American National Standard
for Information Technology—

Geographic Information Framework – Data Content Standards For Digital Orthoimagery

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for Information Technology

Geographic Information Framework Data Content Standards For Digital Orthoimagery

(Part XXX)

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Note to Commenters: Although this working draft is presented as a stand-alone standard in ANSI format, it is intended to become part of a single, harmonized NSDI Framework Data Content Standard. In all, five transportation subthemes and seven Framework themes will be harmonized into one standard for presentation to the InterNational Committee on Information Technology Standards, Geographic Information Systems[1]*. Structural and formatting changes are likely to occur to this and other working drafts during the harmonization process. While editorial comments are very welcome on this and any working draft, standards' development would benefit most, at this time, from comments on scientific and technical issues. The single, harmonized draft will also be made available for public review and comment.*

To comment on working drafts, please use the Microsoft Excel spreadsheet located at http://www.geo-one-stop.gov/Standards/index.html. Only comments received in this format will be considered. You can email comments to GeospatialComments@geo-one-stop.gov., or mail them to the following address:

Geospatial Comments
The MNG Center at SRA International
2425 Wilson Blvd.
Suite 400
Arlington, VA 22201

[1] See the diagram, "Nested Relationship of NSDI Framework Data Content Standard Harmonization" at the end of this document.

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1 Scope, Purpose, and Application

The objective of this Geospatial One-Stop standard is to set a common baseline that will ensure the widest utility of digital orthoimagery data for the user and producer communities through enhanced data sharing and the reduction of redundant data processing and production. It is the intent of this standard to set a common baseline that will ensure the widest utility of digital orthoimagery for the user and producer communities through enhanced data sharing and the reduction of redundant data production. The framework will provide a base on which to collect, register, and integrate digital geospatial information accurately. Digital orthoimagery is one of the basic digital geospatial data framework themes as envisioned by the GeoSpatial One-Stop (GOS) Initiative.

This standard is intended to facilitate the interchange and use of digital orthoimagery data under the framework concept. Because of rapidly changing technologies in the geospatial sciences, this standard for digital orthoimagery covers a range of specification issues, many in general terms. This document stresses complete and accurate reporting of information relating to quality control and standards employed in testing orthoimagery data.

The orthoimagery standard applies to National Spatial Data Infrastructure (NSDI) Framework orthoimagery data produced or disseminated by or for the federal government. According to Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure (Clinton, 1994, Sec. 4., Data Standards Activities), federal agencies collecting or producing geospatial data, either directly or indirectly (e.g., through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the Federal Geographic Data Committee (FGDC) process.

2 Referenced and Related Publications

The following standards contain provisions, which through reference in this text constitute provisions of this DRAFT American National Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this American National Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below:

- ANSI NCITS 320-1998, *Spatial Data Transfer Standard (SDTS)*.
- FGDC-STD-012-2002, *Content Standard for Digital Geospatial Metadata: Extensions for Remote Sensing Metadata*
- FGDC-STD-001-1998, *Content Standard for Digital Geospatial Metadata (version 2.0)*.
- FGDC-STD-002.5, *Spatial Data Transfer Standard (SDTS), Part 5: Raster Profile and Extensions*.
- FGDC-STD-007.1-1998,*Geospatial Positioning Accuracy Standard, Part 1, Reporting Methodology*.
- FGDC-STD-007.3-1998,*Geospatial Positioning Accuracy Standards Part 3: National Standard for Spatial Data Accuracy*.
- ISO 19115, *Geographic Information—Metadata*.
- ISO 19123, *Geographic Information—Schema for coverage geometry and functions*
- Schowengerdt, Robert A. 1997, Remote Sensing – Models and Methods for Image Processing, 2nd Ed. San Diego, CA, 522 pp.
- USGS *Aerial Camera Specifications* (Revised 01/03)
- U.S. Department of Agriculture, 1990. *Basic Photo Interpretation*, Rashere, M.E., Weaver, W. USDA, Washington DC

3 Definitions

Aliasing – The loss of detail in a digital image due to the use of too few pixels to represent an image or portion of the image.

Band - a range of wavelengths of electromagnetic radiation specified to produce a single response to a sensing device.

Band Interleaved - the ordered mixing of lines (band interleaved by line) or pixels (band interleaved by pixels) of one or more bands with corresponding lines or pixels of other bands, for the purpose of forming a single image file.

Band Sequential (BSQ) - a sequence of one image band followed by another image band. A band sequential file can be formed by appending bands in sequence within a single file.

Bilinear interpolation - the mathematical computation for an unknown value based on the linear interpolation along two axes. The axes are derived using a coordinate transformation algorithm to locate the quadrilateral of the four nearest profile points surrounding the unknown point. The interpolation computes the unknown value based on the average, by use of weights and distances, of the four nearest known values.

Brightness value (Digital Number or DN) - A discrete integer value representing a measurement of the ground radiance as detected by a sensor

Color infra-red (CIR): pertaining to or designating images sensed in the portion of the electro-magnetic spectrum from about 0.7mm to an upper boundary set at 2.6mm

Cubic Convolution - a mathematical computation for the interpolation of an unknown value based on a third degree polynomial equation using surrounding known values.

Density number (DN) – See brightness value.

Digital Orthoimage - a georeferenced digital image prepared from a perspective photograph, or other remotely-sensed data, in which displacement of objects in the image, due to sensor orientation and terrain relief, have been removed.

Georegistration - The alignment of one image to another image of the same area by placing any two pixels at the same location in both images "in register" resulting in samples at the same point on the earth.

Mosaic – The assemblage of overlapping or adjacent photographs or digital images whose edges have been matched to form a continuous pictorial representation of a portion of the earth's surface.

Orthorectification: Correction of the image, pixel-by-pixel, for topographic distortions resulting in an image that is in an orthographic projection. –

Panchromatic – a black and white aerial photography film that records images in the visable spectrum - 0.4 to 0.9 micrometers.

Radiometric resolution - see resolution

Resampling - the interpolation of new values for pixels from existing values.

Resolution –The ability of a sensor to render a sharply defined image. It may be expressed in many ways depending on the sensor. For orthoimagery, resolution refers either to *spectral* and *spatial* resolutions.

> **Spectral (radiometric) resolution** is the total range of reflectance (the width and number of bands in the electromagnetic spectrum) of a given band to produce an image.
>
> **Spatial resolution** is the ground sample distance (GSD) or interval (GSI) that is the spacing of pixels on the ground.

Void areas – Locations in an elevation coverage where no image data are available.

4 Standards Development

The standard is based on the FGDC standard, "Content Standards for Digital Orthoimagery, FGDC-STD-008-1999", developed initially by the Subcommittee on Base Cartographic Data of the FGDC. The Standards Reference Model, developed by the Standards Working Group of the FGDC, provides guidance to FGDC subcommittees for the standards development process. The model also defines the expectations of FGDC standards, describes different types of geospatial standards, and documents the FGDC standards process. [insert text about the ANSI process].

4.1 Standards Maintenance

The U.S. Department of the Interior, United States Geological Survey (USGS), Geography Discipline, maintains the Content Standards for Framework Digital Orthoimagery for the Federal Geographic Data Committee. Address questions concerning this standard to: Chief Geographer, USGS, Mail Stop102, National Center, Reston, VA 20192.

4.2 Maintenance Authority

The U.S. Department of the Interior, United States Geological Survey (USGS), holds primary responsibility for the orthoimagery theme of the National Spatial Data Infrastructure, defined in OMB Circular A-16. The USGS Geography Discipline is the maintenance authority for the Standards for Digital Orthoimagery Data in support of the Geospatial One Stop, E-Government initiative. Address questions concerning this standard to: Associate Director for Geography, USGS, Mail Stop 516, 12201 Sunrise Valley Drive, Reston, VA 20192.

5 Data Description

Digital orthoimagery are georeferenced images of the Earth's surface, collected by a sensor in which image object displacement has been removed for sensor distortions and orientation, and terrain relief. For very large surface areas, an Earth curvature correction may be applied. Digital orthoimages encode the optical electromagnetic spectrum as discrete values modeled in an array of georeferenced pixels. Digital orthoimages have the geometric characteristics of a map, and image qualities of a photograph. Digital orthoimagery comes from various sources and in a number of formats, spatial resolutions, and areas of coverage. Many geographic features, including some in other framework data themes, can be interpreted and compiled from an orthoimage.

6 Digital Orthoimagery Structure

Framework digital orthoimagery shall consist of images, each of which consist of a two-dimensional, rectangular array of pixels. Pixels correspond to ground areas called ground resolution cells. The pixels shall be arranged in horizontal rows (lines) and vertical columns (samples). The order of the rows shall be from top to bottom; the order of columns shall be from left to right. The uppermost left-hand pixel shall be designated pixel (0,0). Each line of image pixels often represents a physical record in the file with the total set of records constituting a single file, but this standard specifies no physical implementation. Images describing more than 1 band of electromagnetic radiation (true color, color-infrared, multi-band) shall be structured in one of three orders: band-interleaved by line (BIL), band interleaved by pixel (BIP or Band interleaved by sample. BIS), or band sequential (BSQ).

The file shall have equal record lengths, resulting in a rectangular or squared image. This may be accomplished by padding with over-edge image or non-image pixels, with digital number (DN) equal to zero (black), to an edge defined by the extremes of the image. The bounding coordinates of the image must be documented in accordance with the FGDC "Content Standard for Digital Geospatial Metadata". For images that contain over-edge imagery or are padded with non-image pixels, descriptions of both the specific area of interest and any over-edge imagery must be documented by the metadata. For instance, some digital orthoimagery quadrangles include over-edge imagery beyond the boundaries of the area of interest. This standard also recognizes that annotations may be included in an image file considered to be over-edge. These image files are generally created using color lookup tables that provide for a transparent pixel value to accommodate the portrayal of the over-edge information; otherwise this standard limits the orthoimage to the significant pixel values of the image. When over-edge information in the image file exists, the producer is obliged to describe the image quadrangle in metadata. Both the image area of interest proper, and the over-edge, shall be documented in the following metadata field:

(Spatial_Domain/Bounding_Coordinates and Data_Quality_information/Attribute_Accuracy/
Completeness_Report)

6.1 Image Radiometry

Relative radiance from the ground resolution cells is described by numerical representations (DNs or brightness values) of reflected radiance amplitudes. The cell value is recorded as a series of binary digits or bits, with the number of bits per cell determining the radiometric resolution of the image. Where Q is a finite number of bits, the number of discrete DNs is given, as follows:

$$N_{DN} = 2^Q$$

The DN can be any integer in the range, as follows:

$$DN_{range} = [0, 2^Q\text{-}1]$$

The number of DNs is sensor dependent and may range from 8 to 12 bits. Brightness values of most digital orthophotos created from aerial photographs are commonly represented as 8-bit binary numbers with a range of values from zero, (black) to 255 (white). SPOT and TM (Thematic Mapper) are both 8 bits per pixel. AVHRR (Advanced Very High Resolution Radiometer) is 10 bits and MODIS (Moderate Resolution Imaging Spectroradiometer) is 12 bits per pixel.

7 Data Transfer Formats

Data transfer formats for digital orthoimagery will not be specified in this standard. However data producers are encouraged to employ ISO and ANSI standards for information exchange. In all cases, producers shall provide detailed descriptions of the format.

8 Production Component Requirements

The primary production components of digital orthoimages are: image sources, elevation data, control, and camera or sensor calibration data.

8.1 Image Sources

Source imagery for digital orthoimagery is collected by a variety of remote sensors and processed in a number of ways. All sources employed in the construction of digital orthoimagery shall be documented in the following metadata field:

(Data_Quality_Information/Lineage/Source_Information)

Remote sensing systems can be divided into two general categories: imaging and non-imaging. This standard focuses on imaging systems. Commonly used types of imaging systems include: photo-optical, electro-optical, passive microwave, RADAR, LIDAR, IFSAR, SONAR.

