2. The attributes are intended to be a primary identification of the system that produces the data (e.g., modality or workstation application providing the content of the SOP Instance) and not the identification of the component that encodes the SOP Instance (e.g., a commonly used DICOM encoding toolkit).

Table C.7-8b
ENHANCED GENERAL EQUIPMENT MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Manufacturer	(0008,0070)	1	Manufacturer of the equipment that produced the composite instances.
Manufacturer's Model Name	(0008,1090)	1	Manufacturer's model name of the equipment that produced the composite instances.
Device Serial Number	(0018,1000)	1	Manufacturer's serial number of the equipment that produced the composite instances.
Software Versions	(0018,1020)	1	Manufacturer's designation of software version of the equipment that produced the composite instances. See Section C.7.5.1.1.3.

C.7.6 Common Image IE Modules

The following Image IE Modules are common to all Composite Image IODs that reference the Image IE.

C.7.6.1 General Image Module

Table C.7-9 specifies the Attributes that identify and describe an image within a particular series.

Table C.7-9
GENERAL IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Instance Number	(0020,0013)	2	A number that identifies this image. Note: This Attribute was named Image Number in earlier versions of this Standard.
Patient Orientation	(0020,0020)	2C	Patient direction of the rows and columns of the image. Required if image does not require Image Orientation (Patient) (0020,0037) and Image Position (Patient) (0020,0032). May be present otherwise. See C.7.6.1.1.1 for further explanation. Note: IOD's may have attributes other than Patient Orientation, Image Orientation, or Image Position (Patient) to describe orientation in which case this attribute will be zero length.
Content Date	(0008,0023)	2C	The date the image pixel data creation started. Required if image is part of a series in which the images are temporally related.

			May be present otherwise. Note: This Attribute was formerly known as Image Date.
Content Time	(0008,0033)	2C	The time the image pixel data creation started. Required if image is part of a series in which the images are temporally related. May be present otherwise.
Image Type	(0008,0008)	3	Image identification characteristics. See C.7.6.1.1.2 for Defined Terms and further explanation.
Acquisition Number	(0020,0012)	3	A number identifying the single continuous gathering of data over a period of time that resulted in this image.
Acquisition Date	(0008,0022)	3	The date the acquisition of data that resulted in this image started
Acquisition Time	(0008,0032)	3	The time the acquisition of data that resulted in this image started
Acquisition DateTime	(0008,002A)	3	The date and time that the acquisition of data that resulted in this image started. Note: The synchronization of this time with an external clock is specified in the Synchronization Module in Acquisition Time Synchronized (0018,1800).
Referenced Image Sequence	(0008,1140)	3	Other images significantly related to this image (e.g. post-localizer CT image or Mammographic biopsy or partial view images). One or more Items are permitted in this sequence.
>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Purpose of Reference Code Sequence	(0040,A170)	3	Describes the purpose for which the reference is made. Only a single Item is permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID 7201.*
Derivation Description	(0008,2111)	3	A text description of how this image was derived. See C.7.6.1.1.3 for further explanation.
Derivation Code Sequence	(0008,9215)	3	A coded description of how this image was derived. See C.7.6.1.1.3 for further explanation. One or more Items are permitted in this Sequence. More than one Item indicates that successive derivation steps have been applied.
>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID 7203.*

Source Image Sequence	(0008,2112)	3	The set of Image SOP Class/Instance pairs of the Images that were used to derive this Image. One or more Items are permitted in this Sequence. See C.7.6.1.1.4 for further explanation.
>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Purpose of Reference Code Sequence	(0040,A170)	3	Describes the purpose for which the reference is made, that is what role the source image or frame(s) played in the derivation of this image. Only a single Item is permitted in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*Defined CID 7202.*
>Spatial Locations Preserved	(0028,135A)	3	The extent to which the spatial locations of all pixels are preserved during the processing of the source image that resulted in the current image Enumerated Values: YES NO REORIENTED_ONLY - A projection radiograph that has been flipped, and/or rotated by a multiple of 90 degrees Notes: 1. This applies not only to images with a known relationship to a 3D space, but also to projection images. For example, a projection radiograph such as a mammogram that is processed by a point image processing operation such as contrast enhancement, or a smoothing or edge enhancing convolution, would have a value of YES for this attribute. A projection radiograph that had been magnified or warped geometrically would have a value of NO for this attribute. A projection radiograph that has been flipped, and/or rotated by a multiple of 90 degrees, such that transformation of pixel locations is possible by comparison of the values of Patient Orientation (0020,0020) would have a value of REORIENTED_ONLY. This attribute is typically of importance in relating images with Presentation Intent Type (0008,0068) values of FOR PROCESSING and FOR

			PRESENTATION. 2. When the value of this attribute is NO, it is not possible to locate on the current image any pixel coordinates that are referenced relative to the source image, such as for example, might be required for rendering CAD findings derived from a referenced FOR PROCESSING image on the current FOR PRESENTATION image.
>Patient Orientation	(0020,0020)	1C	The Patient Orientation values of the source image. Required if the value of Spatial Locations Preserved (0028,135A) is REORIENTED_ONLY.
Referenced Instance Sequence	(0008,114A)	3	Non-image composite SOP Instances that are significantly related to this Image, including waveforms that may or may not be temporally synchronized with this image. One or more Items are permitted in this sequence.
>Include SOP Instance Reference Macro Table 10-11			
>Purpose of Reference Code Sequence	(0040,A170)	1	Code describing the purpose of the reference to the Instance(s). Only a single Item shall be included in this sequence.
>>Include 'Code Sequence Macro' Table 8.8-1		*Defined CID 7004 for referenced waveforms.*	
Images in Acquisition	(0020,1002)	3	Number of images that resulted from this acquisition of data
Image Comments	(0020,4000)	3	User-defined comments about the image
Quality Control Image	(0028,0300)	3	Indicates whether or not this image is a quality control or phantom image. Enumerated Values: YES NO If this Attribute is absent, then the image may or may not be a quality control or phantom image. The phantom device in the image can be described using the Device Module. See C.7.6.12
Burned In Annotation	(0028,0301)	3	Indicates whether or not image contains sufficient burned in annotation to identify the patient and date the image was acquired. Enumerated Values: YES NO

