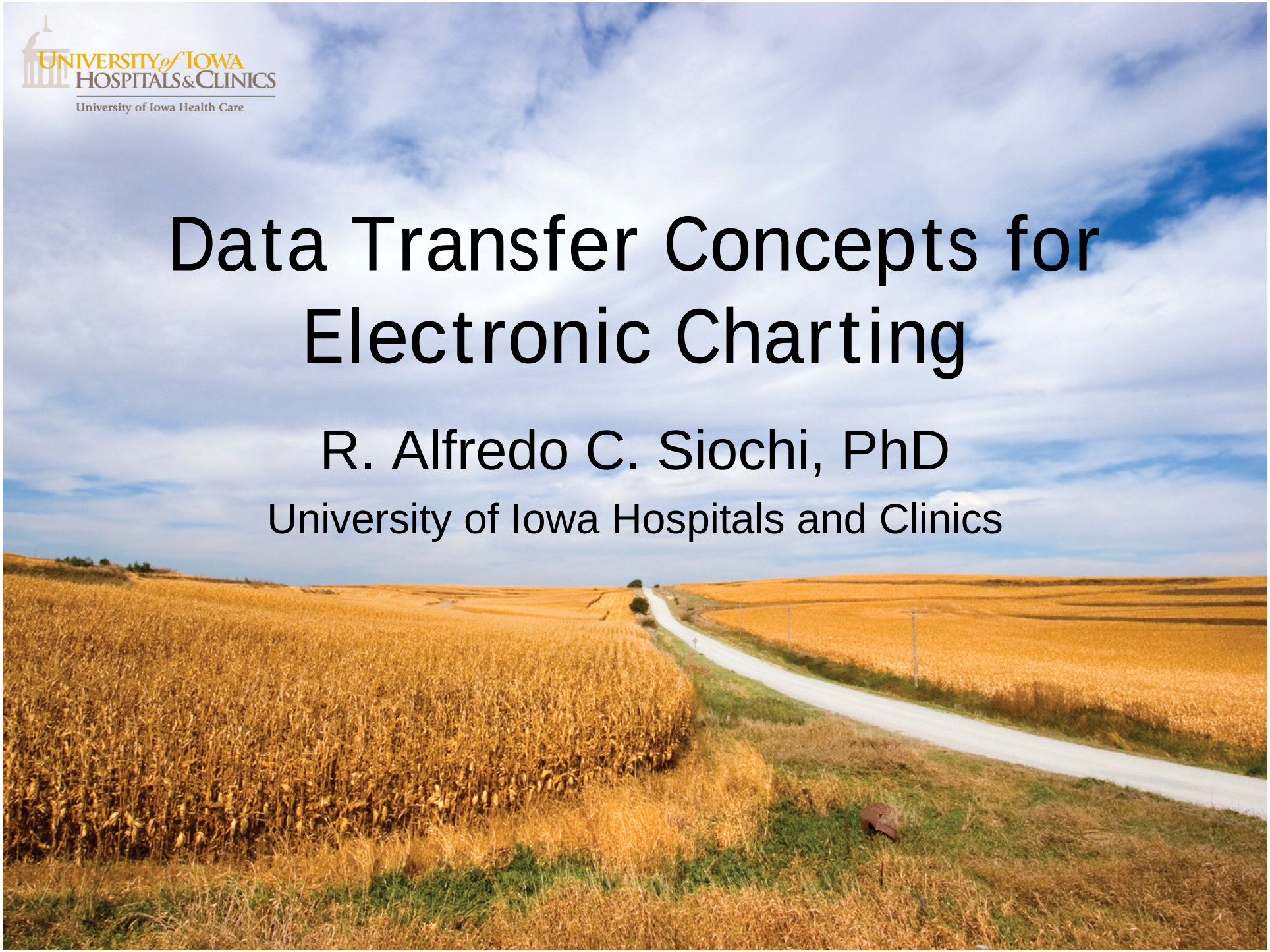


Data Transfer Concepts for Electronic Charting

R. Alfredo C. Siochi, PhD

University of Iowa Hospitals and Clinics

Outline

1. IT Infrastructure
    a) Networks – physical structure
    b) Transport Protocols
    c) DICOM, HL7
2. Data Repositories
    a) File Systems
    b) Databases
3. Models of Data Flow
    a) Distributed
    b) Centralized
    c) Examples

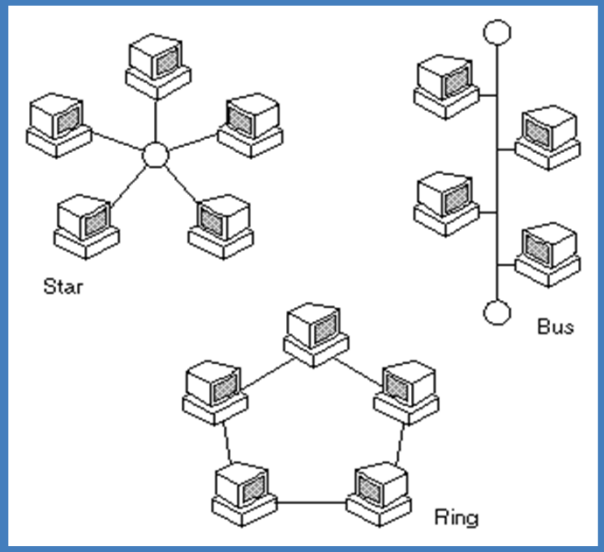
Outline-II

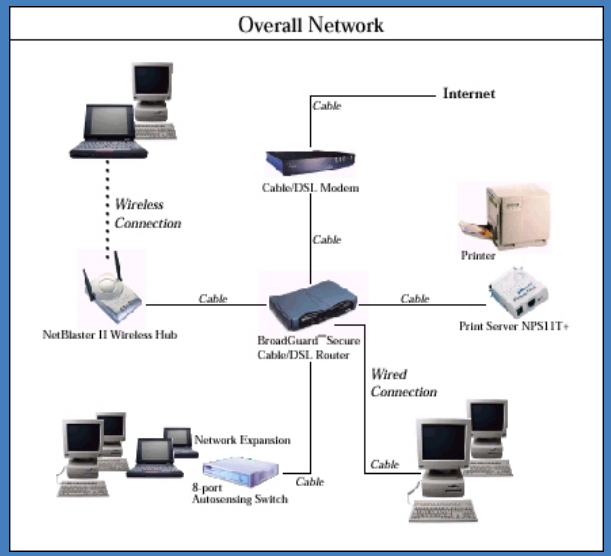
4. Data Transfer Matrix
    a) Subsystems in Rad Onc
    b) Example Matrix
    c) Testing
5. Quality Assurance and Control Basics
    a) Principal concepts: Physical Integrity and Logical Consistency
    b) ATP and Commissioning
    c) Annual
    d) Patient QC

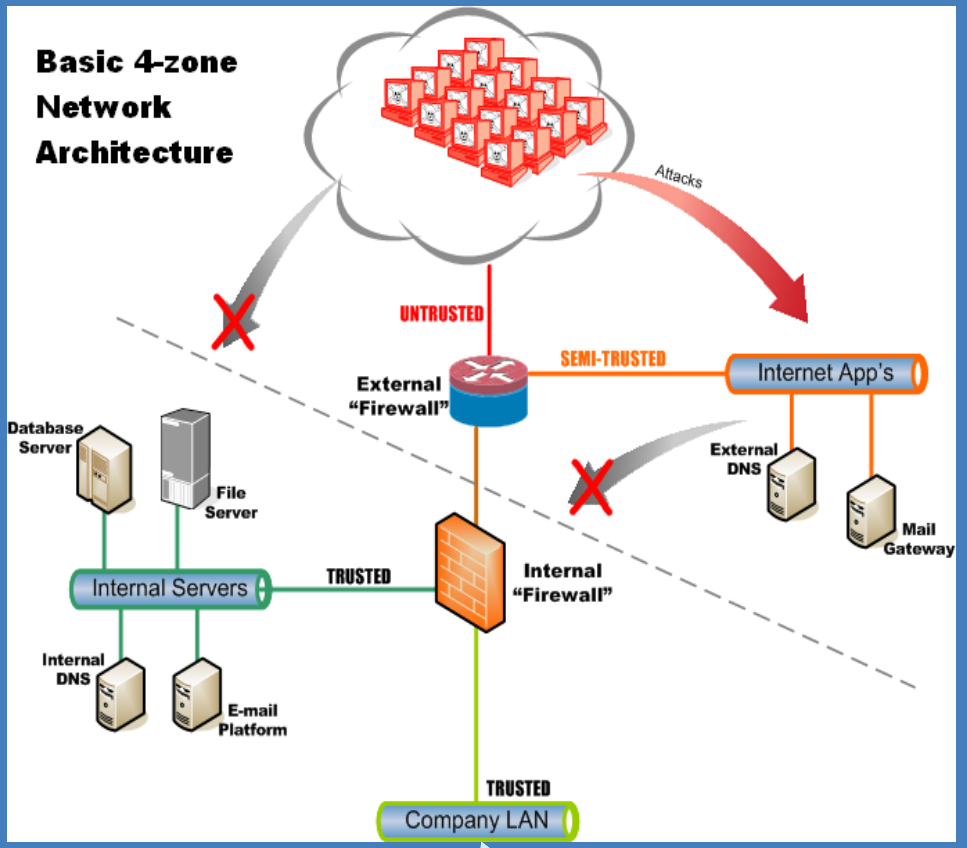
Networks

- Link computers together
  - Including computers that drive treatments!
  - Can be across continents
- Various architectures possible
- Rad Onc should be behind a firewall
- Connections: cables, optical fiber, routers, “wireless”…

Network Diagrams







Is Your Rad Onc Network Here ?

