Digital Radigraphy in Aerospace

Underlying principles and migration from film technology

CINDE
CANADIAN INSTITUTE FOR NON-DESTRUCTIVE EVALUATION

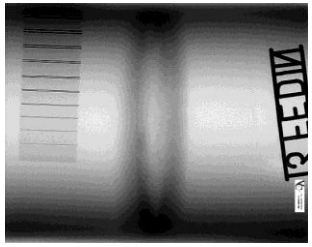
NDT in Canada
NDTiC 2018
Canada's NDT Conference

June 19 - 21
Halifax Convention Centre
Halifax, Nova Scotia

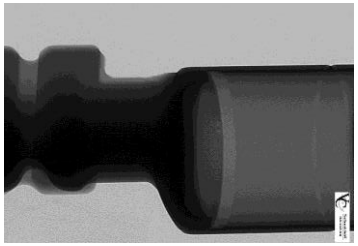
- The big challenge?

Different applications

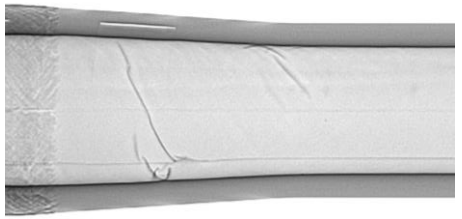
- Disbonds
- Cracks
- Delaminations



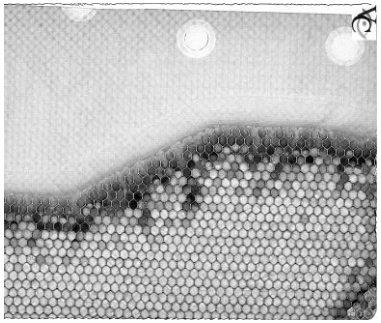
- Cracks
- Pores
- Inclusions

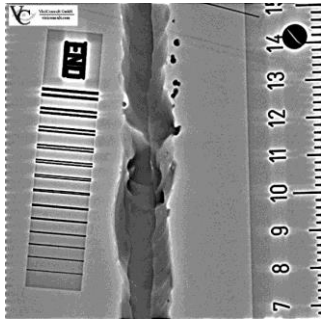


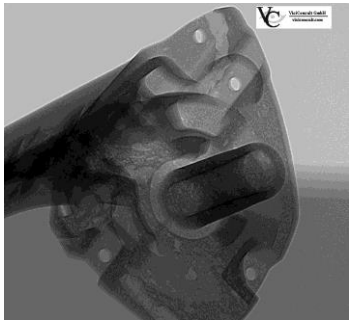
- Porosities
- Inclusions
- Geometry

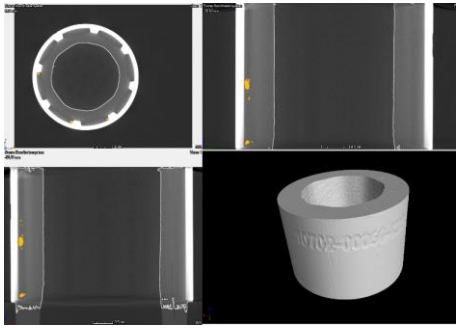


- Delaminations
- Pores
- Inclusions









X-ray tube types

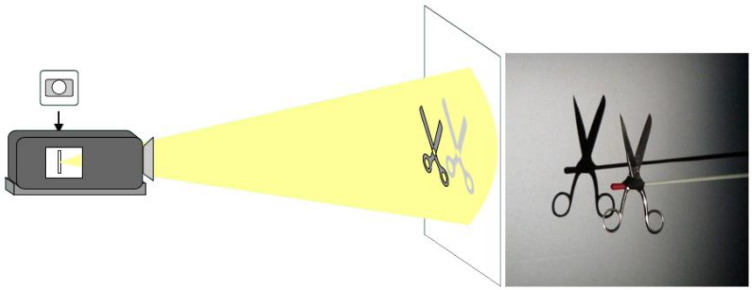
www.excillum.com

www.x-ray-worx.com

www.varian.com

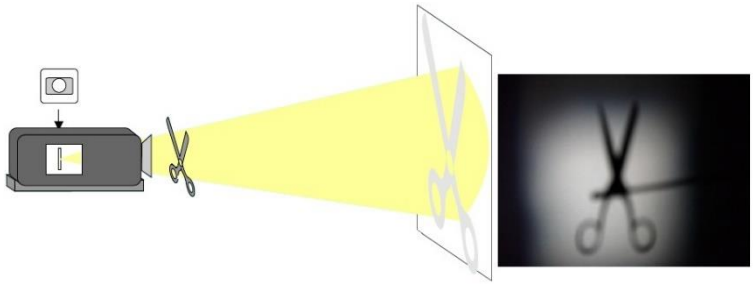
	Nanofocus-Tube	Microfocus-Tube	Minifocus-Tube
Focal spot size d	150 nm	2 µm – 300 µm	0,3 – 1 mm
Voltage U	Up to 190 kV	Up to 450 kV	Up to 600 kV

Focal spots



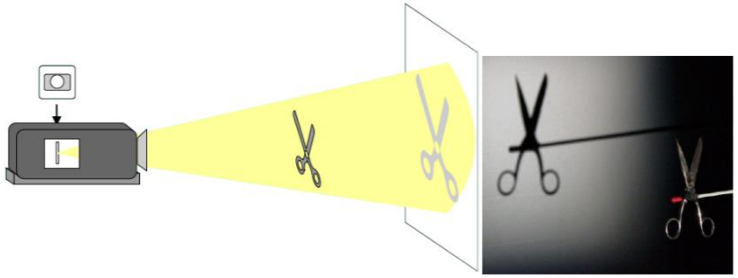
- Close to the flatpanel
- Big focal spot

