Evolution of the UC Davis Breast CT Scanner

Breast Tomography Project

University of California Davis

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Cancer Screening

Cancer screening aims to detect cancer before symptoms appear.

Lung Cancer —— smokers —— Low Dose CT

Breast Cancer —— women —— Mammogram

Prostate Cancer — men — PSA (blood test)

Colon Cancer — people > 50 —— Colonoscopy

Breast Cancer Statistics (2006)

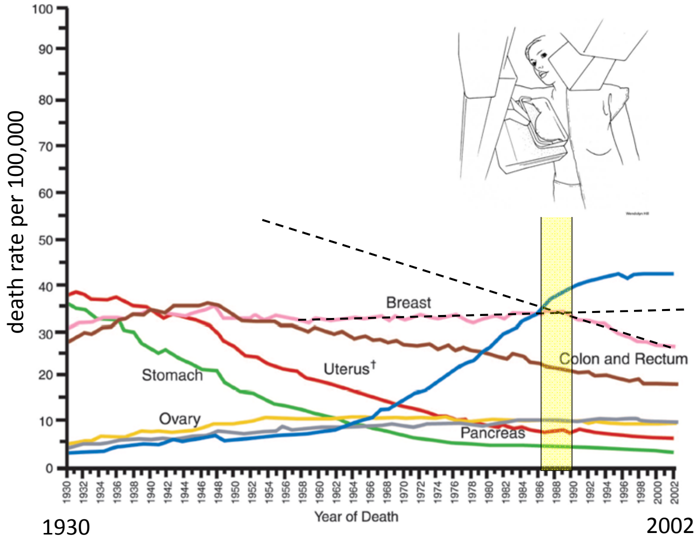
212,290 new cases

40,970 deaths

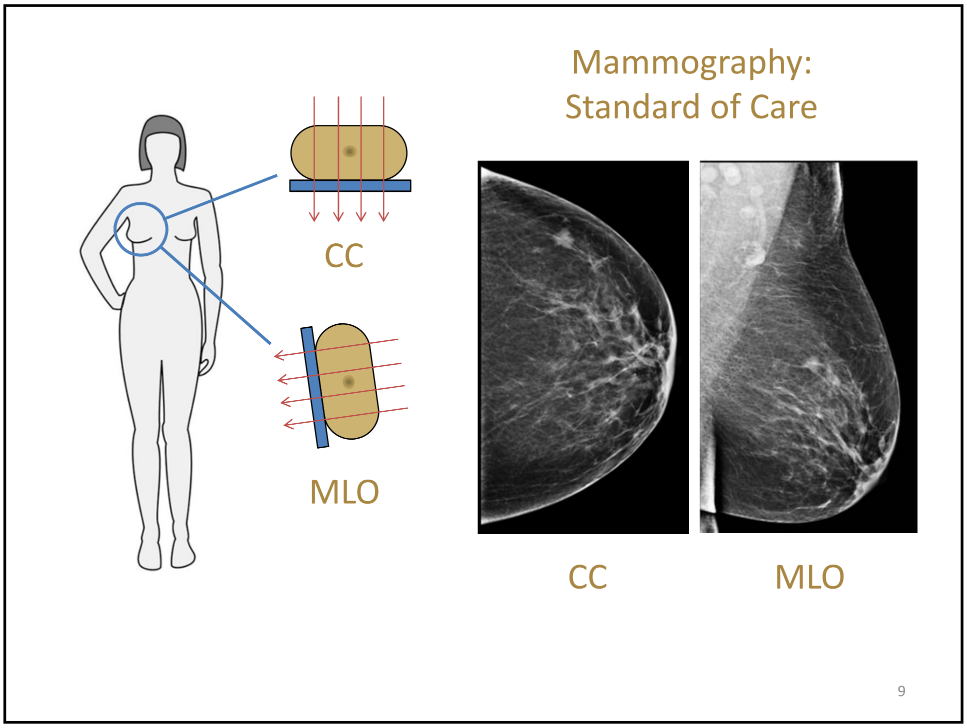
1 / 8 women will get breast cancer (12.5%)

Ravdin, *et al*., NEJM

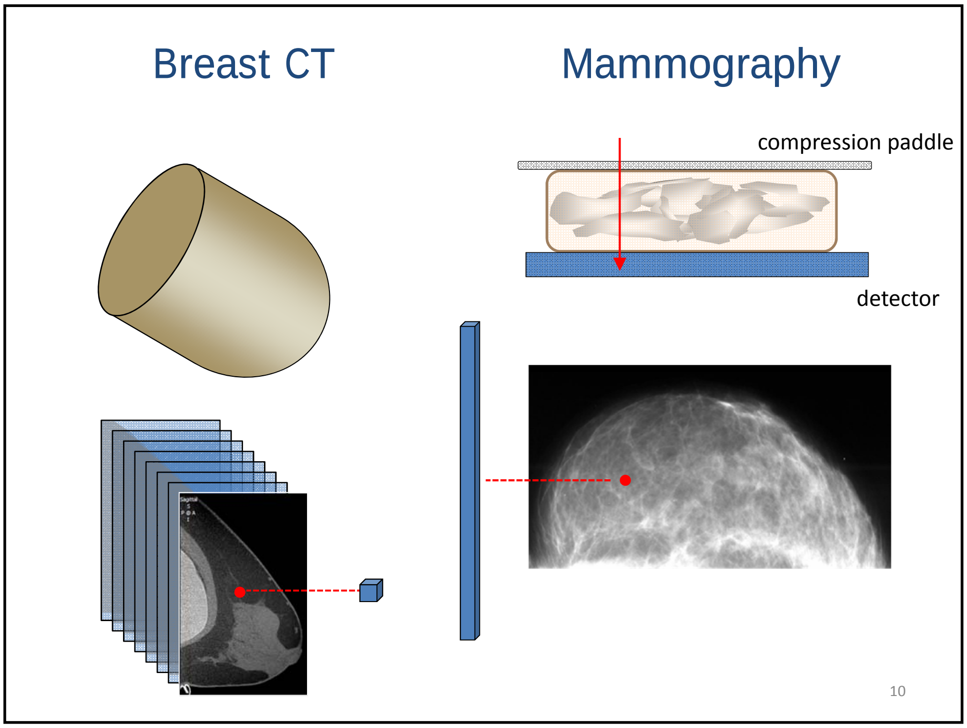
Cancer Incidence and Screening



Jemal A, *et al*., Cancer Statistics 2006



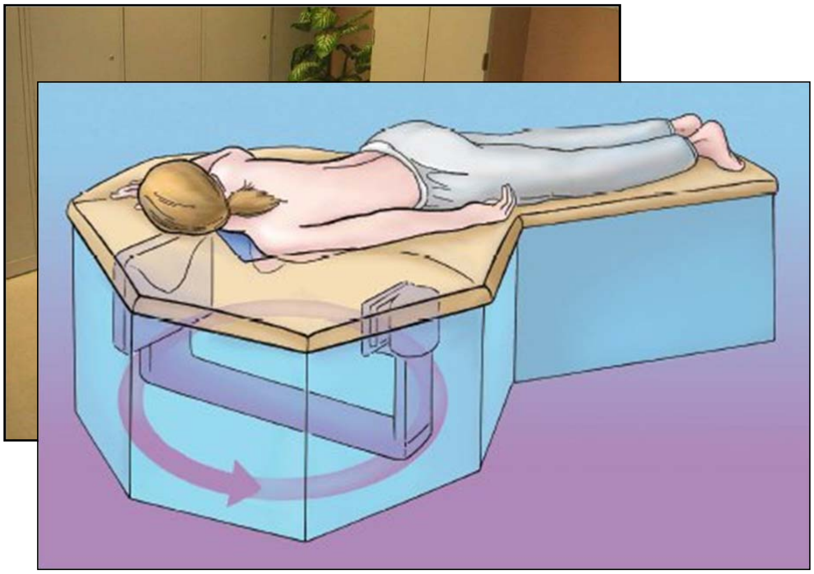
Mammography: Standard of Care



Breast CT

Mammography

Dedicated Breast CT



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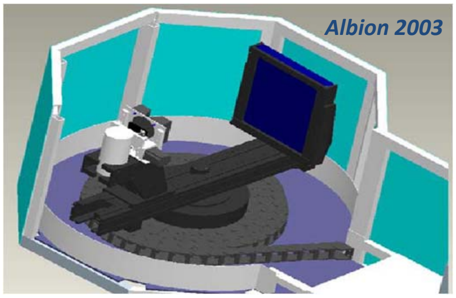
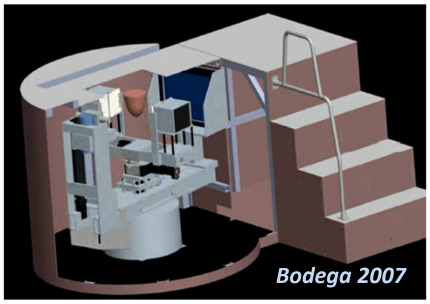
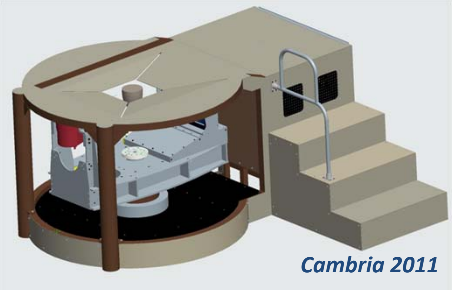
Computer aided design / computer aided manufacture (CAD/CAM)



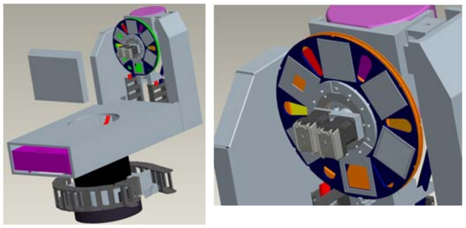
Albion 2003



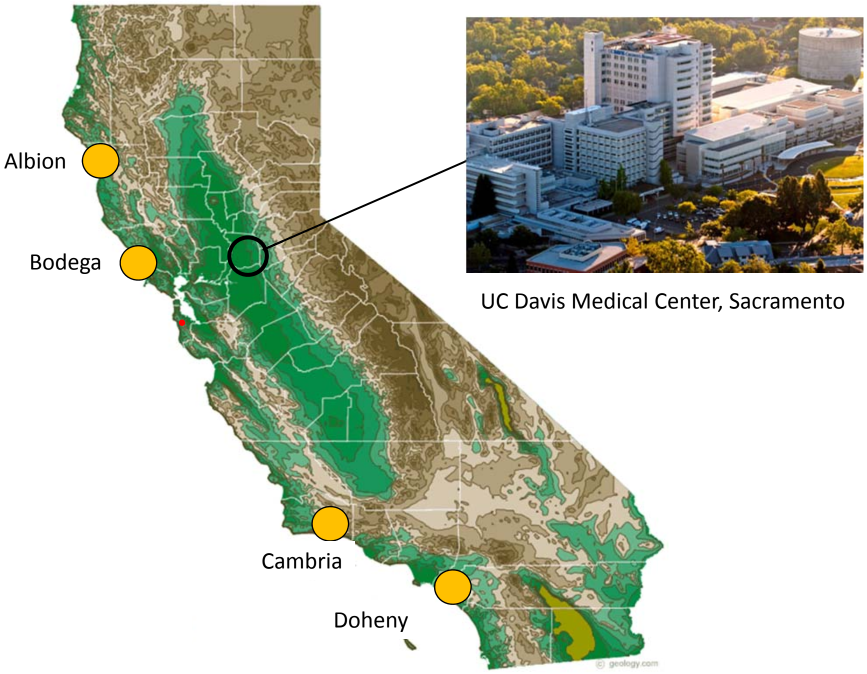
Bodega 2007



Cambria 2011



Doheny 2014



UC Davis Medical Center, Sacramento

Albion 2003

Bodega 2007

Components (Albion and Bodega)

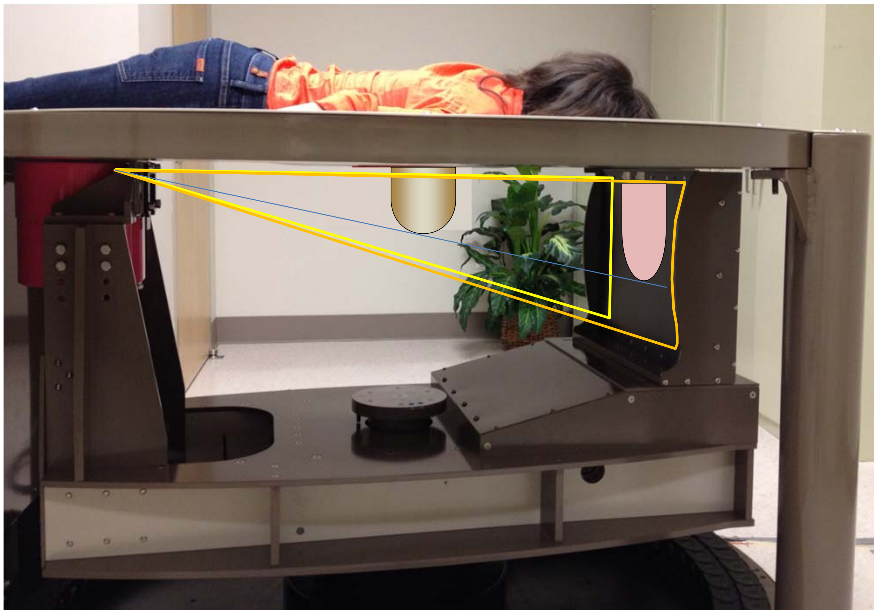
Varian 4030CB
194 μm pixels
2x2 388 μm
1024 x 768 x 30 FPS

Kollmorgen
Servo Motor
- Propulsion
- Bearing
- Angle Encoder

Comet 1 kW Tube

Cambria 2011

Half Cone Beam CT Geometry

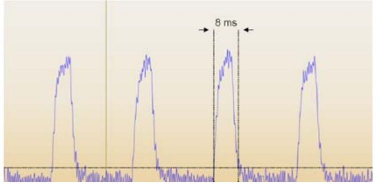


Components (Cambria and Doheny)

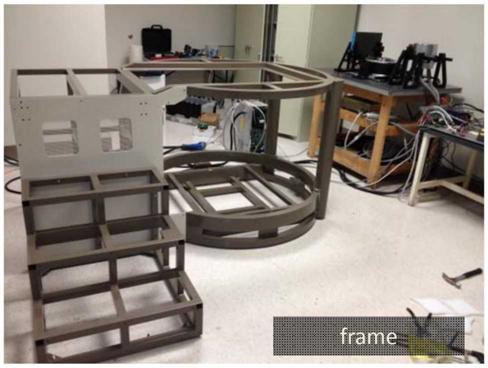
Varian 4030CB

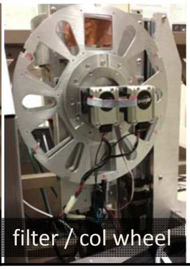
Dexela 2329
.075 mm pixels
26 FPS / CMOS
70 FPS @ 2x2

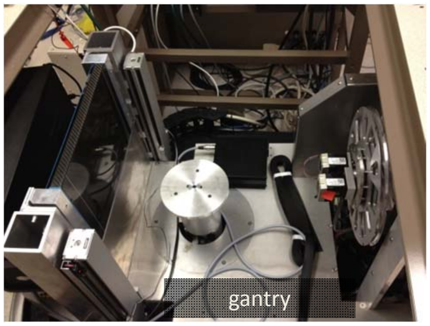
Yaskawa
Servo Motor
  Propulsion
  Bearing
  Angle Encoder

