How Best to Create, Standardize, and Promote Data Models for Dermatology in the Mobile Era?

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Pixelmed Publishing, LLC.

Background & Disclosures

- Owner, PixelMed Publishing, LLC
- Radiologist

- Independent Consultant – GE, Carestream, MDDX/Bioclinica, Hologic, Lunit

- Editor of DICOM Standard (NEMA contract)
- Formerly co-chair DICOM Standards Committee
- Formerly co-chair IHE Radiology Technical Committee

Overview

- Modality types
- Interoperability – how and why?
- Metadata
- Enterprise scalability & security
- Mobility differences
- Data types – more than images
- Barriers to interoperability

Range of modalities +/- mobility

- Digital cameras – hand-held
  - DSLRs – tethered, wireless (WiFi, Bluetooth), memory card
  - mobile phones/tablets
- Dermoscopy/Epiluminescence Microscopy (ELM)
  - standalone or addition to mobile phone
- Total Body Photography (TBP)
  - manual following template
  - semi- or fully automated
- Reflective Confocal Microscopy (RCM)
- Optical Coherence Tomography (OCT)
- Dermatopathology
  - microscope attached camera or mobile phone
  - Whole Slide Imaging (WSI)

Interoperability

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

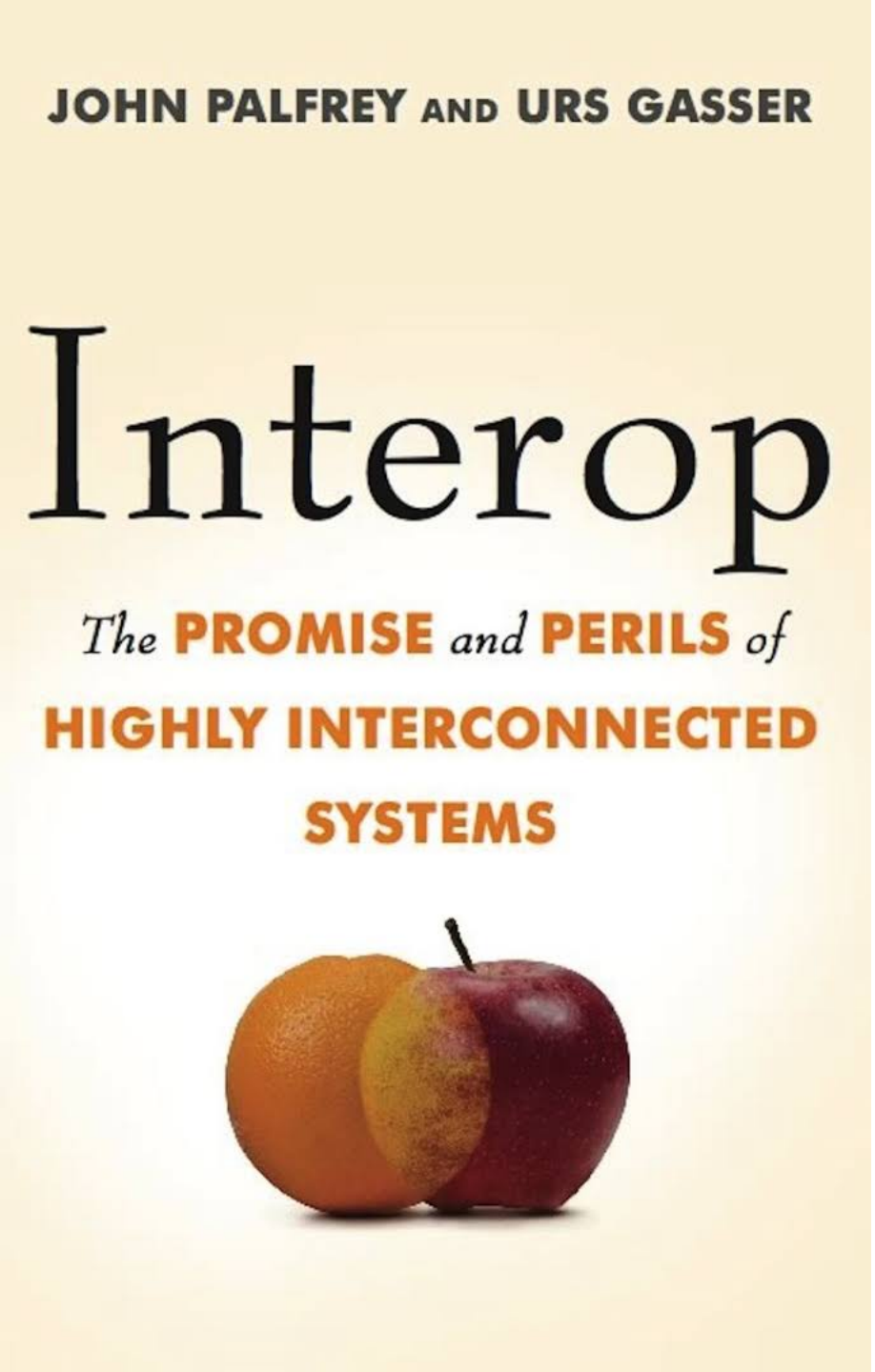
IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries. 1990

NATIONAL ACADEMY OF MEDICINE

PROCURING INTEROPERABILITY

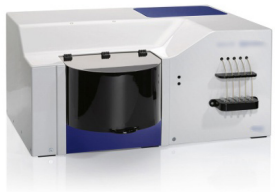
ACHIEVING HIGH-QUALITY, CONNECTED, AND PERSON-CENTERED CARE

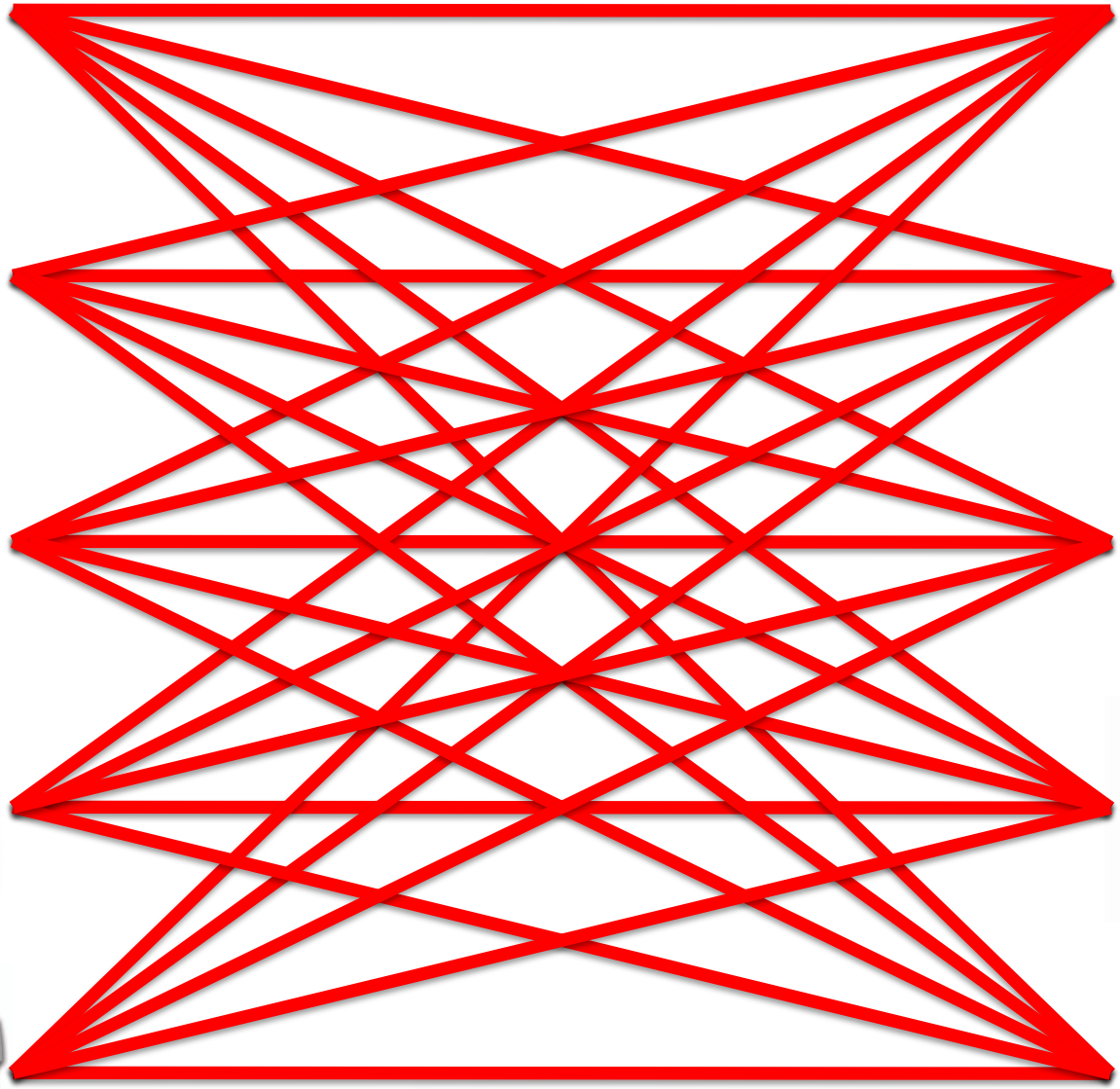
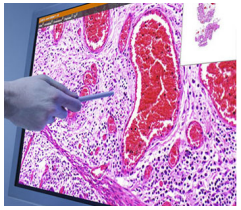
Peter Pronovost, Michael M. E. Johns, Sezin Palmer, Raquel C. Bono, Douglas B. Fridsma, Andrew Gettinger, Julian Goldman, William Johnson, Meredith Karney, Craig Samitt, Ram D. Sriram, Ashwini Zenooz, and Y. Claire Wang, *Editors*



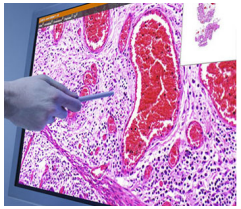
- *layers: technology, data, human, institutional*
- *consumer empowerment*
- *privacy, security*
- *competition, homogeneity, innovation*
- *efficiencies, complexity*
- *by design*
- *over time*
- *architectures*

