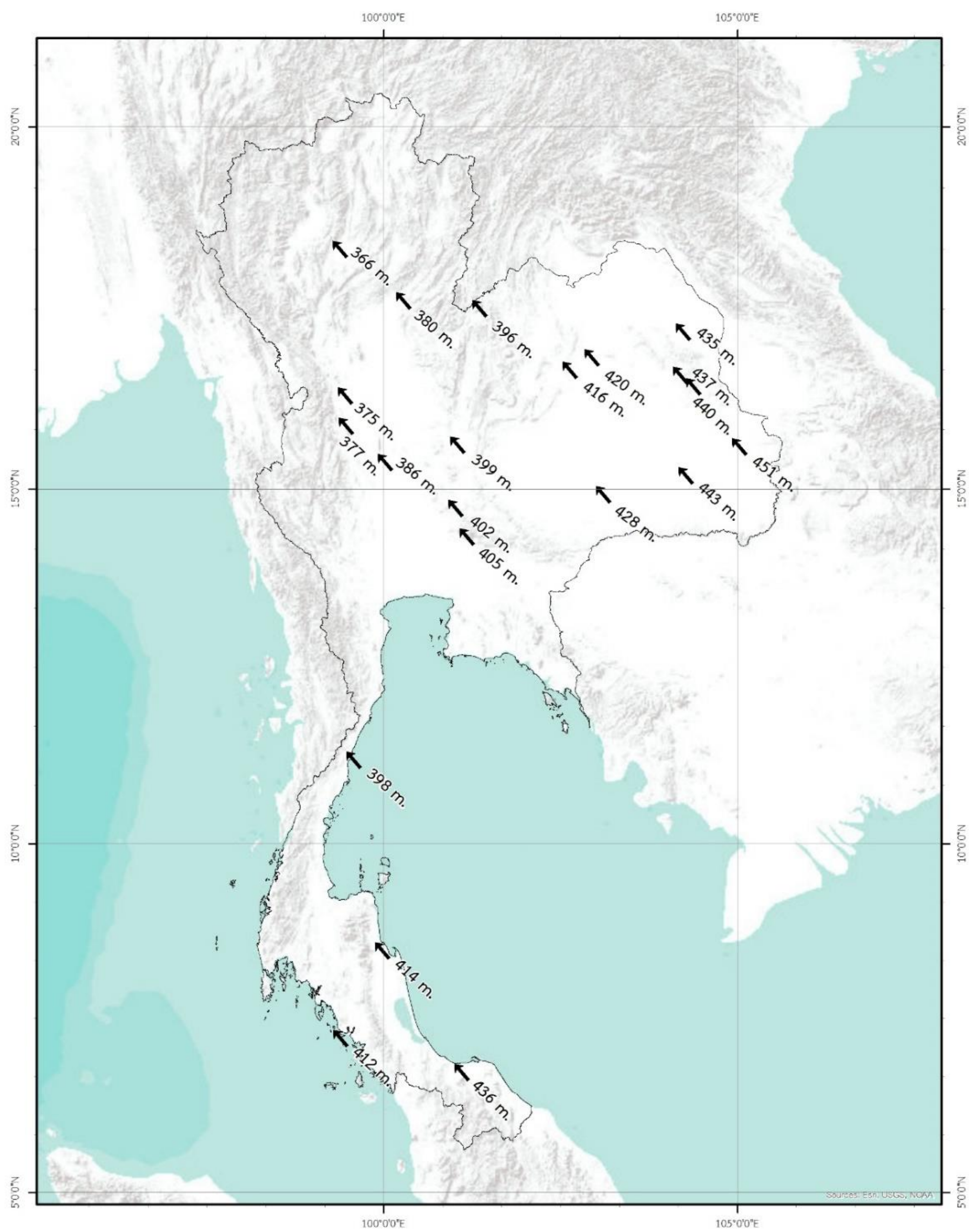


Figure 3: Thailand ΔLAT, ΔLON between Local Datum (Indian 1975) and WGS-84 in metres.

For ground-based uses, the Royal Thai Survey Department announced the parametre to transform Indian 1975 coordinate to WGS84 datum as follow:

$$\Delta X = -206 \text{ m.}$$
$$\Delta Y = -837 \text{ m.}$$
$$\Delta Z = -295 \text{ m.}$$

3. NAVIGATIONAL IMPLICATIONS

Geographical coordinates used in the civil aviation environment today are generally of two types:

3.1 GROUND-DERIVED COORDINATES.

Ground-derived coordinates are those that are obtained through surveys, calculations and measurements. They are published by the civil aviation authorities in Aeronautical Information Publications (AIPs) and charts made available to the public.

Ground-derived coordinates (latitude and longitude) are determined with measurements and calculations on mathematical reference models. These models represent the shape of the earth in a particular geographic region and are called geodetic datums. For example, coordinates used by civil aviation in the United States are mathematically referenced or calculated to the North American Datum (NAD), in Japan to the Tokyo Datum (TD) and in mainland Europe to the European Datum (ED).

Each of these datums uses a different mathematical model that "best fits" or provides the best representation of the earth's shape in that specific geographic region. It is common practice for a State to use a specific datum for all mapping, charting and geodetic activities. The mathematical parametres of these datums differ, the location of the centre of each datum differs and, except for those States that have already converted to an earth-centred datum, none of the datum centres coincides with the centre of gravity of the earth

4. NAVIGATION SYSTEM-DERIVED COORDINATES.

Navigation system-derived coordinates, on the other hand, are coordinates generated by the airborne systems from accelerometres and ground based or satellite-based signals. Unlike ground-derived coordinates, navigation-system derived coordinates are Earth-Centred.

The Inertial Navigation System (INS) uses accelerometres on a gyro or laser ring stabilized platform to sense movement and determine aircraft position. The alignment of the platform relates to the Earth's centre of mass and rotation resulting in INS-generated coordinates that are referenced to the Earth's centre. This means that published coordinates as referenced to local geodetic datums will not compare, directly, with INS-generated coordinates.

Because INS is aligned with local coordinates before take-off, it is most accurate within the area defined by the local datum. Inter-datum flights up to the use of satellite navigation, have not been hindered by the "coordinate shift" which is small compared with the drift of the INS on the en-route phase of long-distance flights

5. GNSS COORDINATES

Coordinates derived by the airborne Global Navigation Satellite System (GNSS) from signals received from satellites will be earth-centred because the GNSS satellites operate with an earth-centred reference model, i.e. WGS-84.

GNSS coordinates will not compare with coordinates based on local geodetic datums except in areas where coordinates have been readjusted to an earth-centred datum. This means that the difference between the coordinates of a point referenced to a local geodetic datum and the coordinates of that same point referenced to the earth-centred WGS-84 datum have to be taken into account.

6. GNSS HEIGHT

GNSS-derived heights are referenced to the WGS-84 ellipsoid which will usually differ from the “normal” (orthometric) height at the same point. The difference will be of significance in the aerodrome environment when navigating with GNSS sensors. The difference between orthometric height (geoid height, elevation) and WGS-84 ellipsoidal height must therefore be made available to the aviation community. The height that separates geoid and WGS-84 ellipsoid is the geoid undulation. Geoid undulation is required for airport elevations, runway thresholds and touchdown and lift-off areas (TLOFs) or thresholds of final approach and take-off areas (FATOs) at heliports. The standard for use in civil aviation is the geoid derived by the earth gravitational model 1996 (EGM 96)

7. SOLUTION TO ELIMINATE DIFFERENT LOCAL DATUM

The solution to this problem was to implement WGS-84 as a common geodetic reference frame. The challenge is to ensure that, for aeronautical purposes, the WGS84 reference frame used meets the accuracy and quality requirements – that it is the correct reference frame.

The most precise geodetic measuring techniques for long base lines are, at present, satellite laser ranging (SLR) and very long base-line interferometry (VLBI). Both techniques guarantee a precision of 1 to 3 cm over distances up to about 5 000 km. Global networks of up to 70 SLR stations and up to 81 VLBI stations were established for continuous observation and data collection. Since 1987, a new International Earth Rotation Service (IERS) has been operating, making use of SLR and VLBI results predominantly, and producing a new global set of X, Y, Z coordinates every year by combining various SLR and VLBI solutions.

The precise SLR technique has led to a precise worldwide terrestrial coordinate system, called the International Terrestrial Reference System (ITRS). The ITRS is maintained by the IERS and the realization of the ITRS is the International Terrestrial Reference Frame (ITRF).

The first step in the implementation of any coordinate transformation proposal is to carry out an inventory. In order to make an assessment of the quality of the published aeronautical geographical coordinates required for air navigation, it is necessary to review all existing related records of aeronautical coordinate data.

A questionnaire for survey inventory is provided by CAAT. Information provided through the use of such a questionnaire will allow for accurate estimates and identification of those items for which a field survey is required in order to verify or correct positions and existing reference datum.

Moreover, analysis of the questionnaire data will identify the navigation aids and aerodrome points and facilities which need to be re-surveyed to update coordinate and datum reference to WGS84. However, where coordinates meet the required accuracy and integrity it will allow direct transformation to the WGS 84 geodetic reference frame by mathematical means.

8. LOCAL DATUM TRANSFORMATION TO WGS-84

In principle, there are two approaches which can be used as stand-alone or combined methods to transform a survey given in adequately accurate coordinates in Thailand, that has local datum as Indian 1975, to WGS-84

1. Survey and establish at least three control stations (covering the area under consideration, and for larger airports more than three control stations will usually be necessary) in accordance with chapter 5 to obtain WGS-84 coordinates and determine the datum parametres between the local reference frame and WGS-84
2. Determine by a computational datum transformation WGS-84 coordinates for all remaining points

There are two general groups of air navigation points for which geographical coordinates are required (see Table 2)

AREA/EN-ROUTE COORDINATES	AERODROME COORDINATES
ATS/RNAV route points	Aerodrome/heliport reference points
Holding points	Runway, FATO thresholds
En-route radio navigation aids	Terminal radio navigation aids

AREA/EN-ROUTE COORDINATES	AERODROME COORDINATES
Restricted/prohibited/danger areas	FAF, FAP and other IAP essential points
Obstacles — en route	Runway centre line points
FIR boundaries	Aircraft standpoints
CTA, CTZ	Aerodrome/heliport obstacles
Other significant points	

Table 2 groups of air navigation coordinates

PART 2. OBJECTIVES OF A SURVEY

1. THE PRIMARY AIMS

1. to meet the Requirements of the CAAT No.12 Air navigation Service Certification and;
2. to meet the Requirements of the CAAT No.14 Aerodrome Standards,
3. the provision of electronic Terrain and Obstacle Data (eTOD), and
4. to provide the aerodrome mapping database for operational purposes in addition to the requirements of the CAAT.

2. SPECIFIC OBJECTIVES

1. Aerodromes;
2. Air navigation service providers;
3. Certification of aerodromes for certain types of operations;
4. Determination of maximum take-off weights through accurate determination of runway declared distances and take-off obstacles;
5. Aircraft operating limitations analysis;
6. Update of aerodrome ground movement and control systems e.g. advanced surface movement guidance and control system (A-SMGCS) and their inclusion in the AMDB;
7. Airport planning and land use studies;
8. Provision of geodetic control for engineering projects;
9. Development of instrument approach and departure flight procedures including circling procedures and PBN approaches / departures;
10. Determination of contingency procedures for use in the event of an emergency during a missed approach or take-off;
11. Determination of en-route “drift-down” procedure and en-route emergency landing location;
12. Setting up eTOD and aerodrome mapping databases to meet both regulatory and additional operational user requirements;
13. Aeronautical chart production;
14. Update of the aeronautical information publication (AIP);
15. Ground proximity warning system (GPWS) with forward looking terrain avoidance function and minimum safe altitude warning system;
16. Update of on-board databases of the flight management systems.

PART 3. RESPONSIBILITIES – AERODROME/ AIRCRAFT OPERATORS/REGULATOR/ ANS & AIS

1. RESPONSIBILITIES – AERODROME/AIRCRAFT OPERATORS/ REGULATOR/ANS & AIS

The aerodrome operator is responsible for meeting all of the Requirements of the CAAT No.14 Aerodrome Standards. This does not necessarily mean that the aerodrome operator will carry out all of the surveys and data collection themselves, but may share the collection of data with the ANSP organised through either a contract or memorandum of understanding which clearly specifies the responsibilities between the two or more parties, including data quality control.

2. RESPONSIBILITIES – ANS & AIS

The ANS service provider is responsible for the collection and dissemination of data in accordance with CAAT Requirements, including the quality control thereof.

AIS is responsible for the promulgation of data, including the quality control thereof.

3. RESPONSIBILITIES – AIRCRAFT OPERATORS

Aircraft operators are responsible for only using State promulgated data, or data that has originated from the State entity.

4. RESPONSIBILITIES – REGULATOR

The CAAT is responsible for specifying the Requirements in accordance with ICAO standards and recommended practices and for promulgating the data, through AIS.

PART 4. THE REFERENCE SYSTEMS: WGS84 AND EGM96

1. THE WORLD GEODETIC SYSTEM — 1984 (WGS-84)

THE WORLD GEODETIC SYSTEM — 1984 (WGS-84) shall be used as the horizontal (geodetic) reference system for international air navigation. Consequently, published aeronautical geographical coordinates (indicating latitude and longitude) shall be expressed in terms of the WGS-84 geodetic reference datum. This is not the same as a local construction surveyor simply reporting coordinates in latitude and longitude, but may require the import of the international terrestrial reference framework, establishment of survey control stations and subsequent survey and collection of data in accordance with both the ICAO Doc 9674, World Geodetic System — 1984 (WGS-84) Manual, and the ICAO Doc 9881, Electronic Terrain and Obstacle and Aerodrome Mapping Manual

With these increased accuracies, the movement of parts of the earth's crust that may cause coordinates to change with time must also be considered. In precise geodetic applications and some air navigation applications, temporal changes in the tectonic plate motion and tidal effects on the Earth's crust should be modelled and estimated. Therefore, to reflect the temporal effect, an epoch should be included with any set of absolute station coordinates, Annex 15 (2018).

The epoch of the WGS-84 (G873) reference frame is 1997.0 while the epoch of the latest updated WGS-84 (G1150) reference frame, which includes a plate motion model, is 2001.0. G indicates that the coordinates were obtained through Global Positioning System (GPS) techniques, and the number following G indicates the GPS week when these coordinates were implemented in the United States' National Geospatial-Intelligence Agency's precise ephemeris estimation process. The set of geodetic coordinates of globally distributed permanent GPS tracking stations for the most recent realization of the WGS-84 reference frame (WGS-84 (G1150)) is provided in Doc 9674.

For each permanent GPS tracking station, the accuracy of an individually estimated position in WGS-84 (G1150) has been in the order of 1 cm (1d). Another precise worldwide terrestrial coordinate system is the International Earth Rotation Service (IERS) Terrestrial Reference System (ITRS), and the realization of ITRS is the IERS Terrestrial Reference Frame (ITRF). Guidance material regarding the ITRS is provided in Appendix C of Doc 9674. The most current realization of WGS-84 (G1150) is referenced to the ITRF 2000 epoch. WGS-84 (G1150) is consistent with ITRF 2000 and in practical realization the difference between these two systems is in the one- to two-centimetre range worldwide, meaning WGS-84 (G1150) and ITRF 2000 are essentially identical.

2. THE EARTH GRAVITATIONAL MODEL- 1996 (EGM-96)

The vertical reference system used shall be the mean sea level (MSL) datum, which gives the relationship of gravity-related height (elevation) to the geoid surface.

The geoid is the equipotential surface in the gravity field of the Earth which coincides with the undisturbed MSL extended continuously through the continents.

Gravity-related heights (elevations) are also referred to as orthometric heights while distances of points above the ellipsoid are referred to as ellipsoidal heights. The geoid model used for mean sea level for aeronautical purposes in Thailand shall be the Earth Gravitational Model-1996 (EGM-96), and not later EGM models. EGM-96 is the ICAO standard.

3. THE ELLIPSOID

The ellipsoid is a mathematical earth model of the true shape of the earth (geoid) in such a way as to minimize the differences between the ellipsoid and the geoid over the area of interest. Each State might have its own ellipsoid for its national mapping purposes, but in aviation, we need a worldwide mathematical model ellipsoid, both for satellite navigation and for consistency between adjacent countries' navigation aids. The world geodetic system ellipsoid is illustrated here:

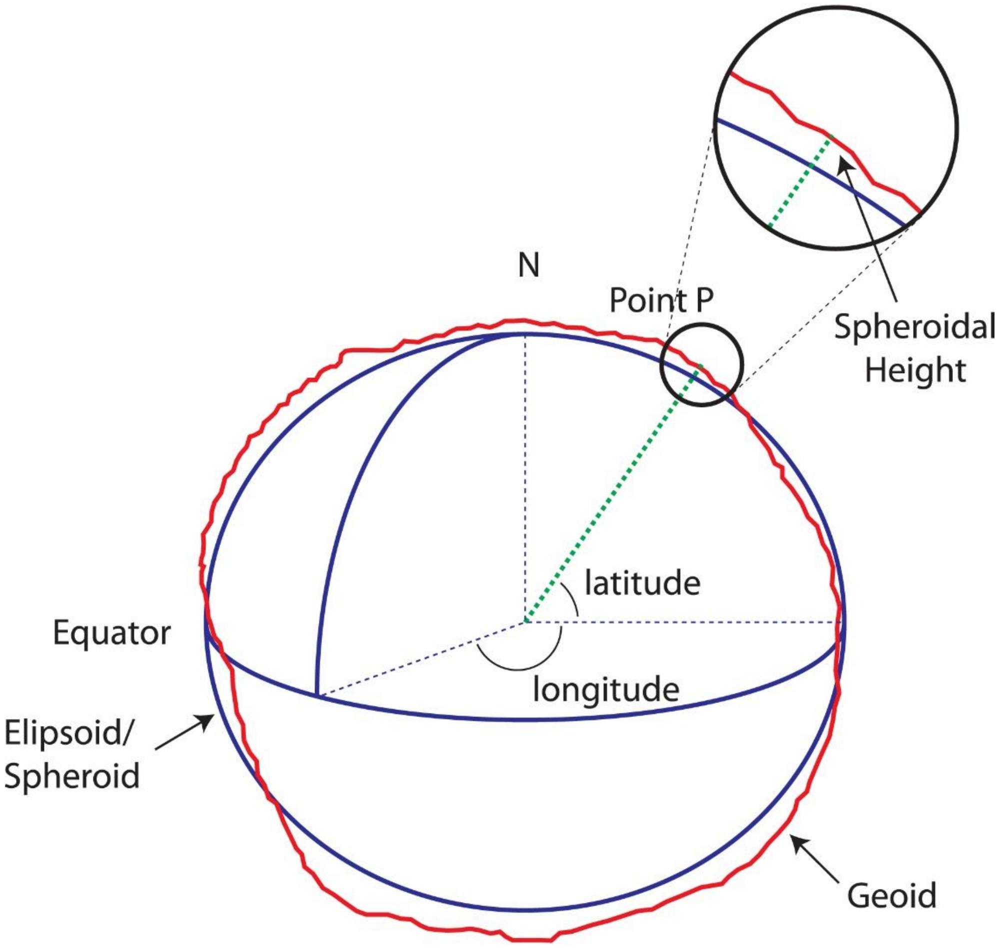


Figure 4: the global ellipsoid

In addition to elevation referenced to the MSL (geoid), for the specific surveyed ground positions, geoid undulation, or GUND, (referenced to the WGS-84 ellipsoid) is also required for the mandatory survey points, but not necessarily for other mapping database features. The geoid undulation (N in the diagram) and the relationship between geoid (MSL), the terrain, and the ellipsoid is illustrated overleaf.

