Digital Imaging and Communications in Medicine (DICOM)

Supplement 145: Whole Slide Microscopic Image IOD and SOP Classes

Prepared by:

DICOM Standards Committee, Working Group 26, Pathology

1300 N. 17th Street, Suite 1752

Rosslyn, Virginia 22209 USA

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Scope and Field of Application

INTRODUCTION

The field of Pathology is undergoing a transformation in which digital imaging is becoming increasingly important. This transformation is fueled by the commercial availability of instruments for digitizing microscope slides. The whole-slide images (WSI) made by digitizing microscope slides at diagnostic resolution are very large. In addition to the size of WSI, the access characteristics of these images differ from other images presently stored in PACS systems. Pathologists need the ability to rapidly pan and zoom images.

In order to facilitate adoption of digital Pathology imaging into hospitals and laboratories, it is desirable that instruments that acquire WSI digital slides store these images into commercially available PACS systems using DICOM-standard messaging. Once this is done, the PACS systems' capabilities for storing, archiving, retrieving, searching, and managing images can be leveraged for these new types of images. Additionally, a given case or experiment may comprise images from multiple modalities, including Radiology and Pathology, and all the images for a case or experiment could be managed together in a PACS system.

Until now, the DICOM Standard did not provide for extremely large two-dimensional images such as the WSI digital slides being created for Pathology, nor did it incorporate a way to handle tiled images (subregion access) nor multiple images at varying resolutions. This document describes WSI image characteristics, and discusses the issues with storing these images with DICOM. It then presents the method for storing WSI using DICOM.

CHARACTERISTICS OF WHOLE-SLIDE IMAGES

Image dimensions, data size

Whole slide images (WSI) are large. A typical sample may be 20mm x 15mm in size, and may be digitized with a resolution of .25 micrometers/pixel (conventionally described as microns per pixel, or mpp) Most optical microscopes have an eyepiece which provides 10X magnification, so using a 40X objective lens actually results in 400X magnification. Although instruments which digitize microscope slides do not use an eyepiece and may not use microscope objective lenses, by convention images captured with a resolution of .25mpp are referred to as 40X, images captured with a resolution of .5mpp are referred to as 20X, etc. The resulting image is therefore about 80,000 x 60,000 pixels, or 4.8Gp. Images are usually captured with 24-bit color, so the image data size is about 15GB.

This is a *typical* example, but larger images may be captured. Sample sizes up to 50mm x 25mm may be captured from conventional 1" x 3" slides, and even larger samples may exist on 2" x 3" slides. Images may be digitized at resolutions higher than .25mpp; some scanning instruments now support oil immersion lenses which can magnify up to 100X, yielding .1mpp resolution. Some sample types are thicker than the depth of field of the objective lens, so capturing multiple focal planes is desirable (by convention the optical axis is Z, so focal planes are often called "Z planes"). Additionally, multi-spectral imaging may capture up to 10 spectral bands at 16-bit per pixel resolution.

Taking an *extreme* example, a sample of 50mm x 25mm could be captured at .1mpp with 10 Z-planes, yielding a stack of 10 images of dimension 500,000 x 250,000 pixels. Each plane would contain 125Gp, or 375GB of data, and the entire image dataset would contain 3.75TB of data. This is a worst case but is conceivable given current technology, and in the future resolution will only increase, as will the practicality of capturing multiple Z-planes.

Access patterns, data organization

Due to the large amount of information on a microscope slide, pathologists cannot view an entire sample at high resolution. Instead, they pan through the slide at a relatively low resolution – typically 5mpp (2X) or 2.5mpp (4X) – and then "zoom in" to higher resolution for selected regions of diagnostic interest. Like all microscopists, pathologists typically focus as they are panning and zooming.

When slides are digitized, the software for viewing WSI must provide equivalent functionality. Pathology image viewers must provide rapid panning and zooming capabilities. When multiple Z-planes are captured, viewers must also provide rapid change of Z-plane selection.

Formally, DICOM is an interchange standard, and thus does not necessarily need to directly support interactive access, whether between an application and a local DICOM object store, or between a client workstation and a server. However, it is desirable that the data organization of the DICOM images of a study should support these types of interactive access patterns. This is especially so because the large data sets of WSI preclude loading an entire image into application random access memory.

To facilitate rapid panning, the image data may be stored in a "tiled" fashion. This enables random access to any subregion of the image without loading large amounts of data. To facilitate rapid zooming, the image may be stored at several pre-computed resolutions. This enables synthesis of subregions at any desired resolution without scaling large amounts of data. Finally, if multiple Z-planes are captured, these may be stored as separate images, to facilitate loading subregions at any desired focal location.

The simplest way to store two-dimensional image data is a *single frame* organization, in which image data are stored in rows which extend across the entire image. Figure 1 shows a single frame image organization:

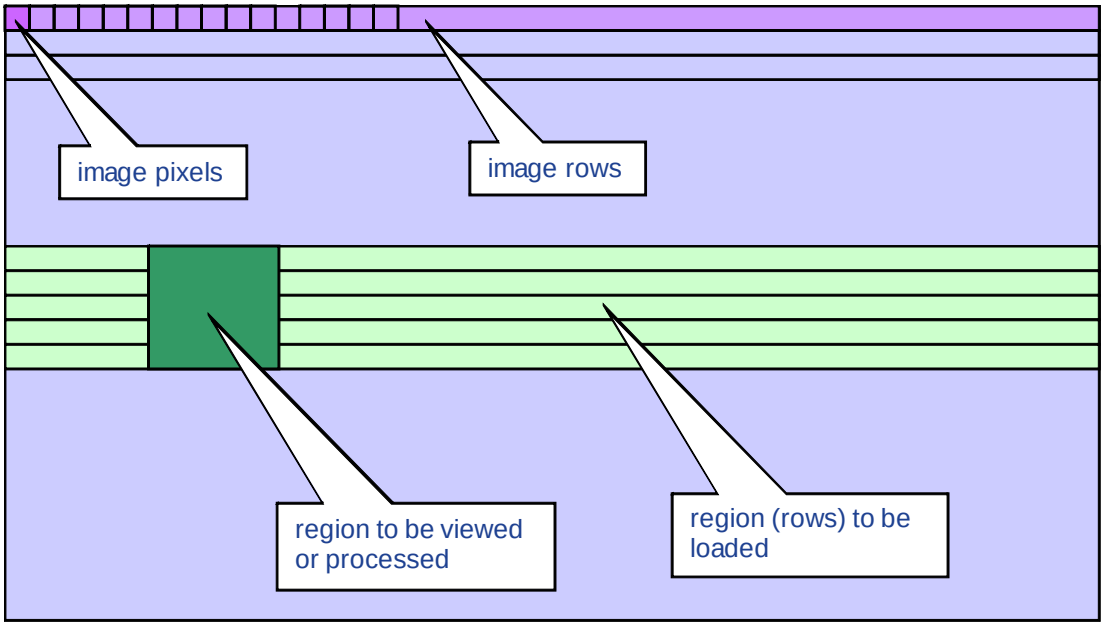

Figure 1 – Single Frame Image Organization

In this single frame organization, image pixels are stored starting from the upper left corner (dark purple square), in rows all the way across the image (medium purple stripe). All the pixels in the image are stored as rows, like text running across a page.

This is a simple organization, but it has an important limitation for large images like WSI: To view or process a subset of the image, a much larger subset of the image must be loaded. For example, in the

illustration above the dark green rectangle indicates a region of the image to be viewed or processed. If a single read operation from secondary store will be used to access this area, the light green region indicates the region of the image which must be loaded to access the dark green region.

A more sophisticated way of storing two-dimensional image data is a *tiled* organization, in which image data are stored in square or rectangular tiles (which are in turn stored by row). Figure 2 shows a tiled image organization:

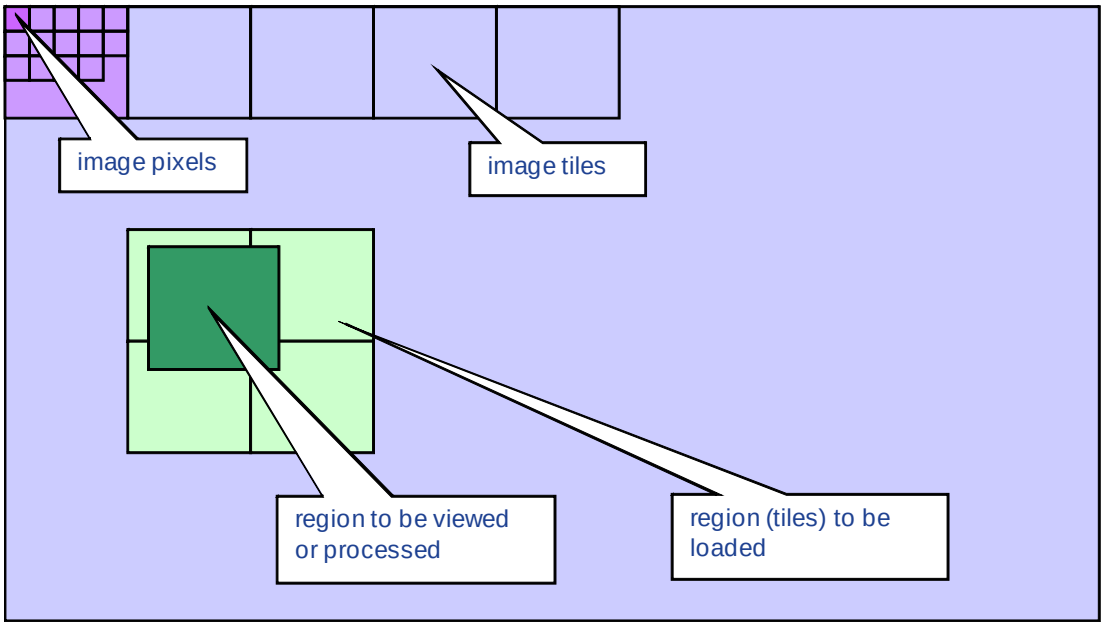

Figure 2 – Tiled Image Organization

Image pixels are stored starting from the upper left corner (dark purple square), in tiles (medium purple rectangle). All the pixels in the image are stored as tiles, like the pages in a book.

This organization is more complicated than single frame images, but it has an important advantage for large images like WSI: To view or process a subset of the image, only a small subset of the image must be loaded (assuming that efficient access to individual tiles on secondary store is supported). For example, in the illustration above the dark green rectangle indicates a region of the image to be viewed or processed. The light green region indicates the tiles of the image which must be loaded to access the dark green region.

The chosen “tile size” for an image affects the performance of accessing the image. Large tiles mean that fewer tiles must be loaded for each region, but more data will be loaded overall. Typical tile sizes might range from 240 x 240 pixels (172KB uncompressed) to 4,096 x 4,096 pixels (50MB uncompressed).

Although storing images with a tiled organization facilitates rapid panning, there is still an issue with rapid zooming. Consider Figure 3:

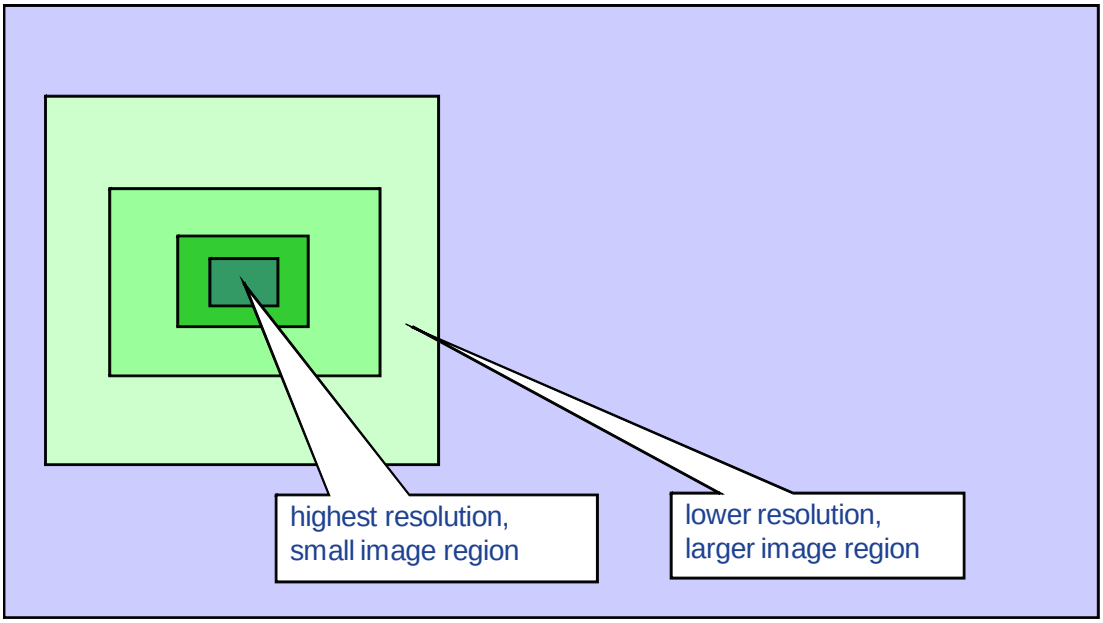

Figure 3 – Issue with Rapid Zooming

The problem is that at high resolution, a small image area must be accessed to render a given region (exemplified by the dark green area in illustration). At lower resolutions, progressively larger image areas must be accessed to render the same size region (lighter green areas in illustration). At the limit, to render a low-resolution thumbnail of the entire image, all the data in the image must be accessed and downsampled!