- less magnification
- less unsharpness



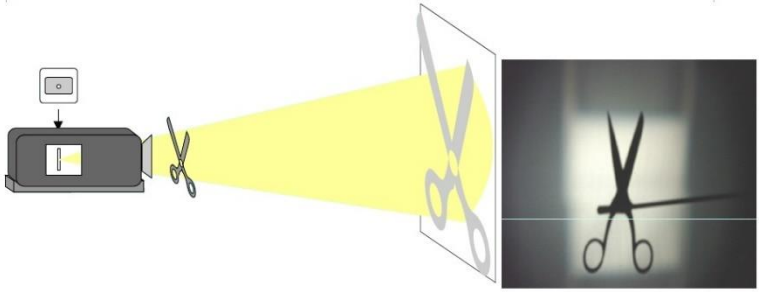
- Close to the tube
- Big focal spot

- high magnification
- high unsharpness



- In the middle
- Big focal spot

- In the middle
- Magnification = 2

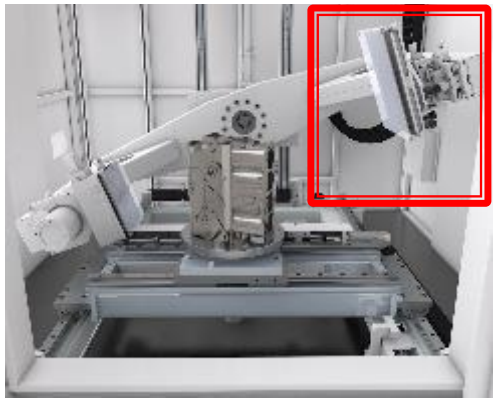


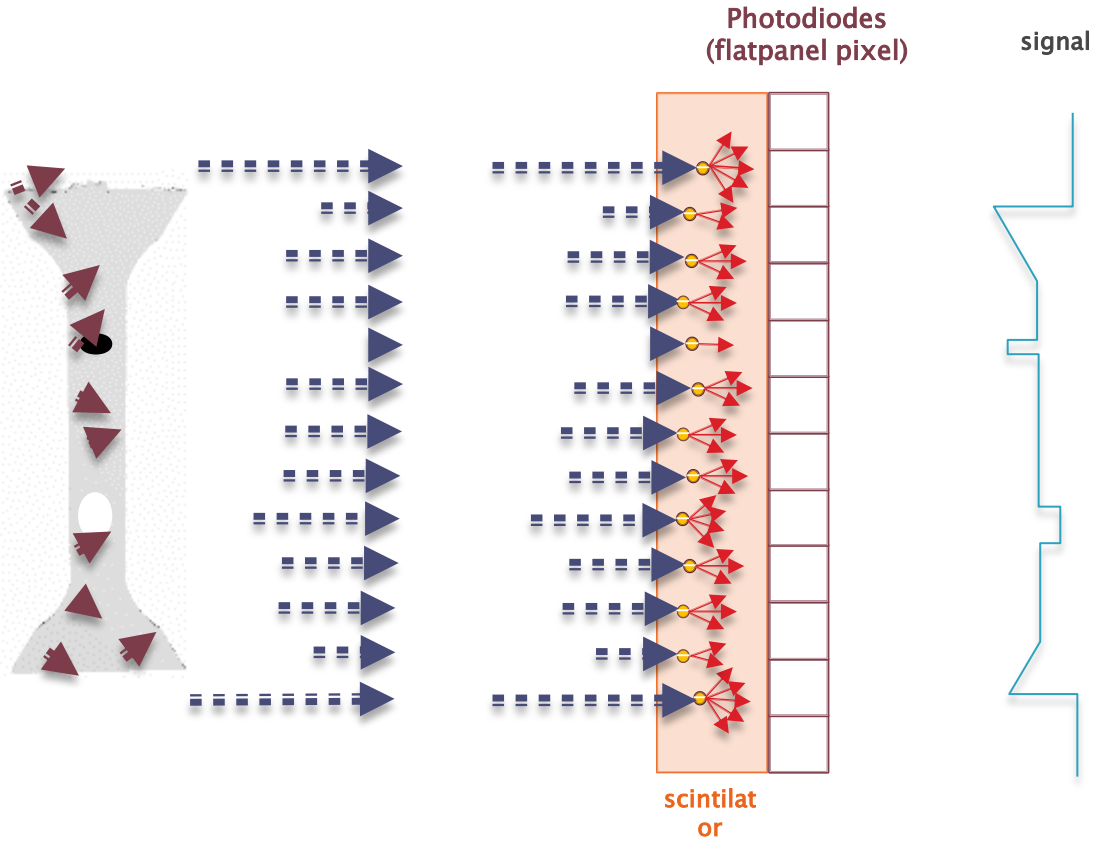
- Close to the tube
- small focal spot

- High magnification
- less unsharpness

Basics of X-ray inspection

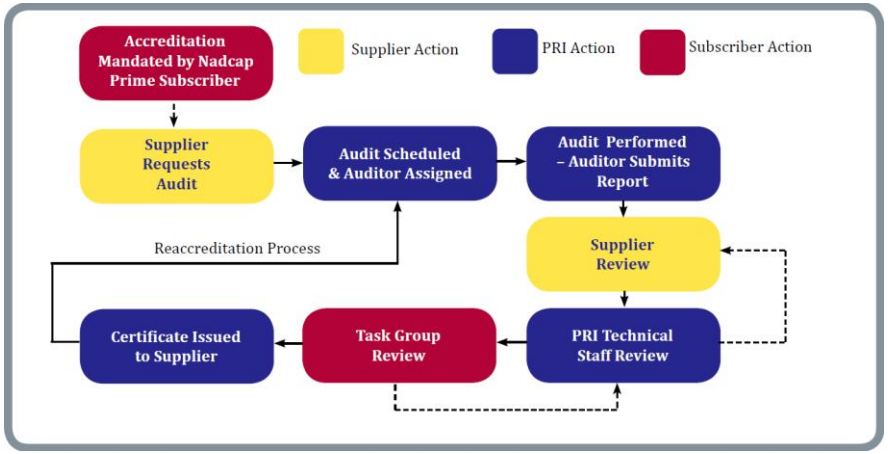
FLAT PANEL



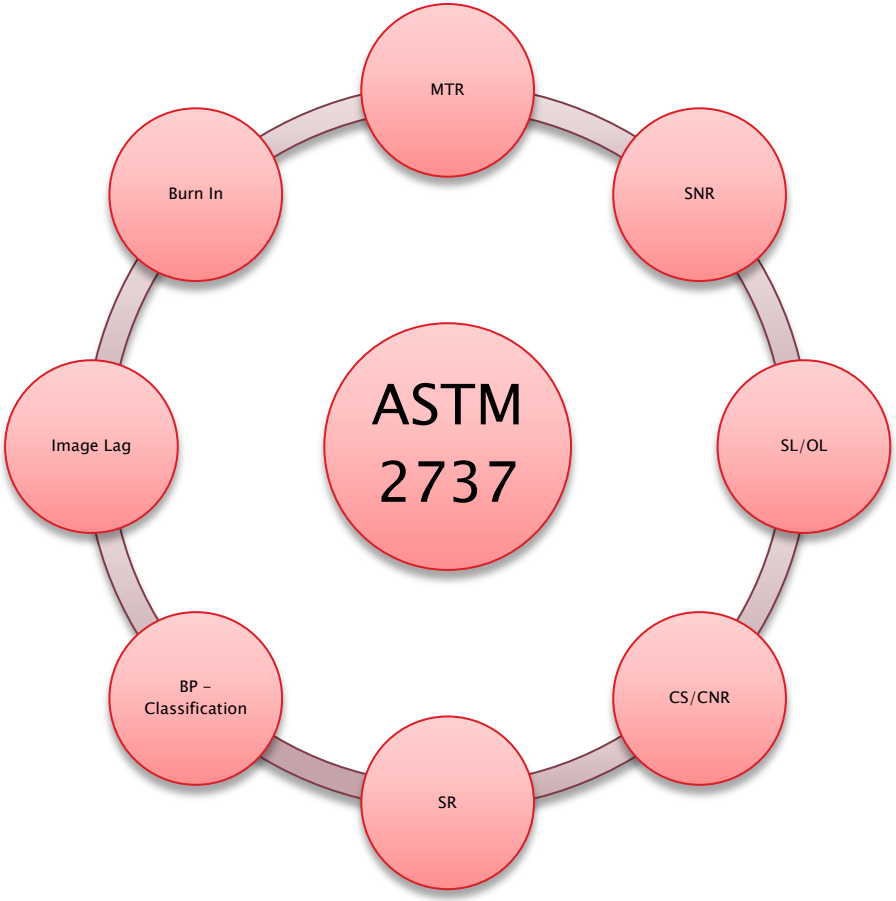


Standards and qualification

- Customer requirements
  - Boeing (BSS 7044), Airbus (AITM), etc.
- Industry requirements
  - NADCAP, ISO 9100 etc.
- Method standards
  - ISO, ASTM, etc.

