Opportunities and Innovations in Digital Mammography

John M. Sandrik, Ph.D.
GE Healthcare
Milwaukee, WI
john.sandrik@med.ge.com

with many thanks to Vince Polkus,
Advanced Applications Product Mgr.

Content

- Issues in Breast Cancer Management
- Exposure Control
- Image Processing
- Digital Breast Tomosynthesis (DBT)
- Detector Updates for DBT
- Contrast-Enhanced Digital Mammography
- FFDM - Ultrasound Fusion

Breast Cancer Management Opportunities

"Personalized Medicine"

- Base screening regimens on personal risk profile
- Diagnose disease earlier, avoid unnecessary biopsies
- Base treatment on predicted effectiveness and tolerance
- Quickly assess treatment effectiveness

GE Life Sciences

- Gene analysis and sequencing
- Protein, cellular analysis
- Drug discovery

Breast Cancer Management Opportunities

GE Healthcare, Diagnostic Imaging

- 35% of cancers missed…70% in dense breasts
- ≈ 10% of those screened recalled,
- > 95% of recalls negative…low specificity
- ≈ 80% biopsies are negative
- 1 in 3 breast cancer patients have undiagnosed multi-focal disease
- 1 in 20 those with breast cancer have undiagnosed bi-lateral disease

Source: American Cancer Society, 2004

Breast Cancer Management Solutions

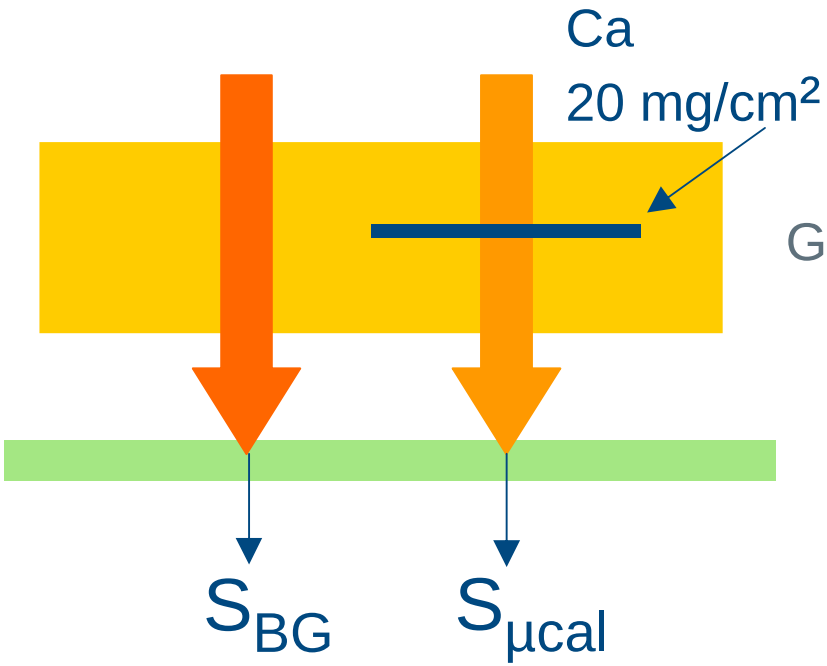
Role of Digital Mammography

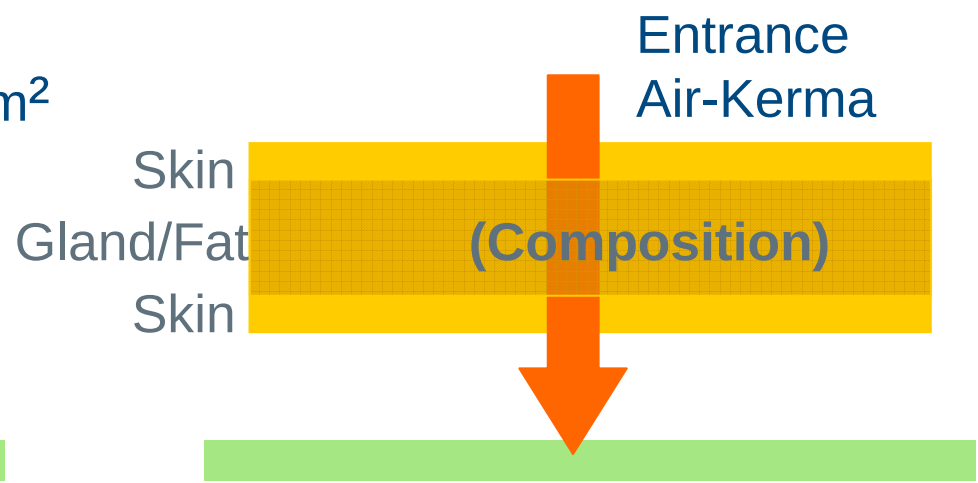
- 2000: FFDM enters market via PMA on the basis of “non-inferiority” to film mammo.
- 2005: ACRIN-DMIST confirms overall similarity to film mammography plus benefit for sub-populations.
- Now →: Do procedures with FFDM that are impractical, impossible with film.

AOP
Automatic Optimization of Parameters

- Re-designed for digital imaging
- Optimize Signal Diff. / Noise, not Contrast
- Effectiveness in dense breasts
- Mo / Mo ↓ ; Rh / Rh ↑

Development of “Digital” AOP



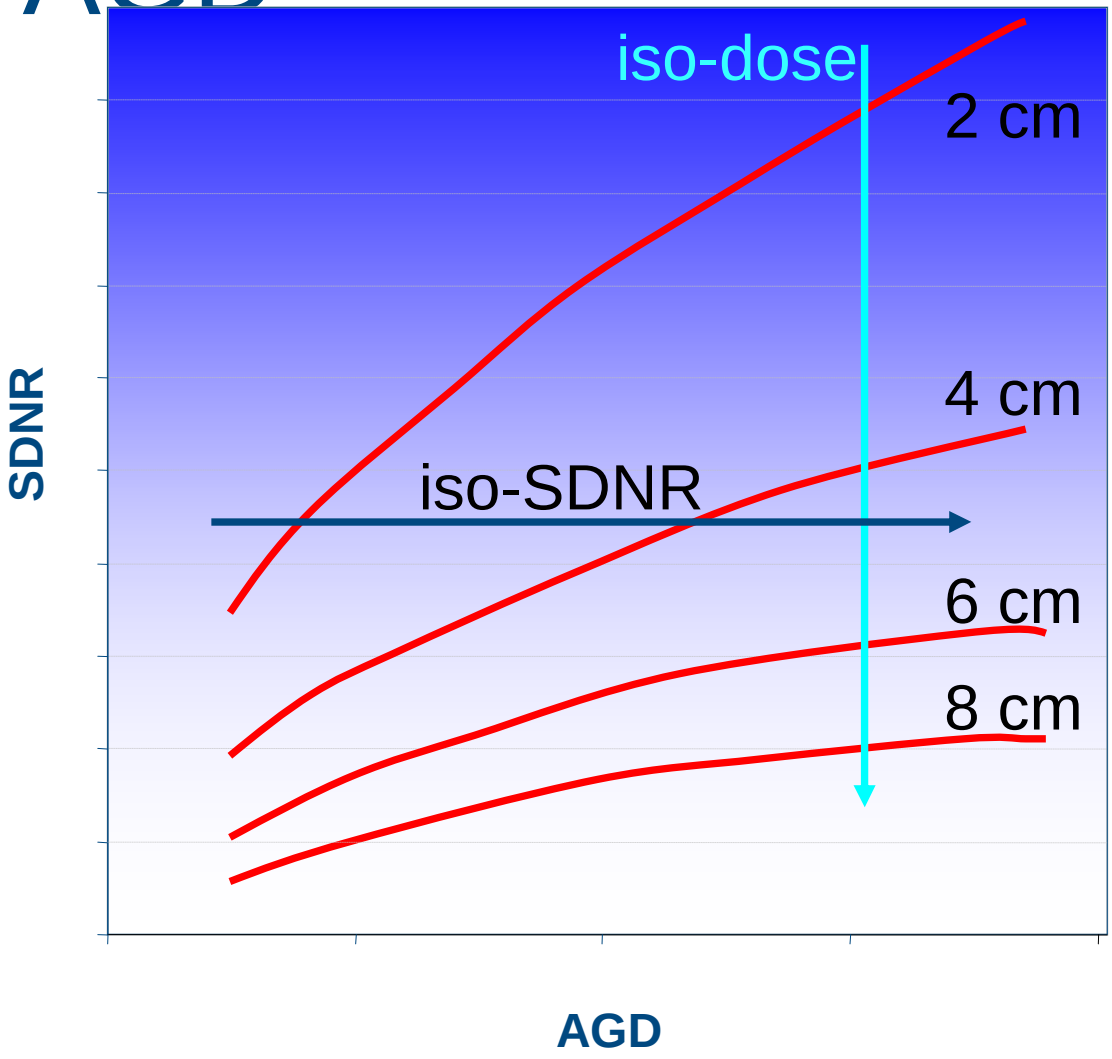


Signal difference to noise ratio
of micro-calcification

Average glandular dose
(AGD)

For each thickness and composition, adjust track, filter, kVp, and mAs to find best SDNR at a given AGD.

