MII PACS Course 2014

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Content

- Standards:
  - DICOM
  - HL7
  - IHE
  - ACR
  - ICD
  - SNOMED
- PACS Integration

DICOM - Digital Image Communications in Medicine

What DICOM Can and Cannot Guarantee

DICOM Can / Does Provide:

- **Facilitates connectivity between devices that claim to support DICOM features.**
  - -Will guarantee network connection
  - -Will guarantee storage of image

DICOM Can Not / Does Not Provide:

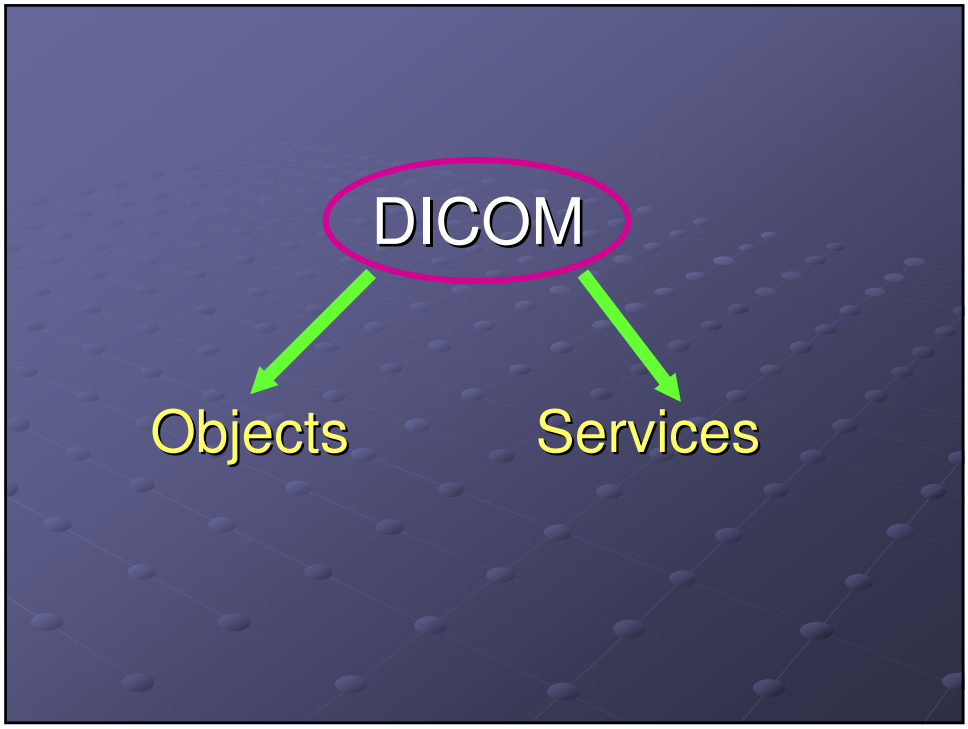
- **DICOM does not guarantee functionality.**
  - - Will not guarantee workstation will display image correctly
  - - Will not guarantee workstation can perform analysis

The DICOM 3.0 Standard

Part 1: Introduction and Overview
Part 2: Conformance
Part 3: Information Object Definitions
Part 4: Service Class Specifications
Part 5: Data Structures and Encoding
Part 6: Data Dictionary
Part 7: Message Exchange
Part 8: Network Communication Support for Message Exchange
Part 10: Media Storage and File Format for Data Interchange
Part 11: Media Storage Application Profiles
Part 12: Media Formats and Physical Media for Media Interchange
Part 14: Grayscale Standard Display Function
(There is a standard calibration (defined in Part 14) to help ensure consistency between various display devices, *including hard copy printout* .)
Part 15: Security and System Management Profiles
Part 16: Content Mapping Resource
Part 17: Explanatory Information
Part 18: Web Access to DICOM Persistent Objects (WADO)
Part 19: Application Hosting
Part 20: Transformation of DICOM to and from HL7 Standards

DICOM Terminology

- Information Object Definition (IOD)
- DICOM Services / Service Class (SC)
- Service Class User (SCU)
- Service Class Provider (SCP)
- Service Object Pair (SOP)
- DICOM Message Service Element (DIMSE)
- Application Entity Title (AET)
- Unique Identifier (UID)
- Value Representation (VR)
- Transfer Syntax
- Abstract Syntax
- Presentation Context



DICOM Objects

- e.g. patients, images, reports
  - called information object (Information Entity) because their function is to carry information
  - the definition of what constitutes an information object in DICOM is called an Information Object Definition (IOD)
    - a list of Attributes
    - Related Attributes are grouped into Modules (mandatory, optional, conditional)

