# An Overview of Digital Imaging Systems for Radiography and Fluoroscopy

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# Outline

- Introduction
- Imaging Considerations
- Receptor Properties
- General Classification and Description of Systems
- System Considerations
- Conclusion

# Introduction

- Starting Specific Technical presentations
- Presentations on Imaging characteristics involved a number of factors; serve as a basis for comparing systems
- Specifics covered in the following section
- General considerations that apply to all DR systems
- Illustrate points to consider as the specifics are given

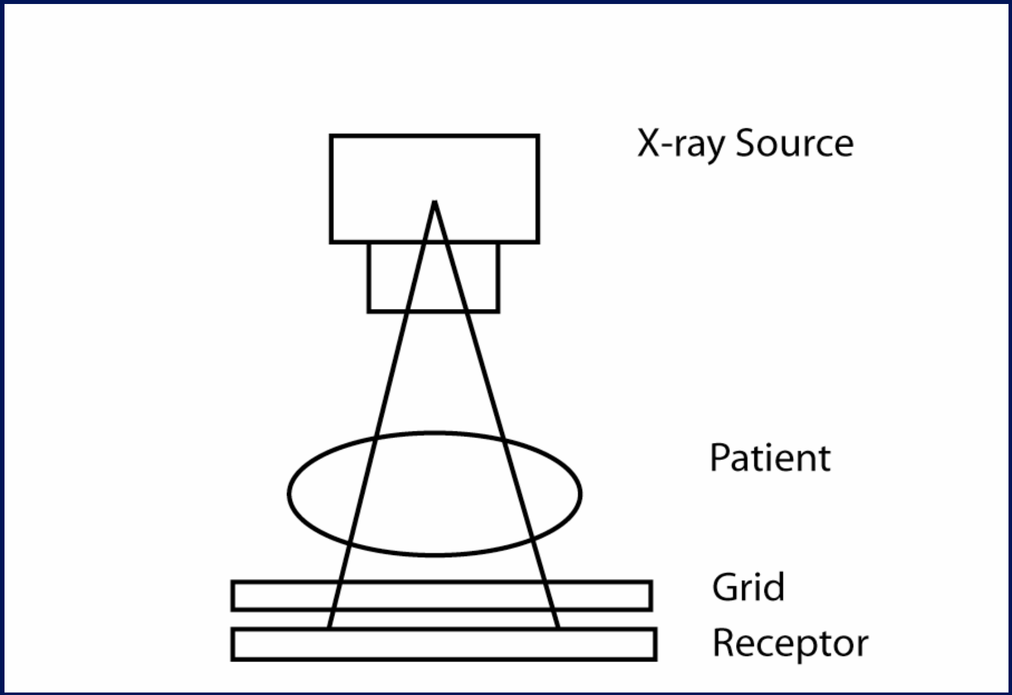
# Fluoroscopy

- Fluoroscopy is expected to remain in its current state for some time, and employment of flat panel digital receptors is expected to lag
- There are some fundamental issues and the big push is in angiography
- Rest of talk will concentrate on Digital Radiography

