Digital Imaging and Communications in Medicine (DICOM)

Supplement 145: Whole Slide Microscopic Image IOD and SOP Classes

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DOCUMENT HISTORY

Document Version	Date	Content
01	2008/01/29	Initial draft
02	2008/02/15	Eichhorn – revisions and additions in advance of WG26 meeting held in Denver together with 2008 USCAP conference
03	2008/06/10	Eichhorn – revisions and additions incorporating feedback and work from WG26 meetings in Denver (2008/03/01) and Toledo (2008/05/17).
04	2009/03/06	Added supplement number
05	2009/03/07	Added revisions from discussion during WG26 meeting in Boston
06	2009/09/02	Solomon - Added D Clunie multi-frame draft, limited to one hierarchical resolution per multi-frame image; add Multi-Resolution Navigation Module
07	2009/09/07	Solomon – after WG26 meeting in Florence (2009/09/05)
08	2009/09/07	All 06 to 07 changes accepted, minor editorial corrections only. For WG comment
09	2009/10/28	Updates for WG6 review

OPEN ISSUES FOR PUBLIC COMMENT

1.	Should we break 16-bit limit on Rows and Columns?
7.	Does the current mechanism for “z” axis cover focal depth adequately? Where is the zero for focal depth? Make this just sequential compared to an arbitrary plane?
8.	What is the impact for modality worklist function?
10.	Defining what data to send to slide scanner in modality worklist (how many focal planes, which part of the slide) We want to just send info that is needed to be known by the scanner to make the scan
11.	**Tasks to be done:** ~~Introduction which covers purpose and what is in/out of scope~~ ~~How this impacts the DICOM information model~~ ~~How this impacts the existing IODs~~ Create a diagram how z planes and sparse matrices work Informative annex material needs to be developed
12.	To highlight in the public comment version – orientation issue, we decided to store orientation data regarding how the image data is stored. Decision made to allow flexibilty for storage on the fly
13.	Another issue to highlight in the public comment version – issue of whether a single pyramid can store multiple types of information (as currently described) or whether separate pyramids should be used (decided against this to allow more flexibility

1. This draft proposes staying within the $(2^{16})^2$ frame (tile) size limit, although the new WSI IOD affords the opportunity to go to a $(2^{32})^2$ image size without tiling. The proposal does provide a conceptual 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. The proposal uses the enhanced multi-frame image paradigm, but limits each multi-frame image to tiles of a single pixel spacing. This means that an image represents only a single layer in a multi-resolution hierarchy. Tiles within a single image object can, however, be at different Z-planes, or at different wavelengths/colors. **All: verify acceptability of the tiling approach.**

2. The proposal uses several of the existing multi-frame functional groups. However, some sets of attributes have been set as fixed for the entire object, and are not encoded in functional groups (such as Plane Orientation, and Volumetric Properties). Even though pixel spacing is fixed, the Pixel Measures functional group is used for consistency with other enhanced MF IODs, but it requires some reinterpretation with regard to slice thickness as optical depth of field. **DICOM experts: verify acceptability of the multi-frame functional groups approach.**

3. The proposal includes an Optical Path Module with a Sequence defining optical paths (including illuminators, filters, lenses, and sensors), and then allows the specification of the applicable path for each frame (tile). It adds this module to existing VL microscopy IODs. We had a discussion in Florence about “macro” images, and it seems to me this can be conveyed simply as a selection of lens. We did not have a complete discussion of the approach to optical path description, and what

concepts need to be conveyed. **Scanner manufacturers and pathologists: verify appropriateness/ completeness of concepts in Optical Path Module, and of the associated Context Group terms.**

4. We had a discussion about images of the slide label area. This draft proposes a LABEL “image flavor”, for images whose intent is specifically to image the label, and those images are required to include the Slide Label Module to provide the decoded label information. In addition, there is a separate attribute Specimen Label in Image to indicate that the label is visible in the image, whether or not that is the intended purpose of the image. **Scanner manufacturers: verify LABEL labeling approach.**

5. This draft proposes a LOCALIZER “image flavor”, with an associated Multi-Resolution Navigation Module to provide linkage across resolution layers. **All: verify acceptability of the localizer approach.**

6. The proposal uses the standard Frame of Reference Module, as used in the VL Slide Coordinates Microscopy Image IOD with the Slide Coordinate System, and clarifies this. There is still work needed here to emphasize the fact that this is not a reproducible Frame of Reference across equipment (due for instance to differences in slide attachment mechanisms and slide sizes), but the approach is consistent with the standard Frame of Reference constructs. **DICOM experts: verify acceptability of the Frame of Reference approach.**

7. We began a discussion of the attributes necessary for Modality Worklist. The draft proposes adding the optical path attributes to Modality Worklist, thus allowing a smart APLIS to control optical path parameters, but this may be overkill. The Protocol Context Sequence allows passing other parameters, such as number of Z-layers to image. **All: verify acceptability of the Modality Worklist approach.**

8. To mitigate the limitations of tiling for annotations using existing Grayscale and Color Softcopy Presentation State IODs, a new attribute is proposed for the Softcopy Presentation State objects that allows display area selection relative to the Total Pixel Matrix, rather than relative to the frame. Note that the Presentation State display area selection already uses 32-bit offsets, so no change is necessary there. **DICOM experts: verify acceptability of the Presentation State approach.**

9. Several items that we did not discuss are highlighted in yellow, or in Word comments.

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 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.

Currently the DICOM standard does not make provision for large two-dimensional images such as the WSI digital slides being created for Pathology, nor does 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 proposal for storing WSI using DICOM.

Description of Problem

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").

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 slides, 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 focusing.

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 *stripped* organization, in which image data are stored in strips which extend across the entire image. Figure 1 shows a stripped image organization:

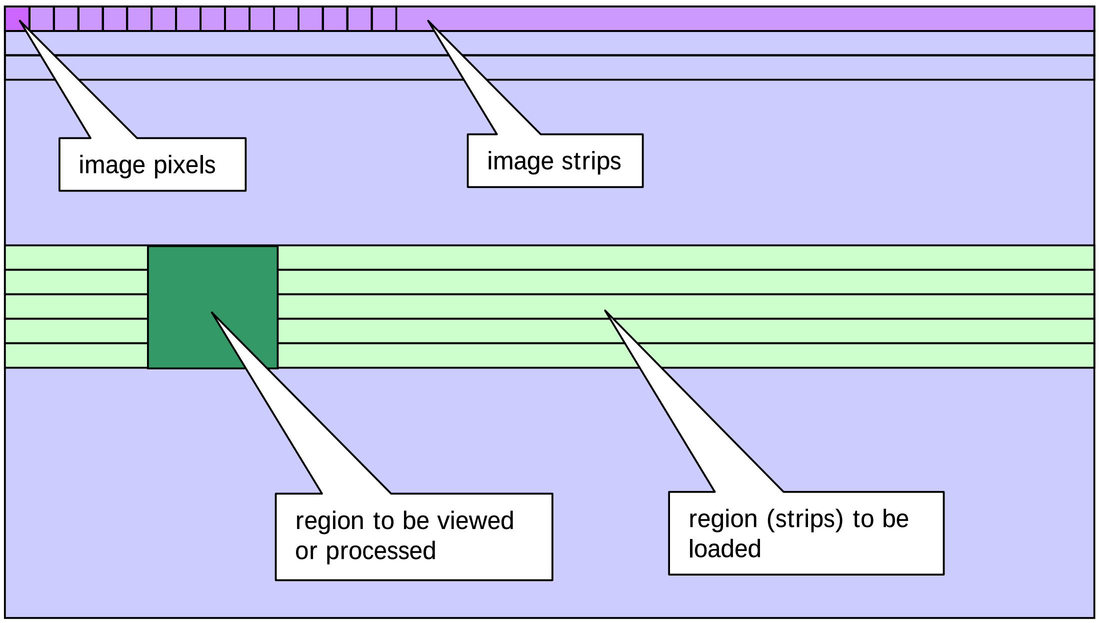

Figure 1 – Stripped Image Organization

Image pixels are stored starting from the upper left corner (dark purple square), in strips all the way across the image (medium purple stripe). All the pixels in the image are stored as strips, 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. The light green region indicates the region of the image which must be loaded to access the dark green region. Each strip in the region of interest must be loaded, all the way across the image.