CT Image IOD Modules

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Plane	C.7.6.2	M
	Image Pixel	C.7.6.3	M
	Contrast/bolus	C.7.6.4	C - Required if contrast media was used in this image
	CT Image	C.8.2.1	M
	Overlay Plane	C.9.2	U
	VOI LUT	C.11.2	U
	SOP Common	C.12.1	M

IE = Information Entity

M = Mandatory

U = User Option

C = Conditional

Patient Module Attributes

Attribute Name	Tag	Attribute Description
Patient's Name	(0010,0010)	Patient's full name
Patient ID	(0010,0020)	Primary hospital identification number or code for the patient.
Issuer of Patient ID	(0010,0021)	Identifier of the Assigning Authority (system, organization, agency, or department) that issued the Patient ID. Note: Issuer of Patient ID (0010,0021) is equivalent to HL7 v2 PID-3 component 4.
Other Patient IDs	(0010,1000)	Other identification numbers or codes used to identify the patient.
Other Patient Names	(0010,1001)	Other names used to identify the patient.
Patient's Birth Name	(0010,1005)	Patient's birth name.
Patient's Mother's Birth Name	(0010,1060)	Birth name of patient's mother.
Medical Record Locator	(0010,1090)	An identifier used to find the patient's existing medical record (e.g. film jacket).

Normalized IOD

- object comprises of only one real world entity
  - e.g. patient, study, result

Composite IOD

- object comprises of more than one entity
  - e.g. CT image

IE	Module	Reference	Usage
Patient	Patient	C.7.1.1	M
	Clinical Trial Subject	C.7.1.3	U
Study	General Study	C.7.2.1	M
	Patient Study	C.7.2.2	U
	Clinical Trial Study	C.7.2.3	U
Series	General Series	C.7.3.1	M
	Clinical Trial Series	C.7.3.2	U
Frame of Reference	Frame of Reference	C.7.4.1	M
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Image Plane	C.7.6.2	M
	Image Pixel	C.7.6.3	M
	Contrast/bolus	C.7.6.4	C - Required if contrast media was used in this image
	CT Image	C.8.2.1	M
	Overlay Plane	C.9.2	U
	VOI LUT	C.11.2	U
	SOP Common	C.12.1	M

The need for Composite IOD

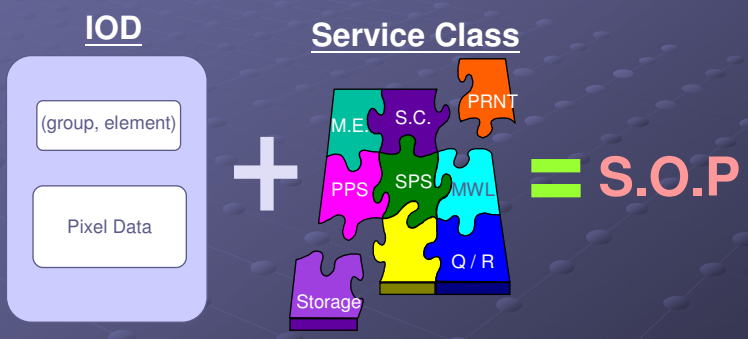
- e.g. in storage and retrieval
  - If the objects were broken up into smaller ones, assembling the smaller objects for use would mean searching the storage device for all of them. Such a task would be more time-consuming than recovering the complex object in a single retrieval.

DICOM SERVICES

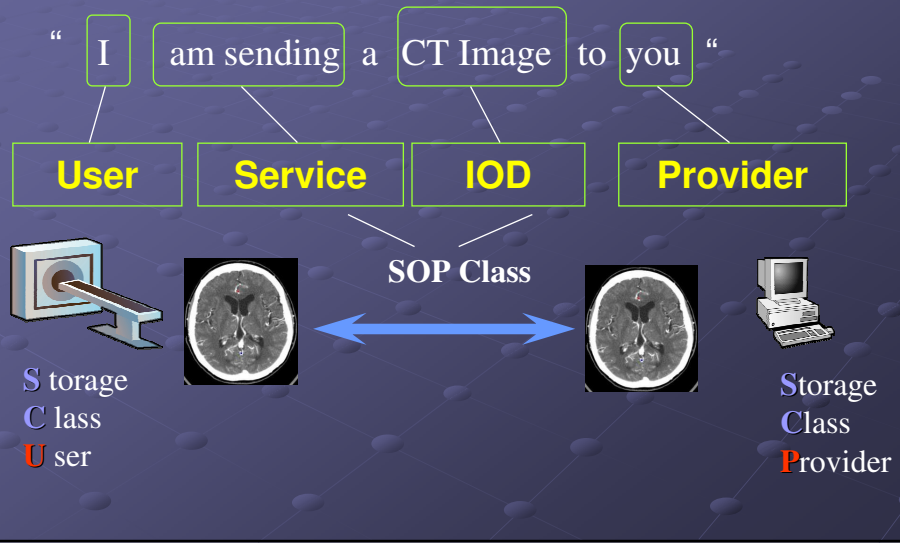
- **Verification**
- **Storage**
- **Query/Retrieve**
- **Procedure Step**
- **Print Management**
- **Media Storage**
- **Storage Commitment**
- **Basic Worklist Management**

