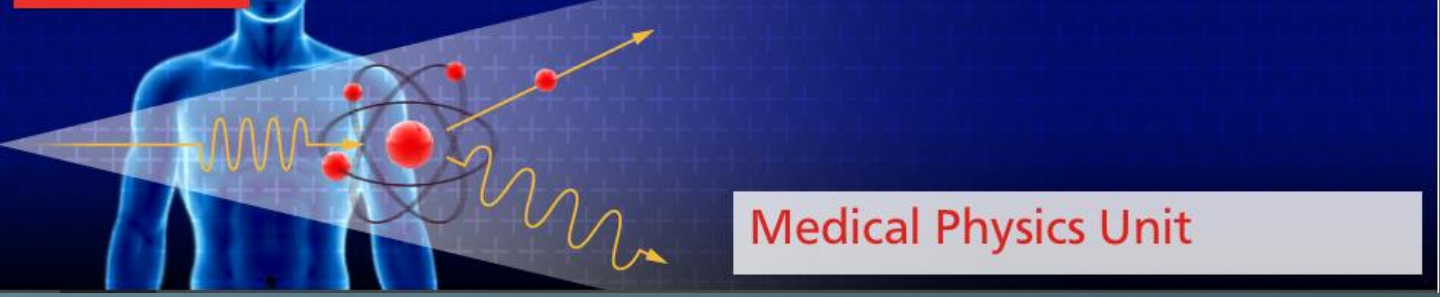


# Medical displays in mammography

Alain Gauvin

McGill

# Disclosure

- Shareholder of Connectimage Medical Inc.
- Shareholder of VoilaCTIC Inc.

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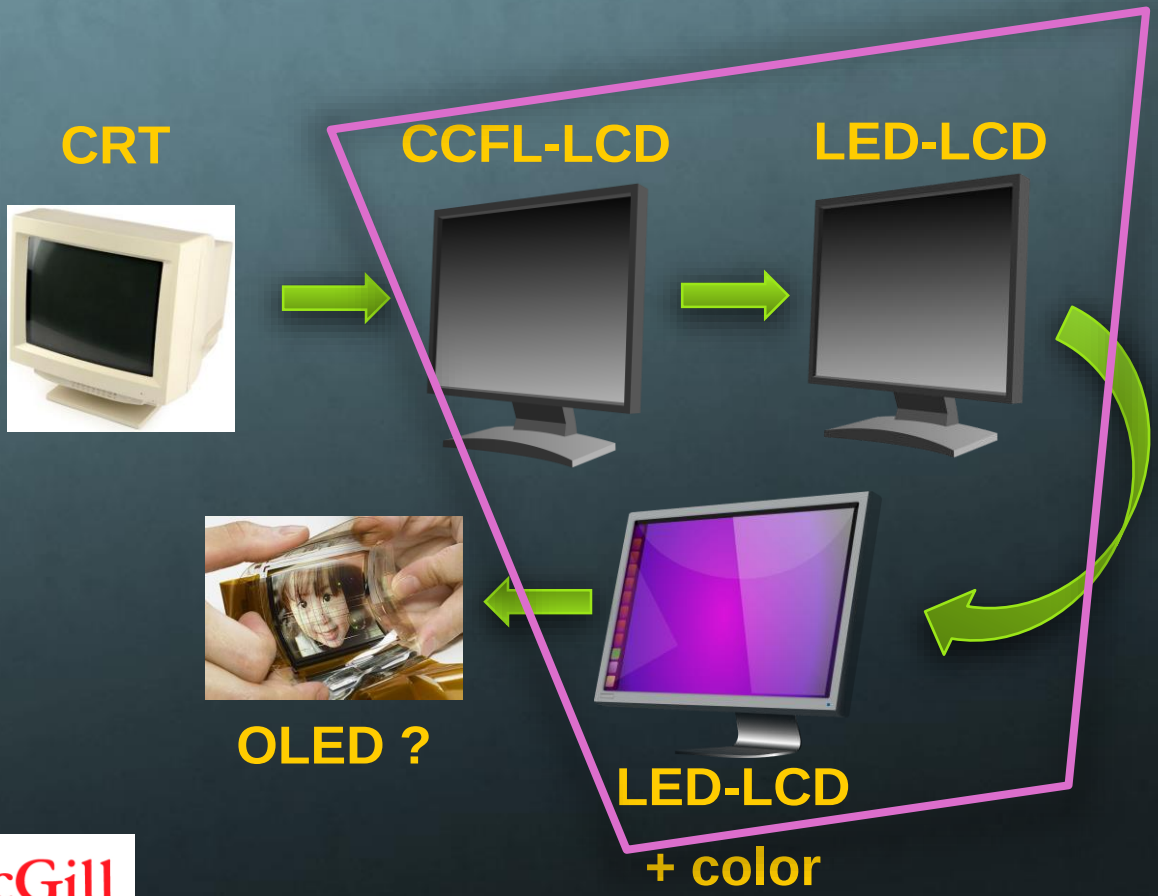
# Medical displays

