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World Geodetic System — 1984 (WGS-84) Manual

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International Civil Aviation Organization

Chapter 2

ACCURACY, RESOLUTION AND INTEGRITY OF AERONAUTICAL DATA

2.1 GENERAL

2.1.1 Traditional navigation techniques have relied upon the ability to fly to or from point navigation aids. While the coordinates of the navigation aids have been provided, this information has not been used as part of the navigation process. Increasing use is being made of Area Navigation (RNAV) systems which derive the aircraft position from such sources as Inertial Navigation Systems (INS), Omega, VHF omni-directional radio range/distance measuring equipment (VOR/DME), dual or multi-DME and Global Navigation Satellite Systems (GNSS). Based on aeronautical data, RNAV systems generate appropriate instructions to the autopilots which enable the aircraft to follow the planned route during the departure, en-route and approach phases and eventually, with the implementation of GNSS, the landing phases.

2.1.2 For such operations, the track actually flown by the aircraft depends upon the coordinates defining both the track and the position of ground-based navigation aids. With the advent of precision RNAV (RNP 1) routes and the extension of RNAV application to terminal area (TMA) procedures, higher precision is required, and it is necessary to ensure that the data defining the track to be flown are of an accuracy, resolution and integrity consistent with the RNP requirements.

2.2 TYPE AND CLASSIFICATION OF POSITIONAL DATA

2.2.1 Air navigation points can be divided into two basic groups (as outlined in Table 1-1):

a) area/en-route points; and

b) aerodrome/heliport points.

2.2.2 Besides this basic categorization, air navigation points can be categorized by the type of positional data. Three types of positional data have been defined: surveyed points, calculated points and declared points (see Tables 2-1 to 2-5).

a) *Surveyed point.* A surveyed point is a clearly defined physical point, specified by latitude and longitude, that has been determined by a survey, conducted in accordance with the guidance provided in this manual. Communication facilities, gates, navaids, navigation checkpoints, obstacles and runway thresholds are usually surveyed points.

b) *Calculated point.* A calculated point is a point in space that need not be specified explicitly in latitude and longitude, but that has been derived, by mathematical manipulation, from a known surveyed point. A fix, specified by radial/bearing and range from a known surveyed point such as a navaid or by the intersection of a number of radial/bearings from a number of navaids, is an example of a calculated point. En-route way-points, which are computed from the intersection of routes or from cross radial fixes on routes, are also calculated points, albeit they are reported in latitude and longitude.

c) *Declared point.* A declared point is a point in space, defined by latitude and longitude, that is not dependent upon, nor formally related to, any known surveyed point. Flight information region (FIR) boundary points and prohibited, restricted or danger area points that are outside control areas are often declared points.

2.3 SOURCE OF RAW AERONAUTICAL DATA

It is the responsibility of relevant technical services, within the appropriate authority of a Contracting State, to ensure the determination of raw aeronautical data required for promulgation by the aeronautical information service (AIS). On receipt of the raw data, the relevant technical services must check, record and edit the data so that they can be released to the next intended user in a standard format. Raw aeronautical data containing positional information can originate from a number of different sources.

a) *En-route.* The surveyed positions of navaids and communication facilities are normally provided by the owner/operator (ATC) of the equipment.

b) *SID, STAR, Instrument approach procedures.* The calculated positions are normally determined by the air traffic service provider responsible for the procedure, in coordination with the technical branch dealing with the procedure design within the State aviation authority.

c) *Aerodrome/heliport.* The surveyed positions of thresholds, gates, obstacles and navaids, etc. located at the aerodrome/heliport are normally provided by the owner or operator of the aerodrome/heliport.

d) *Airspace divisions and restrictions*. The declared positions are normally defined by State civil aviation or military authorities or other government bodies.

2.4 ACCURACY REQUIREMENTS

2.4.1 For aeronautical data to be usable, it must be accurate and, in this context, can be subdivided into two distinct categories:

a) evaluated aeronautical data; and

b) reference aeronautical data.

2.4.2 Evaluated aeronautical data include such information as positional data, elevation, runway length, declared distances, platform-bearing characteristics and magnetic variation. Reference aeronautical data include navaid identifiers, navaid frequencies, way-point names, rescue and fire-fighting facilities, hours of operation, telephone numbers, etc.

