DICOM
Digital Imaging and Communications in Medicine

DICOM Educational Conference
Brisbane, Australia

SEPTEMBER 24-25, 2018

DICOM DIGITAL PATHOLOGY
WHOLE SLIDE IMAGING

DAVID A. CLUNIE

PIXELMED PUBLISHING, LLC

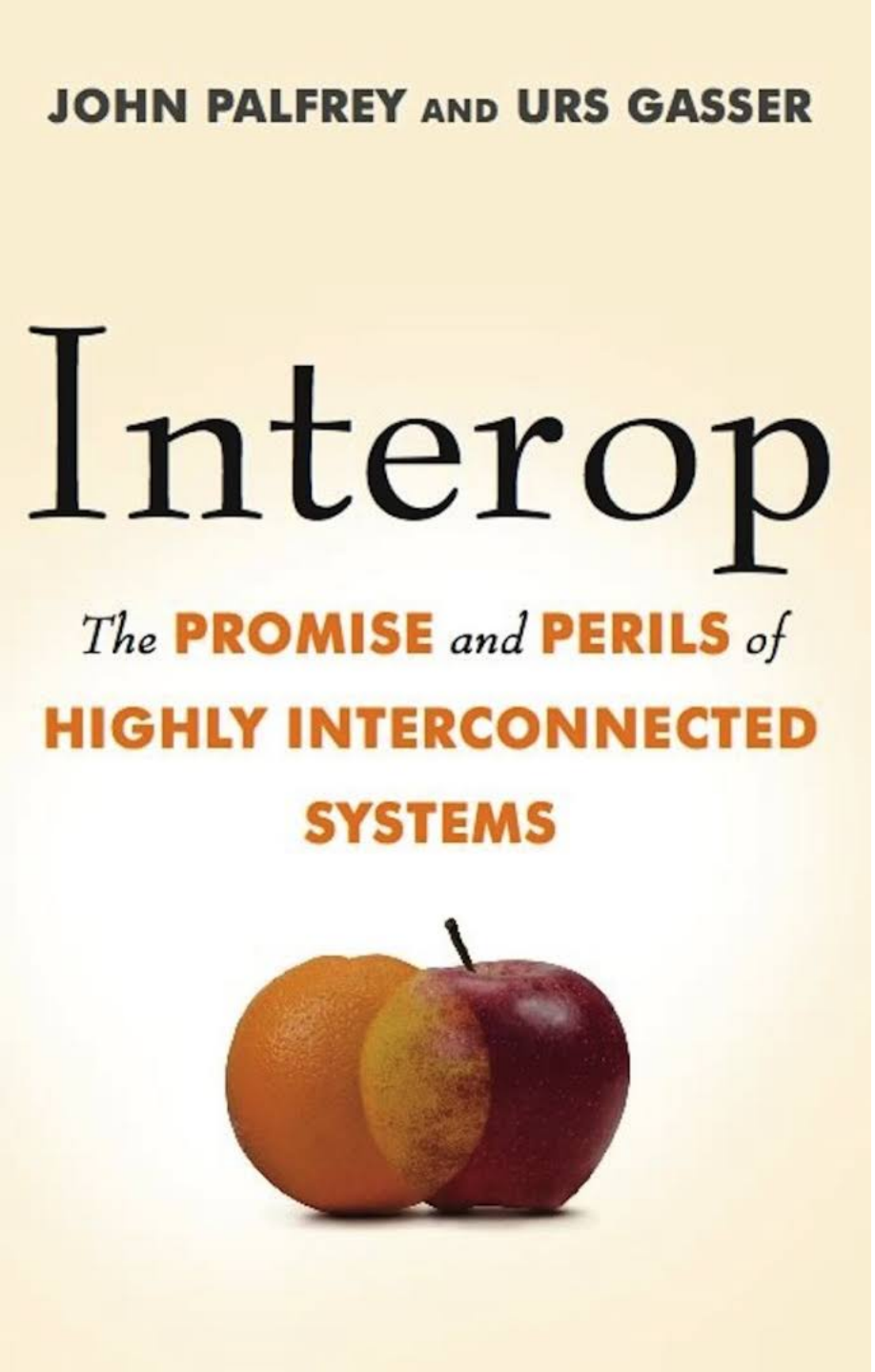
Disclosures

- Editor of the DICOM Standard (NEMA Contract)
- Owner of PixelMed Publishing, LLC
- Consulting for GE, Carestream, MDDX (Bioclinica), Curemetrix, HCTS, Hologic
- Supported by NIH U24CA180918 QIICR, NCI Leidos BOA 29XS219 Task Order #05

Interoperability

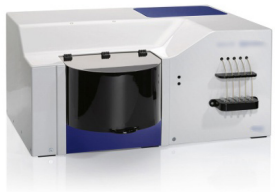
*"the ability of two or more systems or components to **exchange** information and to **use** the information that has been exchanged"*

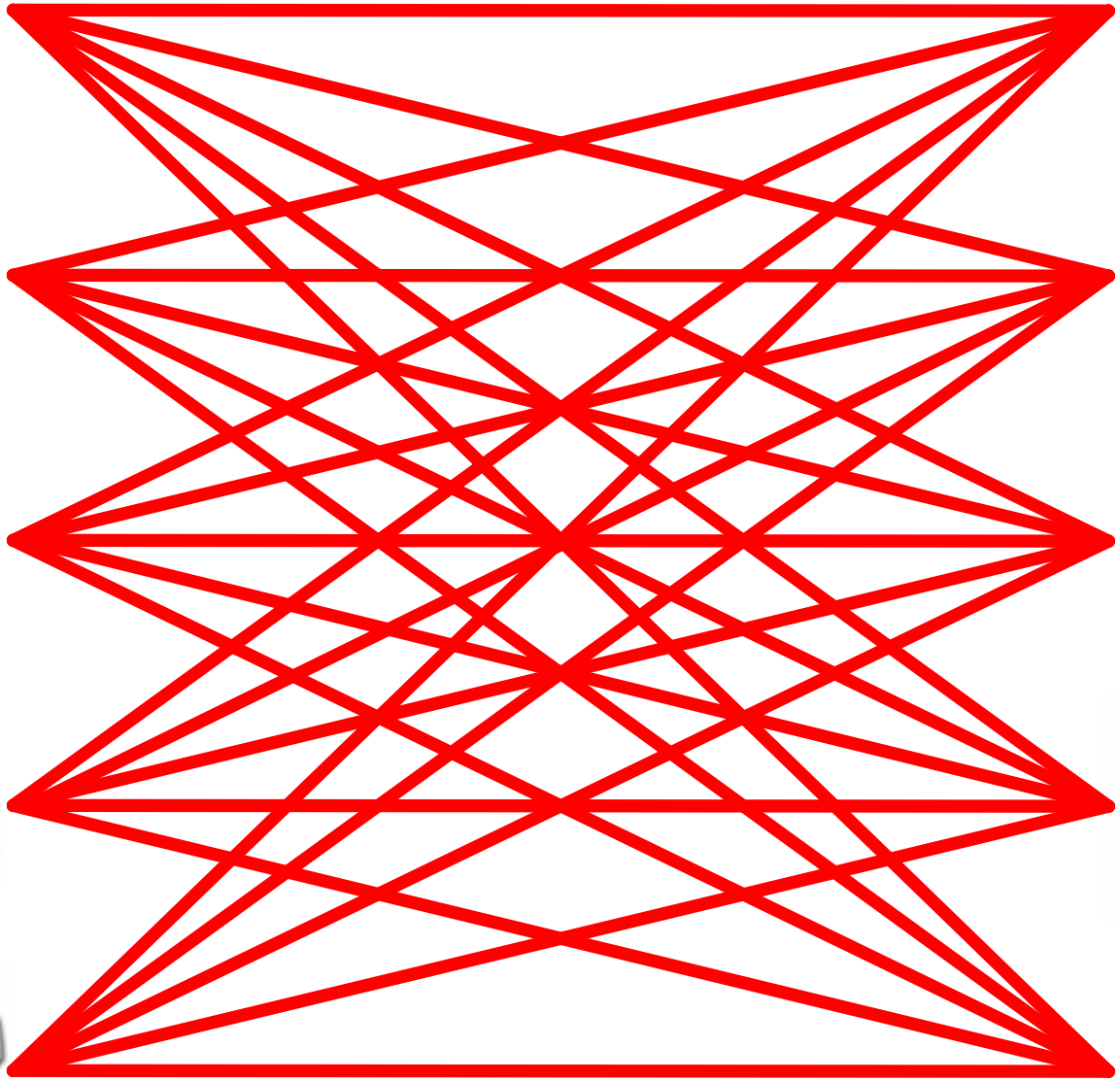
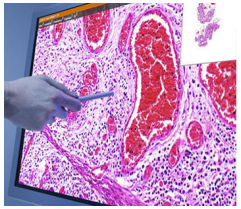
IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. 1990



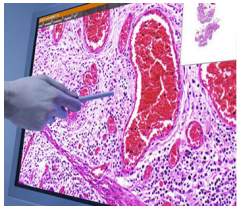
- *layers: technology, data, human, institutional*
- *consumer empowerment*
- *privacy, security*
- *competition, homogeneity, innovation*
- *efficiencies, complexity*
- *by design*
- *over time*
- *architectures*

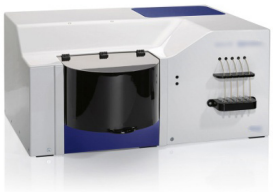










Photoelectronic radiology department

M. Paul Capp, Sol Nudelman, Donald Fisher, Theron W. Ovitt, Gerald D. Pond,
Meryl M. Frost, Hans Roehrig, Joachim Seeger, Donald Oimette
Department of Radiology, University of Arizona Health Sciences Center, Tucson, Arizona 85724

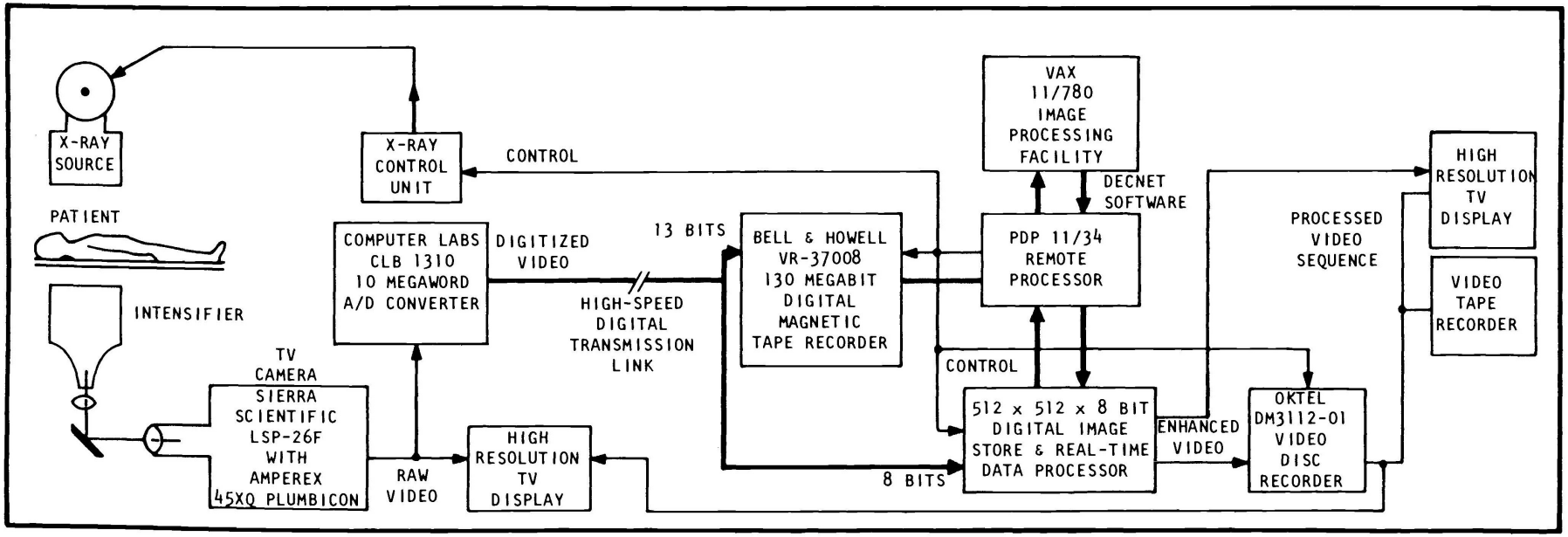
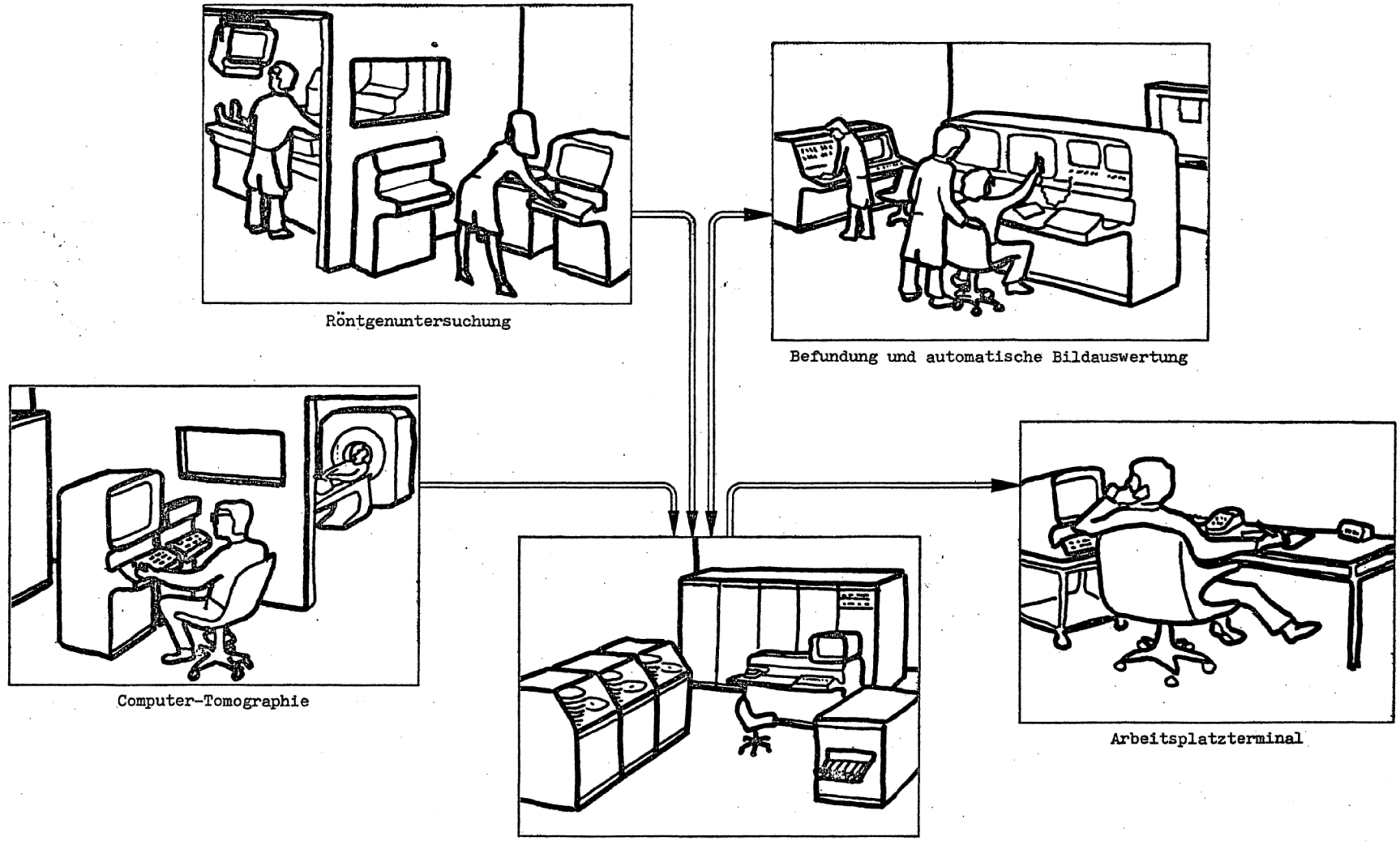


