Pathways To The Future – Navigating The Next Evolution Of DICOM In Enterprise Imaging
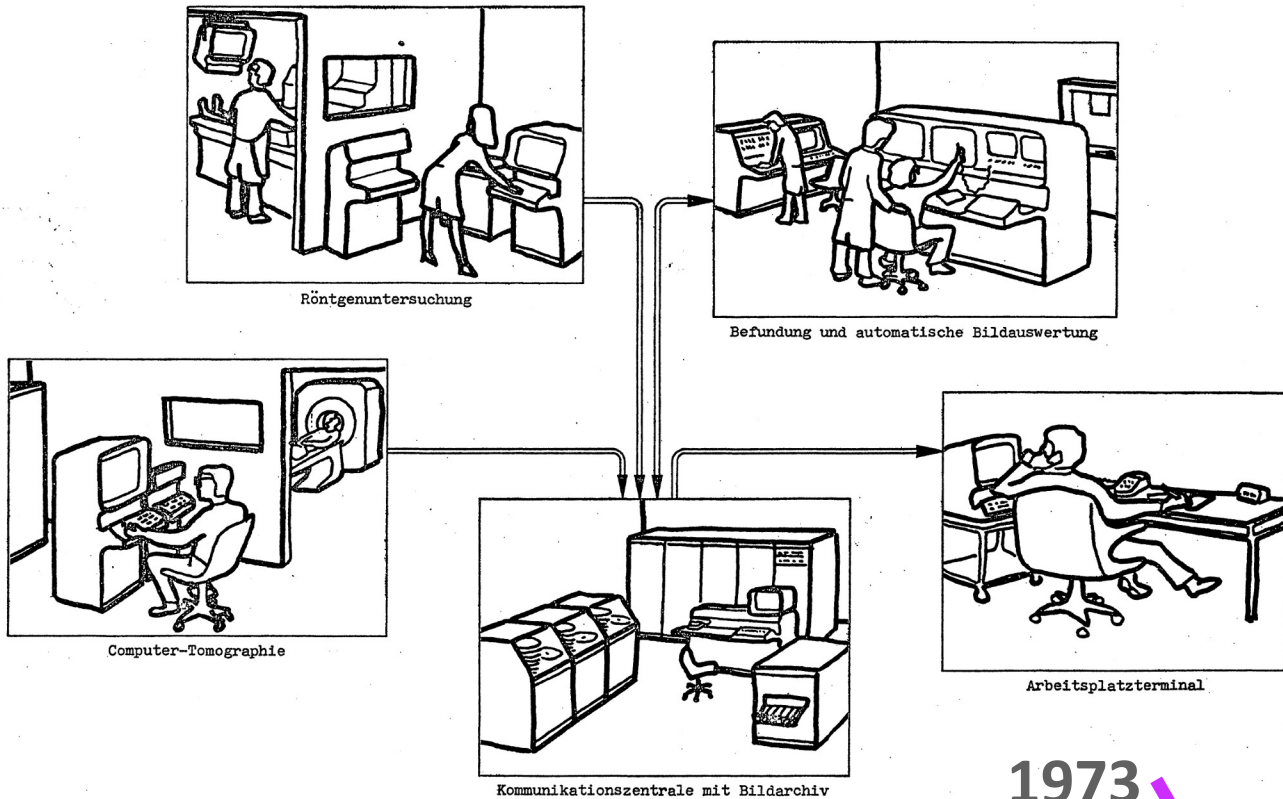
David Clunie, PixelMed

Disclosures

- Editor of the DICOM Standard (NEMA contract)
- NCI FNL Leidos Essex sub-contractor (SME DICOM, de-identification)
- NCI Imaging Data Commons (IDC) sub-contractor
- Consult with various equipment manufacturers regarding DICOM

Overview

- History of ACR-NEMA and DICOM
- History of DICOMweb
- DICOM and Enterprise Imaging
- What's next for DICOM
- Why there will not be a DICOM 4 at this time
- How DICOM will incrementally improve

Röntgenuntersuchung

Befundung und automatische Bildauswertung

Computer-Tomographie

Kommunikationszentrale mit Bildarchiv

Arbeitsplatzterminal

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.

