CURRENT STANDARDS FOR INFORMATION EXCHANGE IN RADIATION ONCOLOGY: DICOM, DICOM-RT, AND HL7

Bruce Curran, MS, ME
Associate Professor of Radiation Oncology
VCU Health System
Chief Therapy Medical Physicist
HH McGuire VA Medical Center
Richmond, VA

Disclosures

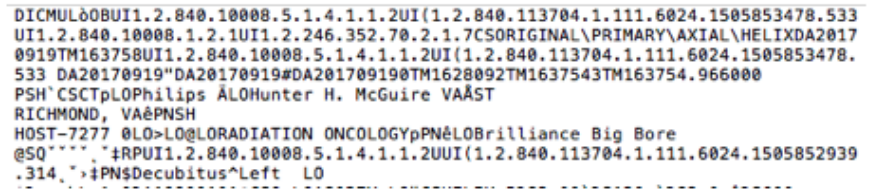
- Member, DICOM Working Group 7 (Radiation Therapy Extensions to DICOM)
  - Participation partially funded by AAPM
- Former Vice-Chair, Integrating the Healthcare Enterprise – Radiation Oncology (IHE-RO) Technical Committee
  - Participation partially funded by ASTRO & AAPM
- Former Chair, Health Informatics Technology (HIT) Committee, ASTRO
- Chair, AAPM Working Group on IHE-RO
- Former Member, Oncology Working Group, Certification Commission on Health Information Technology (CCHIT)
- Confirmed Workaholic

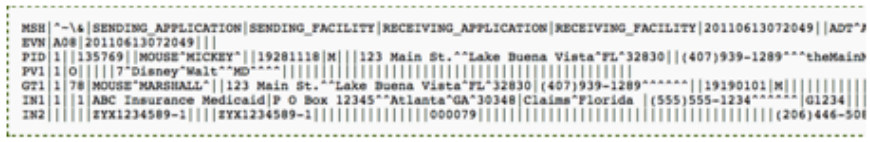
Acknowledgements

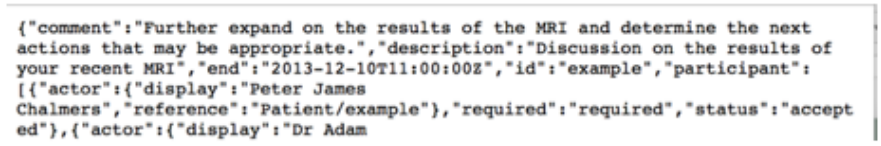
- http://www.dicomstandard.org
  - Figures from DICOM (2018a) standard (parts 1, 2, 3)
  - Medema, DICOM Overview (from DICOM Resources Section)

- http://www.mieweb.com/wiki/Sample_HL7_Messages
- http://docs.smarthealthit.org/dstu2-examples/examples/appointment-example-request.canonical.json

Pop Quiz: Name the Format

1. 

2. 

3. 

The examples above are stream captures of messages from either DICOM, HL7, or FHIR and opened in a Notepad-like application. The answers are:

1. DICOM
    1. Note the existence of a number of data elements of the form 1.2.xxx.xxx… These are Unique Identifiers (UIDs). UIDs are global identifiers meant to be unique globally. Manufacturers apply to standards agencies, e.g. ANSI, for the initial elements of an identifier and are responsible for making the remainder of the UID unique.
2. HL7
    1. In HL7, fields are separated by “;”, hence the sets of ‘;’ indicating blank fields.
3. FHIR
    1. FHIR is a candidate for replacing HL7 in many areas and is based on an XML-like syntax.

