Objective measures of image quality and F792-OE

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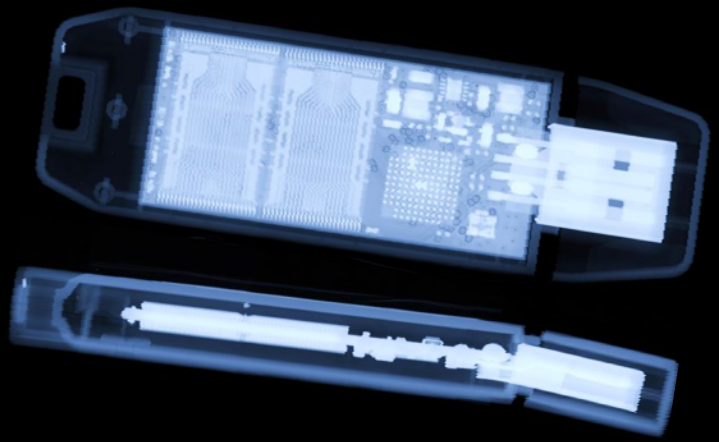
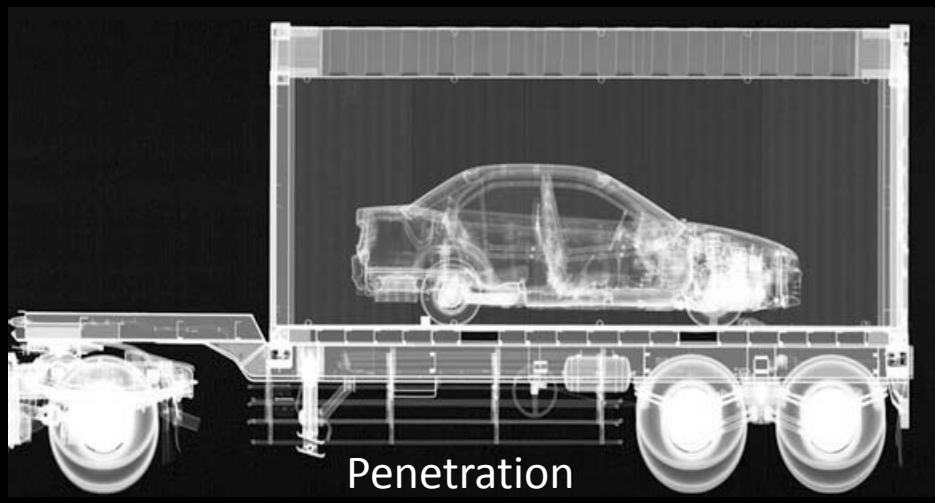


Checkpoint x-ray screening

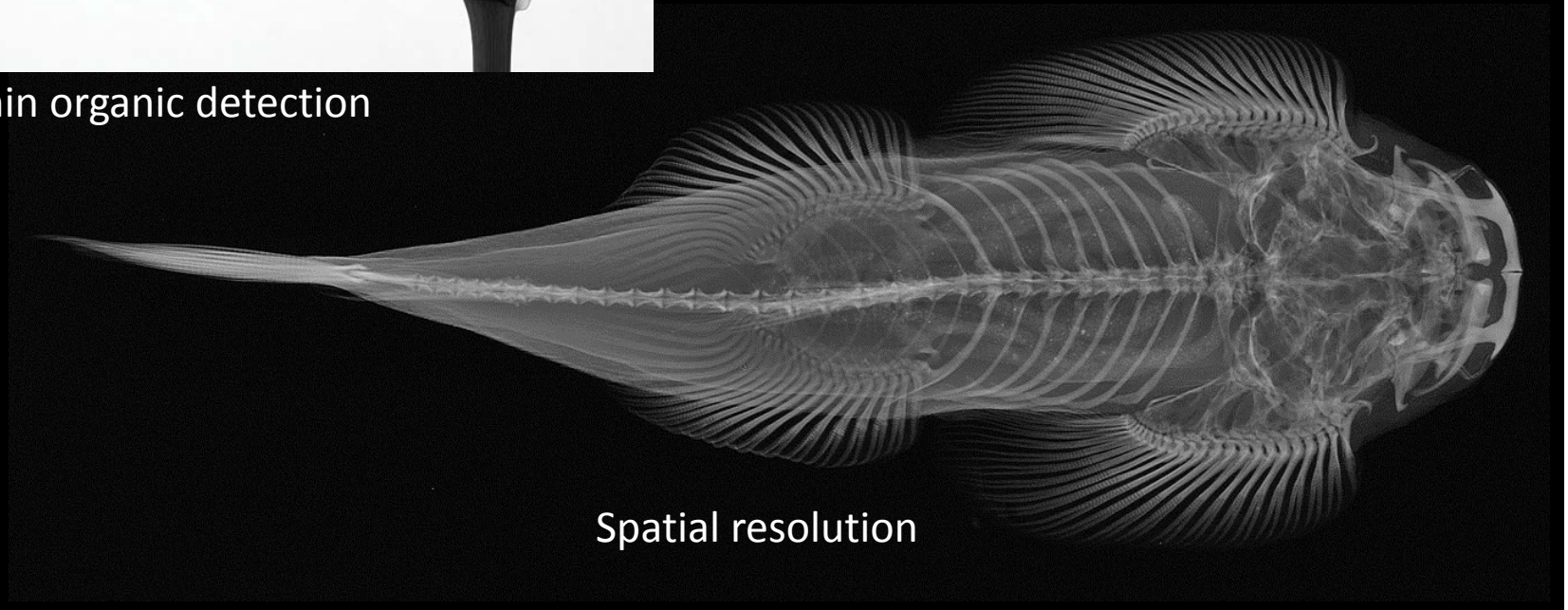
- Image quality standard ASTM F792-08
- Currently under revision and may be split into 3
- One sub-working group is developing an Objectively Evaluated (OE) standard
- General trend toward objectively-evaluated image quality standards

Measuring x-ray image quality

Thin organic detection



Penetration



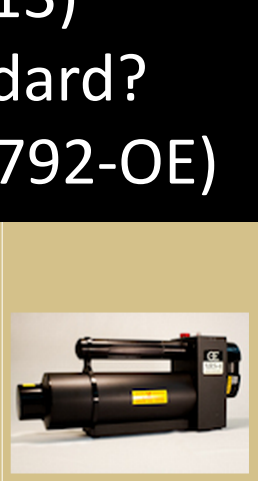
Spatial resolution

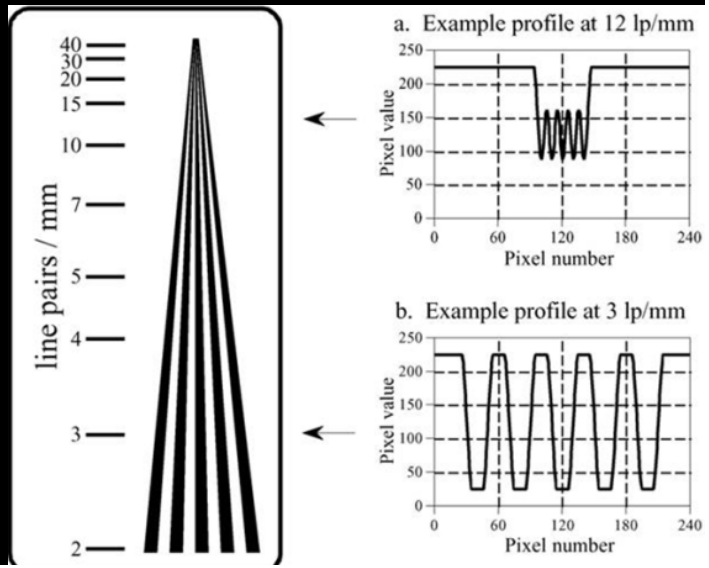
Objective standards

- Create a common language of image quality
- Easy comparison of specifications
- Objective standards are evaluated by an algorithm, rather than a human
- Recent trend towards objective standards
  - CT image quality standard (N42.45-2011)
  - Portable x-ray systems for bomb squads (ANSI N42.45-2013)
  - Checkpoint standard? (proposed ASTM F792-OE)

