

# 074: 150 Medical Imaging Informatics

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# Fundamental Medical Imaging Informatics

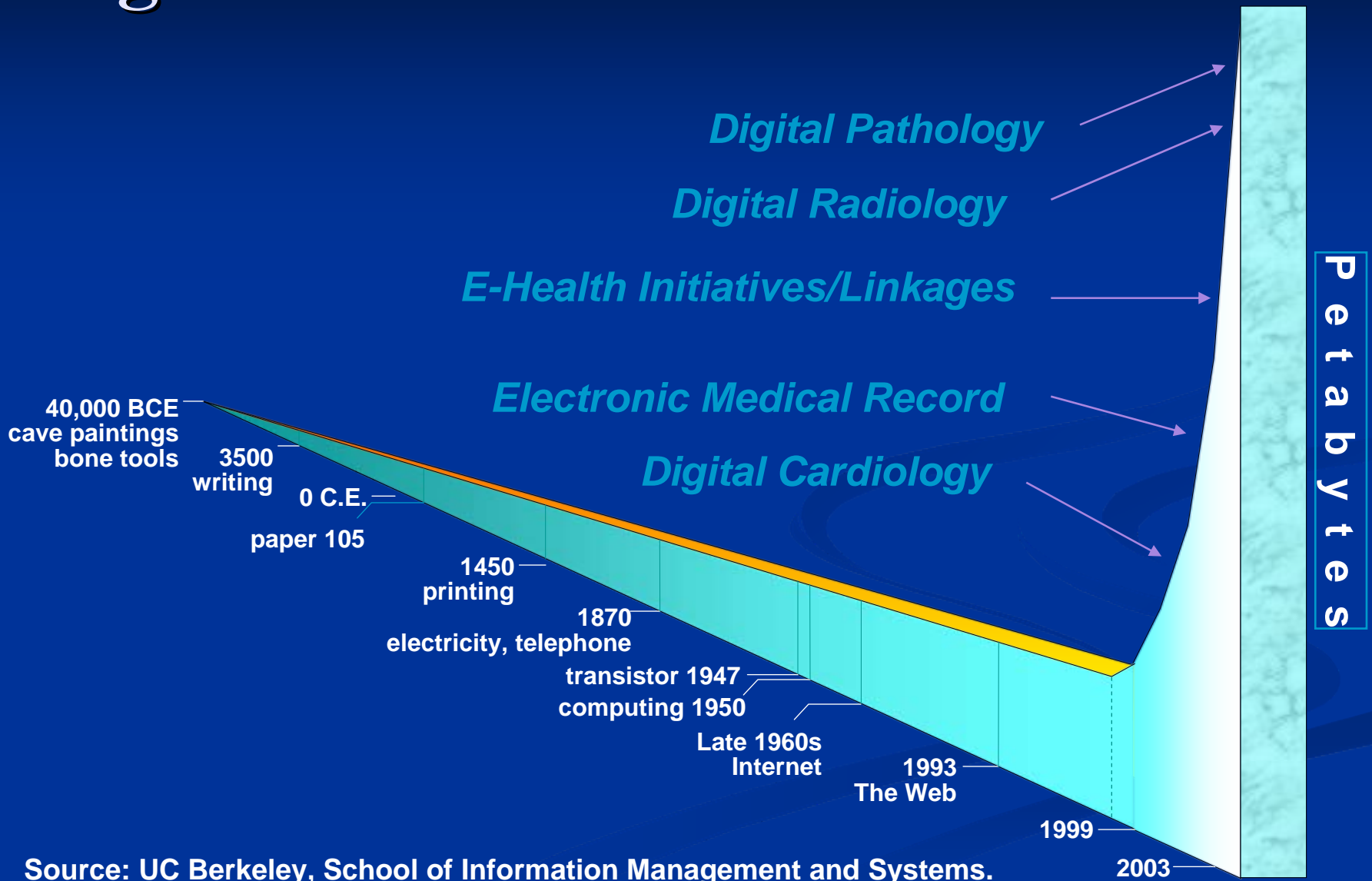
## ■ Topics

- Information science and technology
- Medical/healthcare information science and technology
- Informatics
- Ontological model and data structures
- Medical image data management
- Medical image processing
- Medical image data formulation and standards
- Medical image data display
- Medical image communication, networks, and distribution
- Medical image workflow, PACS design and implementation

# What is Medical Imaging Informatics?

- Digitalization in today's hospital systems
- Picture Archiving and Communications systems (PACS)
  - One of technological cores of a modern and digital radiology
  - Their core function is the medical image
    - **Storage** (database management system)
    - **Distribution** (data communication and networks)
    - **Analysis and processing**
    - **Display** (data visualization)

# Digitization in Medical Sciences



Source: UC Berkeley, School of Information Management and Systems.