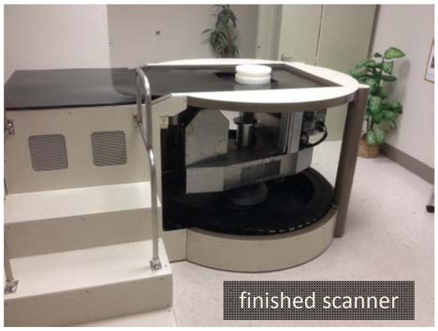


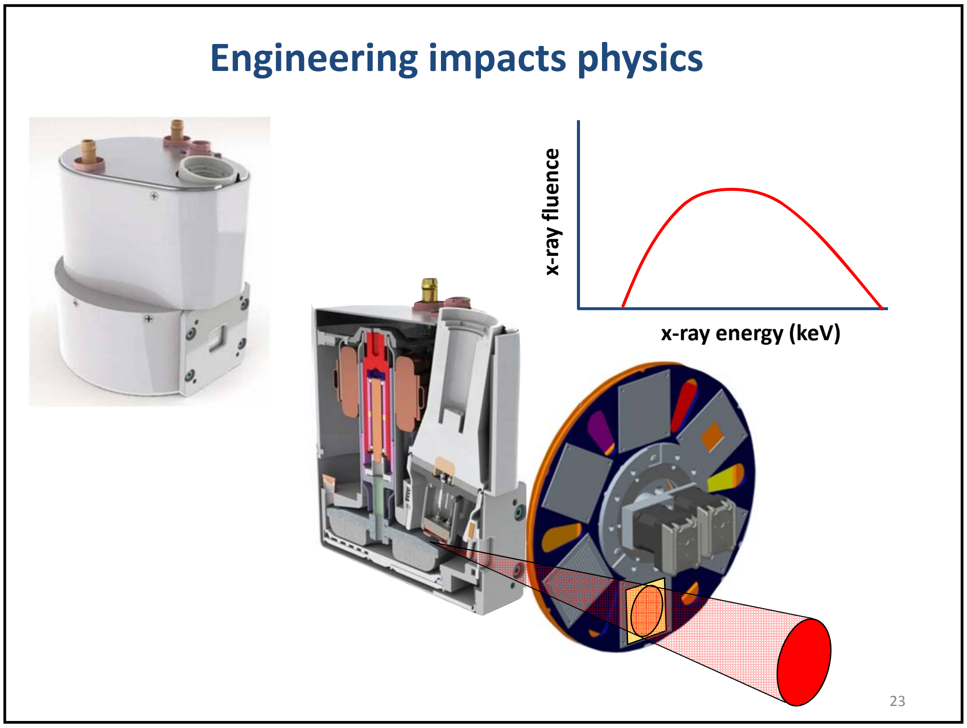
Doheny Fabrication





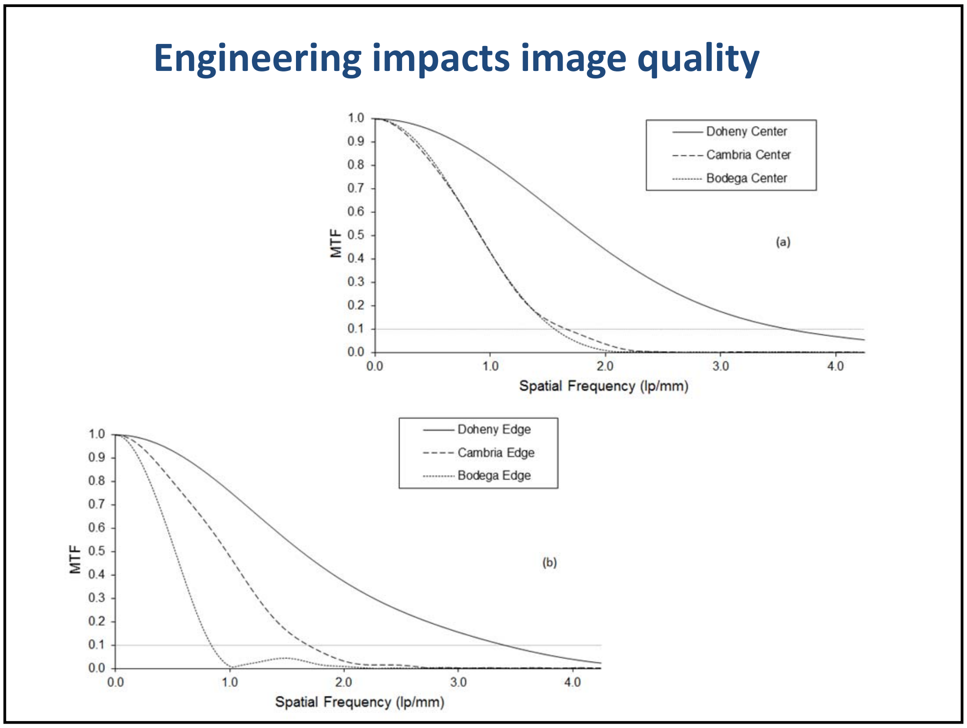






Engineering impacts physics

23



Engineering impacts image quality

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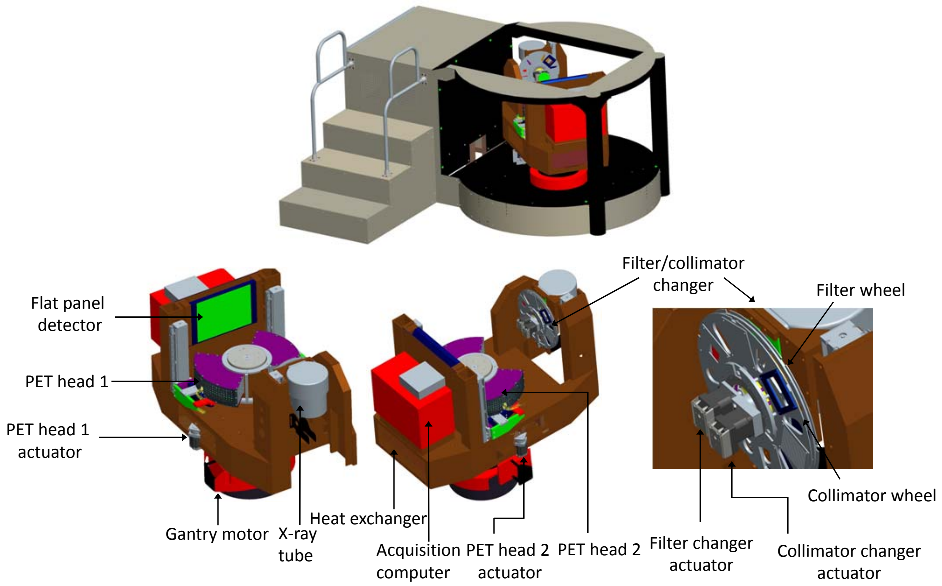
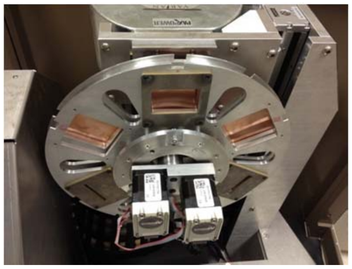
Doheny: Software Control of Hardware Components

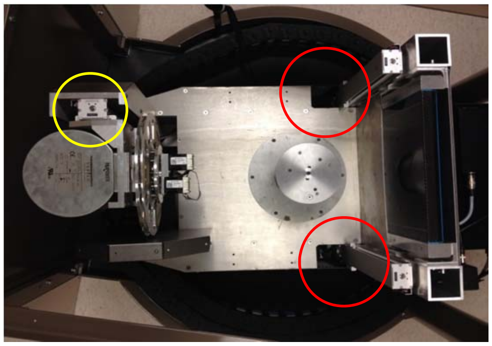




2 NEMA #17 stepping motors

Yaskawa gantry servo motor / bearing system / angle encoder / TTL & RS232 console language

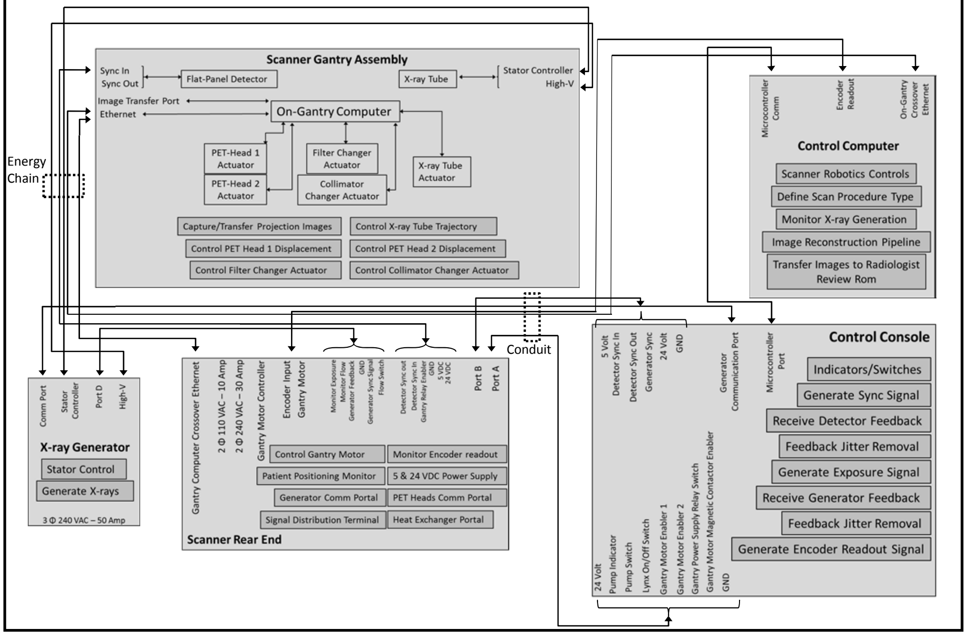
3 NEMA #23 stepping motors for vertical translation of PET heads (2) and x-ray tube (1)



Arduino micro-controller

Stepping motor with integrated controller (uses programmable firmware)

Doheny - Wiring



Scanner Gantry Assembly

Sync In
Sync Out
Flat-Panel Detector
X-ray Tube
Stator Controller
High-V
Image Transfer Port
Ethernet
On-Gantry Computer
PET-Head 1 Actuator
PET-Head 2 Actuator
Filter Changer Actuator
Collimator Changer Actuator
X-ray Tube Actuator
Capture/Transfer Projection Images
Control X-ray Tube Trajectory
Control PET Head 1 Displacement
Control PET Head 2 Displacement
Control Filter Changer Actuator
Control Collimator Changer Actuator

Energy Chain

Conduit

Control Computer

Microcontroller Comm
Encoder Readout
On-Gantry Crossover Ethernet
Scanner Robotics Controls
Define Scan Procedure Type
Monitor X-ray Generation
Image Reconstruction Pipeline
Transfer Images to Radiologist Review Rom

X-ray Generator

Comm Port
Stator Controller
Port D
High-V
Stator Control
Generate X-rays
3 Φ 240 VAC – 50 Amp

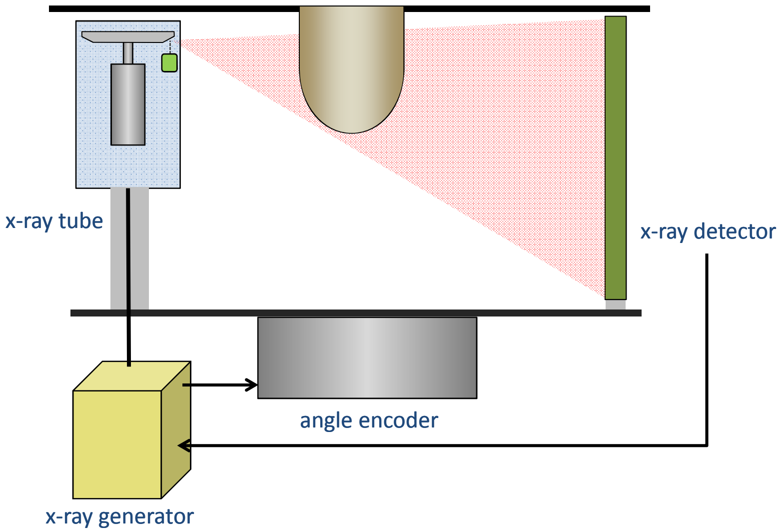
Scanner Rear End

Gantry Computer Crossover Ethernet
2 Φ 110 VAC – 10 Amp
2 Φ 240 VAC – 30 Amp
Gantry Motor Controller
Encoder Input
Gantry Motor
Monitor Exposure
Monitor Flow
Generator Feedback
GND
Generator Sync Signal
Flow Switch
Detector Sync out
Detector Sync In
Gantry Relay Enabler
GND
5 VDC
24 VDC
Port B
Port A
Control Gantry Motor
Monitor Encoder readout
Patient Positioning Monitor
5 & 24 VDC Power Supply
Generator Comm Portal
PET Heads Comm Portal
Signal Distribution Terminal
Heat Exchanger Portal

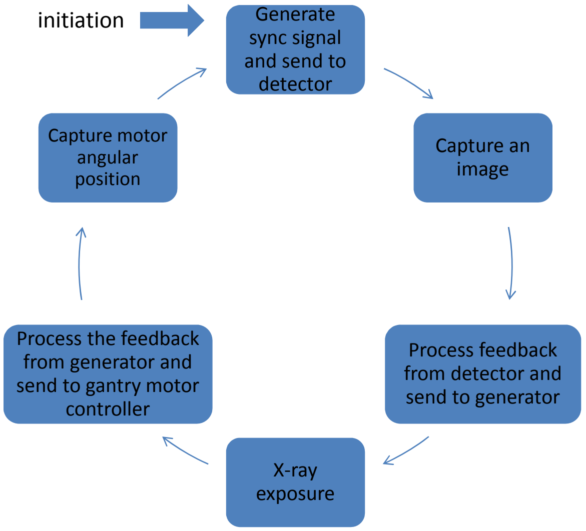
Control Console

5 Volt
Detector Sync In
Detector Sync Out
Generator Sync
24 Volt
GND
Generator Communication Port
Microcontroller Port
Indicators/Switches
Generate Sync Signal
Receive Detector Feedback
Feedback Jitter Removal
Generate Exposure Signal
Receive Generator Feedback
Feedback Jitter Removal
Generate Encoder Readout Signal
24 Volt
Pump Indicator
Pump Switch
Lynx On/Off Switch
Gantry Motor Enabler 1
Gantry Motor Enabler 2
Gantry Power Supply Relay Switch
Gantry Motor Magnetic Contactor Enabler
GND

Synchronization Requirements



CT Scan Acquisition



initiation

Generate sync signal and send to detector

Capture an image

Process feedback from detector and send to generator

X-ray exposure

Process the feedback from generator and send to gantry motor controller

Capture motor angular position

- Acquire 800 views in 16 seconds
- 60 kVp
- mA dependent on the size of breast
- 3 mSec pulse width

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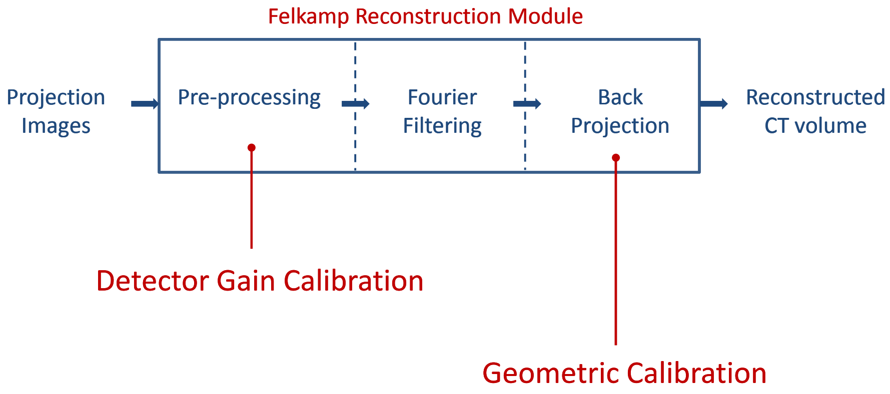


Felkamp Reconstruction Module

Projection Images

Pre-processing

Fourier Filtering

Back Projection

Reconstructed CT volume

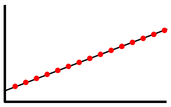
Detector Gain Calibration

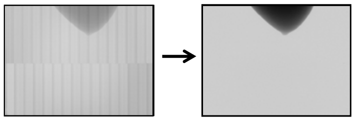
Geometric Calibration

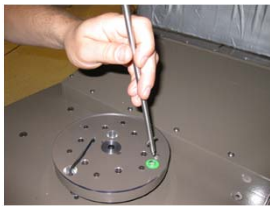
calibration, corrections, reconstruction

Flat Field Correction

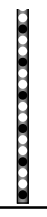
$$I_{corr} = \bar{g} \frac{\lfloor I_{raw} - I_{r-offset} \rfloor}{\lfloor I_{grain} - I_{g-offset} \rfloor}$$

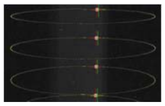




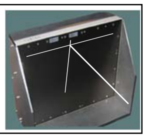


Geometric Calibration



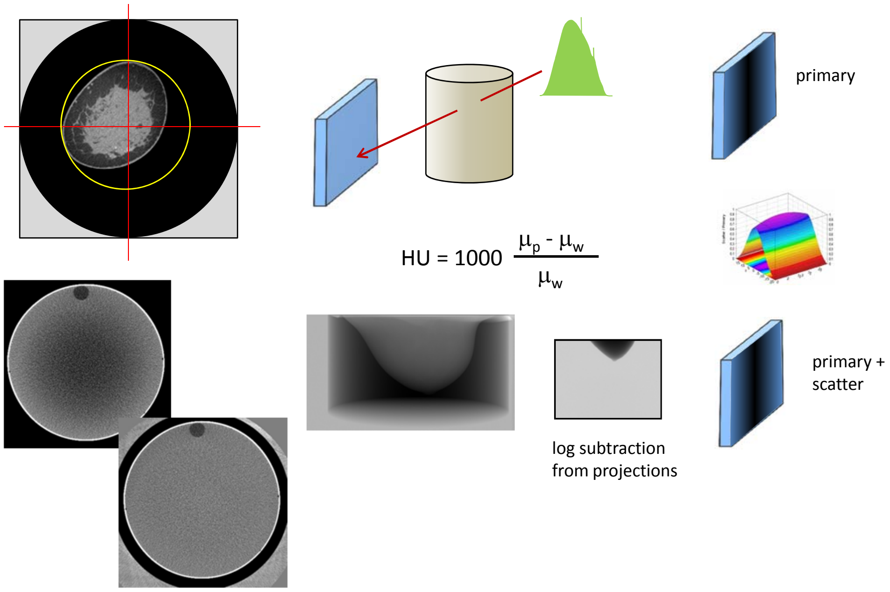


$$u_{wr} = y_{obj} \cdot \frac{D + u_{wr} \cdot \sin\phi}{C + x_{obj}} \cdot \frac{1}{\cos\phi}, \; v_{wr} = z_{obj} \cdot \frac{D + u_{wr} \cdot \sin\phi}{C + x_{obj}} .$$



calibration, corrections, reconstruction

Hounsfield Unit Calibration



$$HU = 1000 \frac{\mu_p - \mu_w}{\mu_w}$$

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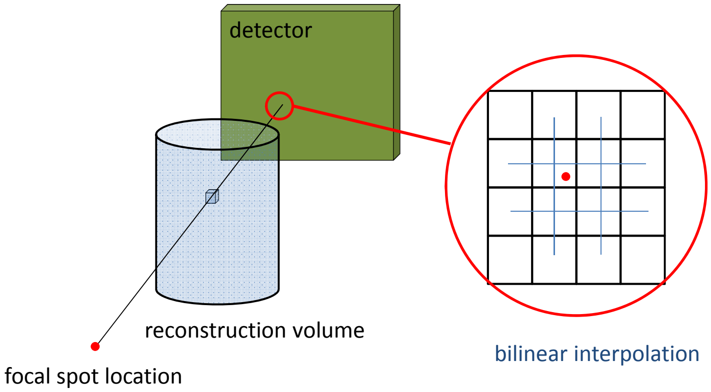
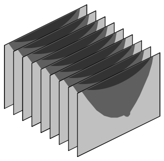
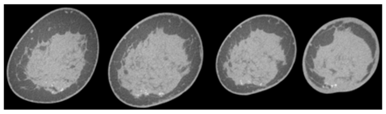
Reconstruction Algorithm (1): Feldkamp

voxel-driven reconstruction



FDK Reconstruction Code





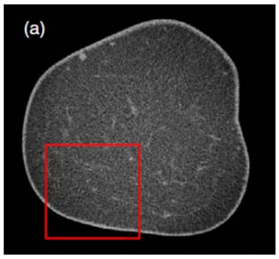
2003	~42 minutes
2008	~35 minutes
2010	~20 seconds

