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MILITARY STANDARD

DEPARTMENT OF DEFENSE
WORLD GEODETIC SYSTEM (WGS)

AMSC N/A **AREA MCGT**

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FOREWORD

1. This Military Standard is approved for use by all Departments and Agencies of the Department of Defense.

2. Beneficial comments (recommendations, additions, deletions) and any pertinent data which may be of use in improving this document should be addressed to: Director, Defense Mapping Agency, ATTN: TI, ST-10, 8613 Lee Highway, Fairfax, VA 22031-2137, by using the Standardization Document Improvement Proposal (DD Form 1426) appearing at the end of this document or by letter.

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1. SCOPE

1.1 Scope. This standard specifies the requirements for use of World Geodetic System 1984 (WGS 84), the defining and derived parameters for WGS 84, and methods for transforming between WGS 84 and other geodetic systems.

1.2 Applicability. This standard applies to all DoD systems and products which require use of a World Geodetic System. A world geodetic system is a consistent global coordinate system which allows an unambiguous representation of positional information. Navigation solutions from the NAVSTAR Global Positioning System (GPS) and the Navy Navigation Satellite System (NNSS) are referred to this system. A WGS 84 ellipsoid provides a reference surface upon which coordinates are calculated and is particularly applicable to inertial systems. A WGS 84 Earth Gravitational Model (EGM) provides necessary force models for accurate global operation of strategic weapons, navigation, and satellite systems. Many MC&G products produced by other agencies and governments (and DMA products not yet placed on WGS 84) are not referred to the WGS 84. Parameters to transform these products to WGS 84 are part of this standard.

1.3 Security. This standard is UNCLASSIFIED. The procedures and processes presented in this standard may be used for classified processing with the addition of appropriate security provisions.

2.1 Government documents.

This section is not applicable to this standard.

The following other Government documents, drawings, and publications form a part of this document to the extent specified herein. Unless otherwise specified, the issues are those cited in the solicitation.

DMATR 8350.2: *Department of Defense World Geodetic System 1984, Its Definition and Relationship with Local Geodetic Systems,* (latest Edition).

(Copies of DMATR 8350.2 may be requested from: Director, Defense Mapping Agency, Combat Support Center, ATTN: PMSR, ST D-17, 6001 MacArthur Boulevard, Bethesda, MD 20816-5001.)

JCS MOP 45: *Joint Chiefs of Staff (JCS) Memorandum of Policy (MOP) 45: Position Reference Procedures*

(Copies of MOP 45. may be requested from: Director, Defense Mapping Agency, ATTN: PR, ST A-13, 8613 Lee Highway, Fairfax, VA 22031-2137.)

2.2 Non-Government publications. This section is not applicable to this standard.

2.3 Order of precedence. In the event of a conflict between the text of this document and the references cited herein (except for related associated detail specification, specification sheets, or MS standards), the text of this document takes precedence. Nothing in this document, however supersedes applicable laws and regulations unless a specific exemption has been obtained.

. The acronyms used in this Standard are defined as follows:

[1] BIH	Bureau International de L'Heure
CIS	Conventional Inertial System
CTP	Conventional Terrestrial Pole
CTS	Conventional Terrestrial System
DMA	Defense Mapping Agency
DoD	Department of Defense
DoDISS	Department of Defense Index of Specifications and Standards
EGM	Earth Gravitational Model
FK5	Fundamental Katlog 5
GPS	Global Positioning System
ITS	Instantaneous Terrestrial System
MC&G	Mapping, Charting and Geodesy
MSL	Mean Sea level
NNSS	Navy Navigation Satellite System
TR	Technical Report
WGS	World Geodetic System

3.2 Definitions.

Geoid - The geoid is a particular equipotential surface of the gravity field of the earth. It is a level surface and the local direction of the gravity vector is normal to it. The mean sea level of the oceans approximates the geoid and it is this surface to which elevations (for instance, on maps) or orthometric heights are referred. The geoid is conveniently described by geoid heights relative to the reference ellipsoid. Geoid heights may be computed with the Earth Gravity Model and are available as pre-computed uniform grids of various resolution.

Elevation (H) - The distance, along the local gravity vertical, from mean sea level (MSL) to the point in question. It is available in local vertical datums and on maps.

Ellipsoid - Mathematical figure generated by the revolution of an ellipse about one of its axes. The ellipsoid that approximates the geoid is an ellipse rotated about its minor axis.