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
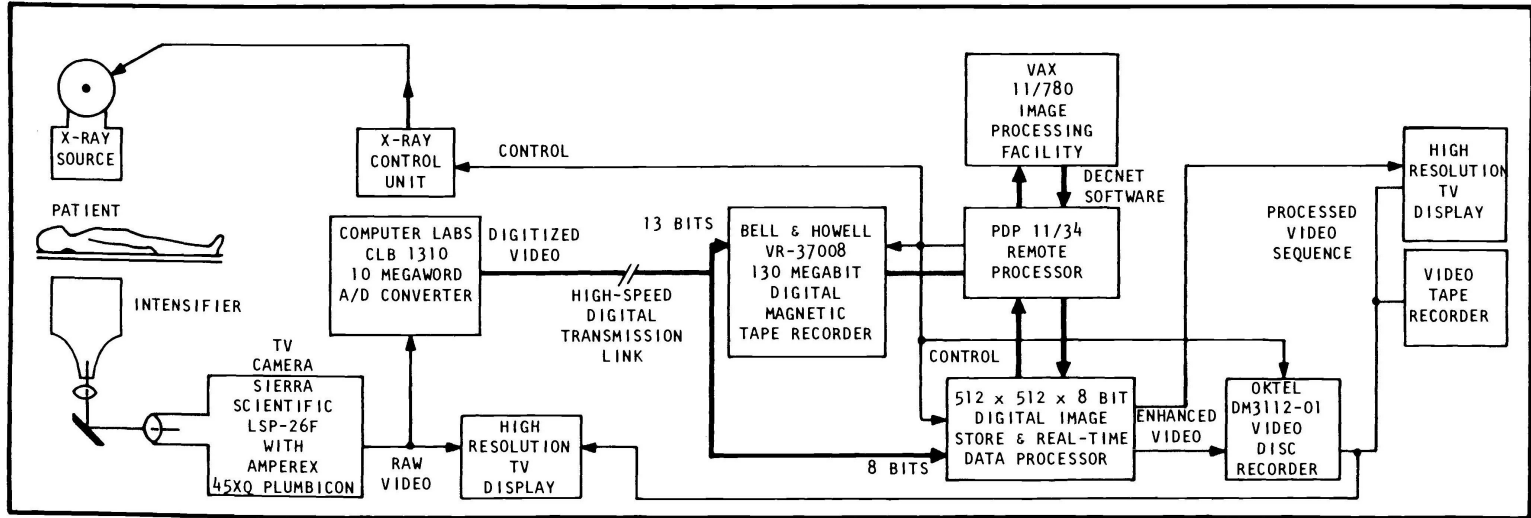
Figure 1.   System block diagram of demonstration facility.

1981

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

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

DICOM – Brief Early History

- 1982 – 1st PACS Conference – session on standards
- 1982 – AAPM Report 10 – Standard Format for Image Interchange
- 1983 – ad hoc meeting between FDA, ACR & NEMA
- 1983 – 1st meeting of ACR-NEMA "Digital Imaging and Communications Standards" Cmte
- 1985 – ACR-NEMA 300-1985 ("version 1.0") issued

- 1988 – ACR-NEMA 300-1988 ("version 2.0") issued
- 1990 – Inter-vendor testing of version 2.0 at Georgetown
- 1992 – Trial of DICOM ("version 3.0) at RSNA

- 1993 – DICOM 3.0 issued

DICOM – Brief Early History

- 1982 – 1st PACS Conference – session on standards
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- 1983 – ad hoc meeting between FDA, ACR & NEMA
- 1983 – 1st meeting of ACR-NEMA "Digital Imaging and Communications Standards" Cmte
- 1985 – ACR-NEMA 300-1985 ("version 1.0") issued
- 1985 – IEEE 802.3 Ethernet (based on 1976 Metcalfe)
- 1986 – Aldus TIFF (version 3; prior versions drafts only)
- 1987 – CompuServe GIF
- 1988 – ACR-NEMA 300-1988 ("version 2.0") issued
- 1990 – Inter-vendor testing of version 2.0 at Georgetown
- 1992 – Trial of DICOM ("version 3.0) at RSNA
- 1992 – JPEG (ITU T.81; ISO 10918-1 1994)
- 1993 – DICOM 3.0 issued

DICOM – Brief History – ACR-NEMA versions 1 and 2

- 50-pin 16 bit parallel interface
- No network (assumed "network interface unit")
- Layered
- Messages with commands and data
- Tag-value pairs
- Described patients, studies, images
- Described modality, acquisition, 3D position, etc.
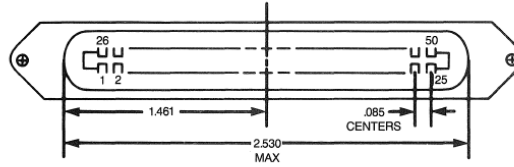
Figure 7-4
CONNECTOR—50 PIN FEMALE RECEPTACLE FRONT VIEW

26   50
1 2   25
1.461
.085
CENTERS
2.530
MAX

D0

DEVICE   DEVICE

D15   D15
PAR   PAR
STBO   STBO
STBI   STBI
REQO   REQO
REQI   REQI
INTO   INTO
INTI   INTI
SIGNAL GND   SIGNAL GND

INTERFACE PLANE

Figure 7-2
PHYSICAL AND LOGICAL INTERFACE

DATA AND PARITY CIRCUITS:

RECEIVE   120Ω   120Ω   TRANSMIT

3-STATE
CONTROL

TRANSMIT   RECEIVE

RELEASED
(3-STATE)
CONTROL

CONTROL CIRCUITS:

RECEIVE   120Ω   TRANSMIT

TRANSMIT   120Ω   RECEIVE

SIGNAL   SIGNAL
GND   GND
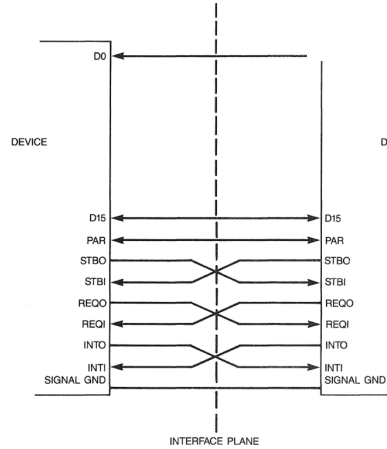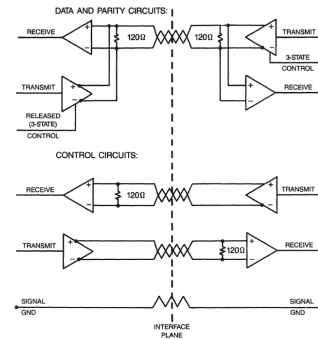
INTERFACE
PLANE