DICOM Services are *ACTIONS* that are applied to Information Objects

Service Object Pair



Service Class User / Provider



Verification Service Class

- Very basic diagnostic function, required by DICOM on all products.
- Allows any system to send a test message to another system to verify the network connection.

Storage Service Class

- Sends and receives image data anywhere on the network.
- Storage SCU implies that the ability is available to **send** DICOM images from the equipment.
- Storage SCP implies that the ability is available to **receive** DICOM images at the equipment.
- Most common service class for scanners and workstations.

Query/Retrieve Service Class

- Allows for the remote access and retrieval of data without interrupting the operator of the remote device.
- Query/Retrieve SCU implies that the ability is available to view and pull the DICOM images from another DICOM node on the network (if the other node is a Q/R SCP).
- Query/Retrieve SCP implies that the ability is available to respond to a Q/R request coming from another DICOM node on the network (if the other node is a Q/R SCU).
- Both devices must have this capability for this function to work.

Modality Performed Procedure Step Service Class

- Sends DICOM conformant information about start and finish of performed procedure steps to a DICOM MPPS SCP (PACS, RIS etc.).
- Once a procedure is COMPLETED, it is considered inactive, and can be filtered out of a modality worklist .
- Also carries other information such as radiation dose (to enable the RIS to store information on patient exposure) and billing & material management codes.

Print Management Service Class

- Digital print to hardcopy device over the network.
- Basic Print SCU implies that the ability is available to **send** DICOM print formatted images to a printer or laser camera.
- Basic Print SCP implies that the ability is available to **receive** DICOM print formatted images and print them.
- This functionality will allow true sharing of laser cameras (similar to two PC's sharing a laser printer across a network).

Media Storage Service Class

- Standardizes the physical media and the logical format in which the images are stored on the archive media.

Storage Commitment Service Class

- Enables a scanner acting as an SCU to request an external device acting as an SCP to make the commitment for the safekeeping of information (i.e. the information will be kept for a specific period of time and can be retrieved).
- The Storage Service Class is used in conjunction to the Storage Commitment Service Class to transfer the images to the storage device.

Basic Worklist Management Service Class

- Allows a scanner (SCU) to obtain patient and requested procedure information for scheduled examinations from an Information Management System (e.g. PACS Broker)

Example of Service Class User / Provider

- MR scanner may say:
  - I am an MR Image Storage SCU
- Workstation may say:
  - I am an MR Image Storage SCP

MR images may be transferred

What happen when a DICOM workstation queries the PACS server to retrieve a historical exam to compare with a current study already available at the workstation?

- First phase: WS acts as Q&R SCU and PACS server acts as Q&R SCP
- Second phase: the Q&R SCP (PACS server) will then become a Storage SCU when it is requested to deliver DICOM data to another DICOM node as part of the retrieve phase

DICOM Message Service Elements (DIMSE)

- to generate appropriate commands and data sets to complete the required services
- DIMSE-N for normalized information objects
  - N-EVENT-REPORT (notification of a change in MPPS SOP Instance e.g. change of procedure status from “IN PROGRESS” to “COMPLETED”)
  - N-GET (get MPPS SOP Instance)
  - N-SET (set procedure status)
  - N-ACTION (update procedure status)
  - N-CREATE (create MPPS SOP Instance)
  - N-DELETE (delete procedure)

DICOM Message Service Elements (DIMSE)

- DIMSE-C for composite information objects
  - C-STORE (store)
  - C-GET (get)
  - C-FIND (query)
  - C-MOVE (retrieve)
  - C-ECHO (verification - for DICOM ping which will issue a C-ECHO command and display the result)

Application Entity Title

During negotiation, the two Implementations present themselves to each other

- This presentation is done using **Application Entity Title** (AE Title)
- This AE Title (max 16 characters) that must be unique on a given network. It is used to identify an application on the network.