# What is Medical Imaging Informatics?

- Picture Archiving and Communications systems (PACS)
  - Increasingly important role in the entire workflow of the radiology department and almost all the medical departments
  - Offers healthcare information integration including radiology records and reports, medical records, and laboratory information
  - Participation in healthcare (hospital and clinic) information systems

# What is Medical Imaging Informatics?

- A PACS ideally replaces all stand-alone, single-modality workstations
- PACS is further strengthened by integration with a hospital's other IT infrastructures
  - hospital information system (HIS)
  - radiology information system (RIS)
- One of leading technical domains in electronic patient record systems (ePR)

# What is Medical Imaging Informatics?

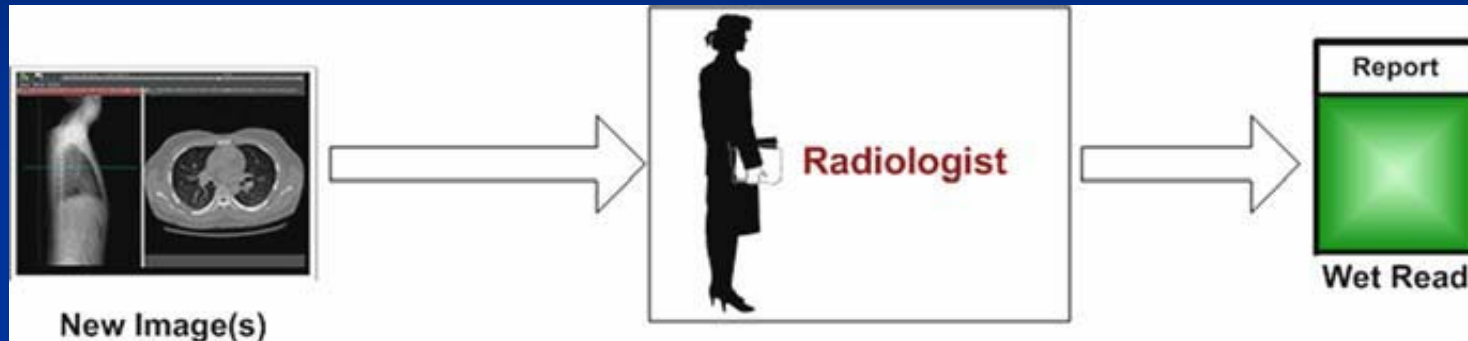
- Integrating the Healthcare Enterprise (IHE)
  - A joint effort of the Radiological Society of North America (RSNA) and Healthcare Information and Management Systems Society (HIMSS).
  - The goal of IHE is to standardize **interoperability** among PACS, RIS, and HIS