Figure 7-3
TYPICAL INTERFACE CIRCUIT

Figure 7-4
CONNECTOR—50 PIN FEMALE RECEPTACLE FRONT

26 50
1 2 25
1.461 .085 CENTERS
2.530 MAX

Figure 7-2
PHYSICAL AND LOGICAL INTERFACE

DEVICE | DEVICE

D0

D15 — D15
PAR — PAR
STBO — STBO
STBI — STBI
REQO — REQO
REQI — REQI
INTO — INTO
INTI — INTI
SIGNAL GND — SIGNAL GND

INTERFACE PLANE

Figure 7-3
TYPICAL INTERFACE CIRCUIT

DATA AND PARITY CIRCUITS:

RECEIVE 120Ω 120Ω TRANSMIT
3-STATE CONTROL
TRANSMIT RECEIVE
RELEASED (3-STATE) CONTROL

CONTROL CIRCUITS:

120Ω TRANSMIT
TRANSMIT 120Ω RECEIVE

SIGNAL GND — SIGNAL GND
INTERFACE PLANE

MESSAGE STRUCTURE
SEND__REQUEST

GROUP	ELEMENT	LENGTH	VALUE	MEANING	DESCRIPTION
0000	0000	0004 0000	0044 0000		Even number of bytes from the end of this field to the beginning of the next group
0000	0001	0004 0000	0190 0010		Even number of bytes from the end of this field to the end of the message
0000	0100	0002 0000	0001	''0001''	Command field = SEND__ REQUEST
0000	0110	0004 0000	3231 4133	''123A''	Device generated message ID
0000	0200	0004 0000	4344 3148	''DCH1''	Logical address of sender
0000	0300	0004 0000	4341 3148	''ACH1''	Logical address of receiver
0000	0800	0002 0000	0000	''0000''	Data type = image
0008	0000	0004 0000	0084 0000		Group length
0008	0001	0004 0000	0140 0010		Message length
0008	0010	000C 0000	4341 2D52 454E 414D 3120 302E	''ACR-NEMA 1.0''	Recognition code
0008	0020	000A 0000	3931 3538 312E 2E31 3532	''1985.11.25''	Study date
0008	0030	0008 0000	3231 303A 3A35 3935	''12:05:59''	Study time
0008	0040	0006 0000	4D49 4741 2045	''Image''	Data set type
0008	0060	0002 0000	5244	''DR''	Modality
0008	0070	0004 0000	4241 4443	''ABCD''	Manufacturer
0008	0080	000E 0000	454D 4352 2059 4F48 5053 5449 4C41	''Mercy Hospital''	Institution ID

MESSAGE STRUCTURE
SEND__REQUEST

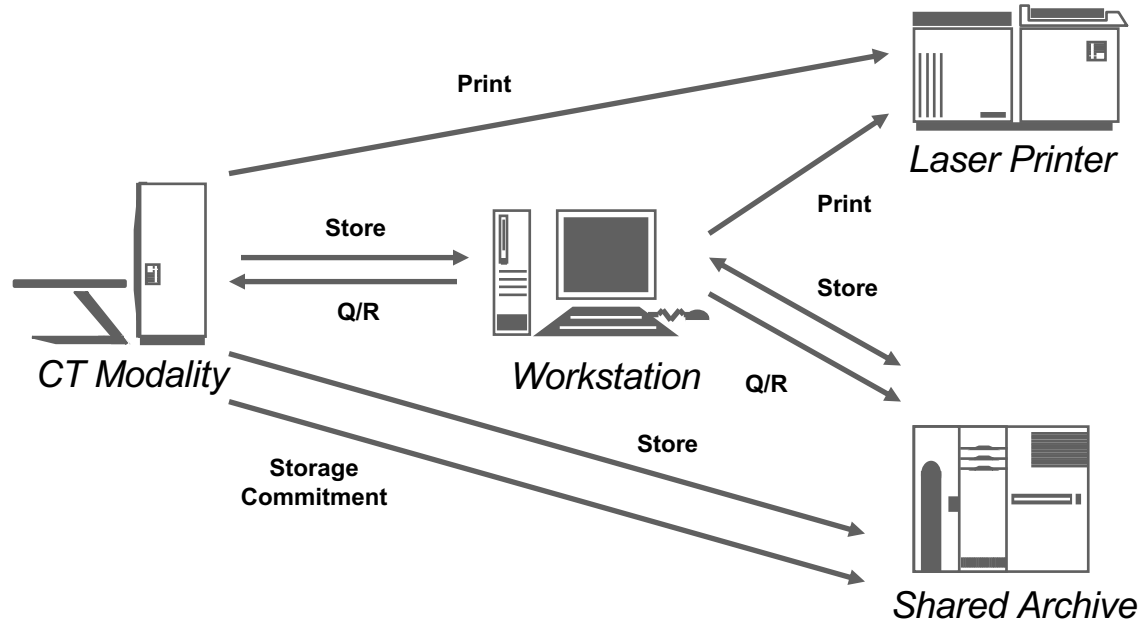| GROUP	ELEMENT	LENGTH	VALUE	MEANING	DESCRIPTION
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DICOM – Brief History – DICOM "3.0" in 1993