8.1.1 Aerial Photography

Aerial photography is the primary image source currently used to produce digital orthoimagery. Film types for orthoimagery compliant with the standard shall be confined to black and white (panchromatic), color infrared (CIR), and natural (true) color. Black and white orthoimagery may be generated from CIR and natural color source. For aerial photo identification, the type of film, manufacturer or agency identification, and roll and exposure number shall be documented in the following metadata field:

(Lineage:Source_Information/Source_Citation)

8.1.1.1 Scanned Images From Aerial Photography

Scanning is the process of converting a conventional analog photographic image to a digital image. The combination of the scanner optical resolution setting and the scale of the source imagery will determine the ground resolution distance that can be attained from the digital image following orthocorrection. The intent of the scanning process is to capture the same level of detail in the digital image as is found on the film. The optical geometric resolution of the scanning process is typically measured in either microns, or dots-per-inch, and should as closely as possible match the intended ground sample distance (GSD) without excessive resampling. Resampling to a coarser resolution is acceptable. However, if the image needs to be resampled to a finer resolution, that is, a smaller GSD, the image should be rescanned using the next optical resolution setting available on the scanner.

8.1.2 Digital Aerial Photography

Electro-optical imaging instruments are non-film detectors which typically use two-dimensional detector arrays of charged-couple devices (CCDs). Each detector in the array is the equivalent of one pixel in the image. Appropriate information about the device, type, array size, pixel resolution, and flight height, will be cited in the following image metadata field:

(Data_Quality_Information/Lineage/Process_Step/Process_Description)

8.1.3 Digital Satellite Imagery

Space-borne imaging instruments provide electro-optical, near infra-red, and RADAR imagery are useful for generating orthoimages. Sun-synchronous orbits allow revisiting timeframes of 1 to 1.5 days. Dynamic range of 11 bits are available. Panchromatic spectral range of . 45 - .90 microns and multispectral range of .45 to .90 microns are common. Radar single frequency C-band systems provide up to an 8-meter resolution.

8.2 Elevation Data

Elevation data used to correct displacement shall be sufficiently accurate to ensure the image meets user defined accuracy requirements for the intended scale. Producers of digital orthoimagery shall use elevation data with the appropriate ground sample distances and aerial coverage to reliably describe the terrain and meet the accuracy requirements of the orthoimage. A detailed description of the source Elevation Model shall be documented in the following metadata field:

(Lineage:Source_Information/Source_Citation)

[Editor’s Note: More precisely defining, or giving examples of what is “sufficiently accurate” would be helpful, but is difficult as references are hard to find. Reviewer comments on this issue are invited.]

For more information on elevation data refer to the Draft *GeoSpatial One-Stop Standard for Framework Digital Elevation Data* (01/03).

8.3 Calibration Data

While camera or imaging instrument calibration parameters are required for production purposes, specifications for that data will not be covered by this standard. Information on camera calibration can be found in the USGS publication "USGS Aerial Camera Specifications" (01/03).

8.4 Control

Surveyed control or control from an aerotriangulation solution are recommended in meeting the requirements for the intended digital orthoimage. Ground control provides coordinates and elevations of known locations on the earth’s surface and helps to establish the location of the imaging platform with respect to the ground. Control can also be provided from an airborne GPS system that provides the coordinates and elevation of the imaging platform. Control derived from a less accurate source, such as a printed map, is not recommended.

9 Areal Extent

This standard places no constraints on the geographic extent of orthoimagery. Areal extent of quadrilateral orthoimagery may be adjusted as appropriate for the type of sensor and sensor platform, height, requirements of the user, etc. It is recommended that producers of digital orthoimagery data utilize a well documented schema for partitioning the Earth's surface. The spatial domain of an image shall be documented in the following metadata field:

(Identification_Information/Spatial_Domain)

Numerous established schemas exist. The USGS 7.5-minute topographic map series utilizes one such method. Diagrammatic outlines based on subsets of the 7.5-minute topographic map could be used for large-scale image partitioning schemas. Other examples include tiles based on the Public Land Survey System (PLSS) or other cadastral systems based on county boundaries, tax plats, etc. The tiling layers, geographic areas, etc. shall be documented in units of distribution (ref. ISO 19115, B2.10.1).

10 Georeferencing

A common method for referencing coordinate positions on the Earth is essential for integrating framework data. While it is *desirable* that framework data be described by **longitude and latitude coordinates,** orthoimagery is more often represented in a grid coordinate system, such as Universal Transverse Mercator (UTM) or State Plane Coordinate Systems (SPCS). The horizontal coordinate system of the image shall be documented in the following metadata field:

(Spatial_Reference_ Information/Horizontal_Coordinate_System_Definition)

The North American Datum of 1983 (NAD83) or World Geodetic System 1984 (WGS84) shall be used as the horizontal datum for digital orthoimagery. The horizontal datum shall be documented in the following metadata field:

(Spatial_Reference_Information/Horizontal_Coordinate_System_Definition/Geodetic_Model)

Georegistration of the image is also essential to complete georeferencing of the image. Georegistration will be described by a 4-tuple in the metadata which will establish the position of the first pixel in the first row of the image [pixel (0,0)]. The metadata will reflect the row # = 0, column # = 0, and georeference values in X and Y for the documented datum and horizontal coordinate system. Under this standard, georegistration (spatial coordinates) refers to the center of the pixel. This establishes the georegistration at one point in the orthoimage. Since row and column offsets are both constant and known, (XY_pixel resolution), all other points can be georegistered. Additional 4-tuples may be provided for additional georegistration. Georegistration of pixel (0,0) shall be documented in the following metadata field:

(Spatial_Reference_Information/Horizontal_Coordinate_System_Definition/Planar_Coordinate_ Information/Local_Planar_Georeference_Information)

11 Resolution

Two separate resolution measurements are important for image data: pixel ground resolution, which is sometimes referred to as horizontal ground resolution or ground sample distance (GSD), and radiometric resolution. For this standard, pixel ground resolution defines the area of the ground represented in each pixel in X and Y components, while radiometric resolution defines the sensitivity of a detector to differences in wavelength as it records radiant flux reflected or emitted from the ground.

11.1 Pixel Ground Resolution

Images may be resampled to create coarser resolution images than the original raster data. Subsampling of images may be applied only within the limits defined by the Nyquist theorem (Pratt, 1978). The Nyquist frequency limits subsampling to a maximum two times (2X) to avoid undesirable aliasing.

The pixel ground resolution shall be documented in the following metadata field:

(Spatial_Reference_Information/Horizontal_Coordinate_System_Definition/Planar/Planar_Coordinate_ Information)

11.2 Radiometric Resolution

Radiometric resolution is the range of wavelengths of the visible and near infrared portion of the electromagnetic spectrum. The radiance value at each pixel is represented by a discrete value. The radiance values for black and white (gray scale) image data are represented as 8 or 12-bit binary data, and color images represented as 24- or 36-bit, 3 byte data. Radiometric resolution shall be documented in the following metadata field:

(Spatial_Data_Organization_Information:Direct_Spatial_Reference_Method/Raster_Object_Information)

12 Processing Components

Different orthoimagery production systems have unique characteristics. However, all accept raw (or unprocessed) imagery that contain some degree of error in geometry (geometric distortion) and in the measured brightness values of the pixels (radiometric distortion). Image rectification and restoration are processes for correcting distortions and degradations that result from image acquisition. This standard requires specification of rectification or restoration procedures only in context of geometric and radiometric corrections.

Detailed descriptions of the processes used to correct distortions in an image shall be documented in the following metadata field:

(Data_Quality_Information/Lineage/Process_Step/Process_Description)

12.1 Geometric Correction

All systematic and random errors shall be removed to the extent required to meet map accuracy requirements as defined by the intended user. Geometric corrections are performed to match raw image data to map geometry. Distortions can be classified as either systematic (predictable errors that follow some definite mathematical or physical law or pattern associated with particular processes and instruments) or random (errors that are wholly due to chance and do not recur). Most of the distortions associated with orthoimagery are random. Terrain relief, platform position, and faulty elevation data are the sources of nonsystematic distortion, or random errors. These random errors can be detected by comparing identifiable points on an image to their known ground coordinates.

Nearest neighbor, bilinear interpolation, and cubic convolution resampling algorithms are common methods used to transform image values to fit map geolocation values. Nearest neighbor resampling is not recommended for the large-scale framework because of the disjointed appearance in the output due to spatial offsets as great as one-half pixel. Images transformed using bilinear interpolations are generally acceptable. A precise resampling method such as cubic convolution is recommended. Most importantly, the resampling process utilized in the production of the image must be documented in the following metadata field:

(Data_Quality_Information/Lineage/Process_Step/Process_Description)

12.1.2 Image Smear

Occasionally, because of spikes in the elevation data or excessive topographic relief, an anomaly or artifact best described as an "image smear" may appear on a rectified image. Basically, the steepness of the terrain is such that some ground image is effectively hidden from view (e.g., on the backside of the mountain or the sides of a steep cliff). This can be especially prominent near the edge of images from large-scale aerial photography (incidence of the anomaly decreases as the altitude of the sensor platform increases). When that portion of the scanned raster image is adjusted to its conjugate area on the elevation model, the void in the image is assigned brightness values via an interpolation algorithm that uses the visible image surrounding the void. This sometimes results in a "smeared" or "stretched" area on the image.

When image smears occur, all reasonable means to correct them shall be applied. Where feasible, areas of image smear may spatially be defined as polygons, linked to documentation in Lineage metadata. Any image restoration or enhancement processes applied to an image shall be documented in the following metadata field:

(Data_Quality_Information/Lineage/Process_Step/Process_Description)

12.1.3 Other Elevation – Related Geometric Distortions

Double or missing features in the image may be indications of a poor Elevation Model or unsuitable control. Such distortions may render the image unusable. If at all possible, producers should recheck the source elevation or control to establish if the distortion is systematic or not. Non-systematic distortions need to be reviewed on a case-by-case basis and if deemed accepted by the producer, identified and recorded in the metadata.

12.2 Radiometric Correction

Image brightness values may deviate from the brightness values of the original imagery, due to image value interpolation during the scanning, rectification, and post-processing procedures and it is common practice to perform some radiometric enhancements and corrections (e.g., contrast stretching, analog dodging, noise filtering, destriping, edge matching) to images prior to release of the data. However, data producers are cautioned to minimize the amount of radiometric correction applied to an image. Data producers shall use processing techniques that minimize data loss from the time the information was captured until its release to the users. Any image restoration or enhancement processes applied to an image shall be documented in the following metadata field:

(Data_Quality_Information/Lineage/Process_Step/Process_Description)

12.3 Data Completeness

Visual verification shall be performed for image completeness, to ensure that, whenever possible, no gaps exist in the image area. Areas of omission, in incomplete images, shall be documented in the following metadata field:

(Data_Quality_Information/Completeness_Report)

12.4 Cloud Cover

Any cloud cover or cloud shadows which obscure image features may render the image unusable. However, for some areas of an image (e.g., over broad bodies of water) cloud cover obstruction may be deemed acceptable to some users. Therefore, some users may find images containing varying percentages of cloud cover or cloud shadow to be acceptable. The percentage of cloud cover obstruction shall be recorded in the following metadata field:

(Data_Quality_Information/Cloud_Cover)

13 Image Mosaicking

Single orthoimages are commonly created through the mosaicking of multiple images and many producers go through extensive image processing steps to attain a "seamless" appearance. This standard will not discuss mosaic procedures nor will it prescribe the degree of quality for the appearance of mosaicked orthoimages. However, all the images that comprise the source of a mosaicked image shall be documented in the metadata field. For example: if five images are used in the creation of a mosaic, those five images shall be noted in the metadata of the mosaic, as follows:

(Data_Quality_Information/Lineage/Source_ Information/Source_Citation)

14 Metadata

GeoSpatial One-Stop emphasizes the importance of good metadata to support the exchange and use of geospatial data. Providing quality information about data that will allow users to match data to their needs. Well-crafted metadata facilitates the search and collection process while alleviating some of the burden on the user to assess quality and applicability of data. The more metadata there is for a product, the more it can support the user's determination of its reliability, quality, and accuracy. Metadata is intended to be of value to the producer as well as to the user.

