



SEAAPM Symposium 2014

Not Your Grandfather's PACS

New Expectations for Image Management

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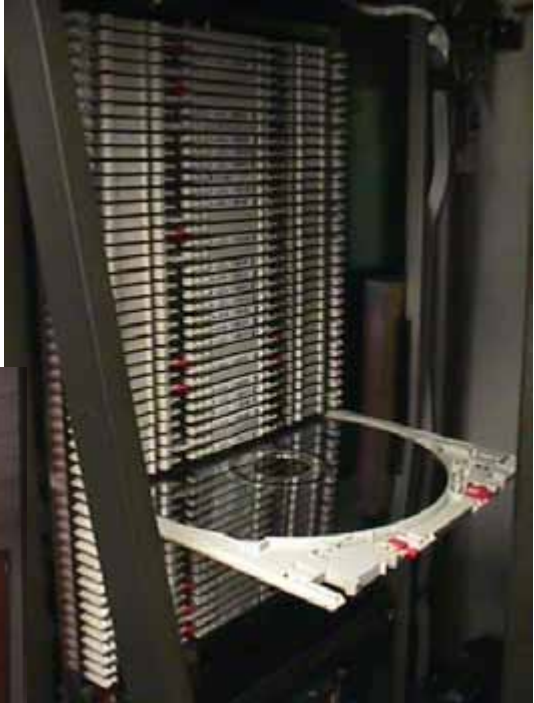
PixelMed Publishing



PACS – Learning Objectives

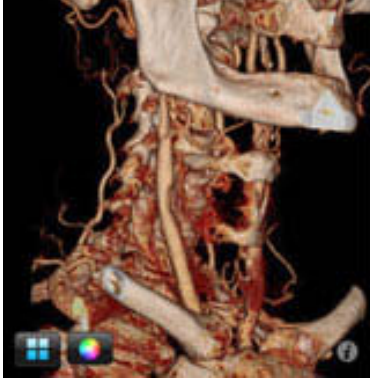
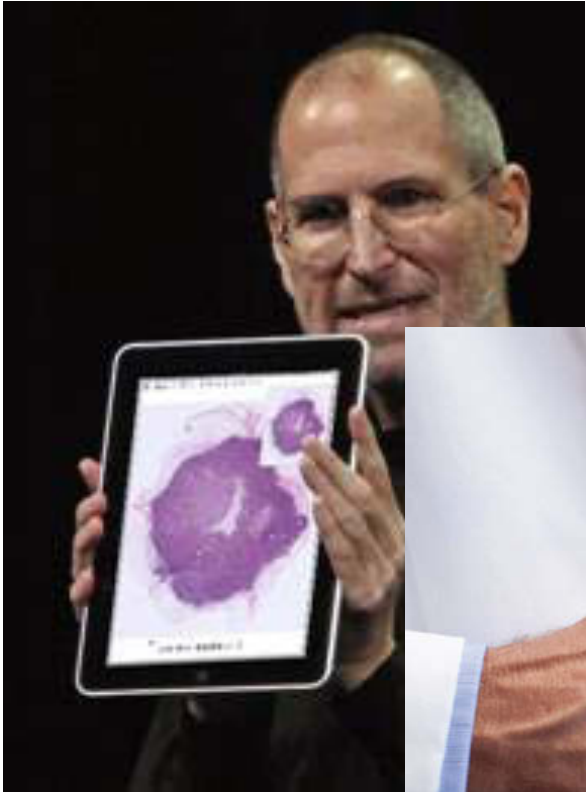
- Understand the traditional roles, challenges and limitations of departmental, enterprise and cross-enterprise PACS
- Identify contemporary forces impinging on PACS choice, migration, design and deployment, including IS consolidation, EHR integration, provider and patient access, advanced quantitative applications, and document integration
- Discuss alternatives to traditional PACS, including the role of Vendor-Neutral Archives and Universal Zero Footprint Viewers, "deconstruction", and other buzzwords of choice
- Review the role of DICOM and IHE standards (or not) in this evolution













PACS Beginnings

- Lemke, 1979
 - “A Network of Medical Workstations for Integrated Word and Picture Communication in Medicine”
- Capp, 1981
 - “Photoelectronic Radiology Department”



1982 - “The year of the PACS”

- First International Conference and Workshop on Picture Archiving and Communications Systems, SPIE, Newport Beach
- First International Symposium on PACS and PHD (Personal Health Data), Japan Association of Medical Imaging Technology



What does PACS mean?

- Physics and Astronomy Classification Scheme
- Political Action Committee(s)
- Pan-American Climate Studies

- Picture Archiving and Communication System



What has PACS meant?

- Multi-modality digital acquisition
- Storage (current, archival, local, off-site)
- Distribution, locally and remotely
- Display (diagnostic and review)
- Reporting creation, distribution, storage
- Workflow management
- Integration with other information (systems)



What did PACS mean in 1982 ?

- Pretty much the same
- Less ambitious in scope
- Not all modalities (CR not yet available)
- More emphasis on storage, transfer and display than workflow
- No standards, but recognition of the need for them
- Relatively impractical given technology of the day
- A grand vision for the future



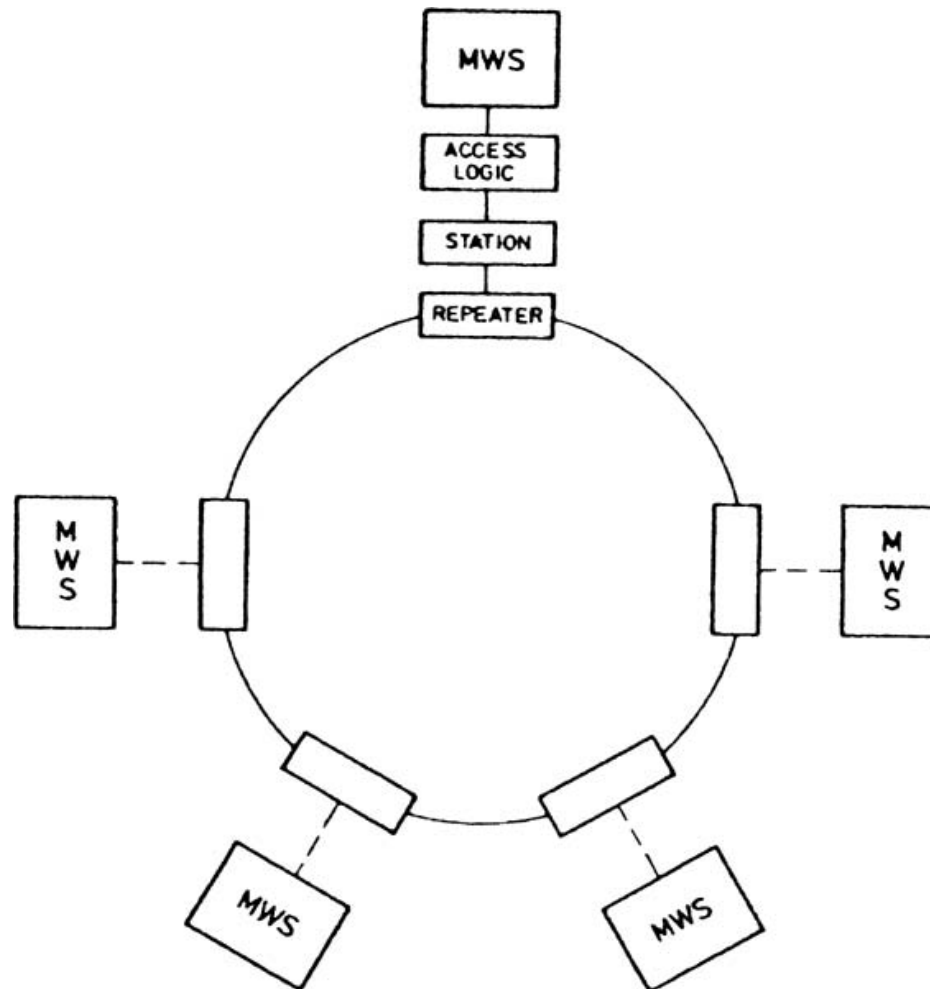
What does PACS mean today?

- Multi-modality digital acquisition
- Storage (current, archival, local, off-site)
- Distribution, locally and remotely
- Display (diagnostic and review)
- Reporting creation, distribution, storage
- Workflow management
- Integration with other information (systems)
- Enterprise wide (multi-specialty)
- EHR Integration
- Access on mobile devices



Infrastructural trends

- Home grown components, all local
- Commercial purchase – monolithic solution
- Commoditization – all vendors similar
- Factor out network and storage (NAS, SAN)
- Sharing enterprise IT infrastructure
- Workstation -> PC -> Web browser viewer
- Proprietary -> DICOM -> HTTP protocols
- Factor out archive (VNA) & viewer
- “Zero footprint” “universal” viewers



Lemke, 1979 – Ring of medical work stations (MWS's)

The photoelectronic radiology department of the future

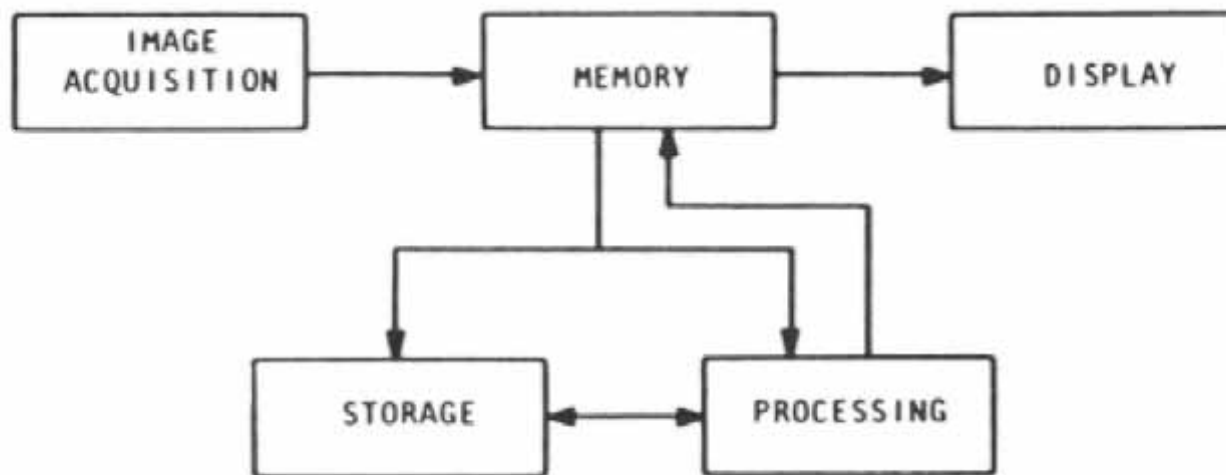


Figure 7. Elements of a photoelectronic-digital radiology department.

Capp, 1981

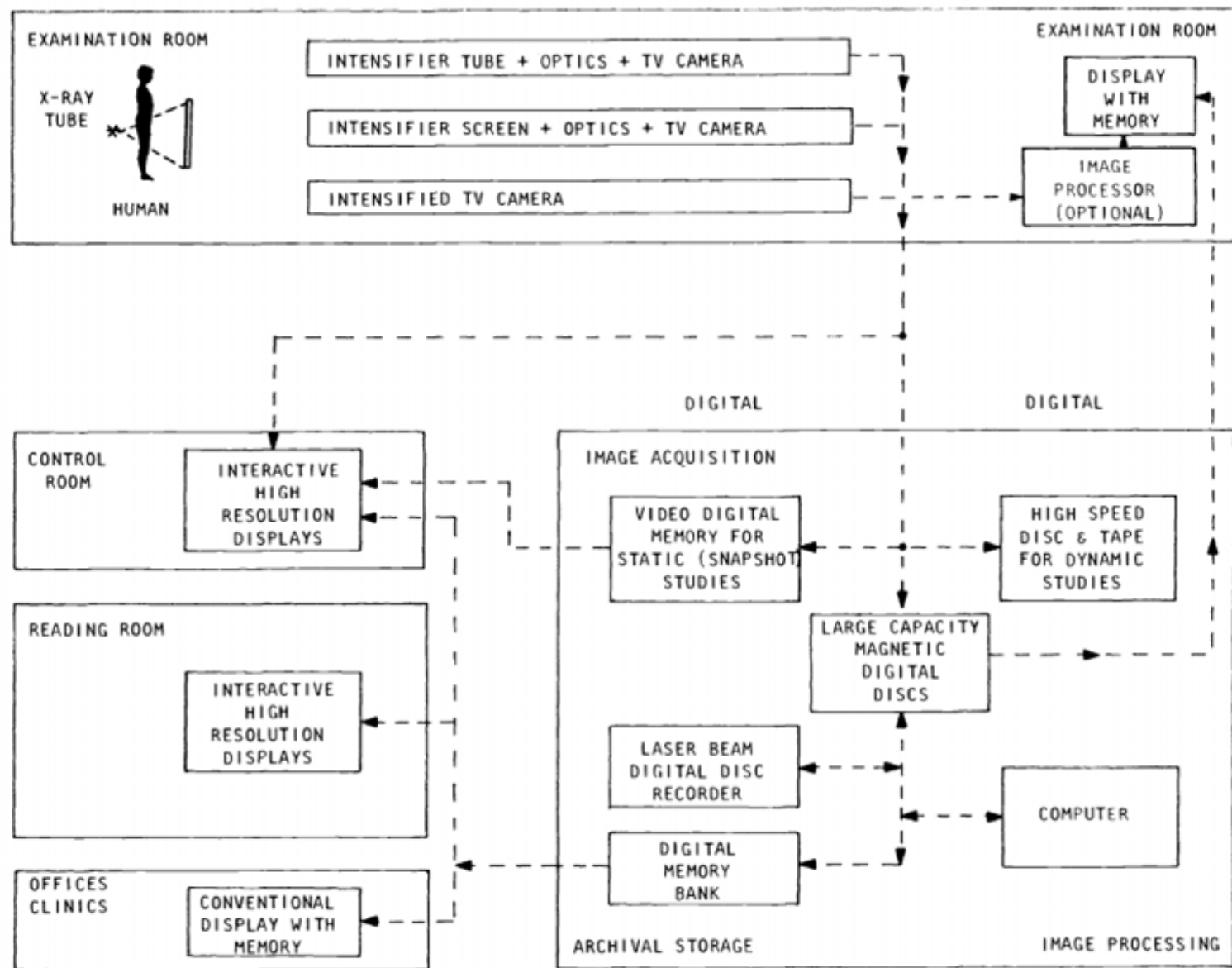
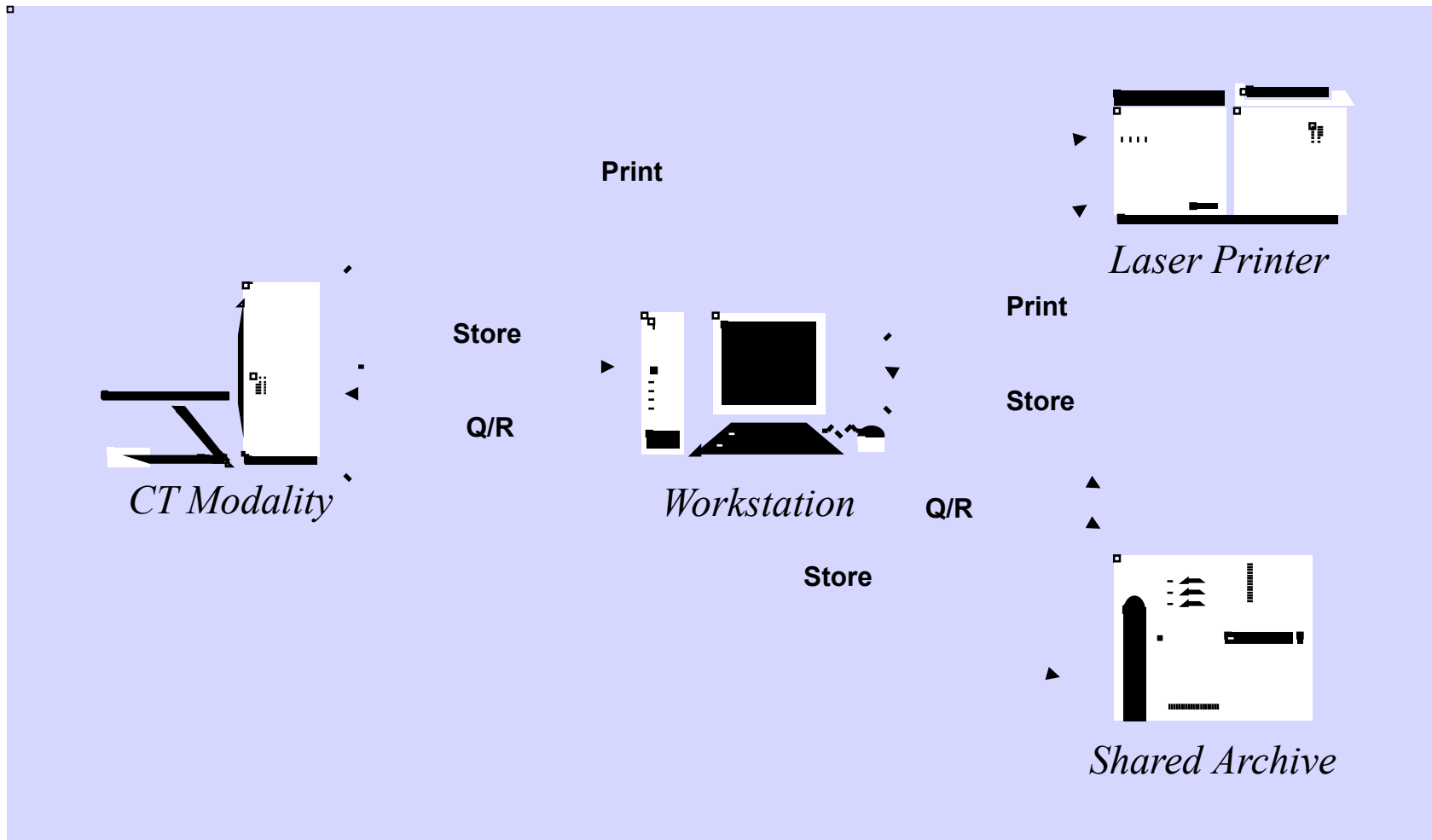
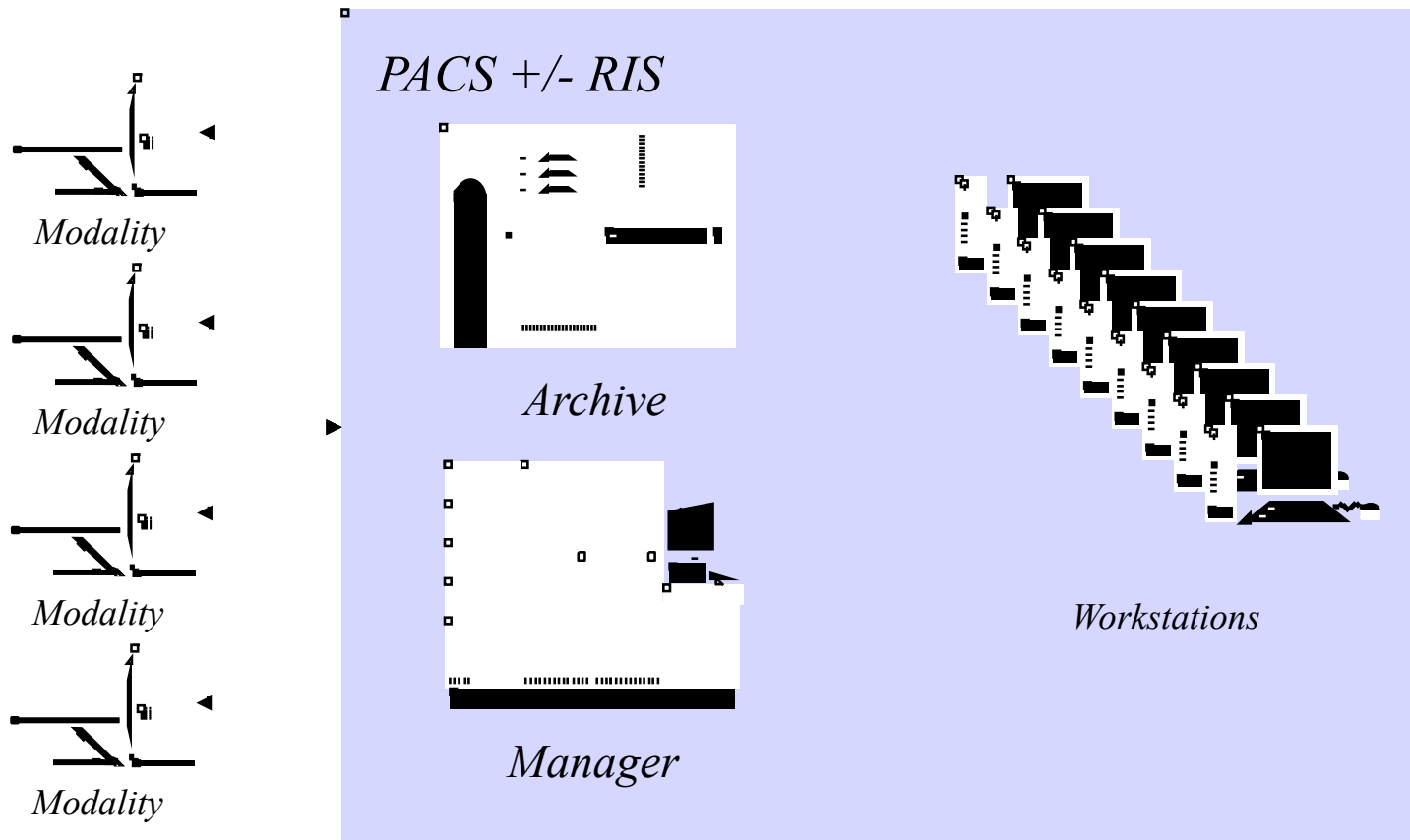