- TCP/IP network protocol
  - OSI semantics (OSI protocols themselves never used)
- "Object-oriented" description
  - IODs and Modules and Attributes
- Conformance
  - SOP Classes
  - Transfer Syntaxes (esp. byte order, compression, lossy and lossless)
- Composite IODs and Storage SOP Classes
  - images with patient, study, series, etc. embedded and repeated
- Normalized IODs and Detached Management SOP Classes
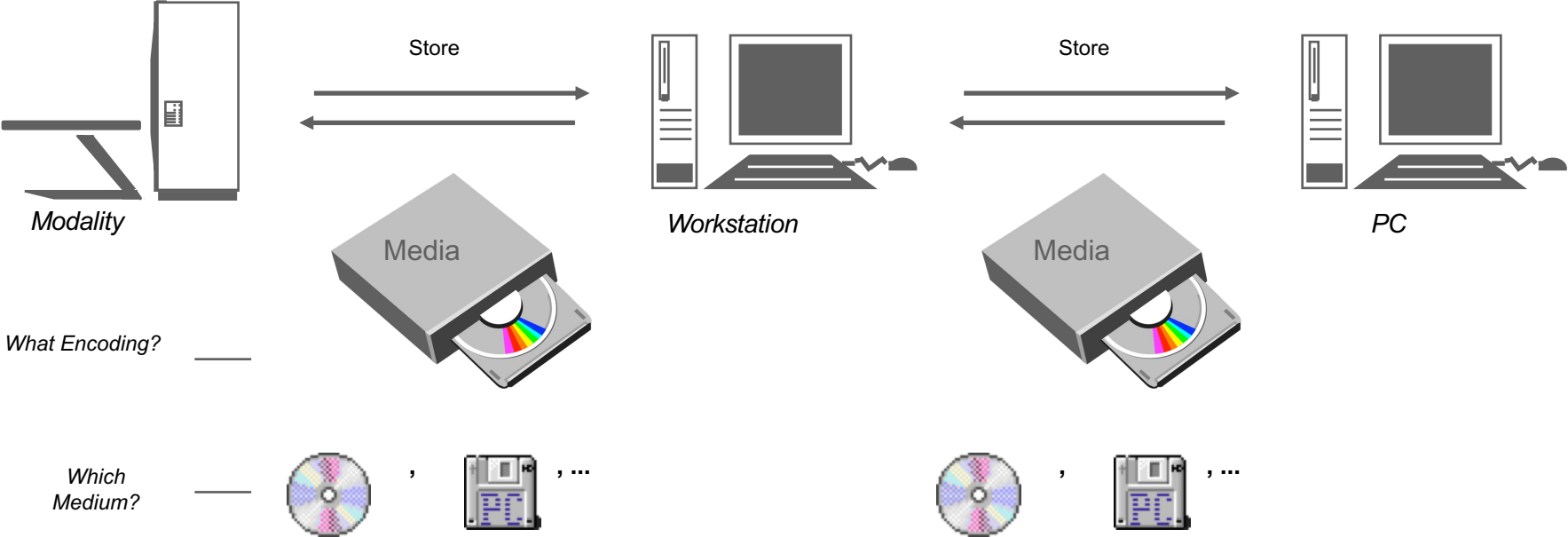 - Patient, Visit, Study, Results, Interpretation (all retired)

DICOM and Radiology Modality

Modality

Storage
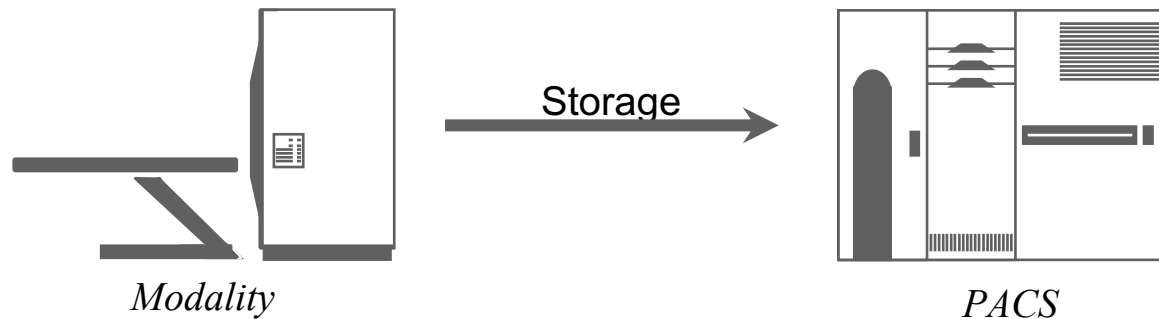
PACS

DICOM and Mini-PACS Cluster

DICOM Network and Media

Store

Store

Modality

Workstation

PC

Media

Media

What Encoding?

Which Medium?

, ...