The FGDC "Content Standards for Digital Geospatial Metadata," in conjunction with ISO TC 211 19115, will be the source for all issues relating to terminology and definitions relating to metadata. Executive Order 12906 "Coordinating Geographic Data Acquisition and Access: The National Spatial Data Infrastructure," requires all Federal agencies to use the standard to document data that they produce beginning in 1995. If and when an ISO standard for digital orthoimagery is issued, the FGDC metadata will need to be converted to match ISO TC 211 19115.

Table 1 (Annex A) contains the minimal metadata requirements for an orthoimage. Depending on a variety of factors or characteristics, not all of elements in the table will be required of every data set and there are some mandatory-if-applicable FGDC elements that won't apply to every dataset.

Annex B contains an example of a metadata file for a specific orthoimage. The example cited is compliant with the FGDC Content Standard for Geospatial Metadata.

Annex A

Metadata Crosswalk

[Editor's Note: This Annex is currently in work. It is here now only for preliminary information purposes only. It will updated or a new external document referenced when FGDC/ISO harmonization work is completed.]

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents

FGDC Element Name	ISO Element Name
Identification Information (Section 1)	MD_Metadata.identificationInfo.MD_Identification
1.1 Citation	MD_Metadata.identificationInfo.MD_Identification
1.2 Description	---
1.2.1 Abstract	MD_Metadata.identificationInfo.MD_Identification. abstract
1.2.2 Purpose	MD_Metadata.identificationInfo.MD_Identification. purpose
1.2.3 Supplemental Information	MD_Metadata.identificationInfo. MD_DataIdentification.supplementalInformation
1.3 Time Period of content	---
1.3.1 Time Period Information	MD_Metadata.identificationInfo. MD_DataIdentification.extent.EX_Extent.tempora Element
1.3.2 Currentness Reference	MD_Metadata.identificationInfo. MD_DataIdentification.extent.EX_Extent.description
1.4 Status	---
1.4.1 Progress	MD_Metadata.identificationInfo.MD_Identification.status
1.4.2 Maintenance and Update Frequency	MD_Metadata.identificationInfo. MD_Identification.resourceMaintenance.MD_Maintenance. maintenanceAndUpdateFrequency
1.5 Spatial domain	---
1.5.1 Bounding coordinates	MD_Metadata.identificationInfo.MD_DataIdentification.extent. EX_Extent.geographicElement.EX_GeographicBoundingBox (where EX_Extent.extentTypeCode = 1)
1.5.1.1 West Bounding Coordinate	MD_Metadata.identificationInfo.MD_DataIdentification.extent. EX_Extent.geographicElement.EX_GeographicBoundingBox. westBoundLongitude
1.5.1.2 East Bounding Coordinate	MD_Metadata.identificationInfo.MD_DataIdentification.extent. EX_Extent.geographicElement.EX_GeographicBoundingBox. eastBoundLongitude

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
1.5.1.3 North Bounding Coordinate	MD_Metadata.identificationInfo.MD_DataIdentification.extent. EX_Extent.geographicElement.EX_GeographicBoundingBox. northBoundLatitude
1.5.1.4 South Bounding Coordinate	MD_Metadata.identificationInfo.MD_DataIdentification.extent. EX_Extent.geographicElement.EX_GeographicBoundingBox. southBoundLatitude
1.6 Keywords	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords
1.6.1 Theme	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.type = theme (code 005)
1.6.1.1 Theme Keyword Thesaurus	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.thesaurusName
1.6.1.2 Theme Keyword	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.keyword
1.6.2 Place	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.tye = place (code 002)
1.6.2.1 Place Keyword Thesaurus	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.thesaurusName
1.6.2.2 Place Keyword	MD_Metadata.identificationInfo.MD_Identification. descriptiveKeywords.MD_Keywords.keyword
1.7 Access Constraints	MD_Metadata.identificationInfo.MD_ Identification.resourceConstraints.MD_LegalConstraints. otherConstraints, and set MD_Metadata.identificationInfo. MD_Identification.resourceConstraints. MD_LegalConstraints.accessConstraints value to other (008)
1.8 Use Constraints	MD_Metadata.identificationInfo.MD_ Identification.resourceConstraints.MD_LegalConstraints. otherConstraints, and set MD_Metadata.identificationInfo. MD_Identification.resourceConstraints. MD_LegalConstraints.useConstraints to other (008)
1.13 Native Data Set Environment	MD_Metadata.identificationInfo.MD_DataIdentification. environmentDescription
Data Quality Information (Section 2)	
2.1 Attribute Accuracy	MD_Metadata.dataQualityInfo.DQ_DataQuality. report.DQ_ThematicAccuracy (abstract)

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
2.1.1 Attribute Accuracy Report	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_QuantatitiveAttributeAccuracy.evaluationMethodDescription
2.1.2 Quantitative Attribute Accuracy Assessment	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_QuantatitiveAttributeAccuracy
2.1.2.1 Attribute Accuracy Value	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_QuantatitiveAttributeAccuracy.result.DQ_QuantatitiveResult.value
2.1.2.2 Attribute Accuracy Explanation	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_QuantatitiveAttributeAccuracy.measureDescription
2.2 Logical Consistency Report	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_LogicalConsistency (abstract).evaluationMethodDescription
2.3 Completeness Report	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_Completeness (abstract).evaluationMethodDescription
2.4 Positional Accuracy	MD_Metadata.dataQualityInfo.DQ_DataQuality.DQ_PositionalAccuracy.(abstract) DQ_AbsoluteExternalPositionalAccuracy.Result
2.4.1 Horizontal Positional Accuracy	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_AbsoluteExternalPositionalAccuracy.result
2.4.1.1 Horizontal Positional Accuracy Report	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_PositionalAccuracy (abstract).evaluationMethodDescription
2.4.1.2 Quantitative Horizontal Positional Accuracy Assessment	NO MATCH all the attributes in DQ_Element
2.4.1.2.1 Horizontal Positional Accuracy Value	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_PositionalAccuracy (abstract)
2.4.1.2.2 Horizontal Positional Accuracy Explanation	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_PositionalAccuracy (abstract).measureDescription
2.4.2 Vertical Positional Accuracy	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_AbsoluteExternalPositionalAccuracy.result
2.4.2.1 Vertical Positional Accuracy Report	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_PositionalAccuracy (abstract).evaluationMethodDescription
2.4.2.2 Quantitative Vertical Positional Accuracy Assessment	NO MATCH all the attributes in DQ_Element
2.4.2.2.1 Vertical Positional Accuracy Value	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.DQ_PositionalAccuracy (abstract)
2.4.2.2.2 Vertical Positional Accuracy	MD_Metadata.dataQualityInfo.DQ_DataQuality.report.

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
Explanation	DQ_PositionalAccuracy (abstract).measureDescription
2.5 Lineage	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage
2.5.1 Source Information	---
2.5.1.1 Source Citation	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.sourceCitation
2.5.1.2 Source Scale Denominator	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.scaleDenominator
2.5.1.3 Type of Source Media	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.description
2.5.1.4 Source Time Period of Content	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.sourceExtent
2.5.1.4.1 Source Currentness Reference	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.sourceExtent
2.5.1.5 Source Citation Abbreviation	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.sourceCitation.CI_Citation. alternateTitle
2.5.1.6 Source Contribution	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.source.LI_Source.description
2.5.2 Process Step	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.processStep
2.5.2.1 Process Description	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.processStep.LI_ProcessStep.description
2.5.2.2 Source Used Citation Abbreviation	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.processStep.LI_ProcessStep.source. LI_Source.sourceCitation.CI_Citation.alternateTitle
2.5.2.3 Process Date	MD_Metadata.dataQualityInfo.DQ_DataQuality.lineage. LI_Lineage.processStep.LI_ProcessStep.dateTime
Spatial Data Organization Information (Section 3)	
3.1 Indirect Spatial Reference	MD_Metadata.identificationInfo. MD_Identification.spatialRepresentationType as textTable (003)
3.2 Direct Spatial Reference Method	MD_Metadata.identificationInfo. MD_Identifiation.spatialRepresentationType as vector (001) or grid (002)
3.4 Raster Object Information	---
3.4.1 Raster Object Type	MD_Metadata.spatialRepresentationInfo. MD_GridSpatialRepresentation. numberOfDimensions

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
3.4.2 Row Count	MD_Metadata.spatialRepresentationInfo. MD_GridSpatialRepresentation. axisDimensionProperties.MD_Dimension.dimensionSize (dimensionName = row, code 001)
3.4.3 Column Count	MD_Metadata.spatialRepresentationInfo. MD_GridSpatialRepresentation. axisDimensionProperties. MD_Dimension.dimensionSize (dimensionName = column, code 002)
Spatial Reference Information (Section 4)	
4.1 Horizontal Coordinate System Definition*	MD_Metadata.referenceSystemInfo.MD_ReferenceSystem. referenceSystemIdentifier.RS_Identifier.authority and code
4.1.1 Geographic * The Horizontal Coordinate System will either be Geographic or Planar, but NEVER both.	MD_Metadata.spatialRepresentationInfo. MD_GridSpatialRepresentation.axisDimensionProperties. MD_Dimension.resolution
4.1.1.1 Latitude Resolution	NO MATCH
4.1.1.2 Longitude Resolution	NO MATCH
4.1.1.3 Geographic Coordinate Units	NO MATCH
4.1.2 Planar	---
4.1.2.1.21 Transverse Mercator	Uses elements 4.1.2.1.23.17, .2, .3, .4, .5
4.1.2.1.23.17 Scale Factor at Central Meridian	NO MATCH
4.1.2.1.23.1 Longitude of Central Meridian	MD_Metadata.referenceSystemInfo.MD_CRS. projectionParameters.MD_ProjectionParameters. longitudeOfCentralMeridian
4.1.2.1.23.3 Latitude of Projection Origin	MD_Metadata.referenceSystemInfo. MD_CRS.projectionParameters.MD_ProjectionParameters. latitudeOfProjectionOrigin
4.1.2.1.23.4 False Easting	MD_Metadata.referenceSystemInfo. MD_CRS.projectionParameters.MD_ProjectionParameters. falseEasting
4.1.2.1.23.5 False Northing	MD_Metadata.referenceSystemInfo. MD_CRS.projectionParameters. MD_ProjectionParameters.falseNorthing
4.1.2.2 Grid Coordinate System	MD_Metadata.referenceSystemInfo
4.1.2.2.1 Grid Coordinate System Name	MD_Metadata.referenceSystemInfo.MD_ReferenceSystem. referenceSystemIdentifier.RS_Identifier.authority and code (replace with codelist, 4.1.2.2.2 – 4.1.2.2.6)
4.1.2.2.2 Universal Transverse Mercator	(selection from codelist in 4.1.2.2.1)

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
4.1.2.2.2.1 UTM Zone Number	NO MATCH
4.1.2.4 Planar Coordinate Information	---
4.1.2.4.1 Planar Coordinate Encoding Method	NO MATCH
4.1.2.4.2 Coordinate Representative	---
4.1.2.4.2.1 Abscissa Resolution	NO MATCH
4.1.2.4.2.2 Ordinate Resolution	NO MATCH
4.1.2.4.4 Planar Distance Units	NO MATCH
4.1.4 Geodetic Model	---
4.1.4.1 Horizontal Datum Name	MD_Metadata.referenceSystemInfo.MD_CRS. datum.RS_Identifier.authority and code
4.1.4.2 Ellipsoid Name	MD_Metadata.referenceSystemInfo.MD_CRS. ellipsoid.RS_Identifier.authority and code
4.1.4.3 Semi-Major Axis	MD_Metadata.referenceSystemInfo.MD_CRS. ellipsoidParameters.MD_EllipsoidParameters. semiMajorAxis
4.1.4.4 Denominator of Flattening Ratio	MD_Metadata.referenceSystemInfo.MD_CRS. ellipsoidParameters.MD_EllipsoidParameters. denominatorOfFlateningRatio
Entity and Attribute Information (Section 5)	
5.2 Overview Description	NO MATCH
5.2.1 Entity and Attribute Overview	---
5.2.2 Entity and Attribute Detail Citation	NO MATCH
Distribution Information (Section 6)	
6.1 Distributor	MD_Metadata.distributionInfo.MD_Distribution. distribution.MD_Distributor.distributorContact
6.2 Resource Description	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions.onLine. CI_OnlineResource.description
6.3 Distribution Liability	NO MATCH
6.4 Standard Order Process	---
6.4.2 Digital Form	---
6.4.2.1 Digital Transfer Information	---
6.4.2.1.1 Format Name	MD_Metadata.distributionInfo.MD_Distribution. distributionFormat.MD_Format.formatName
6.4.2.1.5 Format Information Content	NO MATCH