Mailman analogy

- Houses = computers
- House Address = ip Address
- Residents = ports
- Post office = finds appropriate routes
- Roads = cables / wireless
- The analogy breaks down with the lower layers…

OSI 7 layers

- Physical through Logical
- package up the information for sending
- Analyze the package for receiving
- Transport information
  - Computer: ip address
  - Software Application: port
    - DICOM layer: AE title

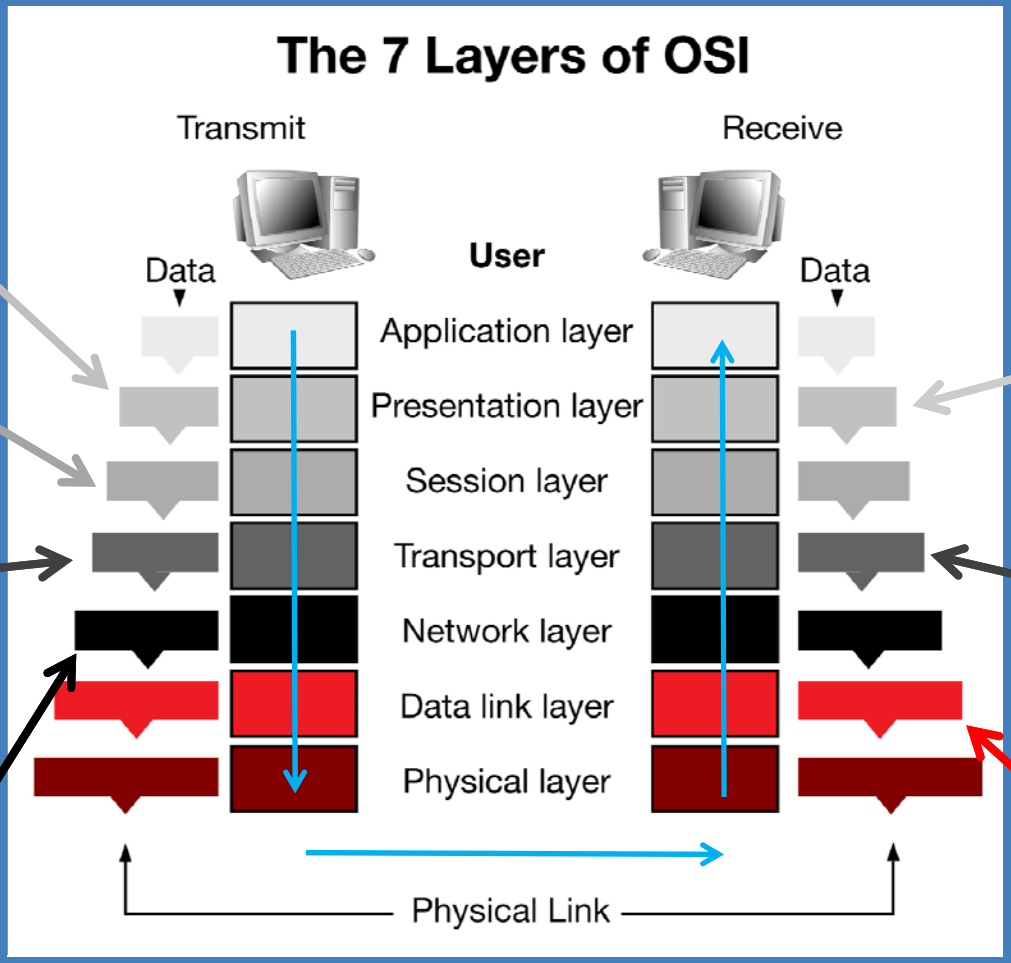
Open Systems Interconnect

Translate, Encrypt, Compress

Establish, Maintain, Synchronize interactions

Split message into smaller parts

Packets from origin to destination, logical-physical address mapping



Decompress, Decrypt, Translate

Entire message reassembled, origin to destination

Node to node transmission of data frames

TCP/IP - OSI

Entire data stream

SMTP (mail), HTTP (web), FTP, Telnet

Packets framed with header (addresses, error checking)

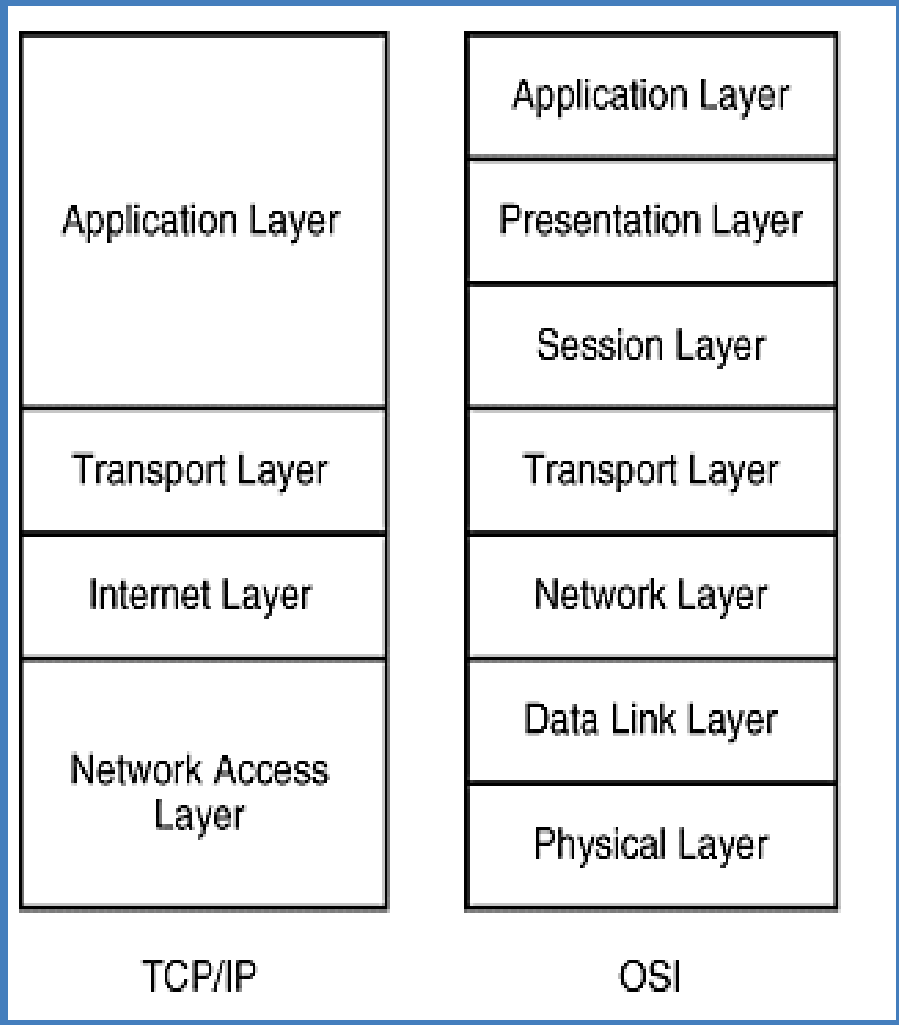
TCP

Determine routing and add IP header

IP

Ethernet, etc

IP frame transmission



DICOM, HL7

- Primary protocols in a hospital setting
- TCP/IP
- DICOM-RT: RT treatment data
- HL7: Admissions, Discharge, Transfer, labs, billing….

Information vs Data

- Data are associated with attributes
- There should be enough attributes to be unambiguous

Value	attribute	information
99	?	?
	age	A very old person
	Code number	Maxwell Smart's sidekick?
	Weight	May be light or heavy. Lbs or Kg?

Attributes determined from:

- DICOM: Information Object Definition (IOD)
- HL7 – message headers and expected record position within the message

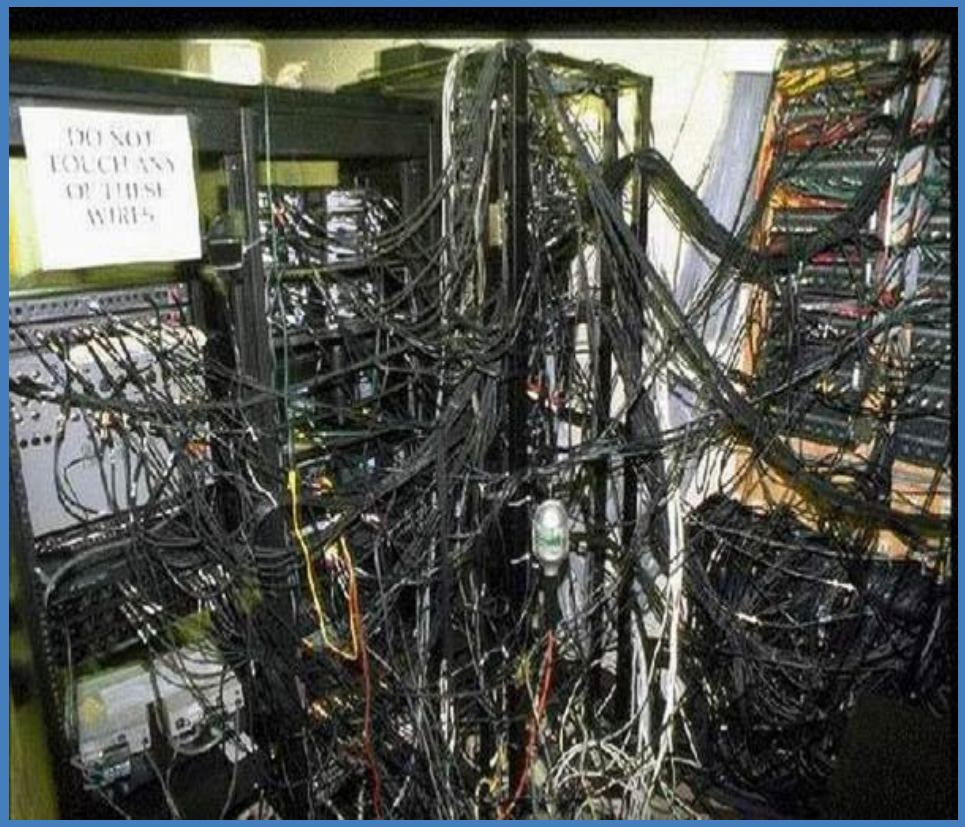
DICOM Applications

- Picture Archiving and Communications System (PACS)
- DICOM-RT capable treatment planning systems, for export to R&V and IGRT systems
- DICOM from imaging systems to treatment planning systems