A solution to this problem is to pre-compute lower resolution versions of the image. These are typically spaced some power of 2 apart, to facilitate rapid and accurate downsampling, and add some "overhead" to the total stored data size. For example, generating resolution levels a factor of 2 apart adds about 32% to the size of the data set, and generating resolution levels a factor of 4 apart adds about 7% to the size of the data set.

The typical organization of a WSI for Pathology may be thought of as a "pyramid" of image data. Figure 4 shows such a pyramid:

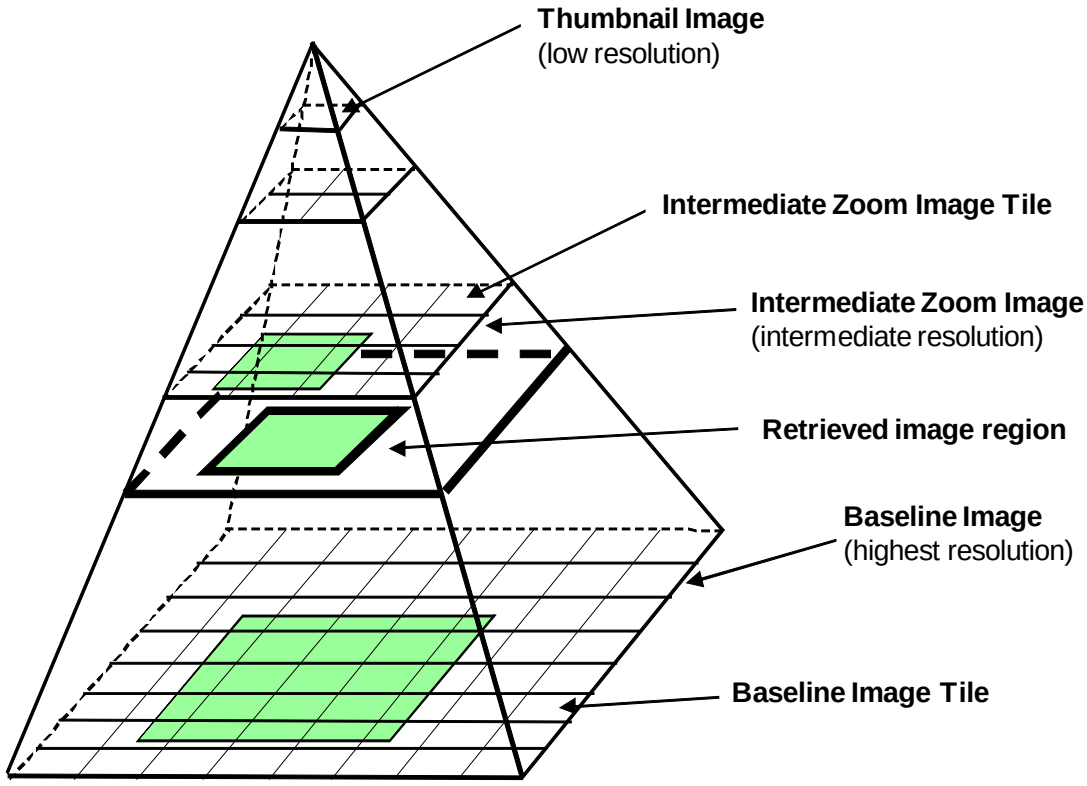

Figure 4 – Whole-slide Image as a "Pyramid" of Image Data

As shown in this figure, the WSI consists of multiple images at different resolutions (the "altitude" of the pyramid corresponds to the "zoom level"). The base of the pyramid is the highest resolution image data as captured by the instrument. A thumbnail image may be created which is a low resolution version of the image to facilitate viewing the entire image at once. One or more intermediate levels of the pyramid may be created, at intermediate resolutions, to facilitate retrieval of image data at arbitrary resolution.

Each image in the pyramid may be stored as a series of tiles, to facilitate rapid retrieval or arbitrary subregions of the image.

Figure 4 shows a retrieved image region at an arbitrary resolution level, between the base level and the first intermediate level. The base image and the intermediate level image are "tiled". The shaded areas indicate the image data which must be retrieved from the images to synthesize the desired subregion at the desired resolution.

Image data compression

Because of their large size, WSI data are often compressed. Depending on the application, lossless or lossy compression techniques may be used. Lossless compression typically yields a 3X-5X reduction in size. The most frequently used lossy compression techniques are JPEG and JPEG2000. For most applications, pathologists have found that there is no loss of diagnostic information when JPEG (at 15X-20X reduction) or JPEG2000 (at 30X-50X reduction) compression is used. Lossy compression is therefore often used in present-day WSI applications. JPEG2000 yields higher compression and fewer image artifacts than JPEG; however, JPEG2000 is compute-intensive.

The "typical" example image described above, which contains 15GB of image data, could be compressed with JPEG2000 to about 300MB. The "extreme" example described above could be compressed from 3.75TB to 75GB.

Sparse image data

Some instruments which digitize microscope slides do not capture all areas of the slide at the highest resolution. In this case the image data within any one level of the conceptual pyramid may be sparse, i.e., lacking some of the tiles.

Similarly, some instruments which capture multiple Z-planes do not capture 3D image information for all areas of a slide. In this case the image data within any one or all Z-planes may be sparse.

DESCRIPTION OF WSI PROPOSAL

Pixel Matrix

In all current DICOM image IODs, pixel matrix dimensions are stored as unsigned 16-bit integers, for a maximum value of 64K columns and rows. As noted above, WSI frequently have pixel dimensions which are larger than this. This proposal stays within the $(64K)^2$ size limit by adopting tiling, although a new WSI IOD would afford the opportunity to go to a $(2^{32})^2$ image size without tiling. The proposal does provide a Total Pixel Matrix up to $(2^{32})^2$, into which the tiles fit, and which defines the spatial orientation of the tiles relative to the slide.

Although an un-tiled approach provides advantages in some access modes, the tiled approach will maximize the ability to leverage existing general DICOM toolkits and infrastructure.

Uncompressed DICOM image pixel data has a maximum size of 2^{32} bytes (4GB). As noted above, WSI may have data sizes which are larger than this. However, compressed DICOM pixel data is sent using a structure that allows unrestricted lengths; since WSI is typically exchanged compressed, this 4GB limitation does not apply.

Tiled images

The basic mechanism proposed for storing WSI images for Pathology in DICOM is **to store the individual "tiles" of a single WSI pyramid level as individual frames in a DICOM multi-frame image object**. The tiles may be small, in which case many individual frames will be stored in the image, or they may be large, and in the limit may be so large that one or more levels of the pyramid require only one "tile". In fact, an entire WSI level can be stored as one single tile (if it fits within the $64K^2$ frame pixel matrix limit).

Where multiple Z-plane images are needed for the WSI, each plane may be stored separately in an object in the series, or all the planes at one level may be stored in the same image object. Similarly, for multispectral imaging each wavelength may be stored separately, or all in the same object.

Each frame is located by three spatial coordinates relative to the WSI: X and Y offsets (by convention, the upper left corner pixel is {1,1}, and X increases down the image to the bottom, while Y ascends across the image to the right), and Z – which indicates the plane in which the image belongs.

Within each image object, tiling is on a regular grid that covers the entire imaged area. The tiling may be sparse or complete. If there are multiple Z-planes in a level, or multiple spectral bands, not only may the tiling may be sparse, but the sparseness may vary between the planes or bands. This applies whether the Z-planes or bands are in separate image objects, or all in the same object.

Within a level there may be several image objects, and the tiling does not need to be the same across those objects. E.g., there may be some image objects with large tiles, and some with small tiles. There may be different alignments of the tiling grid relative to the imaged area. Thus tiling on non-regular basis can be accommodated by using separate image objects.

The edge tiles may include areas that are not part of the scanned volume; those areas may use padding to fill out the tile.

Storing an Image Pyramid as a Series

Where multiple resolution images are needed or desired for the WSI, each "level" is stored separately in the series.

An image object describes one level. Levels are composed of tiles, and so may be sparse (not all tiles present). For any level the resolution is fixed for all tiles in the level, and all tiles have the same width and height, and may not overlap, although the level may be sparse and any number of tiles may be absent.

Figure 5 illustrates the correspondence of an image pyramid to DICOM images and series:

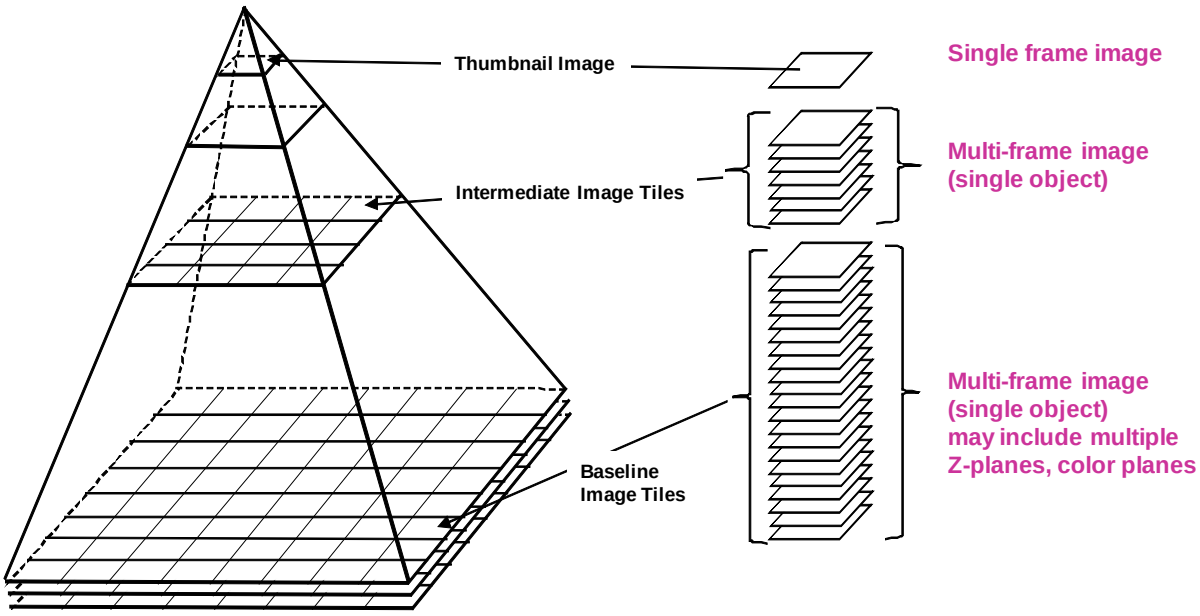

Figure 5 – Mapping a WSI Pyramid into a DICOM Series

The Series may also contain ancillary images, such as a slide label image or whole slide macro image.

Color / Optical Path

Different WSI images may have different numbers of color channels and different numbers of bits per channel. The most typical format for simple color images will be three channels, typically RGB data or transformed to YC_BC_R color space, with pixels having 8-bit samples for each channel.

Multi-spectral images may have a single frequency band encoded in each frame with up to 16 bits pixel depth; such images will be identified as monochrome, although the image object may include many co-extensive frames representing a tile in different spectral bands. The color mapping of each frame is conveyed through a description of the optical path.

The optical path description for each frame allows the specification of the illumination and the detection spectra (which may differ with fluorescence), lenses, polarization, and other parameters. In the simple color image case, illumination would be white light with RGB detection.

The color characteristics of an RGB image are corrected by an ICC Profile (included in the image object) to account for the illumination characteristics.

For multi-spectral images, each frequency band has a recommended display color. It is the responsibility of the display application to decide how to display multiple bands (encoded in separate frames), and how to use that recommended color (including blending of multiple spectral band frames).

WSI Frame of Reference

The current DICOM Slide Coordinates Microscopy Visible Light IOD defines a Frame of Reference for localizing slide images using a slide-based coordinate system (comparable to the DICOM patient-based coordinate system). It specifies a particular corner of the slide as a nominal reference origin, and a right handed (X,Y,Z) coordinate system for positioning from that origin.

This WSI proposal retains that Frame of Reference and coordinate system, using it to localize each frame (tile), as well as the top left hand corner of the total imaging area.

Note that while the nominal reference origin and coordinate system are clearly defined, they are not intended to be reproducible across different mountings of a slide, even on the same equipment. Also note that the slide-based (X,Y) coordinate system is rotated 180° from the conventional image matrix (row, column) orientation of the image frames with the label on the left. See Figure 6.

