

Recent Progress with Whole Slide Imaging in DICOM

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Topics

- Background and goals
- Current progress
 - DICOM Supplement 145 - WSI
 - Technical decisions and issues
 - Remainder of the process



DICOM

- Digital Imaging and Communications in Medicine
- Voluntary standards organization
- Image exchange standard for CLINICAL images
- 27 working groups
- Anyone with a material interest may participate
- Version 3 of standard released 1992



DICOM Working Groups

Modality, clinical domain, or function specific teams,
assigned to develop Supplements or Change Proposals

WG-01: Cardiac and Vascular Information

**WG-02: Projection Radiography and
Angiography**

WG-03: Nuclear Medicine

WG-04: Compression

WG-05: Exchange Media

WG-06: Base Standard

WG-07: Radiotherapy

WG-08: Structured Reporting

WG-09: Ophthalmology

WG-10: Strategic Advisory

WG-11: Display Function Standard

WG-12: Ultrasound

WG-13: Visible Light

WG-14: Security

WG-15: Digital Mammography and CAD

WG-16: Magnetic Resonance

WG-17: 3D

WG-18: Clinical Trials and Education

WG-19: Dermatology

**WG-20: Integration of Imaging and
Information Systems**

WG-21: Computed Tomography

WG-22: Dentistry

WG-23: Application Hosting

WG-24: Surgery

WG-25: Veterinary Medicine

WG-26: Pathology

WG-27: Web Technology for DICOM



DICOM Overview

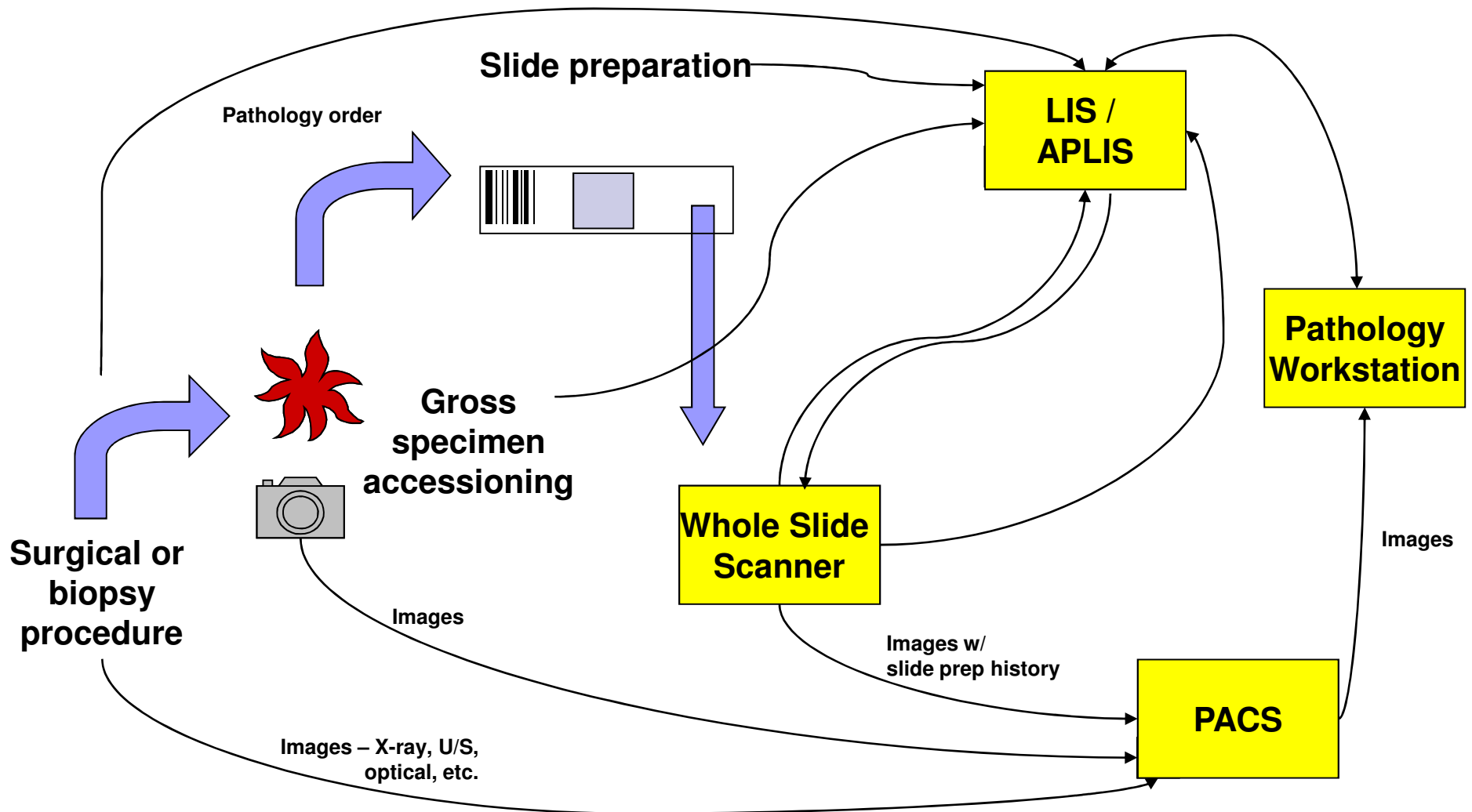
- Communication standard
- High level standard, conceptual
- Facilitates interchange, doesn't mandate internal storage formats within PACS
- Image object definitions are central
- Widely adopted in radiology
- Addresses workflow as well as images



Pathology in DICOM

- Visible light supplement approved 1999
 - Incomplete and rarely used
 - Doesn't support the complexity of Pathology practice
- Pathology WG needed
 - Created WG-26 Fall 2005
 - Has met about 20 times
 - Representatives from most major pathology imaging vendors
 - Also pathologists, consultants and researchers
 - 90+ subscribers to email listserve
 - 60+ organizations
 - >10 countries

AP - Imaging Overview





WG-26 Goals

- Initial goals:

- Extend minimal capabilities to describe specimens in DICOM
- Create a mechanism to allow exchange and use of whole slide microscopic images within DICOM

- Long term goals:

- Other imaging modalities, such as multi-spectral images, electron microscopy, flow cytometry, clinical lab images



Supplement 122

- Specifies a specimen description model which allows description of:
 - Type of specimen
 - Procurement and processing steps
 - Sampling methods
 - Physical attributes of slides
- Final text approved June 2008