- Final component of the imaging
- Mammography diagnostic calls for the most stringent specs
- Until recently grayscale

# Display technologies in mammo

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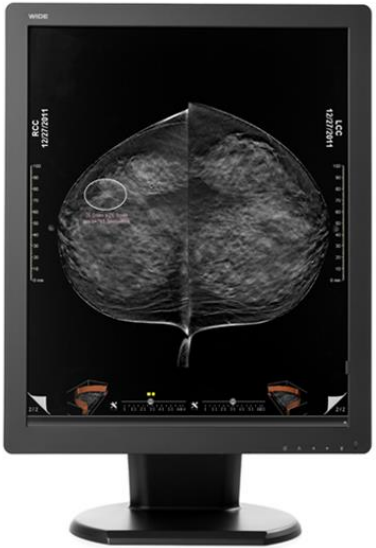
# LCD monitors

- Array of shutters (LCD pannel) in front of diffuse light source
- Light source either CCFL or LED
- Each element let through a variable amount of light
- Modern LCD element: in place switching (IPS) for better angular response
- Adding color filter allow to compose white or colors at the expense of output





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# Attributes of quality

- Brightness uniformity
- Gradation of brightness
- Spatial resolution
- Temporal resolution
- Minimal noise
- Light color, adequate and stable (time, space and as brightness)

# Photometry

- Lumen: luminous power weighted by human eye response (lm)
- Lux: light power (weighted) per area (lum/m$^2$)

  Used to measure *illuminance*, or light incident on a surface from all sources per surface unit
- Candela (Cd): luminous power (weighted) per unit solid angle from a point light source
- Cd/m$^2$: luminous power per unit solid angle per source surface. Used to measure *luminance*, or light power emitted per source surface unit per steraradian

# Measurement

- Luminance meter
  - Contact
  - telescopic
- Illuminance meter / adapter
- Test patterns