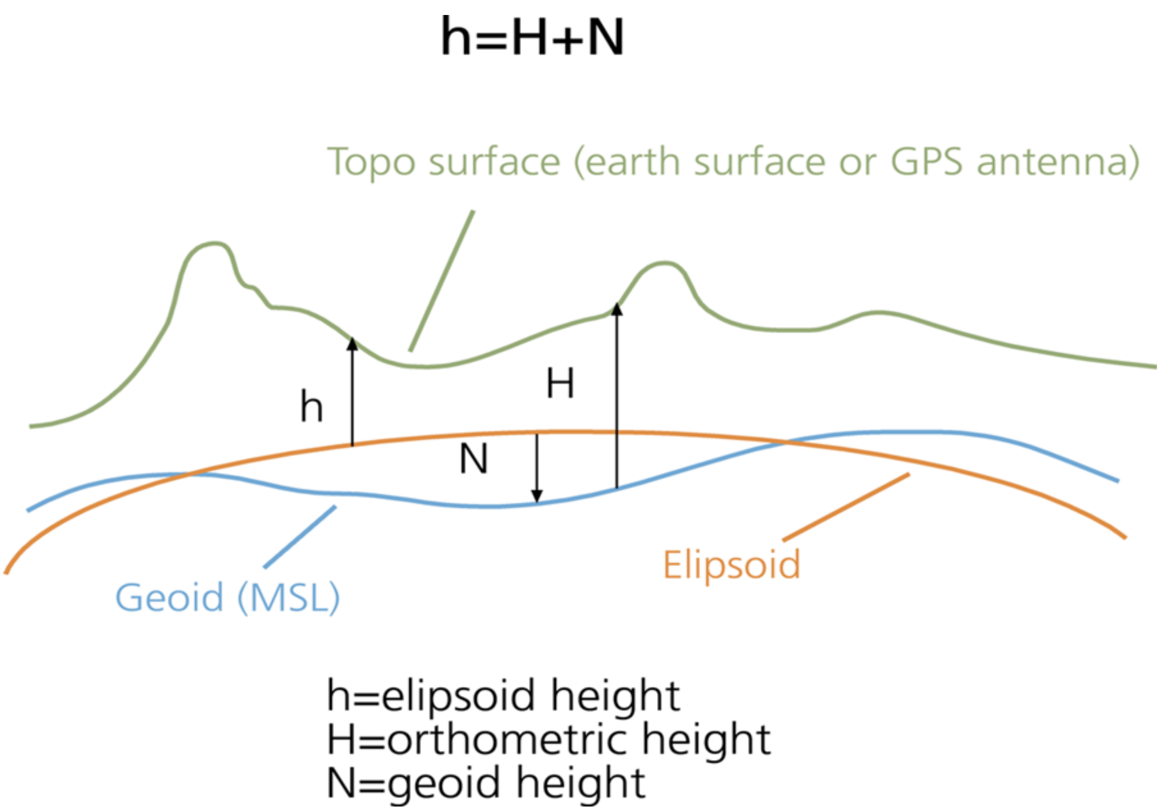


Figure 5: Ellipsoid, geoid and terrain

As shown, the geoid undulation can be either positive or negative, meaning that the geoid can be either below or above the ellipsoid. This mathematical ellipsoid provides a constant reference globally for the satellites used in satellite navigation; this would not be practical using hundreds of different national datums around the world.

PART 5. SURVEY AREA

1. THE ETOD AREA

Different areas need to be surveyed, and these are broken down within the scheme for electronic terrain and obstacle data (eTOD), ICAO Annex 15. The definitions of the different eTOD areas are:

Area 1: the entire territory of a State;

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

Area 2a: a rectangular area around a runway that comprises the runway strip, according to the aerodrome reference codes and runway type n the Aerodrome Standards, plus any clearway that exists;

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

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

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

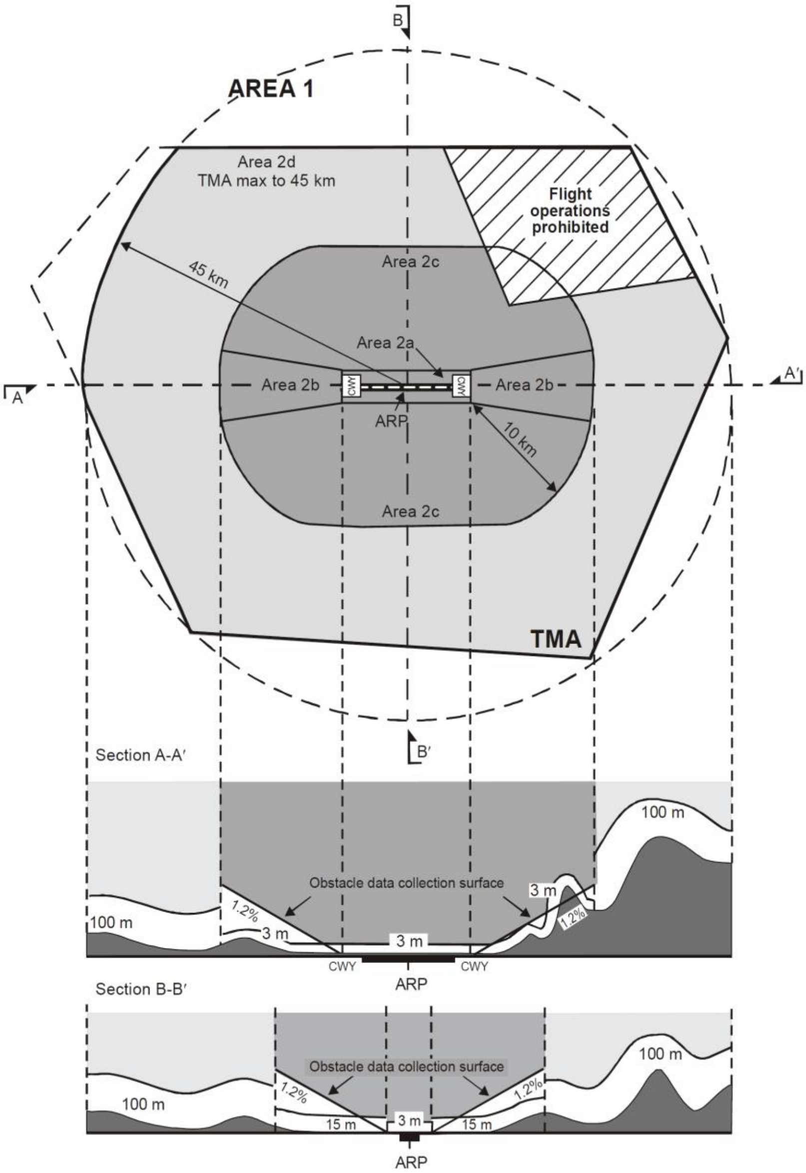
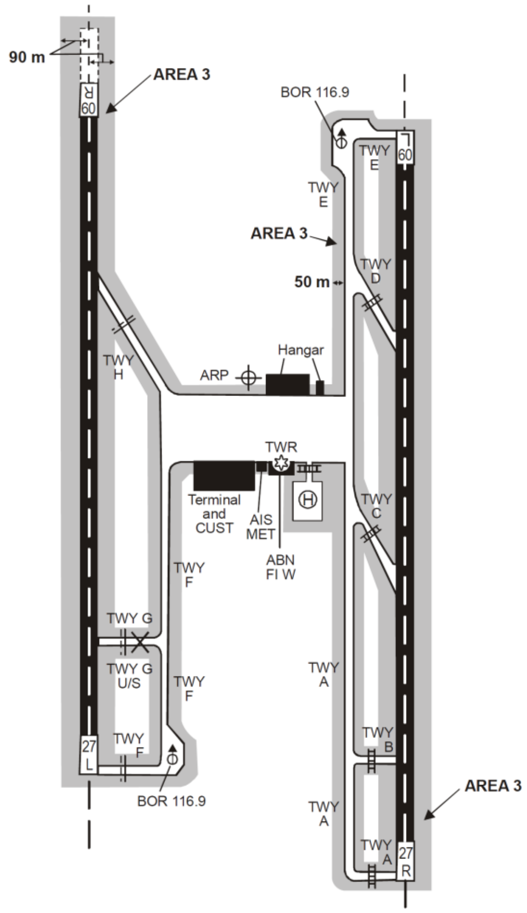


Figure 6: Obstacle data collection surfaces — Area 1 and Area 2

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

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



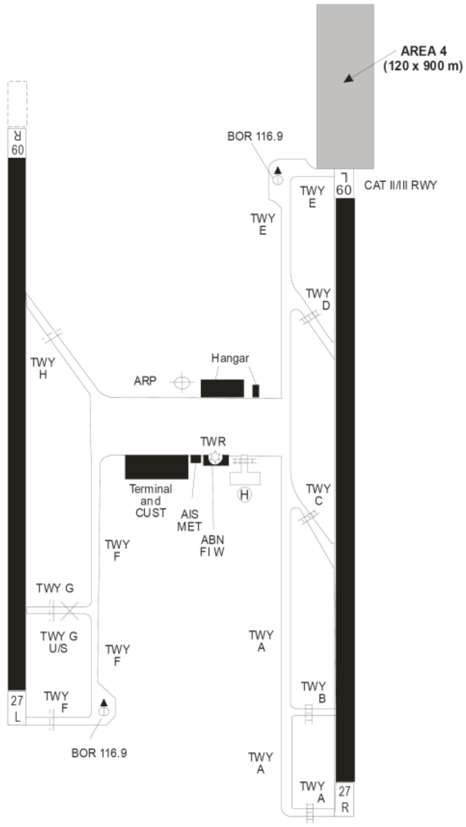


Figure 2-6. Terrain data collection surface — Area 4

Figure 7: Obstacle data collection surfaces — Areas 3 and 4

Additional data and information gathering for the aerodrome mapping database (AMDB), and further explanation of the AMDB is detailed below in section 10.

PART 6. SCOPE OF THE SURVEY WORKS

Aeronautical surveying is a highly specialised task, so an aerodrome operator might contract the survey and collection of data or agree with another service provider to share the responsibility. For guidance in compiling a contract or letter of agreement specifications the following is a suggested scope of the survey works that may be required.

1. Mobilisation to/from the work sites;
2. Carrying out community sensitizations, whenever necessary, in the areas to be mapped;
3. The repair or resurvey and monumentation of any existing Airport Survey Control Network in compliance with ICAO Document 9674 specifications;
4. Supply and positioning of sufficient ground based Global Navigation Satellite System base stations as required to achieve the specified survey accuracy. As far as practicable, the survey control stations shall be located in secure areas, including airside, where they are unlikely to be disrupted in the future;
5. Setting out and monumentation of the Aerodrome Reference Point (ARP). Where practicable, the ARP monument shall geo-connect with Royal Thai Survey Department monument Secondary Network within the appropriate baseline length (may be 100 Km).;
6. Identification and survey of the aerodrome elevation location, which is the elevation of the highest point of the landing area;
7. Provision of aviation services, installation and calibration of aerial camera and LiDAR equipment plus associated ancillary aircraft services/provisions as necessary, if photogrammetry and/or LiDAR methods are to be used;
8. Gaining of all necessary approvals from the relevant aviation, military, government or other authorities as may be required, for the execution of the project;
9. Ground survey and satellite and/or aerial photography and LiDAR survey, as appropriate, of the required area (Outer Horizontal Surface, Area 2, 3 and 4), in order to meet the CAAT Aerodrome Standards, in addition to obtaining the required point density, swath coverage and digital imagery product requirements;
10. Processing and formatting of the aeronautical survey data and maps/charts in accordance with the technical specification requirements described in the referenced documents;
11. Delivery of the 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, and ICAO Doc 10066 PANS-AIM;
12. Invite the CAAT AGA and ANS surveying and engineering personnel to participate in or observe the surveying operation, including the capture of features or points within the project area of the outer horizontal surface. This participation includes but is not

limited to the setting out of survey controls like the airport survey control network, aerial photogrammetry control as well as airside survey data capture;

13. Data usage, integration and interpretation training with comprehensive training records and certification; loading the data onto the client's databases, auto generating an aerodrome terrain and obstacle chart, and providing instructions on the use of the data.
14. Complete a checklist, compliant with Appendix 2, of air navigation elements or positions with the specified related accuracy and integrity classification whose geographical coordinates must be surveyed according to the WGS-84 reference frame and elevations/heights determined according to the Earth Gravitation Model 1996 (EGM-96).
15. In addition to items above and in Appendix 2, the following aerodrome related elements may need to be included and have their geographic coordinates and elevations surveyed:
    a. aerodrome reference point coordinates and elevations,
    b. aerodrome elevation location,
    c. navigation checkpoints,
    d. navigation aid buildings,
    e. operational features,
    f. obstacle elements,
    g. AGL: approach runway taxiway and apron lights,
    h. aerodrome signs,
    i. floodlights, and obstacle lights;
    j. the top point and foundation level of each of the PAPI units, and the centre of PAPIs' lenses, for MEHT calculation purposes;
    k. aerodrome beacon (Identification or location beacon),
    l. stand alone transformers on the aerodrome,
    m. aircraft stand points (T at head of each stand),
    n. passenger boarding bridges,
    o. meteorological stations, anemometers, IRVR sensors, wind direction indicators,
    p. ATC tower,
    q. Navigation aids: DME, VOR, NDB, VHF & UHF direction finding, ILS localizer, glidepath and monitors
    r. radar antenna, radio communication antenna,
    s. ground based GNSS local area augmentation system equipment
    t. HF and VHF transmitters and receivers,

u. lightning conductors of navigation aids, where fitted above the level of the antennae
v. runway centre-line elevation points,
w. runway holding positions, intermediate-holding positions, road holding positions,
x. thresholds, and pre-threshold markings,
y. coordinates and elevations of start and end of TORA if not otherwise captured,
z. End of ASDA, LDA, TODA
aa. runway extremities if not included in the declared distances above
bb. FATO and TLOF,
cc. drainage channels in the runway strips and at emergency exit gates
dd. fire stations, and fire training facilities, emergency water supply tanks,
ee. airport rendezvous point, and emergency access/egress gates and routes,
ff. water rescue station jetties/launching sites,
gg. aerodrome boundary fence, and normal airside vehicle access gates/control points,
hh. aerodrome/heliport magnetic variation,
ii. VOR station declination used for technical line-up and
jj. ILS localizer antenna magnetic variation.

16. The surveyor/ consultant should submit a risk register indicating clearly all the anticipated risks and proposed mitigation measures to address such risks, and maintain this register up to date throughout the survey operation.

PART 7. METHODOLOGY

1. PROPOSE OF SURVEY METHODOLOGY

The proposed survey and data gathering solution should generate spatial and non-spatial data / information of the area of interest to be used for aerodrome mapping, terrain modelling and obstacle mapping for the safe operation of aerodromes and aircraft. The project implementation plan should be reviewed with the relevant parties, such as aerodrome operator and ANSP to check the work plan and deliverables. Appropriate reference should be made to the WGS-84 Manual, (ICAO Doc 9674), Electronic terrain and obstacle and aerodrome mapping manual (ICAO Doc 9881), Requirements of CAAT No.14 Aerodrome Standards, and all reference material indicated in section 15 of this guidance material during the implementation of the entire project.

2. WORK METHOD

The preferred work method may vary according to the different areas and deliverables, and may include:

2.1 CONVENTIONAL SURVEYING TECHNIQUES

conventional surveying techniques to supplement the GPS surveying procedure. (Refer to ICAO Doc 9674 Appendix A and E).

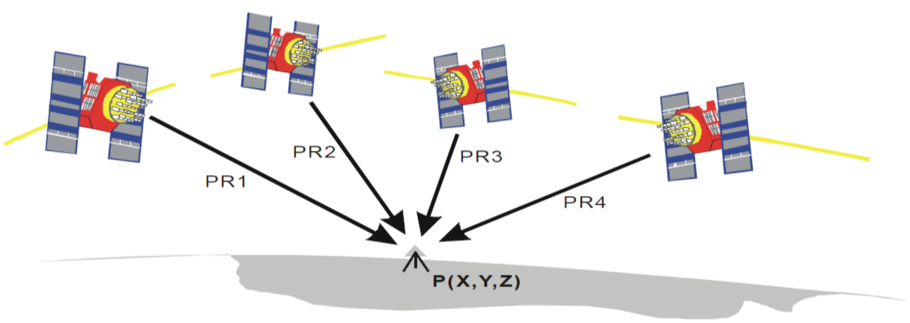


Figure 8: Principle of GPS absolute positioning

2.2 PHOTOGRAMMETRY

Overlapping photo strips forming a block to make a stereo model photography

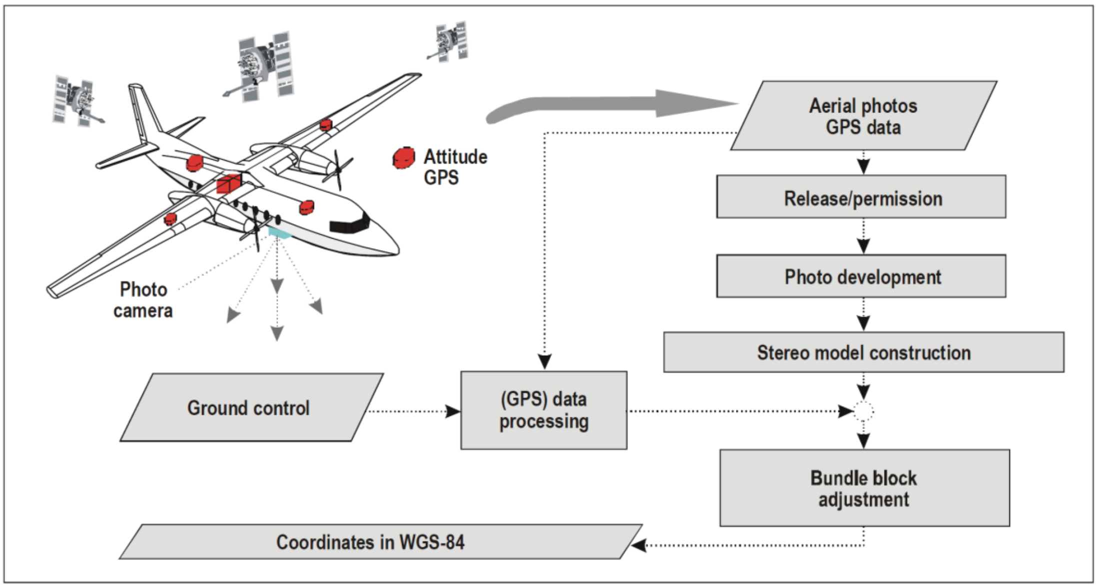


Figure 9: Flow diagram of results of photogrammetric flights to WGS-84 coordinates

2.3 DIFFERENTIAL GEODETIC SATELLITE SURVEYING TECHNIQUES

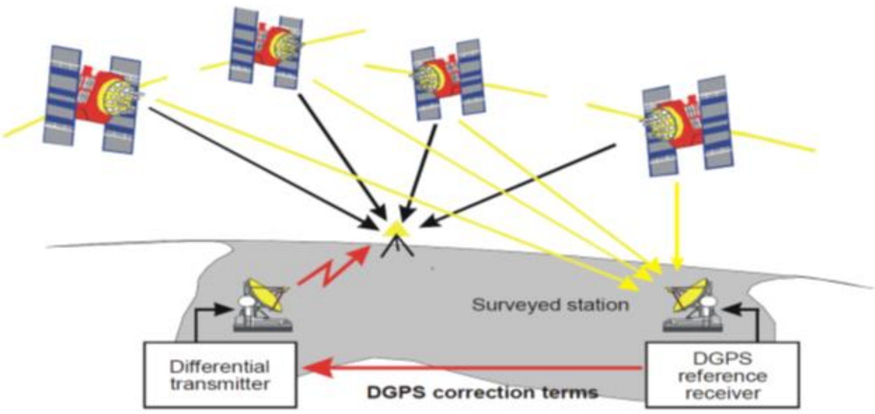


Figure 10: Differential GPS real-time positioning

2.4 LIDAR (LIGHT DETECTION AND RANGING)

LIDAR, which stands for Light Detection and Ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure ranges (variable distances) to the Earth. These light pulses—combined with other data recorded by the airborne system— generate precise, three-dimensional information about the shape of the Earth and its surface characteristics.