, ...
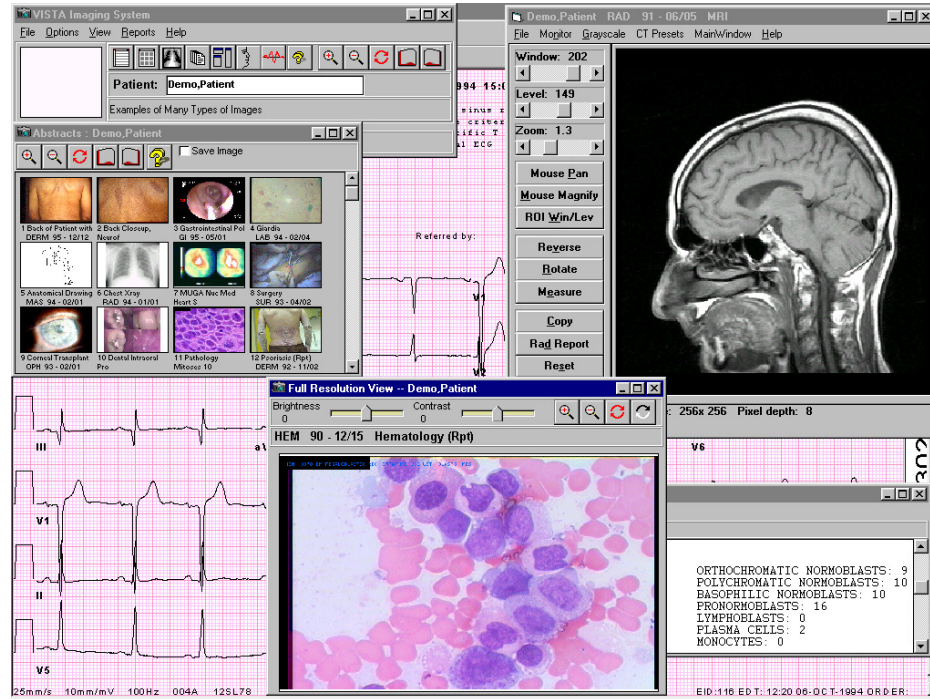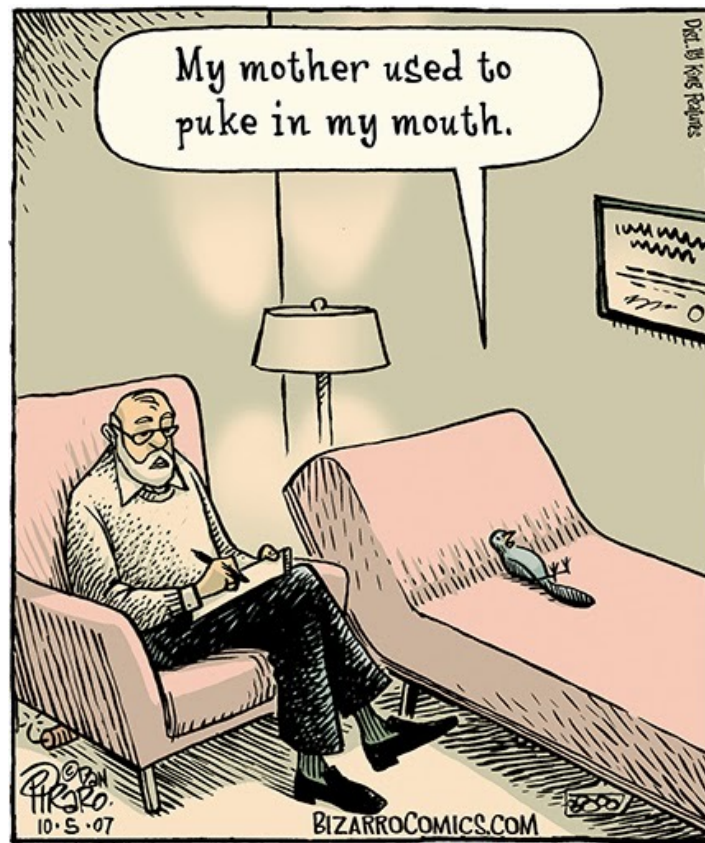
Enterprise Imaging is not new – DICOM beyond just radiology, cardiology & RT
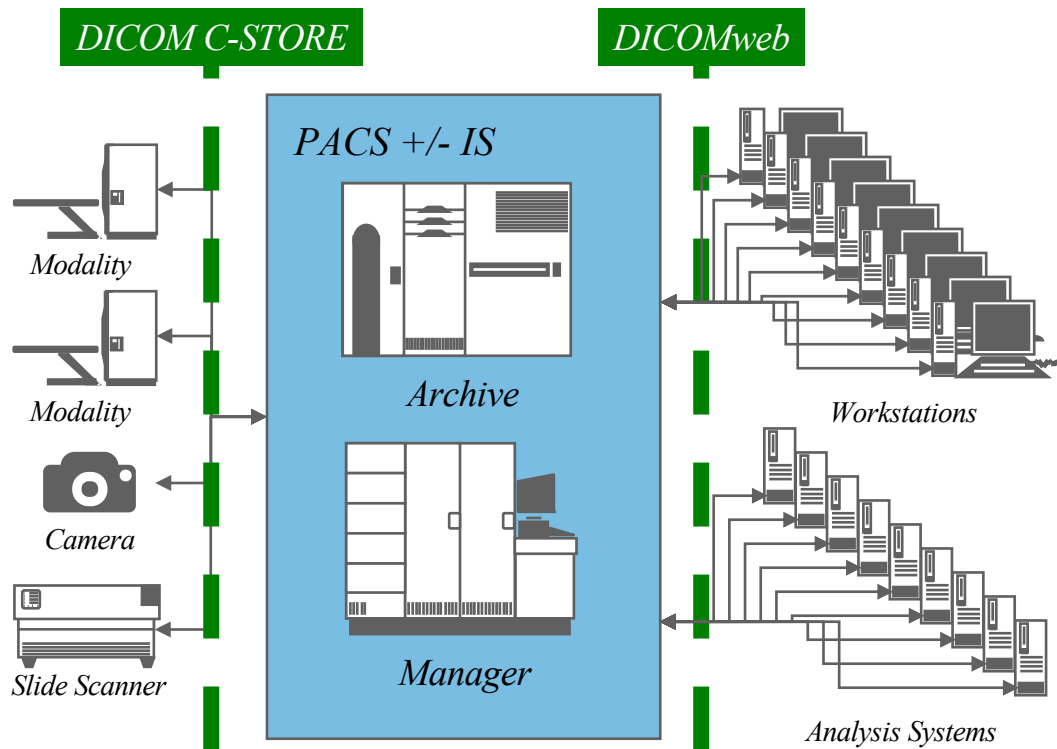
Cardiology
Bronchoscopy
Gastrointestinal
Endoscopy
Hematology
Pathology
Surgery
Nuclear Medicine
Dental
Radiology
Dermatology
Ophthalmology
Podiatry
Vascular
Urology
Nursing
Electrocardiography
Scanned Documents

