DICOM Correction Proposal

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Submitter Name	Dan Hosseinzadeh
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Correction Number CP-1713	
Log Summary: More compact use of Per-Frame Functional Group Macros in Non-Sparse VL Whole Slide Microscopy Image IOD	
Type of Modification Addition	DICOM Correction Proposal

Rationale for Correction:

The mandatory inclusion of the Plane Position Slide Functional Group Macro (PPSFGM) and the Optical Path Identifcation Functional Group Macro (OPIFGM) in Whole Slide Microscopy IOD and the need to use it to determine the tile order leads to unecessarily large headers and parsing time in some cases.

PPSFGM and OPIFGM are redundant if frames in the object are non-sparse and sequentially (left to right, row by row, plane by plane, optical path by optical path) encoded, which is a very common scenario in digital pathology today. Non-sparse and sequential encoding can be indicated in a more compact and efficient manner by the use of a flag to indicate the raster organization of the tiles, after which the physical position of each tile can be computed by the recipient from the mandatory Total Pixel Matrix Origin Sequence (0048,0008).

Currently, PPSFGM and OPIFGM are mandatory and affect performance because the size of the PPSFGM and OPIFGM grow linearly with the number of frames in the object (which can have tens-of-thousands of frames). The following performance issues have been identified:

- Increased load time when headers are put into memory
- Increased delays when headers are transmitted over networks
- Increased complexity when headers are parsed by workstation software

DICOM services such as C-GET-WithoutBulkData and WADO-RS and QIDO-RS services which are required for streaming WSI objects therefore suffer from noticeable loading/transfer lags in routine conditions. There are performance issues related to rendering WSI objects as well since the PPFGM must be parsed and validated by workstations.

Since the IOD does not require the Frame Content FGM, or any other PFFGM in the simple case, it is then possible to entirely omit the Per-Frame Functional Group Sequence (5200,9230) Attribute, which would otherwise consist of a very large number of empty Sequence Items that would servre no purpose.

To fully define the non-sparse encoding matrix size, additional attributes are required to describe the number of Z depths and optical paths, and it is also useful to require the physical spacing corresponding to the Z depths when evenly sampled. This CP does not describe a new mechanism for uneven physical spacing along the Z direction (just as there is no mechanism to describe uneven in-plane spacing in the row and column directions within a tile) (e.g., does not factor out the Z offset from the PPSFGM into a Z-specific per-frame functional group). Also, the focus stacking attributes, already used when collapsing multiple focal planes into a single encoded image plane, are not reused for the case when separate planes are encoded, and these Attributes are highlighted as being distinct and for a different purpose.

Concatentations are permitted for non-sparse encoding, and the organization is defined to span all instances of a concatentation, so it is not required that the non-sparse encoding be entirely contained within a single SOP Instance.

Sections of documents affected

PS3.3, PS3.6

Correction Wording:

In PS 3.3 Table A.32.8.4-2, Make Plane Position and Optical Path Identification Functional Group Macros conditional:

Table A.32.8-2. VL Whole Slide Microscopy Image 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~~ **U** - Shall not be used as a Shared Functional Group.
Referenced Image	C.7.6.16.2.5	U
Derivation Image	C.7.6.16.2.6	C - Required if the image or frame has been derived from another SOP Instance.
Real World Value Mapping	C.7.6.16.2.11	U
Plane Position (Slide)	C.8.12.6.1	~~M~~ **C - Required if Dimension Organization Type (0020,9311) is not TILED_FULL; may be present otherwise**
Optical Path Identification	C.8.12.6.2	~~M~~ **C - Required if Dimension Organization Type (0020,9311) is not TILED_FULL; may be present otherwise**
Specimen Reference	C.8.12.6.3	U

Note: The Plane Position (Slide) and Optical Path Identification Macros are Type C, which allows the Per-Frame Functional Group Sequence (5200,9230) to be entirely omitted in those cases in which there are no other Per-Frame Functional Group Macros with content (i.e., the Frame Content Macro is empty).