# What is Medical Imaging Informatics?

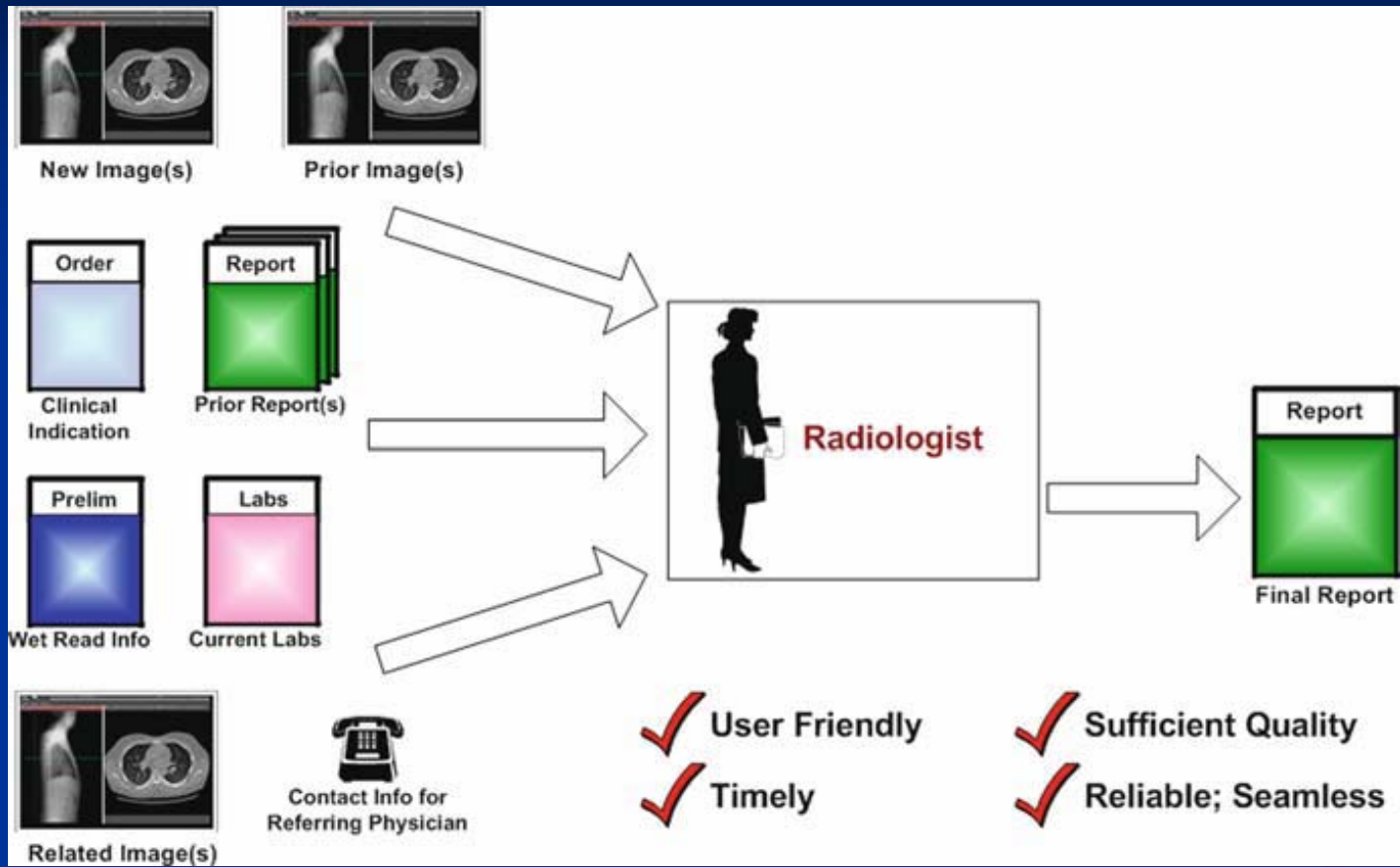
- Modern PACS are complex and require **skilled and dedicated personnel** for proper setup and ongoing functionality
  - **Specifically require** strong background and knowledge in both clinic and IT
- PACS is a **relatively expensive** undertaking both for
  - system hardware/software supports
  - technical staff
- Cost/performance consideration of developing/building PACS becomes crucial in radiology department

# What is Medical Imaging Informatics?

- Fundamentally different from traditional radiology purchases (like CT or MRI scanners)
- Not result in additional income for radiology
  - Supportive system for digital radiology
  - PACS must therefore pay for itself in cost savings from the reduced need to produce, store, and handle film and by reducing the likelihood of preventable medical errors, which is a harder cost to quantify



Oversimplified view of PACS workflow: this is what traditional teleradiology provided in the 1990s. This was an exciting innovation at the time, allowing radiologists to render preliminary readings (“wet read”) based on single exams, usually without access to the prior studies on that patient.



More realistic depiction of PACS workflow today: in order to provide the best possible result, the radiologist needs more than the current images to render a final report.

# What is Medical Imaging Informatics?

## ■ Data Acquisition (Medical Imaging Modalities)

■ X-Ray

■ CT

■ MRI

■ NM



# What is Medical Imaging Informatics?

## ■ Data Acquisition (Medical Imaging Modalities)

- Ultrasound



- Mammogram



- Tomosynthesis



# What is Medical Imaging Informatics?

- Data Management and Processing
  - Study how medical images (within radiology and throughout medical systems) is
    - Acquired
    - Archived
    - Retrieved
    - Processed
    - Analyzed
    - Enhanced
    - Visualized
    - Exchanged

