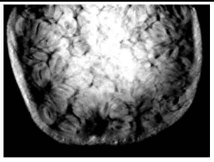
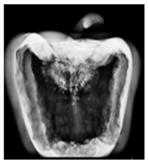
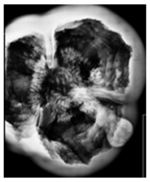





Digital Breast Tomosynthesis (DBT)

Advanced Health Education Center
www.aheconline.com

Deborah Thames, BSRS R.T.(R)(M)(QM)

About me

- Work full time at a cancer hospital in Houston, Texas, born in South Dakota
- Done X-rays/Mammography for 23 years
- Taught classes for AHEC for 16 years
- Believe to always improve yourself through education and trying something new.

Please turn off all cell phones and pagers And be kind to your neighbor and not talk outLoud in class-



You can get up and use the restroom anytime but be discreet please

References and Resources:

- Digital Breast Tomosynthesis Presenter Training-Hologic-Bedford, MA October 6-7, 2011
- FDA Executive Summary-September 24, 2010
- Selenia Dimensions Quality Control Manual-MAN-01116
- Design Considerations in Optimizing a Breast Tomosynthesis System-Andrew Smith, Ph.D-Imaging Science-Hologic
- Fundamentals of Breast Tomosynthesis-Improving the Performance of Mammography-Andrew Smith, Ph.D.-Imaging Science-Hologic
- Three-Dimensional Digital Breast Tomosynthesis: An Introduction
- Peninsula MRI, Ultrasound/Mammography-San Mateo, CA
- TOPS Comprehensive Breast Center
- GE training on line and white papers
- Siemens white papers
- M.D. Anderson Cancer Center

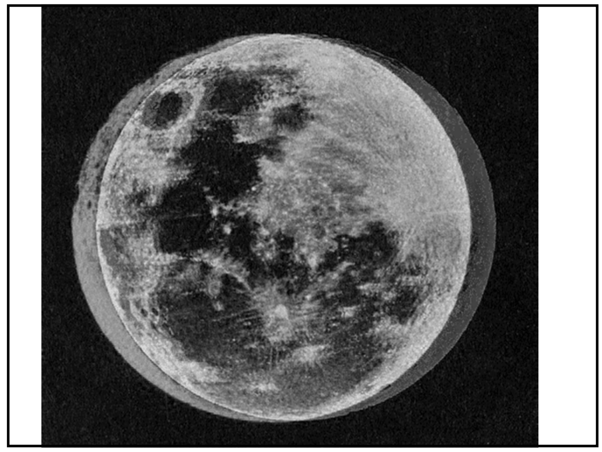
June 2016 DBT stats for first time

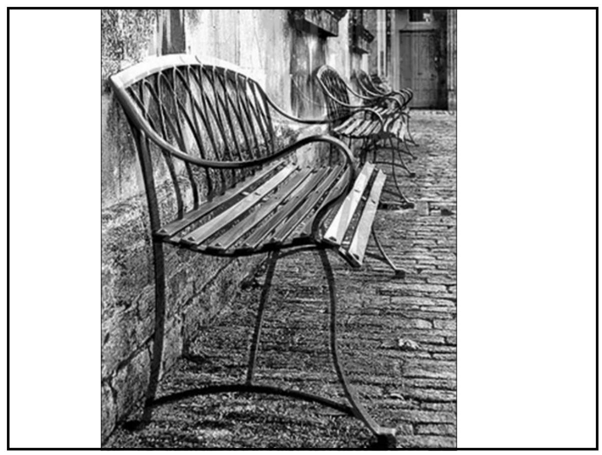
Certified facilities, as of October 1, 2015	8,737
Certification statistics, as of June 1, 2016	
Total certified facilities / Total accredited units	8,740 / 16,155
Certified facilities with FFDM[2] units / Accredited FFDM units	8,506 / 12,508
Certified facilities with DBT[3] units / Accredited DBT units	2,444 / 3,362
FY2016 inspection statistics, as of June 1, 2016	
Facilities inspected	5,271
Total units at inspected facilities	9,257
Percent of inspections where the highest noncompliance was a:	
Level 1 violation	0.6%
Level 2 violation	7.8%
Level 3 violation	3.6%
Percent of inspections with no violation	88%
Total annual mammography procedures reported, as of June 1, 2016[1]	39,298,731

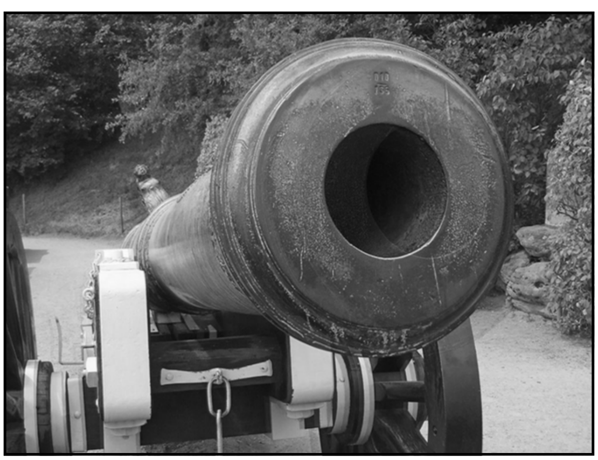
94 F/S

Certified facilities, as of October 1, 2017	8,726
Certification statistics, as of October 1, 2018	
Total certified facilities / Total accredited units	8,704 / 19,564
Certified facilities with digital units[2] / Accredited digital units	8,649 / 12,858
Certified facilities with DBT[3,4] units / Accredited DBT units	4,708 / 6,635
FY 2019 inspection statistics, as of October 1, 2018	
Facilities inspected	8,477
Total units at inspected facilities	17,822
Percent of inspections where the highest noncompliance was a:	
Level 1 violation	.8%
Level 2 violation	15.2%
Percent of inspections with no violation	84%
Total annual mammography procedures reported, as of October 1, 2018[1]	39,265,435

November 2003	
Certified facilities, as of October 1, 2003	9,114
Certified statistics as of November 1, 2003	
Total certified facilities / Total accredited units	9,123 / 13,632
Certified facilities with FFDM[2] units / Accredited FFDM units	339 / 448
FY 2004 Inspection Statistics, as of November 1, 2003	
Facilities inspected	652
Total units at inspected facilities	974
Percent of inspections where the highest noncompliance was a:	
Level 1 violation	2.4%
Level 2 violation	21.4%
Level 3 violation	9.8%
Percent of inspections with no violation	66.4%
Total annual mammography procedures reported, as of November 1, 2003[1]	31,001,447







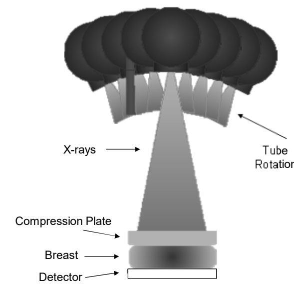
Breast tomosynthesis goes by a number of names in the radiology and general press. Digital breast tomosynthesis (DBT), 3D mammography, 3D breast tomosynthesis, 3D tomosynthesis, tomosynthesis, and tomo are all used.