XRS-4

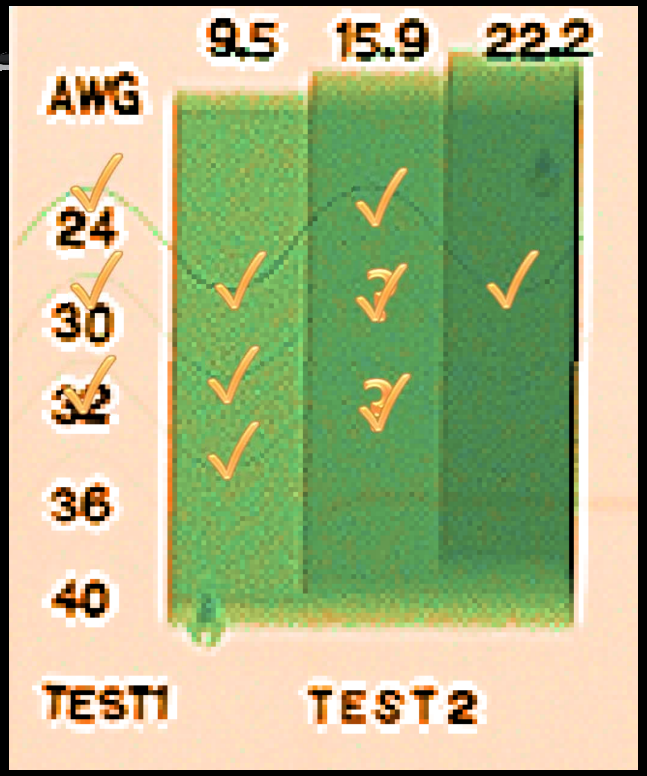
- 370 KVP
- Penetrates 1.5" Steel
- Weighs 22 Pounds with battery
- DeWalt® 18V Battery pack
- One hour DeWalt® Battery Charger





Objective vs subjective image quality

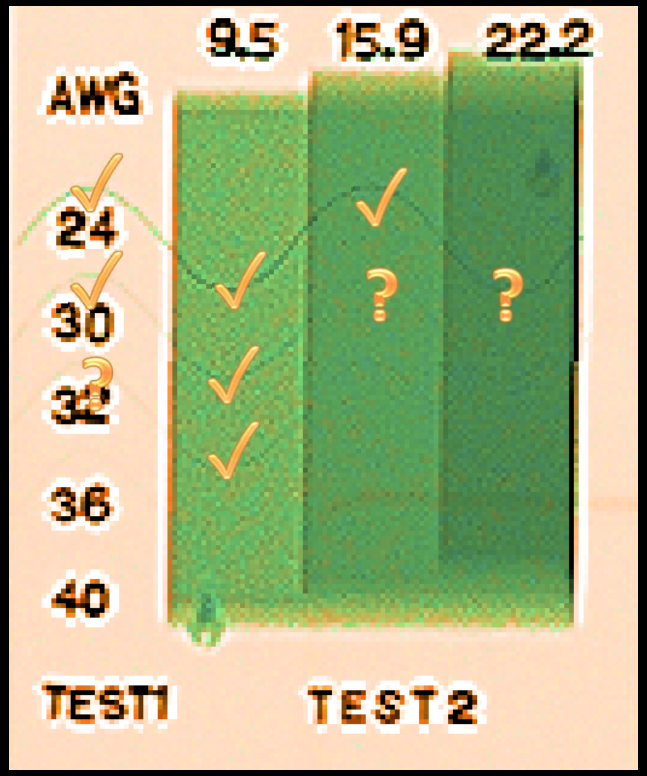
ASTM F792



Subjective test (i.e. judged by a person)

Objective vs subjective image quality

ASTM F792



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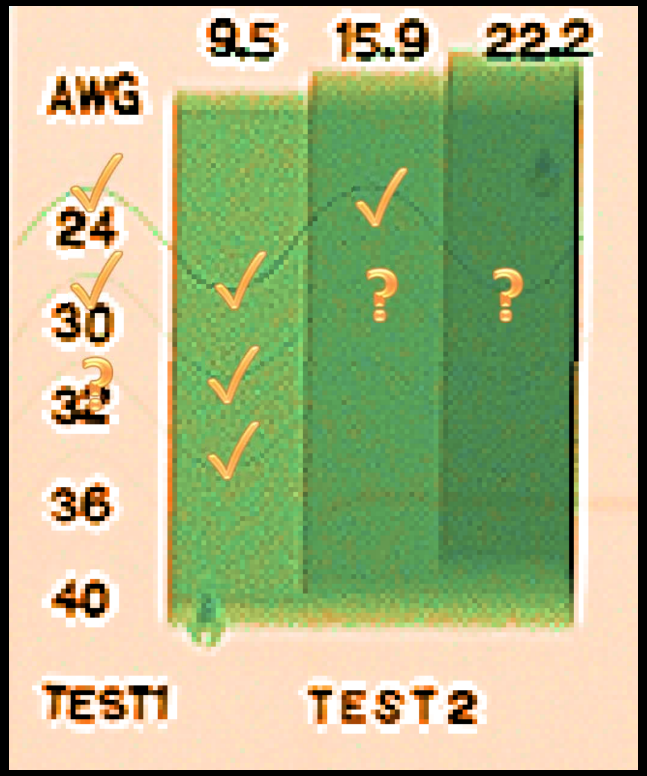
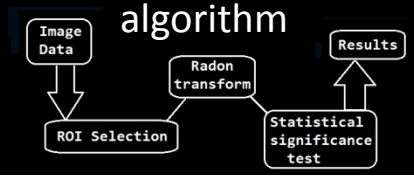
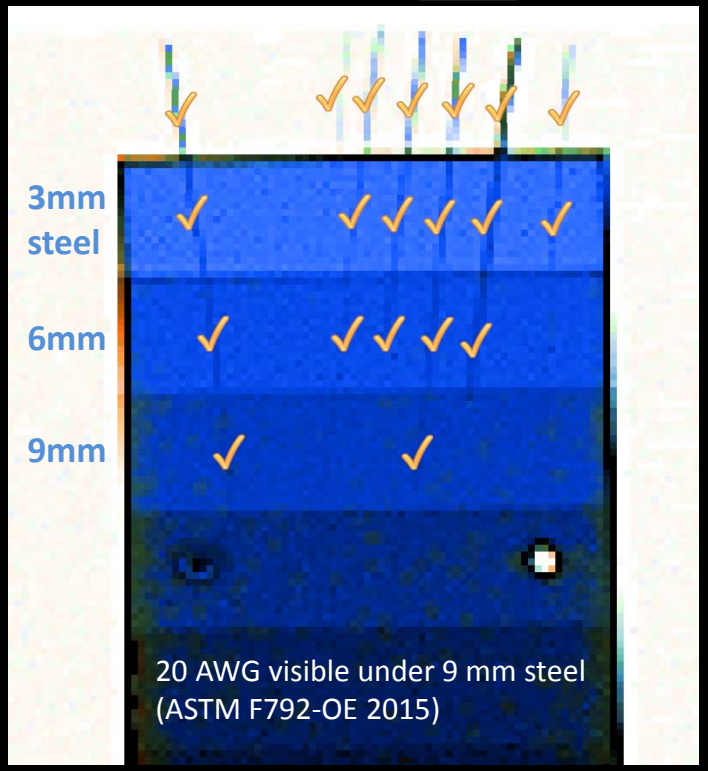
ASTM F792