In PS 3.3 Table C.7.6.16-1, require Per-Frame Functional Group Sequence only if necessary:

C.7.6.16 Multi-frame Functional Groups Module

...

Table C.7.6.16-1. Multi-frame Functional Groups Module Attributes

Attribute Name	Tag	Type	Attribute Description
Shared Functional Groups Sequence	(5200,9229)	1	Sequence that contains the Functional Group Macros that are shared for all frames in this SOP Instance and Concatenation. Note The contents of this sequence are the same in all SOP Instances that comprise a Concatenation. Only a single Item shall be included in this Sequence. See Section C.7.6.16.1.1 for further explanation.
>Include one or more Functional Group Macros that are shared by all frames. The selected Functional Group Macros shall not be present in the Per-frame Functional			For each IOD that includes this module, a table is defined in which the permitted

Attribute Name	Tag	Type	Attribute Description
Groups Sequence (5200,9230).			Functional Group Macros and their usage is specified. The Item may be empty if the requirements for inclusion of the Functional Groups are not satisfied.
Per-frame Functional Groups Sequence	(5200,9230)	1**C**	Sequence that contains the Functional Group Sequence Attributes corresponding to each frame of the Multi-frame Image. The first Item corresponds with the first frame, and so on. One or more Items shall be included in this Sequence. The number of Items shall be the same as the number of frames in the Multi-frame image. See Section C.7.6.16.1.2 for further explanation. **Required if for any frame, there are Per-Frame Functional Groups that are not empty.**
>Include one or more Functional Group Macros.			For each IOD that includes this module, a table is defined in which the permitted Functional Group Macros and their usage is specified. An Item may be empty if the requirements for inclusion of the Functional Groups for the corresponding frame are not satisfied.
...	...	...	...

C.7.6.16.1 Multi-frame Functional Groups Module Attribute Description

C.7.6.16.1.1 Functional Group

A Functional Group is a set of Attributes that are logically related and may vary together. Functional Groups are defined by editorial convention in Macros. Those Functional Groups that apply to all frames are included in the Shared Functional Groups Sequence (5200,9229). Functional Groups whose attribute values may vary from frame to frame are included in the Per-frame Functional Groups Sequence (5200,9230).

A single Functional Group shall not be included in both the Shared Functional Groups Sequence (5200,9229) and the Per-frame Functional Groups Sequence (5200,9230).

Note

- In the case of a SOP Instance containing a single frame, some Functional Groups may be contained in the Shared Functional Groups Sequence (5200,9229) and others in the one Item of the Per-frame Functional Groups Sequence (5200,9230).
- Even if there are no Functional Groups in the Per-frame Functional Groups Sequence (5200,9230) an empty Item is encoded for every frame, which an IOD is permitted to specify for a Type 1 Sequence, as described in PS3.5**, unless all Items for all frames are empty, in which case the Per-frame Functional Groups Sequence (5200,9230) may be entirely omitted**.

It may happen that the Data Set for the Item of a Functional Group Sequence Attribute does not contain any Attributes (e.g., a condition for a single Type 1C attribute in the sequence is not met). In this case, the Item is included but is empty.

Note

PS3.5 describes that an empty Item is permitted for a Type 1 or Type 2 Sequence depending on what the IOD in PS3.3 defines for the Data Set that is defined for that Sequence Item.

It may happen that a Functional Group Sequence Attribute is not required for a particular frame (e.g., an optional Functional Group). In this case the Functional Group Sequence Attribute is not included in the Per-frame Functional Groups Sequence (5200,9230) Item for that frame.

Note

The absence of the sequence attribute corresponding to a particular functional group indicates that the functional group is not used for a particular frame.

Private Functional Groups may be defined. The attributes of such a group may be standard or private attributes. A Private Functional Group may not replicate the attributes of a standard Functional Group.

A Private Functional Group can be added to either the Shared Functional Groups Sequence (5200,9229) or the Per-frame Functional Groups Sequence (5200,9230).