- Hologic Selenia Genius 6/2017
- Ge Senographe Pristina 3D approved 3/2017
- Fujifilm Cristalle 3D approved 1/2017
- Siemens Mammomat Fusion on 09/14/15
- Siemens Mammomat Inspiration with Tomosynthesis Option (DBT) System on 4/21/15
- GE SenoClaire Digital Breast Tomosynthesis (DBT) System on 8/26/14
- Fuji Aspire Cristalle Full-Field Digital Mammography (FFDM) System on 03/25/14
- Siemens Mammomat Inspiration Prime Full-Field Digital Mammography (FFDM) System on 06/11/13
- iCRco 3600M Mammography Computed Radiography (CR) System on 04/26/13
- Philips MicroDose SI Model L50 Full-Field Digital Mammography (FFDM) System on 02/01/13
- Fuji Aspire HD Plus Full-Field Digital Mammography (FFDM) System on 09/21/12
- Fuji Aspire HD-s Full-Field Digital Mammography (FFDM) System on 09/21/12

Carestream Direct-view Computed Radiography (CR) Mammography System on 11/3/10
Hologic Selenia Dimensions 2D Full Field Digital Mammography (FFDM) System on 2/11/09
Hologic Selenia S Full Field Digital Mammography (FFDM) System on 2/11/09
Siemens Mammomat Novation S Full Field Digital Mammography (FFDM) System on 2/11/09
Hologic Selenia Full Field Digital Mammography (FFDM) System with a Tungsten target in 11/2007
Fuji Computed Radiography Mammography Suite (FCRMS) on 07/10/06
GE Senographe Essential Full Field Digital Mammography (FFDM) System on 04/11/06
Siemens Mammomat Novation DR Full Field Digital Mammography (FFDM) System on 08/20/04
GE Senographe DS Full Field Digital Mammography (FFDM) System on 02/19/04
Lorad/Hologic Selenia Full Field Digital Mammography (FFDM) System on 10/2/02
Lorad Digital Breast Imager Full Field Digital Mammography (FFDM) System on 03/15/02
Fischer Imaging SenoScan Full Field Digital Mammography (FFDM) System on 09/25/01
GE Senographe 2000D Full Field Digital Mammography (FFDM) System on 01/28/00

3D Breast Tomosynthesis

Tomographic Imaging

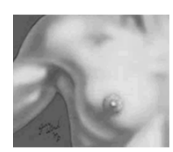


October 2011

Hologic Proprietary Information for Training Purposes Only PRE-00109

Konica Minolta Xpress Digital Mammography Computed Radiography (CR) System on 12/23/11
Agfa Computed Radiography (CR) Mammography System on 12/22/11
Fuji Aspire Computed Radiography for Mammography (CRM) System on 12/8/11
Giotto Image 3D-3DL Full-Field Digital Mammography (FFDM) System on 10/27/11
Fuji Aspire HD Full-Field Digital Mammography (FFDM) System on 9/1/11
GE Senographe Care Full-Field Digital Mammography (FFDM) System on 10/7/11
Planmed Nuance Excel Full-Field Digital Mammography (FFDM) System on 9/23/11
Planmed Nuance Full-Field Digital Mammography (FFDM) System on 9/23/11
Siemens Mammomat Inspiration Pure Full-Field Digital Mammography (FFDM) System on 8/16/11
Hologic Selenia Encore Full-Field Digital Mammography (FFDM) System on 6/15/11
Philips (Sectra) MicroDose L30 Full-Field Digital Mammography (FFDM) System on 4/28/11
Hologic Selenia Dimensions Digital Breast Tomosynthesis (DBT) System on 2/11/11
Siemens Mammomat Inspiration Full Field Digital Mammography (FFDM) System on 2/11/11

Breast Cancer Fact



1 in 8

This is the lifetime risk of a woman in the United States of developing breast cancer

There is no way to prevent breast cancer…

American Cancer Society 2010

October 2011

Hologic Proprietary Information for Training Purposes Only PRE-00109

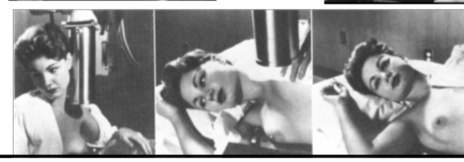
Breast Cancer Fact

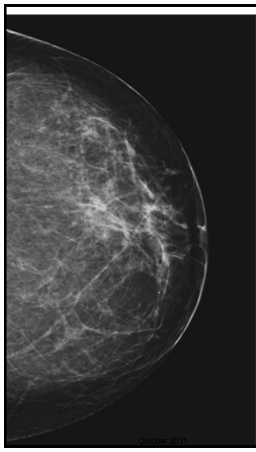
However -
if found early, 98% will survive
(if tumor is 2 cm or less)

This makes Screening Mammography the best tool in the fight against breast cancer.

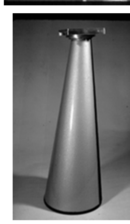
American Cancer Society 2010

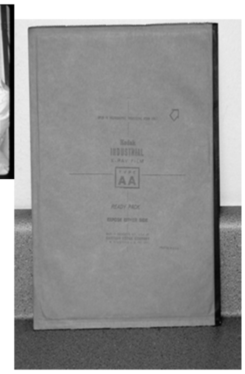
1950's-industrial film-no compression-reg. x-ray unit with modified control panel
to get lower kVp-manual processing 7-8 min.



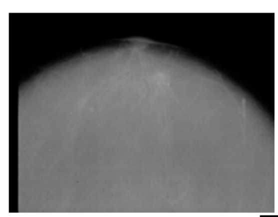


Mammography, in particular digital mammography, is the gold standard in breast cancer screening.

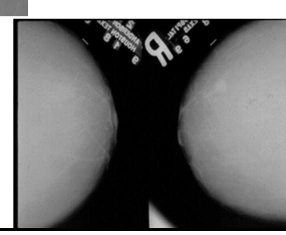




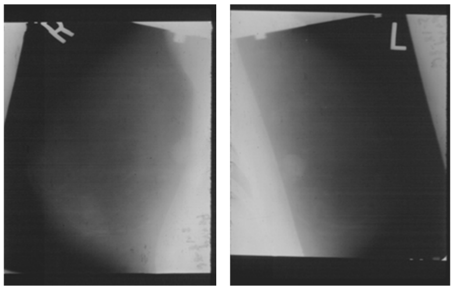
Looking back



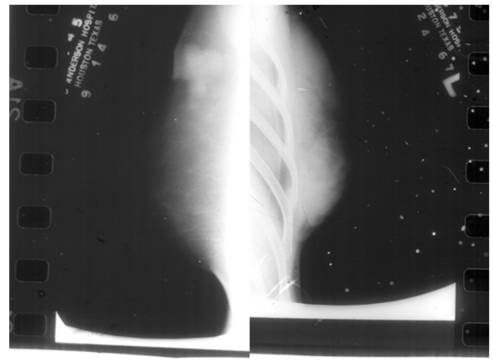
Industrial film images

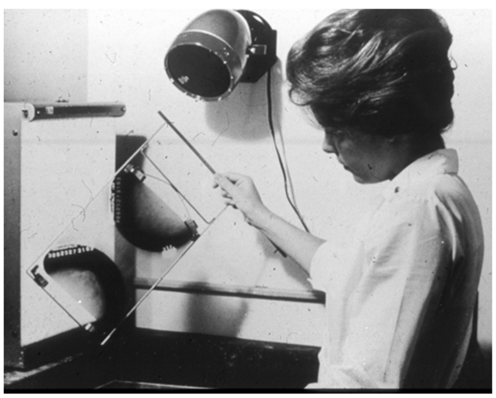


Advancements in Breast Cancer



Mammography
Industrial Film Images



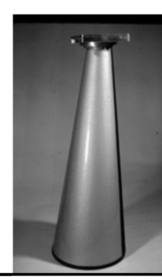


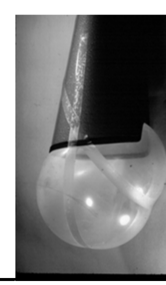
FILM PROCESSORS

1972 DuPont Lo-Dose screen-film

- calcium tungstate screen – no cassette
- black polyethylene vacuum bag
- entrance skin exposure, 1 – 1.5 R

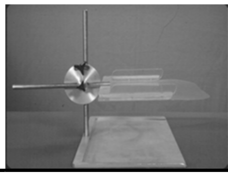
1960's-balloon for compression-industrial film-typical exposure-20-28 kVp-300 mA-6-11 sec. exposure=3000 mr/view-manual processing





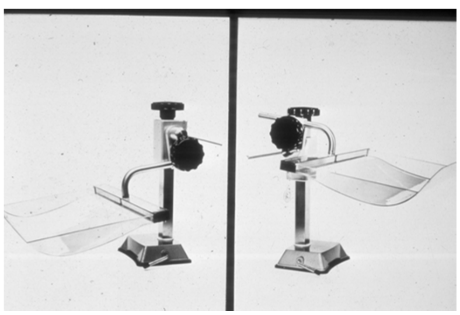
Early Attempts at Compression



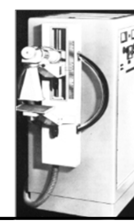
Advancements in Breast Cancer

Mammograhy
1966 – First dedicated mammography unit
Charles Gros in Cooperation with CGR company



1967- research team designed a basic unit using a moly tube-unit was a tube and a lens on a three legged stand