Subjective test (i.e. judged by a person)

ASTM F792-OE algorithm

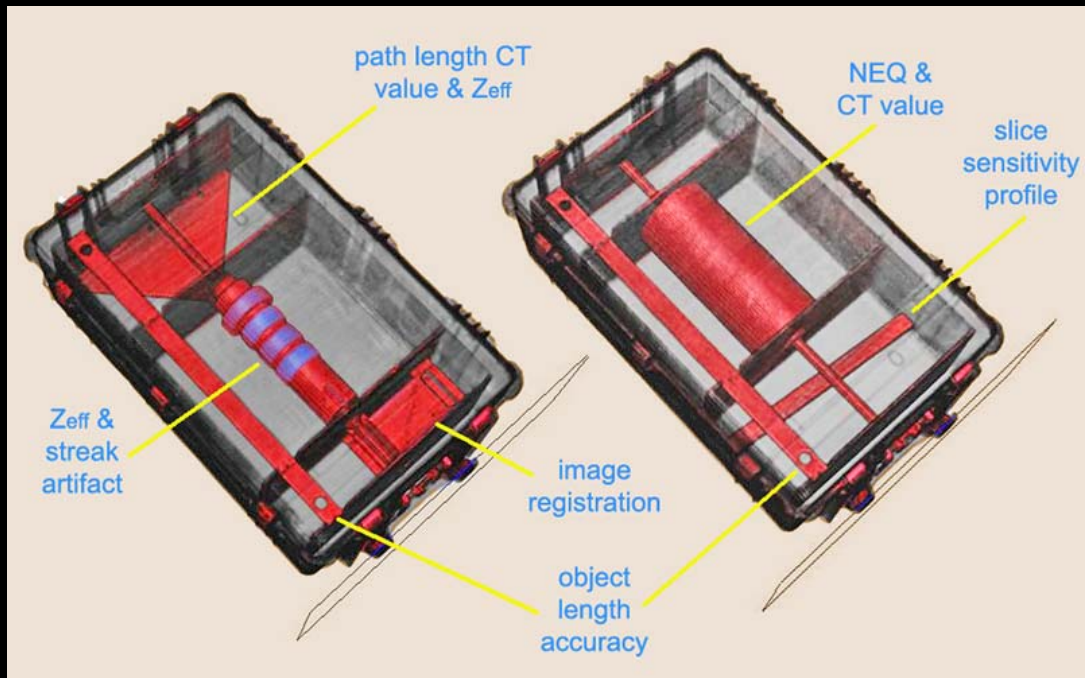




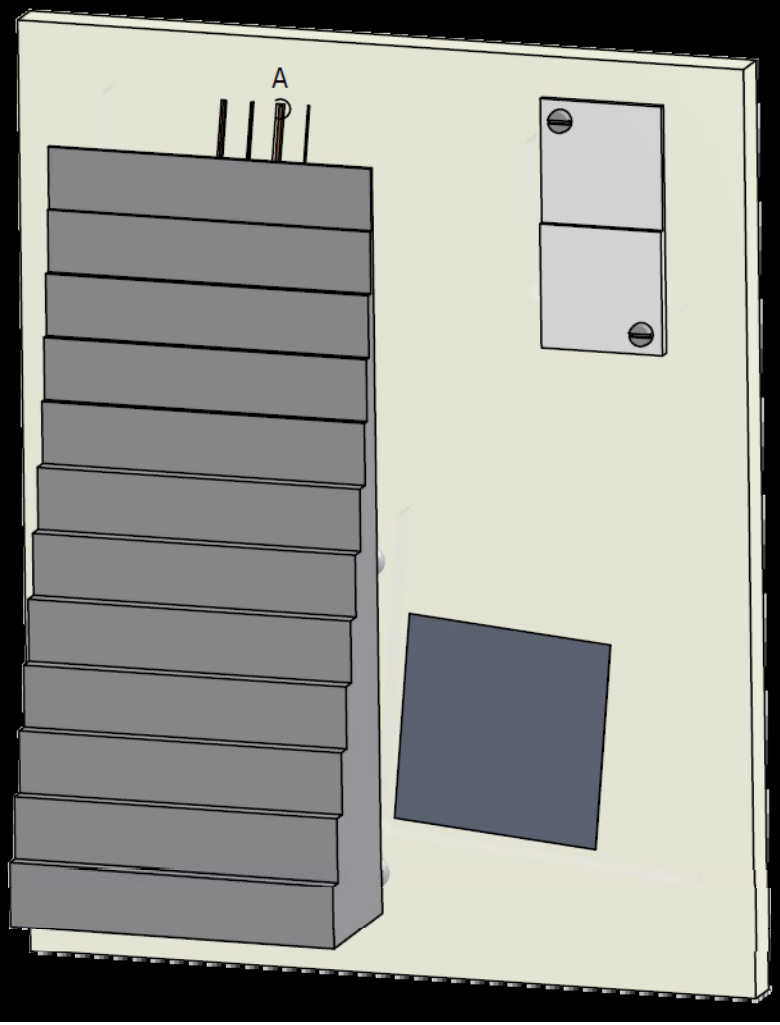
Objective test (i.e. judged by an algorithm)