Kuzmak P, Dayhoff R. 10 Years of DICOM at the Department of Veterans Affairs. DICOM Workshop; 2003

Use DICOM to Store, Find & Regurgitate +/- View ANYTHING

DICOM – Enterprise Imaging

DICOM C-STORE

DICOMweb

PACS +/- IS

Modality

Modality

Camera

Slide Scanner

Archive

Manager

Workstations

Analysis Systems

DICOM – Cloud
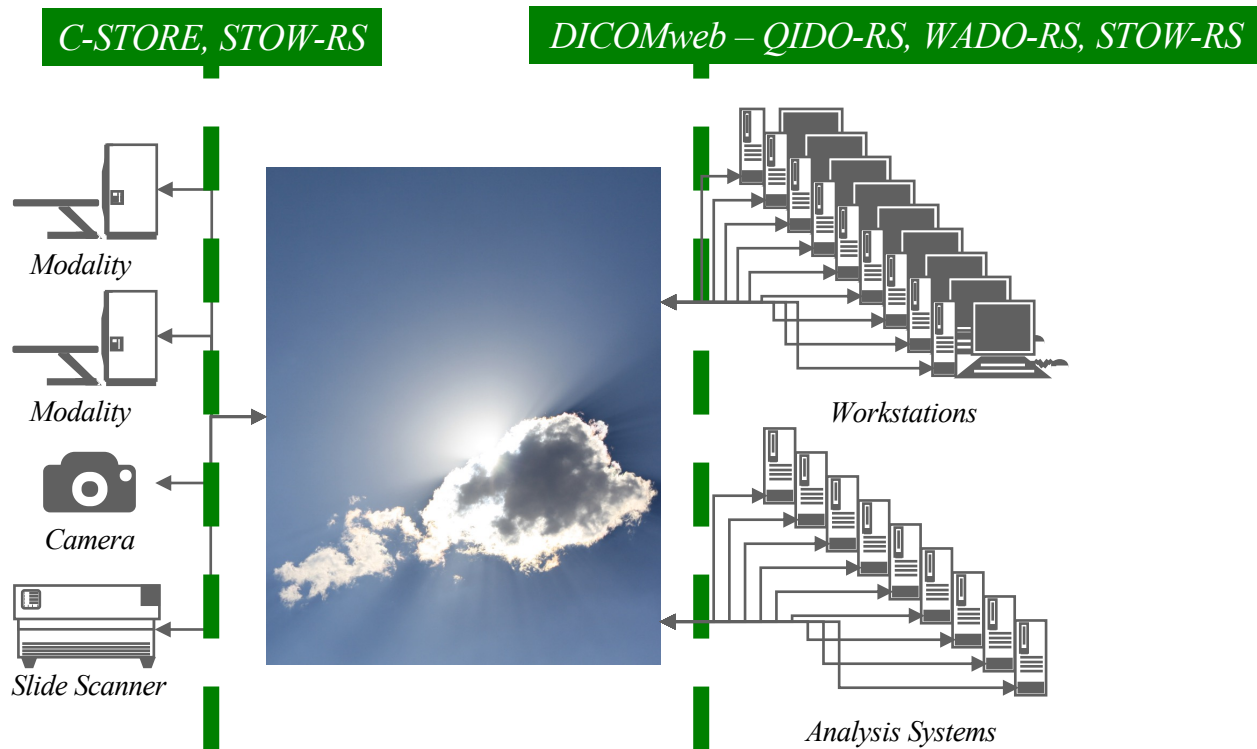
DICOMweb – Brief History

- 1993 – DICOM 3.0 issued – TCP/IP-based but not HTTP
- 1993 – NCSA MOSAIC web browser released
- 2003 – ISO TC/215 joint project with DICOM on web access (became ISO 17432:2005)
- 2004 – Web Access to DICOM Objects (WADO) (Sup 85) – now called WADO-URI – JPEG or PS3.10
- 2010 – Medical Imaging Network Transport (MINT) – HTTP, JSON metadata separate from pixel data
- 2011 – WADO Web Service (WS) (Sup 148) (related of IHE XDS-I; since retired in favor of REST)
- 2013 – Web Access to DICOM Persistent Objects by RESTful Services (WADO-RS) (Sup 161)
- 2013 – STore Over the Web by REpresentations State Transfer (REST) Services (STOW-RS) (Sup 163)
- 2013 – Query based on ID for DICOM Objects by REST Services (QIDO-RS) (Sup 166)
- 2014 – Service Capabilities for RESTful Services (Sup 170)
- 2014 – Unified Procedure Step by REST Services (Sup 171)
- 2015 – RESTful Rendering (Sup 174)
- 2019 – PS3.18 Web Services Re-Documentation (Sup 183)
- …

What's next for DICOM?