Geodetic height (h) - The distance along the ellipsoidal normal, from the ellipsoid to the point in question.

Orthometric height (H) - The distance along the vertical to the geoid, between the geoid and the point in question.

Geoidal height (N) - The vertical distance between the ellipsoid and geoid, along the ellipsoidal normal.

[1] BIH does not longer exist as an organization. It has been superseded by the International Earth Rotation Service (IEAS).

4. GENERAL REQUIREMENTS

4.1 WGS 84. WGS 84 shall provide the basic reference frame (coordinate system), geometric figure for the earth (ellipsoid), earth gravitational model, and means to relate positions on various geodetic datums and systems for DoD operations and applications.

4.2 Application of WGS 84. WGS 84 shall be the primary geodetic system used in DoD systems and Mapping, Charting and Geodesy (MC&G) products. Standardization or co-production agreements may preclude use of WGS 84 for certain areas or products. Requirements to use existing data or products may necessitate use of other geodetic systems or transforming between WGS 84 and other geodetic systems.

5. DETAILED REQUIREMENTS

5.1 WGS 84 parameters. The tables which follow contain physical and mathematical quantities which are part of the definition of WGS 84. Numerical values for these parameters shall be as specified in DMA TR 8350.2. Applications requiring conformance to this standard shall use these parameters as stated.

Parameter	Notation
Semimajor Axis	a
Normalized Second Degree Zonal Harmonic Coefficient of the Gravitational Potential	$\bar{C}_{2,0}$
Angular Velocity of the Earth	ω
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Included)	GM
The Earth's Gravitational Constant (Mass of Earth's Atmosphere Not Included)	GM'
Angular Velocity of the Earth (In a Precessing Reference Frame)	ω^*

TABLE I. WGS Ellipsoid defining parameters.

Constant	Notation
Reciprocal Flattening	$1/f$
Semiminor Axis	b
First Eccentricity	e
First Eccentricity Squared	e^2
Second Eccentricity	e'
Second Eccentricity Squared	e'^2
Linear Eccentricity	E
Polar Radius of Curvature	c
Axis Ratio	b/a
Mean Radius of Semiaxes	R_1
Radius of Sphere With Equal Area	R_2
Radius of Sphere With Equal Volume	R_3
Theoretical (Normal) Gravity Potential of (at) the Ellipsoid	U_o
Theoretical (Normal) Gravity at the Equator (on the Ellipsoid)	γ_e
Theoretical (Normal) Gravity at the Poles (on the Ellipsoid)	γ_p
Mean Value of Theoretical (Normal) Gravity	$\bar{\gamma}$
Theoretical (Normal) Gravity Formula Constant	k
Mass of Earth (Includes the Atmosphere)	M
$m = \omega^2 a^2 b/GM$	m

TABLE II. WGS Ellipsoid-derived constants.

Constant	Notation
Velocity of Light (in a Vacuum)	c
Dynamical Ellipticity	H
Earth's Angular Velocity	ω*
Universal Constant of Gravitation	G
GM of the Earth's Atmosphere	GM_A
Earth's Gravitational Constant (Excluding the Mass of the Earth's Atmosphere)	GM'
Earth's Principal Moments of Inertia (Dynamic Solution)	A B C
Conversion Factors	
Meter	to US Survey Feet
Meter	to International Feet
International Foot	to Meter (Exact)
US Survey Foot	to Meter (Exact)
US Survey Foot	to Meter
Nautical Mile	to Meters (Exact) to US Survey Feet to International Feet
Statute Mile	to Meters (Exact) to International Feet (Exact)

TABLE III. Relevant miscellaneous constants and conversion factors.

Provides Gravity Values at (on) the Surface of the WGS 84 Ellipsoid

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Notation

γ = Theoretical acceleration of a unit test mass due to gravity.

γ_e = Theoretical acceleration at the equator (on the WGS 84 Ellipsoid) of a unit test mass due to gravity.

k = Constant=$(b\gamma_p/a\gamma_e)-1$

a = Semimajor axis (WGS 84 Ellipsoid)

b = Semiminor axis (WGS 84 Ellipsoid)

γ_p = Theoretical gravity at the poles (on the WGS 84 Ellipsoid)

ϕ = Geodetic latitude

e^2 = First eccentricity squared (WGS 84 Ellipsoid).

Analytical Form

$$\gamma = \gamma_e\ (1 + k\ \sin^2\phi)\ /\ (1 - e^2\ \sin^2\phi)^{1/2}$$

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1 milligal = An acceleration due to gravity of 1×10^{-3} centimeters/second^2.