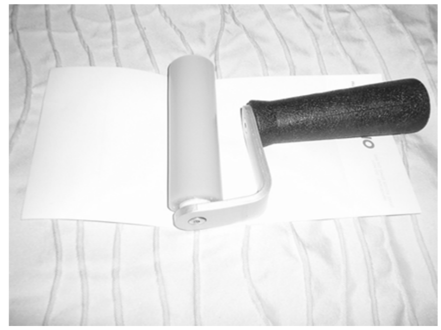
1969- first commercial model of "Senographe" (French for "picture of the breast") became available



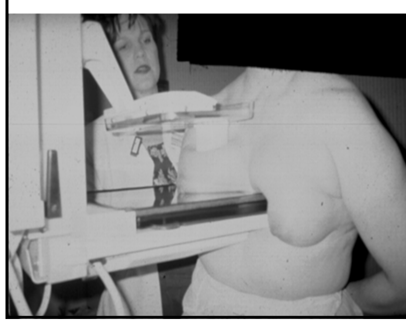
- 1960's non-screen industrial film
  - hand processing – 5 minutes
- 1970 Kodak RP/M non-screen film
  - 90 second processing
  - entrance skin exposure, 3 – 10 R

Advancements in Breast Cancer

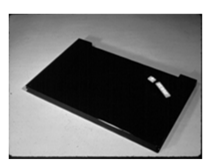
- Mammography
  - Film screen mammography
    - 1973 –DuPont developed a high-definition intensifying screen with industrial film held in intimate contact within an air-evacuated polyethylene envelope.

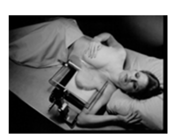


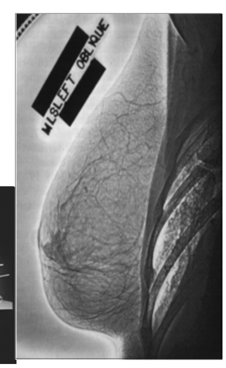
No spot compression paddles….No Problem!