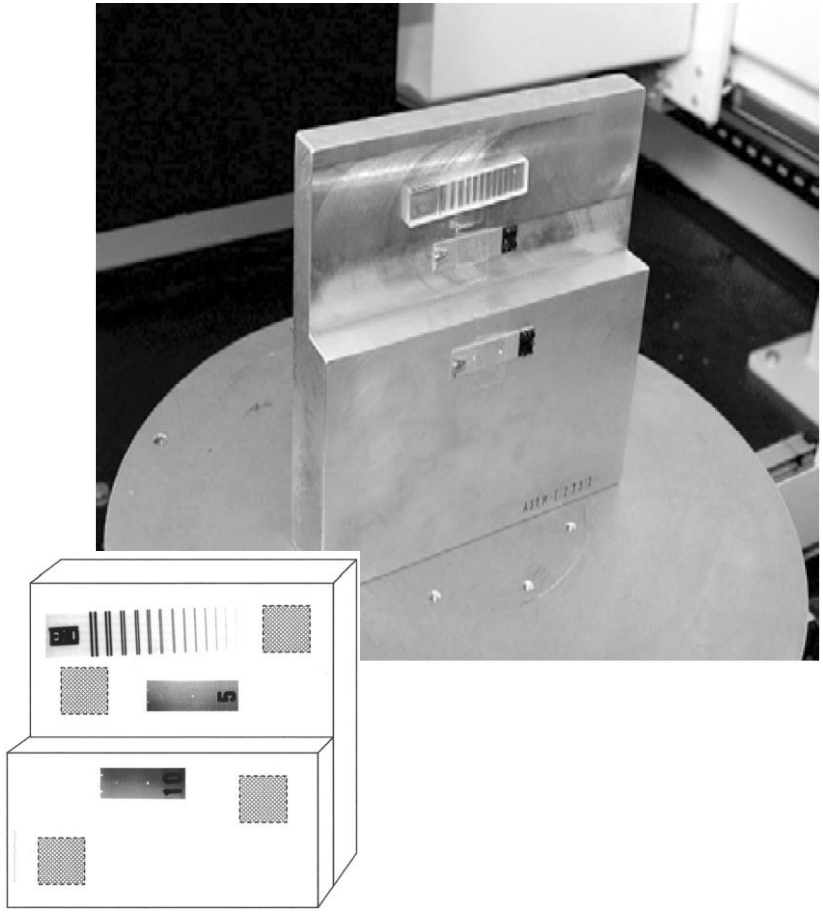


System Performance Checks



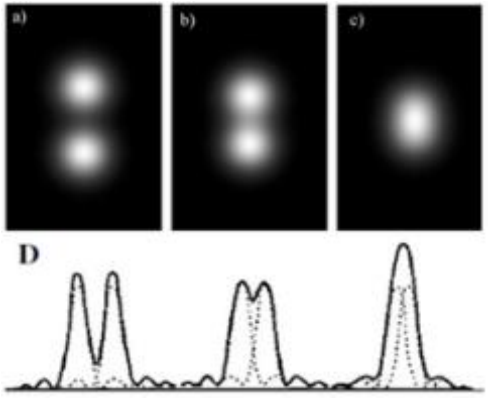
Long-term eval. – ASTM2737

- DR phantom for detector evaluation
- Containing: Step wedge, two hole penetrometers, 2 Duplex IOI's
- Standardized performance evaluation
- Report generation according to ASTM
- Other company specific phantoms available as well

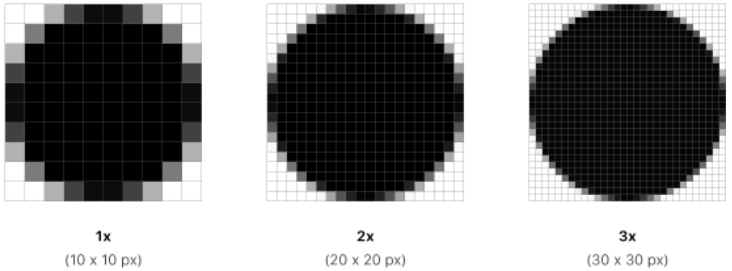


Spatial Resolution (SRb)

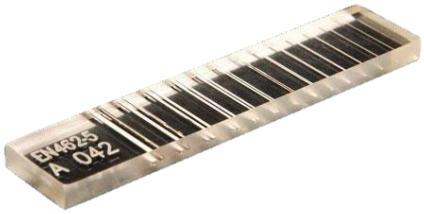
IMAGE QUALITY – RESOLUTION



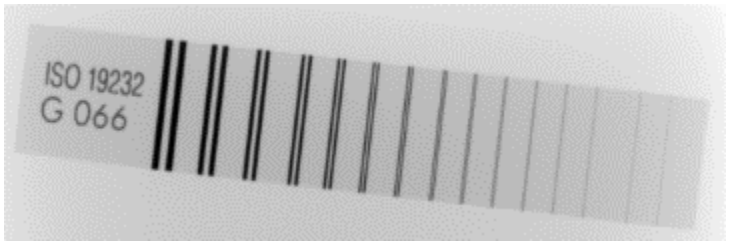
http://physwiki.apps01.yorku.ca/images/thumb/3/3e/Fig15_airy.png/400px-Fig15_airy.png



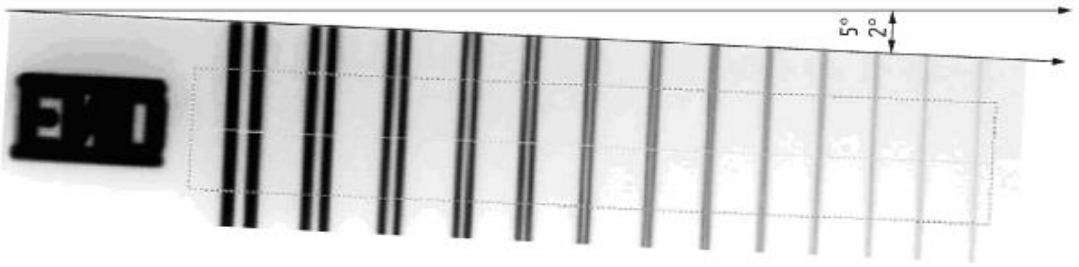
https://developer.apple.com/ios/human-interface-guidelines/icons-and-images/image-size-and-resolution/



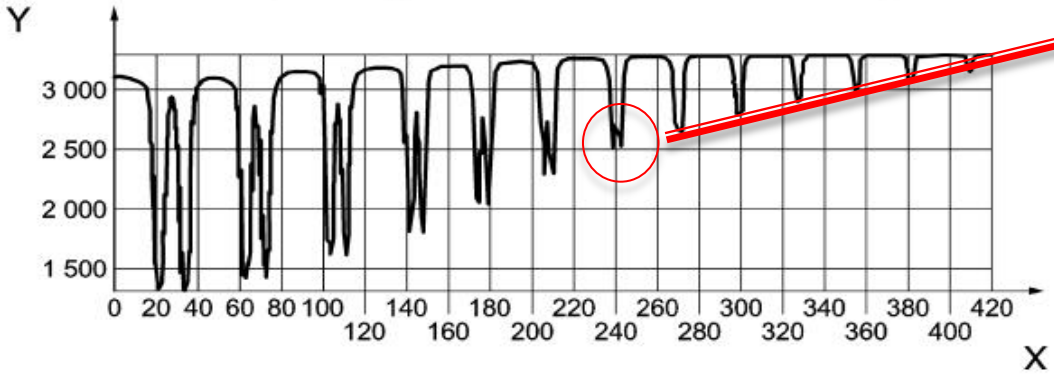
Duplex Image quality indicator (IQI)



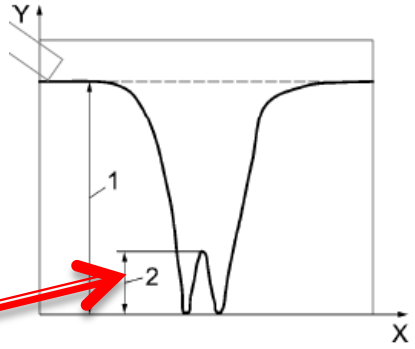
Spatial Resolution (SRb)



