Standards in Ion Therapy

Stuart Swerdloff, PhD
Co-Chair, IHE-RO Technical Committee
IMPAC Ion Therapy Team Lead

Standards in Ion Therapy

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- Objectives
  - Identify the Standard used for communication of data between systems involved in planning and delivery of Proton Therapy
  - Examine practical issues involved in communication of data and interoperability between systems involved in planning and delivery of proton therapy
  - Identify practical means for determining the likelihood of interoperability between systems utilized in proton therapy
  - Explore current and future areas of technological development in communication between systems in proton therapy

Defining some preliminary terms

- A (technical) **Standard** is a document that establishes uniform engineering or technical specifications.
- ***De jure***: “of law”
- ***De facto***: “in fact”
  - Steering Wheel on the Left Hand Side is a De Facto standard in the USA
  - Driving on the Right Hand Side of the street is a De Jure standard in the USA

Why bother with Standards?

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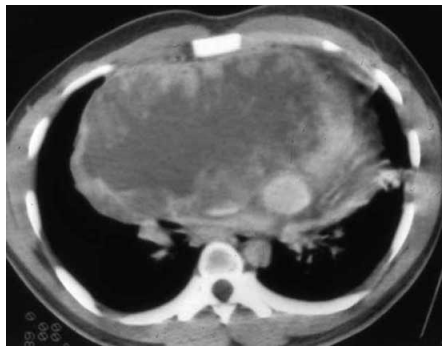
- **Interoperability**
- Interoperability
- Interoperability
- **Compatibility**
- **Safety**
- **Repeatability**
- Interoperability (did I mention interoperability?)
- **Commoditization** (enabling choice of vendors for “Best of Breed”)
- **Simplify RFP’s**

- For those who like to have just one vendor’s product: What happens when one vendor acquires another vendor? When you need something that one vendor simply doesn’t offer?
- For those vendors who prefer proprietary lock-in: What happens when you acquire another vendor? Care to save $$ on engineering design?

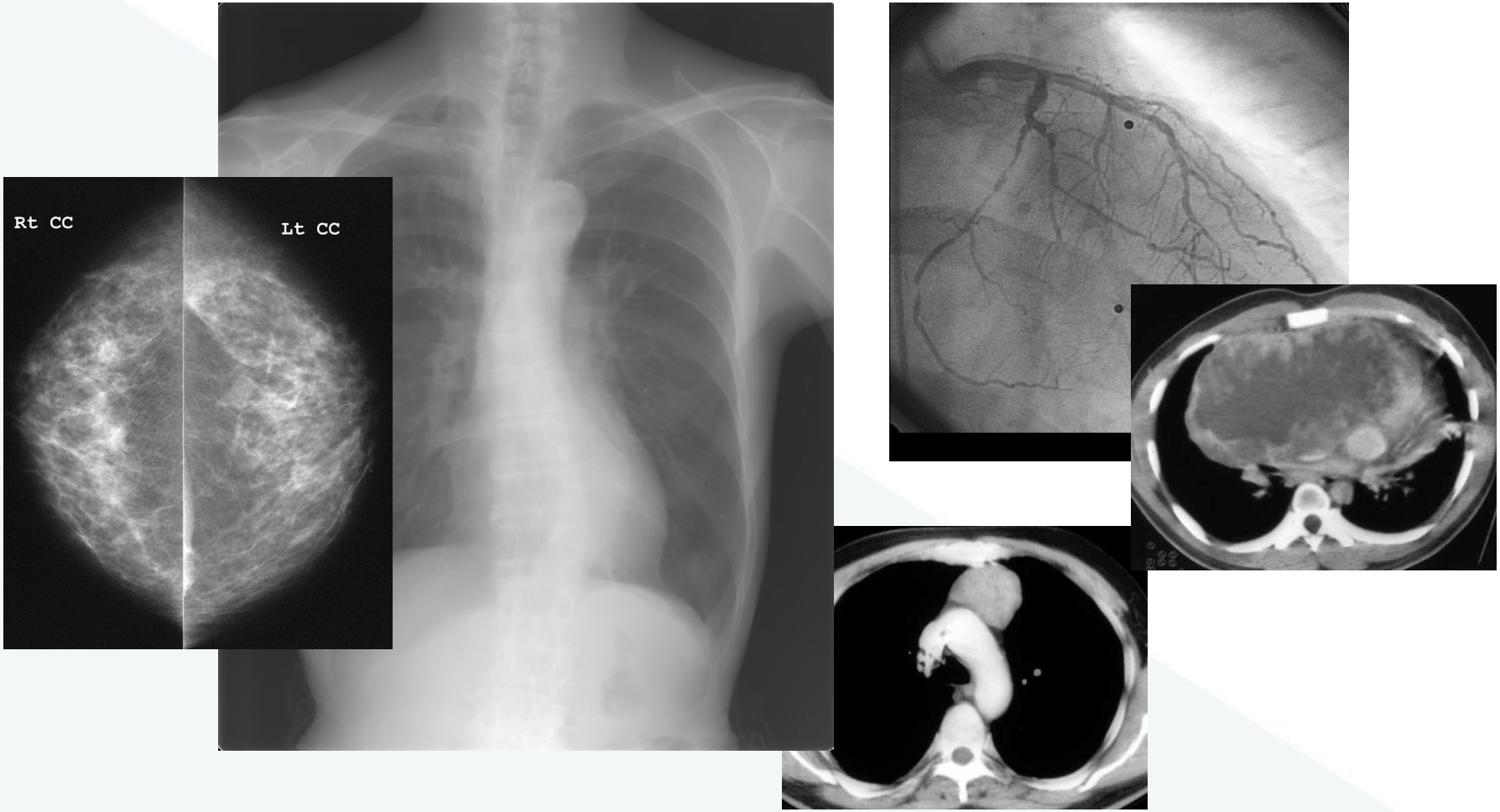
DICOM in Depth



- DICOM 101- Intro to DICOM
- DICOM 201- DICOM-RT
- DICOM 301- Ions in DICOM
- DICOM 401- Machine Interfaces in DICOM
- DICOM 501- The Interoperability challenge; IHE:Technical Frameworks using DICOM and HL7
- DICOM 601- IHE-RO: A Technical Framework specific to Radiation Oncology

DICOM 101

Introduction to DICOM



Whose idea was it anyway?

