APIII 2009

Lessons Learned in Radiology – How do they Translate to Digital Imaging Issues in Pathology?

DICOM for Pathology

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Overview

- Applicability of standards
- Whole Slide Imaging
- Other pathology images
- Workflow
- Information model
- Specimen identification
- Application hosting

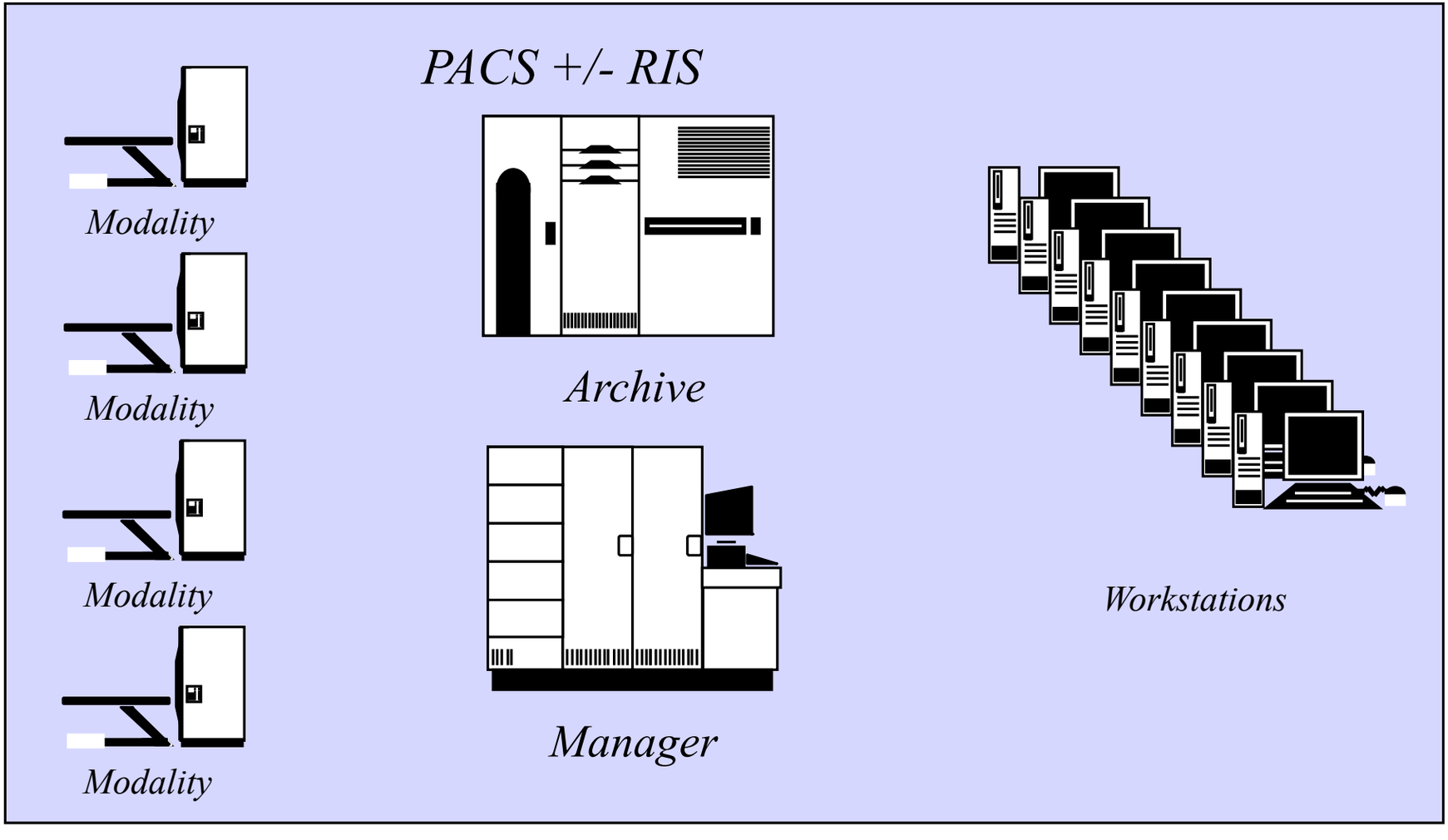
Why standards ?

- Interoperability
- Between
  - different vendors' devices
  - devices with different roles
  - devices & 3rd party software
  - devices & research software
  - devices & enterprise infrastructure
- Definition of interoperability ?

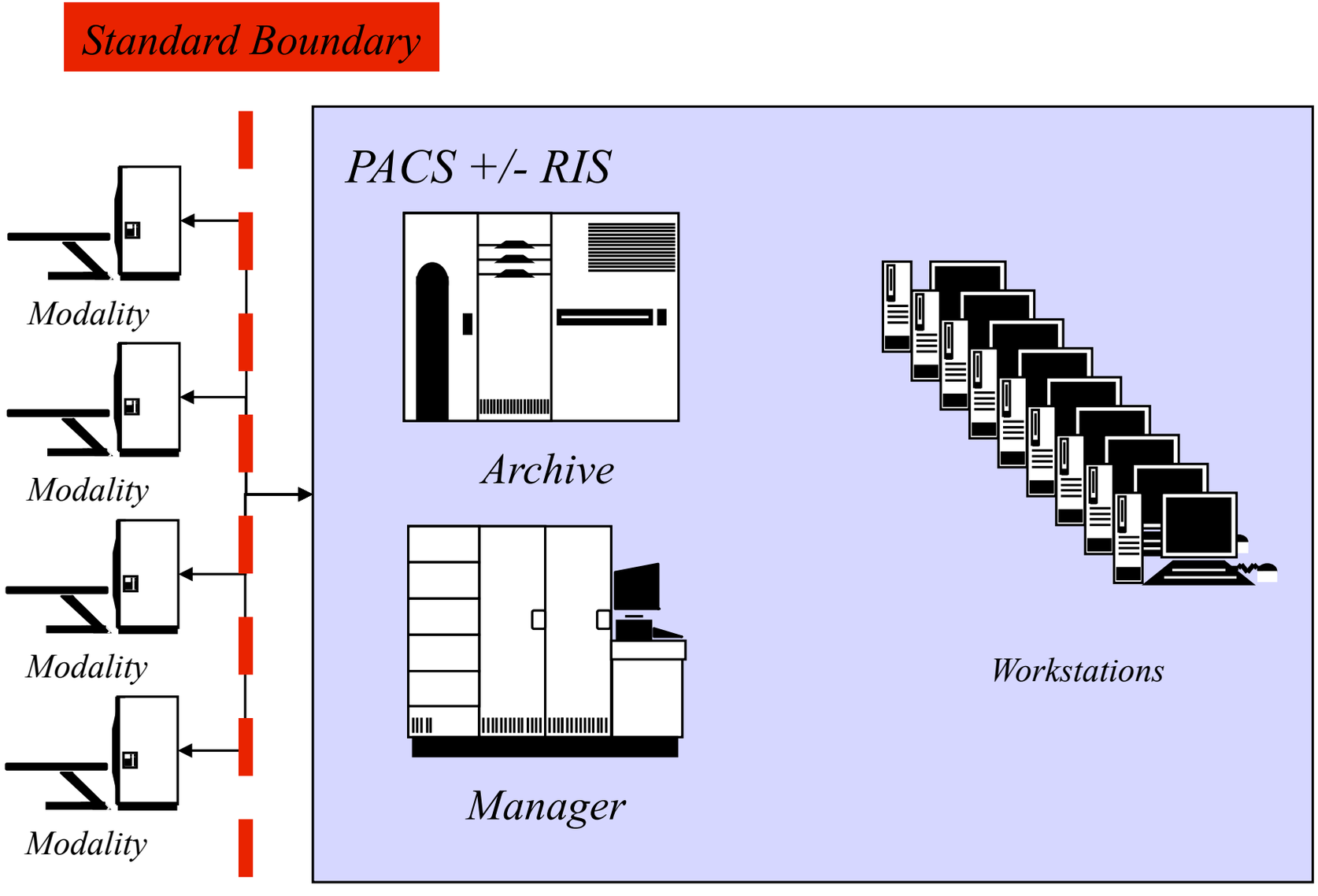
Standards for what ?

- Workflow
- Acquisition
- Transmission
- Analysis
- Display
- Annotation
- Reporting
- Archival