>100x

```
float tempi,tempr;
double theta,wi,wpi,wpr,wr,wtemp;

ntot=1;
for (idim=1;idim<=ndim;idim++)
        ntot *= nn[idim];
nprev=1;
for (idim=ndim;idim>=1;idim--) {
        n=nn[idim];
        nrem=ntot/(n*nprev);
        ip1=nprev << 1;
        ip2=ip1*n;
        ip3=ip2*nrem;
        i2rev=1;
        for (i2=1;i2<=ip2;i2+=ip1) {
                if (i2 < i2rev) {
                        for (i1=i2;i1<=i2+ip1-2;i1+=2) {
                                for (i3=i1;i3<=ip3;i3+=ip2) {
                                        i3rev=i2rev+i3-i2;
                                        SWAP(data[i3],data[i3rev]);
                                        SWAP(data[i3+1],data[i3rev+1]);
                                }
                        }
                }
                ibit=ip2 >> 1;
                while (ibit >= ip1 && i2rev > ibit) {
                        i2rev -= ibit;
                        ibit >>= 1;
                }
                i2rev += ibit;
        }
        ifp1=ip1;
        while (ifp1 < ip2) {
                ifp2=ifp1 << 1;
                theta=isign*6.28318530717959/(ifp2/ip1);
                wtemp=sin(0.5*theta);
                wpr = -2.0*wtemp*wtemp;
                wpi=sin(theta);
                wr=1.0;
                wi=0.0;
                for (i3=1;i3<=ifp1;i3+=ip1) {
                        for (i1=i3;i1<=i3+ip1-2;i1+=2) {
                                for (i2=i1;i2<=ip3;i2+=ifp2) {
                                        k1=i2;
                                        k2=k1+ifp1;
                                        tempr=wr*data[k2]-wi*data[k2+1];
                                        tempi=wr*data[k2+1]+wi*data[k2];
                                        data[k2]=data[k1]-tempr;
                                        data[k2+1]=data[k1+1]-tempi;
                                        data[k1] += tempr;
                                        data[k1+1] += tempi;
                                }
                        }
                        wr=(wtemp=wr)*wpr-wi*wpi+wr;
                        wi=wi*wpr+wtemp*wpi+wi;
                }
                ifp1=ifp2;
        }
        nprev *= n;
}
```

Reconstruction Algorithm (2): constrained TV minimization



Investigation of iterative image reconstruction in low-dose breast CT

Junguo Bian[1], **Kai Yang**[2], **John M Boone**[2], **Xiao Han**[3], **Emil Y Sidky**[3] **and Xiaochuan Pan**[4,5]

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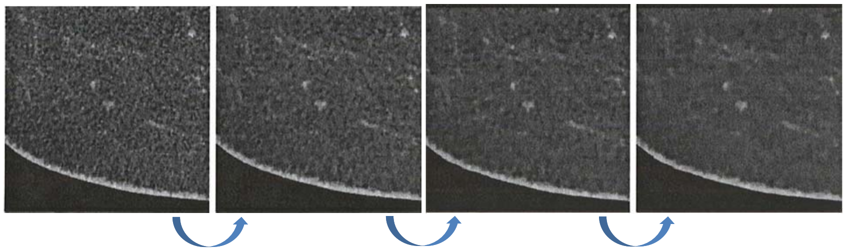
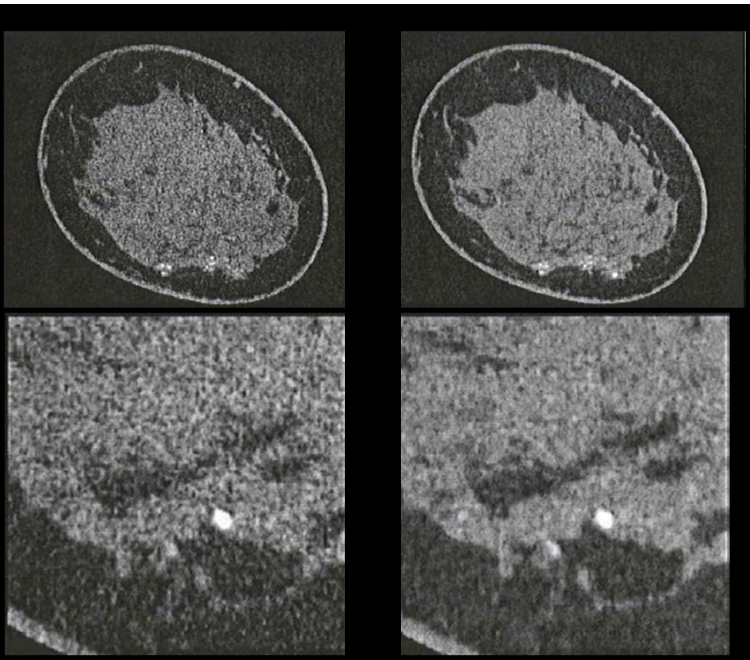
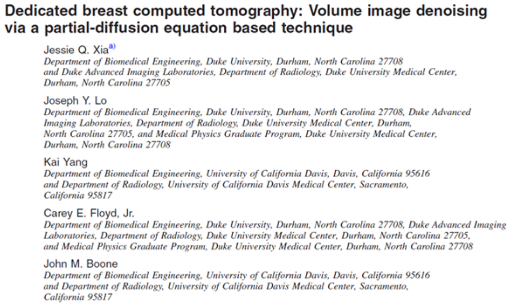




Feldkamp TV minimization

Reconstruction Algorithm (3): denoising projections



Dedicated breast computed tomography: Volume image denoising via a partial-diffusion equation based technique

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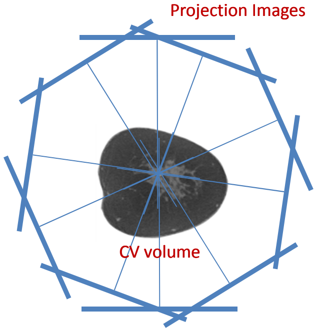
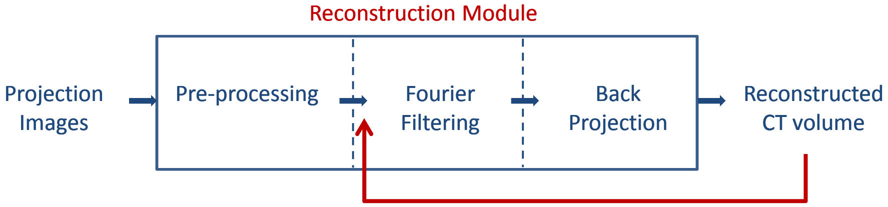
John M. Boone
Department of Biomedical Engineering, University of California Davis, Davis, California 95616 and Department of Radiology, University of California Davis Medical Center, Sacramento, California 95817

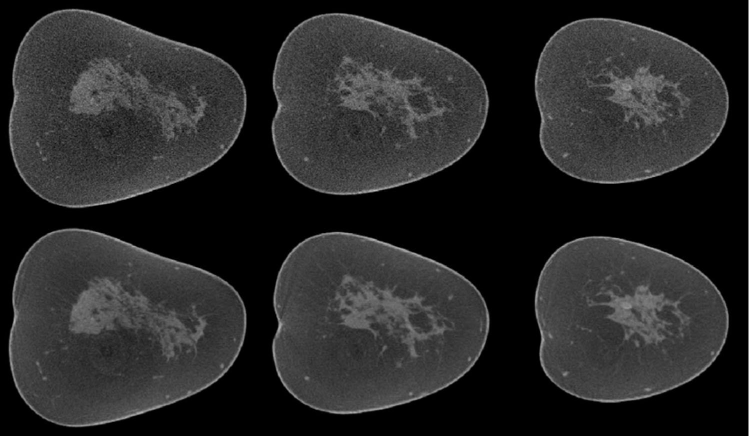




Reconstruction Module

Projection Images → Pre-processing → Fourier Filtering → Back Projection → Reconstructed CT volume

---



Feldkamp

PDE Denoising

Evolution of the UC Davis Breast CT Scanner

- Introduction to Breast Cancer Screening
- Breast CT Hardware (evolution)
- Breast CT Software
  - Integrating Hardware with Software
  - System Calibrations
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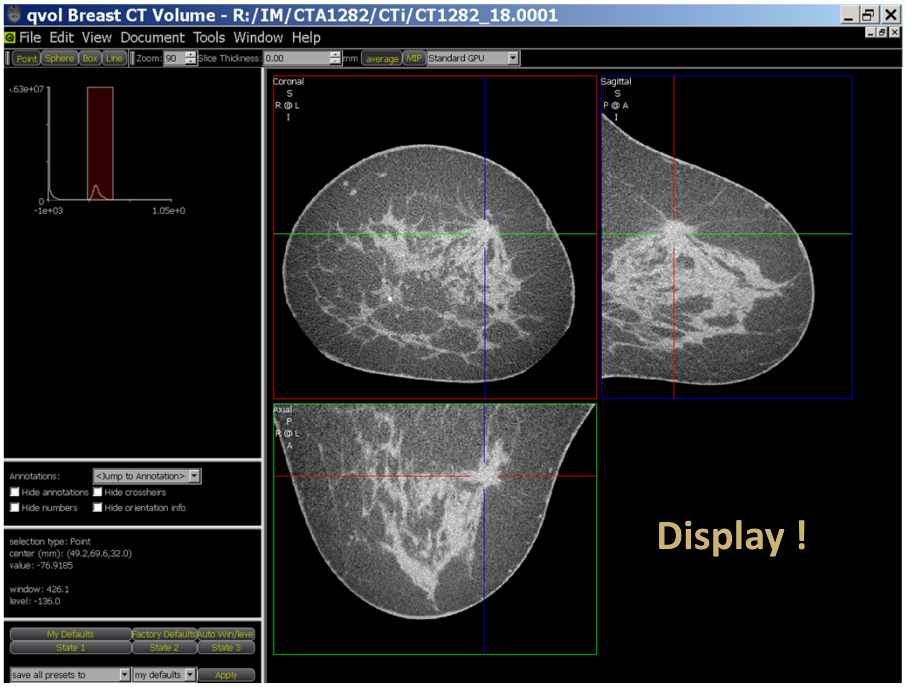
    - Breast Density Analysis
    - Breast Texture / Comparisons to Mammo & Tomo
    - Ideal Observer Performance Analysis
  - Monte Carlo Analysis / Radiation Dosimetry
- Summary



qvol Breast CT Volume - R:/IM/CTA1282/CTi/CT1282_18.0001

Zoom: 90 Slice Thickness: 0.00 mm

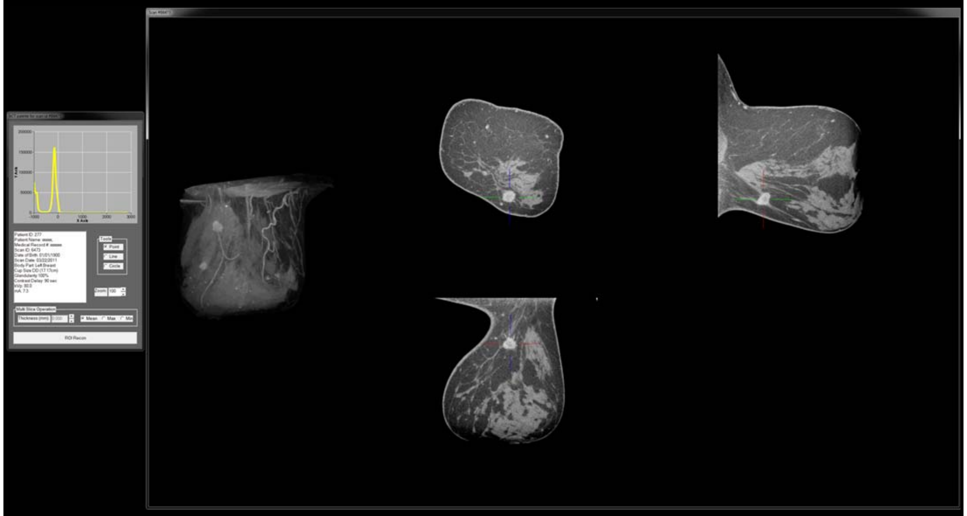
☐ Hide annotations ☐ Hide crossheirs
☐ Hide numbers ☐ Hide orientation info

```
selection type: Point
center (mm): (49.2,69.6,32.0)
value: -76.9185

window: 426.1
level: -136.0
```

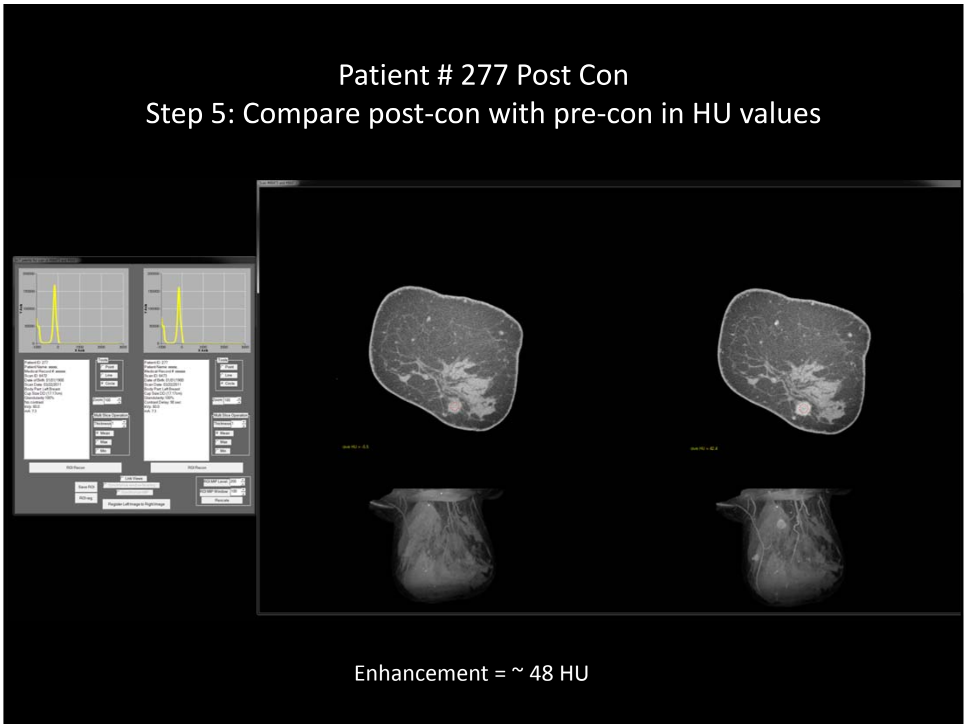
Display !

Patient # 277 Post Con
Step 1: Initial observation-post con



Patient ID: 277
Patient Name: xxxxx,
Medical Record #: xxxxxx
Scan ID: 6473
Date of Birth: 01/01/1900
Scan Date: 03/22/2011
Body Part: Left Breast
Cup Size: DD (17.17cm)
Glandularity: 100%
Contrast Delay: 90 sec
kVp: 80.0
mA: 7.3

Zoom: 100



Patient # 277 Post Con
Step 5: Compare post-con with pre-con in HU values

Enhancement = ~ 48 HU

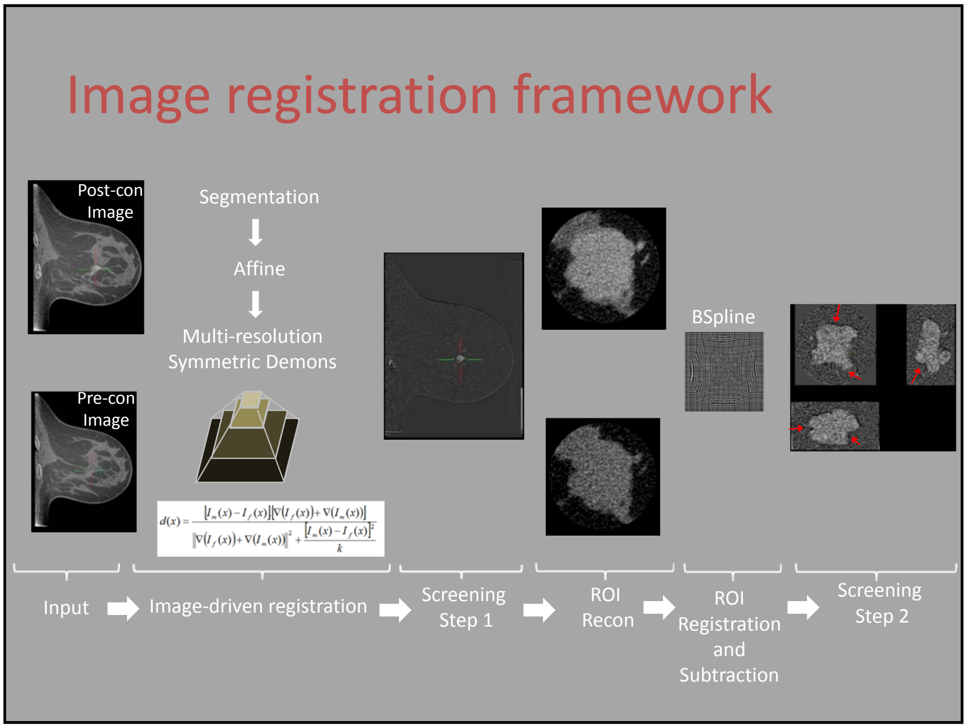
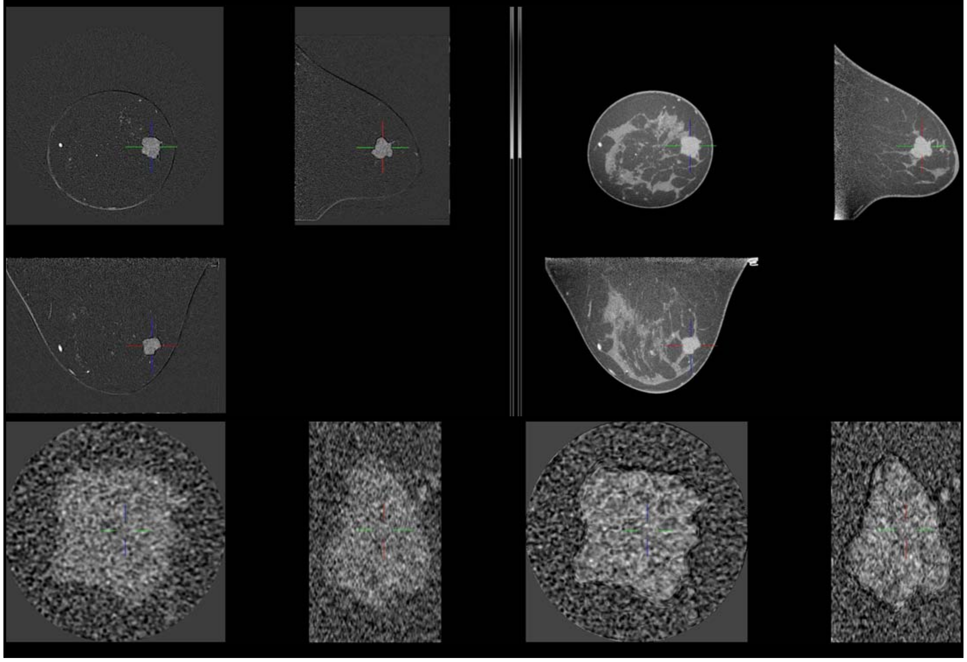