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 stripped). Figure 2 shows a tiled image organization:

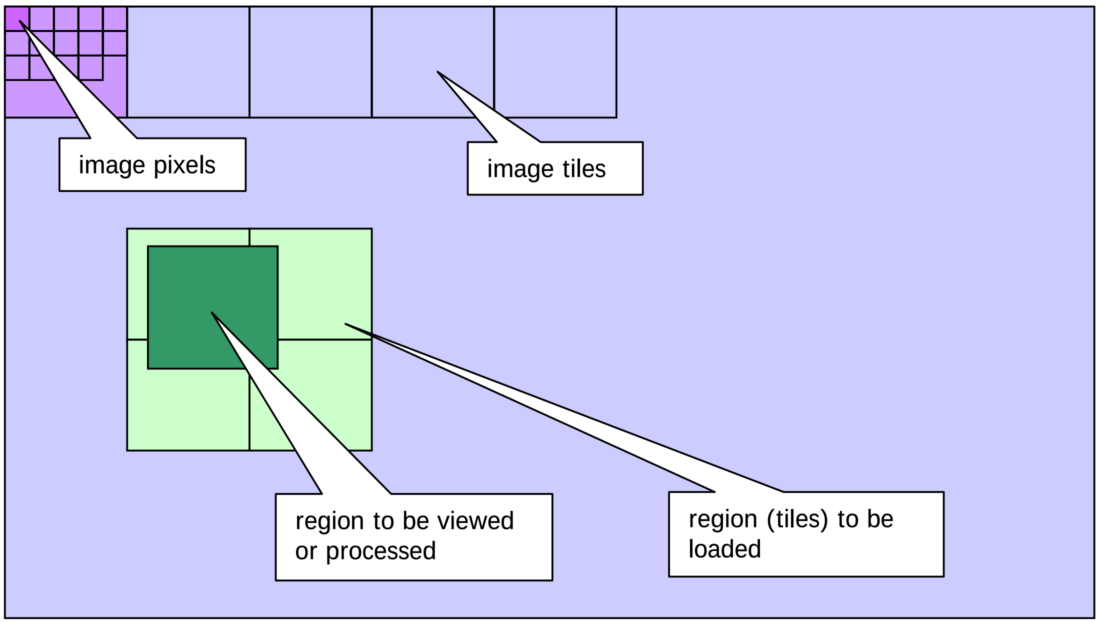

Figure 2 – Tiled Image Organization

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 stripped files, 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. 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 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:

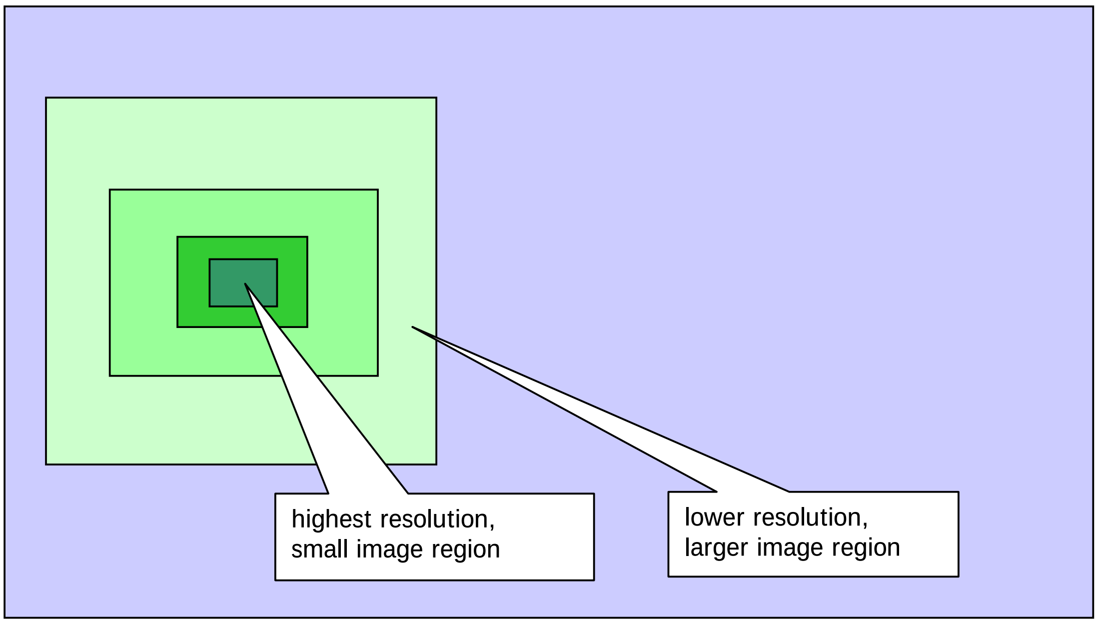

Figure 3 – Issue with Rapid Zooming

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!

The 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 stored image 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:

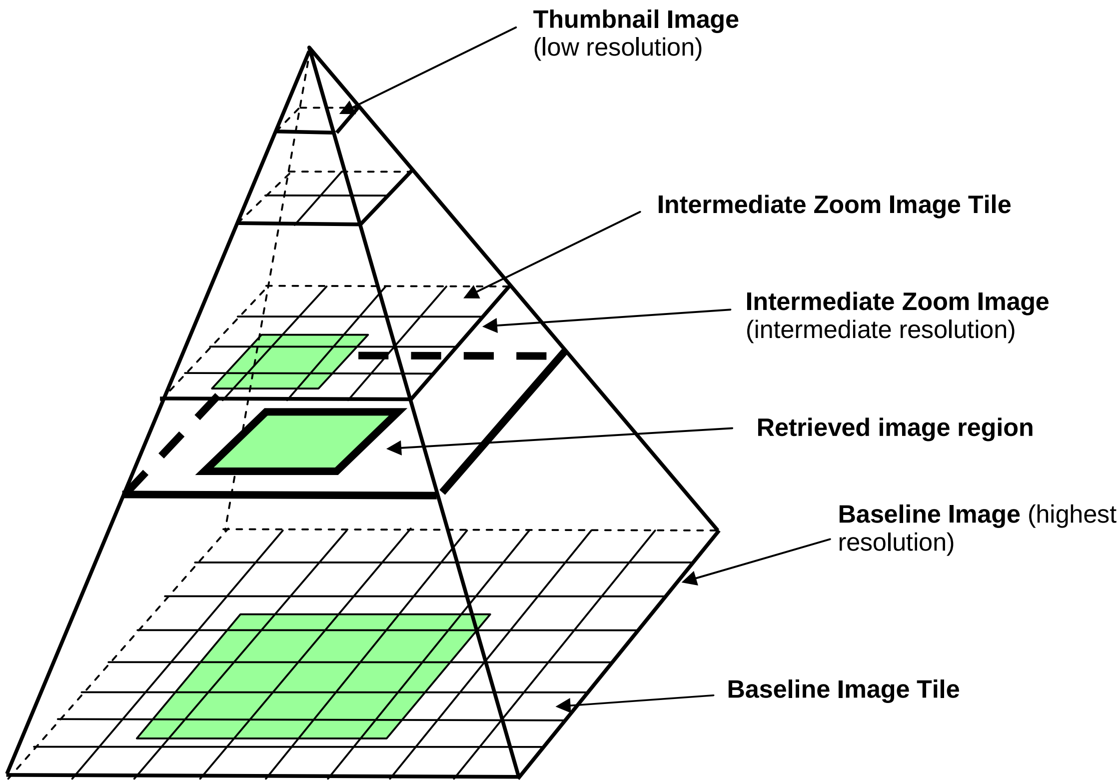

Figure 4 – Whose-slide Image as a “Pyramid” of Image Data

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 1 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. The most frequently used lossless compression technique is LZW. This typically yields a 3X-5X reduction in size. The most frequently used lossy compression techniques are JPEG and JPEG2000. JPEG yields a 15X-20X reduction in image size, while JPEG2000 yields a 30X-50X reduction in size. For most applications Pathologists have found that there is no loss of diagnostic information when JPEG or JPEG2000 compression is used. Lossy compression is therefore often used in present-day WSI applications. Because JPEG2000 yields higher compression and fewer image artifacts than JPEG, it is currently the compression method of choice. However JPEG2000 is compute-intensive and not universally supported, so most WSI applications today use JPEG compression, and/or support both JPEG and JPEG2000.