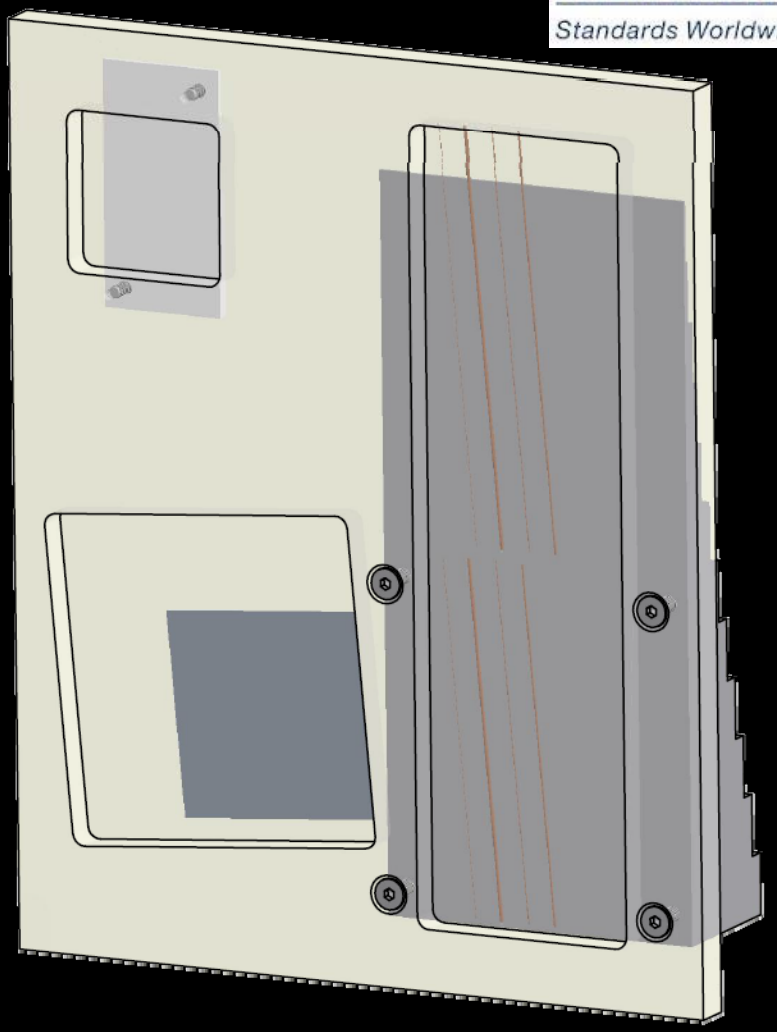
CT screening of checked luggage

- Image quality standard: ANSI N42.45
- Objectively evaluated image quality metrics
- Has proved extremely useful for TSA/TSL and manufacturers

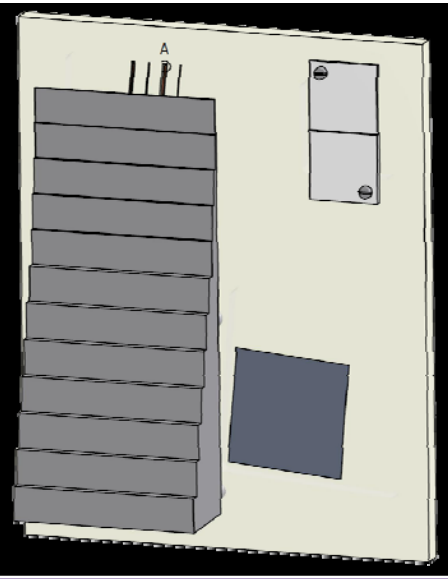


ASTM F792-OE prototype



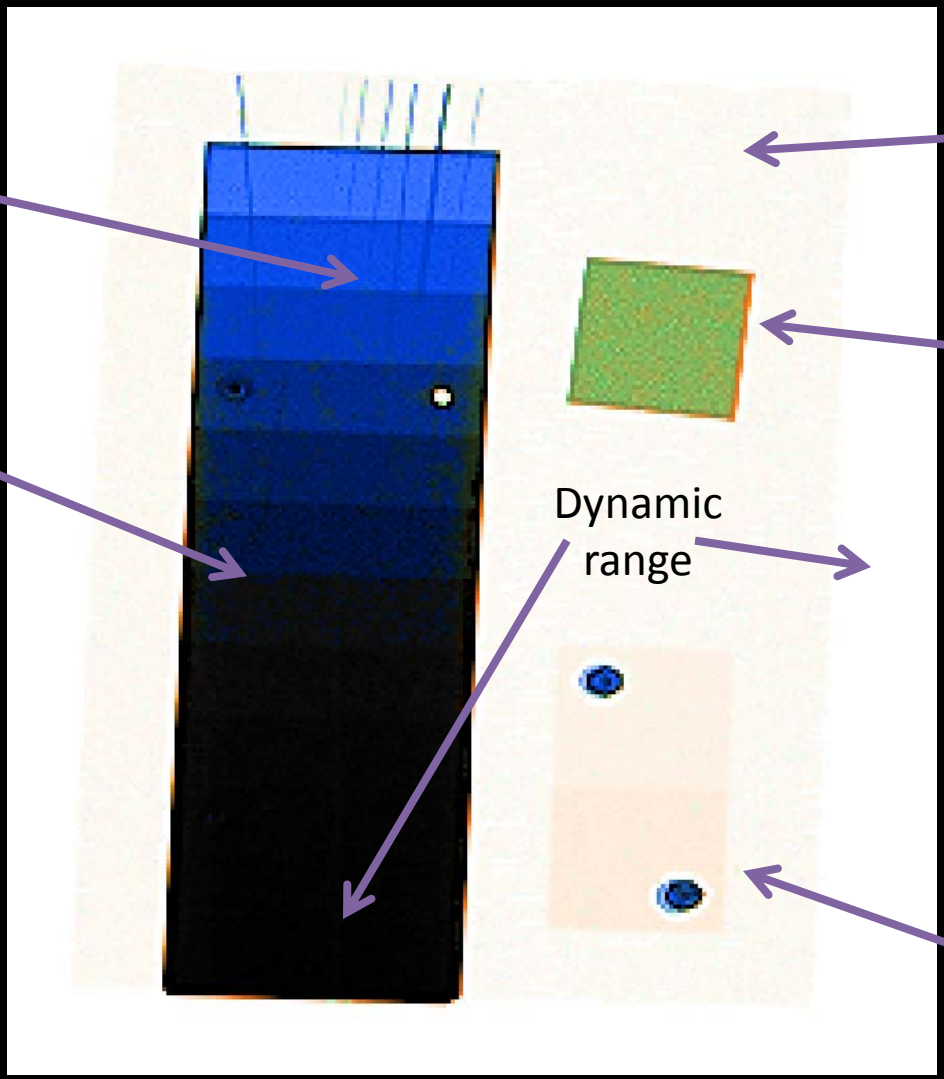


Proposed F792-OE metrics



Test name	What is meant to be measured	Object on test pattern
Test 1: Steel Penetration	thickest step that can be discerned from adjacent steps	stainless steel step wedge
Test 2: Organic Contrast Sensitivity	contrast between thin organic objects	polyoxymethylene (POM), *e.g*. Delrin™ step
Test 3: Resolution	spatial resolution in the two lateral dimensions	lead foil
Test 4: Dynamic Range	how much useful information the system is capable of storing in a pixel	stainless steel step wedge
Test 5: Noise	quantifies the frequency-dependent noise	with no test object present
Test 6: Useful Penetration	wire visibility through different thicknesses of steel	wires of different diameters behind steel step wedge

