The Spatial Data Transfer Standard Mapping of the USGS Digital Elevation Model

11/13/97 Version 1.0

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Preface

The purpose of this document is to describe how the Digital Elevation Model (DEM) maps into the Spatial Data Transfer Standard (SDTS). This document is written from the perspective of the DEM. The terminology and concepts are those of the DEM unless specifically stated to be of the SDTS. The DEM is breifly described to aid in the comprehension of the mapping. A fimliary with the concepts and structures of the SDTS and Raster Profile (RP) is assumed.

The mapping herein conforms to the Raster Profile implementation of the SDTS. The mass conversion of DEM data was completed using a draft version of this document,the portion that discusses the DEM is stable.

The document is divided into three sections. Section 1 describes the DEM, Section 2 describes the mapping of the USGS DEM into the Raster profile of the SDTS, Section 3 DEM transfers as sets of modules and groups of module records.

References

FIPS PUB 173: Spatial Data Transfer Standard (August 28, 1992). Avaiable from The Nationam Technical Information Service, U.S. Department of Commerce, Springfield, VA 22161. Text online at Anonymous FTP site sdts.er.usgs.gov, directory “standard”.

Proposed ANSI Draft Version: Spatial Data Transfer Standard (October 1997). For the latest available, see Anonymous FTP site sdts.er.usgs.gov directory “latest_draft” under the “standard” directory.

Part 5: SDTS Raster Profile with BIIF Extension (Draft Version July 1997). Available from the FDGC Home Page http://www.fdgc.gov.

Cartograny and Geographic Information Systems, Vol 19, No. 5, December 1992, American Congress on Surveying and Mapping, Special Issue on SDTS. Text of some articles online at Anonymous FTP site sdts.er.usgs.gov, directory “articles”.

USGS Standards for Digital Elevation Models: Available from U.S. Geological Survey, National Center, Reston, VA 22092.

SDTS Software and Datasets. For the latest available, see Anonymous FTP Site sdts.er.usgs.gov, directories “software” and “datasets”.

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The USGS Digital Elevation Model

Section 1: The USGS Digital Elevation Model (DEM) is a brief overview of the product and how it is mapped into the Spatial Data Transfer Standard (SDTS)- Raster Profile.

1. What is a DEM?

The Digital Elevation Models (DEM) are terrain elevations at regularly spaced horizontal intervals, i.e., an a grid of regularly spaced elevations.

1.1 Overview of DEM

Two types of grids, UTM and arc second, are used for the USGS DEM program.

UTM Structured DEM

A typical 7.5-minute UTM DEM is shown in figure 1-1. The 7.5-minute DEM profiles are clipped to the straight line intercept between the four geographic corners of the quadrangle, an approximation of the geographic map boundary (neatline). The resulting area of coverage for the DEM is a quadrilateral, the opposite sides of which are not parallel. (See appendix 2-D for an example of UTM coordinates describing a 7.5-minute quadrilateral figure.)

The UTM coordinates of the four corners (bounds) of the DEM are listed in the type A record, as shown in appendix 2-A, data element 11; the UTM coordinates of the starting points of each profile are listed in the type B record (profiles), appendix 2-B, data element 3. These coordinates describe the shape of the quadrilateral and the variable x, y starting position of each profile. Because of the variable orientation of the quadrilateral in relation to the UTM grid, profiles intersect the east and west neatlines as well as the north and south neatlines as shown in figure 1-1. In addition, DEM's have profile easting values that are continuous from one DEM to the adjoining DEM only if the adjoining DEM is contained within the same UTM zone. Profiles that pass within the bounds of the DEM quadrilateral, but are void of elevation grid points, are not represented in the DEM (Referred to as "missing profile condition." This condition occurs occasionally and is always the first or last profile of the DEM. Typically such a profile intersects the DEM corner, but there is no grid node within the quad bounds).

The use of UTM coordinates to define the horizontal grid spacing of DEM's is restricted at this time to the 7.5-minute DEM program.

Arc second structured DEM

A typical 1-degree arc second DEM is shown in figure 1-2. The 1-degree DEM west-and-east profiles are coincident with the west and east neat- lines respectively. The distribution of elevation data is as illustrated in figure 1-2. The resulting area of coverage for the DEM is a geographic rectangle.

The arc second coordinates of the four corners (bounds) of the DEM are listed in the type A record, as shown in appendix 2-A, data element 11; the arc second coordinates of the starting points of each profile are listed in the type B record (profiles), appendix 2-B, data element 3. These coordinates describe the shape of the geographic rectangle and the x, y starting position of each profile.

The use of arc second coordinates to define the horizontal grid spacing of DEM's is mandatory for all DEM series, except for 7.5-minute UTM DEM's.

1.2 Difference Between Product Series

The USGS produces five primary types of DEM data. The following describes these products as they are archived in the NDCDB in standard DEM format (see table 1-1 and 1-2):

1. 7.5-minute DEM (up to 30-meter square grid spacing, cast on Universal Transverse Mercator (UTM) projection). Allowable spacings range from 1-meter to 30-meter. Unless otherwise specified DEM data collected will have 10-meter or 30-meter spacings. Provides coverage in 7.5- by 7.5-minute blocks. Each product provides the same coverage as a standard USGS 7.5-minute quadrangle without overedge. Coverage: Contiguous United States, Hawaii, and Puerto Rico.

2. 2-arc second (2- by 2-arc second data spacing). This product was formerly known as a 30-minute DEM. 2-arc second DEM's provide the same coverage as a standard USGS 30- by 60-minute quadrangle. Saleable units are 30- by 30-minute blocks, that is, four 15- by 15-minute DEM's representing one half of a 1:100,000-scale map. Coverage: Contiguous United States, and Hawaii.

3. 1-degree DEM (3- by 3-arc second data spacing). Provides coverage in 1- by 1-degree blocks. Two products (three in some regions of Alaska) provide the same coverage as a standard USGS 1- by 2-degree quadrangle. The basic elevation model is produced by or for the National Imergery and Mapping Agency (NIMA), formerly known as the Defense Mapping Agency. Data is distributed by the USGS in the DEM data record format. Coverage: United States.

4. 7.5-minute Alaska DEM (1- by 2-arc second data spacing, latitude by longitude). Provides coverage similar to a 7.5-minute DEM, except that the longitudinal cell limits vary from 10 minutes at the southernmost latitude of Alaska to 18 minutes at the northernmost latitude limits of Alaska.

5. 15-minute Alaska DEM (2- by 3-arc second data spacing, latitude by longitude). Coverage is 15 minutes of latitude by 20 minutes of longitude at the southernmost latitude of Alaska, to 36 minutes of longitude at the northernmost latitude limits of Alaska. Coverage of one DEM corresponds to a l:63,360-scale quadrangle.

Note: The term "block," as used in 1, 2, and 3 above, is used to describe the physical extent of a DEM quadrangle, and implies that the DEM is trimmed to the quadrangle neatlines and that no overedge is allowed beyond the "block" boundaries.

Table 1-1

Specifications for digital elevation models

	Horizontal Coordinate system	Units of coverage	Elevations	Profile spacing	Data order
7.5-minute DEM	UTM on North American Datum of 1927 (NAD 27) or North American Datum of 1983 (NAD 83).	7.5-minute quadrangle; overedge coverage is not provided.	Decimal or whole units of meters or feet relative the National Geodetic Vertical Datum of 1929 (NGVD 29) in the continental U.S., and local mean sea level for Hawaii and Puerto Rico.	Spacing of elevations along and between each profile is dependent on square grid resolution. Allowable spacings range from 1-meter to 30-meters. Unless otherwise specified in acooperative agreement, DEM data collected by or for the USGS will have 10- or 30-meter spacings.	Data are ordered south to north in profiles ordered west to east. The profiles do not always have the same number of elevations because of the variable angle between true north and the grid north of the UTM coordinate system.
2-arc second DEM	Geographic (lat/long) on NAD 27 or NAD 83.	30- by 30-minute block. Saleable units are four 15-minute DEM's covering a 30- by 30-minute block.	Meters or feet relative to NGVD 29 in the continental U.S., and local mean sea level in Hawaii and Puerto Rico.	Spacing of elevations along and between each profile is 2 arc seconds.	Data are ordered south to north in profiles ordered west to east.
1-degree DEM	Geographic (lat/long) on World Geodetic Survey (WGS) 72 or WGS 84.	1- by 1-degree block; elevation data on the integer degree lines correspond with the profiles on the surrounding eight blocks.	Meters relative to NGVD 29 in the continental U.S. and Alaska, and in local mean sea level in Hawaii and Puerto Rico.	Spacing of elevations along each profile is 3 arc seconds. Spacing between profiles is 3 arc seconds south of 50°N latitude, 6 arc seconds between 50°N and 70°N, and 9 arc seconds north of 70°N.	Data are ordered south to north in profiles ordered west to east.
7.5-minute Alaska DEM	Geographic (lat/long) on NAD 27 or NAD 83.	7.5 by 10 minutes south of 59°N; 7.5 by 11.25 minutes between 59°N and 62°N; 7.5 by 15 minutes between 62°N and 68°N; and 7.5 by 18 minutes north of 68°N.	Meters or feet relative to NGVD 29.	Spacing of elevations along and between each profile is 1 by 2 arc seconds, respectively.	Data are ordered south to north in profiles ordered west to east.

15-minute Alaska DEM	Geographic (lat/long) on NAD 27 or NAD 83.	15 by 20 minutes south of 59°N; 15 by 22.5 minutes between 59°N and 62°N; 15 by 30 minutes between 62°N and 68°N; and 15 by 36 minutes north of 68°N.	Meters or feet relative to NGVD 29.	Spacing of elevations along and between each profile is 2 by 3 arc seconds, respectively.	Data are ordered south to north in profiles ordered west to east.

Table 1-2

Data production of digital elevation models

DEM level**	DEM series*	Production process	Instructions and comments
Level 1	7.5-minute DEM 30-minute DEM	DEM created by auto correlation or manual profiling from aerial photographs. Source photography is typically from National Aerial Photography Program or National High Altitude Photography Program. Depending on the specific production process used, a given DEM shall meet the maximum 7-meter root mean square error (RMSE) or may have an RMSE less than one-half of the contour interval of the corresponding topographic series map. Level 1 30-minute DEM's may be derived or resampled from level 1 7.5-minute DEM.	May be derived from a wide variety of sources using any of a number of USGS approved techniques and instrumentation. The primary objective is that the resulting product meet the minimum accuracy requirements required to support production of orthophotos at a scale of 1:24,000. This DEM product must also meet minimum RMSE test standards as specified in part 2, sections 2.1.4 and 2.3.1.
Level 2	All series*	DEM created from digital line graph (DLG) contours or equivalent, from any USGS map series up to 1:100,000 scale.	The accuracy and data spacing are intended to support computer applications that analyze hypsographic features to a level of detail similar to manual interpolations of information from printed source maps.
Level 3	7.5-minute DEM	DEM created from DLG that have been vertically integrated with all categories of hypsography, hydrography, ridge line, break line, drain files, and all vertical and horizontal control networks.	Requires a system of logic incorporated into the software interpolation algorithms that clearly differentiates and correctly interpolates between the various types of terrain, data densities, and data distribution.