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.

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.

ISSUES WITH WSI IN DICOM

Issues with Storing WSI in DICOM

Presently there are two limitations on single image objects within DICOM which may be exceeded by WSI for pathology. First, DICOM image objects' pixel dimensions are stored as unsigned 16-bit integers, for a maximum value of 64K. As noted above, WSI frequently have pixel dimensions which are larger than this. Second, DICOM image objects data size are stored as signed 32-bit integers, for a maximum value of 2GB. As noted above, WSI may have data sizes which are larger than this.

DICOM presently supports storage of image objects in a variety of pixel formats, including raw [uncompressed] pixels, lossless compression such as LZW, and lossy compression such as JPEG and JPEG2000. DICOM presently supports storage of image objects from a variety of file formats, including JFIF, TIFF, and JP2. These pixel formats and file formats are compatible with WSI. The issues with storing WSI in DICOM are a result of limitations in the IOD field sizes.

Issues with Accessing WSI in DICOM

In addition to these "hard" restrictions, another consideration is that entire WSI objects are not accessed all at once. Typically for viewing applications a client requests image data incrementally from a server, at random, supporting rapid panning and zooming without first transmitting and storing the entire WSI object to the client. Typically for image analysis and other data processing applications a client requests image data incrementally from a server, sequentially, supporting high performance processing without first transmitting and storing the entire WSI object to the client. In order to support these applications, image data must be addressed and retrieved from WSI objects with a smaller granularity than the entire image. As noted above, a tiled organization is preferred to support rapid panning. As noted above, precalculation of multiple image resolutions is preferred to support rapid zooming. DICOM Supplement 119, adopted in Spring 2009, specifies a mechanism for frame-level access to multiframe images. If WSI tiles are stored as frames in a multi-frame image, a client could retrieve only desired frames from the server that implements this SOP Class.

DICOM also presently supports access to image data incrementally via the JPIP protocol (providing the image data are stored as JP2 objects using JPEG2000 compression.) The JPIP protocol is compatible with WSI. The issues with accessing WSI in DICOM are a result of limitations in the DICOM message specifications and capabilities.

The JP2 object format has a limitation that individual code streams can only contain 64K tiles, because the format uses an unsigned 16-bit integer for tile indices. This means that as image sizes increase, the underlying tile size must increase to ensure the image contains less than 64K tiles. This limitation applies to communication protocols based on the JP2 object format, including JPIP. It does not apply when JPEG2000-compressed image tiles are stored in other object formats, such as TIFF, because then only the individual tiles are restricted to 4GB, while the entire object can be larger.

Despite being functionally compatible with WSI access, some vendors have found that the JPIP protocol is inefficient for accessing WSI. Clients accessing image data generally have to make more requests resulting in more network messages than with simpler access mechanisms. Additionally JPIP may impose additional overhead on servers, since assembly of responses to requests requires fragmented access to image data and assembly of response images. Typically it is more efficient to distribute processing by moving as much overhead from servers to clients as possible. For these reasons and to support a broader variety of image formats, whole slide images will be stored in DICOM using a mechanism which is *compatible with* JPIP but which *does not require* JPIP. When an image object is stored as a JPEG2000 code stream JPIP *may* be used, but other tiled access methods may also be used.

Description of WSI Storage and Access

Storing an Image Pyramid as a Series

The basic mechanism for storing WSI images for Pathology in DICOM is **to store the individual "tiles" of a WSI pyramid 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 object can be stored as one single tile (if it fits within the $64k^2$ frame pixel matrix limit).

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

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 would be defined by three spatial coordinates relative to the WSI: X and Y offsets (by convention, the upper left corner is {0,0}, and X ascends across the image to the right, while Y increases down the image to the bottom), and Z – which indicates the plane in which the image belongs.

Figure 4 illustrates the correspondence of an image pyramid to DICOM images and series:

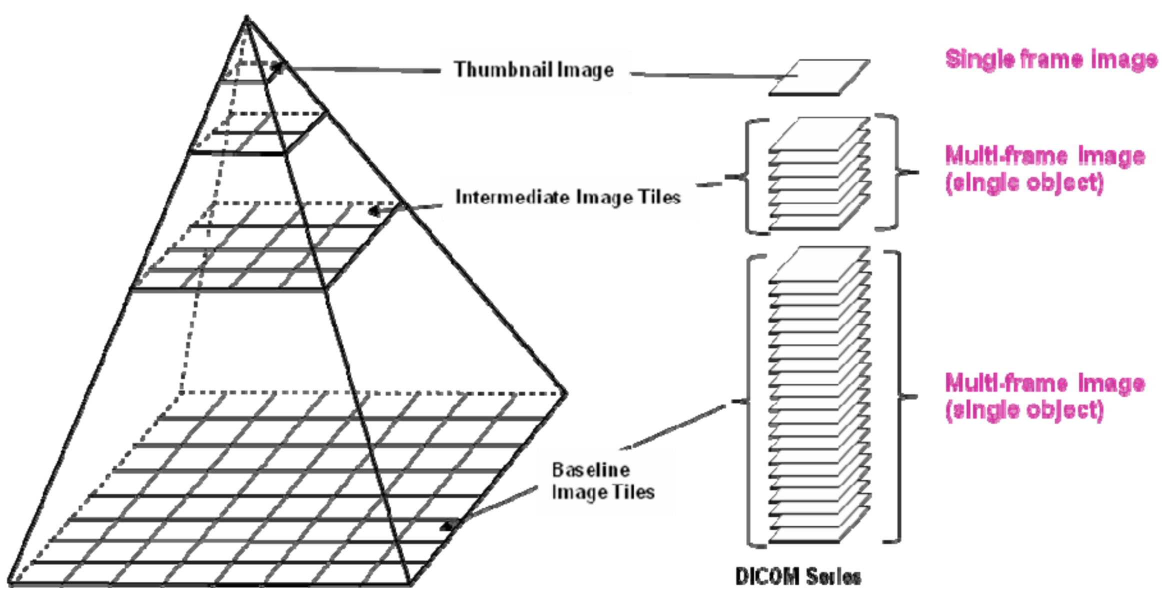

Figure 4 – Mapping a WSI Pyramid into a DICOM Series

Images within DICOM Series

The sequence of tiles from the WSI pyramid in the series will be as follows:

- Thumbnail image, if any (a single low resolution version of the image)
- All tiles from each level of pyramid.
    - Tiles are sequenced from upper left to lower right within each pyramid level.

        - Any given level may be sparse (some tiles missing) or complete.
    - Levels are sequenced from highest resolution to lowest.
    - Within each level, there may be multiple layers corresponding to multiple Z-planes. Layers are sequenced from closest to sample to furthest away.
        - Any given Z-plane may be sparse (some tiles missing) or complete.
- Ancillary images, if any, such as slide label image or whole slide macro image

The WSI IOD

It is necessary to provide a description of the "mapping" from images in the DICOM series to the tiles in the conceptual WSI pyramid. There are also metadata useful for pathology applications which should be stored for the overall image object, each pyramid level, and [possibly] each tile. The role of the WSI IOD is to provide a repository for these data, consisting primarily of the tile map and image / tile metadata.

A new DICOM IOD will be created to describe the sequence of images within the series, indicating which images and tiles are present. This IOD will be known as the WSI IOD, and will contain a "data map" describing which data are present and how they are stored within the DICOM series. The data encompassed by the WSI IOD will include:

The WSI IOD is stored as an XML-formatted string. This maximizes compatibility and provides for easy extension.