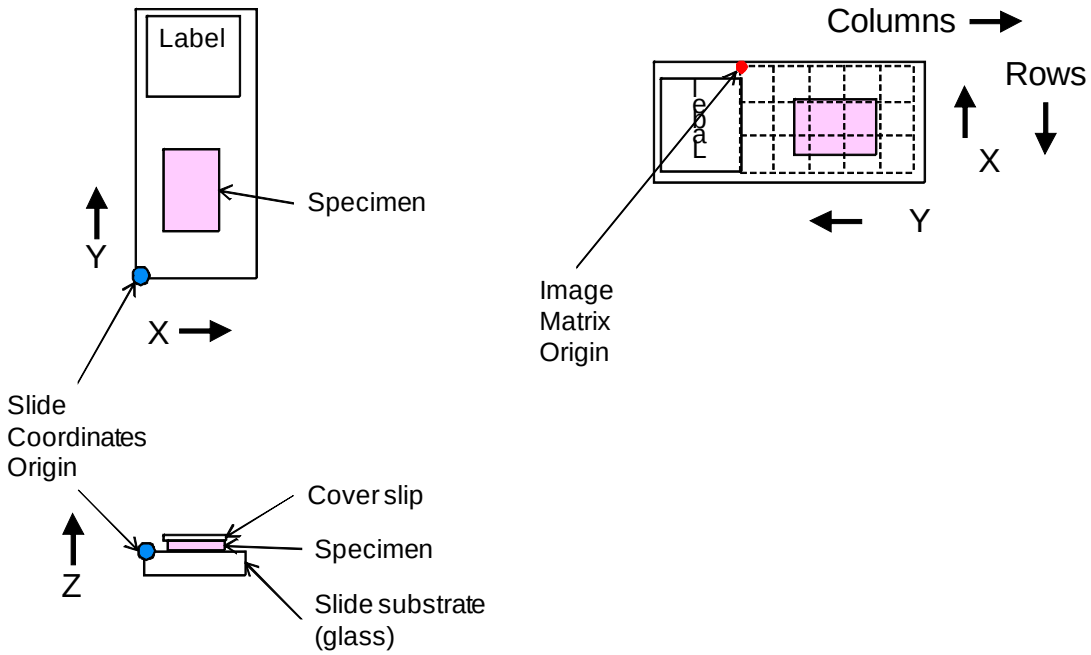

Figure 6 – Slide Coordinates Origin and (X,Y,Z) vs. Image Matrix Origin and (Rows,Columns)

Z-Planes

The focal plane of a frame, or Z-plane, is identified as the nominal physical height (in µm) of image focus above the reference surface, which in the slide-based coordinate system is the top surface of the (glass) slide substrate, i.e., the side on which the specimen is placed.

Z-plane information is used for relative spatial positioning of image planes, and *nominal* inter-plane distance. An imaging focal plane may track variations in specimen thickness or the specimen surface contour, but only one Z-value is used. It thus has meaning only in a local context; it can be used for relative depths of different frames at the same (X,Y) tile position, and it can be used to match the frame at one tile position to a frame at an adjacent tile position with the same Z-plane depth. The Z value should not be used as an absolute depth measurement. See Figure 7.

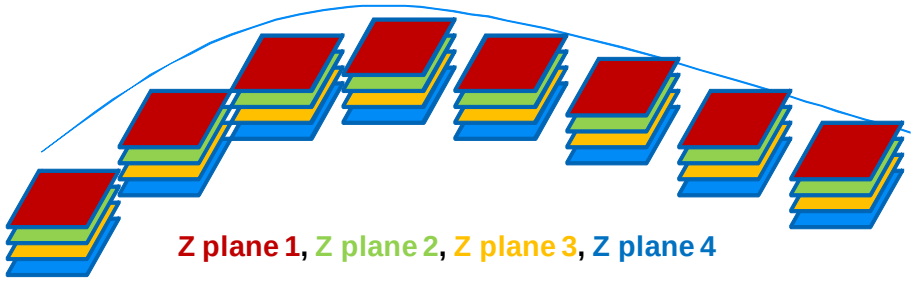

Figure 7 – Z planes track curved surface

Localizer and Navigation

This proposal includes several mechanisms to facilitate navigation across the WSI data set (series).

First, it proposes a LOCALIZER "image flavor" as a visual guide to the various resolution levels and tiles/frames within those levels, Although DICOM does not specify display application behavior, the Multi-Resolution Navigation Module in the localizer image provides sufficient information for an application to navigate through all frames of images in the series. It identifies the corresponding location in the localizer image of all frames, and provides their salient characteristics (resolution, color, Z-plane).

Each multi-frame image may also provide linkage to other images in the series using the Referenced Image Sequence. This can be used to identify images at other resolutions, other Z-planes, or other colors (if those are stored separately).

Within each multi-frame image, the dimension indices allow a display application to traverse the frames by a variety of dimensions for display, including lateral spatial dimensions, Z-planes, or optical parameter (color).

WSI ANNOTATION AND ANALYSIS RESULTS

Introduction

As a general principle in DICOM, annotations are conveyed in information objects separate from the image. Since annotations may be created at a time much later than the image acquisition in a different Procedure Step, and on different equipment, and because annotations are of a different "modality" than image acquisition (i.e., they are created by a different type of process), they must be recorded in a separate Series (as a DICOM Series is limited to objects of a single Modality, produced by a single Equipment, in a single Procedure Step).

As independent objects, multiple annotation objects can reference the same image.

Types of annotation

There are several types of annotation objects serving different purposes:

- Presentation States – convey the parameters of a display rendering of the image, including display area selection, rotate/flip, zoom, windowing or pseudo-coloring (for grayscale images),and graphic annotation (ROI indicators and text labels). As display parameters, the display application can use these as initial settings, allowing the receiving user to further interact with display controls.
- Segmentation – provides a categorization (anatomic, structural, functional, chemical, etc.) of areas of an image, typically rendered as an overlay.
- Structured Reporting – captures measurements, clinical observations, analyses, and findings, with explicit context and inference, and with robust reference to image evidence. Includes CAD results, procedure logs and notes, and study content manifests,
- Real World Value Mapping – specifies a mapping of the stored pixel values of images into some real world value in defined units.

Each of these has potential applicability to WSI.

Presentation States

The Grayscale Softcopy Presentation State (GSPS), Color Softcopy Presentation State (CSPS), and Pseudo-Color Softcopy Presentation State (PCSPS) can be used as is for annotating individual frames (tiles). However, if we want to be able to have a single annotation extend across tile boundaries, we need a bit of tweaking to allow the annotation anchor locations to be relative to the whole image matrix, which is provided in this Supplement.

Note that a Presentation State annotation can apply to multiple frames. Thus a single annotation can be identified as applying to all the tiles of different spectra (colors) and/or different focal planes that are at the same position in the Image Pixel Matrix

Structured Display is another type of Presentation State that lays out multiple windows on a screen, and describes the images (and their initial presentation states) to be displayed in those windows.

Segmentation

Segmentation is a type of derived image, and is encoded using the enhanced multi-frame paradigm. (Note there is also a DICOM capability for Surface Segmentation, which is not discussed here.) Each segment is linked to a categorization or classification of a corresponding area in an analyzed source image. Typically, a segmentation image frame is encoded with only 1-bit/pixel to show the presence or absence of the specified category at that pixel location. Alternatively, encoding can be 1-byte/pixel to allow a fractional assessment of the classification (either probability of the classification in the referenced pixel, or fractional occupancy of the pixel by the classification).

A segmentation image can be in the same Frame of Reference as the source image, in which case the spatial alignment can be specified relative to the Frame of Reference origin, and the spatial resolution (pixel spacing) can be different than the source image. However, the segmentation can also be aligned on a pixel-by-pixel basis with a source image, whether or not there is a Frame of Reference used. In that case, the segmentation frame has the same pixel spatial resolution and extent as the source frame. For WSI, segmentations can be created for any selected frames (tiles); it is not necessary to perform a segmentation across the entire image.

A segmentation frame can be derived from multiple source frames. Thus, multiple color channels can be used to perform the segmentation.

For a grayscale source image, the Blending Softcopy Presentation State can be used to control an initial presentation of the source image with the segmentation as a color overlay, with variable relative opacity. With a color source image, the segmentation image object itself can convey a recommended display color for the overlay, but there is currently no standard presentation state controlling color on color blending.

Structured Reporting

While Presentation State objects can carry textual annotation, that annotation is for human use only – it is not formally processable by automated applications in an interoperable manner. It does not use controlled and coded vocabulary, and conveys no structural semantics (relationships between annotations). Those capabilities are available with Structured Reporting (SR).

The areas in which SR is important are those where the annotations are intended to be used in the imaging analysis and review processes. For example, CAD analysis results, intended to be overlaid on images, and which require full contextual description of their evidentiary and inferential chain, are defined as SR objects. Similarly, SR can facilitate conveying provisional image measurements and findings (internal departmental work products), to be reviewed by a physician together with the imaging, as part of the clinical review and reporting process.

The final clinical report, intended for broad distribution outside the imaging environment, may be encoded as an HL7 CDA document. However, there are standard means of encoding DICOM object references in CDA, so that such reports can link to the imaging evidence (including reference of Presentation States to control display of referenced images).

Real World Value Mapping

In quantitative multi-spectral microscopy, pixel values can be mapped to activity, concentration, or other physical measurements. Real World Value Mapping objects can provide the conversion from pixel values to physical measurement values through a linear equation (slope and intercept), or through a look up table.

WSI WORKFLOW - MWL AND MPPS

Introduction

Workflow management in the DICOM imaging environment utilizes the Modality Worklist (MWL) and Modality Performed Procedure Step (MPPS) services. Although these were defined for supporting human controlled imaging (radiologic technicians operating a scanner modality), they should be adequate for automated slide scanning modalities as well. This section provides a high level description of MWL and MPPS.

Modality Worklist

The Scheduled Specimen Sequence was added to the Modality Worklist service in Supplement 122. This feature allows a scanner to query for work items by slide barcode (Container ID). Thus when a WSI scanner loads a slide, it can scan the label and interpret the barcode, and send an MWL query with that barcode to the lab information system (the worklist server). The LIS can then return all the necessary information for creating a DICOM WSI image, including patient identity, the complete slide processing history (including stain applied) to be used for imaging set up and/or inclusion in the WSI image object header.

Typically, the set up of scanning modalities is done through a Protocol Code that references a canned set of acquisition parameters. In the case of WSI, that might include scan resolution, number of Z-planes, fluorescence wavelengths, etc. Additional set-up parameters can be passed in the associated Protocol Context Sequence; this might be important if the reading pathologist requests a rescan of the slide with slightly different settings.

Note: In DICOM, the term “Protocol” refers to a defined process for an imaging procedure step, and should not be confused with larger scope laboratory or clinical protocols.

Modality Performed Procedure Step

Upon completion of a scan, the scanner reports the work completed in a Modality Performed Procedure Step transaction. Supplement 122 also enhanced MPPS by adding slide identifier information, so that the workflow manager (laboratory information system) is advised of the image unique identifiers associated with each imaged slide.

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Changes to NEMA Standards Publication PS 3.17-2009

Digital Imaging and Communications in Medicine (DICOM)

Part 17: Explanatory Information

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Add new section NN.7 to PS 3.17 Annex NN

Annex NN – Specimen Identification and Management

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NN.7 SPECIMEN DATA IN PATHOLOGY IMAGING WORKFLOW MANAGEMENT

Workflow management in the DICOM imaging environment utilizes the Modality Worklist (MWL) and Modality Performed Procedure Step (MPPS) services. Within the pathology department, these services support both human controlled imaging (e.g., gross specimen photography), as well as automated slide scanning modalities.

While this section provides an overview of the DICOM services for managing workflow, the reader is referred to the IHE Anatomic Pathology Domain Technical Framework for specific use cases and profiles for pathology imaging workflow management.

NN.7.1 Modality Worklist

The contents of the Specimen Module may be conveyed in the Scheduled Specimen Sequence of the Modality Worklist query. This feature allows an imaging system (Modality Worklist SCU) to query for work items by Container ID. The worklist server (SCP) of the laboratory information system can then return all the necessary information for creating a DICOM specimen-related image. This information includes patient identity and the complete slide processing history (including stain applied). It may be used for imaging set-up and/or inclusion in the Image SOP Instance.

NN.7.1.1 MWL for Whole Slide Imaging

In addition to the Specimen Module attributes, the set up of an automated whole slide scanner requires the acquisition parameters such as scan resolution, number of Z-planes, fluorescence wavelengths, etc. A managed set of such parameters is called a Protocol (see PS 3.3), and the MWL response may contain a Protocol Code to control scanning set up. Additional set-up parameters can be passed as Content Items in the associated Protocol Context Sequence; this might be important when the reading pathologist requests a rescan of the slide with slightly different settings.

NN.7.2 Modality Performed Procedure Step

When scanning is initiated, the scanner reports the procedure step in a Modality Performed Procedure Step (MPPS) transaction.

Upon completion (or cancellation) of an image acquisition, the modality reports the work completed in an update to the MPPS. The MPPS can convey both the Container ID and the image UIDs, so that the workflow manager (laboratory information system) is advised of the image UIDs associated with each imaged specimen.

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Changes to NEMA Standards Publication PS 3.2-2009

530 ## Digital Imaging and Communications in Medicine (DICOM)

Part 2: Conformance

Add new row to PS 3.2 Annex A Table A.1-2

Table A.1-2
UID VALUES

UID Value	UID NAME	Category
…	…	…
1.2.840.10008.5.1.4.1.1.77.1.6	**VL Whole Slide Microscopy Image Storage**	**Transfer**
…	…	…

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540 **Changes to NEMA Standards Publication PS 3.3-2009**

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions

Add new reference in Section 2

OTHER REFERENCES

US Patent 6,272,235 Bacus, JV, and Bacus, JW, "Method and Apparatus for Creating a Virtual Microscope Slide"

Update PS 3.3 A.32.2.2 and A.32.3.2 to add Optical Path Module for attributes that might otherwise be coded in Acquisition Context, clarify the language, and correct the VL SCM IOD which does indeed use the Frame of Reference IE and has a Mandatory Specimen Module (improperly transcribed from Sup122 into PS3.3-2009)

A.32.2.2 VL Microscopic Image IOD Entity-Relationship Model

The E-R Model in Section A.1.2 of this Part depicts those components of the DICOM Information Model that ~~**directly**~~ **are** reference**d by** the VL Microscopic Image IOD~~**, with exception of the VOI LUT, Frame of Reference and Modality LUT entities, which are not used. Additionally, Image in figure A.1.2 of PS3.3. Below the Series IE, only the Image IE is used, which**~~ represents a Single Frame image. ~~**A frame denotes a two-dimensional organization of pixels recorded as a single exposure.**~~ Table A.32.1-2 specifies the Modules of the VL Microscopic Image IOD.