Outline

- DICOM & DICOM-RT
- HL7
- Playing with FHIR

The DICOM Standard

- Administered and published by
  - National Electrical Manufacturers Association – NEMA
    and it's medical imaging division
  - Medical Imaging Technology Alliance – MITA
- Intellectual property
  - DICOM trademark and copyright is held by NEMA
  - No license required to use the DICOM Standard in products
- http://dicom.nema.org
  - Download free electronic copies of the standard
    - All 20 parts are available in PDF, Word, HTML, and XML format
    - Paper copies are available for purchase
  - Plans and activities are publicly posted

Medema, DICOM Overview

DICOM SOP Class

- Service + Object = Service Object Pair
  - Storage + MR Image = MR Image Storage

- SCU – Service Class User
  - the system that uses the service
- SCP – Service Class Provider
  - the system that provides the service

Medema, DICOM Overview

For example, in RT, generally an application requests an image or other object from an imaging device. A CT-Sim could be the SCU, sending images to a planning system acting as the SCP.

DICOM Association Negotiation

- Before two Application Entities (AE) perform a DICOM transaction they first agree on
  - who will be the SCU, who will be the SCP
  - what SOP Class they will use (e.g. MR Image Storage)
  - what the Transfer Syntax will be (e.g. JPEG Lossless)
- This process is called Association Negotiation

- Note that Character Sets are not negotiated!

Medema, DICOM Overview

Information Model Elements

- An *Image* (or other object) holds acquired data
- A *Series* may group closely related Images from the same PPS, same protocol & same piece of Equipment
- A *Study* groups all Series for a given Req. Procedure
- A *Patient* may have many Studies

- *Instances* are data that are structured according specific object definitions
- DICOM uses Unique Identifiers (*UID*s) for identification
  - specific Instances, SOP Classes, Study / Series, …

Medema, DICOM Overview

Attribute

- DICOM Data Stream = …00100010Smith^John^^^…

Tag	Attribute Name	VR	VM	Value
(0010,0010)	Patient Name	PN	1	Smith^John^^^

(See DICOM Part 6: Data Dictionary)

- Tag (Group #, Element #)
  - Defines key of an attribute / data element
- Value Representation (VR)
  - Defines data type used to encode the value(s)
- Value Multiplicity (VM)
  - Defines how many values can be in the attribute

Medema, DICOM Overview

DICOM is a structured format, in that information sent consists of sequences following the structure above. In principle, it is possible, using a DICOM Data Dictionary, to decode a data stream of information by searching for a starting tag and then following the message through.

Module

- An architectural convenience; a logical group of attributes about a common topic, e.g. Patient Module

Attribute	*Tag*	*Type*	*Attribute Description*
Patient Name	(0010,0010)	2	Patient's Full Name
Patient ID	(0010,0020)	2	Primary hospital identification number or code for the patient
Issuer of Patient ID	(0010,0021)	3	Identifier of the Assigning Authority that issued the Patient ID
…			

(See DICOM Part 3: Information Object Definitions)

- Macro – purely an editing convenience; a table of attributes that can be easily copied into modules
- Type – (1) Required (2) May Be Empty if Unknown (3) Optional (1C or 2C) Conditional

Medema, DICOM Overview

DICOM Decoded

DICMULòO
UI1.2.84
0919TM16
533 DA20
PSH`CSCT
RICHMOND
HOST-727
@SQ˘˘˘˘
.314.˘>‡

Tag	Attribute Name	Def VR	VM	Values
(0008,0005)	Specific Character Set	CS	1	ISO_IR 100
(0008,0012)	Instance Creation Date	DA	1	20141007
(0008,0013)	Instance Creation Time	TM	1	123357
(0008,0016)	SOP Class UID	UI	1	1.2.840.10008.5.1.4.1.1.481.5
(0008,0018)	SOP Instance UID	UI	1	1.2.246.352.71.5.248636840124.183.20141001120012
(0008,0020)	Study Date	DA	1	20110301
(0008,0030)	Study Time	TM	1	162532
(0008,0050)	Accession Number	SH	0	
(0008,0060)	Modality	CS	1	RTPLAN
(0008,0070)	Manufacturer	LO	1	Varian Medical Systems
(0008,0090)	Referring Physician's Name	PN	0	
(0008,1010)	Station Name	SH	1	Kari-PC
(0008,1030)	Study Description	LO	1	H/N Patient (HFS)
(0008,103e)	Series Description	LO	1	ARIA RadOnc Plan ARTI/10 IMRT Sliding Window
(0008,1070)	Operators' Name	PN	1	max
(0008,1090)	Manufacturer's Model Name	LO	1	ARIA RadOnc
(0010,0010)	Patient's Name	PN	1	ARTI14P01VA^Varian Medical Systems
(0010,0020)	Patient ID	LO	1	ARTI14P01VA
(0010,0030)	Patient's Birth Date	DA	1	19630506
(0010,0032)	Patient's Birth Time	TM	1	000000
(0010,0040)	Patient's Sex	CS	1	O

