Imaging Informatics

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A PDF version of this lecture can also be found at:

http://faculty.washington.edu/bstewart

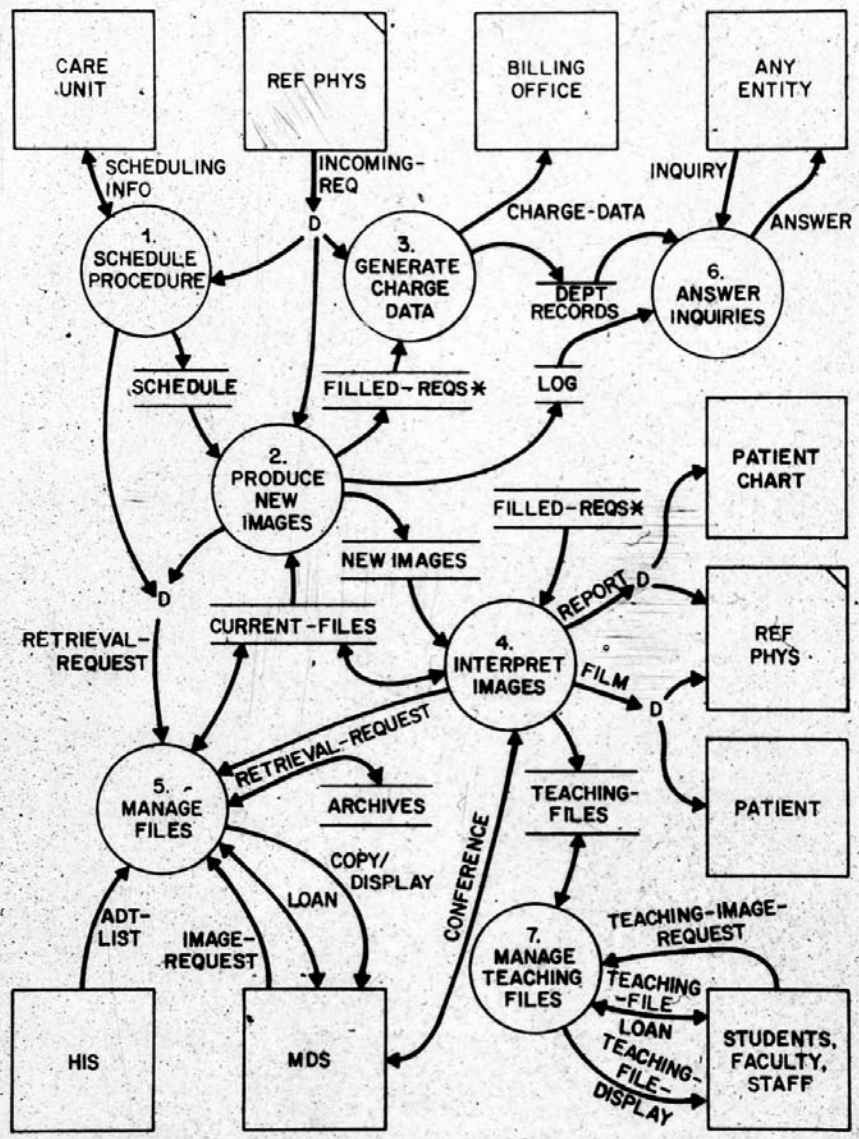
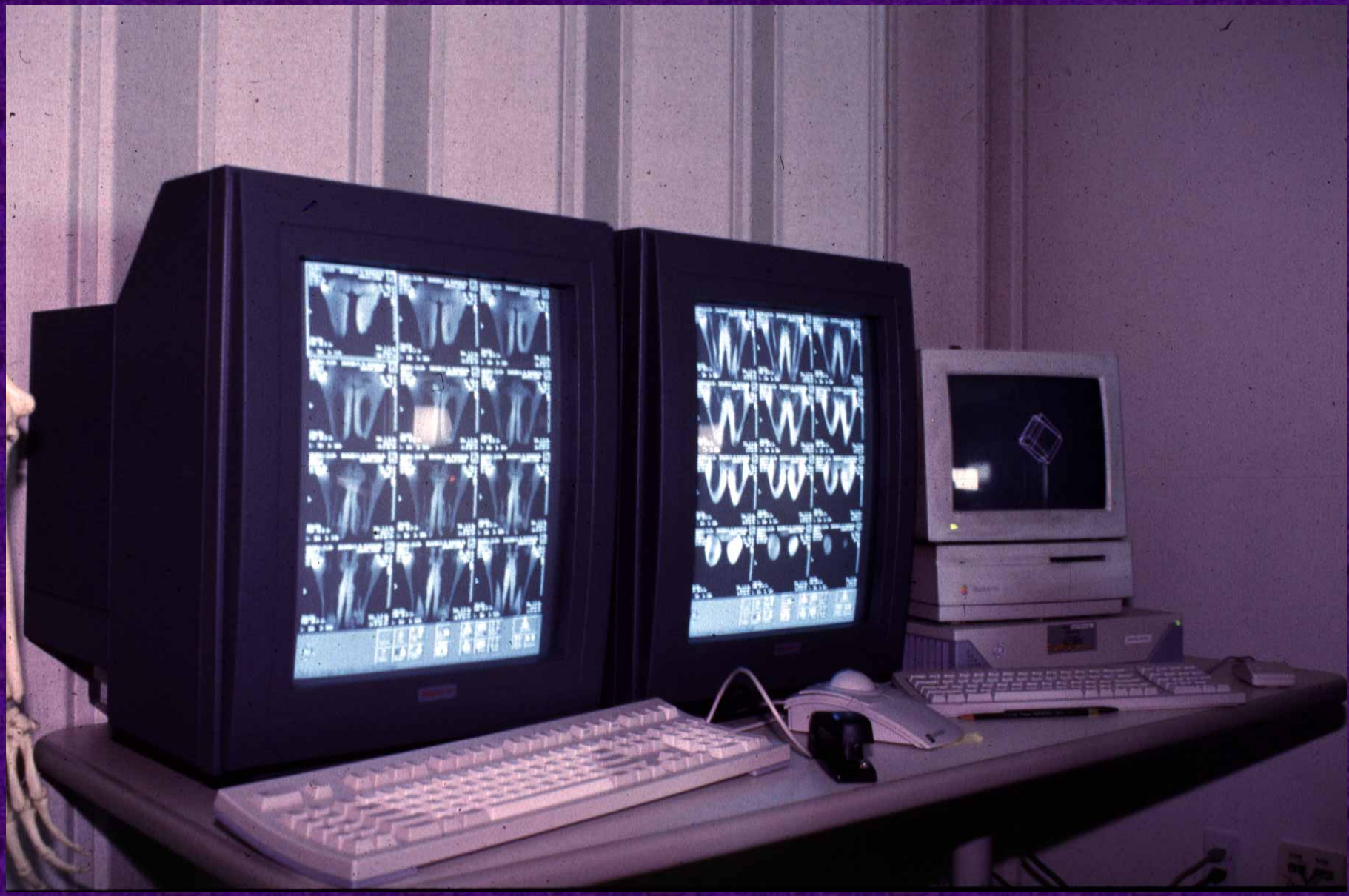
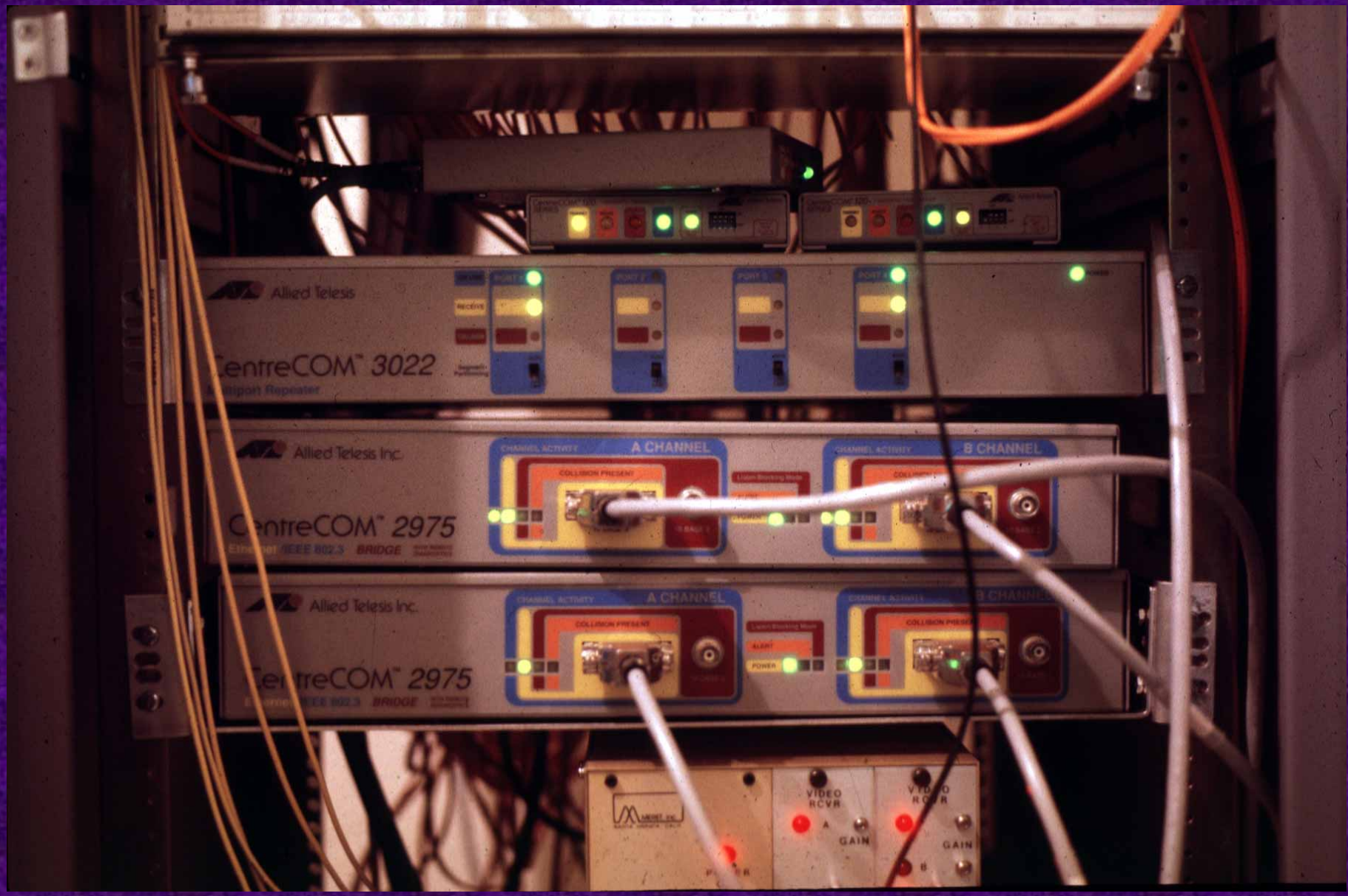


FIGURE 1 -DIAGRAM 0
-RADIOLOGY DEPARTMENT

Radiology Informatics - The First Generation

- Replace film hardcopy with softcopy display systems
- Replace film and tapes with media of higher density and shorter access time
- Replace film librarians with networks and software
- Post-office functionality