2.4.3 The accuracy requirement for the reference data is absolute; the information is either correct or incorrect. Conversely, the required degree of accuracy of the evaluated data will vary depending upon the use to which the data are put. This manual addresses primarily evaluated positional data but many of the procedures may be applied to other evaluated aeronautical data and to reference data, if required. Tables 2-1 to 2-5 contain accuracy requirements for aeronautical data as specified in Annex 11 and in Annex 14, Volumes I and II. The requirements for quality assurance and aeronautical data processing procedures are provided in more detail in Chapter 6.

Definition of ***Accuracy.*** A degree of conformance between the estimated or measured value and the true value.

Note.— For measured positional data the accuracy is normally expressed in terms of a distance from a stated position within which there is a defined confidence of the true position falling.

2.4.4 Accuracy requirements are based upon a 95% confidence level (see Table 2-6). The underlying statistical distribution for positional data in two dimensions is usually taken to be the circular normal distribution. The probability P of a point actually falling within a circle of radius $c\sigma$ around its reported position, where σ represents the standard univariate deviation and c is a numeric coefficient, is:

$$P = 1 - \exp(-c^2/2).$$

2.4.5 The Circular Error Probable (CEP) is the radius of the circle within which 50% of the measurements lie, that is, 1.1774 σ. The radius within which 95% of the measurements lie is 2.448 δ or 2.079 × CEP. Table 2-6 relates σ error values, probable errors and probabilities in one, two and three dimensions.

2.4.6 The RNP types (see Table 2-7) specify the navigation performance accuracy of all the user and navigation system combinations within an airspace. RNP types can be used by airspace planners to determine airspace utilization potential and as input for defining route widths and traffic separation requirements, although RNP by itself is not a sufficient basis for setting a separation standard.

2.5 RESOLUTION REQUIREMENTS

Definition of ***Resolution.*** A number of units or digits to which a measured or calculated value is expressed and used.

2.5.1 Resolution of positional data is the smallest separation that can be represented by the method employed to make the positional statement. Care must be taken that the resolution does not affect accuracy; the resolution is always a rounded value as opposed to a truncated value. The order of publication and the charting resolution of aeronautical data must be that specified in Tables 2-1 to 2-5.

Definition of ***Precision.*** The smallest difference that can be reliably distinguished by a measurement process.

Note.— In reference to the 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.

2.5.2 The terms "precision" and "resolution" are often interchangeable in general use. Here precision is a measure of the data field capacities that are available within a specific system design. (Example: 54° 33' 15" is expressed to a resolution of one second.) Any process that manipulates data subsequent to the original measurement or definition cannot increase the precision to which the data were originally measured or defined, regardless of the resolution available within the system itself.

2.6 INTEGRITY REQUIREMENTS

Definition of ***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.

2.6.1 General

2.6.1.1 The integrity of the data can be regarded as the degree of assurance that any data item retrieved from a storage system has not been corrupted or altered in any way since the original data entry or its latest authorized amendment. This integrity must be maintained throughout the data process from survey to data application. In respect to AIS, integrity must be maintained to the next intended user.

2.6.1.2 Integrity is expressed in terms of the probability that a data item, retrieved from a storage system with no evidence of corruption, does not hold the same value as intended. For example, an integrity of 1×10^{-8} means that an undetected corruption can be expected in no more than one data item in every 100 000 000 data items processed. Loss of integrity does not necessarily mean loss of accuracy. However, it does mean that it is no longer possible to prove that the data are accurate without a further verification of the data from the point at which integrity can be confirmed.

2.6.1.3 The integrity requirements for data are not absolute. The risk associated with a point being in error is dependent upon how that data point is being used. Thus, the integrity of a point at threshold used for landing needs a higher integrity than one used for en-route guidance. It is important to note that a lower accuracy does not necessarily imply a lower integrity requirement.

2.6.2 Requirement for integrity

2.6.2.1 A data item's use forms the basis for determining its integrity requirement. Aeronautical data integrity requirements must therefore be based upon the potential risk resulting from the corruption of data and upon the particular use of the data item. Consequently, the following classification of data integrity must apply.

a) *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.