Proposed F792-OE metrics



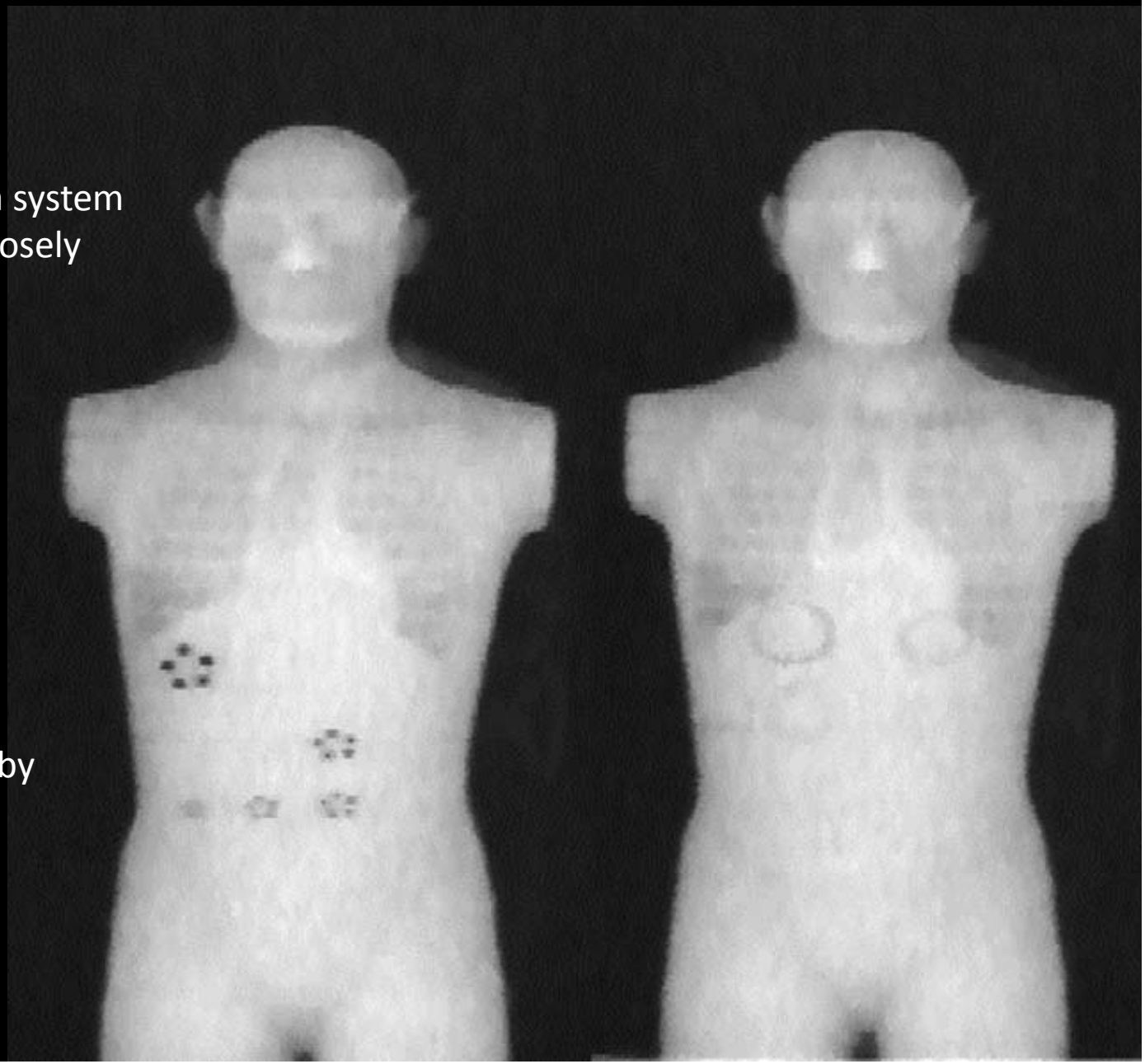
Spatial resolution

Extremely important aspect of image quality

Definition: the ability of a system to resolve, as separate, closely spaced small objects.

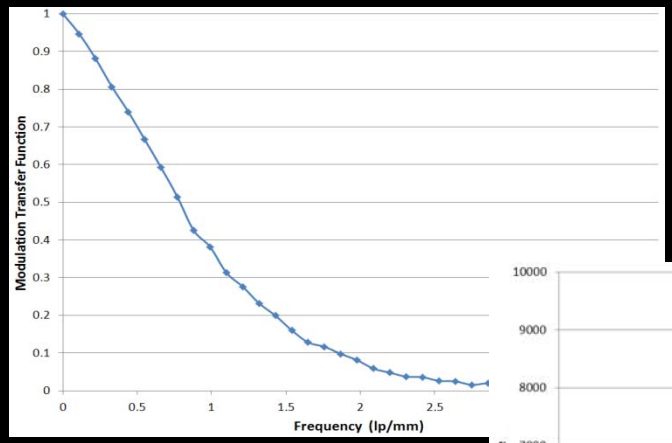
NOT the smallest object that can be seen

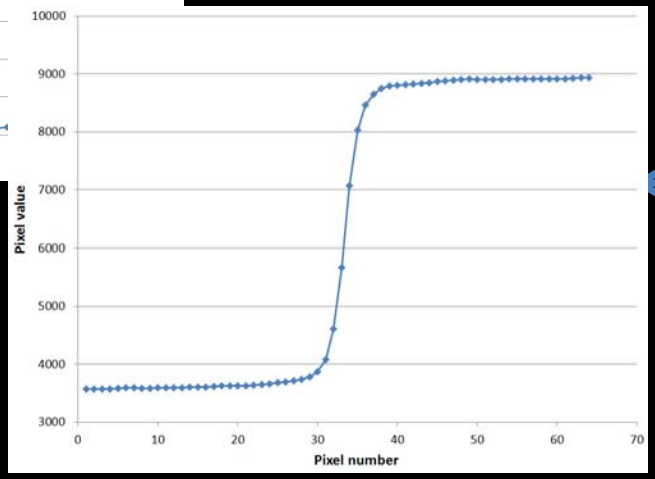
NOT wholly determined by number of pixels or pixel size

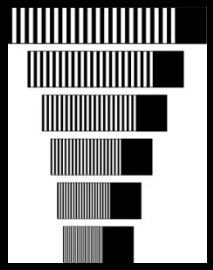


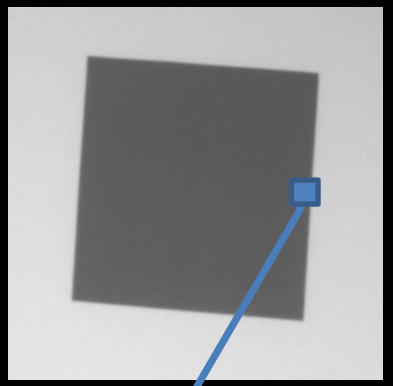
Spatial resolution in F792-OE

- Measured using a widely-used method called the slanted-edge MTF method
- Result in line-pairs per millimeter