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Pressure from clinicians forced vendors to consider a universal medical image format.

So what is it, exactly?

DICOM - The Digital Imaging and Communications in Medicine (DICOM) standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images.

A single DICOM file contains both a header (which stores information about the patient's name, the type of scan, image dimensions, etc), as well as all of the image data (which can contain information in many dimensions).

Then what is DICOM-RT, exactly?

DICOM-RT – An unofficial name applied to parts of the DICOM standard that are utilized specifically for Radiation Therapy. The first steps to address RT needs in DICOM were made in 1995 with the foundation of DICOM Working Group 7 (WG-7)

Concepts that were not part of diagnostic imaging:

- DRRs and Portal images (RT Image)
- Contours (RT Structure Set)
- Plans (RT Plan)
- Dose (RT Dose) (… and more to be described later)

But wait…. There is more…

In addition to being a data format for transmitting medical image data and Radiation Therapy data, DICOM also functions as a communication protocol.

The two-headed DICOM beast:

1. Data format
2. Communication protocol

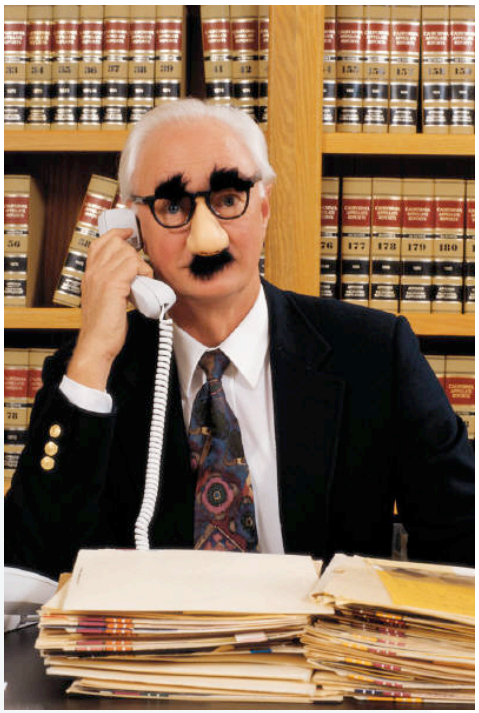
Speak DICOM like a Pro or DICOM top 10

- **AE** = Application Entity
- **IOD** = Information Object Definition
- **SOP** = Service-Object Pair
- **VR** = Value Representation
- **UID** = Unique Identifier
- **SCP** = Service Class Provider
- **SCU** = Service Class User
- **DIMSE** = DICOM Message Service Element
- **UWPS** = Unified Worklist and Procedure Step
- **FSC** = File Set Creator

DICOM Association

A communication connection established between two DICOM applications by which DICOM information is exchanged.

1. **AE Title and IP address**
2. **List of Transfer Syntaxes**
3. **Supported SOP classes (including the role the AE will play)**



DICOM configuration file

Each DICOM implementation, in general, maintains a configuration file listing the other devices that it is allowed to form associations with. The devices are identified by their AE Title, IP address and port number.

DICOM Service Classes (overview)

One can consolidate the services conceptually in to:

- Verification (“Echo”, determining if a system is willing and able to talk)
- Storage (Push a copy of an object)
- Query (Find out what is available)
- Retrieve (Request that a copy be sent)
- Work List (Task Management, based on polling)
- Notification (Task Management)
- Print (Making pretty pictures on paper or film)

DICOM Service Classes

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1. Verification
2. Storage
3. Query/Retrieve
4. Print Management
5. Media Storage
6. Storage Commitment
7. Unified Worklist and Procedure Step Management
    1. Eventual replacement for Modality Worklist and Modality Performed Procedure Step classes
    2. Immediate replacement for General Purpose Worklist and General Purpose Performed Procedure Step classes

DICOM Service Classes (cont)

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8. Softcopy Presentation State
9. Structured Reporting
10. Application Event Logging
11. Relevant Patient Information Query
12. Instance Availability Notification
13. Media Creation Management
14. Hanging Protocol Storage
15. Hanging Protocol Query/Retrieve
16. Substance Administration Query

DICOM Information Object Definitions

The IODs define particular sets of medical images.

Formally, each of the IODs define an SOP Class.

Examples include:

- CR - Computed Radiography IOD
- CT - Computed Tomography IOD
- MR – Magnetic Resonance IOD
- US – Ultrasound IOD
- SC – Secondary Capture IOD
- etc.

These, in the DICOM world, are commonly thought of as modalities. This means, for example, that a Fluoro image that is being read through a CR reader will have a CR IOD, and be treated as a CR modality.

Creating Service-Object Pairs

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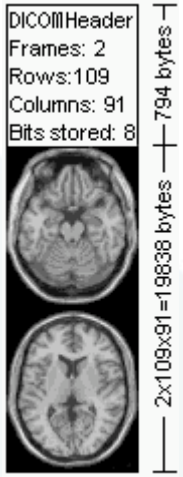
The service classes and information objects are combined to form the functional units of DICOM. This combination is called a service-object pair, or SOP. Since DICOM is nominally an object-oriented standard, the combination is actually called a *service-object pair class*, or SOP class. The SOP class is the elemental unit of DICOM; everything that DICOM does when implemented is based on the use of SOP classes.

For example: Take a Storage Service Class, add a CT IOD and you have an SOP that will send a store command for a CT image.

DICOM File Format
So what does a DICOM Image file look like?