Figure 8. Schematic of a photoelectronic radiology department which electronically disseminates imaging data to other locations:

DICOM Cluster or Mini-PACS

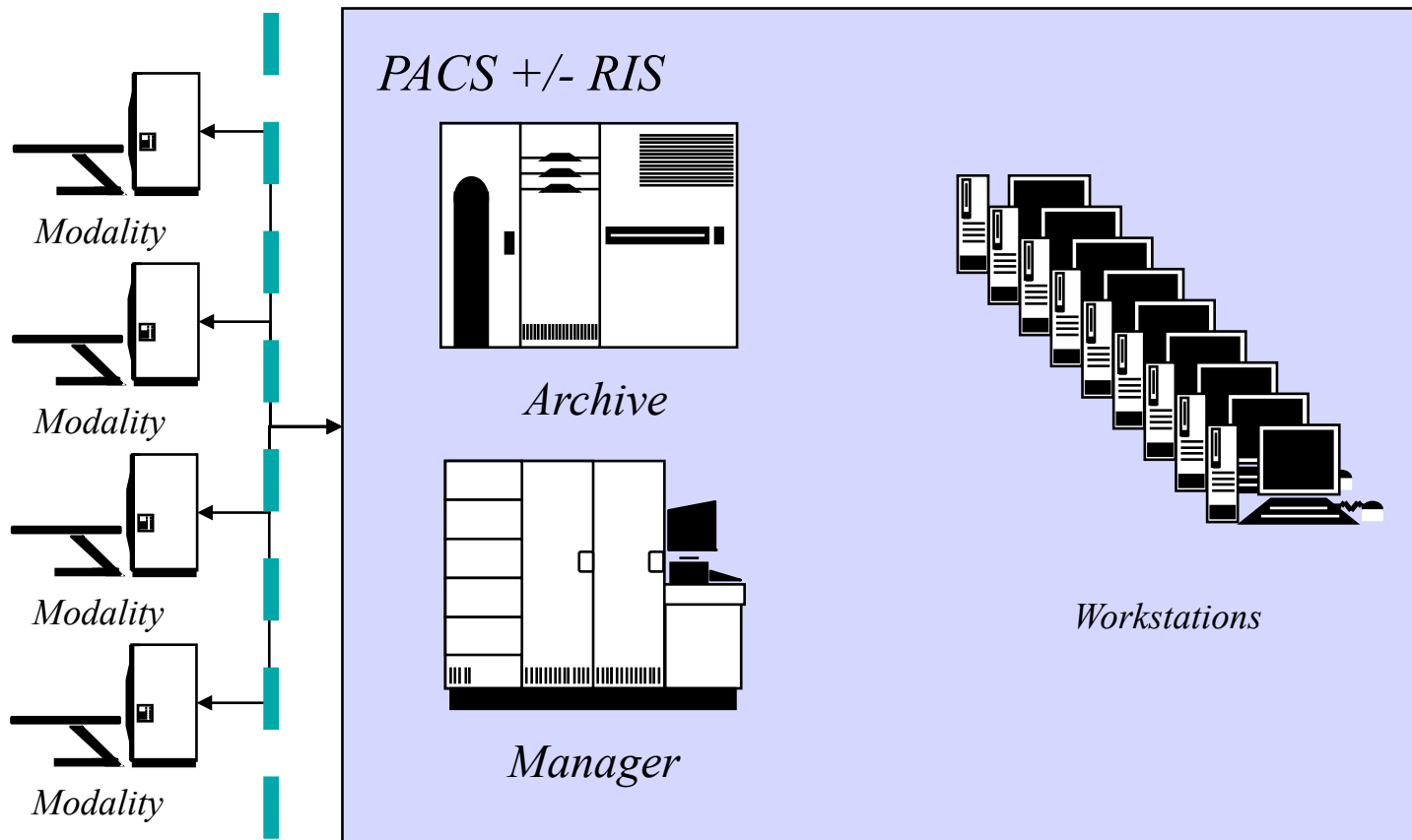


Basic PACS Components

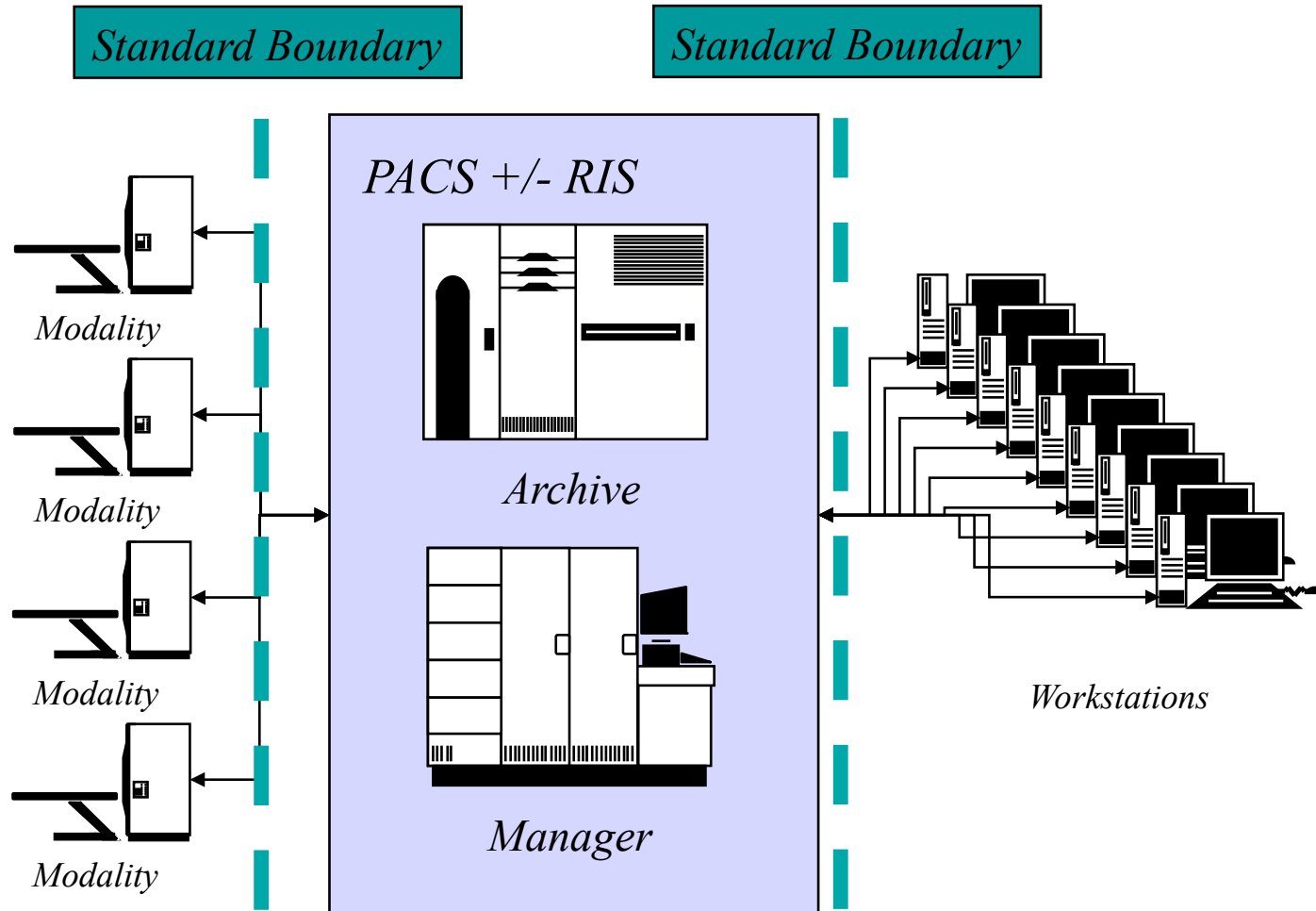


Monolithic + DICOM Modalities

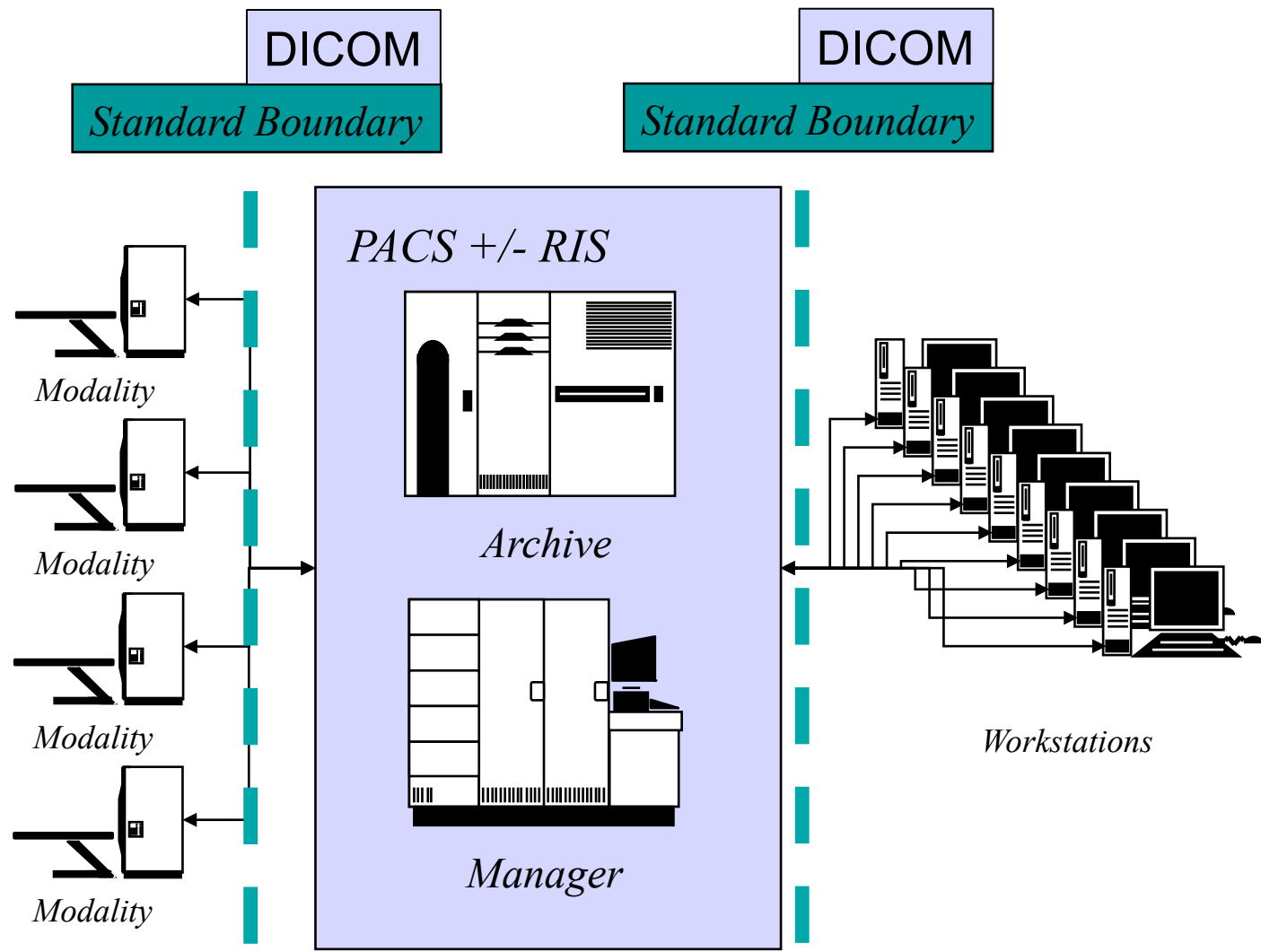
Standard Boundary