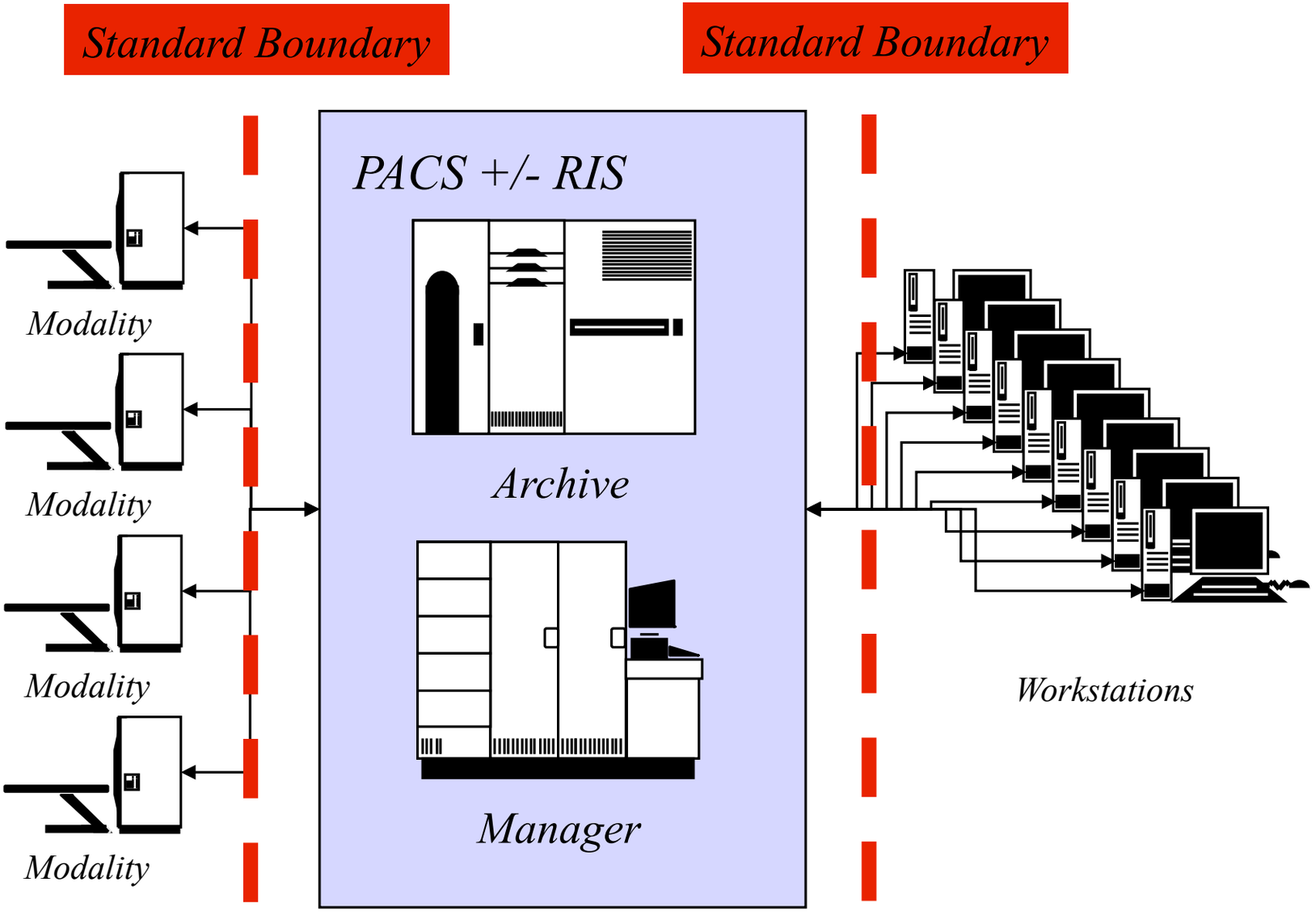
One vendor for everything



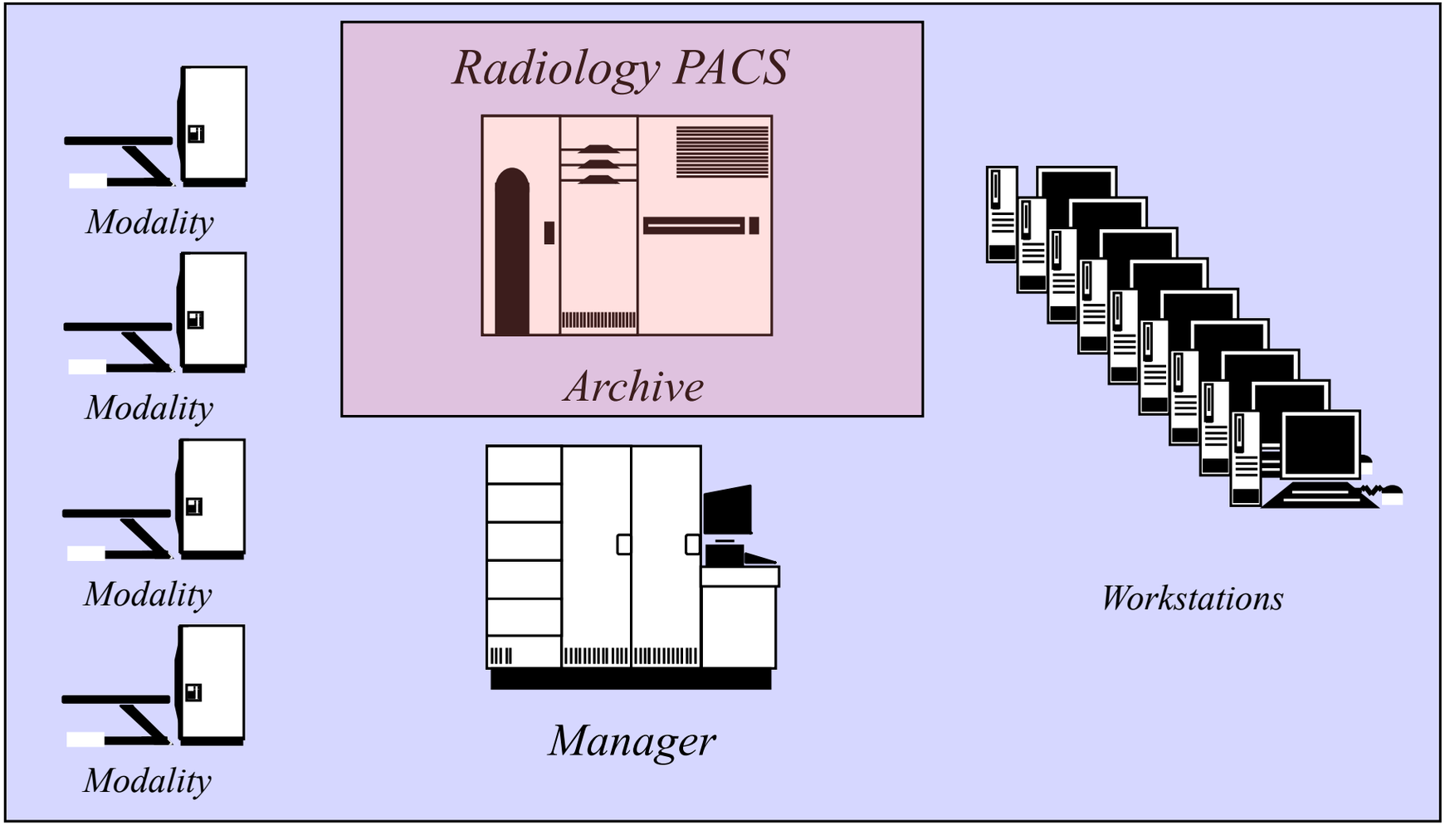
Factor out Acquisition



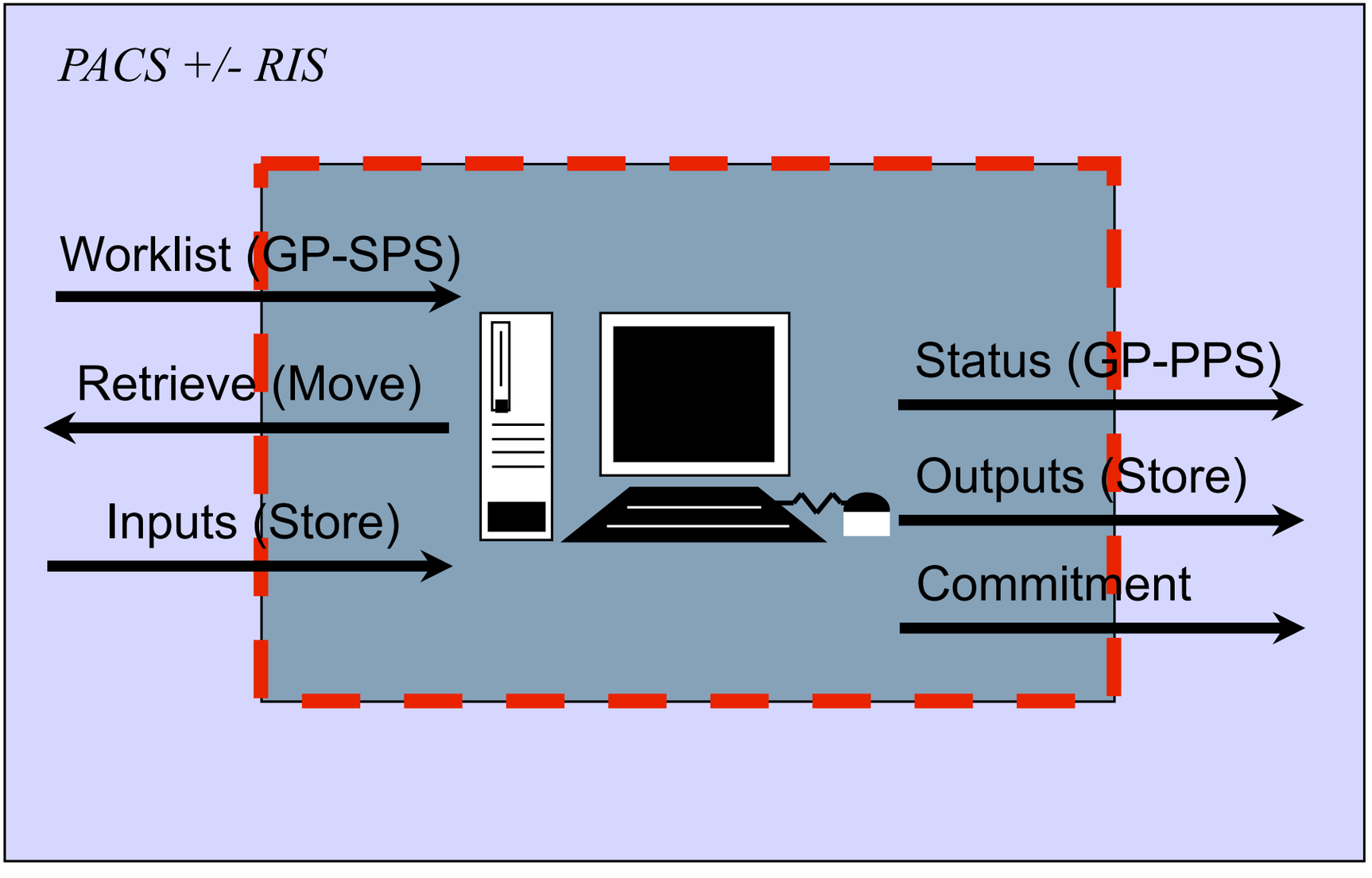
Factor our Display



One vendor for everything but re-use of PACS archive



Factor out any device



Which standard ?

- DICOM ubiquitous
  - radiology
  - cardiology
  - some visible light – endoscopy
- DICOM supports
  - image encoding
  - information model
  - services
  - workflow

But ?