C.7.6.16.1.2 Per-frame Functional Groups Sequence

The Per-frame Functional Groups Sequence Attribute (5200,9230) consists of a Sequence of Items. Each Item describes the frame of the same rank in the multi-frame pixel data. The first Item describes frame 1, the second Item describes frame 2, etc. Frames are implicitly numbered starting from 1. ...

In PS 3.3 Table C.7.6.16-2, require if TILED_FULL and more than one focal plane:

C.7.6.16.2.1 Pixel Measures 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 included 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 Section 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, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or

Attribute Name	Tag	Type	Attribute Description
			• SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"). May be present otherwise.
>Slice Thickness	(0018,0050)	1C	Nominal reconstructed slice thickness (for tomographic imaging) or depth of field (for optical non-tomographic imaging), in mm. See Section C.7.6.16.2.3.1 for further explanation. Note Depth of field may be an extended depth of field created by focus stacking (see Section C.8.12.4). Required if: • Volumetric Properties (0008,9206) is VOLUME or SAMPLED, or • SOP Class UID is Segmentation Storage ("1.2.840.10008.5.1.4.1.1.66.4") and Frame of Reference UID (0020,0052) is present, or • SOP Class UID is Ophthalmic Tomography Image Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.4") and Ophthalmic Volumetric Properties Flag (0022,1622) is YES, or • SOP Class UID is Ophthalmic Optical Coherence Tomography B-scan Volume Analysis Storage ("1.2.840.10008.5.1.4.1.1.77.1.5.8"). May be present otherwise.
>Spacing Between Slices	(0018,0088)	~~3~~1C	Spacing between adjacent slices, in mm. The spacing is measured from the center-to-center of each slice, and if present shall not be negative. **Required if Dimension Organization Type (0020,9311) is TILED_FULL and Total Pixel Matrix Focal Planes (0048,0303) is greater than 1. May be present otherwise.** **Note: In the case of Whole Slide Images, Spacing Between Slices (0018,0088) describes the spacing of focal planes separately encoded, and is distinct from Distance Between Focal Planes (0048,0014), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).**

In PS 3.3 Table C.7.6.16-3, change conditions on temporal attributes that are not needed for WSI and allows its omission:

C.7.6.16.2.2 Frame Content Macro

...

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 included 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 Section C.7.6.16.2.2.1 and Section 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 and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) **or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage)**. 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 Section C.7.6.16.2.2.1 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) **or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage)**. 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 Section C.7.6.16.2.2.1 and Section C.7.6.16.2.2.3 for further explanation. Required if Frame Type (0008,9007) Value 1 of this frame is ORIGINAL and the SOP Class UID is not "1.2.840.10008.5.1.4.1.1.2.2" or "1.2.840.10008.5.1.4.1.1.4.4" or "1.2.840.10008.5.1.4.1.1.128.1" (Legacy Converted) **or 1.2.840.10008.5.1.4.1.1.77.1.6 (VL Whole Slide Microscopy Image Storage)**. May be present otherwise.
>Cardiac Cycle Position	(0018,9236)	3	Description of the position in the cardiac cycle that is most representative of this frame. Defined Terms: **END_SYSTOLE** **END_DIASTOLE** **UNDETERMINED**
>Respiratory Cycle Position	(0018,9214)	3	Description of the position in the respiratory cycle that is most representative of this frame. Defined Terms: **START _RESPIR**

Attribute Name	Tag	Type	Attribute Description
			END_RESPIR **UNDETERMINED**
>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. Note In Section C.7.6.17.1, the index values are defined to start from 1 and monotonically increase by 1, within the scope of the Dimension Organization UID (0020,9164). Required if the value of Dimension Index Sequence (0020,9222) exists.
>Temporal Position Index	(0020,9128)	1C	Ordinal number (starting from 1) of the frame in the set of frames with different temporal positions. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.6 and Section C.7.6.16.2.2.8.
>Stack ID	(0020,9056)	1C	Identification of a group of frames, with different positions and/or orientations that belong together, within a dimension organization. See Section C.7.6.16.2.2.4 for further explanation. Required if the value of SOP Class UID (0008,0016) equals "1.2.840.10008.5.1.4.1.1.130" or Functional MR Sequence (0018,9621) is present. May be present otherwise. See Section C.7.6.16.2.2.7 and Section C.7.6.16.2.2.8.
>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) or Functional MR Sequence (0018,9621) is present. See Section C.7.6.16.2.2.4 and Section C.7.6.16.2.2.8 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 Section C.7.6.16.2.2.5 for further explanation.