05853478.533
\HELIXDA2017
.1505853478.
000

4.1505852939

By using a DICOM-knowledgeable application (in the above case the DVTK DICOM Editor), one can extract a human-readable rendition of the DICOM message.

Object (IOD)

IE	*Module*	*Reference*	*Usage*
Patient	Patient	C.7.1.1	M
…			
Equipment	General Equipment	C.7.5.1	M
Image	General Image	C.7.6.1	M
	Contrast/Bolus	C.7.6.4	C – Required if contrast media was used in this image
	CT Image	C.8.2.1	M

(See DICOM Part 3: Information Object Definitions)

- Information Entity (IE): a group of modules representing a Real-World object
- Reference: a Section in Part 3 where it is defined
- Usage: (M) Mandatory; (C) Conditional; (U) Optional

Medema, DICOM Overview

DICOM Communication Model

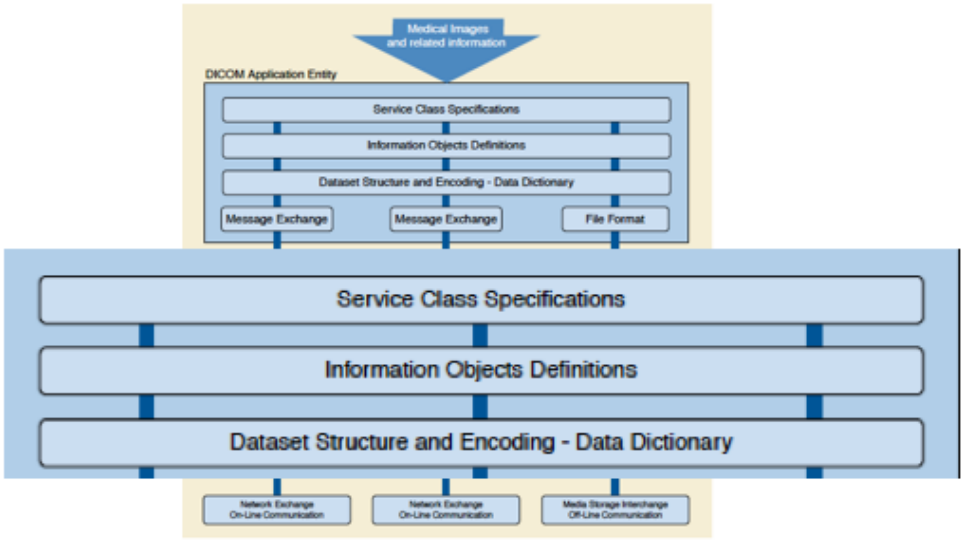
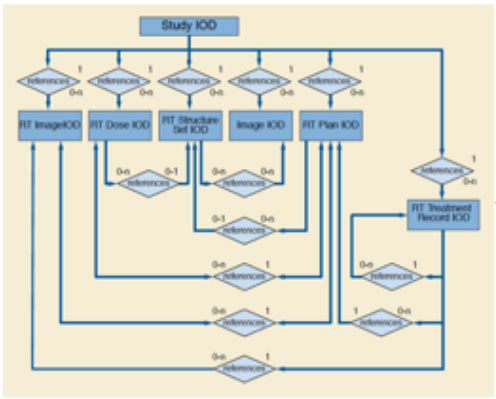
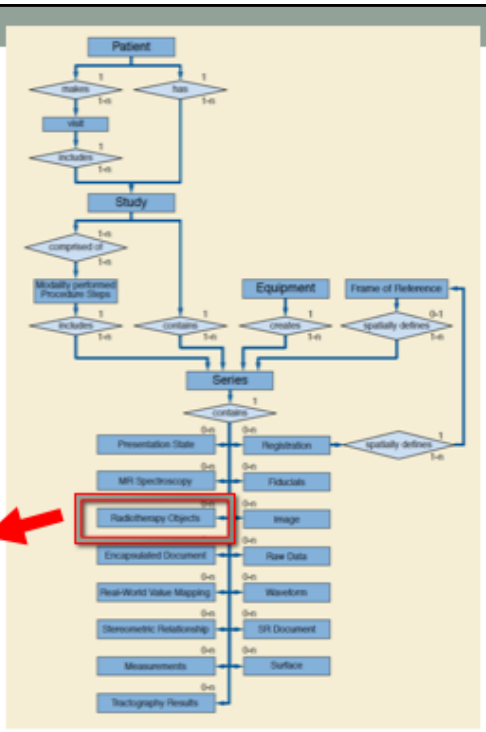