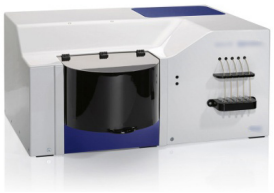




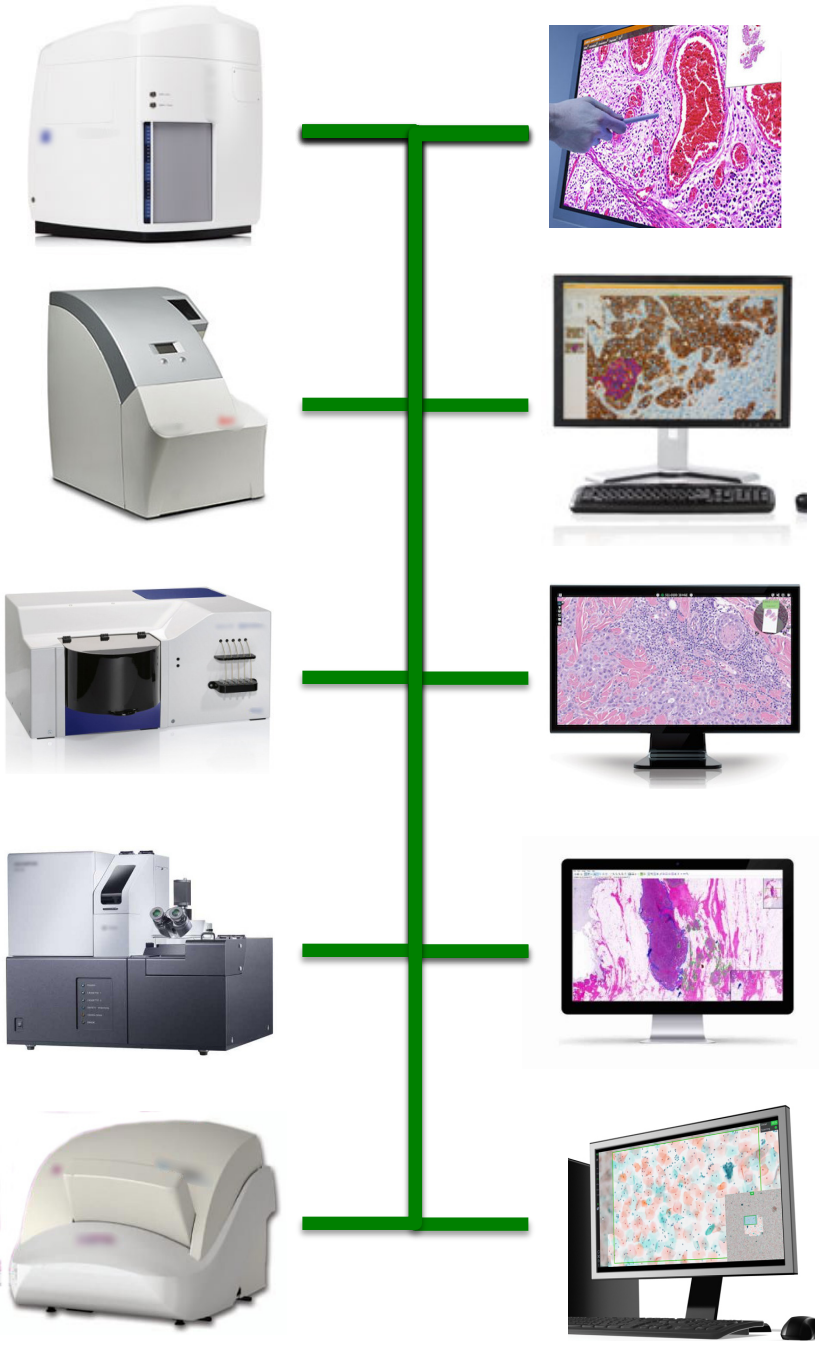




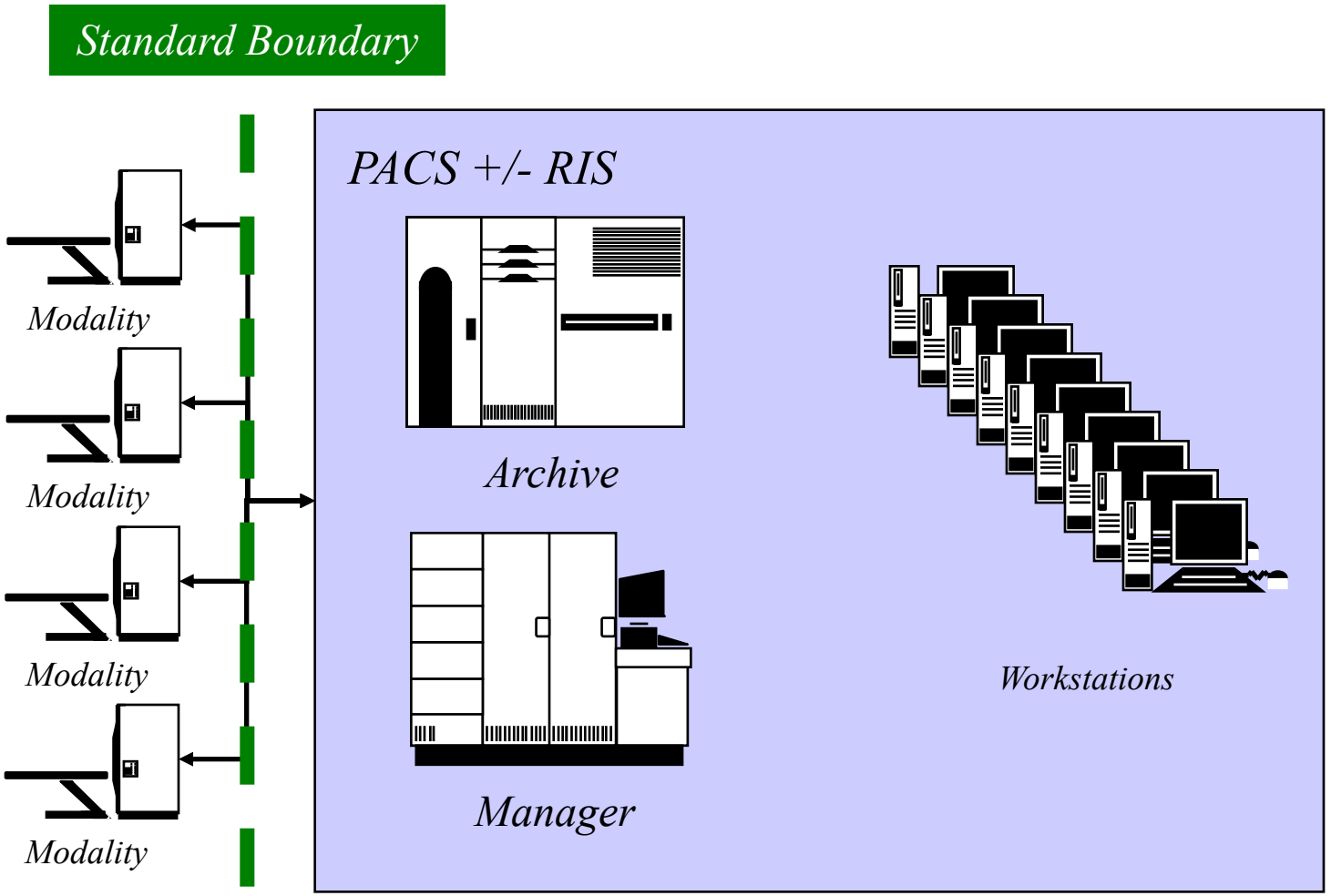


DICOM℠

Digital Imaging and Communications in Medicine



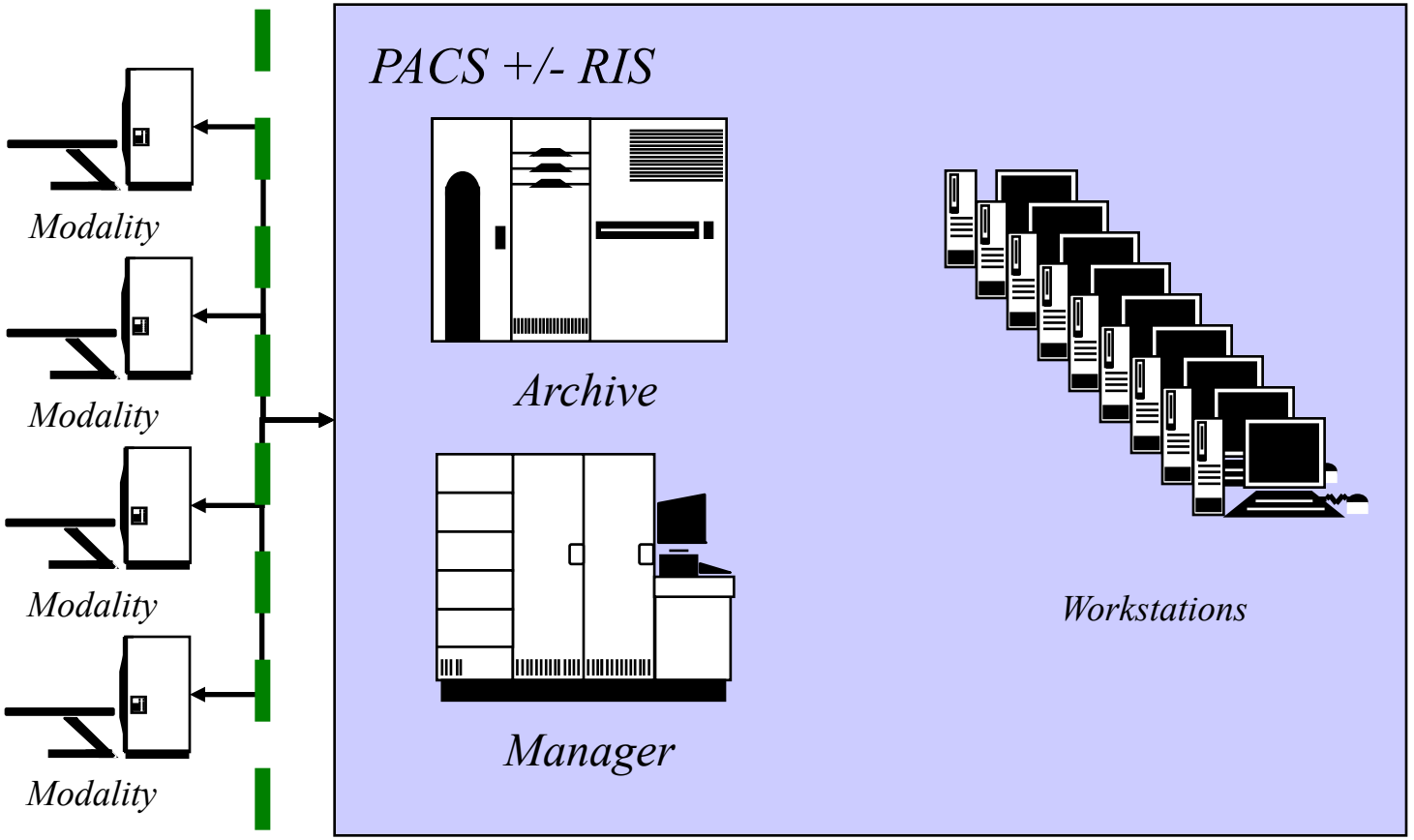
Radiology Interoperability



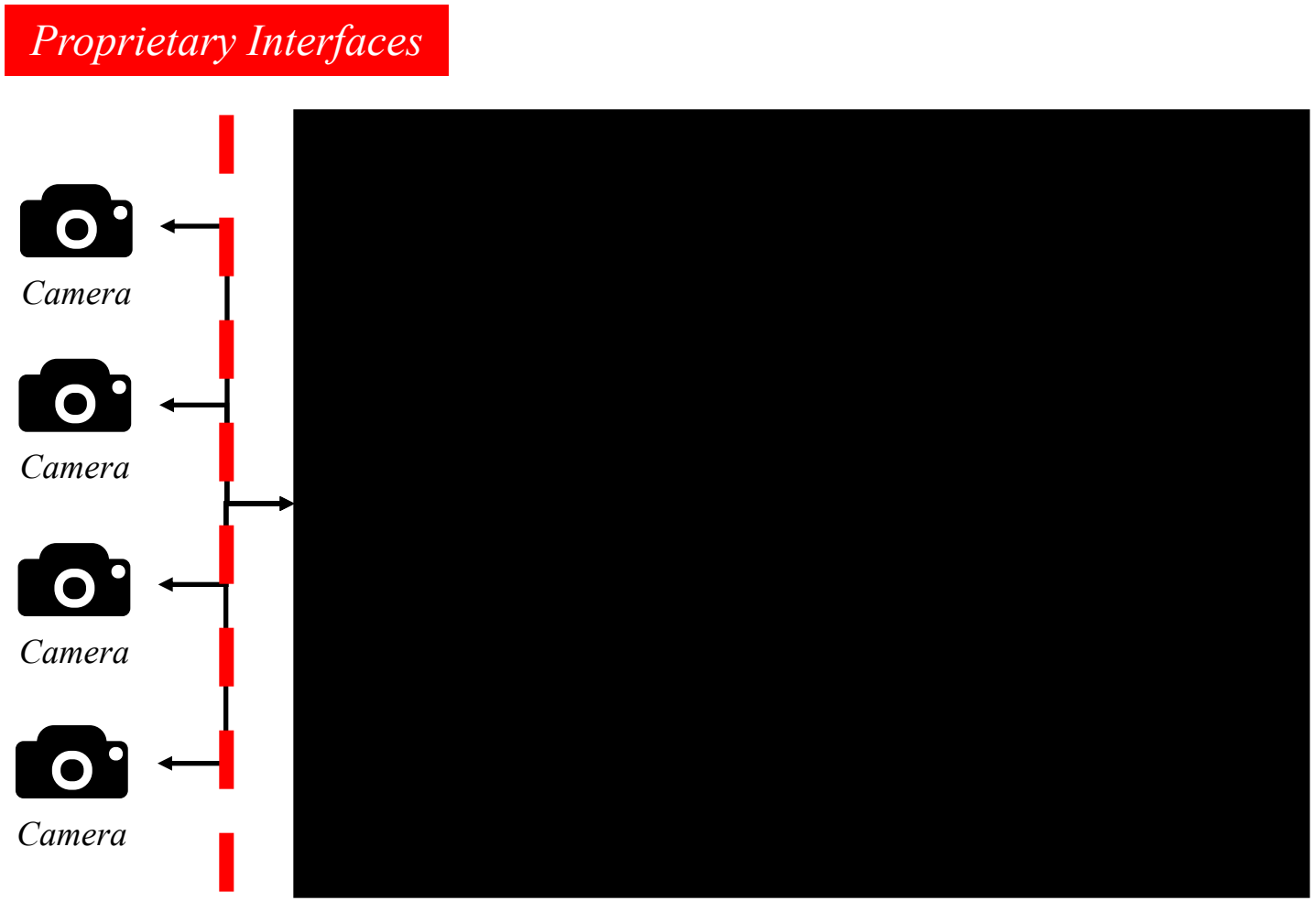
Radiology Interoperability

DICOM℠
Digital Imaging and Communications in Medicine

1993 – 25 years!



Dermatology – Black Box



Dermatology – Black Box

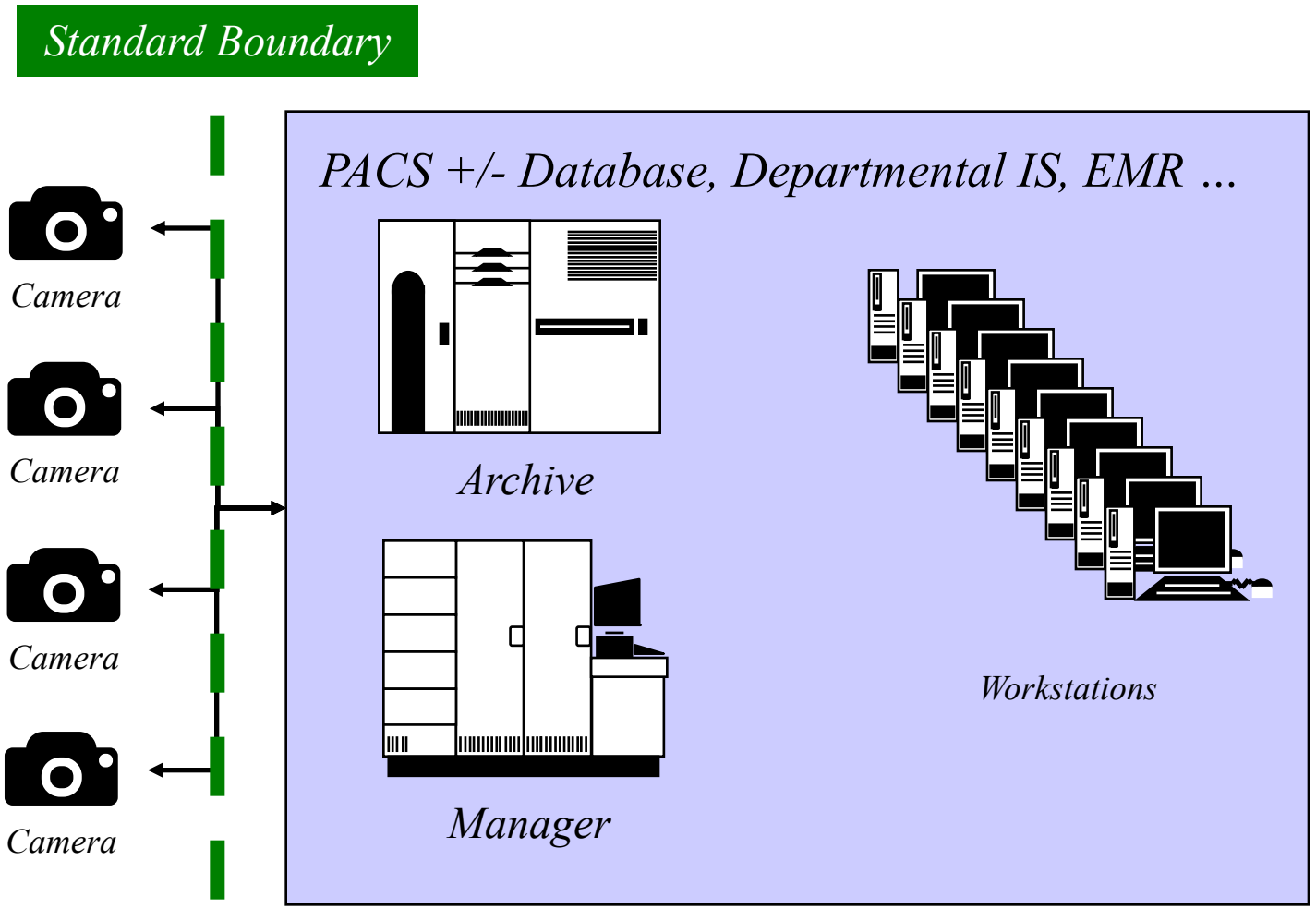
Proprietary black box issues

- interface to EMR?
- share with other sites?
- persist/represent/query the metadata?
- persist/represent/query the annotations?
- apply 3rd party tools & analysis?
- migrate at end-of-life?
- deal with vendor failure?
- handle security/single sign on/access control?
- handle business continuity/disaster recovery?
- …