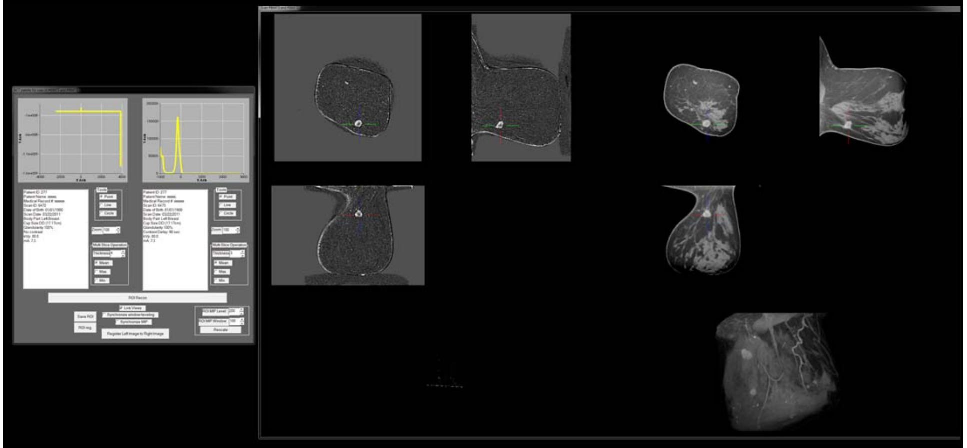
Image registration framework

$$d(x) = \frac{[I_m(x)-I_f(x)][\nabla(I_f(x))+\nabla(I_m(x))]}{\|\nabla(I_f(x))+\nabla(I_m(x))\|^2+\frac{[I_m(x)-I_f(x)]^2}{k}}$$

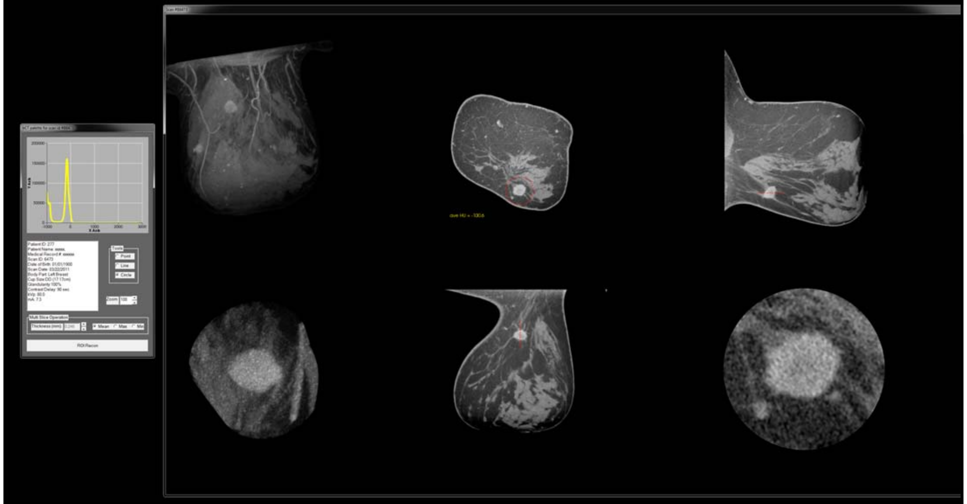
Input ➡ Image-driven registration ➡ Screening Step 1 ➡ ROI Recon ➡ ROI Registration and Subtraction ➡ Screening Step 2



Patient # 277 Post Con
Step 2: Compare with registered/subtracted dataset



Patient # 277 Post Con
Step 3: ROI Recon



Patient ID: 277
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Detector Performance

- ➡ Noise (texture) Analysis (NPS)
- Spatial Resolution Analysis (MTF)

Detector Performance (noise)

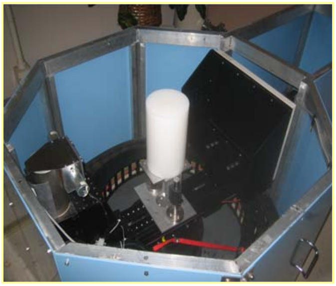
total noise

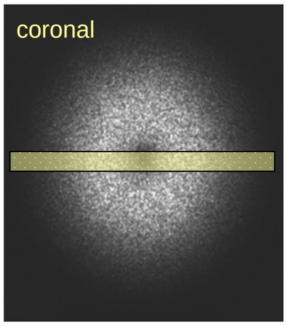
anatomical noise

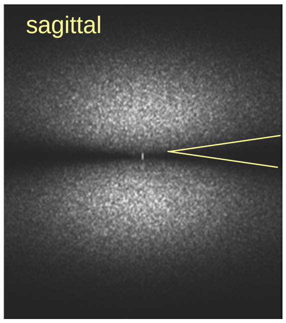
quantum noise

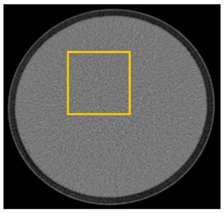
$$\text{NPS}(f) = \text{NPS}_a(f) + \text{NPS}_q(f)$$

Contrast Resolution: NPS measurements

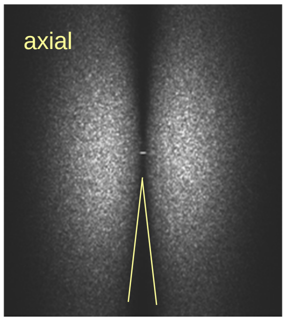


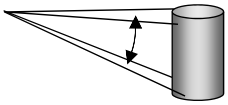






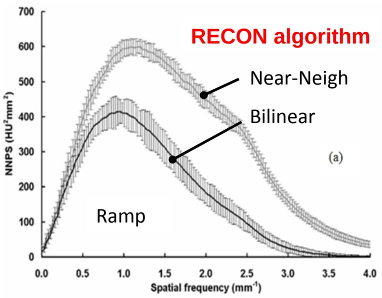
$$NPS(u,v) = \frac{|F(u,v)|^2}{N_X N_Y} \Delta_X \Delta_Y$$

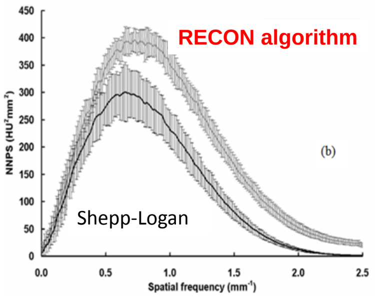


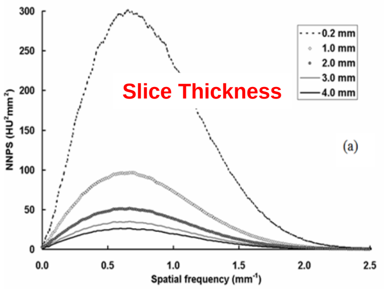


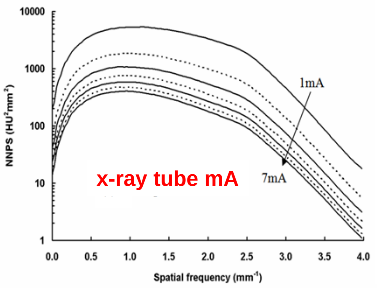
cone angle

Noise Power Spectrum (NPS) measurements

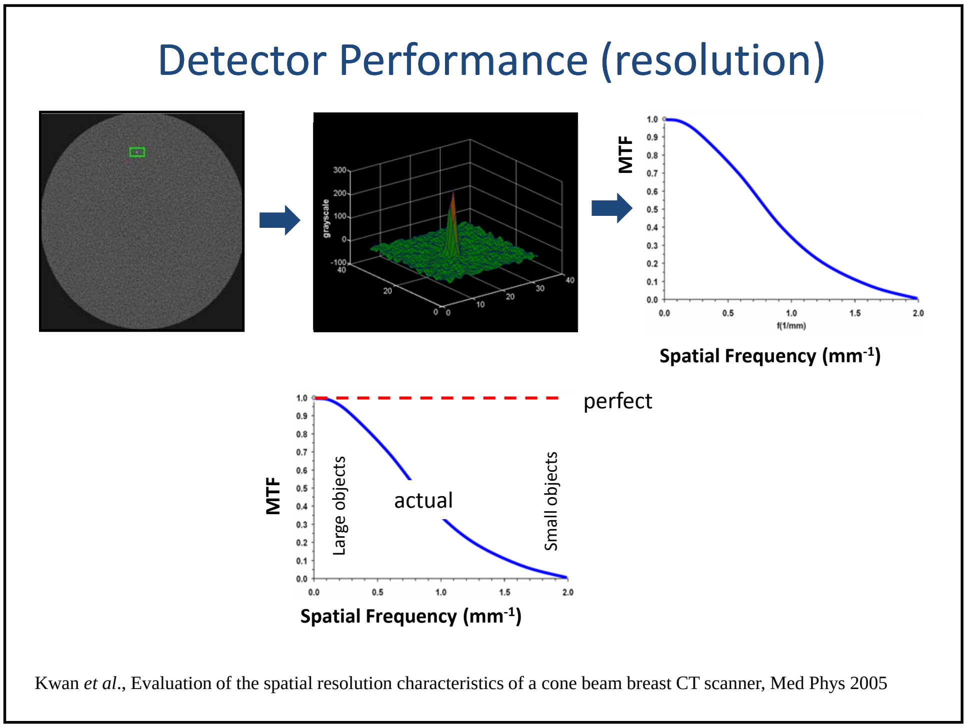






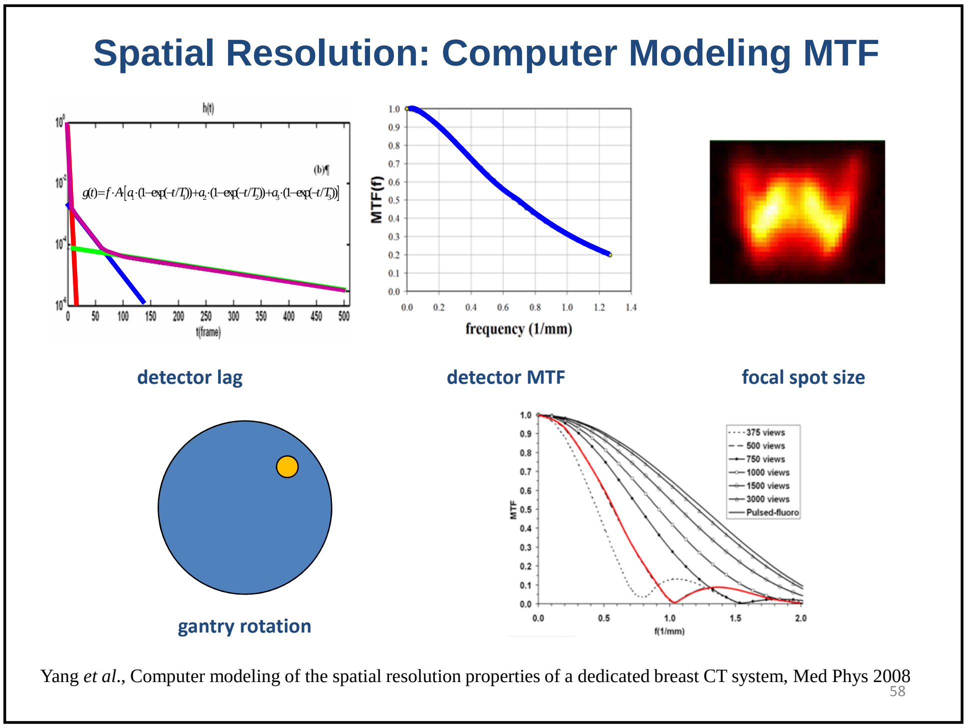


Yang *et al*., Noise power properties of a cone beam CT system for breast cancer detection, Med Phys. 2008



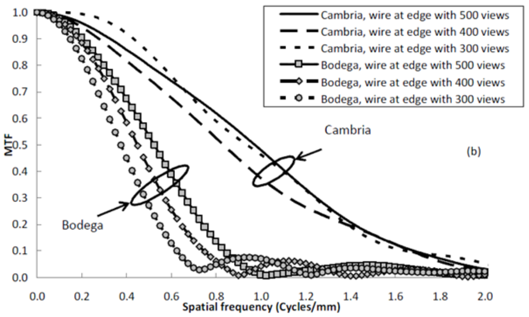
Detector Performance (resolution)

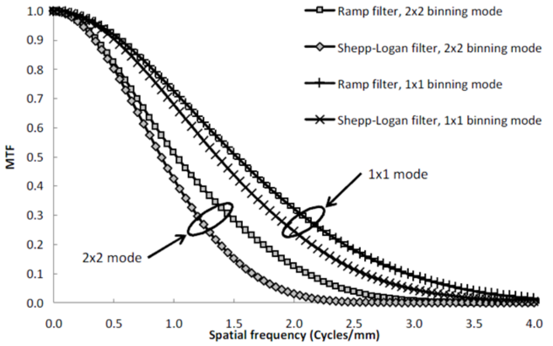
Kwan *et al*., Evaluation of the spatial resolution characteristics of a cone beam breast CT scanner, Med Phys 2005

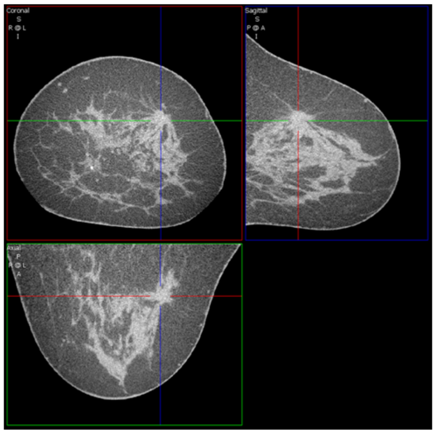


Spatial Resolution: Computer Modeling MTF

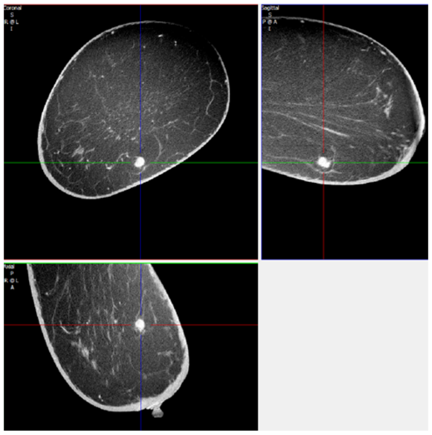
Yang *et al*., Computer modeling of the spatial resolution properties of a dedicated breast CT system, Med Phys 2008





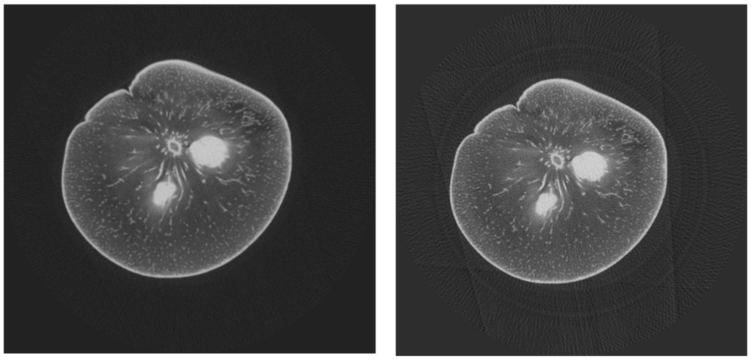


Bodega (2 x 2)



Cambria (2 x 2)