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
6.4.2.1.6 File Decompression Technique	MD_Metadata.distributionInfo.MD_Distribution. distributionFormat.MD_Format. fileDecompressionTechnique
6.4.2.2 Digital Transfer Option	---
6.4.2.2.1 Online Option	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions.onLine
6.4.2.2.1.1 Computer Contact Information	---
6.4.2.2.1.1.1 Network Address	---
6.4.2.2.1.1.1.1 Network Resource Name	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions. onLine.CI_OnlineResource.name
6.4.2.2.2 Offline Option	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions.offLine
6.4.2.2.2.1 Offline Media	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions. offLine.MD_Medium.name
6.4.2.2.2.3 Recording Format	MD_Metadata.distributionInfo.MD_Distribution. transferOptions.MD_DigitalTransferOptions.offLine. MD_Medium.mediumFormat
6.4.3 Fees	MD_Metadata.distributionInfo.MD_Distribution.distributor. MD_Distributor.distributionOrderProcess. MD_StandardOrderProcess.fees
Metadata Reference Information (Section 7)	
7.1 Metadata Date	MD_Metadata.dateStamp.
7.4 Metadata Contact	MD_Metadata.contact
7.5 Metadata Standard Name	MD_Metadata.metadataStandardName
7.6 Metadata Standard Version	MD_Metadata.metadataStandardVersion
Citation Information (Section 8)	
8.1 Originator	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. individualName OR organisationName (roleCode = originator, code 006)
8.2 Publication Date	CI_Citation.date.CI_Date.date (dateType = publication, code 002)
8.4 Title	CI_Citation.title

Table 1 – Minimal FGDC metadata requirements with ISO metadata equivalents *(continued)*

FGDC Element Name	ISO Element Name
Time Period Information (Section 9)	
9.1 Single Date/Time	NO MATCH
9.1.1 Calendar Date	NO MATCH
9.2 Multiple Dates/Times	NO MATCH
9.3 Range of Dates/Times	NO MATCH
9.3.1 Beginning Date	NO MATCH
9.3.3 Ending Date	NO MATCH
Contact Information (Section 10)	
10.1 Contact Person Primary	CI_Citation.citedResponsibleParty
10.1.1 Contact Person	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. individualName
10.2 Contact Organization Primary	CI_Citation.citedResponsibleParty.CI_ResponsibleParty
10.2.1 Contact Organization	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. organisationName
10.3 Contact Position	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. positionName
10.4 Contact Address	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address
10.4.1 Address Type	NO MATCH
10.4.2 Address	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address.deliveryPoint
10.4.3 City	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address.city
10.4.4 State or Province	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address.administrativeArea
10.4.5 Postal Code	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address.postalCode
10.4 6 Country	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address.country
10.8 Contact Electronic Mail Address	CI_Citation.citedResponsibleParty.CI_ResponsibleParty. contact.CI_Contact.address.CI_Address. electronicMailAddress

Annex B

Example of FGDC Metadata for Framework Orthoimagery

The following text illustrates a file specific, FGDC-compliant implementation of the "Content Standards for Digital Geospatial Metadata" using a USGS 3.75-minute digital orthophoto (Washington West SE) as an example. Numbers preceding element names indicate the location of the element definition in the "Content Standards for Digital Geospatial Metadata" standard, and are for reference only. Reference line numbers should not be included in metadata produced for actual products.

1. Identification_Information:
1.1 Citation:
8.1 Originator:
8.2 Publication_Date:
8.4 Title:
8.6 Geospatial_Data_Presentation_Form: remote-sensing image
8.8 Publication_Information:
8.8.1 Publication_Place: Reston, VA
8.8.2 Publisher: U.S. Geological Survey
1.2 Description:
1.2.1 Abstract:

A digital orthophoto is a raster image of remotely sensed data in which displacement in the image due to sensor orientation and terrain relief have been removed. Orthophotos combine the image characteristics of a photograph with the geometric qualities of a map. The primary digital orthophoto quad (DOQ) is a 1-meter ground resolution, quarter-quadrangle (3.75-minutes of latitude by 3.75-minutes of longitude) image cast on the Universal Transverse Mercator Projection (UTM) on the North American Datum of 1983 (NAD83). The geographic extent of the DOQ is equivalent to a quarter-quad plus overedge. The overedge ranges a minimum of 50 meters to a maximum of 300 meters beyond the extremes of the primary and secondary corner points. The overedge is included to facilitate tonal matching for mosaicking and for the placement of the NAD83 and secondary datum corner ticks. The normal orientation of data is by lines (rows) and samples (columns). Each line contains a series of pixels ordered from west to east with the order of the lines from north to south. The standard, archived digital orthophoto is formatted as four ASCII header records, followed by a series of 8-bit binary image data records. The radiometric image brightness values are stored as 256 gray levels ranging from 0 to 255. The metadata provided in the digital orthophoto contain a wide range of descriptive information including format source information, production instrumentation and dates, and data to assist with displaying and georeferencing the image. The standard distribution format of DOQs will be JPEG compressed images on CD-ROM by counties or special regions. The reconstituted image from the CD-ROM will exhibit some radiometric differences when compared to its uncompressed original but will retain the geometry of the uncompressed DOQ. Uncompressed DOQs are distributed on tape.

1.2.2 Purpose:

DOQ's serve a variety of purposes, from interim maps to field references for earth science investigations and analysis. The DOQ is useful as a layer of a geographic information system and as a tool for revision of digital line graphs and topographic maps.

1.3 Time_Period_of_Content:
9.1 Single Time/Date:
9.1.1 Calendar Date: 19930514
1.3.1 Currentness_Reference: ground condition
1.4 Status:
1.4.1 Progress: Complete
1.4.2 Maintenance_and_Update_Frequency: Irregular
1.5 Spatial_Domain:
1.5.1 Bounding_Coordinates:

1.5.1.1 West_Bounding_Coordinate: -077.0625
1.5.1.2 East_Bounding_Coordinate: -077.00
1.5.1.3 North_Bounding_Coordinate: 38.9375
1.5.1.4 South_Bounding_Coordinate: 38.875
1.6 Keywords:
1.6.1 Theme:
1.6.1.1 Theme_Keyword_Thesaurus: None
1.6.1.2 Theme_Keyword: DOQ
1.6.1.2 Theme_Keyword: DOQQ
1.6.1.2 Theme_Keyword: digital orthophoto
1.6.1.2 Theme_Keyword: digital orthophoto quad
1.6.1.2 Theme_Keyword: digital image map
1.6.1.2 Theme_Keyword: aerial photograph
1.6.1.2 Theme_Keyword: rectified photograph
1.6.1.2 Theme_Keyword: rectified image
1.6.1.2 Theme_Keyword: orthophoto
1.6.1.2 Theme_Keyword: quarter-quadrangle orthophoto
1.6.1.2 Theme_Keyword: 1-meter orthophoto
1.6.1.2 Theme_Keyword: 2-meter orthophoto
1.6.1.2 Theme_Keyword: 3.75- x 3.75-minute orthophoto
1.6.1.2 Theme_Keyword: 7.5- x 7.5-minute orthophoto
1.6.2 Place:
1.6.2.1 Place_Keyword_Thesaurus:
U.S. Department of Commerce, 1977, Countries, dependencies, areas of special sovereignty, and their principal administrative divisions (Federal Information Processing Standard 10-3):Washington, D.C., National Institute of Standards and Technology.
1.6.2.2 Place_Keyword: US
1.6.2.1 Place_Keyword_Thesaurus:
U.S. Department of Commerce, 1987, Codes for the identification of the States, the District of Columbia and the outlying areas of The United States, and associated areas (Federal Information Processing Standard 5-2): Washington, D. C., National Institute of Standards and Technology.
1.6.2.2 Place_Keyword: DC
1.6.2.2 Place_Keyword: VA
1.6.2.1 Place_Keyword_Thesaurus:
U.S. Department of Commerce, 1990, Counties and equivalent entities of The United States, its possessions, and associated areas (Federal Information Processing Standard 6-4): Washington, D.C. National Institute of Standards and Technology.
1.6.2.2 Place_Keyword: 001
1.6.2.2 Place_Keyword: 013
1.7 Access_Constraints: None
1.8 Use_Constraints: None. Acknowledgment of the U.S. Geological Survey would be appreciated in products derived from these data.
1.13 Native_Data_Set_Environment: DV1.2 03/94 OV1.1 04/93 bytes=47702272

2. Data_Quality_Information
2.1 Attribute_Accuracy:
2.1.1 Attribute_Accuracy_Report:
During photographic reproduction of the source photography, limited analog dodging is performed to improve image quality. Analog dodging consists of holding back light from certain areas of the sensitized photographic material to avoid overexposure. The diapositive is inspected to insure clarity and radiometric uniformity. Diapositive image brightness values are collected with a minimum of image quality manipulation. Image brightness values may deviate from brightness values of the original imagery due to image value interpolation during the scanning and rectification processes. Radiometry is verified by visual inspection of the digital orthophoto quadrangle with the original unrectified image to determine if the digital orthophoto has the same or better image quality as the original unrectified input image. Slight systematic radiometric differences can be detected between adjacent DOQ files due primarily to differences

in source photography capture dates and sun angles of aerial photography along flight lines. These differences can be observed in an image's general lightness or darkness when compared to adjacent DOQ file coverages.

2.2 Logical_Consistency_Report:

All DOQ header data and image file sizes are validated by the Tape Validation System (TVS) software prior to archiving in the National Digital Cartographic Data Base (NDCDB). This validation procedure assures correct physical format and field values for header record elements. Logical relationships between header record elements are tested.

2.3 Completeness_Report:

All DOQ imagery is visually inspected for completeness to ensure that no gaps, or image misplacement exists in the 3.75' image area or in overedge coverage. DOQ images may be derived by mosaicking multiple images, in order to insure complete coverage. All DOQ's are cloud free within the 3.75' image area. Some clouds may, very infrequently, be encountered only in the overedge coverage. Source photography is leaf-off in deciduous vegetation regions. Void areas having a radiometric value of zero and appearing black may exist. These are areas for which no photographic source is available or result from image transformation from other planimetric systems to the Universal Transverse Mercator (UTM). In the latter case, the void sliver areas are on the outside edges of the overedge area. The data set field content of each DOQ header record element is validated to assure completeness prior to archiving in the NDCDB.

The area of coverage for a standard USGS digital orthophoto is either a quarter-quadrangle (3.75-minutes of latitude by 3.75-minutes of longitude plus overedge) or quadrangle (7.5-minutes of latitude by 7.5-minutes of longitude plus overedge).

USGS requires image overedge to provide overlap coverage between adjoining DOQ's to facilitate edge matching and mosaicking. That overedge extent is 300 (30) meters beyond the extremes of the primary and secondary datum corner points for the standard digital orthophoto quad. However, some Federal, State and local agencies, and private entities not associated with the National Digital Orthophoto Program (NDOP) may provide DOQs to the USGS under cooperative agreement programs.

In order to meet the requirements of the NDOP program and include other sources of DOQs, the geographic extent for DOQs shall be:

- For DOQs produced under National Digital Orthophoto Program funding agreements: 300 (30) meters minimum beyond the extremes of the primary and secondary datum corner points.
- For DOQs produced under other cooperative agreements: a minimum of 50 meters beyond the primary and secondary horizontal datum corner point extremes.

The resulting digital orthophoto is a rectangle whose size may vary in relation to adjoining digital orthophotos.