2.5 DIGITAL AERODROME MAPPING

including extraction of DEM, DTM, DSM and generation of contours at appropriate intervals

2.6 DATA FROM GROUND SURVEY

For the aerodrome survey control network and aerial photography/LiDAR survey, the ground control survey shall include

1. Location of ground control points (GCPs);
2. Monumentation of aerodrome survey control network stations as well as aerial photography control points;
3. Survey stations/ground control points must be strategically located to provide maximum utility and durability in subsequent surveys, whether by the same surveyor again, or by other surveyors;
4. Global Positioning System (GPS) and GNSS observations;
5. Processing WGS-84 coordinate information;
6. Field and office operations;
7. Aerial Photography & LiDAR Survey

3. SURVEY POSITION

Illustrations of the exact points to be surveyed are illustrated in the following pages. Details for collection of information and data for the aerodrome mapping database are included in chapter 10, below.

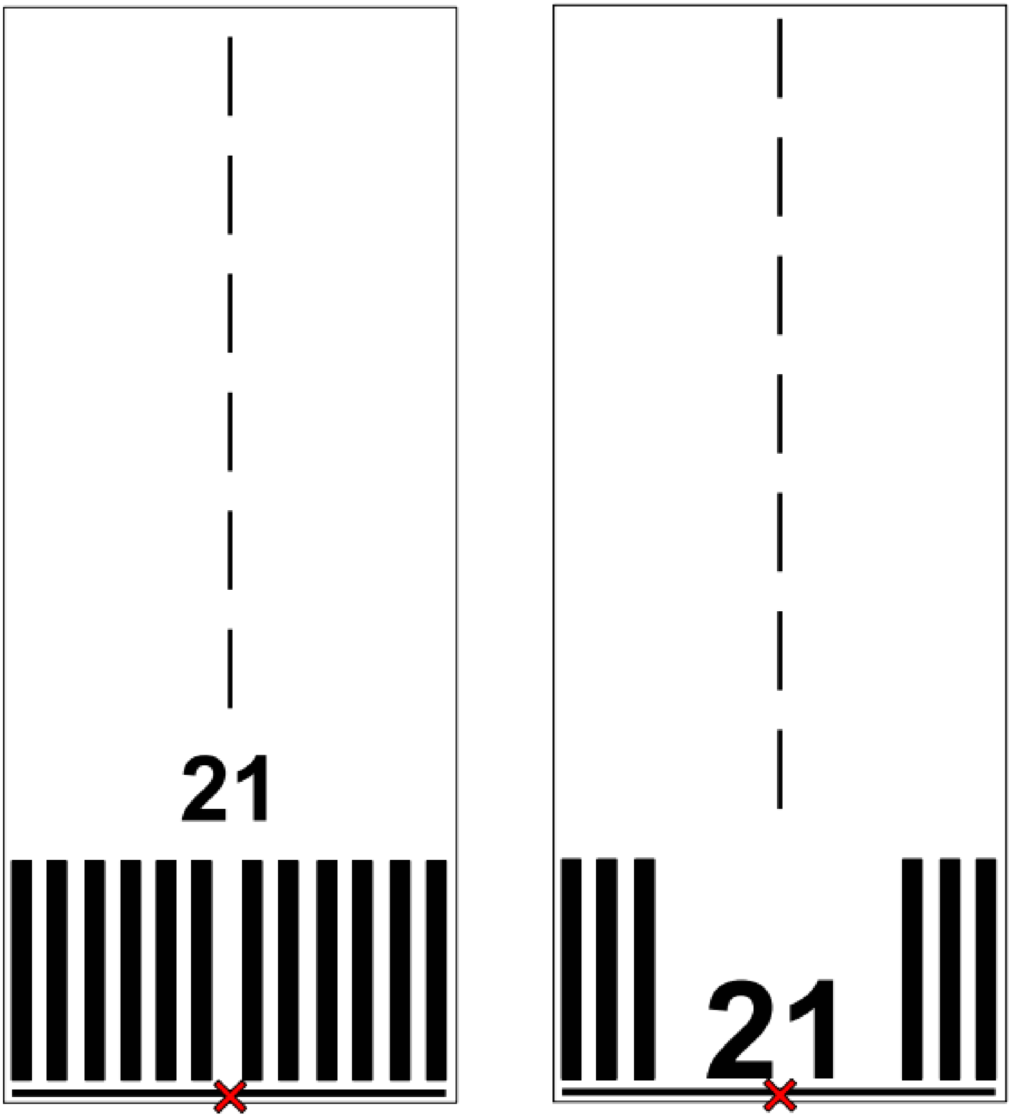


Figure 11: Sample detail for the location of a threshold survey point marker

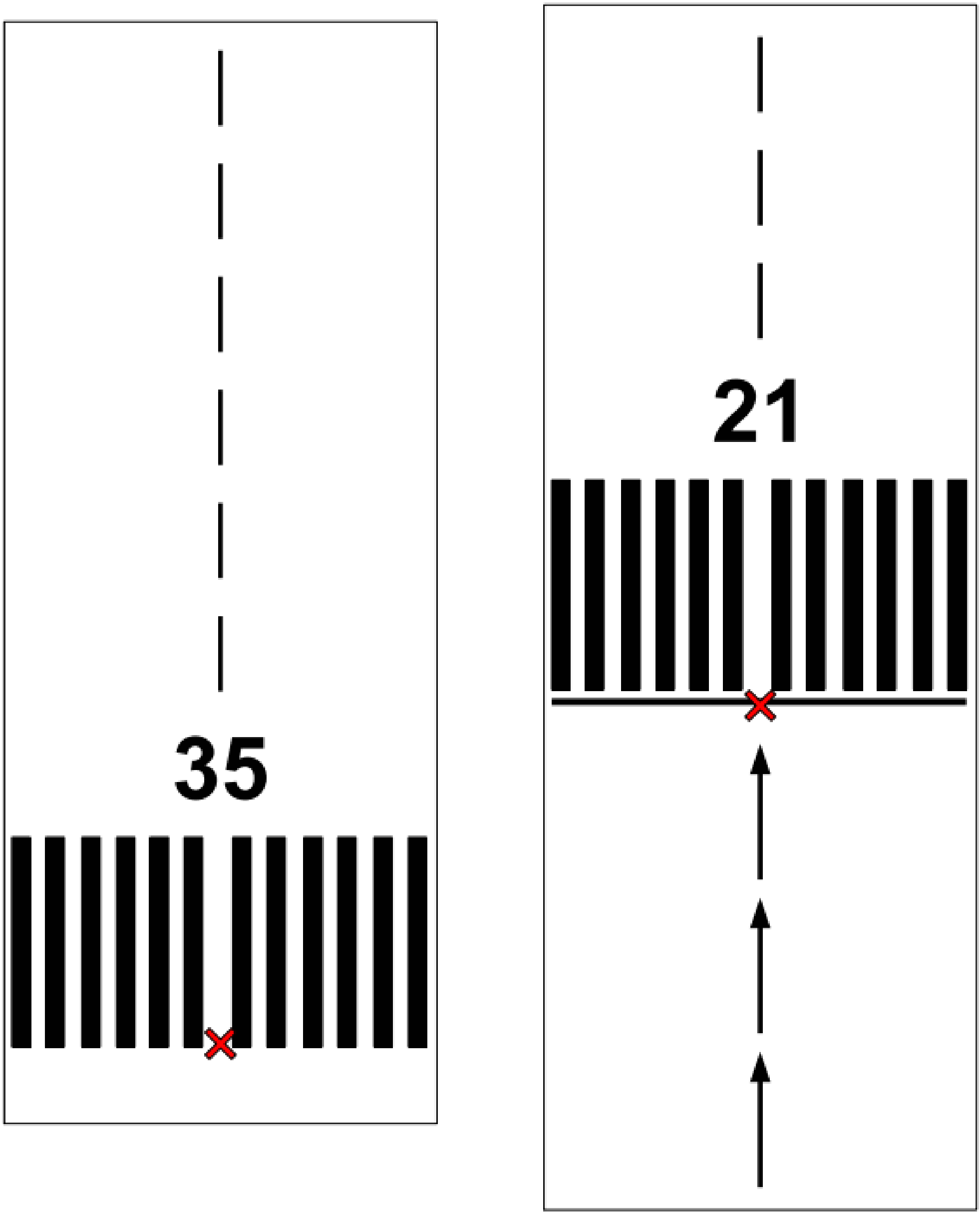


Figure 12: Sample detail for the location of a threshold survey point marker

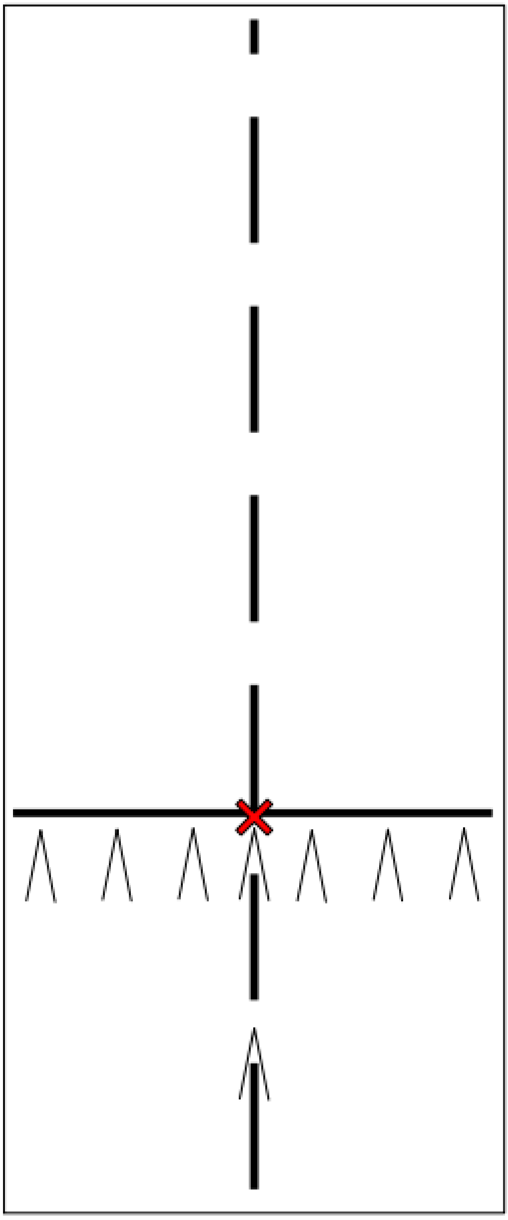


Figure 13: Sample detail for the location of a threshold survey point marker

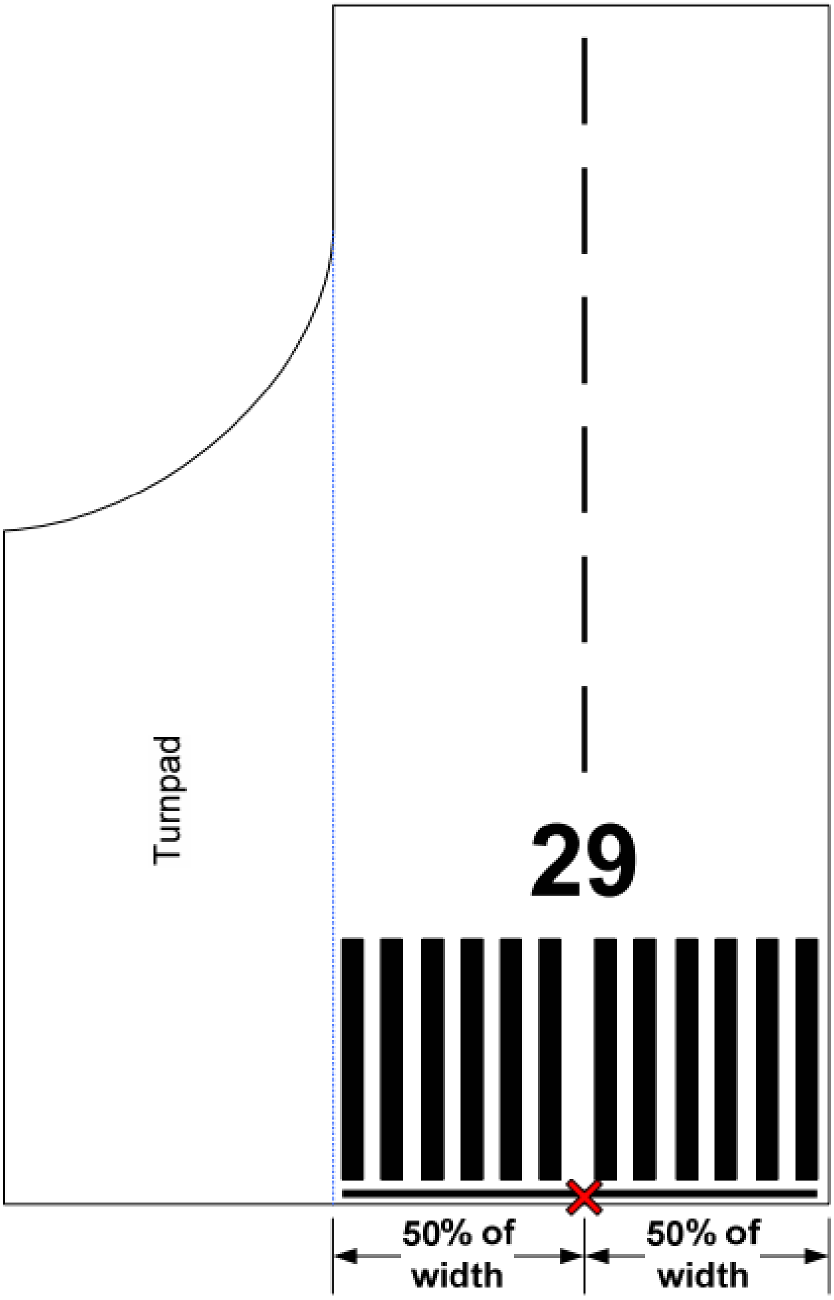


Figure 14: Sample detail for Runway Centre line with Turnpad

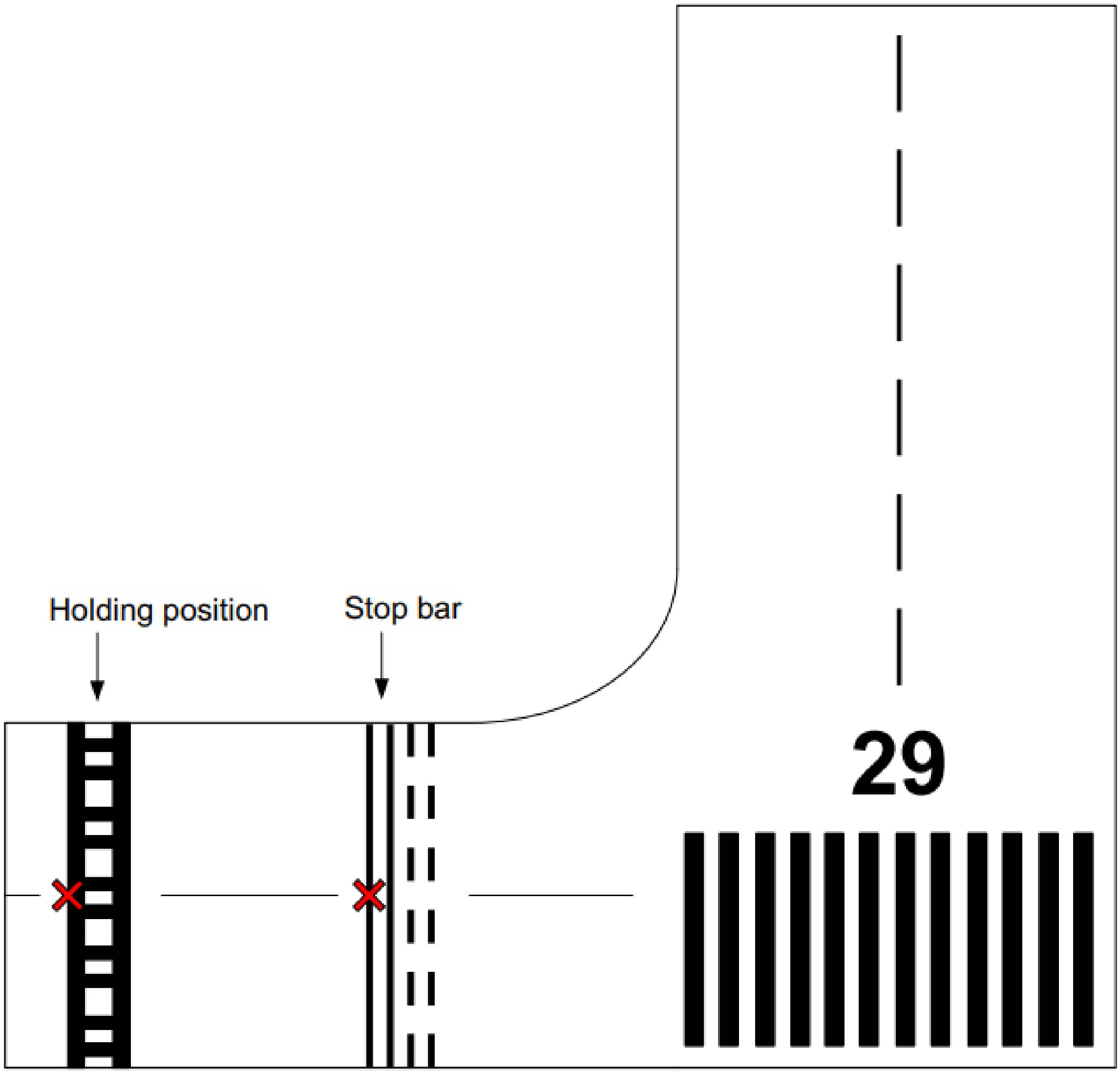


Figure 15: Sample detail for Intermediate Holding Positions and Stop Bars

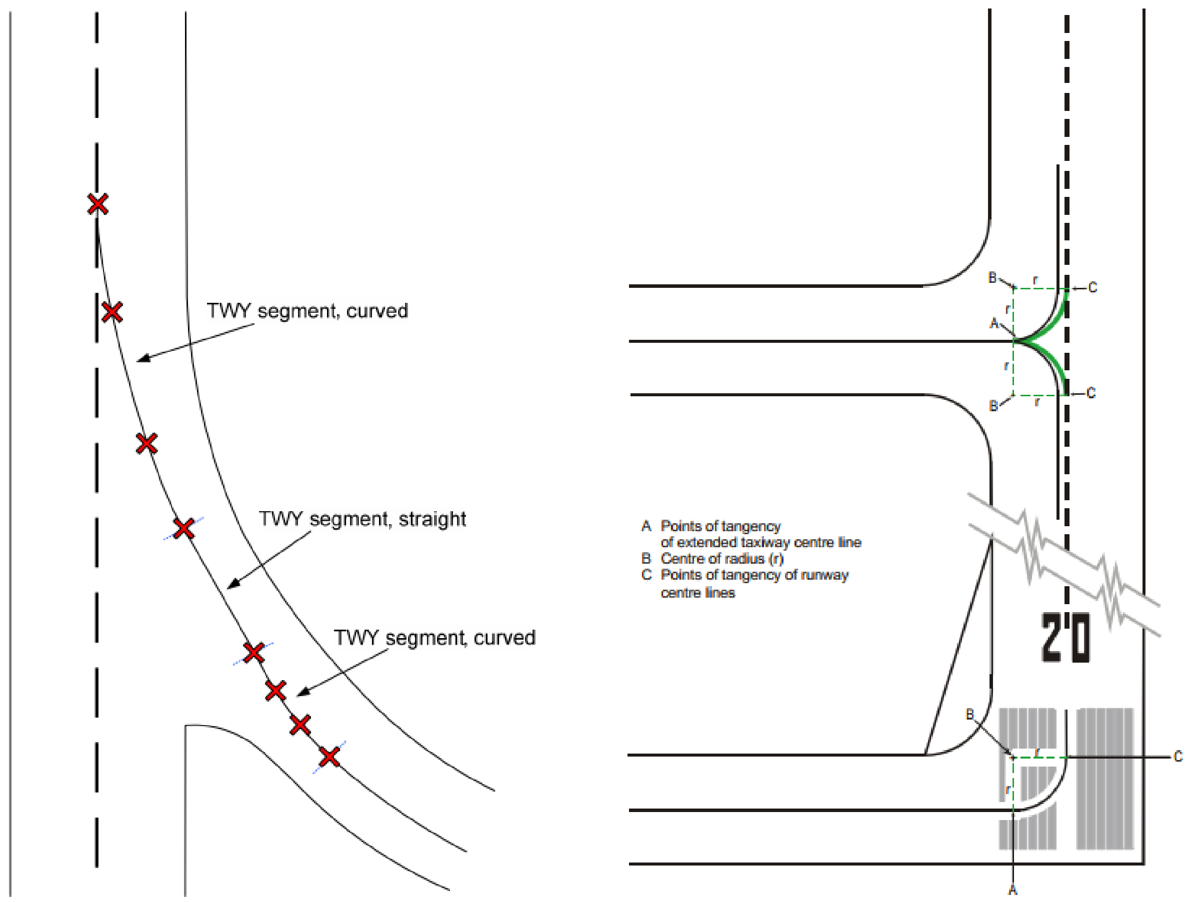


Figure 16: Sample detail for Taxiway Markings

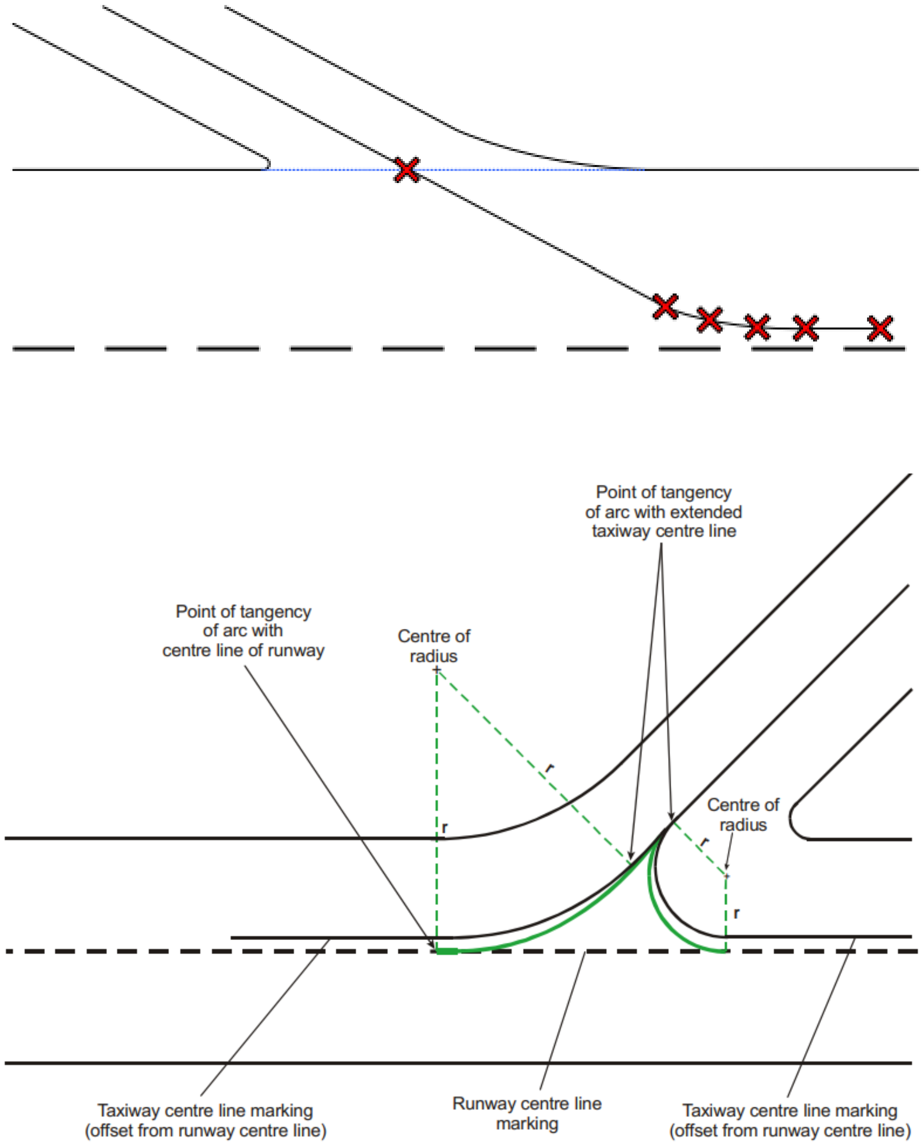


Figure 17: Sample detail for Taxiway on Runway Marking

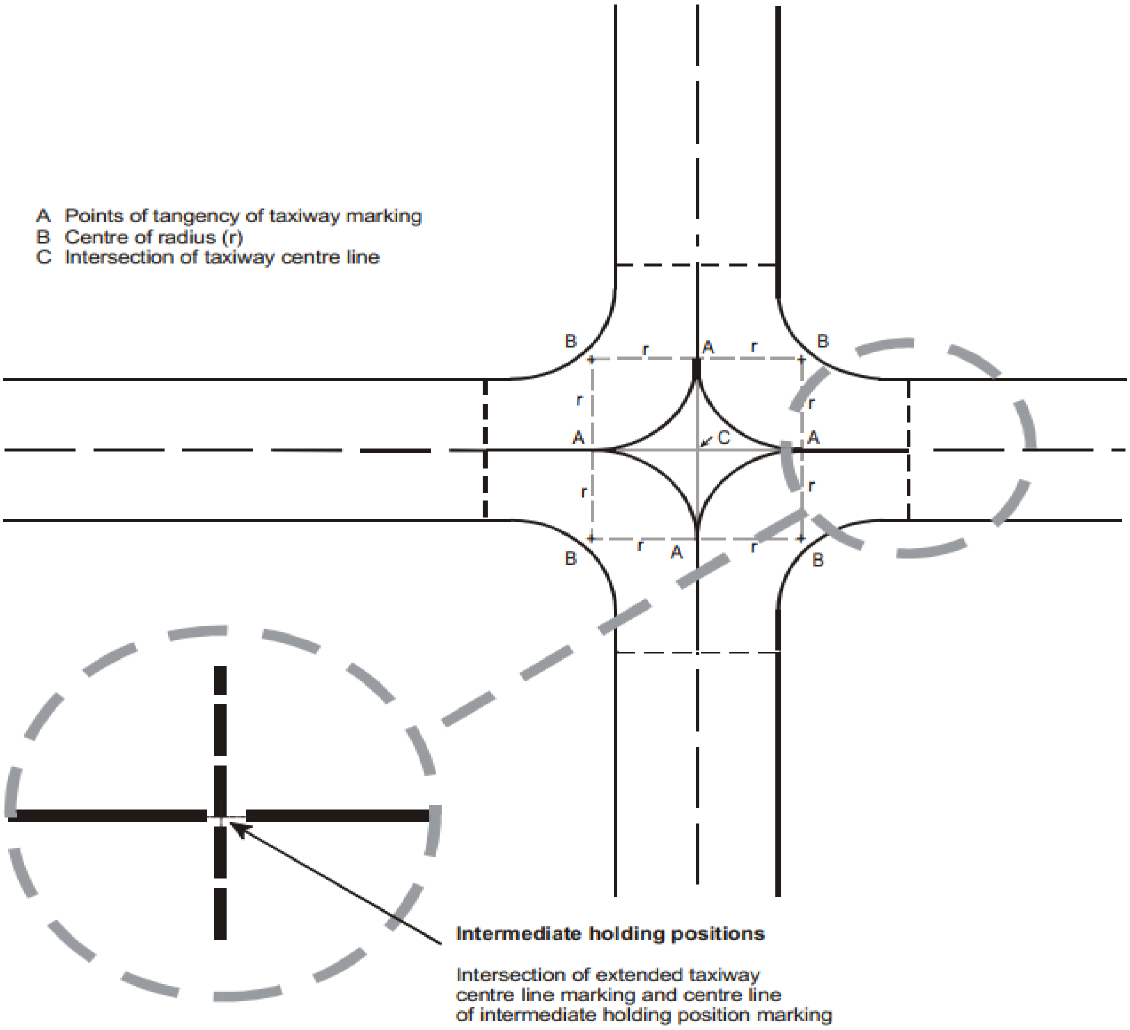


Figure 18: Taxiway intersections to be surveyed

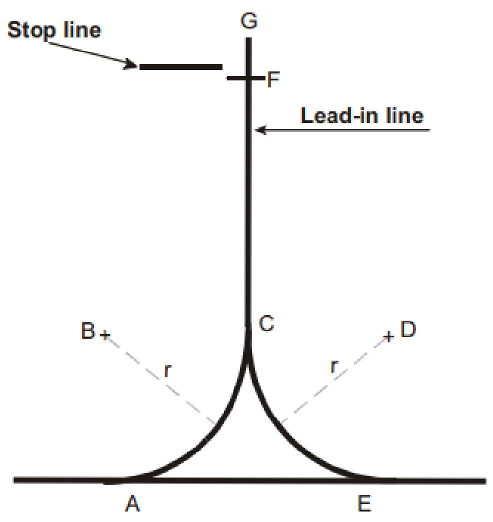


Figure 19: Simple nosewheel lead-in line

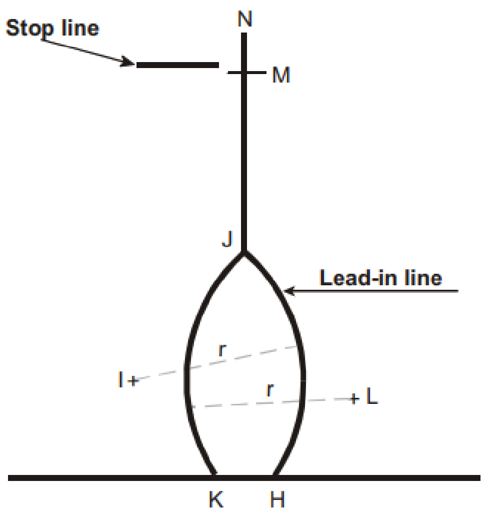


Figure 20: Offset nosewheel lead-in line

Position	Description of point to be surveyed
A	Point of tangency of centre of lead-in marking with centre of taxilane marking
B	Centre of arc of lead-in line and radius
C	Point of tangency with centre of lead-in line marking
D	Centre of arc of lead-in line and radius
E	Point of tangency of centre of lead-in marking with centre of taxilane marking
F	Nosewheel position of parked aircraft
G	End of lead-in line marking
H	Intersection of centre of lead-in line marking and centre of taxilane marking
I	Centre of arc of lead-in line and radius
J	Centre of commencement of straight section of lead-in line
K	Intersection of centre of lead-in line marking and centre of taxilane marking
L	Centre of arc of lead-in line and radius
M	Nosewheel position of parked aircraft
N	End of lead-in line marking

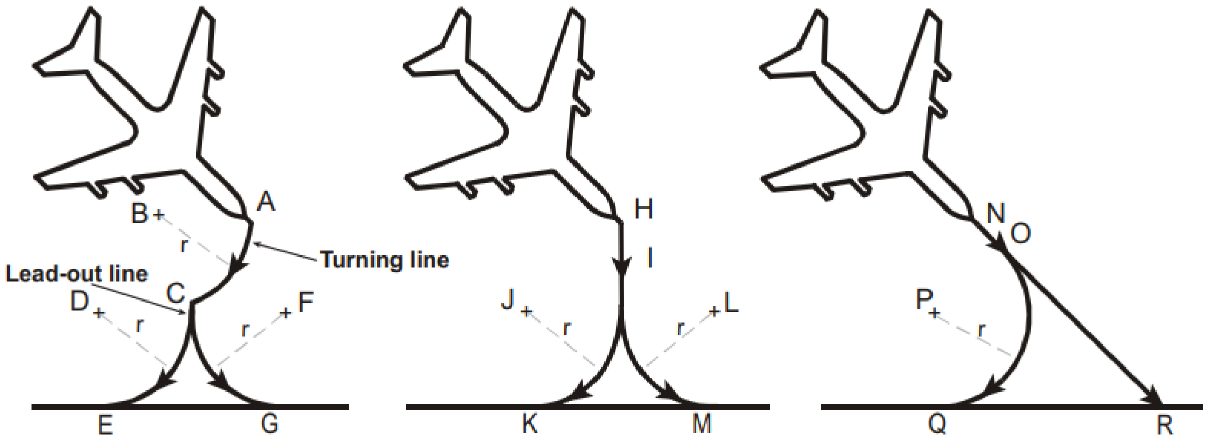


Figure 21: Simple nosewheel lead-out lines

Position	Description of point to be surveyed
A	Centre of commencement of turning line marking
B	Centre of arc of turning line and radius
C	Centre of intersection of turning line marking and lead-out line marking