https://siim.org/page/displays_chapter2

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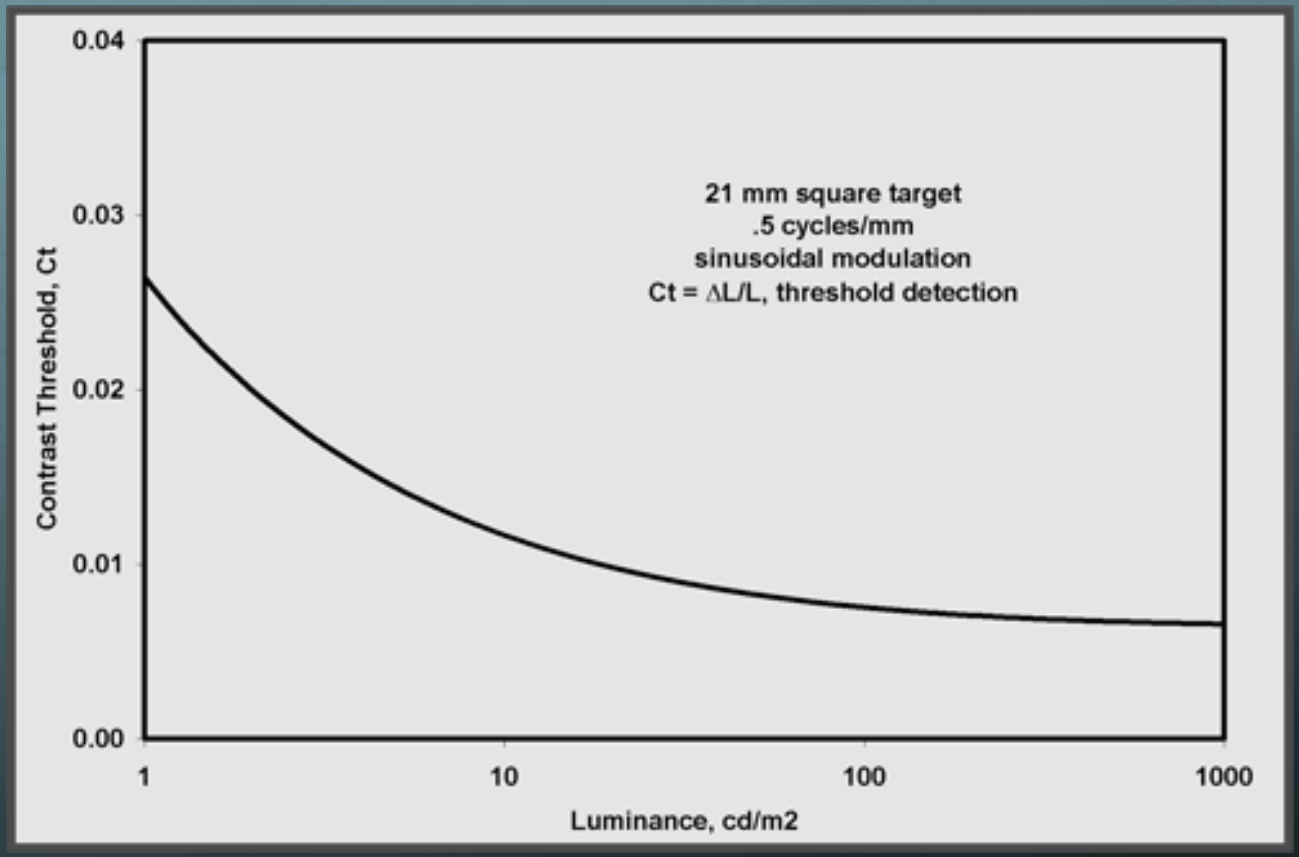
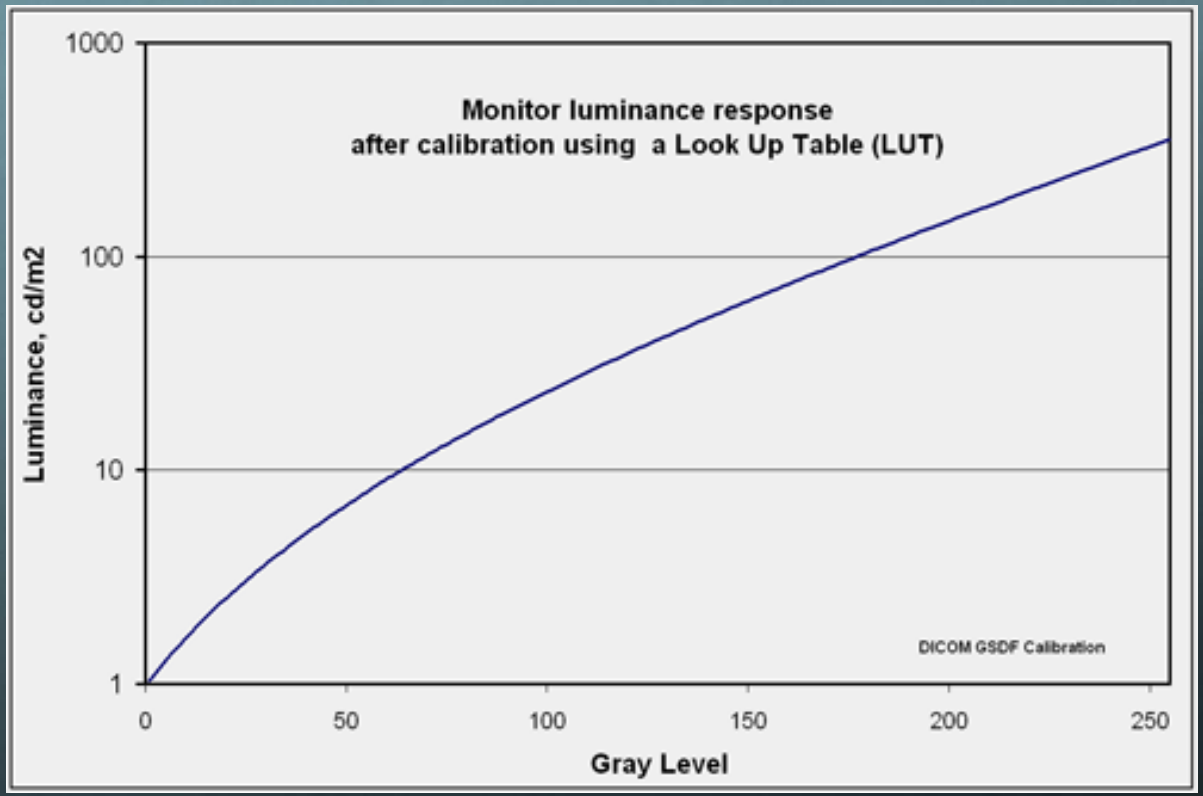
# Perceptual linearization