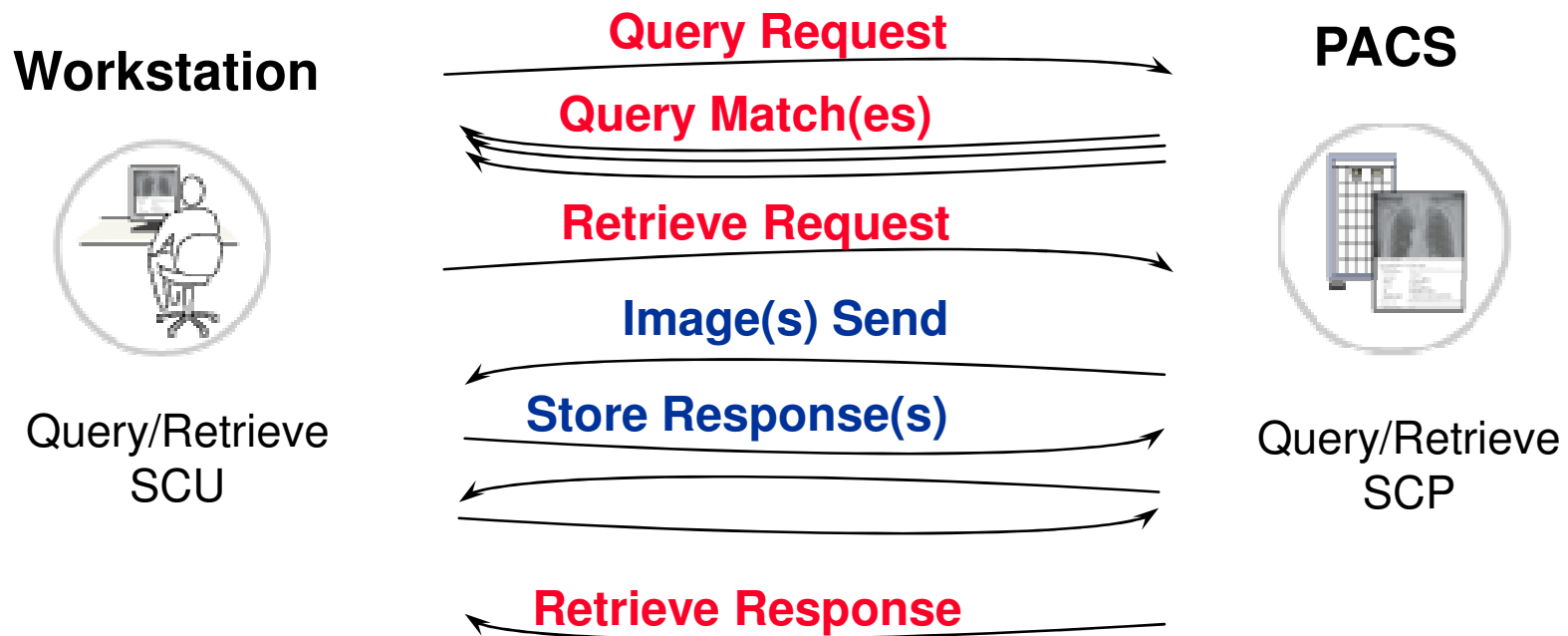


Supp 145 - Whole Slide Images

- Need a new DICOM Image Object Definition
- Challenges
 - Vast size
 - Need for intuitive and fast viewing interface
- DICOM specific issues
 - Image pixel dimensions limited to 64k x 64k
 - Image size description limited to 4GB
 - Desirable to be backwards compatible
 - Efficient sub-region access
 - Most DICOM services assume entire image transmission

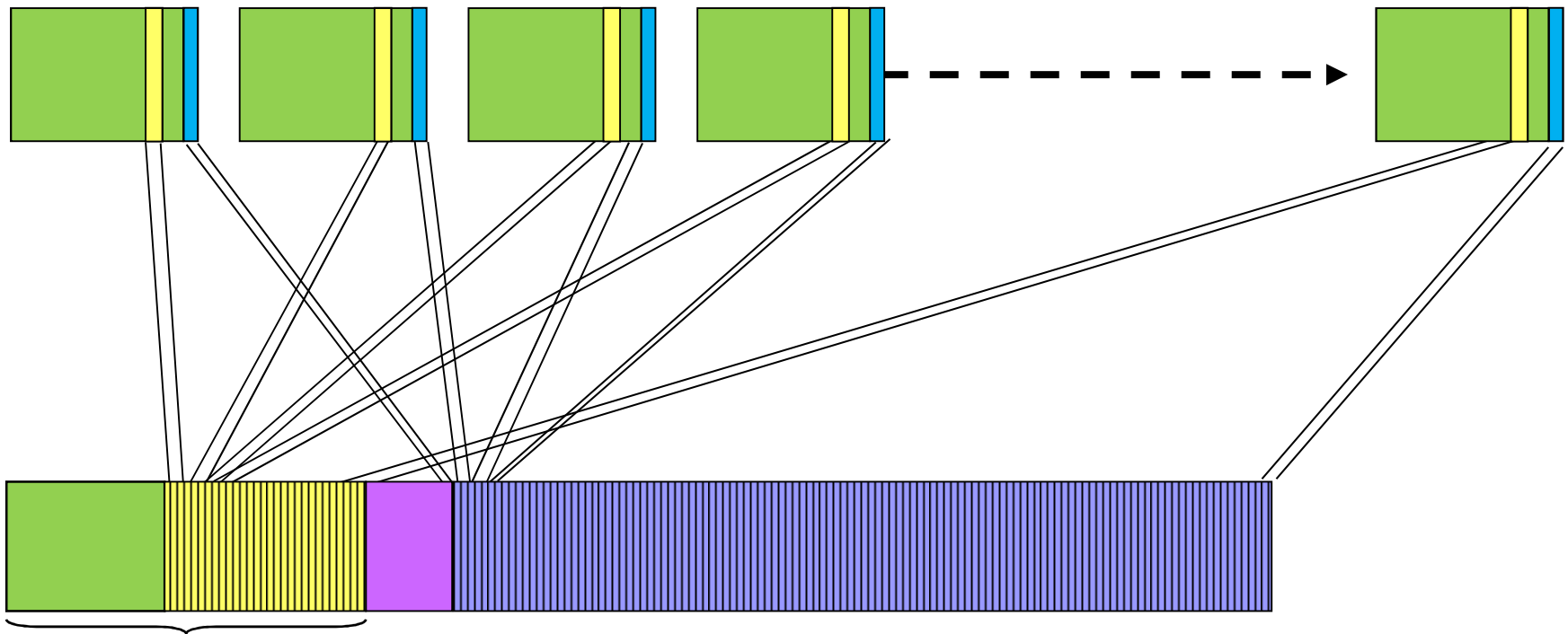
DICOM Query/Retrieve

- Allows a system to query another system for a list of available images (query)
- Also allows a system to request another system to send images (retrieve)



Single-frame to MultiFrame

N Objects, N Headers



N Frames, **One** Header



Fixed Header



Per-frame header



Dimension data



Pixel data

Frame-based retrieve

- New in 2009, supplement 119
- Retrieve subset of frames from a multi-frame image
 - Selected frames of a volumetric stack (ROI)
 - Decimated volume (e.g., every 10th slice)
 - Single dimension of a multi-dimensional image
 - Time snippet of motion image (video)
 - Individual tiles from a tiled WSI
- Requester (workstation) specifies selected frames or time interval
- Provider (PACS) creates new multi-frame image with derivation attributes