			If this Attribute is absent, then the image may or may not contain burned in annotation.
Recognizable Visual Features	(0028,0302)	3	Indicates whether or not the image contains sufficiently recognizable visual features to allow the image or a reconstruction from a set of images to identify the patient. Enumerated Values: YES NO If this Attribute is absent, then the image may or may not contain recognizable visual features.
Lossy Image Compression	(0028,2110)	3	Specifies whether an Image has undergone lossy compression. Enumerated Values: 00 = Image has NOT been subjected to lossy compression. 01 = Image has been subjected to lossy compression. See C.7.6.1.1.5
Lossy Image Compression Ratio	(0028,2112)	3	Describes the approximate lossy compression ratio(s) that have been applied to this image. See C.7.6.1.1.5 for further explanation. May be multivalued if successive lossy compression steps have been applied. Notes: 1. For example, a compression ratio of 30:1 would be described in this Attribute with a single value of 30. 2. For historical reasons, the lossy compression ratio may also be described in Derivation Description (0008,2111).
Lossy Image Compression Method	(0028,2114)	3	A label for the lossy compression method(s) that have been applied to this image. See C.7.6.1.1.5 for further explanation. May be multivalued if successive lossy compression steps have been applied; the value order shall correspond to the values of Lossy Image Compression Ratio (0028,2112). Note: For historical reasons, the lossy compression method may also be described in Derivation Description (0008,2111).

Icon Image Sequence	(0088,0200)	3	This icon image is representative of the Image. Only a single Item is permitted in this Sequence.
>Include 'Image Pixel Macro' Table C.7-11b			See C.7.6.1.1.6 for further explanation.
Presentation LUT Shape	(2050,0020)	3	When present, specifies an identity transformation for the Presentation LUT such that the output of all grayscale transformations, if any, are defined to be in P-Values. Enumerated Values are: IDENTITY - output is in P-Values - shall be used if Photometric Interpretation (0028,0004) is MONOCHROME2 or any color photometric interpretation. INVERSE - output after inversion is in P-Values - shall be used if Photometric Interpretation (0028,0004) is MONOCHROME1. When this attribute is used with a color photometric interpretation then the luminance component is in P-Values.
Irradiation Event UID	(0008,3010)	3	Unique identification of the irradiation event(s) associated with the acquisition of this image. See C.7.6.1.1.7.

Note: Previous editions of this Standard specified use of the Referenced Waveform Sequence (0008,113A), but that use has been superseded by Referenced Instance Sequence (0008,114A). See PS3.3-2004.

C.7.6.1.1 General Image Attribute Descriptions

C.7.6.1.1.1 Patient Orientation

The Patient Orientation (0020,0020) relative to the image plane shall be specified by two values that designate the anatomical direction of the positive row axis (left to right) and the positive column axis (top to bottom). The first entry is the direction of the rows, given by the direction of the last pixel in the first row from the first pixel in that row. The second entry is the direction of the columns, given by the direction of the last pixel in the first column from the first pixel in that column. Shall be consistent with Image Orientation (Patient) (0020,0037), if both Attributes are present and Patient Orientation (0020,0020) is not zero length.

If Anatomical Orientation Type (0010,2210) is absent or has a value of BIPED, anatomical direction shall be designated by abbreviations using the capital letters:

- A (anterior)
- P (posterior)
- R (right)
- L (left)

- H (head)
- F (foot)

If Anatomical Orientation Type (0010,2210) has a value of QUADRUPED, anatomical direction shall be designated by the abbreviations using capital letters:

- LE (Le or Left)
- RT (Rt or Right)
- D (Dorsal)
- V (Ventral)
- CR (Cr or Cranial)
- CD (Cd or Caudal)
- R (Rostral)
- M (Medial)
- L (Lateral)
- PR (Pr or Proximal)
- DI (Di or Distal)
- PA (Pa or Palmar)
- PL (Pl or Plantar)

Notes: 1. These abbreviations are capitalized versions of those defined in Smallwood et al for describing radiographic projections. Because of the Code String (CS) Value Representation of the Patient Orientation (0020,0020), lowercase letters cannot be used.

2, It is unfortunate that the conventional veterinary abbreviations (e.g., R for rostral and Rt for right) differ from those chosen for humans for DICOM usage (e.g., R for right), but confusion with in the respective human and animal domains will be reduced. Hanging protocols may need to account for the difference by checking for the correct species.

3. Smallwood et al define an O (Oblique) abbreviation, which is useful for describing radiographic projections, but do not specify its use for directional terms, and hence it is not included here for describing the row and column directions.

4. The terms “anterior” and “posterior” are commonly used in vertebrate zoology to describe the cranial and caudal directions respectively, the veterinary terms are used in preference here, also in order to avoid confusion with the contradictory human use of anterior and posterior to mean ventral and dorsal.

5. For animals other than quadrupeds, for example, birds and fish, it is anticipated that the same nomenclature can be logically extended to describe, for example, wings and fins.

Each value of the orientation attribute shall contain at least one of these abbreviations. If refinements in the orientation descriptions are to be specified, then they shall be designated by one or two additional abbreviations in each value. Within each value, the abbreviations shall be ordered with the principal orientation designated in the first abbreviations.