Making the Connection

http://worldrec.info/2006/10/26/the-worlds-messiest-network-cable-arrangements

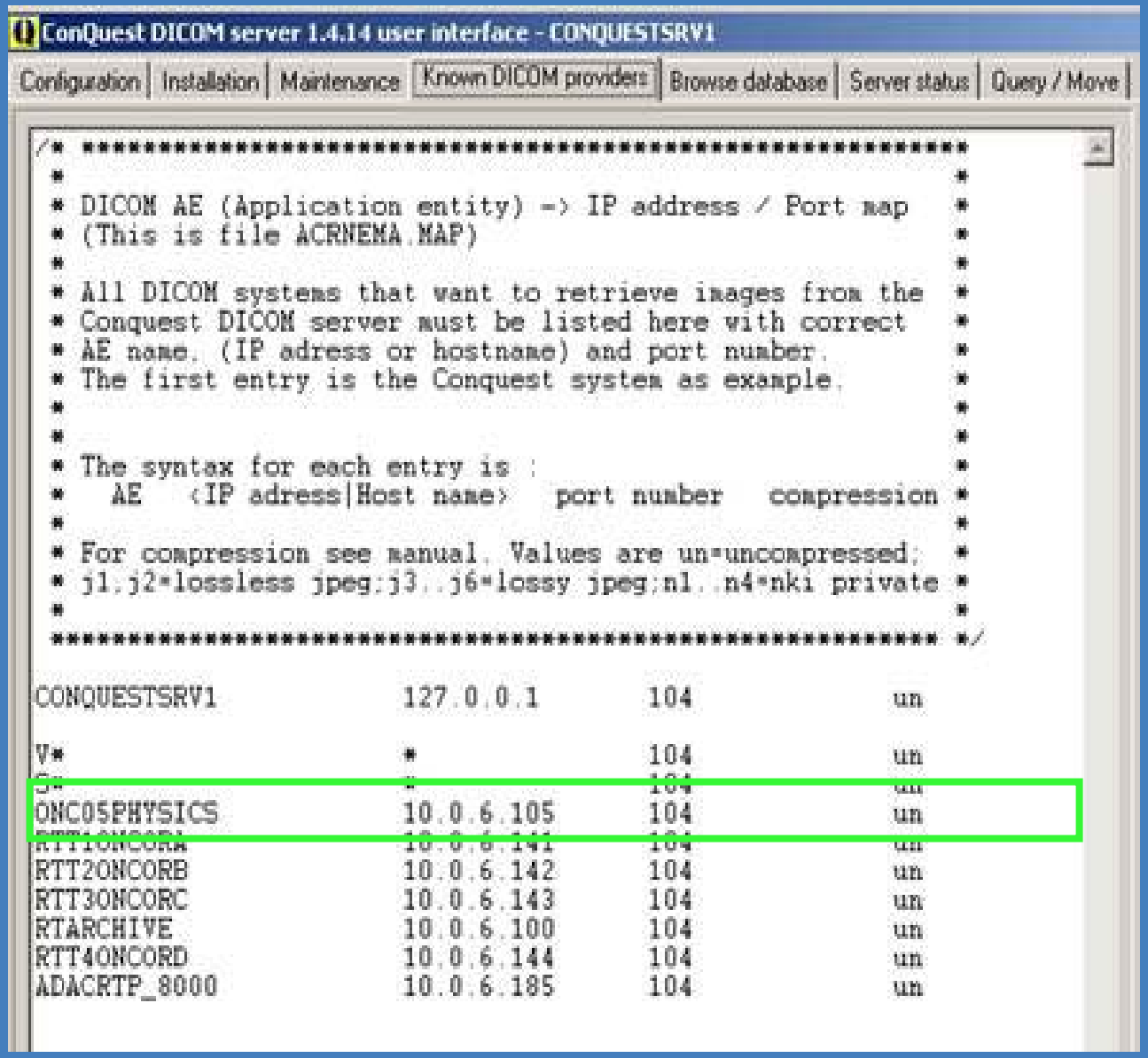
I hope your DICOM "physical layer" looks better than this!



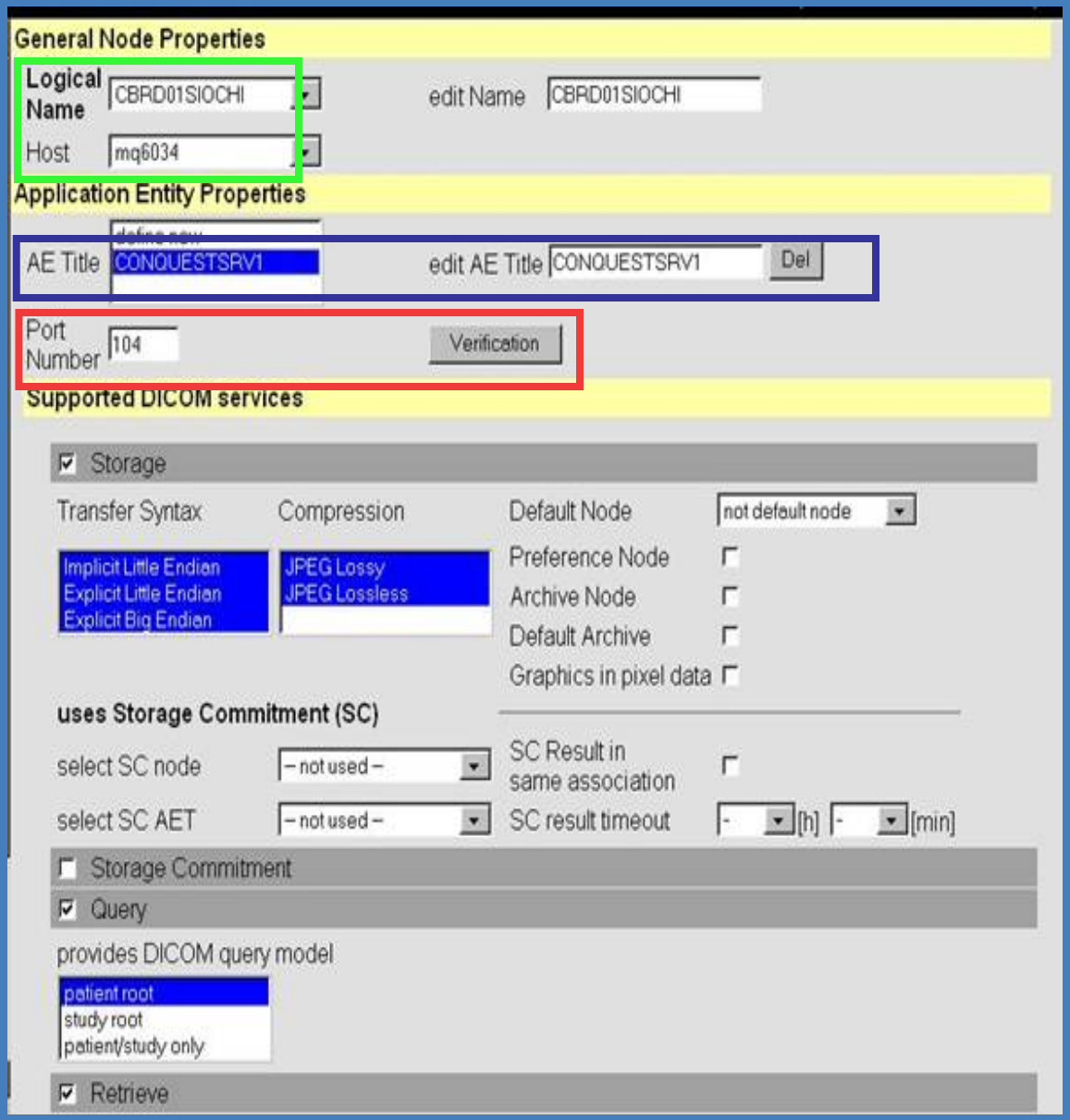
A DICOM network uses the underlying TCP/IP infrastructure.