* This table is exclusive of 1-degree DEM's that are produced for or by DMA according to DMA program requirements. Level designation is referenced in a different context
than that used by the USGS. The DMA designation of digital terrain data (DTED) "level" is similar to the USGS designation of DEM "series." Under a cooperative agreement,
selected 1-degree DEM's are being regridded by the USGS from 7.5-minute DEM's and 30-minute DEM's. These DEM's are subject to quality control procedures as specified in a
Memorandum of Understanding between the two agencies.

** DEM levels are defined in section 2.3.

1.3 Large Overview of Mapping to SDTS

[Convert this statement pertaining to DEM]

The DEM mapping will be compliant with the Raster Profile of SDTS and the default implementation, i.e. .... As a large data producer. The product mapping will be compliant with the proposed FGDC Content Standard for Digital Geospatial Metadata (CSDGM) Mapping to SDTS. Elements will be mapped to SDTS in a standardized way. The DEM mapping for NMD Products should be as similiar as possible. Similarity of DEM, DOQ, DRG ...

Packaging decisions with regard to SDTS Transfers

will follow traditional data distribution based on saleable unit:
Each 24k DEM file will be a single SDTS Transfer.

Each 30-minute DEM will be a two transfers-(The 30-minute DEMs in their native format are normally distributed in 30-by 30-minute area of coverage representing the DEM for the east or west half of a 1:100,000-scale source map.

2. Mapping of DEM Elements

This section describes the mapping of the elements contained in the NMD DEM file format to modules, fields and subfields of the SDTS. The mapping of the DEM elements is based on the descriptions from the standards for Digital Elevation Models.

2.1 Mapping to SDTS Module, Field and Subfield

The NMD DEM file format contains three types of records, called A, B, and C. The type A record contains information defining the general characteristics of the DEM including name, boundaries, units of measurement, minimum and maximum data values, number of type B records, and projection parameters. There is only one type A record for each DEM file, and it appears as the first record in the data file. The type B record contains elevation data and associated header information. There is a B record for each one-dimensional band of elevations (called profiles.) The type C record contains statistics on the accuracy of the elevation data in the file. There is only one type C record for each DEM file, and it appears as the last record in the data file.

The mapping of DEM elements to SDTS modules, fields and subfields is done using DEM element descriptions in the Standards for Digital Elevation Models (Referral Number ST2-5-2; Open File Number 86-004 including revisions up to July 1997) and the SDTS element descriptions in the FIPSPUB 173, Part 1. The results of the mapping are contained in the table following this section. The first two columns contain a DEM header identifier and element description. *(The element ID corresponds to the record format descriptions in the Data Users guide.)* The last column contains the appropriate SDTS module, field and subfield with a brief description.

Table 2.1: Mapping to SDTS Module, Field and Subfield

ID	Header Element Description	SDTS Module/Field/Subfield
A1a	File name	IDEN/IDEN/TITL Title of the transfer
A1b	Free format text - descriptor	DQHL/DQHL/COMT Comment
A1c	SE Geographic Corner (used as a geographic cell locator)	IDEN/IDEN/DAID Dataset Identifier
A1d	Process code	DQHL/DQHL/COMT Comment
A1e	Sectional indicator	IDEN/IDEN/DAID Dataset Identifier IDEN/IDEN/TITL Title
A2	Mapping Center origin code	DQHL/DQHL/COMT Comment
A3	DEM level code	DQPA/DQPA/COMT DQHL/DQHL/COMT Comment
A4	Code defining elevation pattern	RSDF/RSDF/OBRP Object Representation
A5	Code defining ground planimetric reference system	XREF/XREF/RSNM Reference System Name
A6	Code defining zone in ground planimetric reference system	XREF/XREF/ZONE Projection Zone Number
A7	Map projection parameters	Not Encoded (always zero because not used for standard DEM product series)
A8	Code defining unit of measure for ground planimetric coordinates (x,y) throughout the file	SDTS requires meters for UTM and decimal degrees for geographic units.
A9	Code defining unit of measure for elevation coordinates throughout the file	DDSH/DDSH/UNIT Unit describing cell value
A10	Number (n) of sides in the polygon that defines the coverage of the DEM file	Not needed (always 4 and implied by Spatial Domain)
A11	A 4,2 array containing the ground coordinates of the quadrangle boundary for the DEM	SPDM/DMSA/X & Y SPDM/SPDM/DTYP 4 sets of Domain Spatial Addresses.
A12	A two-element array containing minimum and maximum elevations for the DEM	DDOM/DDOM/DVAL Domain Value Min-max of cell value.

ID	Header Element Description	SDTS Module/Field/Subfield
A13	Counterclockwise angle (in radians) from the primary axis of ground planimetric reference to the primary axis of the DEM local reference system	Not Encoded (always 0 because not in use)
A14	Accuracy code for elevations	DQPA/DQPA/COMT Comment
A15	A three-element array of DEM spatial resolution for x, y, z. Units of measure are consistent with those indicated by data elements 8 and 9 in this record	IREF/IREF/XHRS IREF/IREF/YHRS X,Y Component of Horizontal Resolution. DDSH/DDSH/PREC Precision of cell values
A16	A two-element array containing the number of rows and columns (m,n) of profiles in the DEM	LDEF/LDEF/NROW RSDF/RSDF/RWXT Number of Rows; Row Extent LDEF/LDEF/NCOL RSDF/RSDF/CLXT Number of Columns; Column extent
A17	Largest primary contour interval	DQPA/DQPA/COMT Comment
A18	Source contour interval units	DQPA/DQPA/COMT Comment
A19	Smallest primary	DQPA/DQPA/COMT Comment
A20	Source contour interval units	DQPA/DQPA/COMT Comment
A21	Data source date	IDEN/IDEN/MPDT Map Date
A22	Data inspection or revision date	DQHL/DQHL/COMT Comment use latest date
A23	Inspection or revision flag	DQHL/DQHL/COMT Comment
A24	Data validation flag	DQHL/DQHL/COMT Comment
A25	Suspect and void area flag	DQCG/DQCG/COMT Comment use for code 0,2,3 - void areas. DQPA/DQPA/COMT Comment use for code 0,1,3 - suspect areas.

ID	Header Element Description	SDTS Module/Field/Subfield
A26	Vertical datum	XREF/VATT/VDAT Vertical Datum Applies to Cell Module
A27	Horizontal datum	XREF/XREF/HDAT Horizontal Datum
A28	Data Edition	DQHL/DQHL/COMT Comment
A29	Percent Void	DQCG/DQCG/COMT Comment
A30	Edge Match Flag	DQLC/DQLC/COMT Comment
A31	Vertical Datum Shift	XREF/XREF/COMT DQPA/DQPA/COMT Comment
B1	A two-element array containing the row and column identification number of the DEM profile contained in this record	Not needed because irrelevant in SDTS form (Profiles reorganized into scanline order)
B2	A two-element array containing the number of elevations in the DEM profile	Not Needed (Profiles reorganized into scanline order and fill values used to create a regular array of SDTS cells)
B3	A two-element array containing the ground planimetric coordinates (X_{gp},Y_{gp}) of the first elevation in the profile	RSDF/SADR/X & Y Spatial Address X and Y Calculated for top left only
B4	Elevation of local datum for the profile	Not Encoded because applied to elevation values (only used in elevation calculations during conversion to SDTS)
B5	A two-element array of minimum and maximum elevations for the profile	Not needed
B6	An m,n array of elevations for the profile. Elevations are expressed in units of resolution	CELL/CVLS/ELEVATION Cells contain Elevation Values. Cell data will be ordered with origin at top left and scan direction from left to right.
C1	Code indicating availability of statistics in data element 2	Not needed (internal flag)
C2	RMSE of file's datum relative to absolute datum (x, y, z)	DQPA/DQPA/COMT Comment
C3	Sample size on which statistics in data element 2 are based	DQPA/DQPA/COMT Comment

ID	Header Element Description	SDTS Module/Field/Subfield
C4	Code indicating availability of statistics in data element 5	Not needed (internal flag)
C5	RMSE of DEM data relative to file's datum (x, y, z)	DQPA/DQPA/COMT Comment
C6	Sample size on which statistics in data element 5 are based	DQPA/DQPA/COMT Comment

2.2 Mapping According to DEM Element Value

Section 2.1 contains the correspondence between DEM file elements and SDTS structures. Section 2.2 will go into more detail on the value that is placed in the SDTS subfield. The DEM file element value often causes different content to be placed in SDTS subfields.

The results of the element-value based mapping are contained in the tables following this section. The mapping tables are organized to reflect SDTS module delineation. The first two columns contain a DEM element identifier and description. The next two columns, Value and Action, contain the domain of element values and the appropriate action for each value. In the Value column, the symbol "<>" is used to generically represent a value so its use in the Action column can be illustrated. The last column contains the SDTS module, field and subfield to which the specific header value is mapped.

Certain elements related to data quality information are converted into textual narration. The text describes the meaning of the value, making the element, as it is portrayed in SDTS structures, self-describing. In the Action column of the tables, you will find that 1 or more elements may be used in combination to construct a sentence. (See Section 2.2.4 Data Quality Elements Table, row A17 and A18 for an example.)

2.2.1 Identification Elements

DEM elements classified as Identification Elements are those used to identify the standard and profile version, and a specific product.

The SDTS module involved in this section is the
Identification Module (IDEN).

Explanation of Sectional Indicator (A1e)

The 30-minute DEM's are based on the 1:100,000-scale source map, and are partitioned into files in the same manner as 1:100,000-scale DLGs. The file (i.e. quadrangle) name field in the DEM type A record contains the name of the 1:100,000-scale source map. The section contained in each DEM native file is identified by a 3 character code XNN where:

X is a single letter indicating size of the section
- F = 15-minute block
- S = 7.5-minute block

NN is a two-digit number indicating the section.
- Sections are numbered starting from the top left and proceeding to the right.

Figure 2.2.1a shows the section indicators for a 1:100,000-scale quadrangle divided into eight 15-minute quads, 4 per 30-minute area.

F01	F02	F03	F04
F05	F06	F07	F08

Figure 2.2.1a

Figure 2.2.1b shows the section indicators for a 1:100,000-scale quad divided into 32 7.5-minute quads, 16 per 30-minute area.

S01	S02	S03	S04	S05	S06	S07	S08
S09	S10	S11	S12	S13	S14	S15	S16
S17	S18	S19	S20	S21	S22	S23	S24
S25	S26	S27	S28	S29	S30	S31	S32

Figure 2.2.1b

As shown in the Action column of the Identification Elements table for element Ale, the section number will be embedded in the Dataset Identifier, and included in the SDTS Title subfield in the Identification Module.

Explanation of Dates (A21 and A22)

Both the "Data Source Date" and the "Data Inspection and Revision Date" need to be inspected to properly set the SDTS subfield of Map Date. In SDTS, the Map Date is the temporal extent of the data, i.e. the date that refers to real-world conditions and not data collection and processing dates. If more than one date is present, then the later of the dates should be used to value the SDTS Map Date subfield.

In addition, to unambigously preserve the date information in a DEM, all the dates will be included in the Data Quality Lineage report embedded in descriptive text.

Prior to July 1997, the DEM date format was YYMM. A change issued i n July1997 modified this to be YYYY in preparation for the year 2000.