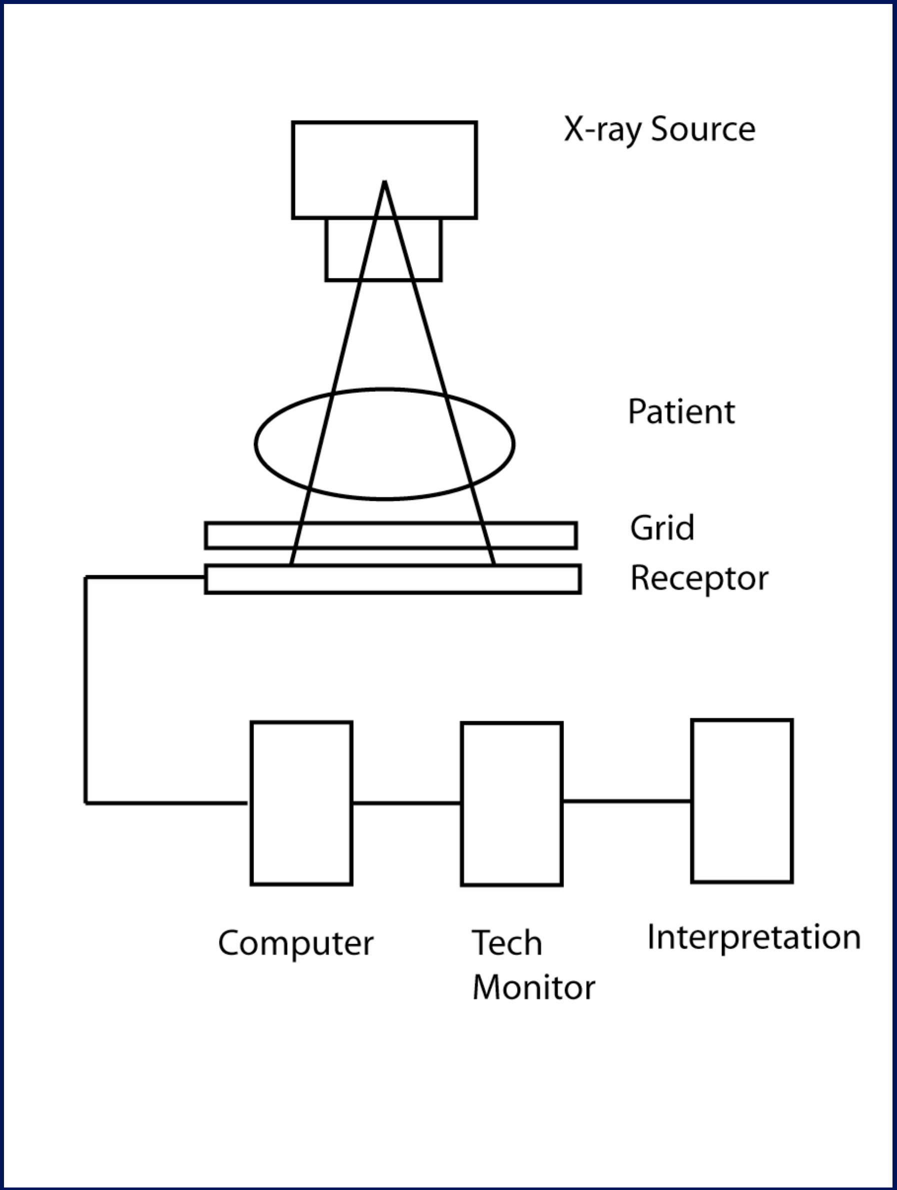
# Digital Radiography

- **Consideration of the image flow will illustrate the important considerations relating to discussions of DR**

# General Schematic



# With DR



X-ray Source
Patient
Grid
Receptor
Computer
Tech
Monitor
Interpretation

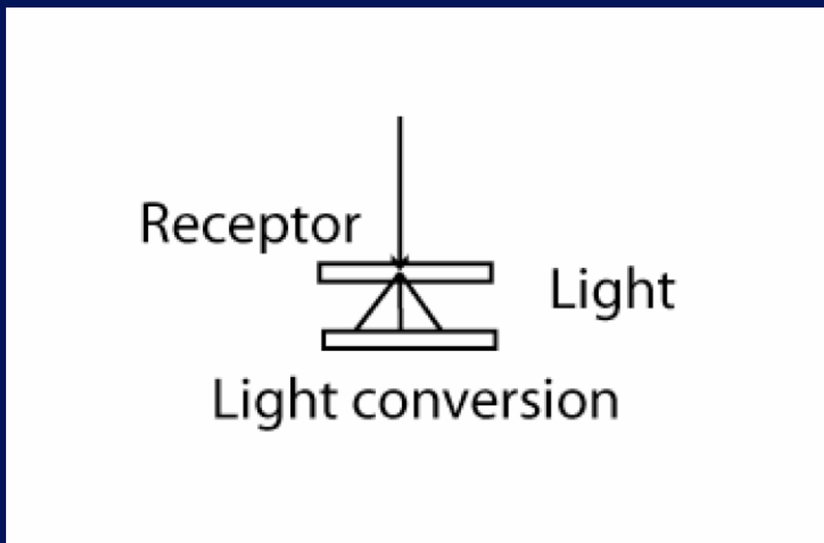
# System for DR

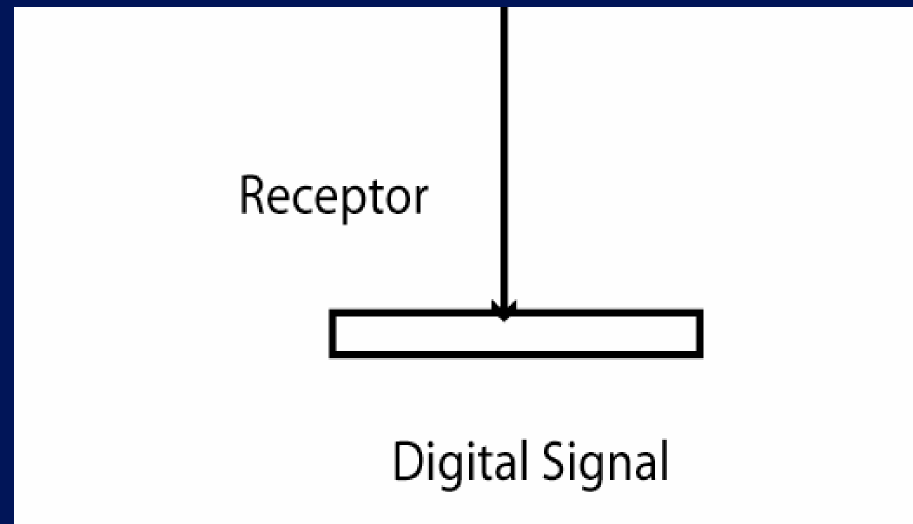
- The main change in DR systems is in the receptor
- System characteristics then become related to the receptor
- System => workflow
  - issues are related to the receptor in different ways

# Important considerations

- Receptor
  - Type
  - Imaging characteristics
  - Related parameters
- System
  - Given receptor may affect system integration
- Dose
- Testing and Quality Control