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.

c) *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.

2.6.2.2 To each of these types of data, an integrity level requirement has been assigned as follows.

a) *Critical data:* 1×10^{-8}. This level is given to the runway threshold data which define the landing point. The level of integrity has been derived from the integrity requirement for autoland and is defined to ensure that the overall process, of which aeronautical data are only a part, has the required integrity.

b) *Essential data:* 1×10^{-5}. This level is assigned to points which, while an error can in itself result in an aircraft being outside of the envelope required, excursion does not necessarily result in a catastrophe. Examples include en-route navigation aids and obstacles. The reason why obstacle data can be held with a relatively lower level of integrity is that, while the data need to be accurate at the time the procedures are designed, any subsequent corruption should have no impact on the safety of the aircraft on the condition that it conforms to the procedure requirements.

c) *Routine data:* 1×10^{-3}. This level is assigned to data for which errors do not affect the navigation performance. These include FIR boundary points.

Note.— A classification of aeronautical data with respect to integrity are provided in Tables 2-1 to 2-5.

TABLES FOR CHAPTER 2

Table 2-1. Aeronautical data quality requirements (latitude and longitude)

Latitude and longitude	*Accuracy data type*	*Publication resolution*	*Chart resolution*	*Integrity classification*
Flight information region boundary points	2 km (1 NM) declared	1 min	as plotted	1×10^{-3} routine
P, R, D area boundary points (outside CTA/CTZ boundaries)	2 km (1 NM) declared	1 min	as plotted	1×10^{-3} routine
P, R, D area boundary points (inside CTA/CTZ boundary)	100 m calculated	1 sec	as plotted	1×10^{-5} essential
CTA/CTZ boundary points	100 m calculated	1 sec	as plotted	1×10^{-5} essential
En-route NAVAIDS and fixes, holding, STAR/SID points	100 m surveyed/ calculated	1 sec	1 sec	1×10^{-5} essential
Obstacles en-route	100 m surveyed	1 sec	as plotted	1×10^{-3} routine
Aerodrome/heliport reference point	30 m surveyed/ calculated	1 sec	1 sec	1×10^{-3} routine
NAVAIDS located at the aerodrome/ heliport	3 m surveyed	1/10 sec	as plotted	1×10^{-5} essential
Obstacles in the circling area and at the aerodrome/heliport	3 m surveyed	1/10 sec	1/10 sec (AOC Type C)	1×10^{-5} essential
Significant obstacles in the approach and take-off area	3 m surveyed	1/10 sec	1/10 sec (AOC Type C)	1×10^{-5} essential
Final approach fixes/points and other essential fixes/points comprising instrument approach procedures	3 m surveyed/ calculated	1/10 sec	1 sec	1×10^{-5} essential
Runway threshold	1 m surveyed	1/100 sec	1 sec	1×10^{-8} critical
Runway end (flight path alignment point)	1 m surveyed	1/100 sec	—	1×10^{-8} critical
Runway centre line points	1 m surveyed	1/100 sec	1/100 sec	1×10^{-8} critical
Taxiway centre line points	0.5 m surveyed	1/100 sec	1/100 sec	1×10^{-5} essential
Ground taxiway centre line points, air taxiways and transit routes points	0.5 m surveyed/ calculated	1/100 sec	1/100 sec	1×10^{-5} essential
Aircraft/helicopter standpoints/INS checkpoints	0.5 m surveyed	1/100 sec	1/100 sec	1×10^{-3} routine
Geometric centre of TLOF or FATO thresholds, heliports	1 m surveyed	1/100 sec	1 sec	1×10^{-8} critical

Table 2-2. Aeronautical data quality requirements (elevation/altitude/height)