Notes**:** 1. The Curve entity was previously included in the list of entities that are not used, but has been retired from DICOM. It is still not used in this IOD. See PS 3.3 2004.

2. The Specimen Identification Module was previously included in this IOD but has been retired, and its functionality replaced by the Specimen Module. See PS 3.3-2008.

Table A.32.1-2
VL MICROSCOPIC IMAGE IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Acquisition Context	C.7.6.14	M
	Device	C.7.6.12	U
	Specimen	C.7.6.22	C - Required if the Imaging Subject is a Specimen
	VL Image	C.8.12.1	M
	Optical Path	**C.8.12.x3**	**U**
	Overlay Plane	C.9.2	U
	SOP Common	C.12.1	M

...

A.32.3.2 VL Slide-Coordinates Microscopic Image IOD Entity-Relationship Model

The E-R Model in Section A.1.2 of this Part depicts those components of the DICOM Information Model that **~~directly~~ are** referenced **by** the VL Slide-Coordinates Microscopic Image IOD**~~, with exception of the VOI LUT, Frame of Reference and Modality LUT entities, which are not used. Additionally, Image in figure A.1.2 of PS3.3.~~** **Below the Series IE, only the Image IE is used, which** represents a Single Frame image. **~~A frame denotes a two-dimensional organization of pixels recorded as a single exposure.~~** Table A.32.1-3 specifies the Modules of the VL Slide-Coordinates Microscopic Image IOD.

Notes: 1. The Curve entity was previously included in the list of entities that are not used, but has been retired from DICOM. It is still not used in this IOD. See PS 3.3 2004.

2. The Specimen Identification Module was previously included in this IOD but has been retired, and its functionality replaced by the Specimen Module. See PS 3.3-2008.

3. The Frame of Reference IE was previously (incorrectly) identified as not used in this IOD, although the Frame of Reference Module was specified as Mandatory. See PS 3.3-2009.

Table A.32.1-3
VL SLIDE-COORDINATES MICROSCOPIC IMAGE IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Acquisition Context	C.7.6.14	M
	Device	C.7.6.12	U
	Specimen	C.7.6.22	**~~C - Required if Imaging Subject is a specimen~~ M**
	VL Image	C.8.12.1	M
	Slide Coordinates	C.8.12.2	M
	Optical Path	**C.8.12.x3**	**U**
	Overlay Plane	C.9.2	U
	SOP Common	C.12.1	M

Add new section for VL WSI IOD

A.32.X VL Whole Slide Microscopy Image Information Object Definition

A.32.X.1 VL Whole Slide Microscopy Image IOD Description

The VL Whole Slide Microscopy Image IOD specifies the Attributes of a multi-frame visible light whole slide microscopy image encoded as a tiled decomposition. Each frame encodes a single tile within a three dimensional imaged volume at a uniform resolution.

Notes: 1. An entire set of tiles for an acquisition may be encoded in the frames of a single SOP Instance, in multiple SOP Instances of a single concatenation, or in multiple SOP Instances in a series (with or without concatenations). E.g., a single SOP Instance may contain an entire low resolution image as a single tile (single frame), or a single SOP Instance may contain an entire high resolution, multi-focal depth, multi-spectral acquisition (multiple frames).

2. Attention is called to the possibility that conformance with the VL Whole Slide Microscopy Image Storage SOP Class utilizing this IOD may involve the use of claimed Intellectual Property Rights, among which may be US Patent 6,272,235 referenced in Section 2. The DICOM Standards Committee takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by members of the DICOM Standards Committee or others.

A.32.X.2 VL Whole Slide Microscopy IOD Entity-Relationship Model

The E-R Model in section A.1.2 depicts those components of the DICOM Information Model that comprise the VL Whole Slide Microscopy IOD.

A.32.X.3 VL Whole Slide Microscopy IOD Module Table

Table A.32.X-1
VL WHOLE SLIDE MICROSCOPY IOD MODULES

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Whole Slide Microscopy Series	C.8.12.X1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Acquisition Context	C.7.6.14	M
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Specimen	C.7.6.22	M
	Whole Slide Microscopy Image	C.8.12.X2	M

IE	Module	Reference	Usage
	Optical Path	C.8.12.x3	M
	Multi-Resolution Navigation	C.8.12.X5	C – Required if Image Type (0008,0008) Value 3 is LOCALIZER
	Slide Label	C.8.12.X6	C – Required if Image Type (0008,0008) Value 3 is LABEL; may be present otherwise
	SOP Common	C.12.1	M
	Common Instance Reference	C.12.2	M

A.32.X.3.1 VL Whole Slide Microscopy IOD Content Constraints

A.32.X.3.1.1 Optical Path Module

The Code Sequences within the Optical Path Sequence (0048,0105) of the Optical Path Module (see C.8.12.x3) are constrained as follows:

Baseline Context ID for Illuminator Type Code Sequence (0048,0100) is CID 8125.

Baseline Context ID for Illumination Color Code Sequence (0048,0108) is CID 8122.

Baseline Context ID for Illumination Type Code Sequence (0022,0016) is CID 8123.

Baseline Context ID for Lenses Code Sequence (0022,0019) is CID 8121.

Baseline Context ID for Light Path Filter Type Stack Code Sequence (0022,0017) and for Image Path Filter Type Stack Code Sequence (0022,0018) is CID 8124.

Baseline Context ID for Channel Description Code Sequence (0022,001A) is CID 8122.

A.32.X.4 VL Whole Slide Microscopy Functional Group Macros

Table A.32.X-2 specifies the use of the Functional Group macros used in the Multi-frame Functional Groups Module for the VL Whole Slide Microscopy IOD.

Table A.32.X-2
VL WHOLE SLIDE MICROSCOPY FUNCTIONAL GROUP MACROS

Functional Group Macro	Section	Usage
Pixel Measures	C.7.6.16.2.1	M – Shall be used as a Shared Functional Group.
Frame Content	C.7.6.16.2.2	M – Shall not be used as a Shared Functional Group.
Referenced Image	C.7.6.16.2.5	U
Derivation Image	C.7.6.16.2.6	C – Required if the image or frame has been derived from another SOP Instance.
Real World Value Mapping	C.7.6.16.2.11	U
Plane Position (Slide)	C.8.12.X4.1	M
Optical Path Identification	C.8.12.X4.2	M
Specimen Reference	C.8.12.X4.3	U

A.32.X.4.1 VL Whole Slide Microscopy Functional Group Macros Content Constraints

A.32.X.4.1.1 Referenced Image

Baseline Context ID for Purpose of Reference Code Sequence (0040,A170) is CID 8120.

A.32.X.4.1.2 Plane Position (Slide)

Frames shall occupy plane positions in a regular tiling of the Total Image Matrix; the frames may extend beyond the edges of the Total Image Matrix. Therefore, the value of Column Position In Total Pixel Matrix (0048,021E) shall be an integer multiple of the value of Columns (0028,0011) plus a constant, and the value of Row Position In Total Pixel Matrix (0048,021F) shall be an integer multiple of the value of Rows (0028,0010) plus a (possibly different) constant.

Note: Pixels beyond the edge of the Total Image Matrix may be encoded with a fixed padding value. For images with MONOCHROME2 Photometric Interpretation, see Pixel Padding Value (0028,0120) in Section C.7.5.1.1.2.

The encoding of tiles may be sparse; i.e., some tiles may not be encoded in frames. There are no constraints on the ordering of frames within the pixel data; each frame specifies its position in the Plane Position (Slide) Functional Group.

Note: Different SOP Instances within a Series may have different tiling boundaries and sizes.

Frames associated with different optical paths may coincide in any spatial dimension.

Update PS 3.3 C.7.4.1 to clarify use for slide coordinates FoR

C.7.4.1 Frame Of Reference Module

Table C.7-6 specifies the Attributes necessary to uniquely identify a frame of reference which insures the spatial relationship of Images within a Series. It also allows Images across multiple Series to share the same Frame Of Reference. This Frame Of Reference (or coordinate system) shall be constant for all Images related to a specific Frame Of Reference.

When a Frame of Reference is identified, it is not important how the **imaging target (**Patient**, specimen, or phantom)** is positioned relative to the imaging equipment or where the origin of the Frame Of Reference is located. It is important that the position of the ~~**Patient**~~ **imaging target** and the origin are constant in relationship to a specific Frame Of Reference.

Note: Since the criteria used to group images into a Series is application specific, it is possible for imaging applications to define multiple Series within a Study that share the same imaging space. Previous versions of the DICOM Standard specified that all images within the Series must be spatially related. However, insufficient information was available to determine if multiple Series within a Study were spatially related.

Table C.7-6
FRAME OF REFERENCE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Frame of Reference UID	(0020,0052)	1	Uniquely identifies the frame of reference for a Series. See C.7.4.1.1.1 for further explanation.
Position Reference Indicator	(0020,1040)	2	Part of the **imaging target** ~~**patient's anatomy**~~ used as a reference~~**, such as the iliac crest, orbital-medial, sternal notch, symphysis pubis, xiphoid, lower coastal margin, external auditory meatus**~~. See C.7.4.1.1.2 for further explanation.

C.7.4.1.1 Frame Of Reference Attribute Descriptions

C.7.4.1.1.1 Frame Of Reference UID

The Frame of Reference UID (0020,0052) shall be used to uniquely identify a frame of reference for a series. Each series shall have a single Frame of Reference UID. However, multiple Series within a Study may share a Frame of Reference UID. All images in a Series that share the same Frame of Reference UID shall be spatially related to each other.

Notes: 1. Previous versions of this Standard defined a Data Element "Location", which has been retired. Frame of Reference UID provides a completely unambiguous identification of the image location reference used to indicate position.

2. A common Frame of Reference UID may be used to spatially relate localizer images with a set of transverse images. However, in some cases (eg. multiple localizer images being related to a single set of transverse images) a common Frame of Reference UID may not be sufficient. The Referenced Image Sequence (0008,1140) provides an unambiguous method for relating localizer images.

C.7.4.1.1.2 Position Reference Indicator

The Position Reference Indicator (0020,1040) specifies the part of the **imaging target** ~~**patient's anatomy**~~ that was used as a~~**n anatomical**~~ reference point associated with a specific Frame of Reference UID. The Position Reference Indicator may or may not coincide with the origin of the fixed frame of reference related to the Frame of Reference UID.

For a Patient-related Frame of Reference, this is an anatomical reference point such as the iliac crest, orbital-medial, sternal notch, symphysis pubis, xiphoid, lower coastal margin, or external

auditory meatus, or a fiducial marker placed on the patient. The patient-based coordinate system is described in C.7.6.2.1.1.

For a slide-related Frame of Reference, this is the slide corner as specified in C.8.12.2.1 and shall be identified in this attribute with the value "SLIDE_CORNER". The slide-based coordinate system is described in C.8.12.2.1.

The Position Reference Indicator shall be used only for annotation purposes and is not intended to be used as a mathematical spatial reference.

Note: The Position Reference Indicator may be sent zero length when it has no meaning, for example, when the Frame of Reference Module is required to relate mammographic images of the breast acquired without releasing breast compression, but where there is no meaningful anatomical reference point as such.

Update PS 3.3 C.7.6.16.2.1 for specimen and microscopy

C.7.6.16.2.1 Pixel Measures Macro

Table C.7.6.16-2 specifies the attributes of the Pixel Measures Functional Group macro.

Table C.7.6.16-2
PIXEL MEASURES MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Pixel Measures Sequence	(0028,9110)	1	Identifies the physical characteristics of the pixels of this frame. Only a single Item shall be permitted in this sequence.
>Pixel Spacing	(0028,0030)	1C	Physical distance in the **imaging target (**patient**, specimen, or phantom)** between the centers 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 of the value order. Note: In the case of CT images with an Acquisition Type (0018,9302) of CONSTANT_ANGLE, the pixel spacing is that in a plane normal to the central ray of the diverging X-Ray beam as it passes through the data collection center. Required if Volumetric Properties (0008,9206) is other than DISTORTED or SAMPLED. May be present otherwise.
>Slice Thickness	(0018,0050)	1C	Nominal reconstructed slice thickness **(for tomographic imaging) or depth of field (for optical non-tomographic imaging)** in mm. See ~~**C.7.6.2.1.1 and**~~ C.7.6.16.2.3.1 for further explanation. **Note: Depth of field may be an extended depth of field created by focus stacking (see C.8.12.X2).** Required if Volumetric Properties (0008,9206) is VOLUME or SAMPLED. May be present otherwise.