- Barten model describes detection contrast threshold of a human observer
- Model derived from empirical data
- Eye adapted for average luminance in question





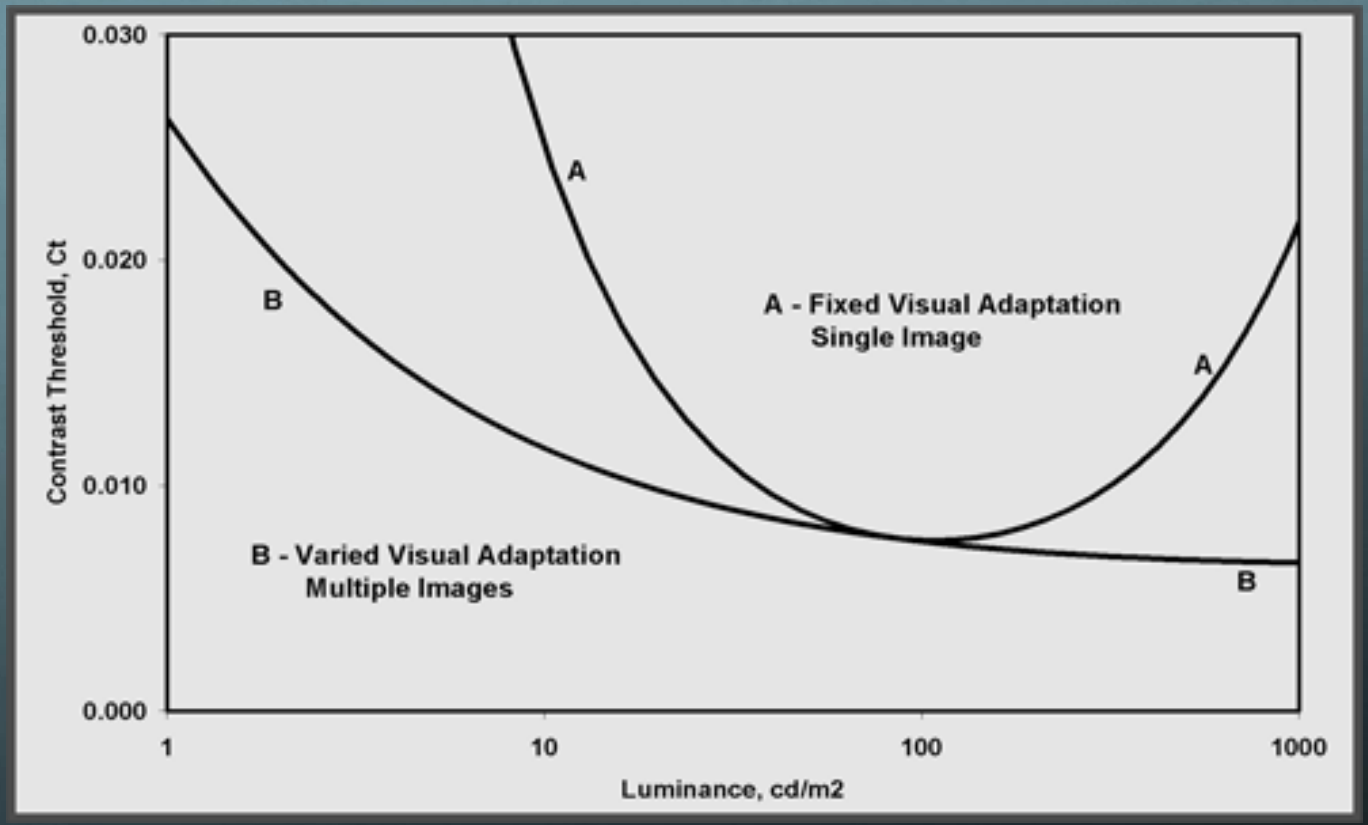

https://siim.org/page/displays_chapter3




https://siim.org/page/displays_chapter3

# Limitations of perceptual linearization

- Contrasts are detected at an average luminance
- GSDF is an approximation
- The eye dynamic range is limited
- Spatial frequency dependance