Elevation/altitude/height	*Accuracy data type*	*Publication resolution*	*Chart resolution*	*Integrity classification*
Aerodrome/heliport elevation	0.5 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
WGS-84 geoid undulation at aerodrome/heliport elevation position	0.5 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
Runway or FATO threshold, non-precision approaches	0.5 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
WGS-84 geoid undulation at runway or FATO threshold, TLOF geometric centre, non-precision approaches	0.5 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
Runway or FATO threshold, precision approaches	0.25 m or 1 ft surveyed	0.5 m or 1 ft	0.5 m or 1 ft	1×10^{-8} critical
WGS-84 geoid undulation at runway or FATO threshold, TLOF geometric centre, precision approaches	0.25 m or 1 ft surveyed	0.5 m or 1 ft	0.5 m or 1 ft	1×10^{-8} critical
Obstacle Clearance Altitude/Height (OCA/H)	as specified in PANS-OPS (Doc 8168)	—	as specified in PANS-OPS (Doc 8168)	1×10^{-5} essential
Threshold crossing height, precision approaches	0.5 m or 1 ft calculated	0.5 m or 1 ft	0.5 m or 1 ft	1×10^{-8} critical
Obstacles in the approach and take-off areas	1 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
Obstacles in the circling areas and at the aerodrome/heliport	1 m or 1 ft surveyed	1 m or 1 ft	1 m or 1 ft	1×10^{-5} essential
Obstacles en-route, elevations	3 m (10 ft) surveyed	3 m (10 ft)	3 m (10 ft)	1×10^{-3} routine
Distance Measuring Equipment/ Precision (DME/P)	3 m (10 ft) surveyed	3 m (10 ft)	—	1×10^{-5} essential
Distance Measuring Equipment (DME) elevation	30 m (100 ft) surveyed	30 m (100 ft)	30 m (100 ft)	1×10^{-5} essential
Instrument approach procedures altitude	as specified in PANS-OPS Doc 8168)	—	as specified in PANS-OPS (Doc 8168)	1×10^{-5} essential
Minimum altitudes	50 m or 100 ft calculated	50 m or 100 ft	50 m or 100 ft	1×10^{-3} routine

Table 2-3. Aeronautical data quality requirements (declination and magnetic variation)

Declination/variation	*Accuracy data type*	*Publication resolution*	*Chart resolution*	*Integrity classification*
VHF NAVAID station declination used for technical line-up	1 degree surveyed	1 degree	—	1×10^{-5} essential
NDB NAVAID magnetic variation	1 degree surveyed	1 degree	—	1×10^{-3} routine
Aerodrome/heliport magnetic variation	1 degree surveyed	1 degree	1 degree	1×10^{-5} essential
ILS localizer antenna magnetic variation	1 degree surveyed	1 degree	—	1×10^{-5} essential
MLS azimuth antenna magnetic variation	1 degree surveyed	1 degree	—	1×10^{-5} essential

Table 2-4. Aeronautical data quality requirements (bearing)

Bearing	*Accuracy data type*	*Publication resolution*	*Chart resolution*	*Integrity classification*
Airway segments	1/10 degree calculated	1 degree	1 degree	1×10^{-3} routine
En-route and terminal fix formations	1/10 degree calculated	1/10 degree	1/10 degree	1×10^{-3} routine
Terminal arrival/departure route segments	1/10 degree calculated	1 degree	1 degree	1×10^{-3} routine
Instrument approach procedure fix formations	1/100 degree calculated	1/100 degree	1/10 degree	1×10^{-5} essential
ILS localizer alignment	1/100 degree surveyed	1/100 degree True	1 degree	1×10^{-5} essential
MLS zero azimuth alignment	1/100 degree surveyed	1/100 degree True	1 degree	1×10^{-5} essential
Runway and FATO bearing	1/100 degree surveyed	1/100 degree True	1 degree	1×10^{-3} routine

Table 2-5. Aeronautical data quality requirements (length/distance/dimension)