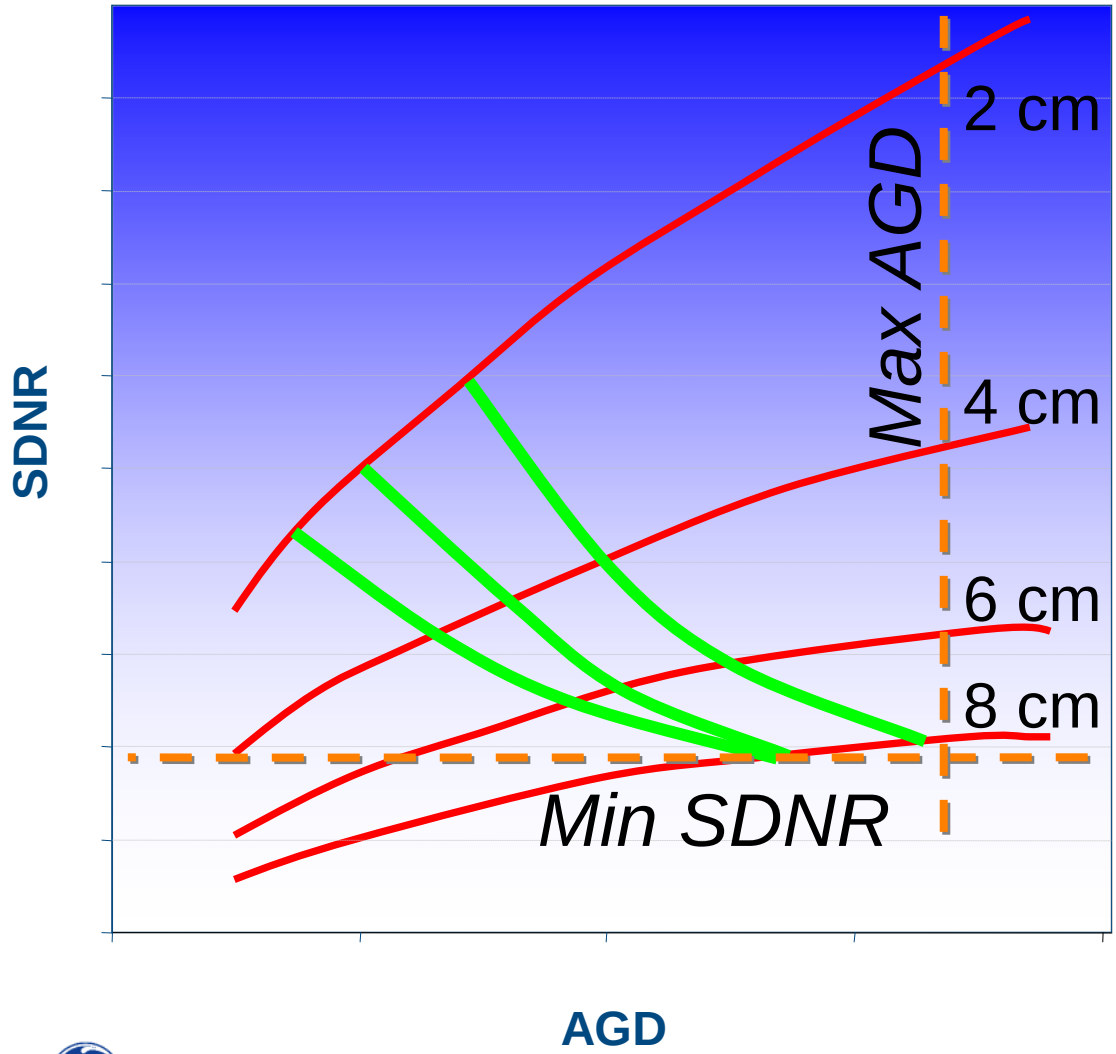
Optimization Results: SDNR vs AGD



Optimum SDNR at AGD for 2, 4, 6, 8 cm

Next step:
Find the best operating point on each curve

Selection of Operating Points



Optimum SDNR at AGD for 2, 4, 6, 8 cm

Solution:
Provide set of "trajectories"
➔ Offer different levels of IQ/Dose compromise
➔ Respect IQ and Dose constraints

AOP Evolution

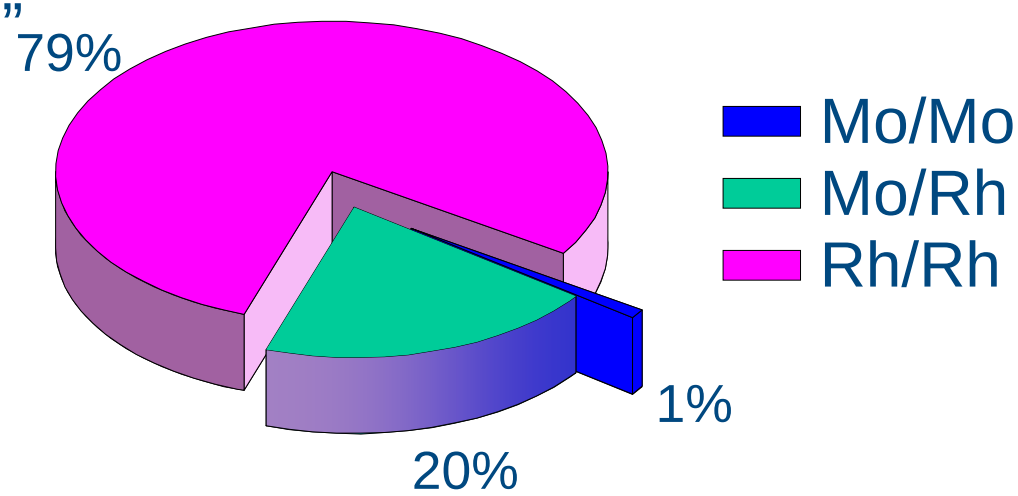
Phantom Imaging

Senographe 2000 D

- Mo / Mo, 26 kVp, 125 mAs
- Typical AOP CNT mode
- “film-like”

Seno DS, Essential

- Rh / Rh, 29 kVp, 56 mAs
- Typical AOP STD mode
- “digital”



Optimization drives to selection of Rh/Rh for most patients

Image Processing

- Optimize display independent of acquisition
- Optimize image resolution, contrast
- Optimize use of display's dynamic range
- Minimize operator intervention with display

