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NGA STANDARDIZATION DOCUMENT

Implementation Profile
for
Tagged Image File Format (TIFF)
and
Geographic Tagged Image File Format (GeoTIFF)

**SPECIFICATION FOR TIFF AND GeoTIFF FORMATTING OF
IMAGERY AND GRIDDED DATA**

2011-10-26

Version 2.0

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TBD/TBR Listing

Page #	TBD/TBR	Description

Change Log

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Foreword

An important area of consideration for the use of imagery and gridded data is the encoding format. Various participants within the National System for Geospatial-Intelligence (NSG) have validated requirements to make selected imagery and gridded data holdings available in Geographic Tagged Image File Format (GeoTIFF), in addition to other NSG-supported formats. The primary rationale is to enable more timely (through automation) support for delivering imagery and gridded data in a form suitable for direct ingest by the imagery and Geospatial Information System (GIS) application software tools readily available to those working in the civilian sector supporting disaster relief, homeland security, and similar activities. Requirements are in place for some NSG imagery libraries to support GeoTIFF, but there has been no standardized implementation profile to guide the deployment of this functional capability. While GeoTIFF is widely used within the civilian sector, it has many options which often result in non-interoperability among disparately developed implementations. This implementation profile was developed to help meet objectives for deployment of GeoTIFF-related capabilities within the NSG that will also be widely supported within the civilian sector.

Most data exchange standards are defined in terms of their encoding format. Often, information about the structure of the format itself dominates, and the information elements that describe the underlying nature of the data (metadata) are a secondary consideration. In many instances, the information elements pertinent to understanding the nature of the data are not included with the data to be exchanged, and users of the data must depend on a priori knowledge that may, or may not be externally documented. GeoTIFF, like other formats popular in the civilian sector, is not robust enough in its defined structure to fully carry even the minimal set of metadata needed to promote interoperability within the NSG. This profile complies with NSG discovery metadata standards by requiring GeoTIFF producers to supplement information not captured by the current GeoTIFF data structures with additional metadata in XML form.

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Introduction

This implementation profile specifies the high-level requirements and encoding rules that shall be used for the exchange of imagery and gridded data when opting to use the Tagged Image File Format (TIFF) and Geographic Tagged Image File Format (GeoTIFF) file format structures. It constitutes a description of the bounds and constraints for the use of TIFF and GeoTIFF within the design objectives of promoting interoperability for the exchange of imagery and gridded data within the National System for Geospatial Intelligence (NSG).

GeoTIFF is a public domain specification that allows georeferencing information to be embedded within a TIFF file. GeoTIFF tags may include information on projection, coordinate systems, ellipsoids, datums, and other information needed to establish the spatial reference for the imagery or gridded data contained in the file. The GeoTIFF format is an augmentation of the TIFF format, so a TIFF-enabled software application will be able to at least view the image data in a GeoTIFF file, even if that application is incapable of reading and interpreting the specialized georeferencing metadata.

The main body of this profile addresses the general approach for using TIFF/GeoTIFF within the general context of imagery and gridded data. Appendix A outlines the internal TIFF/GeoTIFF data structures and defines the rules for representing imagery and gridded data using the syntax, structure and coding scheme available within the TIFF/GeoTIFF format. Appendix B describes the additional data and/or metadata to be associated with each GeoTIFF file, and provides an example of supplemental metadata to include a sample XML-encoded instance document. Lastly, Appendix C defines the abstract test criteria for measuring conformance with this profile when representing imagery and gridded data using TIFF/GeoTIFF.

Users of this profile are encouraged to develop application-specific product profiles to capture the detailed design for using TIFF/GeoTIFF within the context of the intended deployment of GeoTIFF-encoded data, services and capabilities. For example, an application-specific implementation may require that some of the TIFF/GeoTIFF tags be populated with specific values from this profile's list of allowed values. Such an implementation would be a specialization of this profile. For the XML requirement, additional xml metadata beyond that required by this profile may be specified, as long as the extension is done in accordance with NSG metadata standards.

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1 Scope

This implementation profile defines the minimum set of format options, features, and data elements (to include metadata) necessary to promote interoperability for the exchange of Geographic Tagged Image File Format (GeoTIFF)-formatted files within the National System for Geospatial-Intelligence (NSG). The profile establishes a common frame of reference to address adequate georeferencing parameters and data value attribution needed by geospatial applications to utilize GeoTIFF-formatted image and gridded data. Only uncompressed imagery, gridded data and transparency masks that have been georeferenced (orthorectified, georectified or equidistant-sampled data) are addressed by this profile. Requirements for compression (see Section 7.13) and georeferencable imagery (see Section 7.2) shall not be addressed by the NSG using the GeoTIFF format.

Tagged Image File Format (TIFF) is an image file format used for storing and exchanging raster images. Gridded data (for example, elevation values, an array of lat/long points, etc.) can be carried as an array much like an image, using the TIFF format. It is an open format; public domain and non-proprietary. It is also a portable format, not specific to or favoring any particular operating systems, file systems, compilers, or processors. Finally, TIFF was designed to be extensible and able to evolve as new needs arise.

GeoTIFF is a set of TIFF tags (extensions to the Baseline TIFF Format) that describe cartographic information associated with TIFF imagery and gridded data that originate from satellite imaging systems, scanned aerial photography, scanned maps, digital elevation models, or as a result of geographic analysis or similar processes. It uses a small set of reserved TIFF tags to store a broad range of georeferencing information.

This profile addresses the following fundamental topics for application and use of TIFF/GeoTIFF:

- Required TIFF/GeoTIFF tags for standardized use of GeoTIFF-formatted files.
- Image data or pixel structures relating to: strips, tiling, compression, precision, number of bands, etc.
- Preferred coordinate reference systems, datums, and projections for use within the NSG.
- Minimum metadata requirements for use within the NSG.

2 Conformance

Any data claiming conformance with this profile shall pass the conformance requirements described in Appendix C.

Any product or system claiming conformance for generating data in compliance with this profile shall pass the conformance requirements described in Appendix C.

Any product or system claiming conformance for interpreting data in compliance with this profile shall pass the conformance requirements described in Appendix C.

3 Normative Documents

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

Implementation Profile for TIFF and GeoTIFF
Version 2.0 26 October 2011

Industry Specifications:

The format and contents of the TIFF and GeoTIFF are based upon the following industry specifications;

TIFF – Tagged Image File Format, Revision 6.0, Adobe Systems Inc., June 1992
<http://partners.adobe.com/public/developer/en/tiff/TIFF6.pdf>
© 1986-1988, 1992 by Adobe Systems Incorporated.

GeoTIFF Format Specification, Revision 1.0, 28 December 2000; version 1.8.2
<http://www.remotesensing.org/geotiff/spec/geotiffhome.html>
Portions are copyrighted by Niles Ritter and Mike Ruth.

Geodetic codes used in GeoTIFF tags are maintained in the EPSG Geodetic Parameter Registry at <http://www.epsg-registry.org/>.

National Standards:

National System for Geospatial Intelligence (NSG) Metadata Foundation (NMF) – Part 1: Conceptual Schema Profile, version 2.0, December 2010, <https://nsgreg.nga.mil/doc/view?i=2142>

National System for Geospatial Intelligence (NSG) Metadata Implementation Specification (NMIS) – Part 2: XML Exchange Schema, version 2.0.0, December 2010, <https://nsgreg.nga.mil/doc/view?i=82072>

NIMA TR 8350.2: Third Edition, Amendment 1: Department of Defense World Geodetic System 1984; Its Definition and Relationships with Local Geodetic Systems. U. S. National Imagery and Mapping Agency 3 January 2000. http://earth-info.nga.mil/GandG/publications/tr8350.2/tr8350_2.html

NIMA TM 8358.2: The Universal Grids: Universal Transverse Mercator (UTM), Universal Polar Stereographic (UPS) http://earth-info.nga.mil/GandG/publications/tm8358.2/TM8358_2.pdf

Director of National Intelligence (DNI) Special Security Center (SSC) Controlled Access Program Coordination Office (CAPCO): Intelligence Community Classification and Control Markings Implementation Manual

Informative References

ISO 19123:2005, *Geographic Information - Schema for coverage geometry and functions*

4 Terms and Definitions

For the purposes of this document, the terms and definitions given in the TIFF and GeoTIFF specifications apply, in addition to the following;

4.1 abstract test case

An encapsulation of one or more test purposes, independent of both the implementation and the values. It enables a test verdict to be assigned unambiguously to each potentially observable test outcome (i.e. sequence of test events).

4.2 abstract test suite (ATS)

A collection of test modules and individual test cases that provide a formal basis for deriving executable test cases.

4.3 band

A well defined range of wavelengths, frequencies or energies of optical, electric, or acoustic radiation. At the pixel level, a band is represented as one of the vector values of the pixel.

4.4 coordinate

One of a sequence of numbers designating the position of a point in N-dimensional space.

4.5 bandwidth

The difference between the limiting frequencies within which performance of a device, in respect to some characteristic, falls within specified limits. 2. The difference between the limiting frequencies of a continuous frequency band.

4.6 coordinate reference system

Coordinate system which is related to the real world by a datum.

4.7 coverage

Feature that acts as a function to return values from its range for any direct position within its spatial, temporal, or spatiotemporal domain. Examples include a digital image, raster map, and digital elevation matrix.

Note: In other words, a coverage is a feature that has multiple values for each attribute type, where each direct position within the geometric representation of the feature has a single value for each attribute type.

4.8 coverage geometry

Configuration of the domain of a coverage described in terms of coordinates.

4.9 data compaction

Reduction of the number of data elements, bandwidth, cost, and time for the generation, transmission, and storage of data without loss of information by eliminating unnecessary redundancy, removing irrelevancy, or using special coding. Note: Whereas data compaction reduces the amount of data used to represent a given amount of information, data compression does not.

4.10 data compression

Compression reduces the amount of storage space required to store a given amount of data, or reducing the length of message required to transfer a given amount of information. Note: Data compression does not reduce the amount of data used to represent a given amount of information, whereas data compaction does. Both data compression and data compaction result in the use of fewer data elements for a given amount of information.

4.11 dataset

Identifiable collection of data.

4.12 domain

Well-defined set. Note: Domains are used to define the domain set and range set of operators and functions.

4.13 direct position

Position described by a single set of coordinates within a coordinate reference system.

4.14 evaluation

Determination of the values of a coverage at a direct position within the spatiotemporal domain of the coverage.

4.15 executable test case

A specific test of an implementation to meet particular requirements.

4.16 function

Rule that associates each element from a domain (source, or domain of the function) to a unique element in another domain (target, co-domain, or range).

4.17 georectified grid

Rectified grid (see 4.30) wherein the external coordinate reference system is related to the real world by a datum. Note: Any cell in the grid can be geolocated given its grid coordinate and the grid origin, cell spacing, and orientation.

4.18 grid

Network composed of two or more sets of curves in which the members of each set intersect the members of the other sets in a systematic way.

4.19 gridded data

Data whose attribute values are associated with positions on a grid coordinate system.

4.20 grid point

Point located at the intersection of two or more curves in a grid.

4.21 imagery

Representation of phenomena as images produced electronically and/or optical techniques.

4.22 implementation conformance Statement (ICS)

Statement of specification requirements and options that have been implemented.

4.23 implementation under test (IUT)

The realization of a specification that is being reviewed for conformance with the specification.

4.24 metadata

Data about data.

4.25 mosaic

For purposes of this profile, a mosaic image is an image composed of two or more separately collected (sensed) images. Supplemental metadata may be used to identify the cut-lines (boundaries and parameters for the images used to compose the mosaic).

4.26 orthorectified grid

Georectified grid (see 4.17) created using ground control points and elevation data where constant interval is maintained throughout the grid.

4.27 pixel

Smallest element of a digital image to which attributes are assigned. Each such information element is not really a dot, nor a square, but an abstract sample.

4.28 range

Set of feature attribute values associated by a function with the elements of the domain of a coverage.

4.29 record

Finite, named collection of related items (objects or values). Note: Logically, a record is a set of pairs <name, item >.

4.30 rectified grid

Grid for which there is an affine transformation between the grid coordinates and the coordinates of an external coordinate reference system.

4.31 referenceable grid

Grid associated with a transformation that can be used to convert grid coordinate values to values of coordinates referenced to an external coordinate reference system

4.32 tile

A tile is a bounded set of data that is edge-matched with other tiles within a tiling scheme.

5 Symbols and Abbreviated Terms

CAPCO	Controlled Access Program Coordination Office (within the Office of the Director of National Intelligence)
DMA	Defense Mapping Agency
GCS	Geographic Coordinate System
GCSE	Geographic Coordinate System, Ellipsoid Only
GeoTIFF	Geographic Tagged Image File Format
GIS	Geospatial Information System / Geographic Information System
GWG	Geospatial Intelligence Standards Working Group
IEEE	Institute of Electrical & Electronic Engineers
IFD	Image File Directory
IHO	International Hydrographic Organization
ISO	International Organization for Standardization
NIMA	National Imagery and Mapping Agency
NSG	National System for Geospatial-Intelligence
TIFF	Tagged Image File Format
UTC	Coordinated Universal Time

UPS	Universal Polar Stereographic
UTM	Universal Transverse Mercator
WGS84	World Geodetic System 1984

6 Applicability and Use

This profile is applicable to the exchange of imagery and gridded data. The use of metadata allows great flexibility of data structure, spatial density, quality, and format, while supporting sharing and reuse of the data.