Allied Telesis
CentreCOM 3022
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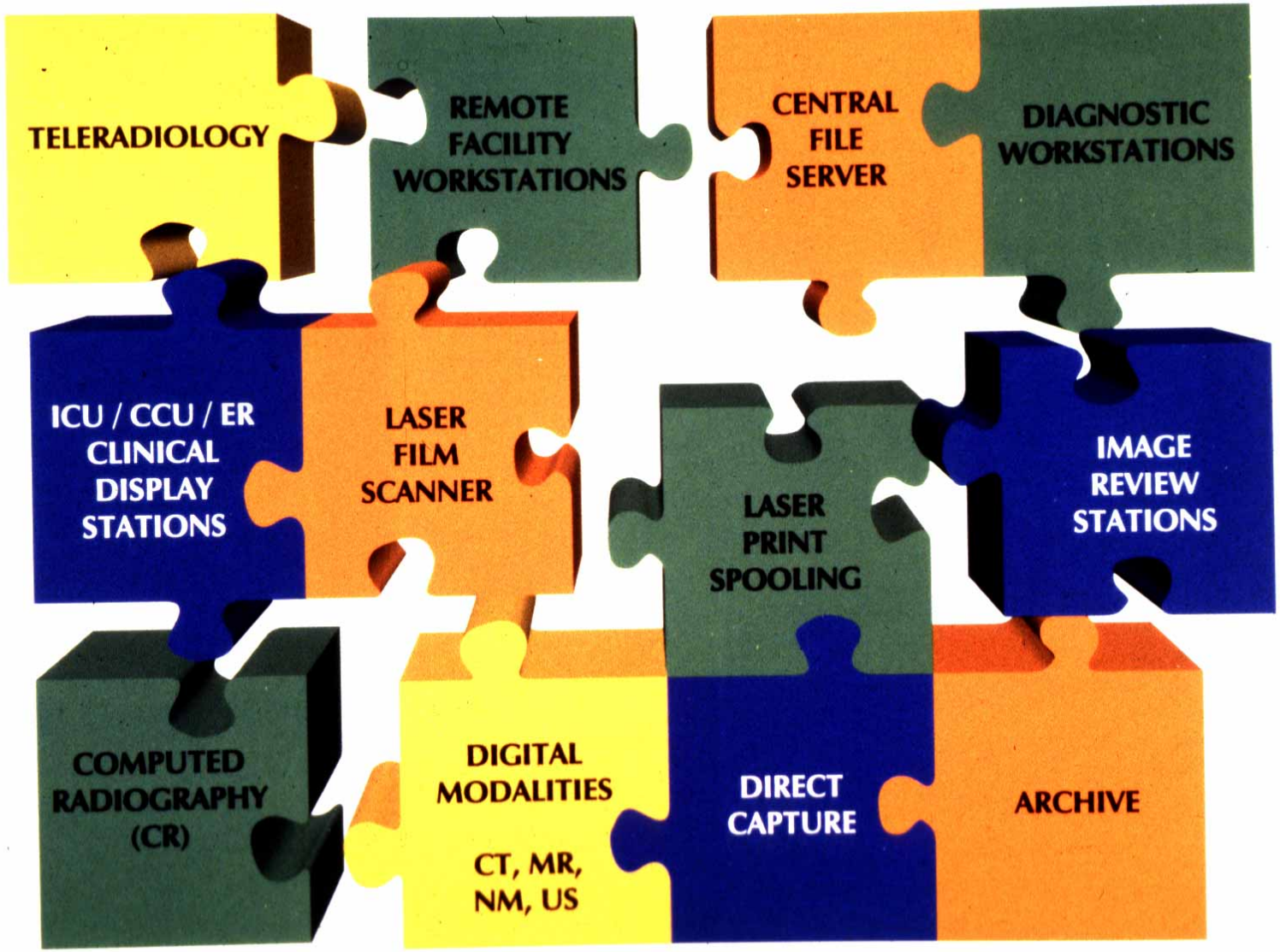
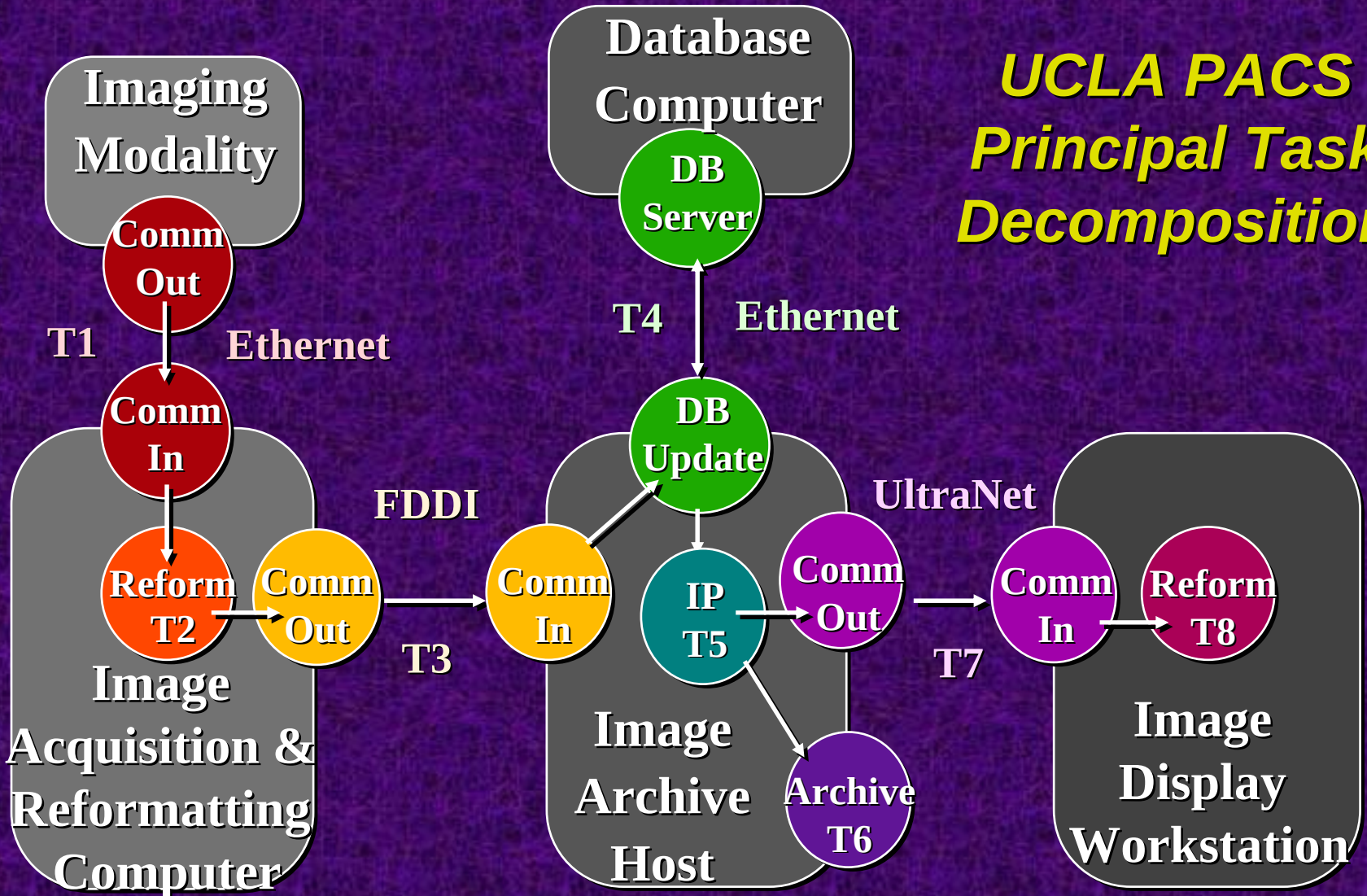
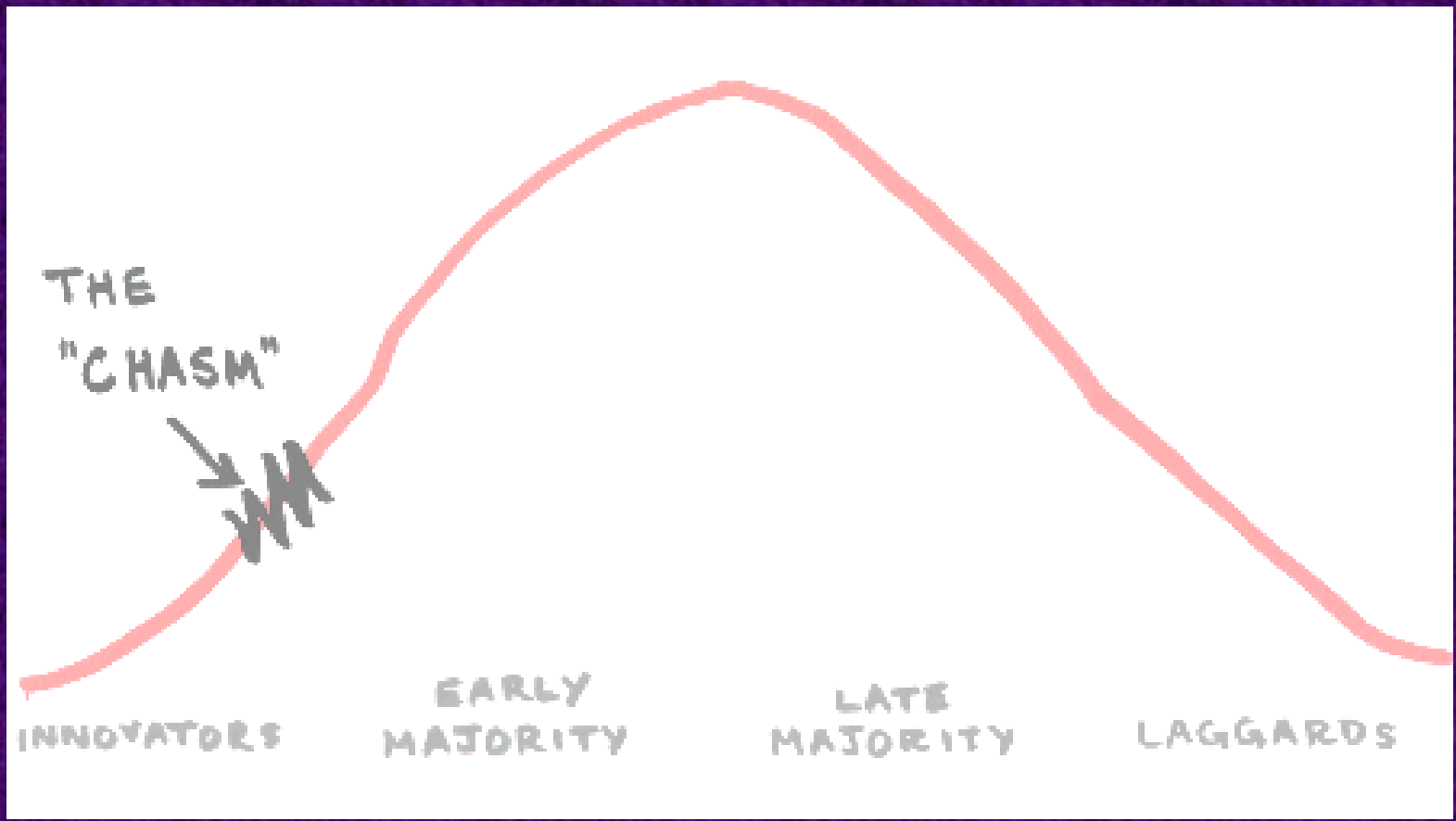

TELERADIOLOGY
REMOTE FACILITY WORKSTATIONS
CENTRAL FILE SERVER
DIAGNOSTIC WORKSTATIONS
ICU / CCU / ER CLINICAL DISPLAY STATIONS
LASER FILM SCANNER
LASER PRINT SPOOLING
IMAGE REVIEW STATIONS
COMPUTED RADIOGRAPHY (CR)
DIGITAL MODALITIES
CT, MR, NM, US
DIRECT CAPTURE
ARCHIVE

UCLA PACS Principal Task Decomposition



*Technology Adoption Life Cycle**



* Geoffrey Moore, Crossing the Chasm, 1991.

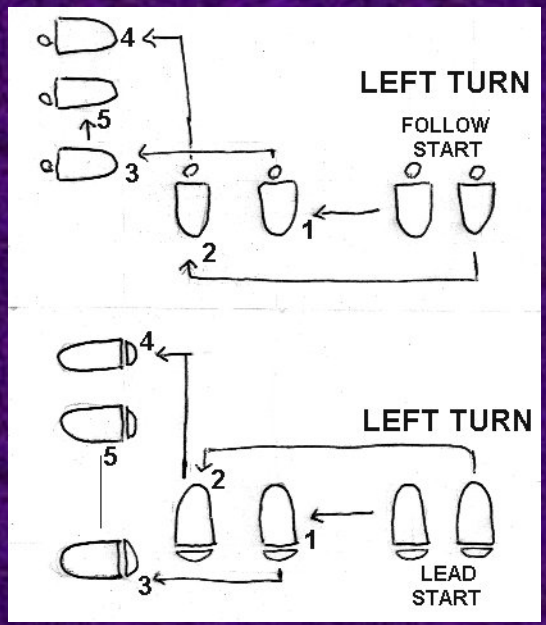
Technology Adoption Psychographics

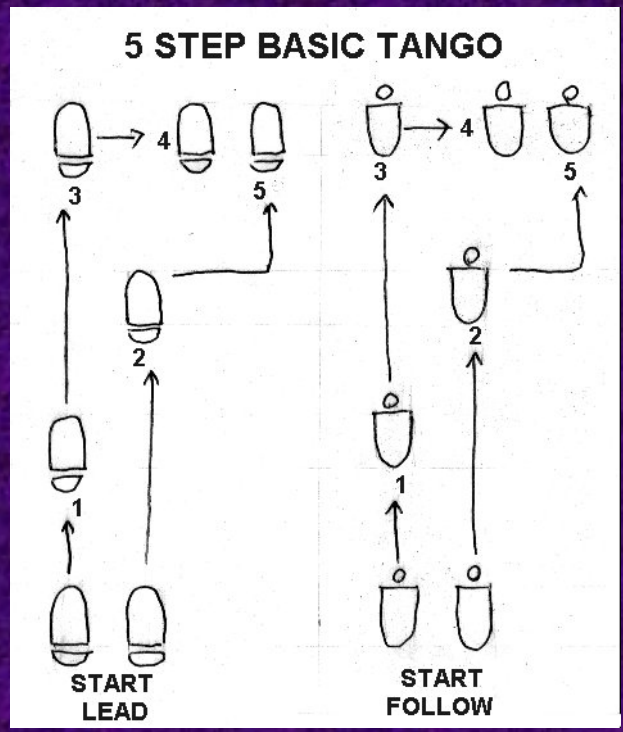
- Innovators: Technology Enthusiasts (2-4%)
  - More interested with tech. itself than applic. to signif. problems
- Visionaries: Early Adopters (12-14%)
  - Matching an emerging technology to a strategic opportunity
  - Looking for a fundamental breakthrough (change agent)
- Pragmatists: Early Majority (34 %)
  - Technology to enhance, not overthrow established practices
  - Incremental improvement - measurable, predictable progress
- Conservatives: Late Majority (34 %)
- Skeptics: Laggards (16%)