Pre-Processing

- Offset and Gain Correction
- FineView

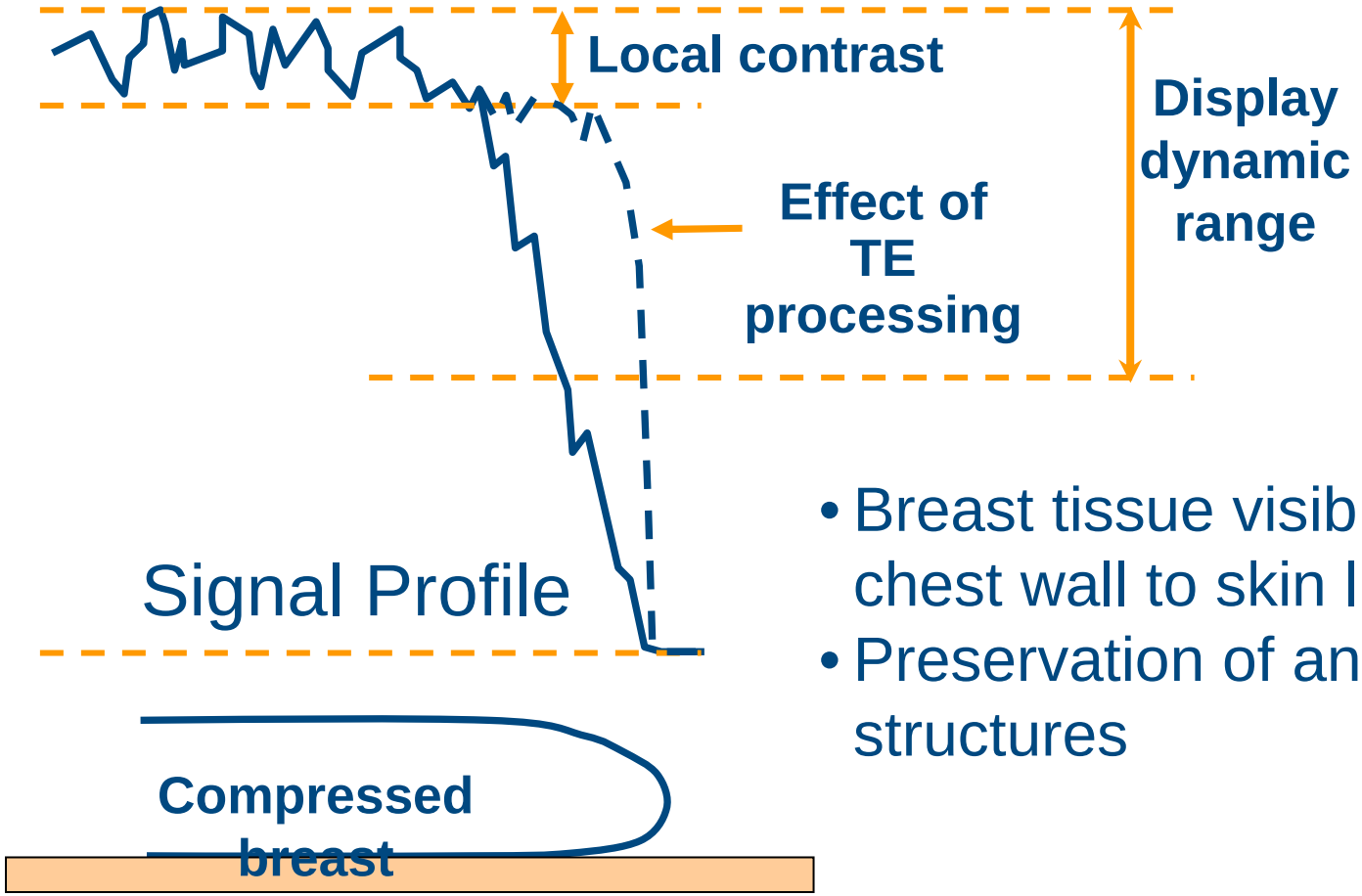
FineView

- Operates on raw images.
- Compensates for the detector MTF.
- Compensation is dose-dependent.
- May produce unexpected results in quantitative measurements, e.g., noise vs. dose.

Post-Processing

- Auto-contrast
- Tissue Equalization
- Premium View

Tissue Equalization

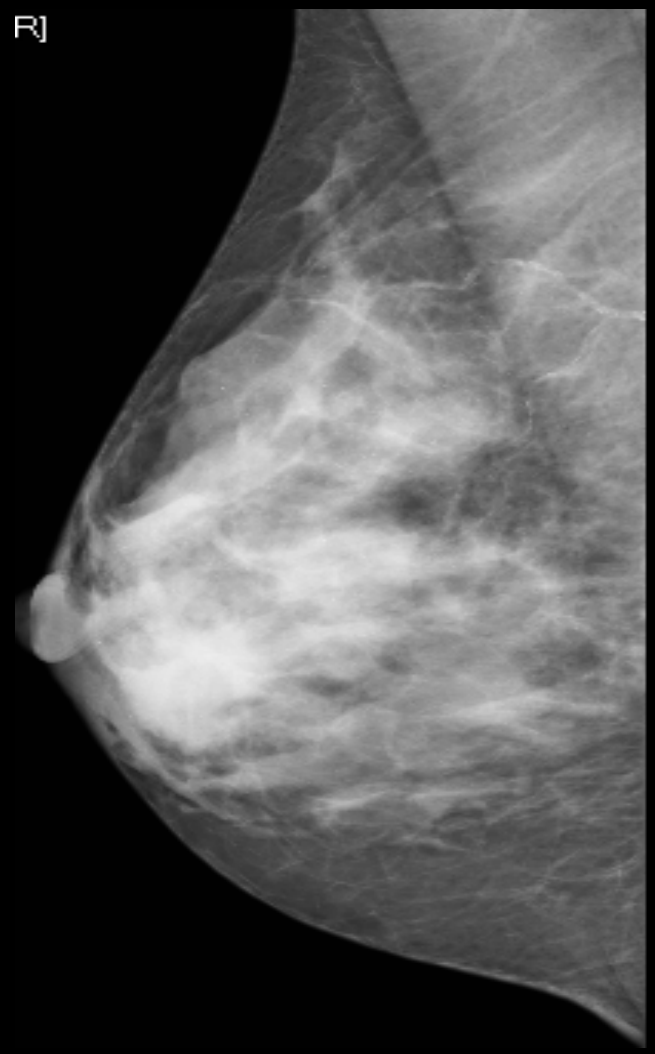


- Breast tissue visible from chest wall to skin line
- Preservation of anatomical structures