Intended users include:

- New and existing imagery and gridded data acquisition systems.
- GeoTIFF exploitation systems and applications.
- GeoTIFF users who create derived data from GeoTIFF files or from other image and gridded data file formats.
- Users who create GeoTIFF files from non-imagery datasets i.e. bathymetry, terrain elevation data, etc.
- Users who need to create GeoTIFF files with a different security classification and/or releasability designation in support of distribution requirements.

Producers of NSG TIFF/GeoTIFF data are encouraged to develop an application-specific implementation profile(s) to capture the detailed design for using TIFF/GeoTIFF within the context of the intended deployment of GeoTIFF-encoded data, services and capabilities.

7 TIFF and GeoTIFF Requirements

In general, imagery and gridded data delivered in GeoTIFF format will conform to (not deviate from) the TIFF and GeoTIFF formats as defined in the referenced TIFF and GeoTIFF specifications. The following clauses constrain the implementation of TIFF and GeoTIFF for the purposes of this implementation profile.

7.1 General File Structure and Data Value Types

The TIFF structure includes an 8-byte image file header that provides the byte order used within the file (both are allowed by this profile) and a pointer to the first Image File Directory (IFD). The TIFF format supports multiple images per TIFF file (with an IFD for each image), although baseline TIFF readers are not required to read any IFD beyond the first one. This profile constrains the number of IFDs to two, with the second IFD only used to support a transparency mask. The first IFD begins with a 2-byte count of the number of directory entries (i.e., the number of fields), followed by a sequence of 12-byte field entries, and followed by a 4-byte offset of the next IFD (0 if a transparency mask is not included). It should be noted that the 4-byte (32 bit) structure of the offset allows GeoTIFF file sizes up to 4GB. This implementation profile supports file sizes up to that limit. For datasets above the 4GB limit, producers may employ external tiling, which is described in sections 7.10 and 7.15.

All of the GeoTIFF information is encoded in six GeoTIFF tags, which are designed to store a broad range of georeferencing information, catering to geographic as well as projected coordinate system needs. GeoKeys are used within the tags to store the projection parameters and coordinate system information. All keys are referenced from one tag, the GeoKeyDirectoryTag. See Table A.2 for details. GeoTIFF uses numerical codes from the EPSG to describe projection types, coordinate systems, datums, ellipsoids, etc. The EPSG Geodetic Parameter Registry at <http://www.epsg-registry.org> shall be used as the source for EPSG codes, as opposed to the GeoTIFF specification.

The GeoTIFF specification requires interpret (reader) implementations to support all documented TIFF 6.0 tag data-types, and in particular requires the Institute of Electrical & Electronic Engineers (IEEE) double-precision floating point 'DOUBLE' type tag. The documented data types for use with TIFF tags are:

- BYTE = 8-bit unsigned integer
- ASCII = 8-bit byte that contains a 7-bit American Standard Code for Information Interchange (ASCII) code. The last bit of an ASCII sequence (string) must be null (binary zero)
- SHORT = 16-bit (2-byte) unsigned integer
- LONG = 32-bit (4-byte) unsigned integer
- FLOAT = Single precision (4-byte) IEEE format
- DOUBLE = Double precision (8-byte) IEEE format
- RATIONAL = Two LONGs: the first represents the numerator of a fraction; the second, the denominator
- SBYTE = 8-bit signed (twos complement) integer
- UNDEFINED = 8-bit byte containing anything, depending on the definition of the field.
- SSHORT = 16-bit (2-byte) signed (twos complement) integer
- SLONG = 32-bit (4-byte) signed (twos complement) integer
- SRATIONAL = Two SLONGs: the first represents the numerator of a fraction; the second, the denominator.

Note: Appendix A identifies which data type applies to each tag selected for use by this implementation profile.

The optional transparency mask, specified in the TIFF "Baseline Field Reference Guide", is common for geospatial raster data. A transparency mask is a bi-level image that is perfectly superposable to the image data (pixel to pixel) specified by first IFD. A GeoTIFF reader uses the mask to determine which parts of the image to display. This profile requires that it be identified through the use of a second IFD and that it will have the same size and resolution as the main image it is associated with. In the transparency mask data, the value of 1 indicates a significant pixel whereas a value of 0 indicates a padding pixel that should be rendered as transparent. A transparency mask contains no GeoTIFF tags. The following TIFF tags and values (see Appendix A) are used to specify a transparency mask:

- BitsPerSample = 1
- Colormap: do not use
- ImageDescription: include 'transparency mask' in abstract portion
- ImageLength = (ImageLength of 1st IFD)
- ImageWidth = (ImageWidth of 1st IFD)
- NewSubfileType: (set second bit = 1, all other bits = 0)
- PhotometricInterpretation = 4
- SamplesPerPixel = 1

TIFF implicitly types all range values (data sample values) as unsigned integer values. The representation of imagery and gridded data range values, however, requires the ability to store the range (data) values in additional representations such as signed integer and floating point. Section 19 of the TIFF specification presents a scheme for describing a variety of data sample formats using the SampleFormat field (tag). The BitsPerSample field in the TIFF Image File Directory defines the number of bits per component.

7.2 Rectification and Orthorectification

A rectified grid is related to the earth (georectified) or other reference by an affine transform based on the location of the origin of the grid and the orientation of and spacing along each axis. An orthorectified grid

is a georectified grid created using ground control points and elevation data where constant scale is maintained throughout the grid.

A referenceable grid is one that can be referenced by some other specified coordinate transform (for example, by a physical sensor geometry model or by a functional fit model of rational polynomials). This profile is concerned only with georectified grids and orthorectified grids. It does not address referenceable grids; for example, those associated with oblique imagery.

The GeoTIFF format specification describes 5 coordinate transformation ‘cases’ that the format is able to address. In cases 1 and 2, the location of at least one point is known, but scale is not. The scope of this profile (only georectified, orthorectified, or equidistant-sampled data) requires that the scale be identified in the GeoTIFF tags and therefore the GeoTIFF format shall not be used within the NSG unless the size of the image pixel spacing is known. Only cases 3 and 4 are supported by this profile. In case 3, the position and scale of the data is known exactly, and no rotation of the image is required. In case 4 (intended for equidistant-sampled data), the original image is not north-oriented (the producer chooses to leave the image unrotated in order to preserve file size and/or accuracy). In this case, the ModelTransformationTag must be used instead of the ModelTiePointTag and ModelPixelScaleTag. The ModelTransformationTag specifies the transformation matrix between raster and model space, which ultimately gives the image consumer the option to correctly rotate the data to north orientation. In case 5 (not allowed by this profile) multiple tie points can be stored in GeoTIFF to allow rubbersheeting of the image. There is no GeoTIFF tag structure to support the sensor model information that would be required to precisely georeference an “as-collected” image. Precise positioning is therefore not a baseline GeoTIFF implementation, and georeferencable images are not supported by this profile.

7.3 Security Classification

There are no fields for storing security classification information in the baseline TIFF/GeoTIFF format. Supplemental metadata in the embedded or associated XML expressions (see section 7.17) shall be used to associate security markings and dissemination controls for content of GeoTIFF files. For this profile, the core metadata requirements of the NSG Metadata Foundation (NMF), which include a specification of the requirements of the Intelligence Community Metadata Standard for Information Security Markings (ICS ISM), will be included in the XML metadata. Additionally, a free text identification of the file’s security classification and handling instructions according to the Intelligence Community Classification and Control Markings (US CAPCO marking) shall be included in the baseline TIFF ImageDescription field.

7.4 Void and Suspect Areas

A void is an area within the coverage where the range value does not represent an actual measurement. Suspect areas are those with elevation values that fall outside of the dataset’s range of logical consistency (i.e. spikes and valleys). There are no baseline TIFF or GeoTIFF tags for storage of information about void and suspect areas. Identification of these postings could be handled via the associated XML metadata defined for the specific application of GeoTIFF. However, for efficiency within the encoding, void and suspect areas shall be represented within the TIFF matrix of range values by use of a designated “out-of-range” value, typically the most negative value available for the data type selected (or the non-number value designated for the selected data type) to represent the range values. An unofficial private TIFF tag, GDAL_NODATA (#42113) exists for the purpose of declaring this value (see Table A.1). Note that since GeoTIFF could be used to support features such as elevation and bathymetric surfaces, due care must be taken when using a negative “out-of-range” value to avoid confusion with actual data values.

7.5 Data Quality

There are no fields for storing data quality information (positional accuracy, lineage, currency, etc.) in the GeoTIFF format. Supplemental data/metadata in the associated XML expressions shall be used to address data quality descriptions.

7.6 Units of Measure

Common industry practice is to allow implied or default units of measure, and this profile allows only the implied 'angular degree' unit for the geographic coordinate system, and the default 'meters' unit for the UTM projected coordinate system. User-defined geographic or projected coordinate systems are not allowed by this profile. In order to prevent the use of other horizontal units of measure, the use of the GeoKeys related to horizontal units of measure are prohibited (see Table A.2).

Several vertical coordinate systems are allowed by this profile, but the vertical unit of measure shall always be the linear meter. Elevation data in GeoTIFF format shall declare this unit using the VerticalUnitsGeoKey in Table A.2.4.

7.7 Date and Time

There is a TIFF field called DateTime for storing the date and time of image creation. The format for the field in ASCII type is "YYYY:MM:DD HH:MM:SS " with 24 hour time used for the hours and one space character between the date and time, and one terminating null character. The length of the string, including the terminating null, is 20 bytes. All dates and times shall be expressed in Coordinated Universal Time (UTC).

The Date/Time stamp that will be represented in the TIFF DateTime field shall be the date/time the imagery or gridded range values were collected. For data composed from data collection conducted at different times (e.g. mosaics), the general guideline is to use the date/time from the oldest (least current) collection. Use the date and time that most closely reflects the currency of the data range values. The associated XML metadata expressions allow other types of date/time elements that deal with modification dates, exchange dates, or processing dates, but there is no provision within TIFF/GeoTIFF to express these other varieties of dates and times.

7.8 Coordinate Reference Systems and Datums

The GeoTIFF Configuration GeoKeys establish the general configuration of the file's coordinate system. Each of these GeoKeys is listed below with their general description followed by limitations and constraints established by this profile.

- GTModelTypeGeoKey – Tag 1024. The GTModelTypeGeoKey defines the general type of model coordinate system used – geographic or projected.
- GTRasterTypeGeoKey– Tag 1025. The GTRasterTypeGeoKey establishes if the raster pixel value (imagery or gridded data range value) is located at a point value or if the value fills the square grid cell.
- GTCitationGeoKey – Tag 1026. The GTCitationGeoKey is used to give an ASCII reference to published documentation on the overall configuration of the GeoTIFF file. This key generally shows the projection name or geographic coordinate system name and the units.

Horizontal datum – GeoTIFF has many datums to choose from in the Geodetic Datum numerical codes. This profile recommends the use of World Geodetic System 1984 (WGS84) DoD standard, but North American Datum 1927 and 1983 (NAD27 and NAD83) are also acceptable.

Vertical datum – No vertical datum codes are currently provided by the GeoTIFF specification, other than those implied by the corresponding vertical coordinate system code. This profile limits the vertical datum to the WGS84 ellipsoid, the WGS-84 Earth Gravity Field Model (EGM 84, 96 or 2008), and hydrographic datums, when required. Note that the Earth Gravity Field Model will provide an approximation of Mean Sea Level.

Coordinate systems – The GeoTIFF format allows for the use of many geographic latitude-longitude systems and many projected coordinate systems. There are also tags for parameters of coordinate systems or projections not available in the codes. This profile limits expression of horizontal coordinate references to WGS84 latitude and longitude (decimal degrees) and UTM Grid System Northing and Easting (meters)

7.9 Collection and Maintenance Constraints

There are several TIFF tags that can carry and address a variety of collection information. These tags should not be populated for the purpose of this format representation. Associated XML metadata expression can be used to carry this type of information when needed.

7.10 Tiling of TIFF/GeoTIFF

It is common industry practice for range value records within imagery or gridded data collections to be organized into tiles. The three primary motivations for organizing range value records into a tiling scheme are: 1) The nature and description of the value records within the collection or dataset is different, thus requiring different metadata descriptions; 2) The physical size of the range value data is so large that it warrants subdivision for ease of data management; and 3) The sampling density varies within the coverage of the dataset.