- Overall WSI image size (X, Y, and Z, as superset of all levels / layers)
- Whether thumbnail and/or ancillary images are present
- Number of levels present, and resolution of each level
    - For each level, number of layers (Z-planes) present, and offset to each layer
        - For each layer in each level, overall pixel dimensions, and offsets to layer / level within entire WSI object
        - For each layer in each level, the tile pixel dimensions
        - For each layer in each level, a description of which tiles are present, and the location of each within the DICOM series.

Description of individual tiles / consituent images within WSI Series

Each tile / constituent image within the DICOM series, representing a portion of the WSI pyramid (or in the limit, the entire WSI object) is described by the existing DICOM IOD for pathology images. Images may be compressed with one of the following compression types:

- none (raw pixels)
- LZW (lossless compression)
- JPEG (lossy compression, with varying quality factors)
- JPEG2000 (lossy compression, with varying quality factors)

Consituent images may have varying numbers of color channels and pixels may have varying numbers of bits per channel, as per the current DICOM IOD for pathology images. The most typical format will be three channels, typically RGB data or transformed to YC_RC_B color space, with pixels having of 8-bit samples for each channel.

WSI image data access modes

For many applications, discrete stateless access to WSI image data is preferred. A client connects to a server encapsulating the WSI image, retrieves the WSI IOD ("data map"), and then accesses individual images from within the WSI series as needed, making separate connections for each. In other applications performance will be greatly enhanced if the client can make one or more relatively permanent connections, which are serially reused to retrieve the WSI IOD and constituent tiles / images from within the WSI DICOM series.

Characteristics of the WSI storage mechanism

The WSI storage mechanism works around the limitations of the present DICOM standard.

- DICOM image dimensions are (continue to be) specified using unsigned 16-bit integers. This limitation means the maximum pixel dimensions of any *image tile* are 64K x 64K. In practice this is not a limitation, since for performance reasons the chosen tile size is smaller than this.
- DICOM image object sizes are (continue to be) specified using signed 32-bit integers. This limitation means the maximum size of any *image tile* is 2GB. In practice this is not a limitation, since for performance reasons the chosen tile size is smaller than this. Any of the supported compression types may be used, as they all support objects less than 2GB in size. Future / alternative compression technologies also can be supported.
- The present DICOM facilities to access individual images from within a series are used (no extension is required for subregion access). Any desired subregion cay be synthesized at any resolution (and for any focus plane) by retrieving the appropriate images from the series (equivalent to retrieving the appropriate tiles from a stored pyramid).

The WSI storage mechanism encompasses storing a single image in a series as a proper subset. For small images or images with subregion substructure (e.g. images compressed with JPEG2000), it may be desirable to store the entire WSI as a single image.

The WSI storage mechanism handles sparse image data within a resolution level of the pyramid and/or within a Z-plane. Since each image in the series is stored with its coordinates, it is not necessary for all data to be present. This is important as a storage optimization, and also for compatibility with existing instruments and captured WSI.

The WSI storage mechanism requires little change on the part of various PACS system vendors, since PACS systems already support storing images in series. This is crucial for fostering adoption.

The WSI storage mechanism will degrade gracefully for existing DICOM viewers. Each image in the series may be viewed as a portion of the entire WSI, including especially the thumbnail and lower resolution image levels (which will usually be stored as a single image, un-tiled). Individual tiles of the high resolution image may also be viewed with no change.

> To display WSI to a Pathologist for diagnostic and analysis purposes a purpose-built viewer is needed, which provides the required rapid panning and zooming capabilities (and focusing). As digital pathology is adopted and becomes mainstream, this type of viewer will be generally available and built into standard DICOM viewers, in the same way that 3D Radiology image data were at first an exception, and then became a standard.

The WSI IOD

Image orientation

By convention the X axis is assumed to be parallel to the long axis of a slide, and the Y axis parallel to the short axis of a slide, with X perpendicular to the plane of the slide. X = 0 is the left edge of the sample area when positioned with the slide label at the left, X ascends to the right. Y = 0 is the top edge of the sample area when positioned with the slide label at the left (usually the top edge of the slide), Y ascends downward. Z = 0 is the surface of the slide at the upper left corner of the sample area (X=0 and Y=0), and Z ascends upward (toward the objective lens in a conventional optical system). Since the slide surface may not be precisely flat, the surface may not be at Z=0 for every value of X and Y in the sample area.

Assumptions

The image object describes one or more layers. Each layer is a two-dimensional image, parallel to the X/Y plane (surface of the slide). Layers may differ in resolution, Z-level, organization (tiled), and/or format. Layers may be composed of tiles, and if so may be sparse (not all tiles present). For any layer the resolution, Z-level, organization, and format is fixed for all tiles in the layer. All tiles within a layer have the same width and height, and may not overlap, although the layer may be sparse and any number of tiles may be absent.

Data Interpretation

Generally image layers are used to store pixels, which are finite measurements of photon intensity reflected or transmitted for a given location of the sample, interpreted as coordinates in a defined color space.

Omissions

The following are presently excluded from the IOD but may be added later:

- preferred visualization hues for multi-spectral images

WSI Frame of Reference

Dimensions, Z-planes, and Multispectral Imaging

WSI Sparse Encoding

Receivers must deal with sparse tiling

Localizer and Navigation

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 disply rendering of the image, including display area selection, rotate/flip, zoom, windowing or pesudo-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 receiveing user to further ineract 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,

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. 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, mutiple 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, provisional image measurements and findings (internal departmental work products), intended to be reviewed by a physician with the imaging as part of the clinical review and reporting process, would be appropriate as SR.

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).

WSI Workflow - MWL and MPPS

Introduction

Annex XX – Pathology Whole Slide Imaging

This annex explains the use of the **Whole Slide Imaging IOD** for microscopic imaging.

XX.1 PATHOLOGY IMAGING WORKFLOW

XX.2 BASIC CONCEPTS AND DEFINITIONS

XX.3 EXAMPLES OF WHOLE SLIDE IMAGING IOD USE

This section includes examples of the use of the Whole slide imaging IOD

Changes to NEMA Standards Publication PS 3.3-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 3: Information Object Definitions

Update PS 3.3 A.32.2.2 and A.32.3.2 (as amended by Sup122) 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 FoR IE

References to Specimen Module C.7.6.2x to be replaced by section number to be assigned in 2009 consolidated publication of the DICOM Standard.

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** referenced **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
	Specimen	C.7.6.2x	C - Required if the Imaging Subject is a Specimen
	Device	C.7.6.12	U
	VL Image	C.8.12.1	M
	Optical Path	**C.8.12.4Y**	**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
	Specimen	C.7.6.2x	M
	Device	C.7.6.12	U
	VL Image	C.8.12.1	M
	Slide Coordinates	C.8.12.2	M
	Optical Path	**C.8.12.4Y**	**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 Information Object Definition

A.32.X.1 VL Whole Slide Microscopy 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 .

Note: An entire set of tiles for an acquisition may be included in a single instance, in multiple instances of a single concatenation, or in multiple instances in a series (with our without concatentations). E.g., a single instance may contain an entire low resolution image as a single tile (single frame), or a single instance may contain an entire high resolution, multi-focal depth, multi-spectral acquisition (multiple frames).

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.X.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
	Enhanced General Equipment	C.7.5.2	M
Image	General Image	C.7.6.1	M
	Image Pixel	C.7.6.3	M
	Specimen	C.7.6.2x	M
	Multi-frame Functional Groups	C.7.6.16	M
	Multi-frame Dimension	C.7.6.17	M
	Acquisition Context	C.7.6.14	M
	Whole Slide Microscopy Image	C.8.12.X3	M
	Optical Path	C.8.12.4Y	M

IE	Module	Reference	Usage
	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
	ICC Profile	C.11.15	C – Required if Photometric Interpretation is not MONOCHROME2
	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 Dimensions

(Ed. Note. … May want to constrain the possibilities for dimensions here, to increase interoperability, e.g., for a tiled decomposition with multiple focal planes and different illuminants, specify those dimensions in that order.)