# General Classification of Receptors




**Indirect**

**X-ray to light to digital**

**Direct**

**X-ray to digital**

# Specific Parameters of Interest

First considerations of a receptor will involve

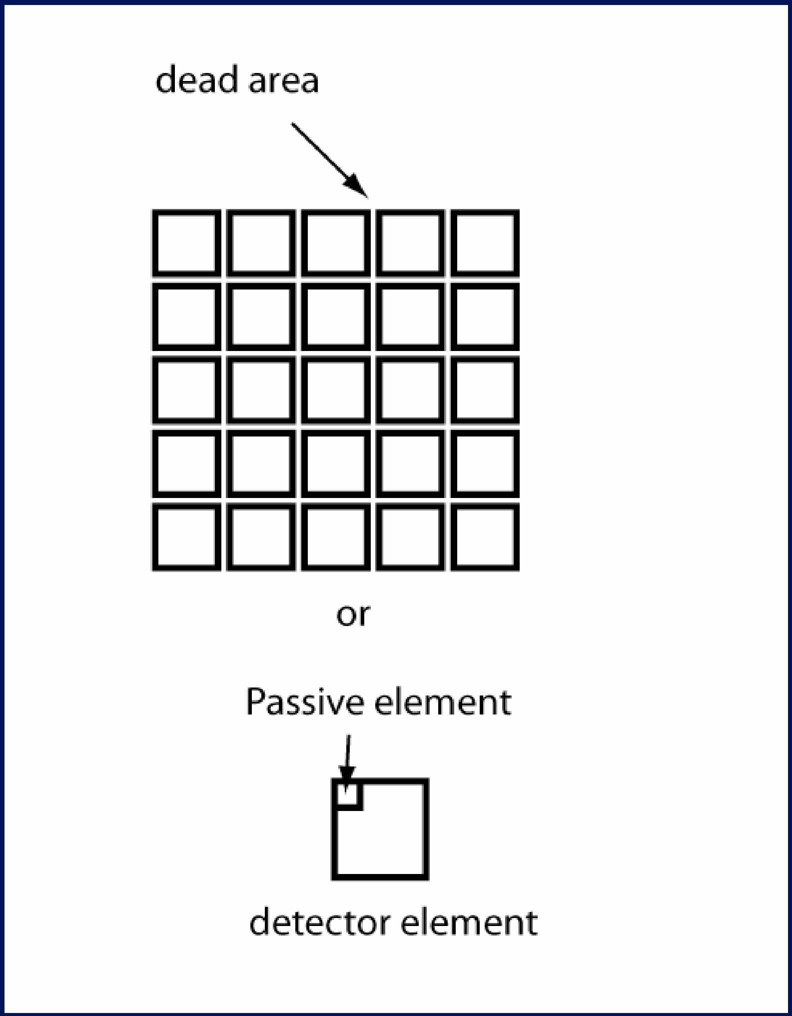
- Spatial resolution
  - MTF
- Contrast
  - CNR
- Dose Efficiency
  - DQE

# Receptor Properties

- Fill factor
  - Percentage of detector area that is active
- x-ray absorption efficiency
  - Material properties
- Dark noise
  - Signal without radiation
- Uniformity
  - Pixel response and readout, receptor response, tiling
- Readout issues

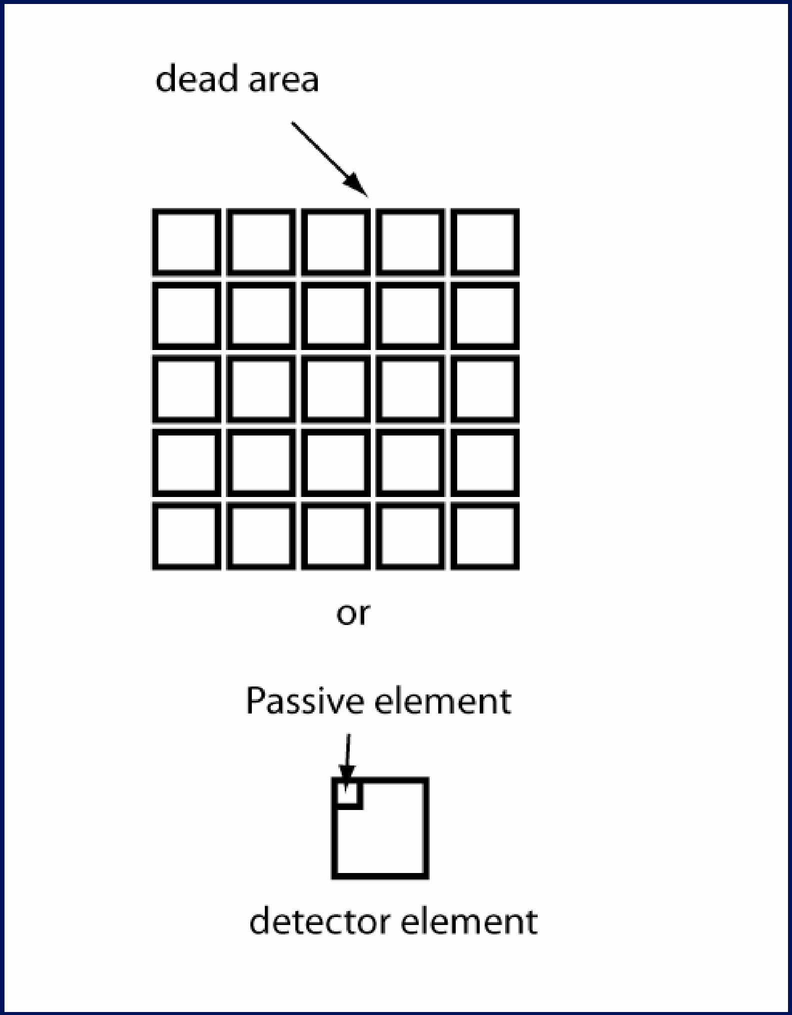
# Fill Factor

- There can be a dead zone between elements
- there can be an area that is part of an element that is not active