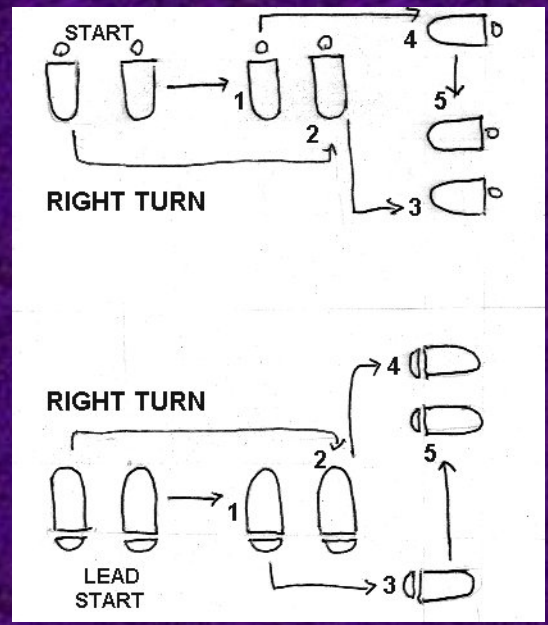
Scenario

- Primary care physician logs into MINDscape (Cerner)
- Selects radiology exam and views images of interest
- Phones radiologist with query
- Radiologist logs into workstation and they review images together over the network (not quite there yet)
- Once impromptu conference has concluded, radiologist saves the newly annotated images
- Primary care physician selects newly annotated image and either copies into patient summary document, stores in a teaching file, or consults colleague

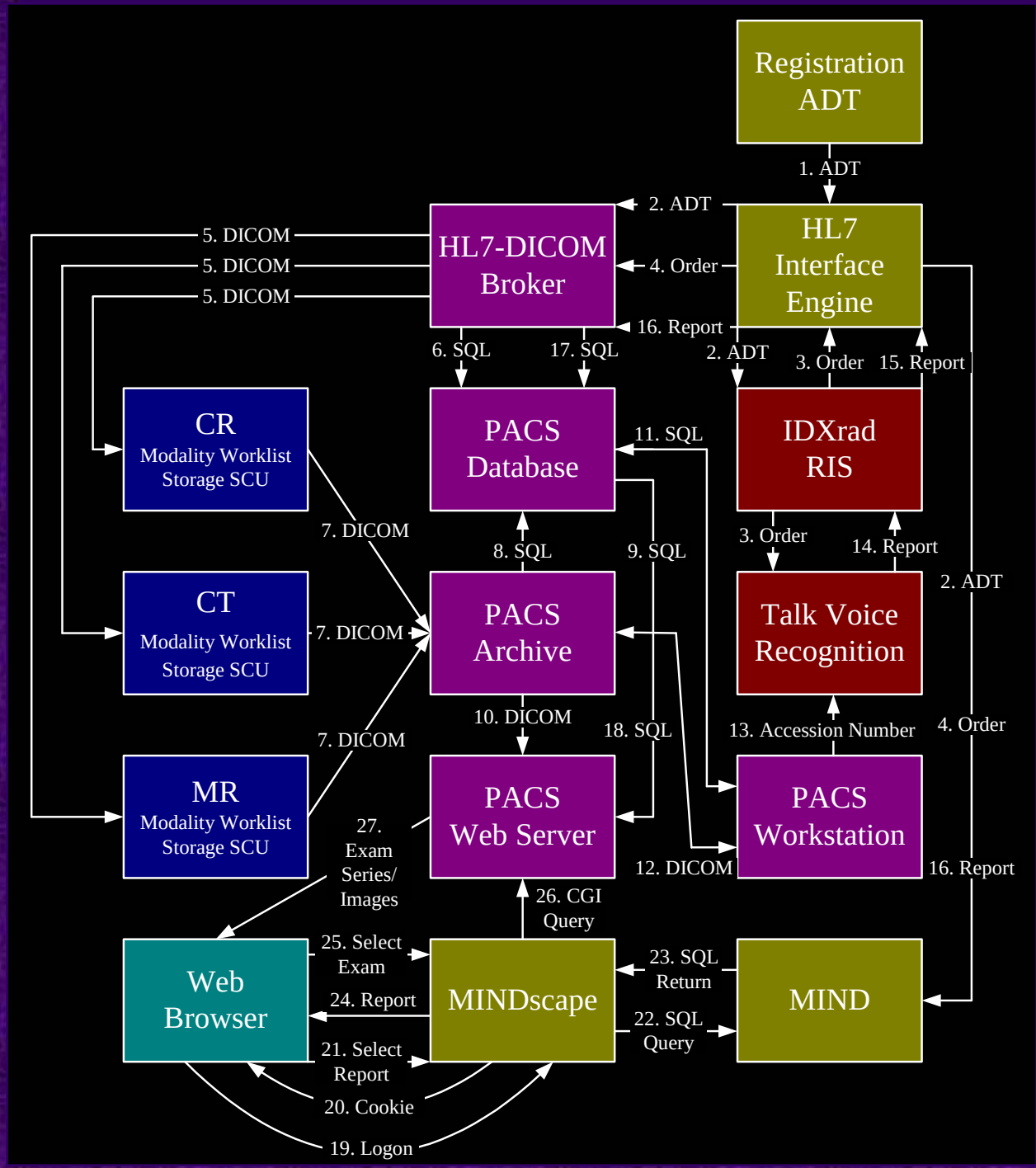
5 Step Basic Tango



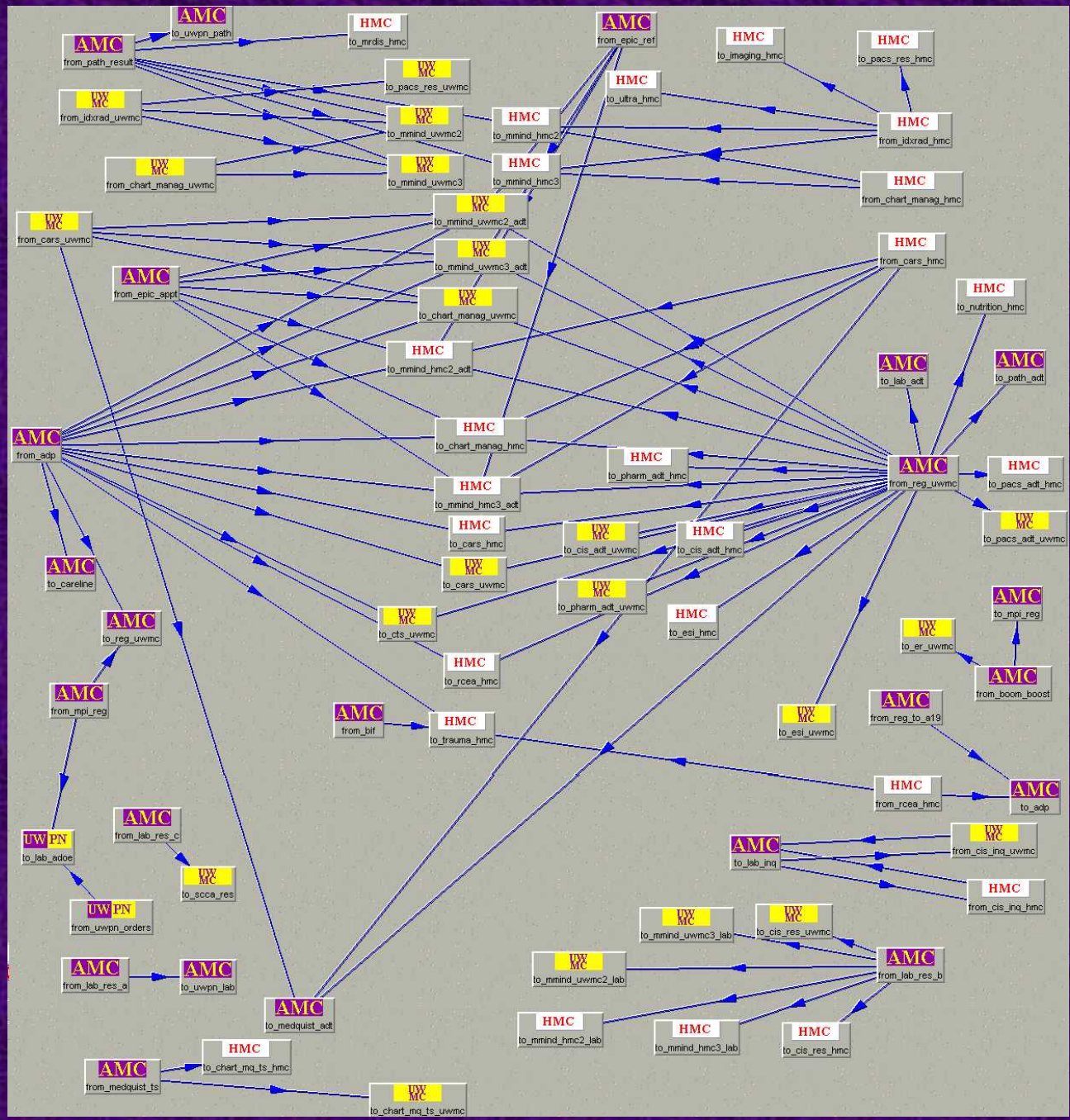




27 Step PACS Shuffle



Routing of HL-7 Messages for Patient Report and Demographics



Health Level 7

- Std. means of transferring medical textual data
  - Triggers
  - Messages
  - Segments
  - Fields
- HL7 became an ANSI Accredited Standards Developing Organization in June 1994
- HL7 corresponds to the conceptual definition of an application-to-application interface placed in the seventh layer of the OSI model
- Web resources:
  - http://www.hl7.org/
  - http://www.mcis.duke.edu/standards/HL7/pubs/version2.3/html/httoc.htm (this is a great reference for HL7 and esp. version 2.3)

Health Level 7 Triggers

- Trigger events - HL7 assumes that an event in the real world of healthcare creates the need for data to flow among systems
- Unsolicited transaction - when the transfer of information is initiated by the application system that deals with the triggering event
- No assumption is made about the design or architecture of the application system
- The scope of HL7 is restricted to the specification of messages between application systems, and the events triggering them

Health Level 7 Messages

- A message is the atomic unit of data transferred between systems
- The message is comprised of a group of segments in a defined sequence
- Each message has a message type that defines its purpose (for example):
  - ADT (Admission, discharge or transfer message)
  - ORM (Order message)
  - ORU (Observation result/unsolicited message)

Health Level 7 Segments

- A segment is a logical grouping of data fields
- Each segment is identified by a unique three character code known as the Segment ID
- For example, the ADT message may contain the following segments:
  - MSH (message header)
  - EVN (event type)
  - PID (patient ID)
  - PV1 (patient visit)

Health Level 7 Fields

- A field is a string of characters
- When fields are transmitted, they are sent as character strings
- In defining a segment, the following information is specified about each field:
  - Position
  - Maximum length
  - Data type
  - Optionality
  - Repetition
  - ID number
  - Name

HL7 Message Delimiters

- In constructing a message certain special characters are used
- They are the segment terminator, the field separator, the component separator, subcomponent separator, repetition separator, and escape character
- The subset of the possible delimiters may be limited by negotiations between applications
- Delimiters are defined in the MSH segment

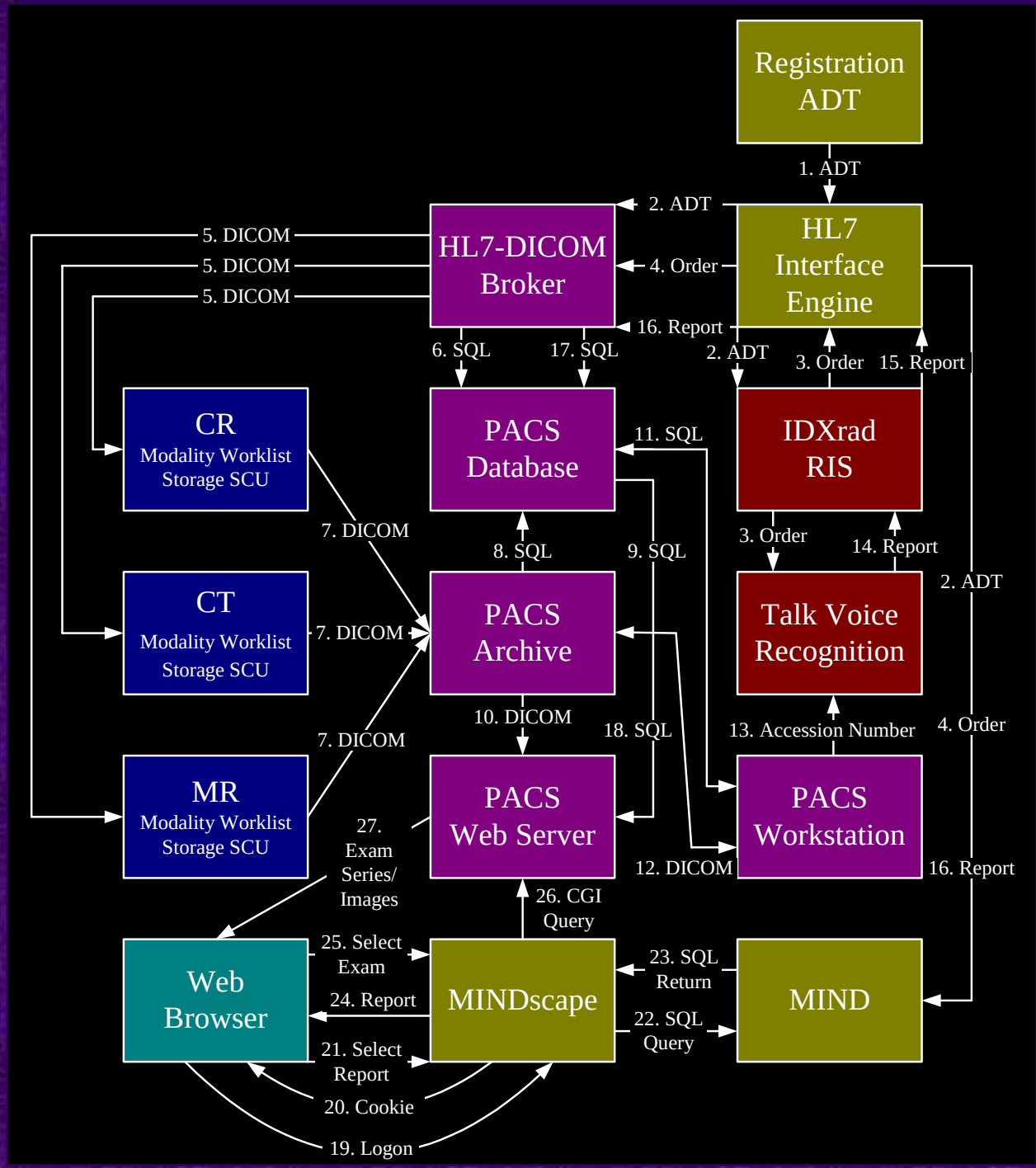
HL7 Sample Message

MSH|^~\&|||||199602071000||ADT^A04|0000017909|P|2.1||
PID|||11-44-87||Patient^Test^c^^^PHD|Maiden|19560101|F
|Patient^Test^A^^^MD|
|P.O. Box 456^1500 MainST.^Anywhere^VT^97543|
|(345)666-3930|(345)888-3456X456|
||||111-11-1111
PV1||C|UNIT^ROOM^BED||||000093^RADWIN^MARTIN^^^^M.D.|
|||||||||||||||||||||||||||||||199602070909|
EVN|A04|199602071000|
DG1||
ZOD|Precautions 1|precautions 2
MRG||