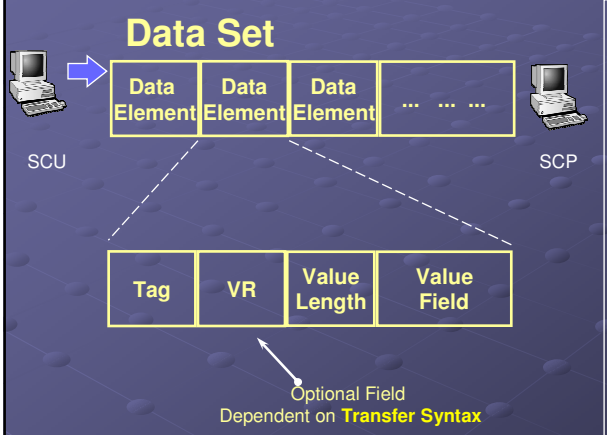
Unique Identifier (UID)

A UID is a string including numbers and "." that MUST be UNIQUE around the world.

- **e.g. 1.2.840.12345.19980924**
- **no leading zero in UID allowed!!**

UIDs are an internal DICOM mechanism to uniquely identify SOP Classes, Studies, Equipment's, Series, Images, etc.....

DICOM Data Structure



Attributes are assigned a unique Tag (group + element)

tag=(0010, 0010)

groups deals with patient information for example

element is patient name for example

Attribute encoding is defined by Value Representation (VR).

Example DICOM Tag

Group / Element	Attribute Name	Attribute Desc.
0008 , 0060	Modality	Orig. Modality
0020 , 2810	Rows	# of rows in image
0010 , 0010	Patient Name	Pat. Full Name
0010 , 0030	Patient Birthdate	Pat. Date of Birth
0010 , 1030	Patient Weight	Wt. of Patient kg
0010 , 2180	Patient Occupation	Occ. of Patient

Value Representation (VR)

- It describes the type and the format of the information sent in a DICOM Message. For instance, the Patient Date of Birth (0010, 0030) is a 8 characters string following the format : YYYYMMDD
- It is in the Value Field of the Data Element.

Value Representation (VR)

- Each VR is enumerated by a 2 character code.
- The codes are: AE (Application Entity), AS (Age String), AT (Attribute Tag), CS (Code String), DA (Date), DS (Decimal String), DT (Date Time), FL (Floating Point Single), FD (Floating Point Double), IS (Integer String), LO (Long String), LT (Long Text), OB (Other Byte), OW (Other Word), PN (Patient Name), SH (Short String), SQ (Sequence of Items), SS (Signed Short),TM (Time), UI (Unique Identifier), UL (Unsigned Long), US (Unsigned Short)

Value Representation (VR)

- **Explicit VR** means that the VR is to be included in each Data Element in the Data Set.
- **Implicit VR** means that the VR is not to be included in each Data Element in the Data Set. The VR of each Data Element must be looked up in the Data Dictionary.

Transfer Syntax

- the encoding methodology used to send data over the network
- such as Data Element Structure, Byte Ordering, and Image Compression

Transfer Syntax

DICOM defines several transfer syntaxes :

- Implicit VR Little Endian (Default DICOM Network Transfer Syntax)
- Explicit VR Little Endian (Default for DICOM Media Storage)
- Explicit VR Big Endian
- JPEG 2000
- Others.....

Transfer Syntax

Little Endian versus Big Endian byte ordering

DICOM defines two different byte orderings that affect binary values sent on more than 1 byte

Example on a 2 byte value: 45 28

Little Endian

Least Significant Byte	Most Significant Byte
28	45

Big Endian

Most Significant Byte	Least Significant Byte
45	28

Abstract Syntax

- another term for the SOP class
- it identifies a set of SOPs which, when taken together, represent a logical grouping

Presentation Context

- **A Presentation Context consist of:**
  - *One or several Transfer Syntax(es)*
  - *One or several SOP Class(es) / Abstract Syntax(es)*
- **Basic information to establish association**