Length/distance/dimension	*Accuracy data type*	*Publication resolution*	*Chart resolution*	*Integrity classification*
Airway segments length	1/10 km or 1/10 NM calculated	1/10 km or 1/10 NM	1 km or 1 NM	1×10^{-3} routine
En-route fix formations distance	1/10 km or 1/10 NM calculated	1/10 km or 1/10 NM	2/10 km (1/10 NM)	1×10^{-3} routine
Terminal arrival/departure route segments length	1/100 km or 1/100 NM calculated	1/100 km or 1/100 NM	1 km or 1 NM	1×10^{-5} essential
Terminal and instrument approach procedure fix formations distance	1/100 km or 1/100 NM calculated	1/100 km or 1/100 NM	2/10 km (1/10 NM)	1×10^{-5} essential
Runway and FATO length, TLOF dimensions	1 m or 1 ft surveyed	1 m or 1 ft	1 m (AD chart) 0.5 m (AOC chart)	1×10^{-8} critical
Stopway length	1 m or 1 ft surveyed	1 m or 1 ft	0.5 m (AOC chart)	1×10^{-8} critical
Landing distance available	1 m or 1 ft surveyed	1 m or 1 ft	1 m (AD chart) 0.5 m (AOC chart)	1×10^{-8} critical
ILS localizer antenna — runway end and FATO end, distance	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-3} routine
ILS glide slope antenna — threshold, distance along centre line	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-3} routine
ILS markers — threshold distance	3 m or 10 ft calculated	3 m (10 ft)	2/10 km (1/10 NM)	1×10^{-5} essential
ILS DME antenna — threshold, distance along centre line	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-5} essential
MLS azimuth antenna — runway end and FATO end, distance	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-3} routine
MLS elevation antenna — threshold, distance along centre line	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-3} routine
MLS DME/P antenna — threshold, distance along centre line	3 m or 10 ft calculated	3 m (10 ft)	as plotted	1×10^{-5} essential

Table 2-6. Accuracy and probability

Accuracy expression	*One-dimensional probability*	*Two-dimensional probability*	*Three-dimensional probability*
Three sigma	99.7%	98.9%	97.1%
Two sigma	95.0%	86.0%	78.8%
One sigma	68.0%	39.3%	19.9%
Probable error	50.0% (0.67 σ)	50.0% (1.18 σ)	50.0% (1.54 σ)

Table 2-7. RNP types

Accuracy	*RNP 1*	*RNP 4*	*RNP 12.6*	*RNP 20*
95% position accuracy in the designated airspace	±1.85 km (±1.0 NM)	±7.4 km (±4.0 NM)	±23.3 km (±12.6 NM)	±37 km (±20.0 NM)

Chapter 3

THE GLOBAL WGS-84 COORDINATE SYSTEM

3.1 DEFINITION OF THE WGS-84 COORDINATE SYSTEM

3.1.1 The World Geodetic System — 1984 (WGS-84) coordinate system is a Conventional Terrestrial System (CTS), realized by modifying the Navy Navigation Satellite System (NNSS), or TRANSIT, Doppler Reference Frame (NSWC 9Z-2), in origin and scale, and rotating it to bring its reference meridian into coincidence with the Bureau International de l'Heure (BIH)-defined zero meridian.

3.1.2 Origin and axes of the WGS-84 coordinate system are defined as follows.

a) *Origin* is the earth's centre of mass.

b) *Z-axis* is the direction of the Conventional Terrestrial Pole (CTP) for polar motion, as defined by BIH on the basis of the coordinates adopted for the BIH stations.

c) *X-axis* is the intersection of the WGS-84 reference meridian plane and the plane of the CTP's equator, the reference meridian being the zero meridian defined by the BIH on the basis of the coordinates adopted for the BIH stations.

d) *Y-axis* completes a right-handed, earth-centred, earth-fixed (ECEF) orthogonal coordinate system, measured in the plane of the CTP equator, 90° east of the X-axis.

Note.— An illustration of the WGS-84 coordinate system origin and axes, which serve also as the geometric centre and the X, Y, and Z axes of the WGS-84 ellipsoid, is given in Figure 3-1.

3.1.3 WGS-84 is an earth-fixed global reference frame, including an earth model, and is defined by a set of primary and secondary parameters. The primary parameters, given in Table 3-1, define the shape of an earth ellipsoid, its angular velocity, and the earth mass which is included in the ellipsoid of reference.

3.1.4 The secondary parameters define a detailed Earth Gravity Field Model (EGFM) of the degree and order $n = m = 180$. The WGS-84 EGFM, through $n = m = 180$, is to be used when calculating WGS-84 geoid heights, WGS-84 gravity disturbance components, and WGS-84 1° × 1° mean gravity anomalies via spherical harmonic expansions. Expansions to this degree and order ($n = m = 180$) are needed to accurately model variations in the earth's gravitational field on or near the earth's surface. The WGS-84 EGFM, through $n = m = 41$, is more appropriate for satellite orbit calculation (e.g. GPS navigation satellites) and prediction purposes.