In contrast to the above use of the term 'tile' wherein the data for each tile is typically stored within separate files, TIFF supports an internal tiling structure that addresses the sequence and interleave of range values within an array internal to the TIFF file. Internal tiling is a distinct concept from external tiling, and both types may be used within a dataset. The terms 'TIFF tile' (internal) and 'metadata tile' (external) are independent of each other and any correlation between the external and internal tiles is either coincidental or by design, but not inherent.

GeoTIFF specific keys do not contain a place to address internal tiling, so all internal tiling information is contained in the TIFF tags. This profile allows use of either the TIFF 'strip' approach or the TIFF internal tiling approach. Generally, for small grids, the data should be organized as a single TIFF tile within the file. When opting to use internal tiles, the range value data may need to be padded to tile boundaries when the grid size is not an integer multiple of the selected tile size.

The TIFF and GeoTIFF formats have no means to describe external tiling, so the associated XML metadata expression is available to meet this need. This profile places no constraints for how an imagery and gridded data collection or dataset is organized into external tiles. External tile boundaries must be defined with geographic locations because metadata boundaries may be independent of the external tile boundaries and subsets of the dataset must be allowed to include all relevant metadata.

7.11 Number of Bands

The number of bands within a GeoTIFF grid may be either 1 (monochrome or transparency mask), 3 (RGB), or multi-band (4 to 8 bands). Multi-band images of more than eight bands shall not be encoded using GeoTIFF. For the 3 and multi-band cases, the band interleave shall be the TIFF 'chunky' format (band interleaved by pixel) or planar (band sequential). The TIFF specification does not address the multi-band case, and therefore a combination of TIFF tags must be used in order to identify a multi-band image (see Table A.1). The order of bands within the pixel data in the TIFF/GeoTIFF file for the multi-

band case shall be the band of shortest wavelength first, followed by the other bands in order of increasing wavelength.

7.12 Range Value Data Types and Precision

For imagery, the range (data) values are constrained to be unsigned integer data, 8 or 16-bits-per-band. A 1-bit bi-level transparency mask is also allowed. The transparency mask is specified by a second IFD (see Section 7.1), and is perfectly superposable to the image data specified by first IFD. In the transparency mask, a value of 1 indicates a significant pixel whereas a value of 0 indicates a padding pixel that should be rendered as transparent. A transparency mask contains no GeoTIFF tags.

For gridded data (e.g. elevation data, matrices of lat/lon values, etc.), the range values may be stored in additional representations to include 8-bit and 16-bit signed integer and 32-bit floating point. For integer values, the MaxSampleValue and MinSampleValue TIFF tags identify the extent of the value range. For floating point (real) number values, the SminSampleValue and SmaxSampleValue tags are used.

7.13 Compression Options

This profile requires that the GeoTIFF range values be uncompressed. Requirements for compressed imagery must be satisfied in formats other than GeoTIFF. Data compaction techniques (such as adjusting sampling frequency) are left to the discretion of the implementer in light of the intended use of the data and associated quality requirements.

7.14 File Naming

This profile places no constraints for naming GeoTIFF files. An example naming convention for illustration purposes is:

Sensor Name + ULLong + ULLat + Acquisition Date + Acquisition Time.TIF

Sensor Name = 10 Char

Upper Left Long Coordinate (ULLong) = +/- (for hemisphere) three digit degree & eight digit decimal (Decimal Degree format)

Upper Left Lat Coordinate (ULLat) = +/- (for hemisphere) two digit degree & eight digit decimal (Decimal Degree format)

Acquisition Date = YYYYMMDD

Acquisition Time = hhhmmss

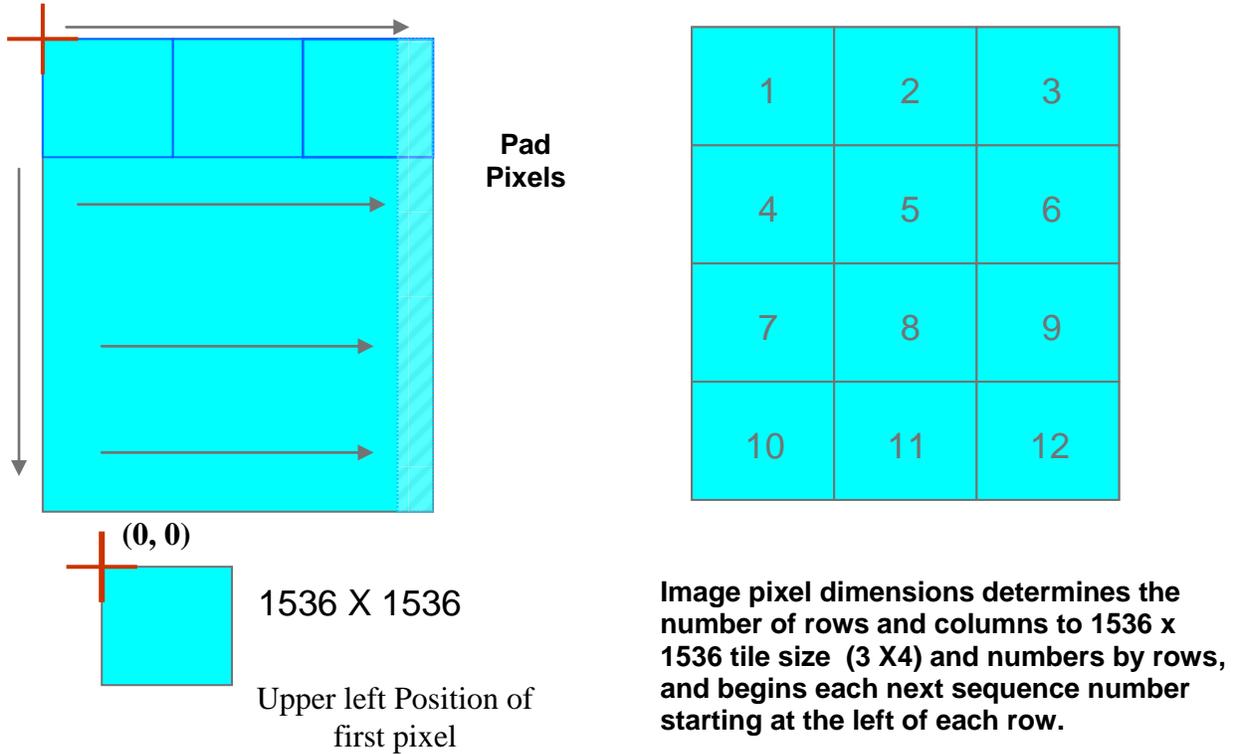
Example: SensorX01_-022.78987654_+30.78654321_20040209_13002028.tif

7.15 Tiling (Framing) Conventions

This profile places no constraints on conventions for organizing a large coverage into an external tiling (otherwise known as framing) scheme. An example framing method/practice for consideration is to follow the 1536 x 1536 external tiling approach described in 7.10.

The image framing orientation is defined by designating the position of origin as the upper left corner (the first image pixel) of the coverage to be externally tiled. Frames are calculated from the orientation position (0, 0) then calculate frame size by the selected tile size (e.g. 1536). Frames are numbered 1 through N, by the calculated extent of the image size or number of pixels in X and Y. Number schema sequencing is left to right in X, then back to the X origin position = 0 and a Y position = to the tile size + 1 to begin the next row of frames. If the number of frame pixels is not complete, pixels must be padded to fill the frame. See Frame Diagram 7.15.1.

It is a recommended best practice for the frame file naming convention to be an extension of the producer's chosen GeoTIFF file naming convention. In other words, frame files should be identified in the same format with the frame sequence number added as part of the file name. Example for frame 1 (using 7.14 file naming example): SensorX01_-022.78987654_+30.78654321_20040209_13002028_1.tif.

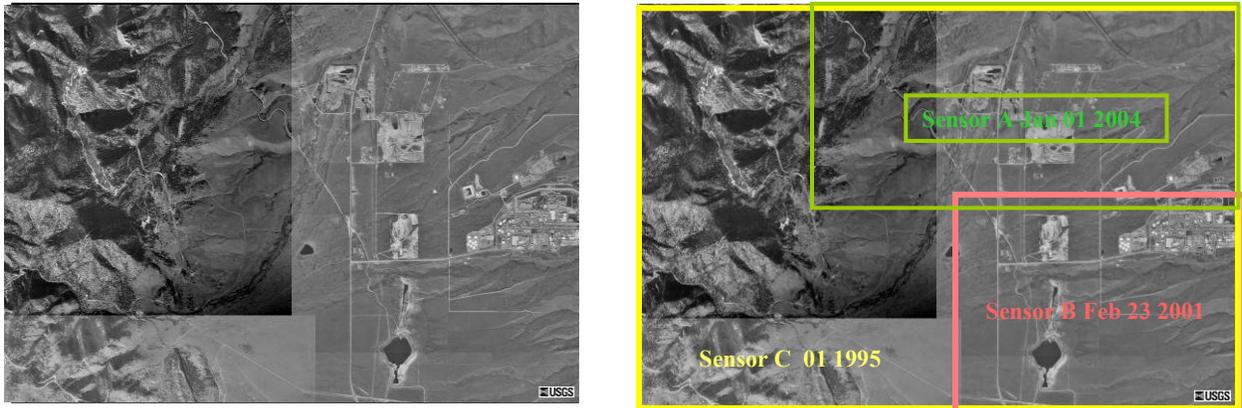


Frame Diagram 7.15.1

7.16 Mosaic Image

This profile addresses GeoTIFF mosaics and the association of metadata for GeoTIFF mosaic images composed of supplemental image files compositely merged together to form a mosaic image. See Mosaic Diagram 7.16.1.

The method to associate parameters and metadata for each image used to compose the mosaic will be addressed in the Supplemental Associated Metadata section 7.17.



GEOTIFF
Mosaic

GEOTIFF
Imagery Coverage

Diagram 7.16.1: GeoTIFF Mosaic

The imagery coverage diagram on the right shows that metadata is described in relation to geographic areas, and not necessarily to scene boundaries.

7.17 Supplemental Associated Data and Metadata

This profile addresses TIFF/GeoTIFF metadata shortfalls to support NSG fundamental imagery metadata requirements. This profile allows additional data and metadata to be embedded within the GeoTIFF file, or to be provided as an external file. The use of any private TIFF or GeoTIFF tags, other than those included in Appendix A, is prohibited by this profile. Additional data and metadata that may be required by the producer should be included only in the supplemental XML file (see Appendix B).

The associated XML data/metadata must comply with the conceptual schema specified in the NSG Metadata Framework (NMF) and the XML encoding specified in the the NSG Metadata Implementation Specification (NMIS). The supplemental set of associated metadata accommodates individual and multi-composite (mosaic) GeoTIFF files. A Private TIFF Geo_Metadata tag has been created to support the option of including this XML file within the TIFF/GeoTIFF encoding. The GEO_METADATA TIFF Tag (Diagram 7.17.1) may be used more than once in a TIFF/GeoTIFF file, with a total of up to 4GB of additional information incorporated into the file (based on the maximum file size for TIFF/GeoTIFF). Producers may choose the option of providing that additional information in an external XML file so that it is not applied to the 4GB limit. Software interpreters are required to read the XML data whether it is carried within the TIFF tag or provided external to the file.

Note: Should a conflict exists between the information provided in the baseline TIFF/GeoTIFF metadata and the supplemental data/metadata, this profile sets no precedence between the two, and the inconsistency is left to be addressed by the user or interpreting software.

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IFD		Image File Directory
Code		50909 (hex 0x87AF)
Name		Geo_Metadata
Type		ASCII
Count		4-byte (max. size = 4GB)
Default		None

Diagram 7.17.1: Registered TIFF Private GEO_METADATA

Appendix A Format Constraints

A.1 TIFF Format

The file structure for the Image File Header and Image File Directory can be found in the TIFF product specification in Part 1, Section 2: TIFF Structure. There are four Baseline TIFF image types – bilevel, grayscale, palette-color, and full-color images. Each type has specific field requirements, and these can be found in Sections 3 through 5 of the TIFF document. For the purpose of representing imagery, the grayscale and full-color image baselines are appropriate. For the purpose of representing gridded data (e.g. elevation data values) in GeoTIFF, none of the Baseline TIFF image types directly apply, however, this implementation profile is still based upon the Baseline TIFF Fields with only a few additional or extension fields. The use of any private tags, other than those included in this appendix, is prohibited by this profile. Additional information that may be required by the producer should be included only in the supplemental XML data.

Table A.1 describes the baseline fields defined in the TIFF specification, version 6.0, and is adapted from Section 8: Baseline Field Reference Guide. Table 1 also includes the additional TIFF fields and extensions needed to support the profile; an asterisk next to the tag number indicates such fields. TIFF format-specific notes and definitions have been left out of this table and can be found in the TIFF specification, revision 6.0. This table includes, where applicable, the equivalent Core Resource Metadata element from the NSG Metadata Foundation.