In PS 3.3 Table C.7.6.17-1, add new defined terms for Dimension Organization Type:

Table C.7.6.17-1. Multi-frame Dimension Module Attributes

Attribute Name	Tag	Type	Attribute Description
Dimension Organization Sequence	(0020,9221)	1	Sequence that lists the Dimension Organization UIDs referenced by the containing SOP Instance. See Section C.7.6.17.2 for further explanation. One or more Items shall be included in this Sequence.
>Dimension Organization UID	(0020,9164)	1	Uniquely identifies a set of dimensions referenced within the containing SOP Instance. See Section C.7.6.17.2 for further explanation.
Dimension Organization Type	(0020,9311)	3	Dimension organization of the instance. Defined Terms: **3D** Spatial Multi-frame image of equally spaced parallel planes (3D volume set) **3D_TEMPORAL** Temporal loop of equally spaced parallel-plane 3D volume sets. **TILED_FULL** **Tiled image in which each frame represents a single tile and the spatial positions of the tiles are implicitly defined as per Section C.7.6.17.3.** **TILED_SPARSE** **Tiled image in which each frame represents a single tile and the spatial positions of tiles are explicitly defined by per-frame functional group macro entries.**
Dimension Index Sequence	(0020,9222)	1	Identifies the sequence containing the indices used to specify the dimension of the multi-frame object. One or more Items shall be included in this Sequence.
...	...	...	...

C.7.6.17.3 Spatial Location and Optical Path of Tiled Images

If Dimension Organization Type (0020,9311) is present with a value of TILED_FULL, then the Per-Frame Functional Group Macros that would otherwise describe the spatial location of each tile explicitly (e.g., the X, Y and Z offsets from the origin in the Slide Coordinate System Plane Position (Slide)), and the optical path, may be omitted.

A value of TILED_FULL indicates that the frames across all Instances of a Concatentation, or a single Instance in the absence of a Concatenation, comprise a non-sparse non-overlapping representation of an entire rectangular region, and are sequentially encoded as successive frames in Pixel Data (7FE0,0010) in an implicit order varying:

- **first along the row direction from left to right, where the row direction is defined in the Slide Coordinate System by the first three values of Image Orientation (Slide) (0048,0102),**
- **then along the column direction from top to bottom, where the column direction is defined in the Slide Coordinate System by the second three values of Image Orientation (Slide) (0048,0102),**
- **then along the depth direction from the glass slide towards the coverslip, where the depth direction is defined in the Slide Coordinate System from zero to positive,**
- **then along optical paths, where the direction is defined by successive Items of the Optical Path Sequence (0048,0105) in the order in which they are listed in that Sequence.**

If Dimension Organization Type (0020,9311) is absent or has a value of TILED_SPARSE, then the spatial location of each tile is explicitly encoded using information in the Per-Frame Functional Group Sequence, and the recipient shall not make any assumption about the spatial position or optical path or order of the encoded frames but shall rely on the values of the relevant Per-Frame Functional Group Macro.

In PS 3.3 for reference unchanged, the definition of Plane Position (Slide) Macro:

C.8.12.6.1 Plane Position (Slide) Macro

Table C.8.12.6.1-1 specifies the attributes of the Plane Position (Slide) Functional Group Macro.