D	Centre of arc of lead-out line and radius
E	Point of tangency of centre of lead-out line marking and taxilane marking
F	Centre of arc of lead-out line and radius
G	Point of tangency of centre of lead-out line marking and taxilane marking
H	Commencement of lead-out line
I	Centre of commencement of curved section of lead-out line
J	Centre of arc of lead-out line and radius
K	Point of tangency of centre of lead-out line marking and taxilane marking
L	Centre of arc of lead-out line and radius
M	Point of tangency of centre of lead-out line marking and taxilane marking
N	Point of tangency of centre of lead-out line marking and taxilane marking
O	Centre of commencement of curved section of lead-out line
P	Centre of arc of lead-out line and radius
Q	Point of tangency of centre of lead-out line marking and taxilane marking
R	Intersection of centre of lead-out line marking and taxilane marking

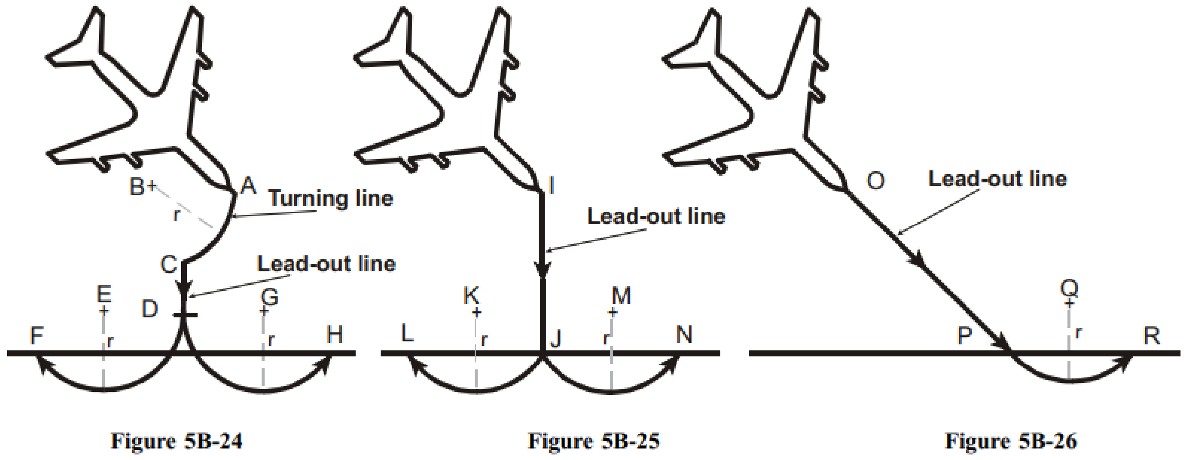


Figure 22: Offset nosewheel lead-out lines

Position	Description of point to be surveyed
A	Centre of commencement of turning line marking
B	Centre of arc of turning line and radius
C	Centre of intersection of turning line marking and lead-out line marking
D	Centre of end of straight section of lead-out line marking
E	Centre of arc of lead-out line and radius
F	Intersection of centre of lead-out line marking and taxilane marking
G	Centre of arc of lead-out line and radius
H	Intersection of centre of lead-out line marking and taxilane marking
I	Commencement of lead-out line
J	Centre of commencement of curved section of lead-out line
K	Centre of arc of lead-out line and radius
L	Intersection of centre of lead-out line marking and taxilane marking
M	Centre of arc of lead-out line and radius
N	Intersection of centre of lead-out line marking and taxilane marking
O	Commencement of lead-out line
P	Centre of commencement of curved section of lead-out line
Q	Centre of arc of lead-out line and radius
R	Intersection of centre of lead-out line marking and taxilane marking

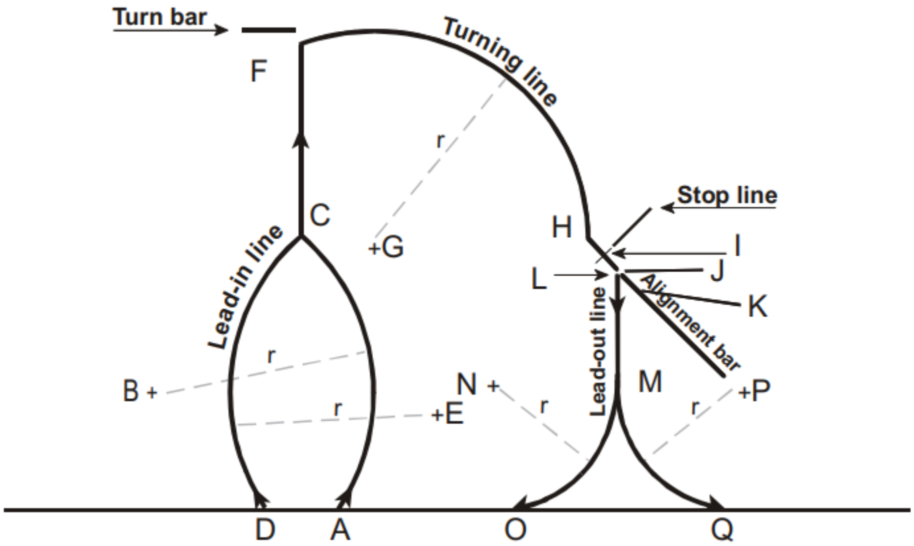


Figure 23: Turning lines

Position	Description of point to be surveyed
A	Intersection of centre of lead-in line marking and centre of taxilane marking
B	Centre of arc of lead-in line and radius
C	Centre of commencement of straight section of lead-in line
D	Intersection of centre of lead-in line marking and centre of taxilane marking
E	Centre of arc of lead-in line and radius
F	End of straight section of lead-in line marking/commencement of turning line marking
G	Centre of arc of turning line and radius
H	Centre of commencement of straight section of turning line marking
I	Nosewheel position of parked aircraft
J	Centre of end of straight section or turning line marking
K	True bearing of alignment bar
L	Commencement of lead-out line
M	Centre of commencement of curved section of lead-out line
N	Centre of commencement of curved section of lead-out line
O	Point of tangency of centre of lead-out line marking and taxilane marking
P	Centre of arc of lead-out line and radius
Q	Point of tangency of centre of lead-out line marking and taxilane marking