2.4 Positional_Accuracy:

2.4.1 Horizontal_Positional_Accuracy:

2.4.1.1 Horizontal_Positional_Accuracy_Report:

The DOQ horizontal positional accuracy and the assurance of that accuracy depend, in part, on the accuracy of the data inputs to the rectification process. These inputs consist of the digital elevation model (DEM),aerotriangulation control and methods, the photo source camera calibration, scanner calibration, and aerial photographs that meet National Aerial Photography Program (NAPP) standards. The vertical accuracy of the verified USGS format Elevation Model is equivalent to or better than a USGS level 1 or 2 DEM, with a root mean square error (RMSE) of no greater than 7.0 meters. Field control is acquired by third order class 1 or better survey methods sufficiently spaced to meet National Map Accuracy Standards (NMAS) for 1:12,000-scale products. Aerial cameras have current certification from the USGS, National Mapping Division, Optical Science Laboratory. Test calibration scans are performed on all source photography scanners. Horizontal positional accuracy is determined by the Orthophoto Accuracy (ORACC) software program for DOQ data produced by the National Mapping Division. The program determines the accuracy by finding the line and sample coordinates of the passpoints in the DOQ and fitting these to their ground coordinates to develop a root mean square error (RMSE). Four to nine points are checked. As a further accuracy test, the image line and sample coordinates of the DEM corners are transformed and compared with the actual X,Y DEM corner values to determine if they are within the RMSE. Additional information on this testing procedure can be found in U.S. Department of the Interior, U.S. Geological Survey, 1993, Technical Instructions, ORACC Users Manual (draft): Reston, VA. Adjacent DOQ's, when displayed together in a common planimetric coordinate system, may exhibit slight positional discrepancies across common DOQ boundaries. Linear features, such as streets, may not be continuous. These edge mismatches, however, still conform to positional horizontal accuracy within the NMAS. Field investigations to validate DOQ positional accuracy reliability are periodically conducted by the USGS, National Mapping Division, Geometronics Standards Section. DOQ's produced by cooperators and contractors use similarly approved RMSE test procedures.

2.4.1.2 Quantitative_Horizontal_Positional_Accuracy_Assessment:
2.4.1.2.1 Horizontal_Positional_Accuracy_Value: 0.8
2.4.1.2.2 Horizontal_Positional_Accuracy_Explanation:
U.S.Bureau of the Budget, 1947, United States National Map Accuracy Standard.
2.5 Lineage:
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
8.1 Originator: U.S. Geological Survey
8.2 Publication_Date: unknown
8.4 Title: digital elevation model
8.8 Publication_Information:
8.8.1 Publication_Place: Reston, VA
8.8.2 Publisher: U.S. Geological Survey
2.5.1.3 Type_of_Source_Media: cartridge tape
2.5.1.4 Source_Time_Period_of_Content:
9.1 Single_Date/Time:
9.1.1 Calendar_Date: 1968
2.5.1.4.1 Source_Currentness_Reference: ground condition
2.5.1.5 Source_Citation_Abbreviation: DEM1
2.5.1.6 Source_Contribution:
Elevation data in the form of an ortho-DEM regridded to user-specified intervals and bounds.
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
8.1 Originator: U.S. Geological Survey
8.2 Publication_Date: Unknown
8.4 Title: NAPP 4-179
8.6 Geospatial_Data_Presentation_Form: remote-sensing image
8.8 Publication_Information:
8.8.1 Publication_Place: Reston, VA
8.8.2 Publisher: U.S. Geological Survey
2.5.1.2 Source_Scale_Denominator: 40000
2.5.1.3 Type_of_Source_Media: cartridge tape
2.5.1.4 Source_Time_Period_of_Content:
9.1 Single_Date/Time:
9.1.1 Calendar_Date: 19880405
2.5.1.4.1 Source_Currentness_Reference: ground condition
2.5.1.5 Source_Citation_Abbreviation: PHOTO1
2.5.1.6 Source_Contribution: Panchromatic Black and White NAPP
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
8.1 Originator: U.S. Geological Survey
8.2 Publication_Date: Unpublished material
8.4 Title: project ground and photo control
8.8 Publication_Information:
8.8.1 Publication_Place: Reston, VA
8.8.2 Publisher: U.S. Geological Survey
2.5.1.3 Type_of_Source_Media: various media
2.5.1.4 Source_Time_Period_of_Content:
9.3 Range_of_Dates/Times:

9.3.1 Beginning_Date: various
9.3.2 Ending_Date: various
2.5.1.4.1 Source_Currentness_Reference: ground condition
2.5.1.5 Source_Citation_Abbreviation: CONTROL_INPUT
2.5.1.6 Source_Contribution:
Horizontal and vertical control used to establish positions and elevations for reference and correlation purposes.
2.5.1 Source_Information:
2.5.1.1 Source_Citation:
8.1 Originator: U.S. Geological Survey
8.2 Publication_Date: Unpublished material
8.4 Title: report of calibration
8.8 Publication_Information:
8.8.1 Publication_Place: Reston, VA
8.8.2 Publisher: U.S. Geological Survey
2.5.1.3 Type_of_Source_Media: disc, paper
2.5.1.4 Source_Time_Period_of_Content:
9.3 Range_of_Dates/Times:
9.3.1 Beginning_Date: various
9.3.2 Ending_Date: various
2.5.1.4.1 Source_Currentness_Reference:
Date of the camera calibration associated with the source photography
2.5.1.5 Source_Citation_Abbreviation: CAMERA_INPUT
2.5.1.6 Source_Contribution: camera calibration parameters
2.5.2 Process_Step:
2.5.2.1 Process_Description:

The production procedures, instrumentation, hardware and software used in the collection of standard USGS DOQ's vary depending on systems used at the contract, cooperator or USGS production sites. The majority of DOQ data sets are acquired through government contract. The process step describes, in general, the process used in the production of standard USGS DOQ data sets.

The rectification process requires a user parameter file as input to control the rectification process, a digital elevation model (DEM1) gridded to user specified bounds, projection, zone, datum and X-Y units, a scanned digital image file (PHOTO1) covering the same area as the DEM, ground X-Y-Z point values (CONTROL_INPUT) and their conjugate photo coordinates in the camera coordinate system, and measurements of the fiducial marks (CAMERA_INPUT) in the digitized image.

The camera calibration report (CAMERA_INPUT) provides the focal length of the camera and the distances in millimeters from the camera's optical center to the camera's 8 fiducial marks. These marks define the frame of reference for spatial measurements made from the photograph. Ground control points (CONTROL_INPUT) acquired from ground surveys or other sources are third order class 1 or better and meet National Map Accuracy Standards (NMAS) for 1:12,000-scale. Ground control points are in the Universal Transverse Mercator or the State Plane Coordinate System on NAD83. Horizontal and vertical residuals of aerotriangulated tie-points are equal to or less than 2.5 meters. Standard aerotriangulation passpoint configuration consists of 9 ground control points, one near each corner, one at the center near each side and 1 near the center of the photograph, are used. The conjugate positions of the ground control points on the photograph are measured and recorded in camera coordinates.

The raster image file (PHOTO_1) is created by scanning an aerial photograph film diapositive with a precision image scanner. An aperture of approximately 25 to 32 microns is used, with an aperture no greater than 32 microns permitted. Using 1:40,000-scale photographs, a 25-micron scan aperture equates to a ground resolution of 1-meter. The scanner converts the photographic image densities to gray scale values ranging from 0 to 255 for black and white photographs. Scan files with ground resolution less than 1 meter or greater than 1 meter but less than 1.28 meters are resampled to 1 meter.

The principal elevation data source (DEM1) are standard DEM data sets from the National Digital Cartographic Data Base (NDCDB). DEM's that meet USGS standards are also produced by contractors to fulfill DOQ production requirements and are subsequently archived in the NDCDB. All DEM data is equivalent to or better than USGS DEM standard level 1. The DEM used in the production of DOQ's generally has a 30-meter grid post spacing and possesses a vertical RMSE of 7-meters or less.

A DEM covering the extent of the photograph is used for the rectification. The DEM is traversed from user-selected minimum to maximum X-Y values and the DEM X-Y-Z values are used to find pixel coordinates in the digitized photograph using transformations mentioned above. For each raster image cell subdivision, a brightness or gray-scale value is obtained using nearest neighbor, bilinear, or cubic convolution resampling of the scanned image. The pixel processing algorithm is indicated in the header file. An inverse transformation relates the image coordinates referenced to the fiducial coordinate space back to scanner coordinate space. For those areas for which a 7.5-minute DEM is unavailable and relief differences are less than 150 feet, a planar-DEM (slope-plane substitute grid) may be used.

Rectification Process: The photo control points and focal length are iteratively fitted to their conjugate ground control points using a single photo space resection equation. From this mathematical fit a rotation matrix of constants about the three axes of the camera is obtained. This rotation matrix can then be used to find the photograph or camera coordinates of any other ground X-Y-Z point. Next a two dimensional fit is made between the measured fiducial marks on the digitized photograph and their conjugate camera coordinates. Transformation constants are developed from the fit and the camera or photo coordinates are used in reverse to find their conjugate pixel coordinates on the digitized photograph.

Quality Control: All data is inspected according to a quality control plan. DOQ contractors must meet DOQ standards for attribute accuracy, logical consistency, data completeness and horizontal positional accuracy. During the initial production phase, all rectification inputs and DOQ data sets are inspected for conformance to standards. After a production source demonstrates high quality, inspections will be made to 10% of delivery lots 40 DOQs per lot). All DOQ's are visually inspected for gross positional errors and tested for physical format standards.

2.5.2.2 Source_Used_Citation_Abbreviation: DEM1, PHOTO1, CONTROL_INPUT, CAMERA_INPUT
2.5.2.3 Process_Date: 19930514

3. Spatial_Data_Organization_Information:
3.2 Direct_Spatial_Reference_Method: raster
3.4 Raster_Object_Information:
3.4.1 Raster_Object_Type: Pixel
3.4.2 Row_Count: 7680
3.4.3 Column_Count: 6208

4. Spatial_Reference_Information:
4.1 Horizontal_Coordinate_System_Definition:
4.1.2 Planar:
4.1.2.2 Grid_Coordinate_System:
4.1.2.2.1 Grid_Coordinate_System_Name: Universal Transverse Mercator
4.1.2.2.2 Universal_Transverse_Mercator:
4.1.2.2.2.1 UTM_Zone_Number: 18
4.1.2.1.2 Transverse_Mercator:
4.1.2.1.2.17 Scale_Factor_at_Central_Meridian: 0.9996
4.1.2.1.2.2 Longitude_of_Central_Meridian: -75.0
4.1.2.1.2.3 Latitude_of_Projection_Origin: 0.0
4.1.2.1.2.4 False_Easting: 500000.
4.1.2.1.2.5 False_Northing: 0.0
4.1.2.4 Planar_Coordinate_Information:
4.1.2.4.1 Planar_Coordinate_Encoding_Method: row and column
4.1.2.4.2 Coordinate_Representation:
4.1.2.4.2.1 Abscissa_Resolution: 1
4.1.2.4.2.2 Ordinate_Resolution: 1
4.1.2.4.4 Planar_Distance_Units: meters
4.1.4 Geodetic_Model:
4.1.4.1 Horizontal_Datum_Name: North American Datum 1983
4.1.4.2 Ellipsoid_Name: Geodetic Reference System 80
4.1.4.3 Semi-major_Axis: 6378137

4.1.4.4 Denominator_of_Flattening_Ratio: 298.257

5. Entity_and_Attribute_Information:
5.2 Overview_Description:
5.2.1 Entity_and_Attribute_Overview:
For DOQ's from panchromatic source, each pixel contains an 8-bit gray-scale value between 0-255. Zero represents black, while 255 represents white. All values between zero and 255 represent a shade of gray varying from black to white. For color-infrared and natural color DOQs', a digital number from zero to 255 will also be assigned to each pixel but that number will refer to a color look-up table which will contain the RGB red, blue and green (RGB) values, each from zero to 255, for that digital number. Areas where the rectification process is incomplete due to incomplete data (i.e., lack of elevation data, gaps), are represented with the numeric value of zero.
5.2.2 Entity_and_Attribute_Detail_Citation:
U.S. Department of the Interior, U.S. Geological Survey, 1992, Standards for Digital Orthophotos: Reston, VA.