Interactive JPIP Retrieve

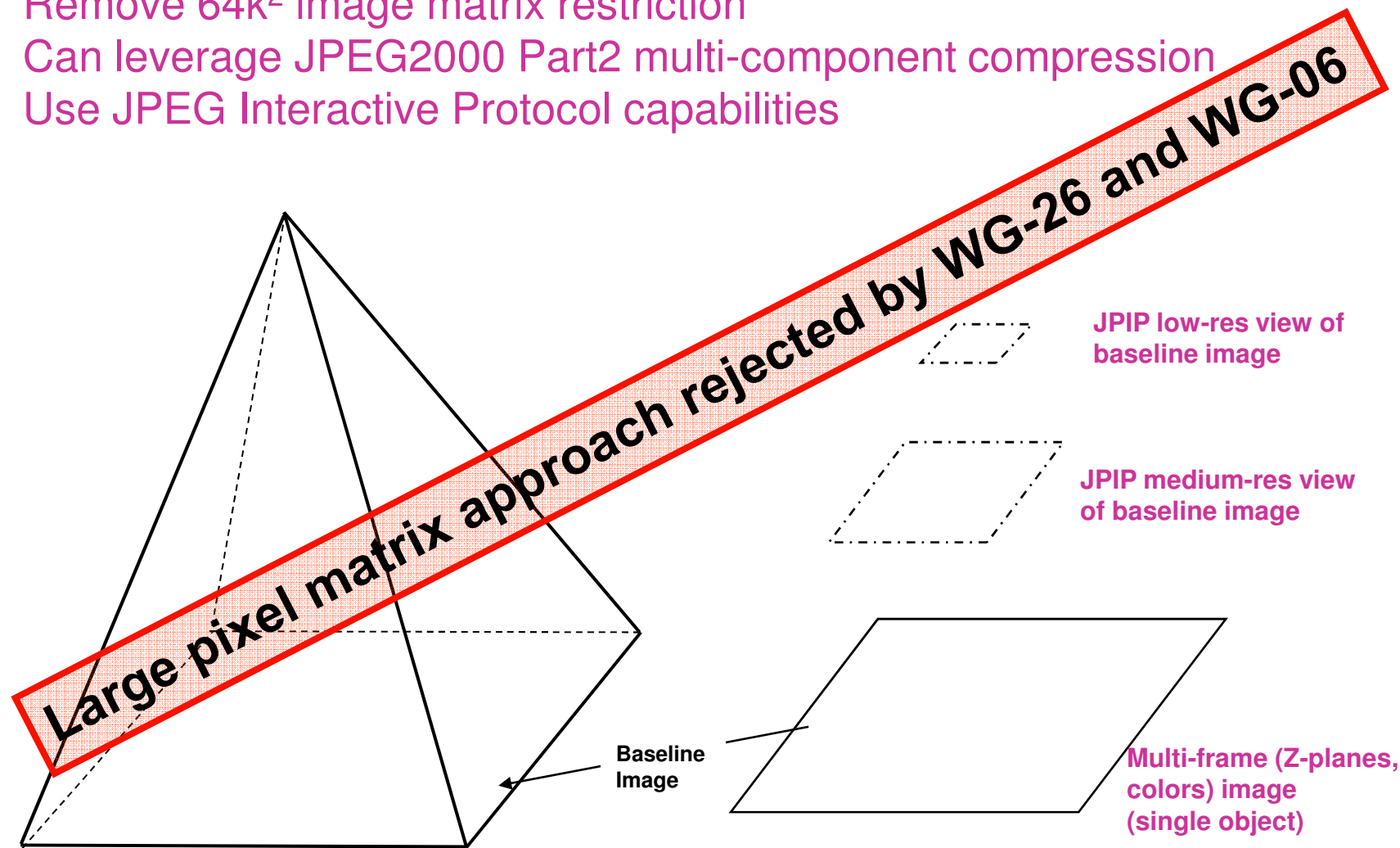
- Applications can negotiate a JPEG 2000 Interactive Protocol (JPIP) Transfer Syntax
 - Image header (i.e., entire object minus pixel data) transferred and confirmed as usual
 - Pixel data replaced by URL to JPIP service for this image
- Limitations
 - Pixel data must be in JPEG 2000 format
 - Storage Commitment not allowed
 - Duration of availability of JPIP service not specified or guaranteed
- Capabilities
 - Retrieve subset of image (ROI)
 - Retrieve at a lower resolution (e.g., for quick navigation)

Non-tiled approach (not in draft!)

Remove $64k^2$ image matrix restriction

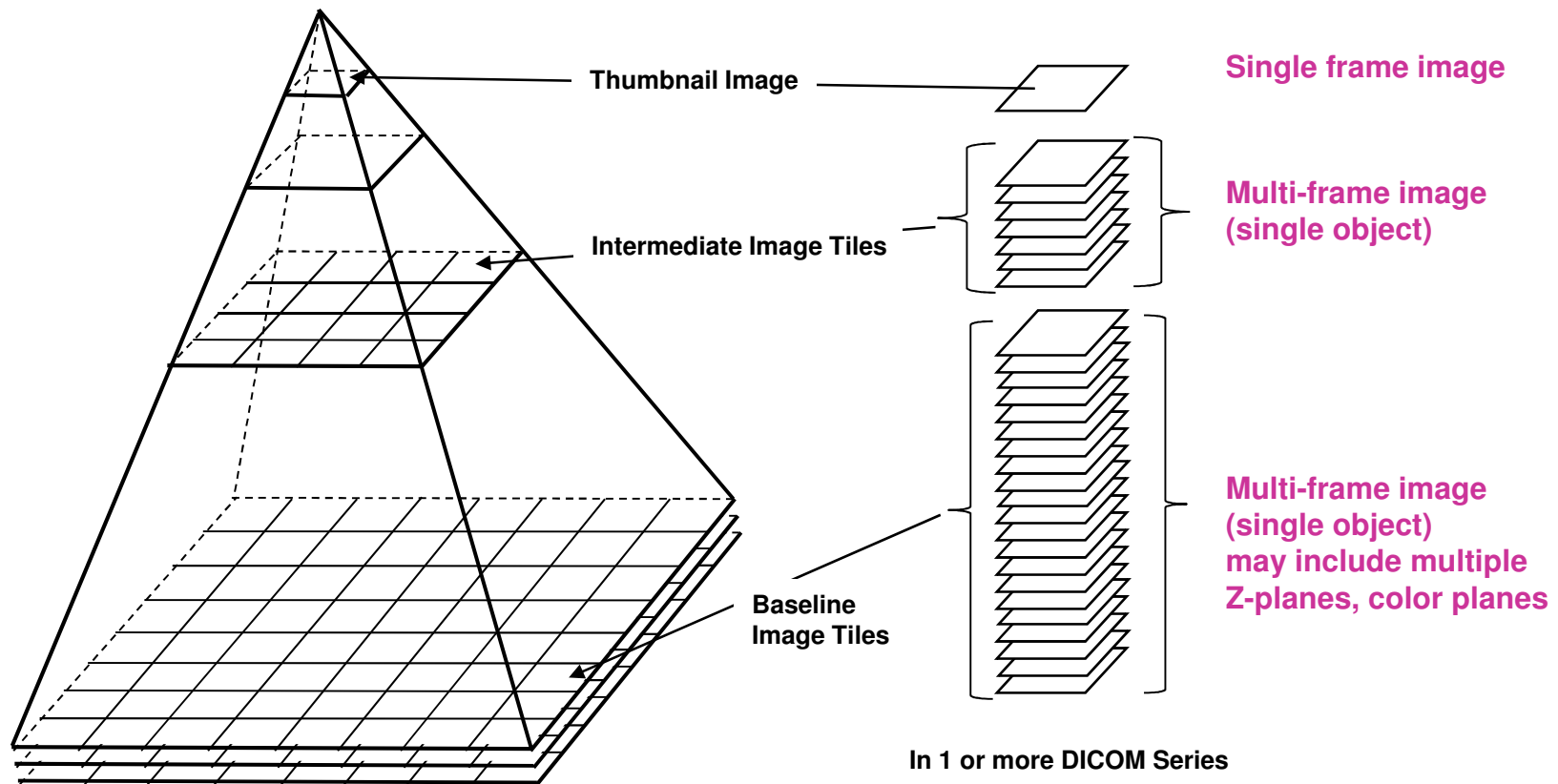
Can leverage JPEG2000 Part2 multi-component compression