Table 2.2.1: Identification Elements

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A1a	File name [START RECORD IDEN-1a]	<>	< (extract cell name and state list)>	IDEN/IDEN/TITL Title of the transfer
A1c	SE Geographic Corner [CONTINUE RECORD IDEN-1c]	<x> <y>	--> "LAT::<x> LONG::<y>"	IDEN/IDEN/DAID
A1e	Sectional Indicator [CONTINUE RECORD IDEN-1d]	blank	No Action	
		Snn	Concatenate this value to File Name. --> “- 7.5-minute section number <nn> of 1:100,000-scale source quad." (Specific to 30-min DEM's)	IDEN/IDEN/TITL
			Concatenate this value to Data Identifier --> "SEC IND:: <Snn>" (Specific to 30-min DEM's)	IDEN/IDEN/DAID
		Fnn	Concatenate this value to File Name. " - 15-minute section number <nn> of 1:100,000-scale source quad." (Specific to 30-min DEM's)	IDEN/IDEN/TITL
			Concatenate this value to Data Identifier "SEC IND:: <Fnn>" (Specific to 30-min DEM's)	IDEN/IDEN/DAID

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A21	Data source date	<>	if A21 > A22, then --> <A21> else --> <A22> (the latest of these two dates, if 2 dates exist; Format in DEM is YYYY as of July 1997)	IDEN/IDEN/MPDT Map Date use latest date
A22	Data inspection and revision date			
n/a	Source Scale - supplied externally [CONTINUE RECORD IDEN-1b]	<>	IDEN/IDEN/TITL--> "-<>" IDEN/IDEN/DAID--> "SCALE:: <>"	IDEN/IDEN/TITL IDEN/IDEN/DAID

2.2.2 Spatial Reference and Domain Elements

DEM elements that identify spatial reference systems and spatial domains are found in DEM record A and include planimetric reference system definitions, resolutions and horizontal datum.

The SDTS modules involved in this section are
External Spatial Reference (XREF),
Internal Spatial Reference (IREF), and
Spatial Domain (SPDM).

Explanation of Reference System (A5)

The integer code from the DEM element must be translated into the appropriate SDTS enumerated value. If a value of 3 or higher is encountered, then issue an error message to a processing log and abort processing.

Explanation of DEM Bounds (A11)

The UTM coordinates of the four corners (bounds) or the arc second coordinates of the four corners (bounds) of the DEM are listed in the header element A-11. In SDTS, the spatial domain will be encoded as a domain "RING". The spatial addresses should be expressed in the External Reference System which is UTM or geographic depending on the DEM product series.

Explanation of Vertical Datum (A26)

Because a DEM is encoded as a SDTS raster, the vertical datum is stored in the Vertical Attribute field of the External Reference Module and the Vertical Encoding Method is that of CELL.

Table 2.2.2: Spatial Reference and Domain Elements

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A5	Code defining ground planimetric reference system	0	Geographic -> "GEO" (Convert value to SDTS enumerated type)	XREF/XREF/RSNM Reference System Name.
		1	UTM -> "UTM" (Convert value to SDTS enumerated type)	
		2	state plane -> "SPCS" (Convert value to SDTS enumerated type)	
		3-20	other sys (appendix 2-G) -> ABORT PROCESSING	
A6	Code defining zone in ground planimetric reference system	<>	<> (Use value as-is)	XREF/XREF/ZONE Projection Zone Number.
A8	Code defining unit of measure for ground planimetric coordinates throughout the file	<>	SDTS requires meters for UTM and decimal degrees for geographic units. *** If <>=2 and A5=1 then units are in meters If <>=3 and A5=0 then units are in arc seconds	(n/a)
A11	A 4,2 array containing the ground coordinates of the quadrangle boundary for the DEM	4<x,y>	SPDM/SPDM/DTYP --> "RING" SPDM/SPDM/DSTP --> "EXTERNAL" SPDM/DMSA/X & Y --> 4 <x,y> (Convert to External System if necessary)	SPDM/DTYP=RING SPDM/SPDM/DSTP=EXTERNAL SPDM/DMSA/X & Y 4 sets of Domain Spatial Addresses.
A15	A three-element array of DEM spatial resolution for x, y, z. Units of measure are consistent with those indicated by data elements 8 and 9 in this record.	<x>	IREF/IREF/XHRS -> <x>	IREF/IREF/XHRS
		<y>	IREF/IREF/YHRS -> <y>	IREF/IREF/YHRS
		<z>	DDSH/DDSH/PREC -> <z> (The elevation record)	DDSH/DDSH/PREC

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A26	Vertical Datum	1	XREF/VATT/VDAT--> "LMSL" XREF/XREF/COMT -->"Local Mean Sea Level" XREF/VATT/VEM--> "CELL" (constant) XREF/VATT/ATLB--> "ELEVATION" (constant) XREF/VATT/AUTH--> "USGS/NMD" (constant)	XREF/VATT/VDAT XREF/XREF/COMT XREF/VATT/VEM XREF/VATT/ATLB XREF/VATT/AUTH
		2	XREF/VATT/VDAT--> "NGVD" XREF/XREF/COMT -->"National Geodetic Vertical Datum 1929" XREF/VATT/VEM--> "CELL" (constant) XREF/VATT/ATLB--> "ELEVATION" (constant) XREF/VATT/AUTH--> "USGS/NMD" (constant)	
		3	XREF/VATT/VDAT--> "NAVD" XREF/XREF/COMT -->"North American Vertical Datum 1988" XREF/VATT/VEM--> "CELL" (constant) XREF/VATT/ATLB--> "ELEVATION" (constant) XREF/VATT/AUTH--> "USGS/NMD" (constant)	
A27	Horizontal datum	1	NAD 27 --> "NAS" (Convert value to SDTS enumerated type)	XREF/XREF/HDAT Horizontal Datum
		2	WGS 72 --> "WGC" (Convert value to SDTS enumerated type)	
		3	WGS 84 --> "WGE" (Convert value to SDTS enumerated type)	
		4	NAD 83 --> "NAX" (Convert value to SDTS enumerated type)	
		5	XREF/XREF/HDAT--> "OHD" XREF/XREF/COMT -->"HDAT abbrev. means Old Hawaii Datum".	XREF/XREF/HDAT XREF/XREF/COMT
		6	XREF/XREF/HDAT --> "PRD" XREF/XREF/COMT -->"HDAT abbrev. means Puerto Rico Datum".	XREF/XREF/HDAT XREF/XREF/COMT

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A31	Vertical Datum shift	< >	If <A26> = NAVD, then --> “Vertical Datum Shift = <>; already in North American Vertical Datum 1988.” Else "Vertical datum shift = " < > "; always add to convert from <A26, spelled out> to North American Vertical Datum 1988."	XREF/XREF/COMT

2.2.3 Data Dictionary Elements

DEM elements that are used in SDTS data dictionary information include precision units, minimum and maximum, of elevation stored in cell values.

The SDTS modules involved in this section include

Data Dictionary/Domain,
Data Dictionary/Schema, and
Data Dictionary/Definition

Table 2.2.3: Data Dictionary Elements

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A9	Code defining unit of measure for elevation coordinates throughout the file	1	--> "FEET"	DDSH/DDSH/UNIT DDOM/DDOM /ADMU Unit describing cell value.
		2	--> "METERS"	
A12	A two-element array containing minimum and maximum elevations for the DEM	<min> <max>	DDOM/DDOM/DVAL --> <min> (Minimum elevation record) DDOM/DDOM/DVAL --> <max> (Maximum elevation record)	DDOM/DDOM/DVAL Min-max of cell value.
A15	A three-element array of DEM spatial resolution for x, y, z.	<z>	DDSH/DDSH/PREC --> <z> (The elevation record)	DDSH/DDSH/PREC

2.2.4 Data Quality Elements

DEM elements that describe aspects of data quality are included in this section. Data Quality elements record statements and clarifications about processes, sources, tests, inspections, corrective actions, and statistics on the accuracy of the data in the file.

The DEM Standard includes explanatory text that apply to all USGS DEMs, i.e. not dataset specific. Where appropriate, text from the DEM standard will be included in SDTS data quality modules.

The SDTS Modules involved in this section include

- Data Quality/Lineage (DQHL)
- Data Quality/Positional Accuracy (DQPA)
- Data Quality/Attribute Accuracy (DQAA)
- Data Quality/Completeness (DQCG)
- Data Quality/Logical Consistency (DQLC)

Void and Suspect Areas (A25, A29)

The void and suspect area flag in record A provides a means to alert the user to the occurrence of grid posts in the DEM array derived from void or suspect areas in the data source. This flag is set when void areas occur in the graphic or digital source and when suspect areas occur in the graphic source (suspect areas are not encoded in DLG's). In cases where the flag is set to suspect, an attempt is made to populate the DEM grid with a reliable elevation estimate, rather than using the false negative value described previously. The information about void and suspect areas goes in the Completeness and the Positional Accuracy modules.

Positional Accuracy - Vertical

For DEM's, the description of the vertical accuracy of the elevation values is included in the Positional Acccuracy report, even though the actual elevation values are stored as cell values and not as z coordinates. DEM accuracy information includes Root Mean Square Error (RMSE) criteria, smoothing to accurately represent slopes as well as elevation, and vertical integration processes. If the accuracy is known, either the estimated or computed RMSE value and sample size are stored for both the file's datum relative to the absolute datum and the DEM data relative to the file's datum. Source contour intervals are stored if applicable. Suspect areas are recorded as being present or absent.

Table 2.2.4.1: Data Quality Elements

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
A1a	File Name	<>	"DEM CELL NAME: < > (from Geographic Names Information System). "	DQHL/DQHL/COMT Comment RECORD HL-1
A1b	Free Format Text NOT APPLIOCABLE TO MASS CONVERSION (not implemented in source)	<>	"The free form header text from the DEM file has been automatically included without being reviewed or enhanced. In certain cases, literal strings contained in this text, when detected by the software, were used to determine other information like Process Descriptions. FREE FORMAT TEXT: <>"	DQHL/DQHL/COMT Comment RECORD HL-2
A1d	Process Code	0	"PROCESS USED <>: Unspecified."	RECORD HL-3
		1	"PROCESS USED <>: Autocorrelation RESAMPLE Simple bilinear."	
		2	"PROCESS USED <>: Manual Profiling (GRIDEM) from stereomodels; Simple bilinear."	
		3	"PROCESS USED <>: DLG/hypsography CTOG 8-direction linear."	
		4	"PROCESS USED <>: Interpolation from photogrammetric system contours DCASS 8-direction linear."	
		5	"PROCESS USED <>: DLG/hypsography LINETRACE, LT4X Complex linear."	
		6	"PROCESS USED <>: DLG/hypsography CPS-3, ANUDEM,GRASS Complex polynomial."	
		7	"PROCESS USED <>: Electronic imaging (non-photogrametric), active or passive, sensor systems."	
A2	Origin Code	NMD	"DEM PRODUCER: National Mapping Division, Reston, VA."	DQHL/DQHL/COMT Comment. RECORD HL-4
		EMC	"DEM PRODUCER: Eastern Mapping Center (Mapping Applications Center), Reston, VA."	
		WMC	"DEM PRODUCER: Western Mapping Center, Menlo Park, CA."	
		MCMC	"DEM PRODUCER: Mid-Continent Mapping Center, Rolla, MO."	