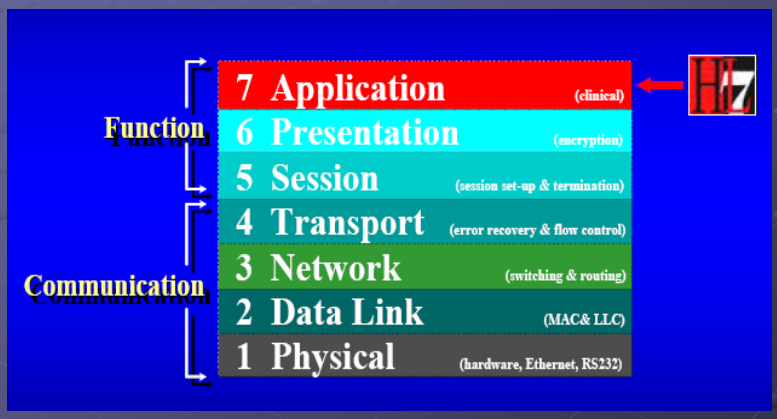
Presentation Context

HL7 – Health Level 7

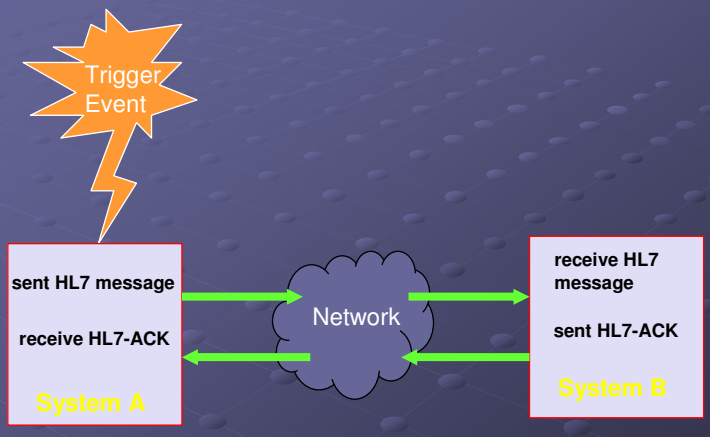
HL7

- Develop messaging standard that enables disparate healthcare applications to exchange key sets of clinical and administrative data.
- Enable healthcare information system interoperability and sharing of electronic health records.

Health Level "Seven"



Basic Principle



ACK: acknowledge exchange of data

Trigger Events

Examples:

- Patient Administration Trigger Events
  - ADT/ACK – Admit patient (event A01)
    – Transfer patient (event A02)
    – Discharge patient (event A03)
- Financial Management Trigger Events
  - BAR/ACK – add patient account (event P01)
    (Billing Account Record)
  - BAR/ACK – update account (event P05)
- Document Management Trigger Events
  - MDM/ACK – document status change notification (event T03)
    (Medical Document Management)