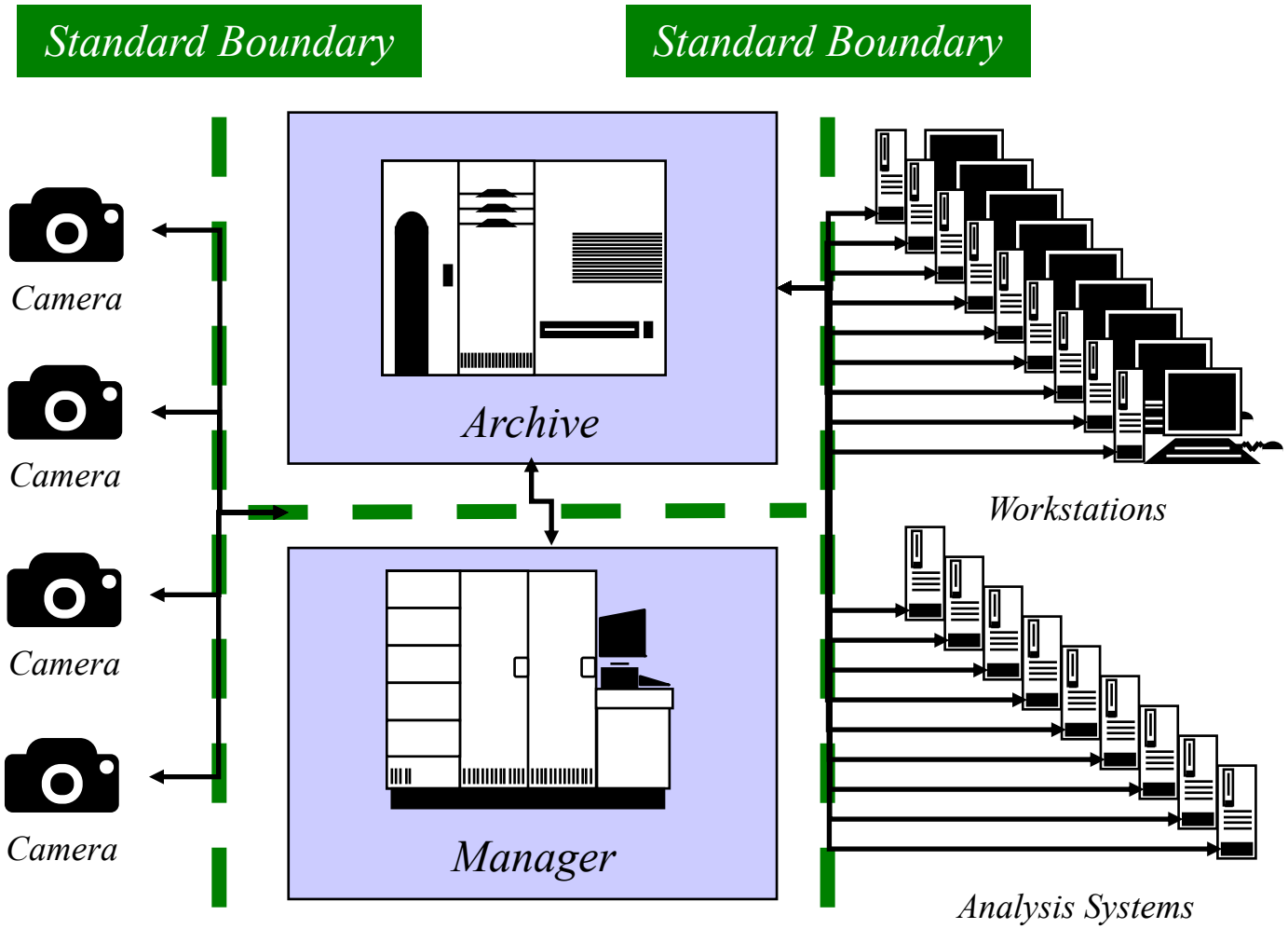
Information Wants to be Free


AI CHANGES THE GAME

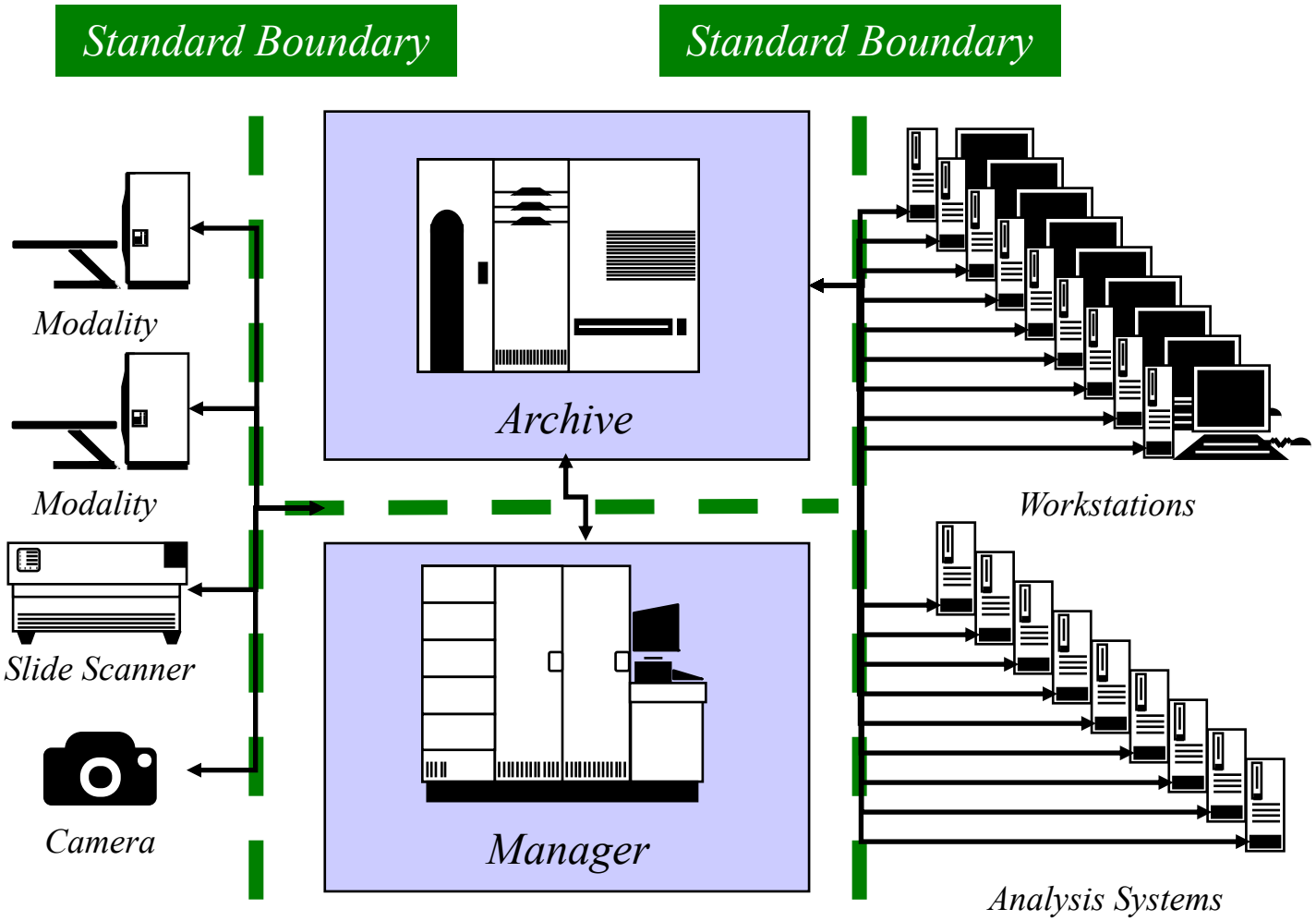
Standard Camera Interface



Capture, Viewing, Analysis

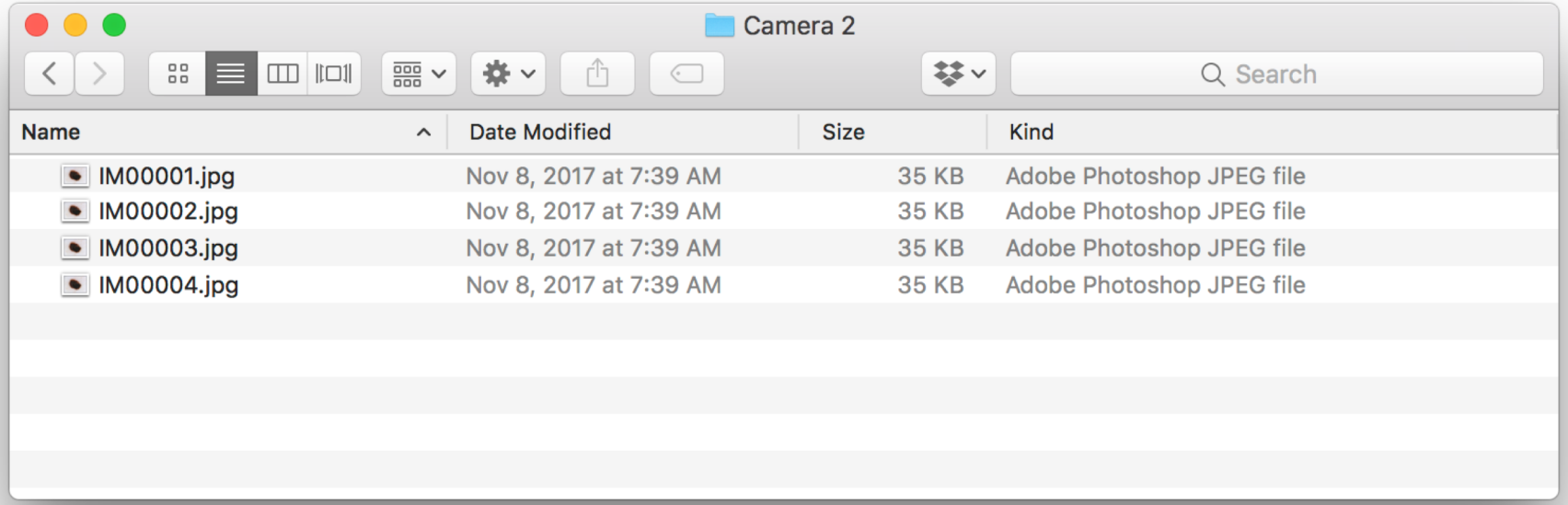


Deconstructed Enterprise PACS



It’s the metadata, stupid

http://medium.com/digital-trends-index/its-the-metadata-stupid-12a4fc121e45#.4zhwdz5y0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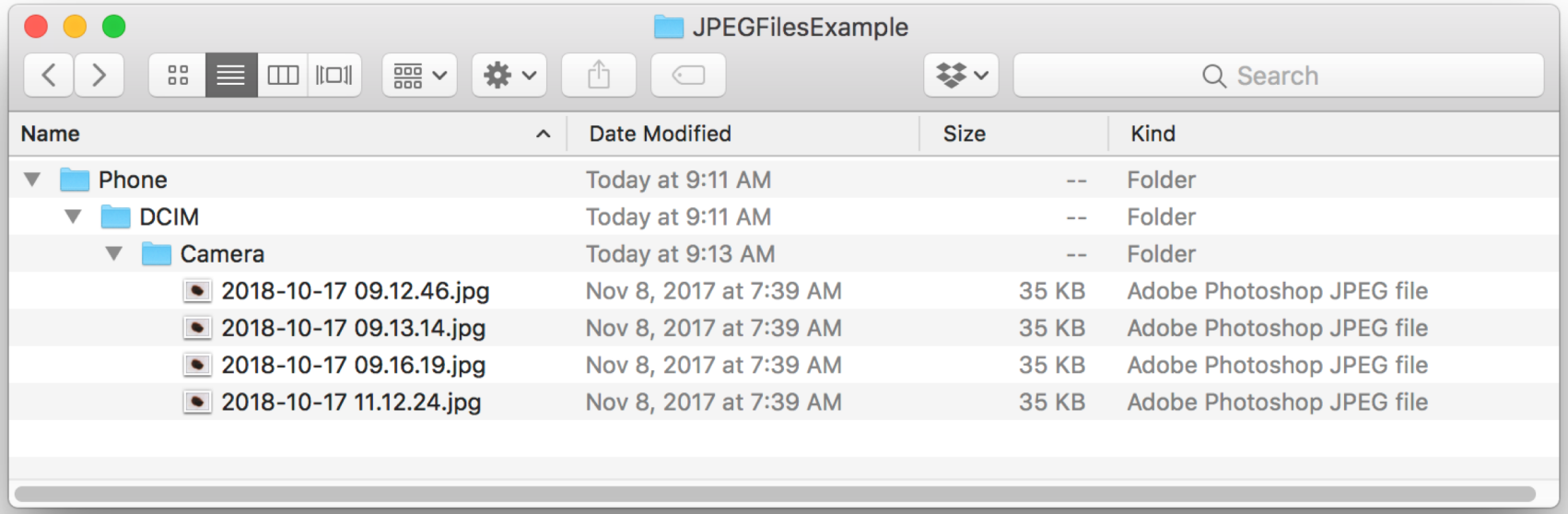
JPEGFilesExample
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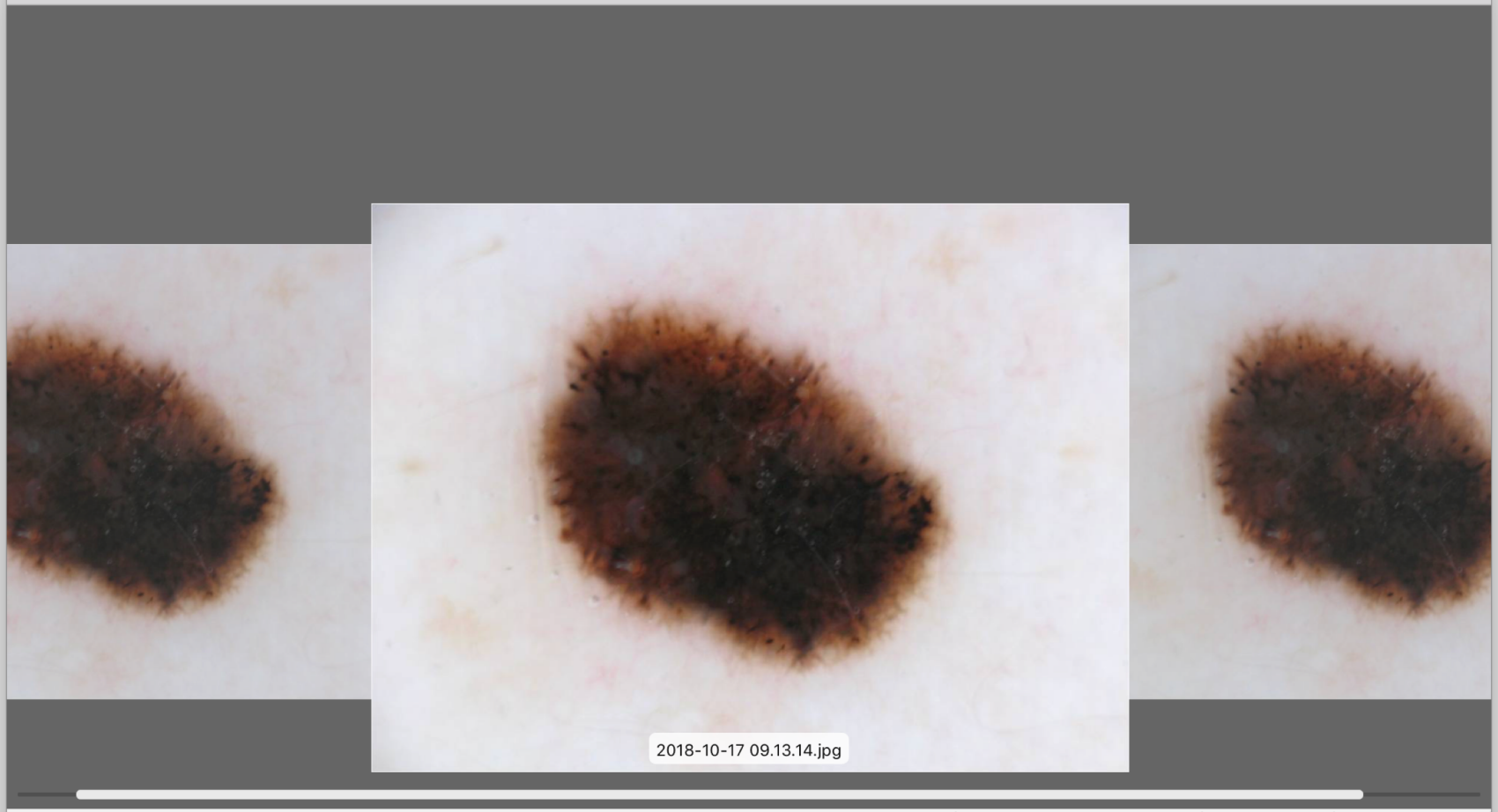
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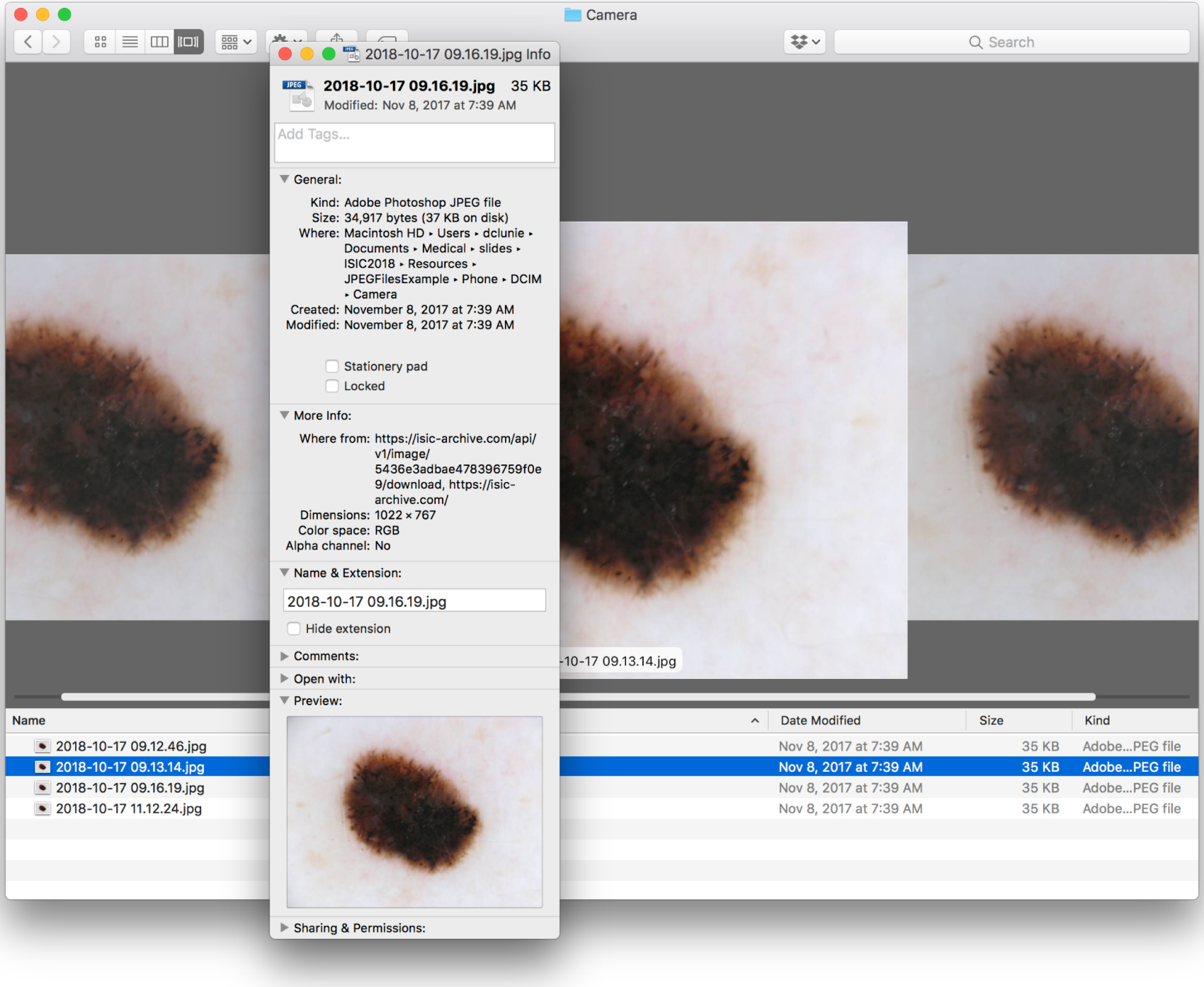
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Color space: RGB
Alpha channel: No
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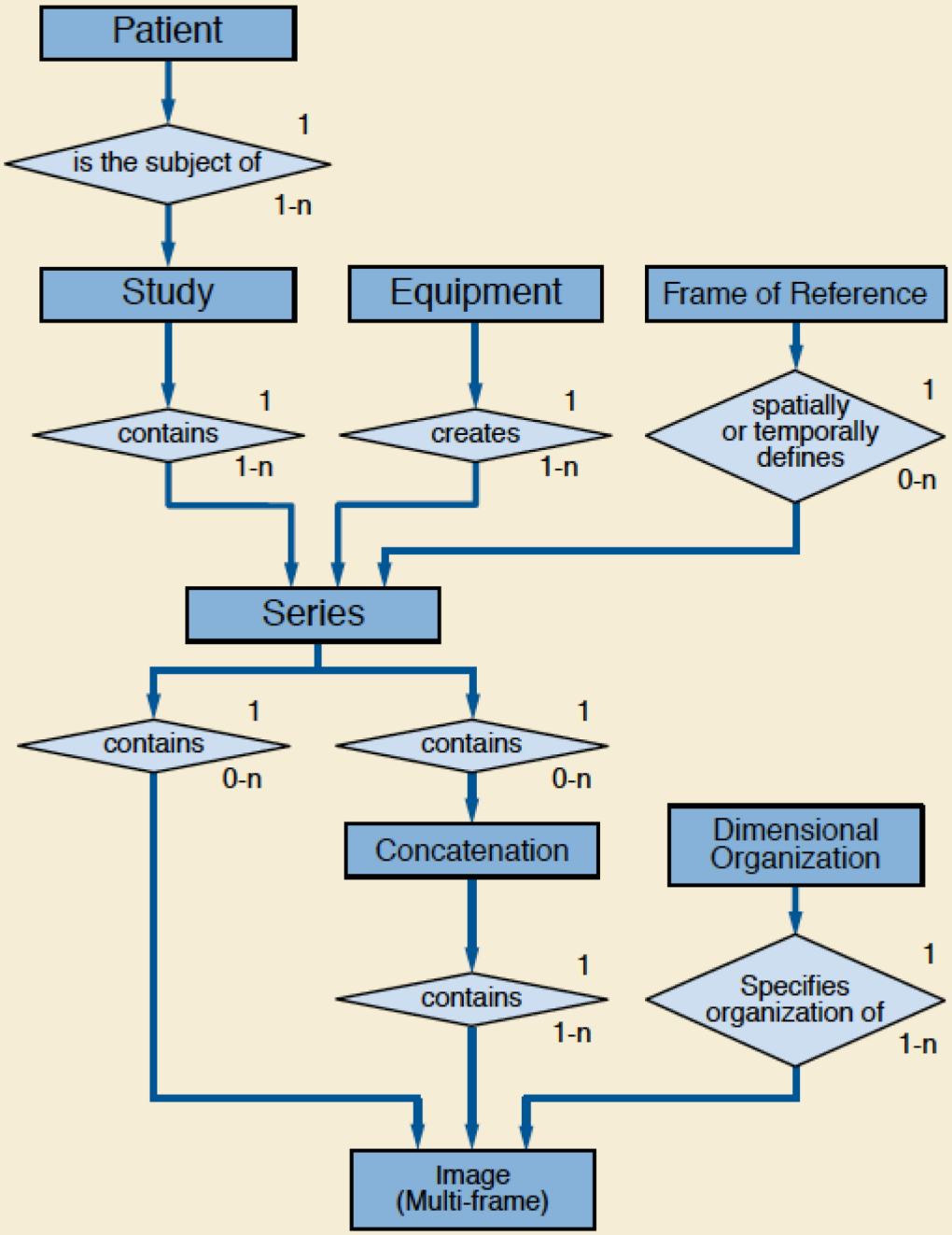
Types of Metadata

- Identifying
  - patient, order/request, encounter/visit
- Clinical
  - reason for study, anatomic location
- Descriptive