Table A.1 TIFF Fields
(from TIFF Specification Section 8: Baseline Field Reference Guide)

Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
Artist (R)	Person who created the image. For Profile: Populate with the name of the organization responsible for the file. i.e. the name of the government organization/office or the commercial company name.	315	ASCII	Resource Originator
BitsPerSample (R)	Number of bits per component. For Profile: Set to the number of bits used to represent each range (sample) value. For imagery, constrained to 8 and 16-bits-per-pixel-per-band. For other gridded data, constrained to 8, 16 and 32 bits per range (sample) value. For a transparency mask, set = 1.	258	SHORT	N/A
CellLength (N)	The length of the dithering or halftoning matrix used to create a dithered or halftoned bilevel file.	265	SHORT	N/A
CellWidth (N)	The width of the dithering or halftoning matrix used to create a dithered or halftoned bilevel file.	264	SHORT	N/A

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Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
ColorMap (C)	Required when a lookup table is used to define an RGB color map for palette color images. Number of values = 3 * (2**BitsPerSample).	320	SHORT	N/A
Compression (O)	Compression scheme used on the image data. For Profile: Desired but optional: Use a value of 1 designating the range value data is not compressed. (D)	259	SHORT	N/A
Copyright (R)	Copyright notice. For Profile: When access or usage restrictions (or both) exist for the dataset, populate with the applicable copyright notice of the person or organization that claims the copyright to the image. The complete copyright statement shall be listed in this field including any dates and statements of claims. If no usage restrictions exist, it shall be so stated in this field. If multiple notices/licenses apply to the file, they should all be listed.	33432	ASCII	Rights
DateTime (R)	Date and time of image creation. For Profile: The date and time of image collection. See section 8 of the TIFF specification for format requirement. Note: Record the collection time only in this tag. Revision dates (processing dates) may be declared using XML metadata.	306	ASCII	Resource Date
ExtraSamples (C)	Description of extra components. For Profile: Use this tag for images with 4 or more bands. Set the value to 0 (unspecified data) and the number of values (count) is equal to the number of additional bands beyond the third band. E.g. for 8-band data, the count is 5 and the values is 0 (0,0,0,0,0).	338	SHORT	N/A
FillOrder (O)	The logical order of bits within a byte. For Profile: Desired but optional. Use a value of 1 (D).	266	SHORT	N/A
FreeByteCounts (N)	For each string of contiguous unused bytes in a TIFF file, the number of bytes in the string.	289	LONG	N/A
FreeOffsets (N)	For each string of contiguous unused bytes in a TIFF file, the byte offset of the string.	288	LONG	N/A
GrayResponseCurve (N)	For grayscale data, the optical density of each possible pixel value.	291	SHORT	N/A
GrayResponseUnit (N)	The precision of the information contained in the GrayResponseCurve.	290	SHORT	N/A
HostComputer (O)	Identification of the hardware/software used in formulation of the image. For Profile: Optional, but not desired. Populate with identification of the system used to process/create the range values from the raw instrument data or other source of sample data. Example: Integrated Exploitation Capability (IEC) workstation	316	ASCII	N/A

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Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
ImageDescription (R)	A string that describes the subject of the image. For Profile: Populate with security marking for the image data and provide abstract description formatted as follows; SECURITY BANNER: security marking information as free text, use DNI CAPCO guidance. ABSTRACT: resource abstract information. Include at least sensor or program name, location collected, spectral type, and ground sample distance.	270	ASCII	N/A
ImageLength (R)	The number of rows of pixels in the image. For Profile: The number of rows of range values in the grid. Note that for GeoTIFF, there is no means to designate that only part of the grid contains meaningful range values.	257	SHORT or LONG	N/A
ImageWidth (R)	The number of columns in the image, i.e. the number of pixels per row. For Profile: The number of columns of range values in the grid. Note that for GeoTIFF, there is no means to designate that only part of the grid contains range values.	256	SHORT or LONG	N/A
Make (O)	The scanner manufacturer. This tag may be used to identify the manufacturer of the instrument used to obtain the range values.	271	ASCII	N/A
MaxSampleValue (C)	The maximum component value used for each sample in the file. Required for Integer case The count for this tag is equal to the number of samples per pixel. For Profile: populate each count with the same value, that of the maximum value for the entire file, and not band-specific values.	281	SHORT	N/A
MinSampleValue (C)	The minimum component value used for each sample in the file. Required for integer case. The count for this tag is equal to the number of samples per pixel.	280	SHORT	N/A
Model (O)	The scanner model name or number. This tag may be used to identify the manufacturer's model name or number of the instrument used to obtain the range values.	272	ASCII	N/A
NewSubfileType (C)	A general indication of the kind of data contained in this subfile. For Profile: Bit 2 is set =1 when the data is a transparency mask	254	LONG	N/A

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Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
Orientation (O)	The orientation of the image with respect to the rows and columns. For Profile: Desired but optional: Set this value to the default (D) value of 1. Orientation of the grid indices to the external coordinate reference system is defined by the GeoTIFF tags.	274	SHORT	N/A
PhotometricInterpretation (R)	The color space of the image data. For Profile: Allowed values are: 1- Black is zero 2- RGB 3- Palette Color 4- Transparency Mask Note: A value for the multi-band case is not defined in the TIFF specification. In the multi-band case, use a value of 2 (RGB) and populate the ExtraSamples tag according to the number of additional bands.	262	SHORT	N/A
PlanarConfiguration (C)	How the components of each pixel are stored. For Profile: When more than one band is described by the range values, Include this tag and set the value to 1 (chunky format) or 2 (planar format).	284	SHORT	N/A
ResolutionUnit (C)	The unit of measurement for XResolution and YResolution. Required for TIFF but unnecessary for GeoTIFF files. For Profile: For TIFF files (not GeoTIFF), set equal to 2 (inches) (D)	296	SHORT	N/A
RowsPerStrip (C)	The number of rows per strip. Not used if Tiling has been used. For Profile: The TIFF specification recommends selecting the value for RowsPerStrip such that each strip is about 8K bytes; it makes buffering simpler for readers.	278	SHORT or LONG	N/A
SampleFormat (R)	This field specifies how to interpret each data sample in a pixel. Possible values are: 1 = unsigned integer data 2 = two's complement signed integer data 3 = IEEE floating point data [IEEE] SampleFormat tag count is equal to the number of samples per pixel in the file. For Profile: Select the value corresponding to the sample format used for representing the range (data) values.	339*	SHORT	N/A

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Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
SamplesPerPixel (R)	The number of components per pixel. For Profile: Allowed values are 1 (monochrome or transparency mask), 3 (RGB), and 4 or more (multi-band data).	277	SHORT	N/A
SminSampleValue (C)	The minimum value for each sample. This tag is used in lieu of MinSampleValue when the sample type is other than integer. For Profile: The minimum component value used for each sample.	340*	The field type that best matches the sample data	N/A
SmaxSampleValue (C)	The maximum value for each sample. This tag is used in lieu of MaxSampleValue when the sample type is other than integer. For Profile: The maximum component value used for each sample.	341*	The field type that best matches the sample data	N/A
Software (R)	Name and version number of the software packages(s) used to create the image. For Profile: Populate with descriptor of the software package(s) used to process/create the range values from the raw instrument data or other source of imagery and gridded data.	305	ASCII	N/A
StripByteCounts (C)	For each strip, the number of bytes in the strip after compression. Not used if Tiling has been used. For Profile: Populate per TIFF specification when opting to use strips.	279	SHORT or LONG	N/A
StripOffsets (C)	For each strip, the byte offset of that strip. Not used if Tiling has been used. For Profile: Populate per TIFF specification when opting to use strips.	273	SHORT or LONG	N/A
SubfileType (N)	A general indication of the kind of data contained in this subfile.	255	SHORT	N/A
Thresholding (O)	For black and white TIFF files that represent shades of gray, the technique used to convert from gray to black and white pixels. For Profile: Desired but optional: Set to 1. (D)	263	SHORT	N/A
TileWidth (C)	The tile width in pixels. This is the number of columns in each tile. For Profile: Populate per TIFF specification when opting to use internal tiles	322*	Short or Long	N/A

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Field (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description (D) – Must use the default value	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
TileLength (C)	The tile length (height) in pixels. This is the number of rows in each tile. For Profile: Populate per TIFF specification when opting to use internal tiles	323*	Short or Long	N/A
TileOffsets (C)	For each tile, the byte offset of that tile, as compressed and stored on disk. For Profile: Populate per TIFF specification when opting to use internal tiles	324*	Long	N/A
TileByteCounts (C)	For each tile, the number of (compressed) bytes in that tile. For Profile: Populate when internal tiling is used.	325*	Short or Long	N/A
XResolution (C)	The number of pixels per ResolutionUnit in the ImageWidth direction. For Profile: Not used for GeoTIFF. For TIFF files, populate with intended display resolution	282	RATIONAL	N/A
YResolution (C)	The number of pixels per ResolutionUnit in the ImageLength direction. For Profile: Not used for GeoTIFF. For TIFF files, populate with intended display resolution	283	RATIONAL	N/A
GDAL_NODATA (C)	An ASCII value intended to specify what pixel value is being used to represent missing or background data. For Profile: When the image or elevation dataset has void and/or suspect areas, populate with a value that represents those areas (see Section 7.4).	42113	ASCII	N/A
Geo_Metadata (C)	Additional Geographic metadata information (when opting to place the xml metadata internal to GeoTIFF file)	50909	ASCII	(Contents will comply with ISO 19139 and NSG metadata standards)

A.2 GeoTIFF Data Format

All of the GeoTIFF information is encoded in six tags, and numerous keys are available to store projection parameters and coordinate system information. Use of keys and parameters is constrained as indicated within this profile. All keys are referenced from one tag, the GeoKeyDirectoryTag. The following information is from the GeoTIFF product specification, Revision 1.0, in Section 1: Baseline GeoTIFF. Specific definitions, formats, and codes can be found in GeoTIFF Format Specification, Revision 1.0.

The use of private GeoTIFF tags other than the GDAL_NODATA and Geo_Metadata tags specified above is prohibited by this profile. Additional metadata that may be required by the producer should be included only in the supplemental XML metadata.

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Table A.2 GeoTIFF Tags

GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Core Metadata Element N/A = Not Addressed
GeoKeyDirectoryTag (R)	Stores GeoKey Directory, which defines and references the “GeoKeys.” All Keys in GeoTIFF are referenced from the GeoKeyDirectoryTag	34735	SHORT	N/A
GeoDoubleParamsTag (N)	Used to store all of the DOUBLE valued GeoKeys, referenced by the GeoKeyDirectoryTag For Profile: Do not use this tag, it is unnecessary because as all Double type GeoKeys are prohibited by this profile.	34736	DOUBLE	N/A
GeoAsciiParamsTag (R)	Used to store all of the ASCII valued GeoKeys, referenced by the GeoKeyDirectoryTag	34737	ASCII	N/A
ModelTiepointTag (C)	Stores raster -> model tiepoint pairs in the order ModelTiepointTag = (...),J,K, X,Y,Z...) where (I,J,K) is the point at location (I,J) in raster space with pixel-value K, and (X,Y,Z) is a vector in model space. The Z value is an offset used in conjunction with the Z pixel scale (tag 33550) to position the data vertically. For Profile: Populate this tag with the tie point pair that correlates to the grid origin (grid coordinates 0,0) For imagery and typical elevation data (no offset), set Z=0. Note: This tag must not be used if the image requires rotation (see section 7.2).	33922	DOUBLE	N/A
ModelPixelScaleTag (C)	Used to specify the size of raster pixel spacing in the model space units, consists of the following three values ModelPixelScaleTag = (ScaleX, ScaleY, ScaleZ) For Profile: Populate per GeoTIFF specification; For imagery, set Z=0, for elevation data, set Z=1. Note: This tag must not be used if the image requires rotation (see section 7.2).	33550	DOUBLE	Resource Spatial Resolution
ModelTransformationTag (C)	Used to specify the transformation matrix between the raster space and the model space, it has the following organization: ModelTransformationTag = (a,b,c,d,e,.....,m,n,o,p) For Profile: Use this tag when the image requires rotation in order to be north-oriented (see section 7.2).	34264	DOUBLE	N/A

A.2.1 GeoTIFF Configuration GeoKeys

These keys are to be used to establish the general configuration of a file's coordinate system, including the types of raster coordinate systems, model coordinate systems, and citations.