Notes: 1. For bipeds, since each abbreviation is a single character, no delimiter is required within a single value and none is used. For quadrupeds, though lowercase letters cannot be used,

delimiters are not necessary within a single value to eliminate ambiguity, since the abbreviations used are sufficiently distinct, and can be parsed from left to right with a single character of lookahead.

2. E.g., a medio-lateral oblique projection of the left breast of a human might be encoded with Patient Orientation values of “A\FR” rather than “A\F”, since the plane is obliquely inclined such that the colums are directed both downwards and medially, which for a left breast is towards the right, though the downwards direction is the principal column orientation.

3. E.g., a right dorsal-left ventral oblique view of a quadruped’s abdomen might be encoded with Patient Orientation values of “LTV\CD”, rather than “LT\CD”, since the plane is obliquely inclined such that the rows are directed both to the left and ventrally, though the left direction is the principal row orientation. The abbreviations “LTV”, “LT” and “CD”, correspond to the designations in Smallwood et al of “LtV”, “Lt” and “Cd”, respectively

C.7.6.1.1.2 Image Type

The Image Type (0008,0008) Attribute identifies important image identification characteristics. These characteristics are:

a. Pixel Data Characteristics
    1. is the image an ORIGINAL Image; an image whose pixel values are based on original or source data
    2. is the image a DERIVED Image; an image whose pixel values have been derived in some manner from the pixel value of one or more other images
b. Patient Examination Characteristics
    1. is the image a PRIMARY Image; an image created as a direct result of the Patient examination
    2. is the image a SECONDARY Image; an image created after the initial Patient examination
c. Modality Specific Characteristics
d. Implementation specific identifiers; other implementation specific identifiers shall be documented in an implementation's conformance statement.

The Image Type attribute is multi-valued and shall be provided in the following manner:

a. Value 1 shall identify the Pixel Data Characteristics; Enumerated Values for the Pixel Data Characteristics are:

ORIGINAL	identifies an Original Image
DERIVED	identifies a Derived Image

b. Value 2 shall identify the Patient Examination Characteristics; Enumerated Values for the Patient Examination Characteristics are:

PRIMARY	identifies a Primary Image
SECONDARY	identifies a Secondary Image

c. Value 3 shall identify any Image IOD specific specialization (optional)
d. Other Values which are implementation specific (optional)

Any of the optional values (value 3 and beyond) may be sent either with a value or zero-length, independent of other optional values, unless otherwise specified by a specialization of this attribute in an IOD.

If the pixel data of the derived Image is different from the pixel data of the source images and this difference is expected to affect professional interpretation of the image, the Derived Image shall have a UID different than all the source images.

C.7.6.1.1.3 Derivation Description

If an Image is identified to be a derived image (see C.7.6.1.1.2 Image Type), Derivation Description (0008,2111) and Derivation Code Sequence (0008,9215) describe the way in which the image was derived. They may be used whether or not the Source Image Sequence (0008,2112) is provided. They may also be used in cases when the Derived Image pixel data is not significantly changed from one of the source images and the SOP Instance UID of the Derived Image is the same as the one used for the source image.

Notes: 1. Examples of Derived Images that would normally be expected to affect professional interpretation and would thus have a new UID include:

a. images resulting from image processing of another image (e.g. unsharp masking),

b. a multiplanar reformatted CT image,

c. a DSA image derived by subtracting pixel values of one image from another.

d. an image that has been decompressed after having been compressed with a lossy compression algorithm. To ensure that the user has the necessary information about the lossy compression, the approximate compression ratio may be included in Derivation Description (0008,2111).

An example of a Derived Image that would normally not be expected to affect professional interpretation and thus would not require a new UID is an image that has been padded with additional rows and columns for more display purposes.

2. An image may be lossy compressed, e.g., for long term archive purposes, and its SOP Instance UID changed. PS3.4 provides a mechanism by which a query for the original image Instance may return a reference to the UID of the lossy compressed version of the image using the Alternate Representation Sequence (0008,3001). This allows an application processing a SOP Instance that references the original image UID, e.g., a Structured Report, to obtain a reference to an accessible version of the image even if the original SOP Instance is no longer available.

C.7.6.1.1.4 Source image sequence

If an Image is identified to be a Derived image (see C.7.6.1.1.2 Image Type), Source Image Sequence (0008,2112) is an optional list of Referenced SOP Class UID (0008,1150)/ Referenced SOP Instance UID (0008,1150) pairs that identify the source images used to create the Derived image. It may be used whether or not there is a description of the way the image was derived in Derivation Description (0008,2111) or Derivation Code Sequence (0008,9215).

Note: Multiple Items may be present within Source Image Sequence (0008,2112), in which case either:

a) those images were combined to make the derived image (e.g. multiple source images to make an MPR or MIP), or

b) each of the items represents a step in the successive derivation of an image (e.g. when an image has had successive lossy compression steps applied to it),

c) some combination of the above.

The Purpose of Reference Code Sequence (0040,A170) and the Attributes within the referenced images themselves may be used to determine the history of the derivation, which is not otherwise explicitly specified.

C.7.6.1.1.5 Lossy Image Compression

The Attribute Lossy Image Compression (0028,2110) conveys that the Image has undergone lossy compression. It provides a means to record that the Image has been compressed (at a point in its lifetime) with a lossy algorithm and changes have been introduced into the pixel data. Once the value has been set to “01”, it shall not be reset.

Note: If an image is compressed with a lossy algorithm, the attribute Lossy Image Compression (0028,2110) is set to “01”. Subsequently, if the image is decompressed and transferred in uncompressed format, this attribute value remains “01”.

The value of the Lossy Image Compression (0028,2110) Attribute in SOP Instances containing multiple frames in which one or more of the frames have undergone lossy compression shall be "01".