  - device and settings
  - kind of image
  - pixel physical size (calibration against known size object)
- Encoding related
  - compression
  - color management
- …


Patient
1
is the subject of
1-n
Study
Equipment
Frame of Reference
1
contains
1-n
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creates
1-n
1
spatially
or temporally
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Dimensional
Organization
1
contains
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1
Specifies
organization of
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Image
(Multi-frame)

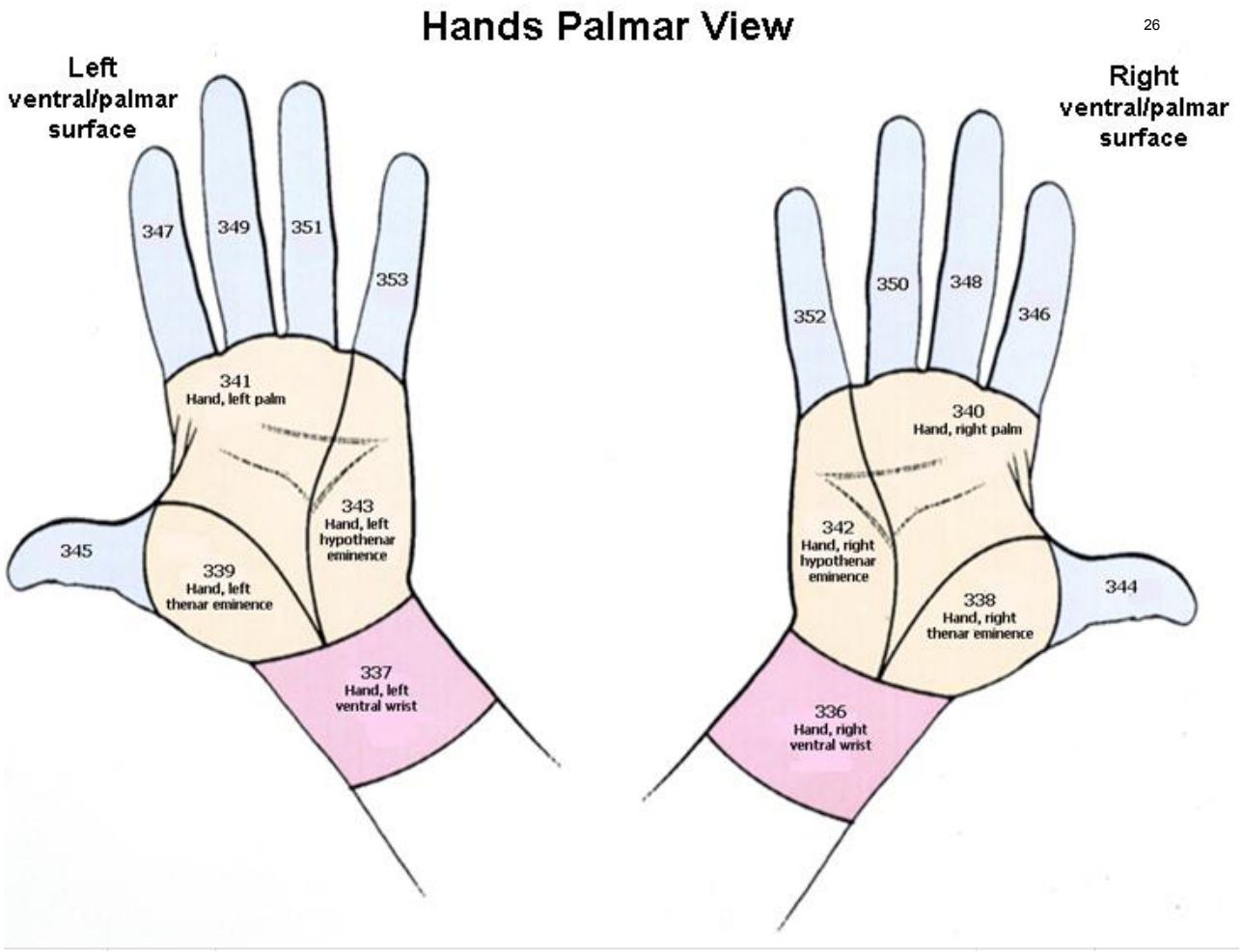
Patient Metadata

Table C.7-1 specifies the Attributes of the Patient that describe and identify the Patient who is the subject of a Study. This Module contains Attributes of the Patient that are needed for interpretation of the Composite Instances and are common for all Studies performed on the Patient. It contains Attributes that are also included in the Patient Modules in Section C.2.