A hypertext version is available at:
http://www-nmd.usgs.gov/www/ti/DOQ/standards_doq.html

Softcopy in ASCII format is available at:
ftp://www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt1.txt
ftp://www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt2.txt
Softcopy in WordPerfect format is available at:
ftp//www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt1.wp5
ftp://www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt2.wp5
Softcopy in PostScript format is available at:
ftp://www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt1.ps
ftp://www-nmd.usgs.gov/pub/ti/DOQ/doqstnds/stdoqpt2.ps

6. Distribution_Information:
6.1 Distributor:
10.2 Contact_Organization_Primary:
10.1.2 Contact_Organization: Earth Science Information Center, U.S. Geological Survey
10.4 Contact_Address:
10.4.1 Address_Type: mailing address
10.4.2 Address: 507 National Center
10.4.3 City: Reston
10.4.4 State_or_Province: VA
10.4.5 Postal_Code: 20192
10.5 Contact_Voice_Telephone: 1 800 USA MAPS
10.9 Hours_of_Service: 0800-1600
10.10 Contact_Instructions:
In addition to the address above there are other ESIC offices throughout the country. A full list of these offices is at:
http://www-nmd.usgs.gov/esic/esic_index.html
6.2 Resource_Description: Digital Orthophoto quad
6.2 Resource_Description: DOQ
6.2 Resource_Description: DOQQ
6.3 Distribution_Liability:
Although these data have been processed successfully on a computer system at the U.S. Geological Survey, no warranty, expressed or implied, is made by the USGS regarding the utility of the data on any other system, nor shall the act of distribution constitute any such warranty. The USGS will warrant the delivery of this product in computer-readable format and will offer appropriate adjustment of credit when the product is determined unreadable by correctly adjusted computer input peripherals, or when the physical medium is delivered in damaged condition. Requests for adjustments of credit must be made within 90 days from the date of this shipment from the ordering site.

6.4 Standard_Order_Process:
6.4.2 Digital_Form:
6.4.2.1 Digital_Transfer_Information:
6.4.2.1.1 Format_Name: DOQ
6.4.2.1.5 Format_Information_Content:
USGS uncompressed DOQ: The uncompressed USGS DOQ is a raw binary image file preceded by a metadata header record which consists of four 400-byte ASCII records, each blank padded to equal the length of a single line of image data.
6.4.2.2 Digital_Transfer_Option:
6.4.2.2.2 Offline_Option:
6.4.2.2.2.1 Offline_Media: 8-mm helical-scan cartridge tape
6.4.2.2.2.3 Recording_Format:
Unlabeled, uncompressed Unix DD archive format. Standard block size: 30,270, but can be provided at 2,048 or multiples of 2,048.
6.4.2.2.2 Offline_Option:
6.4.2.2.2.1 Offline_Media: 9-track tape
6.4.2.2.2.3 Recording_Format:
Unlabeled, uncompressed Unix DD archive format. Blocksize = 6250.
6.4.2.2.2 Offline_Option:
6.4.2.2.2.1 Offline_Media: 3480 cartridge tape
6.4.2.2.2.3 Recording_Format:
Unlabelled, uncompressed Unix DD archive format. Blocksize = 6250.
6.4.3 Fees:
The online copy of the data set (when available electronically) may be accessed without charge. For 8-mm cartridge and 9-track tapes the costs are:
1 digital product = $40
2 digital products = $60
3 digital products = $80
4 digital products = $100
5 digital products = $120
6 or more = $90 plus $7 per each product over six
6.4 Standard_Order_Process:
6.4.2 Digital_Form:
6.4.2.1 Digital_Transfer_Information:
6.4.2.1.1 Format_Name: JPEG
6.4.2.1.5 Format_Information_Content:
The USGS compressed DOQ is an IJG JPEG-compressed file. JPEG is a lossy compression technique. Unlike uncompressed DOQ's the compressed DOQ does not contain an attached header record as data compression corrupts ASCII text. A separate metadata file accompanies the compressed image file. The compressed data are distributed on CD-ROM, generally by county. However, some CD's may contain regions or partial counties and some counties may require multiple CD-ROM's. The presence of a DOQ in the NDCDB does not necessarily indicate the file is available on a compressed, county based CD-ROM.
6.4.2.1.6 File_Decompression_Technique:
The algorithm employed by USGS for compressing DOQs is IJG JPEG, Version 4.0. This is a lossy compression using a standard Q or quality factor of 30.
6.4.2.1.7 Transfer_Size: 4.5
6.4.2.2 Digital_Transfer_Option:
6.4.2.2.1 Offline_Option:
6.4.2.2.2.1 Offline_Media: CD-ROM
6.4.2.2.2.3 Recording_Format: ISO 9660
6.4.2.2.2.4 Compatibility_Information:
This CD-ROM can be used with all computer operating systems that support CD-ROM as a logical storage device. All text files on this disc are in ASCII format. Data files are in ASCII or binary format.
6.4.3 Fees: The charge is $32 per CD-ROM.

7. Metadata_Reference_Information:
7.1 Metadata_Date: 19950627
7.4 Metadata_Contact:
10.2 Contact_Organization_Primary:
10.1.2 Contact_Organization: U.S. Geological Survey
10.4 Contact_Address:
10.4.2 Address: 590 National Center
10.4.3 City: Reston
10.4.4 State_or_Province: VA
10.4.5 Postal_Code: 20192
10.5 Contact_Voice_Telephone: 703 648 5514
10.7 Contact_Facsimile_Telephone: 703 648 5755
10.8 Contact_Electronic_Mail_Address: fgdc@www.fgdc.gov
7.5 Metadata_Standard_Name: *Content Standards for Digital Geospatial Metadata*
7.6 Metadata_Standard_Version:19940608

Annex C

UML Model, Part 1: Orthoimagery UML Model

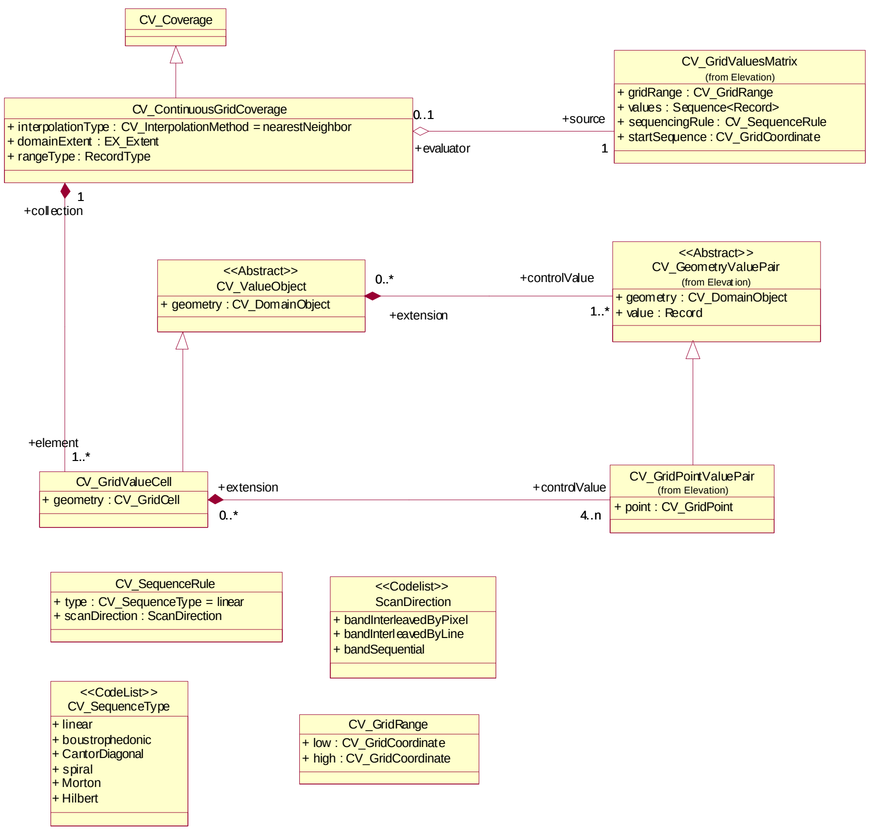

Figure 1 – CV_ContinuousGridCoverage Classes from ISO TC211 19123, modified for use with digital orthoimagery

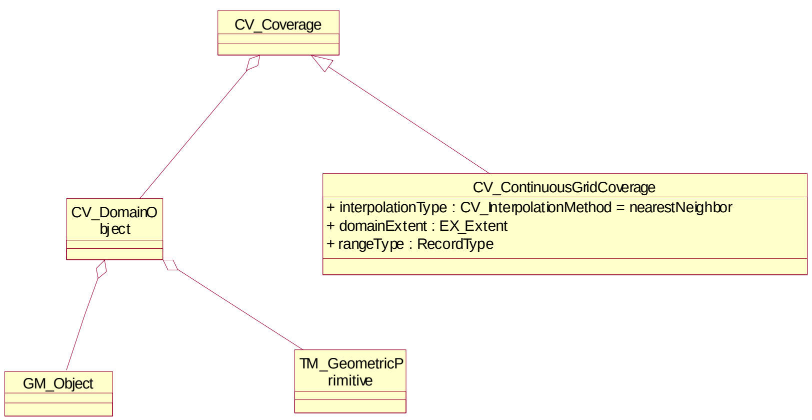

Figure 2 – CV_Coverage Classes from ISO TC211 19123, extracted for use with digital orthoimagery

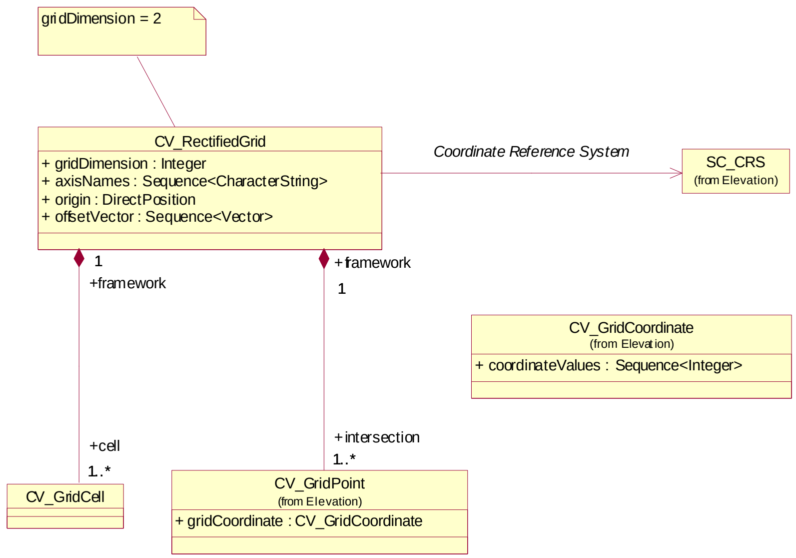

Figure 3 – CV_RectifiedGrid Classes from ISO TC211 19123,

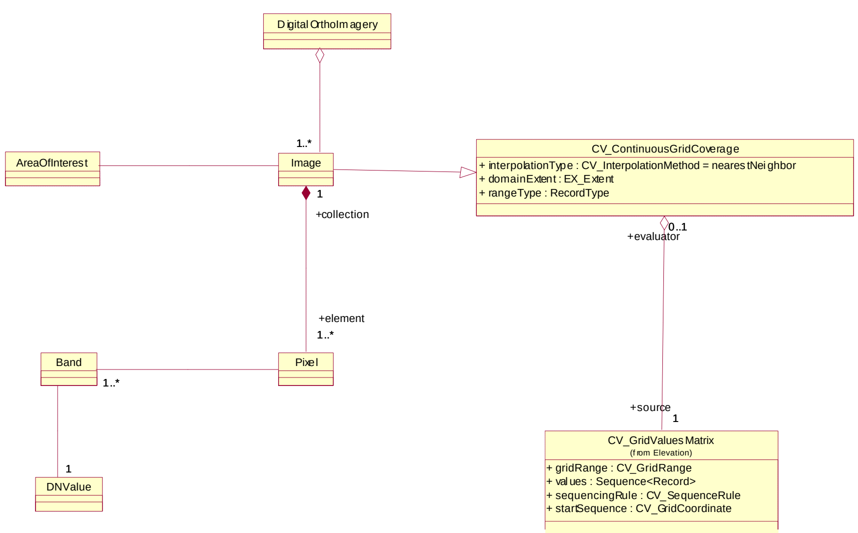

Figure 4 – Digital Orthoimagery Classes, top level

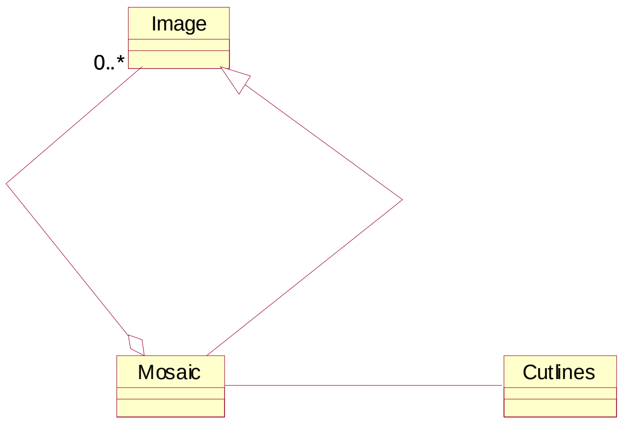

Figure 5 – Image Mosaic Classes

Annex C

UML Model, Part 2: Data Dictionary

[Editor's Note: These classes have been extracted from ISO 19123, *Geographic Information—Schema for coverage geometry and functions*, currently in committee draft status.]