- DICOM needs work to support WSI
  - specimen identification
  - large image encoding
  - large image access
  - coded vocabulary for processing
- DICOM originally designed for
  - store and forward
  - multiple modest size images
  - e.g., early (1999) Sup 15 VL SM, GM IODs

DICOM work related to WSI

- Sup 122 – Specimen Identification
- Sup 145 – Whole Slide Image
- Sup 61 – JPEG 2000
- Sup 106 – JPEG Interactive Protocol
- Sup 119 – Frame Level Retrieve

- DICOM WG 26 Pathology
- IHE Anatomical Pathology Domain

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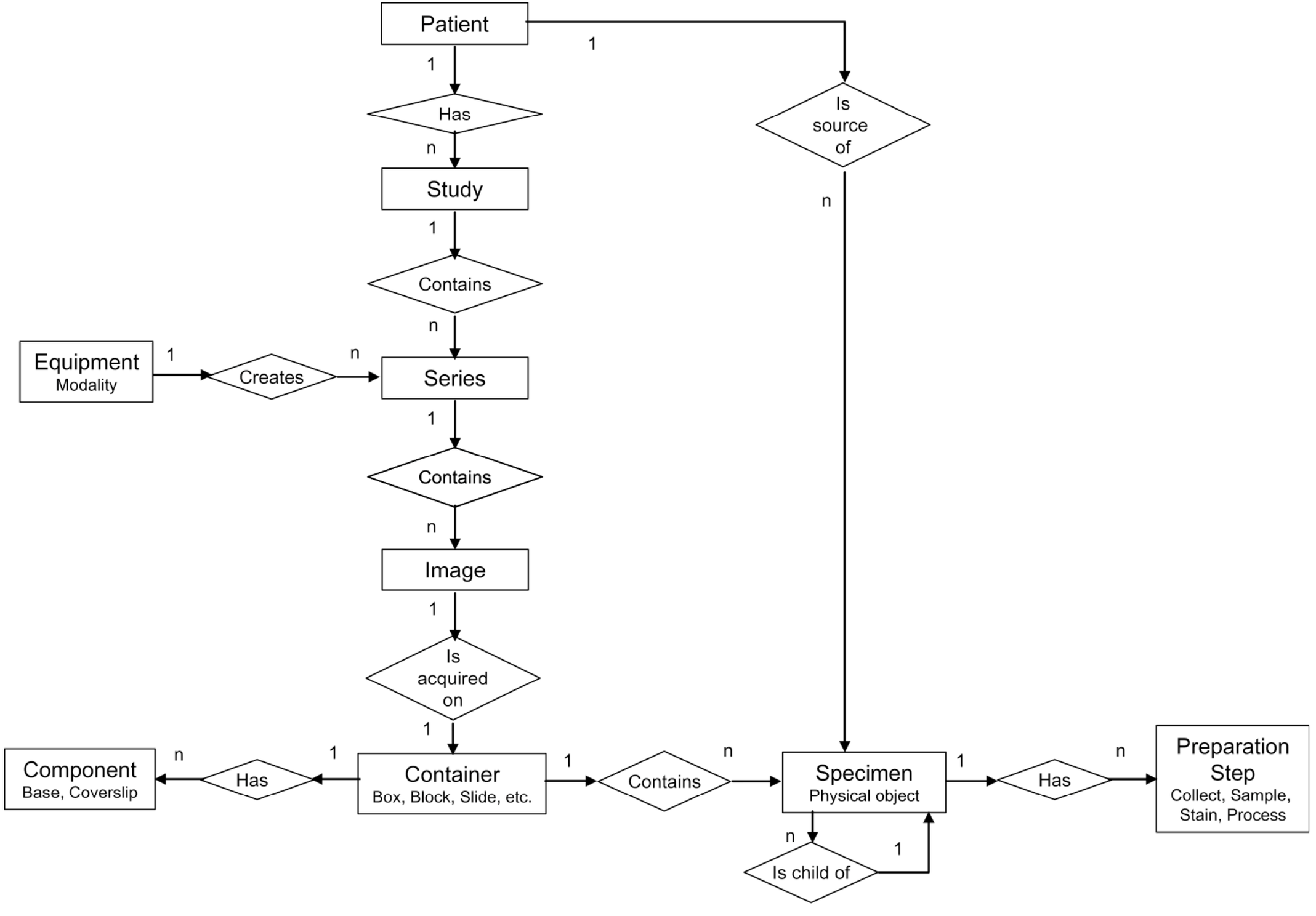
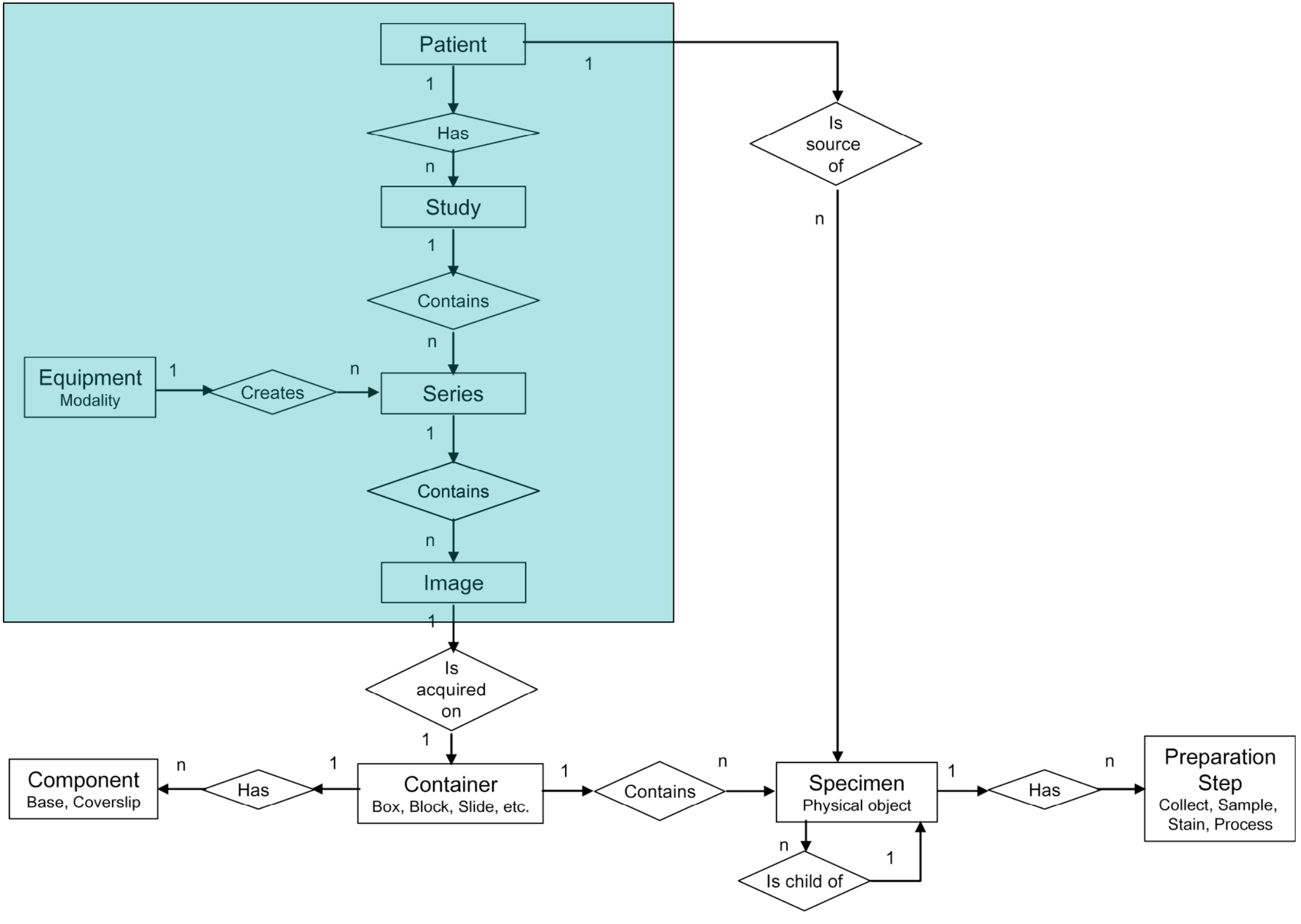
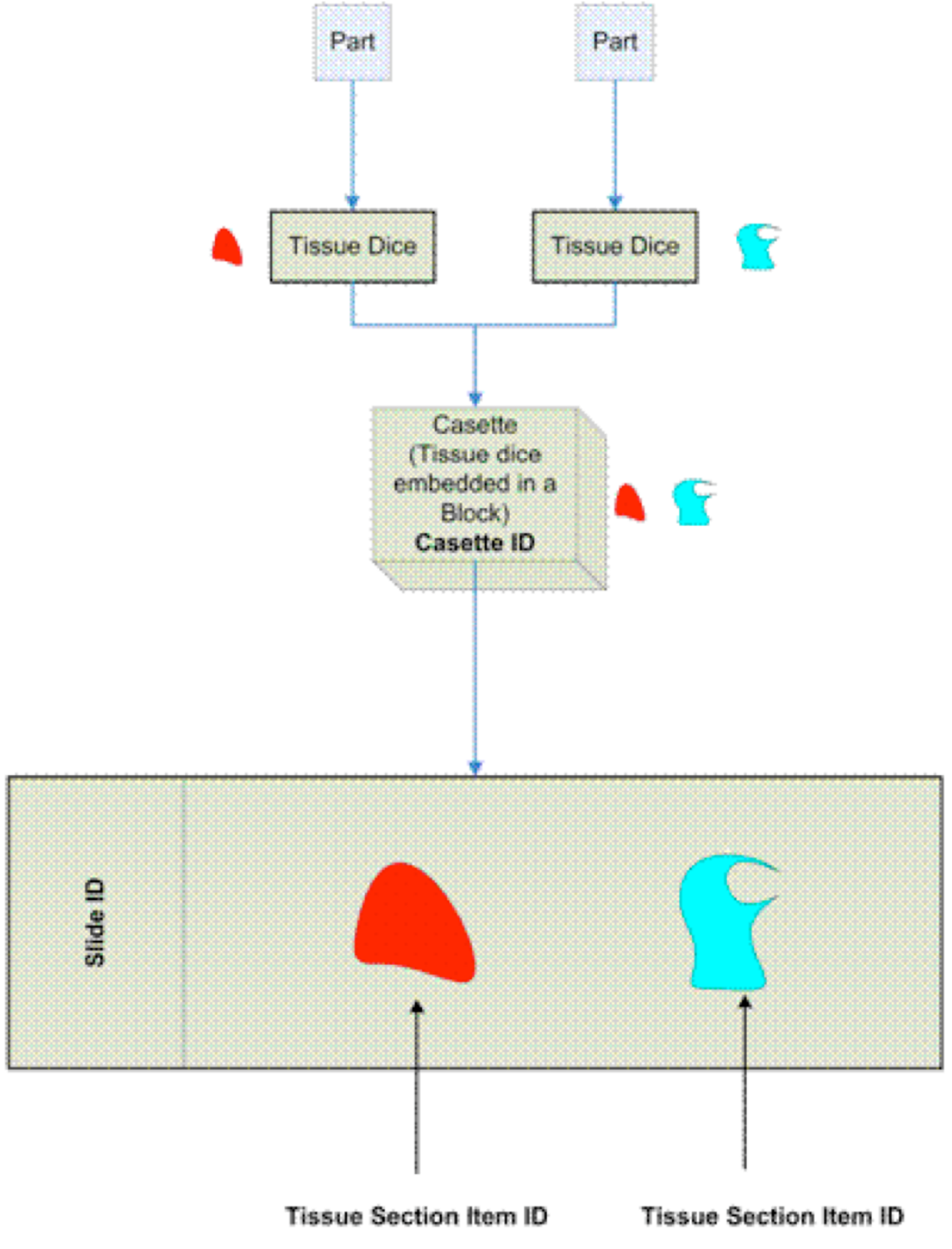
Specimen Identification