Table A.2.1 GeoTIFF Configuration GeoKeys

GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
GTModelTypeGeoKey (R)	Defines general type of model coordinate system used, and to which the raster space will be transformed. For Profile: The applicable codes are: 1 – ModelTypeProjected 2 – ModelTypeGeographic	1024	SHORT	N/A
GTRasterTypeGeoKey (R)	Establishes the raster space coordinate system – RasterPixellsPoint, RasterPixellsArea. For Profile: The applicable codes are: 1 – RasterPixellsArea (for imagery) 2 – RasterPixellsPoint (for elevation data)	1025	6.3.1.2 codes	N/A
GTCitationGeoKey (R)	Provided to give an ASCII reference to published documentation on the overall configuration of this GeoTIFF file. For Profile: The ASCII value for this key is: GeoTIFF Revision 1.0, Version 1.8.2, NGA Implementation Profile Version 2.0, <i>FormatSpecification</i> (identify the detailed product specification, if any, used to define this GeoTIFF file).	1026	ASCII	N/A

A.2.2 Geographic Coordinate System Parameter Keys

In general, the coordinate system used will be implied by the projected coordinate system code (Table A.2.3). However, If the model type was chosen to be Geographic (GTModelTypeGeoKey = 2), then the system must be explicitly defined with the following keys: For identification of horizontal and vertical coordinate systems and datums, the GeoTIFF specification lists codes from the European Petroleum Survey Group (EPSG), which has been absorbed into the International Association of Oil and Gas Producers (OGP). The EPSG codes are now maintained on the EPSG online registry at <http://www.epsg-registry.org>. This registry shall be used where possible to identify horizontal and vertical CRS and datums in the Geographic Coordinate System Parameter Keys, specified in Table A.2.2.

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Table A.2.2 Geographic Coordinate System Parameter Keys

GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
GeographicTypeGeoKey (C)	This key may be used to specify the code for the geographic coordinate system used to map lat-long to a specific ellipsoid over the earth. For Profile: Use code from http://www.epsg-registry.org . E.g. 4326 for WGS84, 4030 for WGS84 Ellipsoid only.	2048	SHORT	Reference System
GeogCitationGeoKey (C)	This key provides a general citation and reference for all Geographic CS parameters. For Profile: WGS84, for example, would be 'NIMA TR 8350.2'	2049	ASCII	Reference System
GeogGeodeticDatumGeoKey (N)	This key may be used to specify the horizontal datum, defining the size, position and orientation of the reference ellipsoid used in userdefined geographic coordinate systems. For Profile: Do not use this key.	2050	SHORT	N/A
GeogPrimeMeridianGeoKey (N)	This key allows specification of the location of the Prime meridian for user-defined Geographic coordinate systems. The default standard is Greenwich, England. For Profile: Do not use this key.	2051	SHORT	N/A
GeogLinearUnitsGeoKey (N)	This key allows the definition of geocentric CS linear units for user-defined GCS. For Profile: Do not use this key.	2052	DOUBLE	N/A
GeogLinearUnitSizeGeoKey (N)	Allows the definition of user-defined linear geocentric units, as measured in meters. For Profile: Do not use this key.	2053	DOUBLE	N/A
GeogAngularUnitsGeoKey (N)	This key Allows the definition of geocentric CS Linear units for user-defined GCS and for ellipsoids. For Profile: Do not use this key.	2054	SHORT	N/A
GeogAngularUnitSizeGeoKey (N)	Allows the definition of user-defined angular geographic units, as measured in radians. For Profile: Do not use this key.	2055	DOUBLE	N/A
GeogEllipsoidGeoKey (N)	This key may be used to specify the coded ellipsoid used in the geodetic datum of the Geographic Coordinate System.	2056	SHORT	N/A

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GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
	For Profile: Do not use this key.			
GeogSemiMajorAxisGeoKey (N)	This key allows the specification of user-defined Ellipsoid Semi-Major Axis (a). For Profile: Do not use this key.	2057	DOUBLE	N/A
GeogSemiMinorAxisGeoKey (N)	This key allows the specification of user-defined Ellipsoid Semi-Minor Axis (b). For Profile: Do not use this key.	2058	DOUBLE	N/A
GeogInvFlatteningGeoKey (N)	This key Allows the specification of the inverse of user-defined Ellipsoid's flattening parameter (f). For Profile: Do not use this key.	2059	DOUBLE	N/A
GeogAzimuthUnitsGeoKey (N)	This key This key may be used to specify the angular units of measurement used to defining azimuths, in geographic coordinate systems. These may be used for defining azimuthal parameters for some projection algorithms, and may not necessarily be the same angular units used for lat-long. For Profile: Do not use this key.	2060	SHORT	N/A
GeogPrimeMeridianLongGeoKey (N)	This key allows definition of user-defined Prime Meridians, the location of which is defined by its longitude relative to Greenwich. For Profile: Do not use this key.	2061	DOUBLE	N/A

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A.2.3 Projected Coordinate System Parameter Keys

Table A.2.3 Projected Coordinate System Parameter Keys

GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
ProjectedCSTypeGeoKey (C)	This code is provided to specify the projected coordinate system. For Profile: UTM projected coordinate systems are allowed Use code from http://www.epsg-registry.org . E.g. 32610 for UTM zone 10 North on WGS 84	3072	SHORT	MD_ReferenceSystem. ReferenceSystemIdentifier.RS_idenfifer.code
PCSCitationGeoKey (C)	This key is provided to give an ASCII reference to published documentation on the Projected Coordinate System. For Profile: When UTM on WGS 84 is used, the ASCII value for this key is: 'UTM Grid System [NIMA TM 8358.2] Note: units (meters) are implicit in the CS Type'	3073	ASCII	N/A
ProjectionGeoKey (N)	This key allows specification of the coordinate transformation method and projection zone parameters. For Profile: Do not use this key.	3074	SHORT	N/A
ProjCoordTransGeoKey (N)	This key allows specification of the coordinate transformation method used. For Profile: Do not use this key.	3075	SHORT	N/A
ProjLinearUnitsGeoKey (N)	This key defines the linear units used by the projection For Profile: Do not use this key	3076	SHORT	N/A
ProjLinearUnitSizeGeoKey (N)	This key defined the size of user-defined linear units in meters. For Profile: Do not use this key.	3077	DOUBLE	N/A
ProjStdParallel1GeoKey (N)	This key specifies the latitude of the primary standard parallel. For Profile: Do not use this key.	3078	DOUBLE	N/A
ProjStdParallel2GeoKey (N)	This key specifies the latitude of the second standard parallel. For Profile: Do not use this key.	3079	DOUBLE	N/A
ProjNatOriginLongGeoKey (N)	This key defines the longitude of the map projection natural origin. For Profile: Do not use this key.	3080	DOUBLE	N/A

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ProjNatOriginLatGeoKey (N)	This key defines the latitude of the map projection natural origin. For Profile: Do not use this key.	3081	DOUBLE	N/A
ProjFalseEastingGeoKey (N)	This key provides the easting coordinate of the map projection natural origin. For Profile: Do not use this key.	3082	DOUBLE	N/A
ProjFalseNorthingGeoKey (N)	This key provides the northing coordinate of the map projection natural origin. For Profile: Do not use this key.	3083	DOUBLE	N/A
ProjFalseOriginLongGeoKey (N)	This key provides the longitude of the false origin. For Profile: Do not use this key.	3084	DOUBLE	N/A
ProjFalseOriginLatGeoKey (N)	This key provides the latitude of the false origin For Profile: Do not use this key.	3085	DOUBLE	N/A
ProjFalseOriginEastingGeoKey (N)	This key provides the easting coordinate of the false origin. For Profile: Do not use this key.	3086	DOUBLE	N/A
ProjFalseOriginNorthingGeoKey (N)	This key provides the northing coordinate of the false origin. For Profile: Do not use this key.	3087	DOUBLE	N/A
ProjCenterLongGeoKey (N)	This key provides the longitude of the center of the projection (not necessarily the origin). For Profile: Do not use this key.	3088	DOUBLE	N/A
ProjCenterLatGeoKey (N)	This key provides the latitude of the center of the projection (not necessarily the origin). For Profile: Do not use this key.	3089	DOUBLE	N/A
ProjCenterEastingGeoKey (N)	This key provides the easting coordinate of the center. For Profile: Do not use this key.	3090	DOUBLE	N/A
ProjCenterNorthingGeoKey (N)	This key provides the northing coordinate of the center. For Profile: Do not use this key.	3091	DOUBLE	N/A

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GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
ProjScaleAtNatOriginGeoKey (N)	This key provides the scale at the natural origin as a ratio. For Profile: Do not use this key.	3092	DOUBLE	N/A
ProjScaleAtCenterGeoKey (N)	This key provides the scale at the projection center as a ratio. For Profile: Do not use this key.	3093	DOUBLE	N/A
ProjAzimuthAngleGeoKey (N)	This key provides the azimuth angle east of true north of the central line passing through the projection center. For Profile: Do not use this key.	3094	DOUBLE	N/A
ProjStraightVertPoleLongGeoKey (N)	This key provides the longitude at the straight vertical pole for Polar Stereographic projections. For Profile: Do not use this key.	3095	DOUBLE	N/A

A.2.4 Vertical CS Parameter Keys

Table A.2.4: Vertical CS Parameter Keys

GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
VerticalCSTypeGeoKey (C)	This key may be used to specify the vertical coordinate system. For Profile: 4979 – WGS_84_ellipsoid 3855 – EGM 2008 geoid 5773 – EGM96 geoid 5798 – EGM84 geoid 32767 – user defined Note: The 'user defined' code shall be used when using a hydrographic datum. The VerticalCitationGeoKey shall be used to identify the coordinate system/datum for the user defined case.	4096	SHORT (Code from EPSG Registry, except user defined, from GeoTIFF spec section 6.3.4.2)	Reference System

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GeoTIFF Tag (R) – Required (O) – Optional (N) – Do Not Use (C) – Conditional	Description	Tag	Type	NSG Metadata Element N/A = Not Addressed
VerticalCitationGeoKey (C)	This key may be used to document the vertical coordinate system used, and its parameters. For Profile: Valid ASCII values for this key are: WGS84 Ellipsoid [NIMA TR8350.2] EGM84/96 [NIMA TR8350.2] EGM 2008 [http://earth-info.nga.mil/GandG/wgs84/gravitymod/egm2008/index.html] (hydrographic datum name): [NOAA Special Publication NOS CO-OPS 1]	4097	ASCII	N/A
VerticalDatumGeoKey (N)	This key may be used to specify the vertical datum for the vertical coordinate system. For Profile: Do not use this key. Note: There are no established codes for this key.	4098	SHORT	N/A
VerticalUnitsGeoKey (C)	This key may be used to specify the vertical units of measurement used in the geographic coordinate system, in cases where geographic CS's needs to reference the vertical coordinate. This, together with the Citation key, comprises the only fully implemented keys in this section, at present. For Profile: 9001 – Linear_Meter	4099	SHORT (Code from Section 6.3.1.3)	N/A

Appendix B Additional Data and Metadata

B.1 NSG Metadata Requirements

Since the popular use of TIFF/GeoTIFF does not support expression of NSG-required metadata, additional metadata to be associated with each GeoTIFF file is required by this profile. This additional metadata shall conform to the NSG Metadata Foundation (NMF) Part 1: Conceptual Schema Model, which defines the conceptual schema profile for specifying geospatial metadata in and for the NSG. The goal of the NMF is to support the data discovery needs of the NSG by requiring metadata elements from both international standards and domestic specifications. The NMF is a profile of ISO 19115:2003/Cor 1:2006, where the ISO core metadata requirements are extended to include, for example, metadata elements necessary to support Intelligence Community security policy. The domain of ISO 19115 and the NMF Profile is a group of data elements that enable the discovery of the data being described. This 'discovery metadata' provides the 'who, what, where, when, and why' information that will assist consumers in locating an individual TIFF/GeoTIFF file when it is part of a large geospatial database.

The NMF Section 6 specifies that core metadata requirements can be extended with additional ISO 19115 and 19115-2 (imagery and gridded data) elements. If necessary, additional metadata elements and entities not described by ISO can be used to extend the MD_Metadata class documented in ISO 19115.

The NMF allows for the documentation of application-specific profiles of the NMF. Profiles of the NMF Conceptual Schema Profile shall conform to the requirements and provisions of NMF Section 7, Profiling the NMF Conceptual Schema. Application or implementation of approved NMF profiles shall conform to the obligations and business rule constraints established by the profile.

B.2 XML Encoding Requirement

B.2.1 Minimum XML Metadata

The minimum metadata requirements of this profile are XML encoding and compliance with the NMF conceptual schema. When NMF core metadata elements (without extensions) are sufficient to meet the information content requirements of the TIFF/GeoTIFF dataset, this profile requires an associated XML file that is compliant with the NSG Metadata Implementation Specification (NMIS) Part 2 – XML Exchange Schema. The NMIS – Part 2 specifies an XML grammar written in XML Schema (XSD) based on the requirements established in the NMF Part 1. Both documents are available at <https://nsgreg.nga.mil/registers.jsp>.

The NMIS applies, in its encoding schema, the following standards:

- ISO/TS 19139:2007 *Metadata – XML schema implementation*;
- ISO 19136:2007 *Geographic Markup Language (GML)*; and
- XML Data Encoding Specification for Information Security Marking Metadata, Version 4 (DES.ISM.XML.V4).