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
		RMMC	"DEM PRODUCER: Rocky Mountain Mapping Center, Denver, CO."	
		FS	"DEM PRODUCER: Forest Service"	
		GPM2	"DEM PRODUCER: Gestalt Photo Mapper low resolution DEM."	
		CONT	"DEM PRODUCER: Contractor."	
		< >	"DEM PRODUCER: < >."	
		blank	"DEM PRODUCER: Unspecified."	
A3	PA-1 Record: DEM LEVEL HL-5 Record: DEM LEVEL	1	"DEM LEVEL 1 means: Depending on the specific production process used, a given DEM shall meet the maximum 7-meter root mean square error (RMSE) or may have an RMSE less than 1/2 of the contour interval of the corresponding topographic series map. A vertical RMSE of 7 meters or less is the desired accuracy standard. A RMSE of 15 meters is the maximum permitted. A 7.5-minute DEM at Level 1 has an absolute elevation error tolerance of 50 meters (approximately three times the 15-meter RMSE) for blunders for any grid node when compared to the true elevation. Any array of points in the DEM can not encompass more than 49 contiguous elevations in error by more than 21 meters (three times the 7-meter RMSE). Systematic errors within the stated accuracy standards are tolerated in level 1 DEM's. "	DQPA/DQPA/COMT RECORD PA-1
			"DEM LEVEL 1 means: DEM created by auto correlation or manual profiling from aerial photographs. Source photography is typically from National Aerial Photography Program or National High Altitude Photography Program. 30-minute DEM's may be derived or resampled from level 1 7.5-minute DEM's."	DQHL/DQHL/COMT RECORD HL-5
		2	"DEM LEVEL 2 means: Data sets have been processed or smoothed for consistency and edited to remove identifiable systematic errors. An RMSE of 1/2 of the contour interval is the maximum permitted, with no errors greater than 1 contour."	DQPA/DQPA/COMT RECORD PA-1

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
			"DEM LEVEL 2 means: DEM created from digital line graph (DLG) contours or equivalent, from any USGS map series up to 1:100,000 scale using stable base contour separate or equivalent. DEM data derived from hypsographic and hydrographic data digitizing, either photogrammetrically or from existing maps, are entered into the level 2 category after review on a DEM editing system. "	DQHL/DQHL/COMT RECORD HL-5
		3	"DEM LEVEL 3 means: An RMSE of 1/3 of the contour interval is the maximum permitted, with no errors greater than 2/3 contour interval. Data is vertically integrated."	DQPA/DQPA/COMTRECORD PA-1
			"DEM LEVEL 3 means: DEM is derived from vertically intergrated digital line graph (DLG) data by using selected elements from both hypsography (contours and spot elevations) and hydrography (lakes, shorelines, and drainage). If necessary, ridge lines and hypsographic effects of major transportation features are also included in the derivation."	DQHL/DQHL/COMT RECORD HL-5
		4	<TBD when NMD starts distributing Level 4 DEMs>	DQPA/DQPA/COMT RECORD PA-1
			<TBD - but for now> "DEM LEVEL 4 means: DEM created from electronic (non-photogrammetric) imaging sensor systems, either active or passive. Active sensor provides its own source of illumination such as radar and laser. Passive sensor acts only in a sense as a receiver of radiant energy and requires source such as sun or other illumination.">	DQHL/DQHL/COMT RECORD HL-5
A14	[**START** RECORD PA-2 topic: **ACCURACY**]	0	--> "ACCURACY: Unspecified."	DQPA/DQPA/COMT RECORD PA-2
		1	[Encode C1 and C4]	
A17	[**CONTINUE** RECORD PA-3c topic: **CONTOUR INTERVAL**]	blank or zero	No action	
		<>	"CONTOUR INTERVAL: Largest Primary contour interval of source is <> <A18>."	DQPA/DQPA/COMT RECORD PA-3c

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
A18	[**CONTINUE** RECORD PA-3d topic: **CONTOUR INTERVAL**]	0	No action	
		1	<A18> in A17 --> "feet"	DQPA/DQPA/COMT RECORD PA-3d
		2	<A18> in A17 --> "meters"	
A19	[**START** RECORD PA-3a topic: **CONTOUR INTERVAL**]	blank or zero	--> "CONTOUR INTERVAL: Unspecified."	DQPA/DQPA/COMT RECORD PA-3a
		<>	and if A17 = blank --> "CONTOUR INTERVAL: Primary contour interval of source is <> <A20>."	
			and if A17 = <> --> "CONTOUR INTERVAL: Smallest contour interval of source is <> <A20>."	
A20	[**CONTINUE** RECORD PA-3b topic: **CONTOUR INTERVAL**]	0	No action	DQPA/DQPA/COMT Comment. RECORD PA-3b
		1	<A20> in A19 --> "feet"	
		2	<A20> in A19 --> "meters"	
A21	[**START** RECORD HL-6 topic: **Source Date**]	blank or zero	"SOURCE DATE OF PUBLISHED MAP OR PHOTOGRAPHY: Unspecified."	DQHL/DQHL/COMT RECORD HL-6
		< >	"SOURCE DATE OF PUBLISHED MAP OR PHOTOGRAPHY: <value of A21>."	
A22	[**START** RECORD HL-7 topic: **INSPECTION AND VALIDATION**]	blank or zero	No Action	
		< >	if A22 ---> "DATE THAT DEM WAS [INSPECTED | REVISED] ON A DEM EDIT SYSTEM: <value of A22>." (select based on A23)	DQHL/DQHL/COMT RECORD HL-7
A23	[**CONTINUE** RECORD HL-7]	blank or zero	No Action	
		I	if value = I then add --> "INSPECTION FLAG <>: indicates All processes of part 3 Quality control have been performed."	DQHL/DQHL/COMT RECORD HL-7

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
		R	if value = R then add --> "INSPECTION FLAG <>: indicates Existing DEM has been revised and re-archived."	
A24	[**CONTINUE** RECORD HL-7]	0	--> "DATA VALIDATION FLAG <>: indicates No validation performed."	DQHL/DQHL/COMT RECORD HL-7
		1	--> "DATA VALIDATION FLAG <>: RMSE computed from test points, no quantitative test, no interactive DEM editing or review."	
		2	--> "DATA VALIDATION FLAG <>: Batch process water body edit and RMSE computation."	
		3	--> "DATA VALIDATION FLAG <>: Review and edit, including water edit. No RMSE computed from test points."	
		4	--> "DATA VALIDATION FLAG <>: Level 1 DEM's reviewed and edited. Includes water body editing. RMSE computed from test points."	
		5	--> "DATA VALIDATION FLAG <>: Level 2 and 3 DEM's reviewed and edited. Includes water body editing and verification or vertical integration of planimetric categories (other than hypsography or hydrography if authorized). RMSE computed from test points."	
A25	[**START** RECORD PA-4 topic: **SUSPECT AREAS**] [**START** RECORD CG-1a topic: **VOID AREAS**]	0	DQPA/DQPA/COMT --> "SUSPECT AREAS: No suspect areas." DQCG/DQCG/COMT --> "VOID AREAS: No void areas."	DQPA/DQPA/COMT RECORD PA-4 DQCG/DQCG/COMT RECORD CG-1a
		1	DQPA/DQPA/COMT --> "SUSPECT AREAS: Suspect areas exist in the data."	DQPA/DQPA/COMT RECORD PA-4
		2	DQCG/DQCG/COMT --> "VOID AREAS: Void areas exist in the data."	DQCG/DQCG/COMT RECORD CG-1a
		3	DQPA/DQPA/COMT --> "SUSPECT AREAS: Suspect areas exist in the data." DQCG/DQCG/COMT --> "VOID AREAS: Void areas exist in the data."	DQPA/DQPA/COMT RECORD PA-4 DQCG/DQCG/COMT RECORD CG-1a

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
A28	Data Edition	01	No action (A NIMA specified field that USGS sets to 01; in here in case it is ever used.)	
		<>	"DATA EDITION: <> (as specified by National Imagery and Mapping Agency, formerly DMA.)"	DQHL/DQHL/COMT RECORD HL-8
A29	[**CONTINUE** RECORD CG-1b topic: **VOID AREAS**]	blank	No action	
		<>	DQCG/DQCG/COMT --> "<> % of nodes in the data are set to void."	DQCG/DQCG/COMT RECORD CG-1b Comment.
A30	Edge Match Flag	0	No action	
		<w> <n> <e> <s>	---> "EDGE MATCH STATUS: West (<w>), North (<n>), East (<e>), South (<s>). Edge matching is a process of matching elevation values along common quadrangle edges. The objective of edge matching is to improve the alignment of ridges and drains, and overall topographic shaping and representation. Code of 0 = not edge matched; 1 = edge match checked and joined; 2 = not edge matched because adjoining DEM is on a different horizontal or vertical datum; 3 = not edge matched because the adjoining DEM is not part of the current project."	DQLC/DQLC/COMT Comment. RECORD LC-1
A31	[**START** RECORD PA-5 topic: **VERTICAL DATUM SHIFT**]	0.0	"VERTICAL DATUM SHIFT: <> Positions are already based on North American Vertical Datum 1988."	DQPA/DQPA/COMT Comment. RECORD PA-5
		< >	"VERTICAL DATUM SHIFT: <>. Adding this value to the elevation values will convert it to North American Vertical Datum 1988. Value is computed by averaging the shift values for the four quadrangle corners obtained from program VERTCON."	DQPA/DQPA/COMT Comment. RECORD PA-5
C1	[**CONTINUE** RECORD PA-2a topic: **ACCURACY**]	0	No Action.	
		1	[Encode C2]	
C2	[**CONTINUE** RECORD PA-2a topic: **ACCURACY**]	<>	--> " ACCURACY: RMSE of the file's datum relative to the absolute datum (x,y,z) is <>; <concatenate C3>".	DQPA/DQPA/COMT Comment. RECORD PA-2a

ID	Header Element Topic	Value	ACTION	SDTS Mod/Fld/Sub
C3	[**CONTINUE** RECORD PA-2b topic: **ACCURACY**]	0	--> <concatenate to C2> "accuracy is estimated not computed."	DQPA/DQPA/COMT Comment. RECORD PA-2b
		<>	--> <concatenate to C2> "accuracy has been calculated based on a sample size of <>."	
C4	[**CONTINUE** RECORD PA-2 topic: **ACCURACY**]	0	No action	
		1	[Encode C5]	
C5	[**CONTINUE** RECORD PA-2c topic: **ACCURACY**]	<>	--> " ACCURACY: RMSE of the DEM data relative to the file's datum (x,y,z) is <>; <concatenate C6>".	DQPA/DQPA/COMT Comment. RECORD PA-2c
C6	[**CONTINUE** RECORD PA-2d topic: **ACCURACY**]	0	--> <concatenate to C5> "accuracy is estimated not computed."	DQPA/DQPA/COMT Comment. RECORD PA-2d
		<>	--> <concatenate to C5> "accuracy has been calculated based on a sample size of <>."	