# Spatial Resolution

- Related to pixel size
- Pixel size related to detector elements
- Fill factor can be a factor
  - dead or passive element size in general is fixed, so as pixel size decreases ratio of dead area to active area increases
- Resolution and efficiency can be related



# Absorption

- Z and density are factors
- K-absorption edge
- Crystalline properties
  - Powder versus “needles”
  - Thickness -- which will relate also to spatial resolution
- For indirect type of receptor, light emission spectrum can be important
- Direct effect on DQE

# Electronic Noise

- Dark noise contribution
- Signal present in absence of radiation
- Signal subtracted out from raw image, but contributes to total system noise

# Uniformity

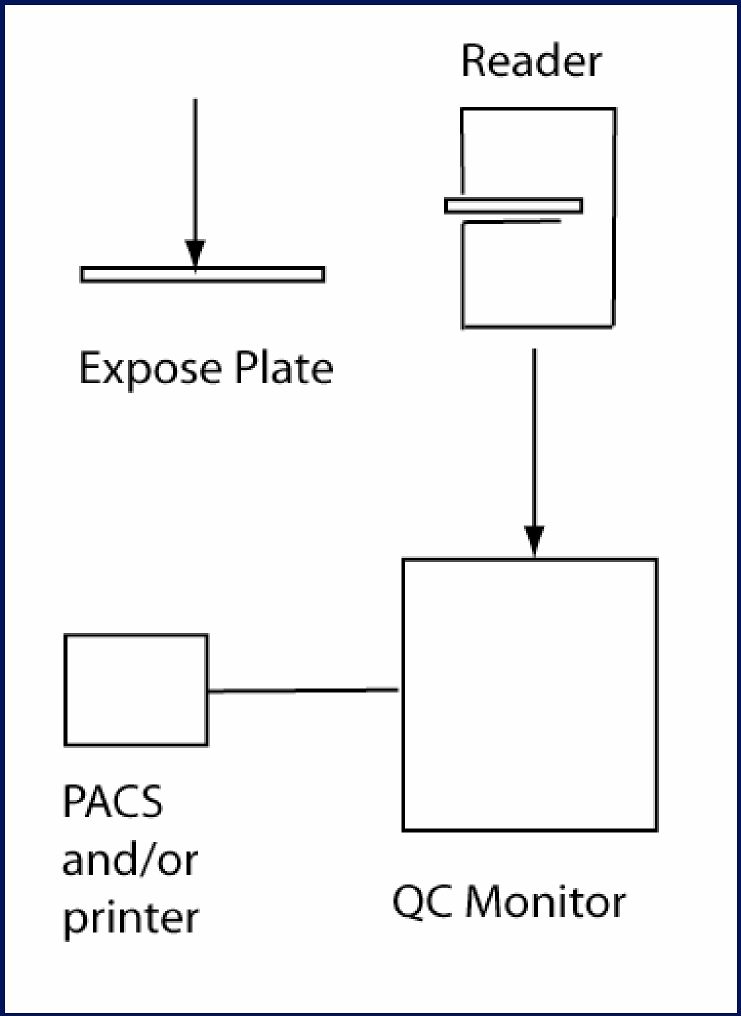
- Natural uniformity of the material and non-uniformity of response
- Readout -- amplifier gain
- Tiling
- Uniformity may be a function of kVp
- Dead pixels
- Corrections can be made but add to overall system noise

# Classifications of Detector Systems

- CR
- CCD
- Flat Panel

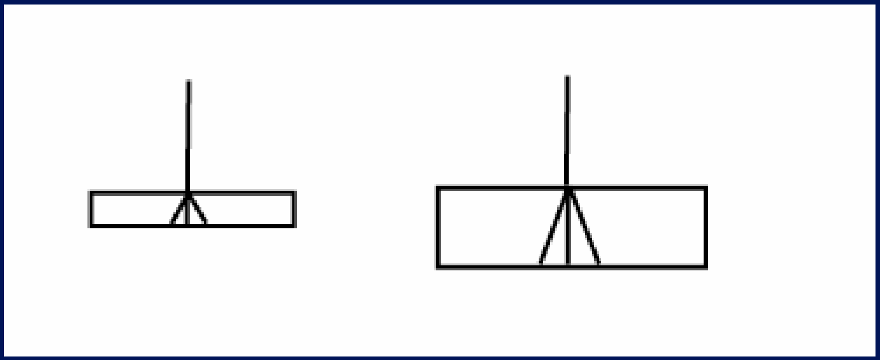
# CR

- Flexible imaging plates using photostimulable phosphors
- Direct replacement for film
- Cost effective means for digital imaging



# CR

- Entire plate is active
- X-ray absorption limited by material
  - (Barium)
- Plate consists of powder + binder
  - thickness, spatial resolution issue
- Uniformity
  - consistency of powder layer
  - readout
  - mechanical forces