Figure 5-1. General Communication Model

The most important parts of the DICOM Communication model and documentation are the Service Class specifications (operations such as Store , Retrieve, Query, …), the Information Object Definitions (e.g. CT Image, RT Plan, RT Dose, …), and the Data Dictionary (definitions of the attributes and their meanings).

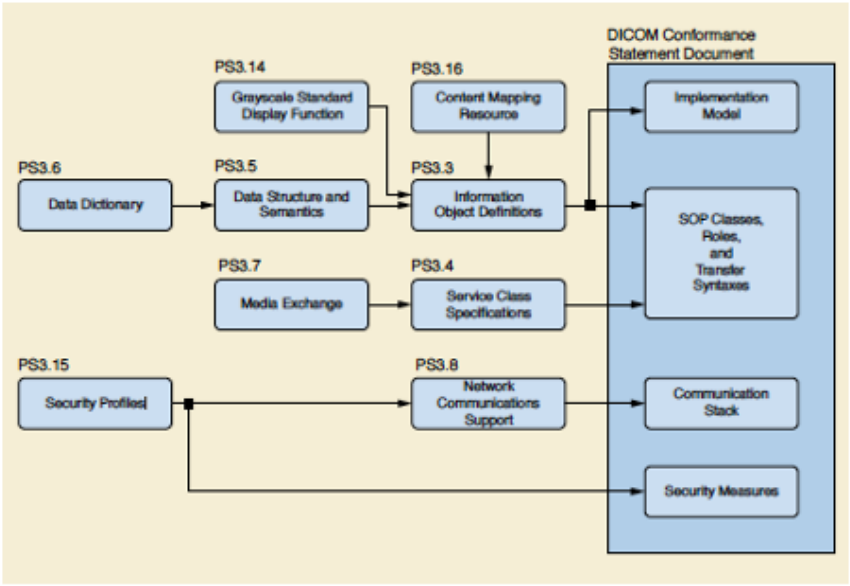
Entity Relationship Model of DICOM's Information Structure





http://dicom.nema.org/medical/dicom/current/output/pdf/part03.pd

Using DICOM



The figure above illustrates which volumes of the DICOM standard contain information on DICOM structures and operations.