Table 2.2.4.2: Other Data Quality Statements

DEM Standards Reference	Text	SDTS Mod/Fld/Sub
	Include explanation: "The 7.5-minute series DEM are gridded based on a UTM grid. Hence, the scans do not always have the same number of elevation posts due to the variable angle between true north and grid north of the UTM coordinate system. Any elevation post that falls outside of the 7.5-minute quadrangle edge is dropped, i.e. there is no overedge. The 7.5-minute DEM will be encoded as a non-ragged grid by filling with a background post value to the edges of the minimum bounding rectangle. The fill value is distinguishable from all other elevation post values, and it will be the same value for all USGS DEM series encoded in SDTS. The Void post value (-32767) will not be reused as the fill value, so the original extent of the DEM data can easily be detected."	DQCG/DQCG/COMT RECORD CG-2
NMD DEM Standards, Part 2, Section 2.6.1, text is edited to address data consumer.	Include explanation --> "Void areas occur in the DEM as a result of interruptions to the contours of the source graphic or DLG (eg. photoimages overprinted onto a topographic map). Each DEM elevation post located within a void area is assigned a false negative value of -32,767. The percentage of void elevation values in the DEM, if present, was calculated from the total number of grid posts in the DEM assigned the false negative value."	DQCG/DQCG/COMT RECORD CG-3
NMD DEM Standards, Part 2, Section 2.6.2, text edited slightly	Include explanation --> "SUSPECT AREAS: Suspect areas in the DEM result from corresponding areas on the graphic source that are shown as disturbed surfaces. They are symbolized by contours that have been overprinted with photorevised or other surface patterns. Examples of disturbed surfaces are: lava flows, land slides, open pit mining, construction cut and fill, and land fill operations. An estimated elevation is supplied for suspect areas based on the presumed elevation at the time the DEM grid is generated; however, the true elevation is subject to change without notice. When an elevation cannot be estimated for a suspect area, the area is downgraded to a void area and assigned a false negative value of -32,767. Grid posts falling in suspect areas are added to the DEM grid as though they were valid elevations; they are distinguishable from normal DEM grid posts only by an independent inspection of the graphic source. For this reason, no percentage value for the total number of cells in the DEM that are assigned an estimated value. Suspect areas relate only to graphic sources. Furthermore, no commensurate code exists for suspect areas in the DLG hypsography category."	DQPA/DQPA/COMT RECORD PA-?
NMD DEM Standards, Part 2. Section 2.6.3, first paragraph verbatim	Include explanation: **"WATER BODIES: Water body areas are naturally occurring areas of constant elevation. Oceans or estuaries at mean sea level are assigned an elevation value of zero. All other water bodies are assigned their known or an estimated elevation."**	DQPA/DQPA/COMT RECORD PA-?

DEM Standards Reference	Text	SDTS Mod/Fld/Sub
NMD DEM Standards, Part 2, Section 2.2.1, first paragraph, first 3 sentences verbatim.	Include explanation: "HORIZONTAL ACCURACY: The horizontal positions of grid posts in USGS DEM's are located at precise mathematically defined positions in UTM meters or arc seconds. These grid posts are fixed in position and can be considered constants for the purpose of determining accuracy. The only measurable or perceivable errors in the DEM exist as vertical errors that may be partially attributable to horizontal error inherent in the source data or to errors in converting horizontal and vertical components of the source to gridded format. "	DQPA/DQPA/COMT RECORD PA-?
NMD DEM Standards, Part 2, Section 2.2, Bullets 2,3,4 included verbatim; Section 2.2.2 4th paragraph included verbatim.	Include explanation: "GENERAL NOTES: A number of factors affect gridding processes and the accuracy of the final DEM product: 1) A dependency exists between the scale of the source materials and the level of detail or grid refinement that is possible from a given source. 2) During the process of changing scale, from large to small, some source data may be generalized or dropped out and, therefore, some features would not be available for formation of, or incorporation into, a grid at that scale. 3) The process of forming a grid with regular spacing requires the transfer of precise point or vector data to generalized grid square corners using a process similar to taking a simple weighted average. This process may alter the apparent position upon display of point or vector source data, reducing the ability to recover positions of specific features whose dimensions are less than the internal grid cell spacing. For all DEM's, the grid spacing and spatial resolution results in data intervals that span terrain discontinuities, such as benches, tops, and drainage. Some features can be appropriately captured at a given grid spacing while other, smaller features are subdued or filtered out altogether."	DQHL/DQHL/COMT RECORD HL-?
NMD DEM Standards, Part 2, Section 2.2.2, second paragraph with minor rewording to address data user and not data collector. AND Part 3, Section 3.3, first paragraph included verbatim.	Include explanation: "VISUAL VERIFICATION: Because of practical limitations inherent in all collection systems there will always be some artifacts such as benches, striations, patches, or some other anomaly that imparts some signature of the collection system in the data set. Some of these artifacts, although falling within normal DEM vertical error tolerances, can coalesce with valid surface features. All DEM's are viewed and edited so corrective actions can be taken to minimize these artifacts. For example, 1) Isolated tops are depicted with their approximate size and shape; 2) Flat trending surfaces are depicted as generally flat trending without confusing patterns or striations; and, 3) Water bodies are flat, lower than the surrounding terrain, and have shorelines clearly delineated. Additional testing is performed using a DEM Editing System (DES) to aid in the identification of blunders such as irregularly gridded data, mistagging of tops and depressions, and spikes. These blunders are generally identified by displaying the DEM with the aid of DES options, which include color banding of elevation gradients, stereoscopic viewing using anaglyphic filters, and shaded-relief enhancement. An elevation matrix is analyzed in suspect areas and corrected as required."	DQHL/DQHL/COMT RECORD HL-?

DEM Standards Reference	Text	SDTS Mod/Fld/Sub
n/a -- meets an SDTS requirement.	Include explanation --> "No Attribute Accuracy to report. See Positional Accuracy modules, because the cell values are elevation measurements."	DQPA/DQPA/COMT Comment RECORD AA-1
n/a --- meets SDTS requirement.	Include explanation -->"NULL SCHEME: The method for indicating no value for a cell in the Cell module records contained in this transfer is described here. In the Data Dictionary Domain module there are specific values that are reserved to mean VOID and FILL for ELEVATION. Void means there is no elevation measurement available for a cell that falls within the *geographic boundaries* of the DEM. (In the geographic coordinate system the bounds of the DEM data are rectangular.) A Fill also means there is no data, but is used to make the DEM rectangular in the UTM coordinate system."	DQLC/DQLC/COMT Comment RECORD LC-2
NMD DEM Standards, Part 2, Section 2.2.3, First paragraph verbatim. AND Section 2.2.4 Description of codes values is paraphrased.	[Included as part of element A30 text in table 2.2.4.1 above]	DQLC/DQLC/COMT Comment RECORD LC-1
NMD DEM Standards, Part 1, Table 1-2, Production Process; Part 2, Classification Levels Section 2.3.1, second paragraph verbatim Section 2.3.2, three sentences verbatim Section 2.3.3 three sentences verbatim	[Included as part of element A3 text in table 2.2.4.1 above]	DQHL/DQHL/COMT Comment RECORD HL-5 DQPA/DQPA/COMT RECORD PA-1
NEW!! (3 of them)	Include "For more information on production processes and data quality tests, see U.S. Geological Survey, National Mapping Division, Digital Elevation Model Standards, Parts 1-3, and the Digital Elevation Data Users Guide 5 that were in effect when this DEM was produced."	DQHL/DQHL/COMT Record Last

DEM Standards Reference	Text	SDTS Mod/Fld/Sub
NMD DEM Standards, Part 3, Section 3.1.2, first paragraph with clauses, minor edits.	”HYDROGRAPHY INCLUDED: For DEM Level 1 and 2, water bodies contained in DEM data are edited when they conform to the following criteria: 1) Type is a pond, lake, reservoir, or double-line drainage; and, 2) Size of a pond, lake or reservoir exceeds approximately 1/2 inch at map scale (1000 feet at 1:24,000 scale, 4167 feet at 1:100,000 scale) along the major axis; or, 3) Size of a double-line drain exceeds 1/4 inch (500 feet at 1:24,000 scale, 2087 feet at 1:100,000 scale) in width.”	DQCG/DQCG/COMT Comment RECORD CG-3
NMD DEM Standards, Part 3, Section 3.1.3, all text verbatim	”For level 3 DEM's, the grid is constrained by all major hydrographic features contained within a DLG hydrography category, including drainage, lakes, swamps, and shorelines. Elevations of hydrographic features are determined through interpolation of contours using a registered DLG hypsography file. DEM surfaces constrained to drains are treated as a special case of hypsographic faulting where the DEM surface is simply creased along the track line of the drain. Additionally, all 30-meter grid cells are tilted consistent with the direction of stream flow, along the track line of the drain. There must not be any unsupported breaks or discontinuities in the rate of slope of the drain.”	DQCG/DQCG/COMT RECORD CG-3

2.2.5 Elements that are Attributes

There are no DEM elements that are encoded as SDTS attributes.

2.3 Mapping of DEM Spatial Objects

GEOMETRY

Profiles are the basic building blocks of DEM's and are defined as one-dimensional arrays, that is, arrays of dimension m rows by 1 column, where m is the length of the profile.

The internal horizontal relationship (xp, yp) of elevations are ordered as profiles in which the spacing of the elevations along each profile is Δy and the spacing between profiles is Δx. The formulas,

$$x_{gp} = ...$$
$$y_{gp} = ...$$

relate the internal array structure to actual ground coordinates (x_{gp}, y_{gp}) based on an origin of the DEM at the lower left corner (x_{go}, y_{go}) and a rotation angle, if any, measured from the coordinate projection system. The rotation angle of 7.5-minute DEM's is zero if profiles are ordered by columns (parallel to the UTM central meridian) or is set to 90^{o} if profiles are ordered by rows (i.e. this would be the case if row ordering has been superseded by column ordering, header element A-16. The rotation angle for all arc second DEM's is always set to zero, header element A-13. In contrast to the 7.5-minute UTM DEM, each arc second DEM profile is composed of the same number of elevations per profile and the DEM array is a geographic square or rectangle.

DIGITAL ELEVATION MODEL STRUCTURE

Two types of grids, UTM and arc second, are used for the USGS DEM.

<u>UTM Structured DEM</u>

The 7.5-minute UTM DEM profiles are clipped to the straight line intercept between the four geographic corners of the quadrangle, an approximation of the geographic map boundary (neatline). The resulting area of coverage for the DEM is a quadrilateral, the opposite sides of which are not parallel.
The UTM coordinates of the four corners (bounds) of the DEM are listed in the element A11; the UTM coordinates of the starting points of each profile are listed in the header element B records (profiles). These coordinates describe the shape of the quadrilateral and the variable x, y starting position of each profile. Because of the variable orientation of the quadrilateral in relation to the UTM grid, profiles intersect the east and west neatlines as well as the north and south neatlines. In addition, DEM's have profile easting values that are continuous from one DEM to the adjoining DEM only if the adjoining DEM is contained within the same UTM zone. Profiles that pass within the bounds of the DEM quadrilateral, but are void of elevation grid points, are not represented in the DEM (Referred to as "missing profile condition." This condition occurs occasionally and is always the first or last profile of the DEM. Typically such a profile intersects the DEM corner, but there is no grid node within the quad bounds).

The use of UTM coordinates to define the horizontal grid spacing of DEM's is restricted at this time to the 7.5-minute DEM program.