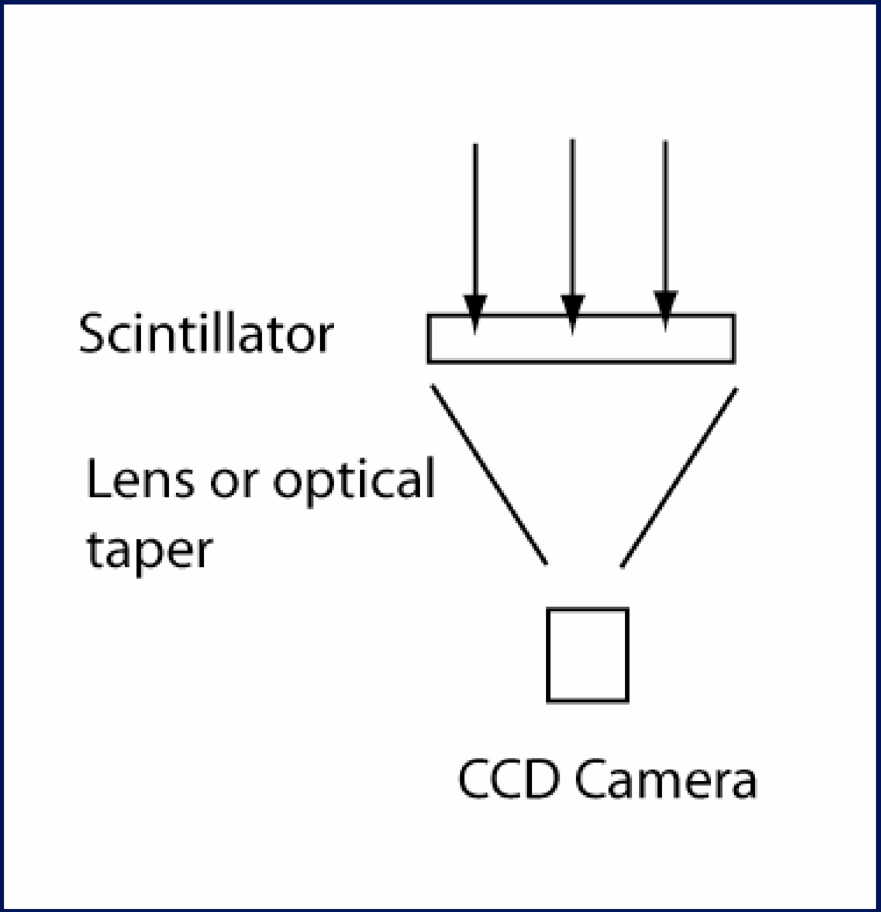


# CR Issues

- Especially valuable for portable x-ray work
- Efficiency of operation (like film)
  - There are integrated CR systems (x-ray system plus reader) but adds to expense
- Low DQE
- Work ongoing on different phosphors

# CCD based systems

- Indirect type of digital system
- CCD familiar from use in digital cameras
- CCD chip size of the order of 5 cm x 5 cm maximum
- Readout is "bucket brigade"



# CCD

- **Typical CCD cameras operate in array mode (full frame)**
- **Entire area is active**
- **Uniformity**
  - **pixel defects, response over the surface, and optics issues**
- **Dark current has to be accounted for**

# CCD Issues

- Size is a major issue
  - Demagnification reduces detection efficiency (loss in light transfer)
  - Can tile CCDs to form a larger imaging area with subsequent uniformity issues
  - DQE higher than CR, CsI commonly used as scintillator
- Modularity -- can change out camera and upgrade systems
- Note:  CMOS based systems are used in some instances, similar issues as with CCD

# Flat Panel + TFT

- Detector system as a unit in place of Bucky
- Scintillator in contact with thin film transistor array (Indirect), or
- Direct -- electron-hole pairs created in receptor (selenium), readout with TFT array
- High DQE

# Flat Panel

- Uniformity -- dead pixels, scintillator or receptor uniformity, pixel gain
- Absorption efficiency
  - Indirect -- CsI common, relatively high efficiency
  - Direct -- selenium less efficient, especially at higher kVps
- Spatial resolution -- primarily dominated by sampling and fill factor
- Readout -- has to be reset before next exposure, selenium has been somewhat more difficult to work with