- File contains BOTH header and pixel data.
- Different elements are grouped together.
- Each tag has a type and a VR associated with it.
- Type of image determines which groups are used to build the header.
- Private groups = odd group numbers.
- Any DICOM viewer

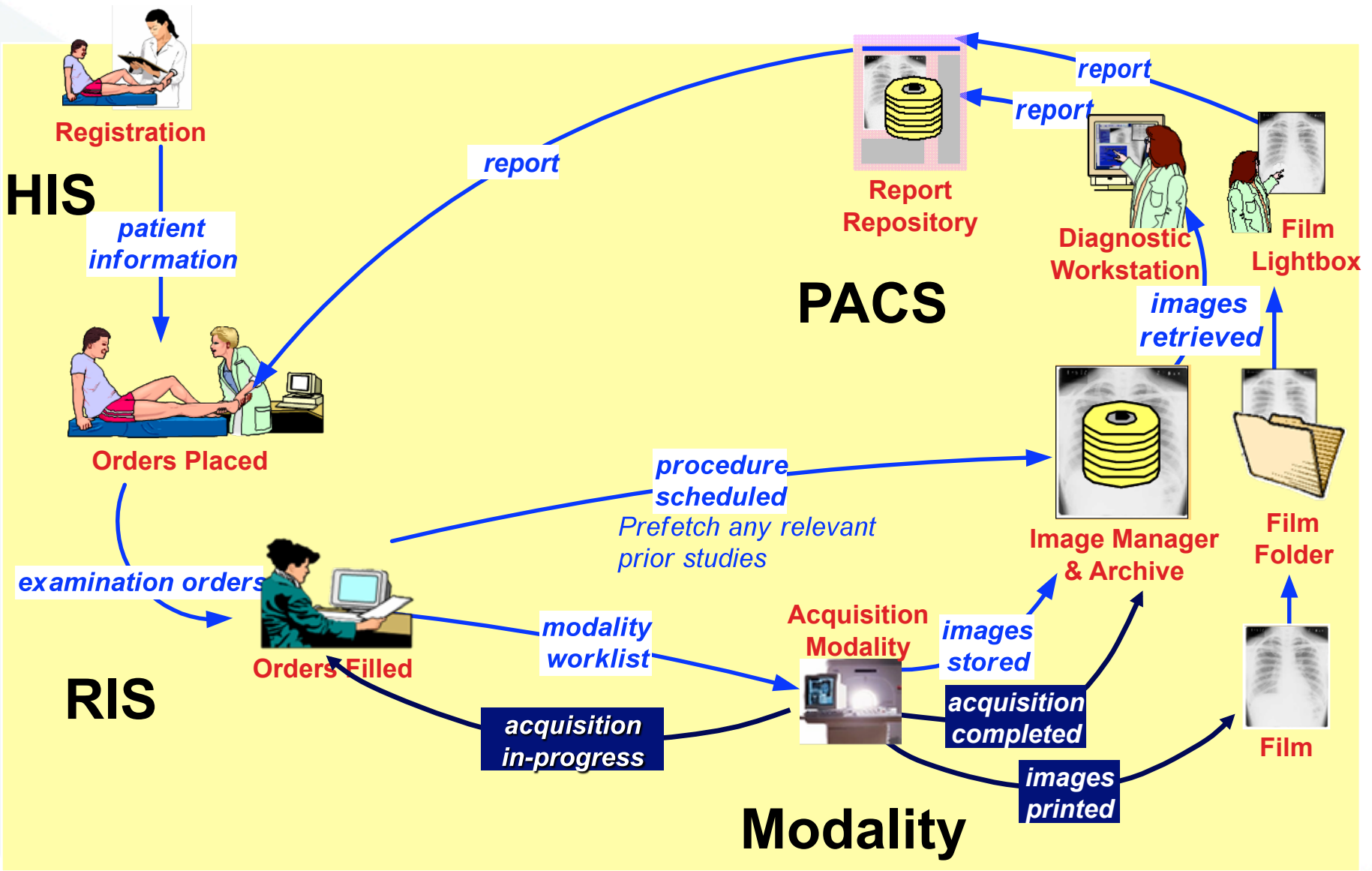


MRI.*

First 128 bytes: unused by DICOM format
Followed by the characters 'D','I','C','M'
This preamble is followed by extra information e.g.:

0002,0000,File Meta Elements Group Len: 132
0002,0001,File Meta Info Version: 256
0002,0010,Transfer Syntax UID: 1.2.840.10008.1.2.1.
0008,0000,Identifying Group Length: 152
0008,0060,Modality: MR
0008,0070,Manufacturer: MRIcro
0018,0000,Acquisition Group Length: 28
0018,0050,Slice Thickness: 2.00
0018,1020,Software Version: 46\64\37
0028,0000,Image Presentation Group Length: 148
0028,0002,Samples Per Pixel: 1
0028,0004,Photometric Interpretation: MONOCHROME2.
0028,0008,Number of Frames: 2
0028,0010,Rows: 109
0028,0011,Columns: 91
0028,0030,Pixel Spacing: 2.00\2.00
0028,0100,Bits Allocated: 8
0028,0101,Bits Stored: 8
0028,0102,High Bit: 7
0028,0103,Pixel Representation: 0
0028,1052,Rescale Intercept: 0.00
0028,1053,Rescale Slope: 0.00392157
7FE0,0000,Pixel Data Group Length: 19850
7FE0,0010,Pixel Data: 19838

Putting the pieces together
Using DICOM in a real world



DICOM Conformance Statements

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- Conformance is voluntary.
- Any vendor claiming conformance HAS to provide a conformance statement.
- The contents of the conformance statement include (*a*) the implementation model of the application; (*b*) the presentation contexts to be used; (*c*) the manner in which associations are to be handled; (*d*) the SOP classes to be supported; (*e*) the communication profiles to be used; and (*f*) any extension, specialization, or privatization to be used.
- Conformance statements for most vendors are available on their Web sites.