Message in Event A02

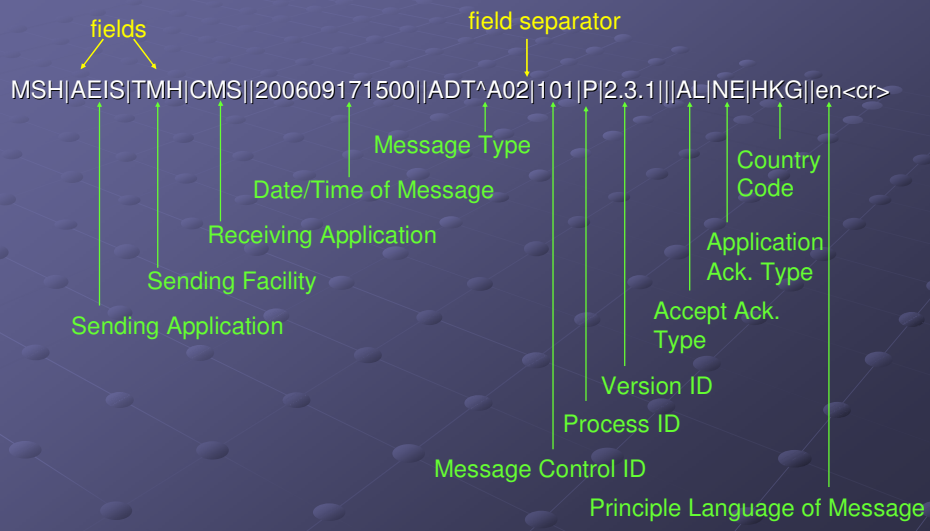
ADT^A02 Message Segments

MSH	Message Header
EVN	Event Type
PID	Patient Identification
PV1	Patient Visit

ACK^A02 Message Segments

MSH	Message Header
MSA	Message Acknowledgment

Example: MSH Segment



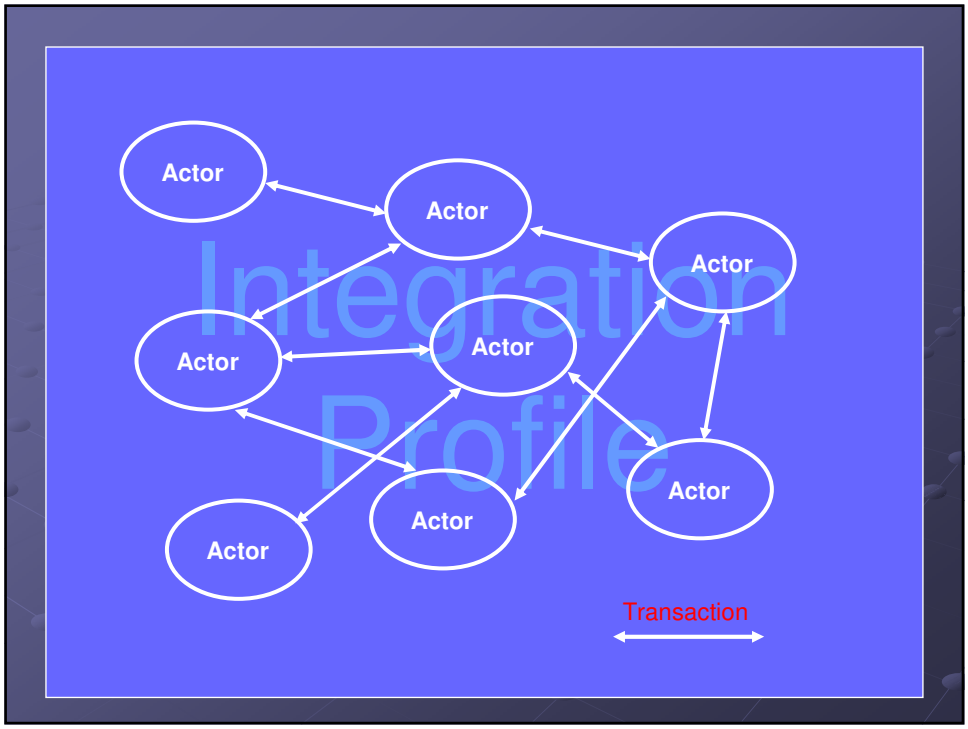
IHE – Integrating the Healthcare Enterprise

IHE promotes the coordinated use of *established standards* such as DICOM, HL7, W3C and others to address specific clinical needs in support of optimal patient care.

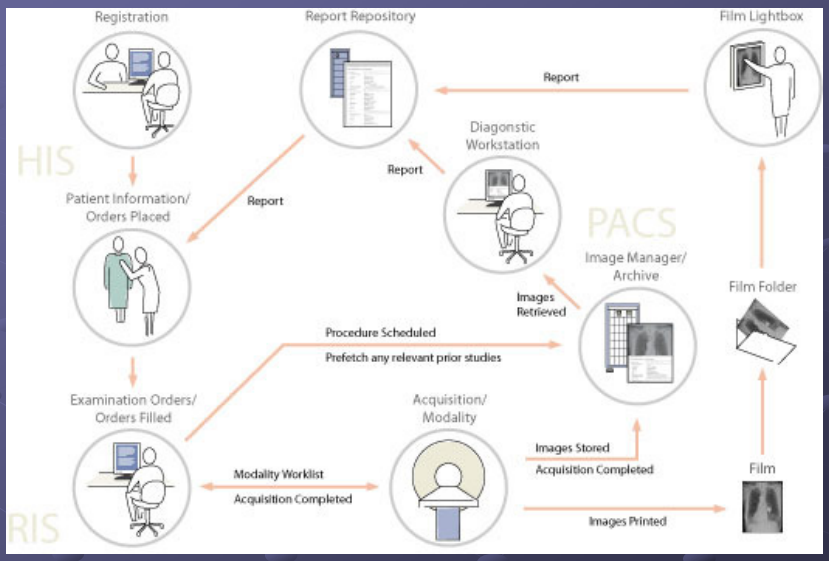
Putting IHE Requirements in the Tender Spec.

Example:

The modality system shall support the IHE Scheduled Workflow Integration Profile as the Acquisition Modality and Image Display Actors.