HL7 MSH Segment

MSH Segment							
Sequence number	**Length**	**Type**	**Required /Optional**	**Repeat**	**Element Name**	**Item number**	**Note**
1	5	ST	R	N	Encoding Characters ("|^~\&")	00509	1
2	15	ST	O	N	Sending Application	00006	2
4	15	ST	O	N	Receiving Application	00009	3
5	30	ST	O	N	Receiving Facility	00513	4
6	12	TS	O	N	Date/Time of Message	00010	
8	7	ID	R	N	Message Type	00012	
9	20	ST	R	N	Message Control Id	00013	5
10	1	ID	R	N	Processing ID Only "P" supported	00014	
11	8	NM	R	N	Version ID	00015	
12	15	NM	O	N	Sequence Number	00633	6

27 Step PACS Shuffle



Digital Image File

HEADER

PATIENT NAME

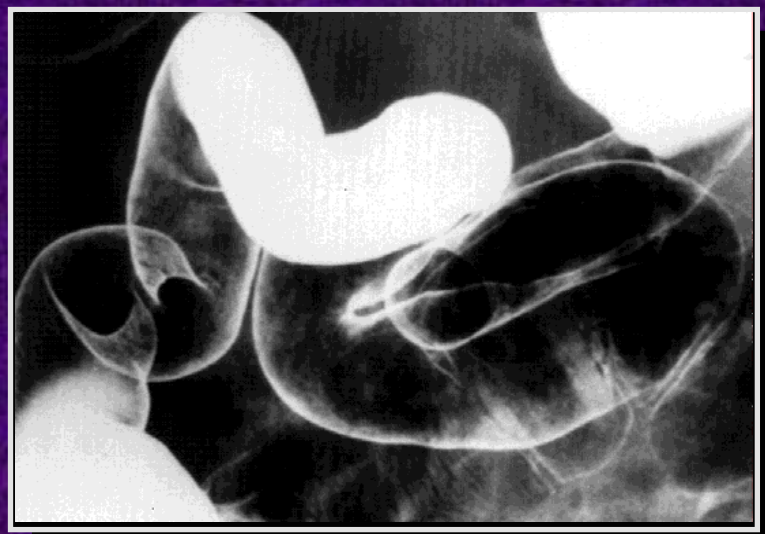
ID NUMBER

DATE / TIME

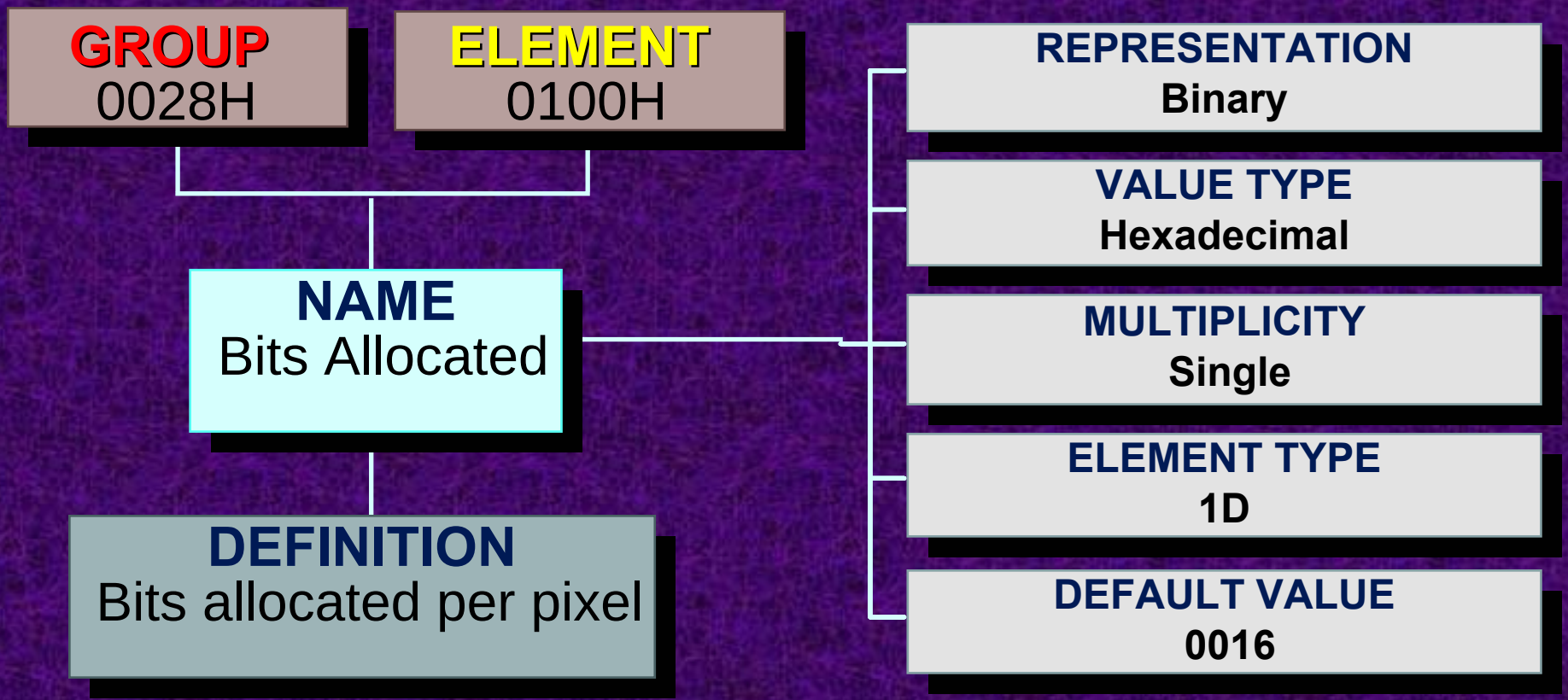
ORIENTATION

OTHER ...

PIXEL DATA



ACR-NEMA Data Dictionary Entry



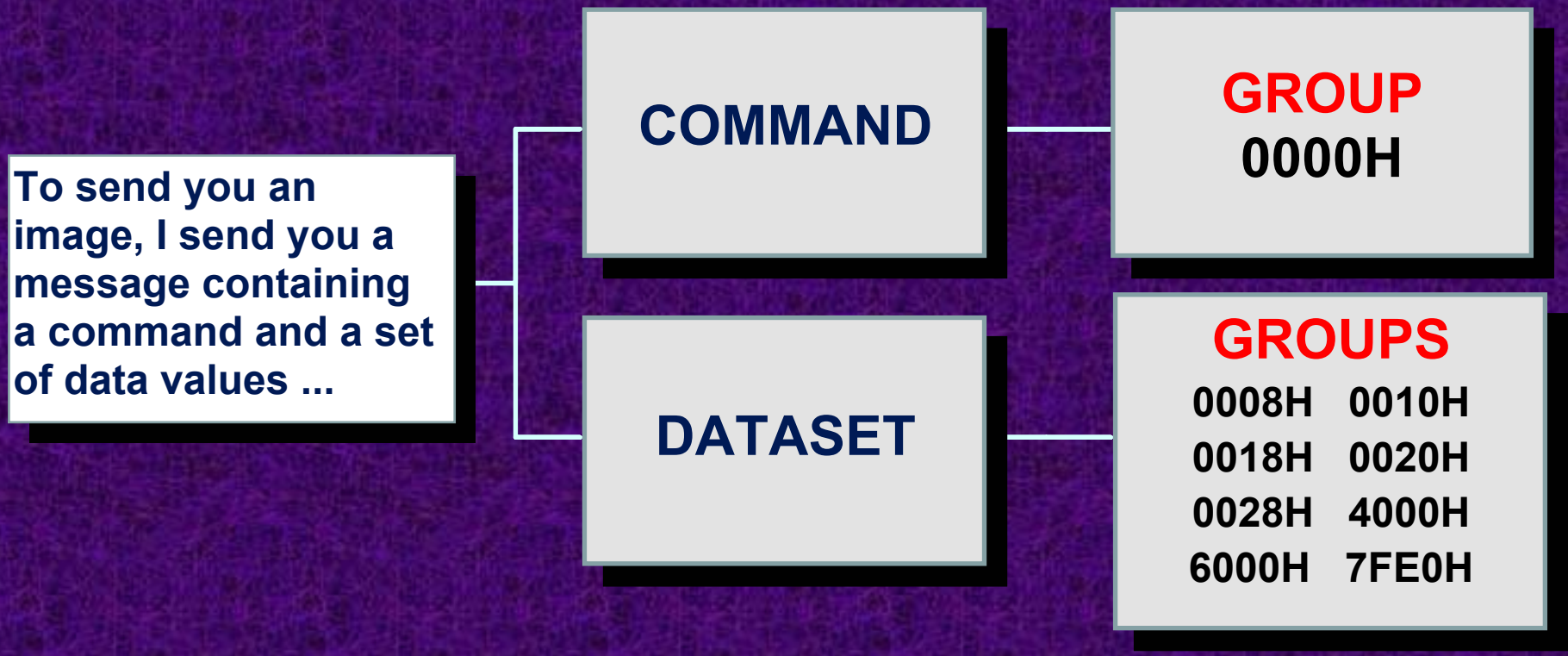
ACR-NEMA Data Element Groups

0000H	COMMAND	Command type, message ID, dataset type...
0008H	IDENTIFYING	Date and time of study, radiologist's name...
0010H	PATIENT	Patient's name, ID numbers, birth date...
0018H	ACQUISITION	Contrast agent, slice thickness, radionuclide...
0020H	RELATIONSHIP	Study, series, acquisition, image number...

ACR-NEMA Data Element Groups (cont.)

0028H	**IMAGE PRESENTATION**	**Rows, columns, pixel size, gray scale ...**
0029H	**SHADOW**	**Custom-defined *image presentation* group ...**
4000H	**TEXT**	**Free-format ASCII text characters ...**
6000H	**OVERLAY**	**Region of interest (ROI), overlay format ...**
7FE0H	**PIXEL DATA**	**The actual image data, pixel by pixel ...**

ACR-NEMA Message Semantic Model



ACR-NEMA Command Element String

More specifically, I send you a command consisting of certain required elements ...

**GROUP, ELEMENT, VALUE **
...next...

**0000H,0000H,value \ 0000H,0010H,value **
etc...

ACR-NEMA Data Element String

... and data elements from the set of required groups specified for the message type (image, text, etc).

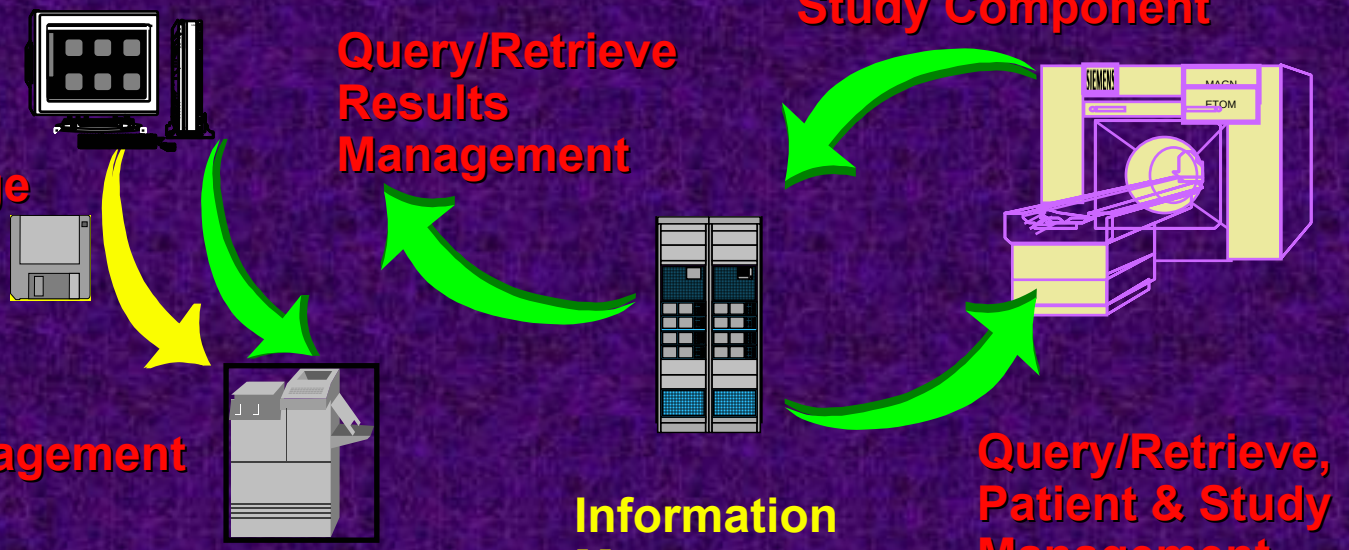
**GROUP, ELEMENT, VALUE **
... next ...