B.2.2 Extensions to NMF Core Elements in XML

ISO/TS 19139 provides an XML schema for ISO 19115 metadata elements. It currently does not provide an XML schema for the ISO 19115-2 metadata elements, which allow for a more extensive description of imagery and gridded data. Additionally, the NMIS schematron rules restrict instance documents to NMF core elements only. When there is a requirement for additional ISO 19115 elements, 19115-2 elements, or any other extensions to the NMF core, this profile recommends that the NMIS schema be imported into a higher-order schema document. However, implementers of this profile may find it more practical to use ISO schema documents directly without importing the NMF core elements via the NMIS schema document. In this case, compliance with the NMF conceptual model is still required, and the NMF rules and codelists must be employed.

B.2.3 Optional Embedding of the XML Instance Document

The XML metadata may be carried external to the TIFF/GeoTIFF file in one or more separate XML files, or may be embedded within the TIFF/GeoTIFF file using the profile-designated private TIFF tag (50909). Some of the metadata elements required by the NMF/NMIS correspond with TIFF and GeoTIFF fields described in Appendix A. This redundancy is intentional, so that when the discovery mechanism is applied to the XML data only, the TIFF/GeoTIFF consumer will benefit from a more complete description of the data file.

B.3 Other NSG TIFF/GeoTIFF Support Data

The XML-based encoding of the application schema specified by the NMIS is intended to integrate with the NSG Application Schema (NAS). In particular, it is a module (sub-schema) of the NAS and may be used to encode metadata associated with the NAS [EntityCollection] and [Dataset] information entities.

When additional support data, other than metadata, is provided with the NSG TIFF/GeoTIFF file, it shall also be encoded in XML and shall conform to the NAS. Documentation of the NAS is also available at <https://nsgreg.nga.mil/registers.jsp>.

B.4 NMIS-Compliant Metadata Example

A generic orthorectified image could include the following example metadata. The human-readable example in B.4.1 is merely an outline that denotes a simple view of how the necessary elements are reported. NMF metadata element names are used, as opposed to the equivalent ISO names. These elements are all within the scope of 'discovery' metadata, as the current version of the NMF does not provide an extension for the imagery-specific elements addressed in ISO 19115-2. In section B.4.2, the equivalent xml instance is provided.

B.4.1 Human-Readable Metadata Example

+ Metadata Entity Set Information

metadata file identifier: **SensorX01_-090.40000000_+38.80000000_19971209_13002028.xml** (Optional)

metadata language: **eng** (Conditional / Mandatory when not defined by encoding)

metadata character set: **utf8** (Optional)

heirarchy level: **dataset** (Mandatory)

hierarchy level name: **cell** (Mandatory)

metadata point of contact:

organization name: **US National Geospatial-Intelligence Agency** (Mandatory)

telephone number: **+1 314 555 1234** (Optional)

delivery point: **3200 S. Second St.** (Optional)

city: **St. Louis** (character string) (Optional)

administrative Area: **MO** (character string) (Optional)

postal code: **63118** (character string) (Optional)

country: **US** (code) (Optional)

role: **originator** (code) (Mandatory)

metadata date stamp: **2011-04-16** (date) (Mandatory)

metadata standard name: **NSG Metadata Foundation (NMF)** (character string) (Mandatory)

metadata standard version: **2.0.0** (character string) (Mandatory)

metadata constraints:

security classification: **unclassified** (code) (Mandatory)

security classification system: **US CAPCO** (Mandatory)

+ Data Identification Information:

citation:

resource title: **SensorX01_-090.40000000_+38.80000000_19971209_13002028.tif** (character string) (Mandatory)

resource date: **2011-04-16** (date) (Mandatory)

resource date type: **creation** (code) (Mandatory)

resource abstract: **Panchromatic orthoimage of St. Louis, MO** (character string) (Mandatory)

resource originator: (at least one of 'individual', 'organization', or 'position') (Mandatory)

organization name: **US National Geospatial-Intelligence Agency** (character string) (Conditional)
role: **originator** (code) (Mandatory)
resource point of contact: (Mandatory)
organization name: **NGA Customer Help Desk** (character string) (Conditional, at least one of 'individual', 'organization', or 'position')
telephone number: **+1 800 555 1234** (character string) (Optional)
role: **point of contact** (code) (Mandatory)
distribution format: (Optional)
name: **GeoTIFF Rev1.0** (character string) (Mandatory)
format version: **1.8.2** (character string) (Mandatory)
distributor: **NGA** (Optional)
transfer size: **75.3** (real) (Optional)
compression: **uncompressed** (character string) (Optional) (Required in baseline TIFF field)
keywords: **imagery, orthoimage** (character string) (Mandatory)
quality: (Optional)
scope level: **dataset** (code) (Mandatory if quality info is described)
name of measure: **horizontal accuracy** (character string) (Optional)
result: **5** (character string) (Mandatory)
result unit: **meters** (character string) (Mandatory)
resource constraints:
security classification: **unclassified** (code) (Mandatory)
security classification system: **US CAPCO** (Mandatory)
rights: **copyright** (code) (Optional)
spatial representation type: **grid** (code) (Optional)
reference system: **Geographic on WGS-84** (code) (Mandatory for GeoTIFF)
resource spatial resolution: (equivalent scale or distance) (Optional)
equivalent scale: **17000** (character string)
resource language: **eng** (character string) (code=eng) (Mandatory)
resource character set: **utf8** (code) (Mandatory)
resource topic category: **imagery** (code) (Mandatory if hierarchy level = 'dataset')
geographic location: (bounding box or description) (Mandatory)
bounding box:
west longitude: **-90.4** (decimal degrees)
east longitude: **-90.2** (decimal degrees)
south latitude: **38.6** (decimal degrees)
north latitude: **38.8** (decimal degrees)
description: **Missouri**

B.4.2 XML Instance Document for Metadata Example

This example xml instance validates against NMIS 2.0.

```
<?xml version="1.0" encoding="UTF-8"?>
<nas:MD_Metadata xmlns:nas="http://metadata.ces.mil/mdr/ns/GSIP/3.0/nas" xmlns:gmd="http://www.isotc211.org/2005/gmd"
xmlns:gco="http://www.isotc211.org/2005/gco" xmlns:gml="http://www.opengis.net/gml/3.2" xmlns:xlink="http://www.w3.org/1999/xlink"
xmlns:ism="urn:us:gov:ic:ism" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://metadata.ces.mil/mdr/ns/GSIP/3.0/nas http://metadata.ces.mil/mdr/ns/GSIP/nmis/2.0.0/nmis.xsd" ism:DESVersion="4"
ism:resourceElement="true" ism:createDate="2011-04-18" ism:classification="U" ism:ownerProducer="USA">
```

<!-- Note that it is necessary to add XML attributes to the root node in order to correctly support ISM.XML. The root node of any ISM.XML-conformant instance document must specify the version of ISM.XML used. Additionally, there must be a node that is identified as the "resource node" that would be used to generate banner marks and the E.O. 12958 classification authority block. The MD_Metadata node serves as the "resource node" and thus must carry, at a minimum, the necessary identification, createDate, classification, and ownerProducer XML attributes.

- The value of createDate shall be the same as that for the <gmd:dateStamp><gco:Date> XML element.
- The values of classification, ownerProducer and any additional ISM.XML attributes shall be based on those assigned for the corresponding gmd:metadataConstraints/nas:MD_SecurityConstraints/nas:capcoMarking and gmd:identificationInfo/nas:MD_DataIdentification/gmd:resourceConstraints/nas:MD_SecurityConstraints/nas:capcoMarking XML attributes as determined by applicable banner and E.O. 12958 classification authority block marking requirements.

-->

```
<!-- Data Content Hierarchy Level: In this example we suppose that this metadata record documents one image in an orthoimage series. -->
<gmd:hierarchyLevel>
  <gmd:MD_ScopeCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/ScopeCode" codeListValue="dataset"/>
</gmd:hierarchyLevel>
<gmd:hierarchyLevelName>
  <nas:ScopeAmplificationCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/ScopeAmplificationCode" codeListValue="cell"/>
</gmd:hierarchyLevelName>
<!-- Resource Metadata Contact: This is the preparer of this metadata record. -->
<gmd:contact>
  <gmd:CI_ResponsibleParty>
    <gmd:organisationName>
      <gco:CharacterString>US National Geospatial-Intelligence Agency</gco:CharacterString>
    </gmd:organisationName>
    <gmd:role>
      <gmd:CI_RoleCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/RoleCode" codeListValue="originator"/>
    </gmd:role>
```

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```
</gmd:CI_ResponsibleParty>
</gmd:contact>
<!-- Metadata Date Stamp: This is the date that this metadata record was prepared (and its content known to be accurate). -->
<gmd:dateStamp>
  <gco:Date>2011-04-16</gco:Date>
</gmd:dateStamp>
<!-- Resource Metadata Standard: This is the metadata specification with regards to which this metadata record is valid.
It is a Recommended Best Practice to use the full name of the metadata standard in order to eliminate ambiguity.
It may be the case that an extension of the NMIS was used and therefore these values may vary. -->
<gmd:metadataStandardName>
  <nas:MetadataStandardNameCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/MetadataStandardNameCode"
codeListValue="nsgMetadataFoundation"/>
</gmd:metadataStandardName>
<gmd:metadataStandardVersion>
  <nas:MetadataStandardVersion>2.0.0</nas:MetadataStandardVersion>
</gmd:metadataStandardVersion>
<!-- Resource Metadata String Localization Information: It is a Recommended Best Practice to explicitly specify
the "locale" of all string-values used in this metadata record. If this information is omitted then it shall be the
case that the string-values are all specified in terms of U.S. English using the UTF-8 character encoding. -->
<gmd:locale>
  <gmd:PT_Locale>
    <gmd:languageCode>
      <gmd:LanguageCode codeList="http://metadata.ces.mil/mdr/ns/GPAS/codelist/iso639-2" codeListValue="eng"/>
    </gmd:languageCode>
    <gmd:country>
      <gmd:Country codeList="http://metadata.ces.mil/mdr/ns/GPAS/codelist/iso3166-1/trigraph" codeListValue="USA"/>
    </gmd:country>
    <gmd:characterEncoding>
      <gmd:MD_CharacterSetCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/CharacterSetCode" codeListValue="utf8"/>
    </gmd:characterEncoding>
  </gmd:PT_Locale>
</gmd:locale>
<!-- Data Content Reference System(s) Information: This specifies the spatial-temporal reference system(s) used
by the Data Content described by this metadata record. These shall always be specified based on the
dynamic resources hosted in the DoD Metadata Registry at: http://metadata.ces.mil/mdr/ns/GSIP/crs -->
<gmd:referenceSystemInfo>
  <gmd:MD_ReferenceSystem>
    <gmd:referenceSystemIdentifier>
      <!-- Both the gmd:code and gmd:codeSpace shall be specified. -->
      <gmd:RS_Identifier>
```

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```
<gmd:code>
  <gco:CharacterString>WGS84E_2D</gco:CharacterString>
</gmd:code>
<gmd:codeSpace>
  <gco:CharacterString>http://metadata.ces.mil/mdr/ns/GSIP/crs</gco:CharacterString>
</gmd:codeSpace>
</gmd:RS_Identifier>
</gmd:referenceSystemIdentifier>
</gmd:MD_ReferenceSystem>
</gmd:referenceSystemInfo>
<!-- Data Content Identification Information: The metadata specifically about the Data Content. -->
<gmd:identificationInfo>
  <nas:MD_DataIdentification>
    <gmd:citation>
      <gmd:CI_Citation>
        <gmd:title>
          <gco:CharacterString>SensorX01_-090.40000000_+38.80000000_19971209_13002028.tif</gco:CharacterString>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2011-04-16</gco:Date>
            </gmd:date>
            <!-- Resource Date Type: For imagery, the collection date is specified by setting DateTypeCode = 'creation'. A
processing date can be reflected by setting DateTypeCode = 'revision' -->
            <gmd:dateType>
              <gmd:CI_DateTypeCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/DateTypeCode"
codeListValue="creation"/>
            </gmd:dateType>
          </gmd:CI_Date>
        </gmd:date>
      </gmd:CI_Citation>
    </gmd:citation>
    <gmd:abstract>
      <gco:CharacterString>Panchromatic orthoimage of St. Louis, MO</gco:CharacterString>
    </gmd:abstract>
    <gmd:pointOfContact>
      <gmd:CI_ResponsibleParty>
        <gmd:organisationName>
          <gco:CharacterString>US National Geospatial-Intelligence Agency</gco:CharacterString>
        </gmd:organisationName>
      </gmd:CI_ResponsibleParty>
    </gmd:pointOfContact>
  </nas:MD_DataIdentification>
</gmd:identificationInfo>
```

