Setting up digital imaging department

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Outline

- **From screen/film to digital radiography**
- **PACS/Tele radiology**
- **Setting up digital department**
- **Digital Imaging**

PACS/Tele Radiology

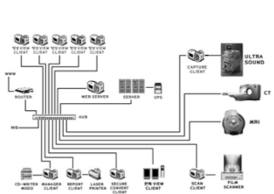
- Picture Archiving and Communication System (PACS)
  - A PACS system displays, archives and communicates medical digital images
- Tele Radiology
  - The transmission of radiological patient images, such x-rays, CTs and MRIs from one location to another for the purpose of interpretation and/or consultation

What is PACS ?

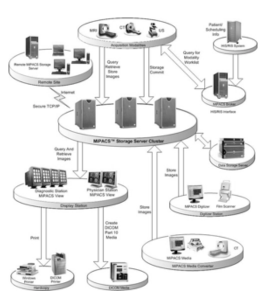
P: Picture, Images & Reports
A: Archive, Online, Near line, Offline
C: Communication, Networking, Transfer Protocols
S: System, Components & Architecture

PACS: for storage and distribution of images and information when necessary

PACS: Small or Large



Web Server Distribution



Scale of PACS

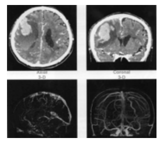
- Hospital Size (No. of beds)/ Exams per year
- Radiology Department (No. of Modalities)
- No. of Switches

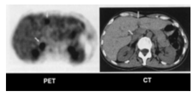
Considerations:

System connectivity, expandability, reliability and cost-effectiveness

Types of images

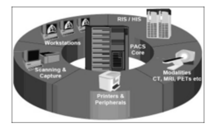
- 1D, 2D, 3D, 4D
- Different DICOM Modality type: Cardiac / PET / 4D U/S…..
- Image size: Resolution and bit depth
- Image quality: Bit Depth and resolution
- Color / Monochromatic
- Exam. Size: image size x no. of images
- Structured Reports
- New DICOM IOD: Endoscopic & Microscopic images / ECGs / Security Profiles…..





PACS

- Consists of different components
  - Radiologist reading stations
  - Clinician review stations
  - Web access
  - Technologist/Radiographer quality control stations
  - Administrative stations
  - Archive systems
  - Multiple interfaces to other hospital and radiology systems



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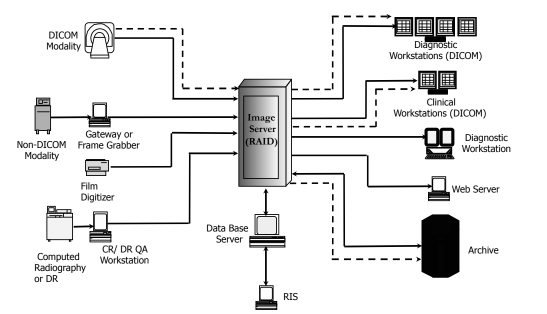
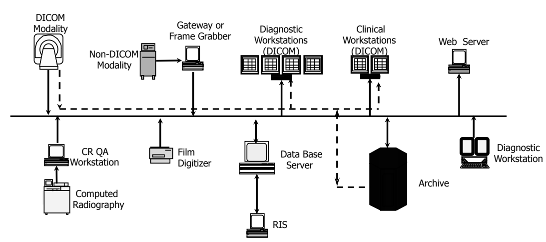
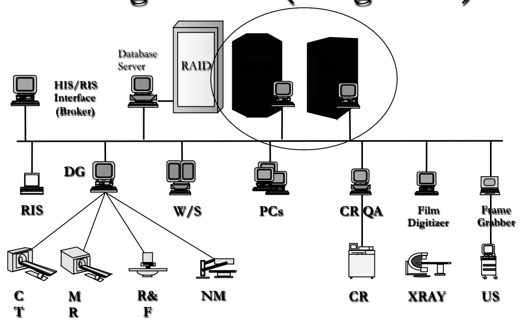
PACS – Central Architecture



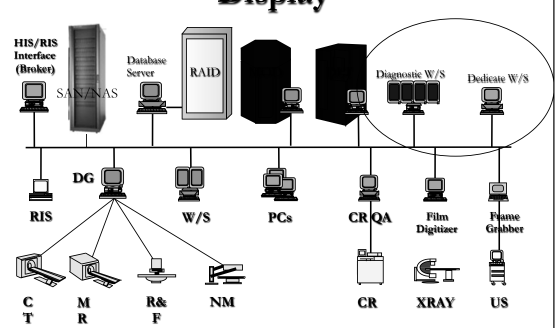
PACS – Distributed Architecture



Storage Device (Long Term)



Display



Why PACS? ….Film Just Can't Keep Up

Quality	Productivity	Cost
Inability to View Images Across Locations	Limited Practitioner Collaboration	$25 - $35 per Study For Management, Distribution and Storage

Source: Philips

Benefit of PACS:

FirstHealth identified the potential Picture Archiving and Communication System (PACS) benefits as a way to increase operational efficiencies, reduce costs and improve patient care.