Cambria: Detector binning mode
1x1 versus 2x2 mode

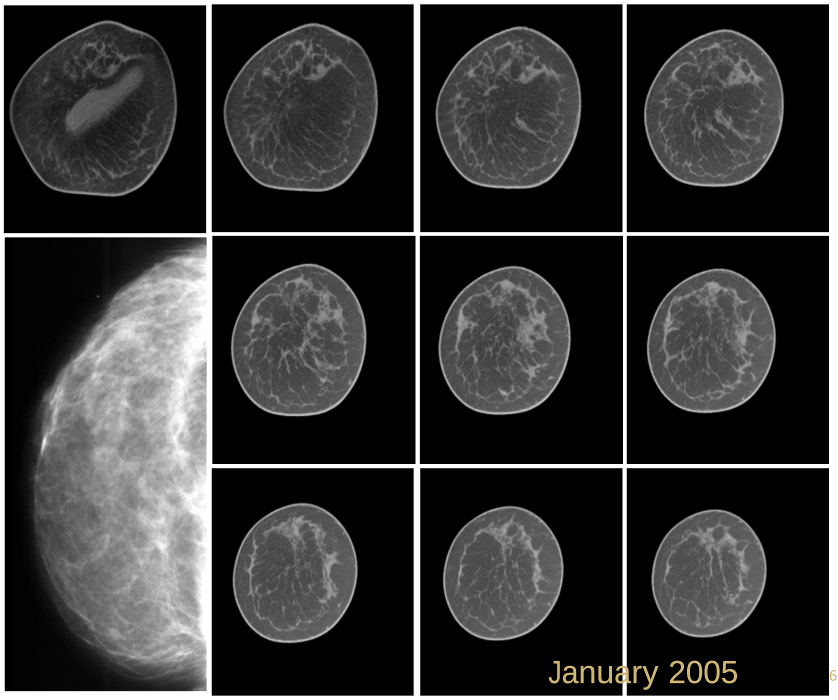


2x2 mode: 500 views

1x1 mode: 285 views

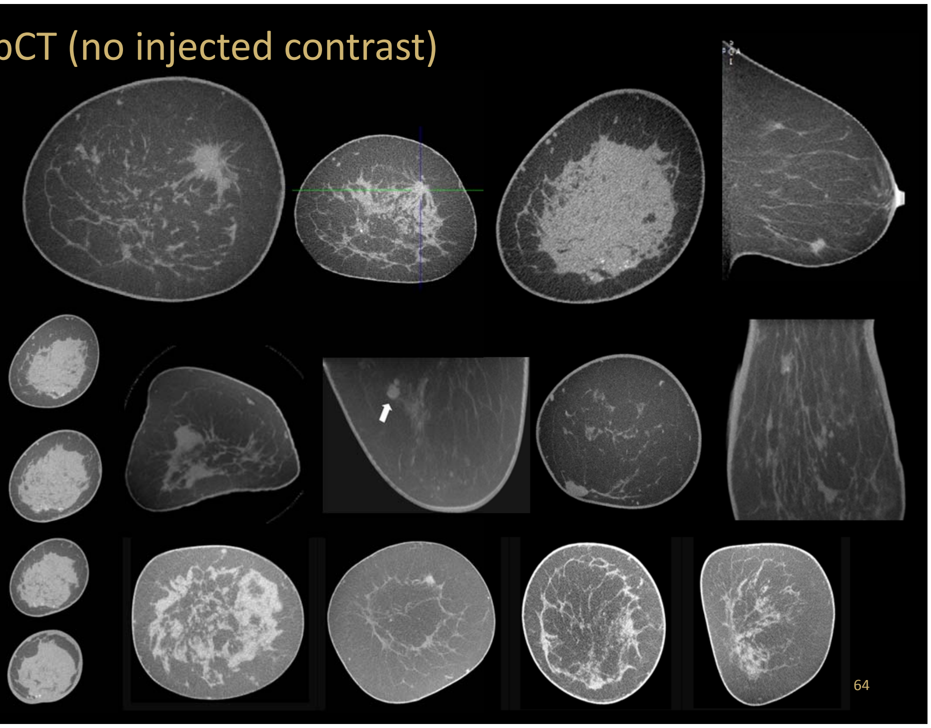
Clinical Imaging

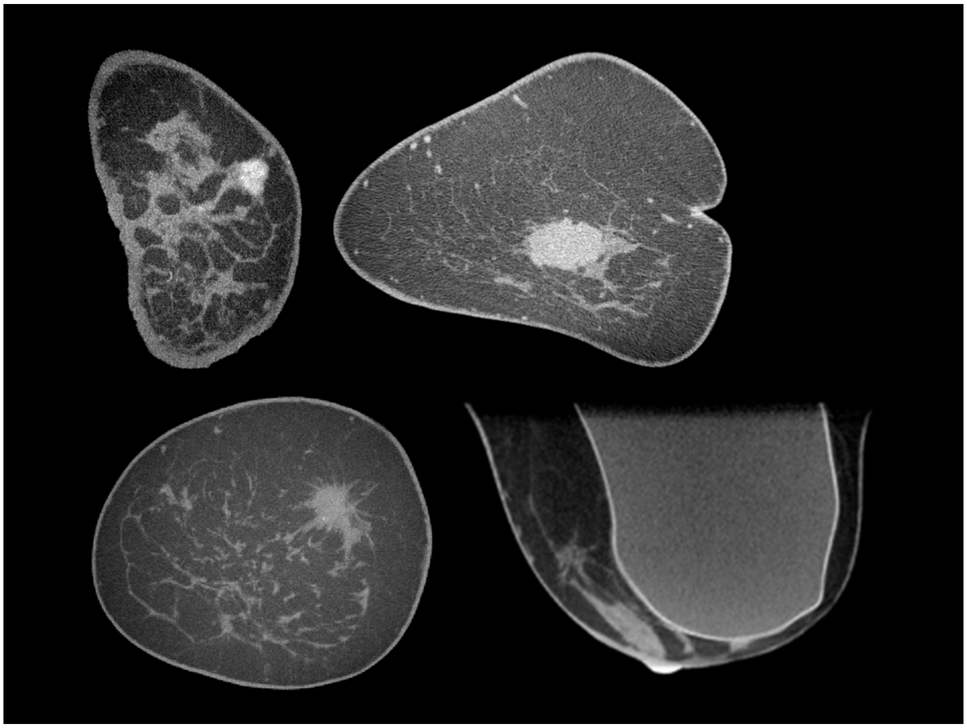
- Over 600 women on UC Davis scanners
- Image women with suspicion of BC
- Informed consent / HIPAA compliant
- 16 second scan (breath hold)
- 500 projection images (1024 x 768)
- 30 frame / sec acquisition rate
- About 200 have had contrast injection
- Radiation dose same as 2V mammography
- Image reconstruction 512^3 or better

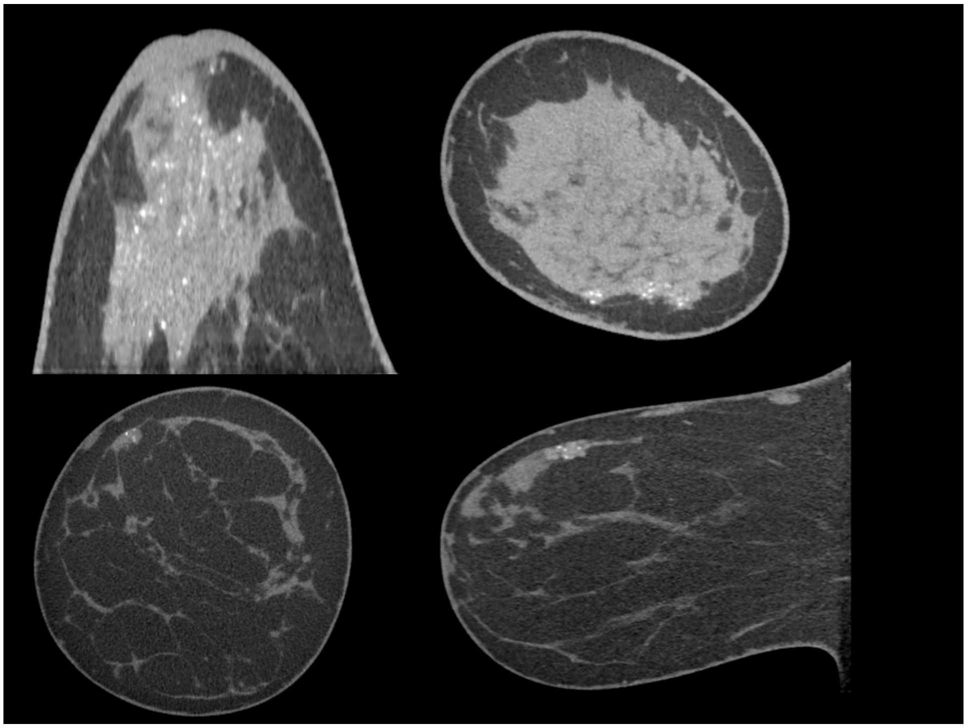


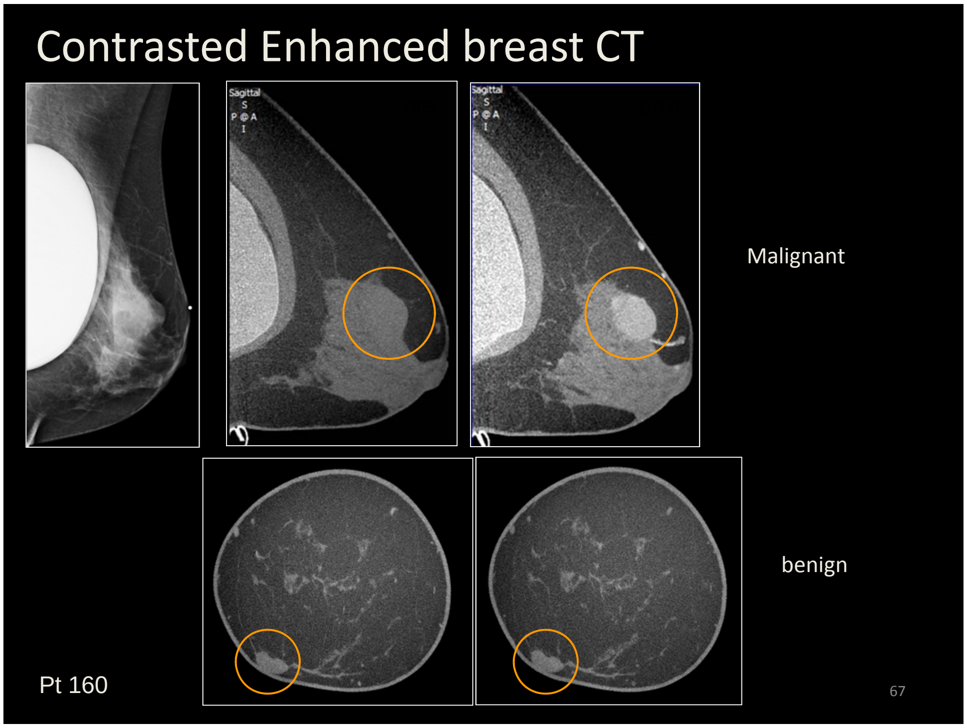
January 2005

bCT (no injected contrast)







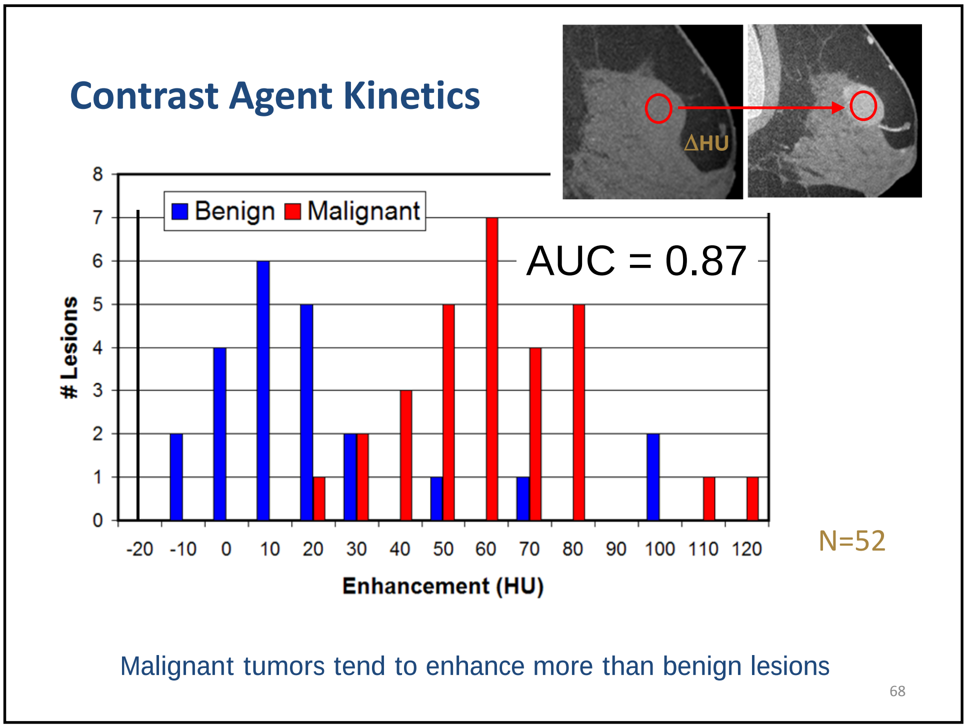


Contrasted Enhanced breast CT

Malignant

benign

Pt 160



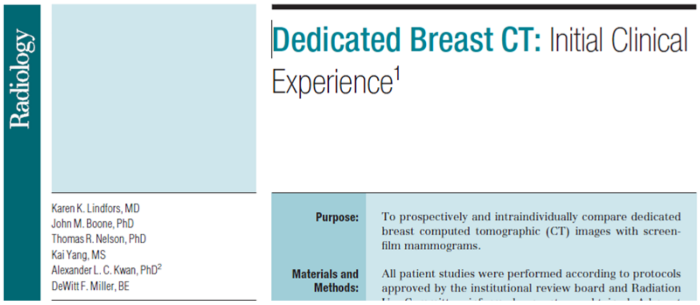
Contrast Agent Kinetics

AUC = 0.87

N=52

	Benign	Malignant
-20		
-10	2	
0	4	
10	6	
20	5	1
30	2	2
40		3
50	1	5
60		7
70	1	4
80		5
90		
100	2	
110		1
120		1

Malignant tumors tend to enhance more than benign lesions



Radiology

Dedicated Breast CT: Initial Clinical Experience[1]

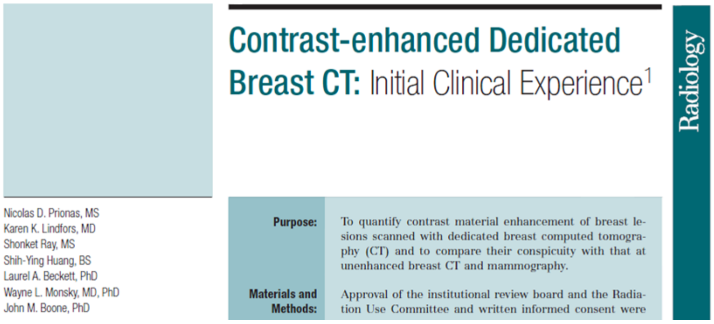
Karen K. Lindfors, MD
John M. Boone, PhD
Thomas R. Nelson, PhD
Kai Yang, MS
Alexander L. C. Kwan, PhD[2]
DeWitt F. Miller, BE

Purpose: To prospectively and intraindividually compare dedicated breast computed tomographic (CT) images with screen-film mammograms.

Materials and Methods: All patient studies were performed according to protocols approved by the institutional review board and Radiation

2008

2010



Contrast-enhanced Dedicated Breast CT: Initial Clinical Experience[1]

Radiology

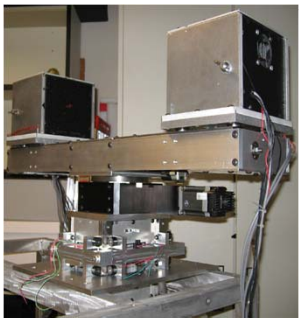
Nicolas D. Prionas, MS
Karen K. Lindfors, MD
Shonket Ray, MS
Shih-Ying Huang, BS
Laurel A. Beckett, PhD
Wayne L. Monsky, MD, PhD
John M. Boone, PhD

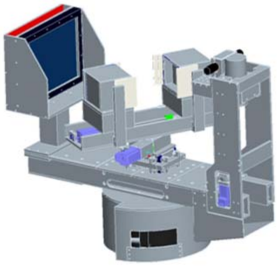
Purpose: To quantify contrast material enhancement of breast lesions scanned with dedicated breast computed tomography (CT) and to compare their conspicuity with that at unenhanced breast CT and mammography.