<u>Arc second structured DEM</u>

The 1-degree DEM west-and-east profiles are coincident with the west and east neat- lines respectively. The resulting area of coverage for the DEM is a geographic rectangle.

The arc second coordinates of the four corners (bounds) of the DEM are listed in the element A11; the arc second coordinates of the starting points of each profile are listed in the type B record (profiles), appendix 2-B, data element 3. These coordinates describe the shape of the geographic rectangle and the x, y starting position of each profile.

The use of arc second coordinates to define the horizontal grid spacing of DEM's is mandatory for all DEM series, except for 7.5-minute UTM DEM's.

Table 2.3: Mapping of DEM Spatial Objects

ID	Header Element Description	Value	ACTION	SDTS Mod/Fld/Sub
A4	Elevation pattern	1	----> "R2" (regular)	RSDF/RSDF/OBRP
		2	----> " (random)	
A8	Code defining unit of measure for ground planimetric coordinates throughout the file	<>	SDTS requires meters for UTM and decimal degrees for geographic units. *** If <>=2 and A5=1 then units are in meters If <>=3 and A5=0 then units are in arc seconds	
A16	A two-element array containing the number of rows and columns (m,n) of profiles in the DEM	<m>	LDEF/LDEF/NROW -> RSDF/RSDF/RWXT -> the maximum number of posts in any single DEM profile - calculate [DO NOT USE <m>]	LDEF/LDEF/NROW RSDF/RSDF/RWXT
		<n>	LDEF/LDEF/NCOL --> <n> RSDF/RSDF/CLXT --> <n>	LDEF/LDEF/NCOL RSDF/RSDF/CLXT
B3	A two-element array containing the ground planimetric coordinates (X_{gp},Y_{gp}) of the first elevation in the profile	<x,y>	(Only the X_{gp}, Y_{gp} of the top left cell is stored in the SDTS Raster Definition.)	RSDF/SADR/X&Y (calculated)
B4	Elevation of local datum for the profile	<>	(This value is applied to native DEM profile values to calculate elevation values for SDTS cells.)	n/a
B6	An m,n array of elevations for the profile. Elevations are expressed in units of resolution	<m,n>	(Elevation (post) values are reordered to SDTS default implementation, i.e. origin is top left, cells are ordered left to right, top to bottom. Each cell module record contains one scan row. Fill values are used to create a regular grid for UTM DEMs.)	CELL/CELL/ROWI CELL/CELL/COLI CELL/CVLS/ELEVATION

3. The DEM/SDTS Transfer

The Spatial Data Transfer Standard (SDTS) is capable of handling a wide variety of spatial data models, i.e. unstructured vector data, full topology vector data, gridded rasters, images, etc. Hence, a full implementation of all of the SDTS capabilities is impratical for most transfer situations. Profiles of the SDTS are defined for specific spatial data models to further restrict options and make implementation of the transfer process more feasible. The Raster Profile with BIIF Extension (Part 5[1]) of the SDTS is for 2-dimensional gridded rasters or image data. The USGS DEM will be encoded into the SDTS using the "Raster Profile with BIFF Extension".

The SDTS defines many types of modules and various rules of usage. The data producer must select the set of modules that will both satisfy the needs of preserving their native data model (i.e. USGS DEM) information and, meet the requirements of the SDTS and the profile.

Part 2 of this document dealt with preserving the information content of the DEM Header and spatial objects (i.e. the grid of elevation data.) The perspective of the Part 2 was that of the DEM. It described how different DEM components would be encoded and how the constructs of the SDTS would be used. The perspective of

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[1] This is currently a proposed draft that will be submitted for FGDC ratification. The portion of the Raster Profile that the DEM requires is sufficiently stable for the USGS to proceed with encoding of its DEM data with little risk of the encoding becoming invalid upon finalization of the Raster Profile.

Part 3 is that of the SDTS and the Raster Profile. Part 3 describes the DEM/SDTS transfer and the set of modules required by both the DEM encoding and the SDTS Raster Profile.

The purpose of this section is to describe a DEM/SDTS transfer. This will be approached by first describing the "transfer" itself, then by describing its set of modules, and finally by describing the module records of each module. This order reflects the succession of SDTS constructs: transfers are composed of modules are composed of records are composed of fields are composed of subfields (which actually contain the data.)

3.1 What is the DEM/SDTS Transfer?

The highest organizational construct in the SDTS is a "transfer". A transfer is a set of modules that conform to the usage rules of SDTS and a profile. An SDTS profile, in general terms, may be defined as a limited subset of the Spatial Data Transfer Standard, designed for use with a specific spatial data model.

The USGS DEM will be encoded as a single layer 2-dimensional rectangular grid under the SDTS Raster Profile. The UTM gridded DEMs will be made rectangular through use of a fill value. The arc-second gridded DEMS are already rectangular.

3.1.1 Scan Pattern

The USGS DEM data, in their native file format, are ordered in south-to-north scans arranged from west to east. (This data organization is founded historically in the old production technique of manual profiling.) The origin of the raster grid is at the southwest corner. The origin and coordinate system matches the orientation of the UTM coordinate system.

The SDTS Raster Profile encourages the use of a particular data organization for the raster cells. The SDTS raster "default" implementation calls for the grid origin to be at the northwest corner. The scans of grid cell data run from west to east, and the set of scans is ordered north to south. This is compatible with current display technology and is used by many popular image transfer formats.

To make the data organization of the DEM data compliant to the SDTS default implementation and the FGDC Elevation Standard, the USGS DEM data will be reorganized to match the recommended data organization. The DEM/SDTS will have its grid origin at the top left, with scans of cell data running from left to right, arranged from top to bottom.

3.1.2 Spatial Referencing System

SDTS Raster Profile recognizes four successions of reference systems for raster data, the external, internal, raster object scan, and layer scan reference systems. The external reference system is the ground based system such as UTM or geographic latitude and longitude or some other map projection. The internal reference system is used to encode spatial addresses (X,Y) in the transfer itself, often as integers. The raster object scan reference system is used to define a common raster space to which all related raster layers can be commonly referenced. The layer scan reference system is used by each raster layer to encode layer coordinates (R,C) in the transfer itself.

The External Reference System for DEMs will be either UTM or geographic. The 7.5-minute DEM grid is based on the UTM coordinate system. The other DEM

series are based on the geographic (arc-second) coordinate system. These are both compliant with the SDTS Raster Profile, External Reference conformance Level 1.

The Internal Reference System is specified by the SDTS Raster Profile. It requires 4-byte signed binary integers (i.e. BI32) for encoding X,Y. SDTS requires units of meters for ground planimetric coordinates. The DEM ground coordinates in the native file format are expressed as real numbers in units of meters (for UTM) or arc seconds (for geographic.) These ground coordinates will be converted to integers and the correct translation and scaling parameters will be calculated and placed in the appropriate subfields to permit conversion of internal coordinates to external coordinates.

The Raster Object Scan Reference System and the Layer Scan Reference System will have the same extents and the same origin, thus making the Raster object coordinate the same as the Layer coordinate.

(Note: The elevation values will not be encoded as z-values, but will be encoded as cell values in an raster data layer.)

3.1.3 Cell Encoding

In SDTS the term *cell* is used to include both terms *pixel* and *grid cell*. The elevation values from the DEM will be encoded as cell values in an SDTS raster layer. The Cell Values (i.e. elevation) format will be 2-byte signed integers (i.e. BI16.) The actual elevation values will be encoded in meters or feet, as they are in the native DEM file.

The organization of cell values into cell module records has many options in SDTS. For DEMs, one west-east run/scan will be encoded per cell record. For example, a DEM with 72 rows and 86 columns, will have 72 Cell Module records and each record will contain 86 cell values.

3.1.4 Data Dictionary

The Raster Profile requires a Data Dictionary to describe any user-defined terms used as entities, attributes, or Layer names. SDTS permits the Data Dictionary Modules to be internal (i.e. included with every transfer) or external (i.e. obtained in a separate transfer.)

The amount of data dictionary information is very small, so an internal data dictionary will be used. With an internal data dictionary, it will be possible to "customize" it for the dataset, like having an elevation domain minimum to maximum range that is specific to a DEM dataset.

More specifically, the Layer Name is "ELEVATION". The domain is the Min/Max Elevation value specific to the dataset. The special values for Void and Fill are denoted and fall outside of the min/max range. However, these special values shall be the same for all DEM transfers. The units on elevation values can be Feet or Meters depending on what was stored in the native DEM file.

3.2 Module Set for a DEM/SDTS Transfer

This section will describe the set of modules needed to create a DEM/SDTS transfer that conforms to the Raster Profile.

The following table lists the set of modules. It has the module type in the first column, the cardinality in the second column, the source of the requirement in the third column, and the DEM concept being represented in the fourth column. The "#" column specifies the number of occurrences of the module type per a single transfer. When the number is followed by a dash ("-") this means it is a maximum and the actual count could be less. The "Reqrd By" column specifies whether the module is required because of the SDTS, or the RP, or because of the DEM Header encoding. The "DEM Concept" column is included to aid in relating the set of modules to DEM components.

Table 3.2: Module Set for a DEM/SDTS Transfer

Module Type	#	Reqrd By	DEM Concept
Identification	1	SDTS	Dataset
Catalog/Directory	1	SDTS	-
Catalog/Spatial Domain	1	RP	-
External Spatial Reference	1	SDTS & DEM	Coordinate Ref. System
Internal Spatial Reference	1	RP & DEM	Internal Coordinates as integers
Spatial Domain	1	DEM	Minimum bounding rectangle of dataset extent
Transfer Statistics	1	SDTS	--
DQ-Lineage	1	SDTS	Digital process history
DQ-Positional Accuracy	1	SDTS	DEM Level; RMSE values and sample size; suspect areas.
DQ-Attribute Accuracy	1	SDTS	Accuracy of cell value; because raster cell data is elevation data, RMSE values are recorded as positional accuracy.
DQ-Logical Consistency	1	SDTS	Edge Matching Status
DQ-Completeness	1	SDTS	Percent void; Fill used for non-ragged grid
Data Dictionary /Schema	1	RP DEM	-- cell values

Module Type	#	Reqrd By	DEM Concept
Data Dictionary /Definition	1	DEM	Define "Elevation"
Data Dictionary /Domain	1	DEM	Minimum and Maximum Elevation of the DEM
Raster Definition	1	DEM	2-d non-ragged grid
Layer Definition	1	DEM	1 Band of Elevation values
Cell	1*	DEM	Elevation Values

There is a fixed set of 18 modules per DEM transfer.

* The Cell Module count depends on the number of native DEM files packed in one transfer.

3.3 Module Records for the DEM/SDTS Transfer

The SDTS contains module specifications for each of its module types (see SDTS Part 1, Section 5.) A module specification describes a generic record layout with fields and subfields and rules for inclusion and repetition. The specifications for the modules were used to design specific module record layouts for the encoding of the DEM elements. This section describes the different types of logical records for each module type.