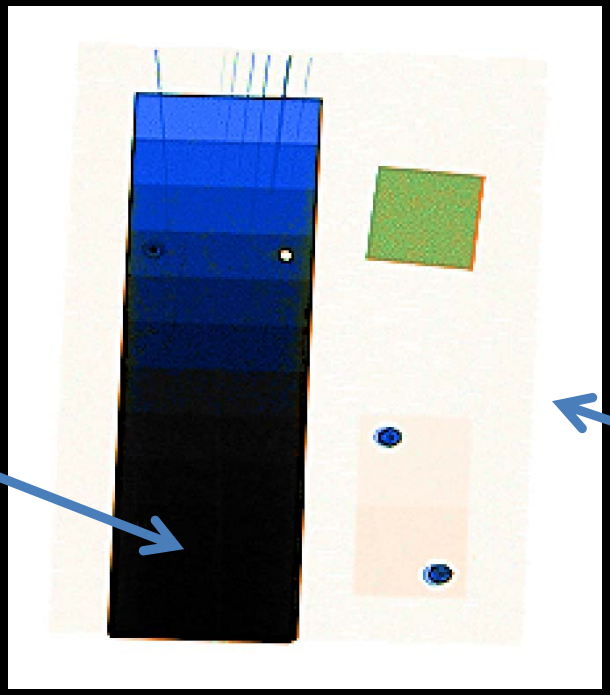






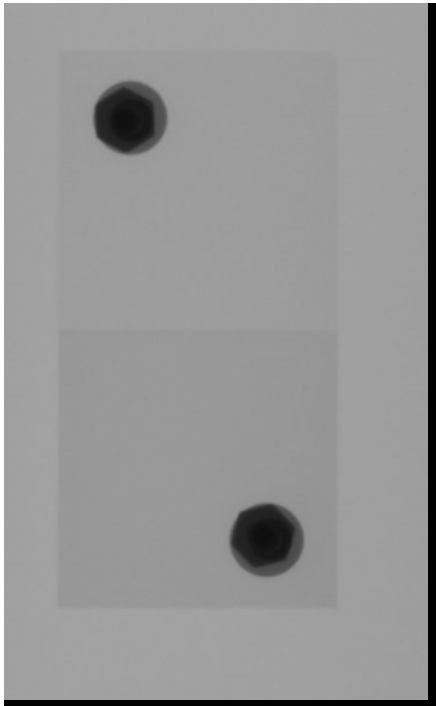
Dynamic Range

- Widely used concept in signal processing
- $\text{Dynamic range} = \dfrac{\text{Largest signal}}{\text{Smallest increment}}$



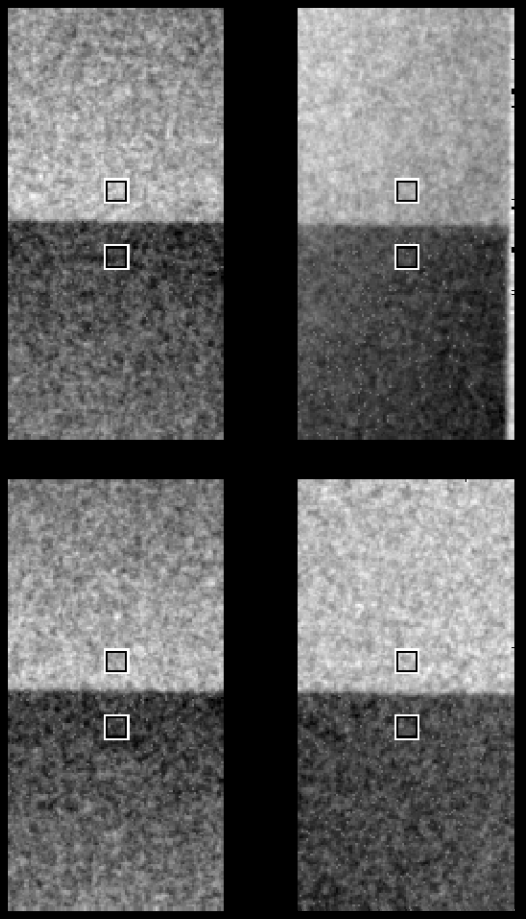
Smallest usable increment
= Standard deviation here

Largest signal
= Pixel value here



Organic detection

BSNR = 6.7



S vals
0.031
0.036
0.025
0.031

Boundary Signal to Noise Ratio (BSNR)

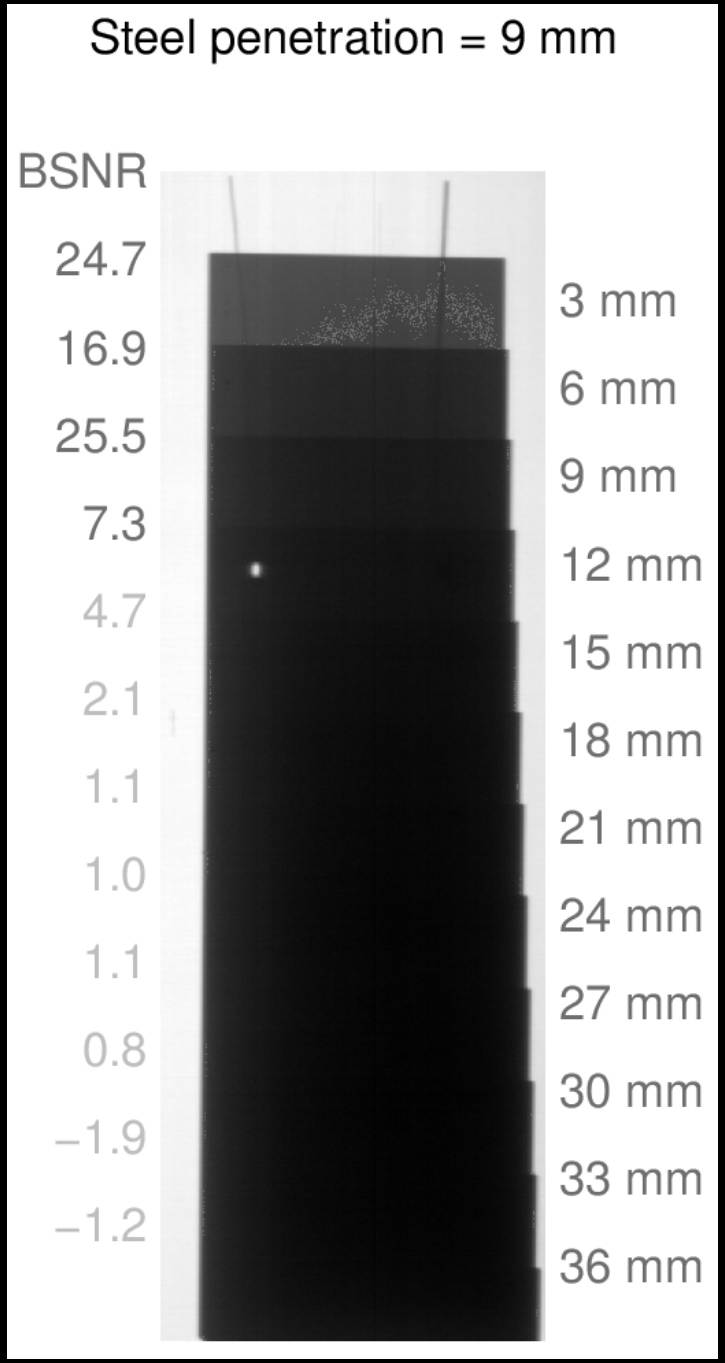
Computed using multiple images
in different orientations