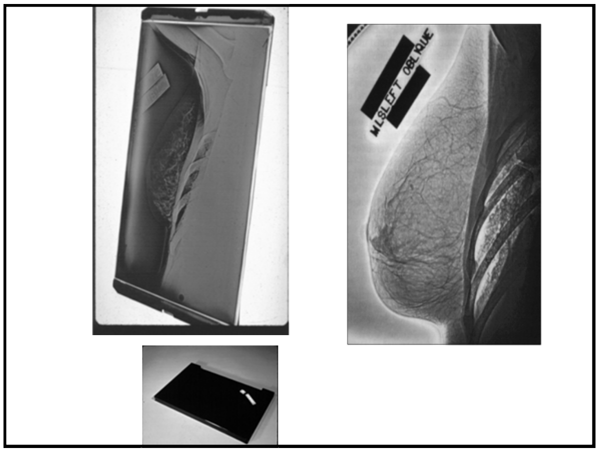


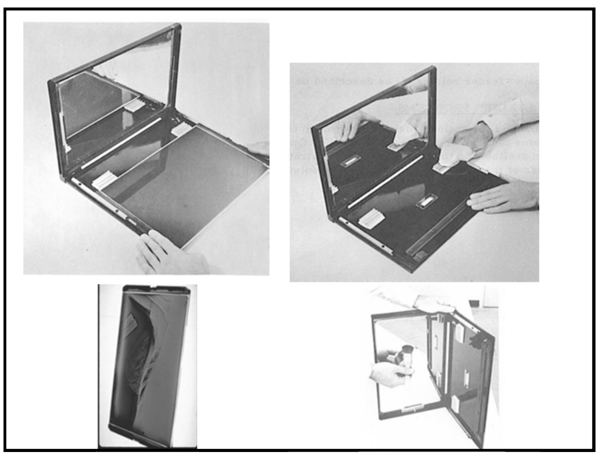
1971's-Xeromammography

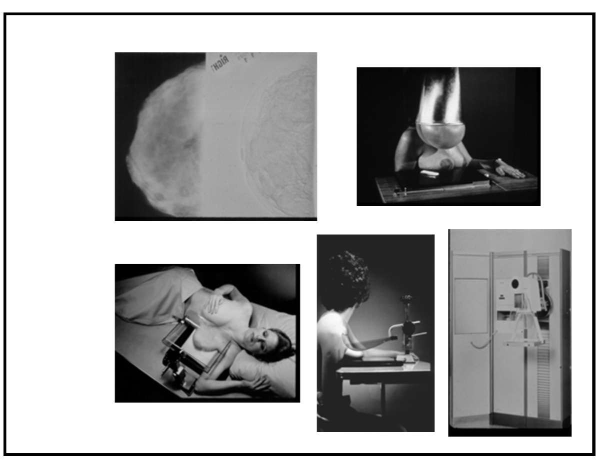


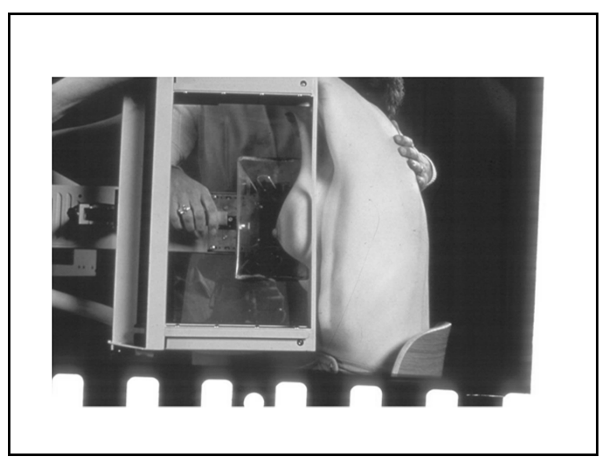


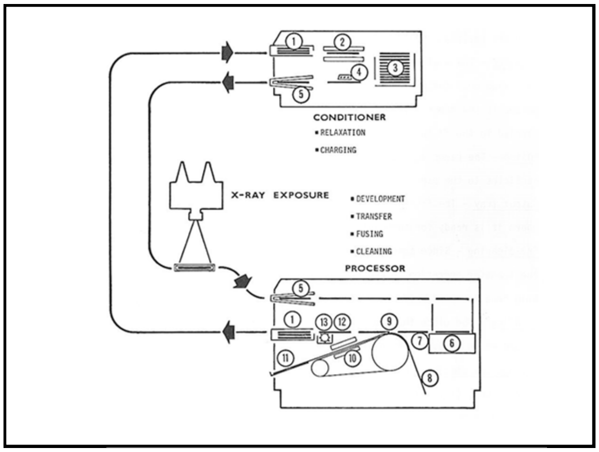


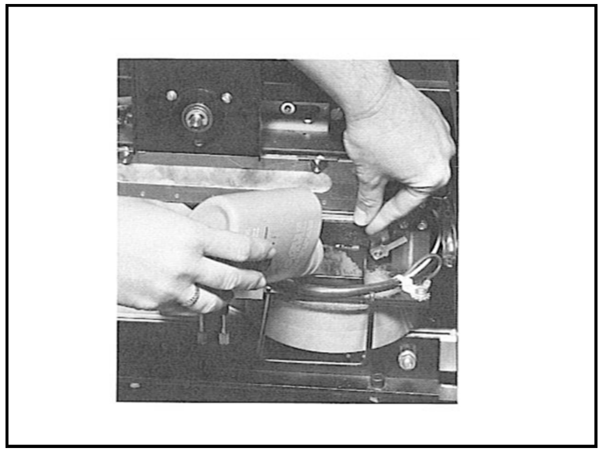

LEFT OBLIQUE

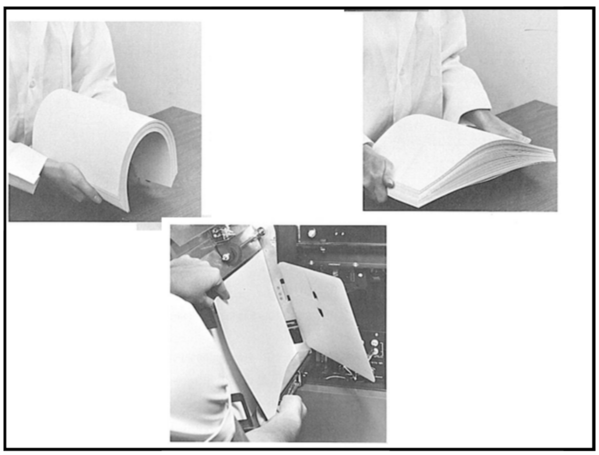







CONDITIONER
• RELAXATION
• CHARGING
X-RAY EXPOSURE
• DEVELOPMENT
• TRANSFER
• FUSING
• CLEANING
PROCESSOR





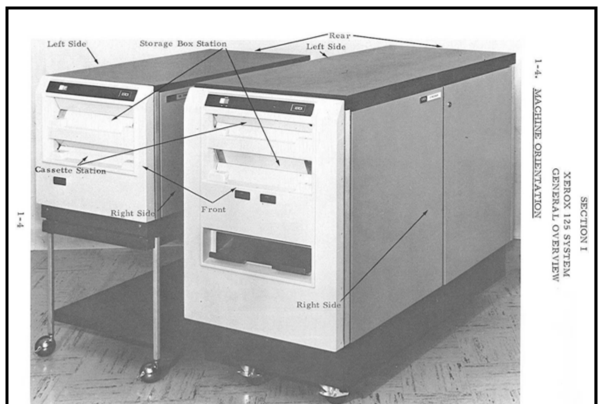
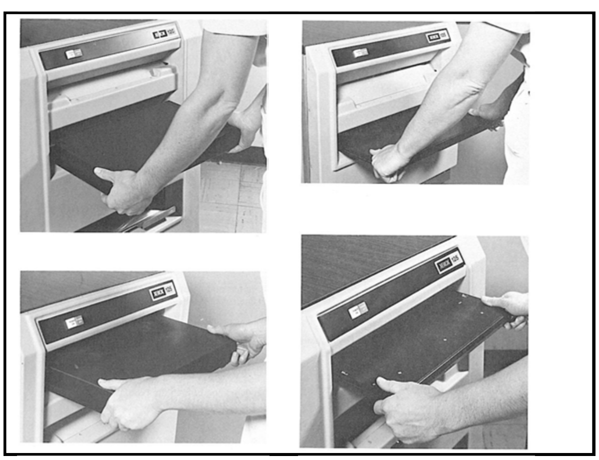
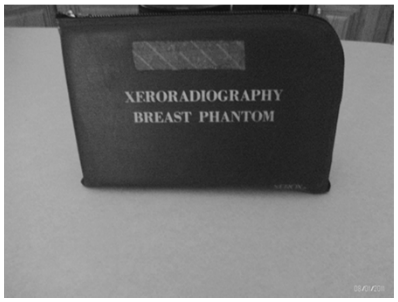
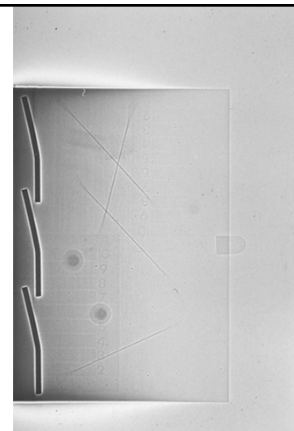

Left Side
Storage Box Station
Rear
Left Side
Cassette Station
Right Side
Front
Right Side
1-4. MACHINE ORIENTATION
SECTION I
XEROX 125 SYSTEM
GENERAL OVERVIEW
1-4