# What is Medical Imaging Informatics?

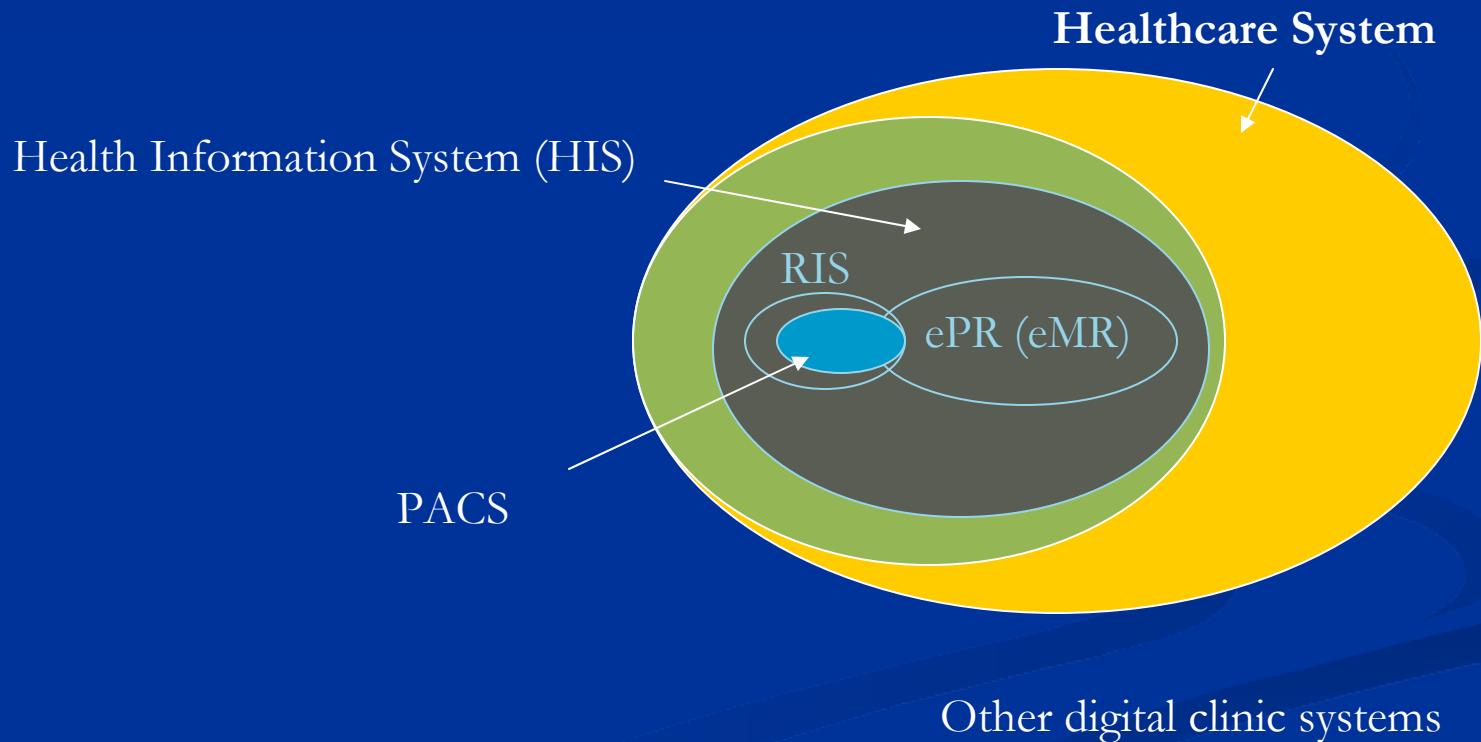
- Carefully design of high performance PACS that assure the accurate identification of patient, exam (image), and associated clinical data required by the radiologist and others, in support of the workflow mainly performed within the radiology department and perhaps outside healthcare units.

# What is Medical Imaging Informatics?

- Radiology Information System (RIS)
  - Software facility that manages radiology daily activities
- Relationship with HIS
  - Receive orders from HIS
  - Must allow radiology personnel to enter and alter orders
  - Bundled with other Hospital Information Systems HIS
  - Uses **Health Level 7 (HL7)**, a standard for electronic data interchange in **healthcare environments**, as its core communication protocol
    - HL7 does not relate to medical images
- Multiple vendor choices
  - ...
  - ...