**0008H,0000H,value \ 0008H,0010H,value **
**0010H,0000H,value \ 0010H,0010H,value **
... etc

DICOM (Digital Imaging and Communications in Medicine)

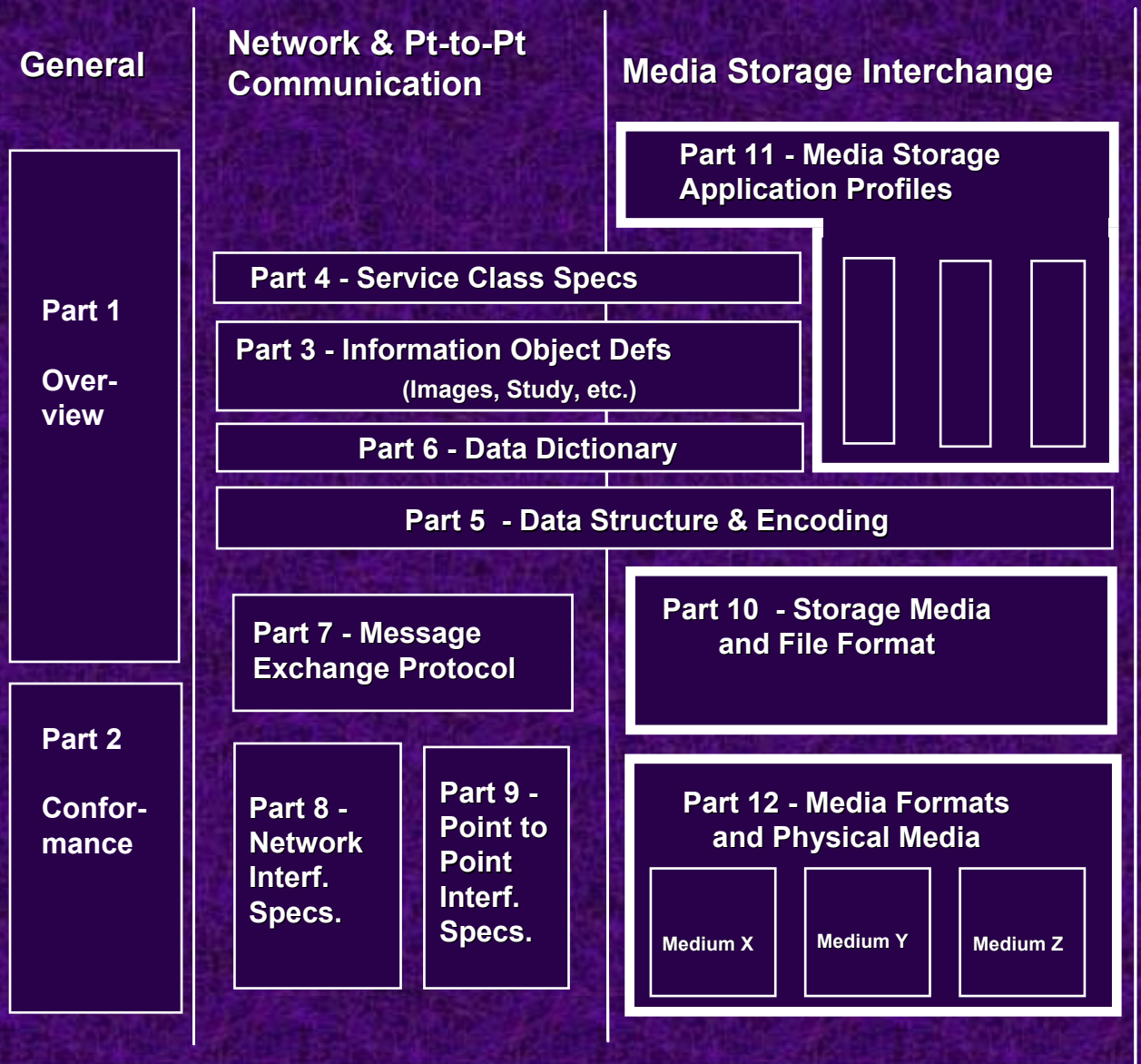
- Most important functions
  - unambiguous definition of terms used
  - define models of image communication
  - agreed upon by those who adopt the standard
- Has become the predominant standard for the communication of medical images
- Takes into account existing standards for networks
- By necessity, written in dry language with a minimum of explanatory information (thousands of pages)
- Web resource: http://medical.nema.org/

DICOM



- Service Classes – Users and Providers
- Information Objects and Information Object Definitions
- Service-object pairs (SOP)

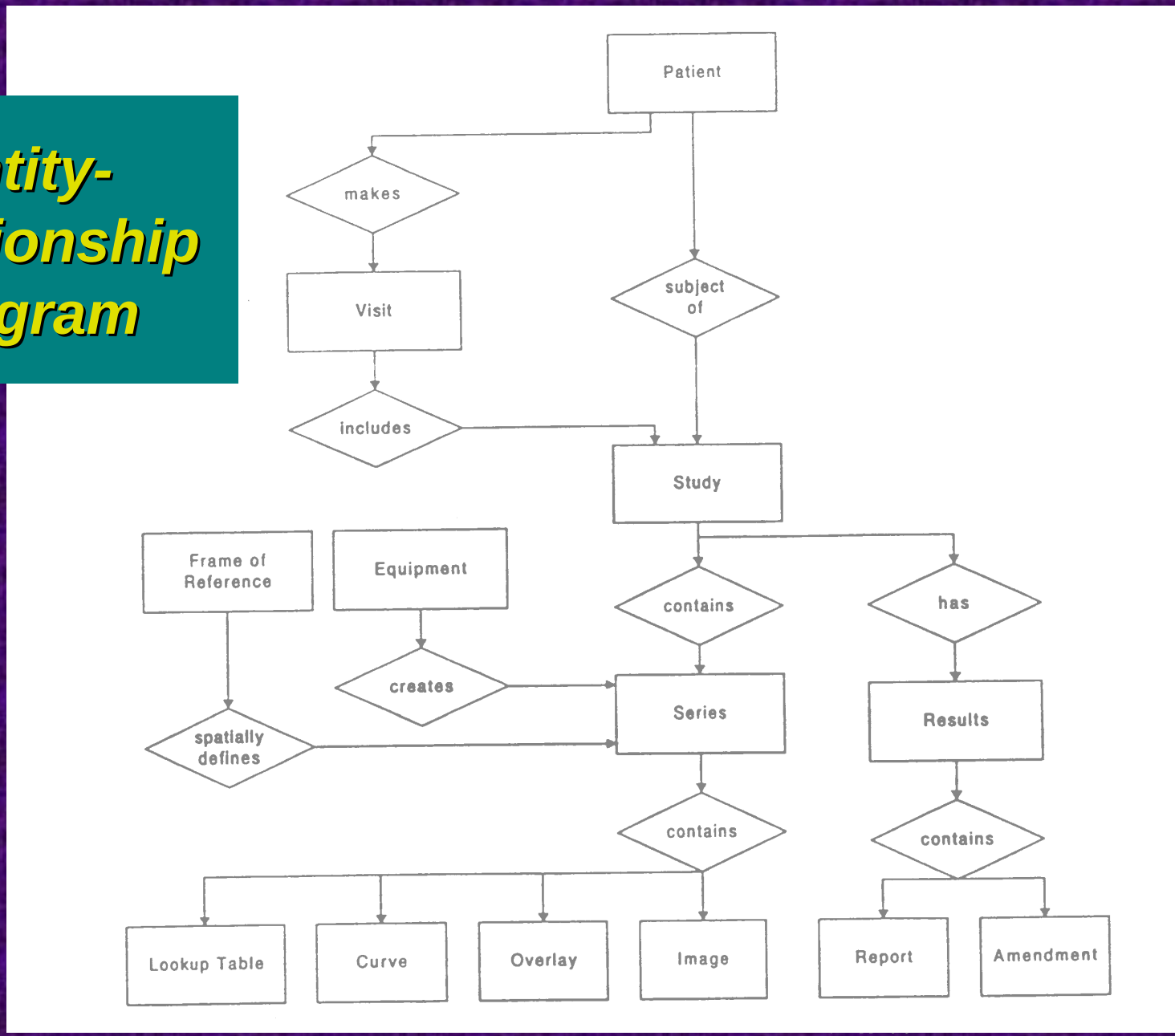
DICOM Parts Topology



DICOM Information Modeling

- An object-oriented model for medical imaging information
- E-R Modeling - how information entities relate to one another
  - Entities (objects) represented by rectangular boxes
  - Entities have attributes (data elements of the ACR-NEMA standard)
  - Relationships denoted by diamond-shaped boxes
  - Images, reports and patients, for example, are all “information objects”

Entity-Relationship Diagram



DICOM Information Modeling (cont.)

- Information objects are the first fundamental component of DICOM
- Information Object Definition (IOD) structure
  - Mandatory attributes
  - Optional attributes
  - Conditional attributes
  - Information object instance

DICOM Information Modeling (cont.)

- **Unique Identifier (UID)**
  - **UID used by DICOM whenever one thing is referenced by another (e.g., transfer syntax)**
  - **Organizational root (e.g., DICOM = 1.2.840.10008)**
  - **The UID exists to provide a unique identity to an object, not to carry information about the object it identifies**

DICOM Service Classes

- The second fundamental component of DICOM
- IOs and communication links between devices are not sufficient in and of themselves to provide functionality
- Need devices to perform some operation (service) with the IOs
- DICOM provides standardized services (negotiated up-front) that are used on the IOs

DICOM Service Classes (cont.)

- In O-O terms, the services are referred to as service classes; a service may be applied to a variety (or class) of information objects
- Because DICOM has both composite and normalized IODs, there are both composite and normalized services

DICOM Service Classes (cont.)

- Service elements - DICOM builds complex services (e.g., storage and query/retrieve) out of more fundamental (primitive) DICOM message service elements (DIMSEs)
  - Five DIMSE-C objects
    - C-Store, C-Get, C-Move, C-Find, C-Echo
  - Six DIMSE-N objects
    - N-Event-Report, N-Get, N-Set, N-Action, N-Create, N-Delete

DICOM Service Classes (cont.)

- DICOM Services
  - Storage (DIMSE Store)
  - Modality Worklist Management
  - Print
  - Query/Retrieve (DIMSE Find/Get/Move)
  - Verification
  - Patient/Study/Results Management
  - Study Content Notification
- Service Class User (SCU)
- Service Class Provider (SCP)

Service-Object Pairs

- The SCs and IOs are combined to form the elemental functional units of DICOM, termed service-object pair (SOP) classes
- Everything DICOM implements is based on the use of SOP classes
  - e.g., CT image storage SOP class
  - each carries a UID (e.g., 1.2.840.10008.5.1.4.1.1.2)
  - Once the attributes are “filled in”: SOP instance
  - The process of DICOM communication involves the exchange of SOP instances with the use of DICOM messages

Service-Object Pair (SOP) Class

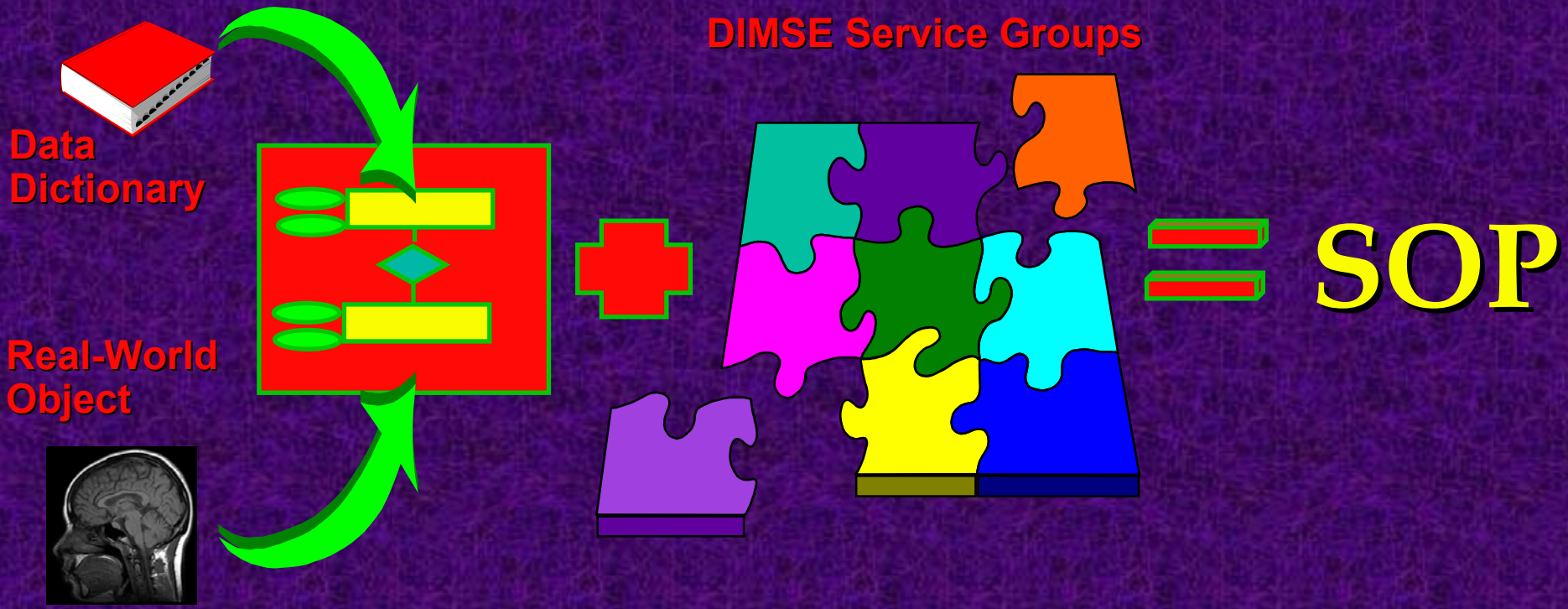


Image Acquisition

- Film digitization and frame grabbers (old)
- DICOM modalities
  - Computed Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
  - Nuclear Medicine (including SPECT and PET)
  - Ultrasound (US)
  - Computed Radiography (CR)
  - Digital Radiography (DR)
  - Digital Fluoroscopy (DF)
- Mammography (some digital, but mostly film)