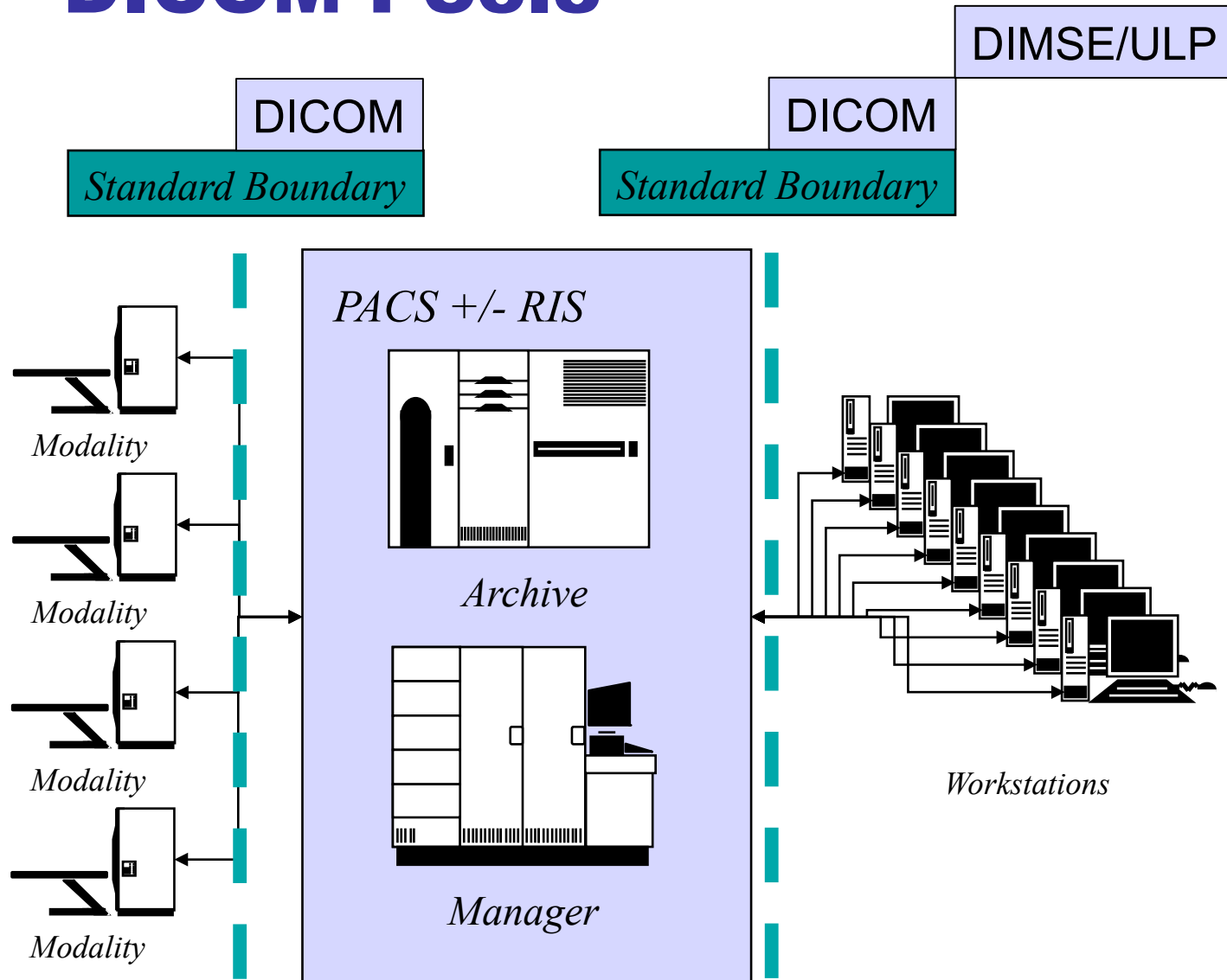
Workstation Interface



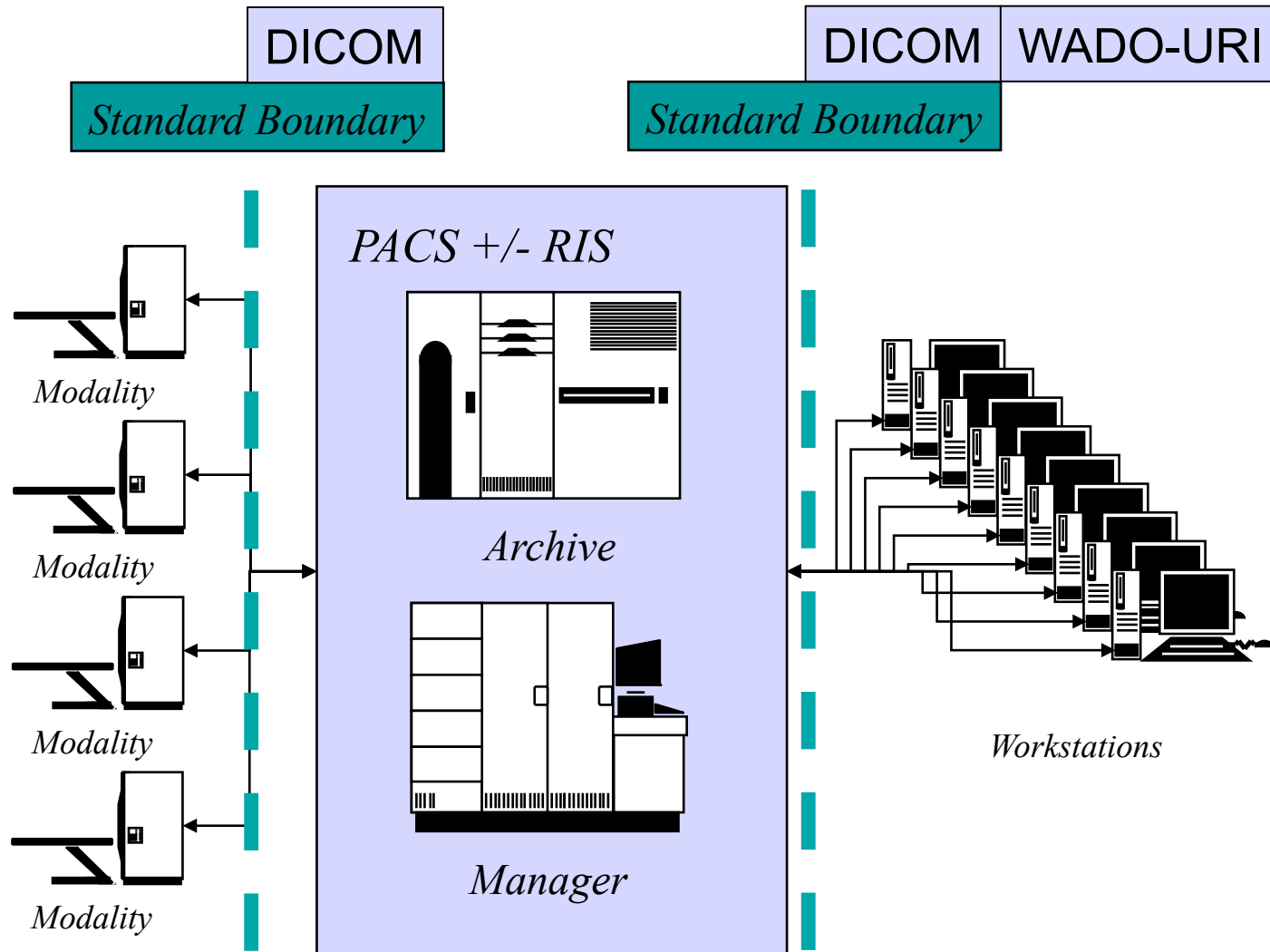
DICOM Standard Interface



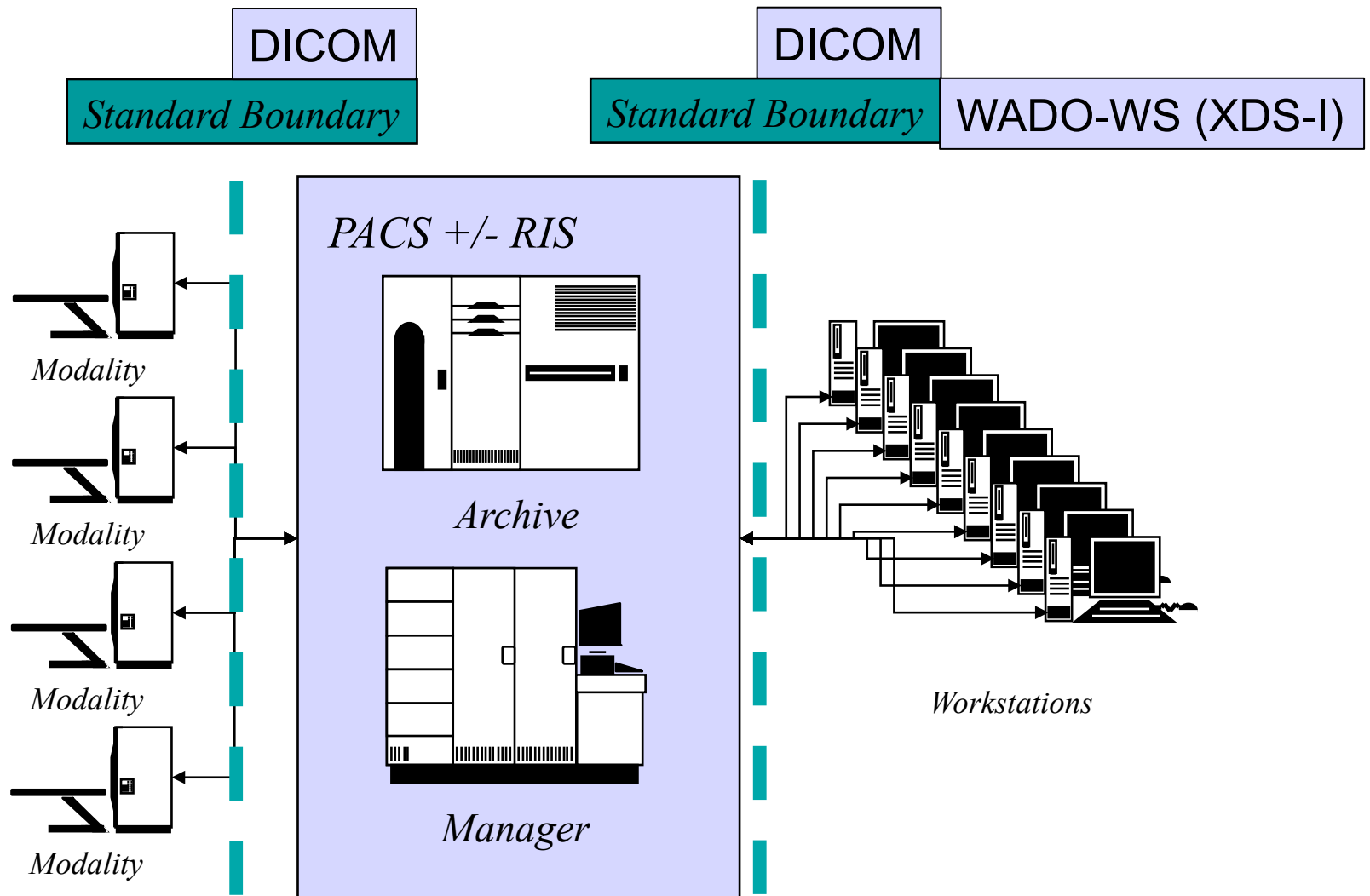
DICOM PS3.8



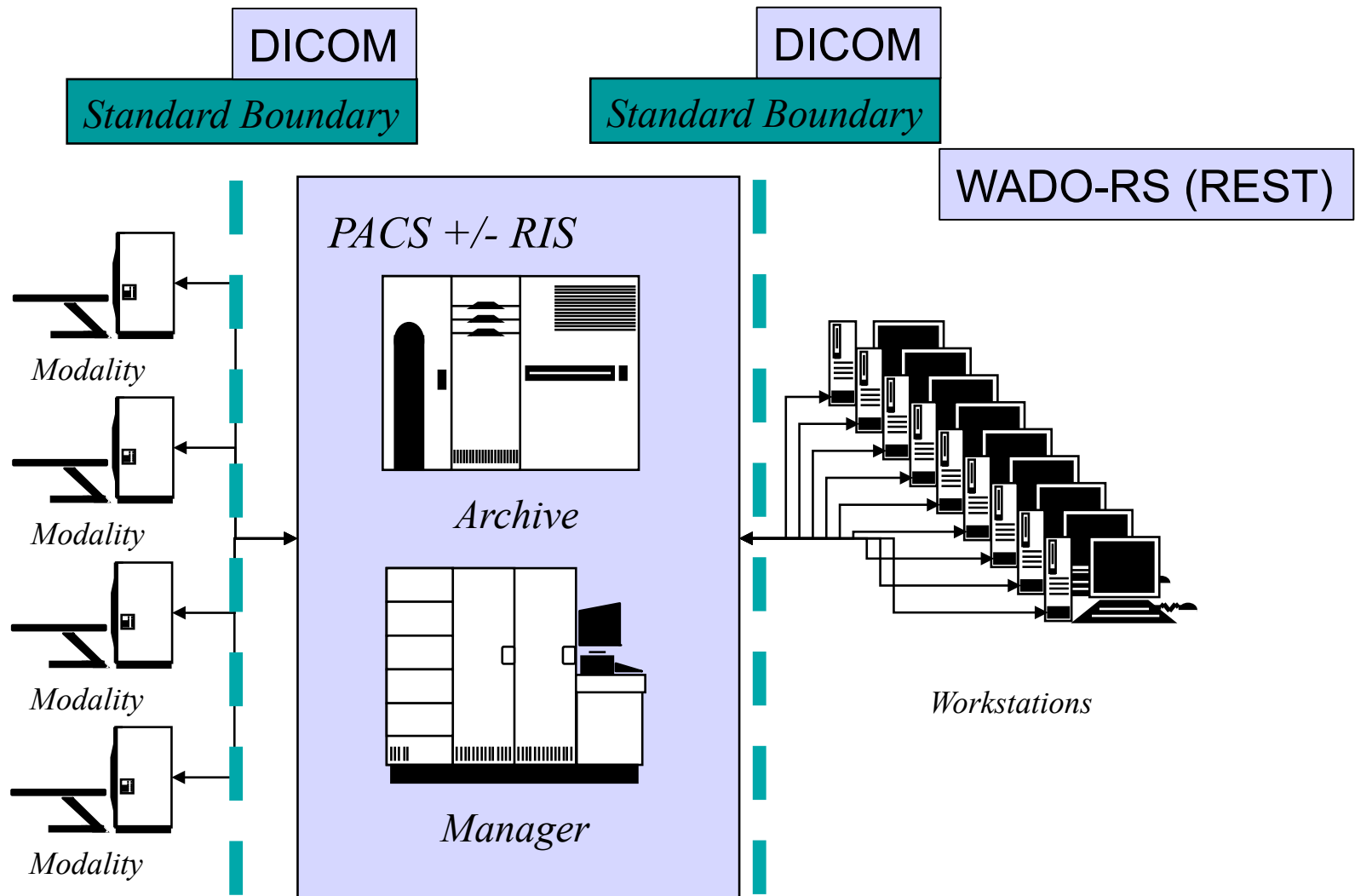
Web Access to DICOM Objects



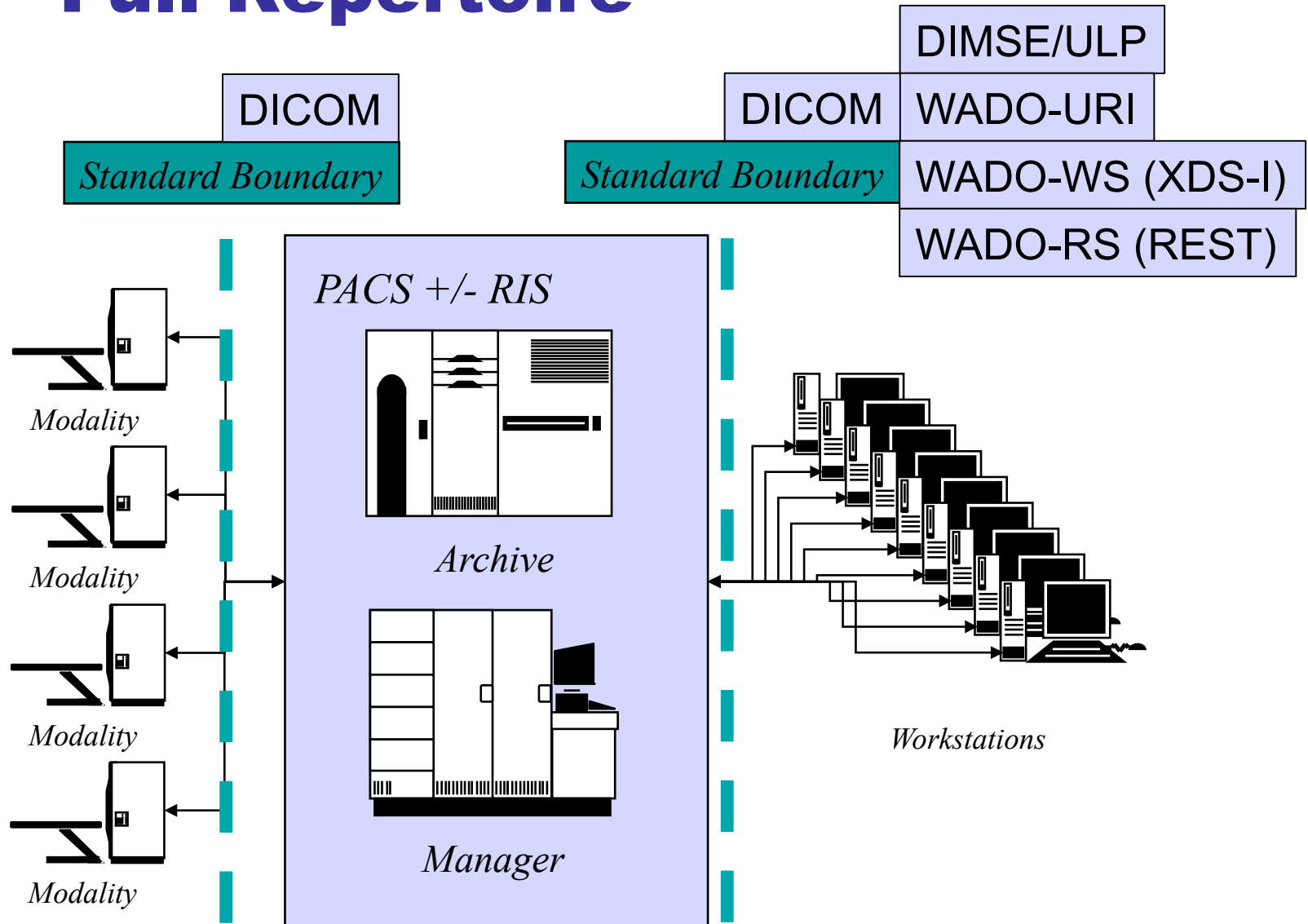
DICOM WS (SOAP)(IHE XDS-I)



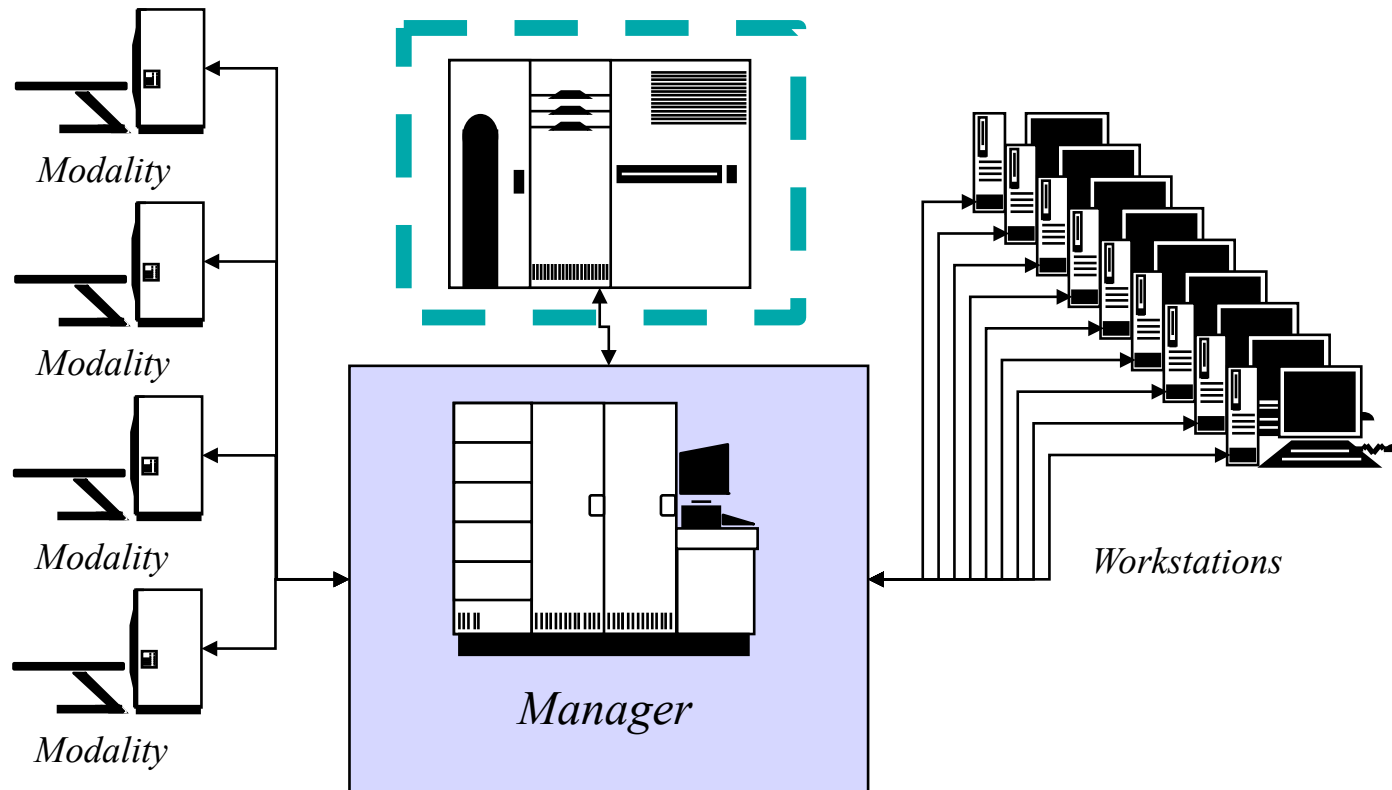
WADO-RS (RESTful)