# RIS Interaction with HIS

- Relationship within Healthcare System





hospital



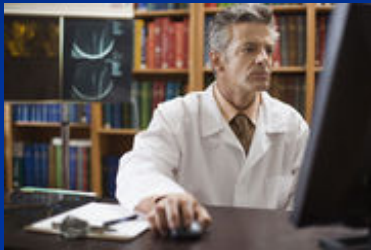
registration



order exam



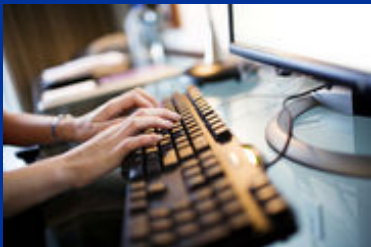
waiting room



final report on RIS



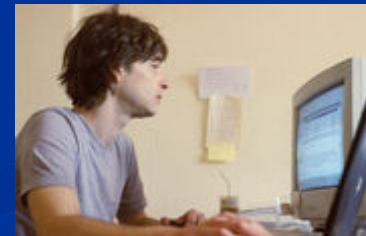
radiologist review



Fetch report to HIS



Radiologist preview



Paperwork film package



send to office



modality



exam operation

**Traditional Genetic Radiology Workflow**



# PACS Benefits

- PACS is expected to **reduce the time and financial cost** associated vs. film and paper storage and transfer.
- PACS permits **rapid image retrieval and simultaneous and remote viewing**
- The use of PACS also compacts the **storage space, reducing archival space** (file rooms), and requiring **fewer personnel** (file room clerks).

# PACS Benefits

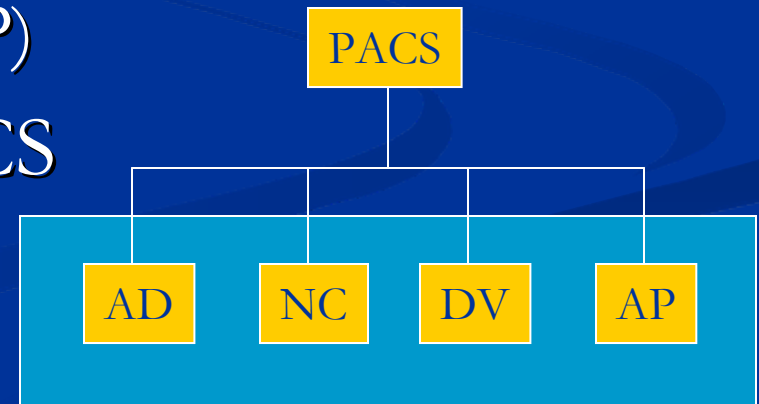
- Problems of lost, misplaced, and sequestered films are potentially **eliminated**.
- PACS promises to **improve operational efficiency**, reduce costs, and provide a much faster service in terms of report time to referring physicians.

# PACS Disadvantages

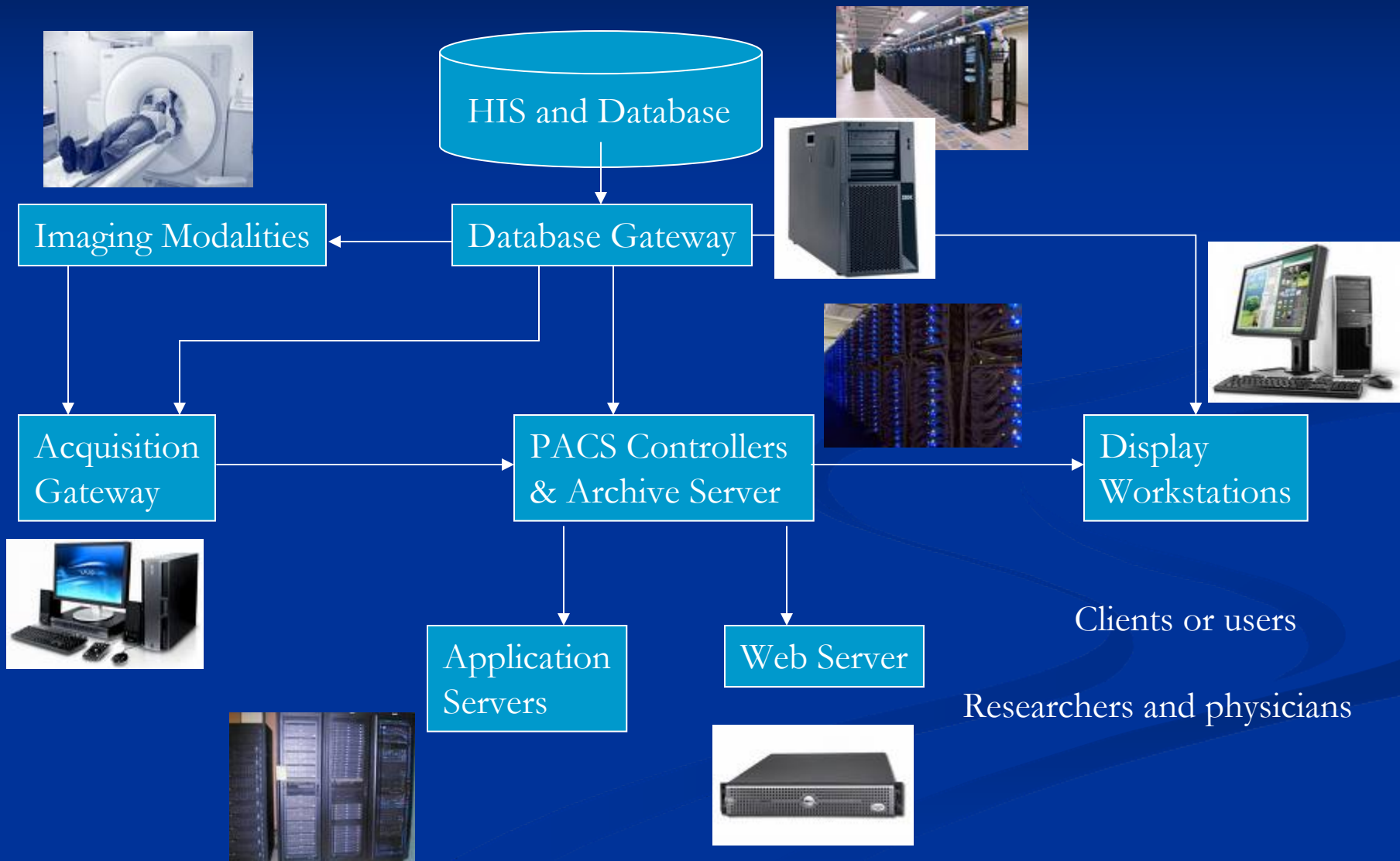
- One major limitation to the widespread introduction of PACS is the **high capital costs** involved.
- The amount of image data generated by a radiology department performing 100,000 exams per year is very large (i.e., several TB). **Large data storage** is required.
- **IT technical personnel** required to support PACS are expensive.
- Other difficulties associated with PACS include **security and reliability**.