a) Abbildung des Doppeldraht-BPK in einem Durchstrahlungsbild



b) Aus mindestens 21 Zeilen gemitteltes Profil des Doppeldraht-BPK

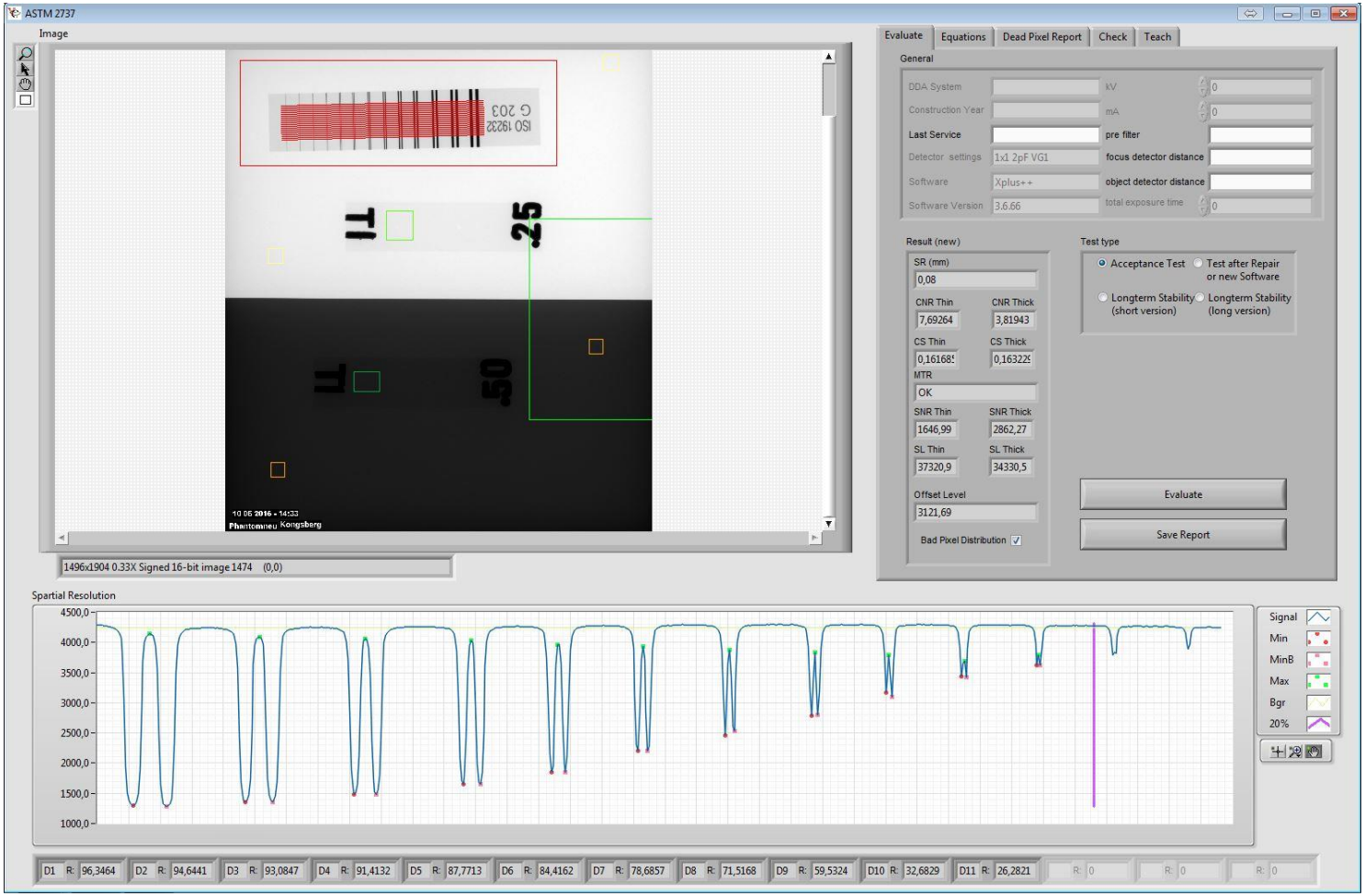


d) Calculation of the dip (in %) by: dip = 100 x dip amplitude/background amplitude

Be aware
The dip (2) must be a minimum of 20% of the maximum (1)

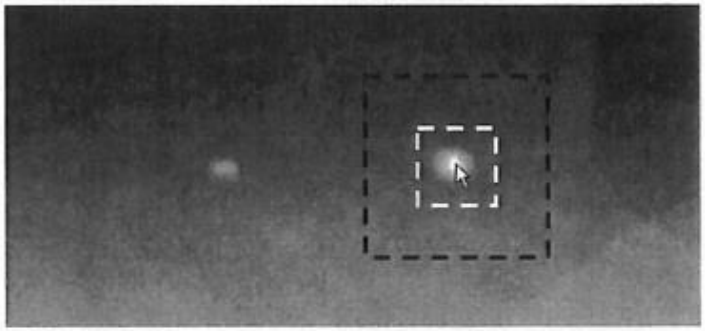
This calculation has to be done by Software and not by human eyes

Spatial Resolution (SRb)



- Contrast Sensitivity (CS)

Contrast Sensitivity (CS)



$$CNR = \frac{GV_{median}[hole] - GV_{mean}[beside\ squares]}{Sigma[beside\ squares]}$$

$$CS\,[\%] = \frac{GBV}{CNR} * \frac{MT_{IQI}}{MT_{total}} * 100$$

Known Parameter:

$MT_{step} = 50mm$; $MT_{IQI} = 0.5mm$

$GBV = 2.5$

Measured Parameter:

GV_{median} [hole] = 4800

GV_{mean} [beside squares] = 4600

Sigma [beside squares] = 50

Calculation:

$MT_{total} = 50.5mm$

CNR = 4800 - 4600 / 50 = 4

CS [%] = 2.5 / 4 * 0.5mm/50.5mm * 100

CS [%] = 0.6188%

Signal to Noise (SNR)

Tabelle D.1 — Erforderliche $SNR_{measured}$-Werte für ausgewählte CR-Systeme mit unterschiedlichen SR_b, die den jeweiligen SNR_N-Werten äquivalent sind

System-parameter	Hochauflösendes System			Standardsystem					
Doppeldraht-BPK-Qualifizierung	13+	13	12	11	10	9	8	7	6
Basis-Ortsauflösung SR_b	40 µm	50 µm	63 µm	80 µm	100 µm	130 µm	160 µm	200 µm	250 µm

$$SNR_N = SNR_{measured} \frac{88{,}6\mu m}{SR_b}$$

$$\text{SNR-measured} = \frac{\text{Meanvalue}}{\text{Standard deviation}}$$

From the image

Report generation

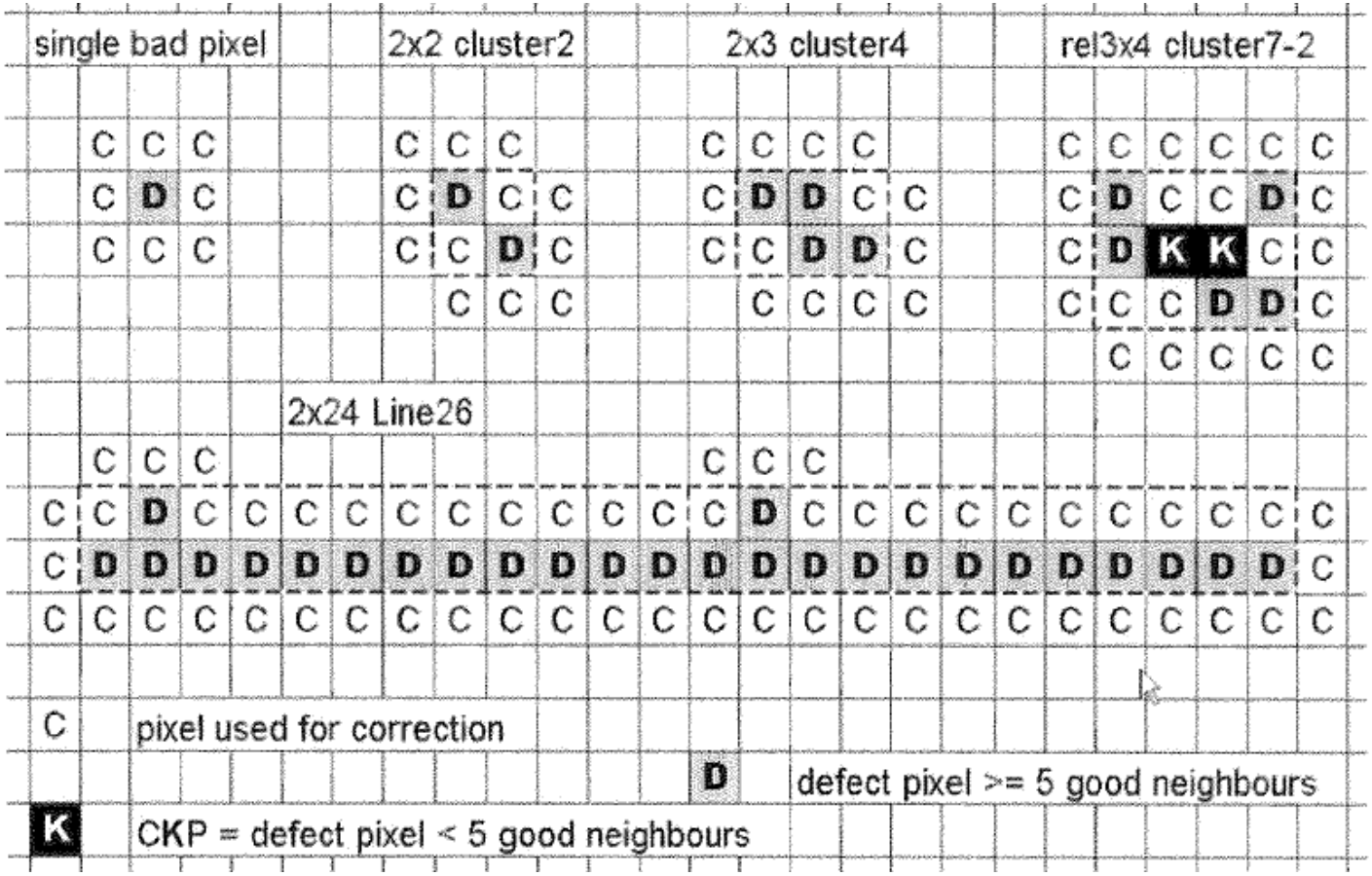
DDA System		voltage	kV		
Construction Year		tube current	mA		
Last Service		pre filter (material and thickness)			
Detector Settings		focus detector distance	mm		
Software		object detector distance	mm		
Software Version		total exposure time per image	s		