Use JPEG Interactive Protocol capabilities

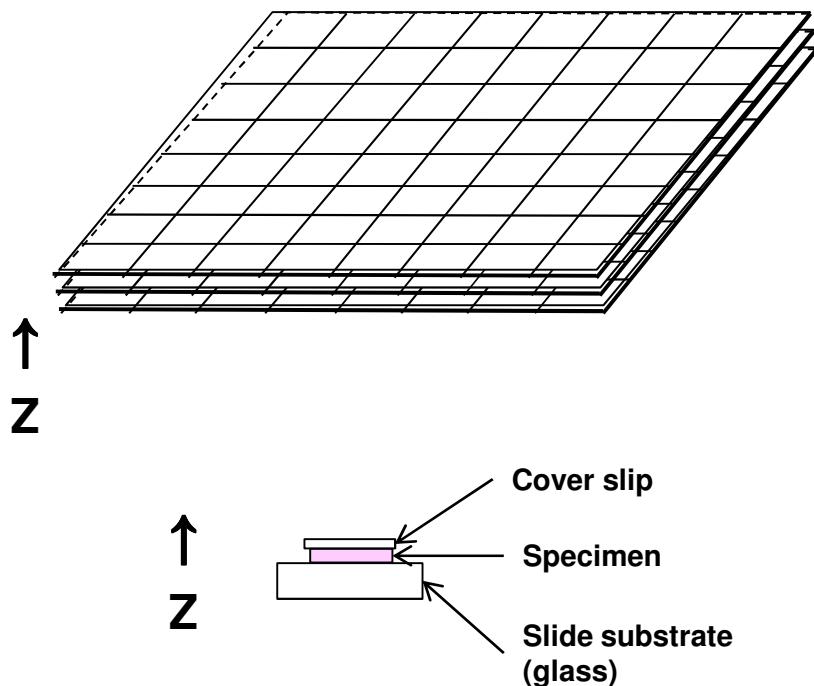


Sup145 multi-frame tiling concept

Use multi-frame image objects (not object per tile)



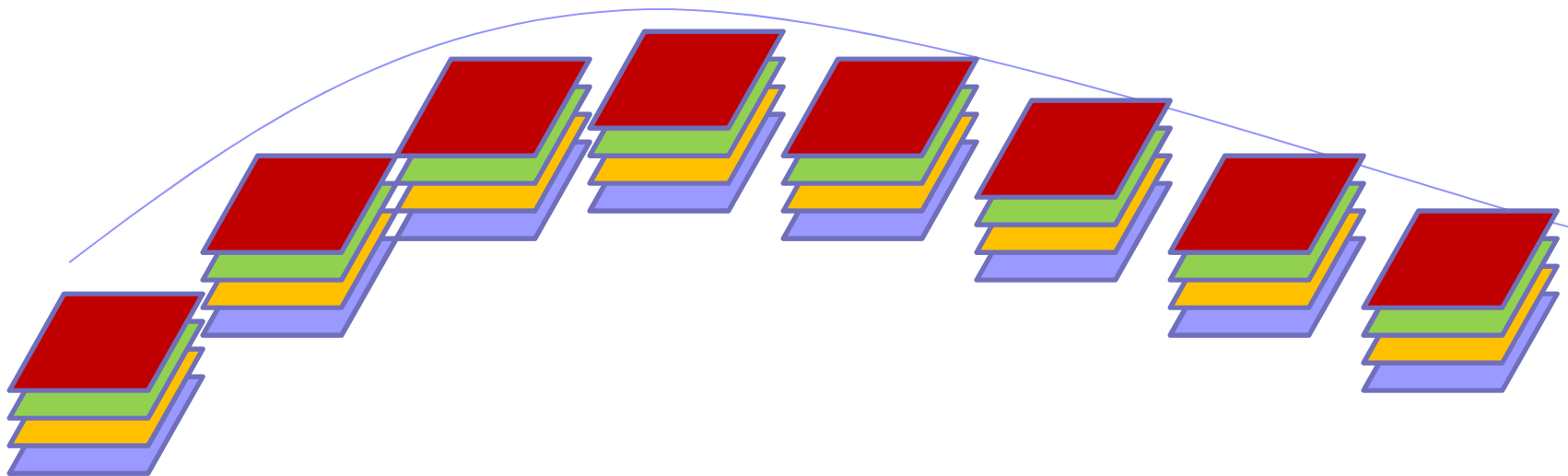
Z-planes



- Z-planes are identified as nominal physical height of image focal plane above reference surface (μm)
- Z-plane information is used for relative spatial positioning of image planes, and *nominal* inter-plane distance
- An image plane may track variable specimen thickness / surface contour, but only one Z-value used

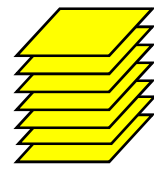
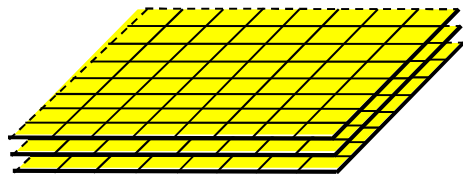
Z planes track curved surface