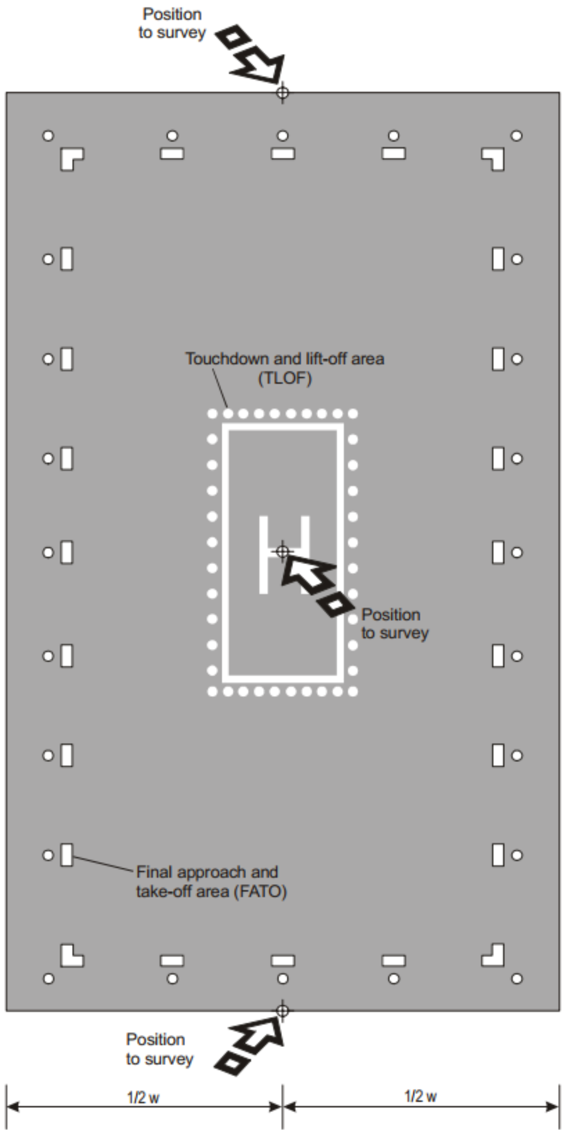


Figure 24: TLOF and FATO planimetric threshold positions to be surveyed

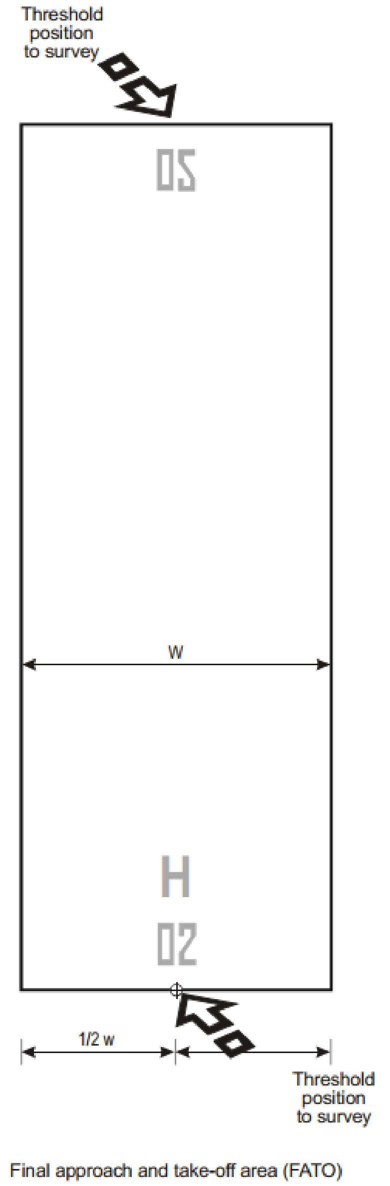
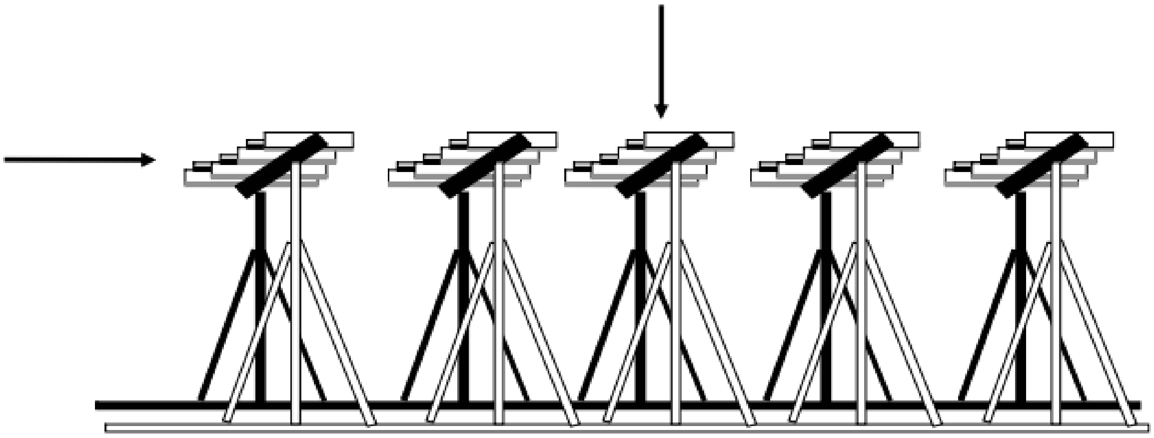


Figure 25: FATO planimetric threshold position to be surveyed



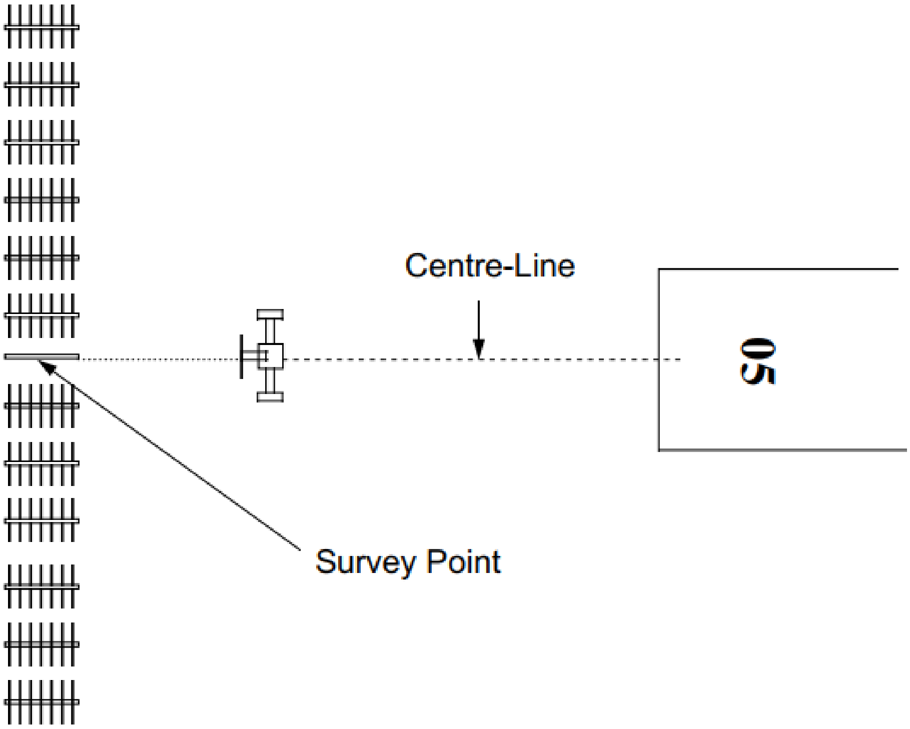


Figure 26: Sample detail for ILS Localizer

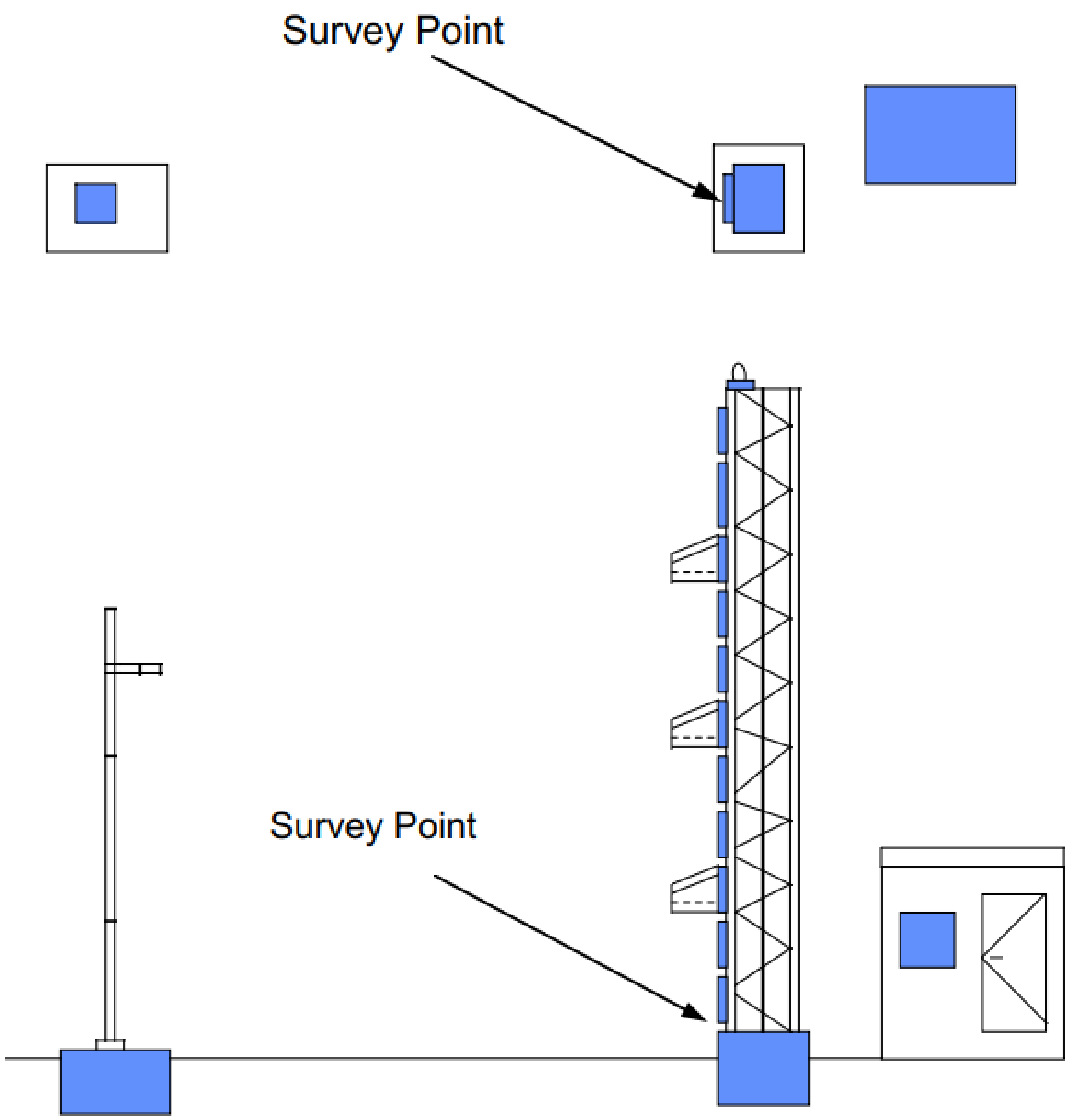


Figure 27: ILS Localizer point to be surveyed for NAVAID (plus any higher obstacles: lights or lightning conductors)

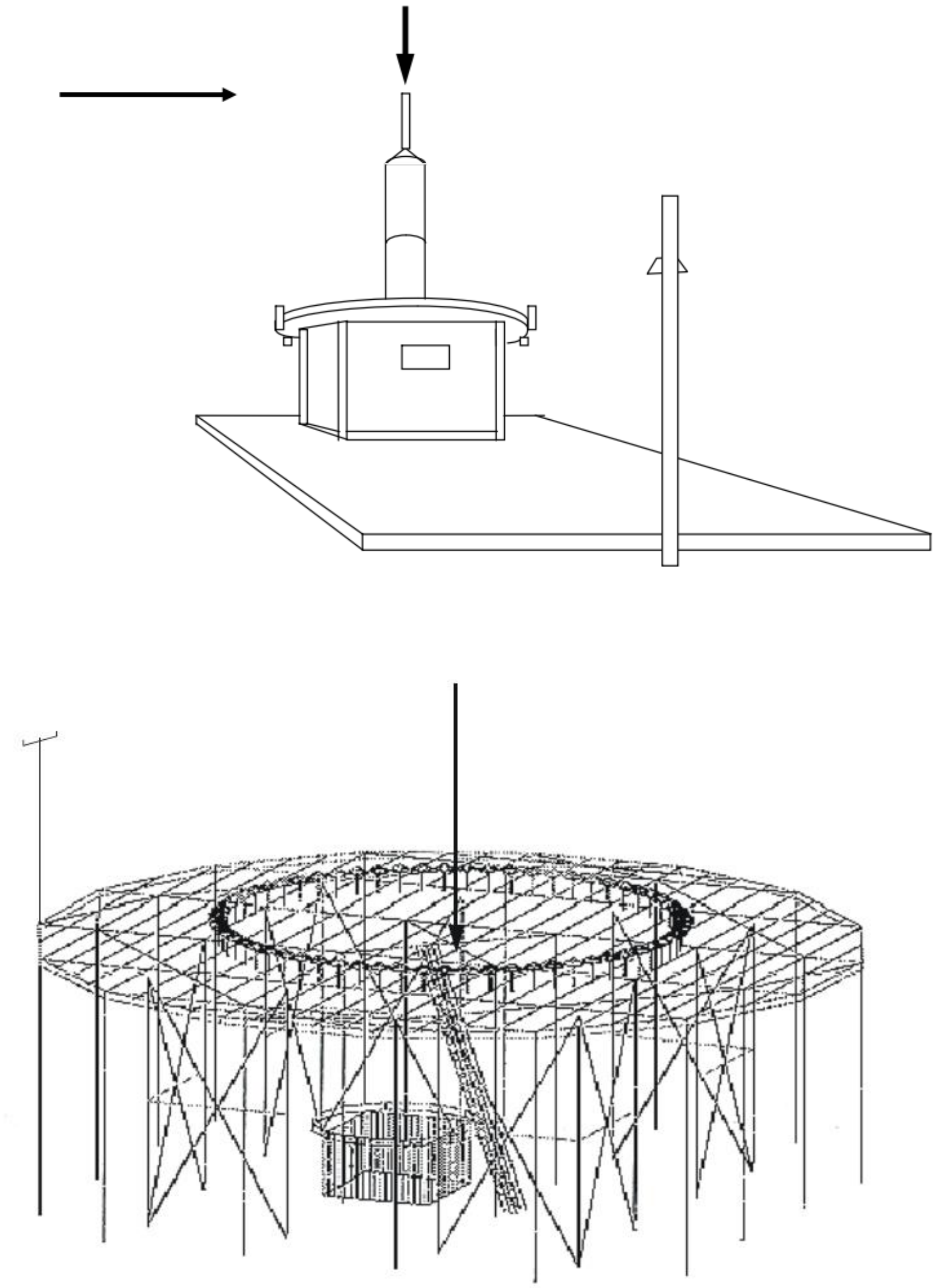


Figure 28: DVOR point to be surveyed for NAVAID (plus any higher obstacles: lights or lightning conductors)

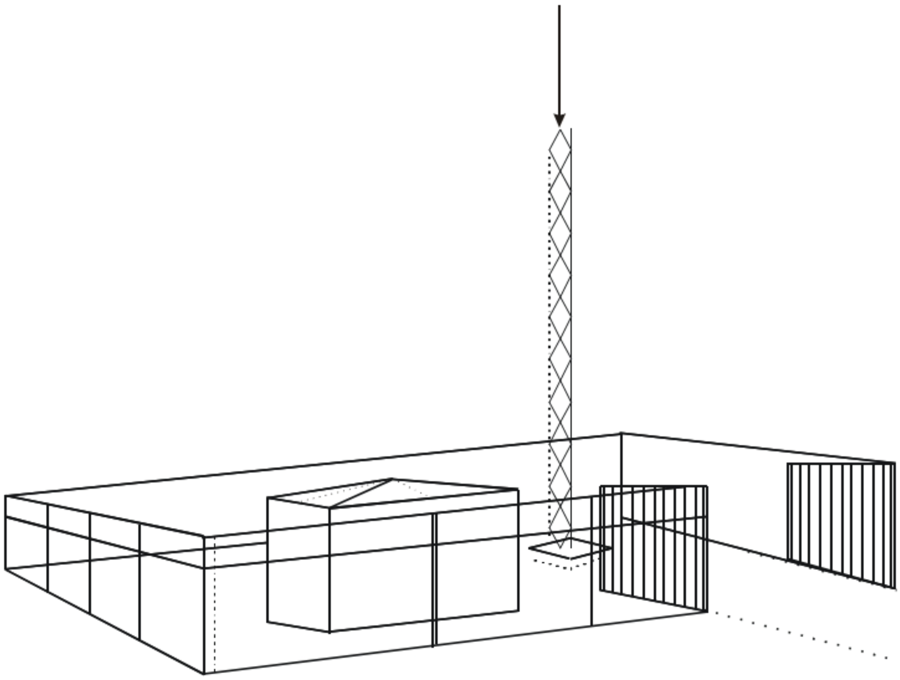


Figure 29: NDB point to be surveyed for NAVAID (plus any higher obstacles: lights or lightning conductors or DME mast/obstacle light)

PART 8. SURVEYOR QUALIFICATIONS AND EXPERIENCE

The surveyor(s) involved in providing the survey data and AMDB must be experienced and competent in the provision of ICAO compliant aeronautical data. Initially, such expertise in the aeronautical data field might not be available in country, but nothing in this guidance material is intended to inhibit the participation of aerodrome operator or ANSP staff from participating in the first surveys in order to gain suitable experience. Typically, the aerodrome operator or ANSP will ensure that the following qualifications, experience and competence are demonstrated:

1. Overall Qualifications: demonstrable experience and evidence of being a prime contractor/provider of an ICAO Document 9674 and 9881 compliant aeronautical data survey projects of a size and nature equivalent or greater than this over the last 10 years.
2. Overall Qualifications: demonstrable experience and evidence of being a prime contractor/provider of an ICAO Document 9674 and 9881 compliant aeronautical data survey projects of a size and nature equivalent or greater than this over the last 10 years.
3. In addition to the technical personnel that will carry out the works, a full time Project Manager may be required for larger surveys and AMDB projects.
4. Degree (or equivalent) in Survey Engineer, photogrammetry, geomatics, Geography or related fields;
5. Minimum of 10 years of experience, for the lead/manager, 3-5 years for other staff, in conducting ICAO Document 9674 and 9881 compliant aeronautical data survey projects of similar or greater size of projects;
6. Good practical and theoretical experience in ensuring that data surveyed or captured complies with the quality assurance requirements specified in Chapter 6 of ICAO Document 9674 and a minimum of 5 years of practical work and project management with similar assignments;
7. The lead project must be registered with the relevant professional body eg. Council of Engineers certificate:
8. Language proficiency - must be fluent in written and spoken English and relevant aeronautical terminology;
9. Good analytic skills and quality management practices providing the necessary check through policies and procedures;
10. Evidence for the timely possession (own, lease, hire, etc.) of the essential equipment; and
11. The organisation carrying out the work should have a current specification survey and digital equipment, total station, 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;

12. The documented evidence confirming the compliance with the requirements above should be examined and approved in advance of any contract / agreement award and start of work.