In PS 3.3 C.7.9, break out Palette Color LUTs as a Macro:

C.7.9 Palette Color Lookup Table Module

…

Table C.7-22
PALETTE COLOR LOOKUP MODULE

Attribute Name	Tag	Type	Attribute Description
Include 'Palette Color Lookup Macro' Table C.7-22a			

Table C.7-22a
PALETTE COLOR LOOKUP ~~MODULE~~ MACRO

Attribute Name	Tag	Type	Attribute Description
Red Palette Color Lookup Table Descriptor	(0028,1101)	1	Specifies the format of the Red Palette Color Lookup Table Data (0028,1201). See C.7.6.3.1.5 for further explanation.
…			

Add to PS 3.3 C.8.12 VL Modality-specific Modules and Macros:

C.8.12 VL Modules and Functional Group Macros

…

C.8.12.X1 VL Whole Slide Microscopy Series Module

Table C.8.12.X1-1 specifies attributes for the VL Whole Slide Microscopy Series Module, including specialization of attributes in the General Series Module for use in the VL Whole Slide Microscopy Series Module.

Table C.8.12.X1-1
VL WHOLE SLIDE MICROSCOPY SERIES MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Modality	(0008,0060)	1	Type of equipment that originally acquired the data used to create the images in this Series. Enumerated Values: SM See section C.7.3.1.1.1 for further explanation.
Referenced Performed Procedure Step Sequence	(0008,1111)	1C	Uniquely identifies the Performed Procedure Step SOP Instance to which the Series is related (e.g. a Modality or General-Purpose Performed Procedure Step SOP Instance). The Sequence shall have one Item. Required if the Modality Performed Procedure Step SOP Class or General Purpose Performed Procedure Step SOP Class is supported.
>Include 'SOP Instance Reference Macro' Table 10-11			

C.8.12.X2 VL Whole Slide Microscopy Image Module

Table C.8.12.X2-1 specifies the Attributes that describe the VL Whole Slide Microscopy Image Module.

Table C.8.12.X2-1
VL WHOLE SLIDE MICROSCOPY IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See C.8.12.X2.1.1 for specialization.
Imaged Volume Width	(0048,0001)	1	Width of total imaged volume (distance in the direction of rows in each frame) in mm. See C.8.12.X2.1.2
Imaged Volume Height	(0048,0002)	1	Height of total imaged volume (distance in the direction of columns in each frame) in mm. See C.8.12.X2.1.2
Imaged Volume Depth	(0048,0003)	1	Depth of total imaged volume (distance in the Z direction of focal planes) in µm. See C.8.12.X2.1.2

Total Pixel Matrix Columns	(0048,0006)	1	Total number of columns in pixel matrix; i.e., width of total imaged volume in pixels. See C.8.12.X2.1.3
Total Pixel Matrix Rows	(0048,0007)	1	Total number of rows in pixel matrix; i.e., height of total imaged volume in pixels. See C.8.12.X2.1.3
Total Pixel Matrix Origin Sequence	(0048,0008)	1	Location of pixel 1\1 of the total pixel matrix in the Slide Coordinate System Frame of Reference. Only a single Item shall be permitted in this sequence. See C.8.12.X2.1.4 and C.8.12.2.1.1 for further explanation
>X Offset in Slide Coordinate System	(0040,072A)	1	The X offset in millimeters from the Origin of the Slide Coordinate System.
>Y Offset in Slide Coordinate System	(0040,073A)	1	The Y offset in millimeters from the Origin of the Slide Coordinate System.
Image Orientation (Slide)	(0048,0102)	1	The direction cosines of the first row and the first column of the total pixel matrix with respect to the Slide Coordinate System Frame of Reference. See C.8.12.X2.1.4
Samples Per Pixel	(0028,0002)	1	Number of samples (color planes) per frame in this image. Enumerated values: 1 or 3. See C.8.12.X2.1.5 for further explanation.
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. See section C.8.12.X2.1.5 for Enumerated Values.
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. Enumerated Value: 0 = color-by-pixel
Number of Frames	(0028,0008)	1	Number of frames in a multi-frame image. If Image Type (0008,0008) Value 3 is LOCALIZER or LABEL, Enumerated Value is 1.
Bits Allocated	(0028,0100)	1	Number of bits allocated for each pixel sample. Enumerated Values: 8, 16
Bits Stored	(0028,0101)	1	Number of bits stored for each pixel sample. Enumerated Values: 8, 16
High Bit	(0028,0102)	1	Most significant bit for pixel sample data. Enumerated Values: 7, 15
Pixel Representation	(0028,0103)	1	Data representation of pixel samples. Enumerated Value: 0 = unsigned integer
Acquisition Datetime	(0008,002A)	1	The date and time that the acquisition of data that resulted in this image started.
Acquisition Duration	(0018,9073)	1	Duration of the image acquisition in ms.

Lossy Image Compression	(0028,2110)	1	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)	1C	See C.7.6.1.1.5 for further explanation. Required if Lossy Image Compression (0028,2110) equals 01.
Lossy Image Compression Method	(0028,2114)	1C	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 multi valued if successive lossy compression steps have been applied; the value order shall correspond to the values of Lossy Image Compression Ratio (0028,2112). Required if Lossy Image Compression (0028,2110) equals 01.
Presentation LUT Shape	(2050,0020)	1C	Specifies an identity transformation for the Presentation LUT, such that the output of all grayscale transformations defined in the IOD containing this Module are defined to be P-Values. Enumerated Values: IDENTITY - output is in P-Values. Required if Photometric Interpretation (0028,0004) is MONOCHROME2.
Rescale Intercept	(0028,1052)	1C	The value b in relationship between stored values (SV) and the output units. Output units = m*SV + b. Enumerated value 0 Required if Photometric Interpretation (0028,0004) is MONOCHROME2.
Rescale Slope	(0028,1053)	1C	m in the equation specified by Rescale Intercept (0028,1052). Enumerated value 1 Required if Photometric Interpretation (0028,0004) is MONOCHROME2.
Volumetric Properties	(0008,9206)	1	Indication if geometric manipulations are possible with frames in the SOP Instance. See C.8.16.2.1.2. Enumerated Value: VOLUME - pixels represent the volume specified for the image, and may be geometrically manipulated

Specimen Label in Image	(0048,0010)	1	Indicates whether the specimen label is captured in the image. Enumerated Values: YES, NO
Burned In Annotation	(0028,0301)	1	Indicates whether or not image contains sufficient burned in annotation to identify the patient. Enumerated Values: YES NO Note: If Specimen Label in Image (0048,0010) value is YES, Burned In Annotation (0028,0301) might be NO if the label includes only a specimen identifier and not patient identifying data.
Focus Method	(0048,0011)	1	Method of focusing image Enumerated Values: AUTO – autofocus MANUAL – includes any human adjustment or verification of autofocus
Extended Depth of Field	(0048,0012)	1	Image pixels were created through combining of image acquisition at multiple focal planes (focus stacking). Enumerated Values: YES, NO
Number of Focal Planes	(0048,0013)	1C	Number acquisition focal planes used for extended depth of field. Required if Extended Depth of Field (0048,0012) value is YES
Distance Between Focal Planes	(0048,0014)	1C	Distance between acquisition focal planes used for extended depth of field, in µm. Required if Extended Depth of Field (0048,0012) value is YES
Acquisition Device Processing Description	(0018,1400)	3	Description of visual processing performed on the image prior to exchange. Examples of this processing are: edge enhanced, gamma corrected, convolved (spatially filtered)
Convolution Kernel	(0018,1210)	3	Label for convolution kernel used in acquisition device visual processing
Recommended Absent Pixel CIELab Value	(0048,0015)	3	A color value with which it is recommended to display the pixels of the Total Pixel Matrix that are not encoded. The units are specified in PCS-Values, and the value is encoded as CIELab. See C.10.7.1.1.

C.8.12.X2.1 VL Whole Slide Microscopy Image Attribute Descriptions

730 #### C.8.12.X2.1.1 Image Type

Image Type (0008,0008) is specified to be Type 1 with the following constraints:

Value 1 shall have a value of ORIGINAL or DERIVED

Value 2 shall have a value of PRIMARY

Value 3 (Image Flavor) shall have the Defined Terms in Table C.8.12.X2-2

Table C.8.12.X2-2
VL WHOLE SLIDE MICROSCOPY IMAGE FLAVORS

LOCALIZER	Collected for the purpose of planning or navigating other images.
VOLUME	Set of frames that define a regularly sampled volume
LABEL	Purpose of image is to capture the slide label; any non-label area captured is incidental to that purpose.

Value 4 (Derived Pixel) shall have the Defined Terms specified in Table C.8.12.X2-3.

Table C.8.12.X2-3
VL WHOLE SLIDE MICROSCOPY DERIVED PIXELS

NONE	No derivation of pixels (original)
RESAMPLED	Pixels were derived by downsampling a higher resolution image

No additional values shall be present.

C.8.12.X2.1.2 Imaged Volume Width, Height, Depth

The full physical extent of the whole slide image target volume is described in the attributes Imaged Volume Width (0048,0001), Imaged Volume Height (0048,0002), and Imaged Volume Depth (0048,0003). These values reflect the maximum extent in these dimensions. There is no requirement that this entire extent is actually encoded in frames of the Image SOP Instance.

The value of Imaged Volume Depth (0048,0003) shall not be 0. If only a single focal plane is imaged, the Imaged Volume Depth may be the optical depth of field as encoded in the Slice Thickness (0018,0050) attribute of the Pixel Measures Functional Group (see C.7.6.16.2.1.1).

C.8.12.X2.1.3 Total Pixel Matrix Columns, Rows

Total Pixel Matrix Columns (0048,0006) and Total Pixel Matrix Rows (0048,0007) describe the size of the entire imaged volume as a single extent across all frames (tiles).

The extent would be as described in these attributes if the whole volume would be imaged and encoded as a non-sparse pixel matrix with the pixel spacing as specified in the Pixel Spacing (0028,0030) attribute of the Pixel Measures Functional Group (see C.7.6.16.2.1.1).

C.8.12.X2.1.4 Total Pixel Matrix Origin Sequence and Image Orientation (Slide)

Total Pixel Matrix Origin Sequence (0048,0008) specifies the location of the top leftmost pixel of the pixel matrix, and Image Orientation (Slide) (0048,0102) specifies the direction cosines of the first row and the first column of the pixel matrix, both with respect to the Slide Coordinate System Frame of Reference (see C.8.12.2). Although the image acquisition may vary the true row and column orientation at the pixel scale to account for local variation in the physical specimen, this attribute describes the orientation as if the Pixel Matrix were flat.

Note: Typically, the Image Orientation (Slide) attribute will describe only a planar rotation, as the image plane is usually nominally parallel to the slide surface.

C.8.12.X2.1.5 Photometric Interpretation and Samples per Pixel

Photometric Interpretation (0028,0004) shall be one of these Enumerated Values (see C.7.6.3.1.2):

MONOCHROME2
RGB
YBR_FULL_422
YBR_ICT

YBR_RCT

The value shall be appropriate to the compression transfer syntax used, if any, and shall be MONOCHROME2 or RGB for uncompressed or lossless compressed transfer syntaxes that do not involve color space transformations, YBR_ICT for irreversible JPEG 2000 transfer syntaxes, YBR_RCT for reversible JPEG 2000 transfer syntaxes, and YBR_FULL_422 for other lossy compressed transfer syntaxes.

Note: Future lossless and lossy transfer syntaxes may lead to the need for new definitions and choices for Photometric Interpretation. The Enumerated Values may therefore be extended with additional Photometric Interpretation values directly associated with new transfer syntaxes that are negotiated, and hence do not render existing implementations non-conformant.

Multi-spectral images may be encoded as a single wavelength band (color) in each frame using MONOCHROME2, or with up to three bands in each frame using one of the color Photometric Interpretations.

Samples per Pixel (0028,0002) shall be 1 for MONOCHROME2, and 3 otherwise.

C.8.12.x3 Optical Path Module

Table C.8.12.x3-1 specifies the attributes of the optical paths used in the VL imaging. Each optical path is a combination of illumination, filters, lenses, and sensors, and each combination is identified for possible reference by attributes in other modules. Additional optical path parameters may be specified in the Acquisition Context Module.

Table C.8.12.x3-1
OPTICAL PATH MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Optical Path Sequence	(0048,0105)	1	Describes the optical paths used during the acquisition of this image. One or more Items shall be present in this sequence. See C.8.12.x3.1.1
>Optical Path Identifier	(0048,0106)	1	Identifier for the optical path specified in the Sequence Item. The identifier shall be unique for each Item within the Optical Path Sequence.
>Optical Path Description	(0048,0107)	3	Description of the optical path specified in the Sequence Item.
>Illuminator Type Code Sequence	(0048,0100)	3	Type of illuminator. Only a single Item may be present in this Sequence.
>>*Include 'Code Sequence Macro' Table 8.8.1*			*Context ID may be defined in the IOD constraints.*
>Illumination Wave Length	(0022,0055)	1C	Nominal wavelength of the illuminator in nm. Required if Illumination Color Code Sequence (0048,ee08) is not present. May be present otherwise.
>Illumination Color Code Sequence	(0048,0108)	1C	Color of the illuminator. Required if Illumination Wave Length (0022,0055) is not present. May be present otherwise. Only a single Item may be present in this sequence.
>>*Include 'Code Sequence Macro' Table 8.8.1*			*Context ID may be defined in the IOD constraints.*
>Illumination Type Code Sequence	(0022,0016)	1	Coded value for illumination method. See C.8.12.x3.1.2. One or more Items shall be present in this sequence.