- **Z plane 1**, **Z plane 2**, **Z plane 3**, **Z plane 4**

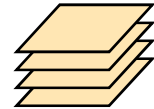
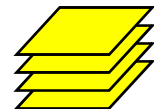
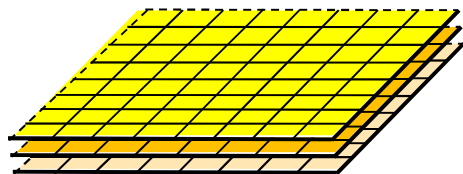


Organization of tiles into objects

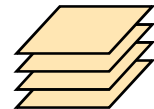
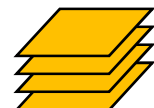
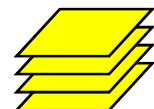
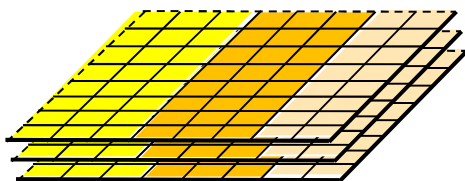
All Valid:



Single Multi-frame image

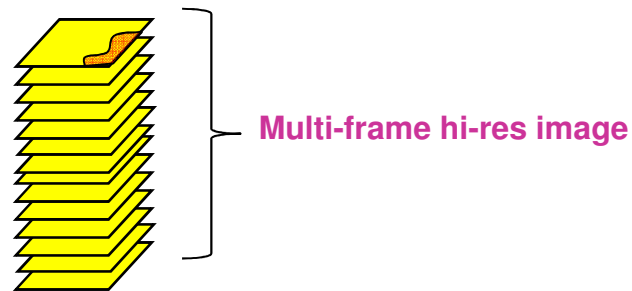
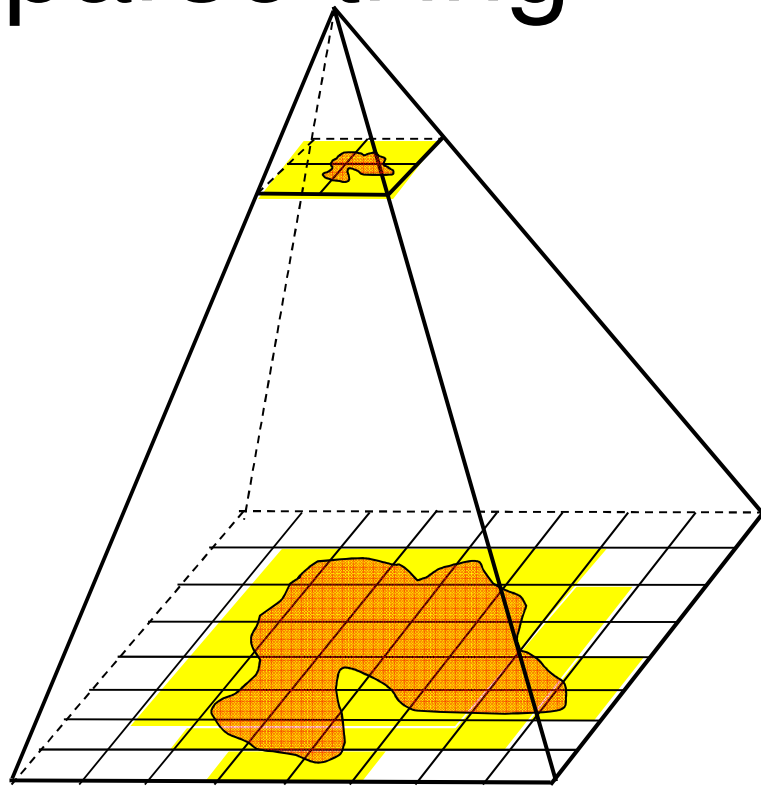


Multi-frame image per Z-plane



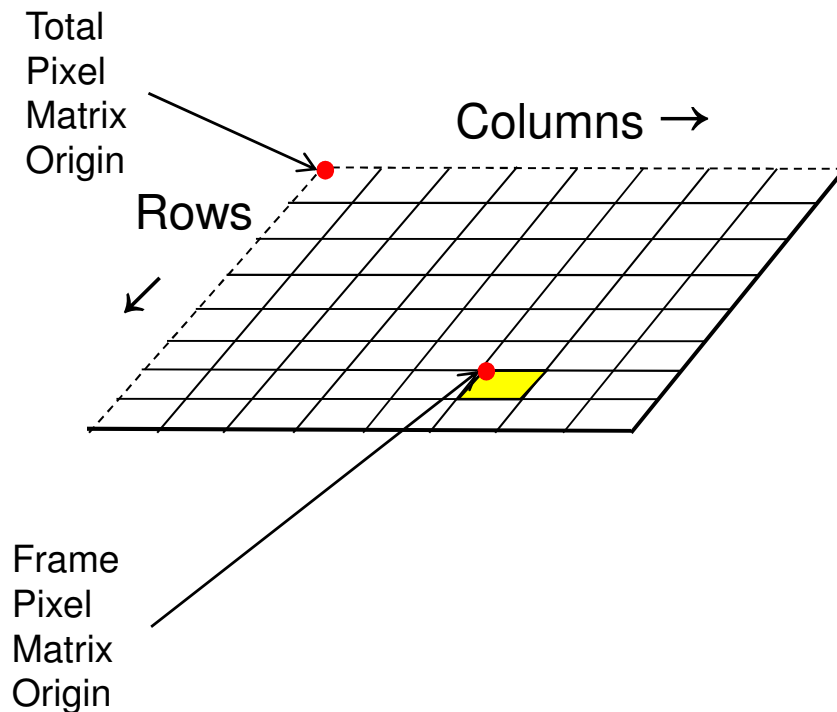
Multi-frame image per spatial region

Sparse tiling



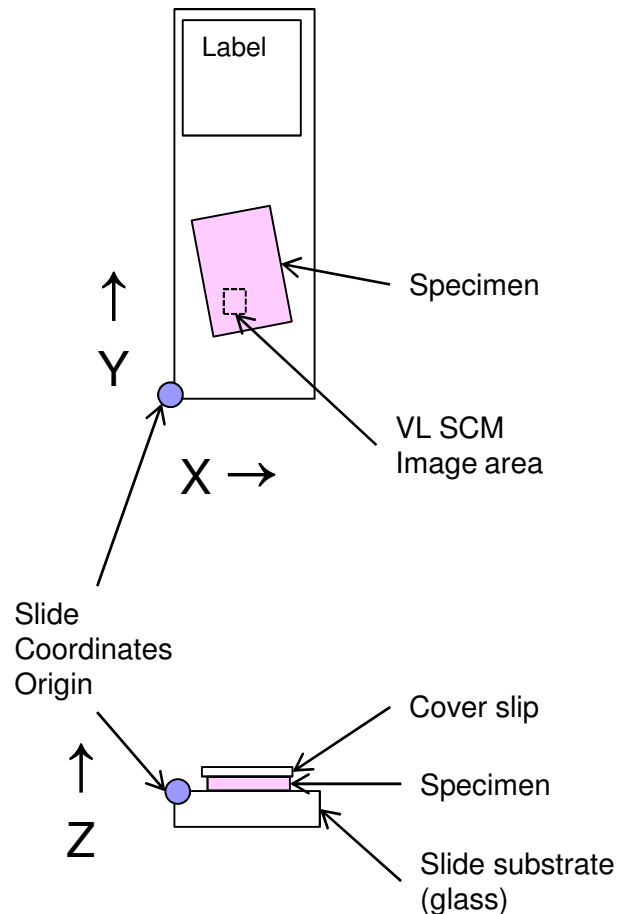
- Only selected tiles encoded
- Full image matrix might be encoded at lower resolution