- Specimen identification
- Specimen description
- Processing description
  - multiple steps
  - staining
  - coded vocabulary
- Anatomic location (within patient)
- Location within container


Patient
1
1
Has
n
Study
1
Contains
n
Equipment
Modality
1
Creates
n
Series
1
Contains
n
Image
1
Is
acquired
on
1
Component
Base, Coverslip
n
Has
1
Container
Box, Block, Slide, etc.
1
Contains
n
Specimen
Physical object
1
Has
n
Preparation
Step
Collect, Sample,
Stain, Process
Is
source
of
n
n
Is child of
1


Patient
1
1
Has
n
Study
1
Contains
n
Equipment
Modality
1
Creates
n
Series
1
Contains
n
Image
1
Is
acquired
on
1
Component
Base, Coverslip
n
Has
1
Container
Box, Block, Slide, etc.
1
Contains
n
Specimen
Physical object
1
Has
n
Preparation
Step
Collect, Sample,
Stain, Process
Is
source
of
n
n
Is child of
1


Part
Part
Tissue Dice
Tissue Dice
Casette
(Tissue dice
embedded in a
Block)
Casette ID
Slide ID
Tissue Section Item ID
Tissue Section Item ID

Specimen Processing – Coded Terminology

Context ID 8112 Specimen Stains

Coding Scheme Designator	Code Value	Code Meaning
SRT	C-22860	acid fast stain
SRT	C-2280A	acid phosphatase stain
SRT	C-2280B	Albert's stain
…	…	…

DICOM work related to WSI

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DICOM WSI Image Encoding

- WSI images are large
  - rows & columns > 2^16
  - total size > 2^32 bytes
  - DICOM has field length limitations
- Access pattern
  - entire high resolution image or sub-regions
  - intermediate resolutions

DICOM WSI Image Encoding

- More than just multi-resolution
  - multiple focal planes
  - multiple sequential stains
  - multiple spectral channels
- Compression
  - lossless and/or lossy

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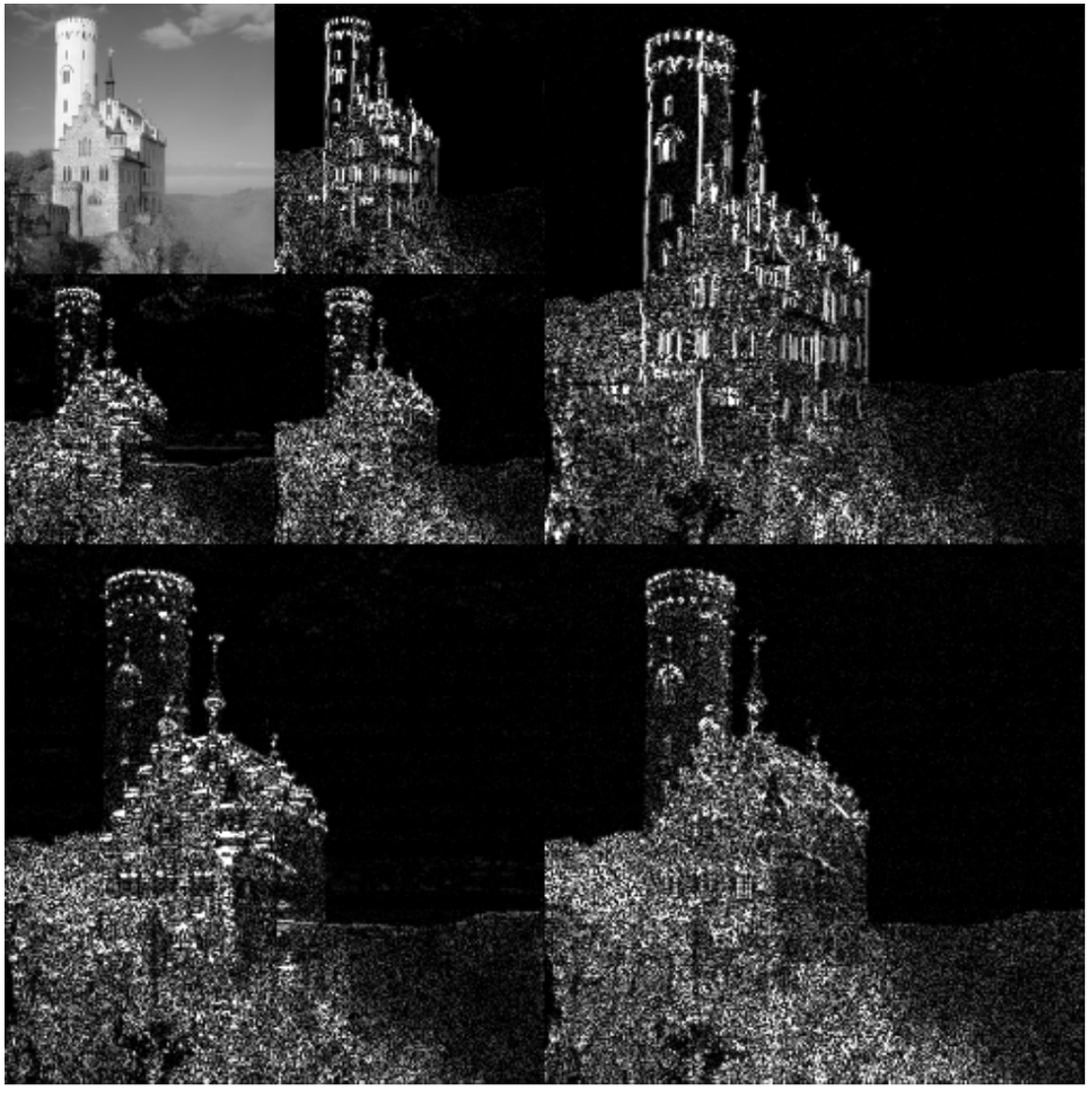
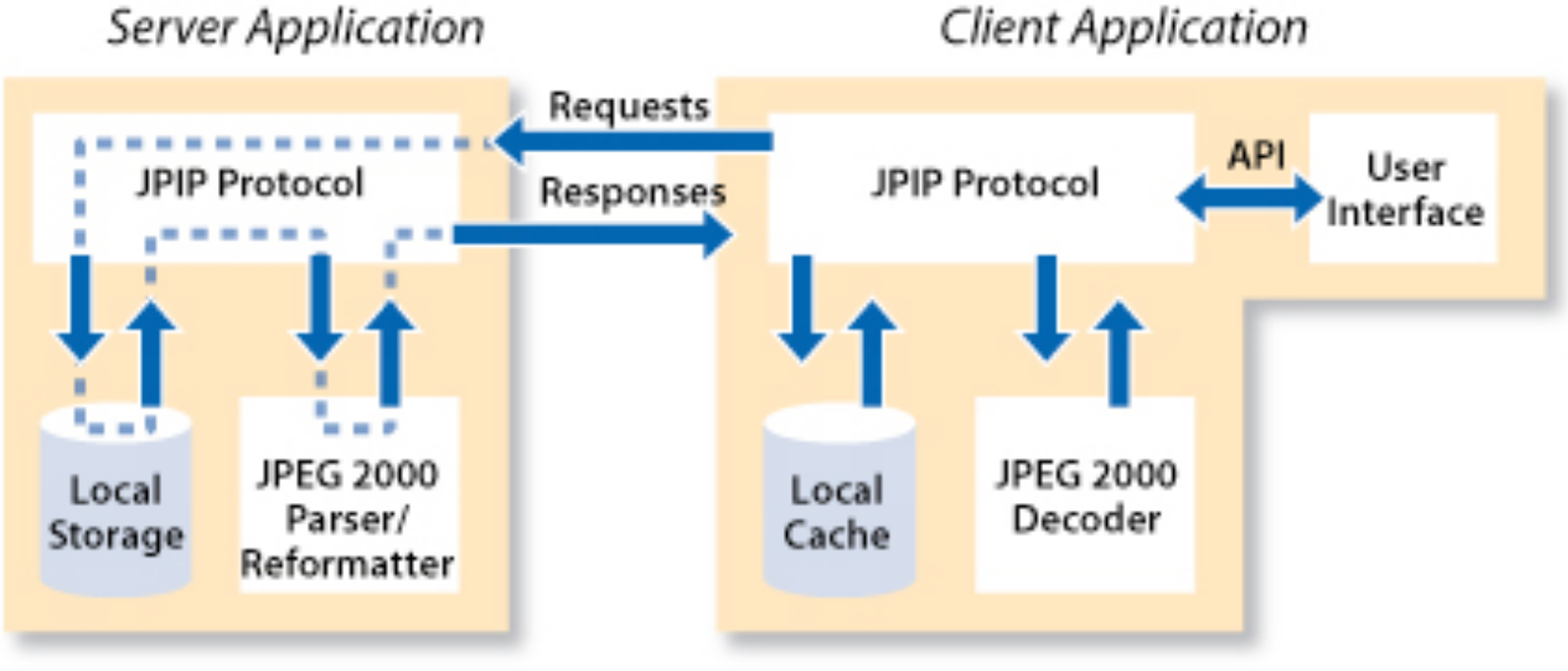
JPEG 2000 or not ?