# PACS Technical Components

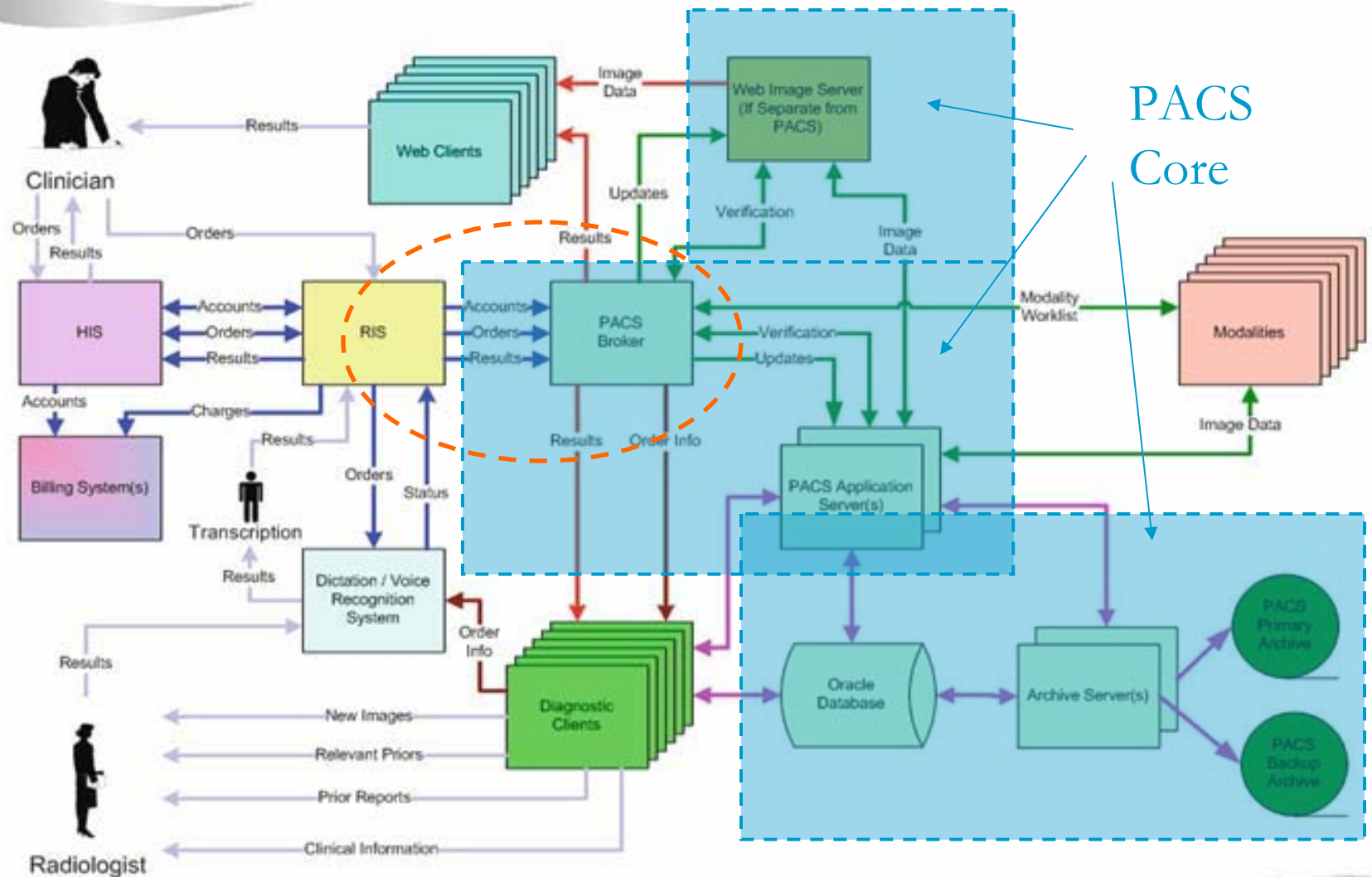
- Four technical components:
  - Acquisition and Digitalization (AD), Archive **DICOM** image data (standard data format)
  - Distribution --- Networking and Communication (NC)
  - Display and Visualization (DV)
  - Analysis and Processing (AP)
- Core workflow within PACS