Figure 1. System block diagram of demonstration facility.

1981



1973

Meyer-Ebrecht D. [Electronic Archival System for X-Rays Images - Work proposal for a research project in the years 1974 and 1975] Elektronisches Archivierungssystem für Röntgenbilder – Arbeitsvorschlag für ein Forschungsprojekt in den Jahren 1974 und 1975. Hamburg, Germany: Philips Research Labs; 1973 Oct.

PROCEEDINGS

Of SPIE-The International Society for Optical Engineering

Volume 318

1st International Conference and Workshop on

PICTURE ARCHIVING AND COMMUNICATION SYSTEMS (PACS)

FOR MEDICAL APPLICATIONS

Part I

André J. Duerinckx
Chairman/Editor

IEEE COMPUTER SOCIETY
THE INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, INC.

IEEE Catalog No. TH0090-1
IEEE Computer Society Order No. [illegible]

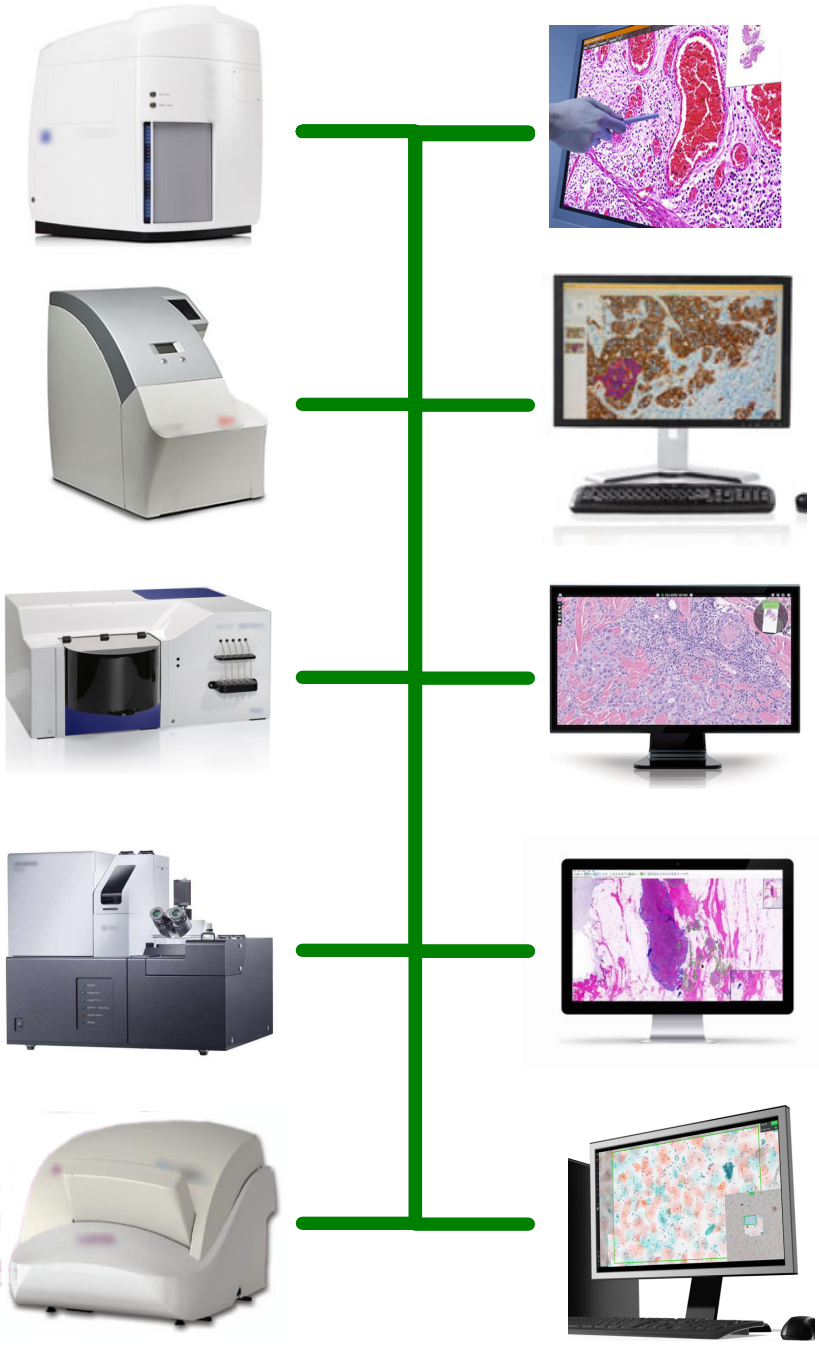
January 18-21, 1982
Newport Beach, California

1982

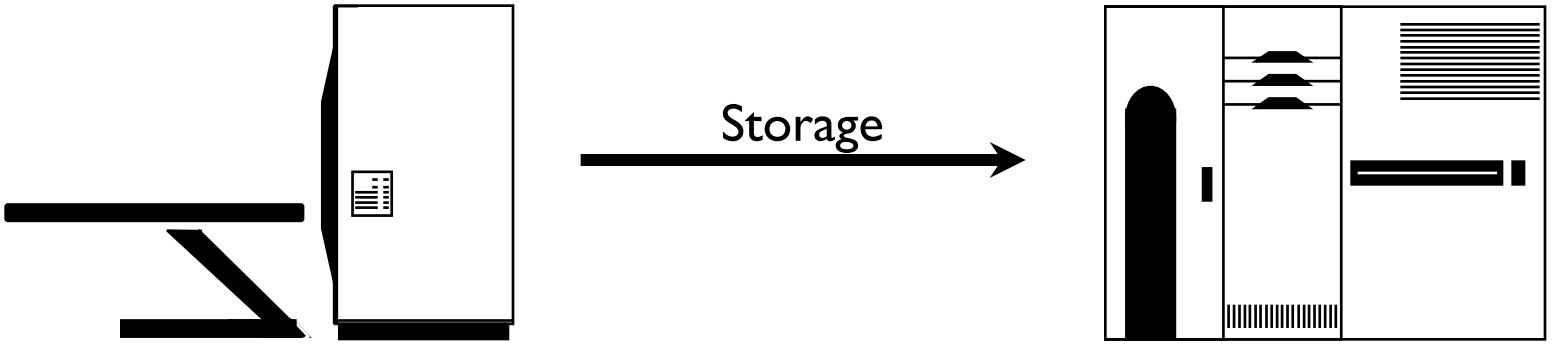
36 years ago – radiology PACS and DICOM ubiquitous 15-20 years later!

DICOM℠

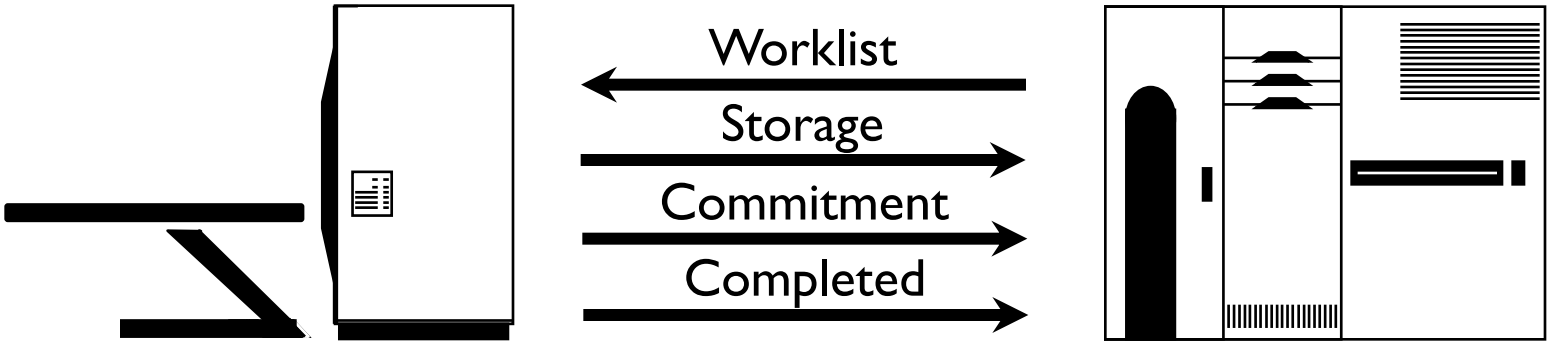
Digital Imaging and Communications in Medicine