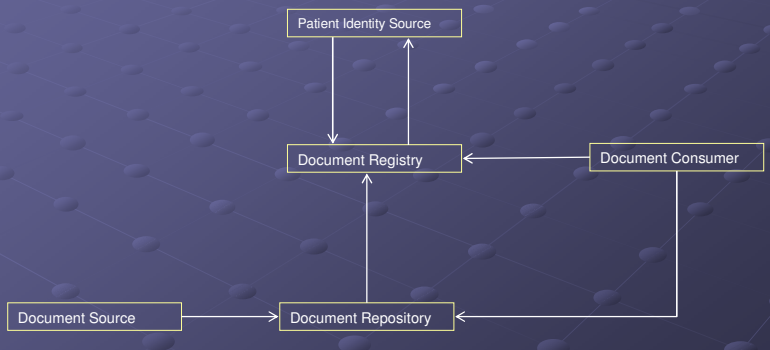


Scheduled Workflow Integration Profile



Cross-Enterprise Document Sharing (XDS) Integration Profile

- Registration, distribution and access across health enterprises of clinical documents (clinical notes, referrals, ECG reports, lab results, scanned documents etc.) forming a patient electronic health record



Cross-enterprise Document Sharing for Imaging (XDS-I) extends XDS to share images across a group of care sites.

ACR – American College of Radiology

ACR

Some Standards on Equipment Specifications

- Image Matrix:
  - For small-matrix image (e.g. CT, MRI, US, digital FL, digital Ang), a minimum of 256 x 256 matrix size at a minimum 10-bit pixel depth.
  - For large-matrix image (e.g. DX, CR, digital Mammo), a minimum of 2.5 lp/mm spatial resolution at a minimum 10-bit pixel depth. An increased spatial resolution of 5 lp/mm at a minimum 10-bit pixel depth should be considered for pediatric imaging or the imaging of small body parts.

ACR

Some Standards on Equipment Specifications

- Image Compression:
  - Both lossy and lossless techniques may be used under the direction of a qualified physician or practitioner, with minimal if any reduction in clinical diagnostic image quality.
  - Algorithms recommended by the DICOM standard such as wavelet or JPEG-2000 compression methods should be used.
  - FDA does not allow compression of digital mammograms at this time for retention, transmission, or final interpretation.

ACR

Some Standards on Equipment Specifications

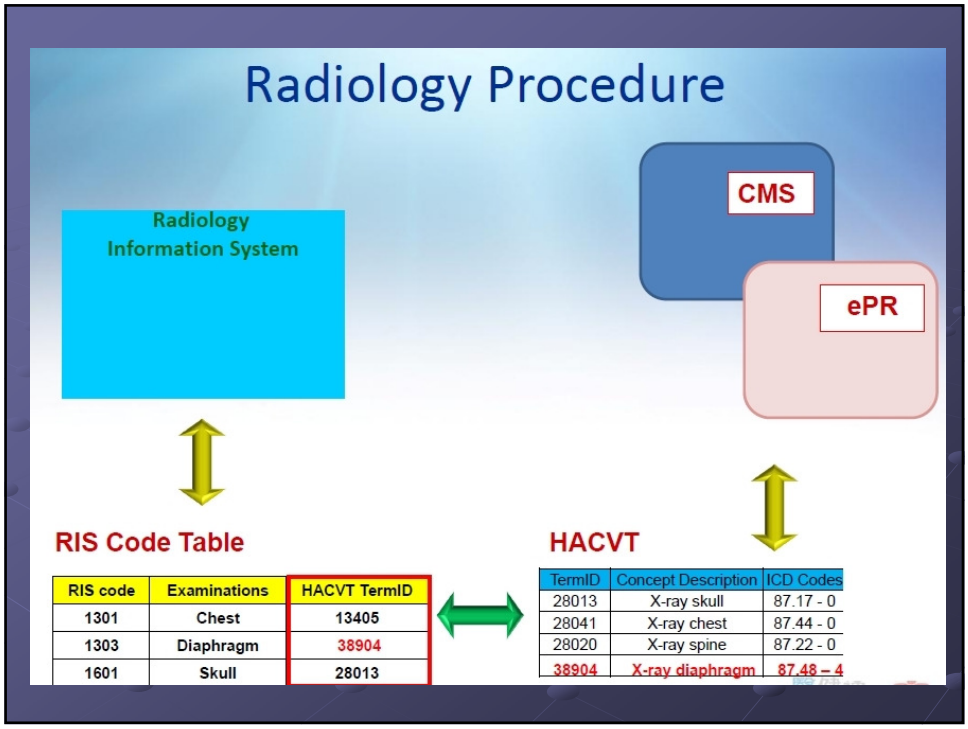
- Display Workstations for Primary Dx:
  - Maximum luminance of the grayscale monitors not used for mammography should be at least 171 cd/m2.
  - Maximum luminance of the grayscale monitors used for mammography should be at least 250 cd/m2.
  - Contrast response should not deviate from the DICOM Grayscale Display Function (GSDF) contrast values by more than 10%.
  - A minimum bit depth (luminance resolution) of 8-bit is required.