Tissue Equalization

Original

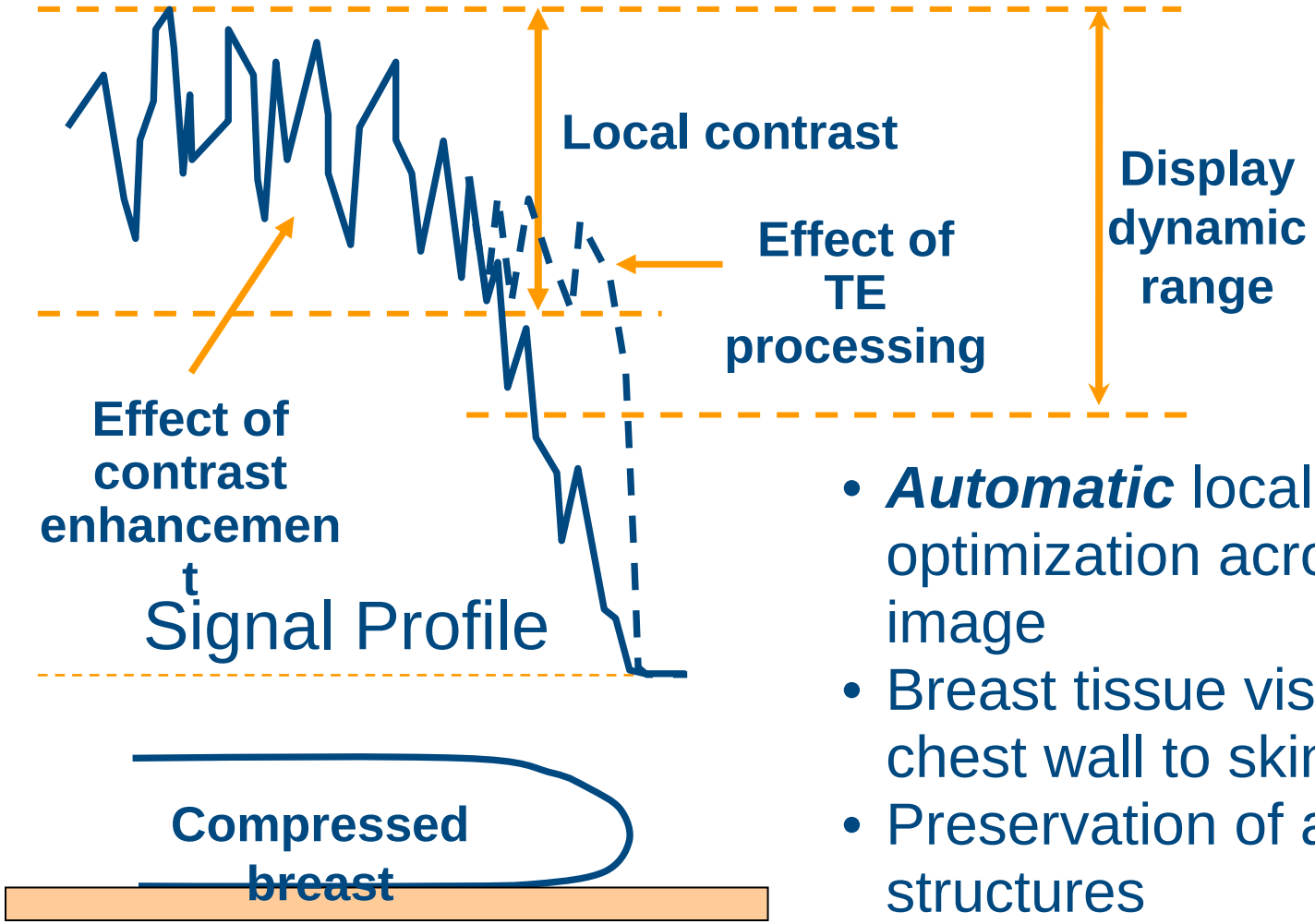
Tissue Equalization



Enhances visualization of the skin line

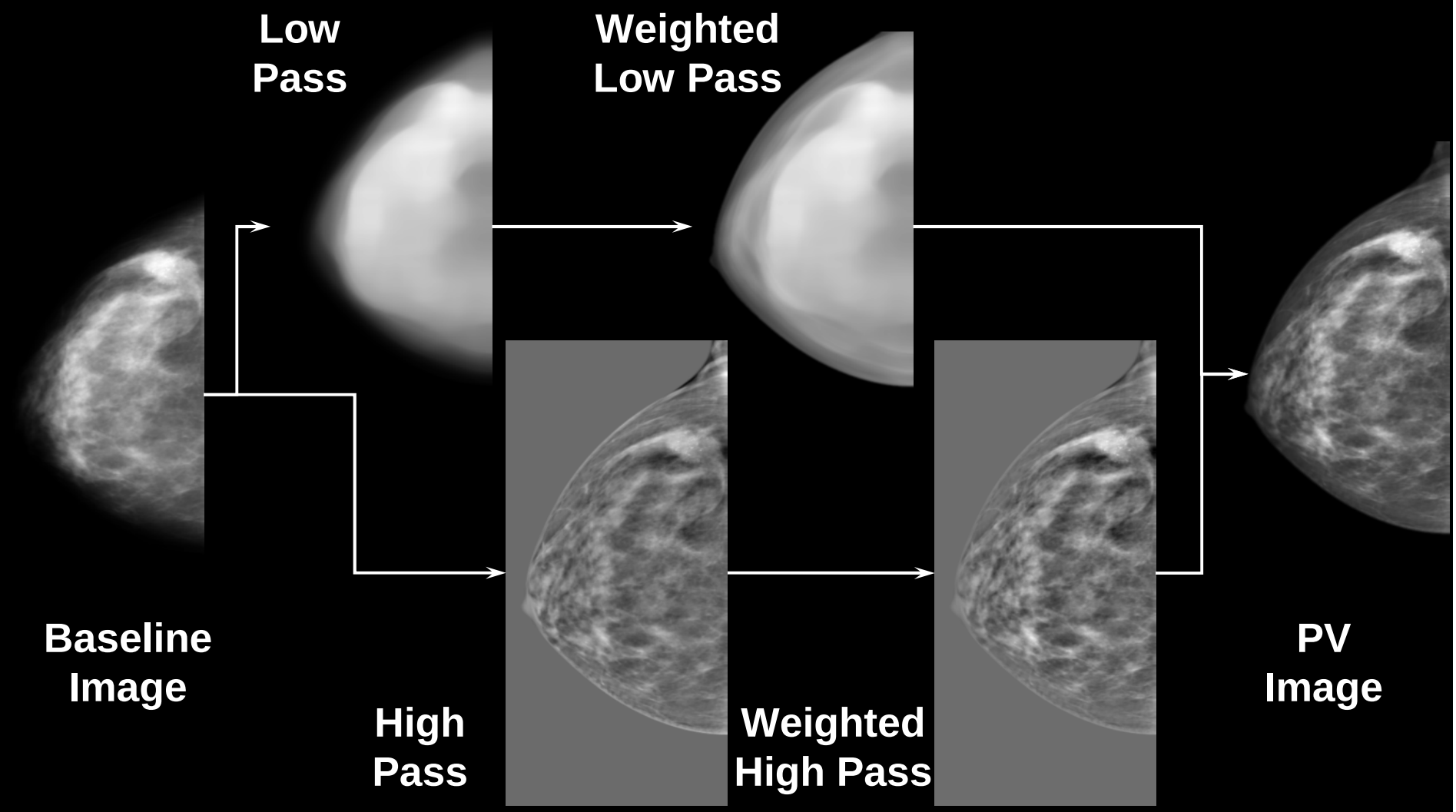
Contrast similar to film

Premium View



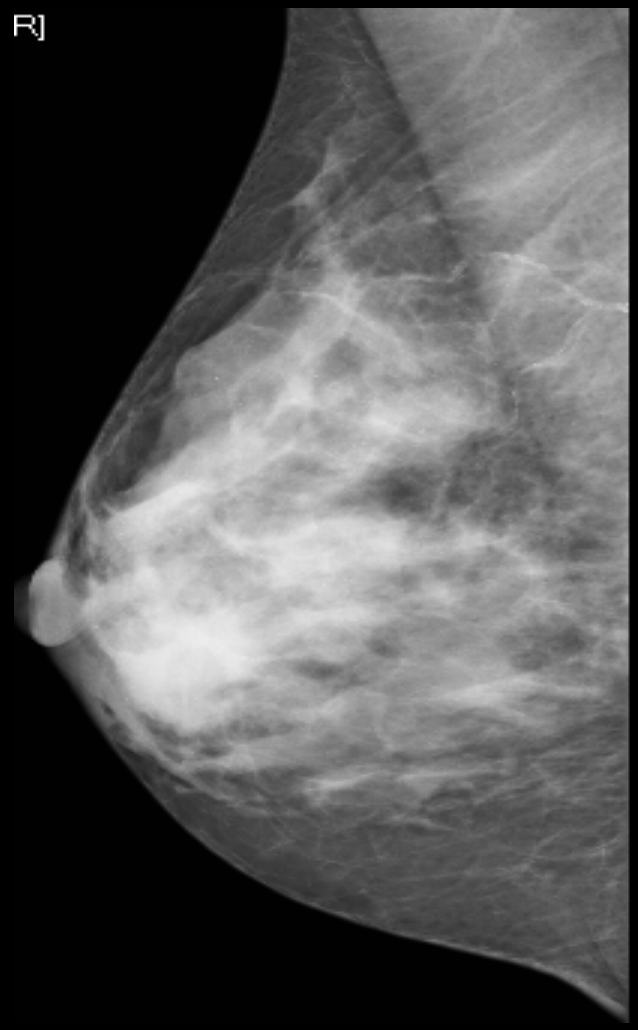
- ***Automatic*** local contrast optimization across entire image
- Breast tissue visible from chest wall to skin line
- Preservation of anatomical structures
- Increased contrast