Application Entities (AEs)

- Software application residing on a computer with a static IP address
- Default port 104
- ***or any unused port as long as receivers and senders use the same one***
- Other configurations possible but more complex



The quad core AE knows about the Coherence workstation ONC05PHYSICS



Coherence knows about the quad core AE and its supported Dicom Services

ASSOCIATIONS

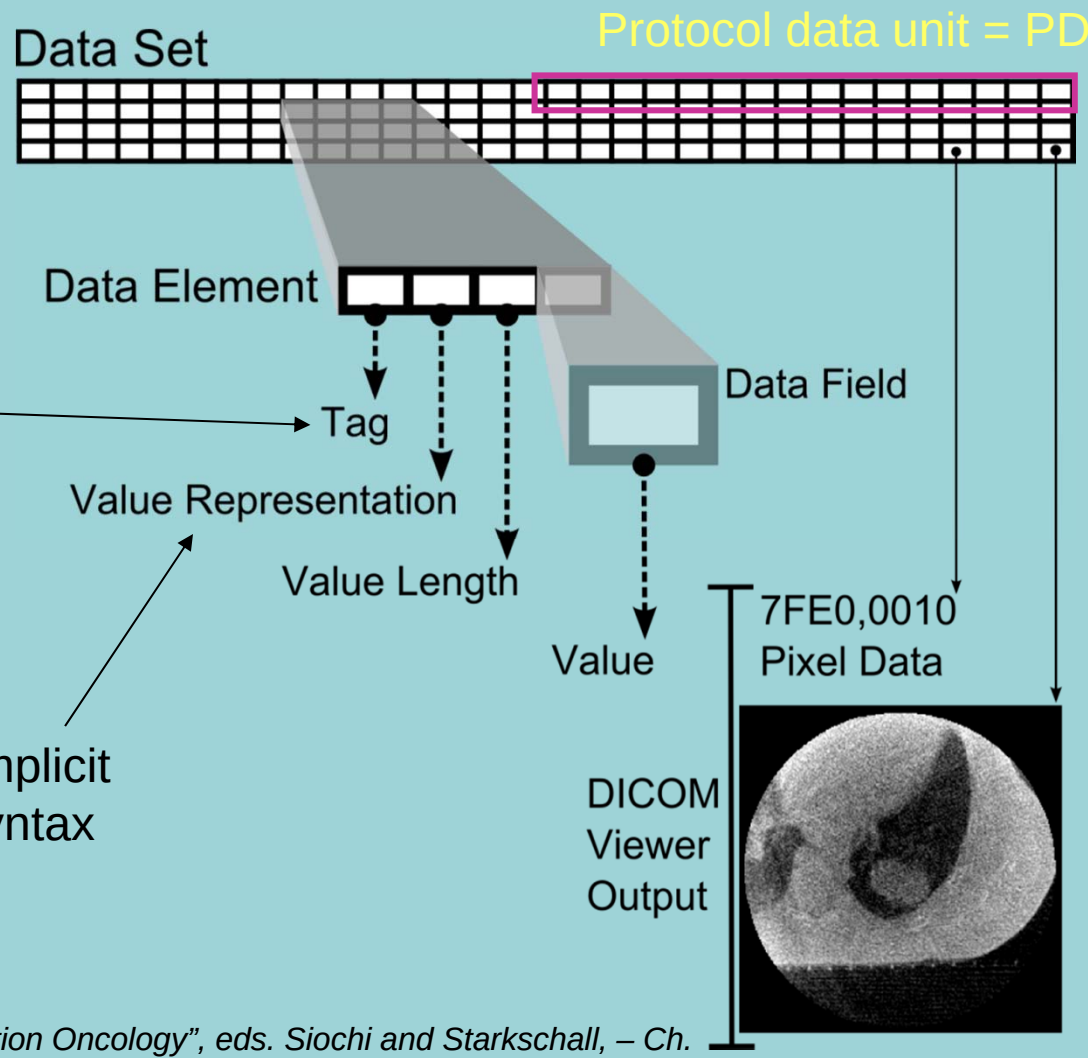
- A handshake, a dialogue to make a contract
- Check that AEs are compatible
  - Able to perform requested service
- Ensure AEs agree on data transfer
  - Have at least one common transfer syntax

Services

- An AE can be a
  - Service Class Provider (SCP)
  - Service Class User (SCU)
- SCP responds to request of SCU to provide a service:
  - Service Object Pair (SOP = command + IOD)
    - CT image Storage = C-Store (push) + CT image
    - Commands (DICOM Message Service Elements, DIMSE): C-Find, C-Echo (ping), C-Move or C-Get (pull)

What gets transferred?

Data set logically comprised of data elements



Data set broken into PData TF PDUs for communication only

Information about data elements are found in the data dictionary by using the tag

Optional for Implicit VR transfer syntax

From "Informatics in Radiation Oncology", eds. Siochi and Starkschall, – Ch. 11, Information Resources for Radiation Oncology by R.A.C. Siochi- In Press.

What happens after the transfer ? Depends on your AE:

- Bytes stored in proprietary format in a proprietary database known only to the AE
- Bytes stored in DICOM part 10 format as a dicom file in a proprietary database.
  - Essentially a “transcript” of the dicom transfer
  - Includes a metafile to handle transfer syntax
- Part 10 format file stored in a folder
- DICOM file service is used to store part 10 format files (becomes abstract to media storage)
- *.dcm, *.ima – let’s take a closer look…

Excerpt from a Data Dictionary

Group,Element:Item Name:VR:VM:RET(IRED)

≥

0010,1005:Patient's Birth Name:PN:1:

≥

0010,1030:Patient's Weight:DS:1:

≥

0010,2110:Contrast Allergies:LO:1-n:

≥

0028,0002:Samples per Pixel:US:1:
0028,0003:Samples per Pixel Used:US:1:
0028,0004:Photometric Interpretation:CS:1:
0028,0005:Image Dimensions:US:1:RET

≥

0028,0010:Rows:US:1:
0028,0011:Columns:US:1:

≥

7FE0,0010:Pixel Data:OW or OB:1:
FFFA,FFFA:Digital Signatures Sequence:SQ:1:
FFFC,FFFC:Data Set Trailing Padding:OB:1:
FFFE,E000:Item:NA:1:
FFFE,E00D:Item Delimitation Item:NA:1:
FFFE,E0DD:Sequence Delimitation Item :NA:1:

Tag: Hexadecimal, 2 bytes each for group and element-unique identifier for the attribute

Value Multiplicity – The number of items in this data element, separated by "\" for character strings

Value Representation (unsigned short)

A stream of words or bytes

From "Informatics in Radiation Oncology", eds. Starkschall and Siochi, – Ch. 11, Information Resources for Radiation Oncology by R.A.C. Siochi- In Press.

Using the Data Dictionary

- IF your application can't read a Dicom file, it might have encountered a data element whose tag is not listed in the application's dictionary
- Implicit VR: VR must be determined from a Dictionary
- Converting the data into human readable form requires getting the Item name from the Dictionary (to serve as a label)

DICOM-RT

- Uses the same paradigm for data elements, file structure and communication
- Several Modules
  - RT Series
  - RT Image (conical imaging geometry)
  - RT Dose
  - RT DVH
  - Structure Set
  - ROI Contour
  - RT Dose ROI
  - RT General Plan*
  - RT Prescription*
  - RT Tolerance Tables*
  - RT Patient Setup*
  - RT Fraction Scheme*
  - RT Beams*
  - RT Brachy Application Setups
  - Approval
  - RT General Treatment Record
  - RT Treatment Machine Record
  - Measured Dose Reference Record
  - Calculated Dose Reference Record
  - RT Beams Session Record
  - RT Brachy Session Record
  - RT Treatment Summary record

RT-Plan Modules for external beam treatments

RT-Record Modules

DICOM-RT Modules

- Designed to completely describe
  - Treatment Plan
  - Delivered Treatments
- References associated Images
- Some images may be the planning images (CT, MR) that were used for contouring
- Others may be RT Images (DRRs, portal images, CBCT).

RT-Plan

- Probably most important DICOM RT IOD to know
- Used by some systems for export/import to/from Record & Verify
- Not easy to read even when put in "human-readable" form
  - Too many references
  - Doesn't easily fit our pre-conceived treatment beam model
  - IEC 61217 coordinate conventions
- Need applications to convert it into something that we are used to seeing (e.g. MUs belong with the field, native coordinates)

Clinical Issues in RT

- DICOM is used to transfer plan information from the TPS to the R&V and IGRT systems
- If there is a problem with the transfer, how do you troubleshoot it?
- If you need to extract other information, what do you do?
- Need DICOM aware applications
- DICOM readers, viewers, editors
- DICOM servers

DICOM software

- Do a Google search
- DICOM +
  - Viewer
  - Reader
  - Server
  - Anonymizer
  - Editor
- They may not do all that you want nor how you want it done
- Shop around, test drive them
- Also, see what your TPS or RT-PACS can do

Example: Connectivity

- Archive A was retired and Data was transferred to Archive B.
- Archive B would not accept a particular study with CT Images from Archive A
- Archive A sent the study to CONQUESTSRV1
- CONQUESTSRV1 sent the study to other stations where it was needed (could not be pushed to or pulled by Archive B, however.)