Total Pixel Matrix



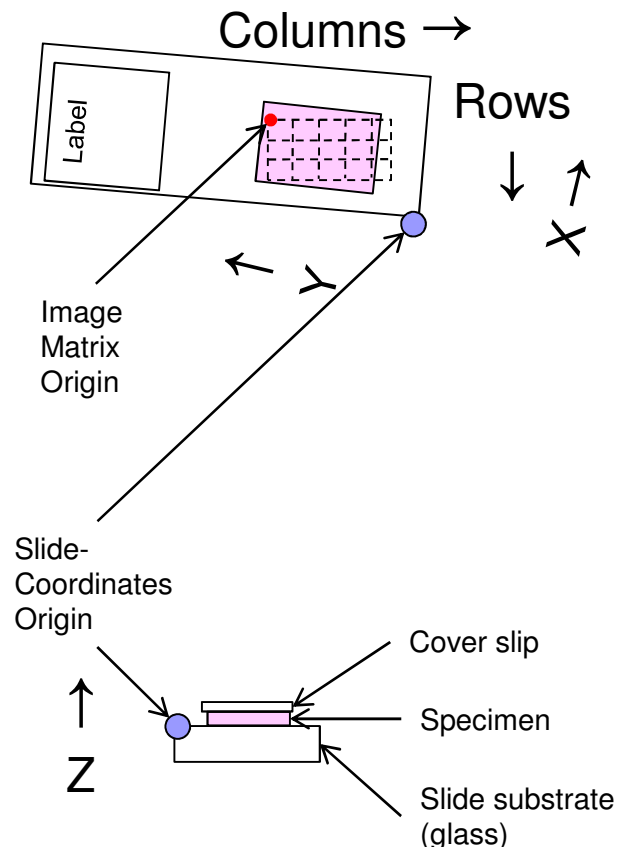
- Total pixel matrix origin at top left hand corner of imaged volume
- Frame (tile) rows and columns align with total pixel matrix rows and columns
- Frames limited to 2^{16} columns and rows
- Total pixel matrix limited to 2^{32} columns and rows

Slide Coordinates



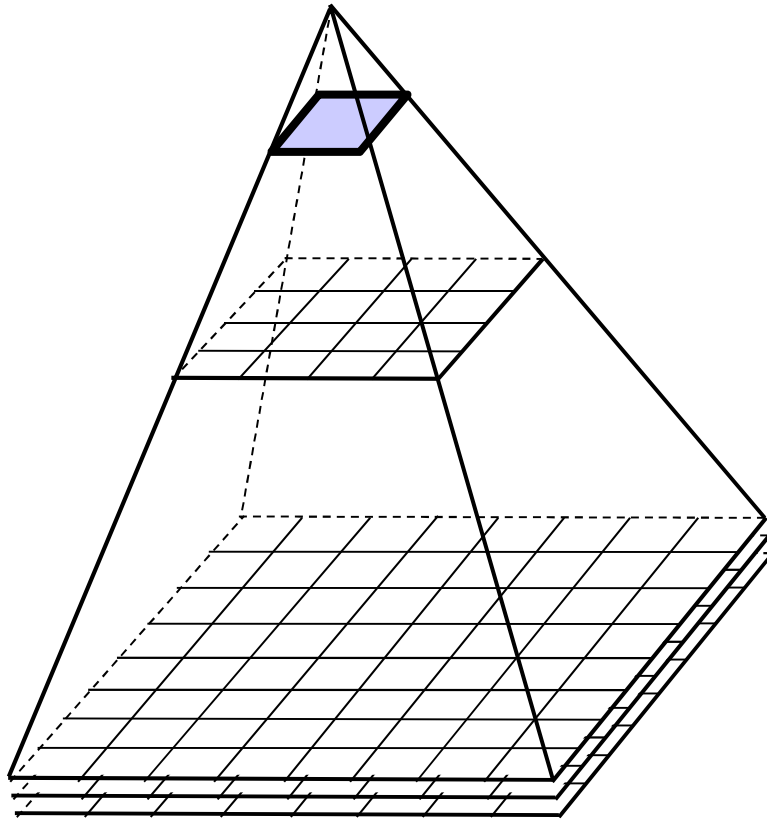
- Used in VL Slide-Coordinates Microscopic Image IOD
 - Single frame image, typically from microscope-mounted camera
- Used to localize **center** of VL SCM Image
- DICOM Frame of Reference associated with slide corner origin
- Reproducibility not guaranteed across different mountings of slide, even on same equipment

WSI Image Pixel Matrix



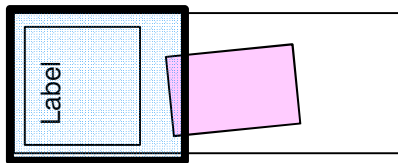
- Image Matrix not necessarily aligned to slide edge, nor to Slide-Coordinates
- Image Matrix origin (top left hand corner) located relative to Slide-Coordinates Frame of Reference origin (X,Y in mm)
- Direction of rows and columns given as cosines in Slide-Coordinates Frame of Reference
- Each tile (frame) TLHC located relative to Image Matrix origin (column, row)
- Each tile *center* located relative to Slide-Coordinates origin (X,Y in mm)

Localizer Image Flavor



- Thumbnail image (single frame) plus multi-resolution navigation links
- Each tile of other resolution images has its corresponding area identified in thumbnail
- Full description of target tiles
 - Object UID and frame #
 - Resolution
 - Z-plane
- Multiple target frames can overlap
 - Different resolution, Z-plane, color, etc.
- Presentation and any interactive behavior is not defined in standard

Label Image Flavor



- Purpose is to capture slide label
 - Any specimen captured is irrelevant
- Image IOD includes Slide Label Module
 - Barcode (if deciphered)
 - Label Text (if deciphered)



Optical Path Acquisition Context

- Each frame may specify a different optical path
 - Allows different colors in a single object, including hyperspectral (n monochrome planes)
 - Identified in Optical Path Functional Group by reference to Optical Path Sequence Item