Data Generated/Exam

Exam Type	Images	Matrix Size	Mbits
Screen-film	4	2048x2560x12	320
	4	4096x5120x12	1280
Ultrasound	60	512x512x8	120
Nuclear Med.	36	256x256x12	36
Comp. Tomo.	250	512x512x12	1000
Mag. Reson.	500	256x256x12	500
Mammography	4	6144x5000x12	1475

SOP Classes Supported: Storage

SOP Class Name	SOP Class UID
Computed Radiography Image Storage	1.2.840.10008.5.1.4.1.1.1
CT Image Storage	1.2.840.10008.5.1.4.1.1.2
MR Image Storage	1.2.840.10008.5.1.4.1.1.4
Secondary Capture Image Storage	1.2.840.10008.5.1.4.1.1.7
Standalone Overlay Storage	1.2.840.10008.5.1.4.1.1.8
X-Ray Angiographic Image Storage	1.2.840.10008.5.1.4.1.1.12.1
X-Ray Radiofluoroscopic Image Storage	1.2.840.10008.5.1.5.1.1.12.2
RT Image Information Storage	1.2.840.10008.5.1.4.1.1.481.1
RT Structure Set Information Storage	1.2.840.10008.5.1.4.1.1.481.3
RT Plan Information Storage	1.2.840.10008.5.1.4.1.1.481.5

PACS - The Next Generation

- New Intelligent Capabilities
  - Intelligent user interface
  - Multimedia support
  - High-level data object management
  - Rule-based processing
  - Computer-aided diagnosis
- Fully Integrated, Enterprise-wide Information Services
  - PACS, HIS / RIS (HL7), Voice Recognition (voice → text)
  - Path / Lab / Nursing / Pharm / etc.
- Library Functionality

Local Area Networks

- **Ethernet**
  - **Shared bandwidth**
  - **Switched – full duplex**
  - **10, 100, 1000 and 10,000 Mbps/sec**
- **ATM/SONET**
  - **Asynchronous Transfer Mode**
  - **Synchronous Optical Network**
  - **155, 622 and 2,500 Mbps**

Image Archives

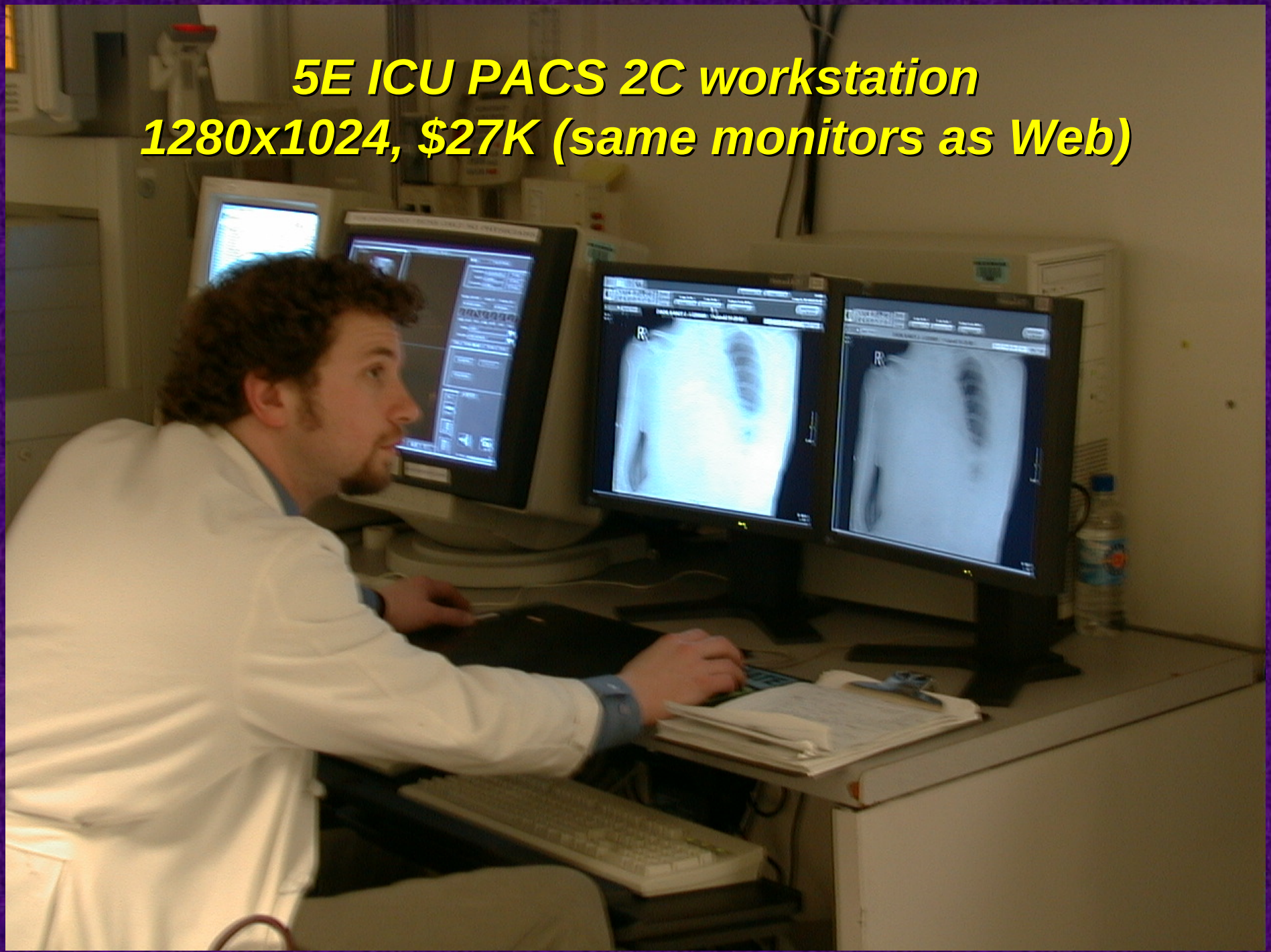
- Data Storage Technologies
  - Hierarchical Storage Management (HSM) systems
  - Magnetic disk
  - Magneto-optic disk (MOD/EOD)
  - WORM optical disks
  - Digital Linear Tape (DLT) cartridges
- Data Compression
  - Lossless (Huffman, Lempel-Ziv-Walsh: LZW)
  - Lossy (JPEG, wavelets)

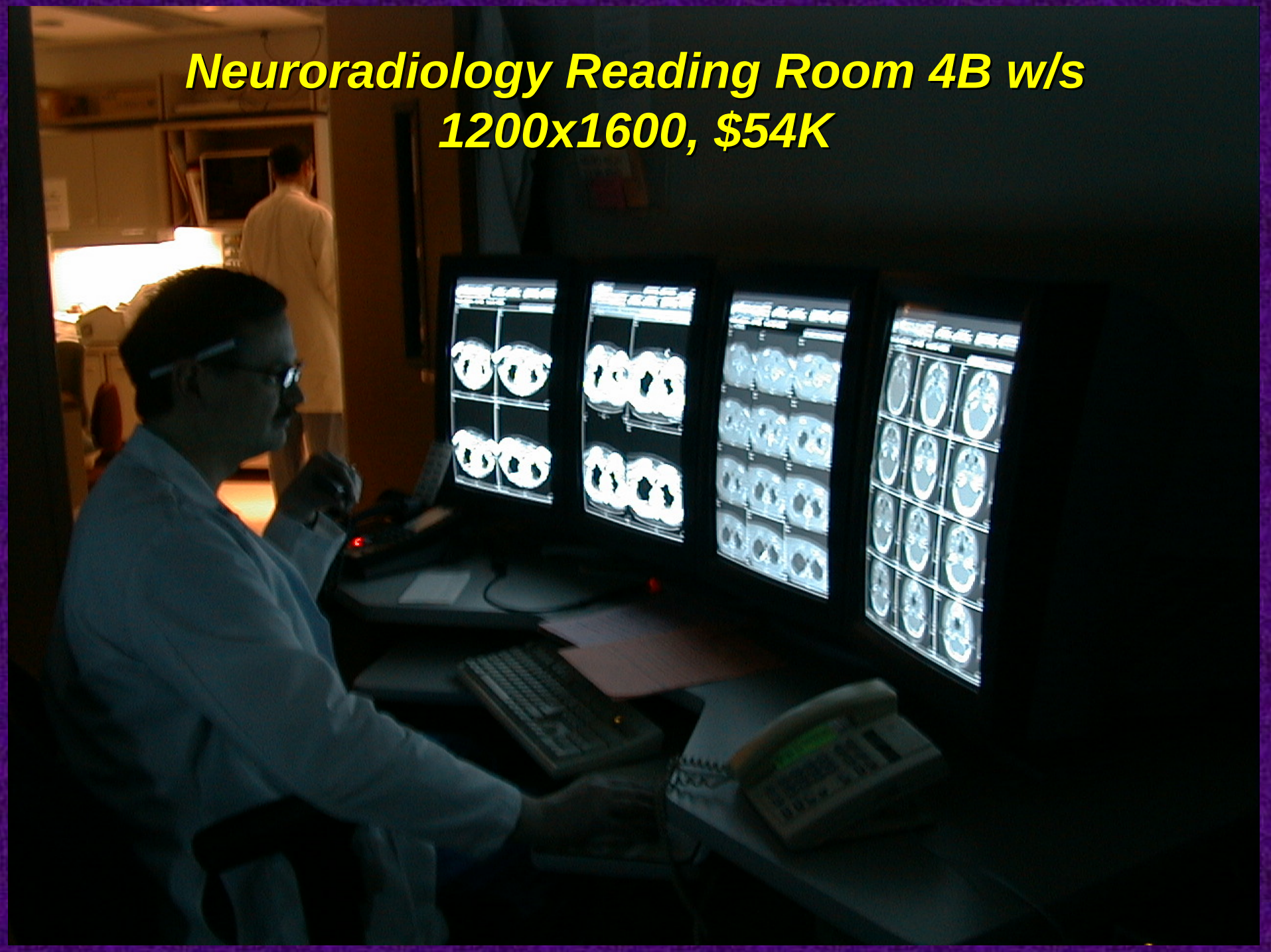
pacscube
Express 200
DELL

Display Hardware

- Large format raster-scanned CRT
- CRT inferior to laser printed film (4096 x 5120)
  - Resolution: 1024x1280 (C), 1200x1600 (B), 1728x2304 (A)
  - Luminance: 500 ft-L vs. 70-80 ft-L
  - Dynamic Range: bit depth (16-bit per pixel frame buffer)
  - Veiling Glare: ambient light
  - ROC Studies: OK for primary diagnosis
- 150-200 ft-L 3840 x 2400 flat panel monitor

PACS Web on MCIS PC 1280x1024 $3K


5E ICU PACS 2C workstation
1280x1024, $27K (same monitors as Web)


Neuroradiology Reading Room 4B w/s
1200x1600, $54K

Scenario (reprise)