And that's exactly what it achieved. The PACS has allowed FirstHealth to **cut its annual film budget by more than 37%**, from around $80,000 to $50,000, FirstHealth Director of Imaging Mike McCarty told *Computerworld*.

Improve Patient Care
As another PACS benefit, FirstHealth also improves patient care by providing **higher-quality images** and therefore **more accurate diagnoses**.

With the system, radiologists can electronically manipulate images to enlarge areas, enhance clarity, rotate images and create 3-D images of organs, tissues, bones and blood vessels, the organization says.

In a recent post, the British Medical Advisor Jobs blog highlights some of the many benefits of PACS on patient care and physician efficiency. We've summarized that information and created the "Top 5 PACS Benefits" list:

1. PACS reduces the need for film in diagnostic imaging, saving on both the costs to buy film and the space needed to house film.

2. PACS facilitates quick and easy access to patient images and reports.

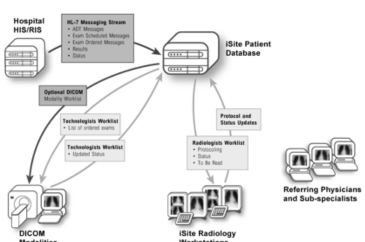
3. PACS can help reduce the number of duplicate images since previous results are available electronically.

4. With PACS, tests can be performed anywhere, as results can be shared electronically with other remote facilities.

5. Physicians can acquire a chronological view of patients' radiology histories.

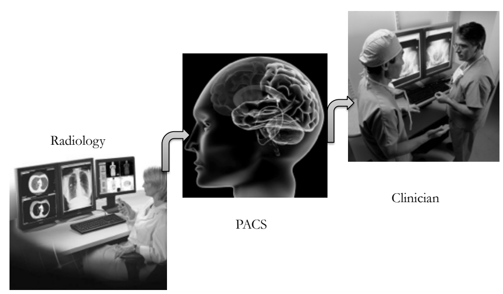
Source: www.medicalimagingtalk.com

Benefit of PACS: Workflow



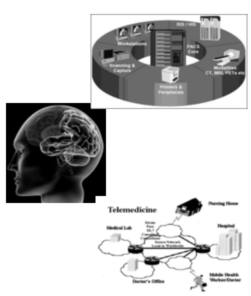
Source: Philips

Benefit of PACS: Real-time clinical consultation

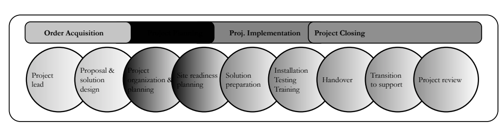


How to get start?

- Set up project management team
- Project planning and execution
- Training



Project Management Methodology
Roadmap to Guaranteed SUCCESS

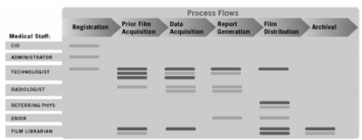


SUCCESS

Source: Philips

Project Organization and Planning

- Workflow analysis prior to installing system
- Facilitate efficiency analysis
- Integration strategies – best practices
- Re-visit workflow analysis post-installation



Source: Philips

Training

- On-site and web-based, role-specific workflow training
- Comprehensive training for application administrators
- Ongoing training and support for software updates

Source: Philips

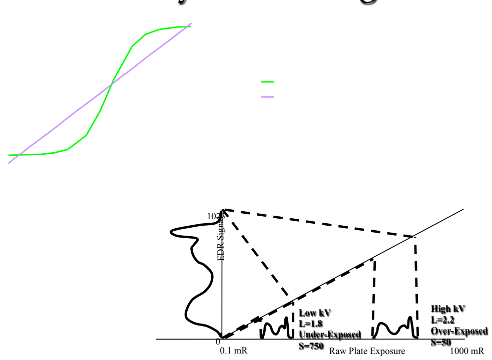
Digital Imaging Modalities

- Digital ready modalities
  - CT
  - MRI
  - NM
- Digital required modality
  - Plain Flim