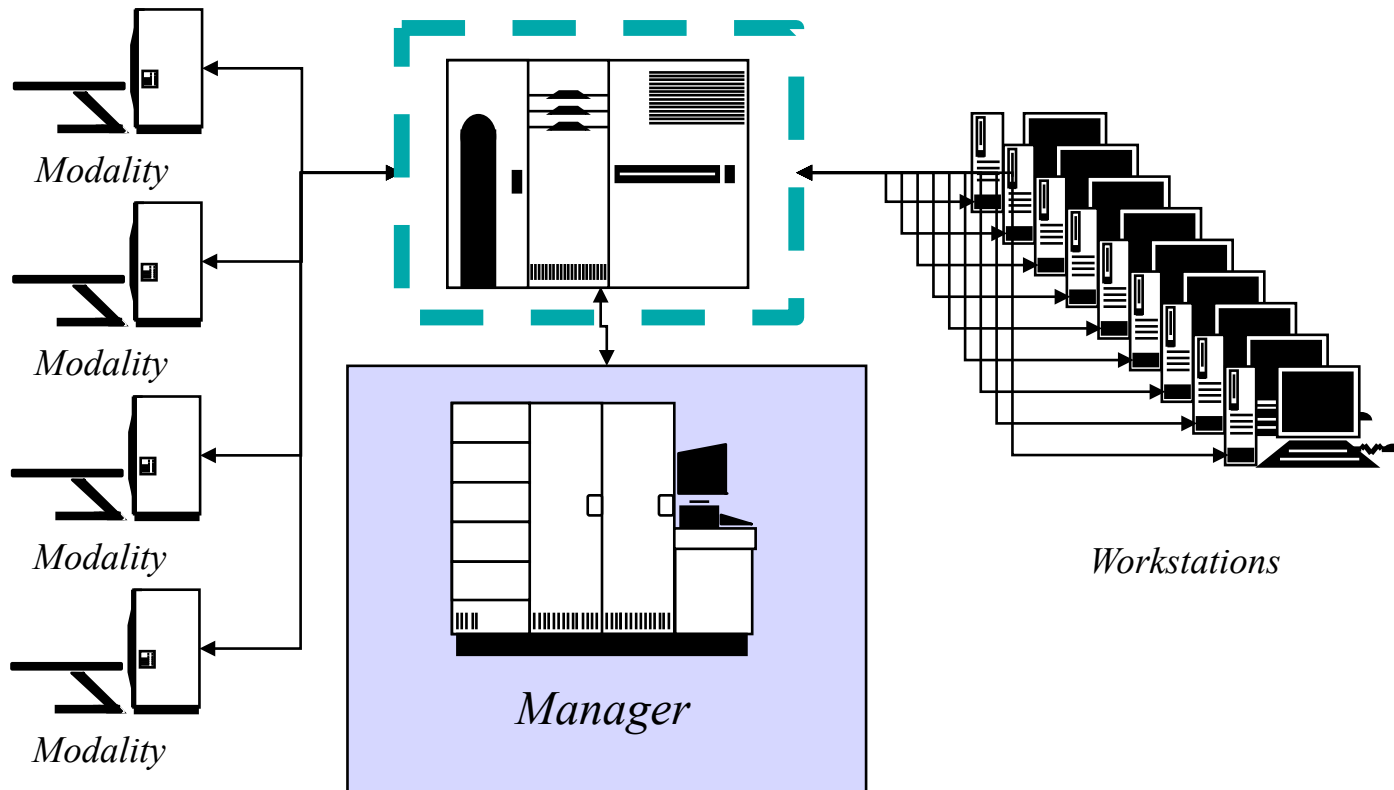
Full Repertoire



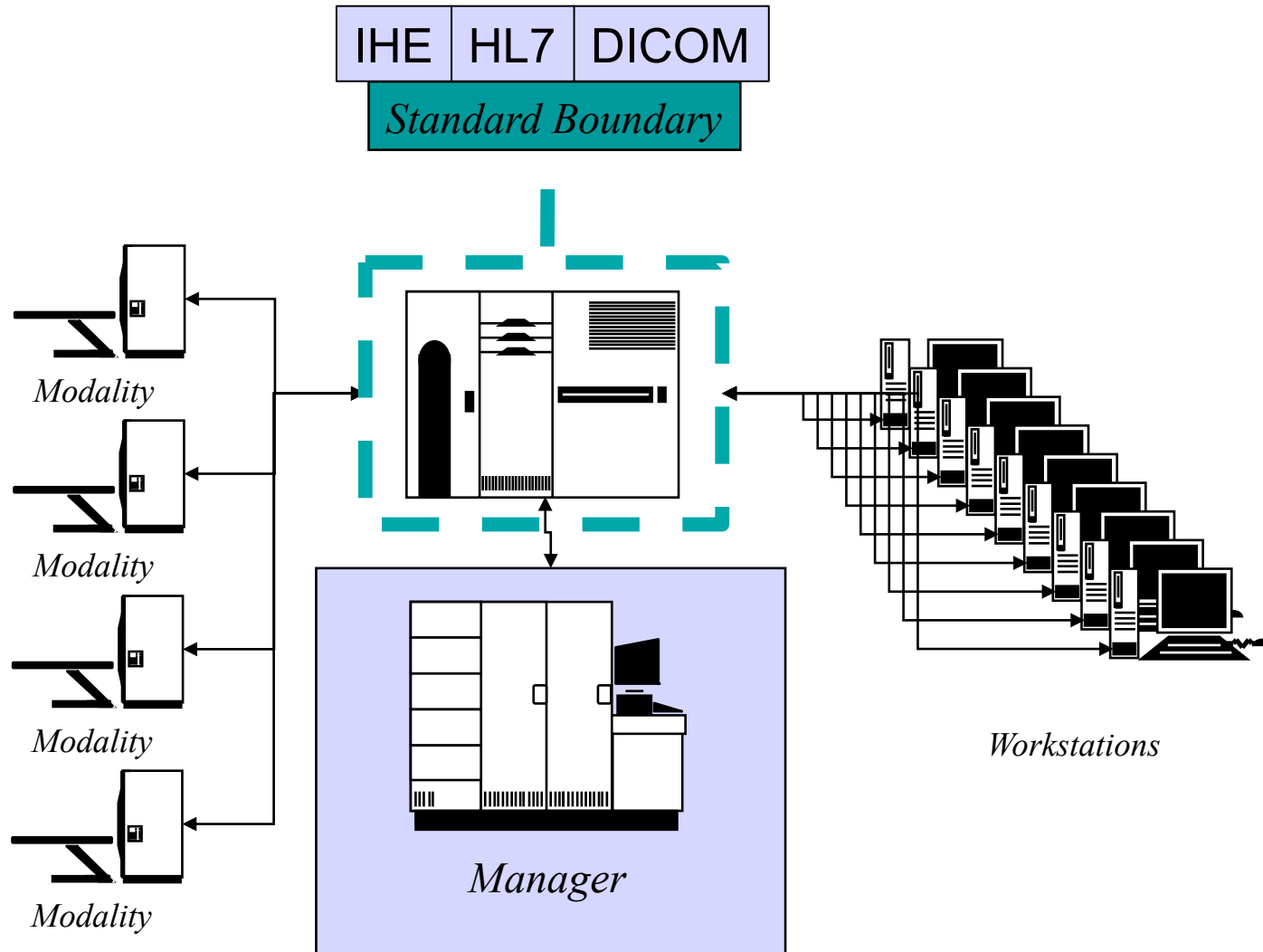
Vendor Neutral Archive



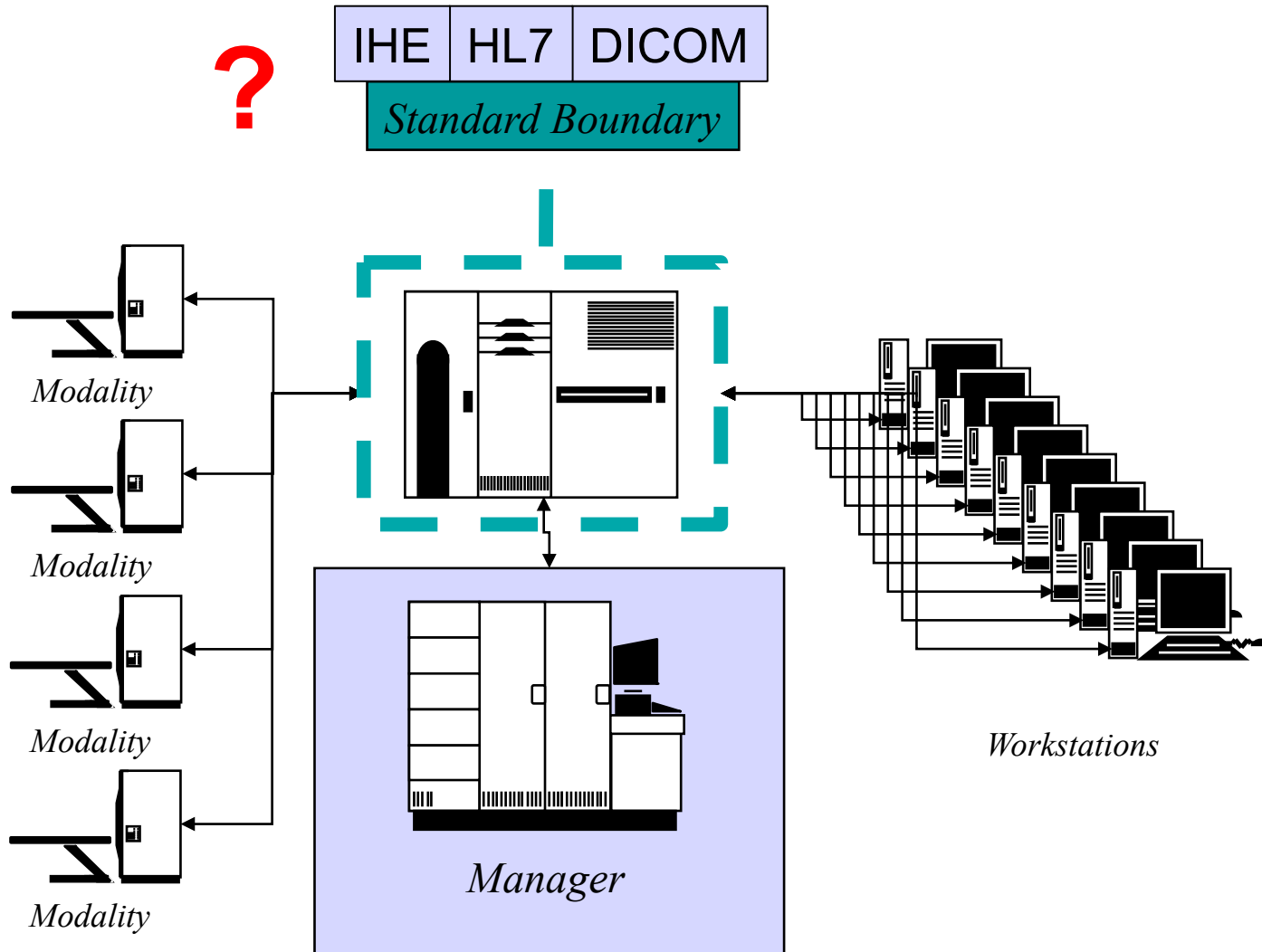
Modality/Workstation <-> VNA



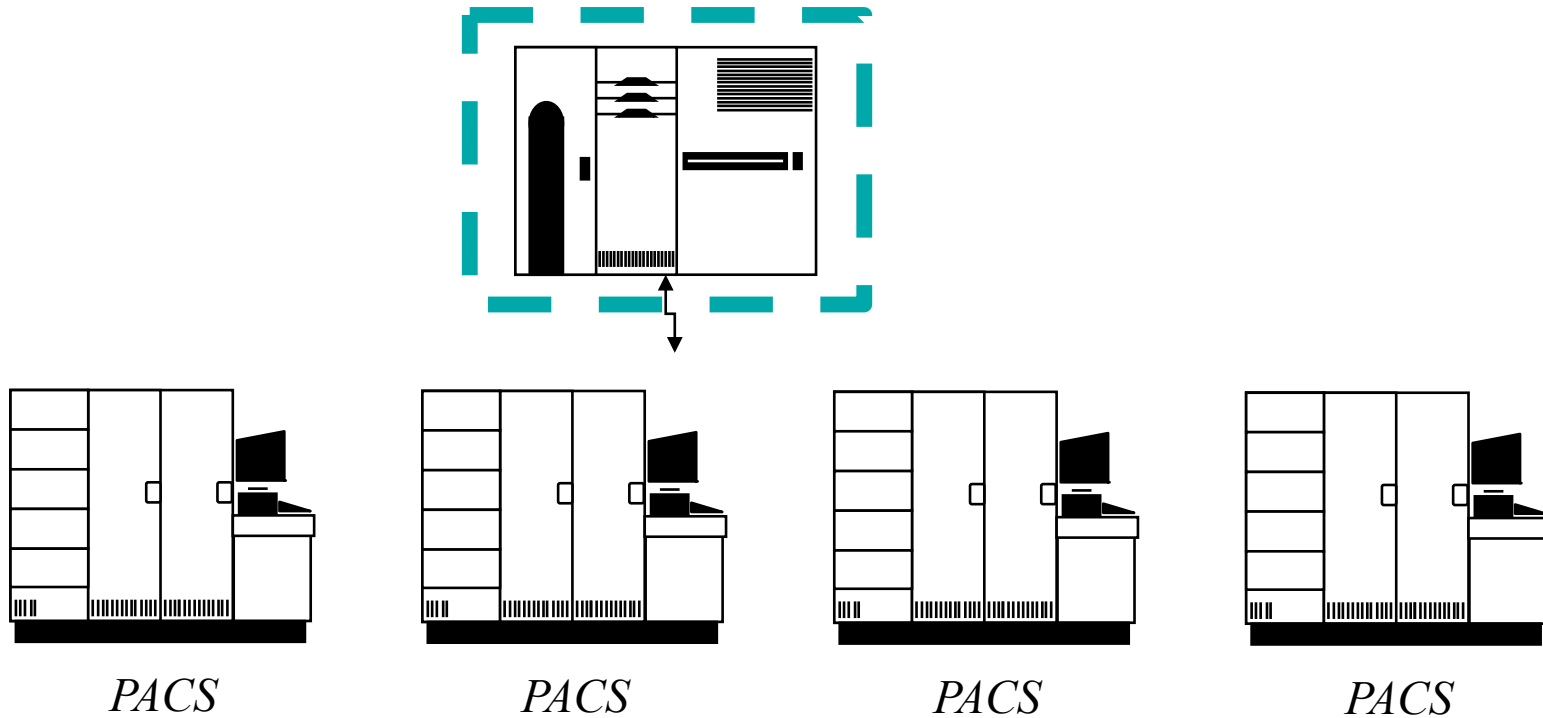
PACS <-> VNA Interface



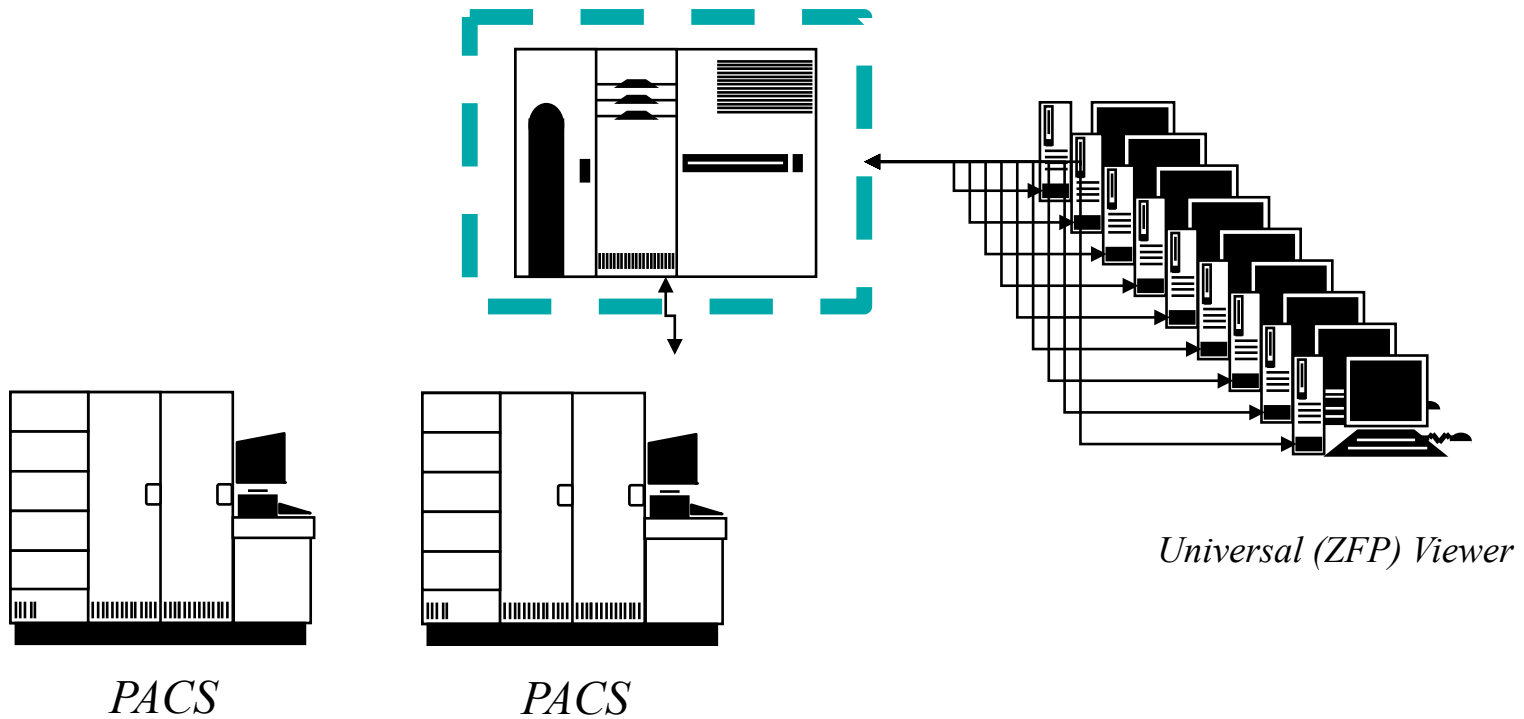
PACS <-> VNA Interface



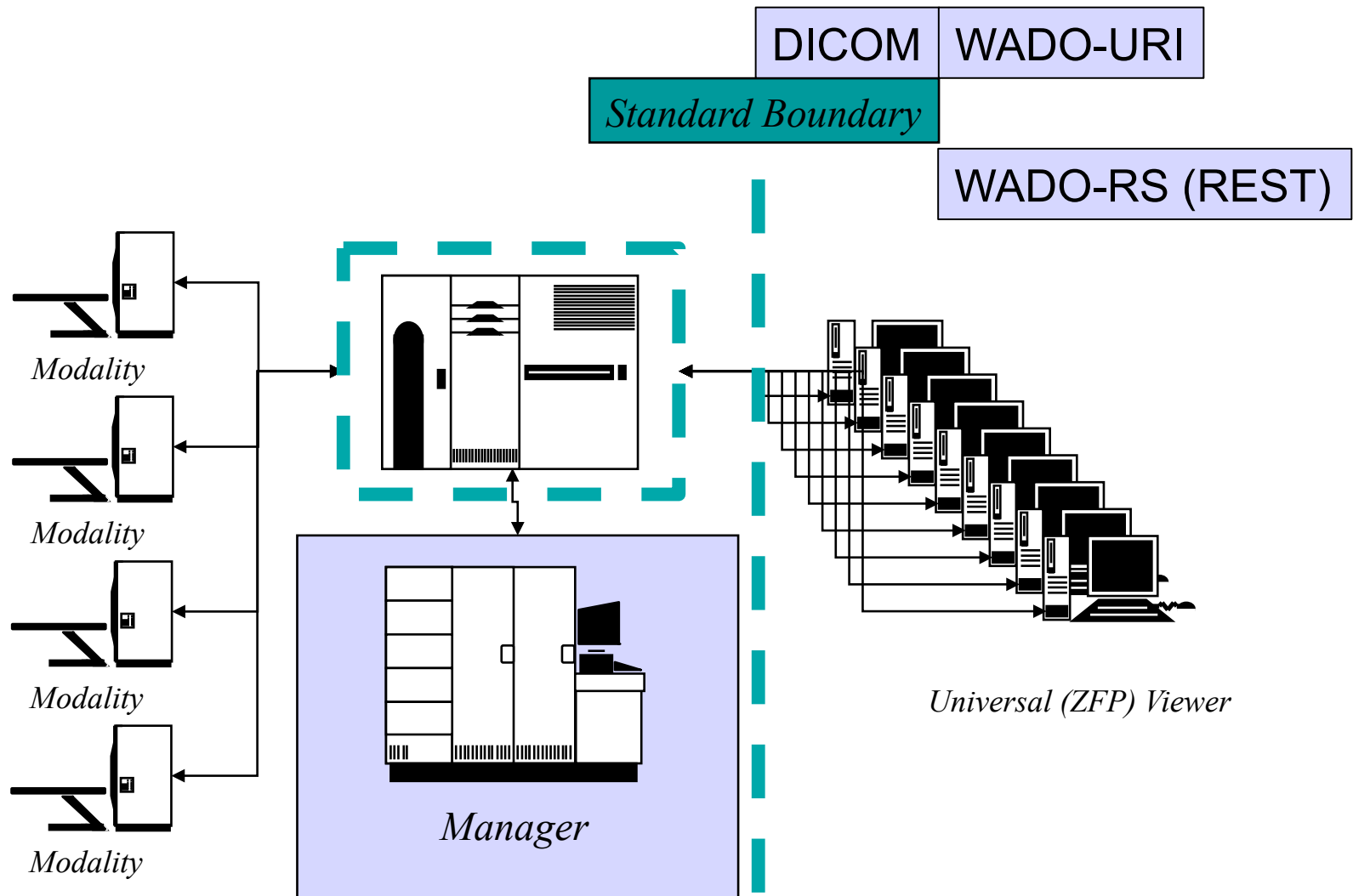
Multiple PACS – One Archive



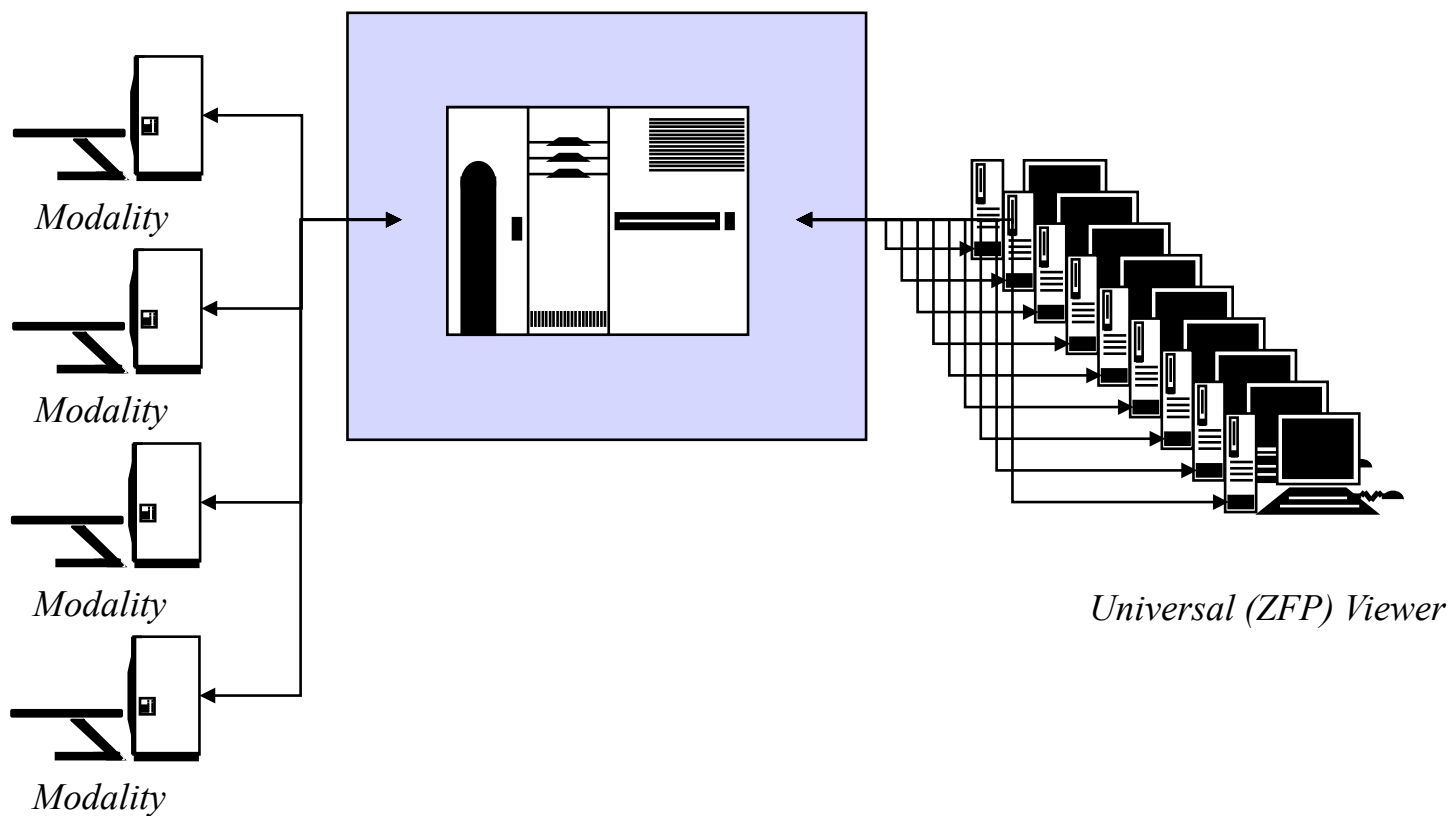
One Archive – Universal Viewer



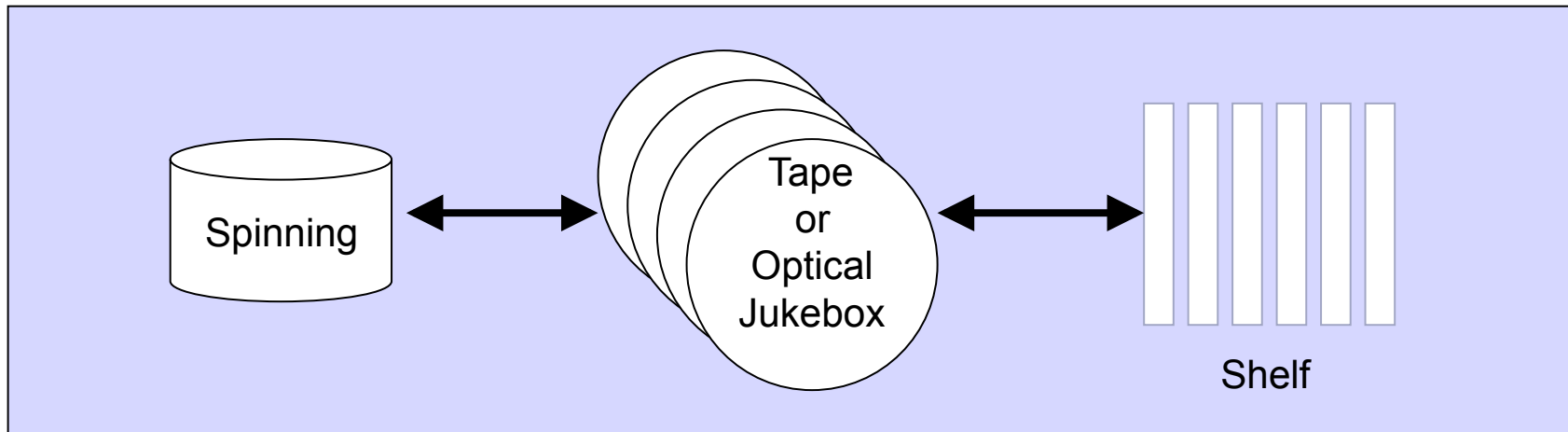
Universal (ZFP) Viewer



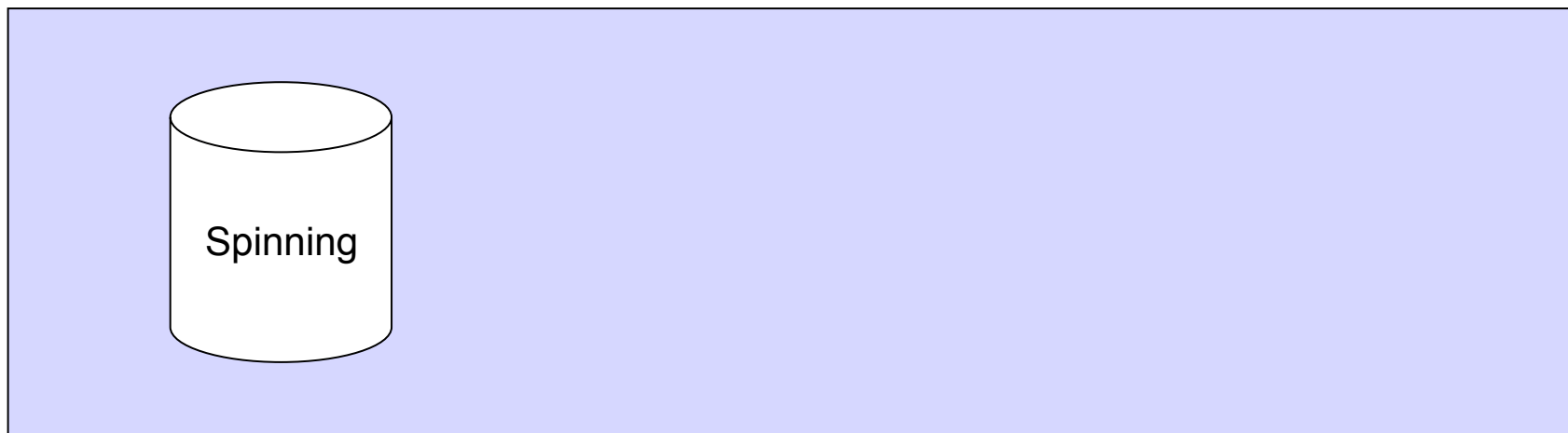
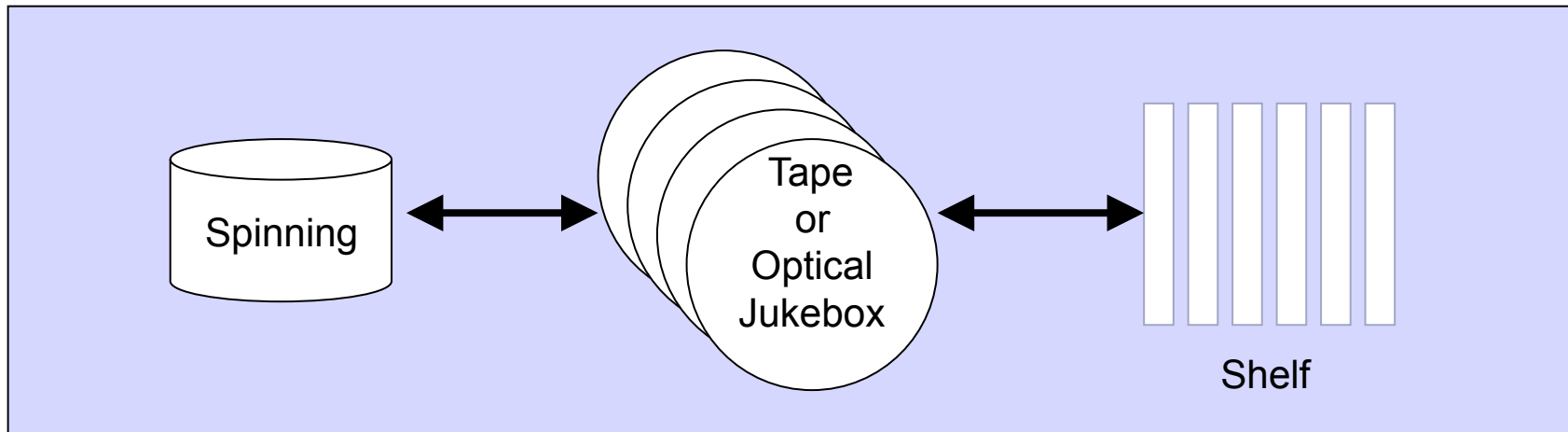
VNA: PACS by any other name



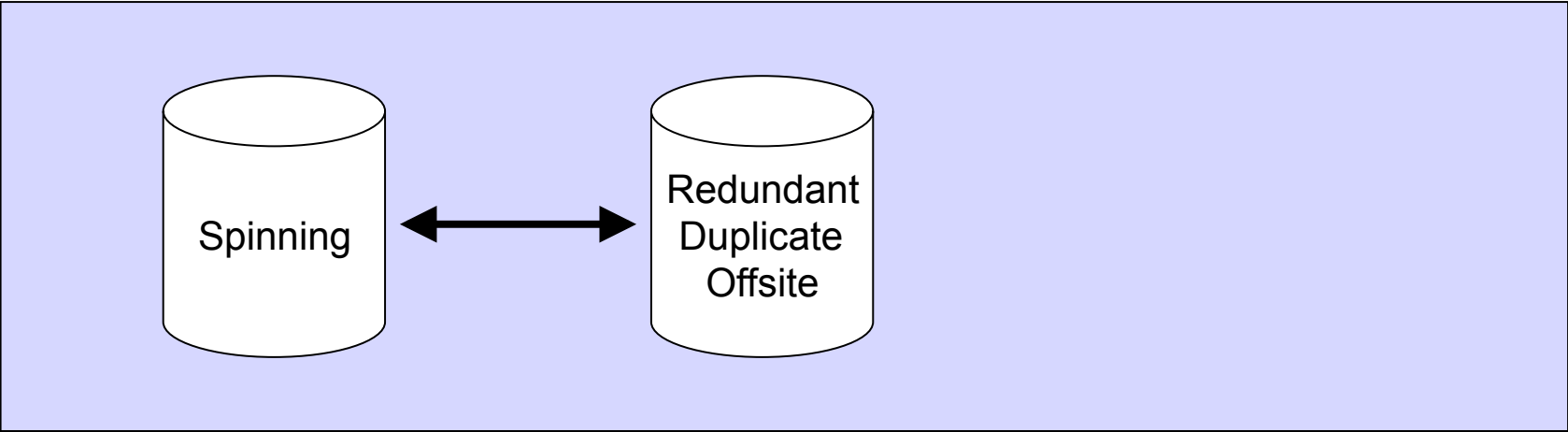
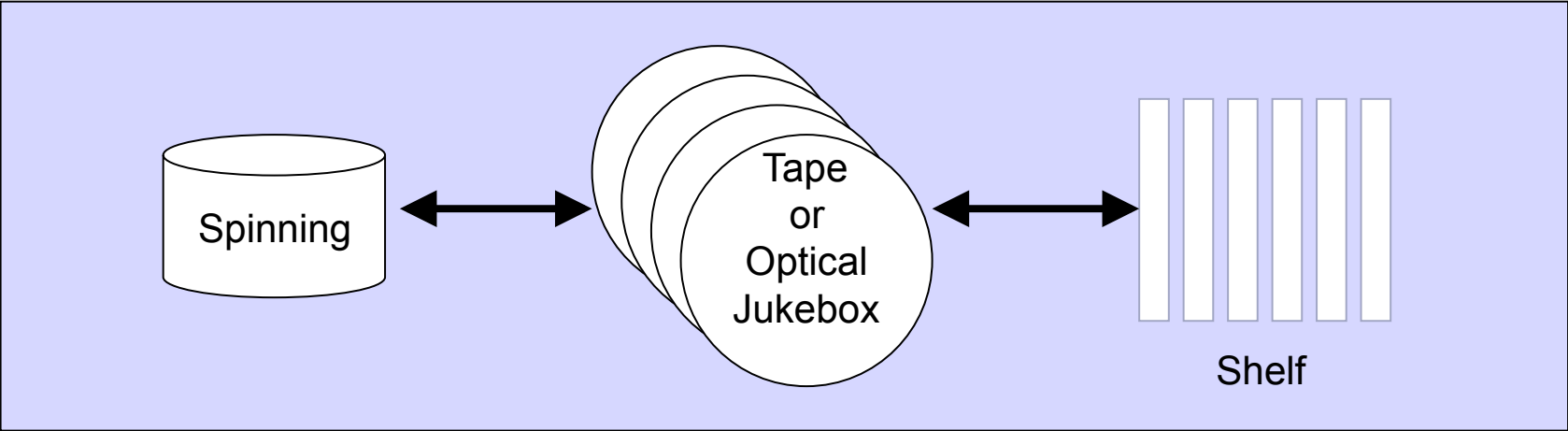
Storage Paradigms



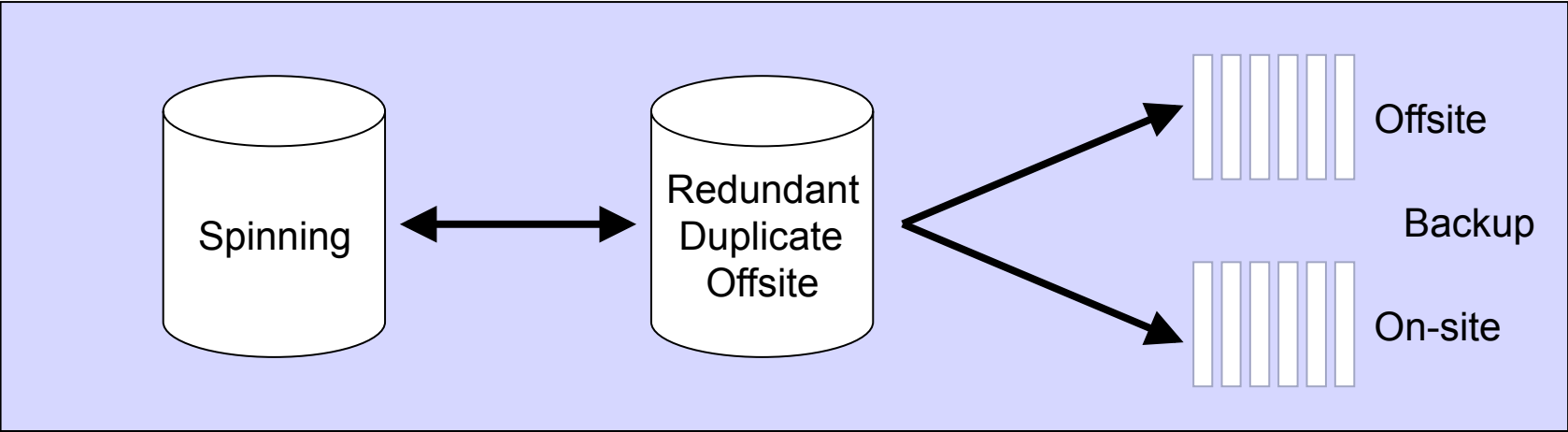
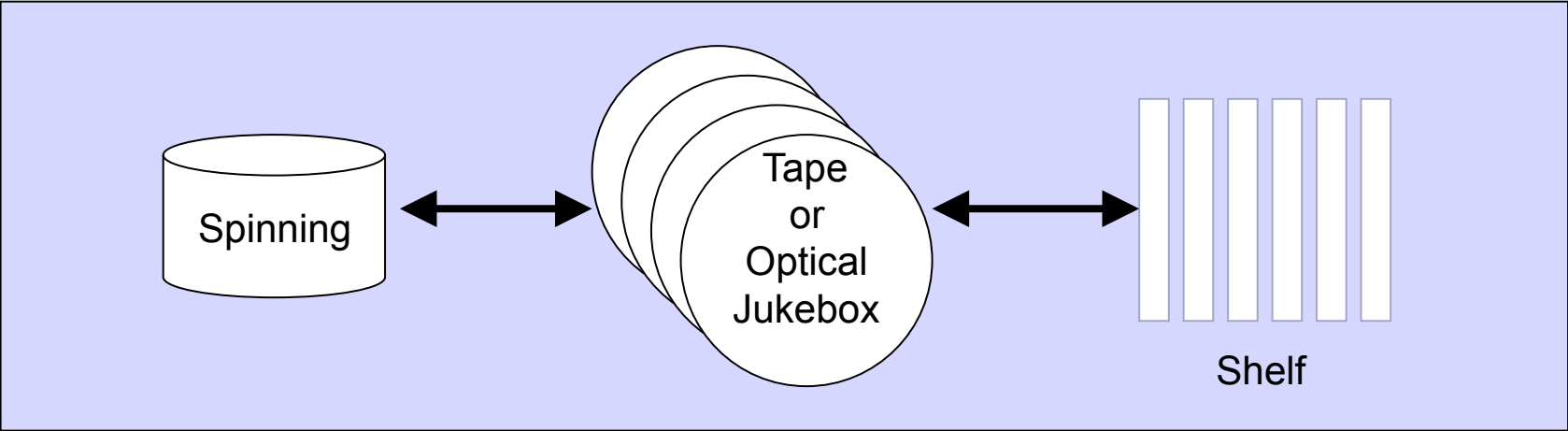
Storage Paradigms



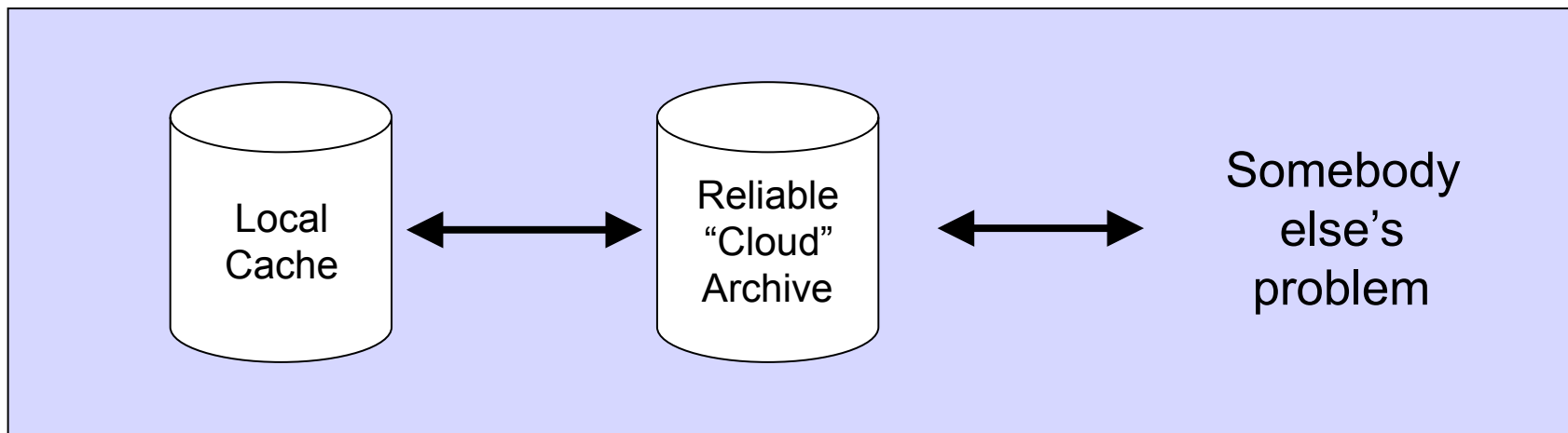
Storage Paradigms



Storage Paradigms

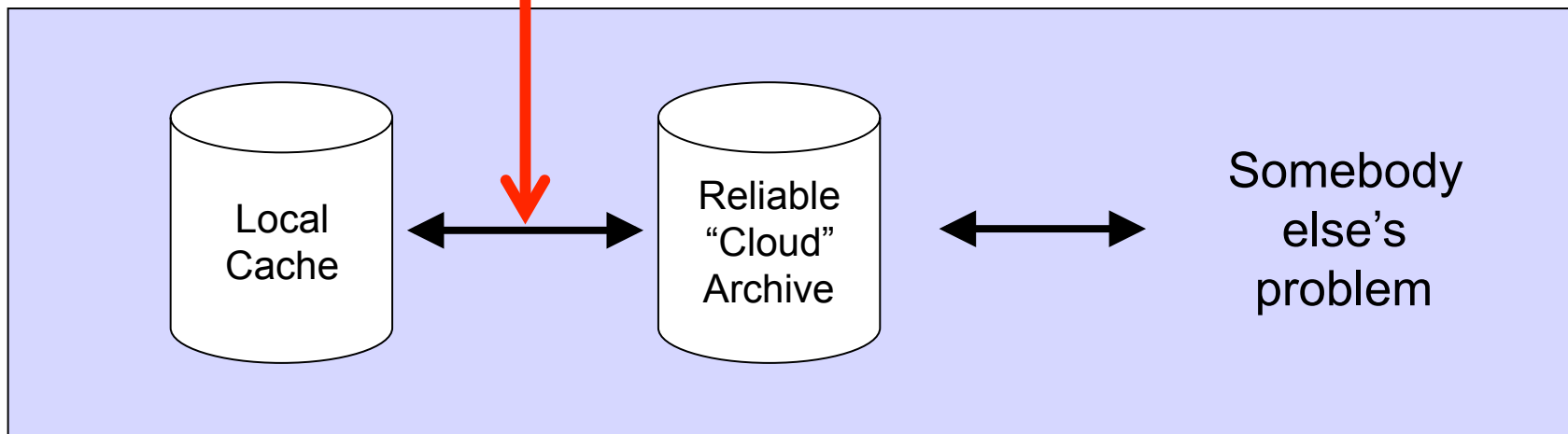


Storage Paradigms



Storage Paradigms

- Cost of (fast) storage
- Cost of bandwidth
- Local versus remote production
- Local versus remote utilization





Zero Footprint Universal Viewer

- Web browser viewer for all types of users
- Zero footprint
 - No helper apps, plugins, applets, Flash or SilverLight
 - Not even any JavaScript ?????
- Absolute zero – HTML pre-5, frames, tables, images
- Almost zero – JavaScript +/- HTML5 Canvas
- Pretending to be zero – Flash (etc.) dependency
- Not zero at all – just fine for many deployments
- Thick client spawned by browser (or EHR “app”)
- “Web-based” PACS & “remote” viewers 1990s