Premium View – How it Works

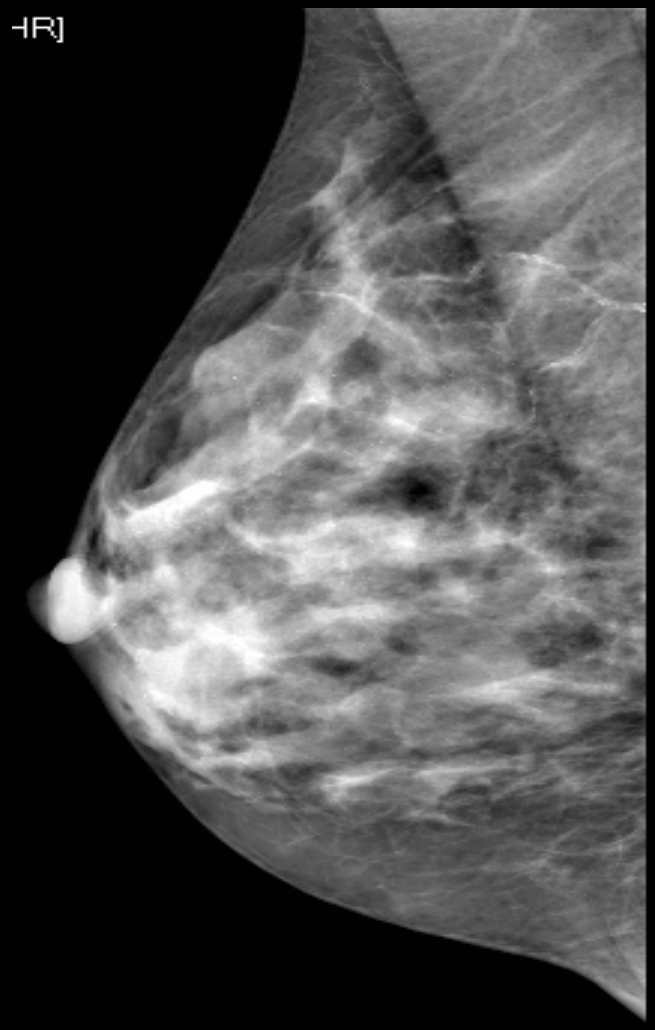


Premium View

Tissue Equalization



Premium View



PV equalizes background and enhances local contrast in high and low exposure regions

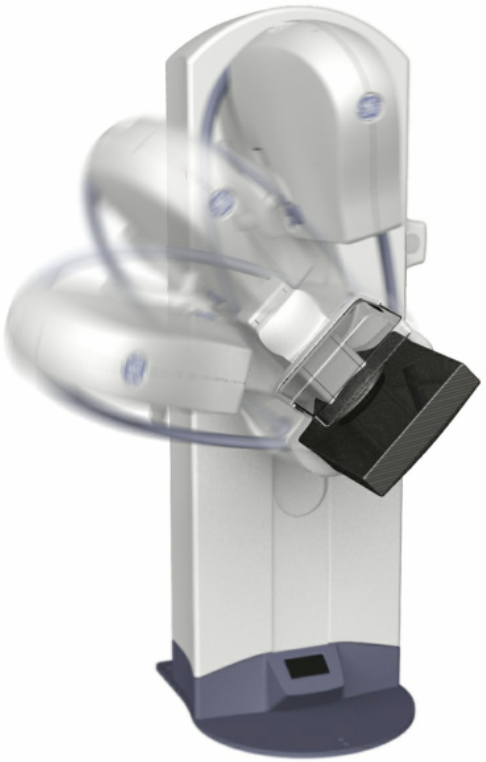
Minimizes need for windowing & leveling

The following devices are investigational and have not been approved for sale within the United States by the US Food and Drug Administration (FDA). These devices may or may not be commercialized in the future

Digital Breast Tomosynthesis

Unmet Needs

- 30%-50% Cancers in dense breast tissue missed with 2D mammography
- High inter-observer variability… missed cancers
- >95% screening recalls are negative
- No direct 3D localization



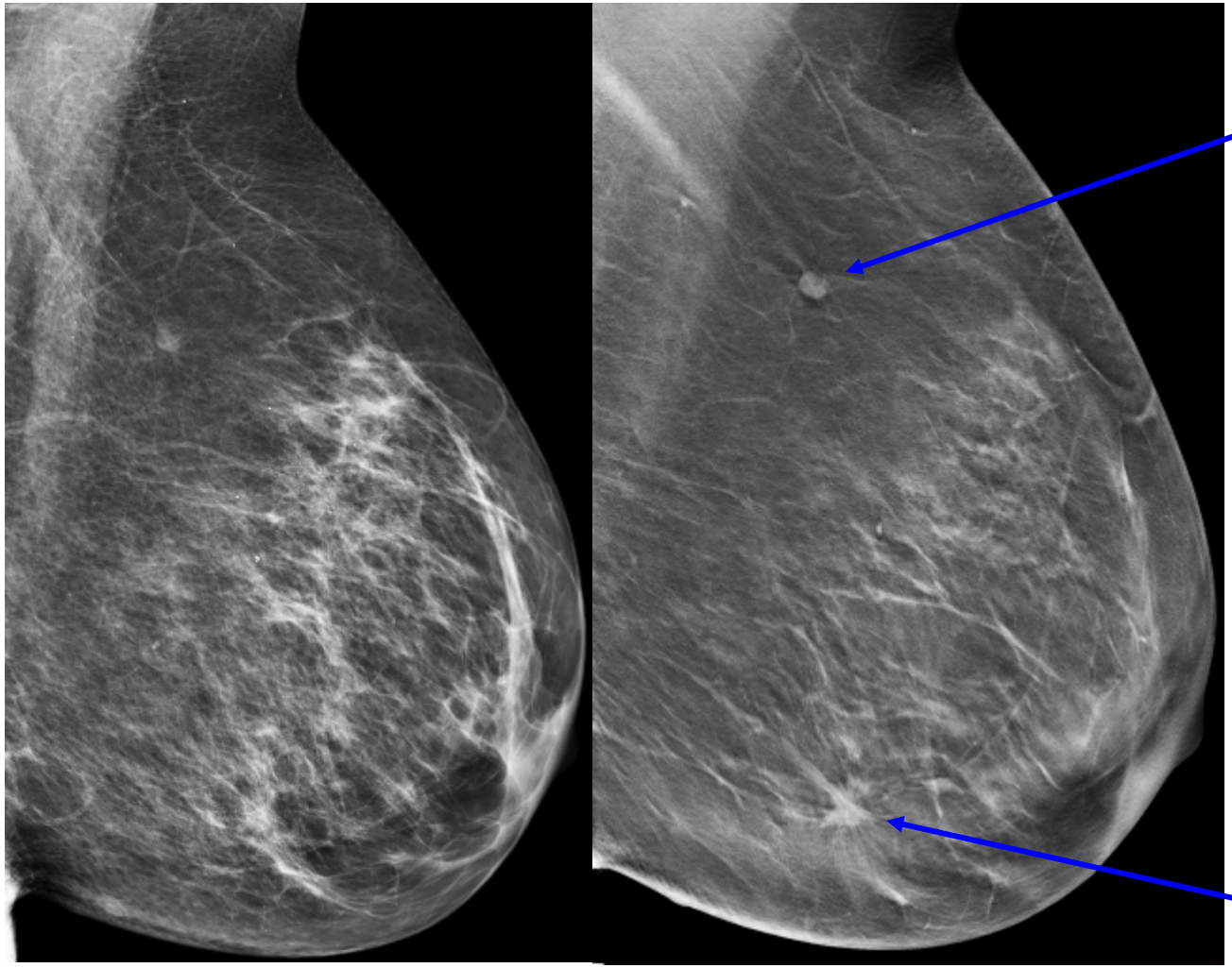
Clinical Value

- Increased clinical accuracy diagnostic confidence
- Less observer variance
- Reduced patient anxiety with fewer recalls
- Direct 3D localization

Promising imaging application for screening and diagnosis of cancer

DBT Reveals Occult ILC

2D FFDM **Tomosynthesis Slice**



Images courtesy of Drs. Di Maggio & G Gennaro,
Istituto Oncologico Veneto I.R.C.C.S. - Padova, Italia

DBT Image Quality Factors

FFDM IQ Drivers

- Radiation Dose
- Beam Quality
- Detector Properties
- 2D Image Processing
- Image Display

+

Additional DBT IQ Drivers

- Aperture Angle
- Number Exposures
- Projection Dose
- Sweep Time
- Pixel Readout
- 3D Display Tools
- 3D Recon Algorithm