PART 9. AERODROME MAPPING DATABASE

1. INTRODUCTION

At large aerodromes, many activities are performed by a number of different participants such as pilots, airline operations personnel, general aviation operations personnel, air traffic controllers, apron controllers, surface vehicle operators, construction / maintenance staff, emergency and security personnel, etc. All the participants involved, must cooperate closely to ensure safe and efficient aircraft operations at the aerodrome.

For this purpose, they must be knowledgeable, and on occasions, precise about the aerodrome layout. For all the activities by the different users detailed aerodrome geospatial information is necessary. This information is commonly made available in aerodrome mapping databases (AMDBs).

These databases contain aerodrome information that is organized and arranged for ease of electronic storage and retrieval in systems that support a range of activities on and around the aerodrome as well as the production of paper maps, such as the aerodrome's emergency grid map.

An AMDB is a Geographic Information System (GIS) database of an airport describing the spatial layout of an aerodrome in terms of its features, such as runways, taxiways, parking stands, buildings, and markings, with geometry described as points, lines or polygons, and with attributes such as surface type, name/object identifier, runway slope providing further information.

AMDBs are produced and exchanged as datasets using global standards and tools of mainstream Geographic Information System (GIS) technology. The database represents a collection of aerodrome information that is organized and arranged for ease of electronic storage and retrieval in systems that support the functions listed below. It is intended that the dataset content generated/surveyed will be interchangeable according to the rules defined in ICAO Doc 9881.

This is because the AMDB is not just a tool for aerodrome operators and air navigation service providers, but is also used in pilots' electronic flight bags and in aircraft flight decks for pilots' displays. Such on-board applications are intended primarily to improve the pilot's situational awareness for surface navigation, thereby improving safety as well as operational efficiency.

GIS is a computer program that combines geographically referenced digital data with spatial and attribute analysis tools. The strength of a GIS lies in the methods it provides to represent and analyse geographic information.

One example of GIS/AMDB use is for maintenance records of aeronautical ground lighting (AGL). Every light fitting should be individually identified on the ground and in the GIS database by a unique number, and all maintenance and replacements related to each fitting be recorded against that number/fitting. The GIS can then show the record when the electrician clicks on the fitting on a map, even whilst in the field, and instantly see the record for that fitting to support the visual observations whilst carrying out in-field inspections.

2. PURPOSE OF AMDB

Additional uses may include multiple user classes that can benefit from using these databases. These include pilots, controllers, aerodrome managers, and aerodrome emergency and security personnel for the following purposes:

1. Runway operations
2. Emergency and security service management
3. Surveillance and runway incursion detection and alerting
4. Aerodrome surface guidance and navigation
5. Aerodrome facility and asset management, including inspection reporting
6. Route and hold-short display and deviation detection and alerting chart information
7. Display of digital ATIS information
8. Aerodrome and airline resource management
9. Training including flight simulation
10. NOTAM, AIP supplements and aeronautical data overlays
11. Synthetic vision, and
12. Digital control towers

3. AMDB RELATED GUIDANCE

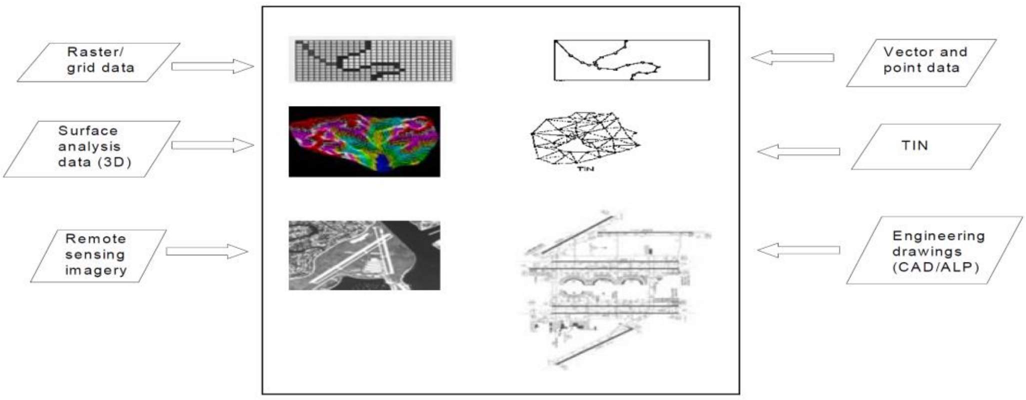
Therefore, it is important that AMDBs are produced in both a quality-controlled compliant with standardised formats. Extensive guidance is available in ICAO Doc 9881, Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information, and further detailed technical guidance is contained in EUROCAE WG44 – RCTA SC217 which defines industry requirements and interchange specifications for AMDBs, and RTCA DO-272D/EUROCAE ED-99D, User Requirements for Aerodrome Mapping Information, that provides minimum requirements and reference material applicable to the content, origination, publication, updating, and enhancement of aerodrome mapping information. RTCA DO-291C/EUROCAE ED-119C, Interchange Standards for Terrain, Obstacle, and Aerodrome Mapping Data, describes requirements for AMDB interchange, applying the concepts of the ISO 19100 series and related OGC implementation specifications. The included Aerodrome Mapping Exchange Model (AMXM 2.0.0), is the EUROCAE WG-44 / RTCA SC-217 SWIM data exchange specification for Aerodrome

Mapping Databases (AMDB). The AMXM consists of the AMXM UML Model and a derived AMXM XML Schema. Other physical formats (e.g. custom GIS format, AIXM5.1) may be used too.

4. THE GEOGRAPHIC INFORMATION SYSTEM AND AMDB

The starting point for aerodrome information is the data published by CAAT in the Aeronautical Information Publication (AIP) in accordance with the Requirements of CAAT Aerodrome Standards, ICAO Annex 15 and PANS AIM (Doc 10066). However, to fully meet the needs of its users, and in particular aerodrome surface operations, AMDBs may need additional data sources because they have evolved from the traditional CAD aerodrome drawing/plan to Geographic Information Systems (GIS). A GIS can include many different types of data including: control networks, vector data, raster grid data, triangulated irregular networks (TINs), 3-D surface representations, remotely sensed data, and other digital source data such as geo-referenced drawings or airport layout plans (ALPs) suitably layered as illustrated below.

Within a GIS, these data sources can be combined, spatially referenced, and analyzed enabling the user to organize information and answer questions about the spatial relationships between the various thematic layers as well as the attribute characteristics of the features. In addition to the use of GIS technology, AMDBs have also been realized by digitizing paper charts such as aerodrome obstacle charts, utilizing Computer-Aided Design (CAD) tools, and in the form of text or tabular files.



A GIS does not comprise just topographical or terrain database with grid points and elevations, but may be compiled from a photogrammetric image of features, not just elevations, that is converted to vectors and assigned themes and attributes using GIS techniques.

These features are more easily characterized by points, lines, and polygons, including runway edges, holding positions, and stand locations. Thus, an AMDB not only properly represents the aerodrome surface in the same way as in traditional terrain databases, but also characterises all existing natural or man-made object features. Aerodrome surface data, unlike terrain data, represents regular geometric objects that can be grouped or classified, and can be described using standard representation classes and attributes in accordance with ICAO Doc 9881. Most such features are related to horizontal positioning, for example:

1. runways,
2. taxiways,
3. service roads,
4. navigation aid antennae and monitor antennae,
5. buildings,
6. emergency facilities
7. radar sites, and other radio navigation facilities, etc.,
8. obstacles mapped as digital representation of the vertical and horizontal extent to manmade and natural significant features such as isolated rock pillars and natural vegetation (trees) that are of a particular height
9. digital line mapping of features such as buildings, pavements, roads, power transmission lines, fences

The survey points required have been illustrated and described in Chapter 7 above.

For AMDB purposes, data collection is more feature orientated, as illustrated below, ICAO Doc 9881. The attributes, such as ldthr:07, as shown in the runway diagram overleaf, are detailed in Doc 9881.