EHRs and Images

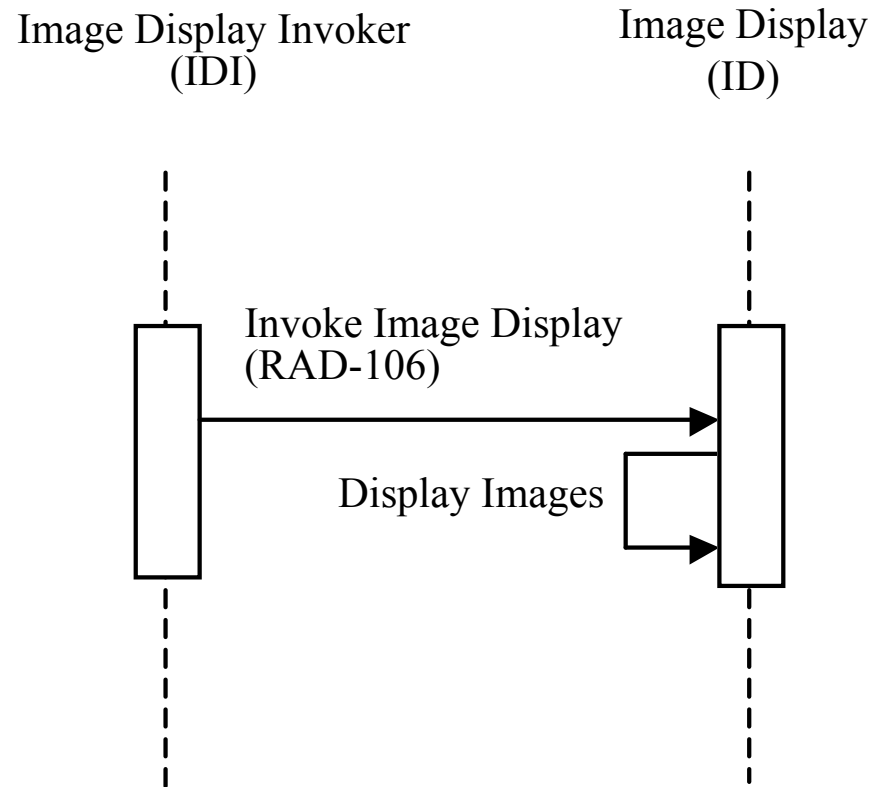
- EHR vendors do NOT want to store images
- Separation of requestor from performer
 - EHR/PHR/etc. user requests viewing of study
 - PACS/VNA/etc. actually performs it
- A “link” - very common proprietary pattern
 - e.g., encrypted URLs – identify, authorize, time-limited
 - n:m permutations of requestor/performer to customize
- Storing fully qualified links (URLs) – go stale
- Common identifiers, dates, etc. more reliable
- IHE Invoke Image Display (IID) profile (new)
 - standard display request – now only n+m permutations



IHE Invoke Image Display

- A minimalist means of image-enabling non-image-aware systems
- Uses simplest available HTTP-based request
- Supports patient and study level invocation
- Usable with or without a priori knowledge of individual study identifiers
- Requires servers to provide at request of the user
 - interactive viewing
 - review or diagnostic quality
 - key images only
- Independent of how/where server gets/stores the images
- Any mutually agreed HTTP security mechanism

IHE IID – Process Flow





Mobile Device Considerations

- Relatively limited memory/CPU/network bandwidth
- Assuming that mobile devices are used only for low quality use cases is not valid – e.g., are now some FDA-cleared mobile “apps”
- RESTful versus SOAP for protocol
- JSON versus XML for meta data
- Not all browsers HTML5/Canvas yet
- New crop of MHD standards mirroring XDS
- Payload: DICOM v. JPEG v. proprietary
- Protocol: DICOM v. WADO v. proprietary
- Viewing environment and display quality (FDA)
- One day all viewing will be on mobile devices?