TABLE IV. WGS Ellipsoidal gravity formula.

$$V = \frac{GM}{r}\left[1 + \sum_{n=2}^{n_{\max}} \sum_{m=0}^{n} (a/r)^n \overline{P}_{n,m}(\sin\phi')(\overline{C}_{n,m}\cos m\lambda + \overline{S}_{n,m}\sin m\lambda)\right]$$

V	=	Gravitational potential function ($m^2 s^{-2}$)
GM	=	Earth's gravitational constant
r	=	Radius vector from the earth's center of mass
a	=	Semimajor axis of the WGS 84 Ellipsoid
n,m	=	Degree and order, respectively
ϕ'	=	Geocentric latitude
λ	=	Geocentric longitude = geodetic longitude
$\overline{C}_{n,m}$ $\overline{S}_{n,m}$	=	Normalized gravitational coefficients*
$\overline{P}_{n,m}(\sin \phi')$	=	Normalized associated Legendre function

Note: See DMATR 8350.2 for complete description of this model.

TABLE V. Formulas for the WGS earth gravitational model.

Parameter	Notation
Semimajor axis of local ellipsoid	a
Reciprocal flattening of local ellipsoid	f^{-1}
Geocentric translations	ΔX, ΔY, ΔZ

TABLE VI. Datum transformation parameters.

5.2 Coordinate systems.

5.2.1 Conventional Terrestrial System (CTS). The WGS 84 coordinate system shall be a Conventional Terrestrial System (CTS) with its reference meridian coincident with the Bureau International de l'Heure (BIH)—defined Zero meridian, its origin at the mass center of the earth, its Z-axis parallel to the Conventional Terrestrial Pole (CTP), its X-axis the intersection of the reference meridian plane and the plane of the CTP equator and its Y—axis completing a right—handed, earth-fixed, orthogonal system.

5.2.2 Instantaneous Terrestrial System (ITS). The WGS 84 coordinate system is the coordinate frame of a mean earth rotating at a constant rate around an average astronomic pole (CTP). A polar motion rotation matrix relates the CTS to the ITS. (See 5.2.3).

5.2.3 Conventional Inertial System (CIS). The Conventional Inertial System (CIS) is defined by the FK5 Star Catalog system and referred to the Epoch J2000.0. The relationship between the WGS 84 CTS and the CIS shall be

$$[X]_{CTS} = [A]\ [B]\ [C]\ [D]\ [X]_{CIS}$$

The rotation matrices for polar motion [A], sidereal time [B], astronomic nutation [C], and precession [D] define this relationship.

5.3 Reference surfaces.

5.3.1 Ellipsoid. The WGS 84 ellipsoid shall be a geocentric oblate ellipsoid of revolution which provides a geometric surface which approximates the size and shape of the earth. This is the level (equipotential) surface upon which position in terms of latitude, longitude, and geodetic height (height above or below the ellipsoid) are calculated. The geometric center and X, Y, and Z axes of the WGS 84 ellipsoid shall be the origin and axes of the WGS 84 Coordinate System. (The WGS 84 ellipsoid rotational axis is the WGS Coordinate System Z axis.)

5.3.2 Ellipsoidal gravity formula. Given that the ellipsoid is an equipotential surface, it is possible to calculate the theoretical (normal) acceleration due to gravity at this surface. The ellipsoidal gravity formula models normal gravity and terrestrial gravimetric measurements are referred to it.

5.4 Height Relationship. The three types of heights, geodetic (h), orthometric or elevation (H), and geoid (N), are related to each other and shall be used to compute elevations from satellite survey-derived ellipsoid height and geoid height as follows:

$$H = h_{84} - N_{84}$$

where N_{84} shall be interpolated from geoid height matrices, available from DMA with spacing at 10, 1.0 and 0.5 degree, or computed from spherical harmonic coefficients, available from DMA, using the methods specified in DMA TR 8350.2.

5.5 Earth Gravitational Model (EGM). Definition of the earth gravity field is an integral part of supporting the definition of WGS 84 and is also required in force models for various military systems. Each WGS has associated with it, an earth gravitation model (EGM) which is physically consistent with the rest of the WGS definition. The EGM is represented by coefficients for a spherical harmonic expansion. The EGM shall be used to calculate geoid heights, gravity force components, and deflection of the vertical.