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```
</gmd:organisationName>
<gmd:contactInfo>
  <gmd:CI_Contact>
    <gmd:phone>
      <gmd:CI_Telephone>
        <gmd:voice>
          <!-- An "internationalized" telephone number as specified in ITU-T Recommendation E.123 Clause 2. -->
          <nas:TelephoneNumber>+1 314 555 1234</nas:TelephoneNumber>
        </gmd:voice>
      </gmd:CI_Telephone>
    </gmd:phone>
    <gmd:address>
      <gmd:CI_Address>
        <gmd:deliveryPoint>
          <gco:CharacterString>3200 S. Second St.</gco:CharacterString>
        </gmd:deliveryPoint>
        <gmd:city>
          <gco:CharacterString>St. Louis</gco:CharacterString>
        </gmd:city>
        <gmd:administrativeArea>
          <gco:CharacterString>MO</gco:CharacterString>
        </gmd:administrativeArea>
        <gmd:postalCode>
          <gco:CharacterString>63118</gco:CharacterString>
        </gmd:postalCode>
        <gmd:country>
          <gco:CharacterString>US</gco:CharacterString>
        </gmd:country>
      </gmd:CI_Address>
    </gmd:address>
  </gmd:CI_Contact>
</gmd:contactInfo>
<gmd:role>
  <gmd:CI_RoleCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/RoleCode" codeListValue="originator"/>
</gmd:role>
</gmd:CI_ResponsibleParty>
</gmd:pointOfContact>
<gmd:resourceFormat>
  <gmd:MD_Format>
    <gmd:name>
```

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```
<gco:CharacterString>GeoTIFF Rev. 1.0</gco:CharacterString>
</gmd:name>
<gmd:version>
  <gco:CharacterString>1.8.2</gco:CharacterString>
</gmd:version>
<gmd:fileDecompressionTechnique>
  <gco:CharacterString>uncompressed</gco:CharacterString>
</gmd:fileDecompressionTechnique>
<gmd:formatDistributor>
  <gmd:MD_Distributor>
    <gmd:distributorContact>
      <gmd:CI_ResponsibleParty>
        <gmd:organisationName>
          <gco:CharacterString>NGA</gco:CharacterString>
        </gmd:organisationName>
        <gmd:role>
          <gmd:CI_RoleCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/RoleCode"
codeListValue="distributor"/>
        </gmd:role>
      </gmd:CI_ResponsibleParty>
    </gmd:distributorContact>
    <gmd:distributorTransferOptions>
      <gmd:MD_DigitalTransferOptions>
        <gmd:transferSize>
          <gco:Real>75.3</gco:Real>
        </gmd:transferSize>
      </gmd:MD_DigitalTransferOptions>
    </gmd:distributorTransferOptions>
  </gmd:MD_Distributor>
</gmd:formatDistributor>
</gmd:MD_Format>
</gmd:resourceFormat>
<!-- Data Content Thematic Keyword(s): Two thematic keywords are identified from a specified thesaurus. -->
<gmd:descriptiveKeywords>
  <gmd:MD_Keywords>
    <gmd:keyword>
      <gco:CharacterString>imagery</gco:CharacterString>
    </gmd:keyword>
    <gmd:keyword>
      <gco:CharacterString>orthoimage</gco:CharacterString>
    </gmd:keyword>
  </gmd:MD_Keywords>
</gmd:descriptiveKeywords>
```

```

    </gmd:keyword>
    <gmd:type>
      <gmd:MD_KeywordTypeCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/KeywordTypeCode"
codeListValue="theme"/>
    </gmd:type>
    <gmd:thesaurusName>
      <gmd:CI_Citation>
        <gmd:title>
          <gco:CharacterString>ISO/TC 211 Terminology spread sheet, edition 29</gco:CharacterString>
        </gmd:title>
        <gmd:date>
          <gmd:CI_Date>
            <gmd:date>
              <gco:Date>2011-01-17</gco:Date>
            </gmd:date>
            <gmd:dateType>
              <gmd:CI_DateTypeCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/DateTypeCode"
codeListValue="publication"/>
            </gmd:dateType>
          </gmd:CI_Date>
        </gmd:date>
      </gmd:CI_Citation>
    </gmd:thesaurusName>
  </gmd:MD_Keywords>
</gmd:descriptiveKeywords>
  <!-- Data Content Security Constraint(s): This specifies any restrictions applicable to the data content itself.
It is required that the CAPCO Marking information be specified and that the corresponding value of the ISO 19115
classification and classificationSystem be specified so that in the case that the CAPCO Marking is removed
that the remaining security constraint specification be unambiguous. -->
  <gmd:resourceConstraints>
    <nas:MD_SecurityConstraints>
      <gmd:classification>
        <gmd:MD_ClassificationCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/ClassificationCode"
codeListValue="unclassified"/>
      </gmd:classification>
      <!-- In the case of CAPCO markings the classification system must be "US CAPCO"
and the DES.ISM.XML attributes populated accordingly. -->
      <gmd:classificationSystem>
        <nas:ClassificationSystem>US CAPCO</nas:ClassificationSystem>
      </gmd:classificationSystem>
    </nas:MD_SecurityConstraints>
  </gmd:resourceConstraints>

```

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```
        <nas:capcoMarking ism:classification="U" ism:ownerProducer="USA"/>
    </nas:MD_SecurityConstraints>
</gmd:resourceConstraints>
<gmd:resourceConstraints>
    <gmd:MD_LegalConstraints>
        <gmd:useConstraints>
            <gmd:MD_RestrictionCode codeListValue="copyright"
codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/RestrictionCode"/>
        </gmd:useConstraints>
    </gmd:MD_LegalConstraints>
</gmd:resourceConstraints>
<gmd:spatialRepresentationType>
    <gmd:MD_SpatialRepresentationTypeCode codeListValue="grid"
codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/SpatialRepresentationTypeCode">
</gmd:MD_SpatialRepresentationTypeCode>
</gmd:spatialRepresentationType>
<gmd:spatialResolution>
    <gmd:MD_Resolution>
        <gmd:equivalentScale>
            <gmd:MD_RepresentativeFraction>
                <gmd:denominator>
                    <gco:Integer>17000</gco:Integer>
                </gmd:denominator>
            </gmd:MD_RepresentativeFraction>
        </gmd:equivalentScale>
    </gmd:MD_Resolution>
</gmd:spatialResolution>
    <!-- Data Content String Localization Information: It is a Recommended Best Practice to explicitly specify
the "locale" of all string-values used in the Data Content resource. In the NSG it is anticipated that all data
resources will at least employ U.S. English using the UTF-8 character encoding for specifying string-values,
however in a coalition environment or where data content is based on open sources and/or legacy data
resources, other languages, country-specific language localizations, and character sets may be employed. -->
    <gmd:language>
        <nas:LanguageCode codeList="http://metadata.ces.mil/mdr/ns/GPAS/codelist/iso639-2" codeListValue="eng"/>
    </gmd:language>
    <gmd:characterSet>
        <gmd:MD_CharacterSetCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/CharacterSetCode" codeListValue="utf8"/>
    </gmd:characterSet>
    <!-- Data Content Topic Category(ies): As specified by ISO 19115, these topic categories furnish a very high-level
means to discover geospatial data across the entire international community, including coalition forces/systems. -->
```

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```
<gmd:topicCategory>
  <gmd:MD_TopicCategoryCode>imageryBaseMapsEarthCover</gmd:MD_TopicCategoryCode>
</gmd:topicCategory>
<gmd:topicCategory>
  <gmd:MD_TopicCategoryCode>intelligenceMilitary</gmd:MD_TopicCategoryCode>
</gmd:topicCategory>
<!-- Data Content Spatio-temporal Extent: Specify the extent of the Data Content in terms of a minimum
bounding rectangle (MBR) within which the data content is spatially located, however for greater
accuracy a polygon specifying the exact extent within that MBR is also specified. -->
<gmd:extent>
  <gmd:EX_Extent>
    <!-- Note that, as specified by ISO 19115, this is only an approximate reference intended principally
for the purposes of data discovery therefore specifying the coordinate reference system is unnecessary.
It is a Recommended Best Practice, however, that the WGS84 Ellipsoid be used as the
horizontal datum when preparing values for this use. -->
    <gmd:geographicElement>
      <gmd:EX_GeographicBoundingBox>
        <gmd:westBoundLongitude>
          <gco:Decimal>-90.4</gco:Decimal>
        </gmd:westBoundLongitude>
        <gmd:eastBoundLongitude>
          <gco:Decimal>-90.2</gco:Decimal>
        </gmd:eastBoundLongitude>
        <gmd:southBoundLatitude>
          <gco:Decimal>38.6</gco:Decimal>
        </gmd:southBoundLatitude>
        <gmd:northBoundLatitude>
          <gco:Decimal>38.8</gco:Decimal>
        </gmd:northBoundLatitude>
      </gmd:EX_GeographicBoundingBox>
    </gmd:geographicElement>
    <!-- Other informal methods may be used to describe the spatial-temporal extent of the data resource content.
One approach leverages ISO 3166 as a gazetteer of countries and their administrative divisions. -->
    <gmd:geographicElement>
      <gmd:EX_GeographicDescription>
        <gmd:geographicIdentifier>
          <!-- Reference to the ISO 3166-2 standard for codes of administrative divisions. The referenced authority
is a MDR-hosted online resource against which the specified code can be dynamically verified
(and its meaning determined). -->
          <gmd:MD_Identifier>
```

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```
<gmd:authority xlink:href="http://metadata.ces.mil/mdr/ns/GPAS/codelist/iso3166-2"/>
  <gmd:code>
    <gco:CharacterString>US-MO</gco:CharacterString>
  </gmd:code>
</gmd:MD_Identifier>
</gmd:geographicIdentifier>
</gmd:EX_GeographicDescription>
</gmd:geographicElement>
</gmd:EX_Extent>
</gmd:extent>
<!-- Remaining Data Content String Localization Information: The last (third) component of the string-localization
triple of characteristics. Specifies the country of the language in order to be able to discriminate, e.g.,
U.S. English from U.K. English, or Canadian French from Senegalese French. -->
  <nas:languageCountry>
    <nas:LanguageCountryCode codeList="http://metadata.ces.mil/mdr/ns/GPAS/codelist/iso3166-1/trigraph" codeListValue="USA"/>
  </nas:languageCountry>
</nas:MD_DataIdentification>
</gmd:identificationInfo>
<gmd:dataQualityInfo>
  <gmd:DQ_DataQuality>
    <gmd:scope>
      <gmd:DQ_Scope>
        <gmd:level>
          <gmd:MD_ScopeCode codeListValue="dataset" codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/ScopeCode"/>
        </gmd:MD_ScopeCode>
        </gmd:level>
      </gmd:DQ_Scope>
    </gmd:scope>
  </gmd:report>
  <gmd:DQ_GridDEDataPositionalAccuracy>
    <gmd:nameOfMeasure>
      <gco:CharacterString>Horizontal Accuracy</gco:CharacterString>
    </gmd:nameOfMeasure>
    <gmd:result>
      <gmd:DQ_QuantitativeResult>
        <gmd:valueUnit>
          <gml:UnitDefinition gml:id="metre">
            <gml:identifier codeSpace="http://metadata.ces.mil/mdr/ns/GSIP/uom/length"/>
          </gml:UnitDefinition>
        </gmd:valueUnit>
```

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```

    <gmd:value>
      <gco:Record>
        <gco:Integer>5</gco:Integer>
      </gco:Record>
    </gmd:value>
  </gmd:DQ_QuantitativeResult>
</gmd:result>
</gmd:DQ_GriddedDataPositionalAccuracy>
</gmd:report>
</gmd:DQ_DataQuality>
</gmd:dataQualityInfo>
<!-- Resource Metadata Constraint(s): This specifies any restrictions applicable to the content of this metadata record.
It is required that the CAPCO Marking information be specified and that the corresponding value of the ISO 19115
classification and classificationSystem be specified so that in the case that the CAPCO Marking is removed
that the remaining security constraint specification be unambiguous. -->
<gmd:metadataConstraints>
  <nas:MD_SecurityConstraints>
    <gmd:classification>
      <gmd:MD_ClassificationCode codeList="http://metadata.ces.mil/mdr/ns/GSIP/codelist/ClassificationCode"
codeListValue="unclassified"/>
    </gmd:classification>
    <!-- In the case of CAPCO markings the classification system must be "US CAPCO"
and the DES.ISM.XML attributes populated accordingly. -->
    <gmd:classificationSystem>
      <nas:ClassificationSystem>US CAPCO</nas:ClassificationSystem>
    </gmd:classificationSystem>
    <nas:capcoMarking ism:classification="U" ism:ownerProducer="USA"/>
  </nas:MD_SecurityConstraints>
</gmd:metadataConstraints>
</nas:MD_Metadata>
```

Appendix C Abstract Test Suite

C.1 Purpose, Scope, and Methodology

C.1.1 Purpose

To determine the extent a system or product conforms to this profile for the interpretation and generation of GeoTIFF and supplemental metadata files as constrained by this implementation profile.