A.32.X.3.1.2 Acquisition Context

The Acquisition Context Module encodes parameters of image acquisition that are not described in specific attributes.

Note: The use of Acquisition Context with private (but explicit) coded vocabulary is an alternative to Private Data Elements. As the Acquisition Context Sequence is Type 2, its content must be maintained by Storage SCPs at Level 1 or above (see PS3.4). There may be evolution in the practice of microscopy following introduction of the VL WSI IOD, and significant acquisition parameters not currently standardized can thus be conveyed in an interoperable manner.

A.32.X.3.1.3 Referenced Image Purpose of Reference

Defined Context ID for Purpose of Reference Code Sequence (0040,A170) within the Referenced Image Sequence (0008,1140) is CIDxxx00.

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

Table A.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 – May 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.
Plane Position (Slide)	C.8.12.X4.2	M
Optical Path Identification	C.8.12.X4.5	M
Specimen Reference	C.8.12.X4.6	U

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

A.32.X.4.1.1 Referenced Image

Defined Context ID for Purpose of Reference Code Sequence (0040,A170) is CIDxxx00.

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

There is no requirement that the set of frames in a single instance or concatenation span the entire imaged volume within any spatial dimension, i.e., the sampling of the slide may be “sparse”.

Frames may overlap within any spatial dimension.

(Ed. Note: no specific tiling pattern is defined, nor is any tile order or tile index provided; it is assumed that the spatial slide positions are sufficient … this could be augmented with integer tile “indices” in the X and Y plane if necessary)

Update C.4.10 to convey Optical Path parameters as part of Protocol in MWL

C.4.10 Scheduled Procedure Step Module

Table C.4-10
SCHEDULED PROCEDURE STEP MODULE ATTRIBUTES

Attribute Name	Tag	Attribute Description
Scheduled Procedure Step Sequence	(0040,0100)	One or more Scheduled Procedure Steps for one Requested Procedure.
…		
>Scheduled Protocol Code Sequence	(0040,0008)	Sequence describing the Scheduled Protocol following a specified coding scheme. This sequence contains one or more Items.
>>Include 'Code Sequence Macro' Table 8.8-1		*No Baseline Context ID is defined.*
>>Protocol Context Sequence	(0040,0440)	Sequence that specifies the context for the Scheduled Protocol Code Sequence Item. One or more items may be included in this sequence. See Section C.4.10.1.
>>>Include 'Content Item Macro' Table 10-2		*No Baseline Template is defined.*
>>> Content Item Modifier Sequence	(0040,0441)	Sequence that specifies modifiers for a Protocol Context Content Item. One or more items may be included in this sequence. See Section C.4.10.1.
>>>>Include 'Content Item Macro' Table 10-2		*No Baseline Template is defined.*
>>Protocol Optical Paths Sequence	**(gggg,nn10)**	**Description of the optical path presribed for the protocol specified in this Scheduled Protocol Code Sequence Item. One or more items may be included in this sequence.**
>>>Include 'Optical Path Macro' Table C.8.12.4Y-2		
>Scheduled Procedure Step ID	(0040,0009)	Identifier that identifies the Scheduled Procedure Step.
…		
Scheduled Specimen Sequence	(0040,0500)	Sequence of Items identifying specimens to be imaged in the identified Scheduled Procedure Step(s), with their characteristics.
>Include 'Specimen Macro' Table C.7.6.2x-2		

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. 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 may be identified in this attribute as "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

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 imaging)** in mm. See ~~**C.7.6.2.1.1 and**~~ C.7.6.16.2.3.1 for further explanation. Required if Volumetric Properties (0008,9206) is VOLUME or SAMPLED. May be present otherwise.

For reference, relevant PS 3.3 C.7.6.16.2 Common Functional Groups:

C.7.6.16.2.2 Frame Content Macro

Table C.7.6.16-3 specifies the attributes of the Frame Content Functional Group macro.

This Functional Group Macro may only be part of the Per-frame Functional Groups Sequence (5200,9230) attribute.

Table C.7.6.16-3
FRAME CONTENT MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Frame Content Sequence	(0020,9111)	1	Identifies general characteristics of this frame. Only a single Item shall be permitted in this sequence.
>Frame Acquisition Number	(0020,9156)	3	A number identifying the single continuous gathering of data over a period of time that resulted in this frame.
>Frame Reference DateTime	(0018,9151)	1C	The point in time that is most representative of when data was acquired for this frame. See C.7.6.16.2.2.1 and C.7.6.16.2.2.2 for further explanation. Note: The synchronization of this time with an external clock is specified in the synchronization Module in Acquisition Time synchronized (0018,1800). Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise.
>Frame Acquisition DateTime	(0018,9074)	1C	The date and time that the acquisition of data that resulted in this frame started. See C.7.6.16.2.2.1 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise.
>Frame Acquisition Duration	(0018,9220)	1C	The actual amount of time [in milliseconds] that was used to acquire data for this frame. See C.7.6.16.2.2.1 and C.7.6.16.2.2.3 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL. May be present otherwise.
…	…	…	…
>Dimension Index Values	(0020,9157)	1C	Contains the values of the indices defined in the Dimension Index Sequence (0020,9222) for this multi-frame header frame. The number of values is equal to the number of Items of the Dimension Index Sequence and shall be applied in the same order. See section C.7.6.17.1 for a description. Required if the value of the Dimension Index Sequence (0020,9222) exists.
…	…	…	…

>Stack ID	(0020,9056)	3	Identification of a group of frames, with different positions and/or orientations that belong together, within a dimension organization. See C.7.6.16.2.2.4 for further explanation
>In-Stack Position Number	(0020,9057)	1C	The ordinal number of a frame in a group of frames, with the same Stack ID Required if Stack ID (0020,9056) is present. See section C.7.6.16.2.2.4 for further explanation.
>Frame Comments	(0020,9158)	3	User-defined comments about the frame.
>Frame Label	(0020,9453)	3	Label corresponding to a specific dimension index value. Selected from a set of dimension values defined by the application. This attribute may be referenced by the Dimension Index Pointer (0020,9165) attribute in the Multi-frame Dimension Module. See C.7.6.16.2.2.5 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.8.12.1-1 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.8.12.1-1
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.X3 VL Whole Slide Microscopy Image Module

Table C.8.12.X3-1 specifies the Attributes that describe the VL Whole Slide Microscopy Image Module.

Table C.8.12.X3-1
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.X3.1.1 for specialization.
Imaged Volume Width	(gggg,aa01)	1	Width of total imaged volume (distance in the direction of rows in each frame) in mm. See C.8.12.X3.1.2
Imaged Volume Height	(gggg,aa02)	1	Height of total imaged volume (distance in the direction of columns in each frame) in mm. See C.8.12.X3.1.2
Imaged Volume Depth	(gggg,aa03)	1	Depth of total imaged volume (distance in the Z direction of focal planes) in mm. See C.8.12.X3.1.2

Total Pixel Matrix Columns	(gggg,aa06)	1	Total number of columns in pixel matrix; i.e., width of total imaged volume in pixels. See C.8.12.X3.1.3
Total Pixel Matrix Rows	(gggg,aa07)	1	Total number of rows in pixel matrix; i.e., height of total imaged volume in pixels. See C.8.12.X3.1.3
Total Pixel Matrix Origin Sequence	(gggg,aa08)	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.X3.1.4 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.
>Z Offset in Slide Coordinate System	(0040,074A)	1	The Z offset in microns from the Origin of the Slide Coordinate System.
Image Orientation (Slide)	(gggg,ee02)	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.X3.1.4
Overlapped Tiling	(gggg,aa09)	1	Indicates whether any frames at any single focal depthrepresent the same slide area. Enumerated values: YES, NO
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.X3.1.5 for further explanation.
Samples per Pixel Used	(0028,0003)	1	The number of samples (color planes) containing information. Enumerated values: 1, 2, or 3. See section C.8.12.X3.1.5
Photometric Interpretation	(0028,0004)	1	Specifies the intended interpretation of the pixel data. See section C.8.12.X3.1.5 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, 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: 0000H = 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 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 is MONOCHROME2.
Rescale Slope	(0028,1053)	1C	m in the equation specified by Rescale Intercept (0028,1052). Enumerated value 1 Required if Photometric Interpretation 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
Burned In Annotation	(0028,0301)	1	Indicates whether or not image contains sufficient burned in annotation to identify the patient and date the image was acquired.
Specimen Label in Image	(gggg,aa10)	1	Indicates whether the specimen label is captured in the image. Enumerated Valuers: YES, NO Note: If the label is captured, Burned In Annotation (0028,0301) might be NO if the label includes only a specimen identifier and not patient identifying data.