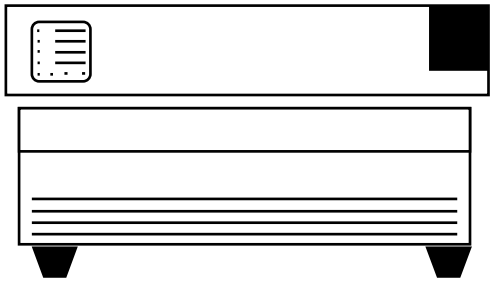
DICOM and Radiology Modality



DICOM and Radiology Modality

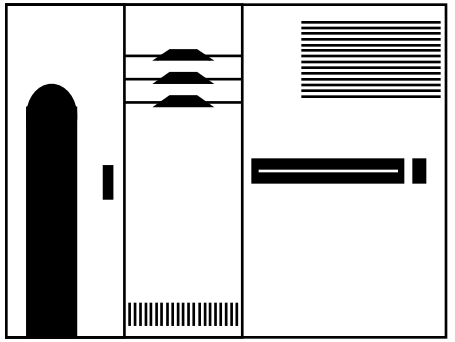


DICOM and Slide Scanner



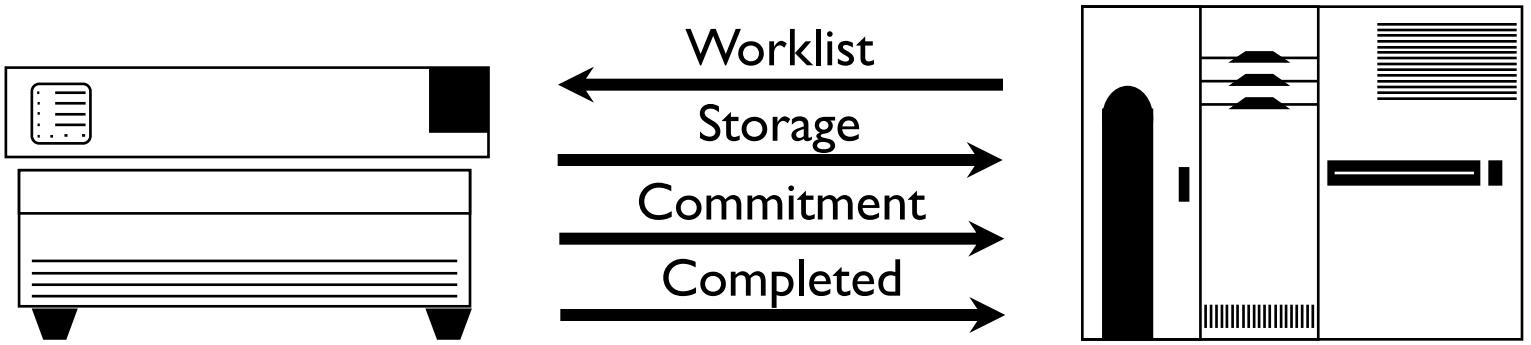
Slide Scanner

Storage

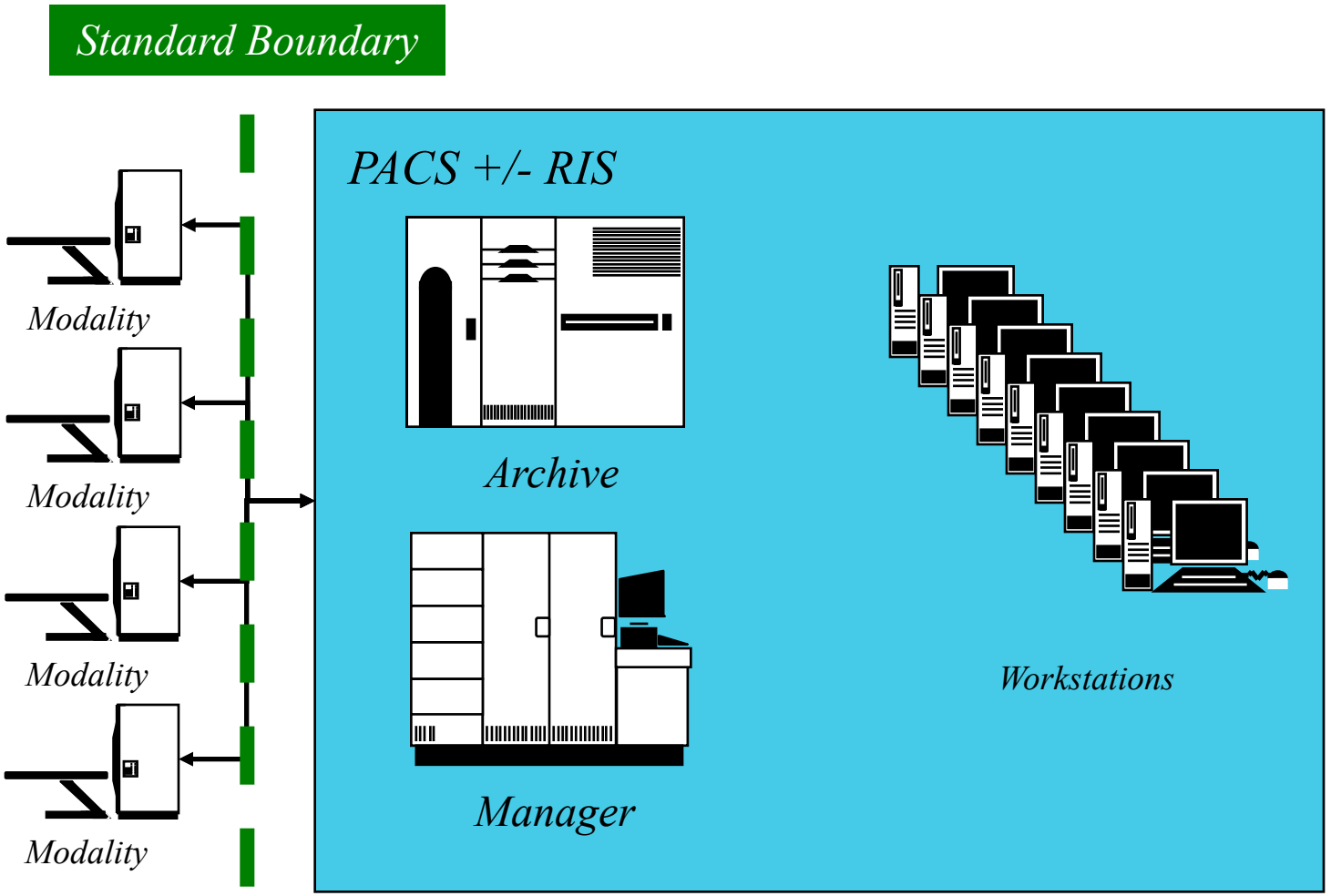


PACS

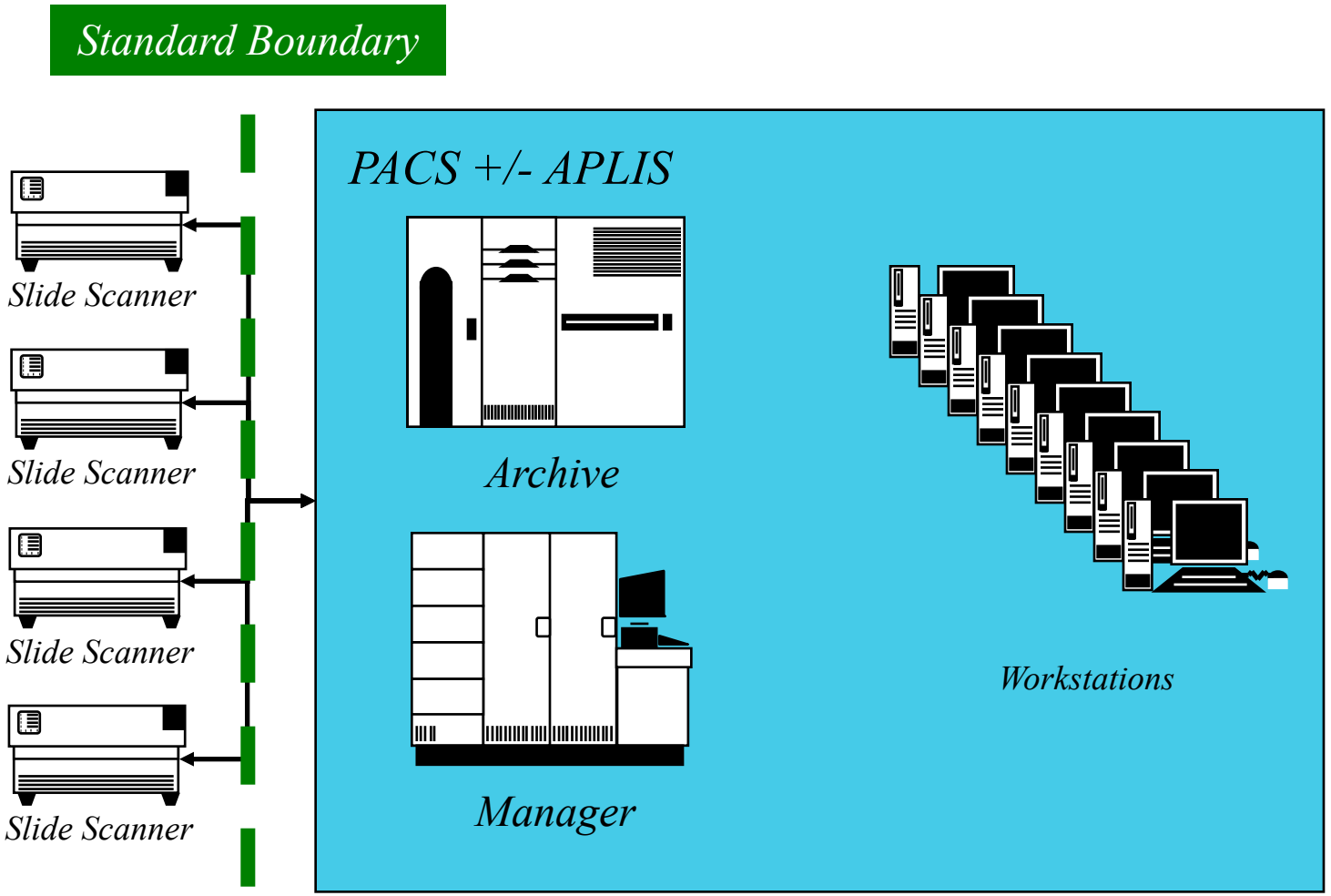
DICOM and Slide Scanner



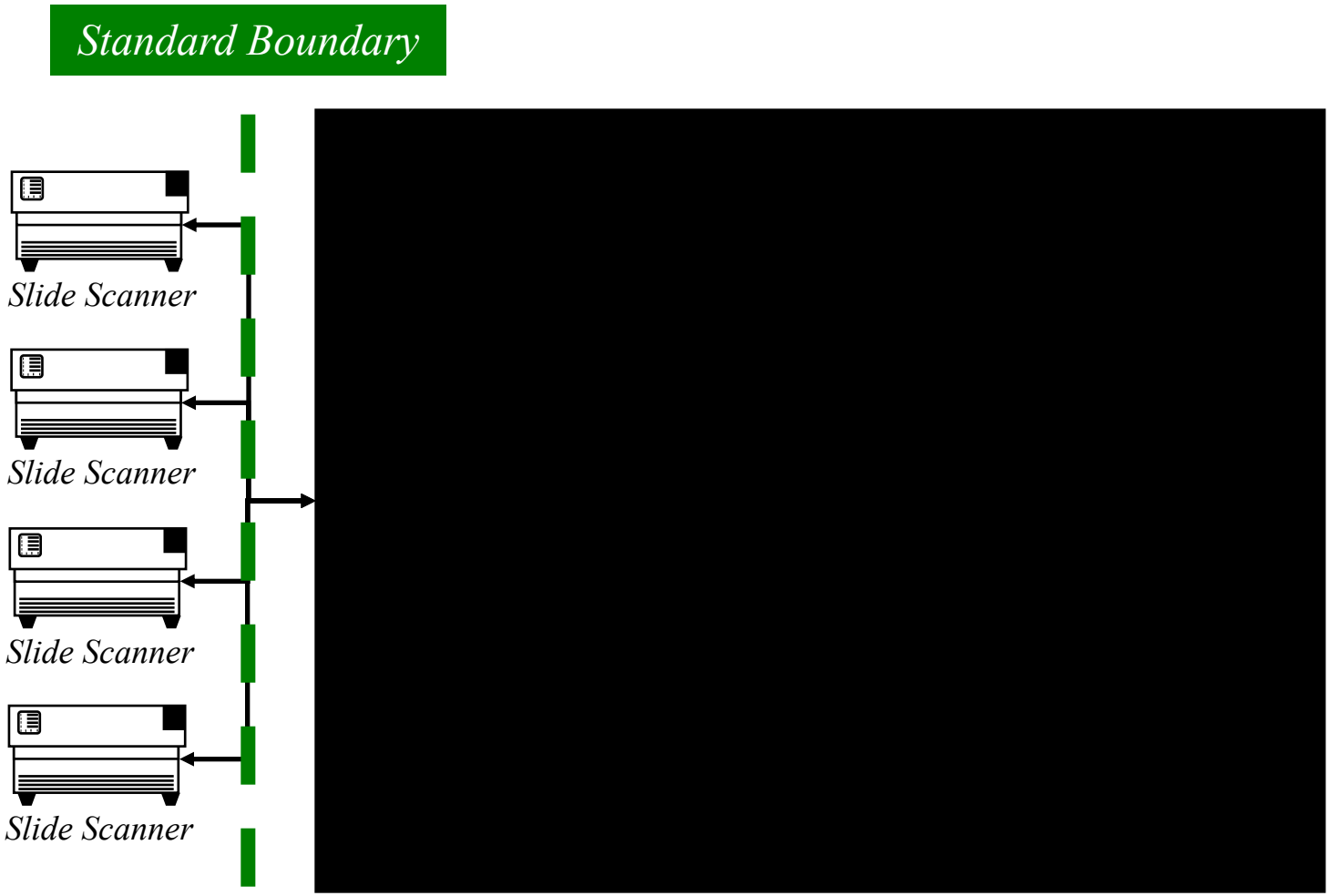
DICOM Modality to PACS



DICOM WSI to PACS



DICOM WSI to Black Box

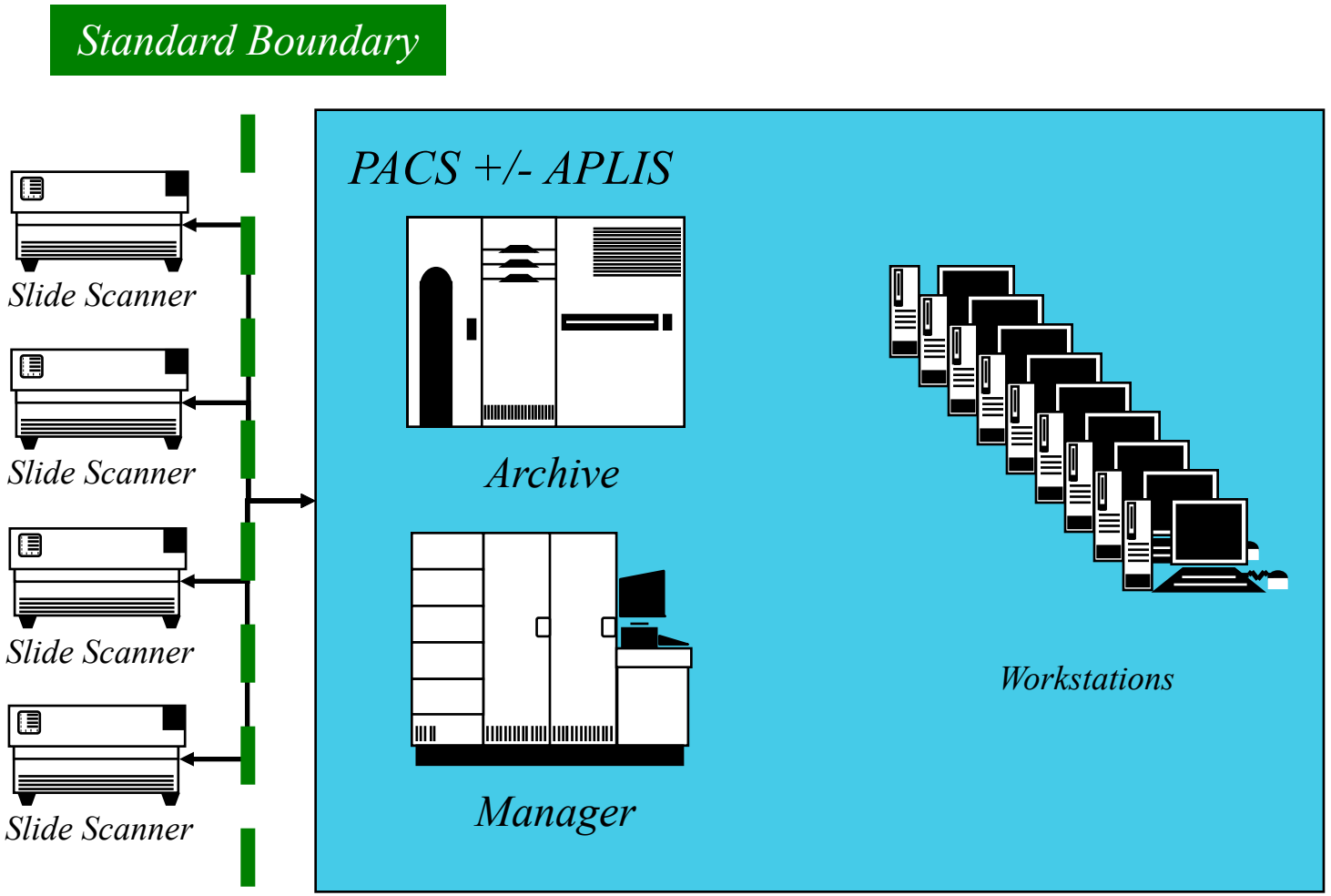


Single Vendor Black Box

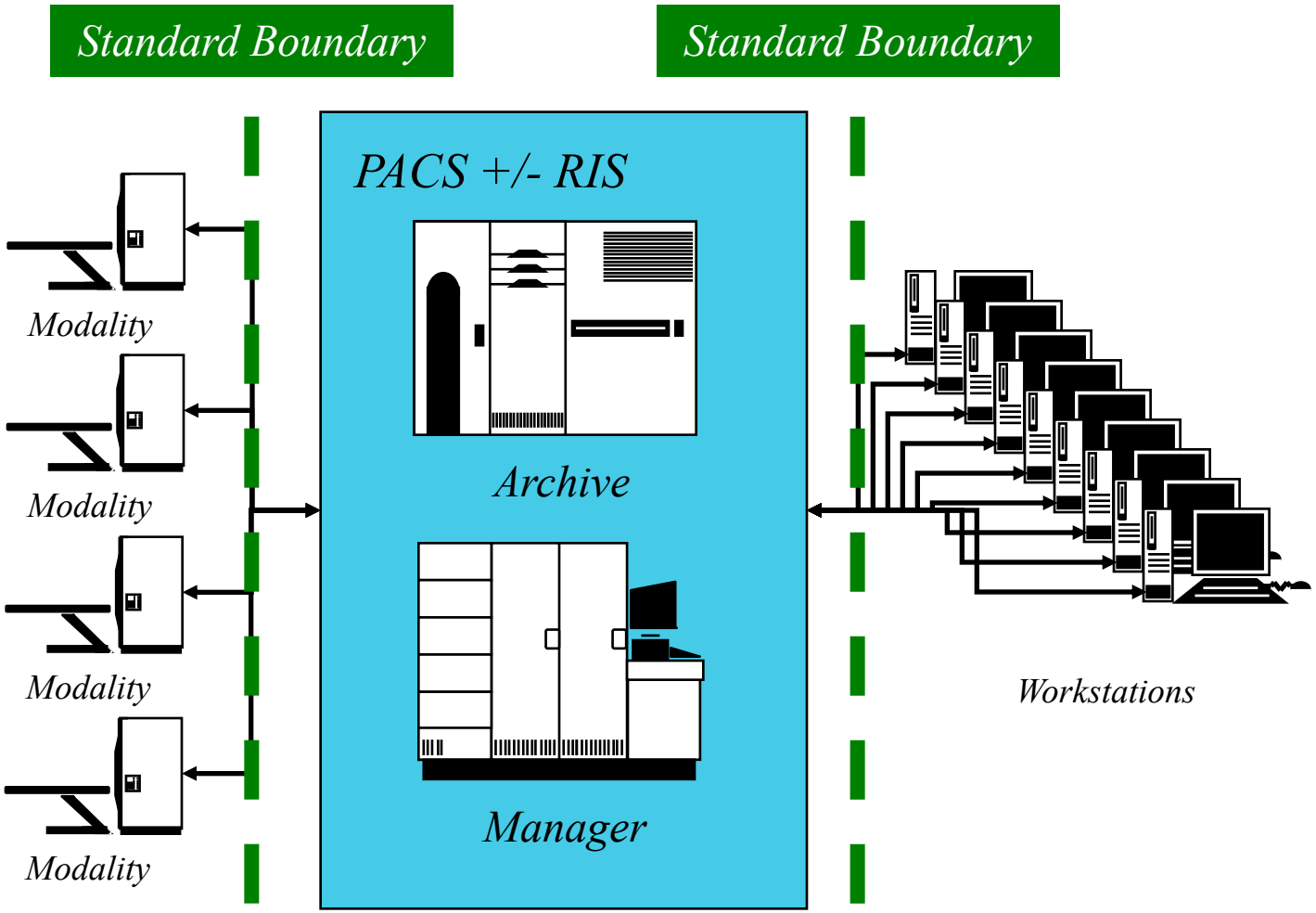
FDA “entire pixel pathway”