Table C.7-1. Patient Module Attributes

Attribute Name	Tag	Type	Attribute Description
Patient's Name	(0010,0010)	2	Patient's full name.
Patient ID	(0010,0020)	2	Primary identifier for the Patient. Note In the case of imaging a group of small animals simultaneously, the single value of this identifier corresponds to the identification of the entire group. See also Section C.7.1.4.1.1.
Include Table 10-18 "Issuer of Patient ID Macro Attributes"			
Patient's Birth Date	(0010,0030)	2	Birth date of the Patient.
Patient's Sex	(0010,0040)	2	Sex of the named Patient. Enumerated Values: **M** male **F** female **O** other

Anatomic Metadata (CP 1764)



Anatomic Metadata (CP 1764)

Table CID nnn1. Dermatology Anatomic Sites

Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID	FMA ID	ICD-11	NYU Code L	NYU Code M	NYU Code R	Mayo Code L	Mayo Code M	Mayo Code R
SRT	T-D03C9	Anterior triangle of neck	182329002	C0446459	57777	XA1NS6	41		42	41		42
SRT	T-AA200	Cornea	28726007	C0229124	58238	XA4C02	109		108			
SRT	T-01530	Eyelash	85803001	C0015422	53669		105		104	105		104
SRT	T-81001	Female external urethral orifice	279479008	C0458493	85266			504				
SRT	T-81206	Frenulum of labia minora	279867004	C0458840	20404	XA0565		508				
SRT	T-01041	Groin skin crease	280387007	C0459399	326449	XA2XG2	519		518			
SRT	T-0130A	Hair	386045008	C0018494	53667						503	
SRT	T-AA500	Iris	41296002	C0022077	58235		109		108	109		108
SRT	T-75181	Male external urethral orifice	279478000	C0458492	85265			513				

Anatomic Metadata (CP 1764)

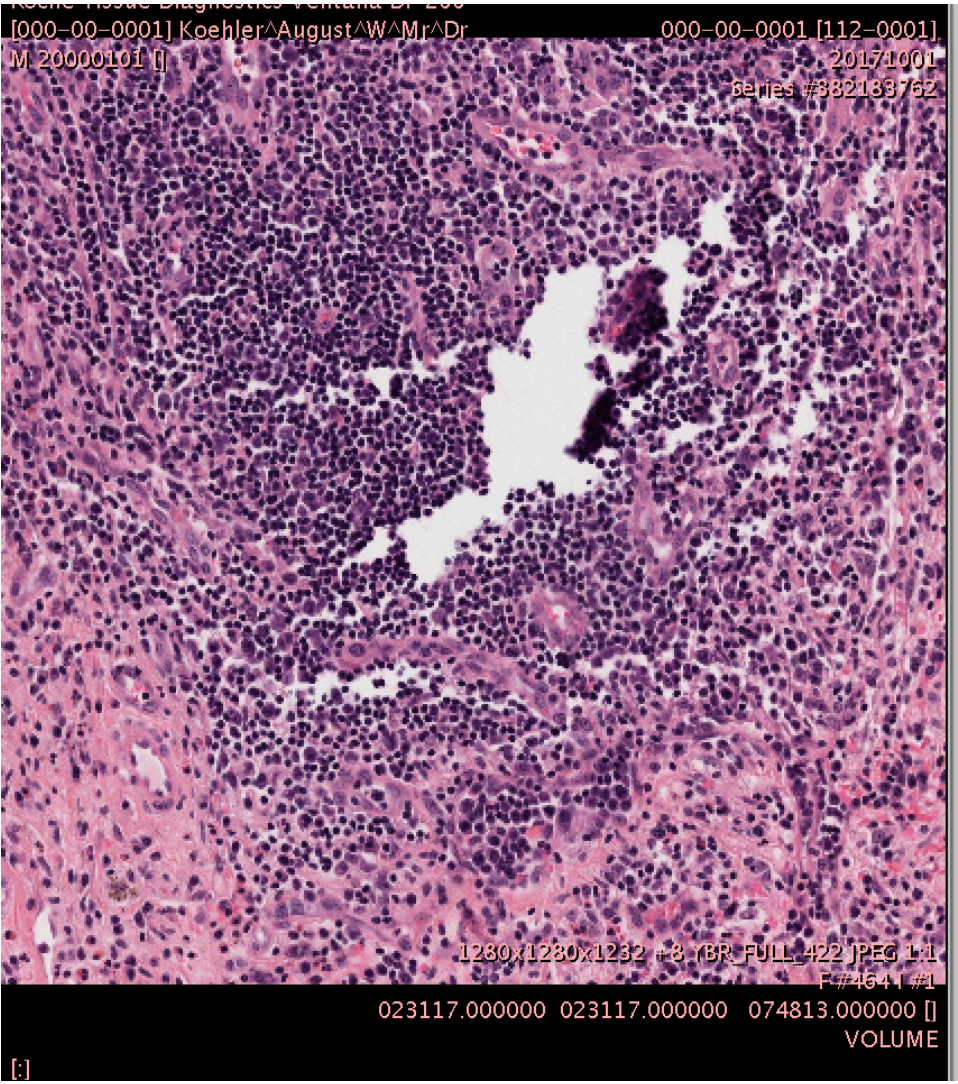
Coding Scheme Designator	Code Value	Code Meaning	SNOMED-CT Concept ID	UMLS Concept Unique ID	FMA ID	ICD-11	NYU Code L	NYU Code M	NYU Code R	Mayo Code L	Mayo Code M	Mayo Code R
SRT	T-02104	Skin of forehead	68698007	C0222074	63883	XA6TR8	7	52	8	7	504	8
SRT	T-02531	Skin of glans penis	7991003	C1261043	19642	XA0MH6	511		511			
SRT	T-02506	Skin of gluteal fold	63029009	C0222179	20233	XA5UE3		238				
SRT	T-02650	Skin of hand	33712006	C0222224	38295	XA5R12				524b	524	524a
SRT	T-02100	Skin of head	70762009	C0205029	12166	XA20Q1					501	
SRT	T-02841	Skin of heel	84607009	C0222287		XA5HK0	463		460	463		462
SRT	T-02202	Skin of helix of ear	79313003	C0222113		XA6B58						
SRT	T-02488	Skin of hypogastric region	367578008	C1288307	323207		235		235			
SRT	T-02666	Skin of hypothenar region of palm	89784008	C0222233	79164	XA5TQ4	343		342	343		342

EXIF Metadata (CP 1736)

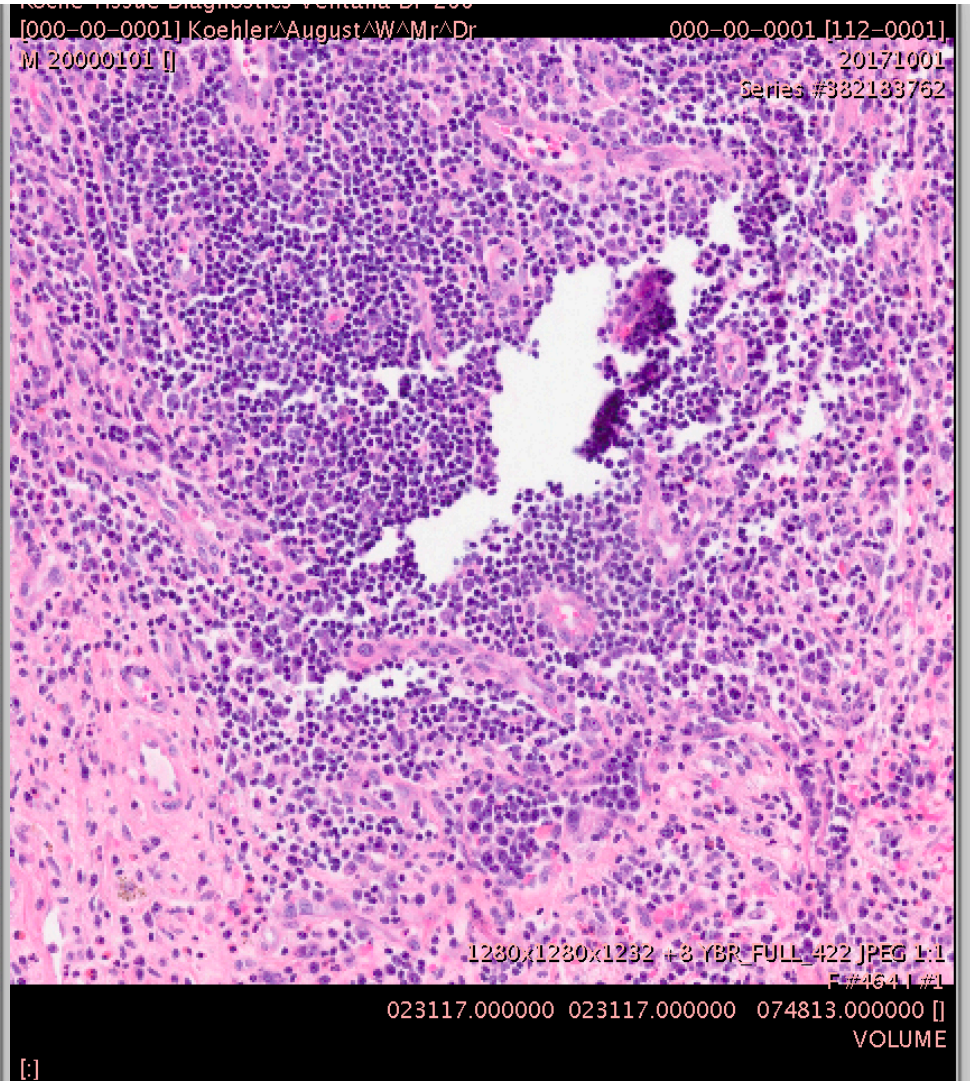
Attribute Name	DICOM Tag	DICOM Module	EXIF or TIFF Tag (hex)	EXIF or TIFF Tag (dec)	EXIF or TIFF IFD	EXIF or TIFF Key	EXIF or TIFF Type	EXIF or TIFF Tag description
(ggpa,9201)	Shutter Speed Value	VL Photographic Acquisition	0x9201	37377	Photo	ShutterSpeedValue	SRational	Shutter speed. The unit is the APEX (Additive System of Photographic Exposure) setting.
(ggpa,9202)	Aperture Value	VL Photographic Acquisition	0x9202	37378	Photo	ApertureValue	Rational	The lens aperture. The unit is the APEX value.
(ggpa,9203)	Brightness Value	VL Photographic Acquisition	0x9203	37379	Photo	BrightnessValue	SRational	The value of brightness. The unit is the APEX value. Ordinarily it is given in the range of -99.99 to 99.99.
(ggpa,9204)	Exposure Bias Value	VL Photographic Acquisition	0x9204	37380	Photo	ExposureBiasValue	SRational	The exposure bias. The units is the APEX value. Ordinarily it is given in the range of -99.99 to 99.99.
(ggpa,9205)	Max Aperture Value	VL Photographic Acquisition	0x9205	37381	Photo	MaxApertureValue	Rational	The smallest F number of the lens. The unit is the APEX value. Ordinarily it is given in the range of 00.00 to 99.99, but it is not limited to this range.
(ggpa,9206)	Subject Distance	VL Photographic Acquisition	0x9206	37382	Photo	SubjectDistance	Rational	The distance to the subject, given in meters.
(ggpa,9207)	Metering Mode	VL Photographic Acquisition	0x9207	37383	Photo	MeteringMode	Short	The metering mode.

Color Management Metadata

- DICOM's goal is only color consistency
  - i.e., all displays show same thing everywhere
  - display as the image creator intended
  - relies on ICC profiles encoded in DICOM file
- Out of scope: province of image creator
  - color calibration – how to create right profile
  - color normalization
- Multi-spectral image storage
  - theoretically possible in DICOM but no experience
  - define spectral characteristics of channels



No ICC Profile Applied



With ICC Profile Applied

Metadata for Specific Modalities

- Total Body Photography
  - ? new object required or re-use existing VL Photographic
  - how to encode stitched image +/ references to source images
  - re-use example of wide-field retinal photography?
- Dermoscopy-specific metadata
  - more specific optical path information
  - re-use ophthalmology, pathology attributes
- Optical Coherence Tomography (OCT)
  - new object required
  - re-use ophthalmology, cardiovascular OCT attributes
- Reflective Confocal Microscopy (RCM)
  - new object and attributes required
- In the interim
  - use extended VL Photographic, Secondary Capture objects, etc.

Device connectivity options

- Physical
  - removable media (memory card)
  - tethered (Ethernet or USB cable)
  - wireless (WiFi, Bluetooth)
- Logical
  - command and control
  - data (image) transfer
- Application
  - metadata pre- or after-load
  - demographics, etc.
  - device firmware or loadable “app”