Test	☐ Acceptance Test	Used IQIs	☐ 5-Groove-Wedge	Material of the used IQIs	☐ Aluminium
	☐ Test after Repair or new Software		☐ Duplex Plate Phantom		☐ Titanium
	☐ Longterm Stability (short version)		☐ Duplex Wire IQI (EN 462-5)		☐ CRES
	☐ Longterm Stability (long version)		☐ Hole IQI		
			☐ Wire IQI (EN 462-1)		
			☐ no IQI required		

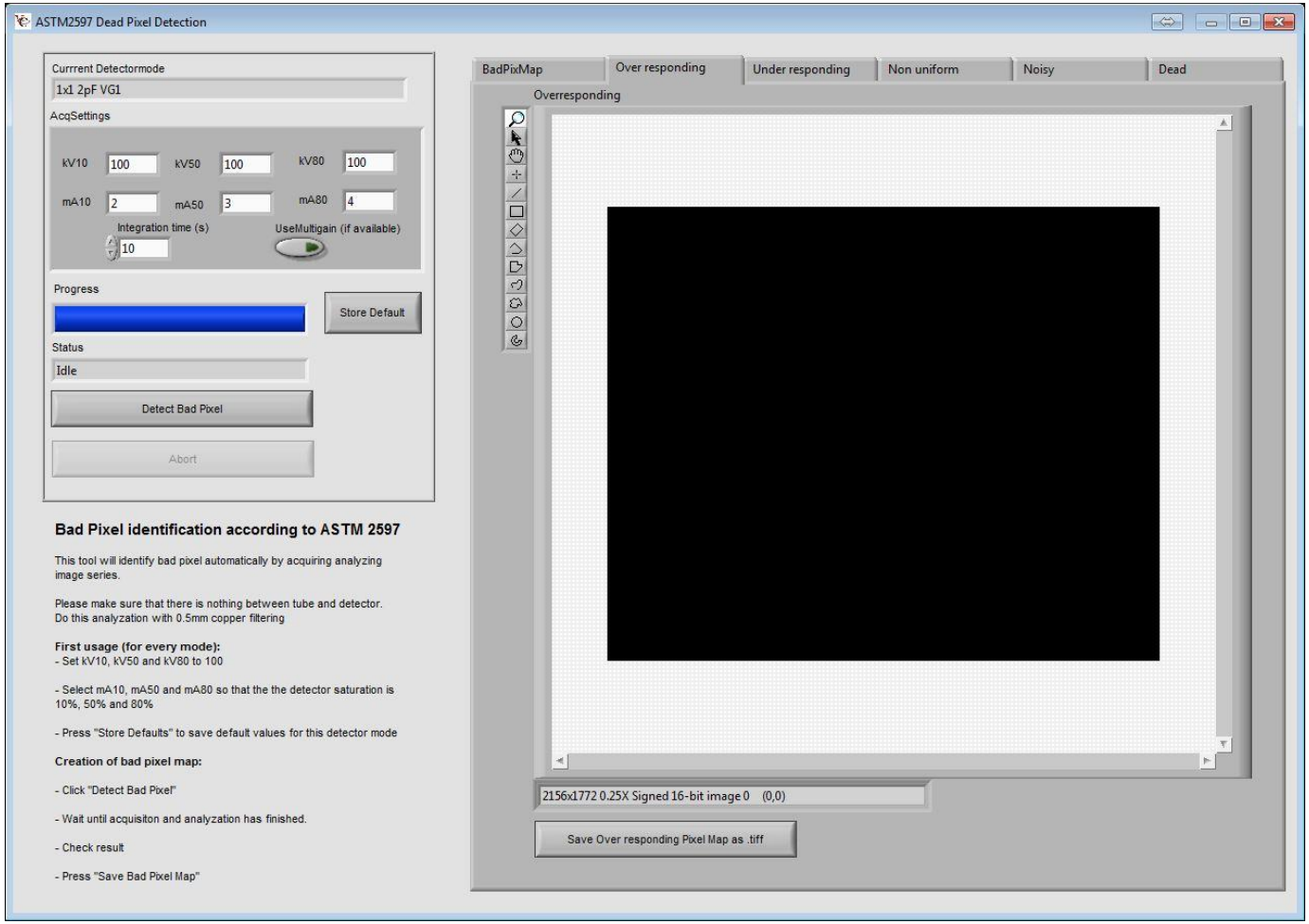
Tests		Unit	Result (new)		Limit		Result		Remark
			thin	thick	thin	thick	thin	thick	
Spatial Resolution	SR	µm							
Contrast Sensitivity	CS	%							
Material Thickness Range	MTR	mm							
Signal-to-Noise Ratio	SNR								
Signal Level	SL								
Image Lag	Lag	%							
Burn In	BI	%							
Offset Level	OL								
Bad Pixel Distribution									