DICOM 201: Radiotherapy in DICOM

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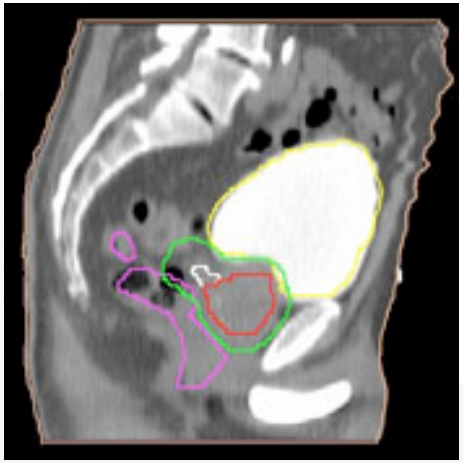
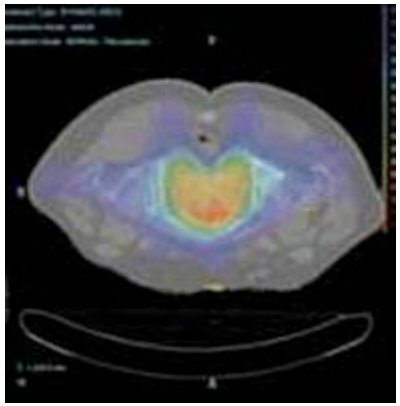
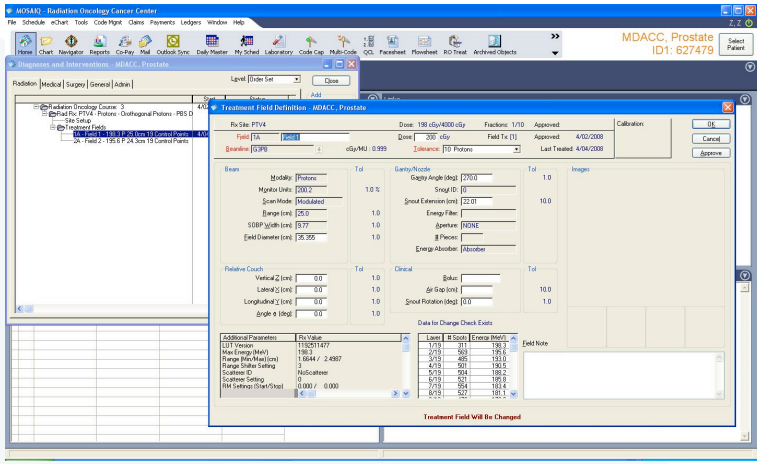
DICOM-RT







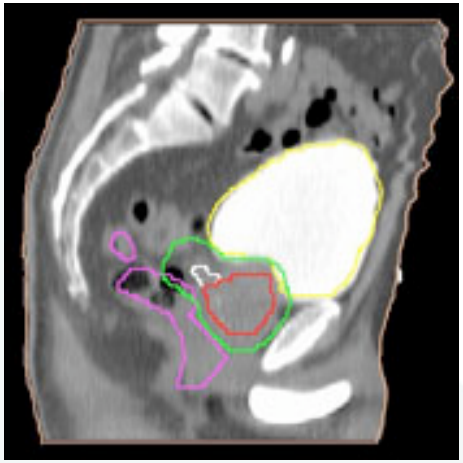
Information Object Definitions

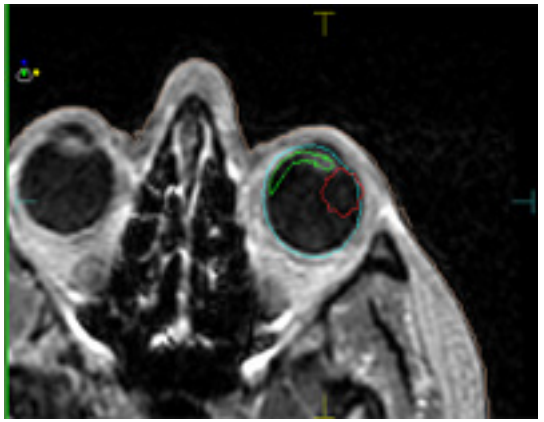
Of particular interest in “Conventional Radiotherapy”

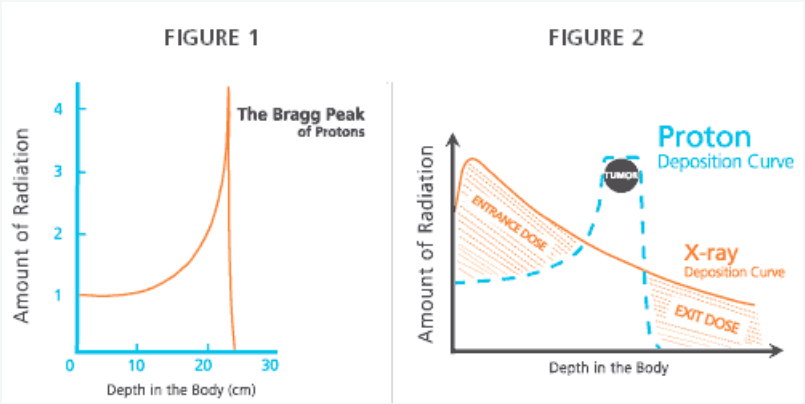
- RT Image (DRRs, Portals, Setup)
- RT Structure Set (Contours)
- RT Plan (Brachy and Tele)
- RT Dose
- RT Beams Treatment Record
- RT Brachy Treatment Record
- RT Treatment Summary Record
- Spatial Registration (Image co-registration, can be used as part of determining couch offsets)

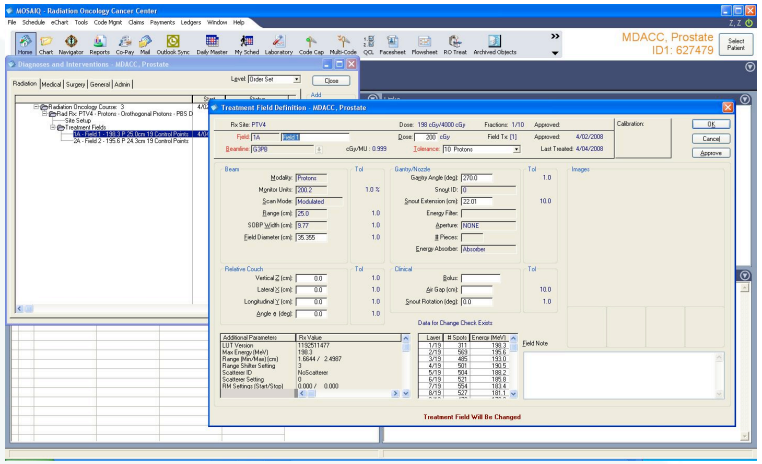
DICOM 301: Ions in DICOM

Supplement 102 Added Ions to DICOM









Proton/Ion IODs

Added to DICOM in Supplement 102

- RT Ion Plan
- RT Ion Beams Treatment Record

New Sequences, elements, etc.:

- Snouts, Range Shifters, Range Modulators, Lateral Spreading Devices
- Table Roll/Pitch, Gantry Pitch Angle, Ion Block, Ion Compensator
- Radiation Type now includes PROTON and ION
- Radiation Mass Number, Atomic Number and Charge State (ION, e.g. Carbon Ion)
- Scan Mode, Scan Spots
- Fixation Lights, SEATED patient position (Ocular)
- Virtual Source Axis Distance

Proton/Ion Workflow

- Construction of Compensators and Apertures
  - The RT Ion Plan should contain the information needed to build the Compensators and Apertures
  - The RT Ion Plan can contain the barcodes for each device

DICOM 401: Machine Interfaces

Proprietary, Open, De Facto, and De Jure

- Initially, each LINAC vendor would define an interface for its machine, and this would often change for each new machine. The interface spec was not necessarily shared freely.
- Later, vendors produced interfaces and offered these as a “De Facto” interface for others to adopt (and utilized DICOM)
  - At least some of these were/are Open in the sense that there are no license fees.
- Recently, a DICOM Standard has been approved (DICOM Supplement 74), and is the De Jure interface (no commercial implementations yet)

DICOM 401: "Standard" Machine Interfaces for Ion Therapy

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One De facto and the new De Jure

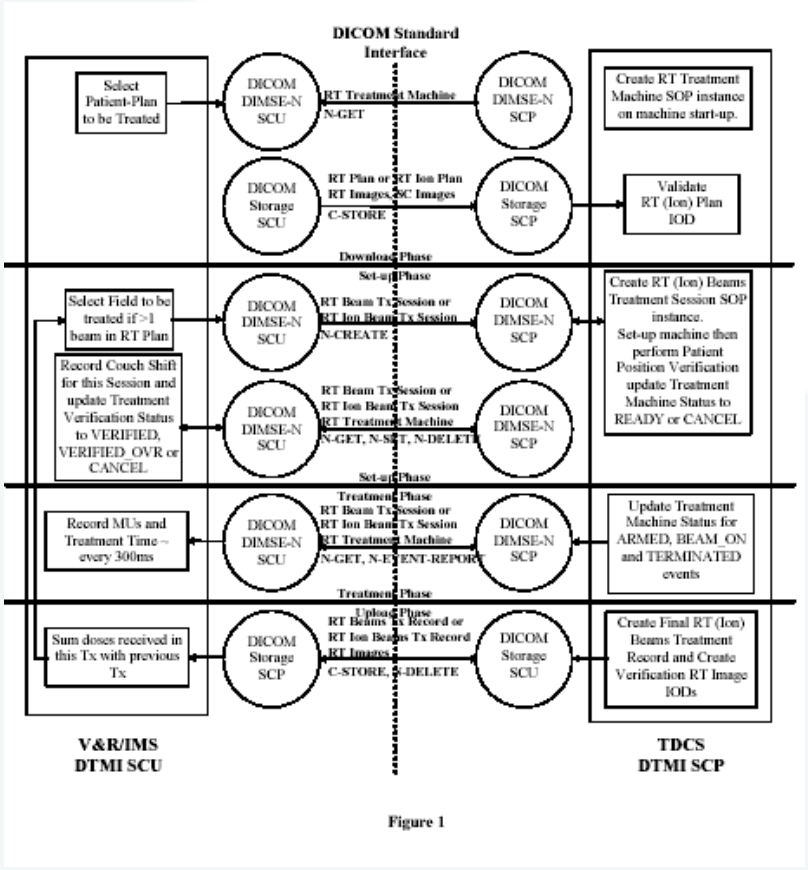
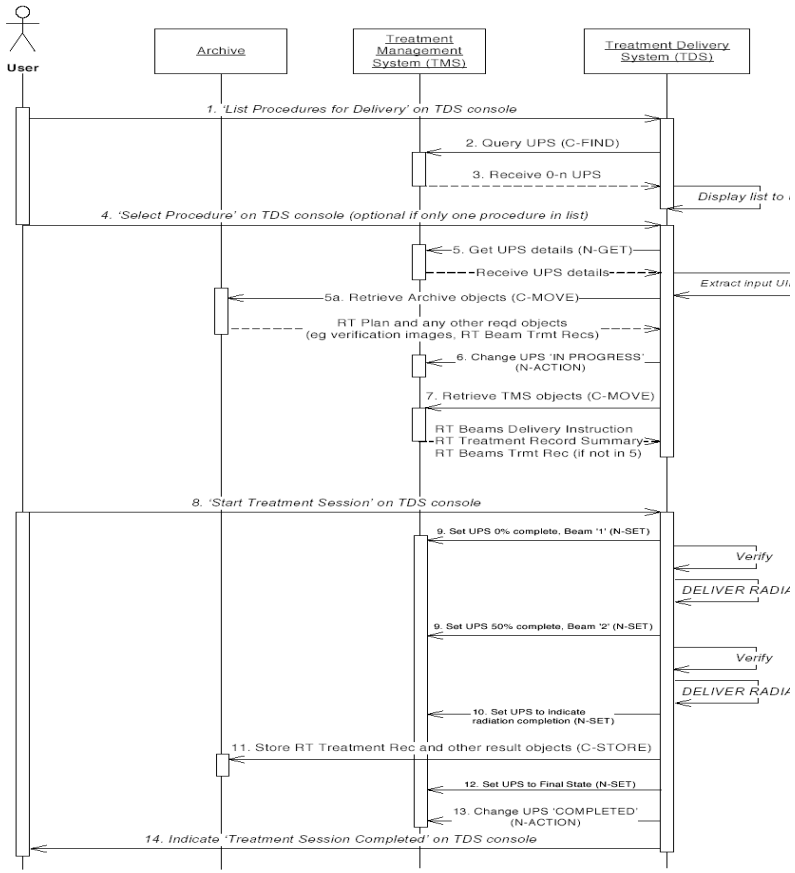