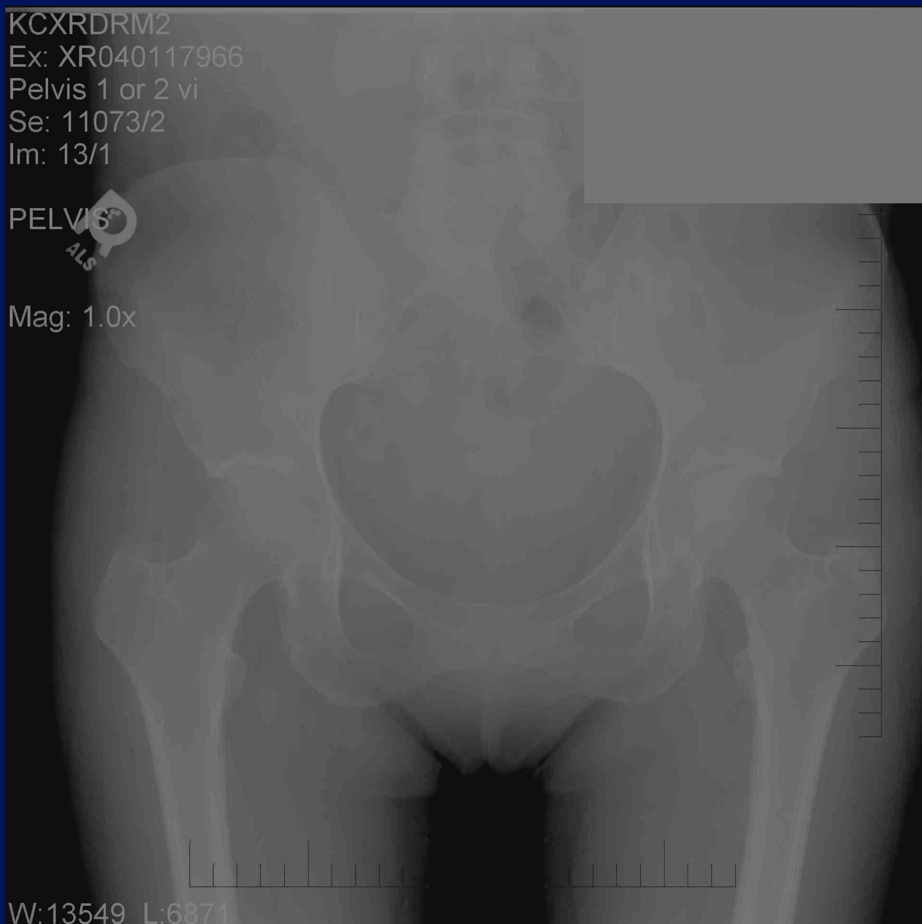
# Flat Panel Issues

- Expensive -- integrated module
- Large field-of-view
- Ghosting -- residual image

# Systems

- Image formed by the devices discussed are initially in raw format
- Apply processing
  - Flat-field correction
  - Dark current correction
  - Mapping of digital to display values (contrast)
  - Edge enhancement
  - Final window/level set

# Example


KCXRDRM2
Ex: XR040117966
Pelvis 1 or 2 vi
Se: 11073/2
Im: 13/1
PELVIS
ALS
Mag: 1.0x
W:13549 L:6871


KCXRDRM2
Ex: XR040117966
Pelvis 1 or 2 vi
Se: 11074/2
Im: 13/1
Mag: 1.0x
ALS
W:2072 L:5326

# System Issues

- Processing takes some time
- Added work for technologist
- But retake for image density no longer a problem
  - Note: poor radiographic technique (kVp) can not be overcome to create perfect image
- Big issue relates to time required for Radiologist interpretation

# Workflow

- Thus necessary to optimize processing parameters for each different exam so that image is readily viewable by the radiologist
- Order of exams taken matched to PACS or with appropriate identifiers for “hanging protocols”
- (Remember the gold standard is a motorized multi-viewer with films pre-loaded by an assistant)
- Also Radiologists want images to look like film

# Workflow

- **PACS becomes a major consideration**
  - **Dicom Worklist**
  - **send**
  - **archive**

# Systems and Workflow

- CR has a major advantage of being used for all views that may be desired (obliques, laterals, etc.)
  - But, CR does require a number of steps like film
- For DR system integration can be more problematical

# DR Configuration

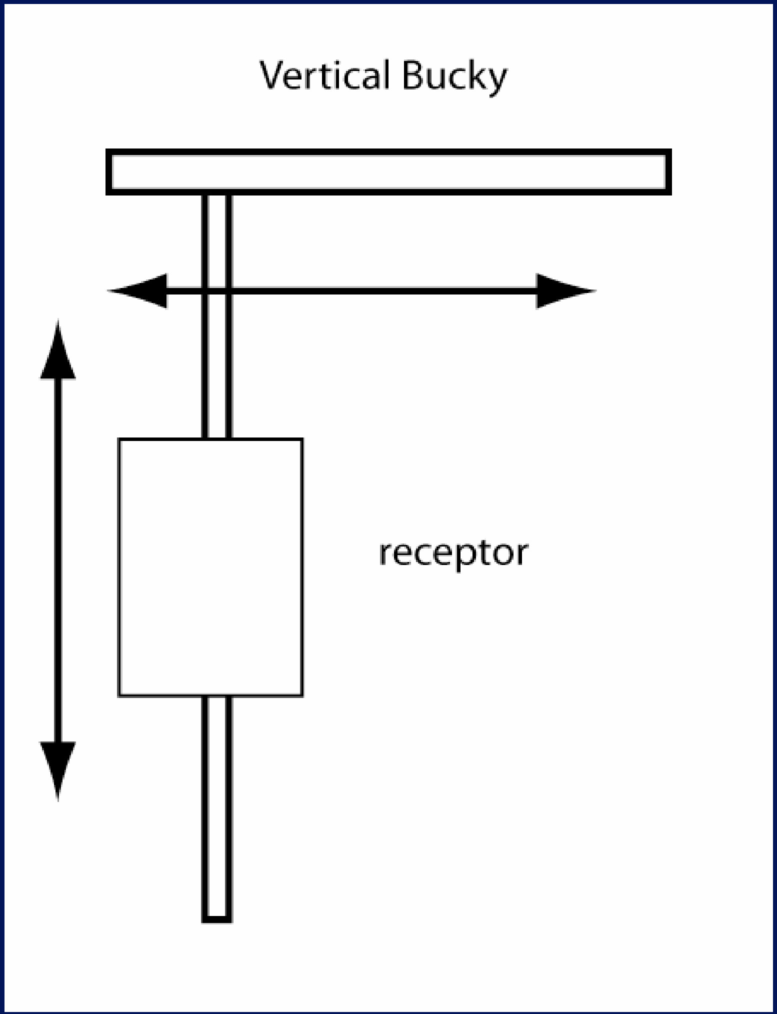
- A standard configuration may be a table Bucky and a wall Bucky, but then this will dramatically increase the expense of the system (two digital receptors)
- In addition, cross table laterals would imply CR