$$S_i = 1 - \overline{thin\ step_i} / \overline{thick\ step_i}$$

$$BSNR = \frac{\bar{S}}{\sigma_S}$$

Steel Penetration

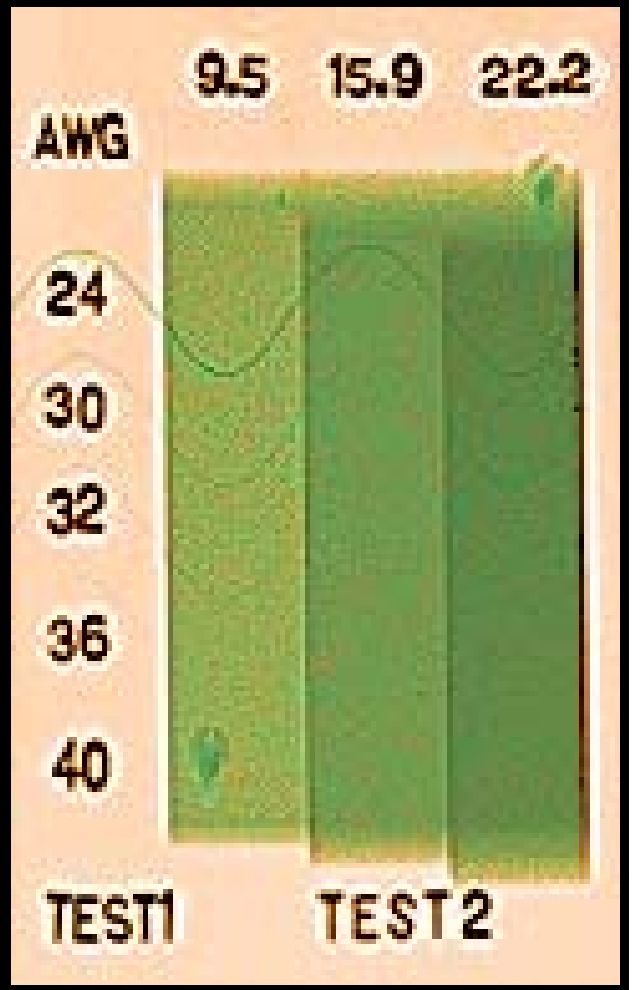
- Uses a steel step wedge
- Measures BSNR at every boundary
- Boundary = visible if, BSNR > 5
- What is the thickest step with both boundaries visible?

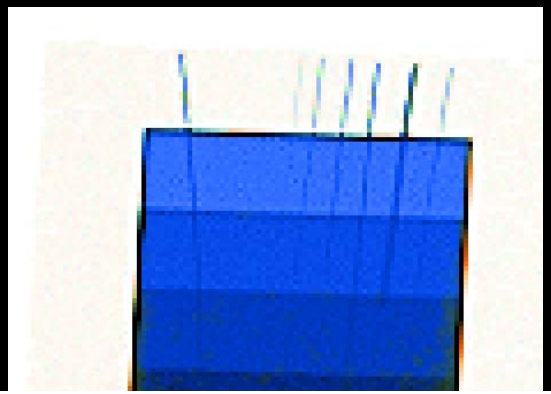


Useful penetration

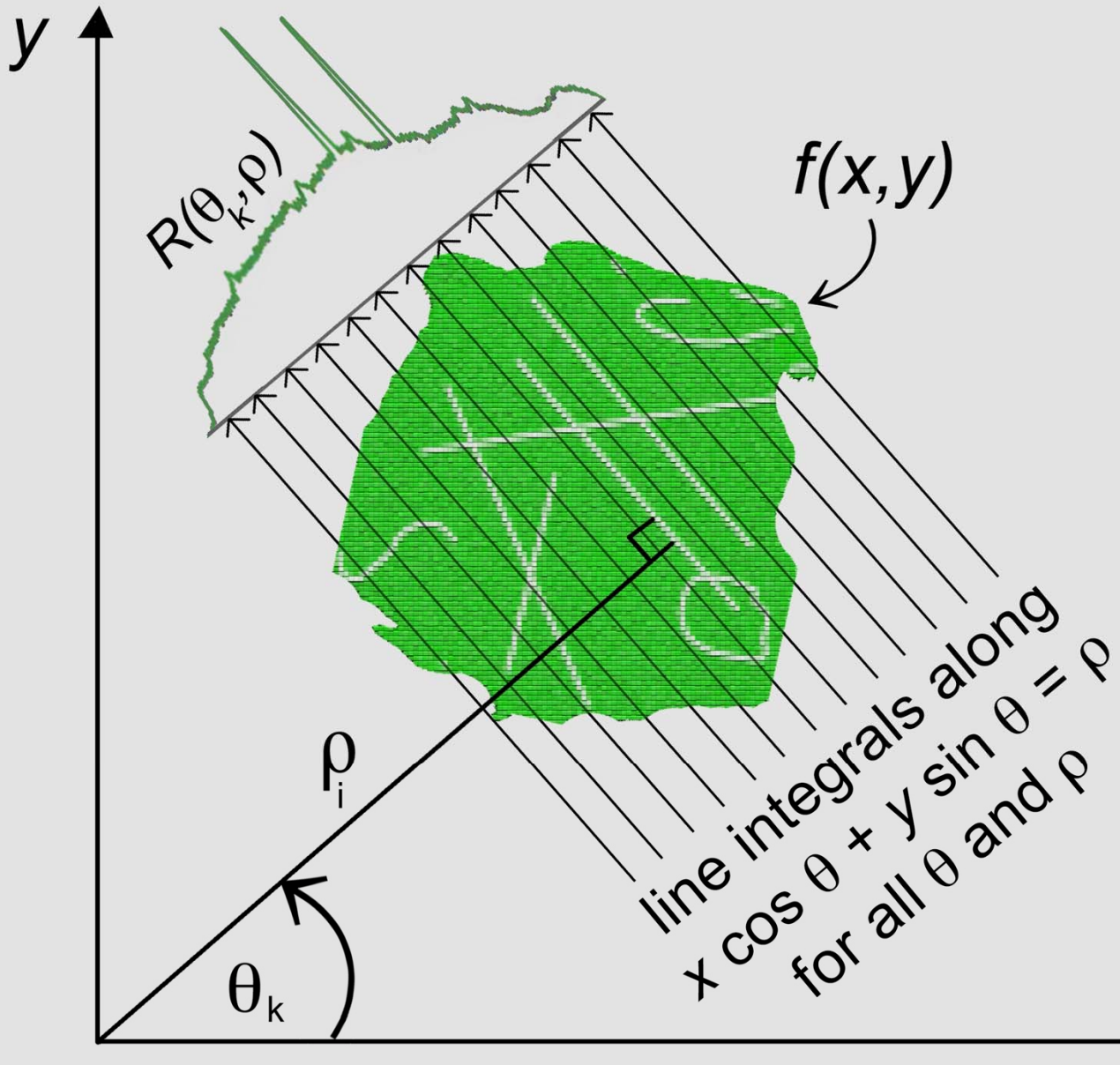
- Ability of a system to image wires under blocking material
- Concept exists in human-judged version of F792

- Objective evaluation
  = a challenge



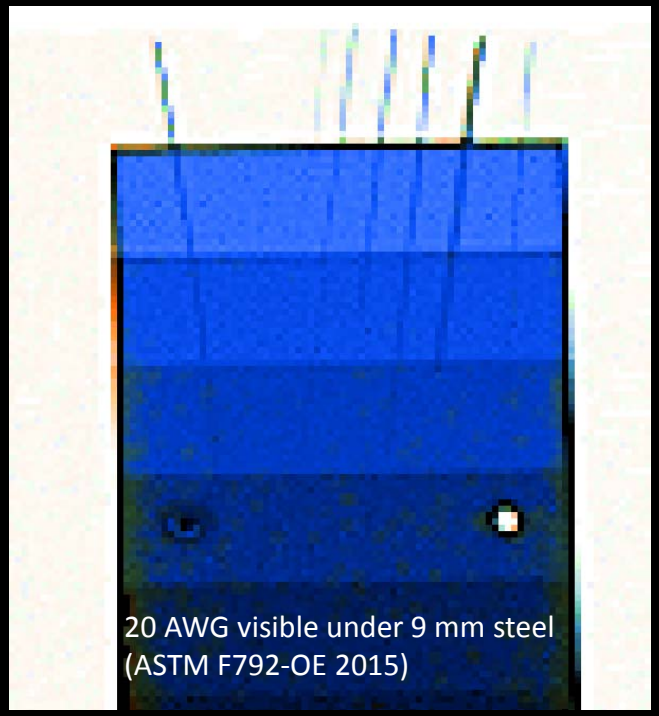


$$R(\rho,\theta) = \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} f(x,y)\delta(x\cos\theta + y\sin\theta - \rho)dxdy$$