Figure 1



DICOM 401: Ion Machine Interfaces

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Current Commercial Implementations

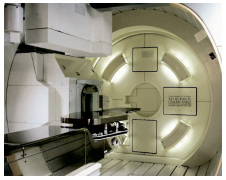
- One “R&V” vendor has produced an interface and offered it for use as a De Jure standard interface.
  - It was not adopted by DICOM WG-7 (RT)
  - No alternative was proposed in the necessary time frame.
  - It has been adopted by multiple Proton accelerator vendors.
  - It has not been adopted by other “R&V” vendors at this time.
- Other “R&V” vendors may choose to produce their own interfaces, and these may become De Facto standards… if there is adoption.

De Facto Interface (IFS1909)

EMR

SEND PLAN

SELECT BEAM



ACCELERATOR

Machine Status

Send Plan

Acknowledge

Beam Status

Plan OK

Select Beam

ADJUST

Beam Status

VERIFIED

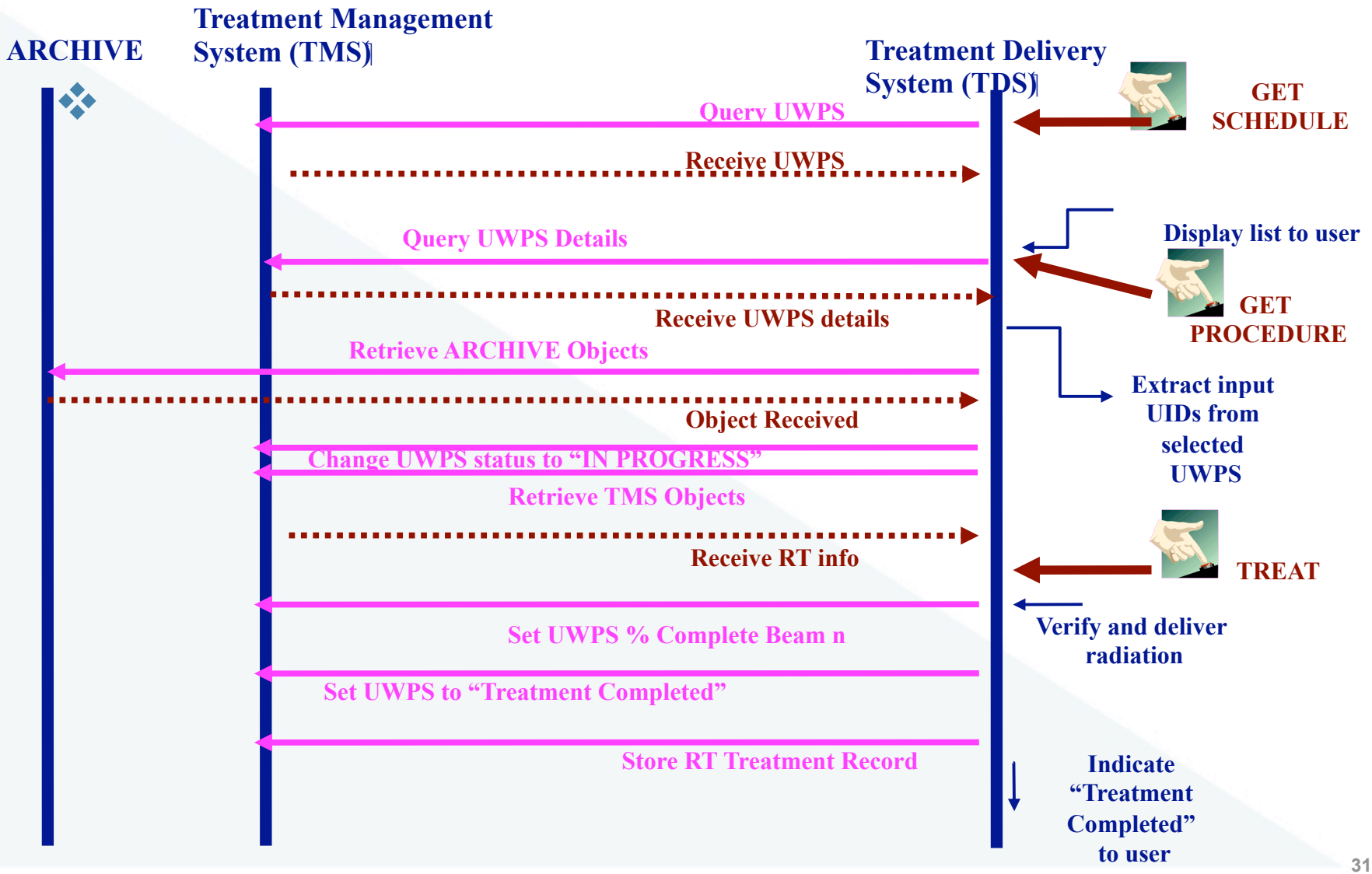
Beam Enabled

BEAM 0

Treatment Record

Delete Beam

De Jure Interface (Sup 74)



DICOM 401: Ion Machine Interfaces

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Relationship between IFS1909 and Supplement 74

- IFS1909 embeds (requires) Verification
- Supplement 74 has Verification as an **option**
- The Verification protocol in Supplement 74 is based on (and nearly identical to) the Verification protocol in IFS1909
- IFS1909 is “EMR Centric” (the user drives from the EMR).
- Supplement 74 is “Machine Centric” (the user drives from the Accelerator/Beamline Console)

DICOM 401: Ion Machine Interfaces

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The road less travelled : Patient Position Verification

- 3D (Volumetric/CT) position verification is not explicitly described in IFS1909 currently
- 2.5D position verification is not uniformly implemented with respect to IFS1909
- Supplement 74 does not fully address coordination between a Patient Position Verification System and the Treatment Delivery System

Interoperability

Why doesn't it work when both devices are DICOM compliant?