3.2 REALIZATION OF THE WGS-84 COORDINATE SYSTEM

3.2.1 The origin and the orientation of coordinate axes in WGS-84 are defined by the X, Y, Z coordinates of the five GPS monitoring stations (see Figure 3-2).

3.2.2 Historically, the coordinates of the GPS tracking sites have been determined by the use of Doppler measurements to the TRANSIT satellite navigation system. Data, observed over long periods, have been processed in order to derive precise station coordinates. The use of TRANSIT Doppler measurements in WGS-84 is a good example of the practical realization of a reference system. It should be pointed out, however, that errors can spread into the procedures used to realize reference frames.

3.3 ACCURACY OF WGS-84 COORDINATES

3.3.1 The accuracy, one sigma, (1 σ) of WGS-84 coordinates directly determined in WGS-84 by GPS Satellite Point Positioning, their respective precise ephemerides and ground-based satellite tracking data acquired in static mode, in terms of geodetic latitude ϕ, geodetic longitude λ, and geodetic height h, is:

a) horizontal — $\sigma\phi = \sigma\lambda = \pm 1$ m (1 σ); and

b) vertical — $\sigma h = \pm 1 \ldots 2$ m (1 σ).

3.3.2 These errors incorporate not only the observational error but also the errors associated with placing the origin of the WGS-84 coordinate system at the earth's centre of mass and with determining the correct scale. These absolute values should not be confused with the centimetre-precision of GPS differential positioning. At the time WGS-84 was established, only satellite Doppler measurements with corresponding accuracy were available to determine the ground control segment of WGS-84.

3.3.3 The WGS-84 coordinates of a non-satellite-derived local geodetic network station will be less accurate than the WGS-84 coordinates of a GPS station. This is due to the distortions and surveying errors present in local geodetic datum networks, i.e. the lack of a sufficient number of properly placed GPS stations collocated with local geodetic networks for use in determining the transformation parameters and the uncertainty introduced by the datum transformation.

3.3.4 The accuracy of ±1 m in the definition of WGS-84 is sufficient for nearly all air navigation applications. Additional considerations may be necessary if, for example, satellite-based landing systems down to Category III are to be used in the future. Precision approach Category III needs a vertical accuracy of 0.6 m and a horizontal accuracy of 6.0 m, which cannot be supplied by WGS-84 according to its accuracy definition, but can be supplied, for instance, by International Terrestrial Reference Frame (ITRF).

Table 3-1. Parameters of WGS-84

Parameter	*Abbreviation*	*WGS-84*
Semi-major axis	a	6 378 137 m
Angular velocity	ω	7.292115×10^{-5} rad s^{-1}
Geocentric gravitational constant (Mass of the earth's atmosphere included)	GM	398 600.5 km^3 s^{-2}
Normalized second degree zonal harmonic coefficient of the gravitational potential	$\overline{C}_{2,0}$	$-484.16685 \times 10^{-6}$
Flattening (derived from $\overline{C}_{2,0}$)	f	1/298.257223563