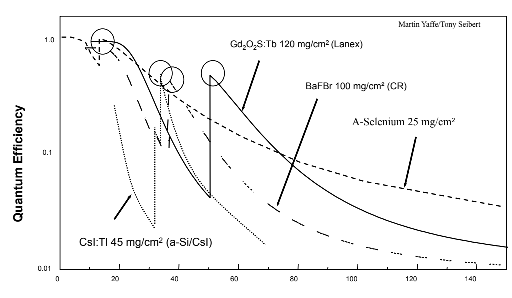
From screen/film to DR

- **Images from analog to digital…**
  - **Image viewing, transferring and archiving**
  - **Digital image processing**
- **Factors affecting techniques:**
  - **Dynamic range**
  - **Detector energy response**
  - **Detector efficiency**

Wide Dynamic Range



Detector energy sensitivity



Wide dynamic range

-
  -
    -
  - (signal-to-noise ratio improves)
    -
    - *High patient dose!*
- Wide dynamic range can lead to higher patient dose

Detector energy response and efficiency

- **Optimal beam quality could be different**
  - **kVp**
  - **Filtration**
  - **Also consider contrast and patient dose**
- **Optimal beam quantity (mAs) could be different**
  - **AEC calibration or manual techniques**
  - **Patient dose (kV dependant)**

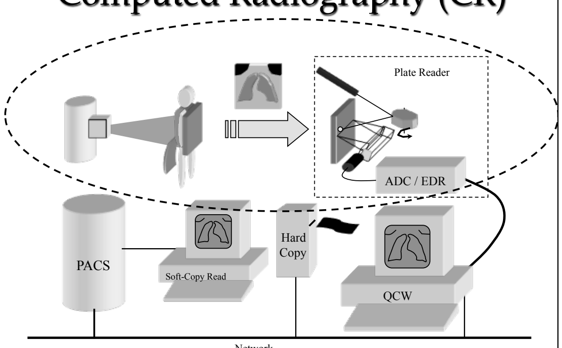
DR: Acquisition Technology

- **Photostimulable Phosphors ("CR" or "PSP")**
  - **Photostimulable phosphor plates**
- **Flat-panel Detectors**
  - **Direct DR (DDR): Amorphous Selenium Detector – matrix of transistors, without photon conversion layer**
  - **Indirect DR (IDR): Amorphous Silicon TFT or CCD with CsI conversion layer**

Sometimes definitions are like …

- **CR= Computed Radiography**
  - ***any imaging system that utilizes photostimulable phosphor (PSP)***
- **DDR=Direct Digital Radiography**
  - ***any imaging system that produces the radiographic image without a latent image, including those that depend on fluorescent intensification screens***
- **DR=Digital Radiography**
  - ***any imaging system that produces a radiographic image as a digital file without photographic film***
  - ***includes CR and DDR***
  - ***excludes film digitizers***

Computed Radiography (CR)



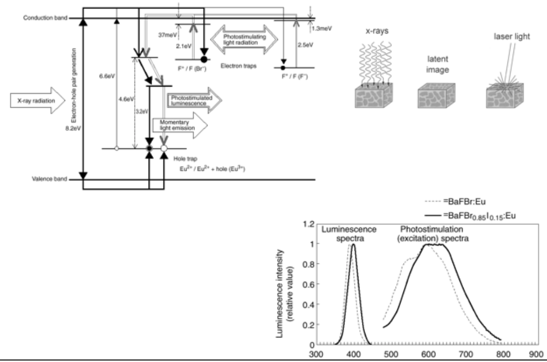
CR is based on the physical process of photostimulable luminescence (PSL)

- **X-rays contribute energy to the electrons by the photoelectric effect**
- **Electrons can give up energy (violet light)…**
  - ***by emitting light immediately (fluorescence)***
  - ***by emitting light slowly (phosphorescence)***
- **Some electrons can retain *(store)* their energy**
  - ***crystal defects can "trap" excited electrons***
  - ***electrons can escape the traps when exposed to the proper wavelength (red) light (photo-stimulated luminescence)***
  - ***electrons can also escape by thermal mechanisms***

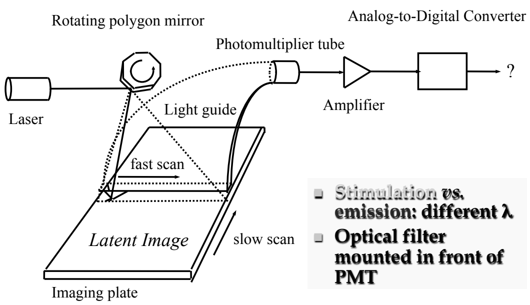
Materials that exhibit PSL are called photostimulable phosphors (PSP)