# Simple and Genetic PACS



# Imaging Systems Integration



Generic workflow of PACS: note the central importance of the PACS broker as the interface engine that links **Hospital HL7 data flow** and **radiology DICOM data flow**.

# PACS Core -- Database

- Archive of **DICOM** data from modalities
  - Ideally redundant
- PACS Database
  - Supports powerful patient-search and study-matching tools.
- Image database system including
  - Patient demographics
  - Associated reports
  - Study description
  - Data acquisition information
  - Data archive information
  - ...

# PACS -- DICOM (Digital Imaging and Communications in Medicine)

- DICOM is an image-based medical protocol that specifies image formats.
- DICOM is now an international standard (ISO).
- ACR-NEMA is a joint committee of the American College of Radiology and the - National Electrical Manufactures Association that developed DICOM.

# PACS Core -- Networking

- Computer networks allow two or more computers to exchange information
- Networks make image data widely available to multiple users at the same time
- Networks also permit instantaneous access to users in multiple locations.

# PACS Core -- Networking

- Network capacity
  - Usually 1 or 10 GB at the core and between large nodes of the enterprise.
  - Minimum 100 MB to the individual PACS workstations.
  - Ideally segregate PACS data traffic from other enterprise data traffic for performance and reliability, but route traffic between networks as needed.

# PACS Core – Networking Terminology

- **Network protocols** are the codes and conventions under which a network operates.
- **Bandwidth** defines the maximum amount of information that can be transferred over a data channel per unit of time and is measured in MBit/s or GBit/s.
- **Topology** refers to the network layout and connection of the various components.
  - **Token ring topology** is a closed loop of point-to-point connections.

# PACS Core -- Networking

- **Ethernet** is a standard often used for local area networks.
- **Backbone** refers to a large network that connects smaller networks.
- A **bridge** connects network segments.
- **Local area networks** (LANs) have devices connected by cable or optical fiber.
- **Wide area networks** (WANs) such as the internet use remote telecommunication devices.

# PACS Core -- Networking

- Network technical connection
  - A **hub** allows physical interconnection of multiple devices to a single network.
  - A **switch** is a network device for connecting multiple devices to a single network in a **point-to-point manner**.
  - A **router** is a **computer system** that connects and directs information from **one network to another** by selecting the **best available pathway**.
  - A **gateway** is a **computer system** for connecting one network to another.