FIGURES FOR CHAPTER 3

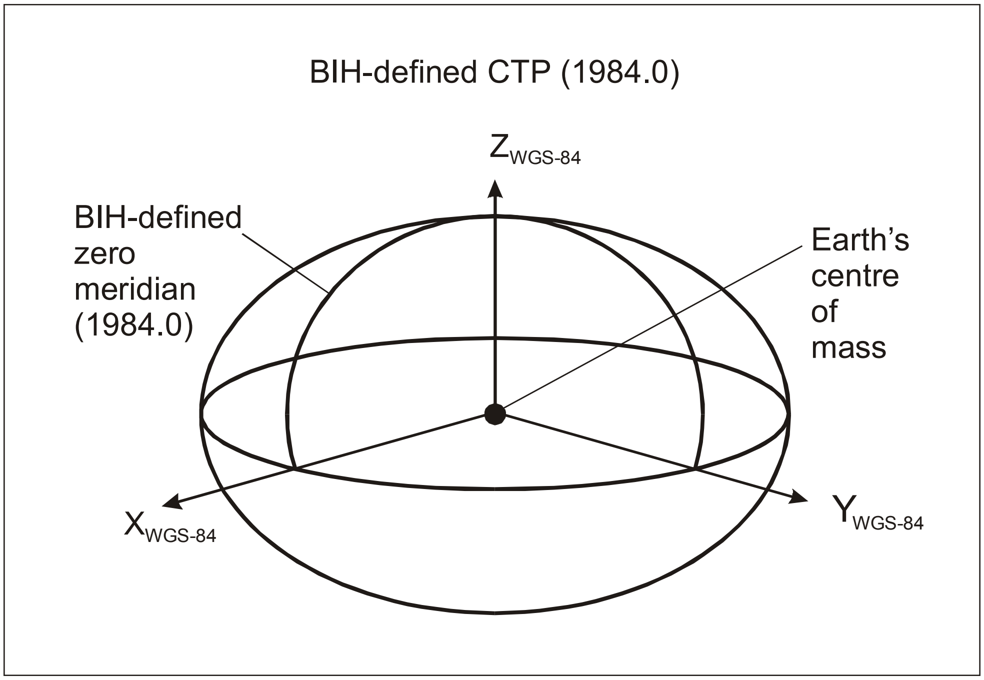

Figure 3-1. The WGS-84 coordinate system definition

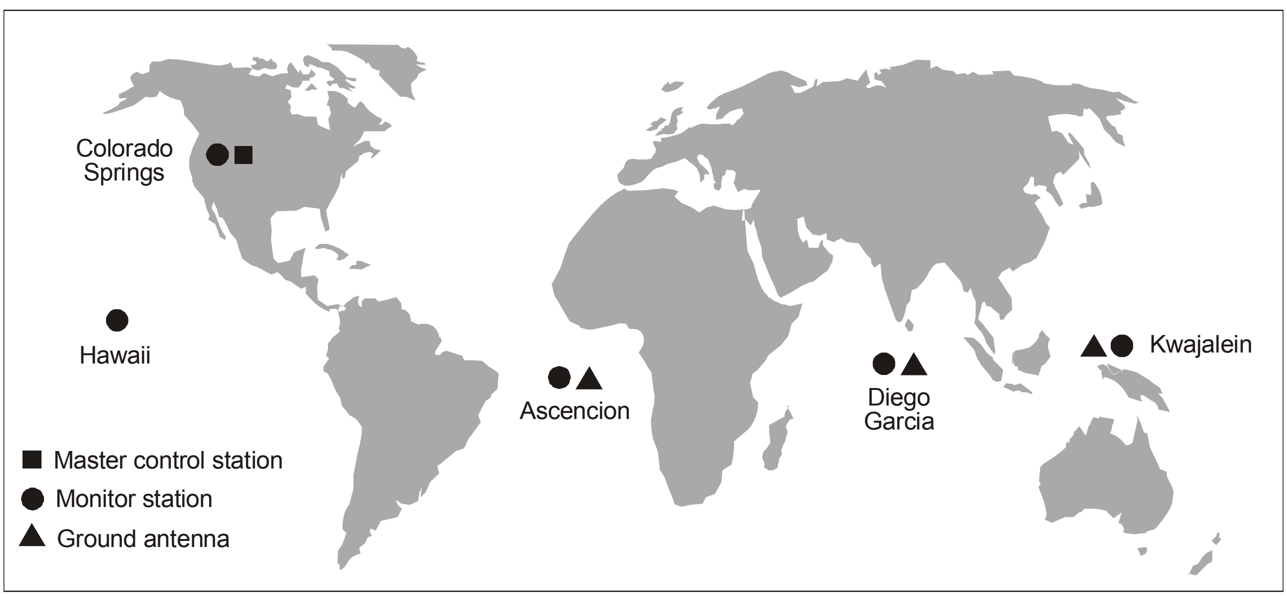

Figure 3-2. Realization of origin and orientation of WGS-84