Materials and Methods: Approval of the institutional review board and the Radiation Use Committee and written informed consent were

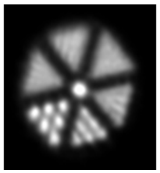
---

PET / CT for dedicated breast imaging

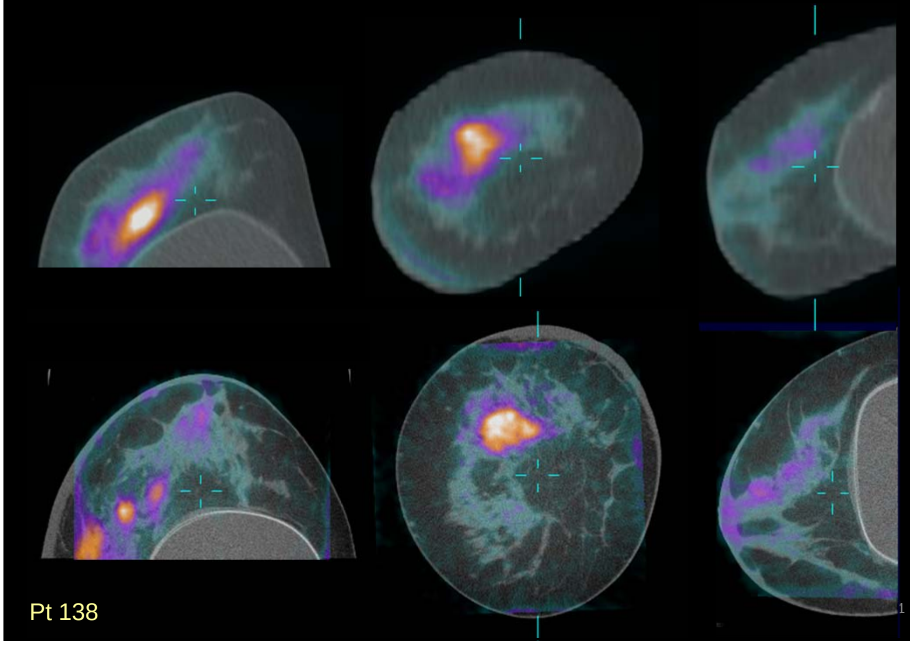




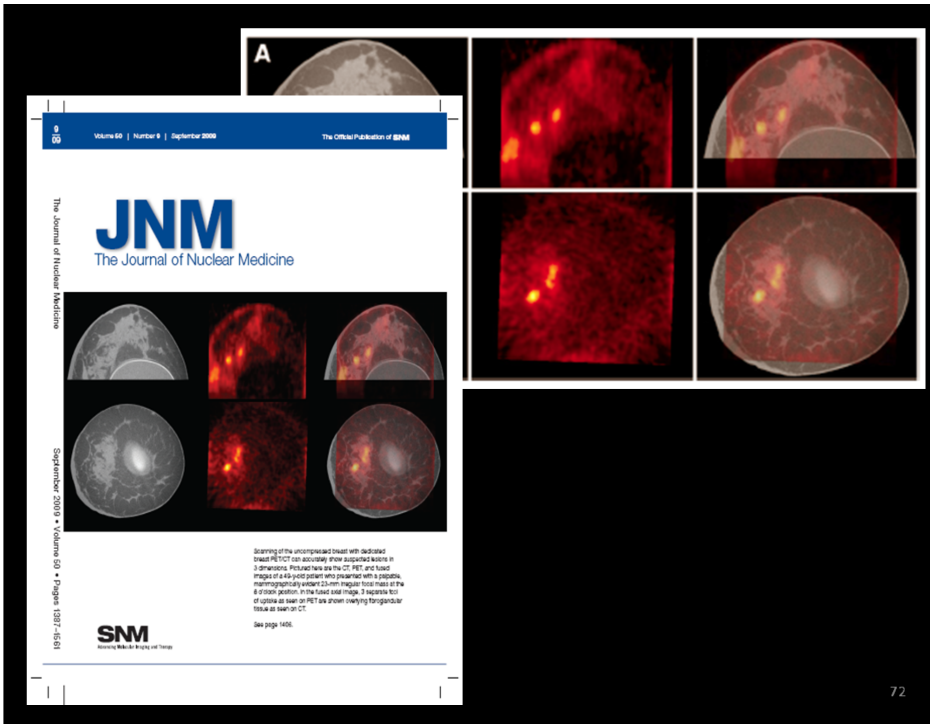
ramsey badawi
simon cherry
abhijit chaudhari
spencer bowen



Invasive Mammary Carcinoma



Pt 138



9
09

Volume 50 | Number 9 | September 2009

The Official Publication of SNM

JNM
The Journal of Nuclear Medicine

Scanning of the uncompressed breast with dedicated breast PET/CT can accurately show suspected lesions in 3 dimensions. Pictured here are the CT, PET, and fused images of a 49-y-old patient who presented with a palpable, mammographically evident 23-mm irregular focal mass at the 8 o'clock position. In the fused axial image, 3 separate foci of uptake as seen on PET are shown overlying fibroglandular tissue as seen on CT.

See page 1406.

SNM
Advancing Molecular Imaging and Therapy

The Journal of Nuclear Medicine

September 2009 • Volume 50 • Pages 1387–1561

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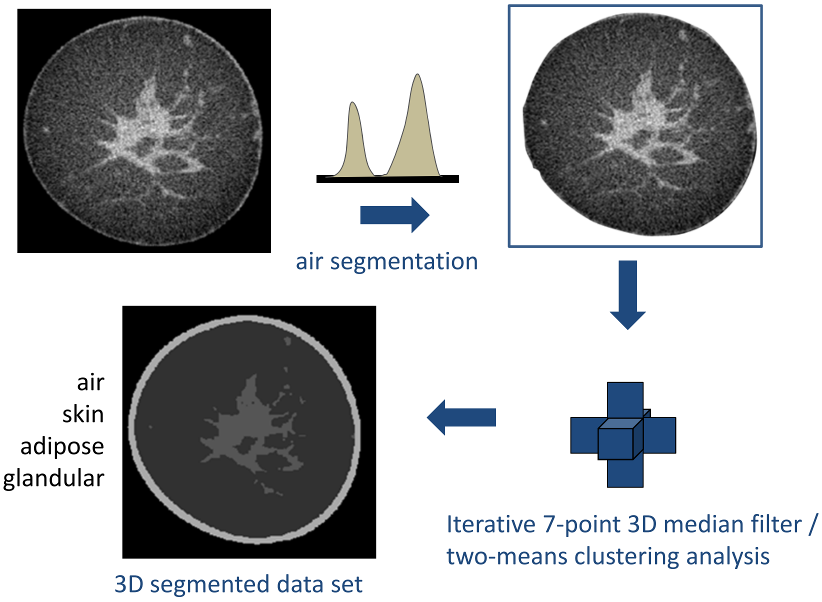
Image Segmentation

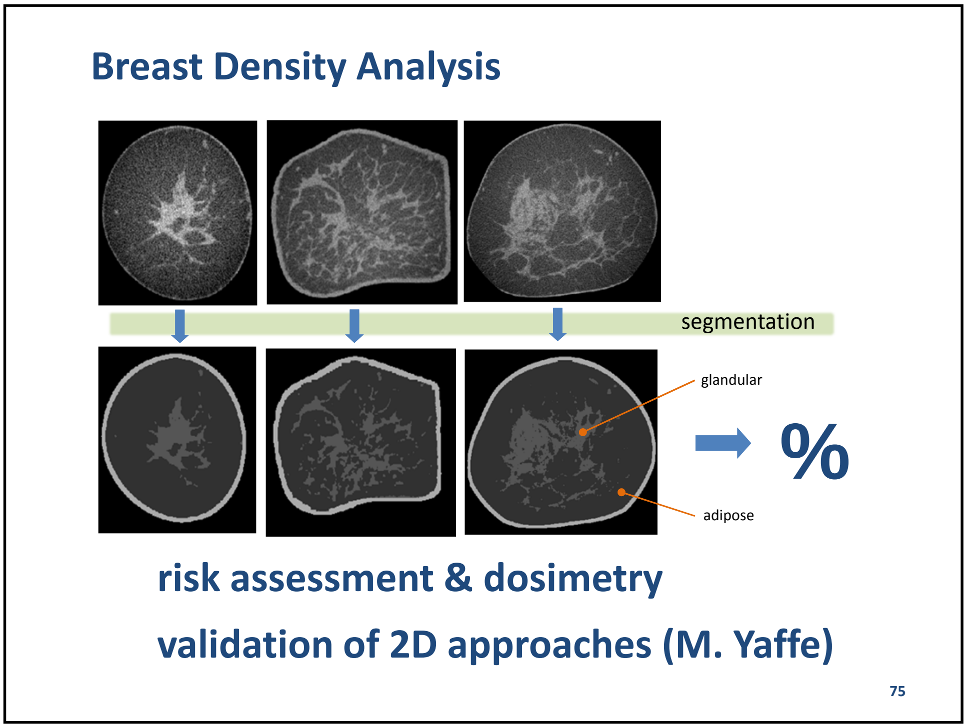


air segmentation

air
skin
adipose
glandular

3D segmented data set

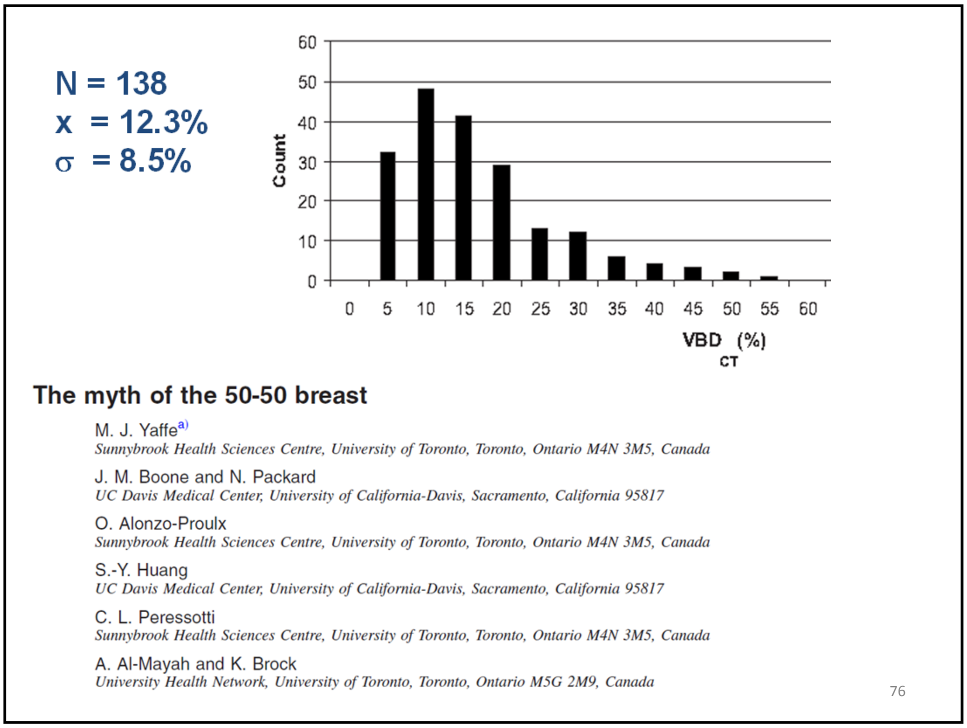
Iterative 7-point 3D median filter / two-means clustering analysis



Breast Density Analysis

risk assessment & dosimetry

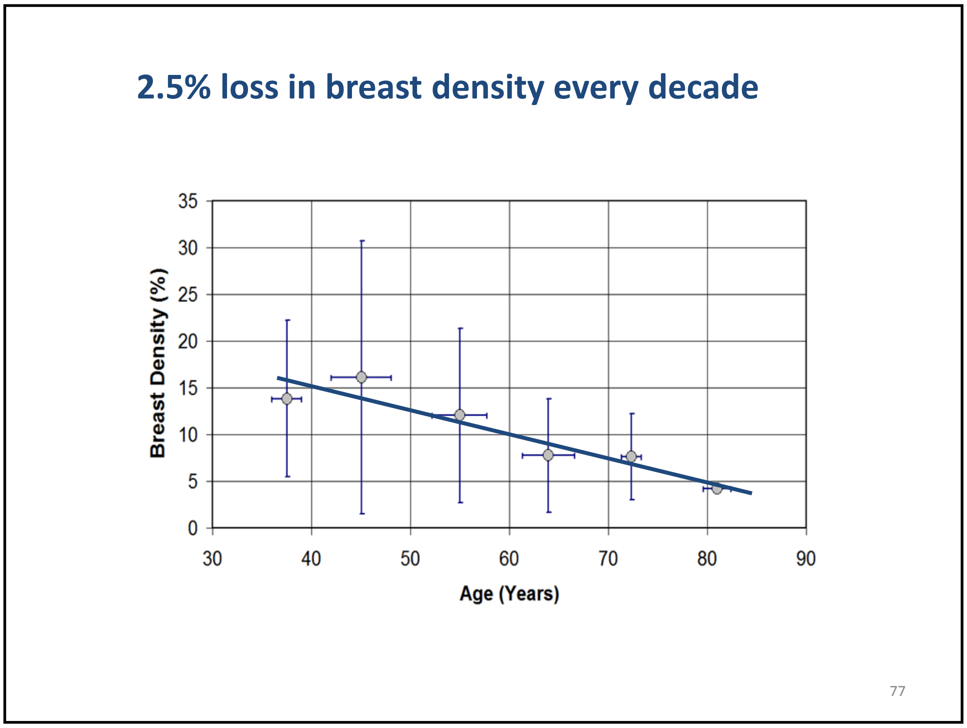
validation of 2D approaches (M. Yaffe)



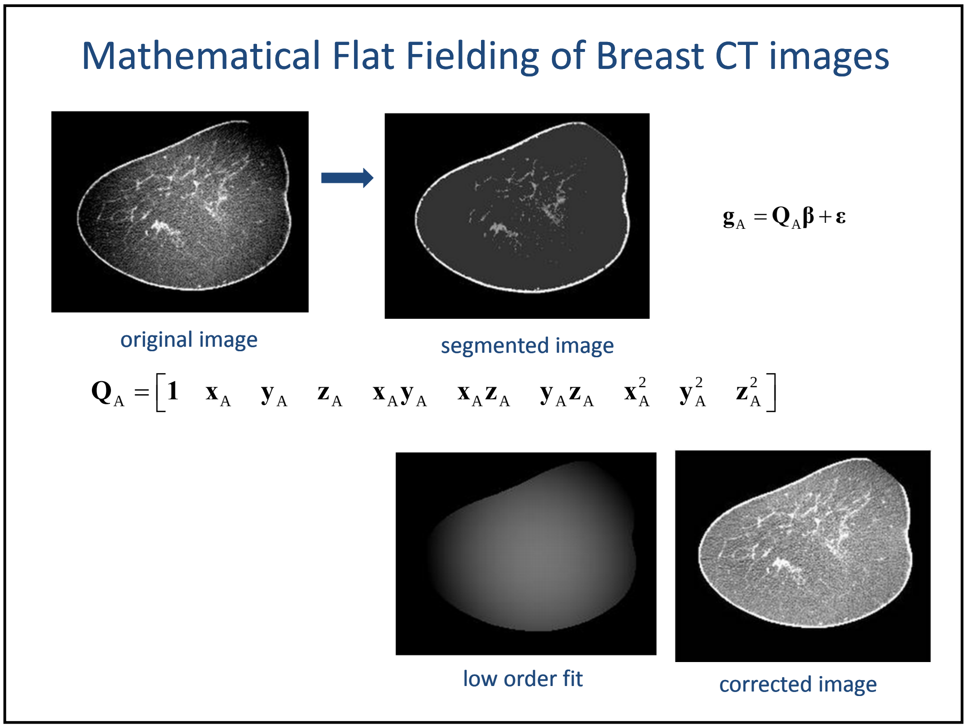
N = 138
x = 12.3%
σ = 8.5%

The myth of the 50-50 breast

M. J. Yaffe[a)]
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada
J. M. Boone and N. Packard
UC Davis Medical Center, University of California-Davis, Sacramento, California 95817
O. Alonzo-Proulx
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada
S.-Y. Huang
UC Davis Medical Center, University of California-Davis, Sacramento, California 95817
C. L. Peressotti
Sunnybrook Health Sciences Centre, University of Toronto, Toronto, Ontario M4N 3M5, Canada
A. Al-Mayah and K. Brock
University Health Network, University of Toronto, Toronto, Ontario M5G 2M9, Canada



2.5% loss in breast density every decade



Mathematical Flat Fielding of Breast CT images

original image

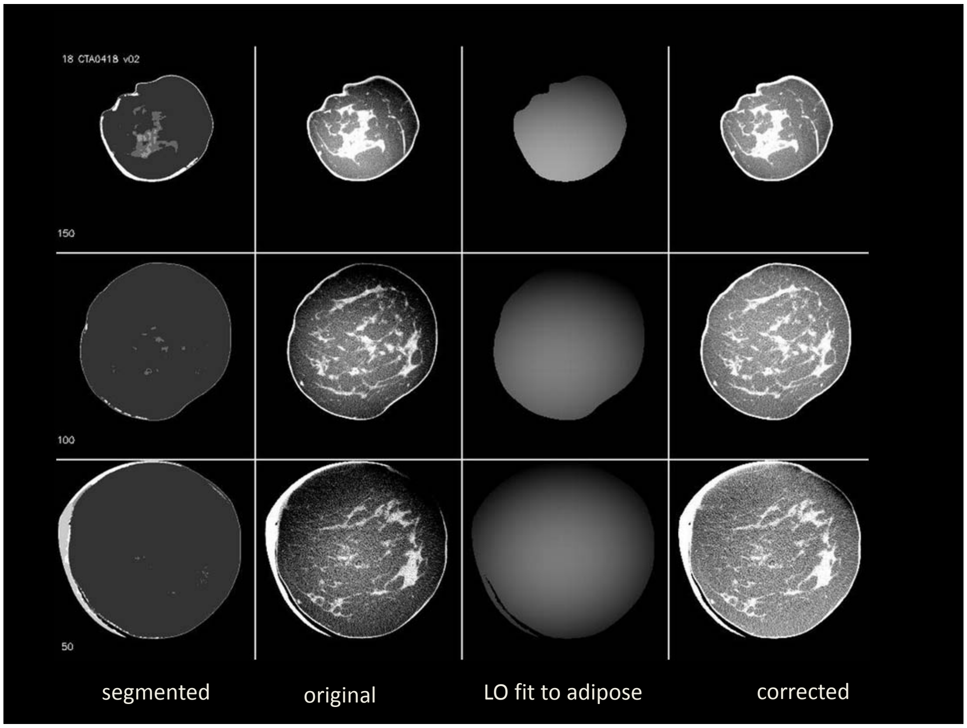
segmented image

$$\mathbf{g}_A = \mathbf{Q}_A \boldsymbol{\beta} + \boldsymbol{\varepsilon}$$

$$\mathbf{Q}_A = \begin{bmatrix} 1 & \mathbf{x}_A & \mathbf{y}_A & \mathbf{z}_A & \mathbf{x}_A\mathbf{y}_A & \mathbf{x}_A\mathbf{z}_A & \mathbf{y}_A\mathbf{z}_A & \mathbf{x}_A^2 & \mathbf{y}_A^2 & \mathbf{z}_A^2 \end{bmatrix}$$