https://siim.org/page/displays_chapter3

# Some standards and recommandations

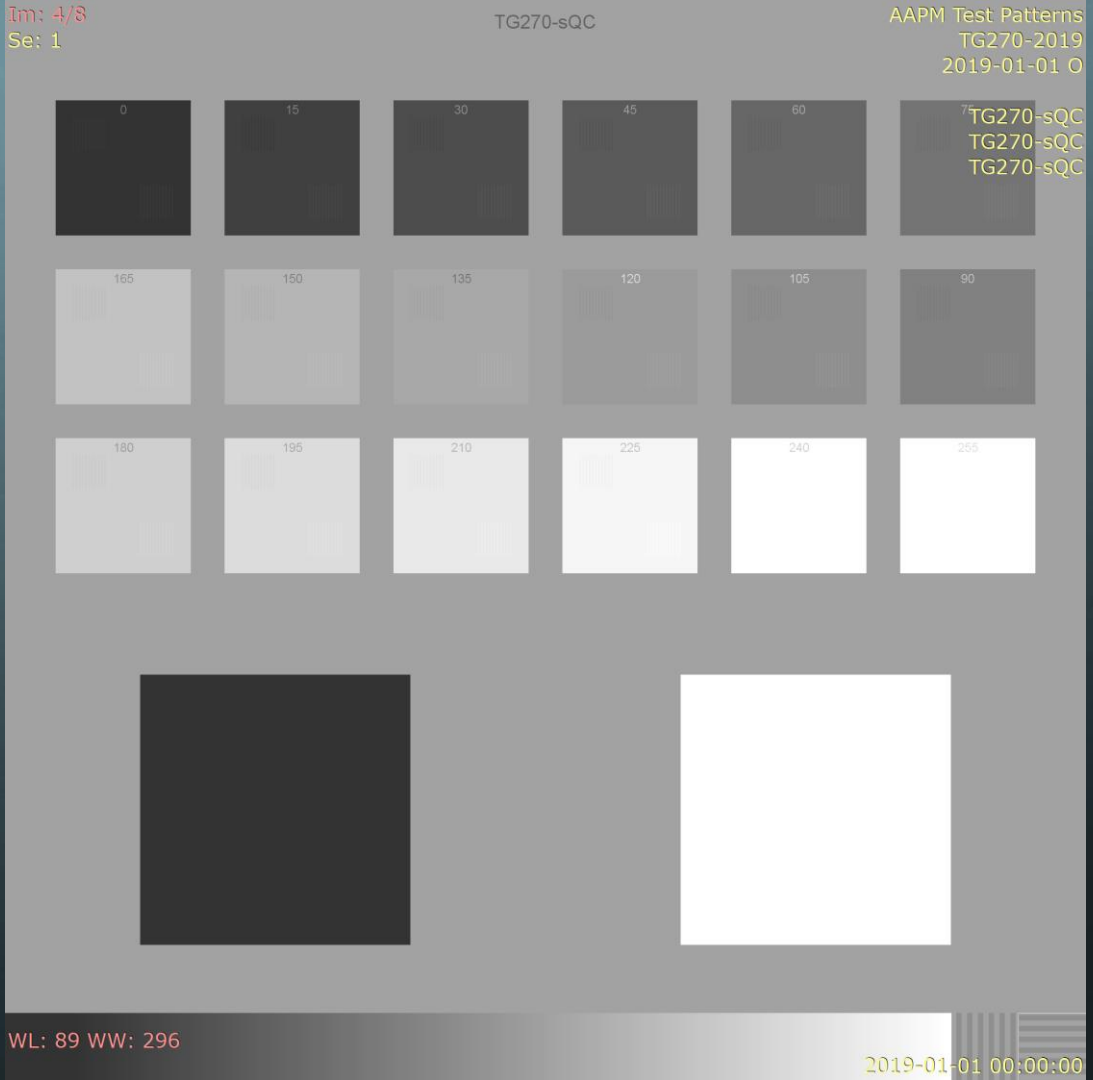
- DICOM part 14 (1996), under IHE radiology CPI (2001)
- AAPM TG18 (2005)
- ISO 9241-3xx (2010)
- ACR-AAPM-SIIM (2017)
- AAPM TG270 (2019)

# TG-270's Classes of display

- Primary displays-> Diagnostic displays
- TG18's secondary diagnostics becomes:
  - Modality displays
  - Clinical specialist displays
  - Displays used for electronic health records

# Testing frequencies, context of mammography

- Quarterly test
  - Qualitative luminance response
  - Qualitative ambient luminance/illuminance
  - Qualitative uniformity
  - Qualitative resolution