Table C.8.12.6.1-1. Plane Position (Slide) Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Plane Position (Slide) Sequence	(0048,021A)	1	Describes position of frame in the Total Pixel Matrix and in the Slide Coordinate System Frame of Reference. Only a single Item shall be included in this Sequence.
>Column Position In Total Image Pixel Matrix	(0048,021E)	1	The column position of the top left hand pixel of the frame in the Total Pixel Matrix (see Section C.8.12.4.1.1). The column position of the top left pixel of the Total Pixel Matrix is 1.
>Row Position In Total Image Pixel Matrix	(0048,021F)	1	The row position of the top left hand pixel of the frame in the Total Pixel Matrix (see Section C.8.12.4.1.1). The row position of the top left pixel of the Total Pixel Matrix is 1.
>X Offset in Slide Coordinate System	(0040,072A)	1	The X offset in mm from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Y Offset in Slide Coordinate System	(0040,073A)	1	The Y offset in mm from the Origin of the Slide Coordinate System. See Figure C.8-16.
>Z Offset in Slide Coordinate System	(0040,074A)	1	The Z offset in µm from the Origin of the Slide Coordinate System, nominally the surface of the glass slide substrate. See Figure C.8-17 Note Required even if only a single focal plane was acquired.

C.8.12.6.2 Optical Path Identification Macro

Table C.8.12.6.2-1 specifies the attributes of the Optical Path Identification Functional Group Macro.

Table C.8.12.6.2-1. Optical Path Identification Macro Attributes

Attribute Name	Tag	Type	Attribute Description
Optical Path Identification Sequence	(0048,0207)	1	Identifies the optical path characteristics of this frame. Only a single Item shall be included in this Sequence.

Attribute Name	Tag	Type	Attribute Description
>Optical Path Identifier	(0048,0106)	1	Uniquely identifies the path described in the Optical Path Sequence (0048,0105) by reference to an Item with the same Optical Path Identifier (0048,0106) value. See Section C.8.12.5.

Add new attribute Total Pixel Matrix Focal Planes to Whole Slide Microscopy Image Module and update descriptions of Attributes:

C.8.12.4 Whole Slide Microscopy Image Module

Table C.8.12.4-1 specifies the Attributes that describe the Whole Slide Microscopy Image Module.

Table C.8.12.4-1. Whole Slide Microscopy Image Module Attributes

Attribute Name	Tag	Type	Attribute Description
Image Type	(0008,0008)	1	Image identification characteristics. See Section C.8.12.4.1.1 for specialization.
Imaged Volume Width	(0048,0001)	1	Width of total imaged volume (distance in the direction of rows in each frame) in mm. See Section C.8.12.4.1.2
Imaged Volume Height	(0048,0002)	1	Height of total imaged volume (distance in the direction of columns in each frame) in mm. See Section C.8.12.4.1.2
Imaged Volume Depth	(0048,0003)	1	Depth of total imaged volume (distance in the Z direction of focal planes) in µm. See Section C.8.12.4.1.2
Total Pixel Matrix Columns	(0048,0006)	1	Total number of columns in pixel matrix; i.e., width of total imaged volume in pixels. See Section C.8.12.4.1.3
Total Pixel Matrix Rows	(0048,0007)	1	Total number of rows in pixel matrix; i.e., height of total imaged volume in pixels. See Section C.8.12.4.1.3
Total Pixel Matrix Focal Planes	**(0048,0303)**	**1C**	**Total number of focal planes (Z locations) in the pixel matrix; i.e., depth of total imaged volume in pixels. See Section C.8.12.4.1.3.** **Required if Dimension Organization Type (0020,9311) is present with a value of TILED_FULL. May be present otherwise.** **Note: Total Pixel Matrix Focal Planes (0048,0303) describes the number of focal planes separately encoded, and is distinct from Number of Focal Planes (0048,0013), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).**
Total Pixel Matrix Origin Sequence	(0048,0008)	1	Location of pixel 1\1 of the total pixel matrix in the Slide Coordinate System Frame of Reference. Only a single Item shall be included in this Sequence.