Note: It is recommended that the applicable frames be noted in the Attribute Derivation Description (0008,2111).

If an image is originally obtained as a lossy compressed image from the sensor, then Lossy Image Compression (0028,2110) is set to "01" and Value 1 of the Attribute Image Type (0008,0008) shall be set to ORIGINAL.

If an image is a compressed version of another image, Lossy Image Compression (0028,2110) is set to "01", Value 1 of the Attribute Image Type (0008,0008) shall be set to DERIVED, and if the predecessor was a DICOM image, then the Image shall receive a new SOP Instance UID.

Note: 1. It is recommended that the approximate compression ratio be provided in the Attribute Derivation Description (0008,2111). Furthermore, it is recommended that Derivation Description (0008,2111) be used to indicate when pixel data changes might affect professional interpretation. (see C.7.6.1.1.3).

2. The attribute Lossy Image Compression (0028,2110) is defined as Type 3 for backward compatibility with existing IODs. It is expected to be required (i.e., defined as Type 1C) for new Image IODs and for existing IODs that undergo a major revision (e.g. a new IOD is specified).

The Defined Terms for Lossy Image Compression Method (0028,2114) are:

ISO_10918_1 = JPEG Lossy Compression
ISO_14495_1 = JPEG-LS Near-lossless Compression
ISO_15444_1 = JPEG 2000 Irreversible Compression
ISO_13818_2 = MPEG2 Compression

C.7.6.1.1.6 Icon Image Sequence

An Icon Image may be used as a key representative of an Image. It is defined as a Sequence that contains a single Item encapsulating the Data Set made of the Data Elements of the Icon Image. The Data Elements are defined by the Image Pixel Macro (see Section C.7.6.3). The restrictions defined in Section F.7 shall apply.

C.7.6.1.1.7 Irradiation Event UID

An irradiation event is the occurrence of radiation being applied to a patient in single continuous time-frame between the start (release) and the stop (cease) of the irradiation. Any on-off switching of the irradiation source during the event shall not be treated as separate events, rather the event includes the time between start and stop of irradiation as triggered by the user. E.g., a pulsed fluoro X-Ray acquisition shall be treated as a single irradiation event.

C.7.6.2 Image Plane Module

Table C.7-10 specifies the Attributes that define the transmitted pixel array of a two dimensional image plane.

Note: In previous versions of this Standard, image position and image orientation were specified relative to a specific equipment coordinate system. This equipment coordinate system was not fully defined and a number of ambiguities existed. The equipment based coordinate system has been retired and replaced by the patient based coordinate system defined in this Module.

Table C.7-10
IMAGE PLANE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Pixel Spacing	(0028,0030)	1	Physical distance in the patient between the center of each pixel, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm. See 10.7.1.3 for further explanation.
Image Orientation (Patient)	(0020,0037)	1	The direction cosines of the first row and the first column with respect to the patient. See C.7.6.2.1.1 for further explanation.
Image Position (Patient)	(0020,0032)	1	The x, y, and z coordinates of the upper left hand corner (center of the first voxel transmitted) of the image, in mm. See C.7.6.2.1.1 for further explanation.
Slice Thickness	(0018,0050)	2	Nominal slice thickness, in mm.
Slice Location	(0020,1041)	3	Relative position of the image plane expressed in mm. C.7.6.2.1.2 for further explanation.

C.7.6.2.1 Image Plane Attribute Descriptions

C.7.6.2.1.1 Image Position And Image Orientation

The Image Position (0020,0032) specifies the x, y, and z coordinates of the upper left hand corner of the image; it is the center of the first voxel transmitted. Image Orientation (0020,0037) specifies the direction cosines of the first row and the first column with respect to the patient. These Attributes shall be provide as a pair. Row value for the x, y, and z axes respectively followed by the Column value for the x, y, and z axes respectively.

The direction of the axes is defined fully by the patient's orientation.

If Anatomical Orientation Type (0010,2210) is absent or has a value of BIPED, the x-axis is increasing to the left hand side of the patient. The y-axis is increasing to the posterior side of the patient. The z-axis is increasing toward the head of the patient.

If Anatomical Orientation Type (0010,2210) has a value of QUADRUPED, the

- x-axis is increasing to the left (as opposed to right) side of the patient
- the y-axis is increasing towards
    - the dorsal (as opposed to ventral) side of the patient for the neck, trunk and tail,
    - the dorsal (as opposed to ventral) side of the patient for the head,
    - the dorsal (as opposed to plantar or palmar) side of the distal limbs,
    - the cranial (as opposed caudal) side of the proximal limbs, and
- the z-axis is increasing towards
    - the cranial (as opposed to caudal) end of the patient for the neck, trunk and tail,
    - the rostral (as opposed to caudal) end of the patient for the head, and

- the proximal (as opposed to distal) end of the limbs

Notes: 1. The axes for quadrupeds are those defined and illustrated in Smallwood et al for proper anatomic directional terms as they apply to various parts of the body.

2. It should be anticipated that when quadrupeds are imaged on human equipment, and particularly when they are position in a manner different from the traditional human prone and supine head or feet first longitudinal position, then the equipment may well not indicate the correct orientation, though it will remain an orthogonal Cartesian right-handed system that could be corrected subsequently.

The patient based coordinate system is a right handed system, i.e. the vector cross product of a unit vector along the positive x-axis and a unit vector along the positive y-axis is equal to a unit vector along the positive z-axis.

Note: If a patient is positioned parallel to the ground, in dorsal recumbency (i.e., for humans, face-up on the table), with the caudo-cranial (i.e., for humans, feet-to-head) direction the same as the front-to-back direction of the imaging equipment, the direction of the axes of this patient based coordinate system and the equipment based coordinate system in previous versions of this Standard will coincide.