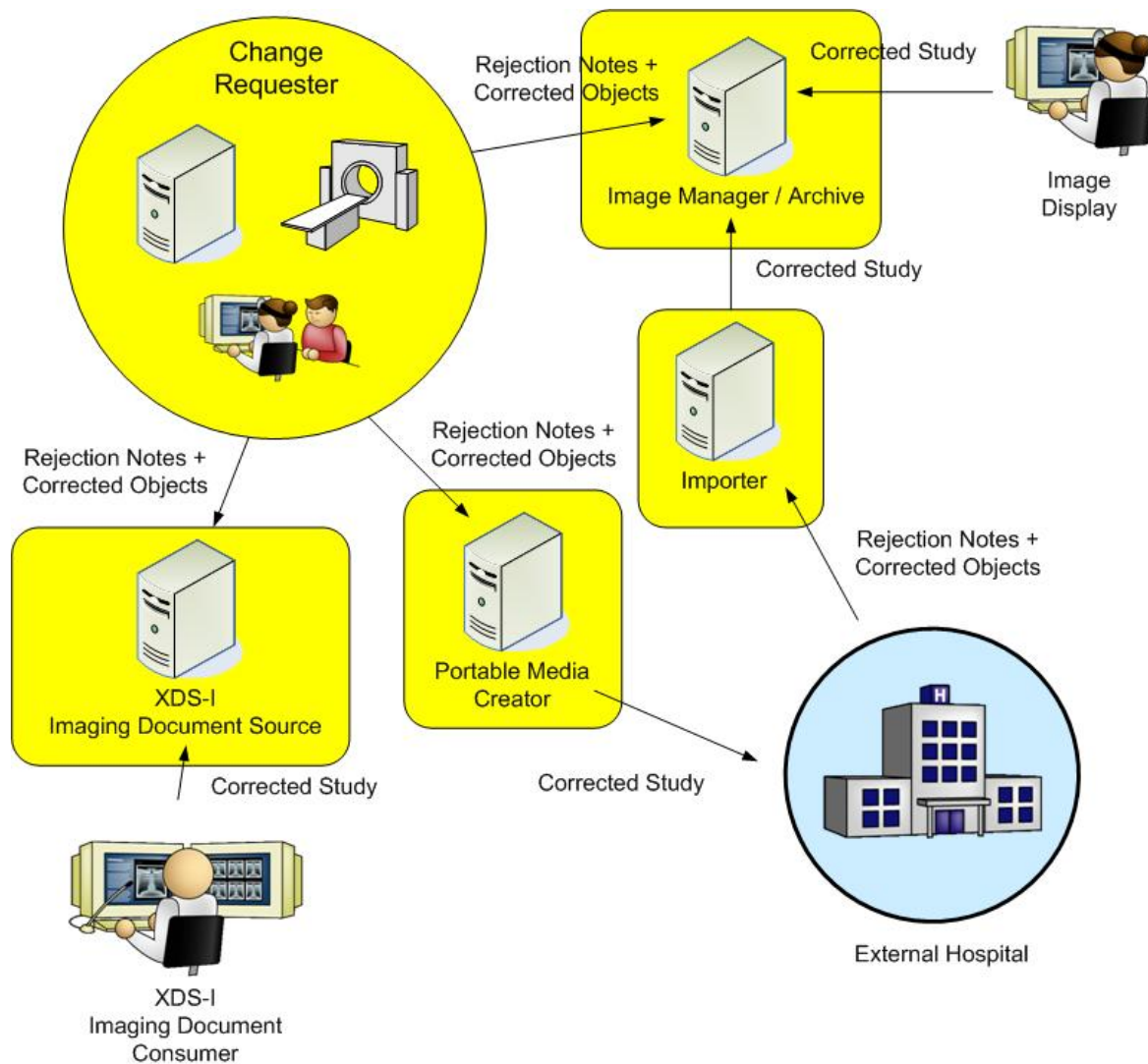




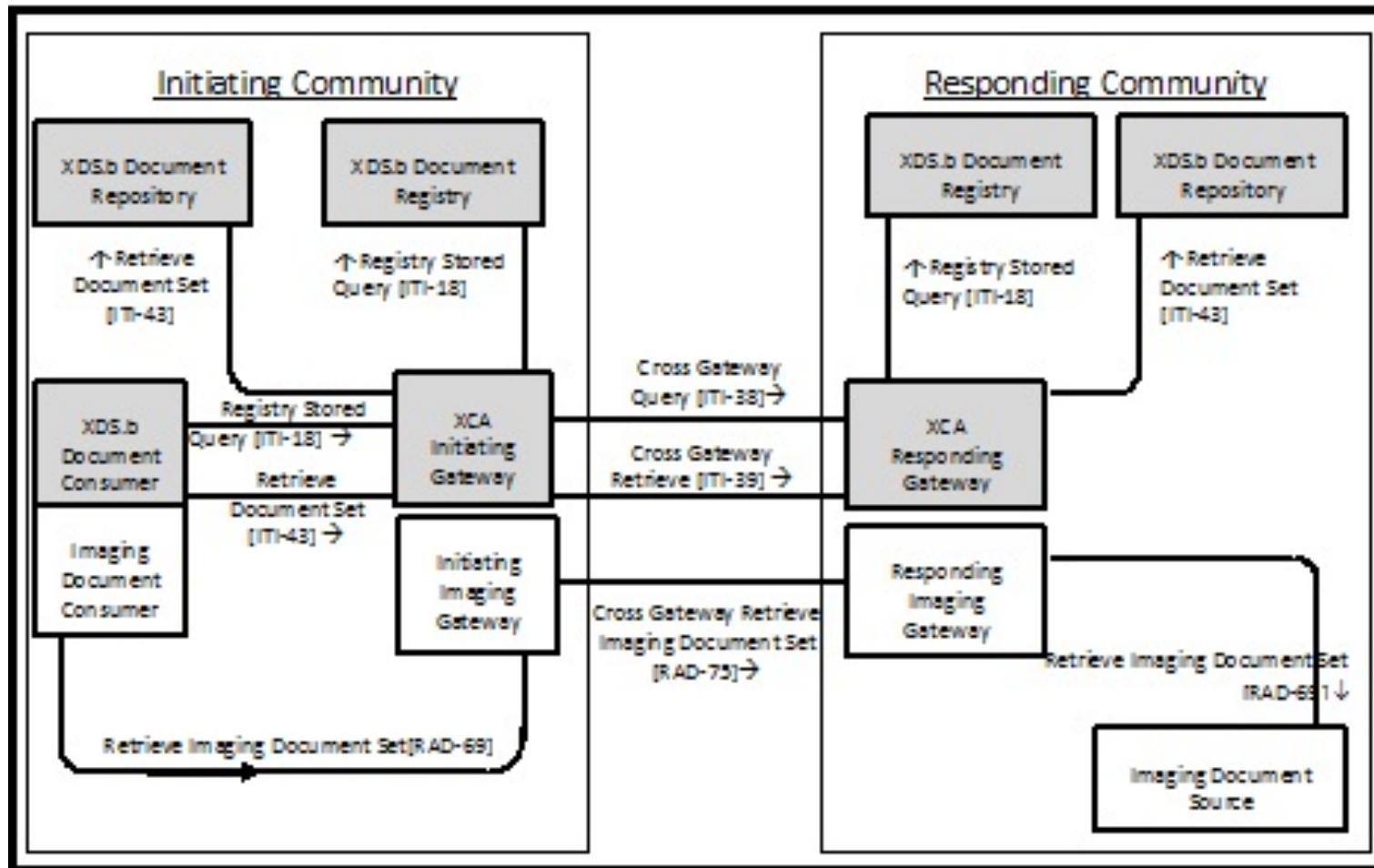
Special Considerations

- Change management
 - deletion, correction
 - life cycle management (purge, expire)
 - IHE Imaging Object Change Management (IOCM)
- Cross-enterprise
 - protocol (DICOM, WADO, XDS-I.b)
 - payload (DICOM images)
 - identifiers (patient ID, accession#), codes
 - PACS <-> PACS, PACS <-> central repository
 - IHE Multiple Image Manager Archive (MIMA)

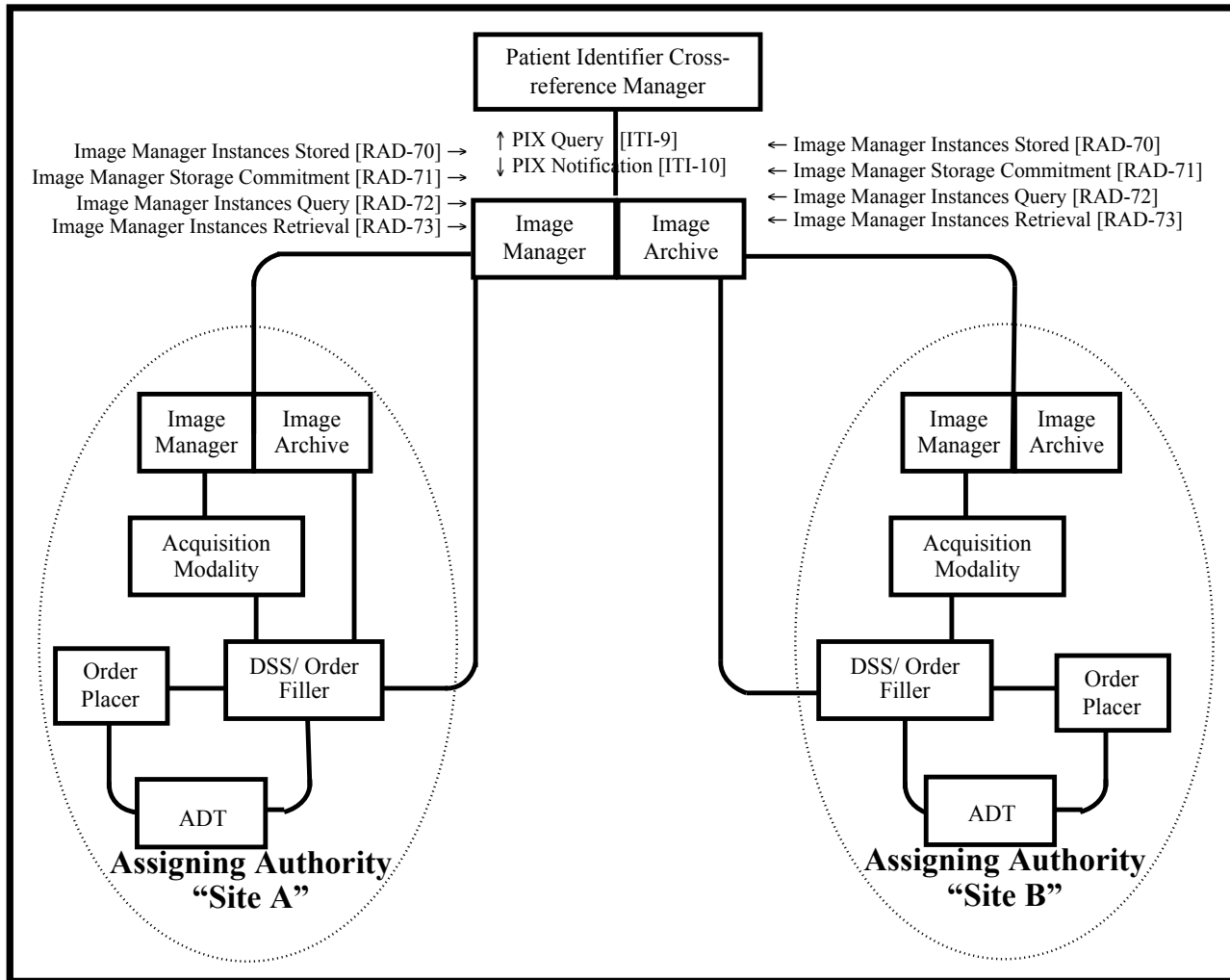
Imaging Object Change Management



Cross Enterprise Gateways



Multiple Image Manager/Archive



Multiple Patient Identifier Assigning Authorities

MU – Health ITSC – Image Sharing

	<u>TIER 1</u> Exchange of Text-Based Reports	<u>TIER 2</u> Exchange of Non-Radiology/ Cardiology Images	<u>TIER 3</u> Exchange of Radiology/ Cardiology Images - Full Study	<u>TIER 4</u> Exchange of Radiology/ Cardiology Images- Key Images
<u>CONTENT</u>	Plain text +/- structured headings, scanned/ rendered document	"Clinical Capture" images with or without metadata	Complete set of images of diagnostic quality	IHE Key Image Note (KIN) and images referenced therein
<u>ENCODING</u>	PDF, HL7 2.x OBX segment content, CDA L1, or CDA L2 + CCDA DIR template	Without metadata: JPEG, PNG, DNG, PDF, H.264; with metadata: DICOM	DICOM (object appropriate to modality)	
<u>VOCABULARY</u>	LOINC to describe study/ procedure, LOINC for structured headings	LOINC to describe study/ procedure (in DICOM header/ XDS metadata)	LOINC to describe study/ procedure	LOINC to describe study/ procedure, DICOM DCID 7010 for titles
<u>PUSH</u>	HL7 V2 ORU/MDM MLLP over VPN/TLS, DIRECT SMTP or XDR preferred	DIRECT SMTP or XDR, DICOM DIMSE/ULP or STOW over VPN/TLS, IHE XDR-I	DICOM DIMSE/ULP or STOW over VPN/TLS, IHE XDR-I	DICOM DIMSE/ULP or STOW over VPN/TLS, IHE XDR-I
<u>PULL</u>	IHE XDS	IHE XDS-I, DICOM WADO-URI or WADO-RS over VPN/TLS	IHE XDS-I, DICOM WADO-URI or WADO-RS over VPN/TLS	IHE XDS-I, DICOM WADO-URI or WADO-RS over VPN/TLS
<u>VIEW</u>			IHE IID, else pull (WADO-URI+/- XDS-I for rendered JPEGs when sufficient)	IHE IID, else pull (WADO-URI+/- XDS-I for rendered JPEGs when sufficient)



New(er) DICOM Objects

- Images for new modalities
 - ophthalmology, Whole Slide Imaging (WSI), ...
- Better images for existing modalities
 - enhanced multi-frame & legacy conversion
- Images for derived stuff
 - pretty pictures (screenshots), parametric maps, segmentations
- Non-images
 - annotations, measurements, ROIs, fiducials, registrations
 - presentation states and structured reports
 - key images (key object selection)
 - radiotherapy stuff
 - Radiation Dose SR (RDSR), Radiopharmaceutical Dose (RRD)
- Encapsulated stuff
 - PDF, CDA

Radiation Dose – Old Way – Screen Shots

Patient Name:

Exam no:

Accession Number:

Patient ID:

Discovery CT750 HD

Exam Description: CT HALS/THORAX/ABDOMEN

Dose Report

Series	Type	Scan Range (mm)	CTDIvol (mGy)	DLP (mGy-cm)	Phantom cm
1	Scout	-	-	-	-
2	Helical	S15.750-I650.250	5.10	373.00	Body 32
5	Helical	S188.000-I105.000	5.10	182.72	Body 32
Total Exam DLP:				555.72	

DICOM CT RDSR

CT RADIATION DOSE SR IOD TEMPLATES

The templates that comprise the CT Radiation Dose SR are interconnected as in Figure A-12