HL7

- Primarily for Hospital Information Systems
- Main issue for Rad Onc: demographics, scheduling, billing.
- Synchronize hospital data with Rad Onc Information System / EMR/TMS (e.g. Mosaiq, Aria)

Example HL7 message

```
MSH|^~\&|CLOVERLEAF|UIHC|LANTIS|UIHC|201301081413||BAR^P01|62830_33_RE|P|2.3|||||ASCII
EVN|P01|201301081413|||JEG475
PID|1||05979249^^^IDX||DOE^JANE||19800302|F|||123 45TH ST^^MARION^IA^52302-1234^US
PV1|001
```

4 Segments in this message:
MSH = Message Header
EVN = Event type
PID = Patient Demographics
PV1 = Patient Visit Information

PID segment made of several fields
| separates fields
Sequence of fields determines the meaning
e.g. 5th field is the patient's name

HL7 transmission

- TCP/IP
- Minimal Lower Layer Protocol
- Add a message header and footer to delimit messages
- Use ACK(nowledgment) and NAK messages
- HL7 TCP/IP listener/router application
- Sender sends to Listener's IP/port

HL7 Issues

- Messaging System
- Needs a log of transactions
- Needs a mechanism to verify uptime
- Mechanism is on sender and listener end
- Example Error: System down, lab results not sent, physician assumed labs OK, and a patient died as a result.

HL7 and Rad Onc

- Primarily demographics
- Name and Birthday are critical identifiers
- How do you know if you have the right patient?
- Verify patient registration in RO EMR with patient

Data Repositories

- Once Data has been generated or transported, where do they go?
- Folders / Files – directories on the hard drive
  - Example: Pinnacle plan.trial file holds all the treatment plan information
- Databases
  - Example: EPIC, MOSAIQ, ARIA

File System

Remote site: /pinnacle_patient_expansion/NewPatients/Institution_3000/Mount_0/Patient_11913/Plan_0

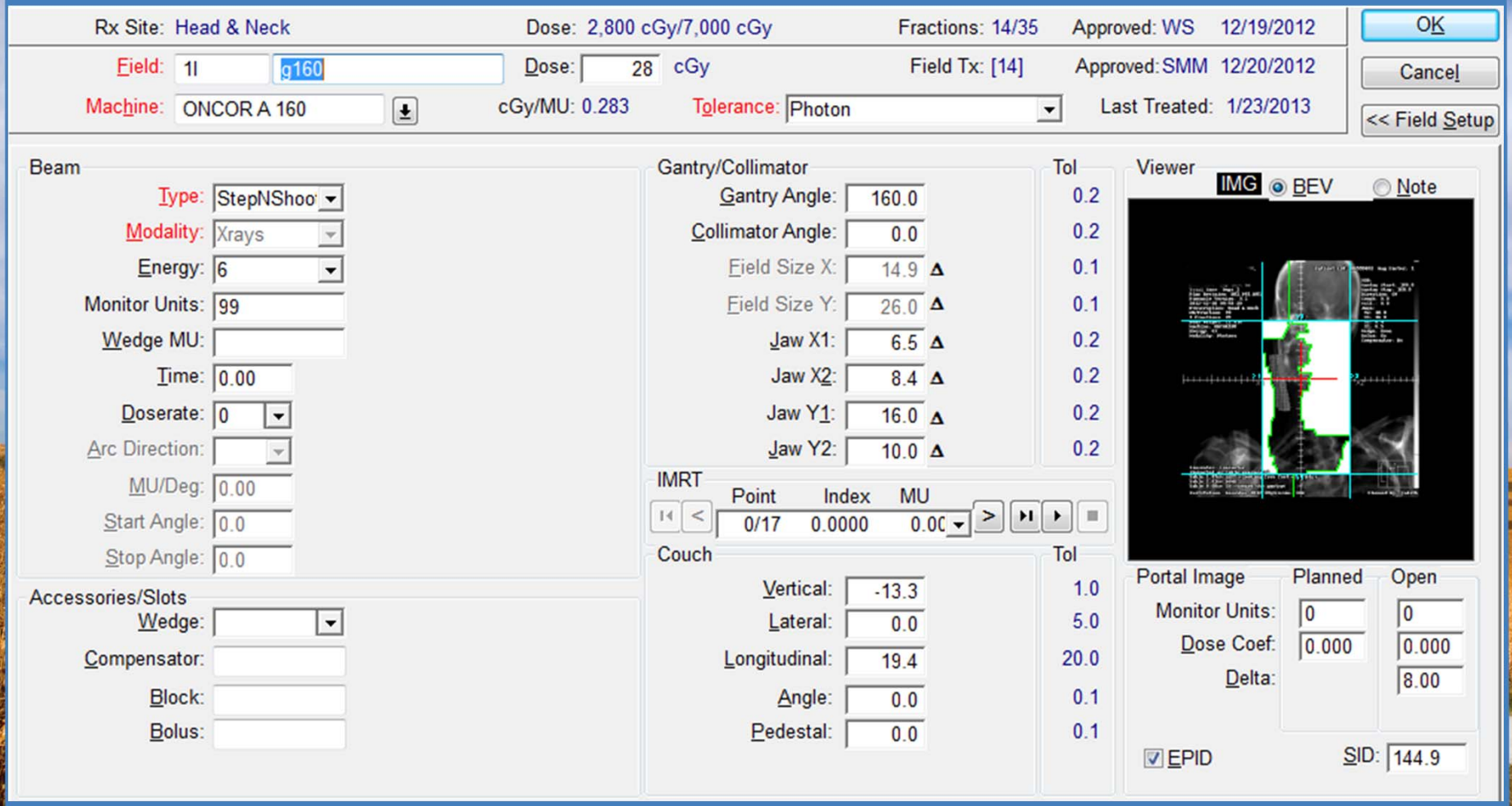
- ImageSet_0.DICOM
- ImageSet_1.DICOM
- ImageSet_2.DICOM
- Plan_0

Filename	Filesize	Filetype	Last modified	Permissions	Owne
plan.edit.roi	332	ROI File	4/25/2012	-rw-rw-r--	p3rtp
plan.Isodose	1,469	ISODOSE File	4/25/2012	-rw-rw-r--	p3rtp
plan.Laser	899	LASER File	4/25/2012	-rw-rw-r--	p3rtp
plan.OrbitBioConstrai...	337	ORBITBIO...	4/25/2012	-rw-rw-r--	p3rtp
plan.OrbitBioObjectives	571	ORBITBIO...	4/25/2012	-rw-rw-r--	p3rtp
plan.OrbitConstraints	577	ORBITCON...	4/25/2012	-rw-rw-r--	p3rtp
plan.OrbitObjectives	24,367	ORBITOBJE...	4/25/2012	-rw-rw-r--	p3rtp
plan.PatientSetup	373	PATIENTSE...	4/25/2012	-rw-rw-r--	p3rtp
plan.Pinnacle	1,783	PINNACLE ...	4/25/2012	-rw-rw-r--	p3rtp
plan.Pinnacle.Machines	960,974	MACHINE...	4/25/2012	-rw-rw-r--	p3rtp
plan.PlanInfo	564	PLANINFO...	4/25/2012	-rw-rw-r--	p3rtp
plan.PlanRev	203	PLANREV F...	4/25/2012	-rw-rw-r--	p3rtp
plan.Plugin.InversePla...	25,830	INVERSEPL...	4/25/2012	-rw-rw-rw-	p3rtp
plan.Plugin.PlanEvalPl...	1,152	PLANEVAL...	4/25/2012	-rw-rw-rw-	p3rtp
plan.Points	584	POINTS File	4/25/2012	-rw-rw-r--	p3rtp
plan.roi	11,785,424	ROI File	4/25/2012	-rw-rw-r--	p3rtp
plan.RoiManager	26	ROIMANA...	4/25/2012	-rw-rw-rw-	p3rtp
plan.Stereo	10	STEREO File	4/25/2012	-rw-rw-r--	p3rtp
plan.Trial	1,419,821	TRIAL File	4/25/2012	-rw-rw-r--	p3rtp
plan.Trial.binary.000	0	000 File	4/25/2012	-rw-rw-r--	p3rtp
plan.Trial.binary.001	1,764	001 File	4/25/2012	-rw-rw-r--	p3rtp
plan.Trial.binary.002	4,800	002 File	4/25/2012	-rw-rw-r--	p3rtp
plan.Trial.binary.003	262,144	003 File	4/25/2012	-rw-rw-r--	p3rtp

277 files. Total size: 148,885,743 bytes

```
Beam ={
  Name = "g180";
  IsocenterName = "Isocenter";
  PrescriptionName = "Right Lung";
  UsePoiForPrescriptionPoint = 1;
  PrescriptionPointName = "Isocenter";
  PrescriptionPointDepth = 5;
  PrescriptionPointXOffset = 0;
  PrescriptionPointYOffset = 0;
  SpecifyDosePerMuAtPrescriptionPoint = 0;
  DosePerMuAtPrescriptionPoint = 1;
  MachineNameAndVersion = "ONCOR160: 2012-03-27 14:39:43";
  Modality = "Photons";
  MachineEnergyName = "10X";
  DesiredLocalizerName = "Laser";
  ActualLocalizerName = "Laser";
  DisplayLaserMotion = "Table";
  SetBeamType = "Step & Shoot MLC";
  PrevBeamType = "Step & Shoot MLC";
  ComputationVersion = "Pinnacle v9.2";
  CPManager ={
    CPManagerObject ={
      IsGantryStartStopLocked = 1;
      IsCouchStartStopLocked = 1;
      IsCollimatorStartStopLocked = 1;
      IsLeftRightIndependent = 1;
      IsTopBottomIndependent = 1;
      NumberOfControlPoints = 12;
      ControlPointList ={
        #0 ={
          Gantry = 180;
          Couch = 0;
          Collimator = 0;
          WedgeContext ={
            WedgeName = "No Wedge";
            Orientation = "NoWedge";
            OffsetOrigin = "Patient Surface";
            OffsetDistance = -2.5;
            Angle = "No Wedge";
            MinDeliverableMU = 0;
            MaxDeliverableMU = 1e+30;
          };
          LeftJawPosition = 7.5;
          RightJawPosition = 7;
```