The Image Plane Attributes, in conjunction with the Pixel Spacing Attribute, describe the position and orientation of the image slices relative to the patient-based coordinate system. In each image frame the Image Position (Patient) (0020,0032) specifies the origin of the image with respect to the patient-based coordinate system. RCS and the Image Orientation (Patient) (0020,0037) attribute values specify the orientation of the image frame rows and columns. The mapping of pixel location (i, j) to the RCS is calculated as follows:

$$\begin{bmatrix} P_x \\ P_y \\ P_z \\ 1 \end{bmatrix} = \begin{bmatrix} X_x\Delta i & Y_x\Delta j & 0 & S_x \\ X_y\Delta i & Y_y\Delta j & 0 & S_y \\ X_z\Delta i & Y_z\Delta j & 0 & S_z \\ 0 & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} i \\ j \\ 0 \\ 1 \end{bmatrix} = \mathbf{M} \begin{bmatrix} i \\ j \\ 0 \\ 1 \end{bmatrix}$$

Where:

P_{xyz} The coordinates of the voxel (i,j) in the frame's image plane in units of mm.

S_{xyz} The three values of the Image Position (Patient) (0020,0032) attributes. It is the location in mm from the origin of the RCS.

X_{xyz} The values from the row (X) direction cosine of the Image Orientation (Patient) (0020,0037) attribute.

Y_{xyz} The values from the column (Y) direction cosine of the Image Orientation (Patient) (0020,0037) attribute.

i Column index to the image plane. The first column is index zero.

Δi Column pixel resolution of the Pixel Spacing (0028,0030) attribute in units of mm.

j Row index to the image plane. The first row index is zero.

Δj Row pixel resolution of the Pixel Spacing (0028,0030) attribute in units of mm.

Additional constraints apply:

1) The row and column direction cosine vectors shall be orthogonal, i.e. their dot product shall be zero.

2) The row and column direction cosine vectors shall be normal, i.e. the dot product of each direction cosine vector with itself shall be unity.

C.7.6.2.1.2 Slice Location

The Slice Location (0020,1041) is defined as the relative position of the image plane expressed in mm. This information is relative to an unspecified implementation specific reference point.

C.7.6.3 Image Pixel Module

Table C.7-11a describes the Image Pixel Module.

Table C.7-11a
IMAGE PIXEL MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Include 'Image Pixel Macro' Table C.7-11b			
Pixel Data Provider URL	(0028,7FE0)	1C	A URL of a provider service that supplies the pixel data of the Image. Required if the image is to be transferred in one of the following presentation contexts identified by Transfer Syntax UID: 1.2.840.10008.1.2.4.94 (DICOM JPIP Referenced Transfer Syntax) 1.2.840.10008.1.2.4.95 (DICOM JPIP Referenced Deflate Transfer Syntax)
Pixel Padding Range Limit	(0028,0121)	1C	Pixel value that represents one limit (inclusive) of a range of padding values used together with Pixel Padding Value (0028,0120) as defined in the General Equipment Module. See C.7.5.1.1.2 for further explanation. Required if pixel padding is to be defined as a range rather than a single value. Notes: 1. The Value Representation of this Attribute is determined by the value of Pixel Representation (0028,0103). 2. Pixel Padding Value (0028,0120) is also required when this Attribute is present.

Table C.7-11b specifies the common attributes that describe the pixel data of the image.

Table C.7-11b
IMAGE PIXEL MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Samples per Pixel	(0028,0002)	1	Number of samples (planes) in this image. See C.7.6.3.1.1 for further explanation.
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. See C.7.6.3.1.2 for further explanation.

Rows	(0028,0010)	1	Number of rows in the image.
Columns	(0028,0011)	1	Number of columns in the image
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Each sample shall have the same number of bits allocated. See PS 3.5 for further explanation.
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Each sample shall have the same number of bits stored. See PS 3.5 for further explanation.
High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Each sample shall have the same high bit. See PS 3.5 for further explanation.
Pixel Representation	(0028,0103)	1	Data representation of the pixel samples. Each sample shall have the same pixel representation. Enumerated Values: 0000H = unsigned integer. 0001H = 2's complement
Pixel Data	(7FE0,0010)	1C	A data stream of the pixel samples that comprise the Image. See C.7.6.3.1.4 for further explanation. Required if Pixel Data Provider URL (0028,7FE0) is not present.
Planar Configuration	(0028,0006)	1C	Indicates whether the pixel data are sent color-by-plane or color-by-pixel. Required if Samples per Pixel (0028,0002) has a value greater than 1. See C.7.6.3.1.3 for further explanation.
Pixel Aspect Ratio	(0028,0034)	1C	Ratio of the vertical size and horizontal size of the pixels in the image specified by a pair of integer values where the first value is the vertical pixel size, and the second value is the horizontal pixel size. Required if the aspect ratio values do not have a ratio of 1:1 and the physical pixel spacing is not specified by Pixel Spacing (0028,0030), or Imager Pixel Spacing (0018,1164) or Nominal Scanned Pixel Spacing (0018,2010), either for the entire Image or per-frame in a Functional Group Macro. See C.7.6.3.1.7.
Smallest Image Pixel Value	(0028,0106)	3	The minimum actual pixel value encountered in this image.
Largest Image Pixel Value	(0028,0107)	3	The maximum actual pixel value encountered in this image.
Red Palette Color Lookup Table Descriptor	(0028,1101)	1C	Specifies the format of the Red Palette Color Lookup Table Data (0028,1201) Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or