- More – stuff – new modalities/applications
- Bigger – higher resolution, more dimensions
- Better – more attributes, more values, more compression schemes

- Different – services, protocols, representations ?
    - priority is to **PRESERVE BACKWARD COMPATIBILITY**
    - … of hardware & software, tools & archives
- Don't chase latest "fad"
    - exceptions – HTTP, JSON, RESTful, a little XML
    - dodged – CORBA, GRID, SOAP, ebXML, etc.
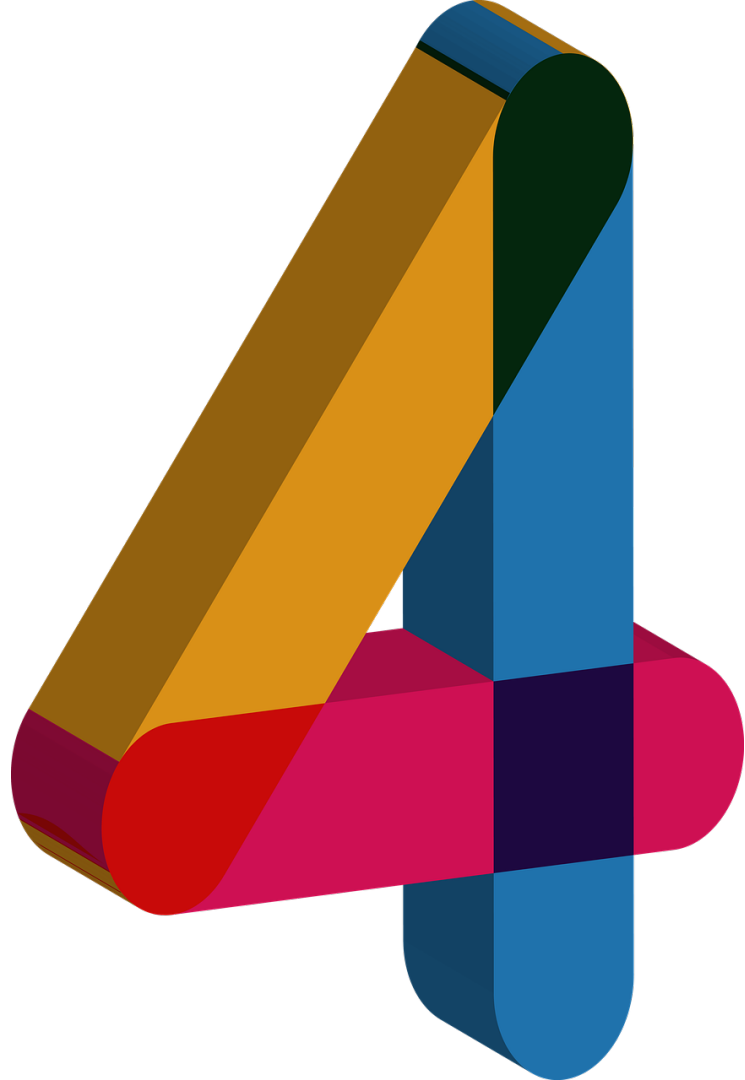- Try to avoid adding new ways to do exactly the same thing

- Only one version, "current" 3.0 – keeps getting bigger, doesn't "change"