Date of Tests	
Conclusion	
Operator	

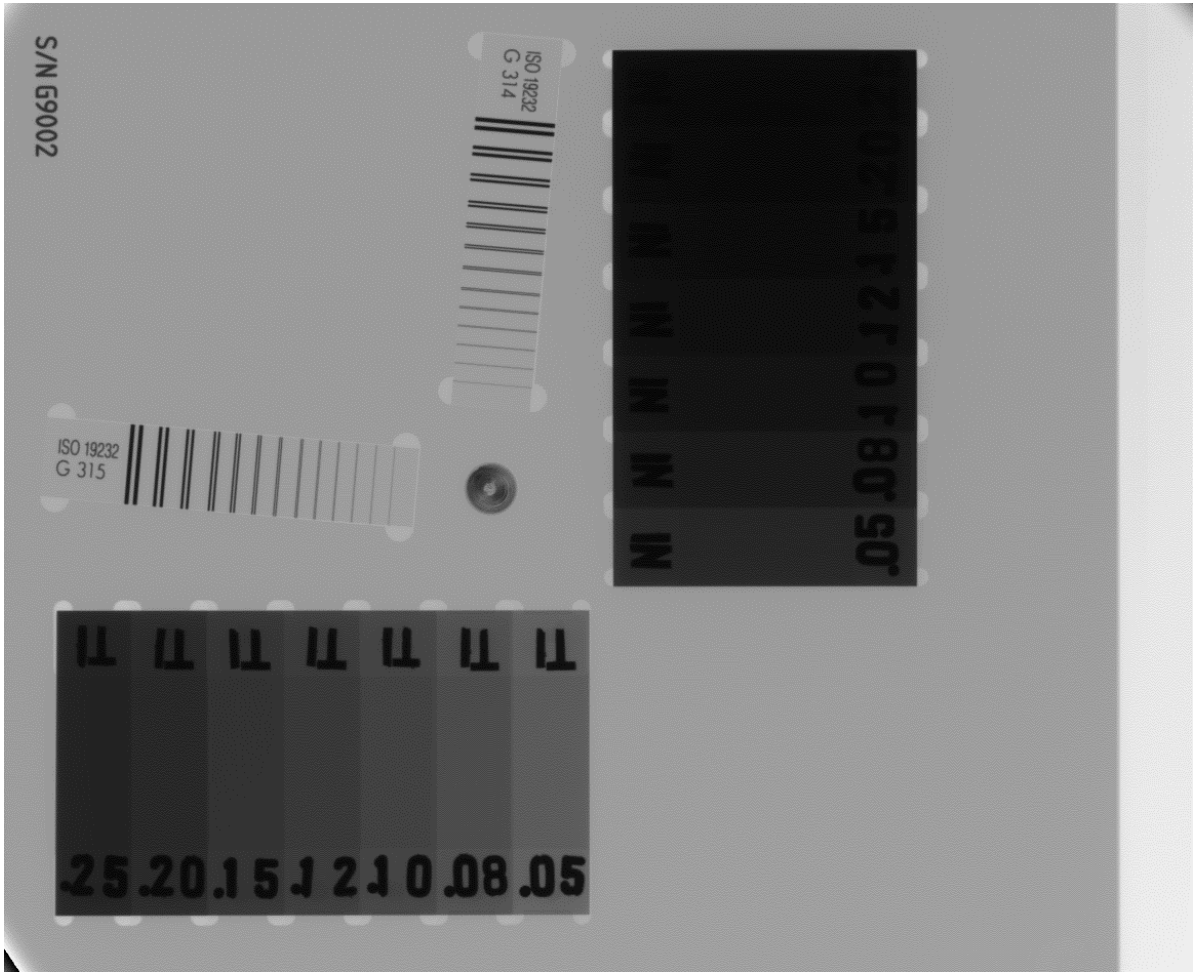
Bad pixel report – ASTM 2597



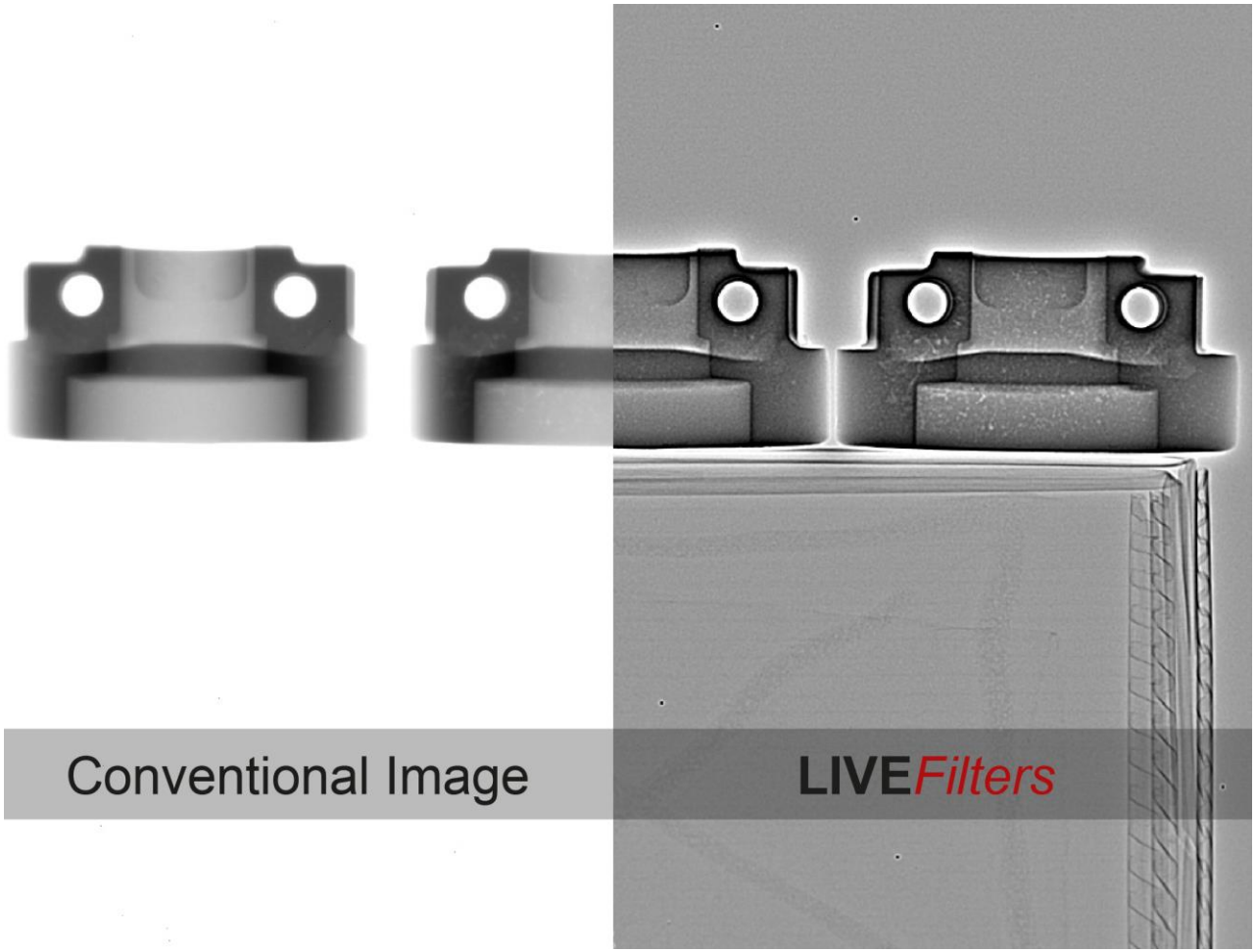
Bad pixel report – ASTM 2597



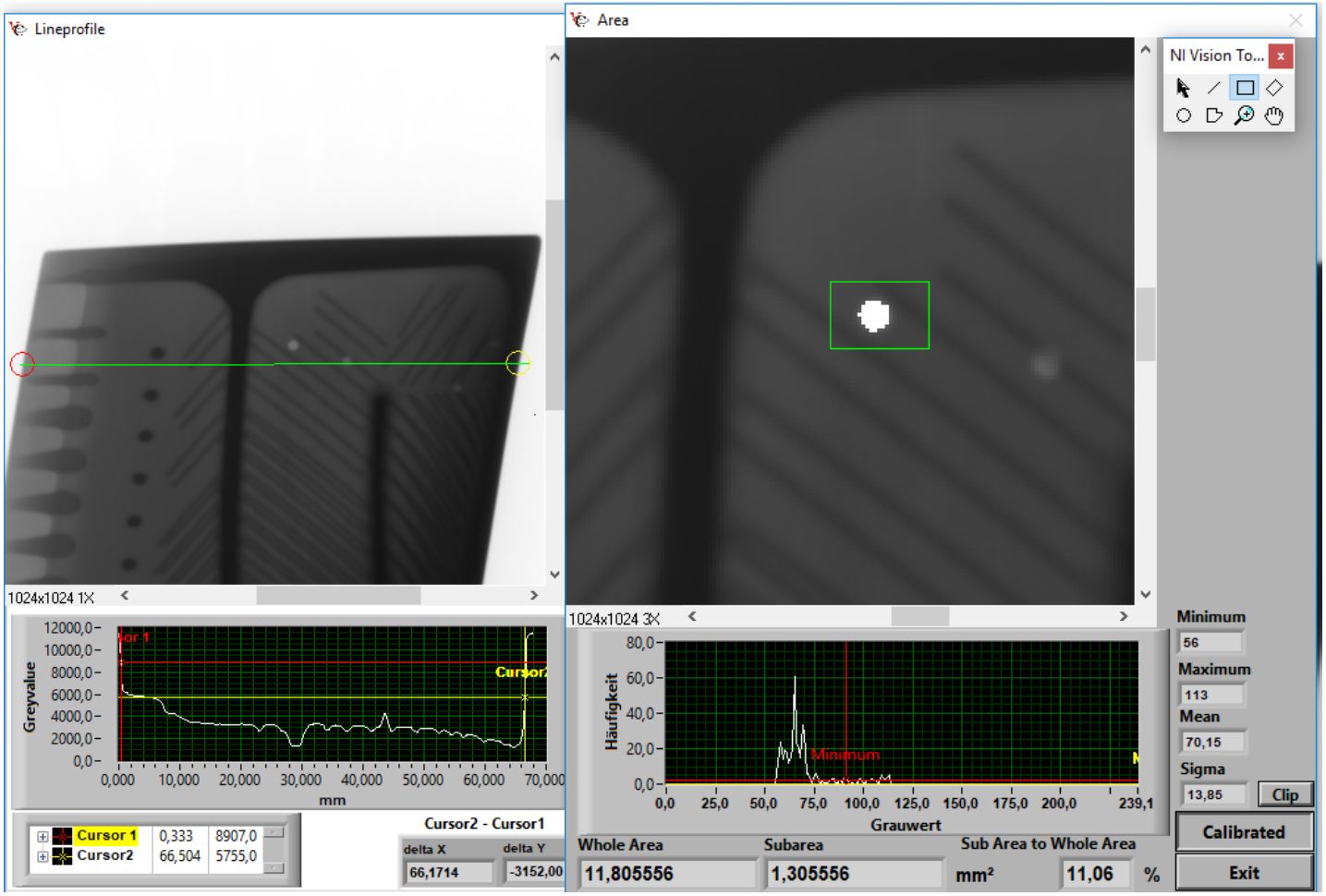
Alternative: TAM Phantom