DBT Challenges

- DBT Patient dose to be ~ same as 2D mammo.
- Number of projections ~ 10 - 20
  - Dose/projection <~ 1/10 dose for 2D mammo.
  - Need low-noise detector
- Compression time ~ same as 2D mammo.
  - Need fast read-out, low-lag detector
- Image processing time
  - 10X more… from seconds to minutes
- Softcopy workflow and productivity
  - > 10X more images… from 4-6 to 100-200
- Transmission & archival
  - 25X more… from 60MB to 1,500MB

Detector

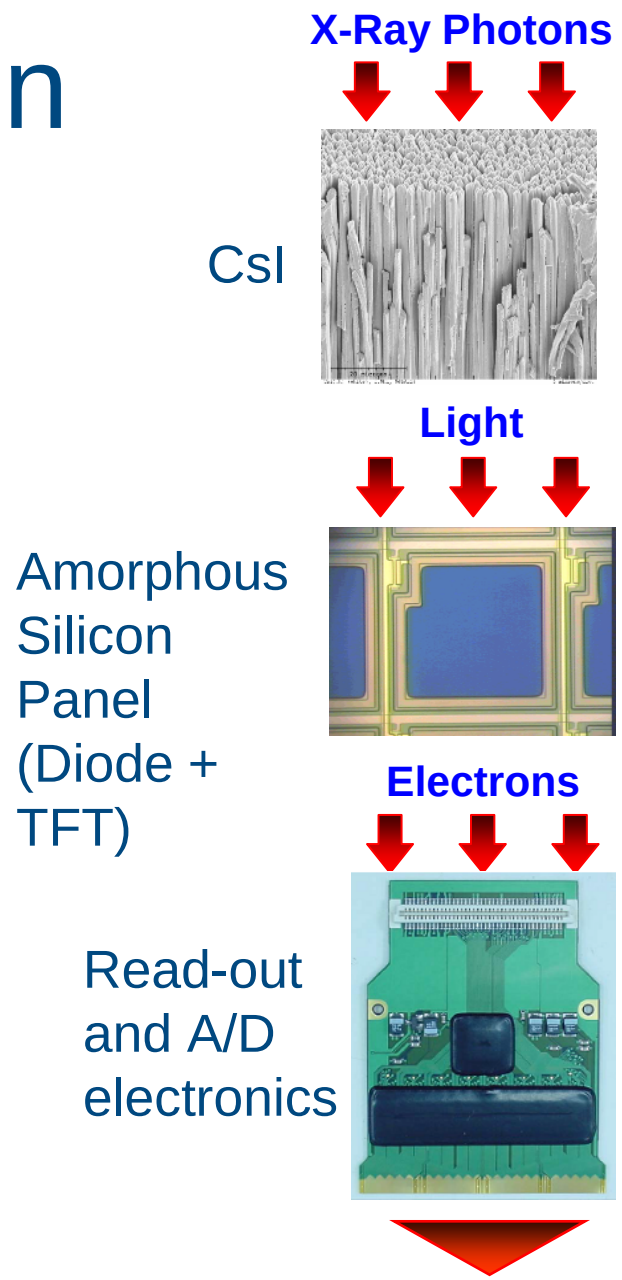
Prepare for DBT

Detector Operation

Cesium iodide converts x-rays to light, crystal acts as light pipe.

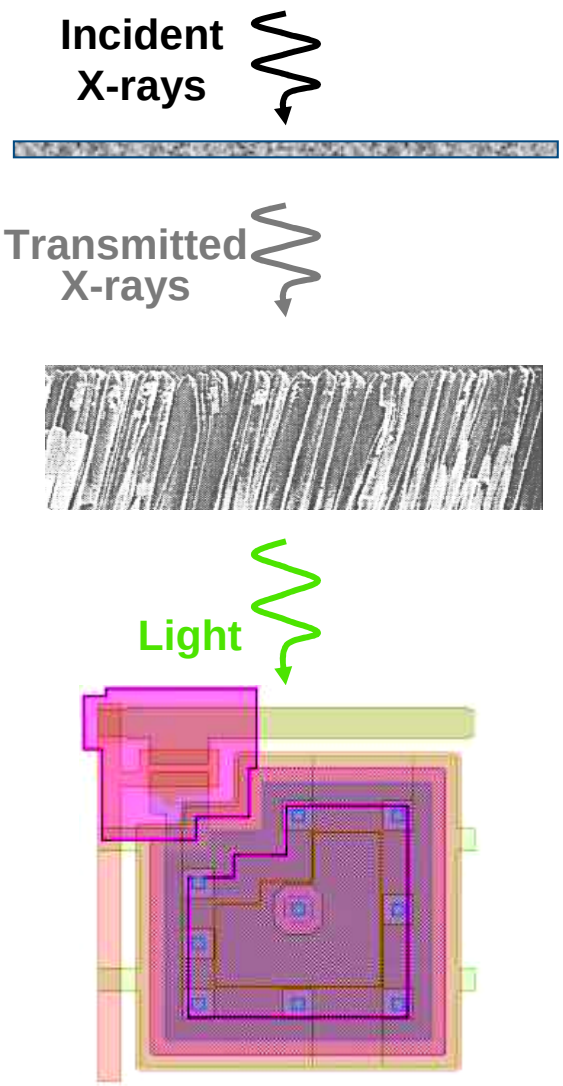
Photodiode converts light to electric charge

Charge at each pixel read out by low-noise electronics and converted to digital data