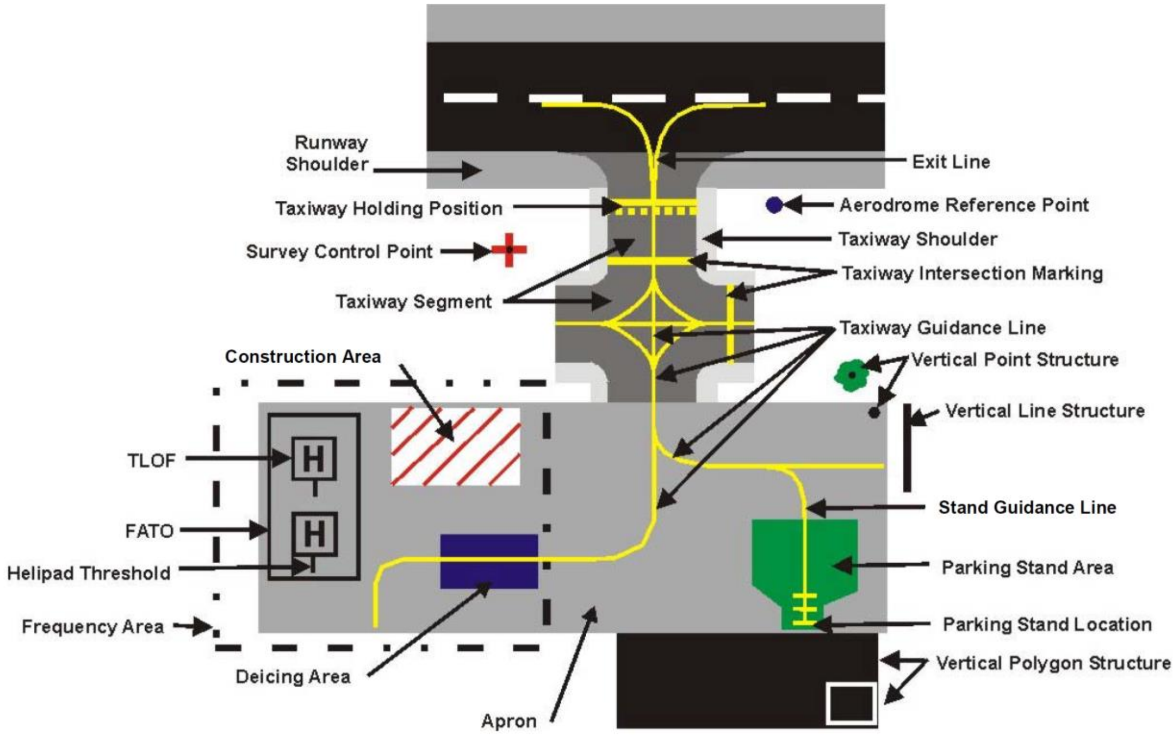


Figure 30: Aerodrome elements

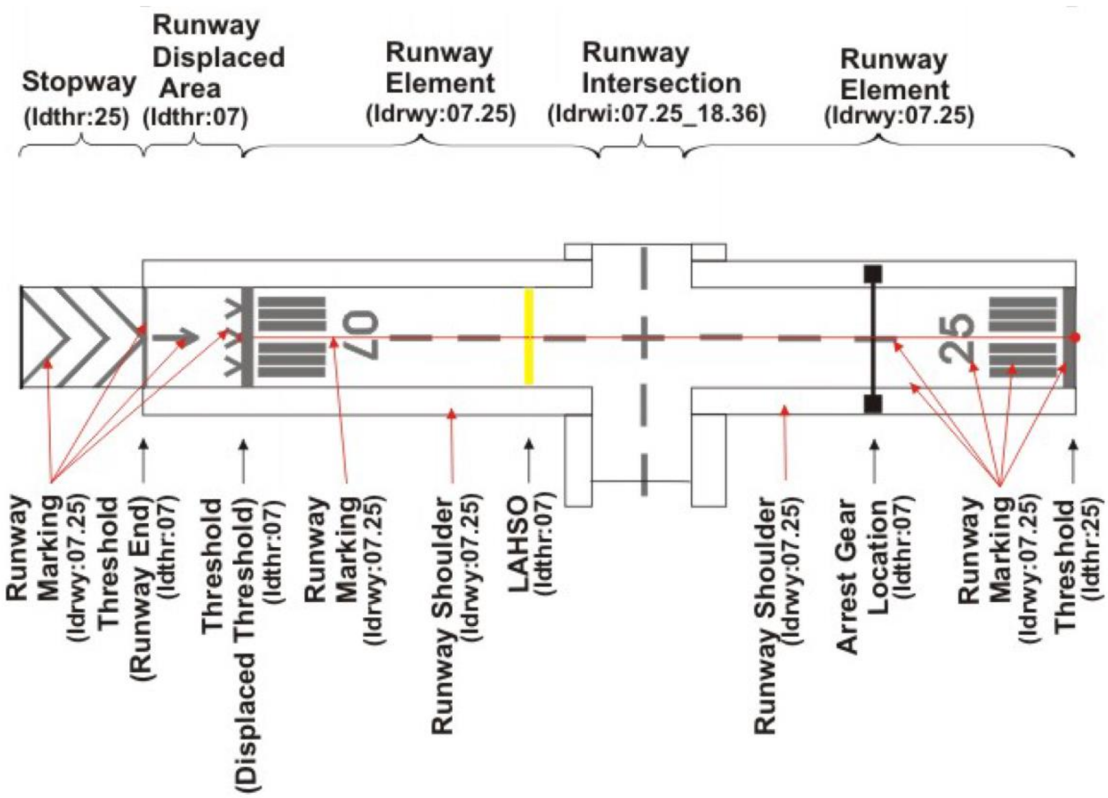


Figure 31: Runway elements

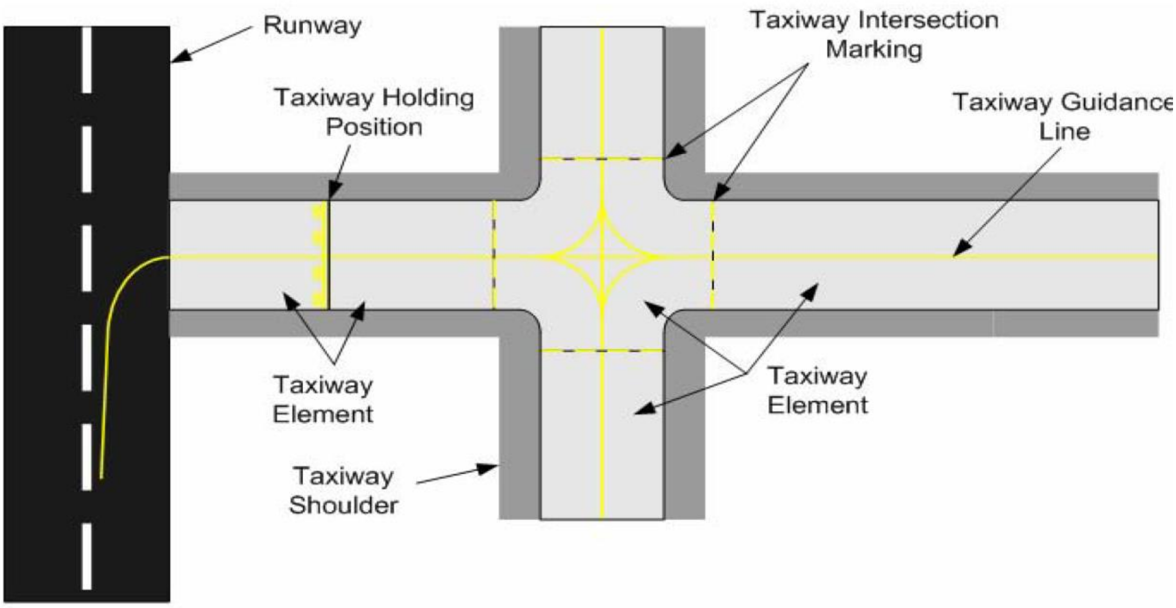


Figure 32: Taxiway elements

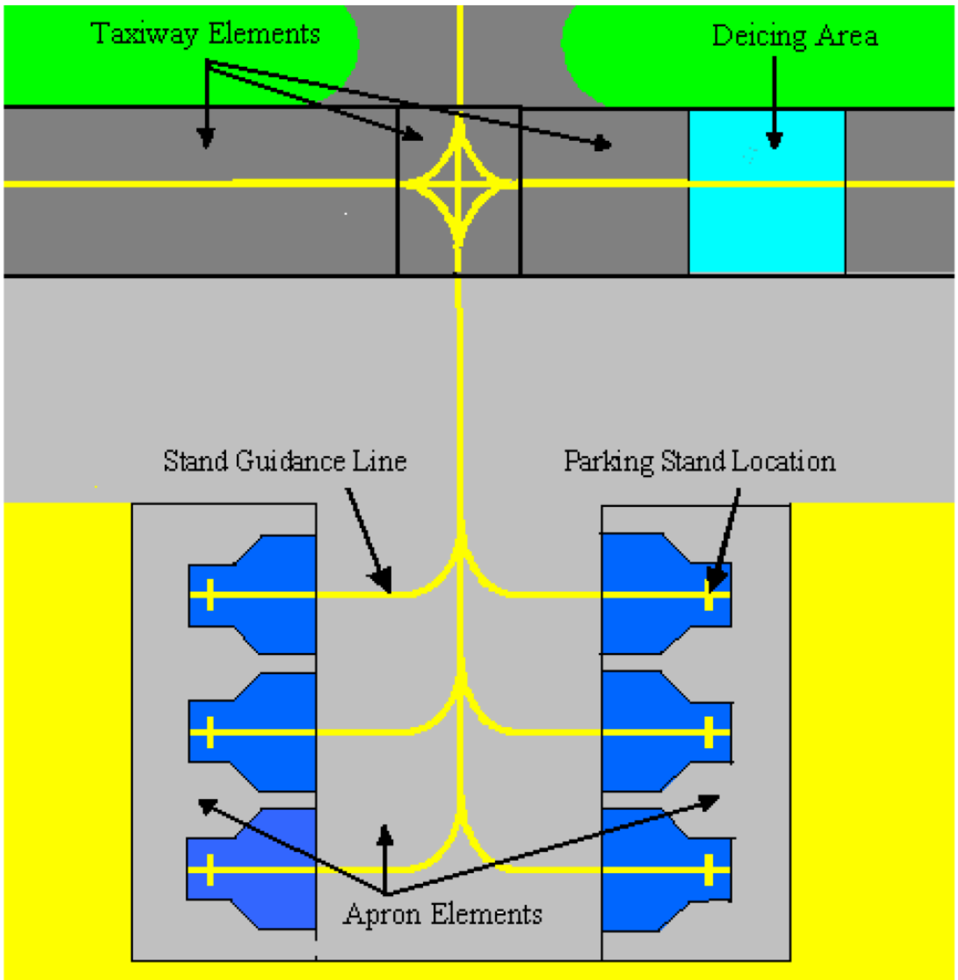


Figure 33: Apron elements

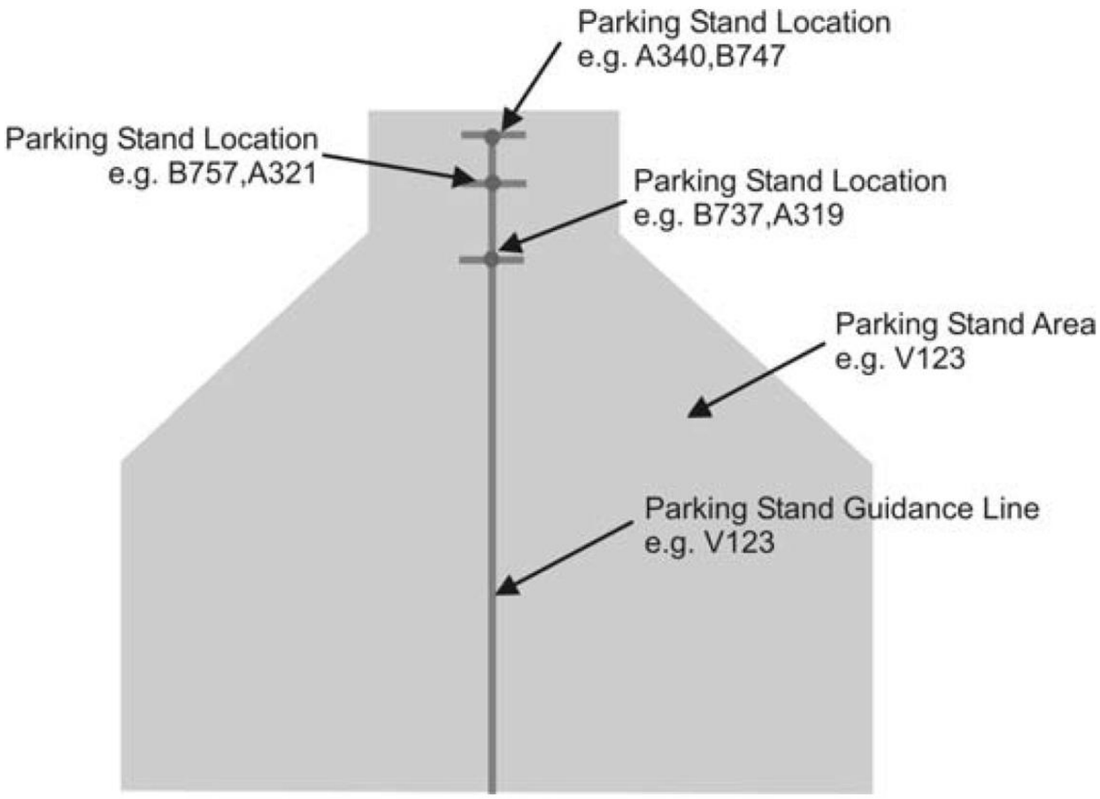


Figure 34: Aircraft parking stand elements

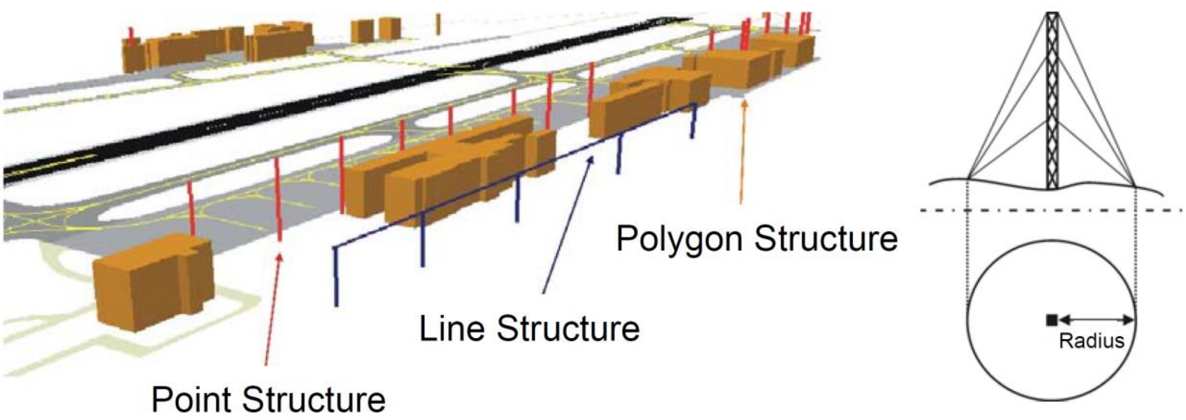
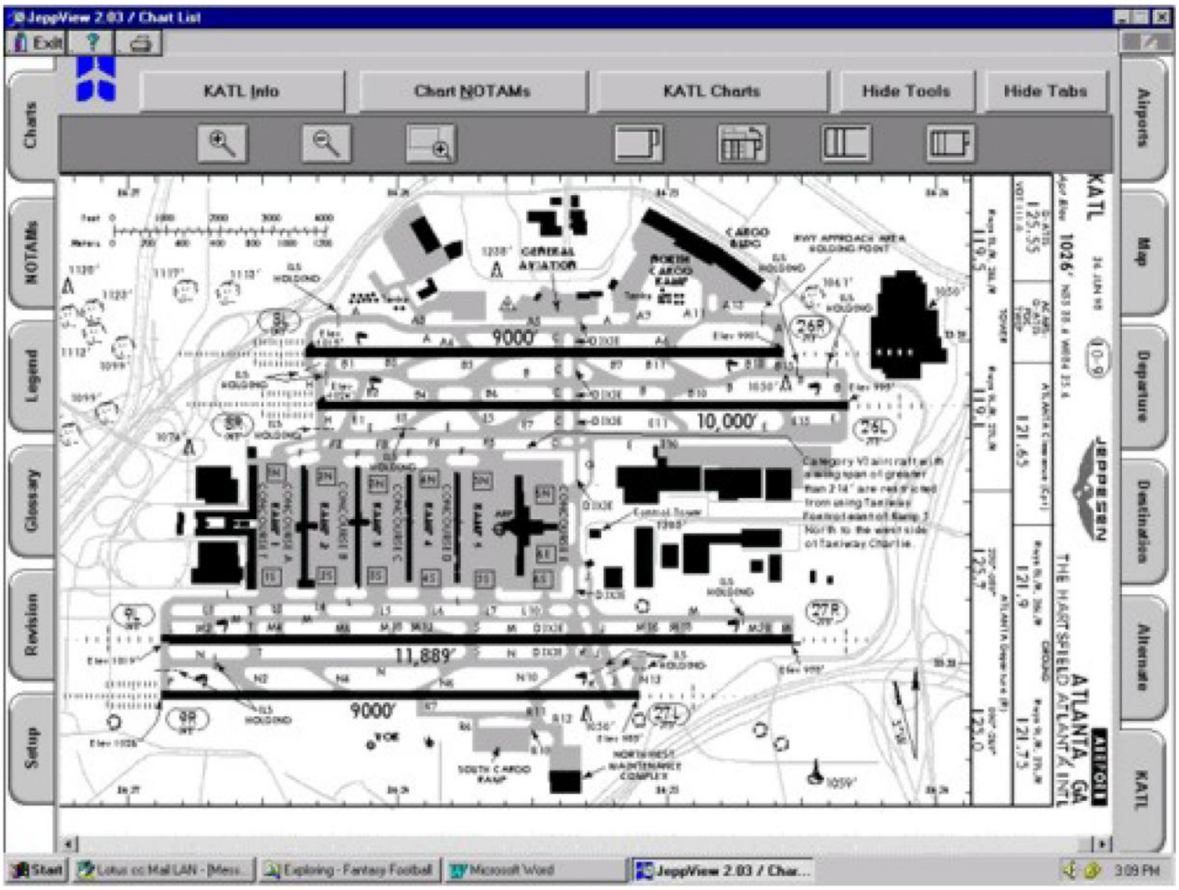


Figure 35: Vertical structure elements: point, line, polygon, radius

A typical user outcome of the AMDB is shown overleaf in an aerodrome mapping information display as would be used in real time on the flight deck of an aircraft.



Not to be used for Navigational Purposes

Figure 36: Aerodrome mapping information display

In addition to the aerodrome facilities and features, part of the AMDB is the obstacle data, both on and off aerodrome. This must be compiled in accordance with the requirements of CAAT Aerodrome Standards, which is drawn from ICAO Annex 14. All obstacle limitation surfaces, Type A Chart, and PAPI obstacle protection surfaces should be surveyed in accordance with the ICAO WGS84/EGM96 requirements of ICAO Doc 9876, WGS-84 Manual. The database of obstacles should be formatted according to the requirements of CAAT AIS Thailand, for inclusion in the AIP as well as in the AMDB.

Similarly, consideration of terrain on and around the aerodrome is essential to terminal area airspace operations such as approach, departure, and contingency procedure planning. Hazards related to terminal area terrain awareness and avoidance have been cited as a major contributing factor in controlled flight into terrain (CFIT) accidents. Terrain is also important to aerodrome surface operations. It defines the surface topography of the ground in and around the surface movement areas. Since terrain data shares a physical boundary with many surface geometric objects on the aerodrome (runways, taxiways, buildings, etc.), it is important that the terrain data be correlated with these other data types. Area 1, the entire territory of the

Kingdom of Thailand is not the responsibility of the aerodrome operators, and is outside the scope of this guidance document. The aerodrome related areas to be surveyed, and the requirements in each eTOD area are:

Area	Description	Survey requirement
2	Area 2: within the vicinity of an aerodrome, subdivided as follows:	For aerodromes regularly used by international civil aviation, obstacle data shall be provided for all obstacles within Area 2 that are assessed as being a hazard to air navigation
2a	Area 2a: a rectangular area around a runway that comprises the runway strip plus any clearway that exists, dimensions of runway strips and clearway, if provided are specified in the CAAT Requirements Aerodrome Standards;	For those obstacles that penetrate an obstacle data collection surface outlined by a rectangular area around a runway that comprises the runway strip plus any clearway that exists. The Area 2a obstacle collection surface shall have a height of 3 m above the nearest runway elevation measured along the runway centre line, and for those portions related to a clearway, if one exists, at the elevation of the nearest runway end

Area	Description	Survey requirement
Type A Chart	A quadrilateral area on the surface of the earth lying directly below, and symmetrically disposed about, the take-off flight path: a) commences at the end of TORA, or at the end of the clearway if clearway has been declared; b) starting width is 180 m which increases at the rate of 0.25D to a maximum of 1 800 m, (D is the distance from the start); c) extends to the point beyond which no obstacles exist or to a distance of 10.0 km, whichever is the lesser.	Objects in the take-off flight path area which project above a plane surface having a 1.2 per cent slope and having a common origin with the take-off flight path area
Obstacle limitation surfaces	Obstacle limitation surfaces according to the aerodrome reference code and runway approach type/category according to the Requirements of CAAT Aerodrome Standards, and Annex 14, Volume 1, Chapter 4	Penetrations of the aerodrome obstacle limitation surfaces
2b	Area 2b: an area extending from the ends of Area 2a in the direction of departure, with a length of 10 km and a splay of 15 per cent to each side;	The Area 2b obstacle collection surface has a 1.2 per cent slope extending from the ends of Area 2a at the elevation of the runway end in the direction of departure, with a length of 10 km and a splay of 15 per cent to each side; except that data need not be collected for obstacles less than a height of 3 m above ground in Area 2b

Area	Description	Survey requirement
2c	Area 2c: an area extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a;	The Area 2c obstacle collection surface has a 1.2 per cent slope extending outside Area 2a and Area 2b at a distance of not more than 10 km from the boundary of Area 2a. The initial elevation of Area 2c has the elevation of the point of Area 2a at which it commences; except that data need not be collected for obstacles less than a height of 15 m above ground in Area 2c
2d	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;	The Area 2d obstacle collection surface has a height of 100 m above ground
3	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;	Obstacle data should be provided for Area 3 for obstacles that penetrate the relevant obstacle data collection surface extending a half-metre (0.5 m) above the horizontal plane passing through the nearest point on the aerodrome movement area.

Area	Description	Survey requirement
4	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, except that where the terrain at a distance greater than 900 m from the runway threshold is mountainous or otherwise significant, the length of Area 4 is extended to a distance not exceeding 2 000 m from the runway threshold.	Obstacle data shall be provided for Area 4 for all runways where precision approach Category II or III operations have been established
other	Other aeronautical requirements, eg: GNSS or PBN approaches, PAPI obstacle protection surface, emergency grid map, etc	Where additional obstacle data is collected to meet other aeronautical requirements, the obstacle data sets should be expanded to include this additional data

Consideration of terrain on and around the aerodrome is essential to terminal area airspace operations such as approach, departure, and contingency procedure planning, and can contribute towards area terrain awareness and avoidance. This is a major contributing factor in controlled flight into terrain (CFIT) accidents. Terrain is also important to aerodrome surface operations. It defines the surface topography of the ground in and around the surface movement areas. Since terrain data shares a physical boundary with many surface geometric objects on the aerodrome (runways, taxiways, buildings, etc.), it is important that the terrain data be correlated with these other data types. Further details are contained in ICAO Docs 9674 and 9881

PART 10. REPORT

The survey and AMDB report is a key component for the aerodrome operator to meet its obligations under the CAAT Requirements. The survey report should comply with reporting requirements (i.e. Geodetic survey and Aerodrome/Heliport survey provisions) specified in the WGS-84 Manual (ICAO Doc 9674).

The final reports should be delivered in paper, PDF(OCR) and MS Word versions. Appendix C of Doc 9881 on Data quality provides guidance on AMDB reporting.

PART 11. SURVEY DELIVERABLES

For guidance in compiling a contract or letter of agreement specifications the following is a suggested list of deliverables that may be required. These are in addition to the scope and survey points listed above.

1. Description and photographs of geographical positions as per the specification provided in ICAO Document 9674 Chapter 5 Attachment B;
2. Survey Reports, namely:
   i. Geodetic Connection Report – that details how the connection was made to the WGS-84 geodetic network, ICAO Doc 9674 Chapter 5 Attachment C 1 and Appendix C;
   ii. Aerodrome Survey Report, ICAO Doc 9674 Chapter 5 Attachment C 2;
   iii. 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.
   iv. When submitting the report, the surveyor should include details of all obstacles surveyed, whether they penetrate the relevant obstacle limitation surfaces or not;
   v. The database of obstacles shall show the measurement of intrusion into the relevant obstacle limitation surface, or Type A chart surface, or PAPI obstacle protection surface, as applicable, and specify for each obstacle the exact surface(s) that is/are infringed;
3. 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.
4. Survey observations of key points such as monuments, runway threshold, stand "T" markings etc. as listed above, should be photographed with the survey equipment in situ to aid identification of exactly the point surveyed, as illustrated overleaf:

Figure 37: Photographic evidence of a survey point

5. Fine obstacles such as lightning conductors or aerials that surmount the object may not be visible over a distance. Therefore, care must be taken when observing distant obstacles to ensure that the highest point is surveyed.

6. Topographic map covering the runway strips, runway end safety areas (RESA) undershoot & overrun areas beyond the RESAs, radio altimeter operating area, at a contour interval appropriate to the terrain, to be specified by the aerodrome operator prior to signing the contract or letter of agreement;

7. Aerodrome emergency grid reference map for the aerodrome and the response area;

8. Multi-coloured safeguarding chart for management of the obstacle limitation surfaces and navigation aid areas;

9. 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;

10. Data shall be complied with CRC-32 procedure when submit to AIS and should be supplied in:
    i. 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).
    ii. Shapefiles,

iii. CAD data format, version to be agreed prior to contract,

iv. AIXM 5.1 data format (the exact data base format to be agreed with AIS prior to tender/ signing of the letter of agreement);

v. UDDF; and

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

11. To cater for the eTOD requirements, the following deliverable specifications may be required:

Description	Attribute	Specification
a) Survey area in km2	Km^2	To be specified according to the aerodrome
b) Equipment to be used (including parameters used in data processing)	All relevant equipment	e.g. Large format digital camera
c) Colour Imagery	Entire area	GeoTIFF, ECW
d) Resolution in cm	cm	Better than 50 Cm
e) XY – accuracy of images in cm	cm	20
f) Z – accuracy in cm	cm	10 – 20 in areas without vegetation
g) Digital Elevation Model (DEM), h) Digital Terrain Model (DTM), i) 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
j) Fully processed geo-referenced and ortho-rectified aerial photo image files in GeoTIFFformat on a hard drive or via ftp account.	For the whole area of coverage	GeoTIFF, ECW

Description	Attribute	Specification
k) 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, Avitech SDO terrain database format files***
l) Digital line mapping	3-D	DXF, DGN, DWG, Shapefiles, ESRI Geodatabase, Avitech formats (if required according to software used by the aerodrome, ANSP and AIS)
m) Topographical maps (both soft and hard copies) Scales: The digital maps should be made at scale 1:2500. The consultant shall also carry out the survey in such a way as to enable the production of maps at other scales e.g. 1:500 (aprons),1:10,000, 1:50,000, 1:250,000	1:2,500, 1: 500, 1:10,000, 1:50,000, 1:250,000	ESRI Geodatabase, ESRI ArcGIS Map documents, Shapefiles, DXF, DGN, DWG, Avitech SDO topographic database format files*** Paper size shall vary according to scale, but preferably A0 size
n) Coordinate System	GCS_WGS_1984 Datum: D_WGS_1984 Spheroid: WGS_1984 Geoid: EGM96	Geographical and projected, Ellipsoidal & Orthometric heights. *WGS-84 Manual (ICAO Doc 9674) refers*

Description	Attribute	Specification
o) Monthly progress reports	Both soft & hard copies	Appropriate
p) Final Survey report	Both soft & hard copies	RINEX/ ASCII; ICAO Doc 9674 WGS-84 Manual report structure
q) All the raw survey data files and the processed data files shall be delivered to CAA 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, Avitech static data files*** (as required according to software used by ANSP and AIS)
r) Obstacle data sets for areas 2a,2b,2c,2d, 3 and 4, as described in ICAO Annex 15 (see ref 3)	Soft and hard copies.	Excel sheets, AIXM 5.1 (XML) obstacle datasets. For each obstacle, provide: Obstacle area; Obstacle identification or designation; Type of obstacle; Obstacle position, represented by geographical coordinates in degrees, minutes, seconds and tenths of seconds; Obstacle elevation and height; Obstacle marking, and type and colour of obstacle lighting (if any); Aeronautical Data quality requirements in the Doc 9674 and other relevant documents must be met, see Appendix B

Description	Attribute	Specification
s) Terrain data sets for areas 2a,2b,2c,2d, 3 and 4, as described in ICAO Annex 15 (see ref 3)	Soft and hard copies	Excel sheets, AIXM 5.1 (XML) terrain datasets. For each set of terrain data for area 2a,2b,2c,2d, 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)
t) eTOD Airspaces	Soft and hard copies	Excel sheets, AIXM 5.1 (XML) files 3D models of areas 2a,2b,2c,2d,3 and 4 airspaces
u) Aerodrome layout within the area of coverage for all aerodromes within the area of influence	Soft and hard copies	ESRI Geodatabase, ESRI ArcGIS Map documents, Shapefiles, DXF, DGN, DWG, Avitech SDO topographic database format files as appropriate according to software used Paper size shall vary according to scale, but preferably A0 size
v) Aerodrome Mapping Data	Soft and hard copies	Excel sheets, AIXM 5.1 (XML) files; ESRI feature classes in feature datasets stored in geodatabases Include metadata as per ISO standards and ISO 19115 – Metadata (section 12 refers) Aeronautical Data quality requirements in the Doc 9674 and other relevant documents must be met (section 11)

Description	Attribute	Specification
w) Monumentation of Airport Survey control network and other specified points	Soft and hard copies	Tabulated WGS-84 coordinates (EGM 96)
x) Data usage, integration and interpretation Training	Customized hands-on training for 6 AIM and ANS personnel, i.e. both regulator and service provider staff.	i. Load the aerodrome mapping data into the clients AMDBs:Avitech AMDB, and ESRI database, ii. Load eTOD into the clients TOD databases: Avitech TOD database, and ESRI database iii. Produce an aerodrome terrain and obstacle chart as evidence (As specified in ICAO Annex 4 and Document 8697 (see section 15, references)) iv. Provide instruction manuals for loading the terrain, obstacle and aerodrome mapping data in the databases, and loading updates to the data v. Provide instruction manuals for developing all the charts and aerodrome layouts produced by the consultant and how to update the charts developed.
Note: Any tender specification should include to which version all AutoCAD drawings should be compatible, and all Shapefiles should be stored as feature classes in feature datasets within geodatabases accompanied by relevant map documents (.mxd)		

PART 12. CAAT CONSULTATION

- CAAT AGA should be consulted throughout the survey and data acquisition processes.