			MIXED. See C.7.6.3.1.5 for further explanation.
Green Palette Color Lookup Table Descriptor	(0028,1102)	1C	Specifies the format of the Green Palette Color Lookup Table Data (0028,1202) Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or MIXED. See C.7.6.3.1.5 for further explanation.
Blue Palette Color Lookup Table Descriptor	(0028,1103)	1C	Specifies the format of the Blue Palette Color Lookup Table Data (0028,1203) Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or MIXED. See C.7.6.3.1.5 for further explanation.
Red Palette Color Lookup Table Data	(0028,1201)	1C	Red Palette Color Lookup Table Data. Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or MIXED. See C.7.6.3.1.6 for further explanation.
Green Palette Color Lookup Table Data	(0028,1202)	1C	Green Palette Color Lookup Table Data. Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or MIXED. See C.7.6.3.1.6 for further explanation.
Blue Palette Color Lookup Table Data	(0028,1203)	1C	Blue Palette Color Lookup Table Data. Required if Photometric Interpretation (0028,0004) has a value of PALETTE COLOR or Pixel Presentation (0008,9205) at the image level equals COLOR or MIXED. See C.7.6.3.1.6 for further explanation.
ICC Profile	(0028,2000)	3	An ICC Profile encoding the transformation of device-dependent color stored pixel values into PCS-Values. See Section C.11.15.1.1. When present, defines the color space of color Pixel Data (7FE0,0010) values, and the output of Palette Color Lookup Table Data (0028,1201-1203). Note: The profile applies only to the Pixel Data (7FE0,0010) attribute at the same level of the dataset and not to any icons nested within sequences, which may or may not have their own ICC profile specified.

C.7.6.3.1 Image Pixel Attribute Descriptions

C.7.6.3.1.1 Samples Per Pixel

Samples per Pixel (0028,0002) is the number of separate planes in this image. One and three image planes are defined. Other numbers of image planes are allowed, but their meaning is not defined by this Standard.

For monochrome (gray scale) and palette color images, the number of planes is 1. For RGB and other three vector color models, the value of this attribute is 3.

Note: The use of a value of 4 was previously described, but the Photometric Interpretations that used it have been retired.

All image planes shall have the same number of Rows (0028,0010), Columns (0028,0011), Bits Allocated (0028,0100), Bits Stored (0028,0101), High Bit (0028,0102), Pixel Representation (0028,0103), and Pixel Aspect Ratio (0028,0034).

The data in each pixel may be represented as a “Composite Pixel Code”. If Samples Per Pixel is one, the Composite Pixel Code is just the “n” bit pixel sample, where “n” = Bits Allocated. If Samples Per Pixel is greater than one, Composite Pixel Code is a “k” bit concatenation of samples, where “k” = Bits Allocated multiplied by Samples Per Pixel, and with the sample representing the vector color designated first in the Photometric Interpretation name comprising the most significant bits of the Composite Pixel Code, followed in order by the samples representing the next vector colors, with the sample representing the vector color designated last in the Photometric Interpretation name comprising the least significant bits of the Composite Pixel Code. For example, for Photometric Interpretation = “RGB”, the most significant “Bits Allocated” bits contain the Red sample, the next “Bits Allocated” bits contain the Green sample, and the least significant “Bits Allocated” bits contain the Blue sample.

C.7.6.3.1.2 Photometric Interpretation

The value of Photometric Interpretation (0028,0004) specifies the intended interpretation of the image pixel data.

See PS 3.5 for restrictions imposed by compressed Transfer Syntaxes.

The following values are defined. Other values are permitted but the meaning is not defined by this Standard.

MONOCHROME1 = Pixel data represent a single monochrome image plane. The minimum sample value is intended to be displayed as white after any VOI gray scale transformations have been performed. See PS 3.4. This value may be used only when Samples per Pixel (0028,0002) has a value of 1.

MONOCHROME2 = Pixel data represent a single monochrome image plane. The minimum sample value is intended to be displayed as black after any VOI gray scale transformations have been performed. See PS 3.4. This value may be used only when Samples per Pixel (0028,0002) has a value of 1.

PALETTE COLOR = Pixel data describe a color image with a single sample per pixel (single image plane). The pixel value is used as an index into each of the Red, Blue, and Green Palette Color Lookup Tables (0028,1101-1103&1201-1203). This value may be used only when Samples per Pixel (0028,0002) has a value of 1. When the Photometric Interpretation is Palette Color; Red, Blue, and Green Palette Color Lookup Tables shall be present.

RGB = Pixel data represent a color image described by red, green, and blue image planes. The minimum sample value for each color plane represents minimum intensity of the color. This value may be used only when Samples per Pixel (0028,0002) has a value of 3.

HSV = *Retired.*

ARGB = *Retired.*

CMYK = *Retired.*

YBR_FULL = Pixel data represent a color image described by one luminance (Y) and two chrominance planes (C_B and C_R). This photometric interpretation may be used only when Samples per Pixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of color is represented by both C_B and C_R values equal to half full scale.

Note: In the case where the Bits Allocated (0028,0100) has value of 8 half full scale is 128.

In the case where Bits Allocated (0028,0100) has a value of 8 then the following equations convert between RGB and YC_BC_R Photometric Interpretation.

$$Y = + .2990R + .5870G + .1140B$$

$$C_B = - .1687R - .3313G + .5000B + 128$$

$$C_R = + .5000R - .4187G - .0813B + 128$$

Note: The above is based on CCIR Recommendation 601-2 dated 1990.

YBR_FULL_422 = The same as YBR_FULL except that the C_B and C_R values are sampled horizontally at half the Y rate and as a result there are half as many C_B and C_R values as Y values.