Im: 4/8
Se: 1
TG270-sQC
AAPM Test Patterns
TG270-2019
2019-01-01 O
TG270-sQC
TG270-sQC
TG270-sQC
0
15
30
45
60
75
165
150
135
120
105
90
180
195
210
225
240
255
WL: 89 WW: 296
2019-01-01 00:00:00

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# Testing frequencies, context of mammography

- Yearly test
  - Qualitative uniformity
  - Quantitative ambient luminance+illuminance
  - Quantitative luminance reponse + max/min ratio
  - Quantitative color assessment

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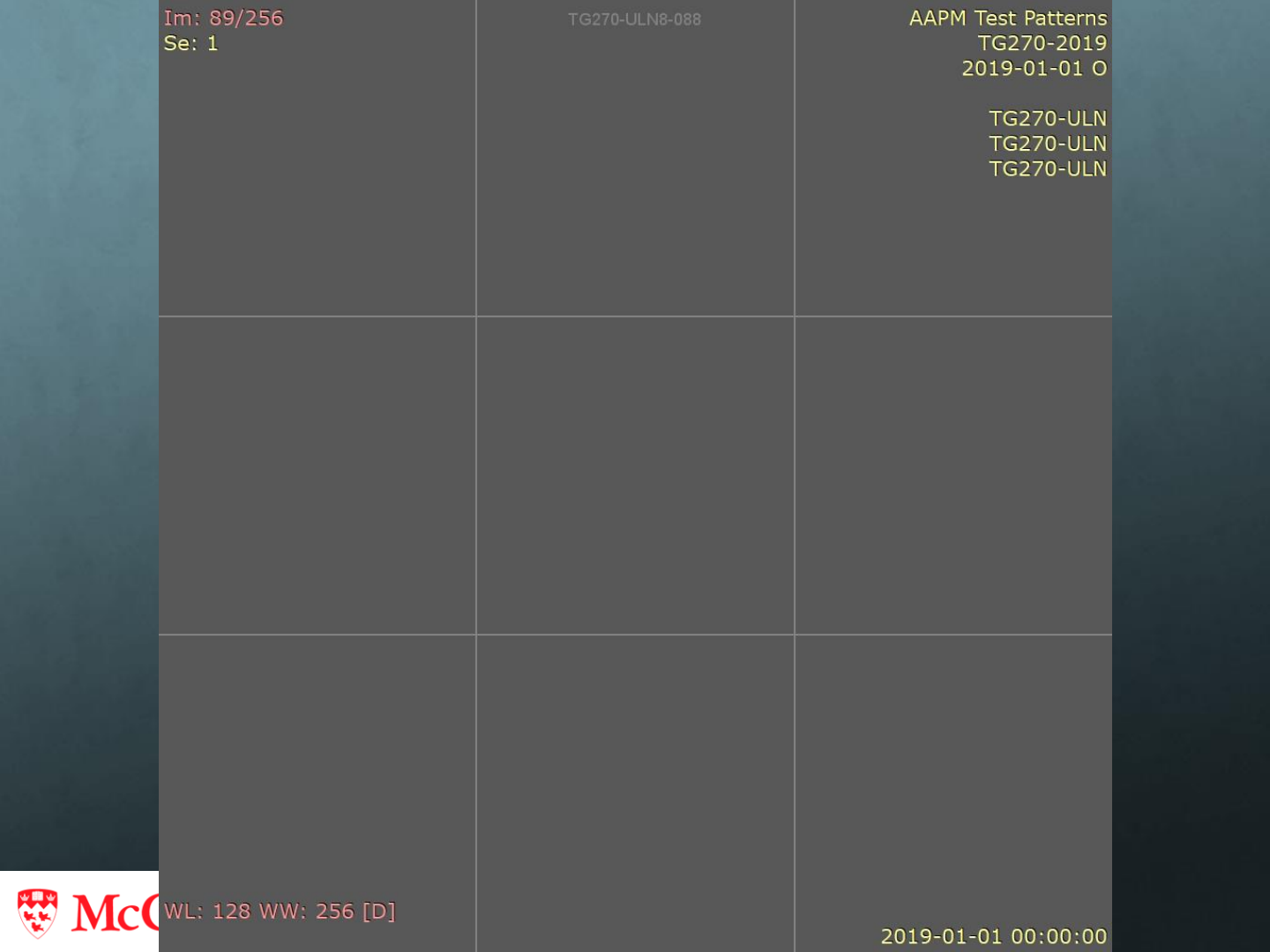
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TG270-ULN
TG270-ULN
TG270-ULN
WL: 128 WW: 256 [D]
2019-01-01 00:00:00