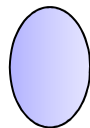
Optical paths

- Each combination of light source, lenses, illumination method, detected wavelengths, etc. used in a scan is an optical path
- Three primary attributes
 - Illumination color or wavelength
 - Illumination method (e.g., transmission, epifluorescence, darkfield, differential interference contrast)
 - Detection color
- Optional attributes for lenses, filters, prisms, etc.
- Examples:
 - Full spectrum light, transmission, RGB color sensors
 - uV light, epifluorescence, monochrome sensor

Optical paths



Illumination
Color(s),
Type (laser)



Filters:
Color(s)
Polarization
Dichromatic
beamsplitter
Hoffman
modulator
Darkfield stop
Phase contrast
plate
Condenser
annulus
Nomarski prism



Lens:

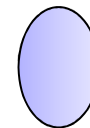


Illumination
Method:

Transmission
Reflection
Epifluorescence
Brightfield
Darkfield
Oblique
Phase contrast
Differential
interference
contrast
Total internal
reflection
fluorescence



Lens:



Filters:



Sensor:
Color(s)

What's NOT in Sup145

- All the modules already standardized
 - Patient, Study, Series, Equipment, General Image
 - Multi-Frame Functional Groups and Dimensions
 - Sup122 Specimen Module
- Explicit description of workflow
 - Use of Modality Worklist, Modality Performed Procedure Step, Image Availability Notification, etc.



Supp. 145 - Next Steps

- Process almost finished – should be finalized Sept. 2010
- Once this is in place, DICOM is able to handle most pathology and lab images
- Most slide scanner vendors have been involved, along with some PACS vendors
- Need to engage LIS vendors and publicize these changes



Summary

- WG-26 has created supplements to incorporate modern digital pathology within DICOM
- The collaboration of DICOM, IHE and HL7 has led to a broad based standards effort for digital pathology
- The availability of a digital workflow for images will enable changes in the practice of pathology



References

- DICOM:

- <http://dicom.nema.org>

- HL7:

- <http://www.hl7.org/>

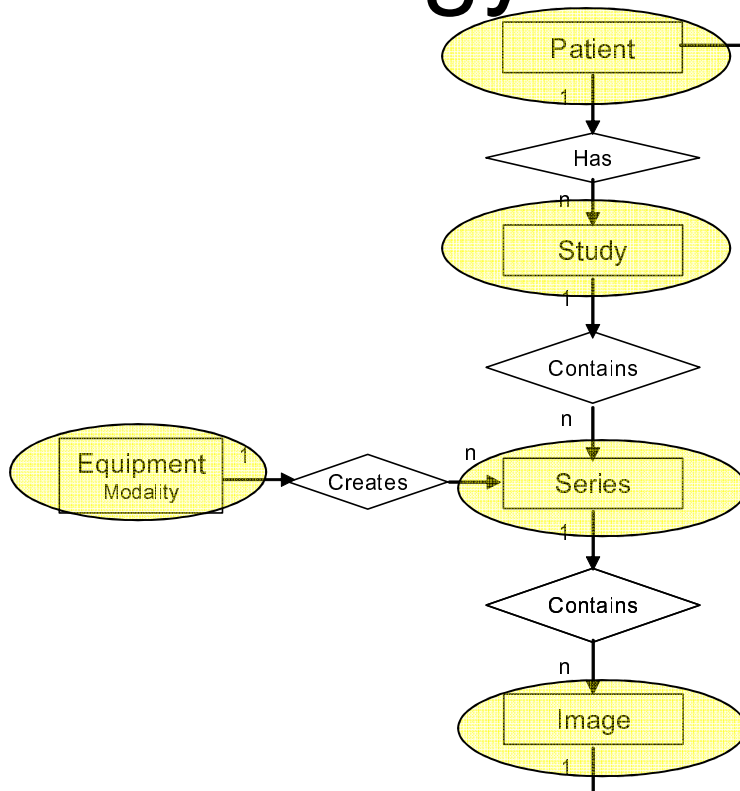
- IHE Pathology:

- [http://wiki.ihe.net/index.php?title=Anatomic Pathology](http://wiki.ihe.net/index.php?title=Anatomic_Pathology)

C.7.4.1 Frame Of Reference Module

- When a Frame of Reference is identified, it is not important how the [imaging target] 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 [imaging target] and the origin are constant in relationship to a specific Frame Of Reference
- 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. The Position Reference Indicator shall be used only for annotation purposes and is not intended to be used as a mathematical spatial reference.

Pathology Imaging in DICOM



Base Std

Supp 122

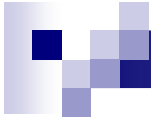
Sup 122 Specimen Identification

- Support for pathology lab workflow, specimen-based imaging
 - Gross specimens, blocks, vials, slides
 - Image-guided biopsy samples
- Specimen Module at image level of hierarchy
 - Identification, processing history
 - May be used with current Visible Light image object definitions
- Update to Modality Worklist to convey Specimen Module
 - Enables automated slide scanning devices to fully populate header
- Update to Modality Performed Procedure Step to identify imaged specimen
 - Allows LIS/APLIS to track images for specimens