>>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the IOD constraints.*
>Light Path Filter Type Stack Code Sequence	(0022,0017)	3	Filters used in the light source (excitation) path. One or more Items shall be present in this sequence. See C.8.12.x3.1.3.
>>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the IOD constraints.*
>Light Path Filter Pass-Through Wavelength	(0022,0001)	3	Nominal pass-through wavelength of light path filter(s) in nm
>Light Path Filter Pass Band	(0022,0002)	3	Pass band of light path filter(s) in nm. This Attribute has two Values. The first is the shorter and the second the longer wavelength relative to the peak. The values are for the – 3dB nominal (1/2 of peak) pass through intensity. One of the two Values may be zero length, in which case it is a cutoff filter.
>Image Path Filter Type Stack Code Sequence	(0022,0018)	3	Describes stack of filters used in image (emission) path between the imaging target and the optical sensor. One or more items shall be present in the sequence. See C.8.12.x3.1.3.
>>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the IOD constraints.*
>Image Path Filter Pass-Through Wavelength	(0022,0003)	3	Nominal pass-through wavelength of image path filter(s) in nm
>Image Path Filter Pass Band	(0022,0004)	3	Pass band of image path filter(s) in nm. This Attribute has two Values. The first is the shorter and the second the longer wavelength relative to the peak. The values are for the – 3dB nominal (1/2 of peak) pass through intensity. One of the two Values may be zero length, in which case it is a cutoff filter
>Lenses Code Sequence	(0022,0019)	3	Lenses that were used in this optical path. One or more items shall be present in the sequence.
>>Include 'Code Sequence Macro' Table 8.8-1			*Context ID may be defined in the IOD constraints.*
>Condenser Lens Power	(0048,0111)	3	Nominal power of the condenser lens
>Objective Lens Power	(0048,0112)	3	Nominal power of the objective lens. If a single lens is used as both condenser and objective, its power is specified in this attribute.
>Objective Lens Numerical Aperture	(0048,0113)	3	Nominal numerical aperture of the objective lens.

>Channel Description Code Sequence	(0022,001A)	1C	Describes the light color sensed for each channel to generate the image. Required if this differs from the natural interpretation. Notes: 1. For MONOCHROME2, the natural interpretation is the full visible light spectrum. A full spectrum sensor may be presented with light of only a single color based on illumination and filters. 2. Equipment may use a color Photometric Interpretation (RGB, YBR) as a container representing up to 3 channels of any detected wavelength. Shall have the same number of Items as the value of Samples per Pixel Used (0028,0003) if present, or otherwise the value of Samples per Pixel (0028,0002). The channels shall be described in the order in which the channels are encoded.
>>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the IOD constraints.*
>Palette Color Lookup Table Sequence	(0048,0120)	3	For MONOCHROME2 images, provides a transform of the pixel values with this optical path into an RGB color representation. The LUT provides a mapping to an appropriate color or pseudo-color for display purposes. Only a single Item may be present in this Sequence.
>>Include 'Palette Color Lookup Macro' Table C.7-22a			
>ICC Profile	(0028,2000)	1C	An ICC Profile encoding the transformation of device-dependent stored pixel values into PCS-Values. See C.8.12.x3.1.4 Required if Photometric Interpretation (0028,0004) is not MONOCHROME2, or if Palette Color Lookup Table Sequence (0048,0120) is present.

C.8.12.x3.1 Optical Path Attribute Descriptions

C.8.12.x3.1.1 Optical Path Sequence and Optical Path Identifier

The Optical Path Sequence (0048,0105) shall include an Item for every optical path used in the acquisition of the current image.

For single frame images that do not include the Multi-frame Functional Groups Module, this Sequence shall include only one Item.

For images that use the Multi-frame Functional Groups Module, the optical path associated with each frame is identified by reference to the Optical Path Identifier (0048,0106) of this Sequence (see Optical Path Identification Sequence (0048,0207) in Section C.8.12.X4.2). The Optical Path Sequence may include Items for defined optical paths that are not referenced by any frame.

For Whole Slide Microscopy Image LOCALIZER images (see C.8.12.X2.1.1 and C.8.12.X5), all the optical paths associated with referenced images shall be described in Items of this Optical Path Sequence. The optical path associated with each referenced frame is identified in the Referenced Image Navigation Sequence (0048,0200) by reference to an Optical Path Identifier (0048,0106) of this

Sequence. The Optical Path Identifiers used in the LOCALIZER image do not have to be identical to those used in the referenced images.

Notes: 1. For example, each of four referenced images may use a different optical path (color), and within each of those image SOP Instances the single Optical Path Sequence Item is identified as "1", although the meaning of optical path "1" is different for each image. The LOCALIZER, however, must include all four optical paths with distinct identifiers "1", "2", "3", and "4".

2. The Optical Path Identifier is not necessarily numeric; it is a string of up to 16 characters (VR SH).

C.8.12.x3.1.2 Illumination Type Code Sequence

Illumination Type Code Sequence (0022,0016) specifies the type of illumination of the imaging target. This attribute may include multiple Items, as some techniques may involve multiple methods, or some method identifiers may not be completely descriptive.

Note: For example, this attribute might include two items, (111741, DCM, "Transmission illumination") and (111748, DCM, "Differential interference contrast") to indicate "Transmission DIC".

The type of illumination often prescribes the set of optical path components such as filters and prisms, and their arrangement in the optical path.

Note: For instance, phase contrast illumination will utilize a condenser annulus and a phase contrast plate; this may be indicated by an item (111747, DCM, "Phase contrast illumination") in this attribute, but with no further specification in the filters and lenses identification attributes.

C.8.12.x3.1.3 Light Path and Image Path Filter Type Stack Code Sequences

In some optical imaging methods, e.g., epifluorescence, there may be a single light path with its associated imaging components that is used in both illumination/excitation of the imaging target and in the transmitted/emitted path to the imaging sensor. In this case, the optical components are to be specified in the Image Path Filter Type Stack Code Sequence (0022,0018).

C.8.12.x3.1.4 ICC Profile

ICC Profile (0028,2000) provides the transform for mapping stored color pixel values into ICC standard color Profile Connection Space (PCS). For MONOCHROME2 pixels that have a preferred color rendering through the Palette Color Lookup Table Sequence (0048,0120), this attribute provides a mapping of that preferred RGB color rendering into PCS. The ICC Profile shall follow the requirements specified in Section C.11.15.1.1.

C.8.12.X4 Whole Slide Microscopy Functional Group Macros

The following sections contain Functional Group macros specific to the VL Whole Slide Microscopy Image IOD.

Note: The attribute descriptions in the Functional Group Macros are written as if they were applicable to a single frame (i.e., the macro is part of the Per-frame Functional Groups Sequence). If an attribute is applicable to all frames (i.e. the macro is part of the Shared Functional Groups Sequence) the phrase "this frame" in the attribute description shall be interpreted to mean "for all frames".

C.8.12.X4.1 Plane Position (Slide) Macro

Table C.8.12.x4.1-1 specifies the attributes of the Plane Position (Slide) Functional Group macro.

Table C.8.12.X4.1-1
PLANE POSITION (SLIDE) MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Plane Position (Slide) Sequence	(0048,021A)	1	Describes position of frame in the Total Pixel Matrix and in the Slide Coordinate System Frame of Reference. Only a single Item may be present in this Sequence.
>Column Position In Total Pixel Matrix	(0048,021E)	1	The column position of the top left hand pixel of the frame in the Total Pixel Matrix (see C.8.12.X2.1.1). The column position of the top left pixel of the Total Pixel Matrix is 1.
>Row Position In Total Pixel Matrix	(0048,021F)	1	The row position of the top left hand pixel of the frame in the Total Pixel Matrix (see C.8.12.X2.1.1). The row position of the top left pixel of the Total Pixel Matrix is 1.
>X Offset in Slide Coordinate System	(0040,072A)	1	The X offset in mm from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Y Offset in Slide Coordinate System	(0040,073A)	1	The Y offset in mm from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Z Offset in Slide Coordinate System	(0040,074A)	1	The Z offset in µm from the Origin of the Slide Coordinate System, nominally the surface of the glass slide substrate. See Figure C.8-17 Note: Required even if only a single focal plane was acquired.

C.8.12.X4.2 Optical Path Identification Macro

Table C.8.12.X4.2-1 specifies the attributes of the Optical Path Identification Functional Group macro.

Table C.8.12.X4.2-1
OPTICAL PATH IDENTIFICATION MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Optical Path Identification Sequence	(0048,0207)	1	Identifies the optical path characteristics of this frame. Only a single Item shall be permitted in this sequence.
>Optical Path Identifier	(0048,0106)	1	Uniquely identifies the path described in the Optical Path Sequence (0048,0105) by reference to an Item with the same Optical Path Identifier (0048,0106) value. See C.8.12.x3.

C.8.12.X4.3 Specimen Reference Macro

Table C.8.12.X4.3-1 specifies the attributes of the Specimen Reference Functional Group macro. This allows association of the frame with specific specimens imaged on the same slide (e.g., tissue micro-arrays).

Table C.8.12.X4.3-1
SPECIMEN REFERENCE MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Specimen Reference Sequence	(0048,0110)	2	Identifies specimens that may be visible in this frame, and which are fully identified in the Specimen Description Sequence (0040,0560). Zero or more Items shall be present in this sequence.
>Specimen UID	(0040,0554)	1	Unique Identifier for Specimen. See Section C.7.6.22.1.2.

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C.8.12.X5 Multi-Resolution Navigation Module

Table C.8.12.X5-1 specifies the Attributes that describe the Multi-Resolution Navigation Module, used in Whole Slide Microscopy LOCALIZER images.

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Table C.8.12.X5-1
MULTI-RESOLUTION NAVIGATION MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Referenced Image Navigation Sequence	(0048,0200)	1	Identification of correspondence between areas of the Pixel Data (07FE,0010) and frames of higher resolution images. One or more Items shall be present.
>Include 'SOP Instance Reference Macro' Table 10-11			Referenced Image Instance
>Referenced Frame Number	(0008,1160)	1	Referenced Frame Number within Referenced Image.
>Top Left Hand Corner of Localizer Area	(0048,0201)	1	Top Left Hand Corner of Localizer image pixel area corresponding to referenced frame, specified as column\row. Column is the horizontal offset and row is the vertical offset.
>Bottom Right Hand Corner of Localizer Area	(0048,0202)	1	Bottom Right Hand Corner of Localizer image pixel area corresponding to referenced frame, specified as column\row. Column is the horizontal offset and row is the vertical offset.
>Pixel Spacing	(0028,0030)	1	Pixel Spacing in Referenced Image, specified as a numeric pair – adjacent row spacing \ adjacent column spacing, in mm.
>Z Offset in Slide Coordinate System	(0040,074A)	1	The Z offset of the referenced frame from the Slide Coordinates System reference plane, in microns
>Samples per Pixel	(0028,0002)	1	The number of samples (color planes) containing information in the referenced image.
>Optical Path Identifier	(0048,0106)	1	Identifies the optical path used in acquiring the referenced Frame by reference to an Item in the Optical Path Sequence (0048,0105) of the current SOP Instance. See C.8.12.x3.

C.8.12.X6 Slide Label Module

880 Table C.8.12.X6-1 specifies the Attributes that describe the interpretation of a scanned Slide Label.

Table C.8.12.X6-1
SLIDE LABEL MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Barcode Value	(2200,0005)	2	Barcode interpreted from the scanned slide label. Note: This may be the same as the Container Identifier (0040,0512)
Label Text	(2200,0002)	2	Label text interpreted from the scanned slide label, e.g., by optical character recognition.

Update PS 3.3 C.8.12.1

C.8.12.1 VL Image Module

Table C.8-77 specifies the Attributes that describe a VL Image produced by Endoscopy (ES), General Microscopy (GM), Automated-Stage Microscopy (SM), External-camera Photography (XC), or other VL imaging Modalities.

Table C.8-77
VL IMAGE MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
…			
Pixel Spacing	**(0028,0030)**	**3**	**Physical distance in the imaging target (patient or specimen) between the center of each pixel, specified as a numeric pair – adjacent row spacing \ adjacent column spacing, in mm. See 10.7.1.3.**

Update PS 3.3 C.8.12.2

C.8.12.2 Slide Coordinates Module

The table in this Section contains Attributes that describe Slide Coordinates. Slide Coordinates provide a means to ~~**position a robotic Microscope Stage reproduceably with respect to the pixel plane of the digital Microscope**~~ **locate an image within a given Frame of Reference**.

Note**s**: **1. A Frame of Reference (identified by a Frame of Reference UID) typically only applies to a single mounting of a slide on a particular microscope stage; there is no guarantee that a subsequent mounting of the slide, even on the same equipment, will allow reproducible positioning to the exact same location. These attributes allow consistent location of multiple images within the Series of a single Frame of Reference.**

2. There is no a priori correspondence of pixels to Slide Coordinates. Therefore, the geometrical symmetry point through the pixel plane of the digital microscope may not correspond to the center of a pixel. The geometrical symmetry point could be between pixels.