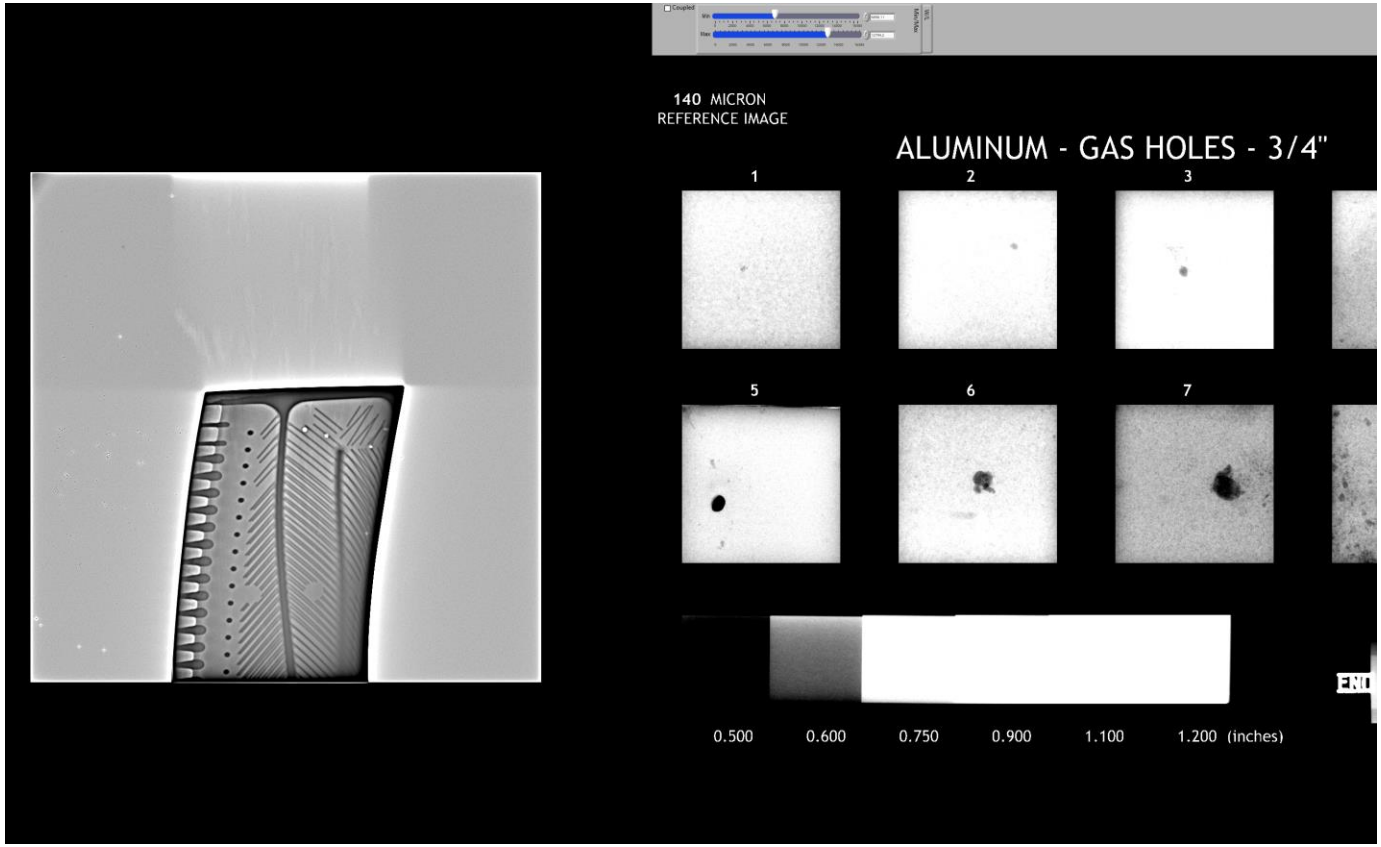
Digital filters



Measurement



Digital references images



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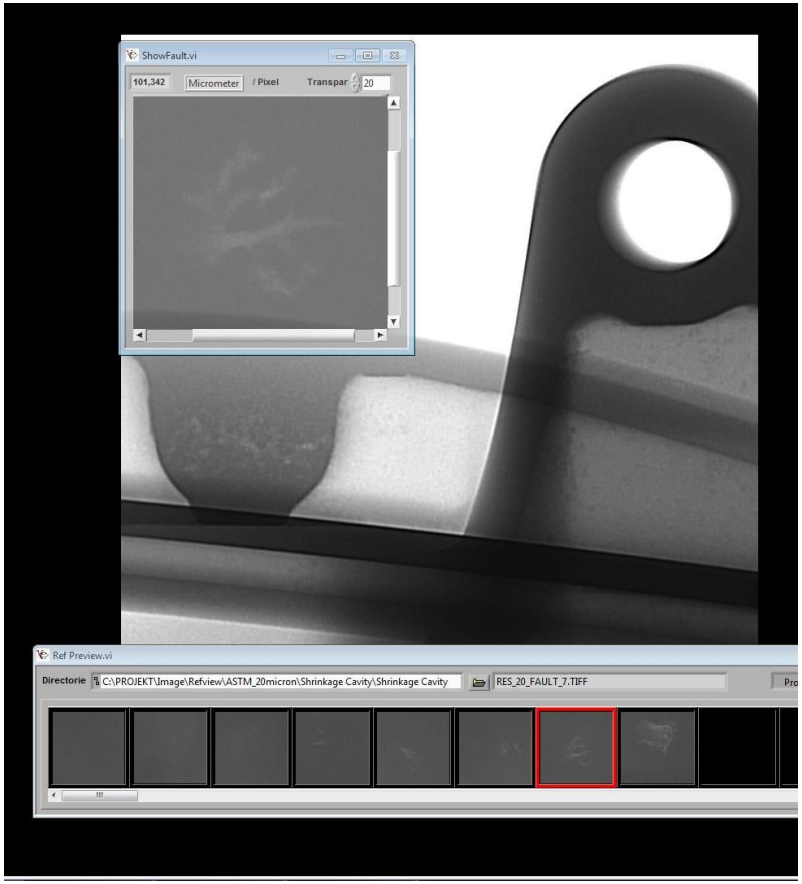
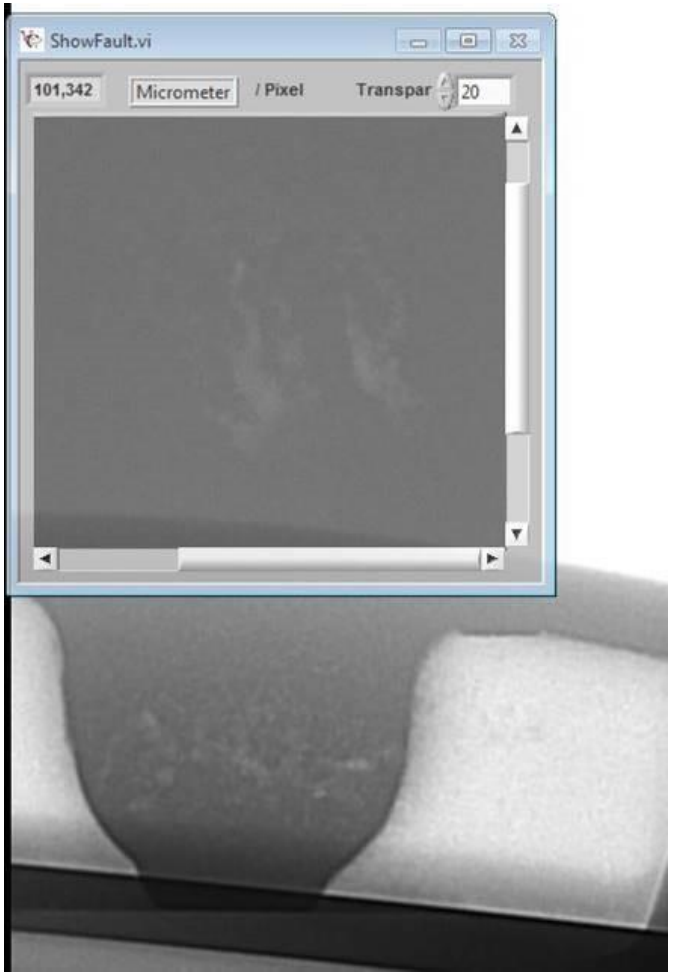
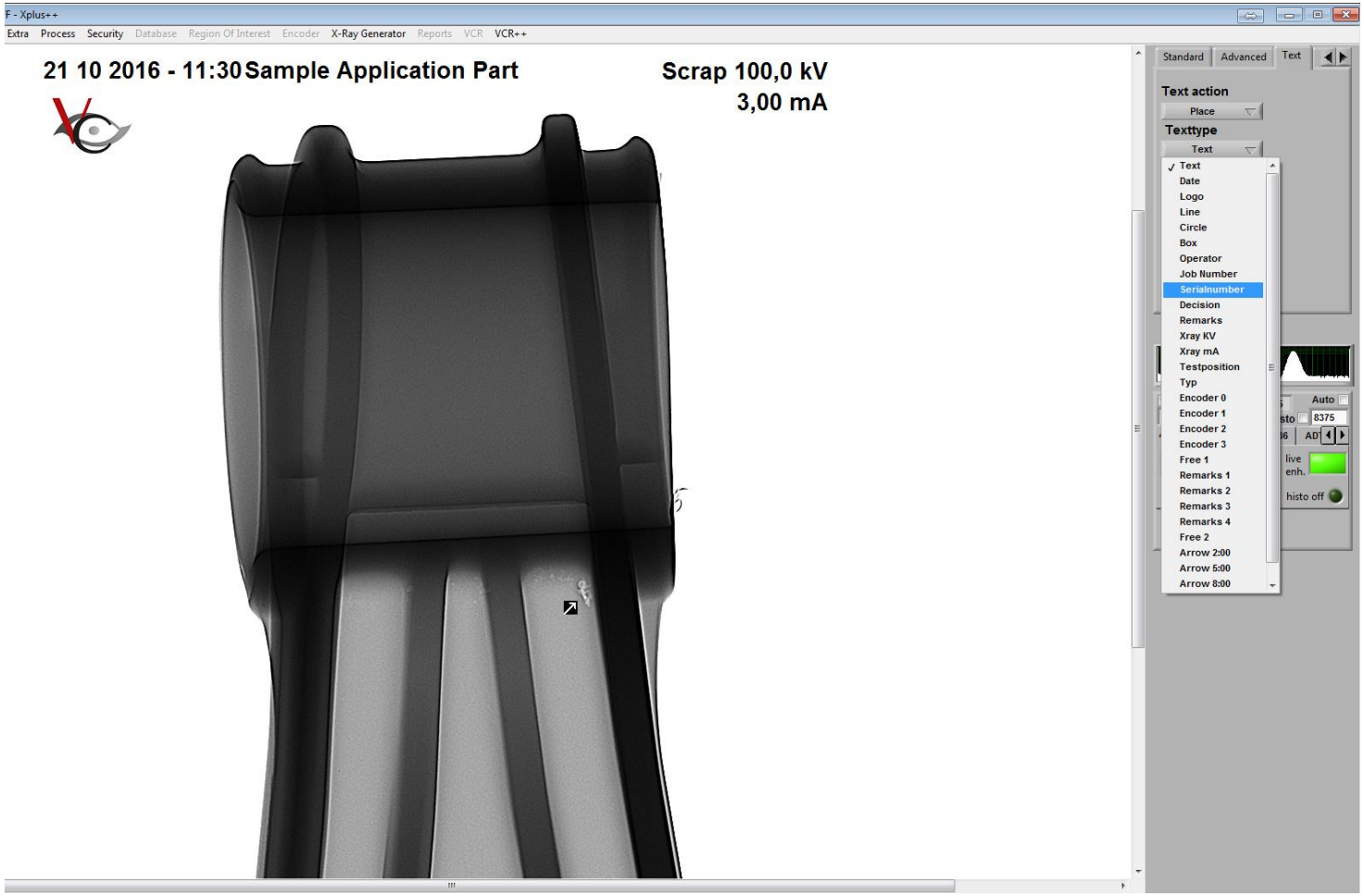