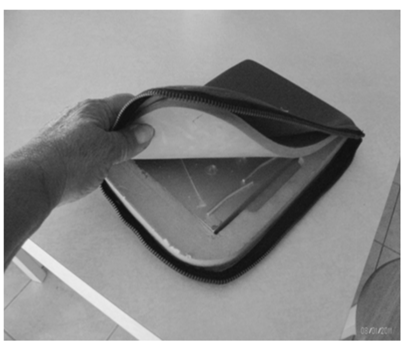
Figure 2

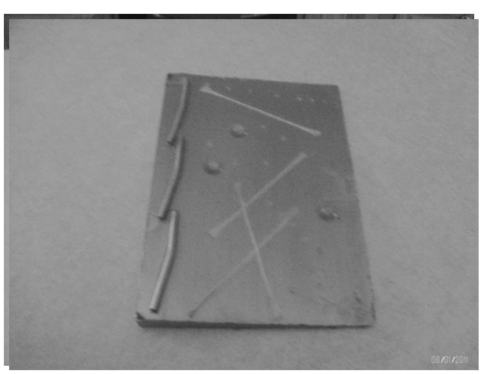


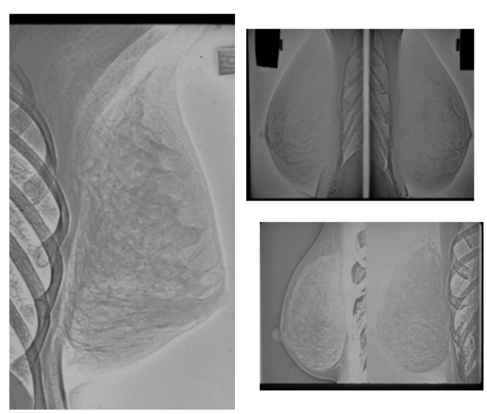
Xeromammography Breast Phantom

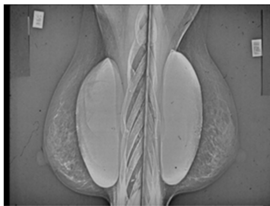


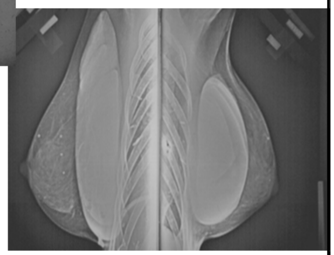






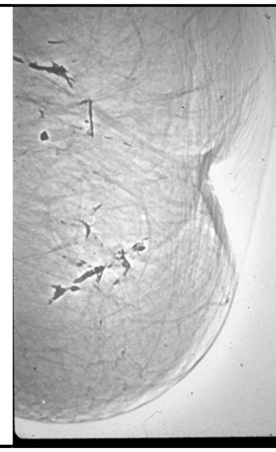


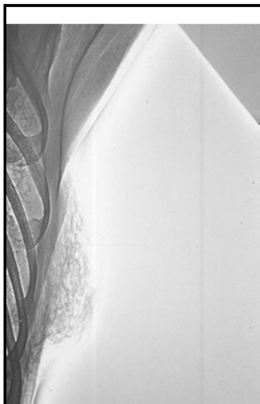


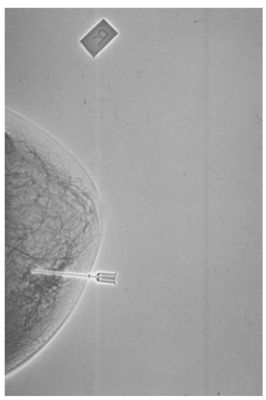


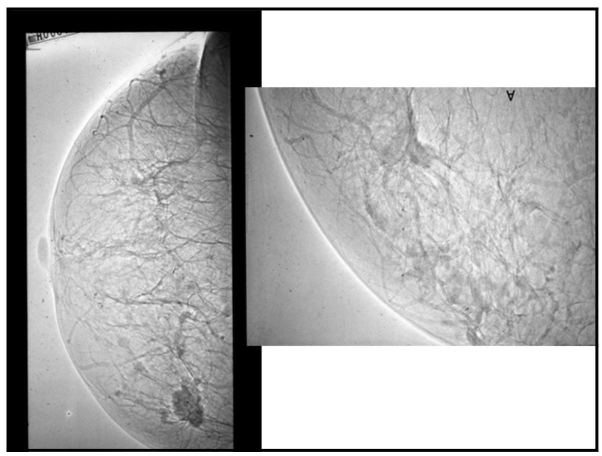
IMPLANTS

Negative Mode Xerography









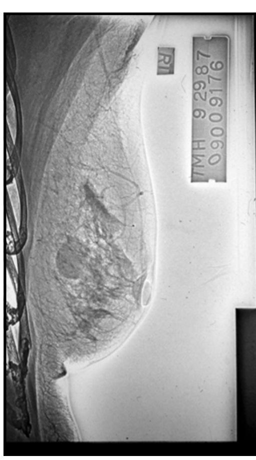


Figure 63. Electrode-dirt Discharge

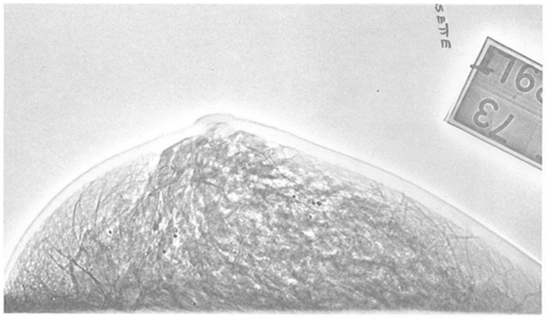
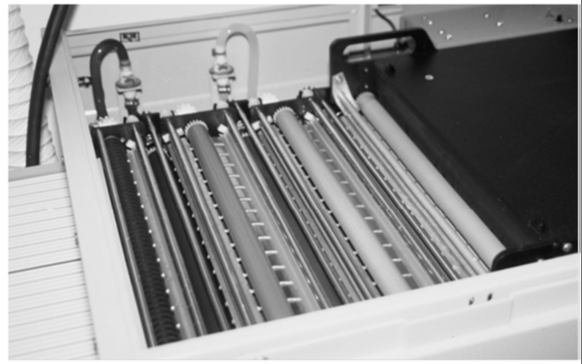


Figure 62. Image Smear (Positive Mode)



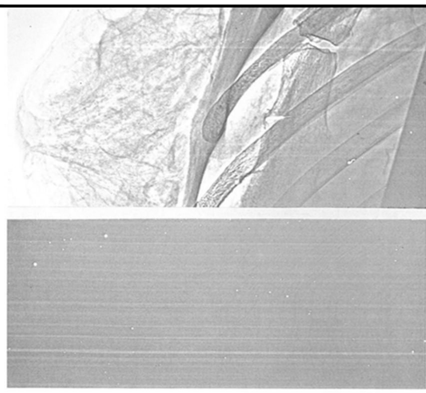


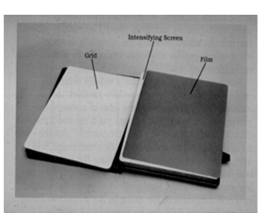
Figure 61. Preclean Corotron Lines

1980 – 2nd Generation Senographe

The early 80's also brought the development of the first motorized compression device.

Advancements in Breast Cancer

Advancements in Breast Cancer



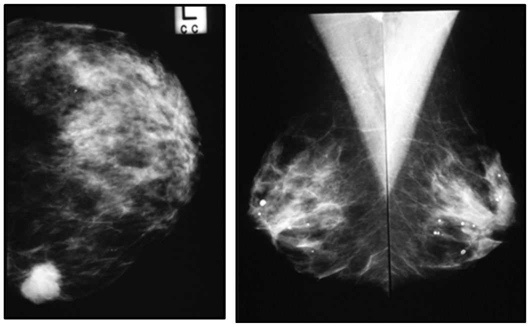
- Mammography
  - Film Screen Mammography
    - Eastman Kodak followed with their own system introducing the vacuum cassette to mammography.
    - 1976

1992 – Third Generation Mammography unit

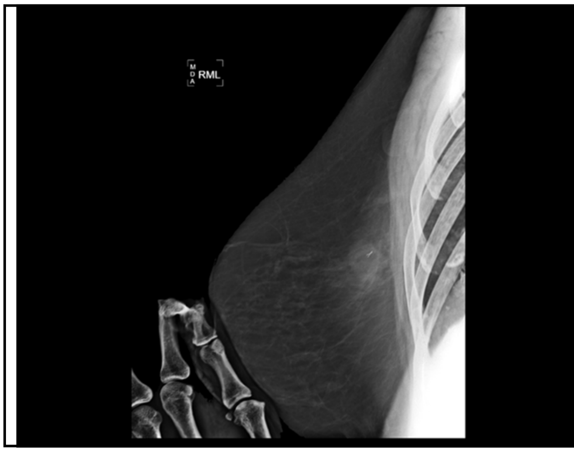
New technology provided by GE and Siemens. GE DMR and Siemens Mammomat 3000 provided multiple anode and filter choices.

Advancements in Breast Cancer

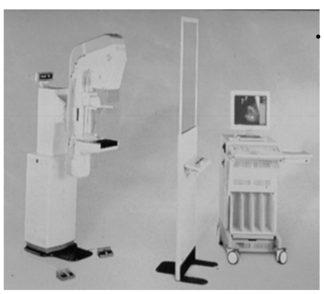
Film Screen Images in 80's



Advancements in Breast Cancer



Advancements in Breast Cancer



- 2000's
  - The introduction of digital mammography.
    - An electronic image of the breast .
    - Stores directly in a computer.

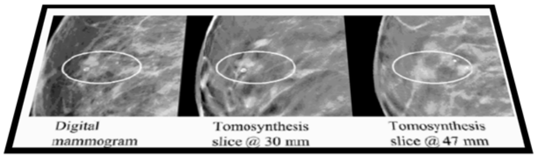
Welcome Digital Mammography 2000

Advancements in Breast Cancer

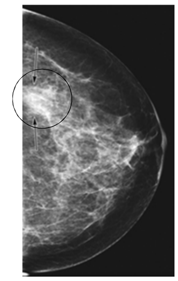
Full Field Digital Mammography

Understanding Digital for DBT

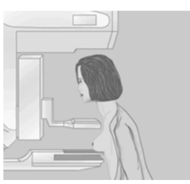
Digital & DBT

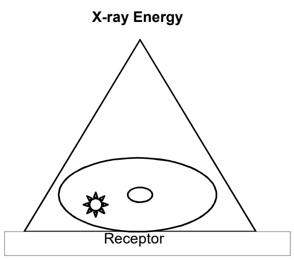


Painting by Numbers – Painting with X-ray

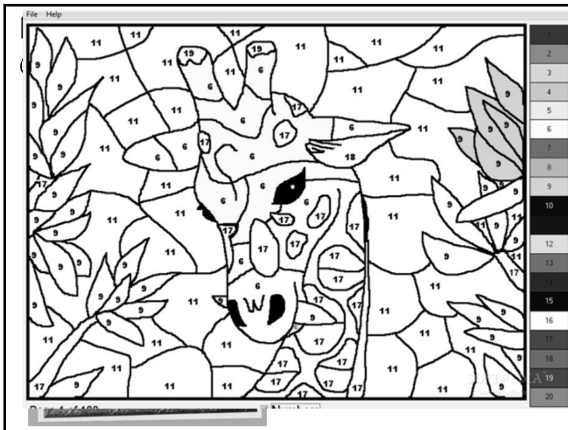


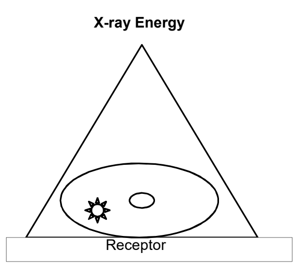
Mammographer's Guide to Digital Imaging of the Breast





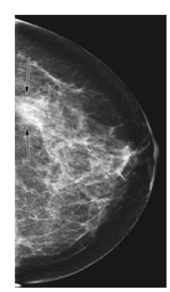
Receptor can be film, indirect digital, direct digital – All receive the remnant radiation to create image!



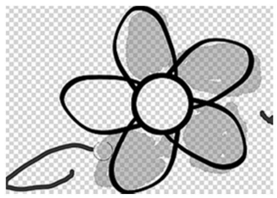


Digital Imaging Can Be Understood Easier if We Use the Analogy of "Painting by Numbers".

Positioning would be equivalent to painting within the lines.



Positioning=paint inside the lines

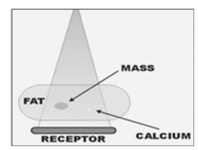


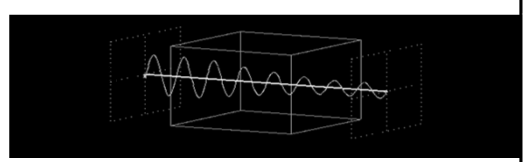
Differential Absorption-do you remember?