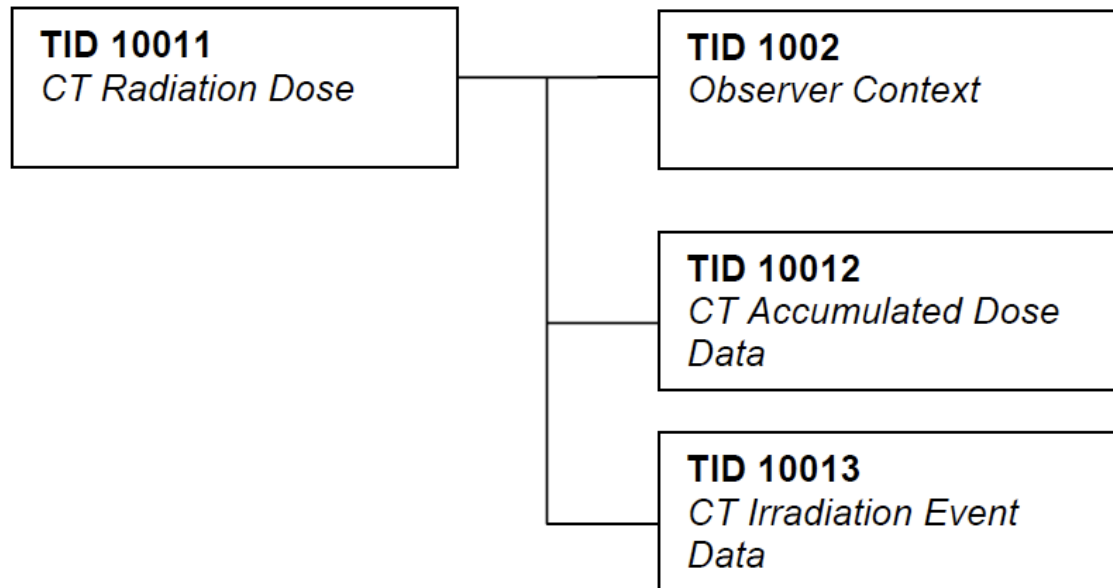
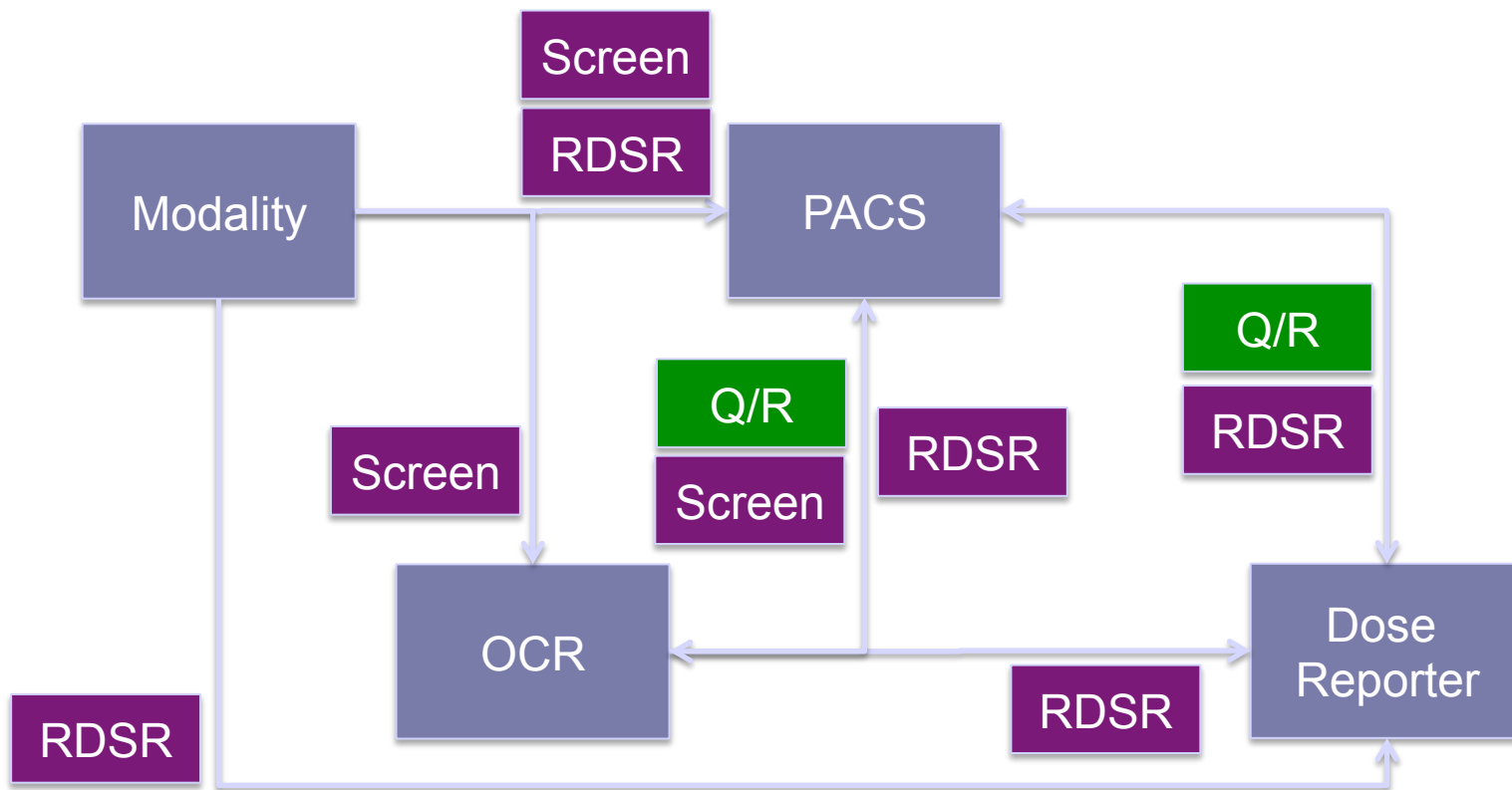


Figure A-12: CT Radiation Dose SR IOD Template Structure

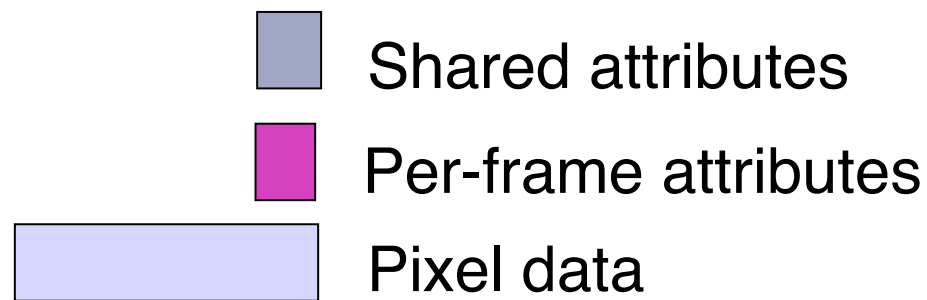
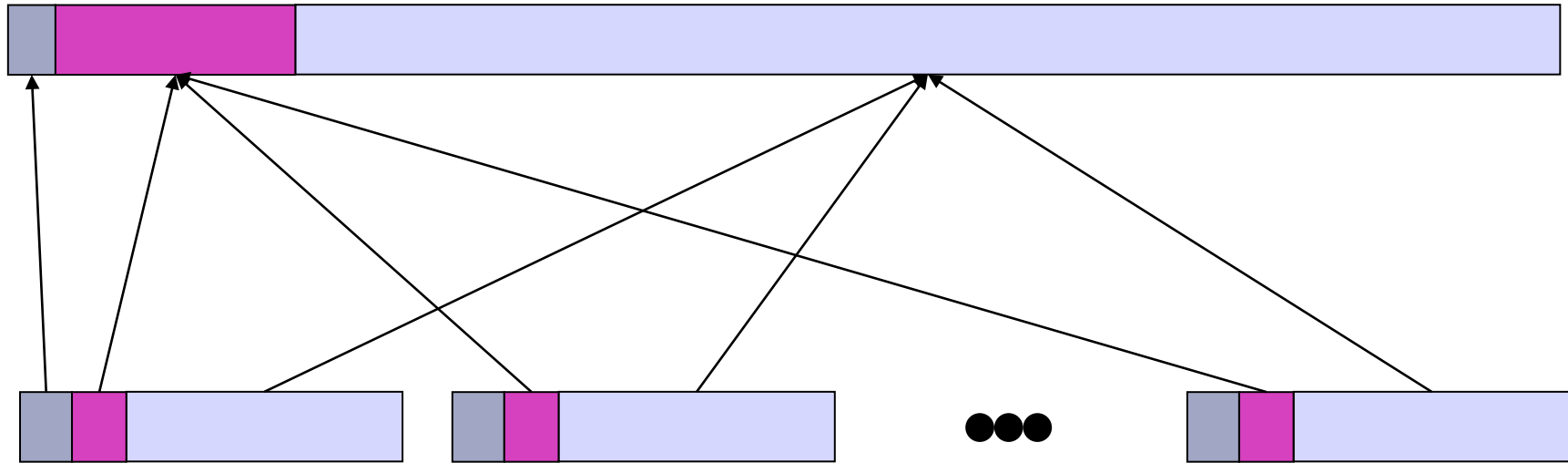
DICOM CT RDSR

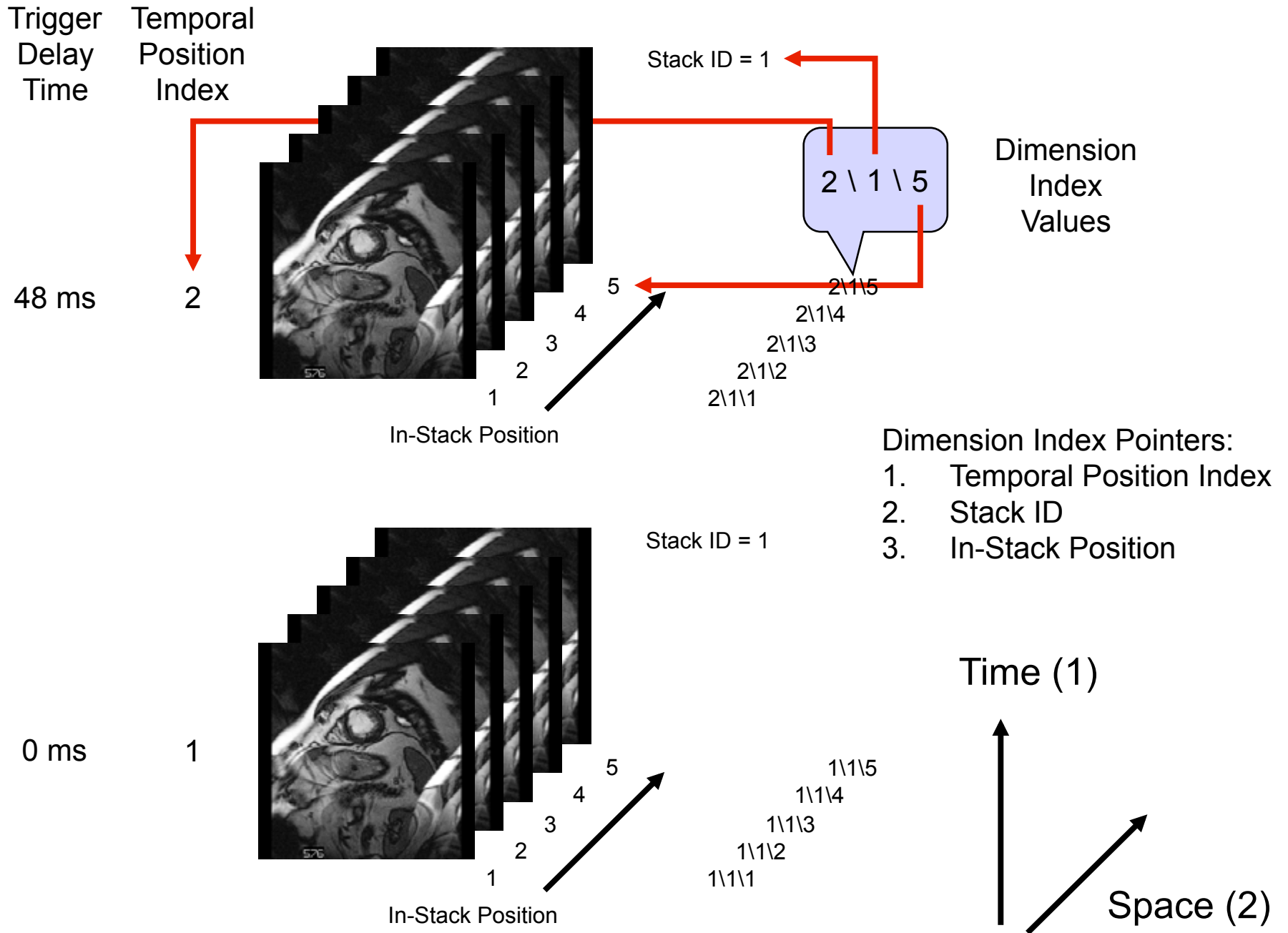
- 📁 : CONTAINER: X-Ray Radiation Dose Report [SEPARATE] (DCMR,10011)
 - ▼ 📁 HAS CONCEPT MOD: CODE: Procedure reported = Computed Tomography X-ray
 - 📄 HAS CONCEPT MOD: CODE: Has Intent = Diagnostic Intent
 - 📄 HAS OBS CONTEXT: CODE: Observer Type = Device
 - 📄 HAS OBS CONTEXT: TEXT: Device Observer Name = ilqhfaatc1ws444
 - 📄 HAS OBS CONTEXT: TEXT: Device Observer Manufacturer = Philips
 - 📄 HAS OBS CONTEXT: TEXT: Device Observer Model Name = Brilliance 64
 - 📄 HAS OBS CONTEXT: TEXT: Device Observer Physical Location During Observation = PMSTL
 - 📄 HAS OBS CONTEXT: DATETIME: Start of X-ray Irradiation = 20100422162839.030
 - ▼ 📁 HAS OBS CONTEXT: CODE: Scope of Accumulation = Study
 - 📄 HAS PROPERTIES: UIDREF: Study Instance UID = 1.2.840.113704.1.111.6084.1271942101.12
 - ▼ 📁 CONTAINS: CONTAINER: CT Accumulated Dose Data [SEPARATE]
 - 📄 CONTAINS: NUM: Total Number of Irradiation Events = 2 events
 - 📄 CONTAINS: NUM: CT Dose Length Product Total = 19.67375 mGycm
 - ▶ 📁 CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
 - ▼ 📁 CONTAINS: CONTAINER: CT Acquisitions [SEPARATE]
 - 📄 CONTAINS: CODE: Acquisition Type = Sequenced Acquisition
 - 📄 CONTAINS: CODE: Procedure Context = CT without contrast
 - 📄 CONTAINS: UIDREF: Irradiation Event UID = 1.2.840.113704.1.111.6084.1271942101.12.2
 - ▼ 📁 CONTAINS: CONTAINER: CT Acquisition Parameters [SEPARATE]
 - 📄 CONTAINS: NUM: Exposure Time = 4254 s
 - 📄 CONTAINS: NUM: Scanning Length = 10 mm
 - 📄 CONTAINS: NUM: Nominal Single Collimator Width = 0.625 mm
 - 📄 CONTAINS: NUM: Nominal Total Collimator Width = 1.25 mm
 - 📄 CONTAINS: NUM: Number of X-ray Sources = 1 X-ray sources
 - ▶ 📁 CONTAINS: CONTAINER: CT X-ray Source Parameters [SEPARATE]
 - ▼ 📁 CONTAINS: CONTAINER: CT Dose [SEPARATE]
 - 📄 CONTAINS: NUM: Mean CTDIvol = 1.3978125 mGy
 - 📄 CONTAINS: CODE: CTDIw Phantom Type = IEC Body Dosimetry Phantom
 - 📄 CONTAINS: NUM: DLP = 16.77375 mGycm
 - ▼ 📁 CONTAINS: CODE: Device Role in Procedure = Irradiating Device
 - 📄 HAS PROPERTIES: TEXT: Device Manufacturer = Philips
 - 📄 HAS PROPERTIES: TEXT: Device Model Name = Brilliance 64
 - 📄 CONTAINS: CODE: Source of Dose Information = Automated Data Collection

RDSR & OCR Deployment

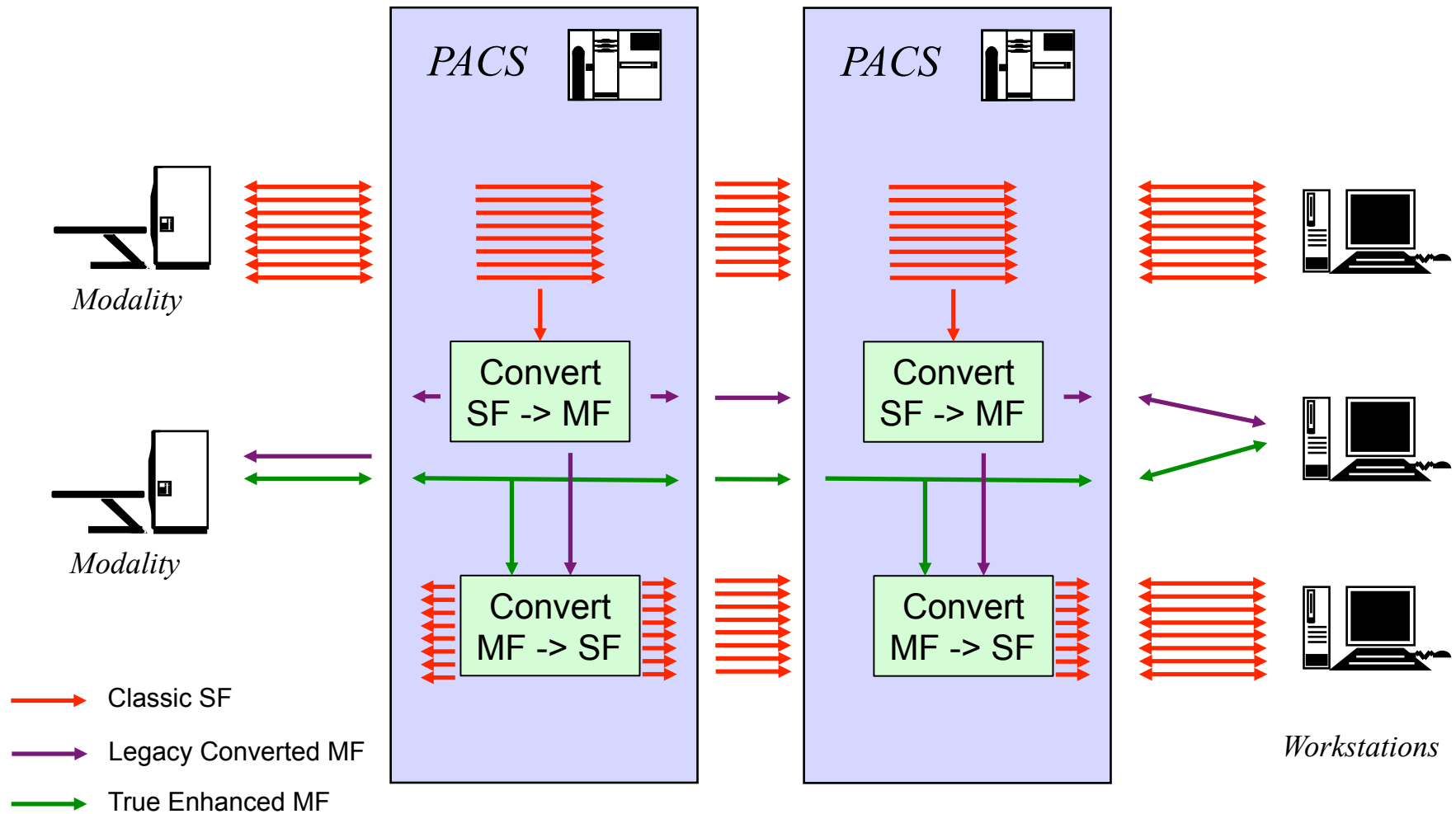


Enhanced Multi-frame Images

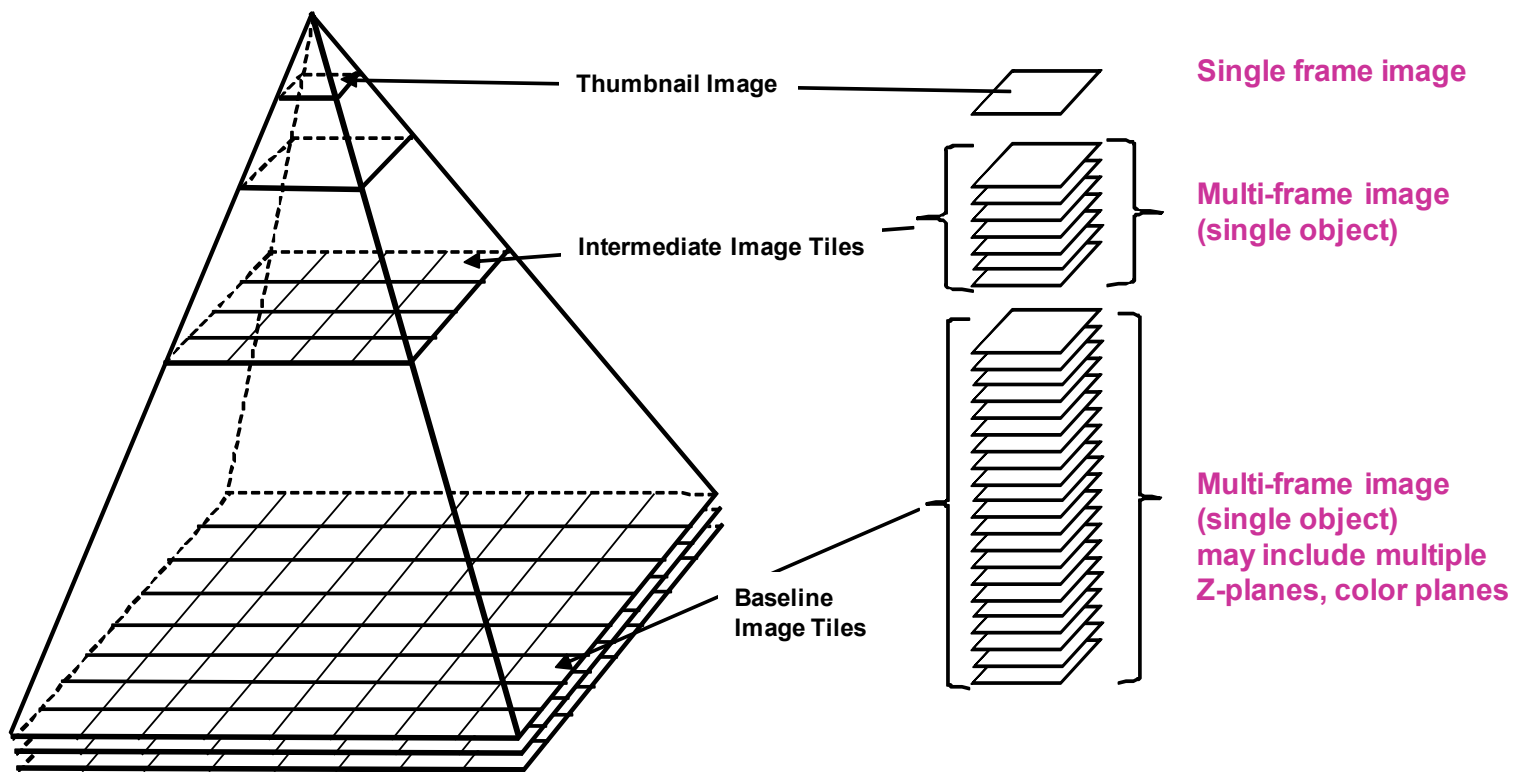




PACS to PACS (or VNA) with Legacy DICOM Object Conversion



DICOM Whole Slide Images





Quantification Considerations

- Increasingly an area of attention for some advanced imaging applications
- Increasingly important applications
 - tumor response assessment, neurodegenerative disease, etc.
 - not just research & clinical trials, but clinical care
- Not novel, just not widely used/available
 - Lemke 1979 paper described segmentation and lateral ventricle volume determination
- Many PACS still fail to provide more than basic measurements