Single Vendor Black Box

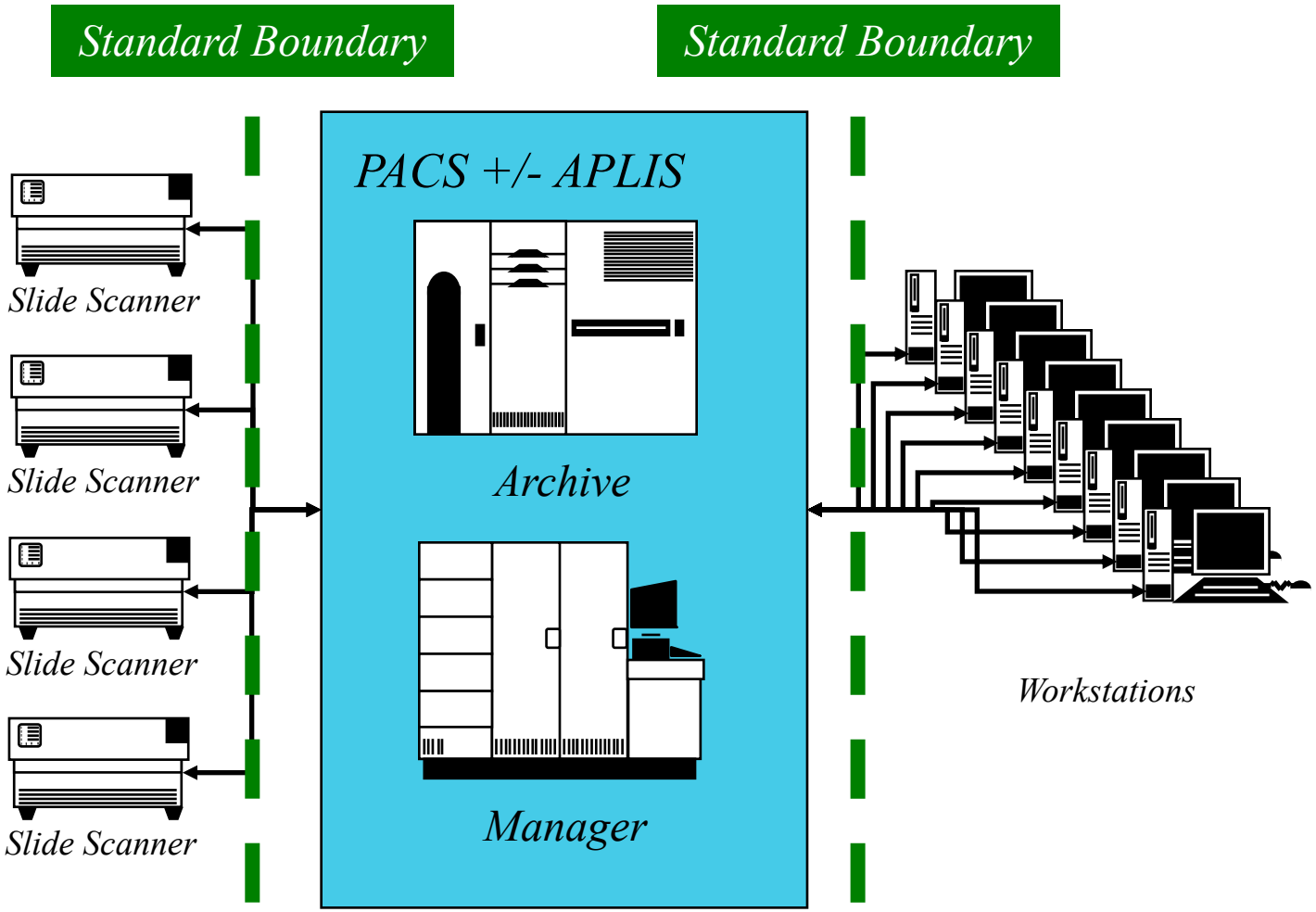
DICOM WSI to PACS



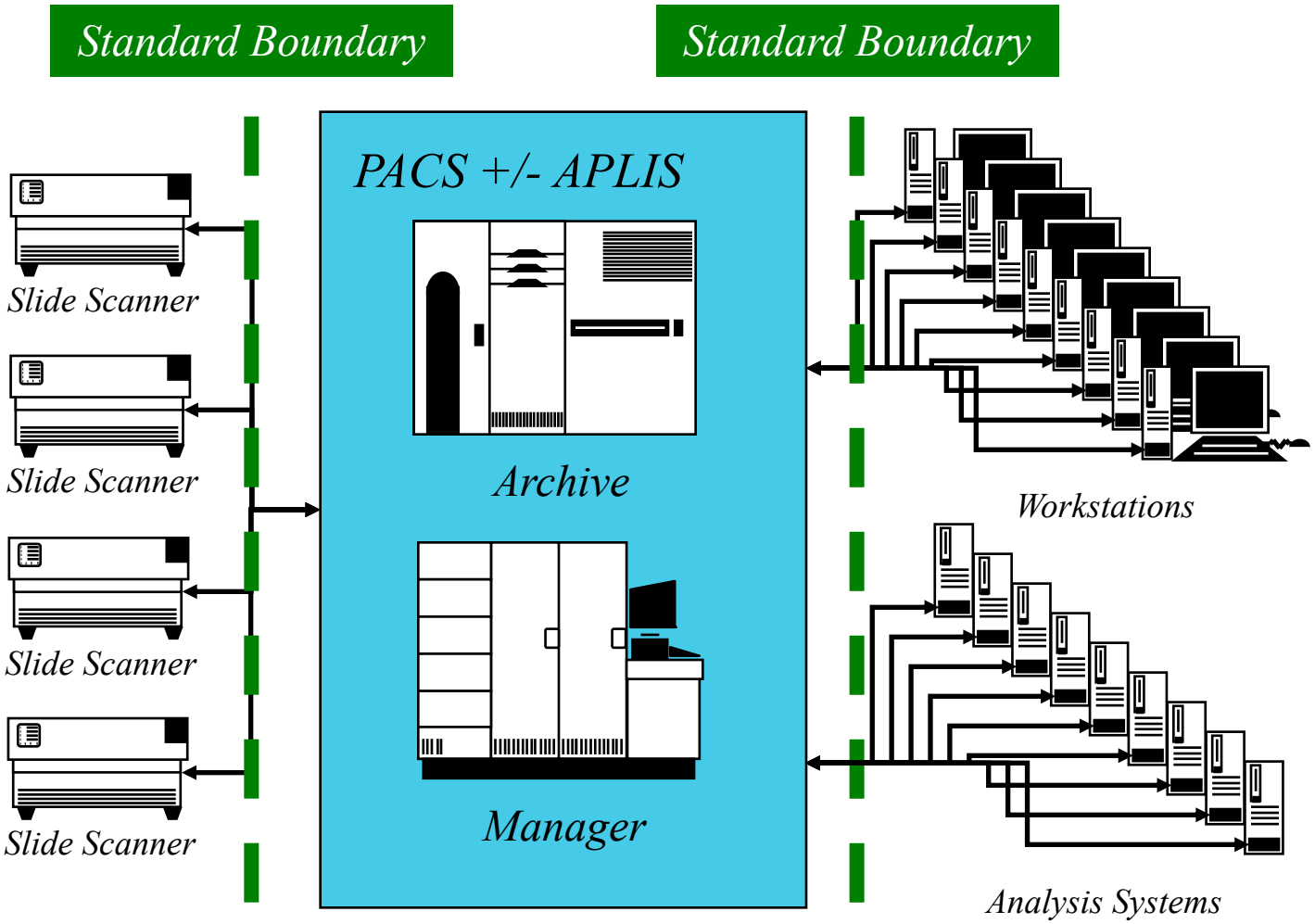
DICOM – Radiology Workstation



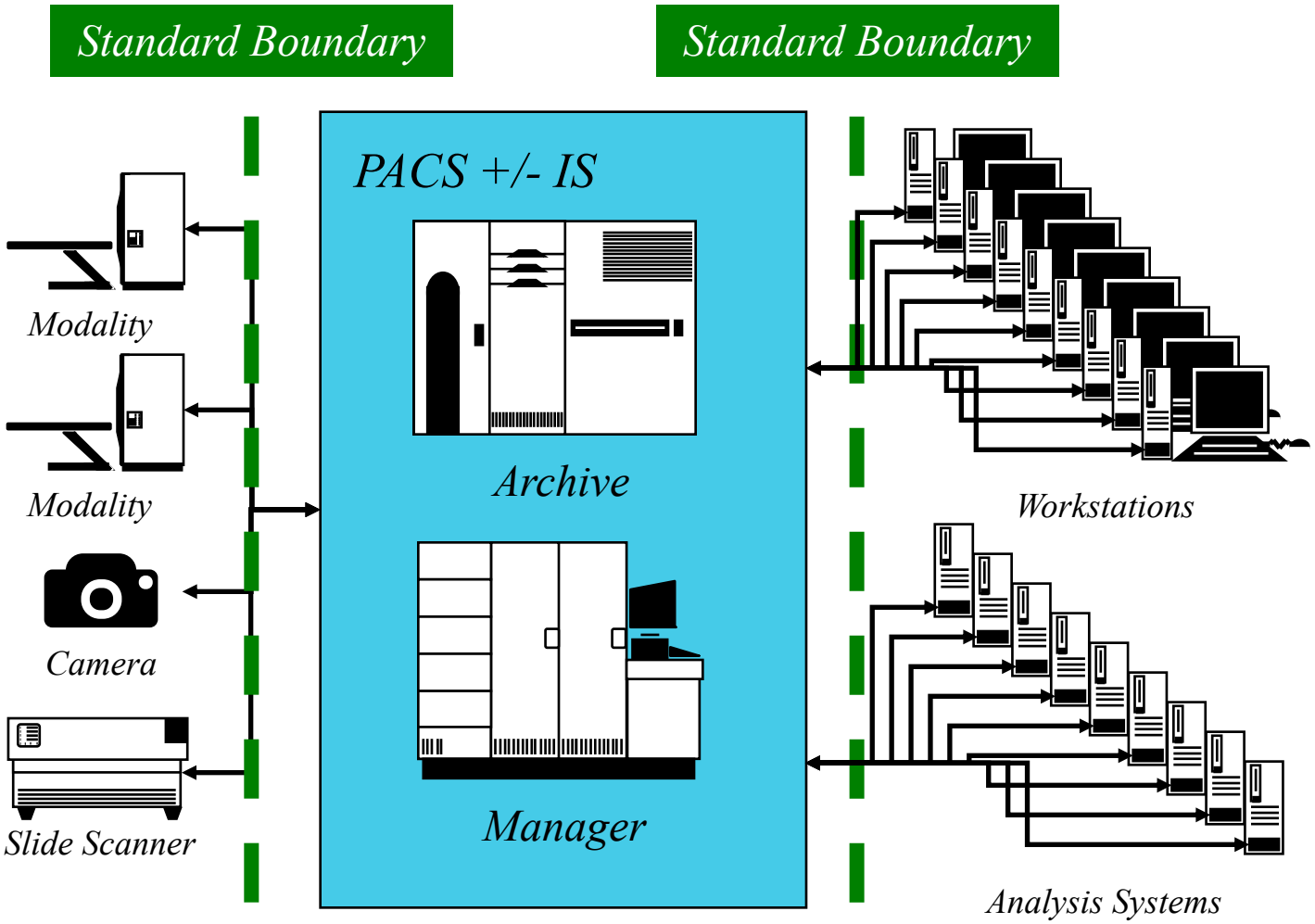
DICOM – Pathology Workstation



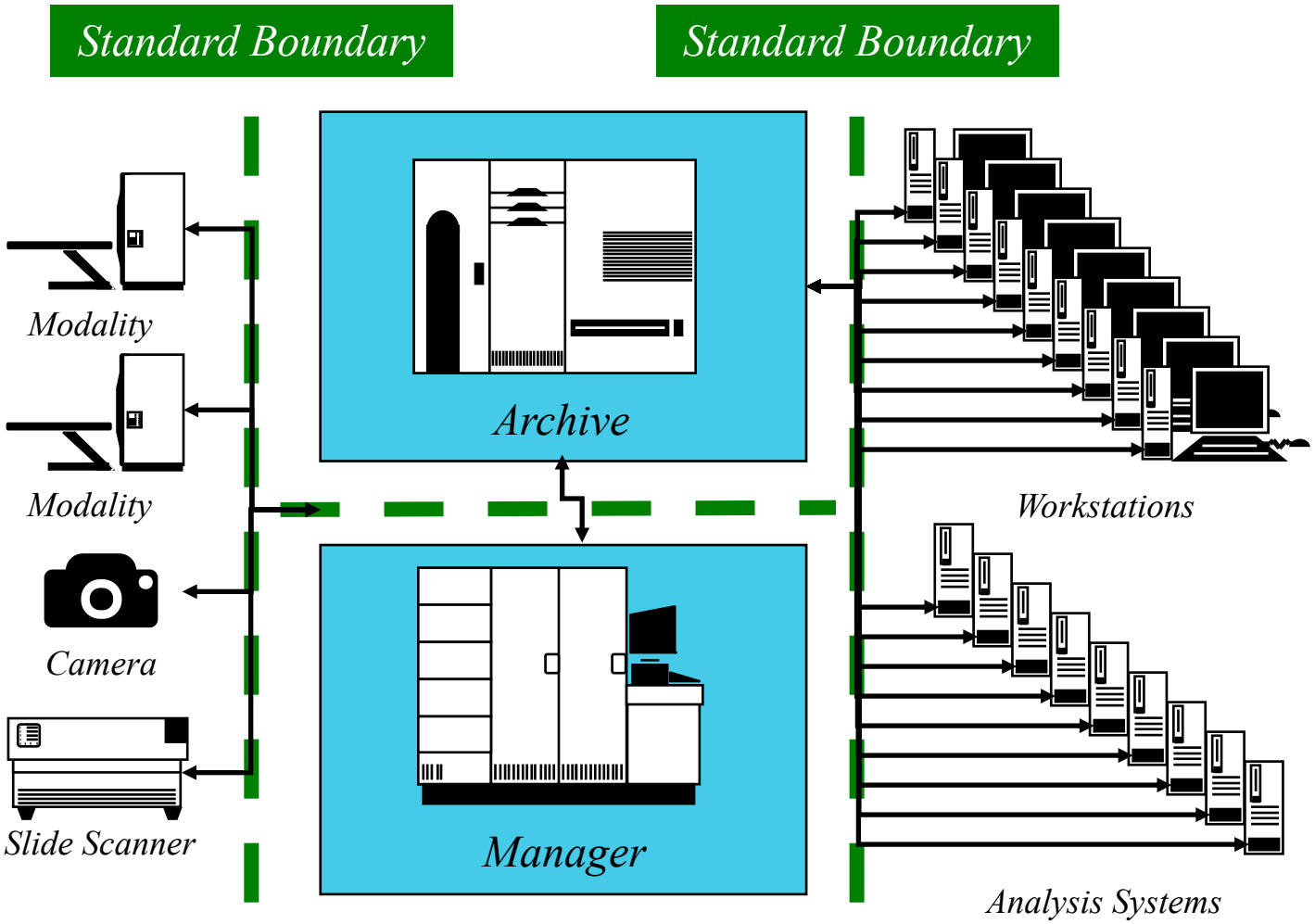
DICOM – Analysis Systems



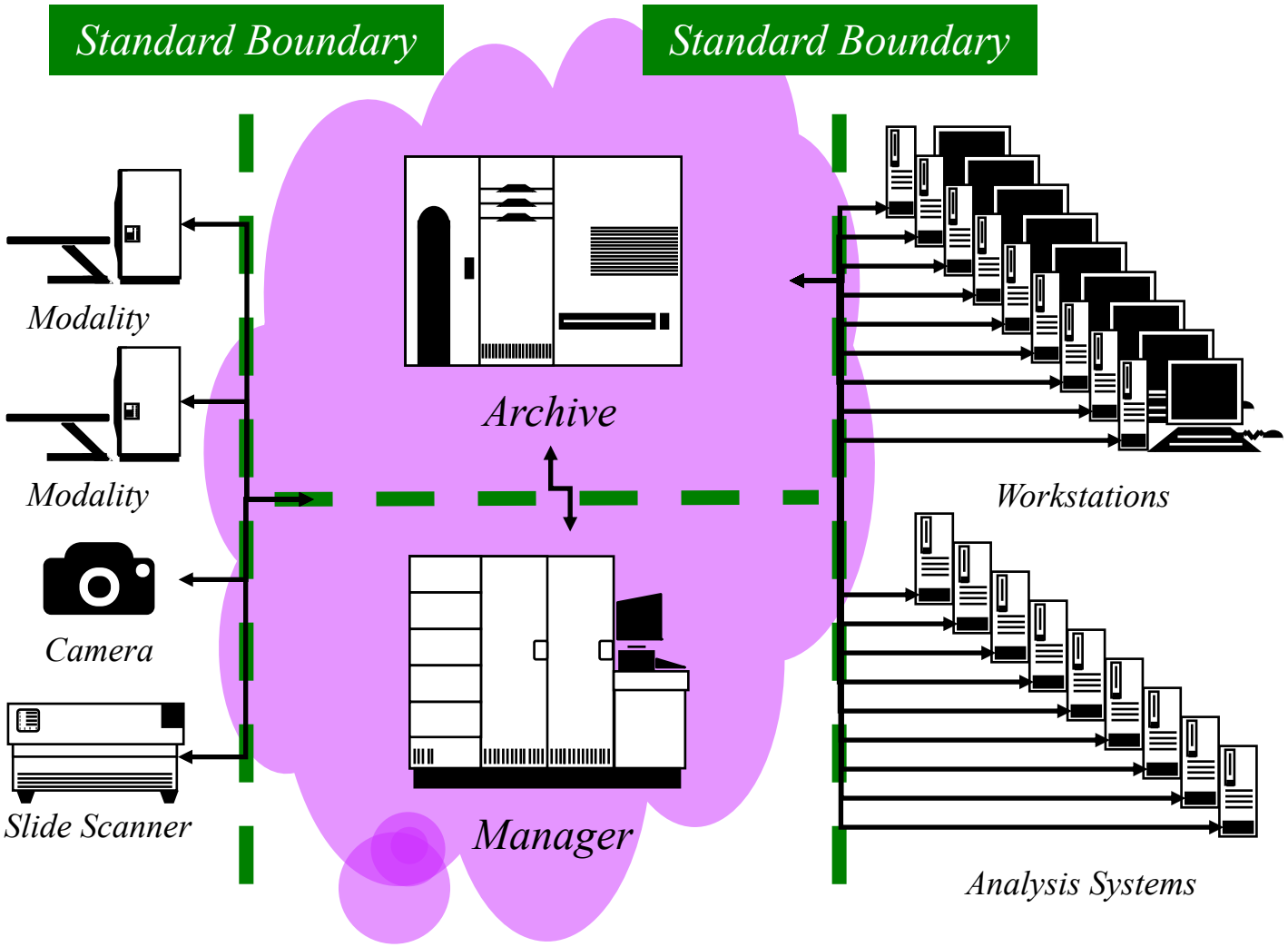
DICOM – Enterprise Imaging



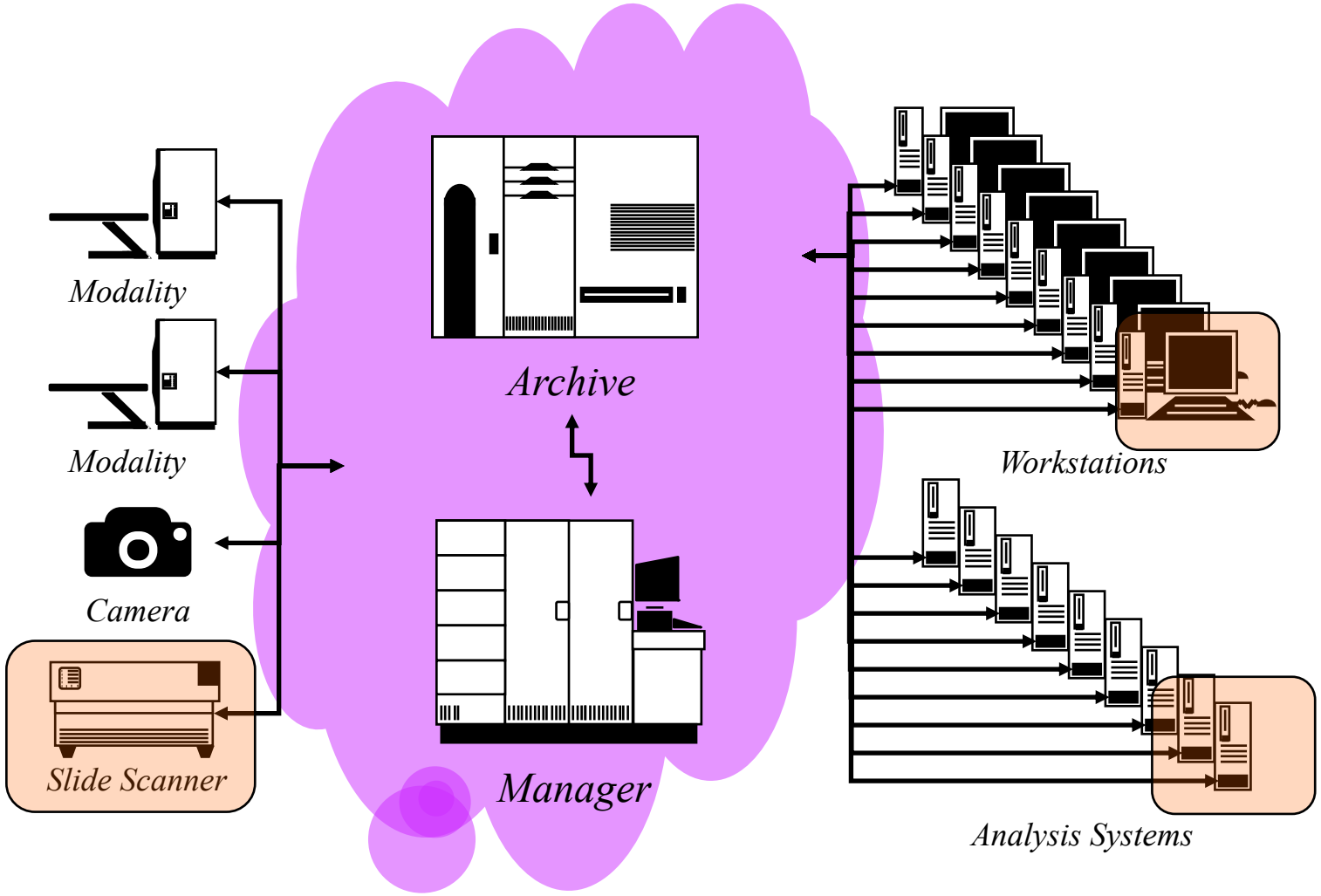
DICOM – Deconstructed PACS



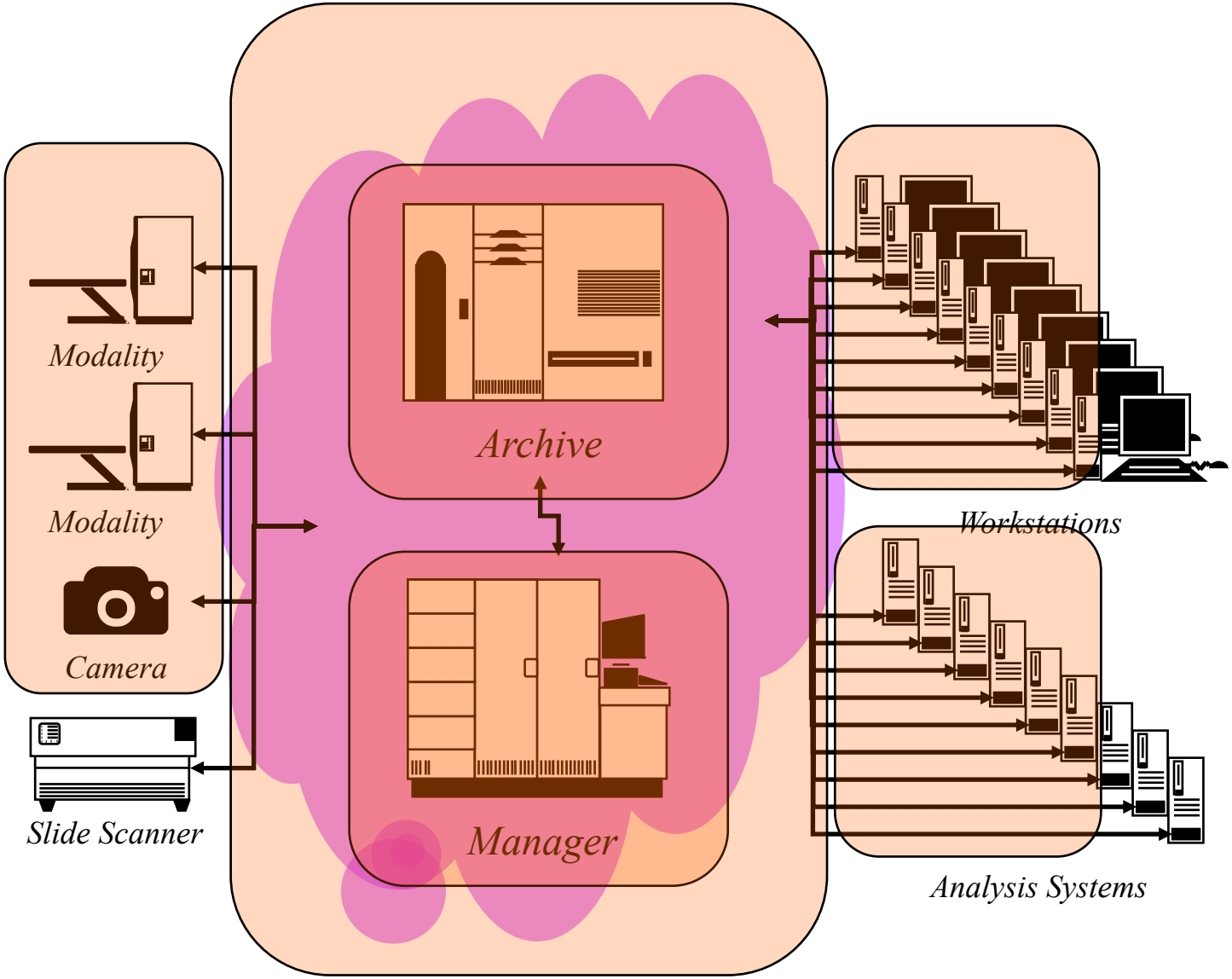
Cloud


Standard Boundary
Standard Boundary
Modality
Modality
Camera
Slide Scanner
Archive
Manager
Workstations
Analysis Systems

Pathologist/Department



Enterprise IT (Someone Else)



Single Vendor Black Box
Everything is Your Problem

DICOM
Digital Imaging and Communications in Medicine

Why DICOM?

DICOM
Digital Imaging and Communications in Medicine

- Enormous experience in radiology and cardiology
- 33 years since ACR-NEMA PS3 Standard (1985)
- A consensus of user and industry representatives. later adopted by ISO as ISO 12052
- 80 million CT studies per year in US (CBS News, 2015) – all DICOM
- Huge supporting infra-structure – for both DICOM file format, protocol and services
- All manner of products essentially commoditized: scanners, archives, workstations, viewers, PACS, toolkits for products, testing, analysis, research
- Both commercial and free, closed and open source tools
- Conformance and interoperability testing venues (e.g., IHE Connectathons)
- Modality agnostic – e.g., XR, MR, NM also Visible Light, esp. Ophthalmology, Endoscopy
- Application agnostic – human, veterinary, small animal research, non-destructive testing (esp. aerospace and nuclear power), security (esp. baggage scanning)
- Emphasis on reliable, consistent, standard metadata (common data elements, value sets)

Why not DICOM?

- More effort than most trivial file formats – toolkits are generally required