- Th
  e
  DICOM standard is open to multiple interpretations
- There is room for data field
  variations
  (
  optional "type 2 and type 3" data, and private data)
- DICOM
  doe

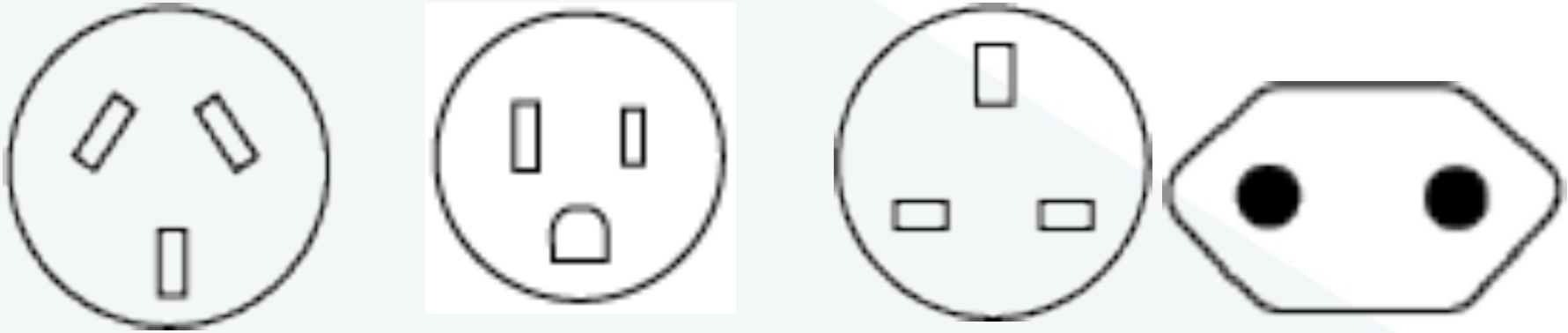
So how do we know it will work?

Vendors generally maintain interoperability matrices listing devices that their equipment has been validated against, however, the only way to really know is to:

CONNECT and TEST!!!

DICOM 501: The Interoperability Challenge

- Even with Standards, there are differences in interpretation.
- There is more to interoperability than a common data format.
- Interoperation involves workflow too



IHE and DICOM

Bringing order to the world of DICOM and HL7

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Integrating the Healthcare Enterprise (IHE)

- IHE attacks real world radiology integration problems
- HL7 and DICOM provide dictionaries
- IHE defines a “phrasebook” that solves real world problems (workflow) by assembling pieces provided by DICOM/HL7

Key IHE Concepts

- Generalized Systems -> Actors
- Interactions between Actors -> Transactions
- Problem/Solution Scenarios -> Integration Profiles

- For each Integration Profile (there are many):
  - the context is described (which real-world problem)
  - the actors are defined (what systems are involved)
  - the transactions are defined (what must they do)
- Adherence (meeting the profile and interoperating with at least 3 other vendors)
- Boilerplate available for inclusion in an RFP

An IHE Profile: Scheduled Workflow

- Putting the pieces together (in Radiology)
  Using DICOM and HL7 in a real world

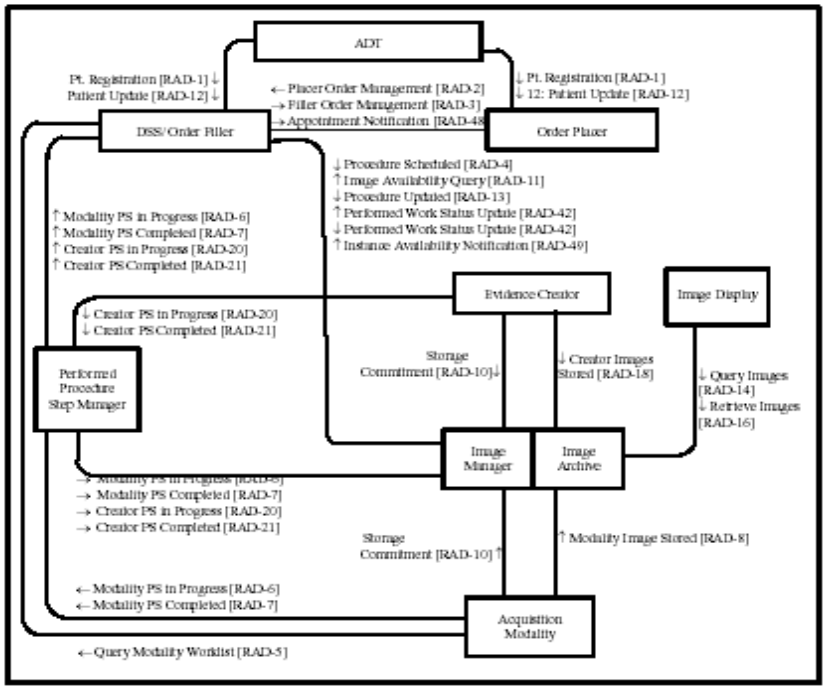


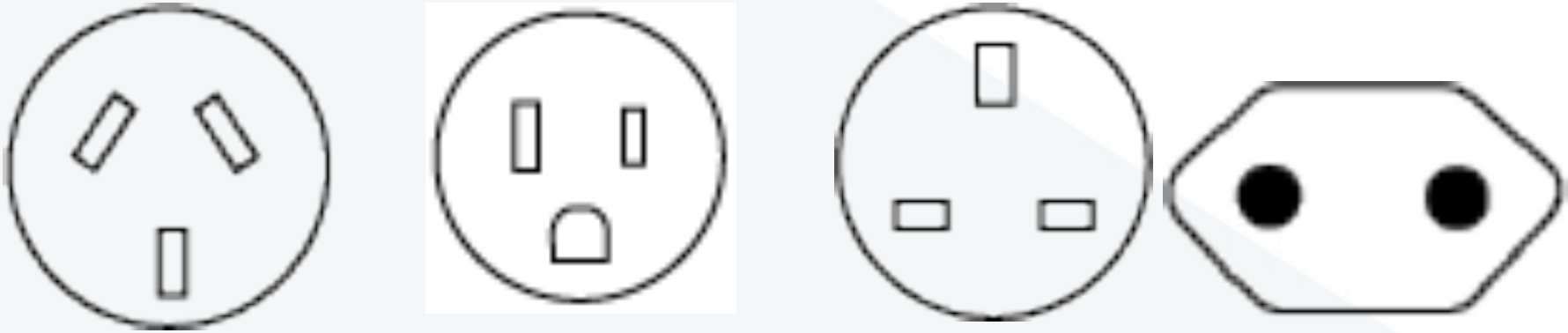
Figure 3.1-1. Scheduled Workflow Diagram