- DICOM already has support for
  - JPEG 2000 compression
  - JPIP – interactive retrieval of regions
- JPEG 2000 is wavelet-based
  - multi-resolution analysis
  - easy access to specific area & resolution
- But …
  - still DICOM frame & size limits
  - allegedly slow to compress & organize

J2K Wavelet Transform & Multi-Resolution Analysis



JPEG Interactive Protocol



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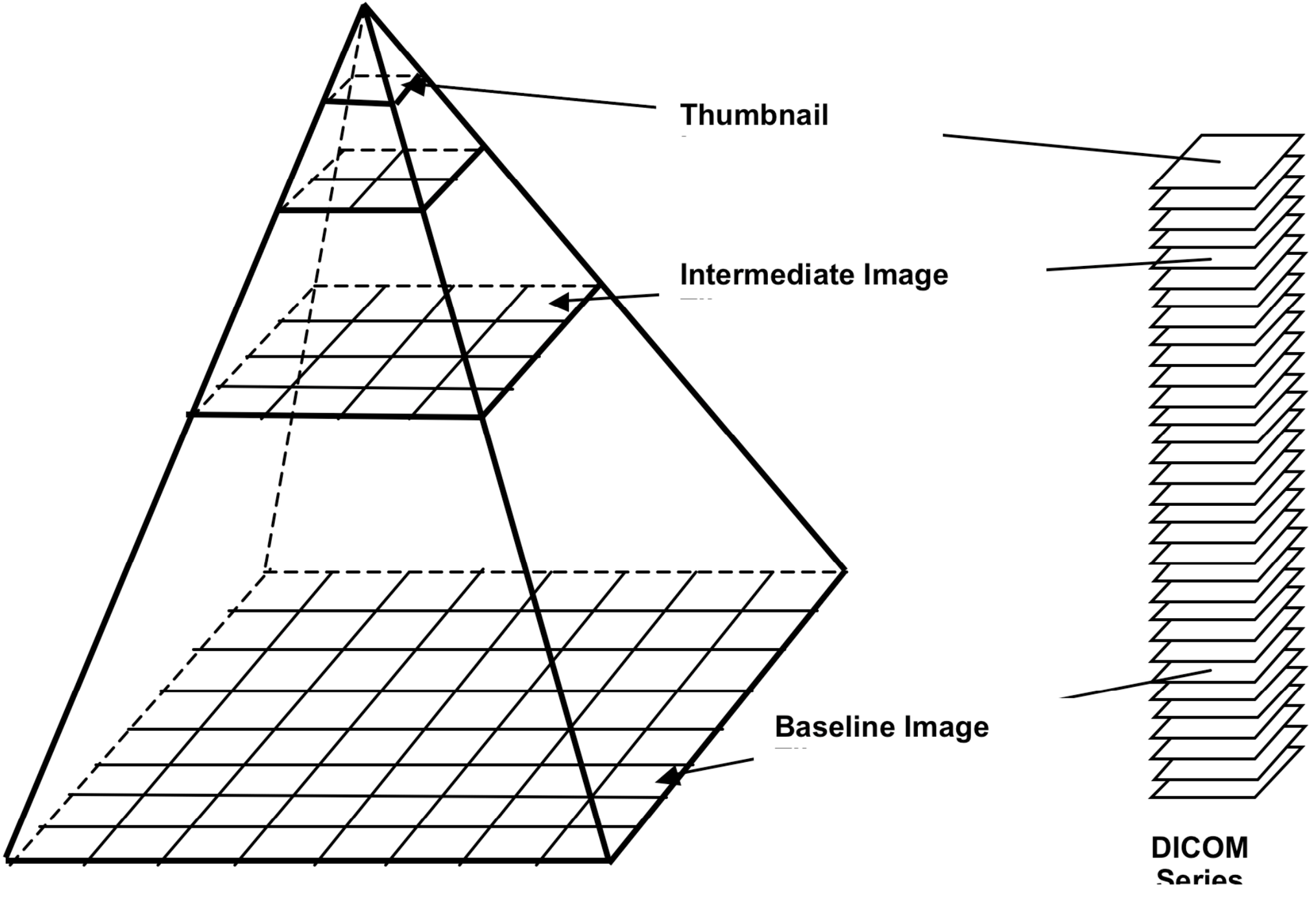
WG 26 – "Simpler" solution – Pyramidal, tiled, encoding

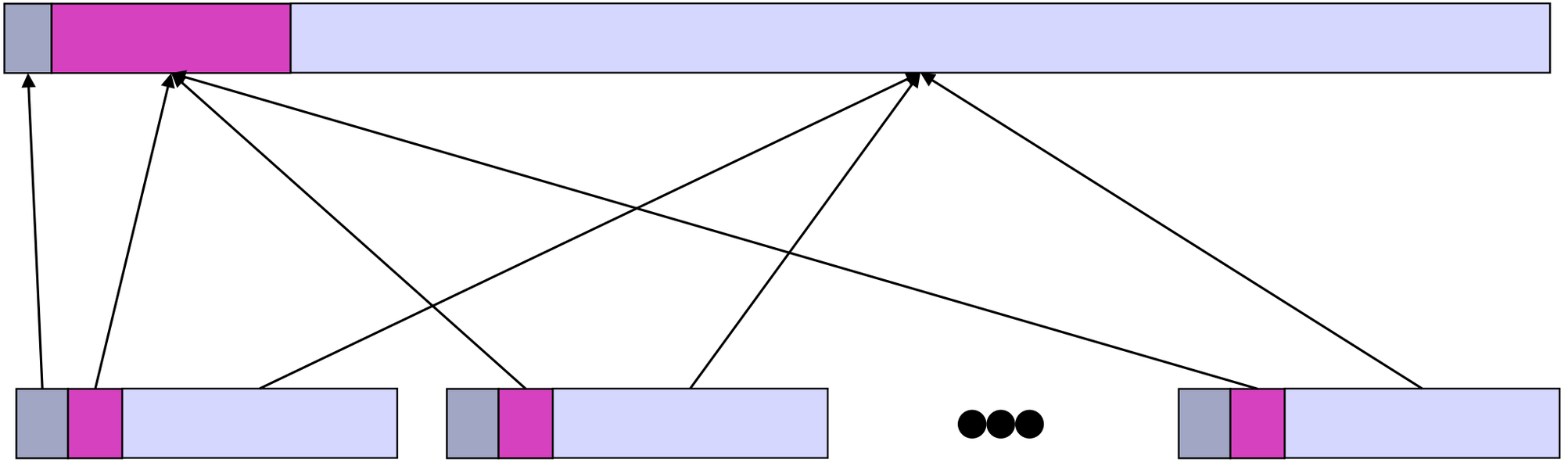
- Tiles encoded as frames
  - overcomes row/column size limit
- Multi-resolution
  - just encode entire layer for each resolution
- Multiple instances
  - overcomes single instance size limit
- Independent of compression choice
  - uncompressed, JPEG, JPEG 2000

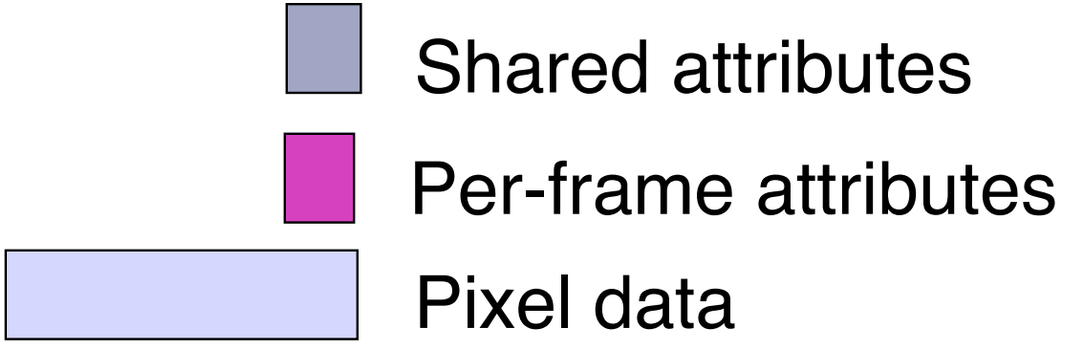

Thumbnail
Intermediate Image
Baseline Image
DICOM
Series

Yet to be determined ...