- Primary care physician logs into MINDscape (Cerner)
- Selects radiology exam and views images of interest
- Phones radiologist with query
- Radiologist logs into workstation and they review images together over the network (not quite there yet)
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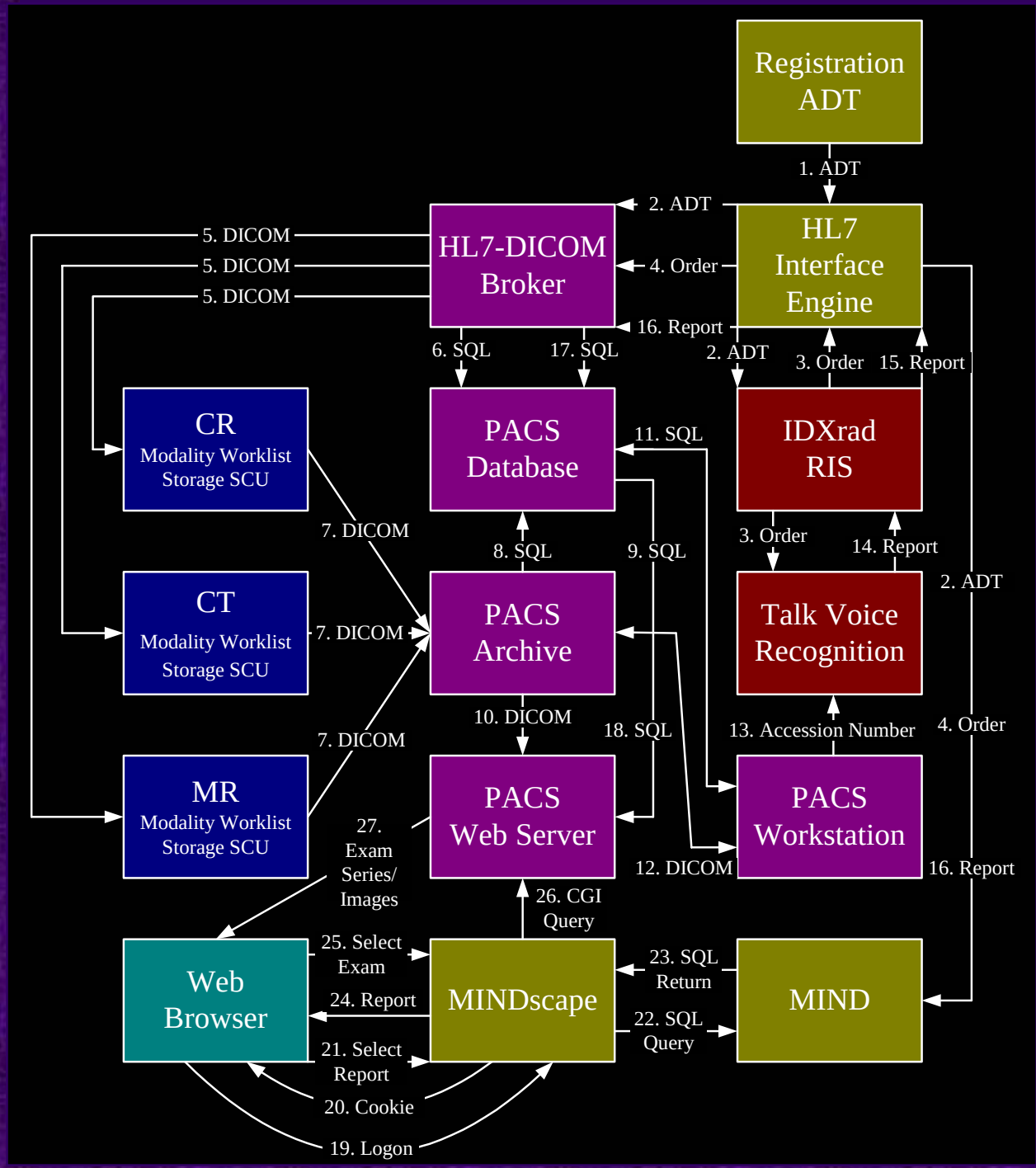
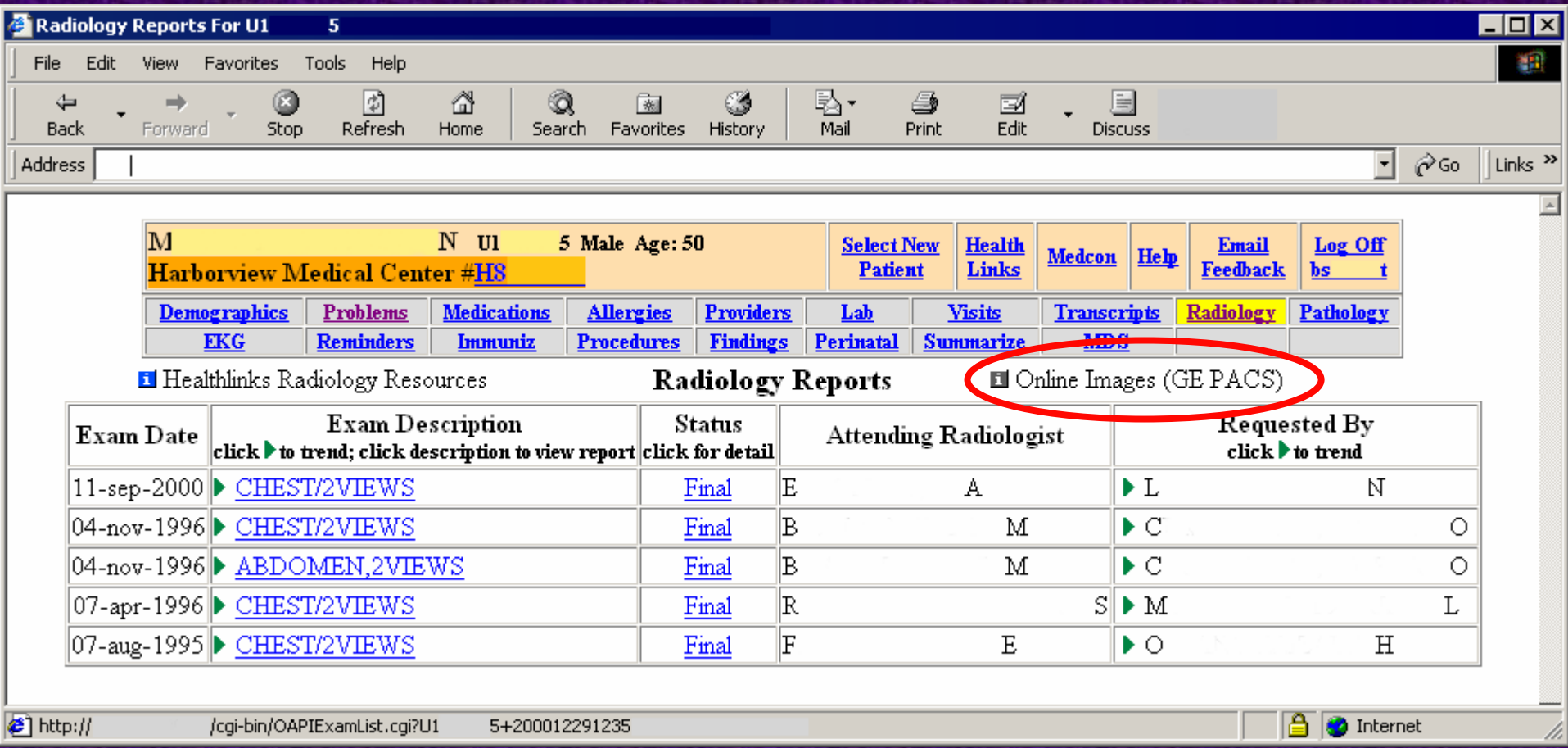
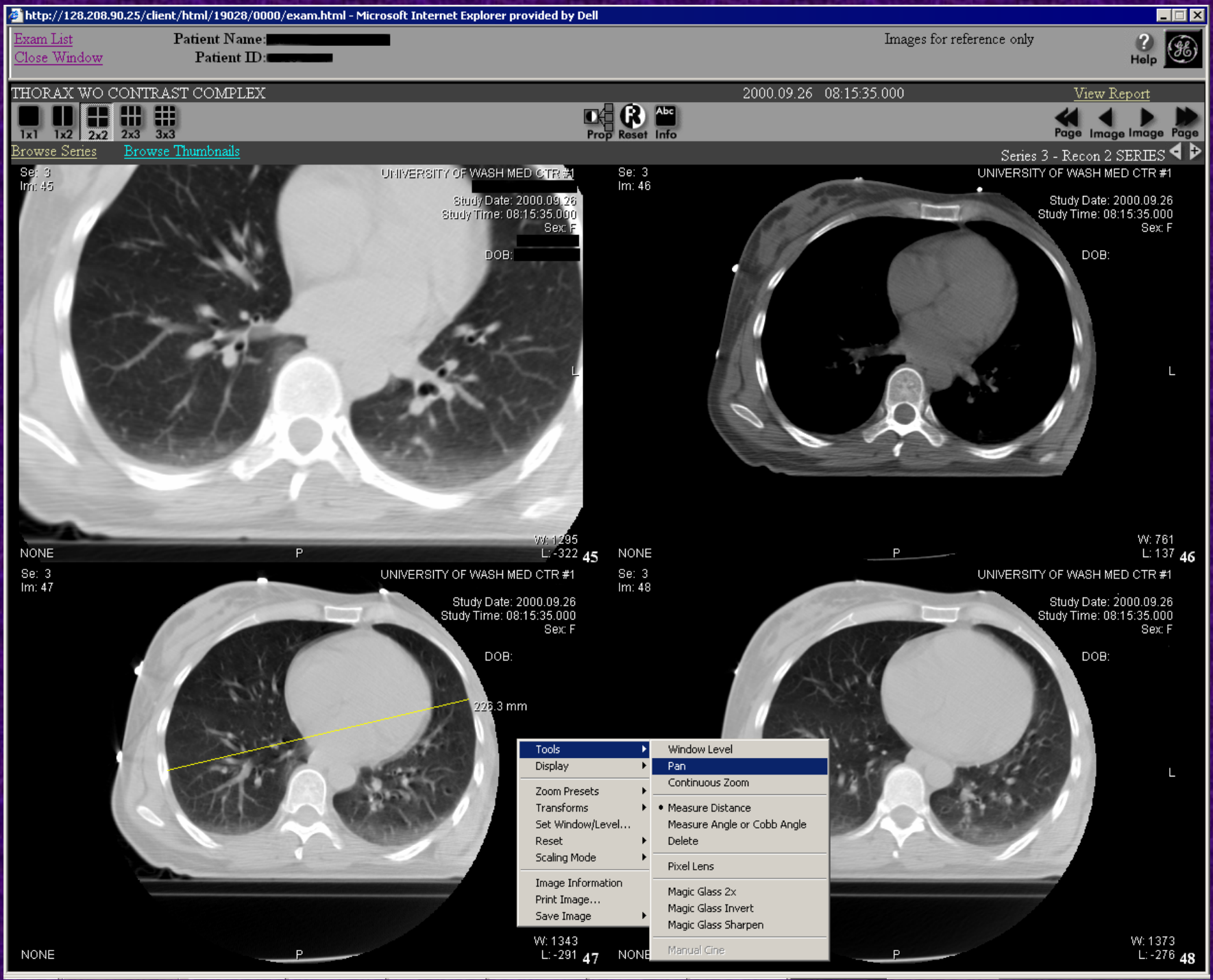


MINDscape Integration – Access Point




http://128.208.90.25/client/html/19028/0000/exam.html - Microsoft Internet Explorer provided by Dell
Exam List
Close Window
Patient Name:
Patient ID:
Images for reference only
Help
THORAX WO CONTRAST COMPLEX
2000.09.26 08:15:35.000
View Report
1x1 1x2 2x2 2x3 3x3
Prop Reset Info
Page Image Image Page
Browse Series
Browse Thumbnails
Series 3 - Recon 2 SERIES
Se: 3
Im: 45
UNIVERSITY OF WASH MED CTR #1
Study Date: 2000.09.26
Study Time: 08:15:35.000
Sex: F
DOB:
L
NONE
P
W: 1295
L: -322
45
Se: 3
Im: 46
UNIVERSITY OF WASH MED CTR #1
Study Date: 2000.09.26
Study Time: 08:15:35.000
Sex: F
DOB:
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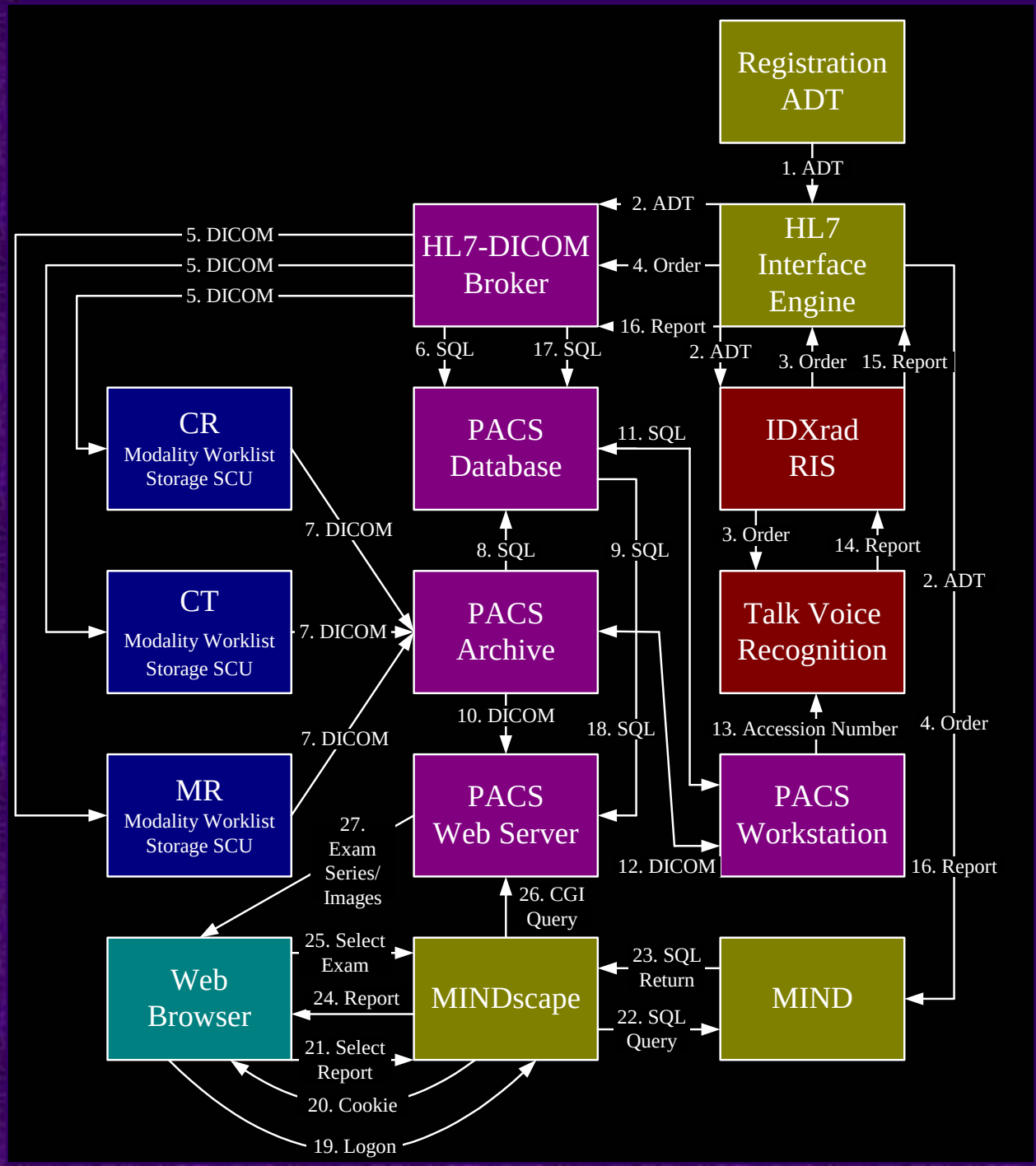
NONE
P
W: 761
L: 137
46
Se: 3
Im: 47
UNIVERSITY OF WASH MED CTR #1
Study Date: 2000.09.26
Study Time: 08:15:35.000
Sex: F
DOB:
226.3 mm
NONE
P
W: 1343
L: -291
47
Se: 3
Im: 48
UNIVERSITY OF WASH MED CTR #1
Study Date: 2000.09.26
Study Time: 08:15:35.000
Sex: F
DOB:
L
NONE
P
W: 1373
L: -276
48
Tools
Display
Zoom Presets
Transforms
Set Window/Level...
Reset
Scaling Mode
Image Information
Print Image...
Save Image
Window Level
Pan
Continuous Zoom
Measure Distance
Measure Angle or Cobb Angle
Delete
Pixel Lens
Magic Glass 2x
Magic Glass Invert
Magic Glass Sharpen
Manual Cine