CV_Coverage

	Name / Role name	Definition	Obligation / Condition	Maximum occurrence	Data type	Domain
1	CV_Coverage		M	1		
2	domainExtent	contains the extent of the spatiotemporal domain of the coverage. The data type EX_Extent is defined in ISO 19115. Extents may be specified in both space and time.	M	*	Class	EX_Extent (19115)
3	rangeType	describes the range of the coverage. The data type RecordType is defined in ISO/TS 19103. It consists of a list of attribute name/data type pairs.	M	1	Class	RecordType (19103)
4	commonPointRule	identifies the procedure to be used for evaluating the CV_Coverage at a position that falls either on a boundary between geometric objects or within the boundaries of two or more overlapping geometric objects, where the geometric objects are either CV_DomainObjects or CV_ValueObjects. The data type CV_CommonPointRule is defined at 5.9.	M	1	Class	CV_CommonPointRule (??)
5	*role name:* CRS	links the CV_Coverage to the coordinate reference system to which the objects in its spatiotemporal domain are referenced. The class SC_CRS is specified in ISO 19111.	M	1	Association	SC_CRS (19111)
6	*role name*: domainElement	links the CV_Coverage to the set of CV_DomainObjects in the spatiotemporal domain.	M	*	Association	CV_DomainObject (???)
7	*role name:* rangeElement	links the CV_Coverage to the set of *AttributeValues* in the range. The range of a CV_Coverage shall be a homogeneous collection of records. That is, the range shall have a constant dimension over the entire spatiotemporal domain, and each field of the record shall provide a value of the same attribute type over the entire spatiotemporal domain.	M	*	Association	CV_AttributeValues (???)

CV_ContinuousCoverage

8	CV_ContinuousCoverage		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_Coverage)	
9	interpolationParameterTypes	specifies the types of parameters that are needed to support the interpolation method identified by interpolationType.	O	1	Class	RecordType (19103)
1	interpolationType	code that identifies the interpolation method that shall be used to derive a feature attribute value at any direct position within the CV_ValueObject.	O	1	Class	CV_InterpolationMethod
1	*role name*: element	links this CV_ContinuousCoverage to the set of CV_ValueObjects of which it is composed.	M	*	Association	CV_ValueObject <<Datetype>> (???)
1	CV_ThiessenPolygonCoverage	evaluates a coverage at direct positions within a Thiessen polygon network constructed from a set of discrete point value pairs. Evaluation is based on interpolation between the centers of the CV_ThiessenValuePolygons surrounding the input position.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ContinuousCoverage)	
1	interpolationType	identifies the interpolation method to be used in evaluating the coverage.	M	1	Class	CV_InterpolationMethod (???) (default = “lost area)
1	clipArea	describes the extent of the CV_ThiessenPolygonNetwork. Its boundary determines the boundaries of the outermost polygons in the network, which would otherwise be unbounded.	M	1	Class	GM_Surface (19107)
1	*role name:* element	links this CV_ThiessenPolygonCoverage to the CV_ThiessenValuePolygons of which it is composed.	M	*	Association	CV_ThiessenValuePolygon (???)
1	*role name:* discreteThiessen		O	1	Association	CV_DiscreteSurfaceCoverage
1	CV_HexagonalGridCoverage	evaluates a coverage at direct positions within a network of hexagons centered on a set of grid points. Evaluation is based on interpolation between the centers of the CV_ValueHexagons surrounding the input position.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ContinuousCoverage)	
1	interpolationType	identifies the interpolation method to be used in evaluating the coverage.	M	1	Class	CV_InterpolationMethod (???) (default = “lost area”)

1	role name: element	links this CV_HexagonalGridCoverage to the CV_ValueHexagons of which it is composed.	M	*	Association	CV_ValueHexagon (???)
2	role name: source	link the CV_HexagonalGridCoverage to the CV_GridValuesMatrix for which it is an evaluator.	M	1	Association	CV_GridValuesMatrix (???)
2	CV_TINCoverage	subclass of CV_ContinuousCoverage characterized by a GM_TIN. The feature attribute values are computed by interpolation within each triangle in the tessellation using the record of feature attribute values provided at each corner; that is, the feature attribute values are produced by an operation on CV_ValueTriangles.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ContinuousCoverage)	
2	geometry	holds the triangulated irregular network that provides the structure for evaluating the coverage.	M	1	Class	GM_TIN (19107)
2	interpolationType	specify the interpolation method to be used in evaluating the coverage. The most common interpolation method is "barycentric"	M	1	Class	CV_InterpolationMethod (???) (default = “barycentric”)
2	*role name*: element	link this CV_TINCoverage to the CV_ValueTriangles of which it is composed.	M	*	Association	CV_ValueTriangle (???)
2	*role name*: discreteTIN		O	1	Association	CV_DiscreteSurfaceCoverage
2	CV_SegmentedCurveCoverage	operates on a spatiotemporal domain composed of GM_Curves. A CV_SegmentedCurveCoverage is composed of a set of CV_ValueCurves, each of which maps feature attribute values to position on a GM_Curve.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ContinuousCoverage)	
2	interpolationType	identifies the interpolation method that shall be used to evaluate the coverage.	M	1	Class	CV_InterpolationMethod (???) (default = “linear”)
2	*role name*: element	links this CV_SegmentedCurveCoverage to the *CV*_ValueCurves of which it is composed.	M	*	Association	CV_ValueCurve (???)

	CV_ContinuousQuadrilateralGridCoverage	subclass of CV_ContinuousCoverage that operates on a CV_GridValuesMatrix (8.9). The spatiotemporal domain of a CV_ContinuousQuadrilateralGridCoverage is the convex hull of the collection of grid points defined by the CV_GridValuesMatrix. Evaluation of a CV_ContinuousQuadrilateralGridCoverage generates feature attribute values at direct positions within the convex hull of the CV_GridPoints provided by the CV_GridValuesMatrix. The general idea is to extend the coverage to direct positions within the interior of each primary grid cell by interpolation from the grid points at the corners of the cell.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ContinuousCoverage)	
	interpolationType	identifies the interpolation method that shall be used to evaluate the coverage.	M	1	Class	CV_InterpolationMethod (???) (default = “bilinear”)
	role name: element	link this CV_ ContinuousQuadrilateralGridCoverage to the set of CV_GridValueCells that provide the structure to support the evaluation of the coverage	M	*	Association	CV_GridValueCell (???)
	role name: source	links this CV_ContinuousQuadrilateralGridCoverage to the CV_GridValuesMatrix that provides the date for the evaluation of the coverage	M	1	Association	CV_GridValuesMatrix (???)

1.1.1 CV_ValueObject

	CV_ValueObject	provides the basis for interpolating feature attribute values within a CV_ContinuousCoverage.	Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_ContinuousCoverage)	
	interpolationParameters		O	1	Class	Record (19103)
	geometry		M	1	Class	CV_DomainObject
	role name: collection		M	1	Association	CV_ContinuousCoverage
	role name: controlValue	links this CV_ValueObject to the set of CV_GeometryValuePairs that provide the basis for constructing the CV_ValueObject and for evaluating the CV_ContinuousCoverage at DirectPositions within this CV_ValueObject.	M	*	Association	CV_GeometryValuePair (???)

3	CV_ThiessenValuePolygon		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ValueObject) Aggregated Class (CV_ThiessenPolygon Coverage)	
3	geometry	holds the geometry of the Thiessen polygon centred on the CV_PointValuePair identified by the association "controlValve".	M	1	Class	GM_Polygon (19107)
4	*role name:* collection		M	1	Association	CV_ThiessenPolygonCoverage
4	*role name*: controlValue	links this CV_ThiessenValuePolygon to the CV_PointValuePair at its centre.	M	1	Association	CV_PointValuePair (???)
4	CV_ValueHexagon		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ValueObject) Aggregated Class (CV_HexagonalGridCoverage)	
4	geometry	holds the geometry of the CV_ValueHexagon centred on the CV_GridPointValuePair identified by the association "controlValue".	M	1	Class	GM_Polygon (19107)
4	*role name:* collection		M	1	Association	CV_HexagonalGridCoverage
4	*role name*: controlValue	links this CV_ValueHexagon to the CV_GridPointValuePair at its centre.	M	1	Association	CV_GridPointValuePair (???)
4	CV_ValueTriangle	consists of three CV_PointValuePairs where the GM_Points are non-collinear. CV_ValueTriangles are used for interpolation of a coverage.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ValueObject) Aggregated Class (CV_TINCoverage)	
4	geometry	holds the GM_Triangle that defines the relative position of the three CV_PointValuePairs at its vertices.	M	1	Class	GM_Triangle (19107)
4	*role name:* collection		M	1	Association	CV_TINCoverage
4	*role name*: controlValue	links this CV_ValueTriangle to the three CV_PointValuePairs at its vertices.	O	*	Association	CV_PointValuePair
5	CV_ValueCurve	composed of a GM_Curve with additional information that supports the determination of feature attribute values at any position on that curve. CV_ValueCurves depend upon the arc-length parameterisation operations defined for GM_Curve in ISO 19107.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ValueObject)	
5	geometry	the GM_Curve that is the basis of this CV_ValueCurve.	M	1	Class	GM_Curve (19107)
5	*role name:* collection		M	1	Association	CV_SegmentedCurveCoverage

5	*role name*: segment	links this CV_ValueCurve to the sequence of CV_ValueSegments of which it is composed.	M	*	Association	CV_ValueSegement (???)
5	CV_GridValueCell	subclass of CV_ValueObject that supports interpolation within a CV_ContinuousQuadrilatreralGridCoverage . A CV_GridValueCell is a collection of CV_GridPointValuePairs with a geometric structure defined by a CV_GridCell.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_ValueObject) Aggregated Class (CV_ContinuousQuadrilateralGridCoverage)	
5	geometry	holds the CV_GridCell that defines the structure of the CV_GridPointValuePairs that support the interpolation of a feature attribute value at a DirectPosition within the CV_GridCell.	M	1	Class	CV_GridCell
5	*role name*: controlValue	linsk the CV_GridValueCell to the CV_GridPointValuePairs at its corners.	M	4..*	Association	CV_GridPointValuePair

CV_DiscreteCoverage

5	CV_DiscreteCoverage	returns the same record of feature attribute values for any direct position within a single CV_DomainObject in its spatiotemporal domain.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_Coverage)	
5	*role name*: element	links this CV_DiscreteCoverage to the set of CV_GeometryValuePair of which it is composed.	M	1	Association	CV_GeometryValuePair (???)
5	CV_DiscretePointCoverage	coverage characterized by a finite spatiotemporal domain consisting of points.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_DiscreteCoverage)	
6	*role name*: element	links this CV_DiscretePointCoverage to the set of CV_PointValuePair of which it is composed.	M	*	Association	CV_PointValuePair (???)
6	CV_DiscreteCurveCoverage	coverage characterized by a finite spatial domain consisting of curves. Often the curves represent features such as roads, railroads, or streams. They may be elements of a network.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_DiscreteCoverage)	
6	*role name*: element	links this CV_DiscreteCurveCoverage to the set of CV_CurveValuePair of which it is composed.	M	1	Association	CV_CurveValuePair (???)