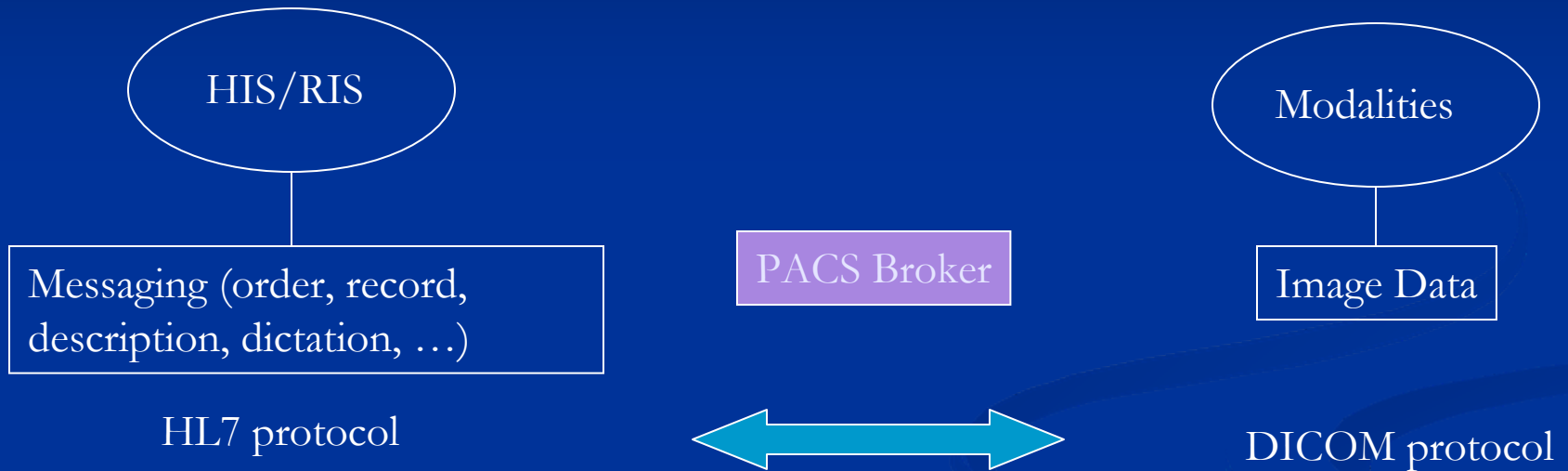
# PACS Core - Distribution

- Distributed computing software
- Software for distribution of images to clinicians
  - Web-based or web-deployable
  - Integrated with an enterprise EMR, or EPR
  - Part of core PACS or a free-standing system
  - Other important but urgently raised issues
    - Interoperability
    - Sustainability
    - Security
    - Reliability
    - Scalability
    - ...

# PACS Broker

- PACS work best when the strongest aspects of the **organizational powers of the RIS** are combined with the **database and archive access tools of PACS**.
  - This requires a “broker” to translate and interconnect the HIS/RIS (which generally uses **HL7 messaging**) with the imaging portion of the PACS, which communicates via the DICOM protocol.
  - The broker will generally provide DICOM capabilities (for example, DICOM modality work-list) to components within the PACS network that use DICOM.

# PACS Broker



# PACS Broker

- Some PACS claim to be “brokerless,” since they are simply embedded into the PACS.
- But the PACS Broker’s function exists

# Diagnostic Workstations

- Radiology workflow has changed.
  - The modern radiologist no longer works in front of fluorescent light boxes, viewing transparency images.
  - The current workflow is accessed by the radiologist at a **high-performance computer**, commonly called the diagnostic workstation.
  - The diagnostic workstation may be a **generic DICOM viewer**, or a proprietary system offered by the **PACS vendor**, or may have more features.

# Diagnostic Workstations

- The workstation has desired functionalities
  - It is usually comprised of a high performance personal computer with
    - high-resolution, high brightness monitor
    - large built-in memory
    - fast CPU or graphic card

# Diagnostic Workstations

- It holds and operates the study retrieval and study viewing software
  - On-line, off-line, client/server based centralized system (powered by CITRIS)
- Usually, a local PACS workstation is linked by standard networking to the PACS core and archive.

# Diagnostic Workstations

- As opposed to early point-to-point networking systems, most modern PACS **do not attempt to automatically route entire studies** (and needed comparison studies) to individual workstations before the radiologist needs them.
- Usually, all the images of the exam and the comparison **studies reside in the PACS core** and are only temporarily retrieved to the PACS workstation for review.

# Diagnostic Workstations

- Functions of PACS workstation for the radiologist:
  - Allows assembly of sets of cases to be sorted and identified (i.e., work-lists) so that individual radiologists can pull their respective workload from the overall archive.
  - Facilitates retrieval of new studies to be read from the PACS core to local memory or the local hard drive.

# Diagnostic Workstations

- Communicates with the PACS core to identify, retrieve, or pre-fetch the pertinent comparison studies that the radiologist is most likely to need.
- Allows viewing both new and old exams.
- Facilitates retrieval and semi-automated display of available prior studies.

# Diagnostic Workstations

- Image manipulation software tools operated via an intuitive GUI.
- Commonly linked to dictation/reporting tools.
- Changes the status of studies to prevent multiple radiologists from trying to dictate the same case.
- Allows the system (for all radiologists) to be aware of what is waiting to be reported.