Databases


Rx Site: Head & Neck
Dose: 2,800 cGy/7,000 cGy
Fractions: 14/35
Approved: WS 12/19/2012
OK
Field: 1l g160
Dose: 28 cGy
Field Tx: [14]
Approved: SMM 12/20/2012
Cancel
Machine: ONCOR A 160
cGy/MU: 0.283
Tolerance: Photon
Last Treated: 1/23/2013
<< Field Setup
Beam
Type: StepNShoo
Modality: Xrays
Energy: 6
Monitor Units: 99
Wedge MU:
Time: 0.00
Doserate: 0
Arc Direction:
MU/Deg: 0.00
Start Angle: 0.0
Stop Angle: 0.0
Accessories/Slots
Wedge:
Compensator:
Block:
Bolus:
Gantry/Collimator
Tol
Gantry Angle: 160.0 0.2
Collimator Angle: 0.0 0.2
Field Size X: 14.9 Δ 0.1
Field Size Y: 26.0 Δ 0.1
Jaw X1: 6.5 Δ 0.2
Jaw X2: 8.4 Δ 0.2
Jaw Y1: 16.0 Δ 0.2
Jaw Y2: 10.0 Δ 0.2
IMRT
Point Index MU
0/17 0.0000 0.0
Couch
Tol
Vertical: -13.3 1.0
Lateral: 0.0 5.0
Longitudinal: 19.4 20.0
Angle: 0.0 0.1
Pedestal: 0.0 0.1
Viewer
IMG
BEV
Note
Portal Image
Planned
Open
Monitor Units: 0 0
Dose Coef: 0.000 0.000
Delta: 8.00
EPID
SID: 144.9

Database basics

- DB consists of Tables
- Table: consists of rows (aka records)
- Row: contains column elements (aka fields)
- Queries
  - E.g. how many patients had IMRT this month?
  - SQL (Structured Query Language)

DB Tables

Primary Key must be unique

Field or Column Names define the table

T_ID	First	Last	MI	SSN	MRN	License
45	Alpha	Omega		123456789	123	abc
72	Primero	Ultimo	M	987654321	456	def
73	Alias	Omega		123456789	123	abc

Record (row)

Field (column)

Normalization

P_ID	First	Last	MI	F_ID
45	Alpha	Omega		29
72	Primero	Ultimo	M	37
73	Alias	Omega		29

P_ID	SSN	MRN	License
29	123456789	123	abc
37	987654321	456	def

Foreign Keys point to a record in a related table

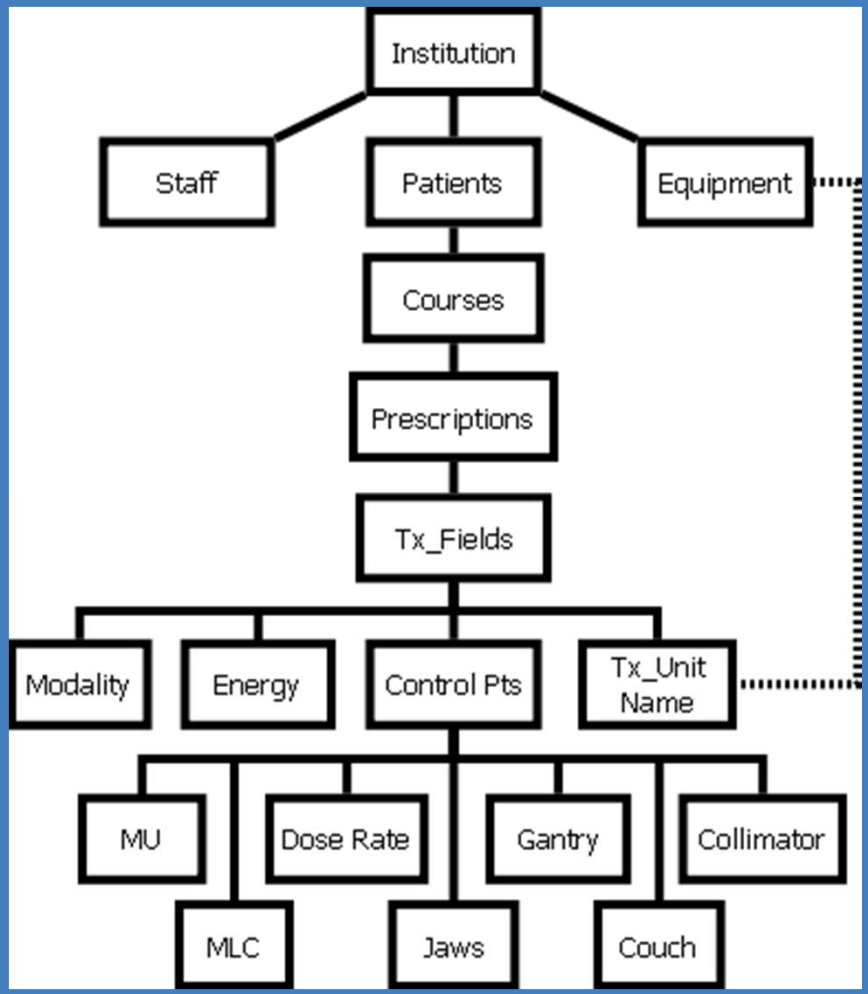
Normalization avoids useless repetition, update anomalies, data loss….

Typical Tables in an RT DB

In order to “incorporate” tables into other tables, foreign keys are used to point back to the related tables.

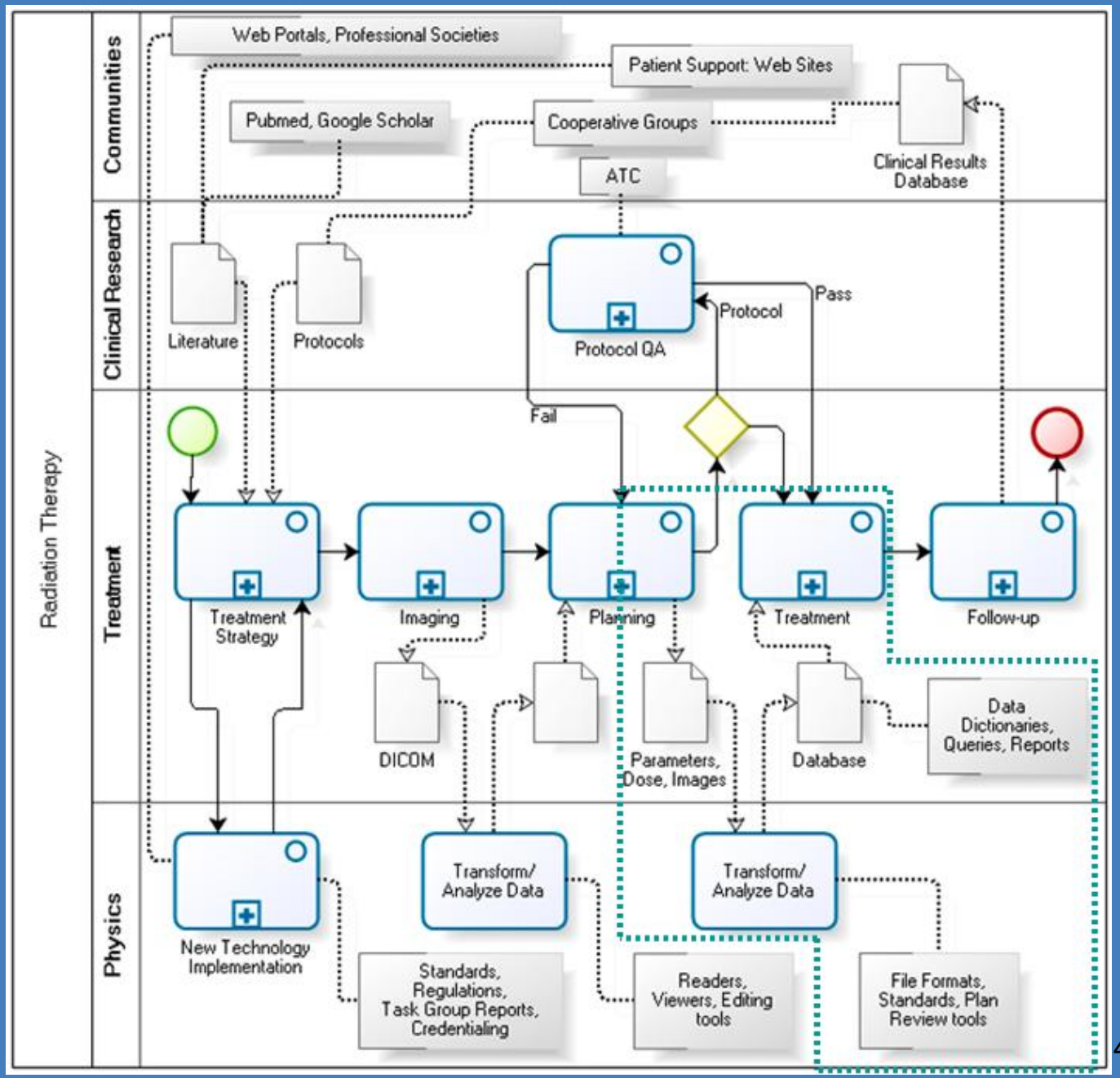
Here, each record in the Tx_Fields table consists of parameters that describe Linac settings. One of the parameters, control points, is a set of records in another table, with a “foreign key” that points back to the Tx_Field record to which it belongs.