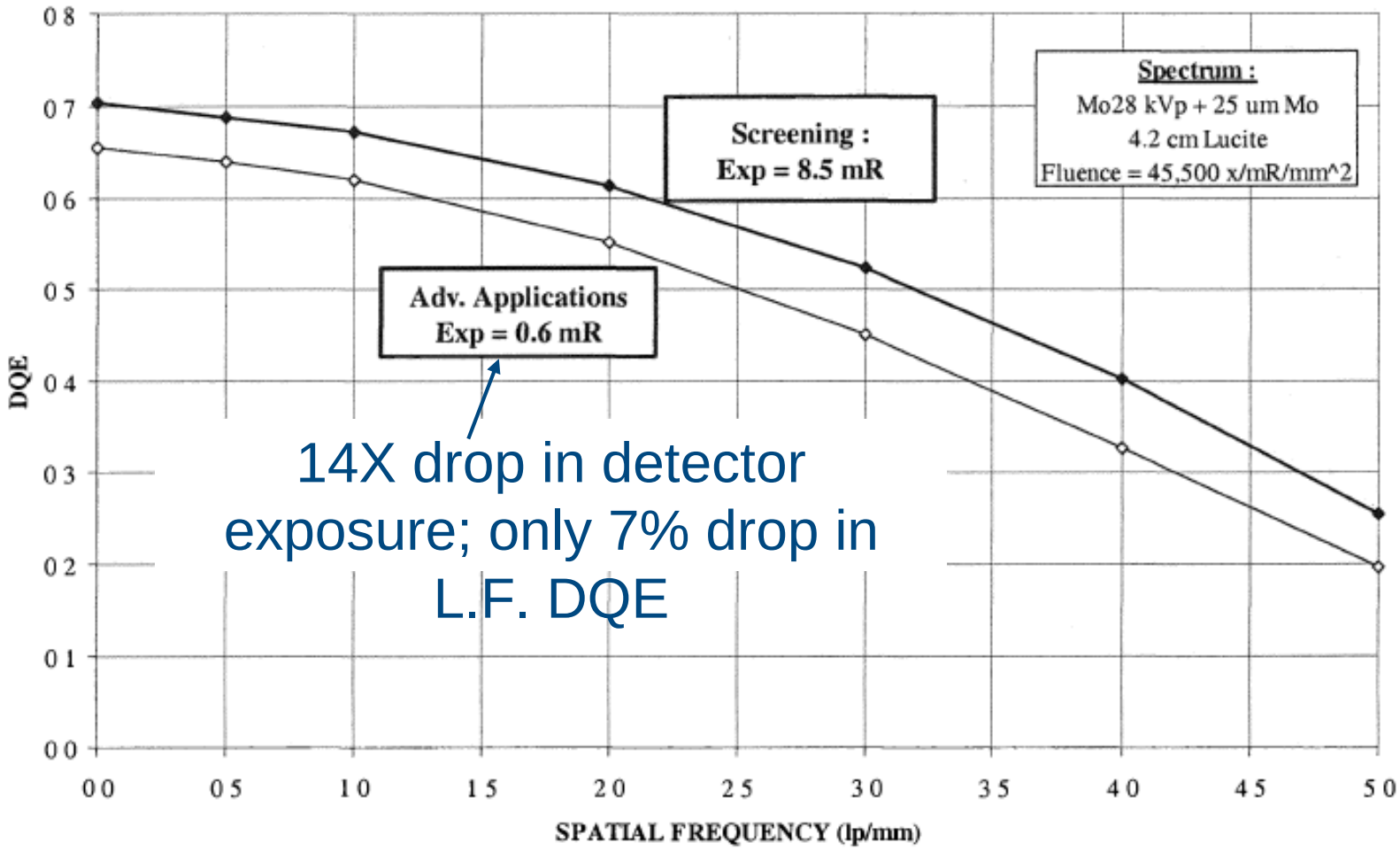


Detector Updates

- Thinner Graphite Cover
  - Decrease x-ray attenuation
  - Slight increase in DQE
- Thicker CsI Scintillator
  - Increase x-ray conversion
  - Increase DQE
- Larger panel size, 24 x 31 cm^2
  - Coverage for oblique incidence
- Storage capacitor added
  - Increase dynamic range
- Revised panel circuitry
  - Increase readout rate
  - Decrease noise



Senographe Essential DQE



14X drop in detector exposure; only 7% drop in L.F. DQE

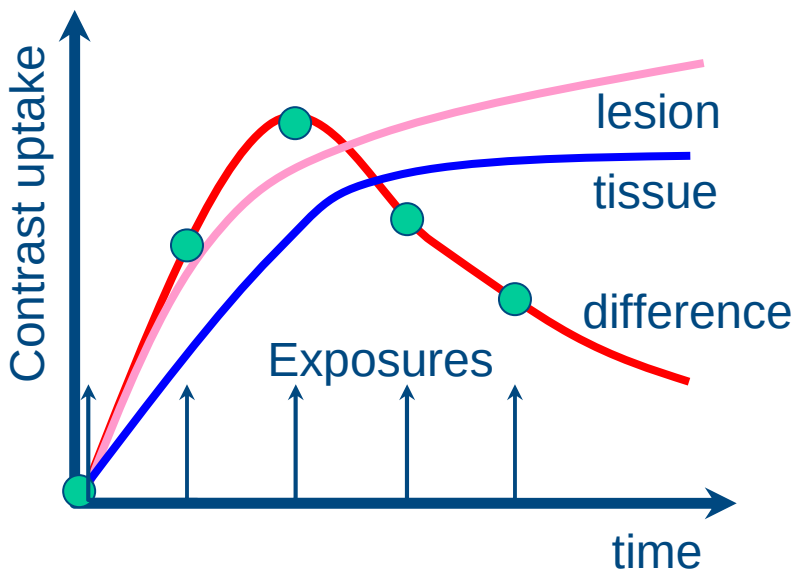
Albagli, SPIE 2005

Contrast Enhanced Digital Mammography (CEDM)

- Screening high-risk women
- Staging, determining extent of disease
- Problem solving
- Therapy planning, response monitoring