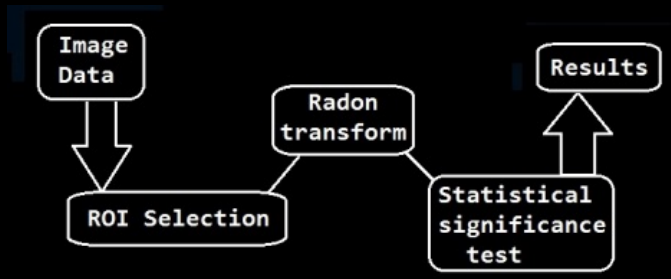


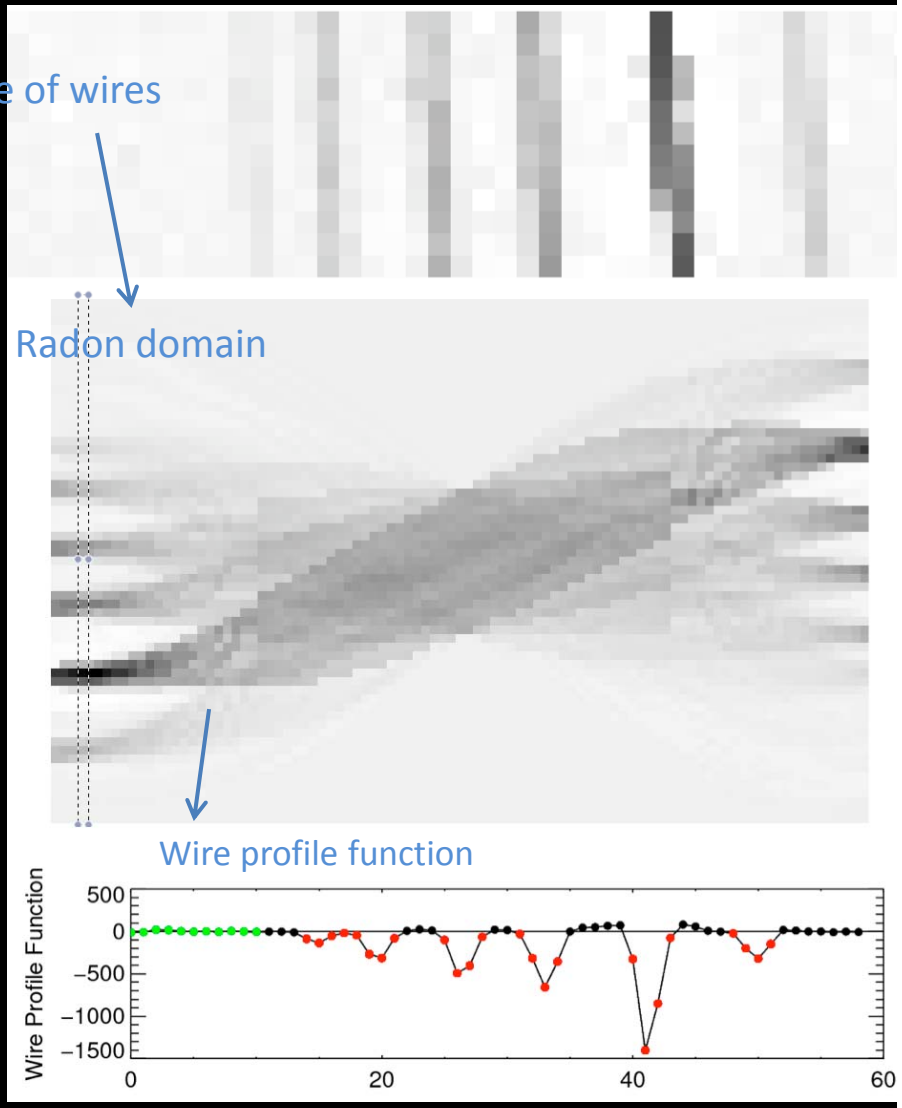
The Radon Transform

Useful penetration



ASTM F792-OE algorithm

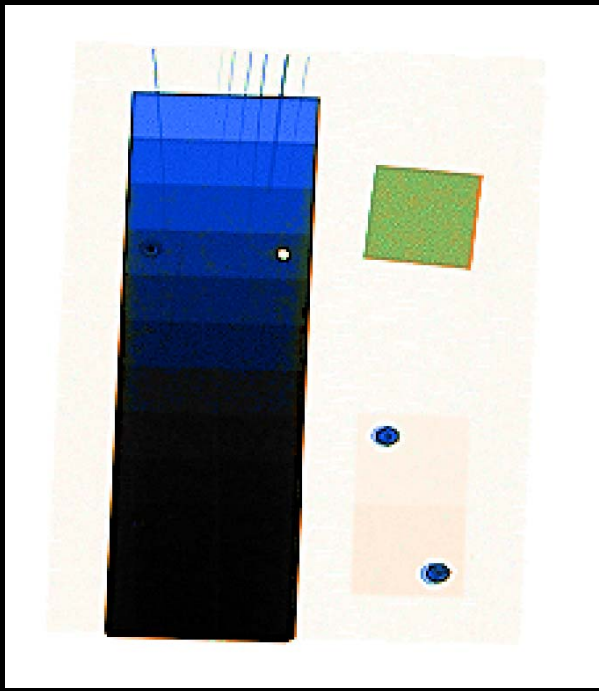




ASTM F792-OE results

- Suite of image quality metrics
- Performance monitoring
- Comparison of systems

Image Quality Metric	Vendor A	Vendor B	Vendor C
Test 1: Steel penetration	24 mm	15 mm	18 mm
Test 2: Organic Contrast Sensitivity	22.9	4.9	2.8
Test 3: Spatial Resolution	x-axis.: 0.56 lp/mm y-axis: 0.76 lp/mm	x-axis: 0.41 lp/mm y-axis: 0.53 lp/mm	x-axis: 0.48 lp/mm y-axis: 0.54 lp/mm
Test 4: Dynamic Range	229	72	204
Test 5: Noise	x-axis: 468^2 y-axis: 492^2	x-axis: 474^2 y-axis: 363^2	x-axis: 151^2 y-axis: 178^2
Test 6: Useful penetration	20 AWG: 9 mm 24 AWG: 6 mm 30 AWG: 6 mm	20 AWG: 6 mm 24 AWG: 3 mm 30 AWG: 0 mm	20 AWG: 3 mm 24 AWG: 0 mm 30 AWG: -



Conclusions

- There is a trend toward objectively evaluated image quality metrics
- Standard objective methods for measuring image quality make results more reliable and useful
- An objectively evaluated image quality standard has been developed by the ASTM F792-OE sub-working group