DATA DICTIONARY – provides the definitions of the tables and the relationships among them.

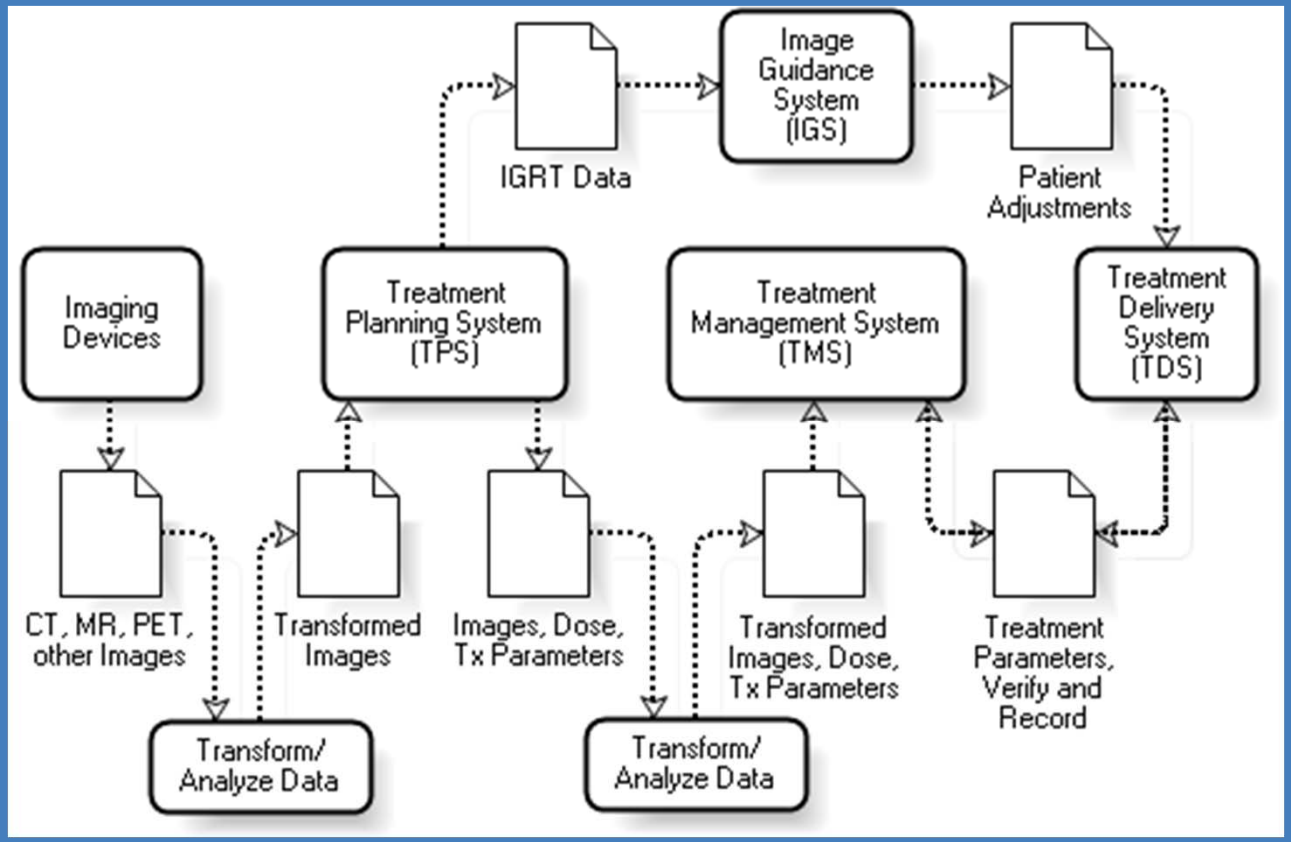


Data Flow in RO

**Fig. 11.1 from Siochi, Information resources for radiation oncology, Ch. 11 of a forthcoming book: Informatics in Radiation Oncology, G. Starkschall, R. Siochi, editors.*



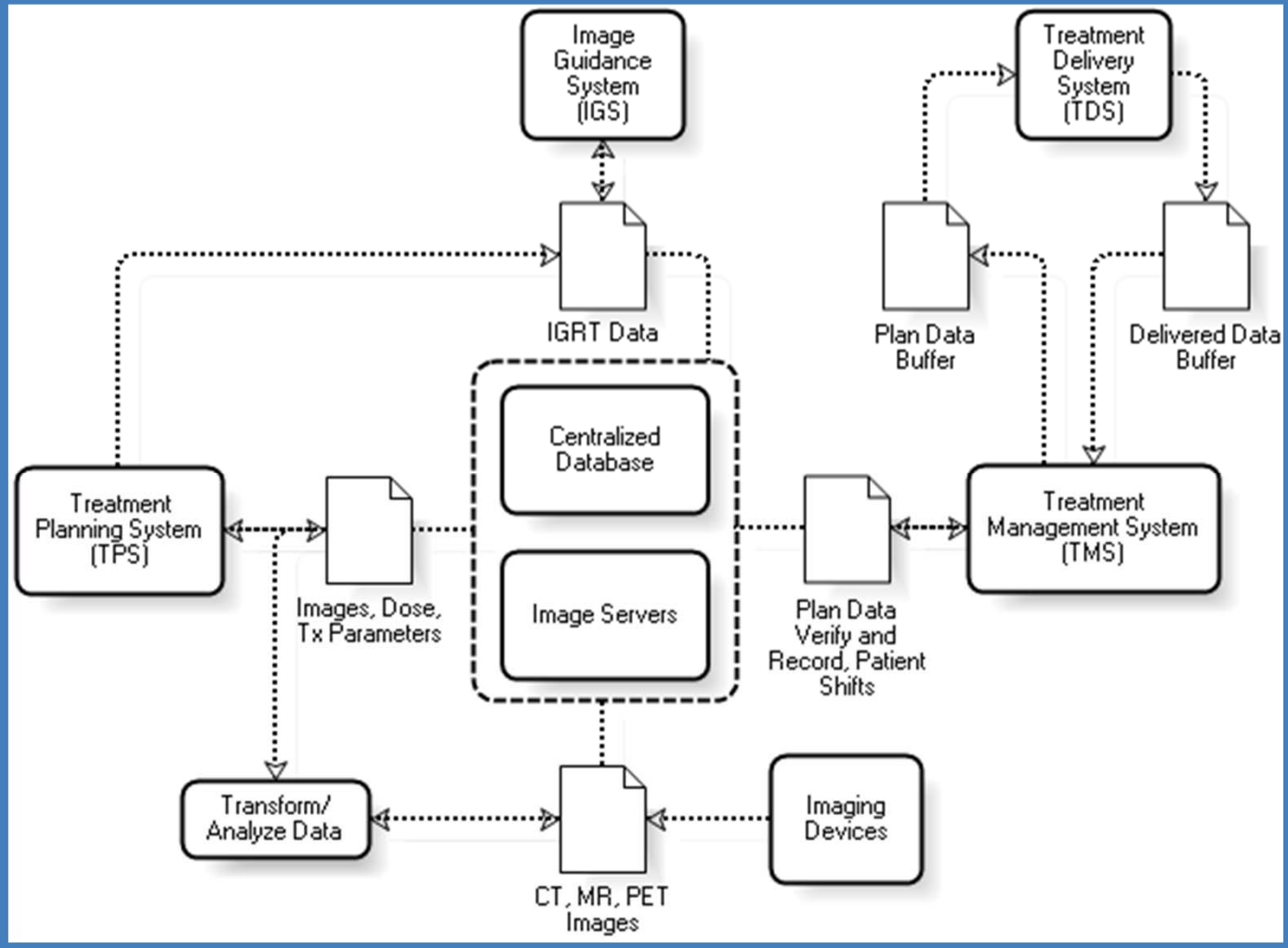
Distributed system data flow



Redundant data living in many places: INFORMATION should match.
(Data might be stored in different forms but mean the same thing.)

Centralized DB dataflow

Multiple applications accessing the same data at different times: They should synchronize!



Examples

- Distributed
  - Pinnacle transfers RT plan to MOSAIQ
  - MOSAIQ transfers RT plan to Linac Console
- "Centralized"
  - Eclipse RT plan is created, using Aria to hold the RT plan database elements
  - …hybrid… still have to transfer to 4D ITC.

Why should it matter what I have?

- Affects testing because of data state
- Centralized DB has to deal with concurrency issues and caching.
- Distributed DB has to deal with data transfer errors and updates to all systems for changed data

Data Transfer Matrix

- Table with 1st column containing source
- 1st row containing destination
- The cell at an intersection is the data to be transferred

Typical elements of the matrix

- Simulation System (SS)
- Treatment Planning System (TPS)
- Treatment Management System (TMS)
- Treatment Delivery System (TDS)
- Image Guidance System (IGS)
- Picture Archiving and Communication System (PACS): The PACS allows for the electronic storage of images.
- Archiving System (AS): storage of a patient's entire treatment history.

Example Matrix

Table I: An example data transfer matrix. The row and column headers provide the source and destination subsystems, respectively. The matrix element at a row and column intersection contains the data to be transferred.