- Complexity is implicit in the use case more than the "format" per se – harder problems require more effort and discipline to be interoperable
- Population of metadata takes effort – is it worth that effort?
- Traditional DICOM network transport protocols are unique, though TCP/IP based – mitigated through more recent use of HTTP (WADO) using XML, JSON metadata
- Pixel data encoding not a perfect match for WSI virtual microscopy – questions of size limits and tile access – multi-frame tiles are a hack (like TIFF), but are workable
- Intellectual property (patent) distractions – now resolved
- Legacy of use of proprietary (albeit mostly TIFF-based) – why change if downstream users/apps are willing to cope?
- DICOM Conformance is not a panacea – claims of support are limited to query, storage and retrieval, worklists, etc., but NOT visualization (but DICOM does enable viewers)

Status quo for WSI

- Hodgepodge of proprietary file formats
- Some (Big-)TIFF-based (good), some not (bad)
- Some with extensions to TIFF (e.g., JPEG 2000 compression)
- Some disclosed publicly, some not
- Usually used with vendor-supplied viewer or proprietary SDK
- Possibly readable by open source or 3rd party
- Limited integration of scanners with Anatomical Laboratory Information Systems (APLIS), if at all, perhaps requiring expensive customization
- No metadata: fragile linkage to contextual data (patient, slide, handling, staining) by filename or scanned slide identifier only
- When decoupled from environment (APLIS, proprietary PACS), lose contextual data

Why care now?
First to market impact

- Lessons from radiology
- First clinically approved systems huge influence on hospital IT infrastructure choices
- First clinically approved systems not necessarily those already in widespread research use, may or may not be standards-based