27 Step PACS Shuffle

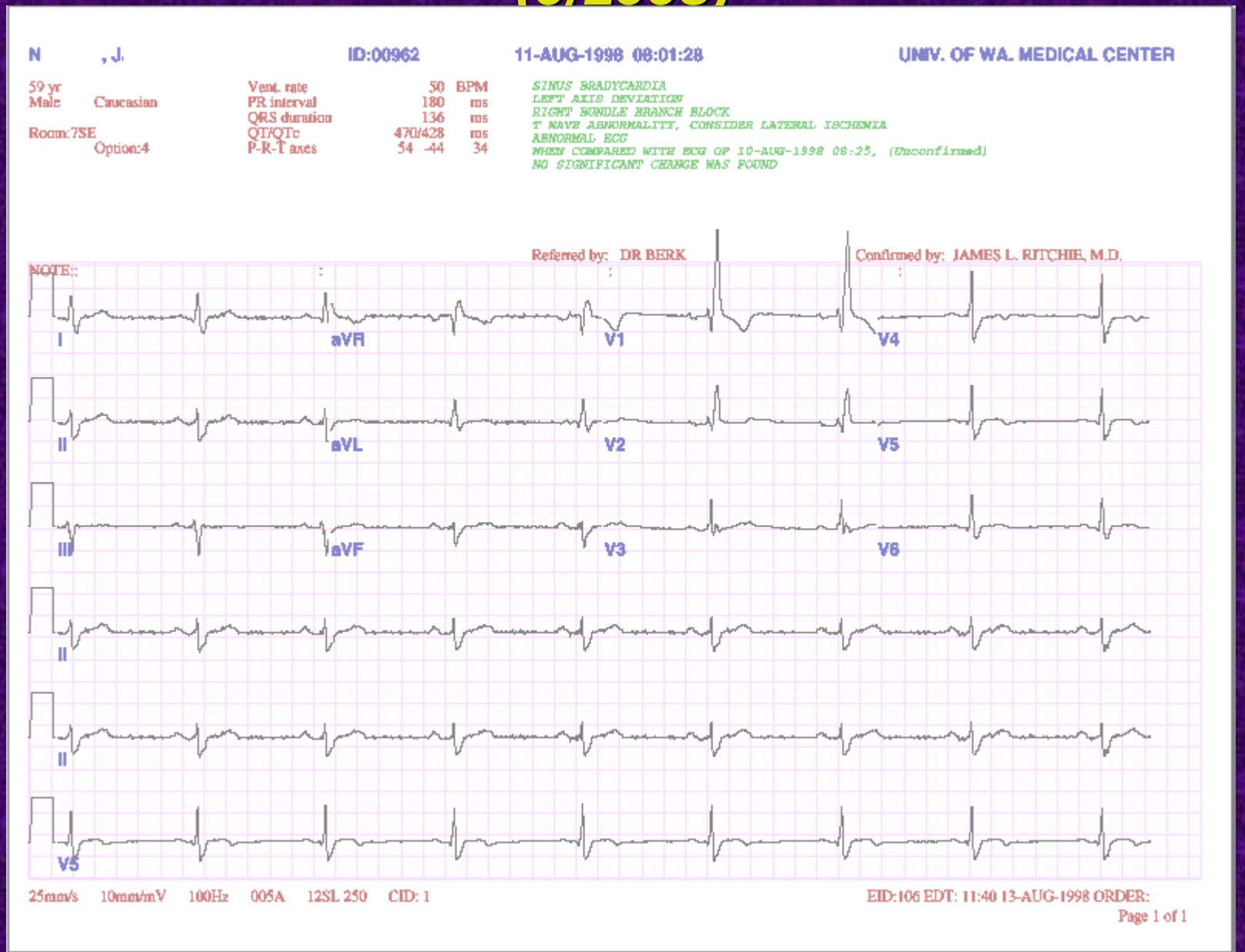


VERICIS Integrated Cardiovascular Repository

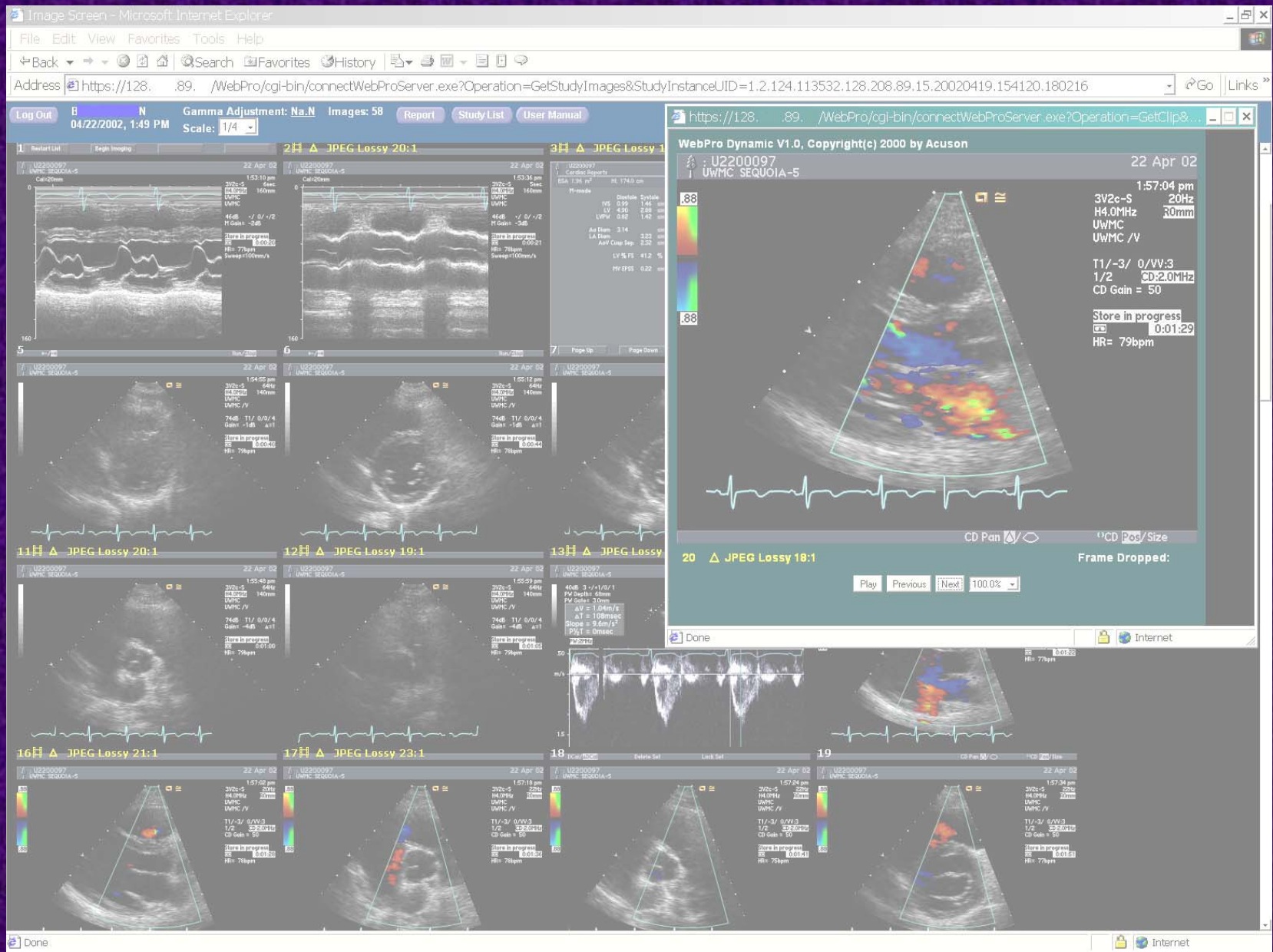
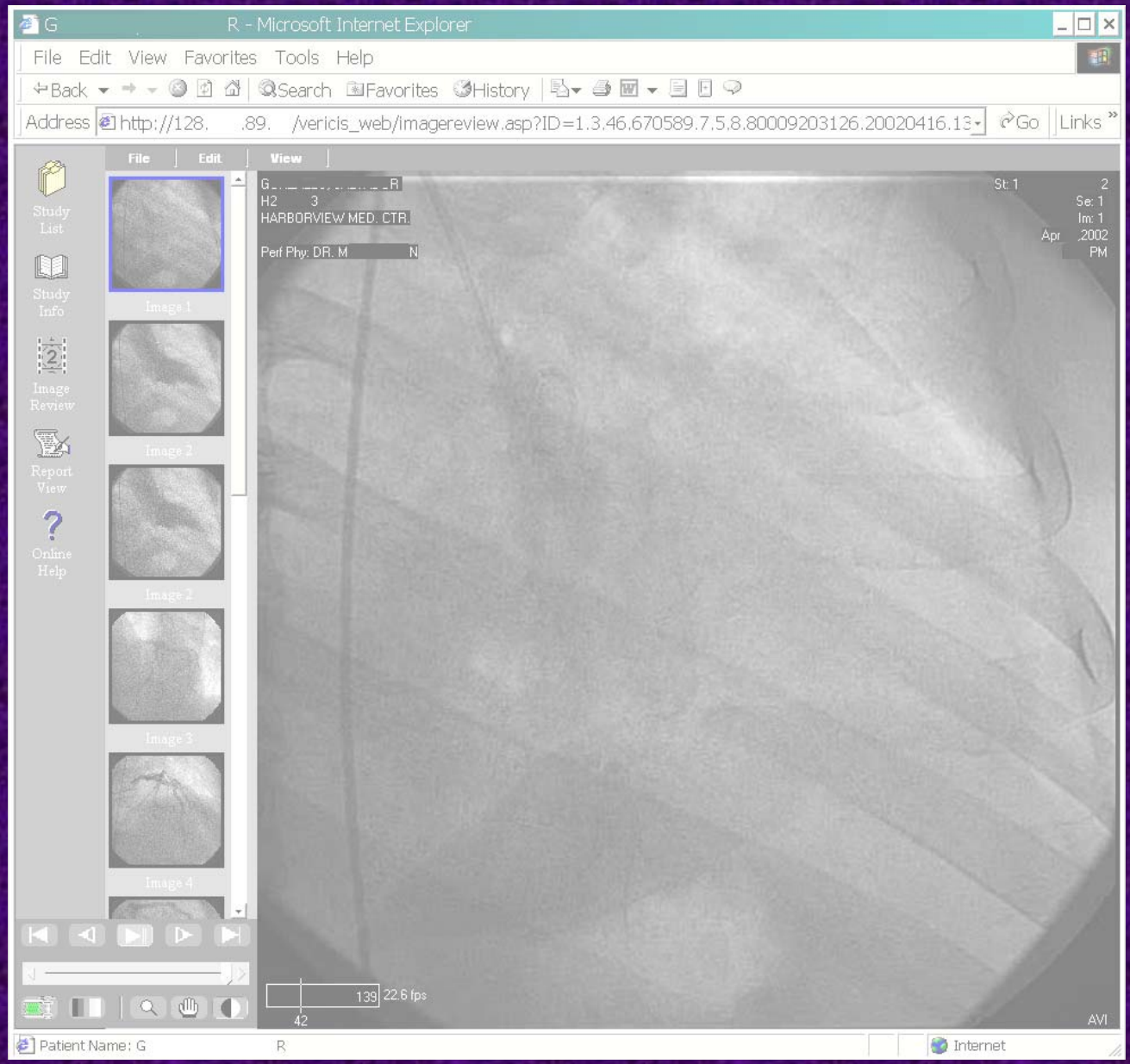
VERICIS Optimizes Department Workflow

- Improved productivity and efficiency
- Enhanced physician-to-physician communication
- Immediate access to Digital Integrated Cardiovascular Records at multiple locations

EKGs Accessible through MINDscape (9/1998)



Acuson EchoPACS



Camtronics Cath Lab PACS