DICOM Configuration

- Application Entity Title (AE_TITLE)
  - 16 character DICOM name, generally specified in UPPERCASE
- DICOM Port
  - Typically 104 is used, 105-6 are also common
- Hostname / IP Address
  - Information identifying the computer supporting the DICOM service
  - Generally, DICOM IP addresses must be STATIC, not DHCP
- Common Configuration Issues
  - Some applications cannot handle multiple DICOM definitions with either (a) the same AE_Title, or (b) the same IP Address.
  - Hospital IT has not enabled the necessary ports to be used.
  - Latency – on slow networks, there may be a delay in making a connection between two DICOM nodes. Most DICOM senders / receivers have a timeout limit beyond which the transfer is aborted.

DICOM Resources

- DVTk - DICOM Validation Tool Kit (DICOM.DVTk.org)
  - Provides API for writing your own code for reading DICOM files
  - Provides a set of applications for reading, analyzing, DICOM files
  - Open source (SourceForge.net) – Windows-based
- DICOM.NEMA.org
  - Homepage for all DICOM Activities, documentation, resources
- DClunie.com –
  - Dave Clunie is a radiologist / DICOM proponent who has developed an extensive resource site.
- MatLab – has an Imaging Toolkit capable of reading DICOM images
- ImageJ – NIH-developed resources for imaging
- Osirix – Mac-based resources for imaging

Conformance

- DICOM Conformance Statement
  - Lists the DICOM building blocks a product supports
  - Describes product implementation details and behaviors

(See DICOM Part 2: Conformance)

- 'Association negotiation' for humans

Medema, DICOM Overview

Conformance statements, while the designated device for determining whether two applications can share data correctly, are generally very difficult to use in radiation therapy. This is because one must review all the individual content items in, for example, an RT Plan to determine if the applications exchange all necessary information.

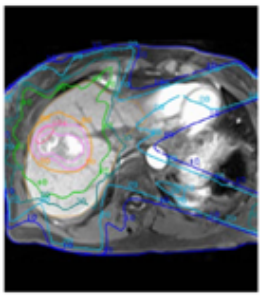
Common DICOM Issues

- Character Set Mismatches
  - Many RO vendors do not allow full ISO-100 character set
- Compression
  - Most RO vendors do not support compressed images
- Image Orientation
  - Most RO vendors do not support images with CT Gantry Angle
  - Many RO vendors do not support decubitus or oblique primary image sets
- Manufacturers have interpreted the DICOM Standard differently
  - DICOM was developed by consensus, not always one way to transfer information
- Different limits assigned to TPS information
  - # of ROIs, Contours, Points
  - Exchange of Dose Information
- "Testing" was envisioned as comparison of DICOM Conformance Statements, too complex in RO
  - IHE / IHE-RO provide testing today

Working Group 7
Radiation Therapy

REQUEST FOR FEEDBACK ON PROPOSED DICOM STANDARDS BY JUNE 1

Request of Feedback from AAPM Members on Proposed DICOM Standard Additions for Radiotherapy During the Forthcoming Public Comment Period



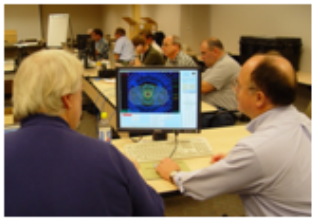
A new DICOM Standard for radiotherapy is being developed that will enable departmental workflow, improve safety through tighter standard definition, improve interoperability, and open DICOM to new technologies and processes in RT. (2nd Generation of DICOM RT Standard.)

Radiotherapy has evolved since the introduction of Radiotherapy objects to DICOM in 1997 ("1st Generation") with new treatment modalities, positioning techniques and more structured workflow. This prompted WG-07 to undertake this multi-year effort to develop the new standard.

This major upgrade to the DICOM Standard consists of a set of Supplements to the existing Standard.

Connectathons

- Cross-vendor, live, supervised, structured tests.
- All participating vendors' products tested together in the same place/time.
- Experts from each vendor available for immediate problem resolution. Fixes are done in minutes, not months!
- Each vendor tests with multiple trading partners (actual product to actual product).
- Testing of real-world clinical scenarios using IHE Integration Profiles.