VENTRICLE VOLUME ANALYSIS

ZKAIN: 44 ZCSF: 26

SLICE: 03F
REGION LABEL: 1 VOLUME: 0.97 ML
REGION LABEL: 2 VOLUME: 0.18 ML

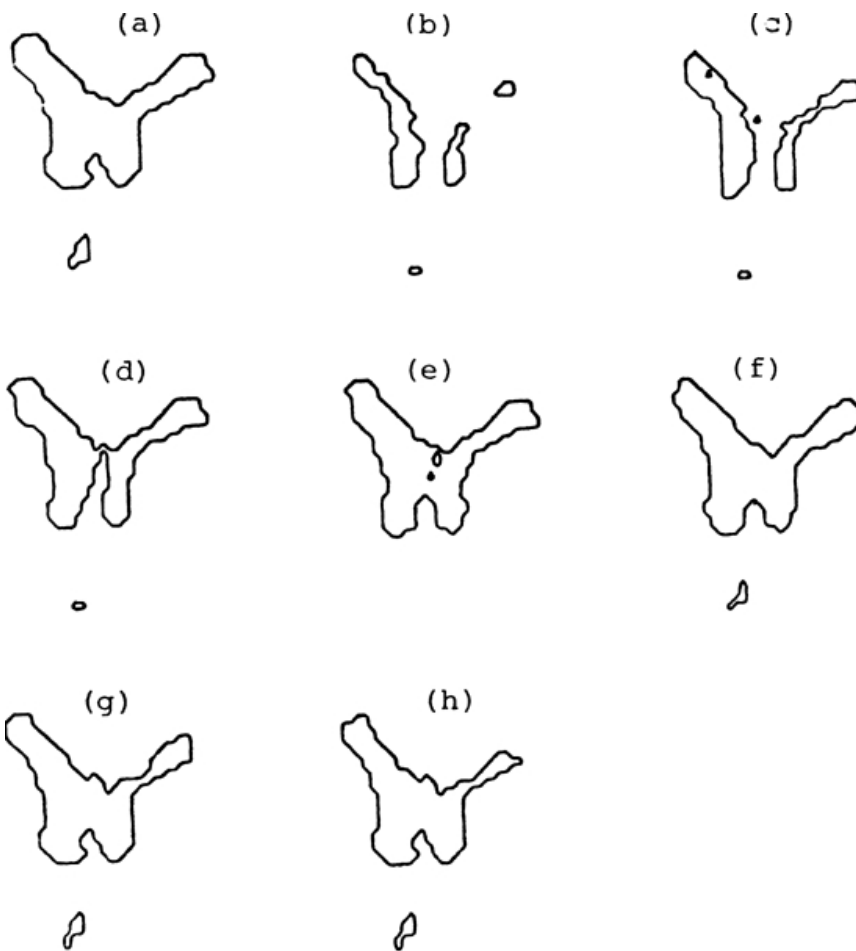
SLICE: 03A
REGION LABEL: 2 VOLUME: 9.88 ML

SLICE: 02E
REGION LABEL: 2 VOLUME: 4.12 ML
REGION LABEL: 9 VOLUME: 0.08 ML

SLICE: 02A
REGION LABEL: 4 VOLUME: 0.02 ML
REGION LABEL: 6 VOLUME: 1.01 ML

SLICE: 01B

SLICE: 01A
REGION LABEL: 35 VOLUME: 0.39 ML
OVERALL VENTRICULAR VOLUME: 16.65 ML

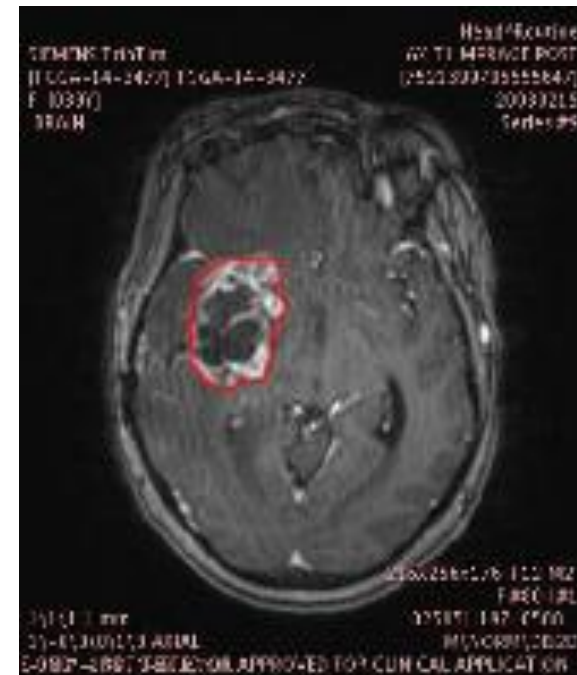




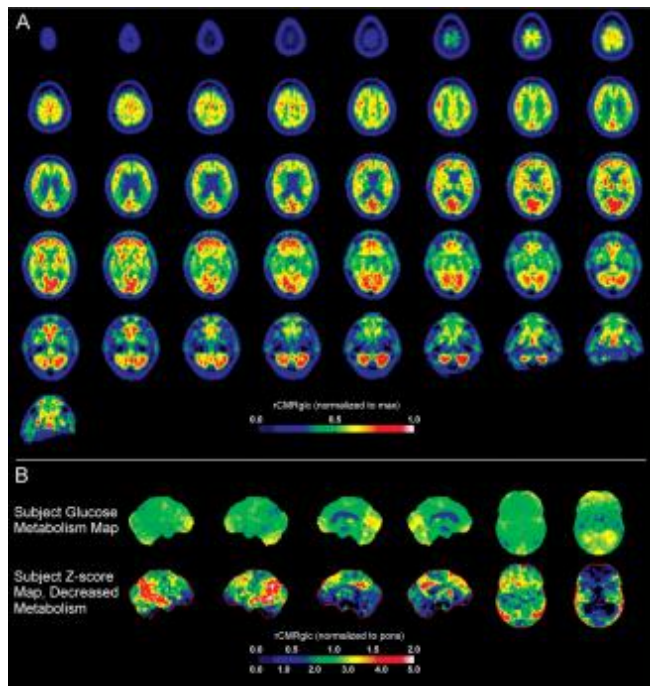
DICOM encoding of ROIs

- Private elements
 - evil & must be stopped
- Curves in image
 - weak semantics, old, retired
- Overlays in image
 - weak semantics
- Presentation States
 - weak semantics, PACS favorite
- Structured Reports
 - best choice, but more work
- RT Structure Sets
 - coordinates only
- Segmentations
 - per-voxel ROIs; use with SR

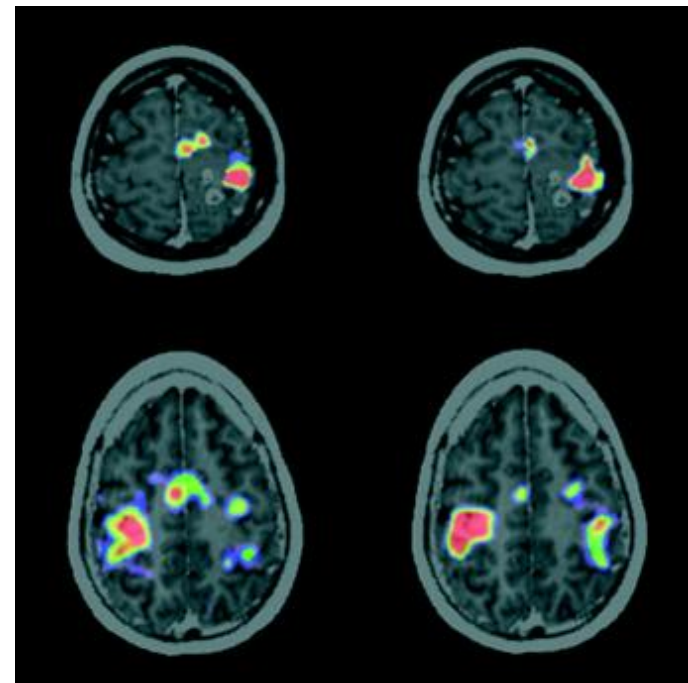
Date	Volume	Auto LD	Auto SD
20021207	27080	49	27
...



Parametric Maps

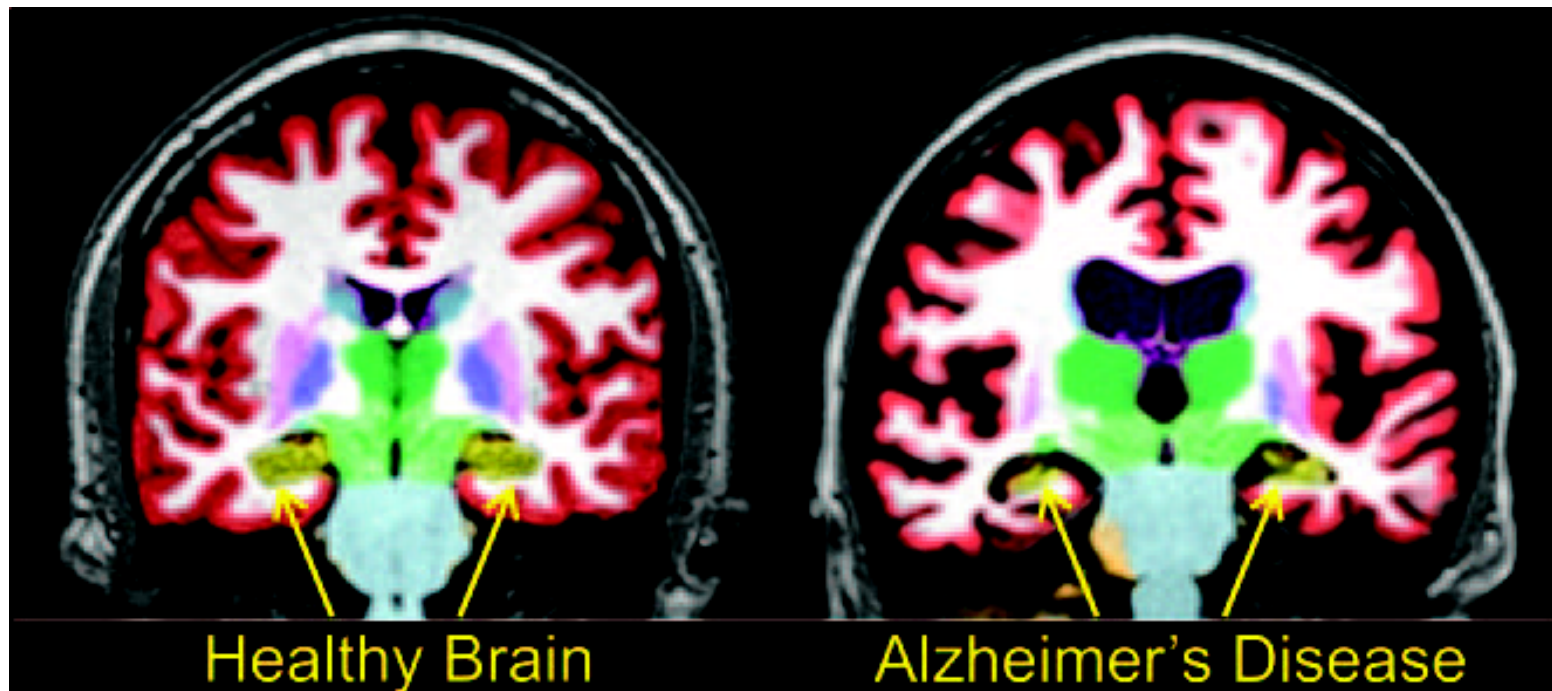


Foster N L et al. *Brain* 2007;130:2616-2635



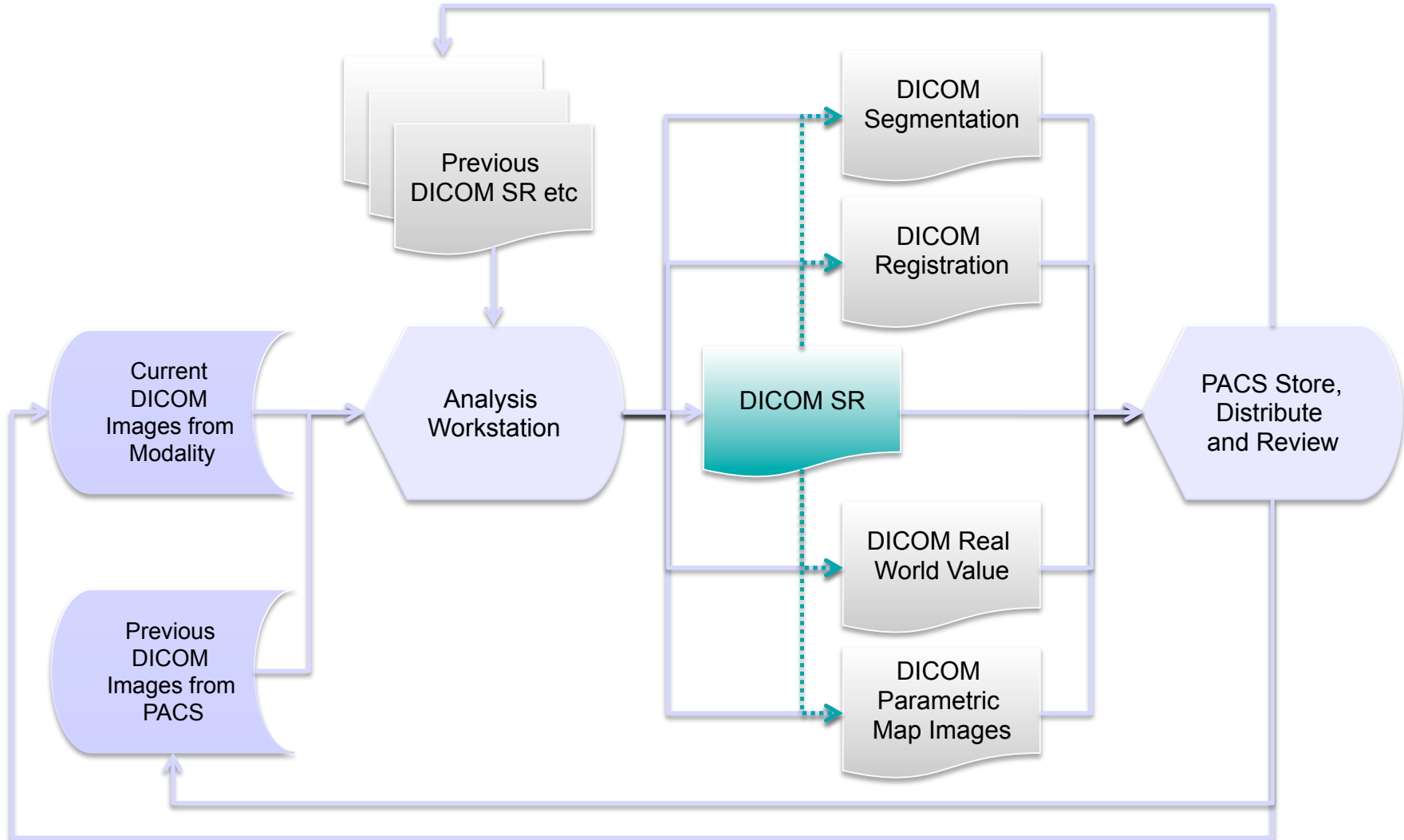
Meyer P T et al. *J Neurol Neurosurg Psychiatry* 2003;74:471-478

Label Maps

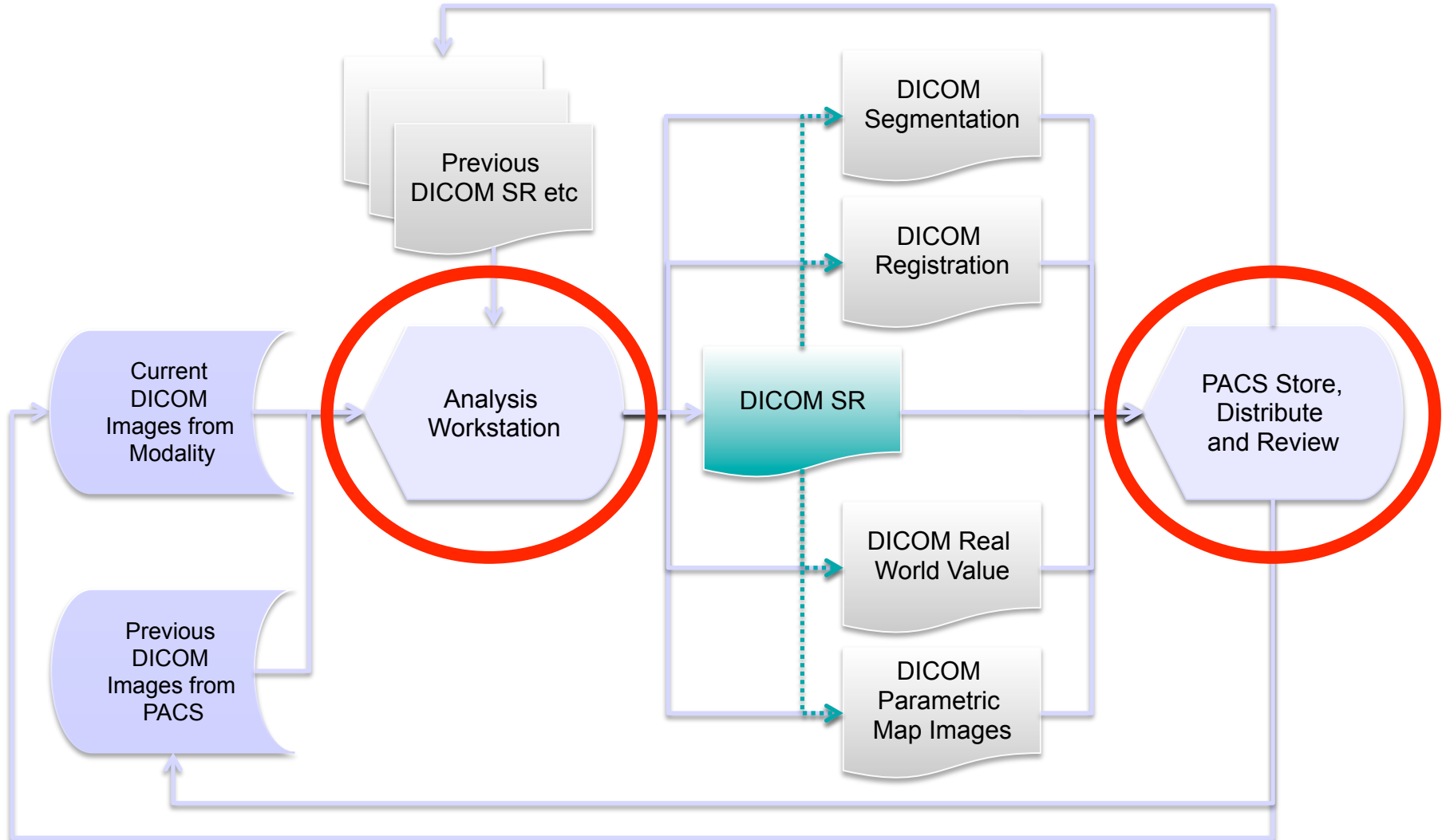


Brewer J et al. AJNR 2009; 30:578-580

Quantitative objects together



Quantitative objects together





Final thoughts ...

- Patient versus provider access
 - just another universal viewer client
 - access through portal rather than EHR
- Universal viewers
 - really as capable as specialty workstations?
 - “union” of all previously implemented features?
- Reality check
 - most sites running an obsolete PACS version
 - migration (vendor/architecture change) is painful
 - VNAs need migration too