- Image formation is dependent upon it
- X-rays penetrate tissue
- Not homogeneously absorbed
- Some absorb more efficiently than others
- If x-ray absorption were uniform the radiograph would be gray or white
- Those that pass through the tissues produce the diagnostic image

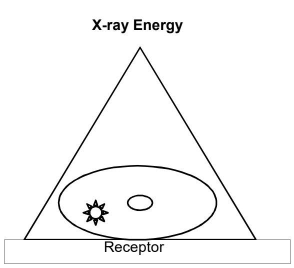
Positioning=Paint inside the lines or not?

Differential Absorption Creates Remnant Radiation -the Colors (shades of gray) What we "Paint With" .

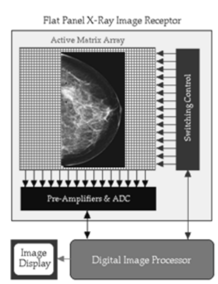




Creating our mammo template to "Paint by the Numbers"



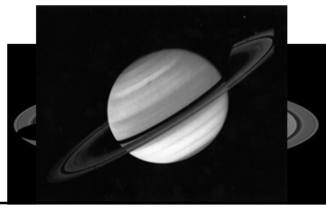
Creating our mammo template to "Paint by the Numbers"



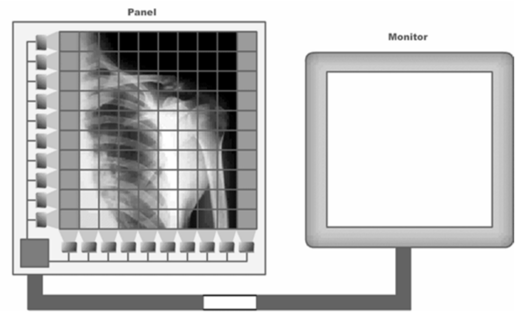
The mammographic image is captured on a Flat Panel Receptor – which divides the image into millions of small "squares/areas" of energy that need to be painted as different shades of gray.

Look Up Table (LUT)

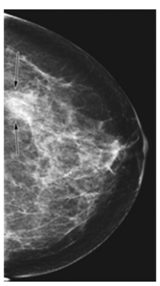
- Used to transform the input data into a more desirable output format
  - Example: a grayscale picture of the planet Saturn will be transformed into a color image to emphasize the differences in its rings



Example – Painting with X-ray



Mammo by the Numbers

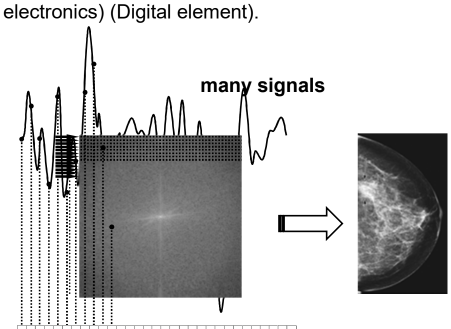


Captured remnant X-ray energy-converted by a computer to shades of gray that we can use to paint our mammogram.

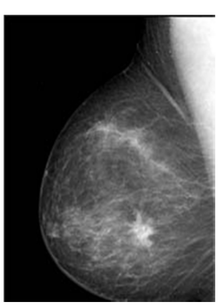
Look Up Table-assigns the shades of gray to each area we are painting.
Look-Up-Table=our "paint selection"

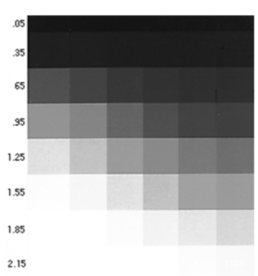
Using the shades of gray from the look-up-table we can paint our mammo image; but we must be careful to "paint within the lines" which is our positioning.

The released energy is converted to shades of gray based upon signal strength from each TFT (thin film transistor) or DEL (detector electronics) (Digital element).

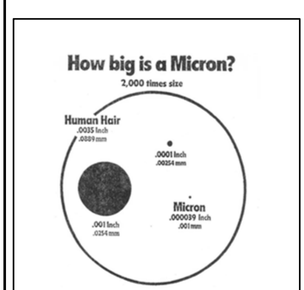


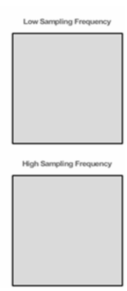
The digital (correlation to intensity) number is matched to a "look-up table" which matches the signal to a shade of gray.





Size – Which Pixel Size (area to paint) would produce the best resolution?



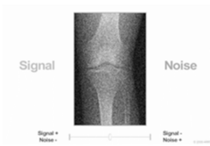


Which size would require the least detail (paint)?

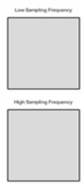
Answer: low sampling frequency-less detail less paint to paint

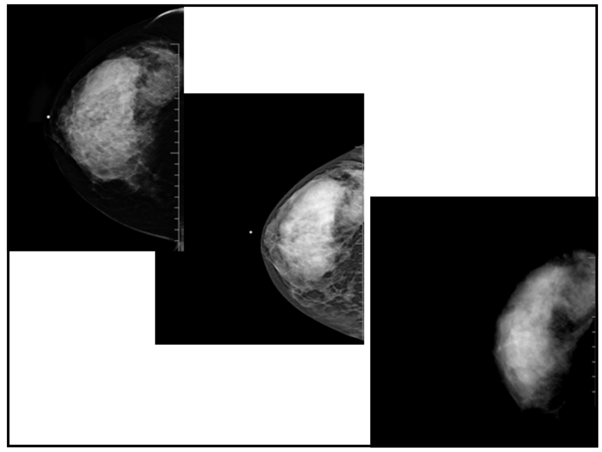
Does Pixel Size Matter?

When pixel size decreases
- Spatial resolution improves
- Noise increases
- Signal to noise decreases which you want SNR to be increased

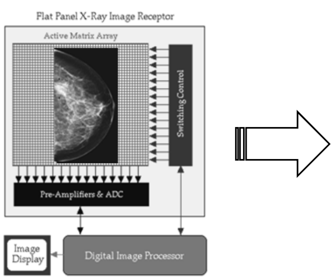


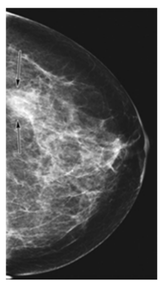
Example Noise



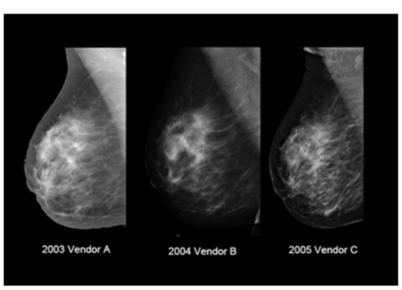


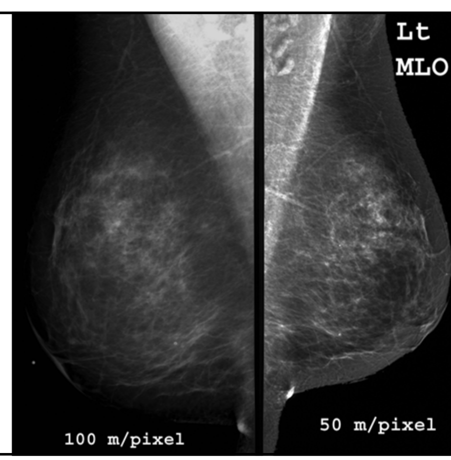
Latent Image is Converted to Display

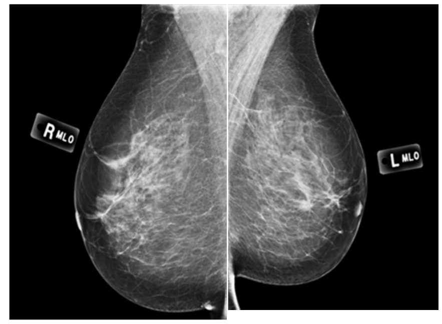




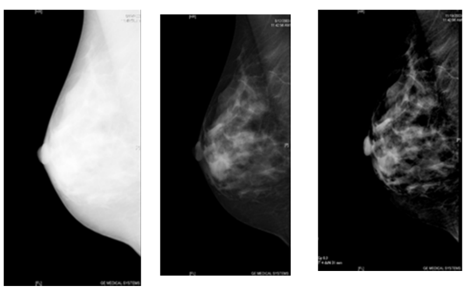
Caveat : Look-Up-Tables are Vendor Dependent!