This Photometric Interpretation is only allowed with Planar Configuration (0028,0006) equal to 0. Two Y values shall be stored followed by one C_B and one C_R value. The C_B and C_R values shall be sampled at the location of the first of the two Y values. For each Row of Pixels, the first C_B and C_R samples shall be at the location of the first Y sample. The next C_B and C_R samples shall be at the location of the third Y sample etc.

Note: This subsampling is often referred to as cosited sampling.

YBR_PARTIAL_422 = The same as YBR_FULL_422 except that:

1. black corresponds to Y = 16;
2. Y is restricted to 220 levels (i.e. the maximum value is 235);
3. C_B and C_R each has a minimum value of 16;
4. C_B and C_R are restricted to 225 levels (i.e. the maximum value is 240);
5. lack of color is represented by C_B and C_R equal to 128.

In the case where Bits Allocated (0028,0100) has value of 8 then the following equations convert between RGB and YBR_PARTIAL_422 Photometric Interpretation

$$Y = + .2568R + .5041G + .0979B + 16$$

$$C_B = - .1482R - .2910G + .4392B + 128$$

$$C_R = + .4392R - .3678G - .0714B + 128$$

Note: The above is based on CCIR Recommendation 601-2 dated 1990.

YBR_PARTIAL_420 = The same as YBR_PARTIAL_422 except that the C_B and C_R values are sampled horizontally and vertically at half the Y rate and as a result there are four times less C_B and C_R values than Y values, versus twice less for YBR_PARTIAL_422.

This Photometric Interpretation is only allowed with Planar Configuration (0028,0006) equal to 0. The C_B and C_R values shall be sampled at the location of the first of the two Y values. For the first Row of Pixels (etc.), the first C_B and C_R samples shall be at the location of the first Y sample. The next C_B and C_R samples shall be at the location of the third Y sample etc. The next Rows of Pixels containing C_B and C_R samples (at the same locations than for the first Row) will be the third etc.

YBR_ICT = Irreversible Color Transformation:

Pixel data represent a color image described by one luminance (Y) and two chrominance planes (C_B and C_R). This photometric interpretation may be used only when Samples per Pixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of color is represented by both C_B and C_R values equal to zero.

Regardless of the value of Bits Allocated (0028,0100), the following equations convert between RGB and YC_BC_R Photometric Interpretation.

$$Y = + .29900R + .58700G + .11400B$$

$$C_B = - .16875R - .33126G + .50000B$$

$$C_R = + .50000R - .41869G - .08131B$$

Notes: 1. The above is based on ISO/IEC 15444-1 (JPEG 2000).

2. In a JPEG 2000 bitstream, DC level shifting (used if the untransformed components are unsigned) is applied before forward color transformation, and the transformed components may be signed (unlike in JPEG ISO/IEC 10918-1).

3. In JPEG 2000, spatial down-sampling of the chrominance components, if performed, is signaled in the JPEG 2000 bitstream.

YBR_RCT = Reversible Color Transformation:

Pixel data represent a color image described by one luminance (Y) and two chrominance planes (C_B and C_R). This photometric interpretation may be used only when Samples per Pixel (0028,0002) has a value of 3. Black is represented by Y equal to zero. The absence of color is represented by both C_B and C_R values equal to zero.

Regardless of the value of Bits Allocated (0028,0100), the following equations convert between RGB and YBR_RCT Photometric Interpretation.

$$Y = \lfloor (R + 2G + B) / 4 \rfloor$$ (Note: $\lfloor ... \rfloor$ mean floor)

$C_B = B - G$

$C_R = R - G$

The following equations convert between YBR_RCT and RGB Photometric Interpretation.

$G = Y - \lfloor (C_R + C_B) / 4 \rfloor$

$R = C_R + G$

$B = C_B + G$

Notes: 1. The above is based on ISO/IEC 15444-1 (JPEG 2000).

2. In a JPEG 2000 bitstream, DC level shifting (used if the untransformed components are unsigned) is applied before forward color transformation, and the transformed components may be signed (unlike in JPEG ISO/IEC 10918-1).

3. This photometric interpretation is a reversible approximation to the YUV transformation used in PAL and SECAM.

C.7.6.3.1.3 Planar Configuration

Planar Configuration (0028,0006) indicates whether the color pixel data are sent color-by-plane or color-by-pixel. This Attribute shall be present if Samples per Pixel (0028,0002) has a value greater than 1. It shall not be present otherwise.

Enumerated Values:

0 = The sample values for the first pixel are followed by the sample values for the second pixel, etc. For RGB images, this means the order of the pixel values sent shall be R1, G1, B1, R2, G2, B2, ..., etc.

1 = Each color plane shall be sent contiguously. For RGB images, this means the order of the pixel values sent is R1, R2, R3, ..., G1, G2, G3, ..., B1, B2, B3, etc.

Note: Planar Configuration (0028,0006) is not meaningful when a compression transfer syntax is used that involves reorganization of sample components in the compressed bit stream. In such cases, since the Attribute is required to be sent, then an appropriate value to use may be specified in the description of the Transfer Syntax in PS 3.5, though in all likelihood the value of the Attribute will be ignored by the receiving implementation.

C.7.6.3.1.4 Pixel Data

Pixel Data (7FE0,0010) for this image. The order of pixels sent for each image plane is left to right, top to bottom, i.e., the upper left pixel (labeled 1,1) is sent first followed by the remainder of row 1, followed by the first pixel of row 2 (labeled 2,1) then the remainder of row 2 and so on.

For multi-plane images see Planar Configuration (0028,0006) in this Section.

C.7.6.3.1.5 Palette Color Lookup Table Descriptor

The four values of Palette Color Lookup Table Descriptor (0028,1101-1104) describe the format of the Lookup Table Data in the corresponding Data Element (0028,1201-1204) or (0028,1221-1223). In this section, the term “input value” is either the Palette Color Lookup Table input value described in the Enhanced Palette Color Lookup Table Sequence (0028,140B) or if that attribute is absent, the stored pixel value.