	Destination				
Source	SS	TPS	TMS	TDS	AS
SS		Images			Images
TPS			Plan, Images		Plan, Images
TMS				RT Plan-fields	Database backup
TDS			Recorded treatment		
AS	Images	Plan, Images	Database backup		

Testing

- Every cell in the data transfer matrix needs to be tested
- Some parts of tests could be used to test many cells (e.g. cells in the same row)
- Design efficient tests to exploit common features

Quality Assurance and Control Basics

- **Principal concepts:**
  - **Physical Integrity**
  - **Logical Consistency**
- **ATP and Commissioning**
- **Annual**
- **Patient QC**

Principal Concepts

- Data Integrity
  - Are the bits and bytes intact?
  - Typically checked with a CRC
  - Were the transferred bits interpreted as the correct information?
- Logical Consistency
  - Are related pieces of information consistent with each other?

ATP and Commissioning

- ATP – typically done with the vendor
  - Might be limited to subsystem
  - Make sure to specify data transfer testing as part of the ATP at time of purchase
- Commissioning
  - Where data becomes information
  - Typically enter coordinate systems, preferences
  - Test data transfer matrix row for the subsystem

Annual

- Somewhat of a misnomer
- Should really be done anytime a system is changed
- If none of your systems change after a year, just test hardware for functionality/efficiency
- Might be a good idea to hold off on software updates until several can be combined

Testing: Quality Assurance

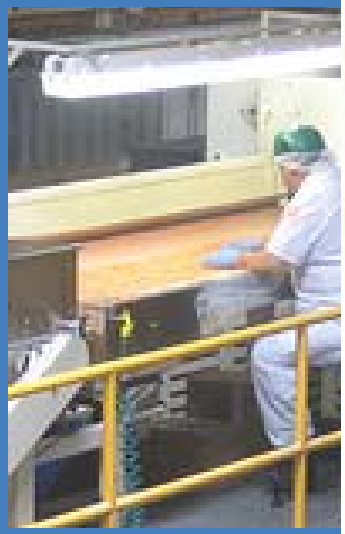
- System Tests
- equipment meets specs
- Given input produces expected output

Can you really dial 999?

Quality Control

- Inspects each service
- Or intermediate product
- Or items on an assembly line
- What we generally refer to mistakenly as QA in “patient-specific QA”

Testing: Quality Control



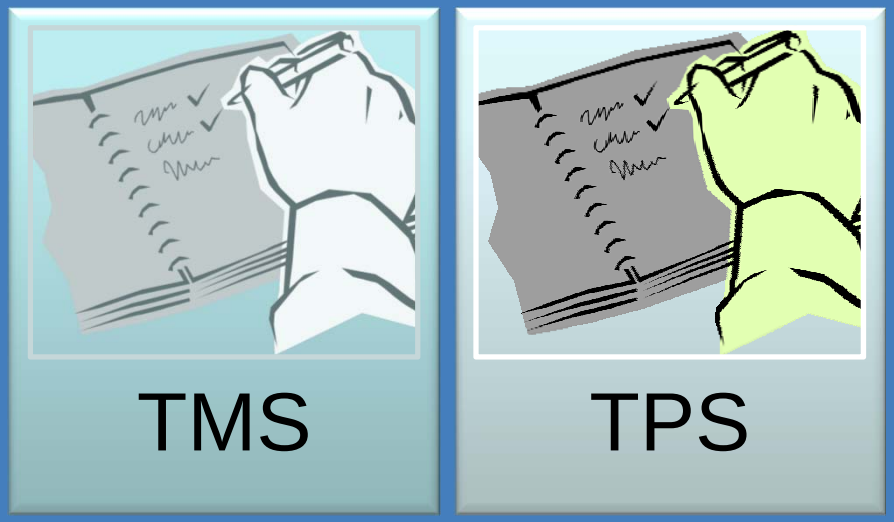
Data Transfer QC

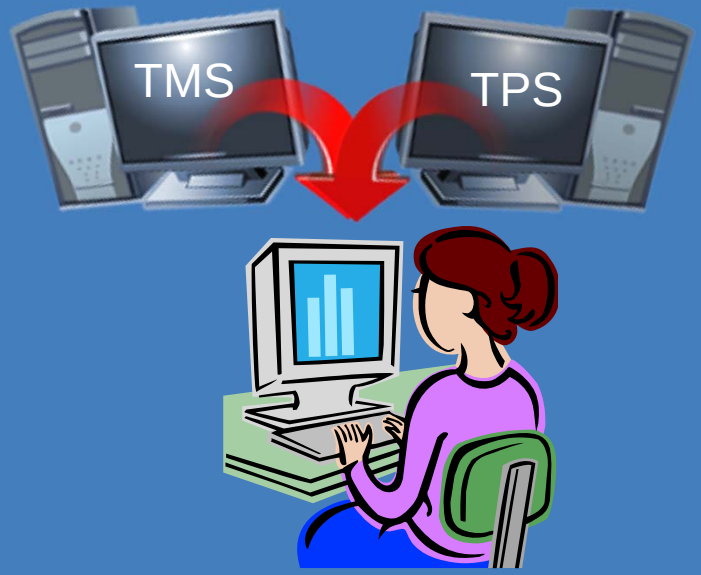
- Done for every patient
- Done for every transfer of data
- Check for Logical Consistency and Data/Information Integrity.

Information Integrity

- Generally a manual check
- Some places have automated systems

Manual vs Automated Check





Manual Comparison of Printouts or Screens

Software Compares Data Sources

Logical Consistency

- Mostly manual process
- Can be automated to some extent
- Example: a prescription calls for a treatment using 6x, but there is a 10x treatment beam within the prescription

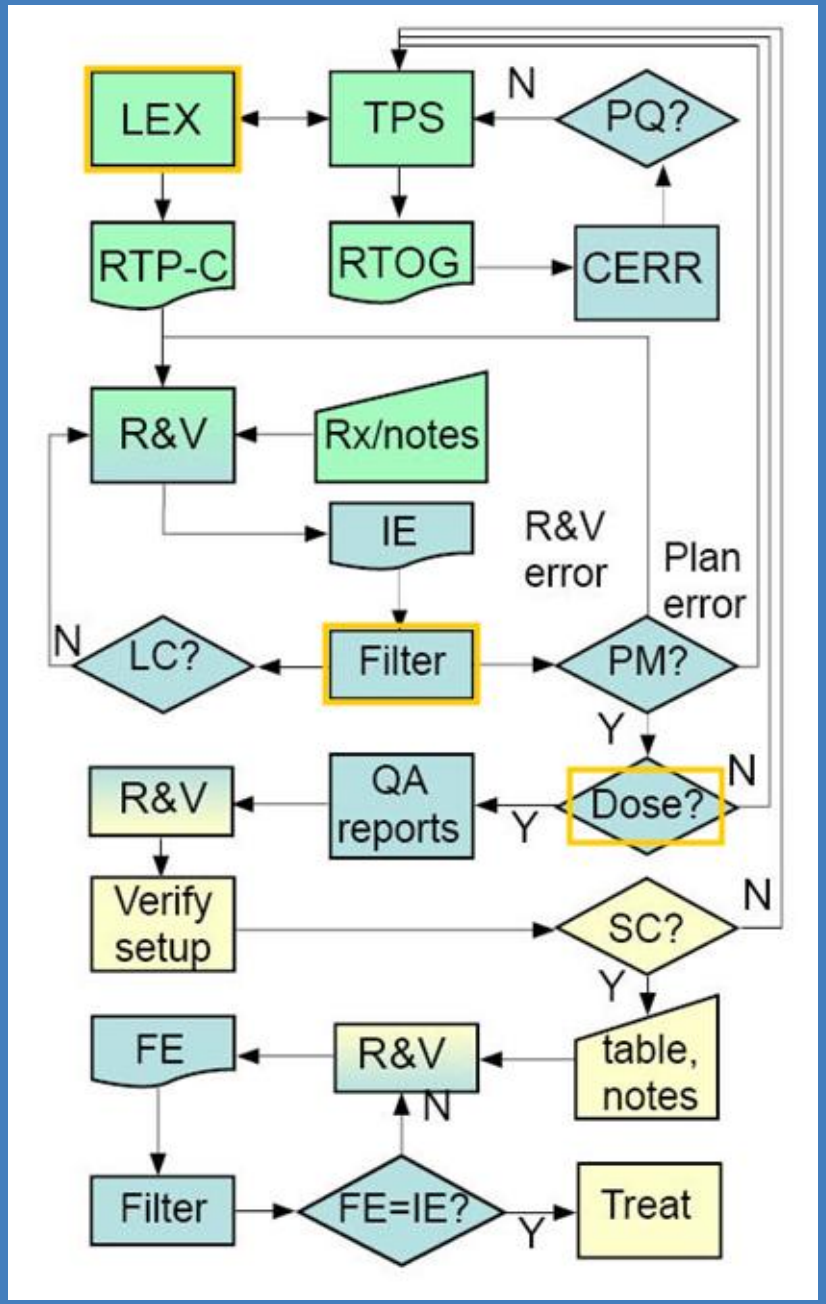
Clinical Interactions, paperless checks

Physicists

Dosimetrists/Physicians

Therapists

In-House Software



Adapted from Fig 5. Siochi, et al. Radiation therapy plan checks in a paperless clinic, J. App. Clin. Med. Phys., 10(1):43-62.

Thank you!