Attribute Name	Tag	Type	Attribute Description
			See Section C.8.12.4.1.4 and 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.
>Y Offset in Slide Coordinate System	(0040,073A)	1	The Y offset in millimeters from the Origin of the Slide Coordinate System.
Image Orientation (Slide)	(0048,0102)	1	The direction cosines of the first row and the first column of the total pixel matrix with respect to the Slide Coordinate System Frame of Reference. See Section C.8.12.4.1.4
Samples Per Pixel	(0028,0002)	1	Number of samples (color planes) per frame in this image. Enumerated Values: **3** **1** See Section C.8.12.4.1.5 for further explanation.
...	...	...	...
Extended Depth of Field	(0048,0012)	1	Image pixels were created through combining of image acquisition at multiple focal planes (focus stacking). Enumerated Values: YES NO
Number of Focal Planes	(0048,0013)	1C	Number **of** acquisition focal planes used for extended depth of field. Required if Extended Depth of Field (0048,0012) value is YES. **Note: Total Pixel Matrix Focal Planes (0048,0303) describes the number of focal planes separately encoded, and is distinct from Number of Focal Planes (0048,0013), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).**
Distance Between Focal Planes	(0048,0014)	1C	Distance between acquisition focal planes used for extended depth of field, in µm. Required if Extended Depth of Field (0048,0012) value is YES. **Note: Spacing Between Slices (0018,0088) describes the spacing of focal planes separately encoded, and is distinct from Distance Between Focal**

Attribute Name	Tag	Type	Attribute Description
			Planes (0048,0014), which describes in what manner different focal planes were combined into a single encoded plane (focus stacking).
...	...	...	...

...

C.8.12.4.1.2 Imaged Volume Width, Height, Depth

The full physical extent of the whole slide image target volume is described in the attributes Imaged Volume Width (0048,0001), Imaged Volume Height (0048,0002), and Imaged Volume Depth (0048,0003). These values reflect the maximum extent in these dimensions. There is no requirement that this entire extent is actually encoded in frames of the Image SOP Instance**, unless Dimension Organization Type (0020,9311) is present with a value of TILED_FULL**.

The value of Imaged Volume Depth (0048,0003) shall not be 0. If only a single focal plane is imaged, the Imaged Volume Depth may be the optical depth of field as encoded in Slice Thickness (0018,0050) of the Pixel Measures Functional Group (see Section C.7.6.16.2.1).

C.8.12.4.1.3 Total Pixel Matrix Columns, Rows, Focal Planes

Total Pixel Matrix Columns (0048,0006) and Total Pixel Matrix Rows (0048,0007) **and Total Pixel Matrix Focal Planes (0048,0303)** 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 Pixel Spacing (0028,0030) of the Pixel Measures Functional Group (see Section C.7.6.16.2.1)**, such as when Dimension Organization Type (0020,9311) is present with a value of TILED_FULL**.

C.8.12.4.1.4 Total Pixel Matrix Origin Sequence and Image Orientation (slide)

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

Note

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

In PS 3.3 Table C.8.12.5-1, add the Number of Optical Paths:

C.8.12.5 Optical Path Module

....

Table C.8.12.5-1. Optical Path Module Attributes

Attribute Name	Tag	Type	Attribute Description
Number of Optical Paths	**(0048,0302)**	**1C**	**Number of Items in the Optical Path Sequence (0048,0105).** **Required if Dimension Organization Type (0020,9311) is**

Attribute Name	Tag	Type	Attribute Description
			present with a value of TILED_FULL. May be present otherwise.
Optical Path Sequence	(0048,0105)	1	Describes the optical paths used during the acquisition of this image. One or more Items shall be included in this Sequence. See Section C.8.12.5.1.1
>Optical Path Identifier	(0048,0106)	1	Identifier for the optical path specified in the Sequence Item. The identifier shall be unique for each Item within the Optical Path Sequence.
...	...	...	...

In PS 3.3 for reference unchanged, the definition of the Slice Coordinate System:

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 is 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.