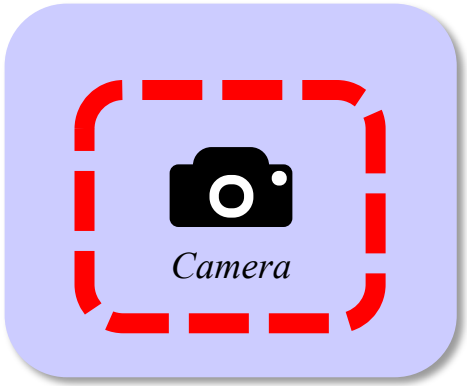
Wrapping a camera device

Camera

Wrapping a camera device

Proprietary Interface

Wrapping a camera device



Interface Application

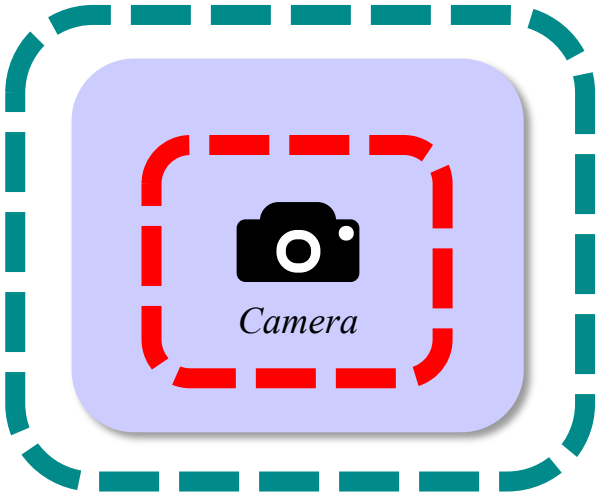
Proprietary Interface

Wrapping a camera device

Standard Boundary

Interface Application

Proprietary Interface



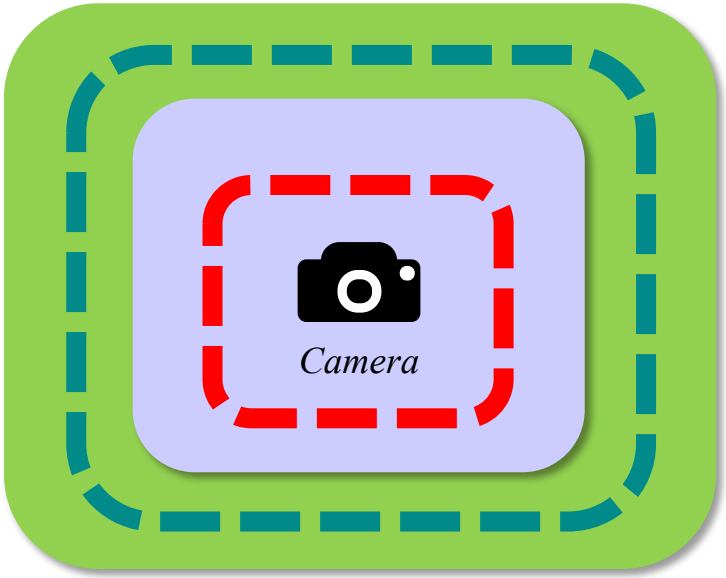
Wrapping a camera device

Standard Infrastructure

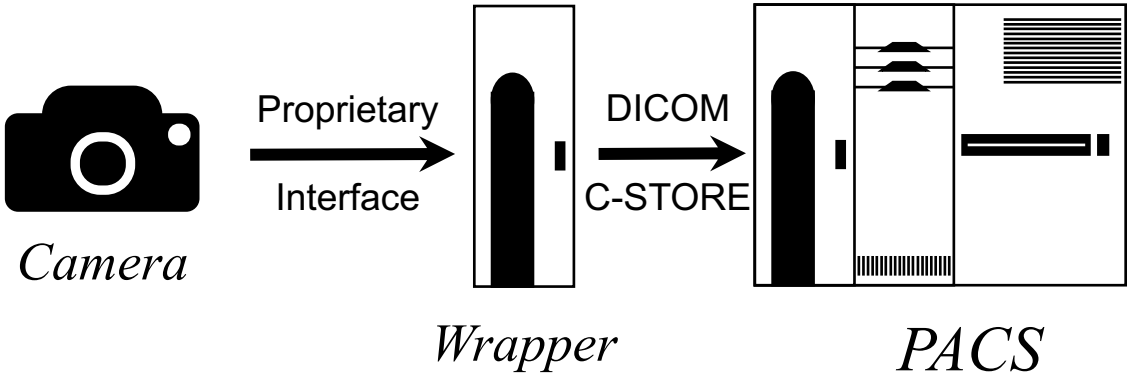
Standard Boundary

Interface Application

Proprietary Interface

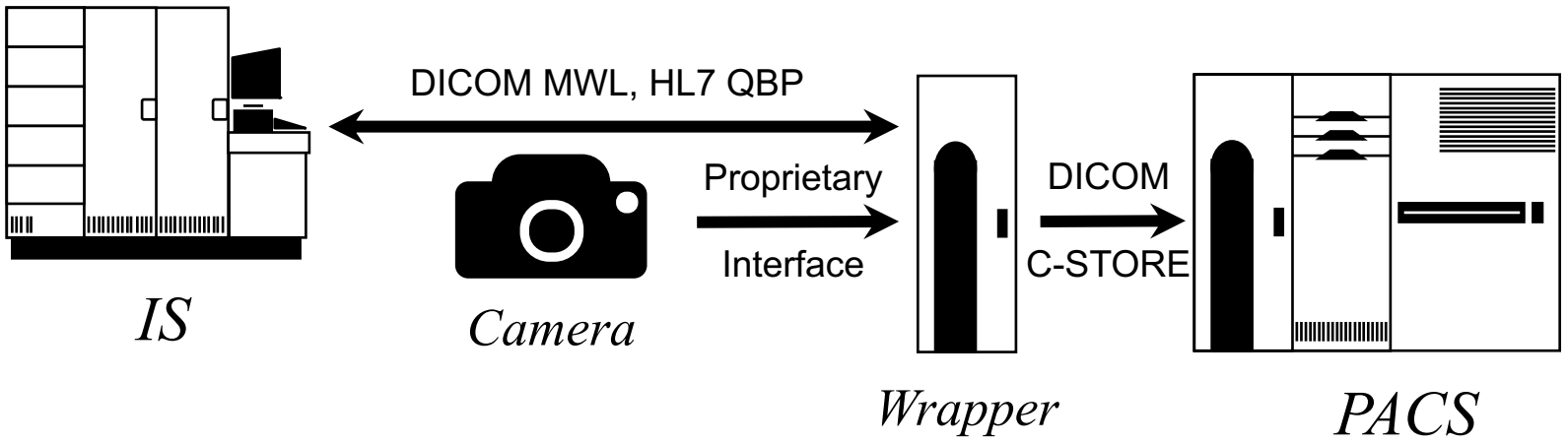


Camera wrapper application



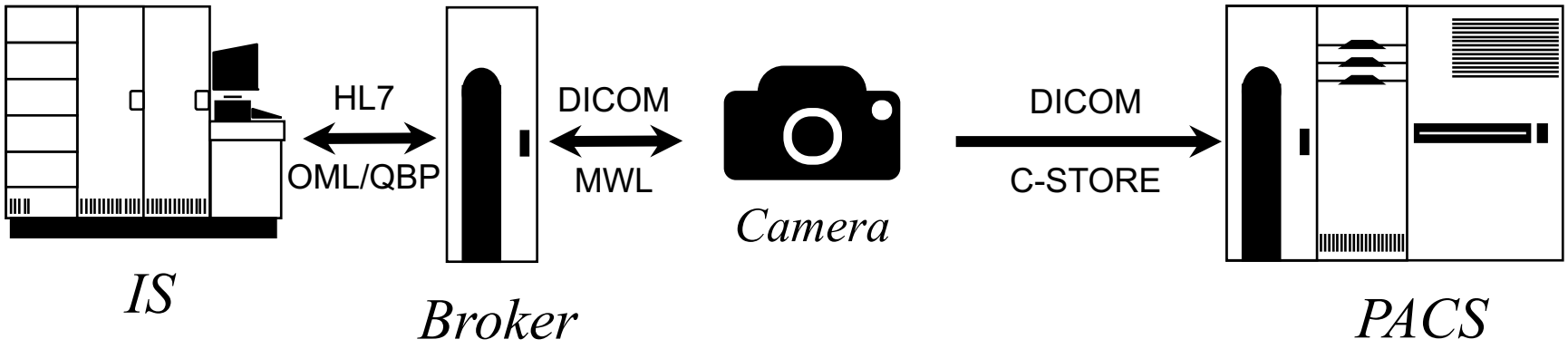
Wrapper provides user interface to populate metadata

IS Integration for Metadata

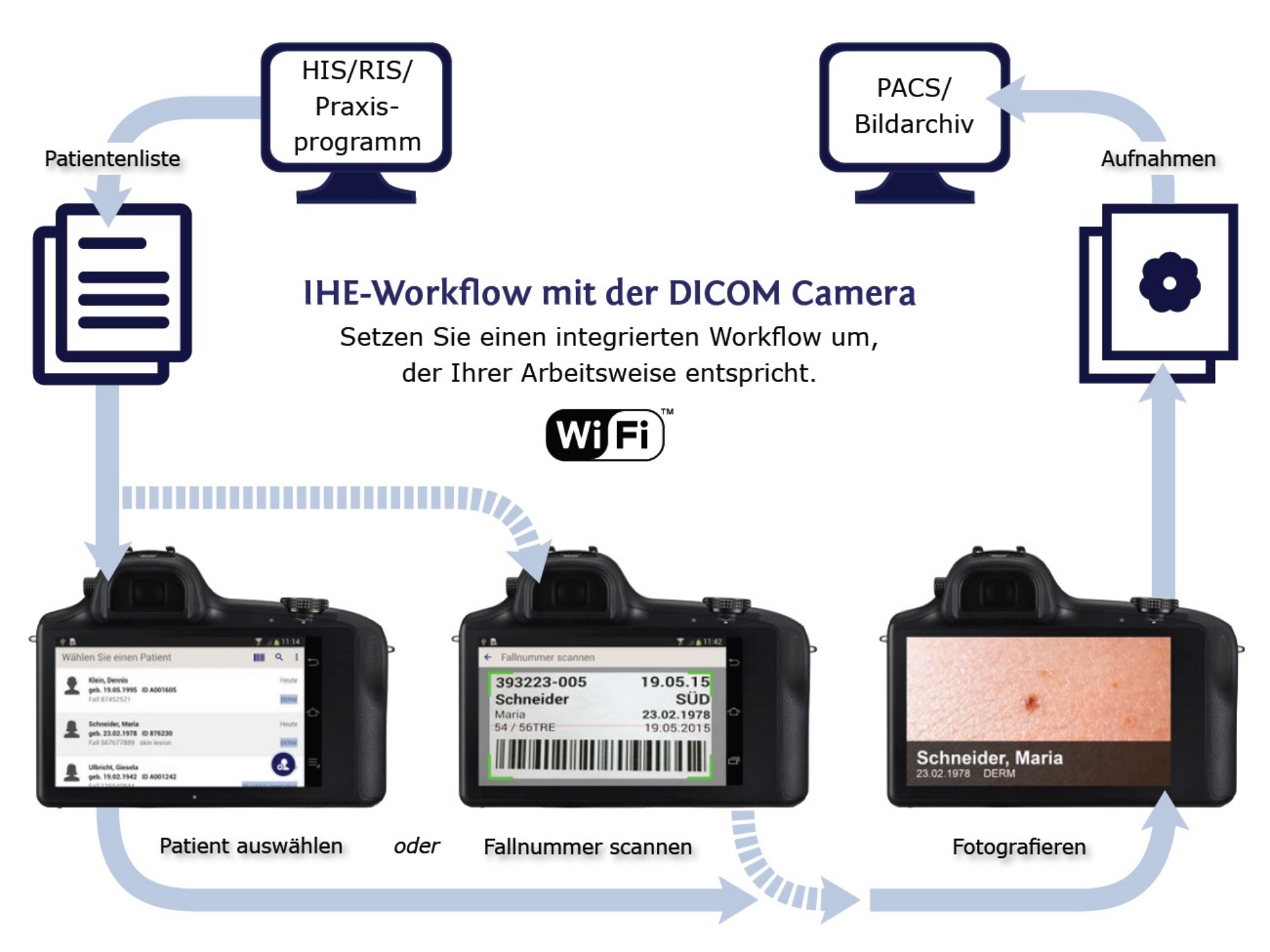


Wrapper re-uses IS-supplied metadata

DICOM Camera with MWL



Standard Images and HL7/DICOM IS Integration


HIS/RIS/
Praxis-
programm
PACS/
Bildarchiv
Patientenliste
Aufnahmen
IHE-Workflow mit der DICOM Camera
Setzen Sie einen integrierten Workflow um,
der Ihrer Arbeitsweise entspricht.
WiFi
Wählen Sie einen Patient
Fallnummer scannen
393223-005
19.05.15
Schneider
SÜD
Maria
23.02.1978
54 / 56TRE
19.05.2015
Schneider, Maria
23.02.1978 DERM
Patient auswählen
oder
Fallnummer scannen
Fotografieren

Dicompass DICOM Camera

App home screen

Select patient from worklist

Scan barcode or enter patient's data manually

Pathology localization (optional)

Take pictures

Crop images (if needed)

DICOM object are created and sent to PACS over WiFi

DICOM in the era of mobility

- Traditional DICOM payloads/protocols
  - designed for local area networks – do work on WAN, WiFi
  - dedicated protocols (i.e., not HTTP) – need toolkit/library
  - services
    - send (C-STORE)
    - retrieve (C-MOVE, C-GET)
    - query (C-FIND)
    - modality worklist (C-FIND)
    - …
  - binary tag-value pair encoding
  - security features rarely used (other than TLS)
  - huge installed base of archives, viewers, tools

DICOM in the era of mobility

- DICOMweb payloads/protocols
  - designed for browser, mobile devices, JavaScript
  - http access to “RESTful” resources
    - URLs for study/series/instance/frame/metadata
  - services
    - send (STOW-RS)
    - retrieve (WADO-RS)
    - query (QIDO-RS)
  - JSON and XML metadata encoding
  - ordinary image/jpeg payload (if compressed)
  - web security: https, OAUTH2, JWT etc.
  - relatively new but rapidly growing, esp. EMR, VNA

DICOMweb Cheatsheet

Study Resources and Actions

Verb	Path	Type	Description
POST	{s}/studies	Store PS3.18 6.6.1	Store instances
GET	{s}/studies?...	Query PS3.18 6.7.1	Query for matching studies
GET	{s}/studies/{studyUID}	Retrieve PS3.18 6.5.1	Retrieve entire study
POST	{s}/studies/{studyUID}	Store PS3.18 6.6.1	Store instances
GET	{s}/studies/{studyUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve metadata
GET	{s}/studies/{studyUID}/series?...	Query PS3.18 6.7.1	Query for matching series in a study
GET	{s}/studies/{studyUID}/series/{seriesUID}	Retrieve PS3.18 6.5.2	Retrieve entire series
GET	{s}/studies/{studyUID}/series/{seriesUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve series metadata
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances?...	Query PS3.18 6.7.1	Query for matching instances in a series
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}	Retrieve PS3.18 6.5.3	Retrieve instance
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}/metadata	Retrieve PS3.18 6.5.6	Retrieve instance metadata
GET	{s}/studies/{studyUID}/series/{seriesUID}/instances/{instanceUID}/frames/{frames}	Retrieve PS3.18 6.5.4	Retrieve frames in an instance
GET	/{bulkdataReference}	Retrieve PS3.18 6.5.5	Retrieve bulk data

More Information

See http://dicomweb.org and Part 18 of the DICOM Standard, http://dicom.nema.org/standard.html.

Workflow Resources and Actions

Verb	Path	Type	Description
POST	{s}/workitems{?AffectedSOPInstanceUID}	PS3.18 6.9.1	CreateUPS
POST	{s}/workitems/{UPSInstanceUID}{?transaction}	PS3.18 6.9.2	UpdateUPS
GET	{s}/workitems{?query*}	PS3.18 6.9.3	SearchForUPS
GET	{s}/workitems/{UPSInstanceUID}	PS3.18 6.9.4	RetrieveUPS
PUT	{s}/workitems/{UPSInstanceUID}/state	PS3.18 6.9.5	ChangeUPSState
POST	{s}/workitems/{UPSInstanceUID}/cancelrequest	PS3.18 6.9.6	RequestUPS Cancellation
POST	{s}/workitems/{UPSInstanceUID}/subscribers/{AETitle}{?deletionlock}	PS3.18 6.9.7	CreateSubscription
POST	{s}/workitems/1.2.840.10008.5.1.4.34.5/	PS3.18 6.9.8	SuspendGlobal Subscription
DELETE	{s}/workitems/{UPSInstanceUID}/subscribers/{AETitle}	PS3.18 6.9.9	DeleteSubscription
GET	{s}/subscribers/{AETitle}	PS3.18 6.9.10	OpenEventChannel
N/A	N/A	PS3.18 6.9.11	SendEventReport

Payloads

XML

```
<NativeDicomModel>
  <DicomAttribute Tag="00080020"
VR="DT" Keyword="StudyDate">
    <Value
number="1">20130409</value>
  </DicomAttribute>
  <DicomAttribute Tag="00080030"
VR="TM" Keyword="StudyTime">
    <Value
number="1">131600.0000</value>
  </DicomAttribute>
  …
</NativeDicomModel>
```

JSON

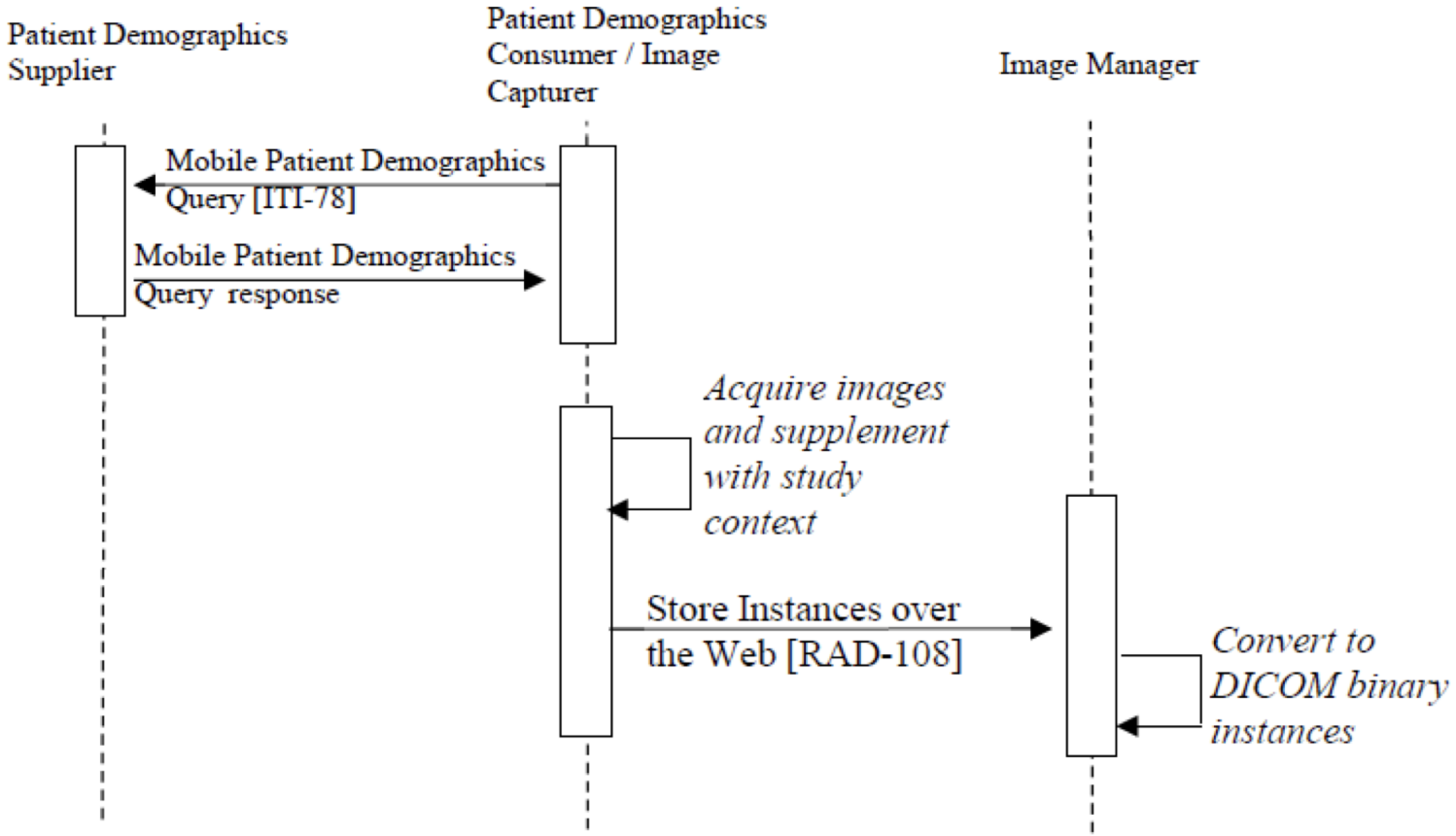
```
{
    "00080020": {
        "vr": "DT",
        "Value":
["20130409"]
    },
    "00080030": {
        "vr": "TM",
        "Value":
["131600.0000"]
    },
    …
}
```