Due to the difficulty in determining compatible applications using DICOM Conformance Statements, much effort has been put into developing the IHE-RO (Integrating the Healthcare Environment – Radiation Oncology) domain. IHE is focused on testing, in a controlled environment, multiple vendor systems / applications and determining their compatibility. IHE-RO is led by ASTRO / AAPM and tests applications by defining clinical situations where difficulties occur, determining a solution path, and then working with vendors during a Connectathon to show that they perform according to the solution defined (known as an IHE Profile). Manufacturers that successfully implement solutions to these profiles are publicly acknowledged and can develop and IHE Integration Statement which, in 1-3 pages, indicates the IHE Profile they adhere to, what functions they supply in support of that profile, and which software and versions have been tested.

What is HL7?

Health Level Seven is one of several American National Standards Institute- accredited Standards Developing Organizations (SDOs) operating in the healthcare arena.

Most SDOs produce standards (sometimes called specifications or protocols) for a particular healthcare domain such as pharmacy, medical devices, imaging or insurance (claims processing) transactions.

HL7's domain is clinical and administrative data.

http://www.hl7.org/

What is HL7?

HL7 provides standards for interoperability that improve care delivery, optimize workflow, reduce ambiguity and enhance knowledge transfer among all of our stakeholders, including healthcare providers, government agencies, the vendor community, fellow SDOs and patients.

In all of our processes we exhibit timeliness, scientific rigor and technical expertise without compromising transparency, accountability, practicality, or our willingness to put the needs of our stakeholders first.

http://www.hl7.org/

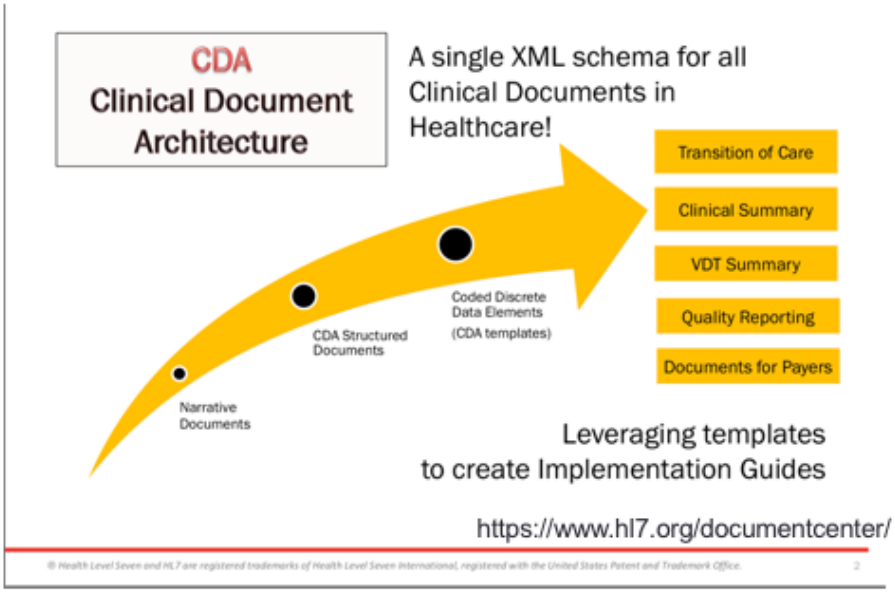
What is HL7?

Like all ANSI-accredited SDOs, Health Level Seven adheres to a strict and well-defined set of operating procedures that ensures consensus, openness and balance of interest. A frequent misconception about Health Level Seven (and presumably about the other SDOs) is that it develops software.