5.6 WGS 84 relationship to other geodetic systems.

5.6.1 Transformation between WGS 72 and WGS 84. Transformations between WGS 72 and WGS 84 shall be made using the equations provided in DMA TR 8350.2

5.6.2 Transformation between local geodetic datums and WGS 84. Coordinates shall be transformed between local geodetic datums and WGS 84 by applying origin shifts, ΔX, ΔY, ΔZ, between the origins of the local datum rectangular coordinate system and the WGS 84 coordinate frame. The origin shifts may be applied directly to the rectangular coordinates or converted to shifts in geodetic (curvilinear) coordinates using the standard Molodensky formulas. Methods for applying origin shifts and the Molodensky formulas are given in DMA TR 8350.2. Other datum transformation methods, such as multiple regression equations, shall not be used for DoD Mapping and Charting (MC&G) applications. Datum transformation between two local datums shall be performed by transforming from the first local datum to WGS 84 and then from WGS 84 to the second local datum.

5.6.2.1 Datum transformation parameters. DMA shall maintain a data base of datum identification, datum transformation parameters, region of coverage for the transformation parameters, and estimated accuracy of the transformation parameters. Because of distortions in local geodetic systems or lack of data to determine a datum transformation, some transformation parameters may be generated for only a portion (region) of a local datum. Users are responsible for insuring transformation parameters are applied only to positions within the valid area of coverage.

5.6.2.2 Obtaining datum transformation parameters. Transformation parameters for a number of datums and regions are contained in DMA TR 8350.2. Since this list is subject to change, developers and users shall obtain the latest list of parameters from DMA when developing new or upgraded systems employing datum transformations.

5.6.2.3 Configuration control. DoD systems shall only use datum transformation parameters provided by DMA. DMA shall provide datum transformation parameters in a standard format. DMA shall maintain lists of datum transformation parameters recommended for use for different classes of applications. Users shall use only those transformation parameters provided or validated by DMA or provided by other competent authority. DMA shall maintain a list of those systems employing datum transformation techniques and provide notification when a new version of the data base is released.

5.6.2.4 System upgradability. Since transformation parameters may change and datums may be added to the data base as new data is acquired, systems employing datum transformation shall be designed to accept upgrades of transformation parameters. Systems should be designed to accept user input of transformation parameters to accommodate changes or additional datums which occur between software upgrades.

6. NOTES

(This section contains information of a general or explanatory nature that may be helpful, but is not mandatory.)

6.1 Intended use. To provide a reference for development of systems which must operate in the DoD World Geodetic System 1984.

6.1.1 Height Systems. Geodetic heights (h) are purely geometric and independent of the effects of variation in the earth gravity. This height is directly obtained through satellite positioning, but is not generally available in local datums. It is not possible to transform between vertical datums as no information exists on the relationship of the various MSL determinations. In practical applications, the difference between orthometric height and elevation is ignored.

6.2 Acquisition requirements. When this standard is used in acquisition, the applicable issue of DoDISS must be cited in the solicitation (see 2.1.1 and 2.2).

6.3 Subject term (Key word) listing.

Angular Velocity of the Earth
Coordinate Systems
Datum Transformations
Earth Gravitational Model
Ellipsoid Flattening
Ellipsoidal Gravity Formula
Ellipsoid Semimajor Axis
Flattening
Geodetic Heights
Geoids
Geoid Heights
Gravitational Potential
Gravity Formula
Gravity Potential
Local Datums
Local Geodetic Datums
Local Geodetic Systems
Molodensky Datum Transformation Formulas
Reference Frames
Reference Systems

6.4 International standardization agreements.

Certain provisions of this specification may be subject to international standardization agreements. When amendment, revision, or cancellation of this specification is proposed that will modify the international agreement concerned, the preparing activity will take appropriate action through international standardization channels, including departmental standardization offices, to change the agreement or make other appropriate accommodations.

6.4.1 International standardization agreements (STANAGs).

This section is not applicable to this specification.

6.4.2 Quadripartite standardization agreements (QSTAGs).

This section is not applicable to this specification.

6.4.3 Air standardization coordinating committee agreements (ASCCs).

This section is not applicable to this specification.

6.4.4 International MC&G agreements.

This section is not applicable to this specification.

6.4.5 Executive orders.

This section is not applicable to this specification.

6.4.6 Inter-Agency agreements.

This section is not applicable to this specification.

6.4.7 Other documentation.

CJCS MOP 45: Position Reference Procedures.

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Review activities:
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(Project MCGT-0087)