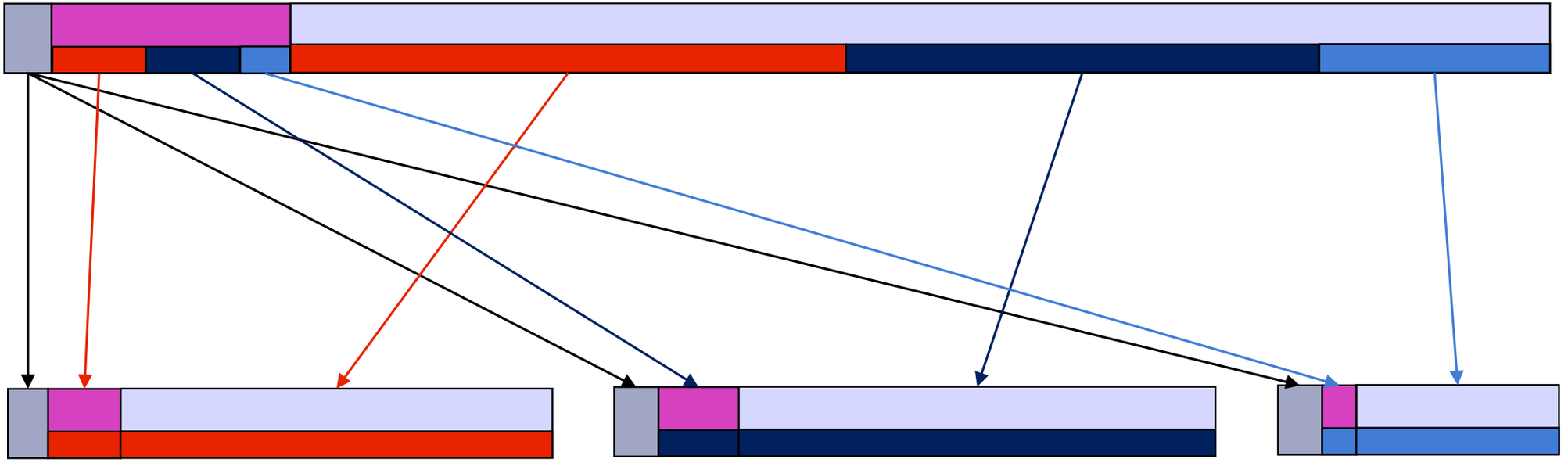
- Specifics of tiled encoding
  - frames, layers versus instances (file) ?
  - currently, one tiled instance per resolution
- Relationship to “enhanced” IODs
  - use of concatenations ?
  - use of dimensions ?
- Other stuff
  - image of slide label
  - “localizers” (e.g., like CT scout)

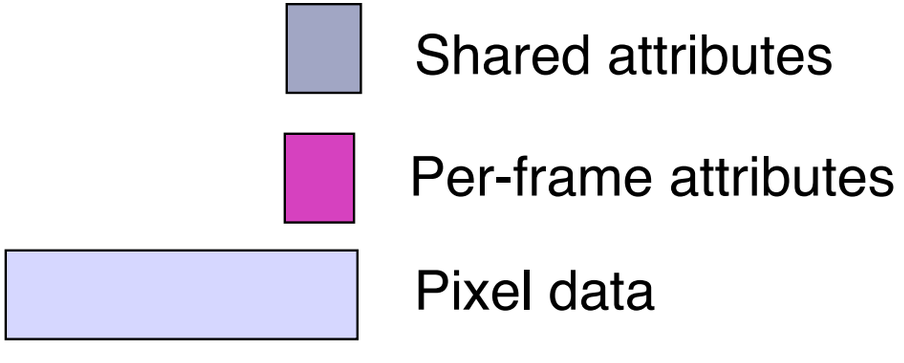
Multi-frame Functional Groups

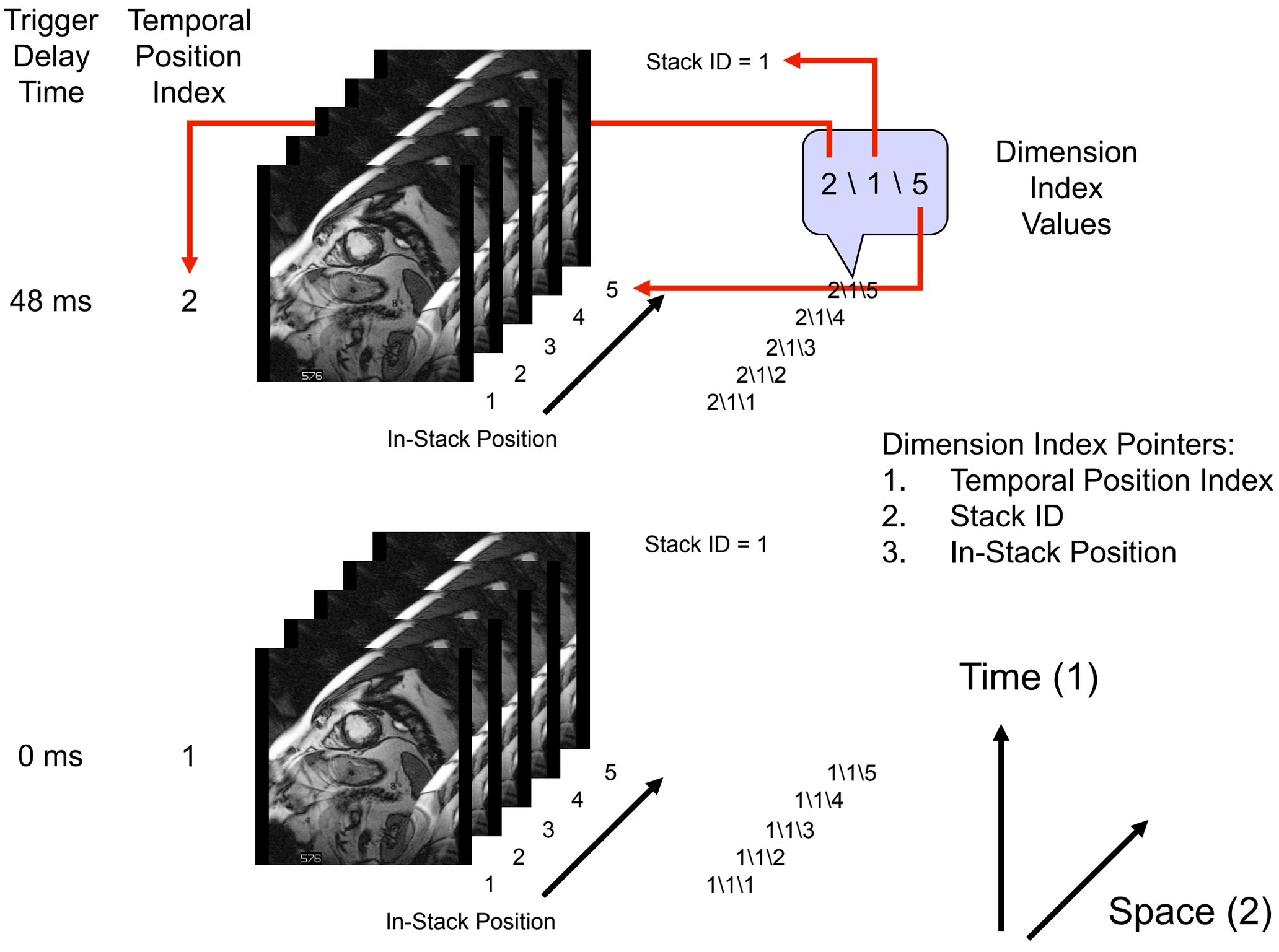


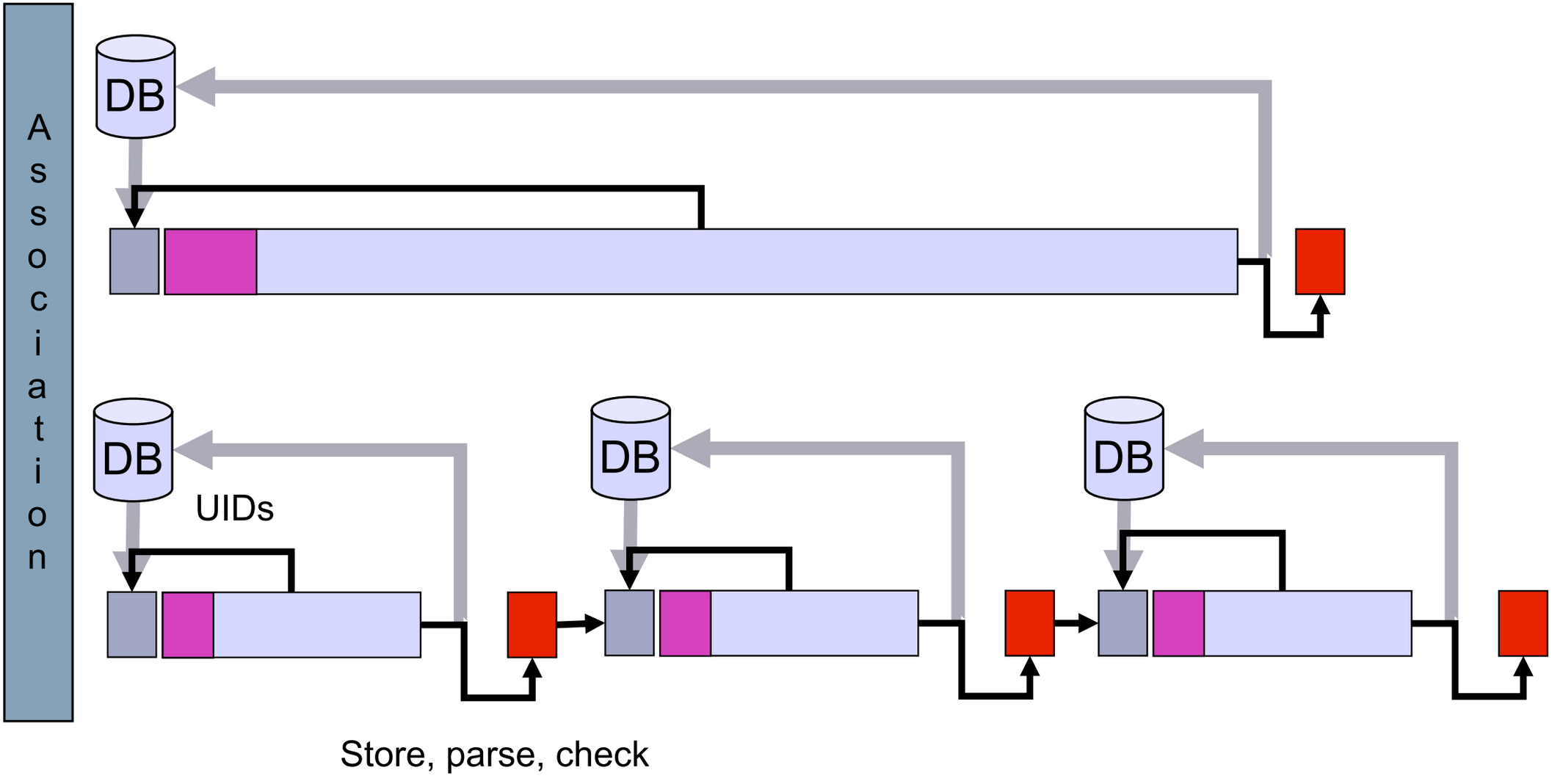


Concatenations






Trigger Delay Time
Temporal Position Index
Stack ID = 1
2 \ 1 \ 5
Dimension Index Values
48 ms
2
5
4
3
2
1
2\1\5
2\1\4
2\1\3
2\1\2
2\1\1
In-Stack Position
Dimension Index Pointers:
1. Temporal Position Index
2. Stack ID
3. In-Stack Position
Stack ID = 1
0 ms
1
5
4
3
2
1
1\1\5
1\1\4
1\1\3
1\1\2
1\1\1
In-Stack Position
Time (1)
Space (2)