# DR System Designs

- Use of CR with DR will in general impede workflow
  - have to register a patient, select the exam on a different system
- Philips offers an integration of its CR with a fixed table based DR
- In this manner patient registration is performed only once
- Other systems may permit integration of CR images into DR system

# Variation of Traditional two detector system

- Quantum Medical + CMT
- Two plates
  - Table Bucky
  - Vertical Bucky
- but wall Bucky on a track and can be moved to position for cross table lateral lateral
- Vertical Bucky can perform upright and sitting views (horizontal)

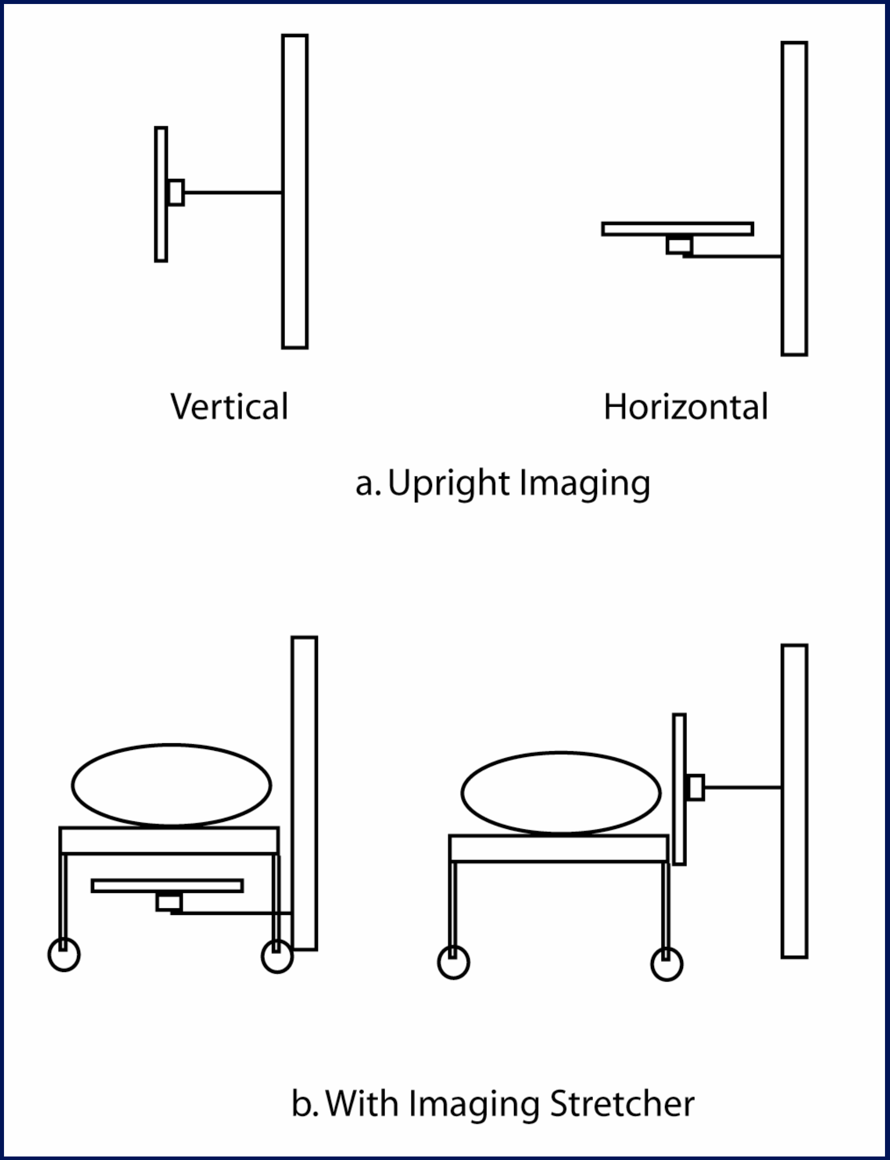


# Other System Designs

- Single plate system capable of multiple motions
- Several different flavors
  - Fixed table and fixed column with articulating arms
  - vertical work, table work (AP, lateral)
  - Fixed table articulating arms and receptor on a track
  - Moving stretcher and flat panel on a rotating arm
  - Computerized gantry, position anywhere within an area

# System Design Example

- Moving stretcher and rotating plate
- Upright and table views
- Moving stretcher not favored by some technologists



# System Design

- Canon has tethered flat panel
- Robustly constructed plate with cable attached to electronics
- Placed in table Bucky, or
- Placed in lateral cassette holder, or
- Placed in vertical Bucky