low order fit

corrected image



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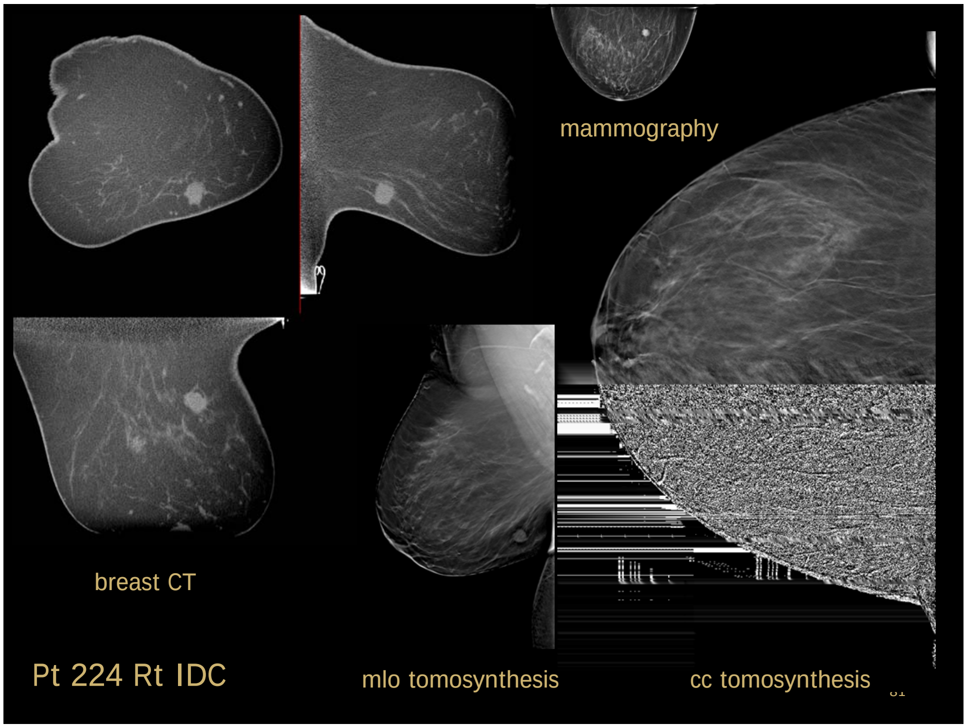


total noise

anatomical noise

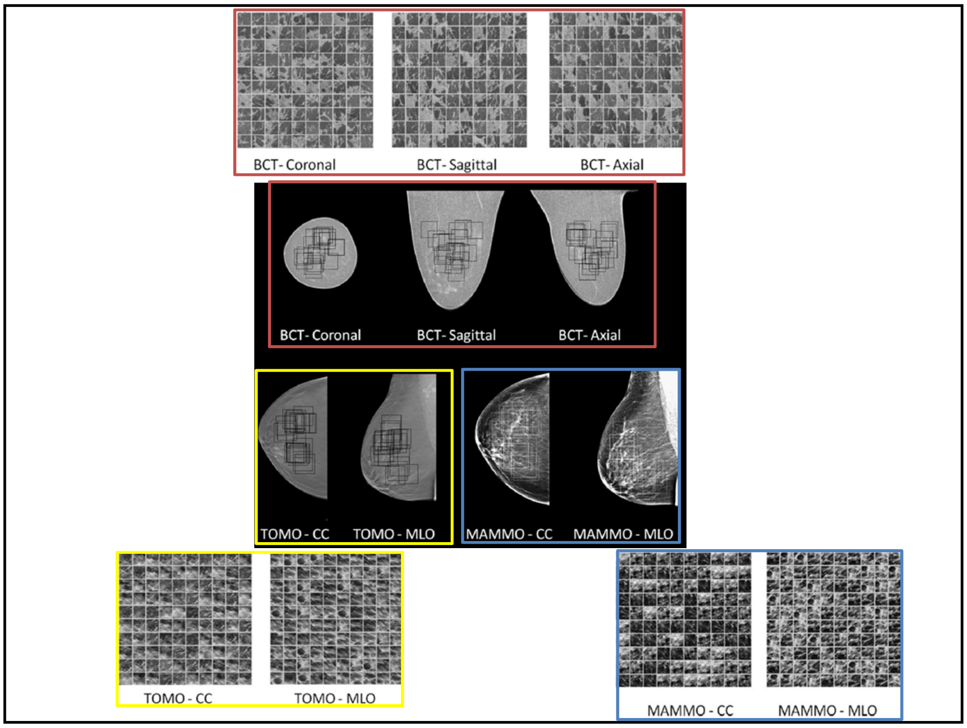
quantum noise

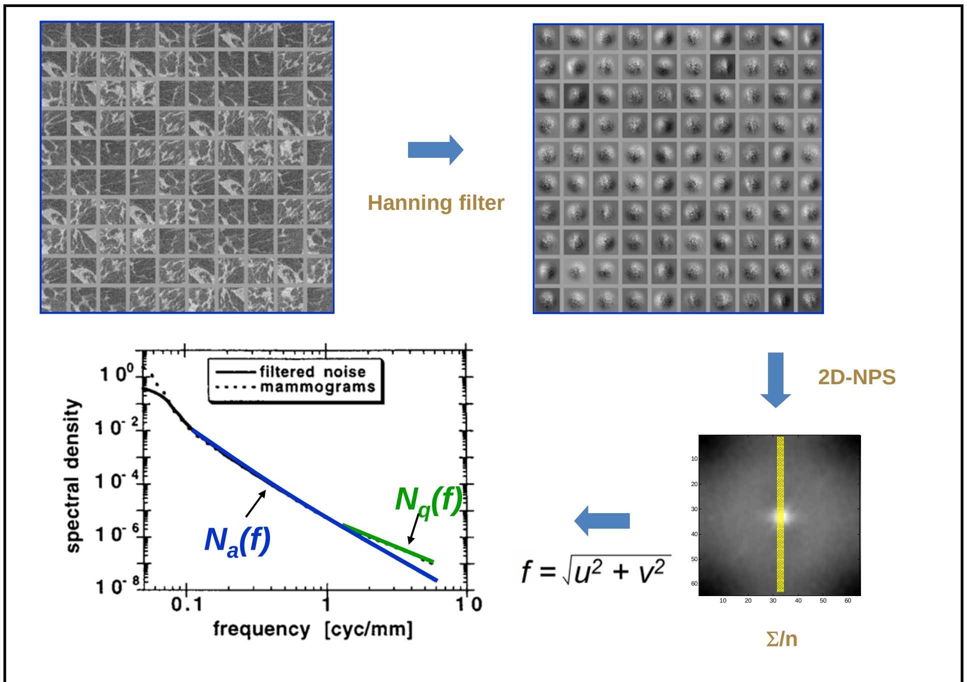
$$NPS(f) = NPS_a(f) + NPS_q(f)$$

$$NPS_a(f) = \alpha\, f^{-\beta}$$

Burgess, et al

A. E. Burgess, F. L. Jacobson, and P. F. Judy, "Human observer detection experiments with mammograms and power-law noise," Med. Phys. **28**, 419–437 (2001).





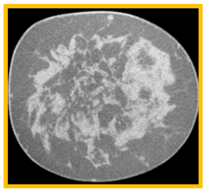
Hanning filter

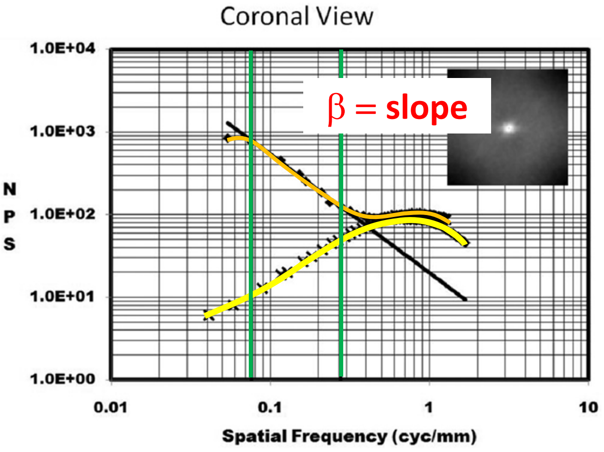
2D-NPS

$$f = \sqrt{u^2 + v^2}$$

Σ/n

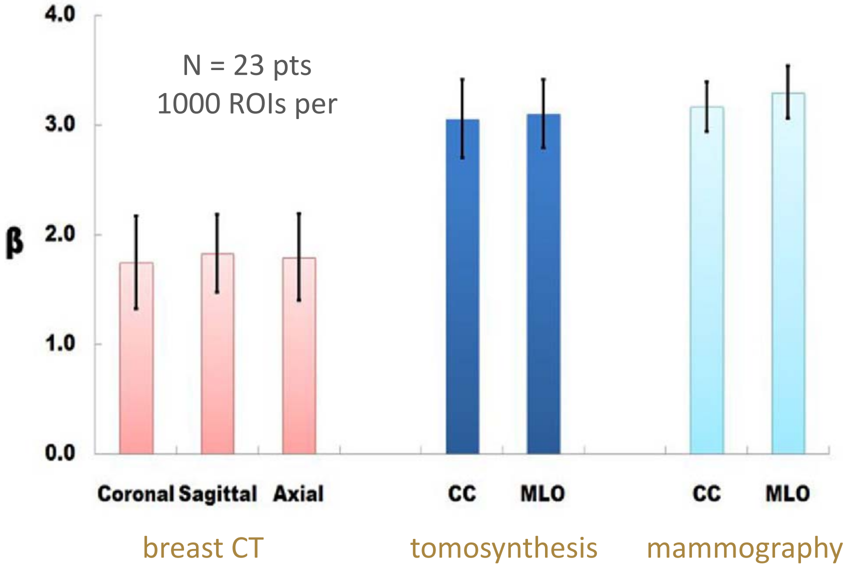
$$NPS(f) = NPS_a(f) + NPS_q(f)$$





$$NPS_a(f) = \alpha\, f^{-\beta}$$

bCT, Tomo, and Mammo Comparisons



N = 23 pts
1000 ROIs per

Anatomical complexity in breast parenchyma and its implications for optimal breast imaging strategies

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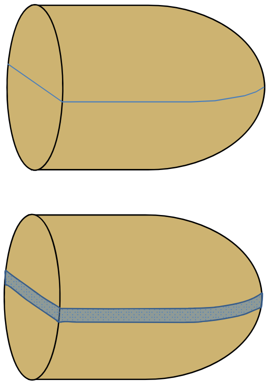
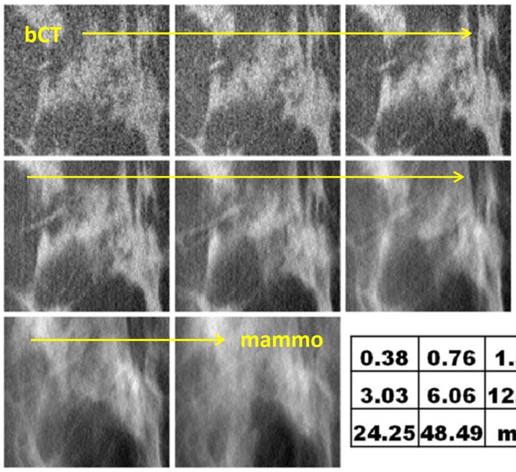
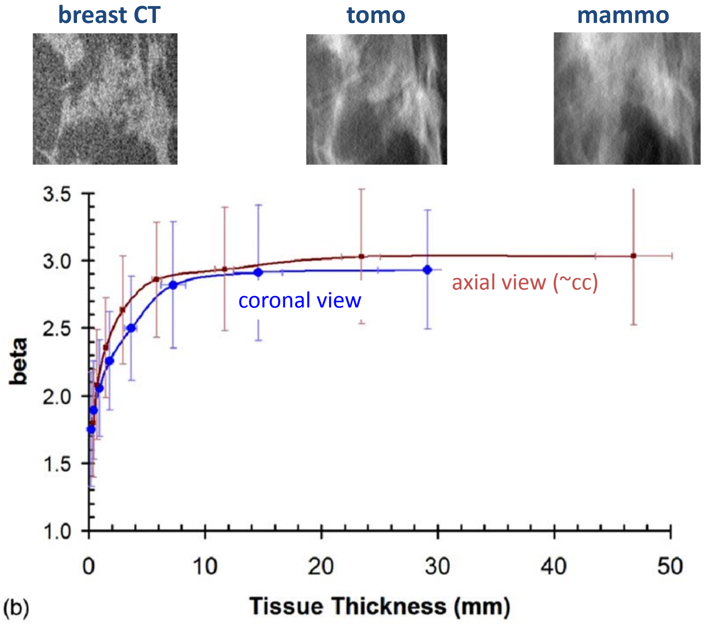


bCT volume data sets



0.38	0.76	1.52
3.03	6.06	12.12
24.25	48.49	mm



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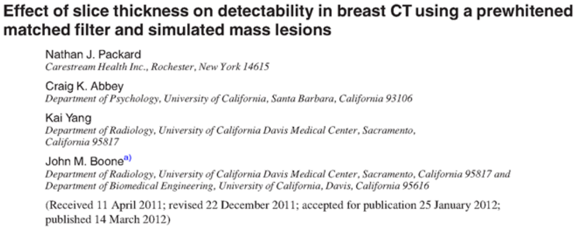
PWMF Observer Performance Analysis



Effect of slice thickness on detectability in breast CT using a prewhitened matched filter and simulated mass lesions

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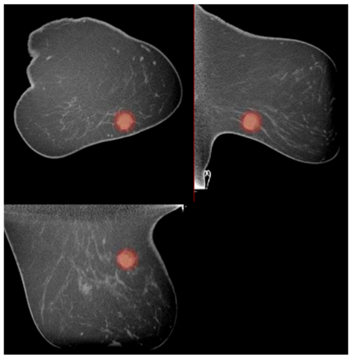
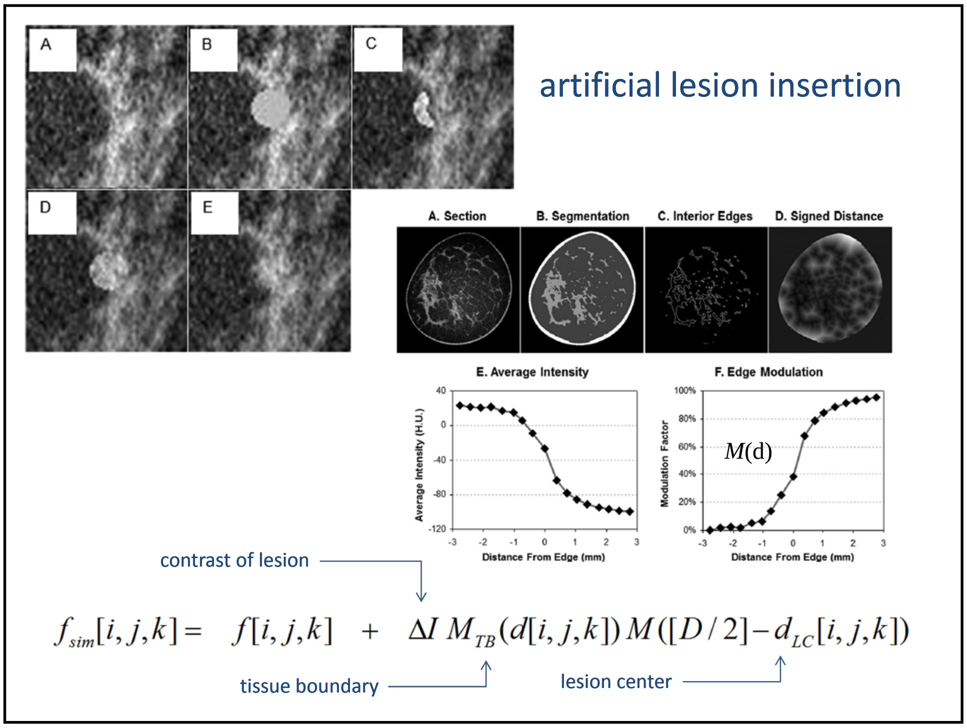
(Received 11 April 2011; revised 22 December 2011; accepted for publication 25 January 2012; published 14 March 2012)





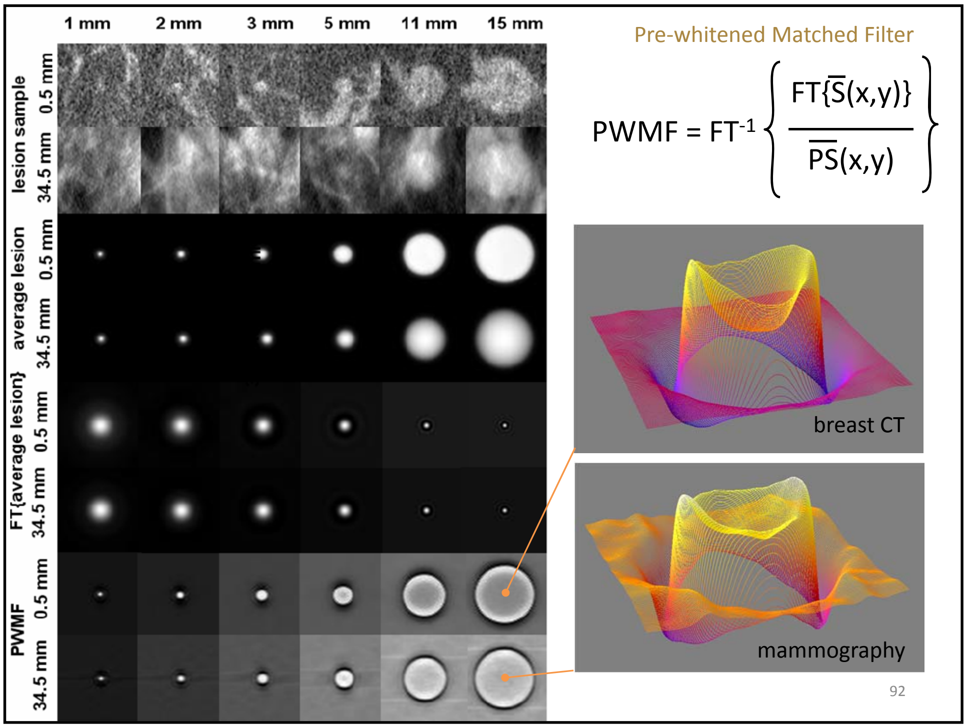
artificial lesion insertion

contrast of lesion

$$f_{sim}[i,j,k] = f[i,j,k] + \Delta I\, M_{TB}(d[i,j,k])\, M([D/2]-d_{LC}[i,j,k])$$

tissue boundary

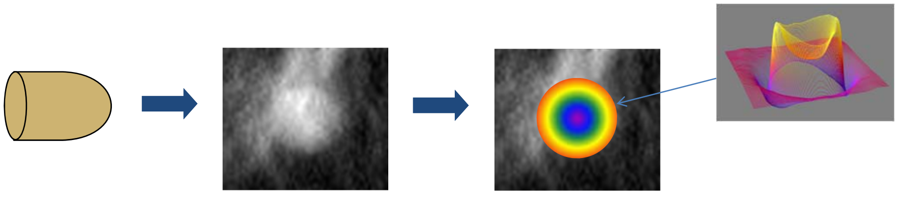
lesion center



Pre-whitened Matched Filter

$$\text{PWMF} = \text{FT}^{-1}\left\{ \frac{\text{FT}\{\overline{\text{S}}(x,y)\}}{\overline{\text{PS}}(x,y)} \right\}$$