DICOM Future – Evolution?
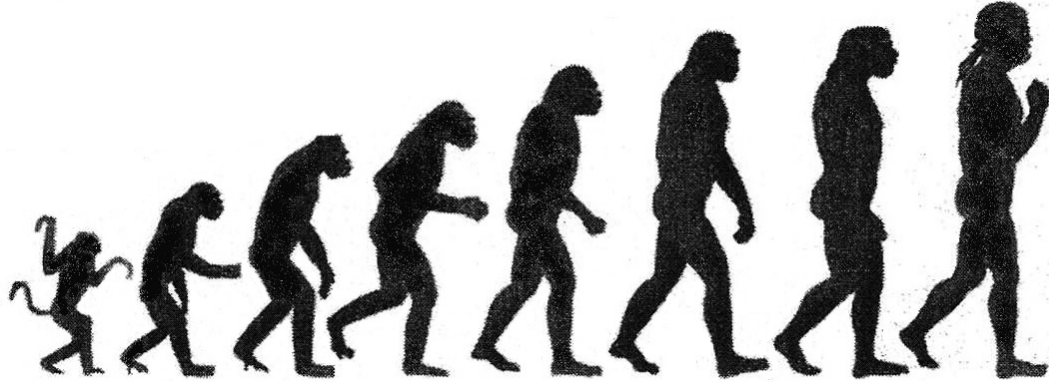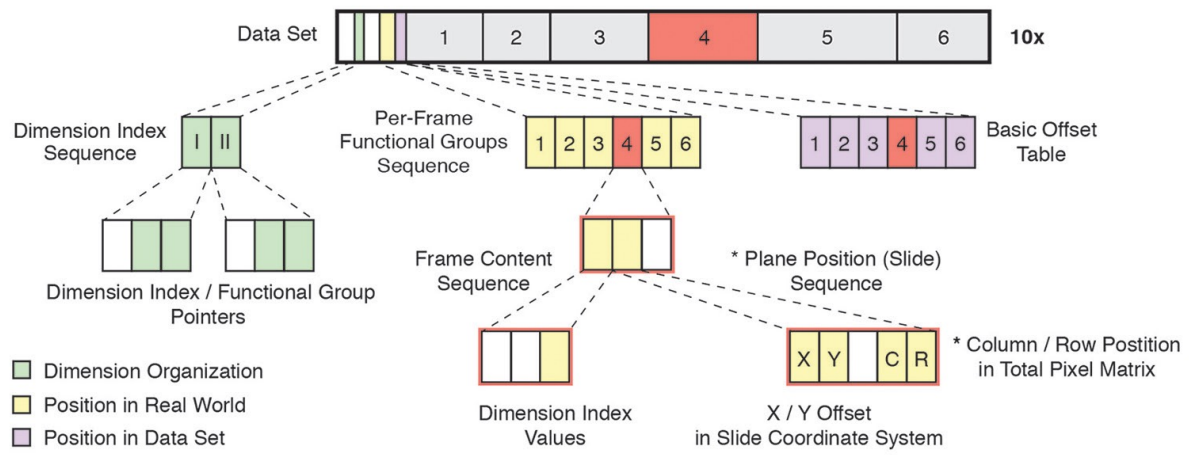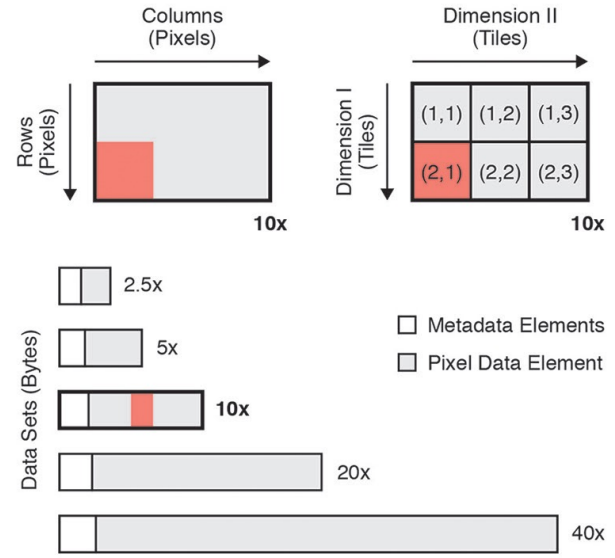
DICOM Future – Revolution?

Future Direction of DICOM

- DICOM could continue to be extended indefinitely
  - incrementally, as historically
  - backward compatibility has long been #1 priority
- DICOM could be completely reconceived (DICOM 4?)
  - new information model
  - new protocols and API
  - new representations
- Does being completely different but solving (mostly) the same problems add value?
- Do solutions for any "new" problems actually **_require_** a "new" standard?
- E.g., high speed parallel read/write of bulk (pixel) data in cloud?
  - N5/Zarr style fragmentation of bulk data and separation from metadata, +/- UDP
- Even if some do, can the industry afford it?
  - huge investment over long period and need legacy support forever anyway

Future Direction of DICOM – Using Existing Features

- Enhanced multi-frame
  - factors out metadata commonality between slices
  - describe multiple dimensions explicitly (e.g., volumes)
  - legacy enhanced – works around single frame conversion issues
  - different "views" of same data and metadata in both forms
    - negotiable option to DIMSE services (C-FIND,C-MOVE,C-GET)
    - not yet taken advantage of in DICOMweb
  - multi-frame functional groups don't scale as well as had been expected
- Concatenations
  - access to manageable chunks of very large objects
  - doesn't address separation of metadata from multiple chunks of large pixel data
- Incremental (preferably optional) enhancements to DICOMweb
  - improve performance for specific use cases that are already supported
  - while allowing fallback for non-optimized existing clients and servers
  - role of UDP and QUIC uncertain yet (beyond HTTP/3)

Downsampled Images

2.5x
5x
10x
20x
40x

Original Image

X (mm)
Y (mm)

Columns (Pixels)

Rows (Pixels)

10x

Dimension II (Tiles)

Dimension I (Tiles)

| (1,1) | (1,2) | (1,3) |
| (2,1) | (2,2) | (2,3) |

10x

Data Sets (Bytes)

2.5x
5x
10x
20x
40x

☐ Metadata Elements
☐ Pixel Data Element

Data Set

| | | | 1 | 2 | 3 | 4 | 5 | 6 | 10x |

Dimension Index Sequence

I II

Dimension Index / Functional Group Pointers

Per-Frame Functional Groups Sequence

1 2 3 4 5 6

Basic Offset Table

1 2 3 4 5 6

Frame Content Sequence

* Plane Position (Slide) Sequence

Dimension Index Values

X / Y Offset in Slide Coordinate System

X Y C R

* Column / Row Position in Total Pixel Matrix

☐ Dimension Organization
☐ Position in Real World
☐ Position in Data Set

Herrmann 2018

http://www.phrases.org.uk/images/throw-out-the-baby-with-the-bathwater.jpg