IHE Connectathons: Connect, Test, be Judged…

- Test tools are used ahead of time as development aids and then to limit entry to those “likely to pass”.
- Many vendors bring their equipment to one place at one time, and test interoperability within a profile against each other.
- Adherence/“Passing” requires interoperating with at least three other vendors. Vendor must publish “Adherence Statement”.

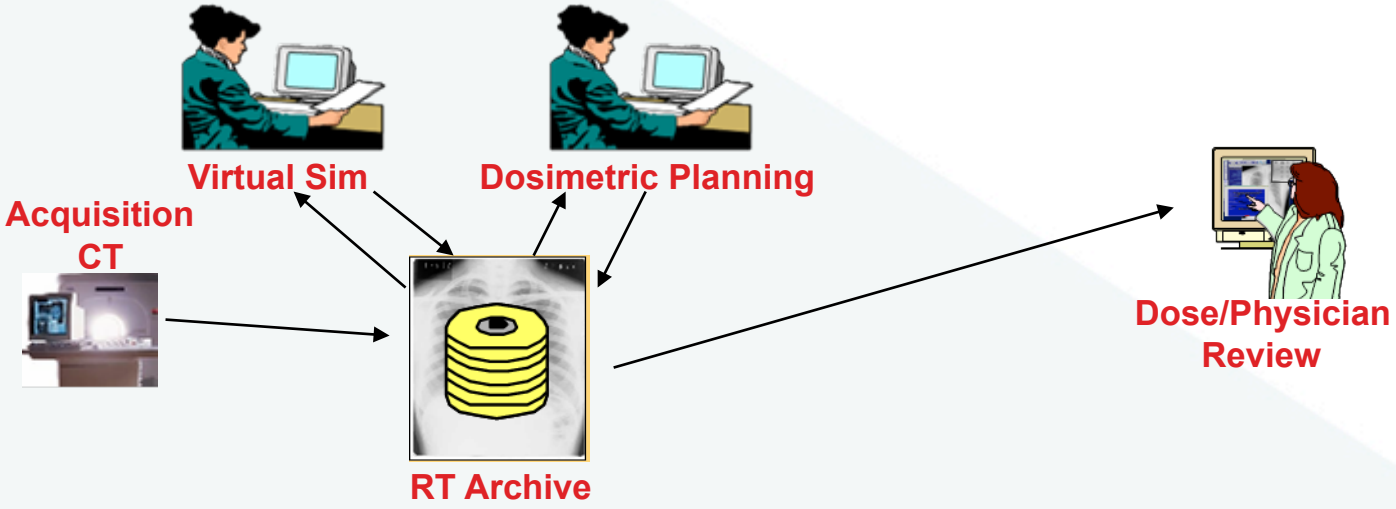
DICOM 601: IHE-RO

- Technical Framework Focused explicitly on Radiation Oncology
- Supported by ASTRO, *-STRO, and others
- One Connectathon with one Profile so far
- 2nd annual connectathon in August for two profiles
- Managed Treatment Delivery Profile on deck



IHE-RO Success Story

- Basic RT Object Interoperability Profile
  - Planning through Dose Review
  - Tightens the rules for certain DICOM Information Objects



IHE-RO Future

- Content and workflow interoperability profiles at a supportable pace (vendors implementations and committee members time availability).
- Incorporate new DICOM Information Objects
- Eventually a “Scheduled Workflow for Radiation Oncology” and a “Transferable Electronic Patient Record” (see ihe.wiki.net)
- Please encourage your Ion vendors to commit time and people to the effort.

DICOM-RT Future

- New Information Objects specific to RT are currently under development
  - Multiple year time frame for standardization and implementation
  - address gaps
  - refine data model
  - incorporate modalities and workflows not available when original “DICOM-RT” IODs were developed.
  - Incorporate lessons learned

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- Summary
  - DICOM is the primary Standard used for communication of data between systems involved in planning and delivery of Proton Therapy
  - Differences in interpretation of the standard and optional elements can limit interoperability
  - Careful review of DICOM conformance statements, inspection of IHE-RO adherence statements, and interface testing help you to avoid interoperability problems.
  - Patient Position Verification Devices/Systems and interfaces to them are evolving.
  - There will be a major evolution in the RT related parts of the DICOM Standard over the next five years.
  - There will be IHE-RO profiles that will cover much of the workflow required in Ion Therapy. These will enable much simplified RFPs

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- Conclusion
  - Demand that your vendors provide Standards compliant systems (the vast majority do, but a little nudge doesn't hurt). Have your provide the documentation of their compliance.
  - Understand your workflow and the points of contact between your systems. Verify that the interface across those points of contact is addressed by a Standard (typically DICOM), and that the systems on either side are in fact interoperable.
  - The Standards and Technical Frameworks are not complete. Keep an eye on those, and encourage your vendors to participate on relevant committees
  - D'viryi, Ni Proveryi ("Trust, but Verify")

Useful References

- http://medical.nema.org (DICOM Standard)
- http://wiki.ihe.net (IHE “in progress” and details)
- http://www.ihe.net (Formal output of IHE)
- http://www.dvtk.org (Free/Open Source DICOM Test Tools, RT Ion definitions recently submitted by IMPAC)

Contact Information

- In the USA, via IMPAC:
- sswerdloff@impac.com

QUESTIONS?

enter a new
dimension
in oncology IT

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