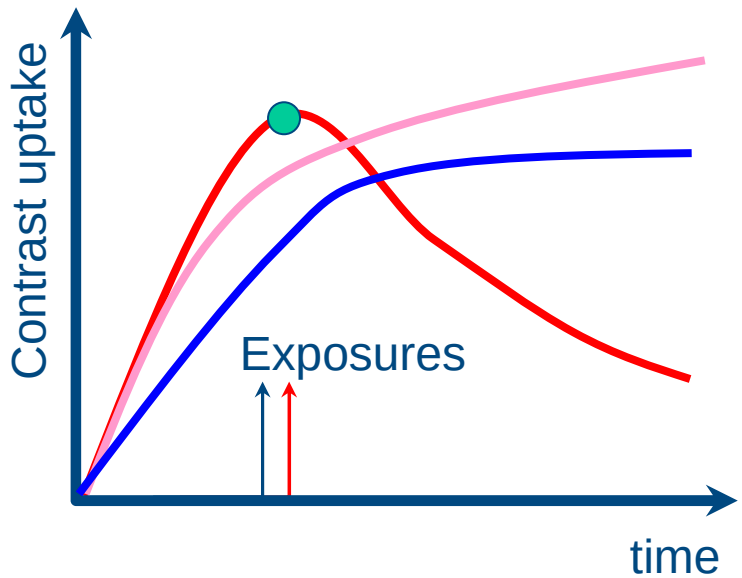
Two Imaging Methods

Temporal Subtraction



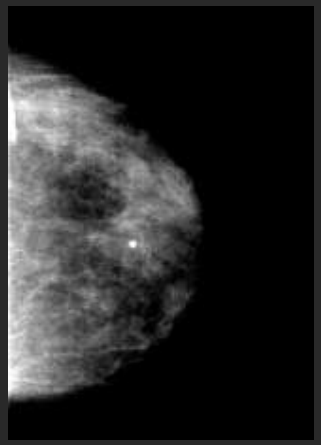
n exposures,
1 energy,
few minutes

Dual-Energy Subtraction

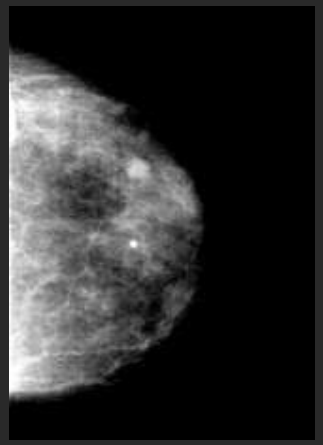


2 exposures,
2 energies,
~ same time

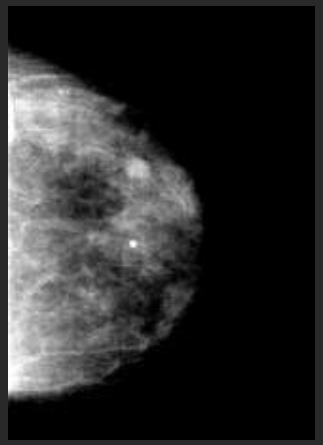
2D Temporal Subtraction



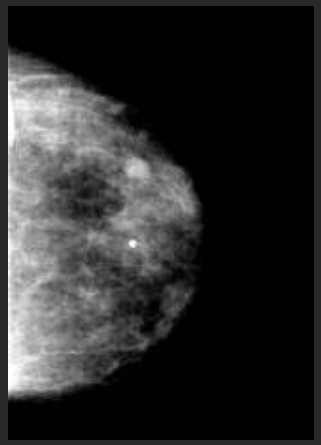
t = 0 s



t = 60 s



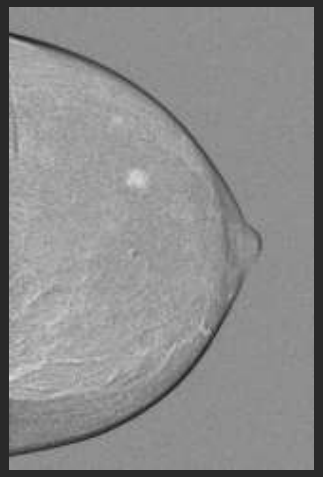
t = 120 s

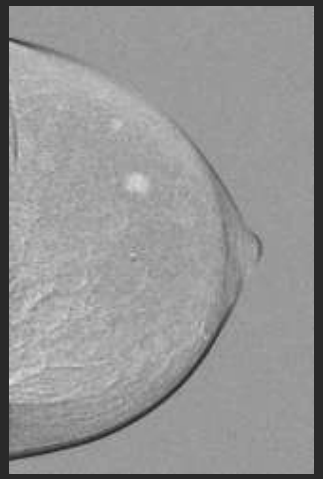


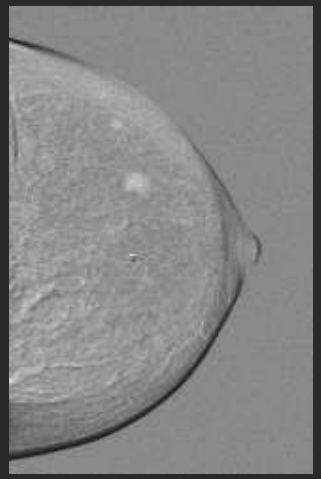
t = 180 s

Technique :
Mo/Cu, 45 kV,
100 mAs

Period:
T = 60 s





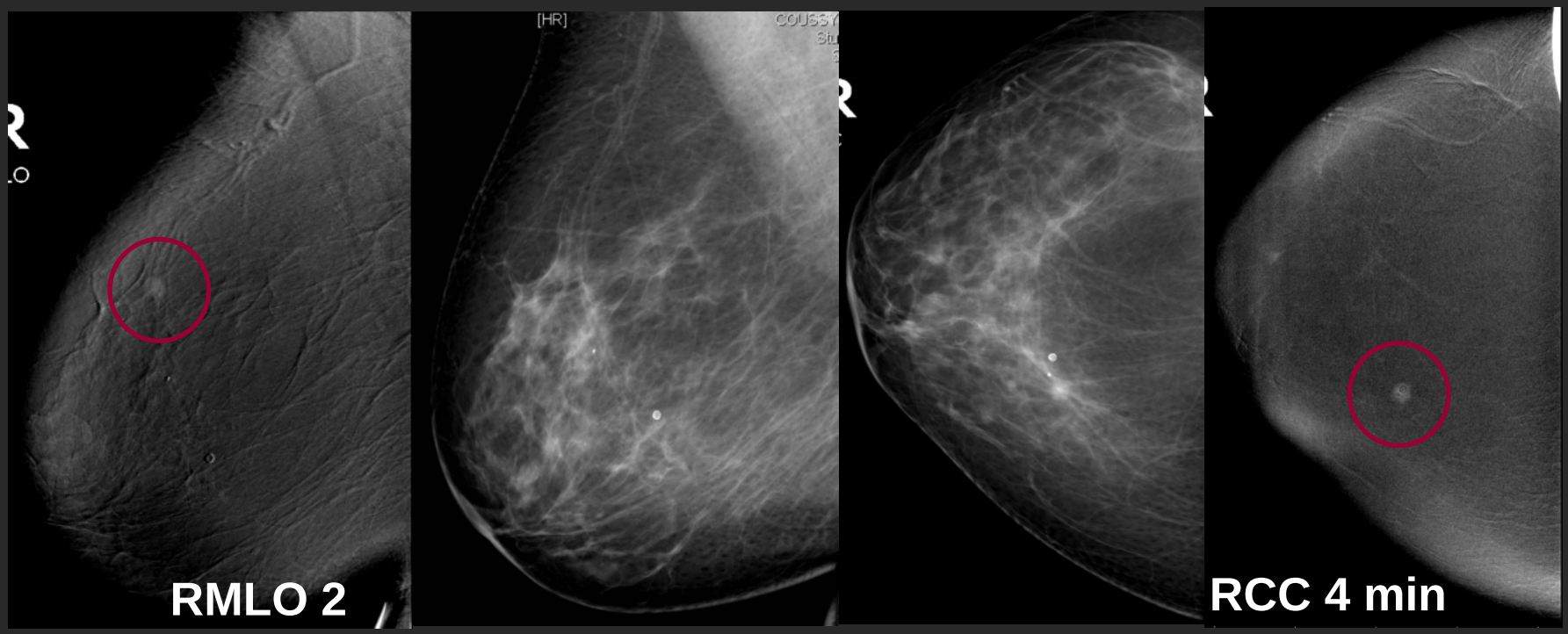


Investigational program. Limited by US federal law to investigational use.

Images courtesy of Charite

Dual-Energy Subtraction

Dual-Energy Sub. **Conventional FFDM** **Dual-Energy Sub.**



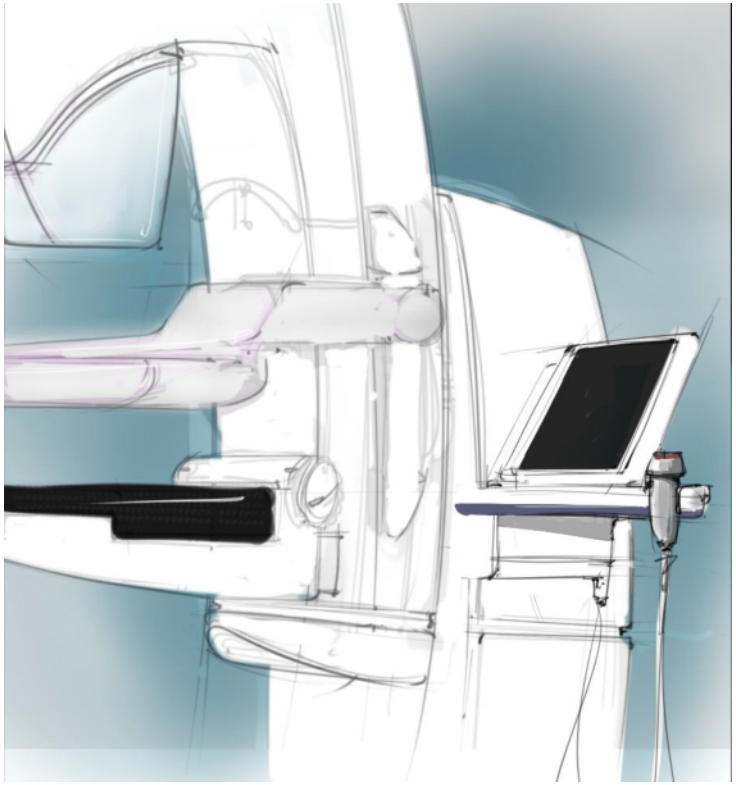
Images courtesy of Dr Dromain,
Institut Gustave Roussy – Villejuif, France

Dual-energy more reproducible…
avoids motion artifacts

FFDM - Ultrasound Fusion

Unmet Needs

- 30%-50% Cancers in dense breast tissue missed with mammography
- Some cancers provide low X-Ray contrast or differentiation
- Ultrasound technique manual, operator-dependent & time consuming



Clinical Value

- Increased diagnostic confidence & accuracy
- Reduced patient anxiety with fewer recalls
- Improved workflow

FFDM/US Fusion

Mammography + Ultrasound = FFDM / US Fusion

+ High resolution
+ High sensitivity
+ Microcalcification detection

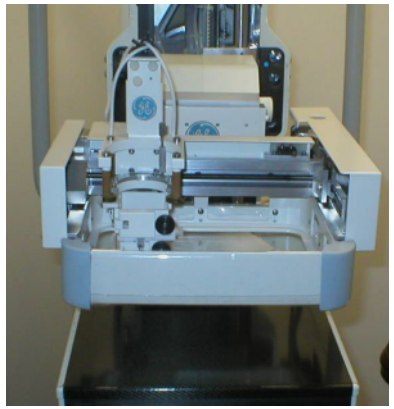
But:

- Low specificity for mass lesions

+ High specificity (i.e., cysts vs. solid)
+ 3D imaging

But:

- Operator dependent
- Can't visualize microcalcifications

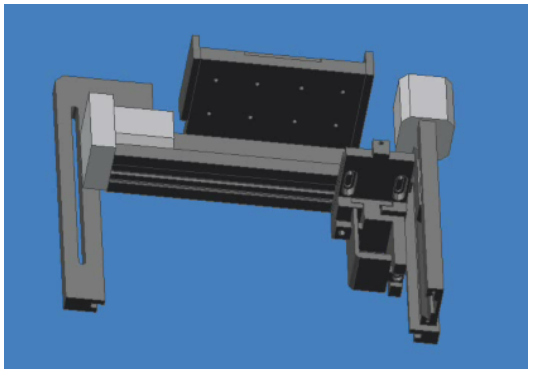


Best of both modalities

Image registration

Real-time imaging

No operator dependence



Thank You