Each module record layout is described by listing its subfields, describing the information needed for the subfield, and explaining the source of the information. The subfields are defined by the SDTS and are referenced here by their mnemonics in column "Subfield". The "Contents" column describes the information or the constant used by the subfield. The sources of information are provided in the table column "Source" via the use of the following codes:

DEM-Xnn	Value extracted from the DEM Header - record and number
RP	A value or limited range is specified within SDTS as implemented by the Raster Profile
<gen>	Generated value; there is a simple generation or counting involved which is normally done within a computer program; all foreign id references are generated
Const	Agency has specified a constant value
Ext	External Value must be obtained from a source requiring human intervention (These are typically satisfied by producing auxiliary files of information to be included when a transfer is created.)
<calc>	Calculated value
Default	Default value
<INST>	Instance in the following subfield table

The order of the module descriptions follows the order of definition in the SDTS.

The order of entries in the tables follow the order that fields and subfields are listed in the SDTS module specification. The tables start with the subfields for the Primary field. A Secondary field is denoted by inserting a line in the table immediately prior to the first subfield of the secondary field.

Secondary fields that are foreign identifier references are handled differently. (These are denoted by a "(^)" in an SDTS module specification.) The field mnemonic will be placed in the subfield column. The field mnemonics will be lower case and preceded by a caret "^". The tables in this section should be used in conjunction with the module specifications in the SDTS so there should be no confusion about field and subfield. For the case of a foreign id field, the "Content" column will describe the contents of the module record that is being referenced.

3.3.1 Identification Module

The Identification Module provides identifying information about the data content of the transfer, about the version of the SDTS and possibly a profile, and about conformance to features and reference systems.

There is one Identification Module. There will only be one record in the Identification module. It will represent the concept of a DEM Dataset.

Note 8/11/1997: There is one difficulty with populating this module prior to mass conversion---both the base standard and the raster profile are drafts that are not yet ratified by any standards body. When the DEM mapping began, the plan was to submit the raster profile to ANSI, but now it is being submitted to FGDC. The base standard, Part1-3 are being submitted to ANSI.

Table 3.3.1: Identification Module

Sub-field	Contents	Source
Primary Field: Identification (IDEN)		
MODN	Module name of "IDEN"	RP
RCID	Unique record id within the module	<gen>
STID	"SPATIAL DATA TRANSFER STANDARD"	Const
STVS	"DRAFT OCTOBER 1997"	Const
DOCU	"ANSI NCITS L1 Committee Draft"	Const
PRID	"SDTS RASTER PROFILE WITH BIIF EXTENSION"	Const
PRVS	"DRAFT VERSION JULY 1997"	Const
PDOC	"Federal Geographic Data Committee (FGDC) SDTS PART 5"	Const
TITL	Title of the data content; use File Name + External Scale + Sectional Indicator	DEM-A1a <Ext scale> DEM-A1e
DAID	SE Geographic corner + External Scale + Sectional Indicator	DEM-A1c <Ext scale> DEM-A1e
DAST	"DEM"	Const
MPDT	Data source or latest revision date; use the latest date.	DEM-A21 | A22

Sub-field	Contents	Source
DCDT	SDTS transfer creation date	<gen>
COMT	n/a	n/a
Secondary Field: Conformance (CONF)		
FFYN	"N" (does not contain composites)	Const
VGYN	"N" (no geometry-only objects)	Const
GTYN	"N" (no topology objects)	Const
RCYN	"Y" (yes raster objects)	RP
EXSP	"1" (one of recommended ref systems used)	Const
FTLV	"4" (user-defined terms)	Const
CDLV	"0" (zero) (Transfer has no Coding Module)	Const
NGDM	"N" (No SADR with nongeospatial dimensions)	Const

Table Note: End results:

TITL = "<DEM-A1a>-<External Scale>-<DEM-A1e Action>"

(External Scale comes in as command line parameter)

DAID = "LAT:: <x of DEM-A1e> LONG:: <y of DEM-A1e> SCALE:: <External Scale> <DEM-A1e Action>"

Example of a TITL: AYRSHIRE,IA - 24000
Example of a DAID: LAT:: 43 LONG:: -94.75 SCALE:: 24000

3.3.2 Catalog/Directory Module

The Catalog/Directory module describes which modules are in which files and whether modules are internal to a transfer or external. The RP requires that each module have its own file. A file can be split only if constrained by file size.

There is one Catalog/Directory module with one record for every module in the transfer. All modules are internal in a USGS DEM transfer.

Table 3.3.2: Catalog/Directory Module

Sub-field	Contents	Source
MODN	Module name of "CATD"	RP
RCID	Unique record id within the module	<gen>
NAME	Name of module referenced by this Directory entry	<gen>
TYPE	Module type of module in "NAME" above; use Primary Field name	<gen>
FILE	File name containing the module; do not include the path	<gen>
EXTR	"N" (not an external module)	<gen>
MVER	Version of module included in this transfer; use "n/a" for STAT and CATD and 1.0 for others.	<gen>
COMT	" " Null string	Const

3.3.3 Catalog/Spatial Domain Module

The Catalog/Spatial Domain module describes the relationships of each module to the keywords of theme, map, and domain; and to the aggregate objects. There is a record for every module in the transfer.

Note: The values below assume that there will only be one DEM partition in any one SDTS transfer.

Table 3.3.3: Catalog/Spatial Domain Module

Sub-field	Contents	Source
MODN	Module name of "CATS"	RP
RCID	Unique record id within the module	<gen>
NAME	Name of module referenced by this record	<gen>
TYPE	Module type of module in "NAME" above; use Primary Field name	<gen>
MAP	Put Quadname here	DEM-A1
THEME	“ELEVATION”	Const
AGOB	“DEM1"	Const
AGTP	“G2"	Const

3.3.4 Internal Spatial Reference Module

The Internal Spatial Reference Module describes the coordinates used in the transfer and defines the translation and scaling to convert from the internal coordinate system to the system defined in the External Spatial Reference Module.

SDTS restricts the unit of measure in the external reference system to meters. Coordinates stored in the internal reference system in feet (State Plane Coordinate System) and coordinates stored in the internal reference system in decimal degrees need to include the effect of feet to meter conversion and degrees to decimal degrees in the scaling factor subfields.

Table 3.3.4: Internal Spatial Reference Module

Sub-field	Contents		Source
Primary field: Internal spatial Reference (IREF)			
MODN	Module name of "IREF"		RP
RCID	Unique record id within the module		<gen>
SATP	"2-TUPLE"		Const
XLBL	"Easting" or "Longitude"	Reference System dependent: UTM | GEOGRAPHIC	DEM-A5
YLBL	"Northing or "Latitude"		DEM-A5
HFMT	"BI32"		Const
SFAX	See Table Note 1.		<Calc>
SFAY			Calc>
XORG	See Table Note 1.		<Calc>
YORG			<Calc>
XHRS	X Horizontal Resolution		DEM-A15
YHRS	Y Horizontal Resolution		DEM-A15

Table Note 1: The actual values are scaled and translated to fit into an integer space as described below.

Use double's ONLY (i.e.) NO float's)

```
DRX = DEM Resolution for X
DRY = DEM Resolution for Y
DRZ = DEM Resolution for Z

DX = DEM X value for the northwest corner
DY = DEM Y value for the northwest corner

if (DEM is in UTM && coords in meters)
{
        CDX = DX;
        CDY = DY;
}
else if (DEM is Geographic && coords in arc-seconds)
{
        CDX = DX / 3600;  /* converted to decimal degrees */
        CDY = DY / 3600;
        DRX = DRX / 3600;
        DRY = DRY / 3600;
}
else ERROR WE WILL NOT ENCODE ANY OTHER COMBINATION OF PROJECTION AND UNITS

IREF:IREF:SFAX = findScale (CDX);
IREF:IREF:SFAY = findScale (CDY);
IREF:IREF:XORG = findTrans (CDX, IREF:IREF:SFAX);
IREF:IREF:YORG = findTrans (CDY, IREF:IREF:SFAY);
IREF:IREF:XHRS = DRX;
IREF:IREF:YHRS = DRY;
IREF:IREF:VHRS = DRZ;

RSDF:SADR:X = (CDX - IREF:IREF:XORG) / IREF:IREF:SFAX
RSDF:SADR:Y = (CDY - IREF:IREF:YORG) / IREF:IREF:SFAY

double findScale (double value)
{
        double scale = 1;
        double temp = value - floor(value);
        typedef enum directions { Up, Down } Directions;
        Directions direction;
        double ttemp;

        if (temp != 0)
```

```
                direction = Up;
        else
                direction = Down;

        while ((temp != 0 && direction == Up) || (temp == 0 && direction == Down))
{
        scale = scale * 10;
        if (direction == Up)
                ttemp = value * scale;
        else
                ttemp = value / scale;
        temp = (ttemp) - floor(ttemp);
}
if (direction == Up)
                scale = 1/scale;
else
        scale = scale / 10;

        return scale;
}
double findTrans(double value, double scale_factor)
{
        double trans;
        double tmp;
        double maxIntMag = le9;
                        /*any value larger than this must be translated!*/
        double invScale = 1 / scale_factor;
        double scaledMaxInt;

        tmp = fabs(value * invScale);

        if (tmp >= maxIntMag)
        {
                trans = floor(tmp / maxIntMag);
                trans = trans * maxIntMag * scale_factor;
        }
        else trans = 0;

        return trans;
}
```

3.3.5 External Spatial Reference Module

The External Spatial Reference Module defines the external spatial reference system and its relationship to latitude and longitude. There is only one External Spatial Reference Module. It contains one record. There shall be only one external coordinate frame of reference within a transfer.

Table 3.3.5: External Spatial Reference Module

Sub-field	Contents	Source
Primary Field: External Spatial Reference (XREF)		
MODN	Module Name of "XREF"	RP
RCID	Unique record id within the module	<gen>
COMT	Vertical Datum Name and Vertical Datum shift (see Table 2.2.2 of this document)	DEM-A26 DEM-A31
RSNM	Reference System Name	DEM-A5
HDAT	Horizontal Datum	DEM-A27
ZONE	Projection Zone Number	DEM-A6
Secondary Field: Vertical Attribute (VATT)		
VDAT	Vertical Datum	DEM-A26
VEM	"CELL"	<Const>
ATLB	"ELEVATION"	<Const>
AUTH	"USGS/NMD"	<Const>

3.3.6 Spatial Domain Module

The Spatial Domain Module specifies the geographic domain within which the coordinates used in the transfer are contained. There is one Spatial Domain Module. It contains one record which uses the "ring" technique.

Table 3.3.6: Spatial Domain Module

Sub-field	Contents	Source
Primary Field: Spatial Domain (SPDM)		
MODN	Module Name of "SPDM"	RP
RCID	Unique record id within the module	<gen>
DTYP	"RING"	DEM-A11
DSTP	"EXTERNAL"	DEM-A11
Secondary Field: Domain spatial Address (DMSA)		
X	4 sets of X,Y bounding quadrangle	Derived from DEM-A11
Y		

3.3.7 Data Dictionary/Schema Module

The Data Dictionary/Schema Module describes the Cell Modules that are contained in the transfer. The cell modules require a SDTS-user to add subfields to meet the needs of their data model. As these are user-defined subfields, the descriptive information about these "subfields" must also be encoded in the transfer---hence schema records. A schema record describes a cell value by giving it a layer label (i.e subfield name), a data format,units, and precision.

There is one Schema Module. There is one schema record for every cell module in a raster. For DEMs, there is one schema record.