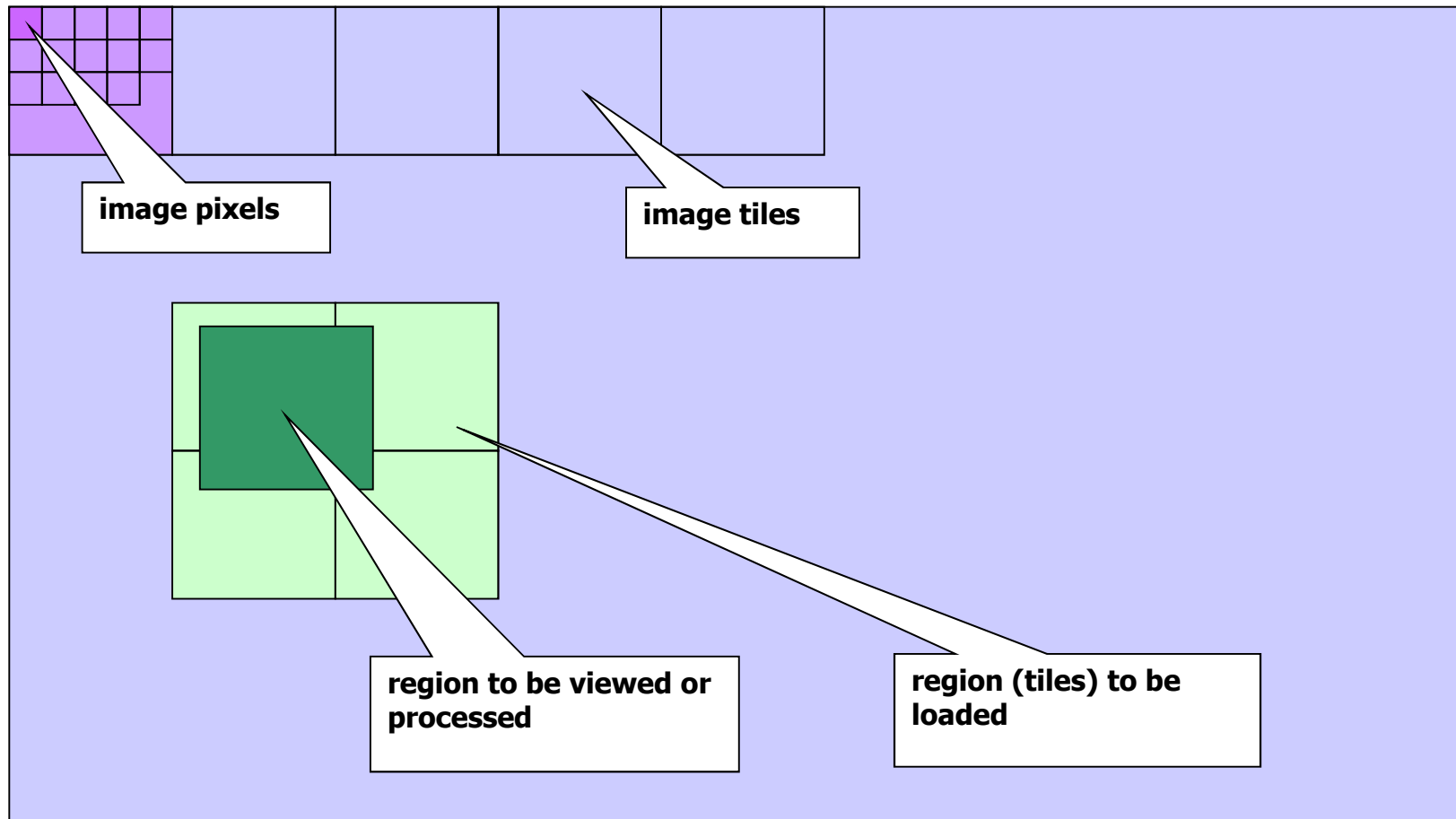


Implementation Issues

- Supp 122 has the needed data elements, BUT most AP LIS Systems don't have these data at the SPECIMEN level, if at all
 - Unique slide ID may not be explicitly present
 - No ability to identify subregions of a slide/block
 - Staining and fixation information often co-mingled
 - Specimen descriptions difficult to parse out from large text blocks
 - Dictionaries may be poorly implemented



WSI Image Tiling



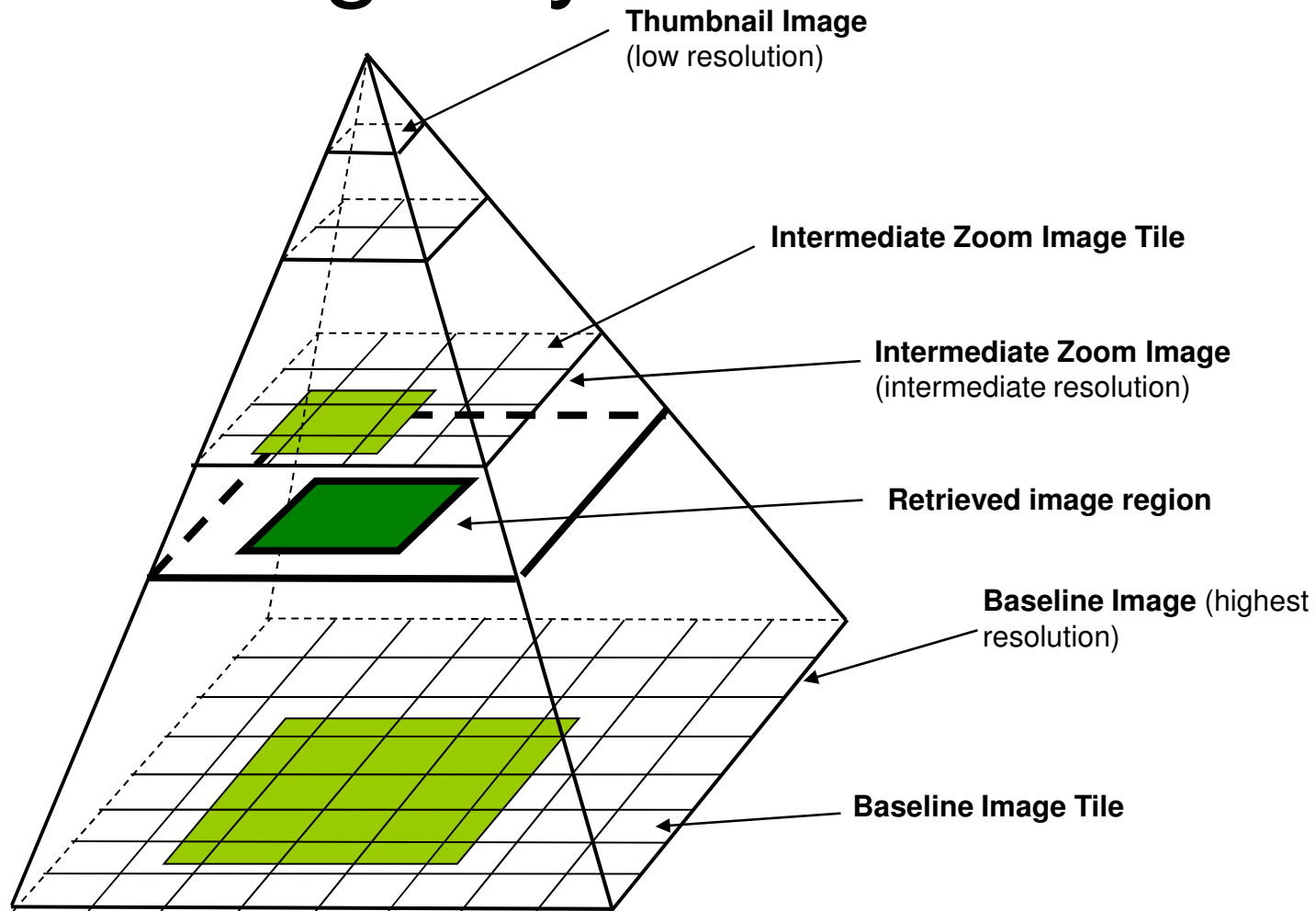


Why Standardize?

- Standardizing enables reliable interoperability
- Interoperability helps medical data flow smoothly – good for patients and labs
- Interoperability of equipment encourages innovation and competition among system providers



WSI Image Pyramid





To Tile or Not To Tile

Tiles

- Allow backwards compatibility with existing installed base of PACS
- Tiling currently used by most/all WSI scanner vendors

No Tiles

- Major change in DICOM architecture
- Change proposal to increase current pixel dimension limit defeated