	CV_DiscreteSurfaceCoverage	coverage whose domain consists of a collection of surfaces. In most cases, the surfaces that constitute the spatiotemporal domain of a coverage are mutually exclusive and exhaustively partition the extent of the coverage.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_DiscreteCoverage)	
	role name: polygonSource		O	1	Association	CV_ThiessenPolygonCoverage
	role name: triangleSource		O	1	Association	CV_TINCoverage
	role name: element	links this CV_DiscreteSurfaceCoverage to the set of CV_SurfaceValuePair of which it is composed.	M	*	Association	CV_SurfaceValuePair(???)
	CV_DiscreteSolidCoverage	coverage whose domain consists of a collection of solids. Solids or their boundaries may be of any shape.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_DiscreteCoverage)	
	role name: element	links this CV_DiscreteSolidCoverage to the set of CV_SolidValuePair of which it is composed.	M	*	Association	CV_SolidValuePair(???)
	CV_DiscreteGridPointCoverage	spatiotemporal domain of a CV_DiscreteGridPointCoverage is a set of CV_GridPoints that are associated with records of feature attribute values through a CV_GridValuesMatrix. In other words, the CV_DiscreteGridPointCoverage operates on a CV_GridValuesMatrix.	Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_DiscreteCoverage)	
	role name: element	links the CV_DiscreteGridCoverage to the CV_GridValuePairs of which it is composed.	M	*	Association	CV_GridPointValuePair (???)
	role name: valueAssignment	links the CV_DiscreteGridPointCoverage to the CV_GridValuesMatrix for which it is an evaluator.	M	1	Association	CV_GridValuesMatrix (???)

1.1.1 CV_GeometryValuePair

	CV_GeometryValuePair	describes an element of a set that defines the relationships of a discrete coverage. Each member of this class consists of two parts: a geometric object and a record of feature attribute values.	Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_DiscreteCoverage)	
	geometry	holds the CV_DomainObject that is a member of this CV_GeometryValuePair.	M	1	Class	CV_DomainObject (???)

	value	hold the record of feature attribute values associated with this CV_DomainObject.	M	1	Class	Record (19103)
	role name: extension			*	Association	CV_ValueObject
	role name: collection	links this CV_GeometryValuePair with the CV_DiscreteCoverage of which it is an element.	O	*	Association	CV_DiscreteCoverage (???)
	CV_PointValuePair		Use obligation from referencing object	Use maximum occurrence from referencing object	Specalized Class (CV_GeometryValuePair) Aggregated Class (CV_DiscretePointCoverage) (CV_TheissenPolygonCoverage) (CV_TINCoverage) (CV_SegmentedCurveCoverage)	
	geometry	holds the CV_DomainObject that is a member of this CV_PointValuePair	M	1	Class	GM_Point (19107)
	role name: extension			*	Association	CV_ValueSegment
	role name: collection	links this CV_PointValuePair with the CV_DiscretePointCoverage of which it is an element.	O	*	Association	CV_DiscretePointCoverage (???)
	CV_CurveValuePair		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_GeometryValuePair) Aggregated Class (CV_DiscreteCurveCoverage)	
	geometry	holds the GM_Curve that is a member of this CV_CurveValuePair.	M	1	Class	GM_Curve (19107)
	role name: collection	links this CV_CurveValuePair with the CV_DiscreteCurveCoverage of which it is an element.	O	*	Association	CV_DiscreteCurveCoverage (???)
	CV_SurfaceValuePair		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_GeometryValuePair) Aggregated Class (CV_DiscreteSurfaceCoverage)	
	geometry	holds the GM_Surface that is a member of this CV_SurfaceValuePair.	M	1	Class	GM_Surface (19107)
	role name: collection	links this CV_SurfaceValuePair with the CV_DiscreteSurfaceCoverage of which it is an element.	O	*	Association	CV_DiscreteSurfaceCoverage (???)

8	CV_SolidValuePair		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_GeometryValuePair) Aggregated Class (CV_DiscreteSolidCoverage)	
8	geometry	holds the GM_Solid that is a member of this CV_SolidValuePair.	M	1	Class	GM_Solid (19107)
8	*role name*: collection	links this CV_SolidValuePair with the CV_DiscreteSolidCoverage of which it is an element.	O	*	Association	CV_DiscreteSolidCoverage (???)
9	CV_GridPointValuePair		Use obligation from referencing object	Use maximum occurrence from referencing object	Specialized Class (CV_GeometryValuePair) Aggregated Class (CV_DiscreteGridPointCoverage)	
9	point	holds the CV_GridPoint that is a member of this CV_GridPointValuePair.	M	1	Class	CV_GridPoint (???)
9	geometry		M	1	Class	CV_GridPoint
9	*role name*: collection	links this CV_GridPointValuePair with the CV_DiscreteGridPointCoverage of which it is an element.	O	1	Association	CV_DiscreteGridPointCoverage (???)

CV_AttributeValues

9	CV_AttributeValues				Aggregated Class (CV_Coverage)	
9	values		M	1	Class	Record (19103)
9	*role name:* collection		O	1	Association	CV_Coverage (???)

CV_DomainObject

9	CV_DomainObject	represents an element of the spatiotemporal domain of the CV_Coverage	Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_Coverage)	
9	*role name:* spatialElement	associates a CV_DomainObject to the set of GM_Objects of which it is composed (which may be an empty set)	O	*	Association	GM_Object

	role name: temporalElement	associates a CV_DomainObject to the set of TM_GeometricPrimitives of which it is composed (which may be an empty set).	O	*	Association	TM_GeometricPrimitive
	role name: collection		O	1	Association	CV_Coverage (???)

CV_Grid

	CV_Grid	contains the geometric characteristics of a quadrilateral grid	Use obligation from referencing object	Use maximum occurrence from referencing object		
	dimension	identifies the dimensionality of the grid	M	1	Integer	Integer
	axisNames	lists the names of the grid axes	M	1	Sequence (19103)	CharacterString
	extent	specifies the limits of a section of the grid.	O	1	Class	CV_GridEnvelope
	role name: cell	link the CV_Grid to the set of CV_GridCells delineated by the primary grid	M	*	Association	CV_GridCell (???)
	role name: intersection	links the CV_Grid to the set of CV_GridPoints that are located at the intersections of the grid lines	M	*	Association	CV_GridPoint (???)
	CV_RectifiedGrid	grid defined by an origin in a specified coordinate reference system, and a set of offset vectors that specify the direction and distance between the grid lines.	Use obligation from referencing object	Use maximum occurrence from referencing object	SpecializedClass (CV_Grid)	
	origin	direct position that locates the origin of the rectified grid in the coordinate reference system identified by CRS.	M	1	Class	DirectPosition (19107)
	offsetVectors	shall be a sequence of offset vectors that determine the grid spacing in each direction	M	1	Sequence (19103)	Vector (19103)
	CV_ReferenceableGrid		Use obligation from referencing object	Use maximum occurrence from referencing object	SpecializedClass (CV_Grid)	
	role name: coordinateReferenceSystem	link the CV_RectifiedGrid to the coordinate reference system within which the grid is rectified	M	1	Association	SC_CRS (19111)

	CV_GridValuesMatrix	subclass of CV_Grid that ties feature attribute values to grid geometry	Use obligation from referencing object	Use maximum occurrence from referencing object	SpecializedClass (CV_Grid)	
	values	sequence of N feature attribute value records where N is the number of grid points within the section of the grid specified by gridRange.	M	1	Sequence (19103)	Record (19103)
	sequencingRule	describes how the grid points are ordered for association to the elements of the sequence values.	M	1	Class	CV_SequenceRule (???)
	startSequence	identifies the grid point to be associated with the first record in the values sequence.	M	1	Class	CV_GridCoordinate (???)
	role name: evaluator			*	Association	CV_HexagonalGridCoverage (???)
	role name: evaluator			*	Association	CV_ContinuousQuadrilateralGridCoverage (???)

CV_GridPoint

	CV_GridPoint	represents the intersections of the grid lines	Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_Grid)	
	gridCoordinate	holds the set of grid coordinates that specifies the location of the CV_GridPoint within the CV_Grid.	M	1	Class	CV_GridCoordinate (???)
	role name: framework	links the CV_GridPoint to the CV_Grid of which it is an element.	M	1	Association	CV_Grid (???)
	role name: cell	links the CV_GridPoint to the set of CV_GridCells for which it is a corner	M	*	Association	CV_GridCell (???)
	role name: footprint	link the CV_GridPoint to the CV_Footprint that represents the sample space in an external coordinate reference system associated with the CV_GridPoint.	O	*	Association	CV_FootPrint (???)
	role name: groundPoint	links the CV_GridPoint to the GM_Point that is its representation in an external coordinate reference system.	O	1	Association	GM_Point (19107)

CV_GridCell

	CV_GridCell	A CV_GridCell is delineated by the grid lines of CV_Grid. Its corners are associated with the CV_GridPoints at the intersections of the grid lines that bound it	Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_Grid)	
	role name: framework	links the CV_GridCell to the CV_Grid of which it is an element	M	1	Association	CV_Grid (???)
	role name: corner	links the CV_GridCell to the set of CV_GridPoints at its corners	M	4..*	Association	CV_GridPoint (???)

• CV_FootPrint

	CV_FootPrint	sample space of a grid in an external coordinate reference system.	Use obligation from referencing object	Use maximum occurrence from referencing object	Associated Class (CV_GridPoint)	
	geometry	describe the geometry of the CV_CellFootprint within the coordinate reference system identified by GM_Object.CRS	M	1	Class	GM_Object (19107)

CV_SequenceRule

	CV_SequenceRule	contains information for mapping grid coordinates to a position within the sequence of records of feature attribute values.	Use obligation from referencing object	Use maximum occurrence from referencing object	Class <<DataType>>	
	type	identifies the type of sequencing method that shall be used. The default value shall be “linear”	M	1	Class	CV_Sequence (???) (default = “linear”)

	scanDirection	list of axis names that indicates the order in which grid points shall be mapped to position within the sequence of records of feature attribute values. An additional element may be included in the list to allow for interleaving of feature attribute values	M	1	Sequence (19103)	CharacterString

CV_ValueSegment

	CV_ValueSegment		Use obligation from referencing object	Use maximum occurrence from referencing object	Aggregated Class (CV_ValueCurve)	
	startParameter	value of the arc-length parameter of the parent curve at the start of this CV_ValueSegment.	M	1	?	Distance
	endParameter	value of the arc-length parameter of the parent curve at the end of this CV_ValueSegment.	M	1	?	Distance
	role name: curve		M	*	Association	CV_ValueCurve
	role name: controlValue	links the CV_ValueSegment to the CV_PointValuePairs that provide control values for interpolation. Linear interpolation requires a minimum of two control values, usually those at the beginning and end of the CV_ValueSegment. Additional control values are required to support interpolation by higher order functions.	M	2..*	Association	CV_PointValuePair

Codelists

CV_CommonPointRule

	Name	Domain code	Definition
1.	CV_CommonPointRule		
2.	average	001	
3.	start	002	
4.	end	003	
5.	low	004	
6.	high	005	

	Name	Domain code	Definition
7.	all	006	

CV_InterpolationMethod

	Name	Domain code	Definition
1.	CV_InterpolationMethod		
2.	nearestNeighbor	001	
3.	linear	002	
4.	bilinear	003	
5.	bicubic	004	
6.	lostArea	005	
7.	barycentric	006	

CV_SequenceType

	Name	Domain code	Definition
1.	CV_SequenceType		
2.	linear	001	
3.	boustrophedonic	002	
4.	cantorDiagonal	003	
5.	spiral	004	
6.	morton	005	
7.	hilbert	006	

Nested Relationship of NSDI Framework Data Content Standard Harmonization