- Early adopters of research systems may find themselves at dead end
- Second clinically approved systems are often significantly delayed, artificially lowering the pressure for incumbent to "interoperate", but building large archive of "priors"
- E.g., breast tomosynthesis (DBT) – correct DICOM object was not used by first (US) vendor, rather image pixel data was buried in private fields to get around limitations of legacy PACS but requiring a proprietary viewer – DBT is now mainstream with multiple vendors and well standardized, but huge mess of unreadable garbage in archives, still sent out by some sites – unreadable as priors and cause safety issue
- Lesson – do it right from the start – think beyond the departmental silo – anticipate integration of lots of new players (enterprise archives, cloud distribution, analytic applications) – adoption of the "right" standard (DICOM) helps


STAN WINSTON

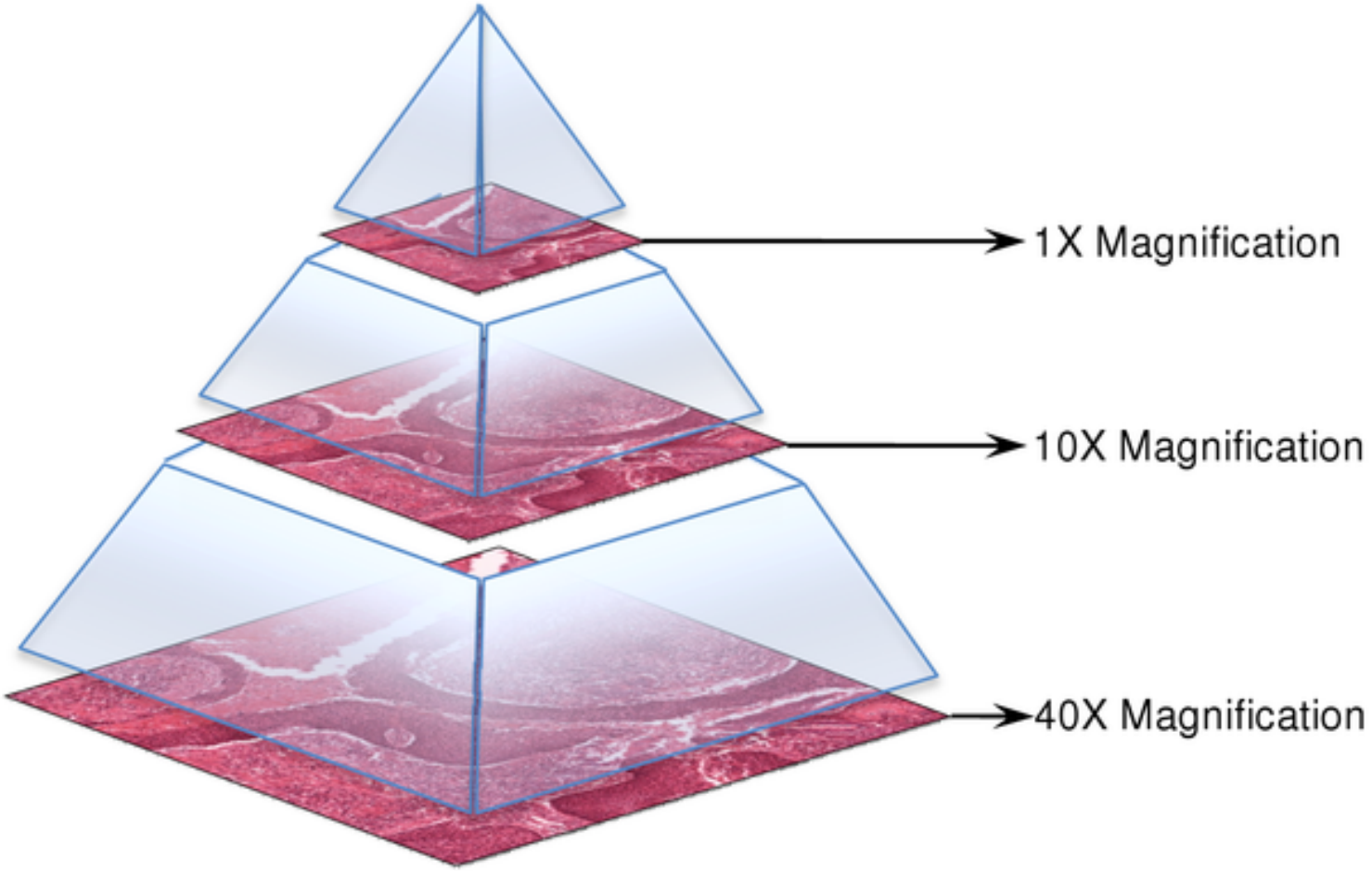
DICOM WSI – 2005 to 2017

- 1999 – Sup 15 – Visible Light including Microscopy
- 2005 – WG 26 got to work on WSI etc.
- 2006 – IHE Anatomic Pathology Domain
- 2008 – Sup 122 – Specimen Module
- 2008 – IHE Anatomic Pathology Workflow
- 2010 – Sup 145 – Whole Slide Microscopic Image IOD
- … *seven years of silence* …
- 2017 – 1st premarket approval for primary diagnostic use
- 2017 – 1st WG 26 Digital Pathology Connectathon (PV)
- 2018 – three Connectathons (PathInfo, ECDP/NDP, PV)

DICOM WSI – What and How

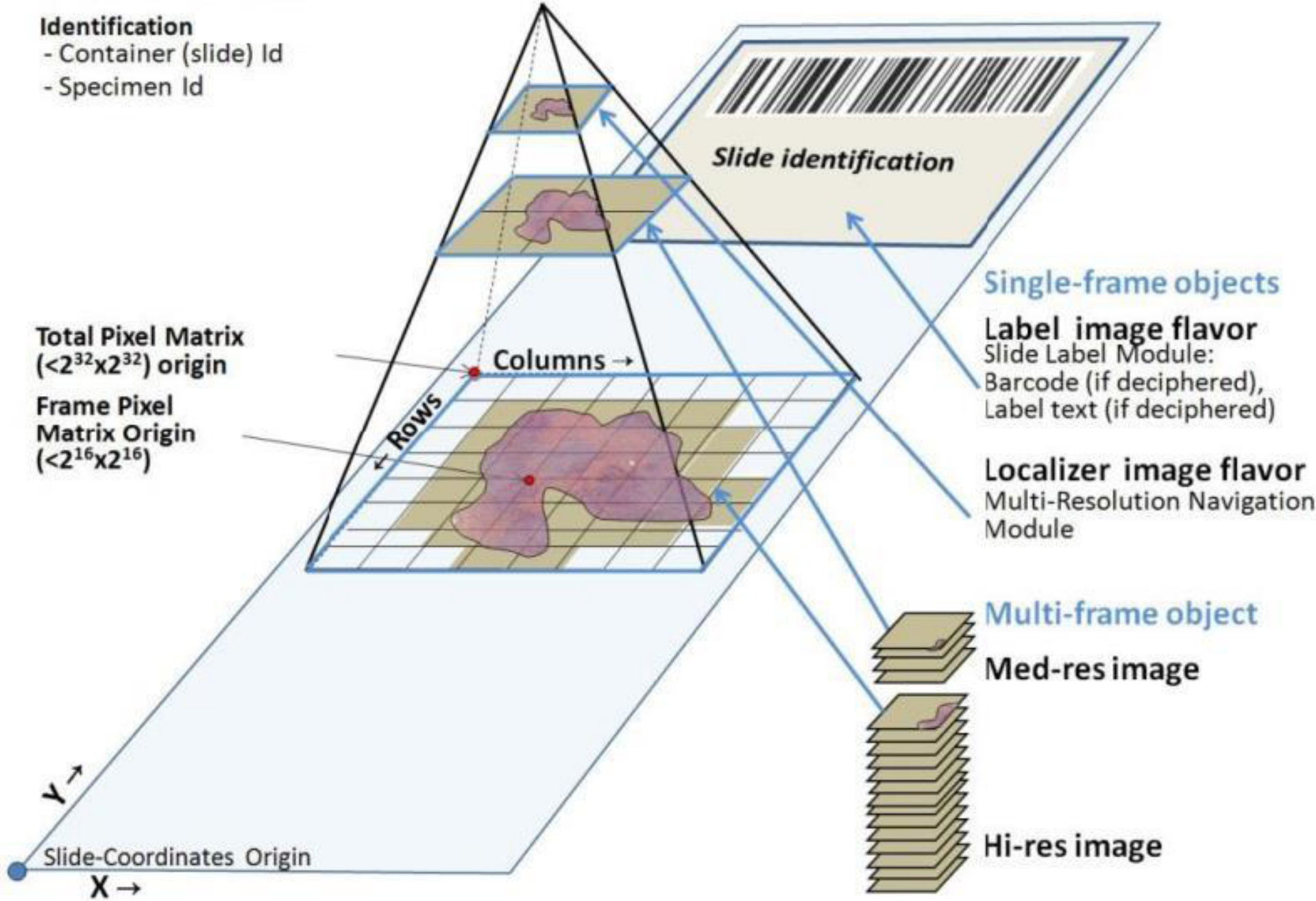
- File format for:
  - whole slide images (tiled pyramid)
  - single fields – slide microscopy
  - gross microscopy
- File contains:
  - compressed pixels (JPEG or JPEG 2000)
  - metadata – identifying AND descriptive
- Protocol for sending and receiving, etc.
- Other stuff like workflow, annotation, segmentation, structured reports, …

How digital slides are stored in a pyramid structure.