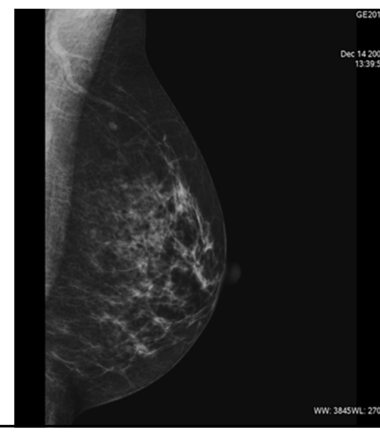




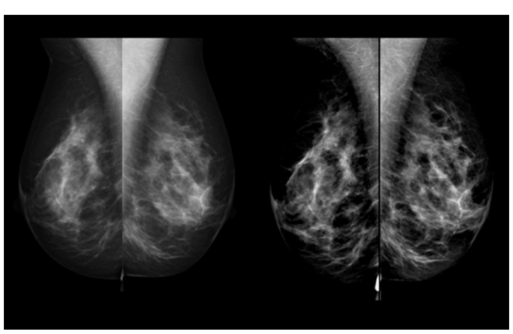
GE



Raw Image Tissue Equalization Premium View



Same vendor different algorithms or instructions (paint by numbers – the numbers are changed) on same patient.



The Digital Receptor

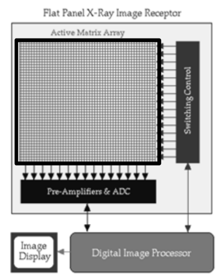
Digital Mammography Technologies

Direct Conversion
Amorphous Selenium (direct conversion) using (TFT) flat panel technology.
~ 70 micron pixels some detectors have 85 micron pixel size

Indirect Conversion
Scintillating phosphor (CsI columns) on an array of amorphous silicon photodiodes using thin film transistor (TFT) flat and curved panel technology.
~ 100 micron pixels
-50 micron pixels Fischer senoscan

CR Mammography which uses a photostimulable luminescence screen inside an imaging plate (IP) which is run through the reader.

Digital Receptor Indirect

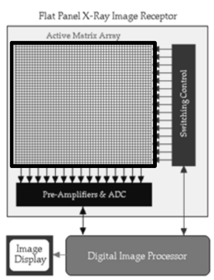


Flat Plate Detectors are made from silicon semiconductor sheets composed of millions of discrete detector electronics (DEL) each of which consists of a charge collection capacitor to trap the energy.

We choose how many of these we would average (sample) to create the "pixel size" we are looking at on our display monitor.

The smaller the pixel size the better the resolution BUT smaller size requires more radiation. So dose impacts resolution.

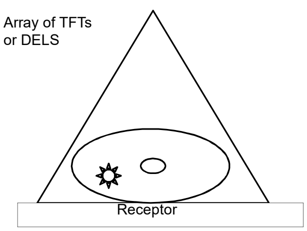
Digital Receptor



Each TFT or DEL collects a charge that is proportional to the remnant x-ray energy.

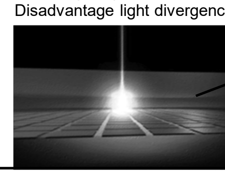
X-ray Energy

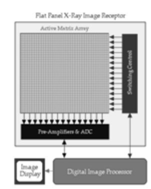
Array of TFTs or DELS



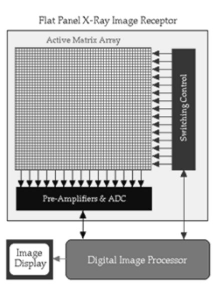
Indirect Conversion Flat Panel Detectors

Indirect conversion uses thin layers of silicon combined with arrays of photodiodes. The photodiodes (these are in the TFT or DEL and they convert the x-ray into electrons) are covered with cesium iodide and when struck by remnant x-rays they emit light. The light is converted in photoelectrons (charges/energies). These energies are then delivered to a computer where the anatomical image is digitally processed and displayed
Advantage high DQE
Disadvantage light divergence



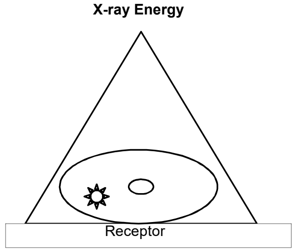


Digital Receptor



Each TFT or DEL collects a charge that is proportional to the remnant x-ray energy.

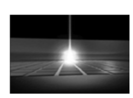
X-ray Energy

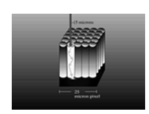


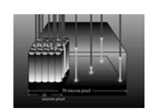
Trapped x-ray energy in the form of an electrical charge.

Indirect Conversion Flat Panel Detectors

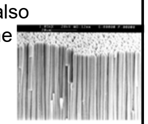
Cesium Iodide





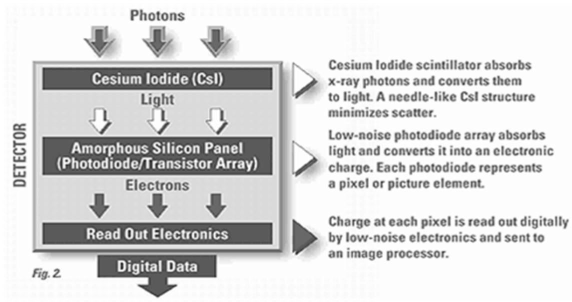


Advantage high DQE-combined effects of the signal (related to image contrast) and noise performance of an imaging system. The DQE is also an important consideration for CCDs, especially those used for low-level imaging in light , because it affects the SNR of the images. It is also similar to the noise factor used to describe some electronic devices.



Disadvantage – light divergence

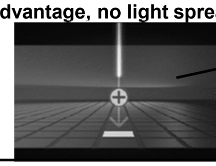
Cesium Iodide Crystals Small amount of divergence as crystals work as "light pipe"

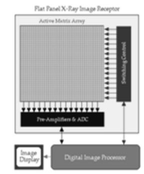


Direct Conversion Flat Panel Detectors

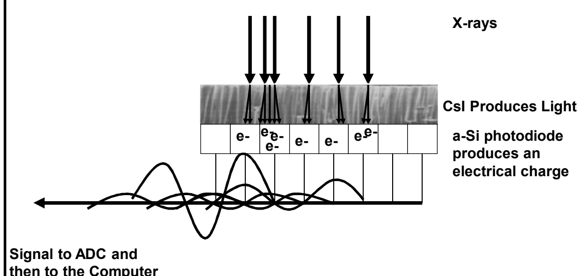
Direct conversion uses an amorphous selenium coated thin film transistor (TFT) array that converts x-ray energy into electrical signal . Remnant x-rays are absorbed in the selenium where they form “electron holes”. Capacitors then collect the charges (electrical energy) and they are delivered to a computer where the anatomical image is digitally processed and displayed.

Advantage, no light spread





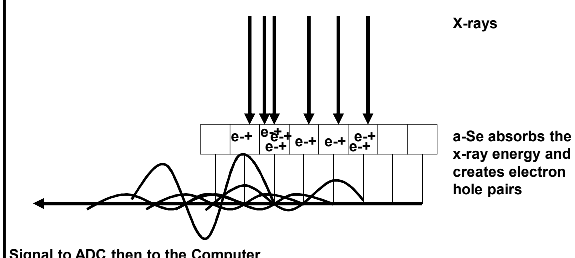
Indirect DR



e-= electrons always negative
Protons are positive

122

Direct DR



ADU-analog to digital converter-digital has to be changed to a number-it measures the signal and changes it to a number

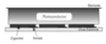
Indirect Conversion

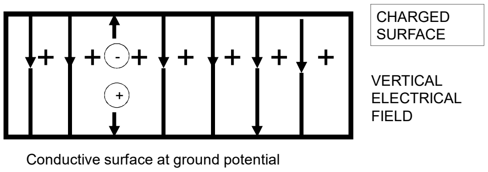
- Remember in x-ray school
  - Took a screen and opened it and exposed it to x-ray and watched it glow
  - As soon as you let off the exposure the glow is gone-over

Direct Conversion

- Signal goes into the TFT or DEL and they have to empty before you can take another exposure
  - Like a pitcher of water

Amorphous Selenium

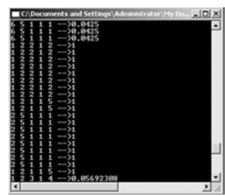


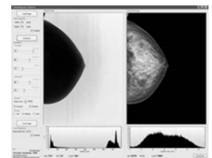


The negative electrons cancel the positive surface charge and thus produce variations in the surface charge that correspond to the incident pattern of the x-rays or an x-ray image.