PART 13. SAFETY MANAGEMENT

As with all other activities on and related to an aerodrome the survey and data acquisition should be carried out in accordance with the aerodrome operator's safety management system. This will include safe working practises, proper authorisation of airside work, and management of change.

PART 14. CONCLUSION

This document has provided an overview of the Requirements of the CAAT Aerodrome Standards in respect of gathering the data and information under the aerodrome and obstacle survey, eTOD areas 2 to 4, and the aerodrome mapping database. It is not possible to include all of the specification for every element that is required, but the guidance has provided examples of what is needed for the aerodrome operator to engage other parties with appropriate experience to undertake surveys and data and information collection on its behalf.

Further details are contained in ICAO Annexes 4, 14, and 15, Doc 10066 PANS AIM, and Docs 9674 and 9881. Other related documents are listed in the next section.

Any queries on the content of this guidance document should be addressed to the Manager AGA, CAAT.

APPENDIX A: REFERENCE

- ICAO SARPs
    i. ICAO Annex 4 - Aeronautical Charts;
    ii. ICAO Annex 10 Vol. 1 and 4: Aeronautical Telecommunications;
    iii. ICAO Annex 14 – Aerodromes Volume 1 and 2: Aerodrome Design and Operations;
    iv. ICAO Annex 15 - Aeronautical Information Services;
- ICAO Guidance Documents
    i. ICAO Document 8697 – Aeronautical Chart Manual;
    ii. ICAO Doc 9137 - Aerodrome Services Manual Part 6: Obstacles;
    iii. ICAO Document 9674 – World Geodetic System 1984 (WGS-84) Manual;
    iv. ICAO Document 9881 -Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information;
- ICAO Procedures for Air Navigation Services
    v. ICAO Doc 10066 PANS AIM (Effective November 2018);
    vi. ICAO Doc 9981 PANS Aerodromes;
    vii. ICAO Doc 8168 Vol. 2: PANS Aircraft Operations;
- Other States' Rules and for Best Practice Guidance
    i. European Aviation Safety Agency (EASA) - Easy Access Rules for ATM-NS (Regulation (EU) No 373/2017) (June 2018);
    ii. European Aviation Safety Agency (EASA) - Easy Access Rules for Aerodromes (Regulation (EU) No 139/2014) (January 2018);
- ISO & EUROCAE
    i. ISO 8601 - Data elements and interchange formats -- Information interchange -- Representation of dates and times;
    ii. ISO 19109 - Geographic information -- Rules for application schema Body Title Edition;
    iii. ISO 19110 – Geographic information -- Methodology for feature cataloguing;
    iv. ISO 19113 - Geographic information -- Quality principles;
    v. ISO 19114 - Geographic information -- Quality evaluation procedures;
    vi. ISO 19115 – Metadata;
    vii. ISO 19117 - Geographic information – Portrayal;
    viii. ISO 19123 - Geographic information -- Schema for coverage geometry and Functions;
    ix. ISO 19131 - Geographic information -- Data product specifications.

x. RTCA DO-272D/EUROCAE ED-99D: User Requirements for Aerodrome Mapping Information
xi. RTCA DO-291C/EUROCAE ED-119C: Interchange Standards for Terrain, Obstacle, and Aerodrome Mapping Data
xii. EUROCAE ED-99C (RTCA DO-272C) — User Requirements for Aerodrome Mapping Information
xiii. EUROCAE ED-119B (RTCA DO-291B) — Interchange Standards for Terrain, Obstacle, and Aerodrome Mapping Data

- **Useful Websites**

i. https://www.eurocontrol.int/articles/aerodrome-mapping-database-amdb
ii. https://www.skybrary.aero/index.php/Airport_Mapping_Database_(AMDB)
iii. www.amxm.aero
iv. https://www.eurocontrol.int/articles/aerodrome-mapping-database-amdb
v. https://global.ihs.com/doc_detail.cfm?document_name=EUROCAE%20ED%2099&item_s_key=00536609
vi. http://www.iso.org/iso/en/prodsservices/ISOstore/orderinfo.html#howtoorder
vii. www.eurocae.org
viii. https://www.esri.com/en-us/about/about-esri/overview

APPENDIX B: DATA QUALITY REQUIREMENTS

Latitude and longitude	Accuracy Data type	Integrity Classification
Aerodrome reference point	30 m surveyed/calculated	routine
Navaids located at the aerodrome	3 m surveyed	essential
Obstacles in Area 3	0.5 m surveyed	essential
Obstacles in Area 2 (the part within the aerodrome boundary)	5 m surveyed	essential
Runway thresholds	1 m surveyed	critical
Runway end (flight path alignment point)	1 m surveyed	critical
Runway centre line points	1 m surveyed	critical
Runway-holding position	0.5 m surveyed	critical
Taxiway centre line/parking guidance line points	0.5 m surveyed	essential
Intermediate holding position marking line	0.5 m surveyed	essential
Exit guidance line	0.5 m surveyed	essential
Apron boundaries (polygon)	1 m surveyed	routine
De-icing/anti-icing facility (polygon)	1 m surveyed	routine
Aircraft stand points/INS checkpoints	0.5 m surveyed	routine

Elevation/altitude/height	Accuracy Data type	Integrity Classification
Aerodrome elevation	0.5 m surveyed	essential
WGS-84 geoid undulation at aerodrome elevation position	0.5 m surveyed	essential
Runway threshold, non-precision approaches	0.5 m surveyed	essential
WGS-84 geoid undulation at runway threshold, non-precision approaches	0.5 m surveyed	essential
Runway threshold, precision approaches	0.25 m surveyed	critical
WGS-84 geoid undulation at runway threshold, precision approaches	0.25 m surveyed	critical
Runway centre line points	0.25 m surveyed	critical
Taxiway centre line/parking guidance line points	1 m surveyed	essential
Obstacles in Area 2 (the part within the aerodrome boundary)	3 m surveyed	essential
Obstacles in Area 3	0.5 m surveyed	essential
Distance measuring equipment/precision (DME/P)	3 m surveyed	essential

Bearing	Accuracy Data type	Integrity Classification
ILS localizer alignment	1/100 degree surveyed	essential
MLS zero azimuth alignment	1/100 degree surveyed	essential
Runway bearing (True)	1/100 degree surveyed	routine

Declination/variation	Accuracy Data type	Integrity Classification
Aerodrome magnetic variation	1 degree surveyed	essential
ILS localizer antenna magnetic variation	1 degree surveyed	essential
MLS azimuth antenna magnetic variation	1 degree surveyed	essential

Length/distance/dimension	Accuracy Data type	Integrity Classification
Runway length	1 m surveyed	critical
Runway width	1 m surveyed	essential
Displaced threshold distance	1 m surveyed	routine
Stopway length and width	1 m surveyed	critical
Clearway length and width	1 m surveyed	essential
Landing distance available	1 m surveyed	critical
Take-off run available	1 m surveyed	critical
Take-off distance available	1 m surveyed	critical
Accelerate-stop distance available	1 m surveyed	critical
Runway shoulder width	1 m surveyed	essential
Taxiway width	1 m surveyed	essential
Taxiway shoulder width	1 m surveyed	essential
ILS localizer antenna-runway end, distance	3 m calculated	routine
ILS glide slope antenna-threshold, distance along centre line	3 m calculated	routine
ILS marker-threshold distance	3 m calculated	essential
ILS DME antenna-threshold, distance along centre line	3 m calculated	essential

APPENDIX C: SAMPLE WGS-84 SURVEY QUESTIONNAIRE

Survey inventory related to WGS-84 implementation

Notes on the completion of Parts I and II:

1. Part I should be completed by CAAT.
2. Part I, 25, items I to ix, should be completed for each navigation aid.
3. Part II should be distributed by CAAT to aerodrome/heliport operators for completion — one questionnaire for each aerodrome/heliport. The cover page is to be completed by CAAT.
4. Initially, Part II should be completed for aerodromes/heliports that have established instrument approach procedure(s) for the runway(s).
5. For aerodromes/heliports where visual approach procedures only are established, the requirement is for information on the aerodrome/heliport reference point (ARP).
6. Parts I and II have been designed so that the responses can be scanned automatically into a digital format. The majority of the questions are in a multiple-choice format. The scanning and formatting of the data will permit analysis using a PC-based tool. This PC programme is available to States from ICAO.
7. Blank templates of the questionnaires are available from ICAO. These may be used by national administrations to insert text in their national language. It is important that the format and layout be maintained so that translated questionnaires may be scanned and analysed by the PC programme referred to in 6 above.

PART I — EN-ROUTE NAVIGATION AIDS

State

Civil Aviation

Administration

Address

Contact Name

Telephone

Facsimile

Navigation Aid Survey Inventory Questionnaire
Part I — En-route navigation aids
(DME, VOR, DME/VOR, NDB, VORTAC and TACAN)

1. By which organization is coordination of navigation aids performed?
   [ ] National aviation administration's internal survey unit
   [ ] Aerodrome/heliport staff surveyors
   [ ] National mapping agency
   [ ] Local government survey unit
   [ ] Military survey department
   [ ] Private survey contractor
   [ ] Other — please specify |_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|
2. Is a written specification used for the method of measurement?
   [ ] Yes [ ] No
3. Which facilities are surveyed?

DME	[ ]	Yes	[ ]	No
VOR	[ ]	Yes	[ ]	No
VOR/DME	[ ]	Yes	[ ]	No
NDB	[ ]	Yes	[ ]	No
VORTAC	[ ]	Yes	[ ]	No
TACAN	[ ]	Yes	[ ]	No

4. Is coordination done by instrument survey or by graphical methods?

DME	[ ]	Instrument survey	[ ]	Graphical method
VOR	[ ]	Instrument survey	[ ]	Graphical method
VOR/DME	[ ]	Instrument survey	[ ]	Graphical method
NDB	[ ]	Instrument survey	[ ]	Graphical method
VORTAC	[ ]	Instrument survey	[ ]	Graphical method
TACAN	[ ]	Instrument survey	[ ]	Graphical method

5. If coordinates are obtained graphically from map products, what map scale (or nearest equivalent) is generally used?

	DME	VOR	DME/VOR	NDB	VORTAC	TACAN
>1/5 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/5 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/10 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/20 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/25 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/50 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/100 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1/250 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1/250 000	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

6. To what accuracy are the coordinates determined?

Note.— This may differ from the resolution quoted in the AIP.

	DME	VOR	DME/VOR	NDB	VORTAC	TACAN
>1 NM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1 NM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
0.1 NM	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
100 m	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
10 m	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
1 m	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]

1. Infrastructure

7. If coordinates are extracted from a map, is it known on which datum the map is based?

[ ] Yes [ ] No

8. Is the information in 7 above recorded as part of the survey?

[ ] Yes [ ] No

9. If instrument surveys are performed,

a) Is a record made of the reference frame used?

[ ] Yes [ ] No

b) Are permanent survey stations established as part of the survey?

[ ] Yes [ ] No

2. Quality Control

10. Is the determination of the geographical coordinates of navigation aids covered by a formal system of quality assurance, such as ISO 9000 or equivalent?

[ ] Yes — please specify |_|_|_|_|_|_|_|_|_|_|_|_|

[ ] No

11. What classification of staff is used for coordinating en-route navaids?

[ ] Professional surveyors

[ ] Qualified cartographers or draughtsmen

[ ] Qualified technicians

[ ] Junior grade staff

[ ] Untrained staff

[ ] Not known

12. Is specific training given for the particular task of surveying navigation aids?

[ ] Yes [ ] No

13. Are field inspections undertaken to verify the location of the navigation aids and, if yes, are they part of an ongoing programme for inspection?

[ ] Yes [ ] No

14. Are such inspections, or similar inspections, part of an ongoing programme for inspection or calibration?

[ ] Yes [ ] No

15. Where coordinates are supplied by other government agencies, is any further form of checking performed?

[ ] Yes [ ] No

3. Records and Archives

16. Are comprehensive records kept on positioning and coordinate data?

[ ] Yes [ ] No

17. Are such records free of inconsistencies?

[ ] Yes [ ] No

18. Is it possible to trace the data and the method of the survey/coordination of individual navaids?

[ ] Yes [ ] No

19. Are the survey records held centrally and, if yes, are they easily accessible?

[ ] Yes [ ] No

20. Are the survey records held on computer?

[ ] Yes [ ] No

21. Are the survey records subject to regular maintenance?

[ ] Yes [ ] No

22. In the case of collocated navigation aids (VOR/DME), is it known to which facility the published coordinates relate?

[ ] Yes [ ] No

23. Is the physical separation of such pairs of facilities known?

[ ] Yes [ ] No

24. Where central records of precise coordinates of navigation aids are kept, are the published AIP coordinates checked for consistency?

[ ] Yes [ ] No

4. Confirmation of AIP Entry

25. Please indicate in Column A the number of navaids for which coordinates are published. In Column B state the number of navaids for which the coordinates are determined by the national civil aviation administration itself.

AID	Column A	Column B
DME		
VOR		
VOR/DME		
NDB		
VORTAC		
TACAN		

The following information is required for each DME, VOR, DME/VOR, TACAN and VORTAC. The information is not required for NDBs.

(i) Identifier

(ii) Type of aid

[ ] DME [ ] VOR [ ] DME/VOR
[ ] TACAN [ ] VORTAC

(iii) Is there any documentary record of the date of survey (i.e. date on which coordinates were determined)?

[ ] Yes [ ] No

(iv) Method of survey, please specify.

(v) To which geodetic datum do the coordinates refer?

[ ] WGS-84 [ ] National Mapping Datum
[ ] ED 50 [ ] Not known

(vi) If the answer to (v) was national mapping datum, please state its name.

|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

(vii) Are original survey observations available?

[ ] Yes [ ] No

(viii) In the case of VOR, TACAN and VORTAC, please state, if available, the value of the SITE DECLINATION (VARIATION) set at the last calibration.

DEGREES.XX |__|__| |__|__| [ ] East [ ] West

Date of last calibration |__|__|__|__|__|

(ix) For collocated aids (e.g. VOR/DME), do the coordinates relate to the distance measuring element?

[ ] Yes [ ] No

PART II — AERODROME/HELIPORT POINTS

Aerodrome/heliport ICAO location indicator |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Aerodrome/heliport |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Address |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Contact name |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Telephone |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Facsimile |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Navigation Aid Survey Inventory Questionnaire - Aerodrome/heliport points

This section to be completed by national administrations.

First name |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Family name |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Position |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Address |__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|__|

Telephone

Facsimile

This section to be completed by the technical officer responsible for providing survey details.

First name

Family name

Position

Address

Telephone

Facsimile

1. Survey Control Network

1. Is there an existing survey control network at the aerodrome/heliport?

[ ] Yes [ ] No [ ] Not known

2. If yes, who installed and surveyed the network?

[ ] National aviation administration's internal survey unit
[ ] Aerodrome/heliport staff surveyor
[ ] National mapping agency
[ ] National geodetic agency
[ ] Local government survey unit
[ ] Military survey department
[ ] Private survey contractor
[ ] Other — specify

3. State the name of the survey organization. (If more than one survey organization has been involved, state the name of the organization having done the most work.)

|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|

4. State the age of the aerodrome/heliport survey control network, in years.

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

5. To which geodetic datum or control frame is the network referenced?

[ ] WGS-84 [ ] National Mapping Datum

[ ] ED 50 [ ] Not known

6. To which order of geodetic network is the aerodrome/heliport survey network connected?

[ ] Primary [ ] Secondary [ ] Tertiary

7. Name of geodetic network.

|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|

8. Method of connection.

[ ] Static GPS [ ] EDM Traverse
[ ] Triangulation [ ] Not known

9. How many stations are in place at the aerodrome/heliport?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

10. What is the relative survey accuracy of the aerodrome/heliport survey control network?

[ ] < 1 metre [ ] < 0.1 metre [ ] < 0.02 metre

11. Types of survey control markers (monuments) used on network.

Concrete:

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

Earth anchor:

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

Surface mark (rivet, stud, metal plate, etc.):

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

12. Are survey station descriptions available?

[ ] Yes [ ] No [ ] Not known

13. Was the survey performed in accordance with the guidance in this manual?

[ ] Yes [ ] No [ ] Not known

14. Is the survey work performed in accordance with a quality assurance scheme (such as ISO 9000)?

[ ] Yes — specify [ ] No scheme

15. Is a survey report available?

[ ] Yes [ ] No [ ] Not known

16. Has a record been kept of the original survey observations?

[ ] Yes [ ] No [ ] Partial

17. Were independent checks made on the survey?

[ ] Yes [ ] No [ ] Not known

18. Which organization made the checks?

19. Were records kept of the checks?

[ ] Yes [ ] No [ ] Not known

2. Aerodrome Obstacles

20. Which organization performed the obstacle survey?

[ ] National aviation administration's internal survey unit

[ ] Aerodrome/heliport staff surveyor

[ ] National mapping agency

[ ] National geodetic agency

[ ] Local government survey unit

[ ] Military survey department

[ ] Private survey contractor

[ ] Other — specify |_|_|_|_|_|_|_|_|_|_|_|_|_|_|

21. State the name of survey organization. (If more than one survey organization has been involved, state the name of the organization having done the most work.)

|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|

22. State how frequently, in years, the aerodrome/heliport obstacle survey is performed?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

23. How long ago, in years, was the last aerodrome/heliport obstacle survey carried out?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

24. To which geodetic datum is the aerodrome/heliport obstacle survey referenced?

[ ] National datum [ ] Local datum

25. Are the obstacle coordinates obtained by original instrument survey or by graphical means from existing mapping?

[ ] Instrument survey [ ] Existing mapping

26. Was the survey performed in accordance with any declared specifications?

[ ] Yes [ ] No [ ] Not known

27. Do full survey records for the aerodrome/heliport obstacles exist?

[ ] Yes [ ] No [ ] Not known

28. Is the survey work performed in accordance with a quality assurance scheme (such as ISO 9000)?

[ ] Yes — specify |_|_|_|_|_|_|_|_|_|_| [ ] No scheme

29. Is the survey report available?

[ ] Yes [ ] No [ ] Not known

30. Has a record been kept of the original survey observations?

[ ] Yes [ ] No [ ] Not known

31. Were independent checks made on the survey?

[ ] Yes [ ] No [ ] Not known

32. Which organization made the checks?

|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|

3. Aerodrome/Heliport Navigation Elements

33. Which organization performed the aerodrome/heliport navigation elements survey?

[ ] National aviation administration's internal survey

unit [ ] Aerodrome/heliport staff surveyor

[ ] National mapping agency

[ ] National geodetic agency

[ ] Local government survey unit

[ ] Military survey department

[ ] Private survey contractor

[ ] Other — specify |_|_|_|_|_|_|_|_|_|_|_|_|_|_|

34. State the name of survey organization. (If more than one survey organization has been involved, state the name of the organization having done the most work.)

|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|_|

4. Runway Thresholds

35. How many runway thresholds are on the aerodrome/heliport?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

36. How many runways with precision approach facilities are on the aerodrome/heliport?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

37. How many thresholds have been surveyed?

[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]	[ ]
<1	1	2	3	4	5	6	7	8	9	10	>10

38. To which accuracy have these thresholds been surveyed?

[ ] < 10 metres [ ] < 3 metres [ ] < 1 metre [ ] < 0.1 metre