- **PSPs currently in use for CR are crystals of alkaline earth and halides "doped" with Eu**
  - **$BaFBr:Eu^{+2}$ =>** *Fuji ST – STIIIA, Kodak?*
  - **$BaFBr_{0.85}I_{0.15}:Eu^{+2}$ =>** *Fuji STV - STVI*
  - **$Ba_{0.86}Sr_{0.14}F_{1.10}Br_{0.84}I_{0.06}:Eu^{+2}$ =>** *Agfa*
  - **$BaFBr_{0.8}I_{0.2}:Eu^{+2}$ =>** *Konica (early)*
  - **$BaFI:Eu^{+2}$ =>** *Konica (current)*
  - **RuBr:Tl =>** *Konica (ancient)*

Photostimulable Luminescence

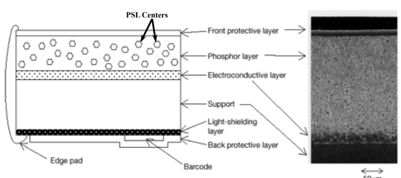


Development and Digitization of the CR latent image

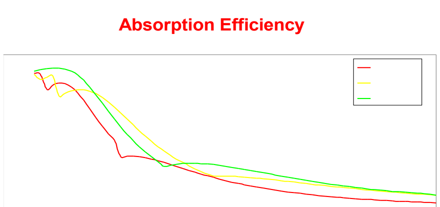


- **Stimulation *vs.* emission: different λ**
- **Optical filter mounted in front of PMT**

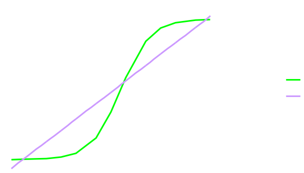
Plate Structure



X-ray absorption by PSP is different from most intensification screens



PSL increases linearly with x-ray exposure (log)



- **Wider dynamic range: *e.g.* good for portable exams**
- **Same contrast w/ over- and under- exposures, but different noise and patient dose**

Sources of unsharpness in CR

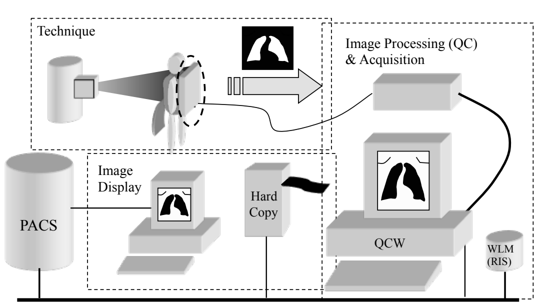
- **Finite dimensions of x-ray focal spot**
- **Finite dimensions of pixel**
- **Spreading of laser beam in PSP**
  - ***Thicker PSP is worse***
- **Spreading of PSL in PSP**
- **Duration of PSL**
  - ***PSL is not instantaneous***
  - ***"Afterglow" in fast scan dimension***
- **Mechanical imprecision in slow-scan dimension**

Sources of noise in CR

- **Finite dimensions of pixel**
  - ***Fewer x-rays contribute to small pixels***
  - ***"Quantum noise" worse for fewer x-rays***
- **"Structure noise"**
  - ***Granularity of the PSP***
- **Quantum noise of PSL**
- **Optical noise** *(stimulation and collection)*
- **Electronic noise (***PMT and amplifier)*
- **Quantization noise** *(ADC)*

minor ↓

Flat Panel System

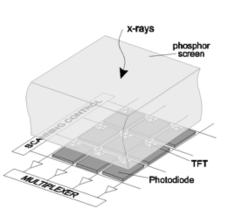


Flat Panel System

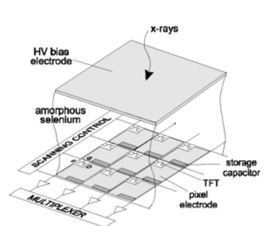
- **Direct x-ray detection (DDR)**
  - **Photoconductor (a-Se) on top of TFT array**
  - **X-rays interact with photon sensors directly**
  - **After exposure, e's are generated and migrated through the Se layer (+) to the TFT layer for readout**
- **Indirect x-ray detection (IDR)**
  - **X-rays interact with an intensifying screen, and secondary photons interact with sensors (a-Si TFT or CCD)**
  - **The screen causes more blurring**
  - **CsI is more commonly used to improve spatial resolution.**

Unlike CR, no mechanical readout process is involved (self-reading)