Wang Y, Williamson KE, Kelly PJ, James JA, Hamilton PW (2012) SurfaceSlide: A Multitouch Digital Pathology Platform. PLOS ONE 7(1): e30783. https://doi.org/10.1371/journal.pone.0030783
http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0030783

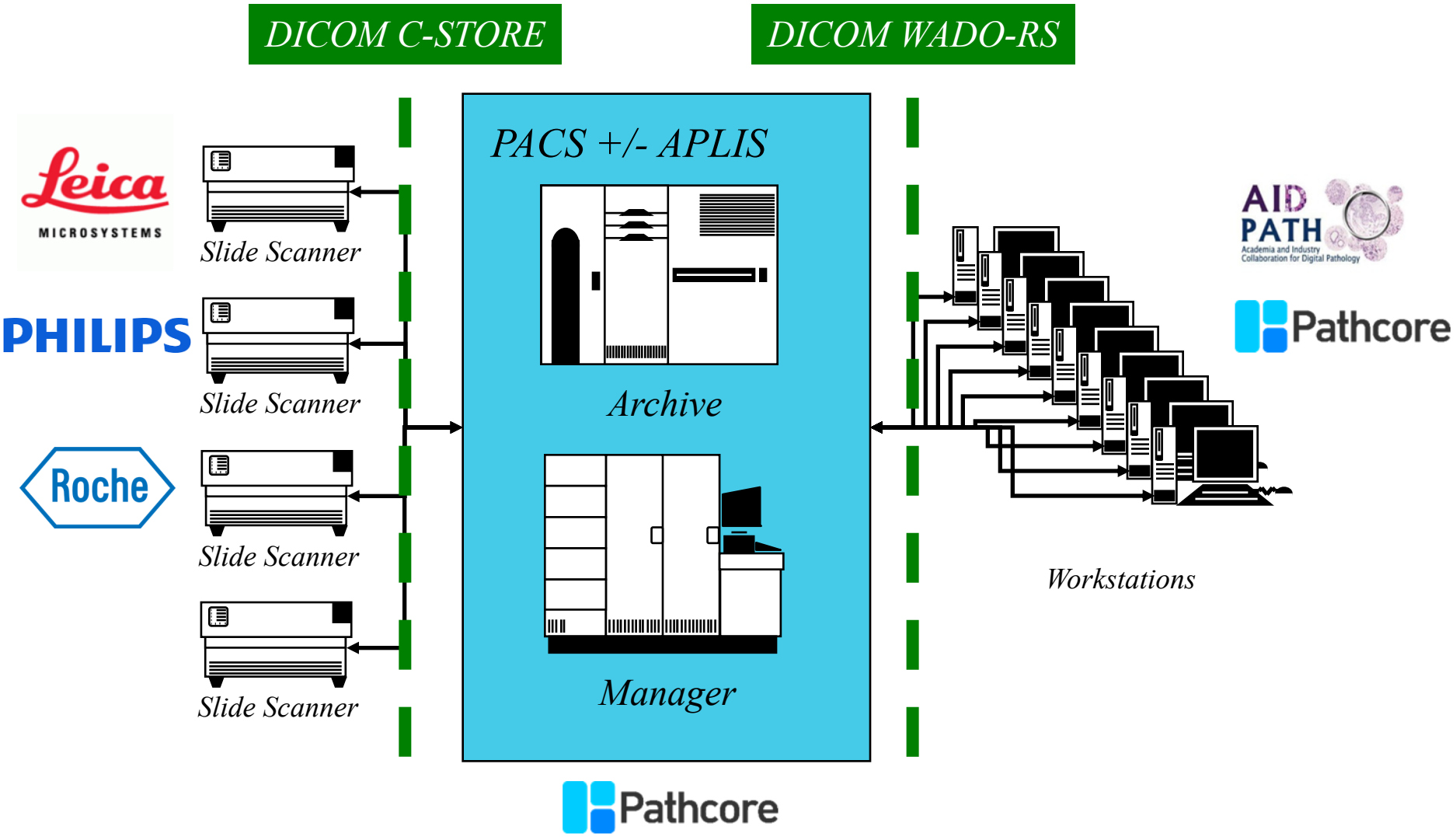
Garcia-Rojo et al. 2016



DICOM WSI: Why tiled pyramids?

- Goal is simplicity of access simulating a microscope
- Zoom and pan
- Tiles (frames): allow access to rectangular sub-regions of each resolution layer (without loading entire huge object)
- Pyramid: entire highest resolution layer is very large, so storing lower magnification layers (for faster zooming) takes negligible extra space
- Works around DICOM single frame size limitations (64k x 64k): no change to underlying DICOM encoding, no change to existing DICOM toolkits and archives
- Do need services for metadata (index: which tile is which frame) and frame-level retrieval – WADO-RS

PV 2017 Connectathon



PV 2017 Connectathon Lessons

- which compression schemes (JPEG, or J2K as well?)
- one layer or entire pyramid from source (viewers expect latter, who makes it?)
- how to recognize which pyramid layer is which (PixelSpacing)
- recognizing a pyramid, in one series, multiple series, multiple per series
- natural order of encoded frames versus their index
- sparseness: entire tile array or selected sub-regions
- tile frame size: same for each resolution layer (e.g., localizer non-square?)
- dimensions described or not?
- localizer with index, or not? in same or separate series?
- concatenations: splitting huge files for transfer, requires reassembly on receipt
- is a label image needed, does it need a barcode? shared between pyramids?
- what optional metadata in image, in query (esp. specimen preparation)?
- specific server services/sequencing for viewing (find vs. metadata retrieve)
- WADO-RS – retrieve or retrieve rendered (multipart MIME burden)
- color consistency – importance of viewer applying embedded ICC profile

PV 2017 Connectathon Lessons

- Need more Connectathons! Need more testing!
- More specific profiling of requirements
  - DICOM CPs to fix details, clarify ambiguities, optimize for common use-cases
  - WG26 or IHE "profile"?
  - clarify patterns of use for specific use cases
  - make choices where alternatives exist, require currently optional features
- Just works, or works for the right reasons?
  - importance of validation against the formal standard requirements
  - currently assisted by mechanical tools (dciodvfy) – could check more
  - avoid using extensions, options, even if agreed upon
  - check with proxy between devices (as used by IHE)
  - create synthetic objects (good & bad) to stress recipients

DICOM
Digital Imaging and Communications in Medicine

Editorial

Digital Imaging and Communications in Medicine Whole Slide Imaging Connectathon at Digital Pathology Association Pathology Visions 2017

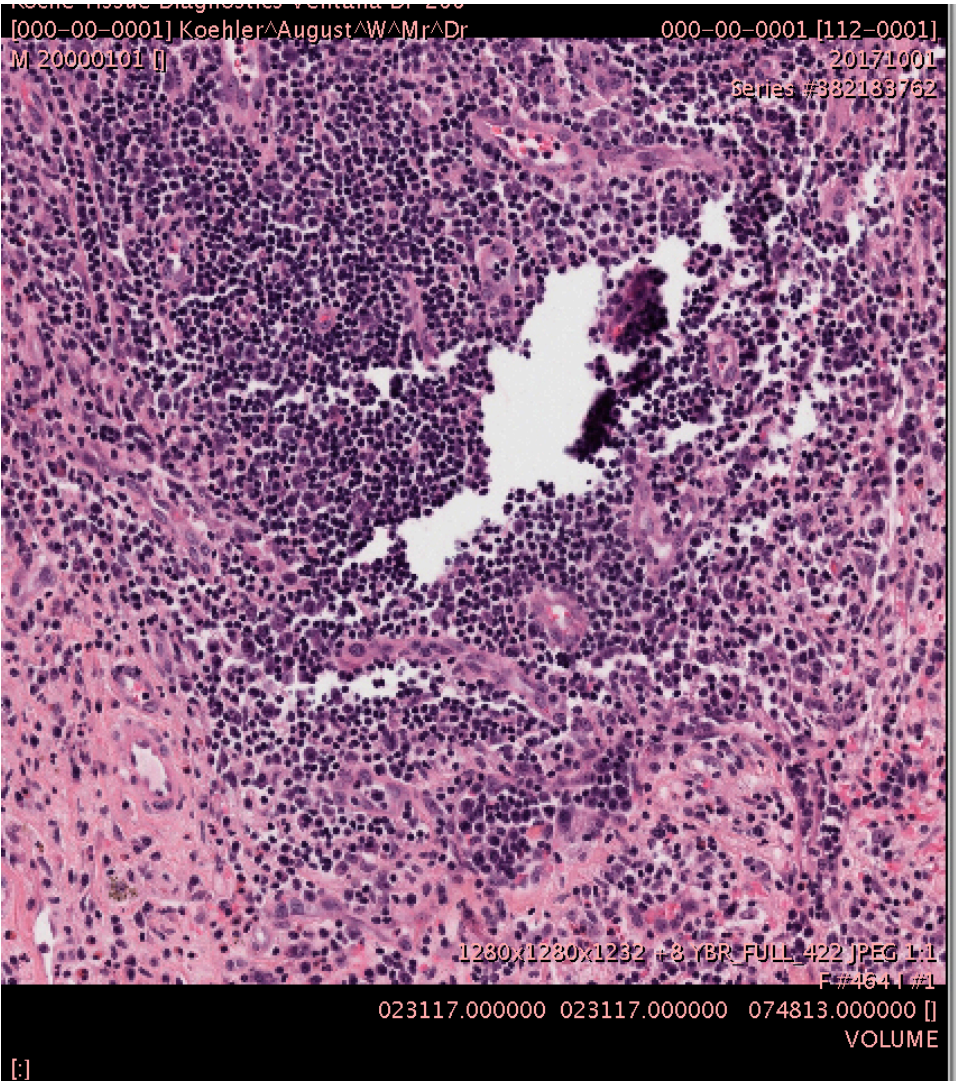
David Clunie[1], Dan Hosseinzadeh[2], Mikael Wintell[3], David De Mena[4], Nieves Lajara[5], Marcial Garcia-Rojo[4], Gloria Bueno[5], Kiran Saligrama[6], Aaron Stearrett[6], David Toomey[6], Esther Abels[7], Frank Van Apeldoorn[7], Stephane Langevin[2], Sean Nichols[2], Joachim Schmid[8], Uwe Horchner[8], Bruce Beckwith[9], Anil Parwani[10], Liron Pantanowitz[11]

[1]Pixelmed Publishing, LLC, Bangor, USA, [2]Pathcore, Toronto, Canada, [3]Department of Regional Health, Region Västra Götalandsregionen, Sweden, [4]Department of Pathology/UGC Anatomía Patológica, Hospital Universitario Puerta del Mar, Cádiz, Spain, [5]VISILAB, Grupo de Visión y Sistemas Inteligentes, E.T.S. Ingenieros Industriales, Universidad De Castilla-La Mancha, Ciudad Real, Spain, [6]Leica Biosystems, Wetzlar, Germany, [7]Philips Digital Pathology Solutions, Best, The Netherlands, [8]Roche-Ventana, Basel, Switzerland, [9]Department of Pathology, North Shore Medical Center, Salem, MA, USA, [10]Department of Pathology, Ohio State University, Columbus, OH, USA, [11]Department of Pathology, University of Pittsburgh Medical Center, Pittsburgh, PA, USA

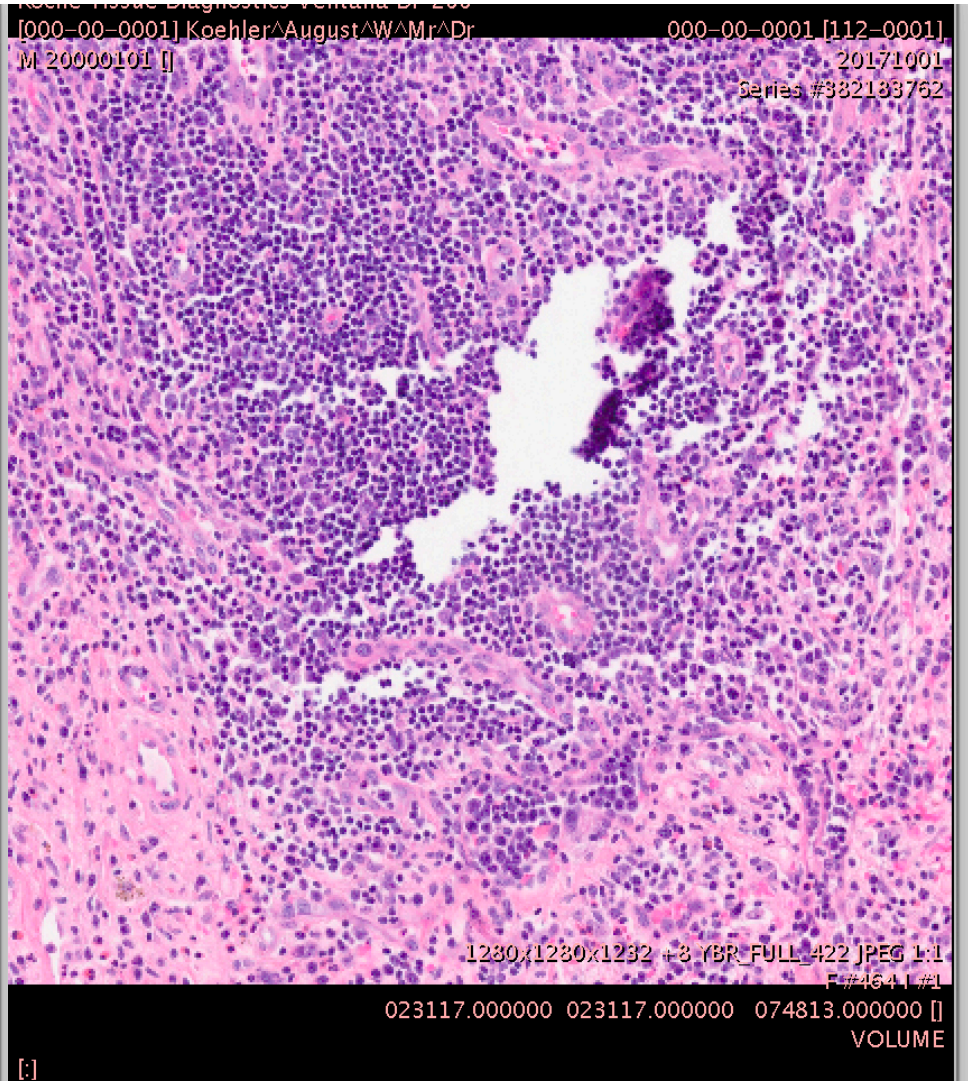
Received: 14 January 2018 Accepted: 05 February 2018 Published: 05 March 2018

What next?