C.8.12.X3.1 VL Whole Slide Microscopy Image Attribute Descriptions

C.8.12.X3.1.1 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 (see C.8.16.1.1)

Note: Value MIXED, used in other multi-frame IODs, is not permitted.

Value 2 shall have a value of PRIMARY (see C.8.16.1.2)

Value 3 (Image Flavor) shall have the Defined Terms in Table C.8.12.X3-2

Table C.8.12.X3-2
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.X3-3.

Table C.8.12.X3-2
VL WHOLE SLIDE MICROSCOPY DERIVED PIXELS

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

Additional values may be present.

C.8.12.X3.1.2 Imaged Volume Width, Height, Depth

The full physical extent of the whole slide image target volume is described in the attributes Imaged Volume Width (gggg,aa01), Imaged Volume Height (gggg,aa02), and Imaged Volume Depth (gggg,aa03). There is no requirement that this entire extent is actually encoded in frames of the Image SOP Instance.

If only a single focal plane is imaged, the Imaged Volume Depth would 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.X3.1.3 Total Pixel Matrix Columns, Rows

Total Pixel Matrix Columns (gggg,aa06) and Total Pixel Matrix Rows (gggg,aa07) 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.X3.1.4 Total Pixel Matrix Origin Sequence and Image Orientation (Slide)

Total Pixel Matrix Origin Sequence (gggg,aa08) specifies the location of the top leftmost pixel of the pixel matrix, and Image Orientation (Slide) (gggg,ee02).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.

C.8.12.X3.1.5 Photometric Interpretation, Samples per Pixel and Samples per Pixel Used

Photometric Interpretation (0028,0004) shall be one of these Enumerated Values:

MONOCHROME2
RGB
YBR_FULL_422
YBR_ICT
YBR_RCT

appropriate to any 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.

Multi-spectral images may be encoded as a single wavelength band (color) in each frame using MONOCHHROME2, 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.

SOP Instances encoding 2-color images using a color Photometric Interpretation are required to use a value of 3 for Samples per Pixel (0028,0002) and a value of 2 for Samples per Pixel Used (0028,0003). For 2-color images with a RGB Photometric Interpretation, the R and G channel shall be used and the B channel shall have all values set to zero.

Note: In the case of Photometric Interpretations typically used for compression such as YBR_FULL_422, the encoding of 2-color images will be as if the RGB values were transformed to YCbCr.

C.8.12.4Y Optical Path Module

Table C.8.12.4Y-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.

Table C.8.12.4Y-1
OPTICAL PATH MODULE ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Optical Path Sequence	(gggg,ee05)	1	Describes the optical paths used during the acquisition of this image. One or more Items shall be present in this sequence.
>Optical Path Identifier	(gggg,ee06)	1	Identifier for the light path specified in the Sequence Item. The identifier shall be unique for each Item within the Light Path Sequence.
>Include 'Optical Path Macro' Table C.8.12.4Y-2			*Baseline Context ID for Illumination Color Code Sequence is CIDxxx02* *Baseline Context ID for Illumination Type Code Sequence is CIDxxx03* *Baseline Context ID for Lenses Code Sequence is CIDxxx00* *Baseline Context ID for Channel Description Code Sequence is CIDxxx06*

Table C.8.12.4Y-2
OPTICAL PATH MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Optical Path Type Description	(gggg,ee07)	3	Description of the light path specified in the Sequence Item.
Optical Path Type Code Sequence	(gggg,ee08)	3	Coded value for light path description. Only a single Item shall be permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the macro invocation.*
Illumination Wave Length	(0022,0055)	1C	Wavelength of the illuminator in nm. Required if Illumination Color (gggg,ee06) is not present. May be present otherwise.
Illumination Color Code Sequence	(gggg,ee06)	1C	Color of the illuminator. Required if Illumination Wave Length (0022,0055) is not present. May be present otherwise. Only a single Item shall be permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the macro invocation.*
Illumination Type Code Sequence	(0022,0016)	1	Coded value for illumination method. Only a single Item shall be permitted in this sequence.
>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the macro invocation.*
Light Path Filter Type Stack Code Sequence	(0022,0017)	1C	Filters used in the light source path. One or more Items shall be present in this sequence. Required if filters used.

>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the macro invocation.*
Light Path Filter Pass-Through Wavelength	(0022,0001)	3	Nominal pass-through wavelength of light path filter in nm
Light Path Filter Pass Band	(0022,0002)	3	Pass band of light path filter 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)	1C	Describes stack of filters used in image path between the imaging target and the optical sensor. One or more items shall be present in the sequence. Required if filters used.
>Include 'Code Sequence Macro' Table 8.8.1			*Context ID may be defined in the macro invocation.*
Image Path Filter Pass-Through Wavelength	(0022,0003)	3	Nominal pass-through wavelength of image path filter in nm
Image Path Filter Pass Band	(0022,0004)	3	Pass band of image path filter 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)	2	Lenses that were used during the image acquisition. Zero or more items may be present in the sequence.
>Include 'Code Sequence Macro' Table 8.8-1			*Context ID may be defined in the macro invocation.*
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. Note: Equipment may use a color Photometric Interpretation (RGB, YBR) as a container representing 2 or 3 channels of any illumination 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 macro invocation.*

C.8.12.X4 Whole Slide Microscopy Functional Group Macros

The following sections contain Functional Group macros specific to the VL Whole Slide Microscopy 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.X4.2 Plane Position (Slide) Macro

Table C.8.12.4.2-1 specifies the attributes of the Plane Position (Slide) Functional Group macro.

Table C.8.12.X4.2-1
PLANE POSITION (SLIDE) MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Plane Position (Slide) Sequence	(gggg,nn1A)	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.
>Position In Image Pixel Matrix	(gggg,nn1F)	1	The coordinate of the top left pixel of the frame in the Total Pixel Matrix (see C.8.12.X3.1.1), given as column\row. Column is the horizontal position and row is the vertical position. The coordinate of the top left pixel of the Total Pixel Matrix is 1\1.
>Image Center Point Coordinates Sequence	(0040,071A)	1	Identifies the coordinates of the center point of this frame in the Slide Coordinate System Frame of Reference. Only a single Item shall be permitted in this sequence. See Section C.8.12.2.1.1 for further explanation. Note: This attribute allows simplified transformation of a single frame of a multi-frame VL WSI SOP Instance into an instance of the VL Slide Coordinates Microscopy SOP Class.
>>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)	1	The Z offset in microns 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.X4.5 Optical Path Identification Macro

Table C.8.12.X4.5-1 specifies the attributes of the Optical Path Identification Functional Group macro.

Table C.8.12.X4.5-1
OPTICAL PATH IDENTIFICATION MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Optical Path Identification Sequence	(gggg,ee07)	1	Identifies the optical path characteristics of this frame. Only a single Item shall be permitted in this sequence.
>Referenced Optical Path Identifier	(gggg,ee08)	1	Uniquely identifies the path described in the Optical Path Sequence (gggg,ee05) by reference to the Optical Path Identifier (gggg,ee06).

C.8.12.X4.6 Specimen Reference Macro

Table C.8.12.X4.6-1 specifies the attributes of the Specimen Reference Functional Group macro.