Note

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

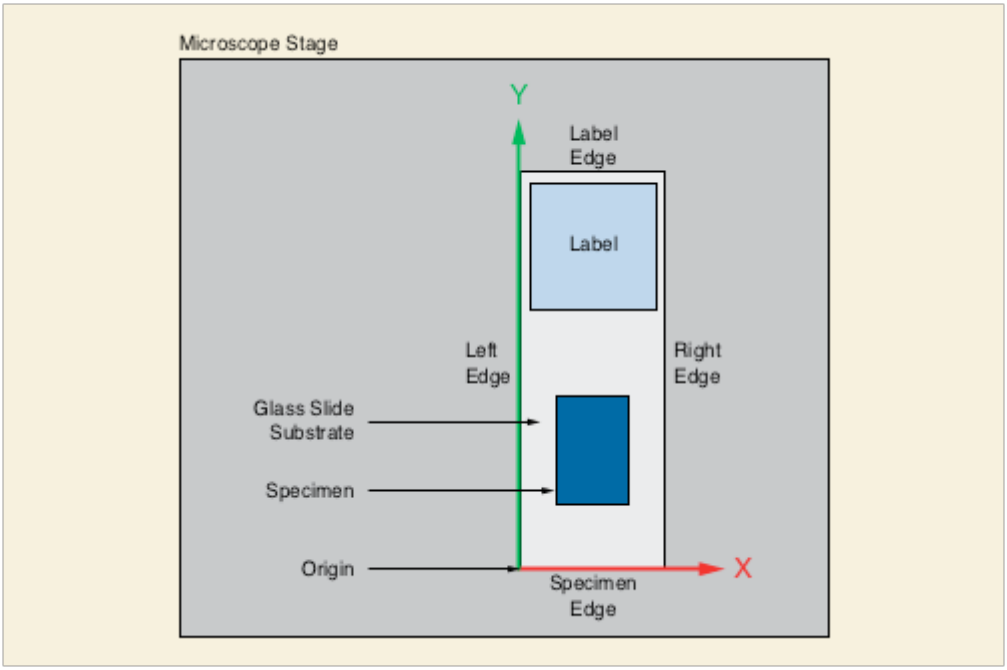

Figure C.8-16. Reference Slide Orientation

Note

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

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

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

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

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

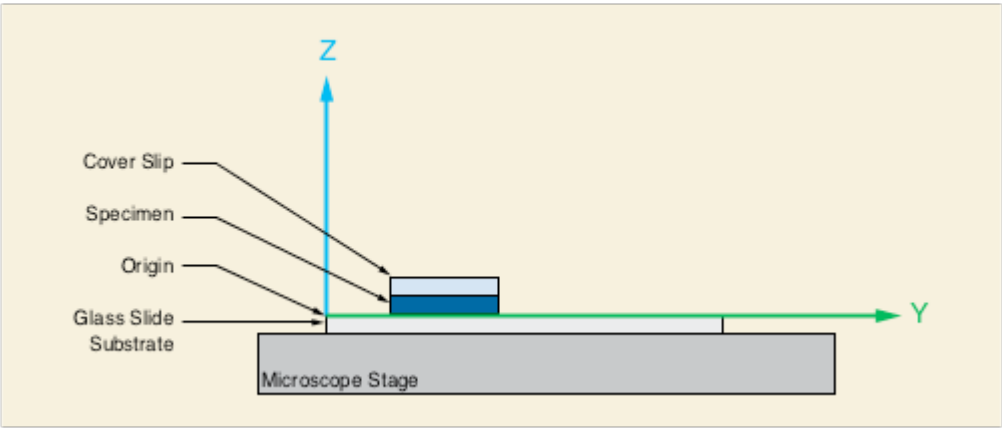

Figure C.8-17. Z-Axis Center Point Location, View From Right Edge of Slide

In PS 3.6 add new Data Elements:

Tag	Name	Keyword	VR	VM	
(0048,0301)	Pixel Origin Interpretation	PixelOriginInterpretation	CS	1	
(0048,0302)	**Number of Optical Paths**	**NumberOfOpticalPaths**	**UL**	**1**	
(0048,0303)	**Total Pixel Matrix Focal Planes**	**TotalPixelMatrixFocalPlanes**	**UL**	**1**	
(0050,0004)	Calibration Image	CalibrationImage	CS	1	