Algorithms

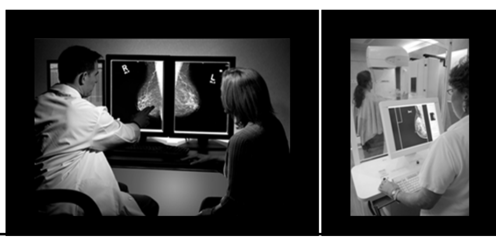
- Digital Mammography systems allow manipulation of fine differences in image contrast by means of image processing algorithms.





Histogram

- Different display algorithms have advantages and disadvantages for the specific tasks required in breast imaging- diagnosis and screening.



Your Mammo Equipment is Evolving

Molybdenum and Rhodium tubes are in the Past with Manufacturing New Mammography Digital machines
With Tungsten tubes and targets with rhodium, aluminum, and silver filters.

Processing Algorithms

- Improve image quality
- Vendor Specific
- Constantly evolving
- In the future we will be using different algorithms for different tissue types and lesions. Which some already do like Senograph with choices of Contrast, Standard, Dose

Digital Images Require Digital Mammographic Equipment!

Sure, you have digital FFDM but how much of your equipment is outdated technology?

KVP (Quality)
Ability of beam to penetrate

kVp is the energy beam controlled by voltage. It is the difference controlled b/t the cathode and the anode. The higher the kVp the more energetic the beam of the x-ray. Remember high contrast (low kVp) has lots of blacks and whites. Low contrast (high kVp) gives you lots of grays because high penetration of beam.

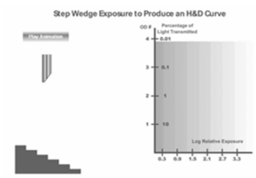
kVp controls your contrast

That is subject contrast and radiograph contrast.

Yes WE Can -

Fact:

In film screen exposure, the mAs controls the density and kVp controls the contrast.



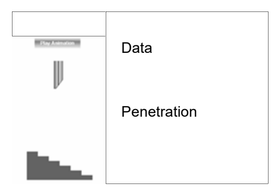
mAs (Quantity) (Intensity)
Number of photons in the beam

The ma control determines how much current is allowed to flow through the filament which is the cathode side of the tube. More current, more electrons. The effect of the mA is linear. If you want to double the number of photons, you double the mAs. This affects the **blackness** of the image. This can be harmful to the pt.

Yes WE Can -

Fact:

In digital imaging, mAs controls density (amount of data) and kVp controls penetration. Image contrast is predetermined by computer look-up-tables.

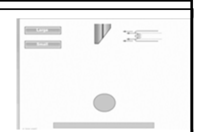


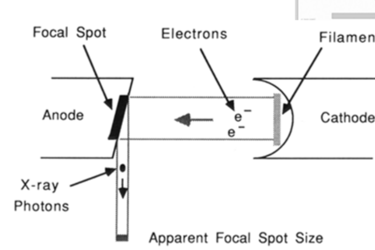
Physics Is Physics – So Why The Need To Change?

Very simple, we used technology possible to create images with a film-screen combination and now we need to apply the same physics principles to utilization of a digital receptor.

QUESTION:
If film screen systems have a built in speed and contrast and digital images are created using a computer that has no built-in speed and contrast; can we change our exposure, reduce dose, and improve images by designing equipment specific to creating a digital image?

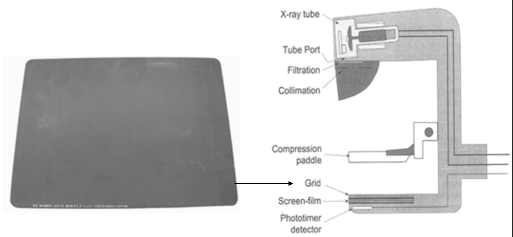
200 mA



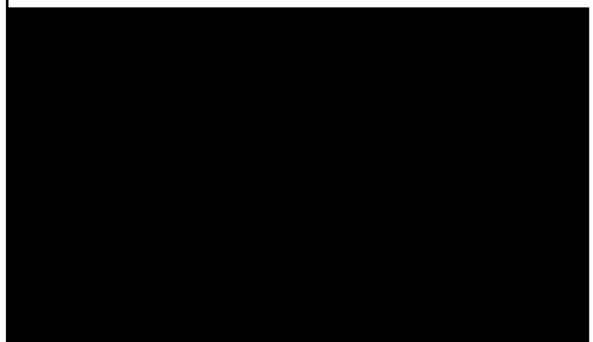


Increasing speed from 100 mA to 200 mA cuts exposure time in half

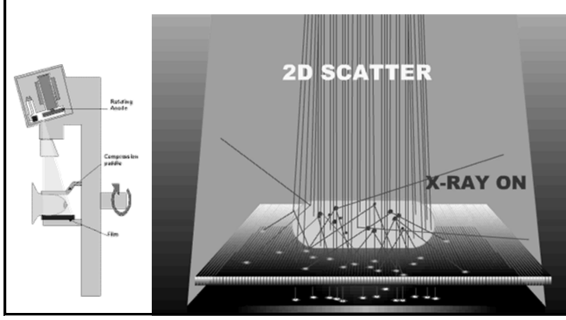
No Grid

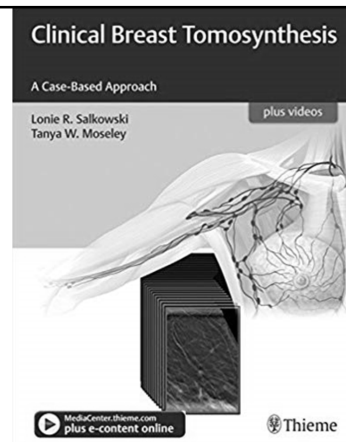


Using a grid requires increased mAs and in DBT grid cut off would appear. Eliminating the grid will cut the exposure significantly.. The need for a grid is eliminated because these are tomo slices that are being created from the projection images.

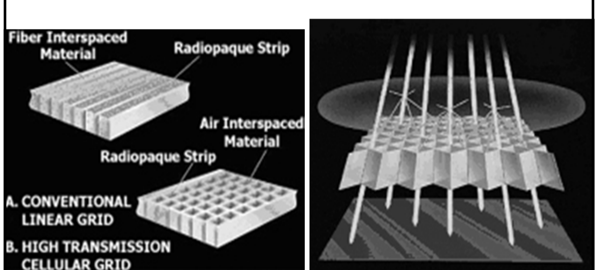


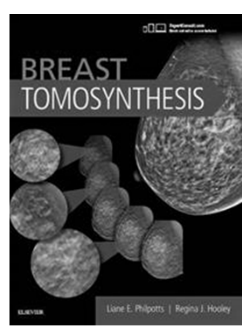
With 2D a grid is needed for scatter but also blocks some of the useful information(primary beam)

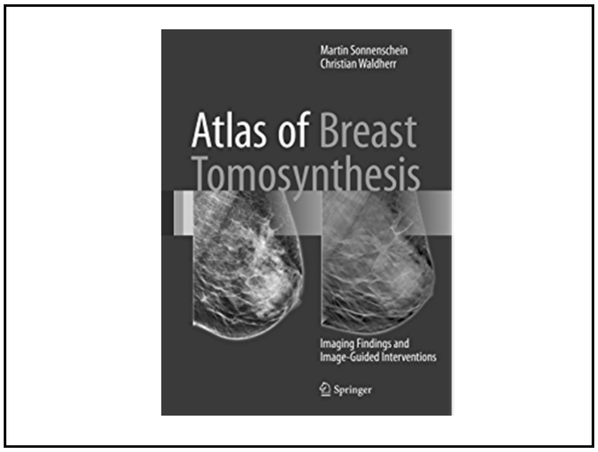




LoRad Selenia™ HTC Grid



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