Table C.8.12.X4.6-1
SPECIMEN REFERENCE MACRO ATTRIBUTES

Attribute Name	Tag	Type	Attribute Description
Specimen Reference Sequence	(gggg,ee10)	1	Identifies specimens that may be visible in this frame, and which are fully identified in the Specimen Description Sequence (0040,0560). One or more Items shall be present in this sequence.
>Specimen UID	(0040,0554)	1	Unique Identifier for Specimen. See Section C.7.6.2x.1.2 (Sup122).

C.8.12.X5 Multi-Resolution Navigation Module

Table C.8.12.X5-1 specifies the Attributes that describe the Multi-Resolution Navigation Module.

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

Attribute Name	Tag	Type	Attribute Description
Navigation Sequence	(gggg,nn00)	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.
>Top Left Hand Corner of Localizer Area	(gggg,nn01)	1	Top Left Hand Corner of Localizer image pixel area corresponding to referenced frame, given as column\row. Column is the horizontal offset and row is the vertical offset.
>Bottom Right Hand Corner of Localizer Area	(gggg,nn02)	1	Bottom Right Hand Corner of Localizer image pixel area corresponding to referenced frame, given as column\row. Column is the horizontal offset and row is the vertical offset.

>Pixel Spacing in Referenced Image	(gggg,nn03)	1	Pixel Spacing in Referenced Image, specified by a numeric pair - adjacent row spacing (delimiter) adjacent column spacing in mm.
>Include 'SOP Instance Reference Macro' Table 10-11			Referenced Image Instance
>Referenced Frame Number	(0008,1160)	1	Referenced Frame Number within Referenced Image
>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 Used	(0028,0003)	1	The number of samples (color planes) containing information in the referenced image.
>Channel Description Code Sequence	(0022,001A)	1C	Describes the light color sensed for each pixel channel to generate the image in the referenced frame. Required if referenced frame is produced using color other than the natural interpretation (i.e., full spectrum for monochrome, red/green/blue for color); may be present otherwise. One to three Items shall be present.
>>Include 'Code Sequence Macro' Table 8.8.1			*Baseline CID CIDxxx06*

C.8.12.X6 Slide Label Module

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
Container Barcode	(gggg,nn11)	2	Barcode interpreted from the scanned slide label. Note: This will typically be the same as the Container Identifier (0040,0512)
Label Text	(gggg,nn12)	2	Label text interpreted from the scanned slide label, e.g., by optical character recognition.

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.

Note: 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.

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 Mounted. 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 the Left Edge of the Slide. The X-axis is a line that is orthogonal to the Y-axis and 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.

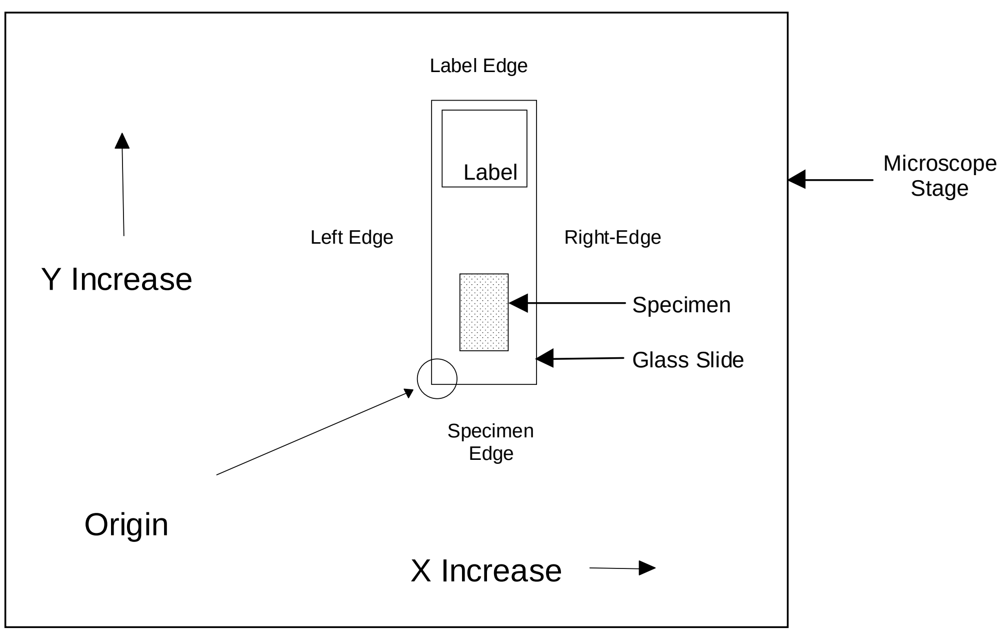

Figure C.8-16
REFERENCE SLIDE ORIENTATION

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 referenced as zero at the image substrate reference plane (i.e. utilized surface of a glass slide) and shall increase in a positive fashion coincident with increased distance from the substrate surface.

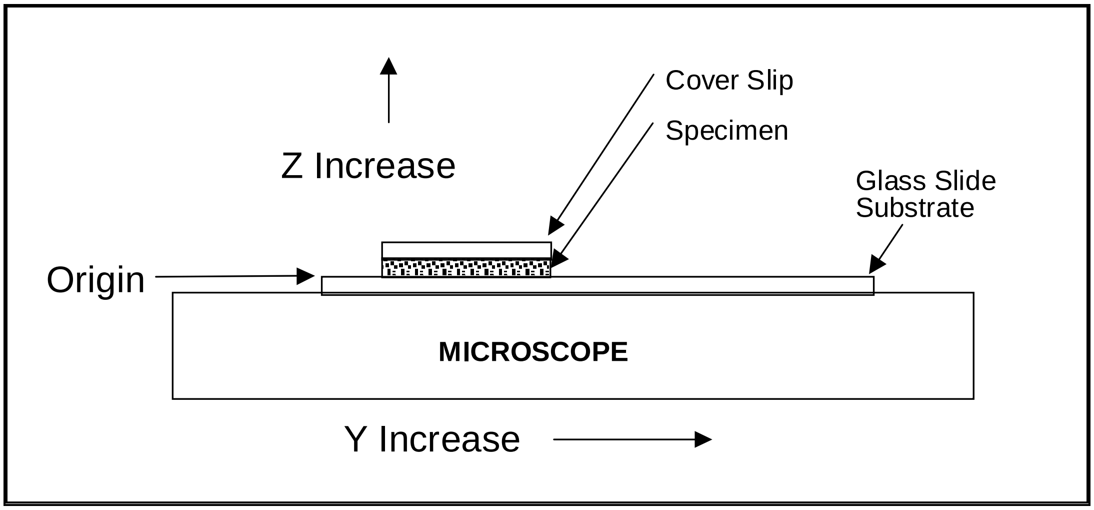

Figure C.8-17
Z-AXIS CENTER POINT LOCATION, VIEW FROM RIGHT EDGE OF SLIDE

Add new attribute to Presentation State Displayed Area for WSI

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.

…

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			
<u>>Pixel Origin Interpretation</u>	**<u>(gggg,bb01)</u>**	**<u>1C</u>**	**<u>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.X3.1.1).</u>** **<u>Required if the Referenced Image Sequence (0008,1140) >Referenced SOP Class UID (0008,1150) value is 1.2.840.10008.5.1.4.1.1.xxx (VL Whole Slide Microscopy Image). May be present otherwise.</u>** **<u>Enumerated Values:</u>** **<u>FRAME</u>** **<u>VOLUME</u>** **<u>If not present, TLHC and BRHC are defined relative to the frame pixel origins.</u>**
>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.
>Presentation Size Mode	(0070,0100)	1	Manner of selection of display size. Enumerated Values: SCALE TO FIT TRUE SIZE MAGNIFY See C.10.4 for further explanation.
>Presentation Pixel Spacing	(0070,0101)	1C	Physical distance between the center of each pixel in the referenced image (before spatial transformation), 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. Notes: 1. This value may be different from Pixel Spacing (0028,0030) or Imager Pixel Spacing (0018,1164) specified in the referenced image, which are ignored, since some form of calibration may have been performed (for example by reference to an object of known size in the image). 2. If the row and column spacing are different, then the pixel aspect ratio of the image is not 1:1. Required if Presentation Size Mode (0070,0100) is TRUE SIZE, in which case the values will correspond to the physical distance between the center of each pixel on the display device. May be present if Presentation Size Mode (0070,0100) is SCALE TO FIT or MAGNIFY, in which case the values are used to compute the aspect ratio of the image pixels.
>Presentation Pixel Aspect Ratio	(0070,0102)	1C	Ratio of the vertical size and the horizontal size of the pixels in the referenced image, to be used to display the referenced image, specified by a pair of integer values where the first value is the vertical pixel size and the second value is the horizontal pixel size. See C.7.6.3.1.7. Required if Presentation Pixel Spacing (0070,0101) is not present.