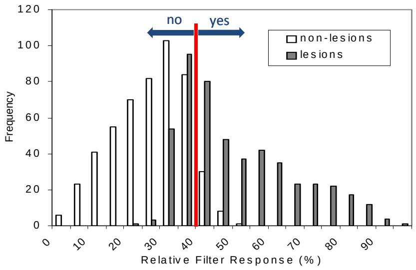
92

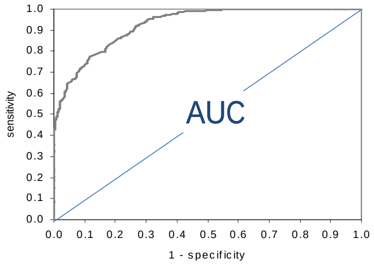


bCT volume data set

SKE ROI selected

PWMF applied





1000 true and 1000 non-lesions per parameter per bCT – ~760,000 lesions evaluated per data point

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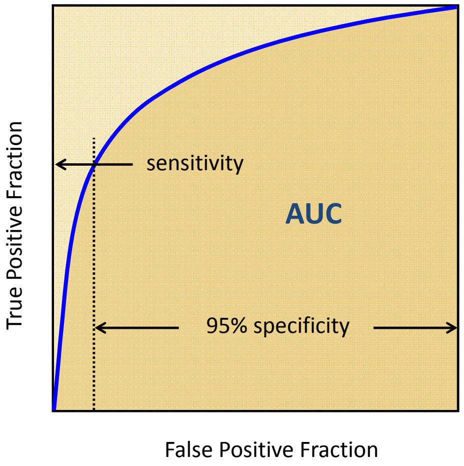
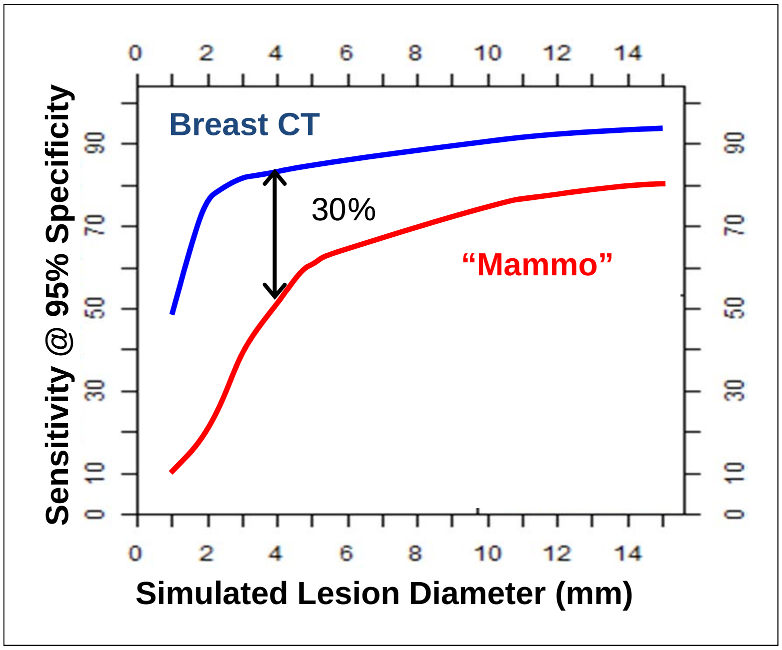
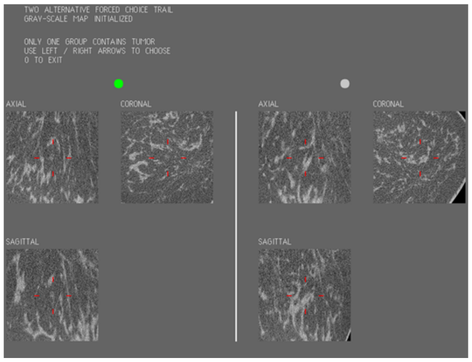
Receiver Operating Characteristic (ROC) Curve



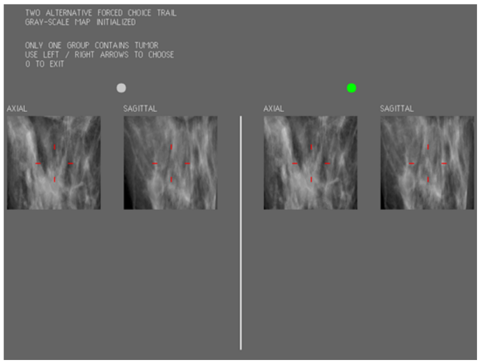


Human Observer Study:
2-Alternative Forced Choice Design


TWO ALTERNATIVE FORCED CHOICE TRAIL
GRAY-SCALE MAP INITIALIZED

ONLY ONE GROUP CONTAINS TUMOR
USE LEFT / RIGHT ARROWS TO CHOOSE
0 TO EXIT

CT images


TWO ALTERNATIVE FORCED CHOICE TRAIL
GRAY-SCALE MAP INITIALIZED

ONLY ONE GROUP CONTAINS TUMOR
USE LEFT / RIGHT ARROWS TO CHOOSE
0 TO EXIT

projection images

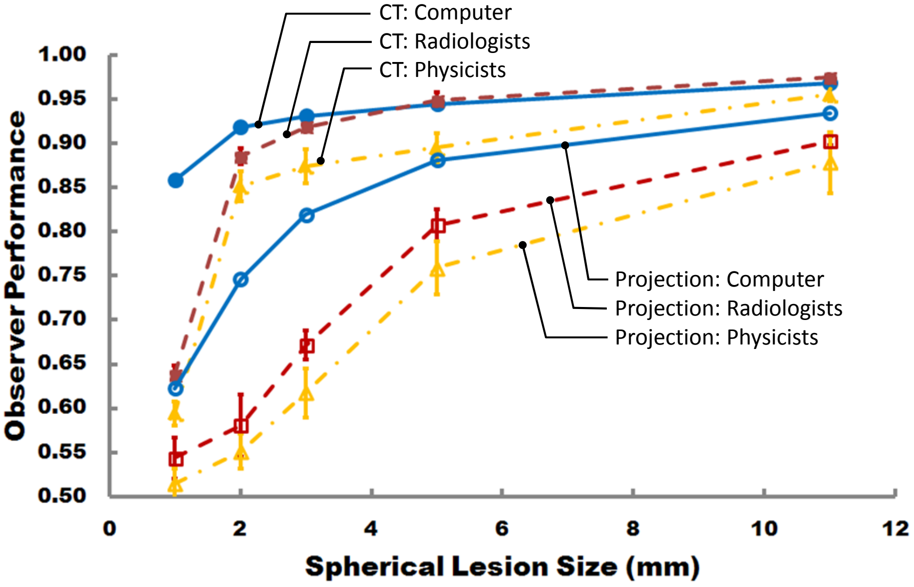
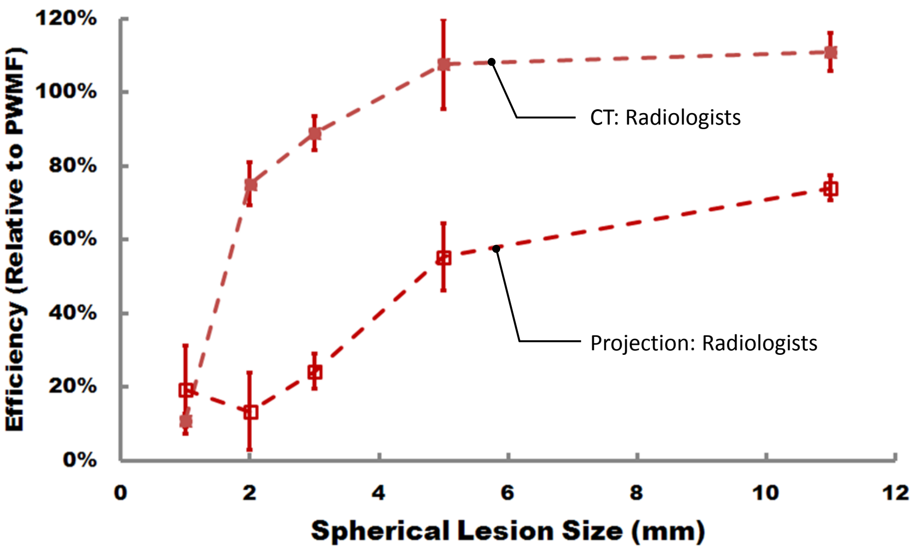

CT: Computer
CT: Radiologists
CT: Physicists
Projection: Computer
Projection: Radiologists
Projection: Physicists
Observer Performance
1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
0
2
4
6
8
10
12
Spherical Lesion Size (mm)

Figure 3


Efficiency (Relative to PWMF)
120%
100%
80%
60%
40%
20%
0%
0
2
4
6
8
10
12
Spherical Lesion Size (mm)
CT: Radiologists
Projection: Radiologists

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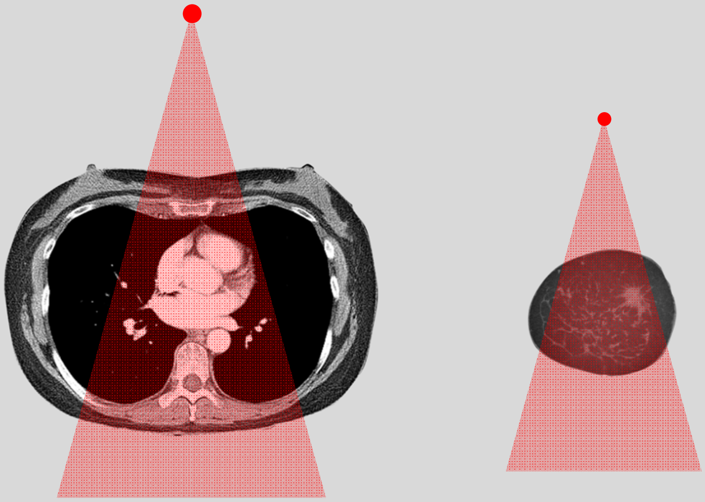
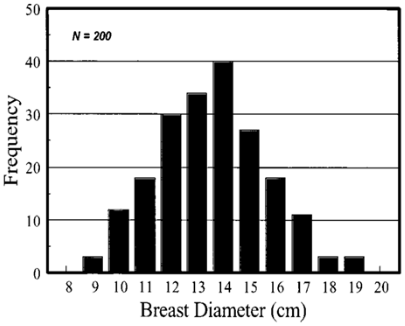
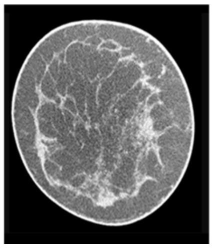
Radiation Dose from Breast CT ?



radiation dose is size dependent!

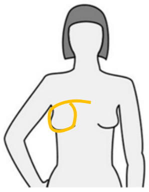


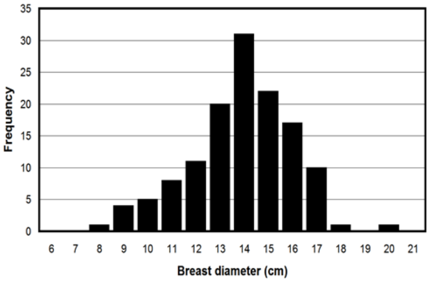


X = 13.4 cm
σ= 2.0 cm
Median = 13.6 cm

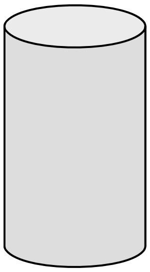
2008 assessment on bCT images (N = 137)

2001 tape measure results (N = 200)

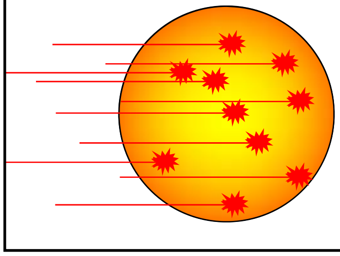




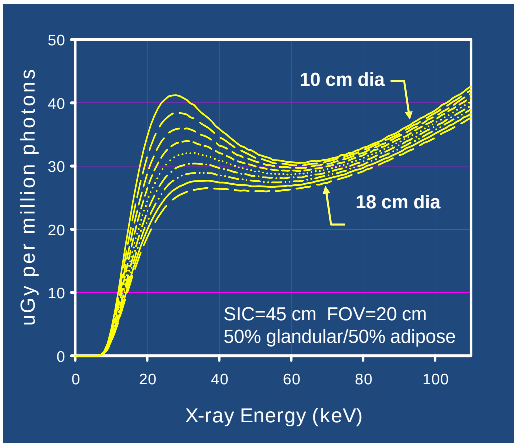
Monte Carlo Assessment of Dose Deposition



breast modeled as a cylinder

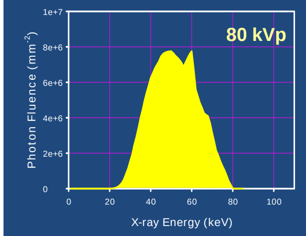


monoenergetic functions



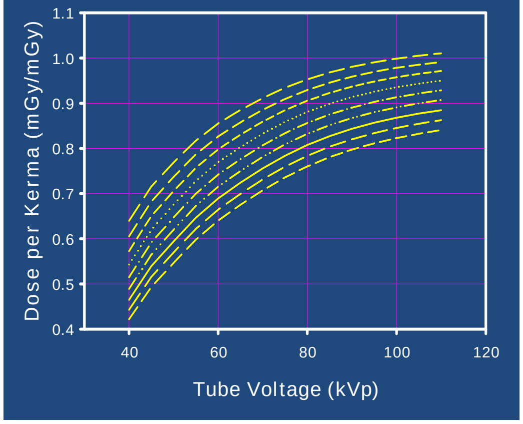
Mean Glandular Dose in Breast CT

spectral model*



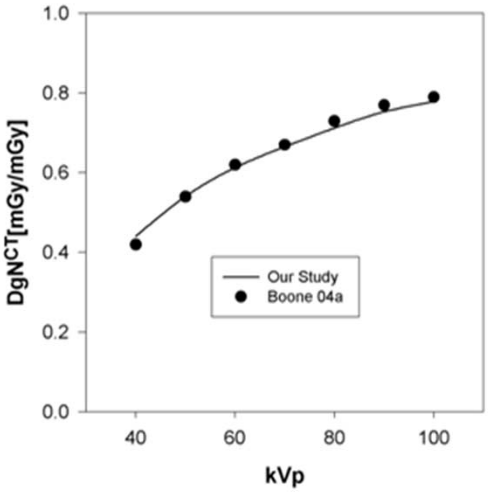
*JM Boone and JA Seibert, *An accurate method for computer-generating tungsten anode x-ray spectra from 30 kV to 140 kV*, Medical Physics 24;1661-670, 1997.

polyenergetic functions



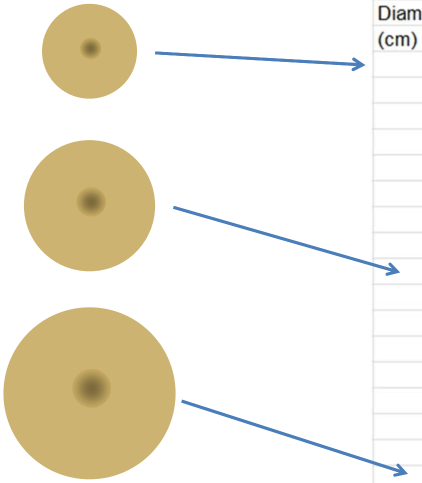
Boone JM, *et al*., Med Phys 2003

Dose assessment repeated by Thacker/Glick



Thacker S and Glick S, PMB 2004, 5433

Breast CT technique chart



mA setting on Cambria			
Breast Diameter (cm)	0% Gland	50% Gland	1.00 Gland
10.0	37	51	72
10.5	48	67	95
11.0	59	82	117
11.5	72	100	143
12.0	87	123	175
12.5	106	150	214
13.0	130	184	263
13.5	157	224	322
14.0	189	271	389
14.5	224	323	465
15.0	262	379	548
15.5	301	437	633
16.0	340	495	719
16.5	377	550	800
17.0	409	598	872
17.5	433	636	929
18.0	447	658	964

Dose in breast CT is set to be EQUAL to the dose of two-view mammography for that women.

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Summary

- The Breast CT scanners at UC Davis have demonstrated that bCT has considerable potential in clinical imaging
- Hardware at UC Davis was refined over a decade
- Software continues to evolve
- The large data set of breast CT images has proven valuable in better understanding breast anatomy and has provided insight WRT breast imaging modalities
- Breast CT continues to be studied for its role in breast imaging

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Evolution of the UC Davis Breast CT Scanner

Breast Tomography Project

University of California Davis

John M. Boone, Ph.D., FAAPM, FSBI, FACR
Professor and Vice Chair (for Research) of Radiology
Professor of Biomedical Engineering
University of California Davis
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IEEE Signal Processing Society, September 10, 2014