- Color management
  - color normalization
  - color consistency - ICC profiles
  - services for application of ICC profiles to simplify (Internet browser based) viewers
- Workflow management
  - provision of identification and specimen preparation
- Annotations
  - input ("hot spots") and output from analysis algorithms
  - DICOM Segmentations
  - DICOM Structured Reports
  - ? something new in DICOM that scales to millions of nuclei, membranes, etc.

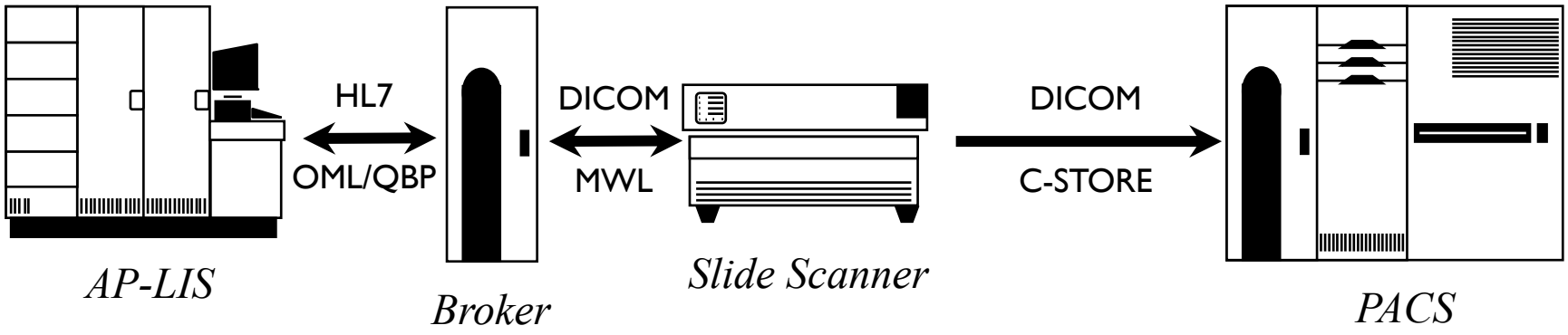


No ICC Profile Applied



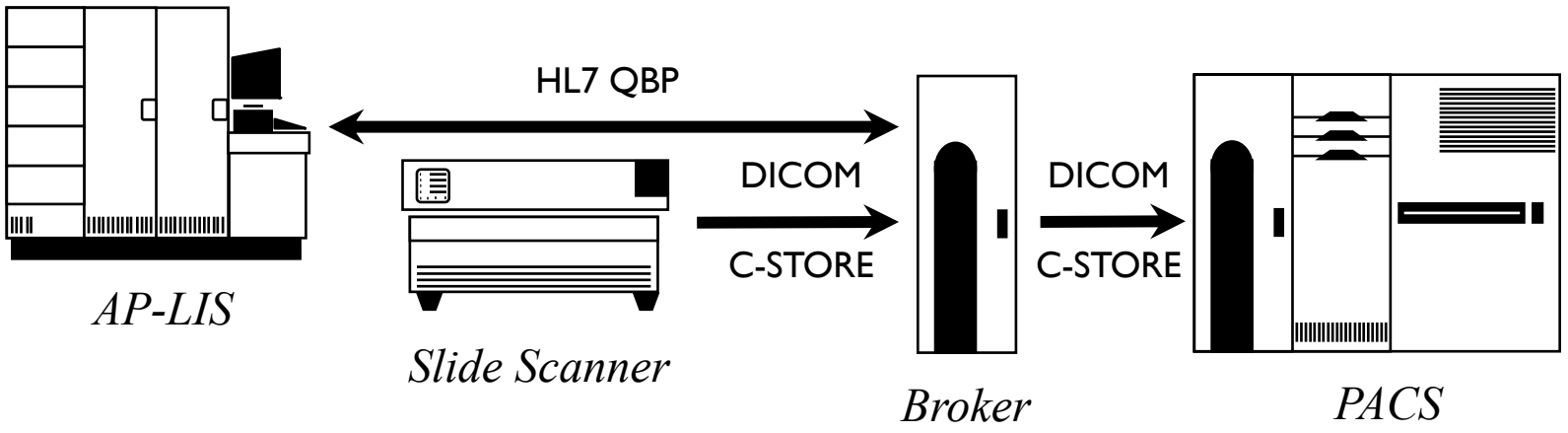
With ICC Profile Applied

Standard Workflow Integration

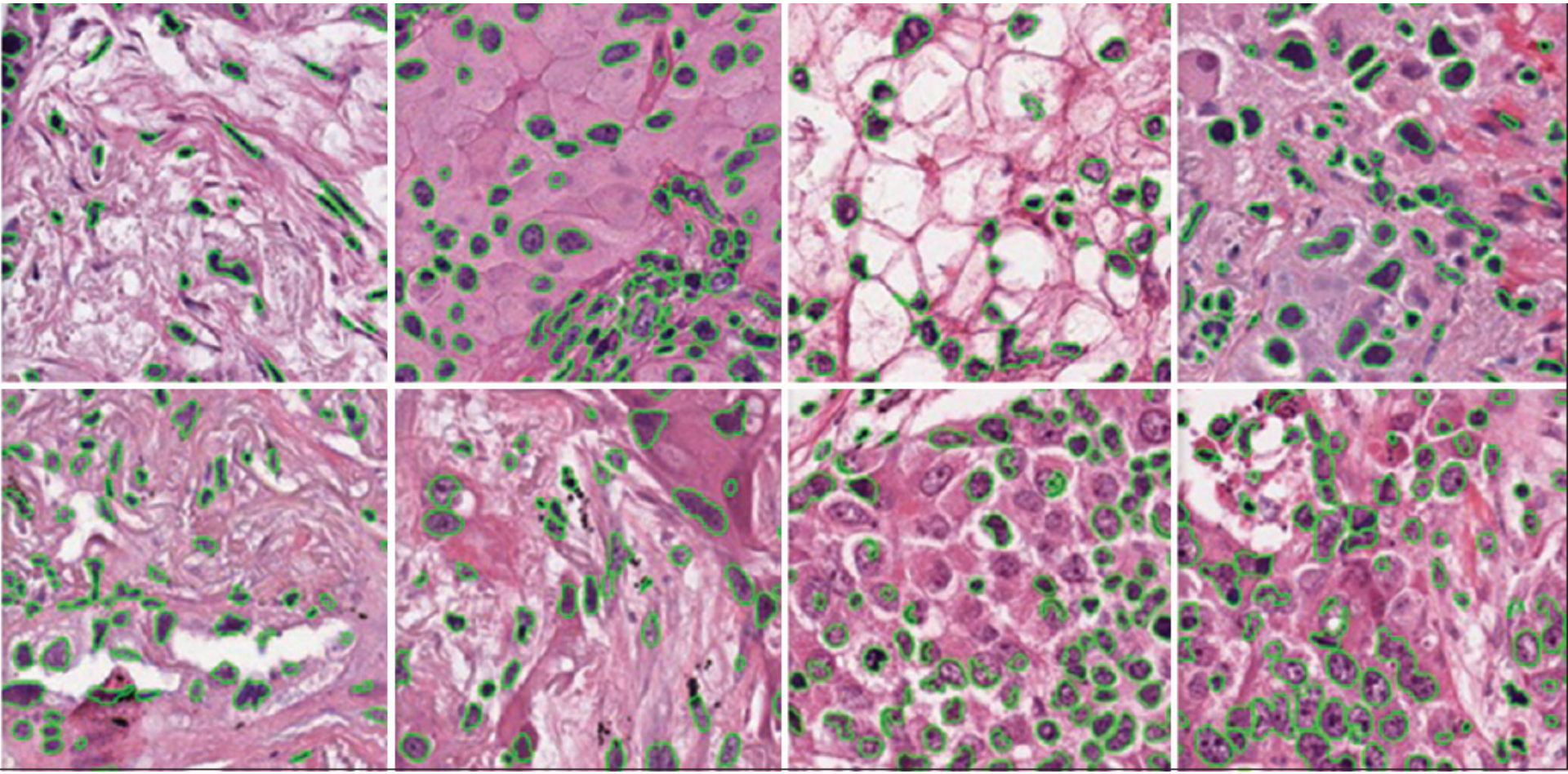


Standard Images and HL7/DICOM IS Integration

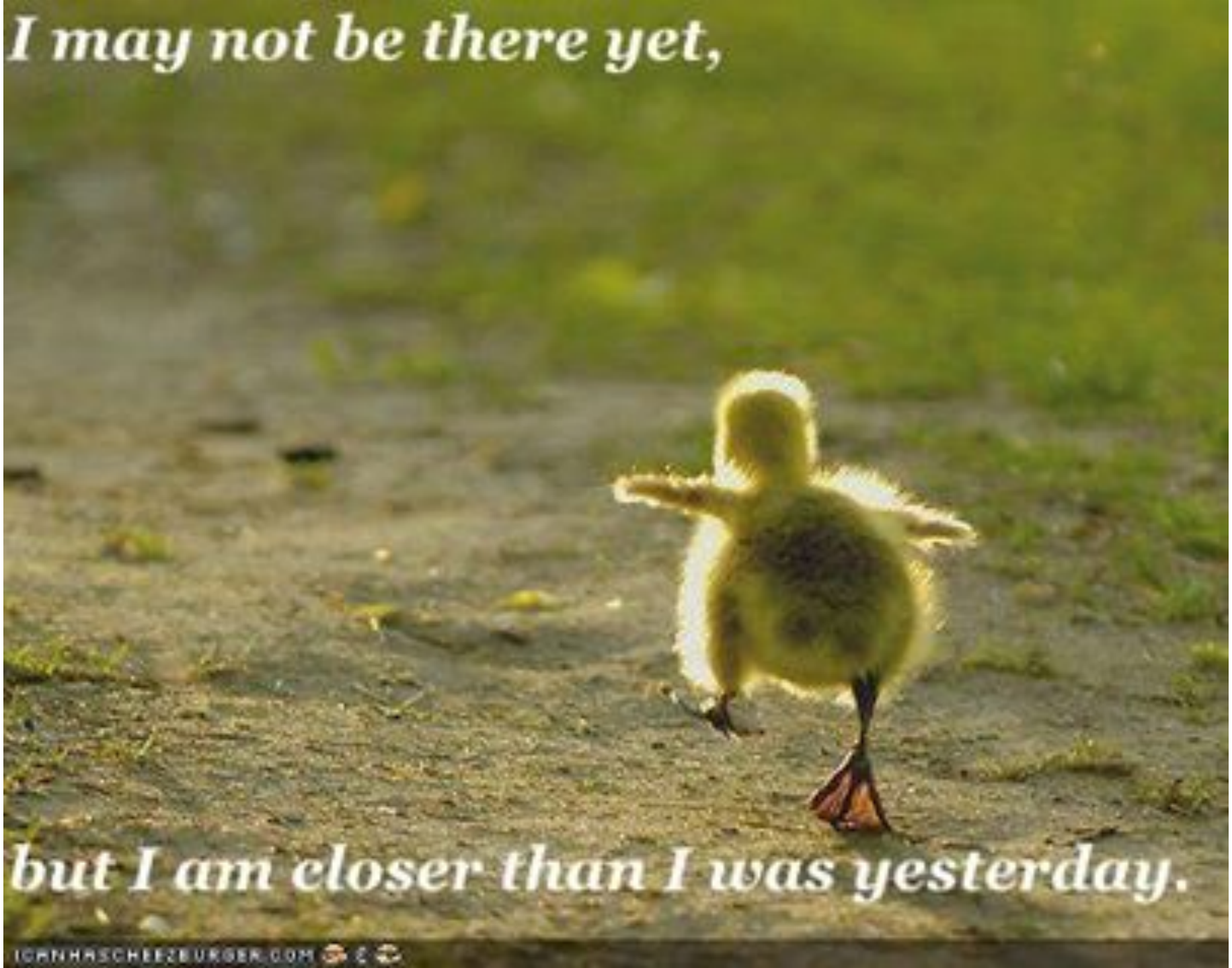
Standard Workflow Integration



Broker "improves" DICOM with IS Metadata



Wen et al. A methodology for texture feature-based quality assessment in nucleus segmentation of histopathology image. JPI. 2017.


I may not be there yet,
but I am closer than I was yesterday.
ICANHASCHEEZBURGER.COM