C-Store request

Dataset (attributes+pixels)

C-Store response (acknowledge)

BigTIFF

- TIFF has been used by some vendors
- Also has size limits -> BigTIFF
- TIFF pyramids, tiles, strips
  - basis for WG 26 proposed encoding
  - DICOM does not “encapsulate” TIFF
  - could be converted easily
- Aperio open source libtiff extensions
  - http://www.aperio.com/bigtiff/

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DICOM WSI Retrieval

- Need an “overview” of what is encoded ?
- Retrieving one tile per instance
- Retrieving selected frames
- Sup 119
  - retrieve header without pixel data
  - retrieve selected frame (range)
- Web Access to DICOM Objects (WADO)
  - also has frame level retrieval mechanism

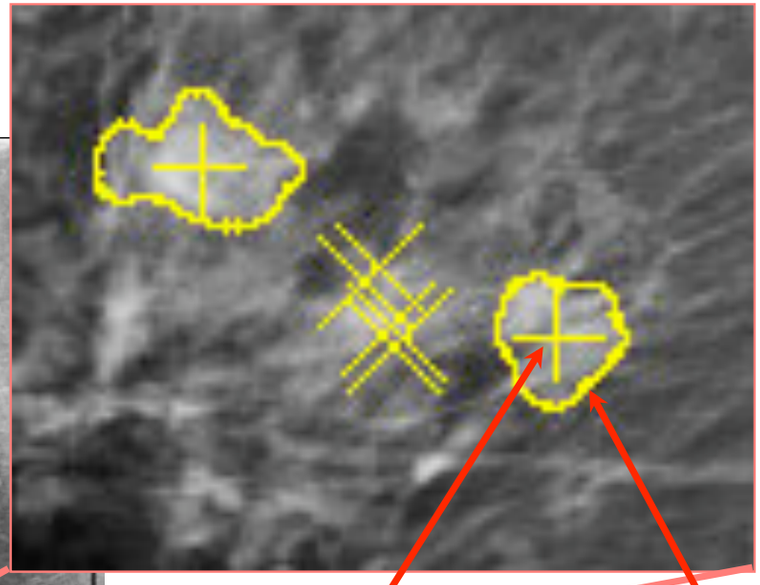
WSI - What is the use-case ?

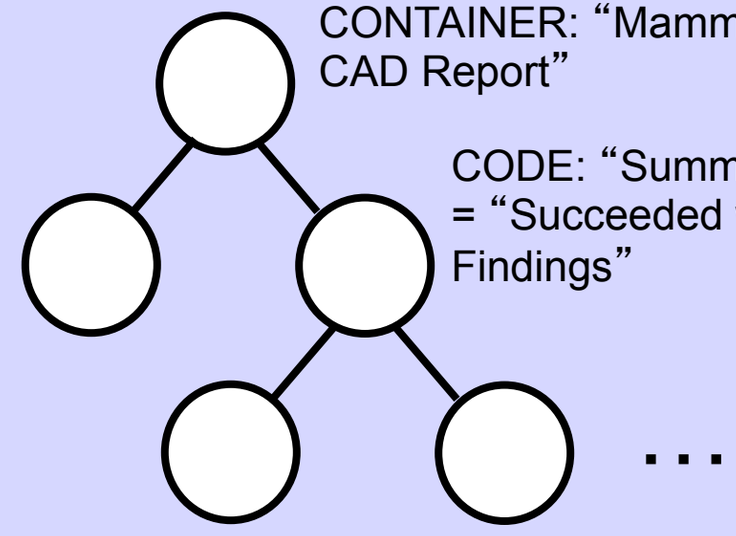
- Persistence (archival) ?
  - DICOM tiled method will work
  - total size is still daunting
- Store-and-forward ?
  - DICOM well suited for this
- Interactive (client-server) access ?
  - really any need for a standard ? e.g., zoomify
  - coexistence of DICOM WG 26 tiles & J2K ?

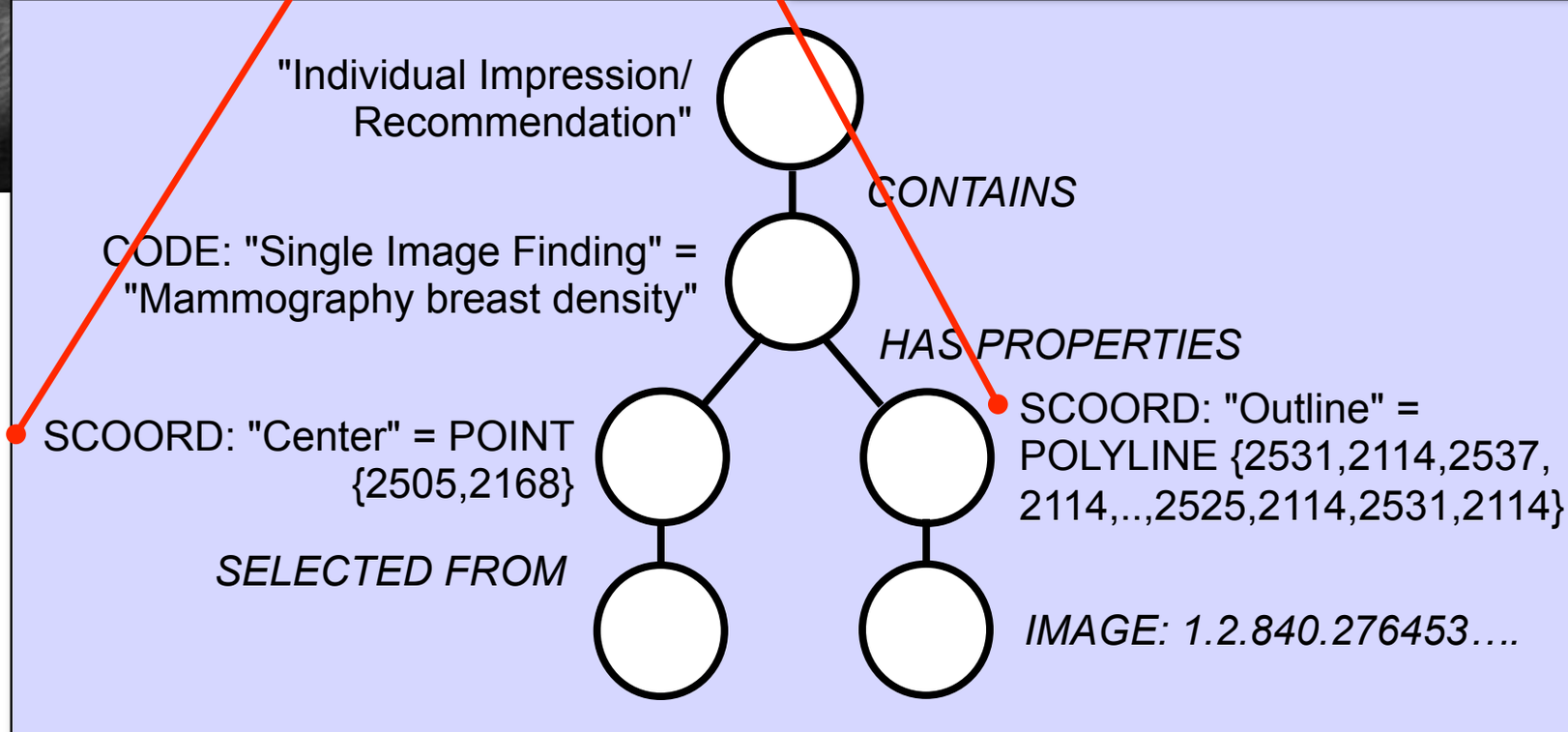
Annotation

- DICOM Structured Reporting (SR)
  - coded terminology & *quantitative* results
  - reference to images and image coordinates
- Widely used by radiology modalities
  - uses same DICOM “header” as images
  - easily stored in PACS
- Toolkits to convert to XML
- More robust than JPEG 2000 ROI


Patient [013001] IHEMammoTest^Four view with CAD
Study# 013001 Acc# Series# Image#
Acquired 20051224 173600
F DOB 19010101 Age 106Y
RMLO
P
1:0.148
[0.472mm]




CONTAINER: “Mammo CAD Report”
CODE: “Summary” = “Succeeded with Findings”
. . .
CONTAINER: "Individual Impression/ Recommendation"


"Individual Impression/ Recommendation"
CONTAINS
CODE: "Single Image Finding" = "Mammography breast density"
HAS PROPERTIES
SCOORD: "Center" = POINT {2505,2168}
SCOORD: "Outline" = POLYLINE {2531,2114,2537, 2114,..,2525,2114,2531,2114}
SELECTED FROM
IMAGE: 1.2.840.276453….

Presentation

- Grayscale & Color Presentation States
  - contrast adjustments
  - zoom/pan (displayed area selection)
  - graphics annotation (without semantics)
- Reference from Structured Reports
  - state to apply for any particular feature
- Additional WSI requirements ?
  - location/resolution/focal depth references
  - color contrast adjustment ?