(these payloads are excerpts to show payload structure; these are not complete)

DICOMweb – easy to capture

- Consider phone app developer's task
  - has a JPEG from the camera API
  - has an identifier from the barcode API
  - wants to send to DICOM PACS
  - knows nothing about DICOM
- Minimal documentation describes
  - URL to which can send JSON header + image/jpeg
  - JSON template to insert identifier into
- Standard DICOMweb server does the rest
  - server "fills in the blanks"
  - uses supplied identifier to look up & insert demographics
  - uses JPEG header to populate required pixel data module

IHE Web Image Capture (WIC)

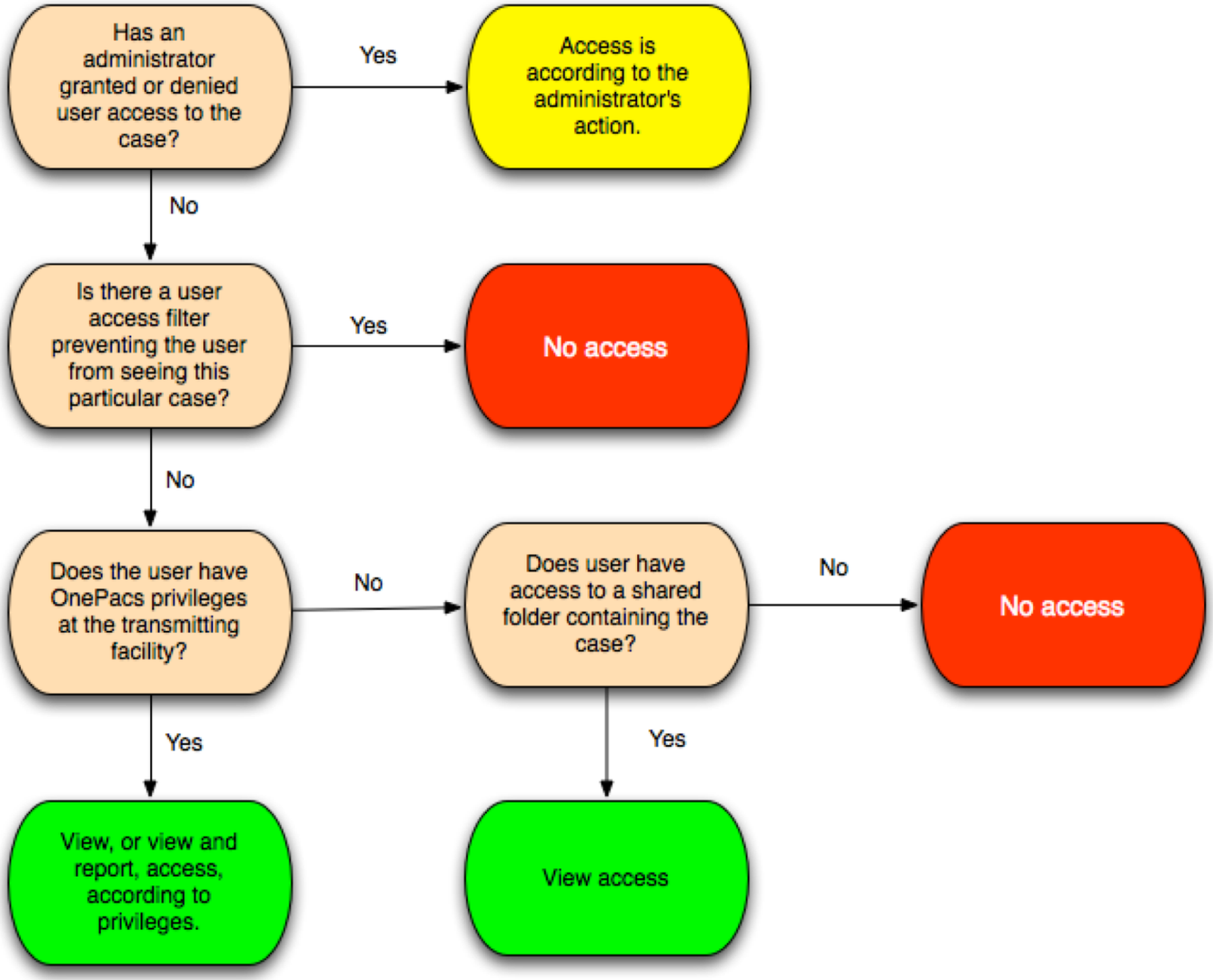


Security & Privacy Concerns

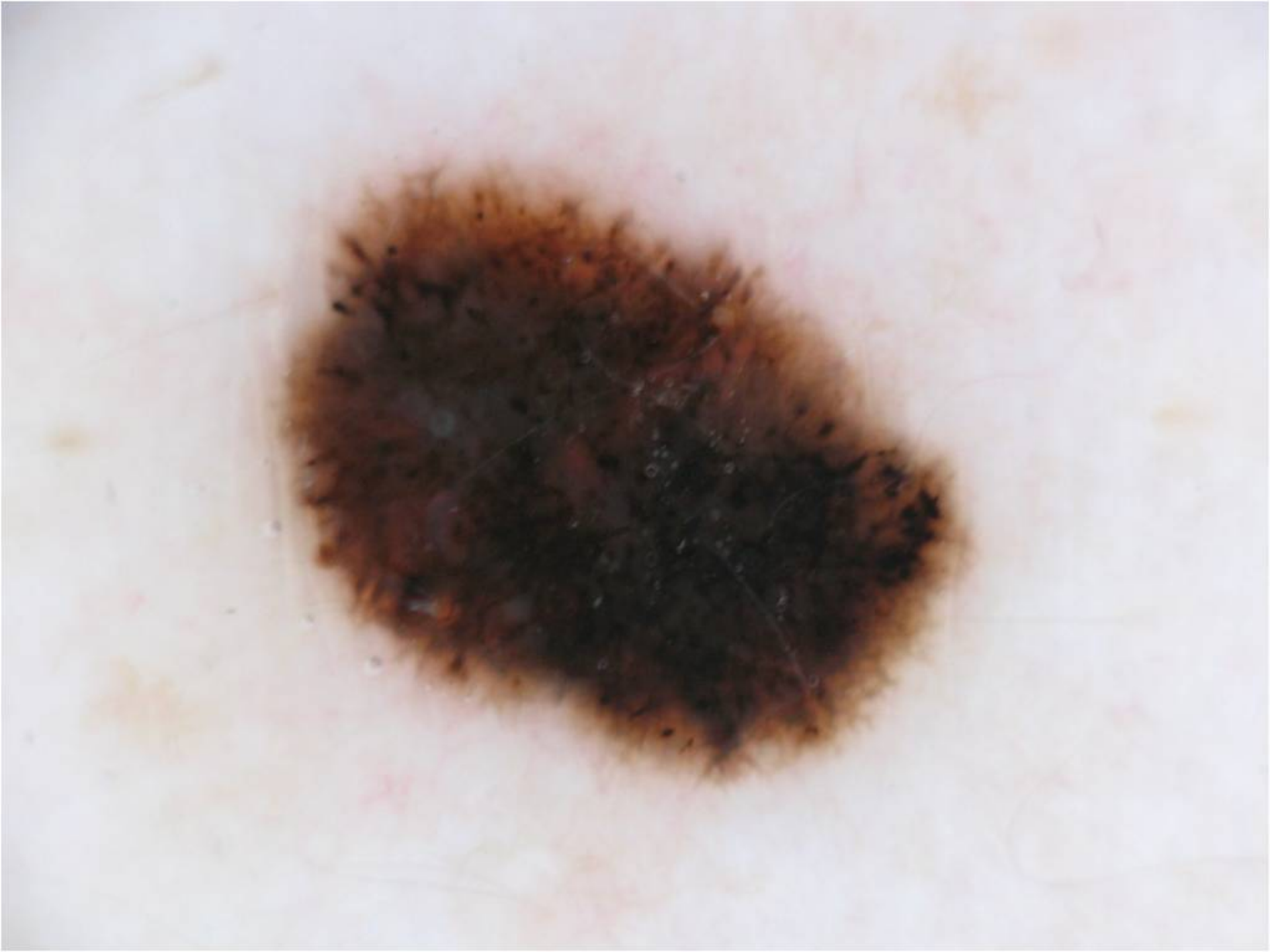
PACS Access Control

- Deployment
  - historically, many radiology deployments unrestricted
  - many contemporary PACS/VNA do provide per user or role based access control, separate databases/folders/facilities
  - needs reliable authentication
- Interface
  - proprietary user interface easily secured
  - traditional DICOM interface can be but is rarely secured
  - newer DICOMweb more easily secured (SSO with EMR)
- Restrict (filter) triggered by DICOM attributes
  - device source, modality, specialty, department, etc.

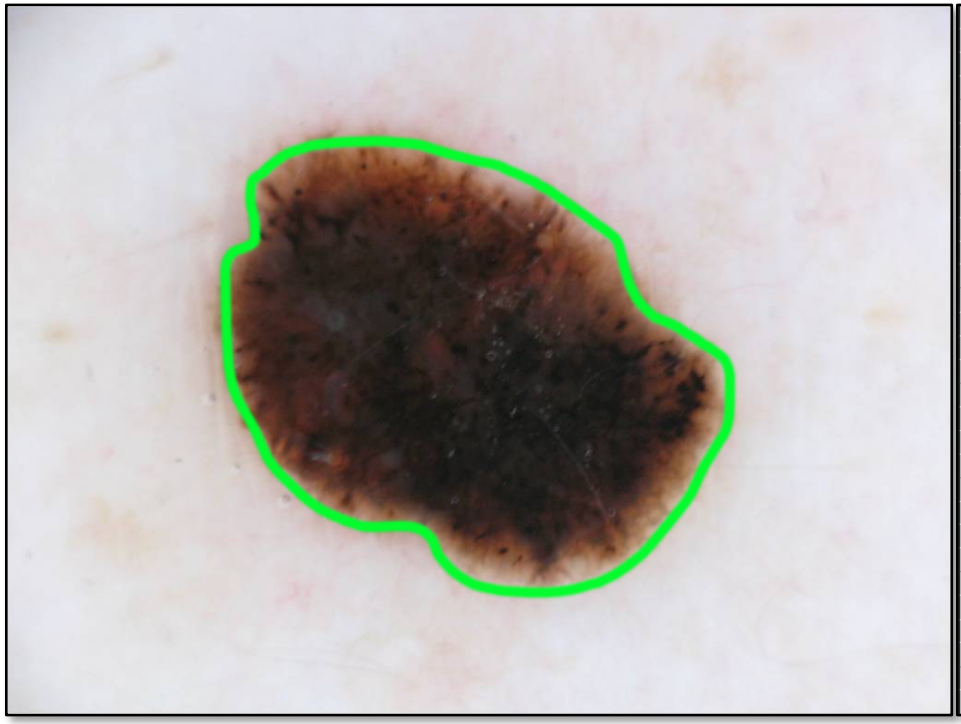
OnePacs Case Access

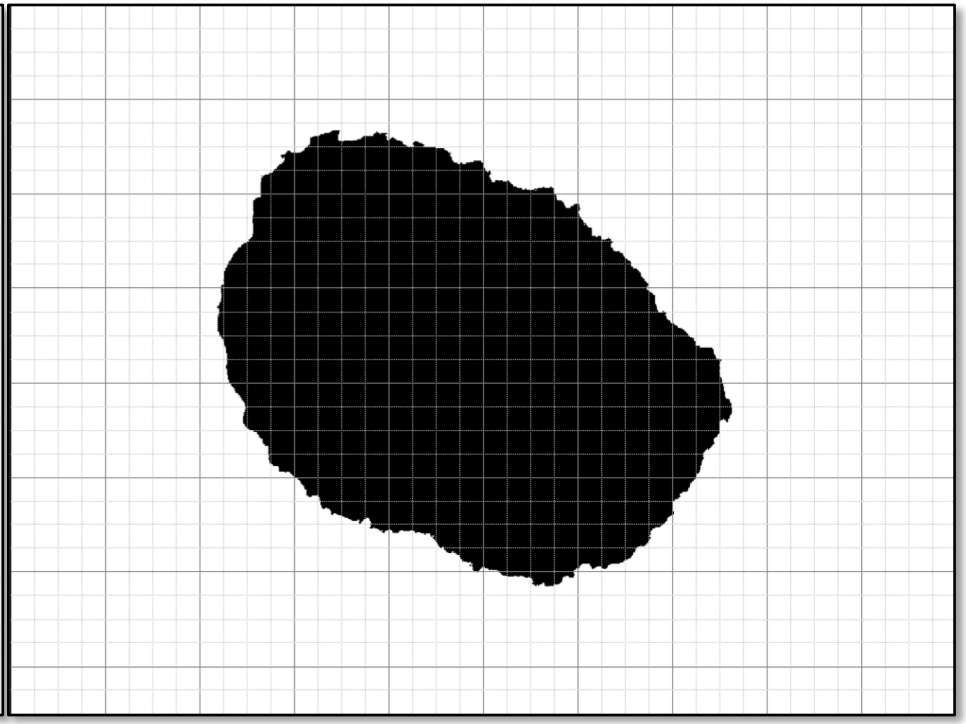


https://onepacshelp.com/display/V12/Managing+Case+Access



Annotation Representation





Contour – 2D Coordinates (SR)

Rasterized Bitmap (SEG)