In reality, HL7 develops specifications, the most widely used being a messaging standard that enables disparate healthcare applications to exchange keys sets of clinical and administrative data.

http://www.hl7.org/

HL7 Clinical Document Architecture



Key Aspects of the CDA

- CDA documents are encoded in Extensible Markup Language (XML).
- CDA documents derive their meaning from the HL7 Reference Information Model (RIM).
- The CDA specification is richly expressive and flexible. Templates and implementation guides can be used to constrain the generic CDA specification.

https://www.hl7.org/documentcenter/

A system of templates…

- **Document-level templates**: These templates constrain fields in the CDA header, and define containment relationships to CDA sections.
- **Section-level templates**: These templates constrain fields in the CDA section, and define containment relationships to CDA entries.
- **Entry-level templates**: These templates constrain the CDA clinical statement model in accordance with real world observations and acts.
- **Reuse templates**: These templates group a common set of constraints for reuse in CDA documents. i.e. names, dates, …

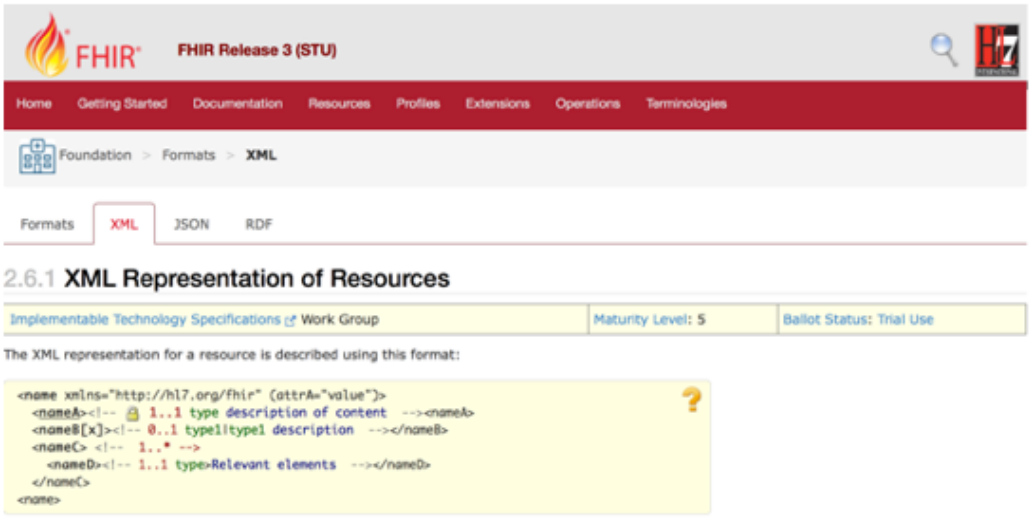
https://www.hl7.org/documentcenter/

Fast Healthcare Interoperability Resources (FHIR)

- FHIR, pronounced "fire", is a draft standard describing data formats and elements (known as "resources") and an application programming interface (API) for exchanging electronic health records. The standard was created by the Health Level Seven International (HL7) health-care standards organization.
- It is easier to implement because it uses a modern web-based suite of API technology, including a HTTP-based RESTful protocol, HTML and Cascading Style Sheets for user interface integration, a choice of JSON or XML for data representation, and Atom for results.

From Wikipedia

FHIR Development



https://www.hl7.org/fhir/xml.htm

DICOM References

- http://dicom.nema.org\dicom\resources.html
  - Main site has links to DICOM activities, resources
- https://www.dicomstandard.org
  - Downloadable standard in several formats
- http://www.dclunie.com
  - Long-standing DICOM resource site maintained by the DICOM standard editor
- http://www.osirix-viewer.com
  - Well-known MacOS-based DICOM viewer, originally freeware, now has lite "demo-version" or purchased product
- http://www.dvtk.org
  - Open-source DICOM Validation ToolKit, includes utilities for editing, viewing, comparing, and DICOM SCU/SCP applications. Windows-based, used by IHE-RO Test Tools.

HL7 / FHIR Resources

- http://www.hl7.org
  - https://www.hl7.org/documentcenter/
- https://www.qvera.com/free-hl7-interface-engine/
  - Free (limited, upgradeable) HL7 Message Engine
- https://www.hl7.org/fhir/xml.html
  - Description of current release of FHIR

Thank you