Other DICOM Objects

- Registration
  - rigid (affine transform)
  - non-rigid (deformation field)
- Segmentation
  - rasterized (binary, fractional, probability)
  - object-based (surface mesh)
- Support 2D (XR) and 3D (CT,MR,PET)
- Waveforms and spectra

Other Microscopy Images

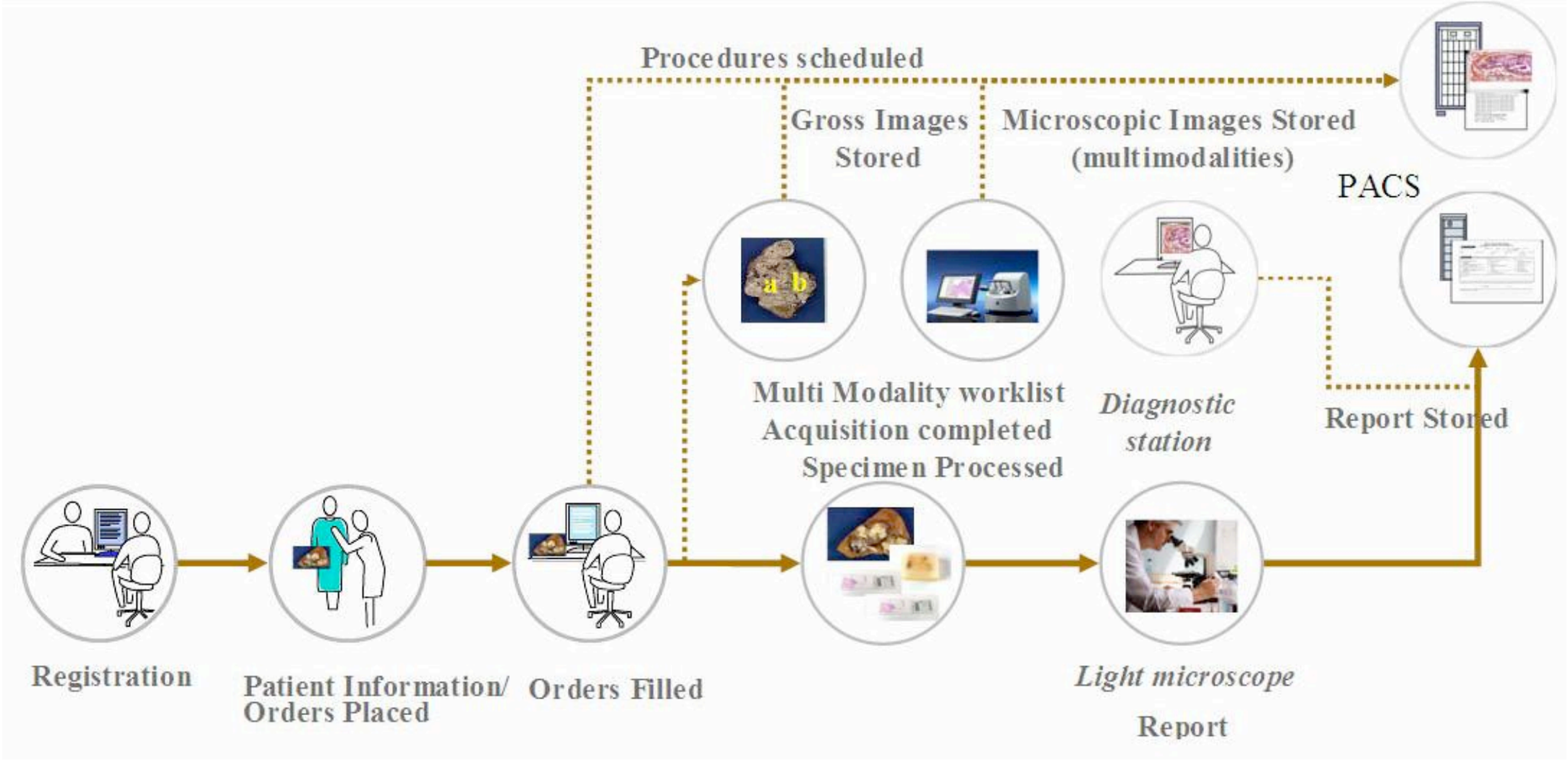
- Microscope-attached devices
  - existing VL SM and GM objects
  - improved identification with Sup 122
  - no reason to wait for WSI standard
  - separate acquisition from analysis & storage
- Electron microscopy
  - surprisingly, no specific interest in DICOM
  - one of the existing objects would be suitable
  - coded terminology required

Workflow

- IHE
  - demographics (patient identity)
  - ordering & scheduling
  - reporting
- Within lab – not yet standardized
  - receipt
  - gross
  - processing

Workflow – Radiology experience

- Modality worklist very successful
  - procedures (steps) are ordered/scheduled
  - “modality” queries information system
  - receives demographics & order
  - performs work
  - reports “performed procedure steps”
- Post-processing & interpretation
  - services defined, but less widely adopted


Procedures scheduled
Gross Images Stored
Microscopic Images Stored (multimodalities)
PACS
a b
Multi Modality worklist
Acquisition completed
Specimen Processed
Diagnostic station
Report Stored
Registration
Patient Information/ Orders Placed
Orders Filled
Light microscope
Report

DICOM Services

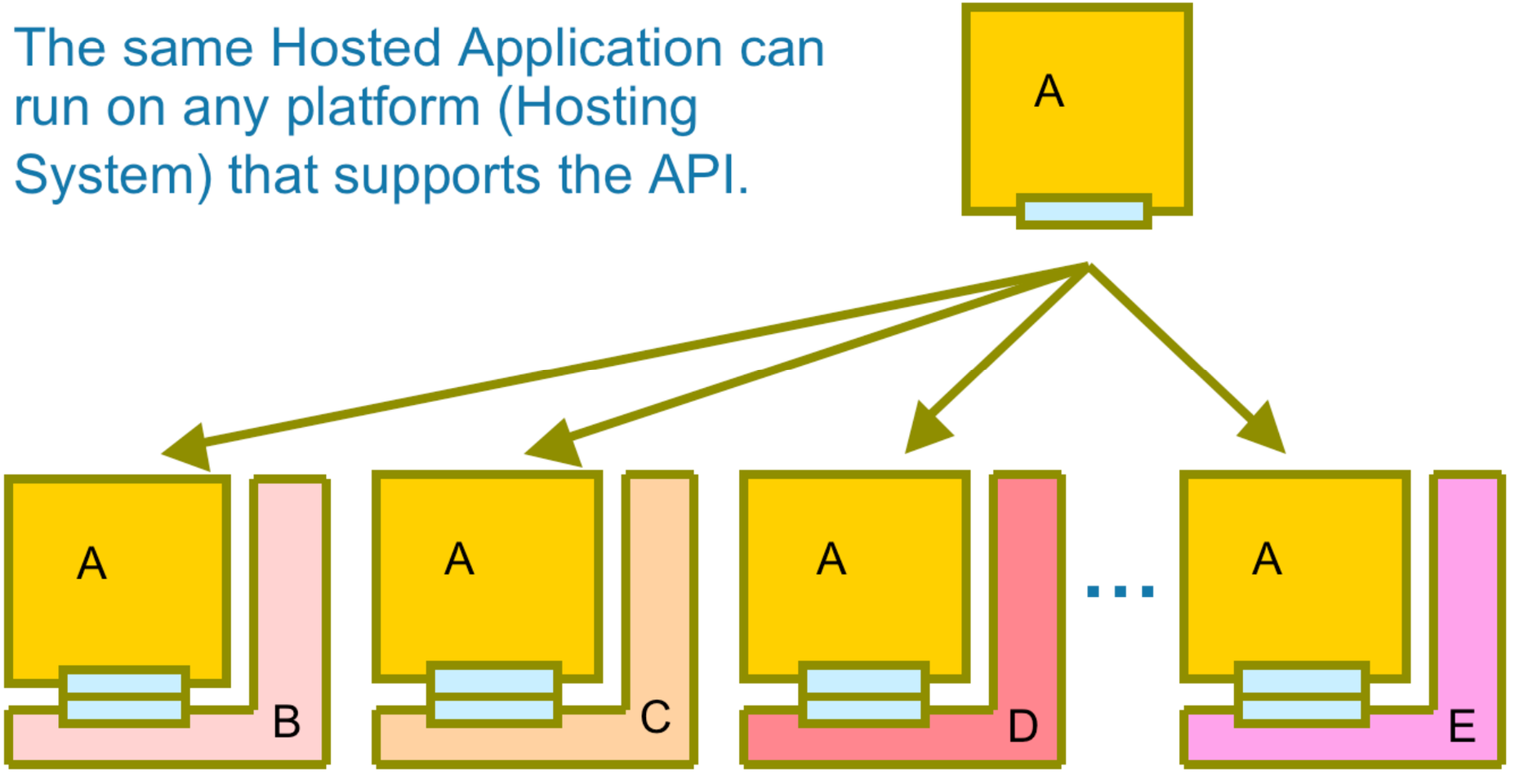
- Storage and transfer of images
- Information model to identify specimens
- Workflow for image acquisition
- Workflow for other steps

- What about display and analysis ?

WG 23 Application Hosting

- Not a format or protocol, but an API
- Access to host provided data
  - binary file
  - native data model
  - abstract data model
- Bidirectional – input & output
- Not specifically designed to support WSI
- Need API for selected regions of WSI

The same Hosted Application can run on any platform (Hosting System) that supports the API.



Conclusion

- Specimen identification done
- Active work to define WSI encoding
- Re-use of existing DICOM mechanisms
- Deal with large frame sizes by tiling
- Access to multiple resolutions
- Re-use SR annotation mechanism
- Interactive access remains uncertain
- Workflow remains to be defined

Further information

- DICOM WG 26 minutes & email
  - http://medical.nema.org/DICOM/minutes/WG-26/
  - http://lists.nema.org/scripts/lyris.pl?enter=wg26