3. This module formerly included a Type 3 attribute Pixel Spacing Sequence (0040,08D8), and subsidiary attributes; see PS 3.3-2009. Pixel spacing is an attribute of the image acquisition, not the slide coordinates, and is inappropriate for this Module. It is now conveyed by Pixel Spacing (0028,0030) in the VL Image Module or the Pixel Measures Functional Group.

Table C.8-78
Slide Coordinates Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Center Point Coordinates Sequence	(0040,071A)	2	The coordinates of the center point of the Image in the Slide Coordinate System Frame of Reference. Zero or one item shall be present in the sequence. See Section C.8.12.2.1.1 for further explanation.
>X Offset in Slide Coordinate System	(0040,072A)	1	The X offset in millimeters from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Y Offset in Slide Coordinate System	(0040,073A)	1	The Y offset in millimeters from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Z Offset in Slide Coordinate System	(0040,074A)	2	The Z offset in microns from the image substrate reference plane (i.e. utilized surface of

			a glass slide).
~~**Pixel Spacing Sequence**~~	~~**(0040,08D8)**~~	~~**3**~~	~~**Physical distance in the Imaging Subject, i.e. Patient or Specimen, between the center of each pixel along specified axes. One or more items may be present.**~~
~~**>Coordinate System Axis Code Sequence**~~	~~**(0040,08DA)**~~	~~**1**~~	~~**Axis of a coordinate system. This sequence shall contain exactly one item.**~~
~~***>>Include 'Code Sequence Macro' Table 8.8-1***~~			~~***Baseline Context ID is 95.***~~
~~**>Numeric Value**~~	~~**(0040,A30A)**~~	~~**1**~~	~~**The distance between the center-points of adjacent pixels along the axis specified by Coordinate System Axis Code Sequence (0040,08DA).**~~
~~**>Measurement Units Code Sequence**~~	~~**(0040,08EA)**~~	~~**1**~~	~~**Units of the measurement. This sequence shall contain exactly one item.**~~
~~***>>Include 'Code Sequence Macro' Table 8.8-1***~~			~~***Baseline Context ID is 82.***~~

C.8.12.2.1 Slide Coordinates Attribute Descriptions

C.8.12.2.1.1 Image Center Point Coordinates Sequence

This Section defines the Slide Coordinate System and specifies the Attributes that shall be used to describe the location of the center point of the Image pixel plane (as captured through a microscope) in the Slide Coordinate System Frame of Reference.

Note: In Slide Microscopy (SM), the Microscope is equipped with a moveable Stage and position sensors that enable storage of the location of the center point of the displayed image with respect to the examined Specimen.

The Stage is the part of the Microscope to which the Slide is attached for viewing. The Objective Lens is the lens that is closest to the Specimen. The Top Surface of the Slide is the surface of the Slide on which the Specimen ~~in~~ **is** ~~M~~**m**ounted. The Bottom Surface of the Slide is the opposite surface. This Specification presumes that: 1) the Slide is rectangular; 2) the Top Surface of the Slide is oriented toward the Objective Lens of the Microscope; and 3) the Bottom Surface of the Slide is in perfect contact with the Microscope Stage when the Slide is attached to the Stage for viewing.

Notes: 1. The Label of the Slide is presumed to be mounted-on or written-on the Top Surface of the Slide.

2. Specification of the mechanical form, function, or tolerances of the Microscope are outside the scope of this Standard.

Figure C.8-16 depicts the Top Surface of the Slide on the Microscope Stage from the perspective of the Objective Lens. This is Reference Slide Orientation. The X, Y, and Z axes of the Slide Coordinate System in Reference Slide Orientation are defined as follows. The Y-axis is a line that ~~**includes**~~ **nominally represents** the Left Edge of the Slide. The X-axis is a line that is orthogonal to the Y-axis and **nominally represents** ~~**includes at least one point of**~~ the Specimen Edge of the Slide. The Z-axis is a line that passes through the intersection of the X-axis and Y-axis and is orthogonal to the Microscope Stage. The Origin (0,0,0) of the Slide Coordinate System is the point of intersection of the X, Y, and Z axes.

Notes: 1. An improperly-placed coverslip or Specimen that overlaps an Edge of a Slide is not considered part of the Edge a Slide for purposes of defining the Slide Coordinate System. However, such objects may cause inaccurate positioning of the Slide on the Stage.

2. If the Left Edge and Specimen Edge of the Slide are not orthogonal (e.g. the Slide is damaged or defective or the Specimen Edge is curvilinear), then the lower left-hand corner of the Slide may not be located at the Origin.

3. The definitions of X, Y, and Z axes are the same for inverted microscopes, with the Top Surface of the slide (i.e. Specimen side of the Slide) still being closest to the Objective Lens.

4. The origin of a Frame of Reference is arbitrary (see C.7.4.1), but its nominal location for consistency of slide coordinates is defined in this section.

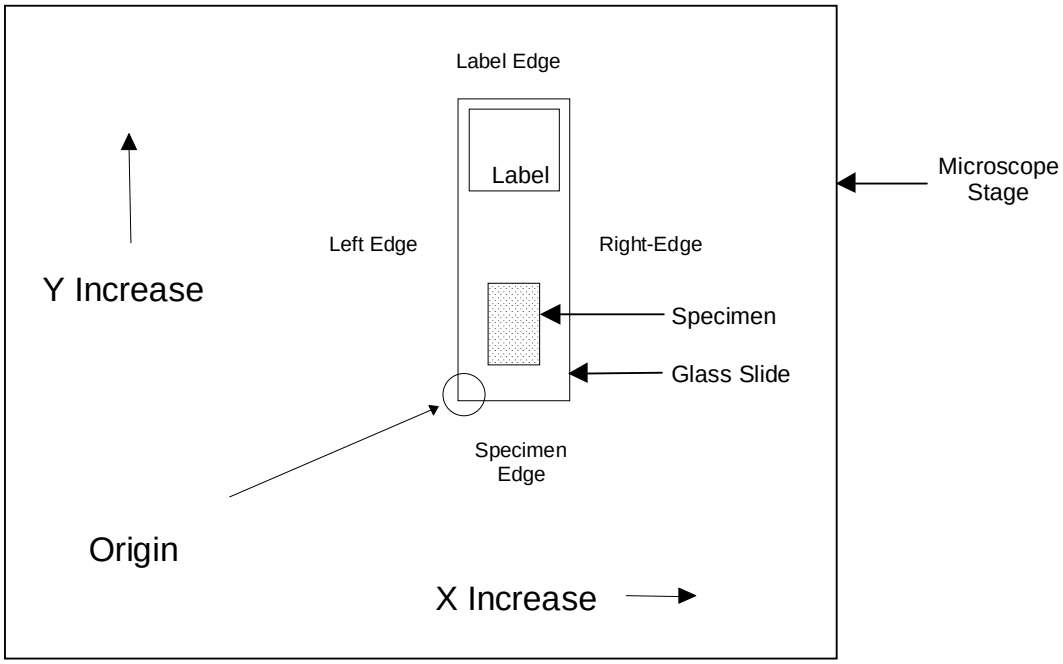

Figure C.8-16
REFERENCE SLIDE ORIENTATION

Figure C.8-17 depicts the Z-axis center point location. The X-axis value of Image Center Point Location (0040,073A) shall increase from the Origin toward the Right Edge in Reference Slide Orientation. The Y-axis value of Image Center Point Location (0040,073A) shall increase from the Origin toward the Label Edge in Reference Slide Orientation. The Z-axis value of Image Center Point Location (0040,073A) shall be **nominally** referenced as zero at the image substrate reference plane (i.e. ~~**utilized**~~ **the top** surface of a glass slide) and shall increase in a positive fashion coincident with increased distance from the substrate surface.

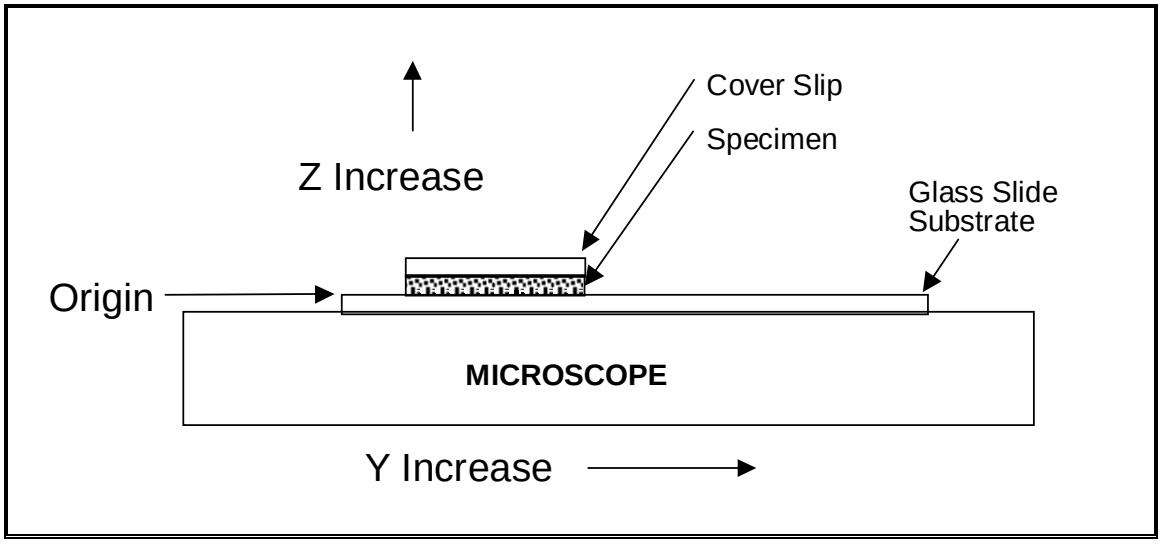

Figure C.8-17
Z-AXIS CENTER POINT LOCATION, VIEW FROM RIGHT EDGE OF SLIDE

965 ***Add new attribute and defined terms to C.10.4 and C.10.5***

C.10.4 Displayed Area Module

This Module describes Attributes required to define a Specified Displayed Area space.

The Specified Displayed Area is that portion of the image displayed on the device.

…

970 **Table C.10-4**
DISPLAYED AREA MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Displayed Area Selection Sequence	(0070,005A)	1	A sequence of Items each of which describes the displayed area selection for a group of images or frames. Sufficient Items shall be present to describe every image and frame listed in the Presentation State Relationship Module. One or more Items shall be present.
>Referenced Image Sequence	(0008,1140)	1C	Sequence of Items where each Item provides reference to a selected set of Image SOP Class/SOP Instance pairs that are defined in the Presentation State Relationship Module. One or more Items shall be present. Required if the displayed area selection in this Item does not apply to all the images and frames listed in the Presentation State Relationship Module.
>>Include 'Image SOP Instance Reference Macro' Table 10-3			
>Pixel Origin Interpretation	**(0048,0301)**	**1C**	**For a referenced multi-frame image, specifies whether the Displayed Area Top Left Hand Corner (0070,0052) and Displayed Area Bottom Right Hand Corner (0070,0053) are to be interpreted relative to the individual frame pixel origins, or relative to the Total Pixel Matrix origin (see C.8.12.X2.1.4).** **Required if the value of Referenced SOP Class UID (0008,1150) within Referenced Image Sequence (0008,1140) is 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image). May be present otherwise.** **Enumerated Values:** **FRAME – relative to individual frame** **VOLUME – relative to Total Image Matrix** **If not present, TLHC and BRHC are defined relative to the frame pixel origins.**
>Displayed Area Top Left Hand Corner	(0070,0052)	1	The top left (after spatial transformation) pixel in the referenced image to be displayed, given as column\row. Column is the horizontal (before spatial transformation) offset (X) and row is the vertical (before spatial transformation) offset (Y) relative to the origin of the pixel data before spatial transformation, which is 1\1. See Figure C.10.4-1.

>Displayed Area Bottom Right Hand Corner	(0070,0053)	1	The bottom right (after spatial transformation) pixel in the referenced image to be displayed, given as column\row. Column is the horizontal (before spatial transformation) offset (X) and row is the vertical (before spatial transformation) offset (Y) relative to the origin of the pixel data before spatial transformation, which is 1\1. See Figure C.10.4-1.
…			

Notes: 1. In scale to fit mode, the Displayed Area Top Left Hand Corner (TLHC)and Bottom Right Hand Corner (BRHC) have the effect of defining how any zoom or magnification and/or pan has been applied to select a region of an image to be displayed (the Specified Displayed Area), without assuming anything about the size of the actual display.

2. The TLHC and BRHC may be outside the boundaries of the image pixel data (e.g. the TLHC may be 0 or negative, or the BRHC may be greater than Rows or Columns), allowing minification or placement of the image pixel data within a larger Specified Displayed Area. There is no provision to position a zoomed selected sub-area of the image pixel data within a larger Specified Displayed Area.

3. When Pixel Origin Interpretation (0048,0301) value is VOLUME, the selected Display Area may extend across multiple frames, and may include pixel locations for which there is no pixel data (outside the edge of the imaged volume, not encoded in a sparse encoding, or not within explicitly selected frames).

C.10.5 Graphic Annotation Module

This Module defines Attributes of vector graphics and text annotation that shall be made available by a display device to be applied to an image. The graphics and text are defined in position and size relative to the image pixel coordinates or the Specified Displayed Area space (defined in C.10.4 Displayed Area Module). A Graphic Annotation shall be related to an Image.