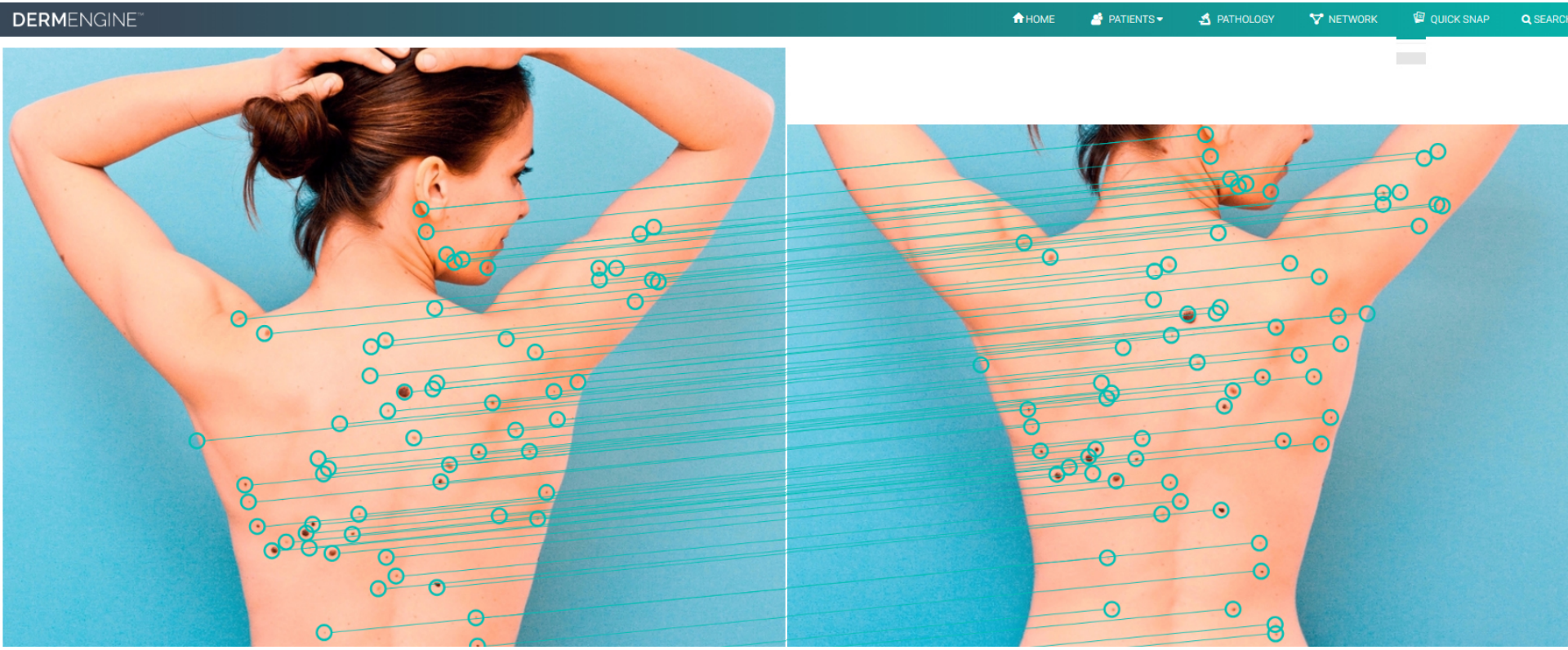
DICOM Segmentation Objects

- Not just for 3D cross-sectional images
  - i.e., photographs, 2D projection images too
  - 1:1 correspondence to original pixel matrix
- Multiple planes
  - different segmentation properties
  - can be overlapping (i.e., not a label map)
- Single bit or fractional
  - fractional can be occupancy or probability

DICOM Structured Reports (SR)

- Spatial coordinates
  - 2D image relative referencing original image
- Can also reference segmentations
- Other coded/structured content
  - measurements (e.g., size)
  - other quantitative values (e.g., texture features)
  - qualitative (categorical) assessments (e.g., malignant)
- Temporal information
  - describe change over time
- Lesion tracking
  - human-readable and unique identifiers

Encoding Lesion Matching



DICOM Tracking ID/UID

Table TID 4108. Tracking Identifier

	NL	Rel with Parent	VT	Concept Name	VM	Req Type	Condition	Value Set Constraint
1			TEXT	EV (112039, DCM, "Tracking Identifier")	1	MC	At least one of row 1 or 2 shall be present.	A string of characters with case being non-significant. Leading and trailing spaces and control characters are forbidden.
2			UIDREF	EV (112040, DCM, "Tracking Unique Identifier")	1	MC	At least one of row 1 or 2 shall be present.	

Content Item Descriptions

Tracking Identifier	A human readable identifier for longitudinal tracking, e.g., "Watchlist Nodule 1".
Tracking Unique Identifier	This is distinct from the Observation UID (0040,A171) that may be present in the data set for each Content Item, which identifies only a specific observation, not an object tracked over time, and each tracked object may have many observations.

In both DICOM Structured Reports and Segmentation Objects

DICOM 3D and Surface Scans

- Surface Segmentation
- Surface Scan Mesh
- Surface Scan Point Cloud

- Rigid and Deformable Registration (field not spline)
- Spatial Fiducials

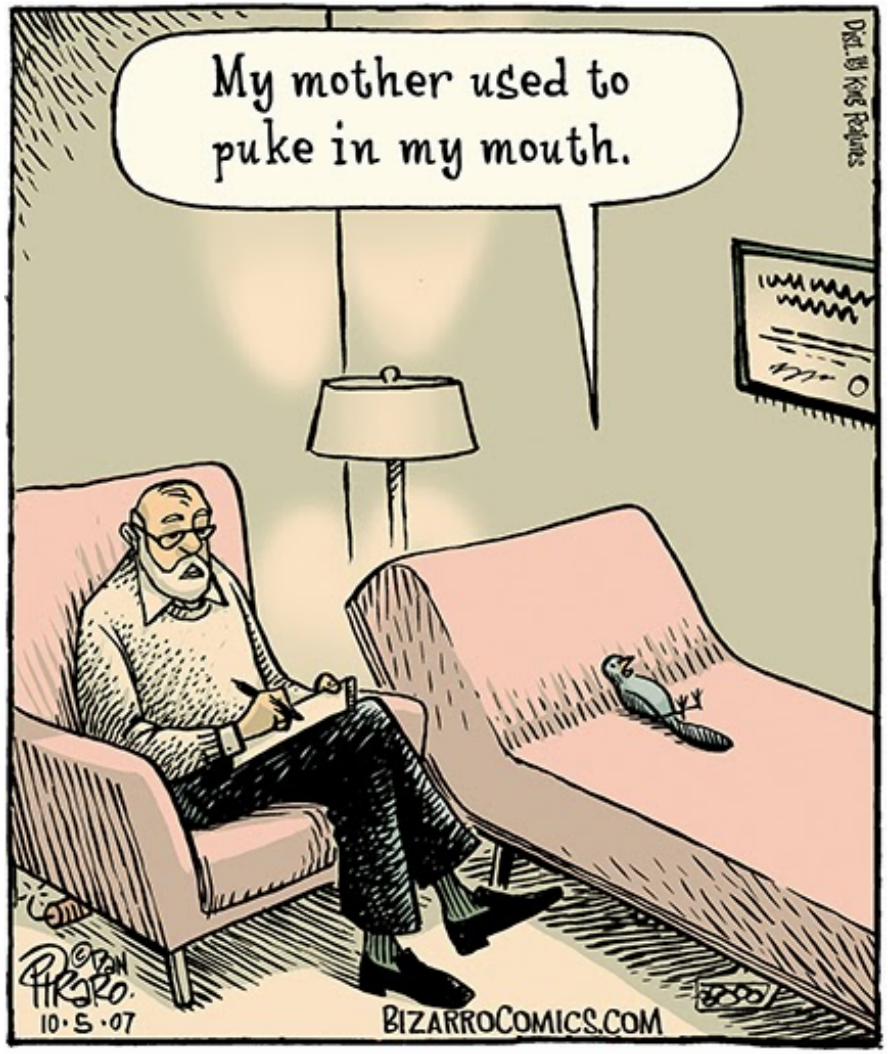
- Encapsulated STL (3D Manufacturing)
- Encapsulated OBJ, etc., (work in progress)

? of interest for TBP +/- stereophotogrammetry

DICOM & Camera RAW images

- From DSLRs and mobile devices (phones)
- Proprietary formats
  - format is dependent on maker, model, version
- Adobe Digital Negative (DNG)
  - TIFF-like structure
  - +/- embedded original RAW file
- DICOM possibilities
  - existing Raw Data object
    - intended for proprietary CT/MR/PET raw data
    - standard composite context + private (image) payload
    - storage & regurgitate from PACS – proprietary viewer
  - new Encapsulated DNG object?
    - +/- EXIF DICOM attributes

Store & Regurgitate



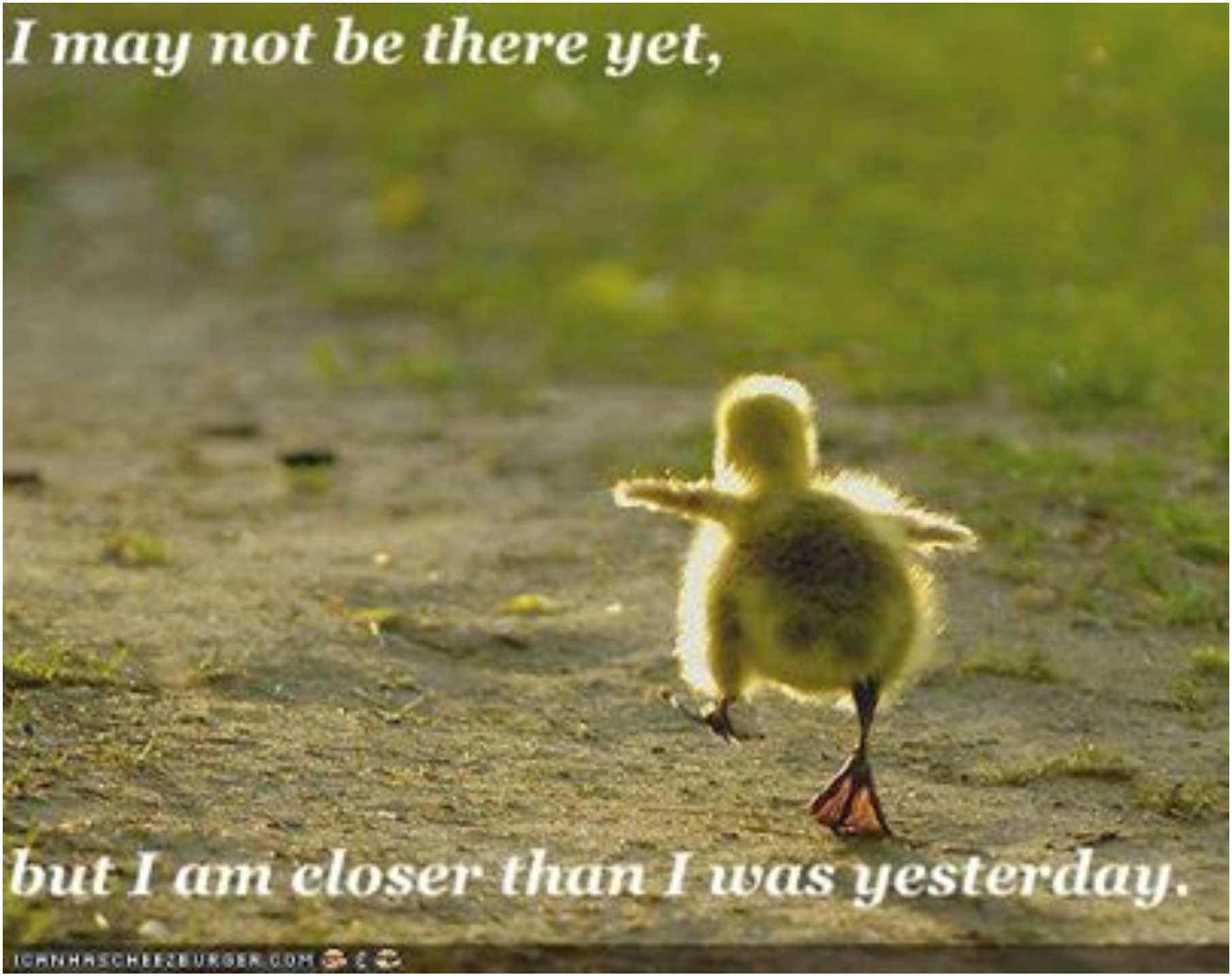
Interoperability

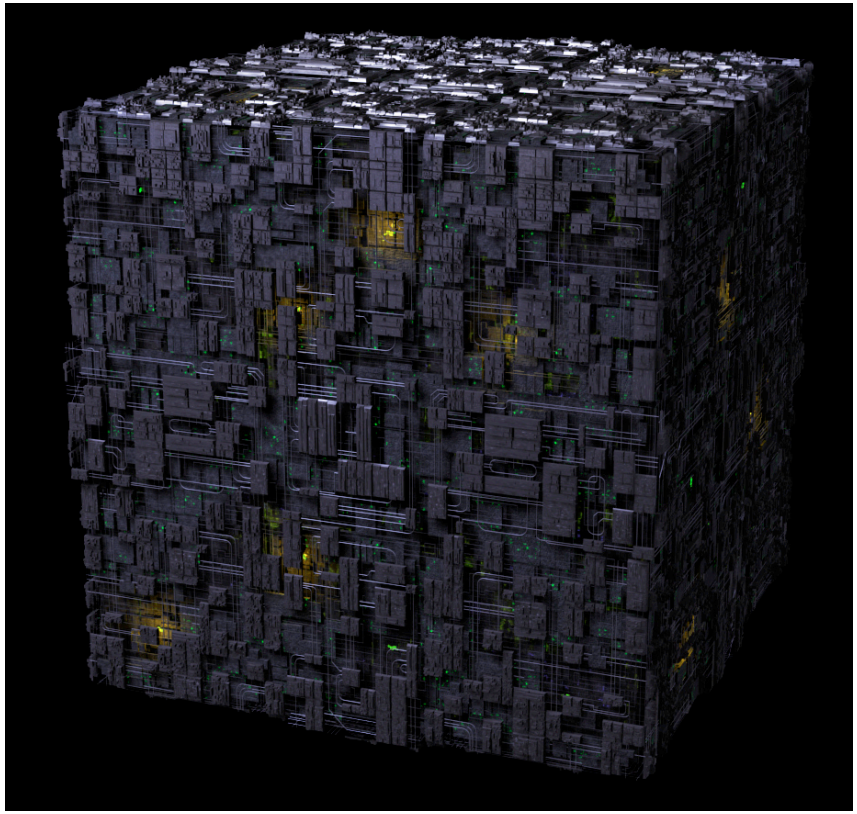
*"the ability of two or more systems or components to **exchange** information and to **use** the information that has been exchanged"*

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

Barriers to Interoperability

- ≈ barriers to adoption of DICOM in dermatology
- Lack of customer demand
  - education about feasibility and opportunities
- Cost of interoperability features
  - economies of scale
  - cost of failure (loss of data, security breach)
- Missing dermatology features (in products/standard)
  - best of breed mix of generic infrastructure & specific tools
  - extend standard
- Need to address security & privacy
  - choose solutions with appropriate segregation/controls


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



DICOM℠

Digital Imaging and Communications in Medicine

“we will add your biological and technological distinctiveness to our own”

“your culture will adapt to service us”

“resistance is futile”