# Quantitative uniformity

- 5 -> 9 points (3x3)
- % from the median of point
- <15 % ideal, 30 % can be assessed
- $L_{min} = 4 \cdot L_{amb}$
- From manufacturing quality and pixel compensation
- Purchase criteria

# Calibration, preparation

- Evaluating $L_{amb}$ , with $L_{amb} = I_s \cdot R_d$
- Choose $L_{min}$ so that $L_{min} = 4 \cdot L_{amb}$
- $L'_{min} = L_{min} + L_{amb}$
- $L_{max} = 350 \cdot L'_{min}$

# Example

- $L_{amb} = I_s \cdot R_d$
  - $L_{amb} = 35 \cdot 0.008 = 0.28$ cd/m$^2$
- $L_{min} = 4 \cdot L_{amb}$
  - $L_{min} = 4 \cdot 0.28 = 1.12$ cd/m2
- $L'_{min} = L_{min} + L_{amb}$
  - $L'_{min} = 1.12 + 0.28 = 1.4$ cd/m2
- $L_{max} = 350 \cdot L'_{min}$
  - $L_{max} = 350 \cdot 1.4 = 490$ cd/m2

# Evaluate GSDF

- TG270-UNL
- Add $L_{amb}$ to puck measurements (unless in possession of a telescopic meter)
- 52 points instead of 18, (256 at acceptance)
- Automatic collection
- Do not use built-in puck, external

# GSDF outcome

- $L'_{max} / L'_{min} \sim 350$
- Contrast change within 10% of GSDF
- $L_{max}$ within 10% for a pair of monitors
- Allow sufficient warmup time


Im: 5/8
Se: 1
TG270-pQC
AAPM Test Patterns
TG270-2019
2019-01-01 0
TG270-pQC
TG270-pQC
TG270-pQC
WL: 128 WW: 256 [D]
2019-01-01 00:00:00

# Acceptance/selection tests

# Resolution

- Mostly not a concern with LCD monitors
- Assuming:
  - matching display board to display resolution
  - IPS or VA pixel structure
  - Digital interface (DVI, display port, USB-c)
  - 210 um diagnostic, traditionnally 2 x 5 megapixels

# Display noise

- Mostly stationary
- Reflects both manufacturing quality and the presence of pixel level compensation technology
- Purchase criteria
- Qualitatively assessed with TG270-pQC