DR Detector Configurations

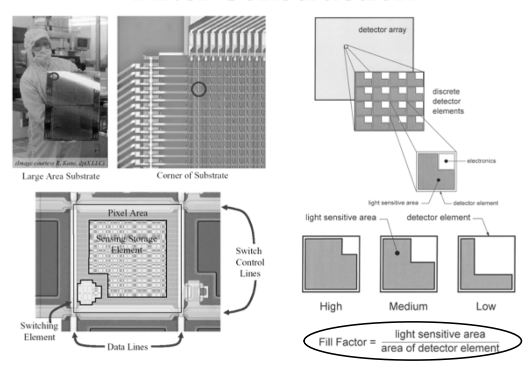


Indirect DR

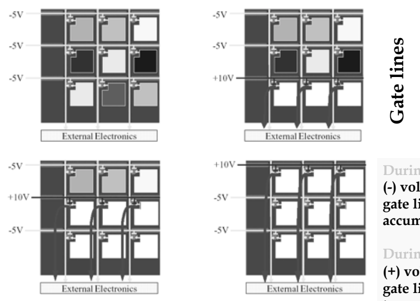


Direct DR

Pixel Construction



TFT Readout

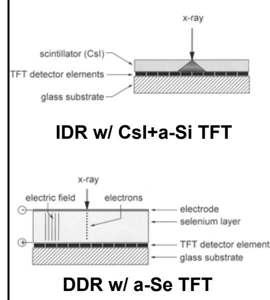


During exposure:
(-) voltage applied to gate lines (charge accumulated)

During readout:
(+) voltage applied to gate lines (so transistor turned on), one gate line at a time.

Readout lines

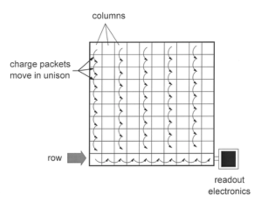
Flat Panel Detectors



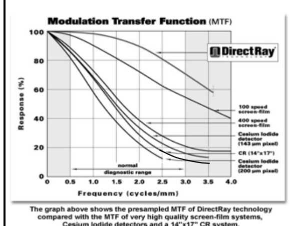
- For IDR, scintillator causes blurring.
- No blurring in Se due to the E- field
- For Se detector, E-field can be designed to direct the e's to sensitive areas of TFT, i.e. increasing effective filling factor
- For DDR, spatial resolution is only limited by element dimension.
- Although Se (34) has higher Z than Si (14), it's still much lower than Gd (64) and Cs (55). Therefore Se layer is made thicker to compensate the low attenuation coeff. (no need to worry about lateral spread)

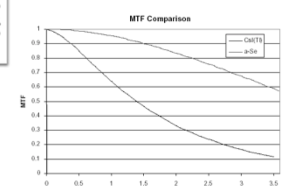
Charged-Coupled Devices

- Convert visible light to form images
- CCD chip = integrated circuit made of silicon, w/ discrete pixel electronics etched into surface
  - Ex. 2.5 x 2.5 cm CCD chip may have 1024 x 1024 or 2048 x 2048 pixels
  - Electrons are liberated after visible light exposure and kept in each pixel because there are electronic barriers (voltage) on each side during exposure.
  - After exposure, charges move down by togging voltages between rows and read out at the last row.

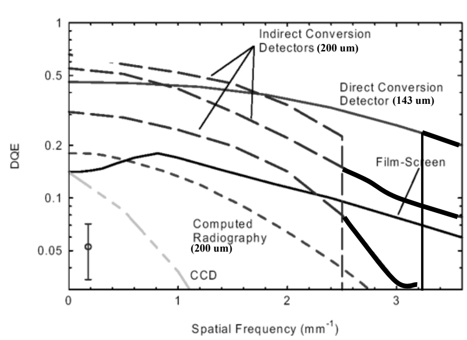


MTF of DR

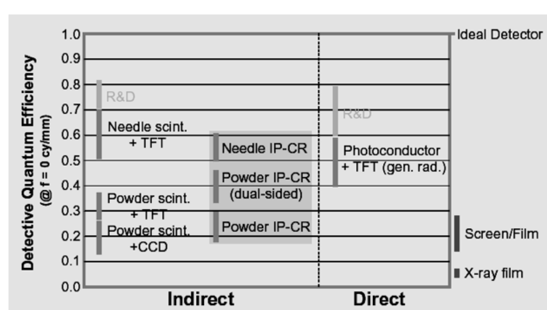




DQE of DR



DQE of DR



Conclusions

- Digital radiography is different from conventional screen/ film system in dynamic range, detector response and the form of images.
- A digital image is a matrix of digits with physical pixel dimensions and gray-level depth.
- DR technologies include direct and indirect systems for x-ray detection, and the indirect systems include PSP and flat-panel detectors.
- Due to different natures of various DR technologies, radiographic techniques may need to modified for different systems.