Table 3.3.7: Data Dictionary/Schema Module

Sub-field	Contents	Source
MODN	Module name of "DDSH"	RP
RCID	Unique record id within the module	<gen>
NAME	Module Name referenced : "CEL0"	Const
TYPE	Type of Module Referenced: "CELL"	Const
ATLB	Attribute label : "ELEVATION"	Const
AUTH	Attribute authority: "USGS/NMD"	Const
FMT	Data format : "BI16"	Const
UNIT	Unit of measurement of the elevation values	DEM-A9
PREC	Precision, z resolution	DEM-A15(z)

3.3.8 Data Dictionary/Definition Module

The Data Dictionary/Definition Module contains a description for the layer, which explains the meaning of its associated layer name. For DEMs, there is one definition record.

Table 3.3.8: Data Dictionary/Definition Module

Sub-field	Contents	Source
MODN	Module name of "DDDF"	RP
RCID	Unique record id within the module	<gen>
EORA	(Entity or Attribute)	<Inst>
EALB	Label of Attribute	<Inst>
DFIN	Definition of attribute label	<Inst>
AUTH	"USGS/NMD"	Const
ADSC	"U.S. Geological Survey/National Mapping Division"	Const

Subfield Values		
EORA	EALB	DFIN
"ATT"	"ELEVATION"	"The vertical distance from a given datum"

3.3.9 Data Dictionary/Domain Module

The Data Dictionary/Domain Module contains at least two records for each layer, one for the minimum value and one for the maximum value the layer will contain. It will also include records for any special cell values. The special values are Fill and Void for a DEM.

Table 3.3.9: Data Dictionary/Domain Module

Sub-field	Contents	Source
MODN	Module name of "DDOM"	RP
RCID	Unique record id within the module	<gen>
ATLB	Attribute label	<Inst>
AUTH	"USGS/NMD" (uniquely identifies attr label)	Const
ATYP	Attribute Domain Type	<Inst>
ADVF	Attribute Domain Value Format; "A" | "I" | "R"	<Inst>
ADMU	Domain Measurement Unit; any text allowed	<Inst>
RAVA	Range or Value Indicator	<Inst>
DVAL	A Domain Value	<Inst>
DVDF	Definition or description of the domain value	<Inst>

Subfield Values						
ATLB	ATYP	ADVF	ADMU	RAVA	DVAL	DVDF
"ELEVATION"	"INTEGER"	"I"	""	"VALUE"	-32767	"Void area in DEM"
"ELEVATION"	"INTEGER"	"I"	""	"VALUE"	-32766	"Fill value used to make the DEM a rectangle"

"ELEVATION"	"INTEGER"	"I"	DEM-A9	"MIN"	DEM-A12	"Minimum Elevation of the DEM"
"ELEVATION"	"INTEGER"	"I"	DEM-A9	"MAX"	DEM-A12	"Maximum Elevation of the DEM"

3.3.10 Transfer Statistics Module

The Transfer Statistics Module describes size information about each module: its number of records and number of spatial addresses. The purpose of this module is to provide data volume information to potential data decoders. There is one Transfer Statistics Module. There will be one record for every module in the DEM transfer.

Table 3.3.10: Transfer Statistics Module

Sub-field	Contents	Source
MODN	Module name of "STAT"	RP
RCID	Unique record id within the module	<gen>
MNTF	Primary Field Name of module referenced	<gen>
MNRF	Name of module referenced	<gen>
NREC	Number of Module Records	<gen>
NSAD	Number of Spatial Address Fields	<gen>

3.3.11 Data Quality/Lineage Module

The Lineage Module describes the derivation of the data contained in the transfer. Lineage of DEM's includes processing information related to the digital process such as method, instrument, and source material.

Table 3.3.11: Lineage Module

Sub-fld	Contents	Source
Primary Field: Lineage (DQHL)		
MODN	Module Name of "DQHL"	RP
RCID	Unique record id within the module	<gen>
COMT	Textual narration	<text for mass conversion case> DEM-A1a, DEM-A1b, DEM-A1d, DEM-A2 DEM-A3, DEM-A21, DEM-A22 DEM-A23, DEM-A24, DEM-A28

Text to Include For MASS CONVERSION:

MASS CONVERSION: This DEM was converted to SDTS Raster Profile as part of a mass conversion of US Geological Survey Digital Elevation Model archive to SDTS. The data organization was changed from southwest origin with south to north scans to a northwest origin with west to east scans. The x,y grid positions were not altered---i.e. the data was not resampled. The UTM gridded DEMS are ragged in their native form. A fill value was used to make the DEM grid rectangular in this transfer.

3.3.12 Data Quality/Positional Accuracy Module

The Positional Accuracy module contains statements regarding the positional accuracy of the x,y coordinates included in the transfer. Also included are statements regarding the Vertical accuracy of the DEM data, even though these are encoded as cell values and not as z values.

Table 3.3.12: Positional Accuracy Module

Sub-field	Contents	Source
Primary Field: Positional Accuracy (DQPA)		
MODN	Module Name of "DQPA"	RP
RCID	Unique record id within the module	<gen>
COMT	Textual narration	DEM-A3, DEM-A14, DEM-A17 DEM-A18, DEM-A19, DEM-A20 DEM-A25, DEM-A31, DEM-C1 DEM-C2, DEM-C3, DEM-C4 DEM-C5, DEM-C6

3.3.13 Data Quality/Attribute Accuracy Module

Attribute Accuracy on cell values is the vertical accuracy and, therefore, is shown on horizontal values. Because raster cell data is elevation data, RMSE values are recorded as positional accuracy.

Table 3.3.13: Attribute Accuracy Module

Sub-field	Contents	Source
MODN	Module name of "DQAA"	RP
RCID	Unique record id within the module	<gen>
COMT	Textual narration	Const

3.3.14 Data Quality/Logical Consistency Module

A report on logical consistency shall describe the fidelity of relationships encoded in the data structure of the digital spatial data. Also this module contains description of non-standard data encoding practices.

The Raster Profile requires an explanation of the null scheme used in the transfer. In addition, there are some aspects of the DEM encoding that will be explained in this module.

Table 3.3.14: Logical Consistency Module

Sub-field	Contents	Source
Primary Field: Logical Consistency (DQLC)		
MODN	Module Name of "DQLC"	RP
RCID	Unique record id within the module	<gen>
COMT	Textual narration	DEM-A30 + Const

3.3.15 Data Quality/Completeness Module

This module contains statements regarding data collection criteria and "completeness" of the data content in the transfer.
The quality report shall include information about selection criteria, definitions used and other relevant mapping rules. For example, geometric thresholds such as minimum area or minimum width shall be reported. Deviations from standard definitions and interpretations shall be described.

Table 3.3.15: Completeness Module

Sub-field	Contents	Source
Primary Field: Completeness (DQCG)		
MODN	Module Name of "DQCG"	RP
RCID	Unique record id within the module	<gen>
COMT	Textual narration	DEM-A25 DEM-A29

3.3.16 Raster Definition Module

The Raster Definition module is used to define each raster object in the transfer. One Raster Definition module record corresponds to one raster object. A raster object is defined by one or more overlapping layers having the same Internal Spatial Reference system. Each layer is composed of a number of pixels or grid cells, referred to collectively as cells. The cell size is described by the Internal Spatial Reference record pointed to by a raster object via the ISID subfield of the Raster Definition module record.

The Raster object Scan Reference system is defined by the Raster Definition Module; this system defines the raster object coordinate. Given a layer coordinate, there will be a simple translate operation to place the coordinate into the raster object scan reference system. Given a raster object coordinate, there will be a scale and a translate operation to place the coordinate into the internal reference system. Given an internal coordinate, there will be a rotate, a scale, and a translate operation to place the coordinate into the external reference system.

For DEM transfers, there is a single raster object and it contains a single layer. The cells of the layer correspond to grid cells whose values are measurements of elevation.

Table 3.3.16: Raster Definition Module

Sub-field	Contents	Source
Primary Field: Raster Definition (RSDF)		
MODN	Module name of "RSDF"	RP
RCID	Unique record id within the module	<gen>
OBRP	Object representation of "G2"	Const & DEM-A4
CSCD	Cell sequencing code of "GI"	Const
DEFI	Default Implementation = "DEF"	Const
RWXT	Row Extent (see Table 2.3, Element A16)	<Calc>
CLXT	Column Extent	DEM-A16(n)
SCOR	Scan origin = "TL"	Default
TIDX	Tesseral indexing = "NOTESS"	Default
ALTN	Number of lines per alternation = "1"	Default
FSCN	First scan direction = "R"	Default
ASPR	Aspect ratio = "1.000"	Default
NLAY	Num of layers = "1"	Const
Secondary Field: Internal Spatial ID Field (ISID)		
ISID	Pointer to Internal Spatial Ref. record	<gen>
Secondary Field: Spatial Address Field (SADR)		
SADR	Spatial address of the origin of the raster object scan ref. sys. Pointer to origin location. (Northwest corner) Calculations are defined in IREF Section.	<Calc>
Secondary Field: Layer ID (LYID)		

Sub-field	Contents	Source
LYID	ID to Layer defn (1 value)	<gen>

3.3.17 Layer Definition Module

The Layer Definition module describes raster layers, including their layer name and a layer scan reference system. Each Layer Definition module record describes one layer of a raster. The format, definition, and domain of the layer are stored in the respective Data Dictionary modules. Each record of the Layer Definition module will be uniquely identified by the name of the layer in conjunction with the name of the cell module into which the cell values for the layer will reside. For the DEM, there is one layer so there is only one Layer Definition module record.

Table 3.3.17: Layer Definition Module

Sub-field	Contents	Source
Primary Field: Definition Field (LDEF)		
MODN	Module name of "LDEF"	RP
RCID	Unique record id within the module	<gen>
CMNM	Cell Module Name = "CEL0"	Ext
LLBL	Layer label = "ELEVATION"	Const
CODE	Cell code = "V"	Const
NROW	Number of rows	<Calc>
NCOL	Number of column	DEM-A16(n)
SORI	Scan origin row = "1"	Default
SOCI	Scan origin column = "1"	Default
RWOO	Row offset origin = "0"	Default
CLOO	Column offset origin = "0"	Default
INTR	Intracell Ref location = "CE"	Const

3.3.18 Cell Module

The Cell Module holds the actual raster data. The Cell module record has been designed to hold information on a number of related cells. There will be one Cell module and it will have a record for each scan row of the DEM. Each record will hold a scan lines worth of cell values. The coordinate of the first cell value (ROWI, COLI)in a cell module record is in the layer scan reference system, which is equivalent to the Raster Object Scan Refernce system coordinate. For example, Layer Coord (3,1) = Raster Object coord (3,1).

Table 3.3.18: Cell Module

Sub-field	Contents	Source
Primary Field: Cell (CELL)		
MODN	Module name of "CEL0"	Ext
ROWI	Row index of first cell in module record	<Calc>
COLI	Column index of first cell in module record = "1"	Const
Secondary Field: Cell values (CVLS)		
ELEVATION	All post values for 1 scan. DEM-A16 width repetitions of CVLS field	DEM-B1-> B6

NOTE: (See B1-B6) One Cell Module record for each scan row; Data (post values) reordered to default implementation.

THE END

All good things must come to and end....but bad things
seem to last forever... :)