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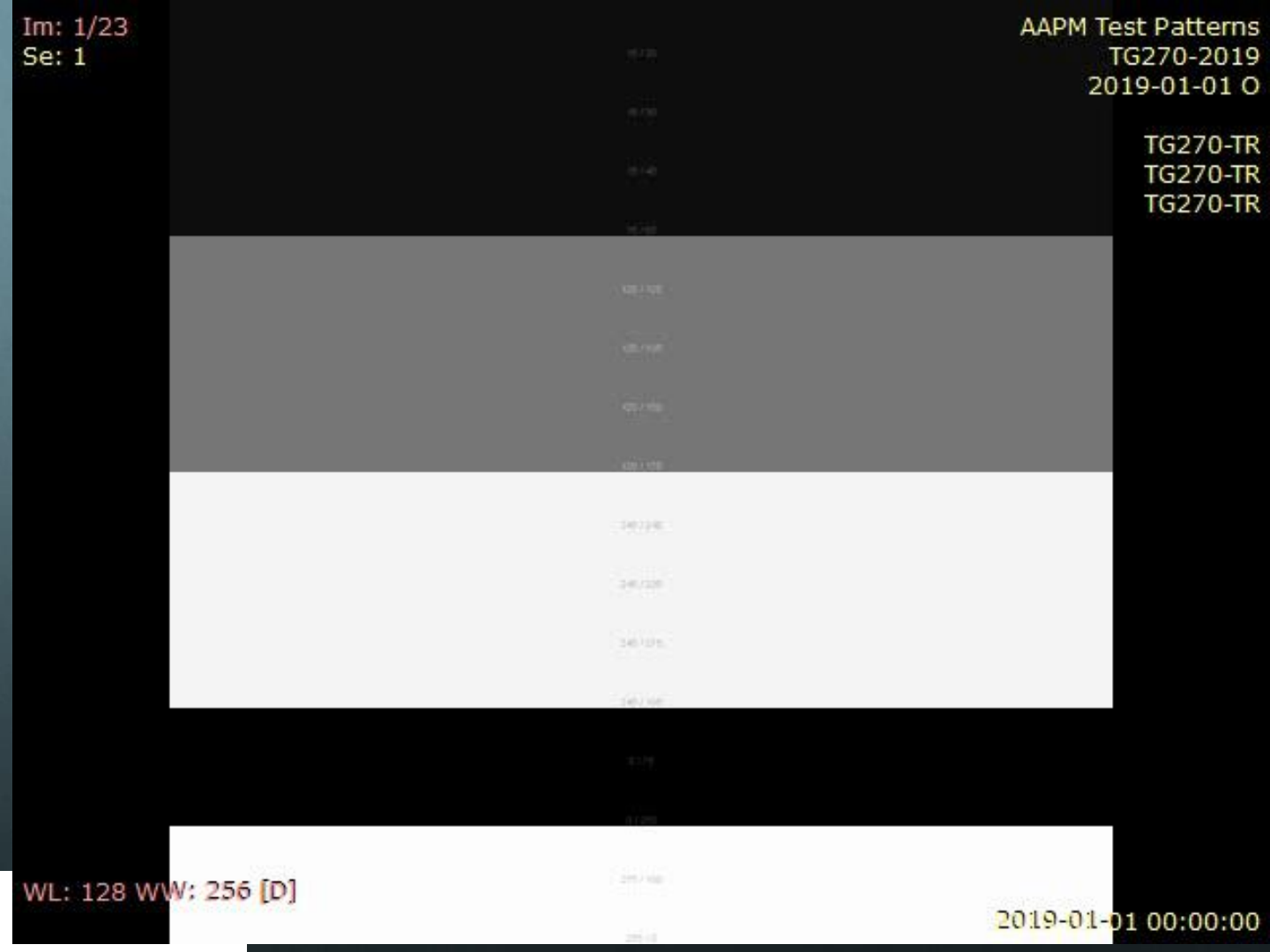
# Temporal resolution

- Important for browsing through a tomosynthesis stack
- Design criteria, purchasing rather than QC
- Evaluated using TG270-TR, a DICOM multiframe object pattern
- Is played in cine mode, at the same frame rate as the display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AAPM Test Patterns
TG270-2019
2019-01-01 O
TG270-TR
TG270-TR
TG270-TR
WL: 128 WW: 256 [D]
2019-01-01 00:00:00

# Color/temperature of gray levels

- Mammography displays will increasingly become color capable
- Absolute color loosely recommended as D65 (more specific than 6500 K)
- Consistency of prime concern
  - Between 2 monitors of the same workstation
  - Between workstations

# Other considerations

# Management QA of monitor fleet

- With built-in puck allows for automation of QA
- Local software communicates with server: GSDF status, dates, # hours BL, displays TG18 patterns
- Server local or remote (via proxy)
- Web interface for result visualization or change of settings
- Easier management of display fleet lifecycle

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# Reading room: lighting

- Positioning should avoid specular reflection
- Room illumination 25-50 lux, heavily opacified windows if present
- Dimmable light in front of monitor
- Weak light on wall behind monitor
- Eye level half way between of top and middle of monitor, at 60 cm
- Weekly cleaning of monitor surface

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# Reading room: environmental

- Air conditioning: about 1000 W / workstation
- Tower attached under the table
- Workstation table height adjustable
- Noise proof panels
- Third monitor: text and color images

# Longevity 1/2

- Determined by backlight (BL) on time
- Typically 20 000 to 50 000 hours of BL on time
- Typically available in monitor software
- LED output (luminance/power) tend to decay more slowly than CCFL

# Longevity 2/2

- Physicist can add much value by detection bad configuration leading to an « always on » BL
- $L_{max}$ initially chosen as ½ of highest achievable $L_{max}$
- $L_{max}$ must remain unchanged throughout the lifetime of the display
- BL power is increased throughout the lifetime of the display

# Support

- Replacement warranty? For pair?
- Clarify color matching, options?
- # of BL hours of replacement monitors
- Transportation included?

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# Future?

- Color will become standard, grayscale will go
- OLED (wider viewing angle, wider color gamut)
- Monitor QA effort will need to be « departementalized »

# Thanks

- Nicholas Bevins, Co-chair, AAPM TG270
- Michael Flynn, Co-chair, AAPM TG270
- Lutz Gilster, Barco