# System Configuration

- Obviously different solutions
- Different factors
  - Cost
  - Table (moving or fixed)
  - Ease of positioning
  - Work environment (general or ER)

# Patient Dose

- AEC still employed
- CR -- will need to consider photocell setting and processing to account for lower efficiency of CR
- Vendors may calibrate system in terms of Speed relative to film/screen combination
  - Note: This may not match the speed of the system you have been using
- Conventional AEC vs using area of digital detector itself

# Patient Dose

- What is a proper exposure?
- Noise is an issue
- No longer have a density reference due to large dynamic range of digital receptors

# Patient Dose

- Dose Index?
- CR -- each manufacturer has a different index that is calculated for each exposure
  - Keep within a defined range and theoretically will have proper exposure and an acceptable dose
  - Values printed on film
- DR -- relative exists and can be incorporated into DICOM Header, not generally displayed
- Histogram may be available showing digital range, but may not be easily viewable

# Patient Dose

- **Dose will be quite dependent on efficiency of detector system and processing**
- **Dose Creep can occur easily**
  - **Dose creep -- exposure may creep to a higher level without notice (no optical density reference)**
  - **Note: lower dose would be evident by noise level**

# Quality Control

- Previously QC involved processor, film storage, changes in emulsion or chemistry
- Digital system adds different complexity
  - Uniformity
  - Spatial resolution
  - Contrast
  - Dynamic range (noise)
- Acceptance testing will incorporate the above in greater detail as well as initial setup of processing and doses

# Quality Control -- CR

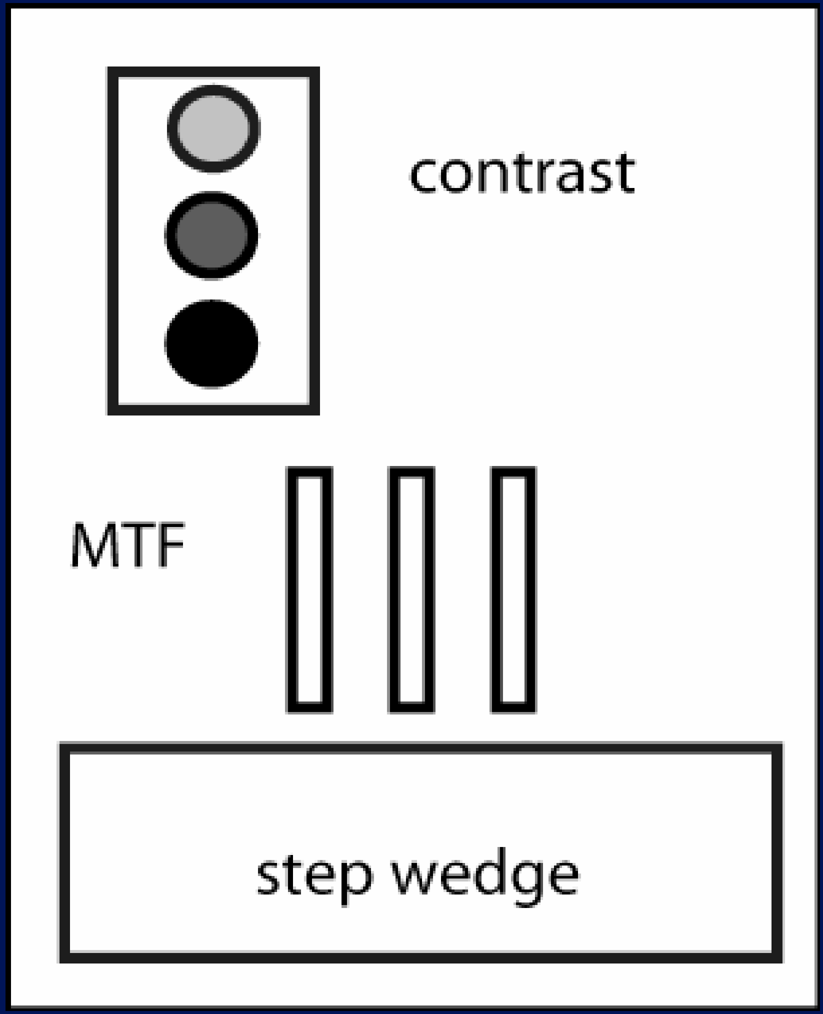
- Uniform sensitivity of plates
- Plate uniformity (wear and tear)
- Resolution (proper operation of reader)
- Standard readout across different readers

# Quality Control (DR)

- Uniformity -- dead pixels
- Contrast/Noise
- Spatial resolution
- Since all of the above depend on the receptor, need to monitor for possible changes

# Routine QC Example

- Simple Phantom
- GE and others have a phantom that is used
- Acquire an image with a set block of Aluminum
  - Uniformity
- Acquire image of phantom that slips into the grid slot
- Number of objects to test the system
- Pass/fail report



# QC Display Monitor

- Technologists monitor needs to be calibrated to similar display characteristics as PACS
- Difficult to do as tech monitors are of lower quality

# Conclusion

- Availability of digital radiography will only increase
- Due to expense, configuration important
- Maintaining high quality and workflow efficiency brings new challenges
- Details to be covered in next set of presentations