			Notes: 1. This value may be different from the aspect ratio specified by Pixel Aspect Ratio (0028,0034) in the referenced image, or implied by the values of Pixel Spacing (0028,0030) or Imager Pixel Spacing (0018,1164) specified in the referenced image, which are ignored. 2. This value must be specified even if the aspect ratio is 1:1.
>Presentation Pixel Magnification Ratio	(0070,0103)	1C	Ratio of displayed pixels to source pixels, specified in one dimension. Required if Presentation Size Mode (0070,0100) is MAGNIFY. Notes: 1. A value of 1.0 would imply that one pixel in the referenced image would be displayed as one pixel on the display (i.e. it would not be interpolated if the aspect ratio of the image pixels is 1:1). 2. A value of 2.0 would imply that one pixel in the referenced image would be displayed as 4 pixels on the display (i.e. up-sampled by a factor of 2 in each of the row and column directions). 3. A value of 0.5 would imply that 4 pixels in the referenced image would be displayed as 1 pixel on the display (i.e. down-sampled by a factor of 2 in each of the row and column directions). 4. If the source pixels have an aspect ratio of other than 1:1, then they are assumed to have been interpolated to a display pixel aspect ratio of 1:1 prior to magnification.

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 (gggg,bb01) 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 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 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.X3.1.3). The values must be within the range 0\0 to Total Pixel Matrix Columns\Total Pixel Matrix Rows. This value is valid only if the Referenced Image Sequence (0008,1140) >Referenced SOP Class UID (0008,1150) value is 1.2.840.10008.5.1.4.1.1.xxx (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.
…			

Changes to NEMA Standards Publication PS 3.4-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 4: Service Class Specifications

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.xxx	VL Whole Slide Microscopy Image

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.xxx	VL Whole Slide Microscopy Image

Changes to NEMA Standards Publication PS 3.6-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 6: Data Dictionary

In PS 3.6 Section 6 add new data elements:

Tag	Name	VR	VM	
(gggg,nn10)	Protocol Optical Paths Sequence			
(gggg,aa01)	Imaged Volume Width			
(gggg,aa02)	Imaged Volume Height			
(gggg,aa03)	Imaged Volume Depth			
(gggg,aa06)	Total Pixel Matrix Columns			
(gggg,aa07)	Total Pixel Matrix Rows			
(gggg,aa08)	Total Pixel Matrix Origin Sequence			
(gggg,ee02)	Image Orientation (Slide)			
(gggg,aa09)	Overlapped Tiling			
(gggg,aa10)	Specimen Label in Image			
(gggg,ee05)	Optical Path Sequence			
(gggg,ee06)	Optical Path Identifier			
(gggg,ee07)	Optical Path Type Description			
(gggg,ee08)	Optical Path Type Code Sequence			
(gggg,ee06)	Illumination Color Code Sequence			
(gggg,nn1A)	Plane Position (Slide) Sequence			
(gggg,nn1F)	Position In Image Pixel Matrix			
(gggg,ee07)	Optical Path Identification Sequence			
(gggg,ee08)	Referenced Optical Path Identifier			
(gggg,ee10)	Specimen Reference Sequence			
(gggg,nn00)	Navigation Sequence			
(gggg,nn01)	Top Left Hand Corner of Localizer Area		2	
(gggg,nn02)	Bottom Right Hand Corner of Localizer Area		2	
(gggg,nn03)	Pixel Spacing in Referenced Image		2	
(gggg,nn11)	Container Barcode			
(gggg,nn12)	Label Text			
(gggg,bb01)	Pixel Origin Interpretation			

Add new rows 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.xxx	**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.x1	CIDXX02	WSI Referenced Image Purposes of Reference
1.2.840.10008.6.1.x2		
1.2.840.10008.6.1.x3		

Changes to NEMA Standards Publication PS 3.16-2008

Digital Imaging and Communications in Medicine (DICOM)

Part 16: Content Mapping Resource

Add new Context Groups to PS 3.16:

CID CIDXXX00 WSI REFERENCED IMAGE PURPOSES OF REFERENCE

Context ID CIDXXX00
WSI Referenced Image Purposes of Reference
Type: Extensible Version: yyyymmdd

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

CID CIDXXX01 WSI LENS TYPE

Context ID CIDxxx01
WSI Lens Type
Type: Extensible Version: yyyymmdd

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
		High resolution
		Macro

CID CIDXXX02 ILLUMINATION COLOR DESCRIPTION

Context ID CIDxxx02
Illumination Color Description
Type: Extensible Version: yyyymmdd

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 CIDXXX03 MICROSCOPY ILLUMINATION METHOD

Context ID CIDxxx03
Microscopy Illumination Method
Type: Extensible Version: yyyymmdd

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
		transmission
		reflection
		fluorescent excitation

CID CIDXXX04 MICROSCOPY FILTER

Context ID CIDxxx04
Microscopy Filter
Type: Extensible Version: yyyymmdd

Coding Scheme Designator (0008,0102)	Code Value (0008,0100)	Code Meaning (0008,0104)
DCM	111601	Green filter
DCM	111602	Red filter
DCM	111603	Blue filter
DCM	111604	Yellow-green filter
DCM	111605	Blue-green filter
DCM	111606	Infrared filter
DCM	111607	Polarizing filter
DCM	111609	No filter

CID CIDXXX06 MICROSCOPY CHANNEL DESCRIPTION

Context ID CIDxxx06
Microscopy Channel Description
Type: Extensible Version: yyyymmdd

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

SRT	G-A132	Red free
SRT	R-102BF	Ultraviolet

In PS 3.16 Annex C, add protocol context templates:

TID x8010 Whole Slide Imaging

This template describes protocol parameters for a Whole Slide Imaging Procedure Step.

TID x8010
Whole Slide Imaging
Type: Extensible

	Value Type	Concept Name	VM	Req Type	Condition	Value Set Constraint
1	NUMERIC	EV (, DCM, “Number of focal planes”)	1	U		
2	NUMERIC	EV (, DCM, “focal plane Z offset”)	1-n	U		UNITS=EV(um, UCUM, “micrometers”)
3	CODE	EV (, DCM, "Subvolume to image”)	1	U		*need Context Group*

For reference, PS 3.16 16 Annex D DICOM Controlled Terminology Definitions:

111601	Green filter	Filter that transmits one third of white light (green) while blocking the other two thirds	
111602	Red filter	Filter that transmits one third of white light (red) while blocking the other two thirds	
111603	Blue filter	Filter that transmits one third of white light (blue) while blocking the other two thirds	
111604	Yellow-green filter	A filter of 560nm that is used for retinal imaging and can provide good contrast and good visibility of the retinal vasculature	
111605	Blue-green filter	A filter of 490nm that is used for retinal imaging because of excessive scattering of some retinal structures at very short wavelengths	
111606	Infrared filter	Filter that transmits the infrared spectrum, which is light that lies outside of the visible spectrum, with wavelengths longer than those of red light, while blocking visible light	
111607	Polarizing filter	A filter that reduces reflections from non-metallic surfaces such as glass or water by blocking light waves that are vibrating at selected angles to the filter.	
111609	No filter	No filter used	