The first value is the number of entries in the lookup table. When the number of table entries is equal to 2^{16} then this value shall be 0. The first value shall be identical for each of the Red, Green, Blue and Alpha Palette Color Lookup Table Descriptors.

The second value is the first input value mapped. This input value is mapped to the first entry in the Lookup Table Data. All input values less than the first value mapped are also mapped to the first entry in the Lookup Table Data if the Photometric Interpretation is PALETTE COLOR.

Note: In the case of the Supplemental Palette Color LUT, the stored pixel values less than the second descriptor value are grayscale values.

An input value one greater than the first value mapped is mapped to the second entry in the Lookup Table Data. Subsequent input values are mapped to the subsequent entries in the Lookup Table Data up to an input value equal to number of entries + first value mapped - 1, which is mapped to the last entry in the Lookup Table Data. Input values greater than or equal to number of entries + first value mapped are also mapped to the last entry in the Lookup Table Data. The second value shall be identical for each of the Red, Green, Blue and Alpha Palette Color Lookup Table Descriptors.

The third value specifies the number of bits for each entry in the Lookup Table Data. It shall take the value of 8 or 16. The LUT Data shall be stored in a format equivalent to 8 bits allocated when the number of bits for each entry is 8, and 16 bits allocated when the number of bits for each entry is 16, where in both cases the high bit is equal to bits allocated-1. The third value shall be identical for each of the Red, Green and Blue Palette Color Lookup Table Descriptors.

Note: Some implementations have encoded 8 bit entries with 16 bits allocated, padding the high bits; this can be detected by comparing the number of entries specified in the LUT Descriptor with the actual value length of the LUT Data entry. The value length in bytes should equal the number of entries if bits allocated is 8, and be twice as long if bits allocated is 16.

When the Red, Green, or Blue Palette Color Lookup Table Descriptor (0028,1101-1103) are used as part of the Palette Color Lookup Table Module or the Supplemental Palette Color Lookup Table Module in an Image or Presentation State IOD, the third value shall be equal to 16. When the Alpha Palette Color Lookup Table Descriptor (0028,1104) is used, the third value shall be equal to 8.

When the Red, Green, or Blue Palette Color Lookup Table Descriptor (0028,1101-1103) are used as part of the Palette Color Lookup Table Module in a Color Palette IOD, the 3rd value of Palette Color Lookup Table Descriptor (0028,1101-1103) (i.e, the number of bits for each entry in the Lookup Table Data) shall be 8.

Notes: 1. A value of 16 indicates the Lookup Table Data will range from (0,0,0) minimum intensity to (65535,65535,65535) maximum intensity.

2. Since the Palette Color Lookup Table Descriptor (0028,1101-1104) Attributes are multi-valued, in an Explicit VR Transfer Syntax, only one value representation (US or SS) may be specified, even though the first and third values are always by definition interpreted as unsigned. The explicit VR actually used is dictated by the VR needed to represent the second value, which will be consistent with Pixel Representation (0028,0103).

C.7.6.3.1.6 Palette Color Lookup Table Data

Palette Color Lookup Table Data (0028,1201-1204) contain the lookup table data corresponding to the Lookup Table Descriptor (0028,1101-1104).

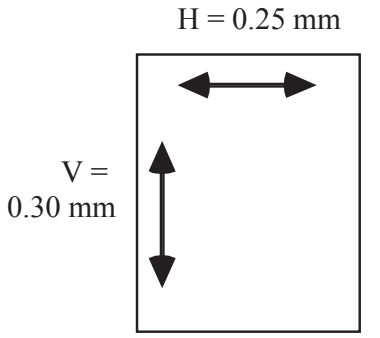
Palette color values must always be scaled across the full range of available intensities. This is indicated by the fact that there are no bits stored and high bit values for palette color data.

Note: For example, if there are 16 bits per entry specified and only 8 bits of value are truly used then the 8 bit intensities from 0 to 255 must be scaled to the corresponding 16 bit intensities from 0 to 65535. To do this for 8 bit values, simply replicate the value in both the most and least significant bytes.

These lookup tables shall be used only when there is a single sample per pixel (single image plane) in the image.

C.7.6.3.1.7 Pixel Aspect Ratio

The pixel aspect ratio is the ratio of the vertical size and horizontal size of the pixels in the image specified by a pair of integer values where the first value is the vertical pixel size, and the second value is the horizontal pixel size. To illustrate, consider the following example pixel size:



Dimensions of pixel

Pixel Aspect Ratio = Vertical Size \ Horizontal Size = 0.30 mm \0.25 mm. Thus the Pixel Aspect Ratio could be represented as the multivalued integer string "6\5", "60\50", or any equivalent integer ratio.

C.7.6.4 Contrast/Bolus Module

Table C.7-12 specifies the Attributes that describe the contrast /bolus used in the acquisition of the Image.

Table C.7-12
CONTRAST/BOLUS MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Contrast/Bolus Agent	(0018,0010)	2	Contrast or bolus agent
Contrast/Bolus Agent Sequence	(0018,0012)	3	Sequence that identifies the contrast agent. One or more Items are permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1		*Baseline CID 12.*	
Contrast/Bolus Route	(0018,1040)	3	Administration route of contrast agent
Contrast/Bolus Administration Route Sequence	(0018,0014)	3	Sequence that identifies the route of administration of contrast agent. Only a single Item is permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8-1		*Baseline CID 11.*	
>Additional Drug Sequence	(0018,002A)	3	Sequence that identifies any additional drug that is administered with the contrast agent bolus. One or more Items are permitted in this sequence.