- Of primary importance is the ability of the monitor and video card to display the acquired image at full resolution and adequate bit depth (panning and zooming may achieve the result but may not be convenient and may impact the productivity of clinicians).
- The DICOM GSDF can be applied to color displays for accurate conformance to grayscale rendition.
- Time to bring an image up on the workstation should be 3 seconds or less for images stored on an internal network with spinning disk storage.

ICD-9 (International Classification of Diseases, ninth revision)

ICD-9-CM

- CM means "clinical modification"
- used by hospitals and other facilities to describe any health challenges a patient has
- from diagnosis to symptoms to outcomes from treatment, to causes of death



SNOMED-CT (Systematized Nomenclature of Medicine-Clinical Terms)

SNOMED

- SNOMED-CT is a systematically organized computer processable collection of medical terms providing codes, terms, synonyms and definitions used in clinical documentation and reporting. It is considered to be the most comprehensive clinical healthcare terminology in the world.
- Managed by the International Health Terminology Standards Development Organization (IHTSDO)

ICD-9-CM	SNOMED-CT
Classification of diseases	Clinical terminologies
Designed for use for admin purposes e.g. billing, monitoring resource utilization, epidemiology	Designed for clinical support, research etc. Because of its complexity, it does not work well as a terminology used for presentation to end users
Not “machine friendly”	Designed for computer applications - improve accuracy in sharing of information between disparate healthcare information systems

PACS Integration

Different Levels of Integration

- API (Application level Programming Interface) Integration
- Procedure-Call Integration
- Messaging Integration
- Integration Profiles
- Physical Integration

API Integration

- Links two software applications
- The interface consists of a well-documented software library
- Example: PACS ↔ Storage
  online/nearline ↔ fast disk/slow disk
- This is the tightest level of integration

Procedure-Call Integration

- An application on a device issues a remote procedure call, or a standard command such as a SQL (Structured Query Language) to another application
- Example: the PACS workstation issues a SQL query to a PACS archive having an Oracle database, requesting a list of the studies for a particular patient including study date, modality type, and number of images
- This is a rather tight level of integration because the workstation must know the exact database schema

Messaging Integration

- It is achieved by using standard messaging, and protocols between applications, such as DICOM for imaging; or HL7 for patient demographics, orders, and results.
- Example:

  RIS ↔ Broker ↔ Modality Worklist

Integration Profiles

- Defining a specific subset of the standard (profile) to enable seamless integration (messaging standard alone is not sufficient)
- The IHE integration profile specifies exactly which attributes, i.e. information should be exchanged, the timing of a service in relationship with other DICOM services, and even mapping between different standards, i.e. DICOM and HL7 messaging.

Physical Integration

- Integrates the physical hardware, typically only sharing the operating system that run the applications
- Especially useful in many departments due to space and power restrictions
- Example: Voice recognition system runs on the same platform as a viewing station

Modality Integration

- IP address: fixed IP address is required for DICOM communication
- AE title: a unique AET is required for DICOM communication
- Port number: 11112 is the officially approved port number for DICOM applications, though the well-known port number of 104 is still widely used

- Protocol Data Unit (PDU) size – matching the PDU size of the modality with the PACS. e.g. A new ultrasound system might propose 10k PDU size at the application level. The PACS might offer 100k block sizes. Configuring the ultrasound PDU for 100k would improve the performance.
- Number of simultaneous associations – configuring to accept more than enough simultaneous associations would be wasting several associations that require buffer (memory) allocation.

- PACS Broker

  - provides the modality work list

  - correct mapping of data fields among RIS, Broker, PACS and modalities is crucial to operation (e.g. RIS region code can automatically select the corresponding protocol in DDR)

  - settings “constraints” to filter out unnecessary items in the worklist

  e.g. modality, resource_name (RIS room code), scheduled_start_date (e.g. today), scheduled_station_ae_title etc.

- Presentation State and Structured Report may not be supported properly in PACS

Thank You