~~**Note: This Module uses a Sequence of Items rather than a Repeating Group to avoid limiting the maximum number of annotation items that may be present. The use of a Repeating Group would limit the number of items to 16. The use of Repeating Groups is also noted in PS 3.5 to be deprecated.**~~

Table C.10-5
GRAPHIC ANNOTATION MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Graphic Annotation Sequence	(0070,0001)	1	A sequence of Items each of which represents a group of annotations composed of graphics or text or both. One or more Items shall be present.
>Referenced Image Sequence	(0008,1140)	1C	Sequence of Items where each Item provides reference to a selected set of Image SOP Class/SOP Instance pairs that are defined in the Presentation State Relationship Module. One or more Items shall be present. Required if graphic annotations in this Item do not apply to all the images and frames listed in the Presentation State Relationship Module.
>>Include 'Image SOP Instance Reference Macro' Table 10-3			

>Graphic Layer	(0070,0002)	1	The layer defined in the Graphic Layer Module C.10.7 in which the graphics or text is to be rendered.
>Text Object Sequence	(0070,0008)	1C	Sequence that describes a text annotation. One or more Items may be present. Either one or both of Text Object Sequence (0070,0008) or Graphic Object Sequence (0070,0009) are required .
>>Bounding Box Annotation Units	(0070,0003)	1C	Units of measure for the axes of the text bounding box. Defines whether or not the annotation is Image or Displayed Area relative. Both dimensions shall have the same units. Enumerated Values: PIXEL = Image relative position specified with sub-pixel resolution such that the origin**, which is** at the Top Left Hand Corner (TLHC) of the TLHC pixel**,** is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel is Columns\Rows (see figure C.10.5-1). The values must be within the range 0\0 to Columns\Rows. DISPLAY = Fraction of Specified Displayed Area where 0.0\0.0 is the TLHC and 1.0\1.0 is the BRHC. The values must be within the range 0.0 to 1.0. **MATRIX = Image relative position specified with sub-pixel resolution such that the origin, which is at the Top Left Hand Corner (TLHC) of the TLHC pixel of the Total Pixel Matrix, is 0.0\0.0, the Bottom Right Hand Corner (BRHC) of the TLHC pixel is 1.0\1.0, and the BRHC of the BRHC pixel of the Total Pixel Matrix is Total Pixel Matrix Columns\Total Pixel Matrix Rows (see C.8.12.X2.1.3). The values must be within the range 0.0\0.0 to Total Pixel Matrix Columns\Total Pixel Matrix Rows. MATRIX may be used only if the value of Referenced SOP Class UID (0008,1150) within Referenced Image Sequence (0008,1140) is 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image).** Required if Bounding Box Top Left Hand Corner (0070,0010) or Bounding Box Bottom Right Hand Corner (0070,0011) is present.

>>Anchor Point Annotation Units	(0070,0004)	1C	Units of measure for the axes of the text anchor point annotation. Enumerated Values for Anchor Point Annotation Units (0070,0004) are the same as for Bounding Box Annotation Units (0070,0003). Required if Anchor Point (0070,0014) is present.
…			

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Changes to NEMA Standards Publication PS 3.4-2009

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

1010

In PS 3.4 Annex B add new SOP Class:

B.5 STANDARD SOP CLASSES

Table B.5-1
STANDARD SOP CLASSES

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
VL Whole Slide Microscopy Image Storage	**1.2.840.10008.5.1.4.1.1.77.1.6**	**VL Whole Slide Microscopy Image**

In PS 3.4 Annex I add new SOP Class:

I.4 MEDIA STANDARD STORAGE SOP CLASSES

Table I.4-1
Media Storage Standard SOP Classes

SOP Class Name	SOP Class UID	IOD (See PS 3.3)
VL Whole Slide Microscopy Image Storage	**1.2.840.10008.5.1.4.1.1.77.1.6**	**VL Whole Slide Microscopy Image**

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Changes to NEMA Standards Publication PS 3.6-2009

1030 ## Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

6 Registry of DICOM data elements

In PS 3.6 Section 6 retire data elements:

Tag	Name	Keyword	VR	VM	
(0040,08D8)	*Pixel Spacing Sequence*	*PixelSpacingSequence*	*SQ*	*1*	***RET***
(0040,08DA)	*Coordinate System Axis Code Sequence*	*CoordinateSystemAxisCodeSequence*	*SQ*	*1*	***RET***

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In PS 3.6 Section 6 add new data elements:

Tag	Name	Keyword	VR	VM	
(0048,0001)	Imaged Volume Width	ImagedVolumeWidth	FL	1	
(0048,0002)	Imaged Volume Height	ImagedVolumeHeight	FL	1	
(0048,0003)	Imaged Volume Depth	ImagedVolumeDepth	FL	1	
(0048,0006)	Total Pixel Matrix Columns	TotalPixelMatrixColumns	UL	1	
(0048,0007)	Total Pixel Matrix Rows	TotalPixelMatrixRows	UL	1	
(0048,0008)	Total Pixel Matrix Origin Sequence	TotalPixelMatrixOriginSequence	SQ	1	
(0048,0010)	Specimen Label in Image	SpecimenLabelInImage	CS	1	
(0048,0011)	Focus Method	FocusMethod	CS	1	
(0048,0012)	Extended Depth of Field	ExtendedDepthOfField	CS	1	
(0048,0013)	Number of Focal Planes	NumberOfFocalPlanes	US	1	
(0048,0014)	Distance Between Focal Planes	DistanceBetweenFocalPlanes	FL	1	
(0048,0015)	Recommended Absent Pixel CIELab Value	RecommendedAbsentPixelCIELabValue	US	3	
(0048,0100)	Illuminator Type Code Sequence	IlluminatorTypeCodeSequence	SQ	1	
(0048,0102)	Image Orientation (Slide)	ImageOrientationSlide	DS	6	
(0048,0105)	Optical Path Sequence	OpticalPathSequence	SQ	1	
(0048,0106)	Optical Path Identifier	OpticalPathIdentifier	SH	1	
(0048,0107)	Optical Path Description	OpticalPathDescription	ST	1	
(0048,0108)	Illumination Color Code Sequence	IlluminationColorCodeSequence	SQ	1	
(0048,0110)	Specimen Reference Sequence	SpecimenReferenceSequence	SQ	1	
(0048,0111)	Condenser Lens Power	CondenserLensPower	DS	1	
(0048,0112)	Objective Lens Power	ObjectiveLensPower	DS	1	
(0048,0113)	Objective Lens Numerical Aperture	ObjectiveLensNumericalAperture	DS	1	
(0048,0120)	Palette Color Lookup Table Sequence	PaletteColorLookupTableSequence	SQ	1	
(0048,0200)	Referenced Image Navigation Sequence	ReferencedImageNavigationSequence	SQ	1	
(0048,0201)	Top Left Hand Corner of Localizer Area	TopLeftHandCornerOfLocalizerArea	US	2	

(0048,0202)	Bottom Right Hand Corner of Localizer Area	BottomRightHandCornerOfLocalizerArea	US	2	
(0048,0207)	Optical Path Identification Sequence	OpticalPathIdentificationSequence	SQ	1	
(0048,021A)	Plane Position (Slide) Sequence	PlanePositionSlideSequence	SQ	1	
(0048,021E)	Column Position In Total Image Pixel Matrix	ColumnPositionInTotalImagePixelMatrix	SL	1	
(0048,021F)	Row Position In Total Image Pixel Matrix	RowPositionInTotalImagePixelMatrix	SL	1	
(0048,0301)	Pixel Origin Interpretation	PixelOriginInterpretation	CS	1	

Annex A Registry of DICOM unique identifiers (UID)

Add new row to PS 3.6 Annex A Table A-1

Table A-1
UID VALUES

UID Value	UID NAME	UID TYPE	Part
1.2.840.10008.5.1.4.1.1.77.1.6	**VL Whole Slide Microscopy Image Storage**	**SOP Class**	**3.4**

Add new rows to PS 3.6 Annex A Table A-3

Table A-3
CONTEXT GROUP UID VALUES

Context UID	Context Identifier	Context Group Name
…		
1.2.840.10008.6.1.897	**8120**	**WSI Referenced Image Purposes of Reference**
1.2.840.10008.6.1.898	**8121**	**WSI Microscopy Lens Type**
1.2.840.10008.6.1.899	**8122**	**Microscopy Illuminator and Sensor Color**
1.2.840.10008.6.1.900	**8123**	**Microscopy Illumination Method**
1.2.840.10008.6.1.901	**8124**	**Microscopy Filter**
1.2.840.10008.6.1.902	**8125**	**Microscopy Illuminator Type**

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1060 **Changes to NEMA Standards Publication PS 3.16-2009**

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Add new Context Groups to PS 3.16 Annex B:

CID 8120 WSI REFERENCED IMAGE PURPOSES OF REFERENCE

Context ID 8120
WSI Referenced Image Purposes of Reference
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	121311	Localizer
DCM	121350	Same acquisition at lower resolution
DCM	121351	Same acquisition at higher resolution
DCM	121352	Same acquisition at different focal depth
DCM	121353	Same acquisition at different spectral band
DCM	121354	Imaged container label

CID 8121 MICROSCOPY LENS TYPE

Context ID 8121
Microscopy Lens Type
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
SRT	A-0011A	High power non-immersion lens
SRT	A-0011B	Oil immersion lens
SRT	A-00118	Slide overview lens

CID 8122 MICROSCOPY ILLUMINATOR AND SENSOR COLOR

Context ID 8122
Microscopy Illuminator and Sensor Color
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
SRT	R-102C0	Full Spectrum
SRT	R-102BE	Infrared
SRT	G-A11A	Red
SRT	G-A11E	Green
SRT	G-A12F	Blue
SRT	R-102BF	Ultraviolet

CID 8123 MICROSCOPY ILLUMINATION METHOD

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Context ID 8123
Microscopy Illumination Method
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	111741	Transmission illumination
DCM	111742	Reflection illumination
DCM	111743	Epifluorescence illumination
DCM	111744	Brightfield illumination
DCM	111745	Darkfield illumination
DCM	111746	Oblique illumination
DCM	111747	Phase contrast illumination
DCM	111748	Differential interference contrast
DCM	111749	Total internal reflection fluorescence

CID 8124 MICROSCOPY FILTER

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Context ID 8124
Microscopy Filter
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
SRT	A-010E2	Green optical filter
SRT	A-010DF	Red optical filter
SRT	A-010DA	Blue optical filter
SRT	A-010DC	Infrared optical filter
SRT	A-010E1	Polarizing optical filter
SRT	A-010DE	Violet optical filter
SRT	A-010DD	Ultraviolet optical filter
SRT	A-0010F	Dichroic beamsplitter
SRT	A-00121	Hoffman modulator
SRT	A-0011D	Darkfield stop
SRT	A-0011C	Rheinberg filter
SRT	A-0011E	Phase contrast plate
SRT	A-00120	Condenser annulus
SRT	A-0011F	Nomarski prism
SRT	A-00123	de Sénarmont compensator
DCM	111609	No filter

CID 8125 MICROSCOPY ILLUMINATOR TYPE

Context ID 8125
Microscopy Illuminator Type
Type: Extensible Version: 20100824

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
SRT	A-00125	Tungsten halogen lamp
SRT	A-00127	Mercury arc lamp
SRT	A-00124	Xenon arc lamp
SRT	A-00126	Light emitting diode
SRT	A-23000	Laser

Annex D DICOM Controlled Terminology Definitions

Modify the following in PS 3.16 Annex D

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Code Value	Code Meaning	Definition	Notes
111601	Green filter	Filter that transmits ~~**one third of white**~~**green** light ~~**(green)**~~ while blocking the other ~~**two thirds**~~**colors, typically centered at 510-540 nm**	
111602	Red filter	Filter that transmits ~~**one third of white**~~ **red** light ~~**(red)**~~ while blocking the other ~~**two thirds**~~**colors, typically centered at 630-680 nm**	
111603	Blue filter	Filter that transmits ~~**one third of white**~~ **blue** light ~~**(blue)**~~ while blocking the other ~~**two thirds**~~**colors, typically centered at 460-480 nm**	

Add the following to PS 3.16 Annex D

Code Value	Code Meaning	Definition	Notes
…			
111741	Transmission illumination	Transmission illumination method for specimen microscopy	
111742	Reflection illumination	Reflection illumination method for specimen microscopy	
111743	Epifluorescence illumination	Epifluorescence illumination method for specimen microscopy	
111744	Brightfield illumination	Brightfield illumination method for specimen microscopy	
111745	Darkfield illumination	Darkfield illumination method for specimen microscopy	
111746	Oblique illumination	Oblique illumination method for specimen microscopy	
111747	Phase contrast illumination	Phase contrast illumination method for specimen microscopy	
111748	Differential interference contrast	Differential interference contrast method for specimen microscopy	
111749	Total internal reflection fluorescence	Total internal reflection fluorescence method for specimen microscopy	
…			
121350	Same acquisition at lower resolution	Image of the same target area at lower resolution acquired in the same acquisition process	

121351	Same acquisition at higher resolution	Image of the same target area at higher resolution acquired in the same acquisition process	
121352	Same acquisition at different focal depth	Image of the same target area at different focal depth (Z-plane) acquired in the same acquisition process	
121353	Same acquisition at different spectral band	Image of the same target area at different spectral band acquired in the same acquisition process	
121354	Imaged container label	Image specifically targeting the container label	

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