C.1.2 Scope

Conformance testing will focus on the GeoTIFF features and supplemental metadata capabilities of the tested system or product. Testers will check for conformance with this profile and also with the standards and specifications that were used as normative documents in the construction of this profile. The intent is to provide a high level of confidence that an implementation conforms to the profile. The term 'GeoTIFF' as used within the context of this appendix generally means TIFF, GeoTIFF and supplemental metadata as specified by this profile.

C.1.3 Methodology

The GeoTIFF testing methodology uses a combination of test cases designed to address the ability of the Implementation Under Test (IUT) to interpret and/or generate GeoTIFF compliant data files. The test sponsor fills out the Implementation Conformance Statements (ICS) shown in E.2. The tester uses this information to design the test scenarios and set of test cases to be used in the test campaign. The test scenarios and test cases exercise the following test strategy:

Interpret: The interpret portion of GeoTIFF compliance testing determines the degree to which a GeoTIFF application can properly interpret GeoTIFF formatted files. Interpret applications, at a minimum, must be robust enough to unpack, interpret, and display any GeoTIFF compliant file. The content of the TIFF and GeoTIFF tags may be displayed along with the image data or may be accessed separately in the interpreter. Testers present the IUT with test case files designed to exercise the minimum required capabilities for all interpret applications. Testers also present the IUT with test case files designed to exercise the optional GeoTIFF features the IUT is required to support as designated by the test sponsor.

Generate: The generate portion of GeoTIFF compliance testing determines whether the GeoTIFF files generated by the IUT are fully compliant with the profile. For generate testing, the test sponsor designates the specific GeoTIFF capabilities and features the IUT is required to support for generation of GeoTIFF files. Testers design test scenarios for production of GeoTIFF files (test cases) that exercise the required capabilities and features against the applicable test criteria. The IUT operator generates test case files under the guidance of these test scenarios. The testers evaluate the output test case files for compliance with the applicable portions of the GeoTIFF profile using automated test tools (when available) and visual inspection.

Data Conformance: Criteria used in the test campaign to evaluate data conformance include:

1. Completeness: checks for presence of mandatory (required) elements. A comparison test shall also be performed to determine if all tags/keys/elements defined as conditional are present when the conditions described in the profile apply.
2. Prohibited Elements: checks for the presence of any tags/keys/elements that are not allowed by the profile, including the presence of conditional elements when the condition does not exist.
3. Maximum occurrence (XML metadata only, all levels of obligation): ensures each metadata element occurs no more than the number of times specified in this profile.
4. Data Type (XML metadata only, all levels of obligation): the value of each provided metadata element is tested to ensure its data type adheres to the data type specified.
5. Domain (XML metadata only, all levels of obligation): the values of each metadata element are tested to ensure they fall within the specified domain.
6. Schema (XML metadata only, all levels of obligation): test each metadata element and ensure it is contained within the specified schema entity.

Note 1: Minimum conformance requires that the supplemental metadata instance (XML) documents can be validated without error against the XML schemas allowed by this profile. While many tools are available to test validation of XML instance documents against the allowed schemas, it is important to understand that not all validation tools implement the full W3C XML Schema recommendation and not all validation tools interpret the W3C XML Schema recommendation in the same manner. It is recommended that a tool with strict interpretation of XML Schema and full support for the W3C XML Schema recommendation be used to ensure conformance.

Note 2: Validation of XML instance documents against the schemas allowed by this profile is not all that is required for conformance to this specification. A property element is designed to have content (by-value) or attributes (by-reference or NULL with reason). However, because of the design, the property element may have no content or attributes, or it may have both content and attributes and still be XML Schema-valid. It is not possible to constrain the co-occurrence of content or attributes. Some mechanism in addition to an XML Schema validation must be used to restrict a property to be exclusively by-value, or by-reference, or expressing a NULL reason.

Note 3: XML Schema does not support the enforcement of certain types of constraints documented in this profile. For example, The NMIS (see B2) includes schematron rules that add conditional constraints that are not enforceable within XML schema. Co-constraints such as requirements to include elements based on values contained in other elements are also not enforceable. These conditions must be evaluated through inspection or a schematron validator.

7. Standard Metadata (XML metadata only, all levels of obligation): Conformance with the provisions of the NSG Metadata Foundation (NMF) is addressed in two related, yet distinct, categories of NMF conformance.

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- *Establishment of conforming profiles of the NMF Conceptual Schema Profile.* The NMF allows for the documentation of application-specific profiles of the NMF Conceptual Schema Profile. Profiles of the NMF Conceptual Schema Profile shall conform to the requirements and provisions of Section 7, Profiling the NMF Conceptual Schema.
- *Conformance with approved profiles of the NMF Conceptual Schema Profile.* The NMF has provision for establishing additional profiles of the Conceptual Schema Profile. Application or implementation of approved NMF profiles shall conform to the obligations and business rule constraints established by the profile. Any application or implementation claiming conformance with the NMF shall pass all requirements for metadata described by the *Conceptual Schema Profile*.

NMF applications and implementations include items such as specifications for NSG datasets, products, systems and services, profiles of the NMF Conceptual Schema Profile, application schemas, and any other documentation that is required to conform with requirements described in Part 1. ISO 19106:2004 *Geographic information - Profiles* details two classes of conformance, which may be generally thought of as profile types. Conformant Class 1 type of profile is a pure subset of the ISO geographic information standards. Conformant Class 2 type of profile has the same basis as Class 1 but includes extensions within the context permitted in the base standard. Additionally a Class 2 profile permits the profiling of non-ISO geographic information standards as parts of profiles. NSG documentation profiling, or otherwise implementing, the NMF Conceptual Schema Profile may extend the requirements of the NMF Conceptual Schema Profile with the metadata requirements of individual organizations and systems. The NMF test strategy includes not only the testing of an implementation's metadata elements and entities that are inherited from the NMF Conceptual Schema Profile, but also those that are extensions *to* the NMF Conceptual Schema Profile. Metadata extensions will be tested using the 19115:2003/Cor 1:2006 rules for metadata extensions, which the NMF test strategy inherits from ISO.

8. Exclusiveness (XML metadata only, all levels of obligation): if the implementer adds metadata beyond what is described in NMF or ISO 19115, each user-defined metadata section, metadata entity, and metadata element is unique and not already defined in NMF or ISO 19115.

Note: user-defined metadata within a subject metadata set must satisfy the same requirements as set forth in this ATS.

9. Definition (XML metadata only, all levels of obligation): if the implementer adds metadata beyond what is described in NMF or ISO 19115, the elements are tested to ensure that all attributes have been defined.
10. File Format (TIFF structure): The TIFF file structure is as defined by the TIFF specification, and as constrained by this profile.
11. GeoTIFF (GeoTIFF tags): The GeoTIFF tag structures are as defined by the GeoTIFF specification, and as constrained by this profile.

C.2 Implementation Conformance Statements (ICS)

Table C.2.1: Baseline TIFF ICS

Tagged Image File Format	ICS									
	INTERPRET					GENERATE				
TIFF Revision 6.0										
Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Copyright										
Include Copyright statement							R			
Copyright statement can be displayed		R								
Date/Time										
Date and time of image creation							R			
Date and time of image creation can be displayed		R								
Fill Order										
Value = 1 (pixels with lower column values are stored in the higher-order bits of the byte)		R					O ⁶			
Host Computer										
System used in creation of range values							O			
System used can be displayed		O								
Image Description										
Security Banner + Abstract Information							R			
Image Description can be displayed		R								
Image Length and Width										
Length and Width in Pixels							R			
Image in Accordance with Length and Width Values can be displayed		R								
Make and Model										
Instrument Make and Model							O			
Instrument Make and Model can be displayed		O								

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Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Max/Min Sample Value										
Max/Min values (integer)							O ¹			
Smax/Smin values (noninteger)							O ¹			
Automatic Dynamic Range Adjustment		O								
Orientation										
Value = 1 (top and left sides displayed are 0 th row and column)		R					O ⁶			
Planar Configuration										
Value = 1 (component values for each pixel are stored contiguously)(chunky format)		R					R ³			
Sequence of increasing wavelength		R ⁴					R ⁴			
Samples Per Pixel										
1 (grayscale)		R					O ¹			
3 (RGB)		R					O ¹			
4-8 (multi-band)		R					O ¹			
ExtraSamples count = x-3 (for x number of bands in 4-8 band case)		O					O ⁴			
Bits Per Sample										
1		R					O ²			
8		R					O			
16		R					O			
32		R					O ⁵			
Transparency Mask										
NewSubfileType: Bit 2 = 1, all other bits = 0							O ²			
Apply a transparency mask to the display		R								
Tiling										
Tile Length and Width		R					O ²			
Tile Offsets		R					O ²			
Tile Byte Counts		R					O ²			

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Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Photometric Interpretation										
1 (Black is Zero)		R					O ¹			
2 (RGB)		R					O ¹			
3 Palette Color		R					O ¹			
4 Transparency Mask		R					O ²			
ColorMap										
Define an RGB Color Map							O ²			
Apply Color Map to Image		R								
Artist										
Populate with Organization Name & Role							R			
Field Contents can be displayed		R								
X/Y Resolution										
Populate with intended display resolution							R ⁷			
Display at specified resolution		O								
Resolution Unit										
Value = 2 (inches)		R					R			
Software										
Populate with Name of Software Package							R			
Software Package Name can be displayed		O								
Sample Format										
1 (unsigned integer)		R					O ¹			
2 (two's complement signed integer)		R					O ¹			
3 (IEEE floating point)		R					O ¹			
Compression										
Value = 1 (no compression)		R					O ⁶			
Strips										
Rows per Strip		R					O ²			
Strip Byte Counts		R					O ²			
Strip Offsets		R					O ²			

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Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Thresholding										
Value = 1 (no dithering or halftoning)		R					O ⁶			
No Data Value										
Populate GDAL_NODATA tag							R			
Interpret value as void/suspect area		R								
Geo Metadata										
Supplemental Metadata		R					O ²			

LEGEND:

N - Non-supported

N/A – Not Applicable

P - Partial support

R/O - Required/Optional

S – Full Support

(1) - At least one of the options must be implemented

(2) - Required if feature is present

(3) - Required if image is RGB or multiband

(4) - Required if image is multiband

(5) - Option for gridded data other than image (prohibited for image data)

(6) - Desired but optional

(7) - Required for TIFF, not used for GeoTIFF

Table C.2.2: GeoTIFF ICS

Tagged Image File Format	ICS									
	INTERPRET					GENERATE				
GeoTIFF Revision 1.0, Specification 1.8.2										
Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Tags										
GeoKeyDirectoryTag										
All keys referenced		R					R			
GeoAsciiParamsTag										
All ASCII type GeoKeys stored		R					R			
ModelTiePointTag										
Grid Origin X, Y		R					R ⁷			
Grid Origin Z		O					R ⁵			
ModelPixelScaleTag										
ScaleX, ScaleY		R					R ⁷			
Scale Z		O					R ⁵			
ModelTransformationTag		R					R ⁶			
Configuration GeoKeys										
GTModelTypeGeoKey										
1 – Projected		R					O ¹			
2 – Geographic		R					O ¹			
GTRasterTypeGeoKey										
1 - Pixel is Area		R ⁸					O ¹			
2 - Pixel is Point		R ⁸					O ¹			
GTCitationGeoKey										
Value as defined in Table A.2.1		R					R			
Coordinate Type is Required for Only One of the Following Sets of Keys:										
Geographic Coordinate System Parameter Keys³										
GeographicTypeGeoKey										
4326 – GCS WGS 84		R					O ²			
4030 - GCSE WGS 84		R					O ²			
GeogCitationGeoKey										
Value = WGS84 [DMA TR 8350.2]		R					R			

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Features	INTERPRET					GENERATE				
	√	R/O	S	P	N	√	R/O	S	P	N
Projected Coordinate System Parameter Keys⁴										
ProjectedCSTypeGeoKey										
326zz – UTM North		R					O ²			
327zz – UTM South		R					O ²			
PCSCitationGeoKey										
Value = see Table A.2.3		R					R			
Vertical Coordinate System Parameter Keys⁵										
VerticalCSTypeGeoKey										
5030 – WGS 84		O					O ²			
5171 – EGM96 Geoid		O					O ²			
5203 – EGM84 Geoid		O					O ²			
32767 – user defined		O					O ²			
VerticalCitationGeoKey										
Value = see Table A.2.4		O					R			
VerticalUnitsGeoKey										
Value = 9001 (linear meter)		O					R			

LEGEND:

N - Non-supported

P - Partial support

R/O - Required/Optional

S – Full Support

(¹) - At least one of the options must be implemented

(²) - At least one of the options must be implemented when feature is present

(³) - Required for unprojected data

(⁴) - Required for projected data

(⁵) - Required for elevation data

(⁶) - Required when image requires rotation in order to be north-oriented, ModelTiePointTag and ModelPixelScaleTag are not used in this case

(⁷) - Required when image does not require rotation in order to be north-oriented, ModelTransformationTag not used in this case

(⁸) - Interpreter must show a .5 pixel shift in geographic location when the key is switched from one option to the other