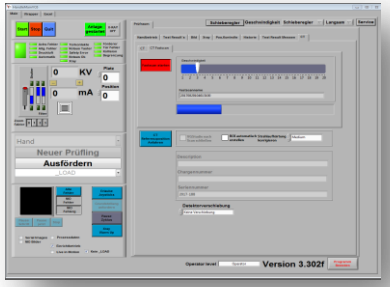


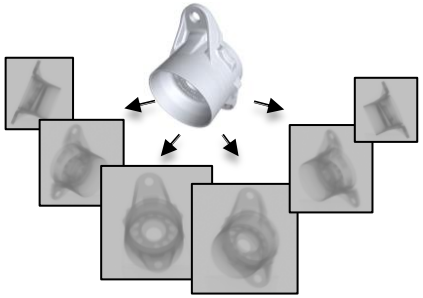
Digital overlays



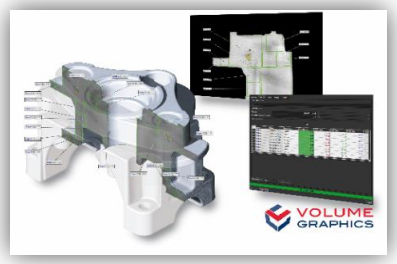
Computed Tomography

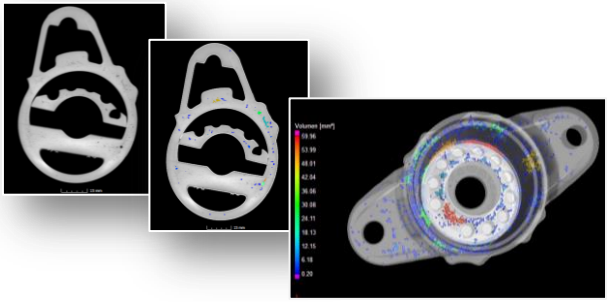
- QUICKScan





- Reconstruction and analysis

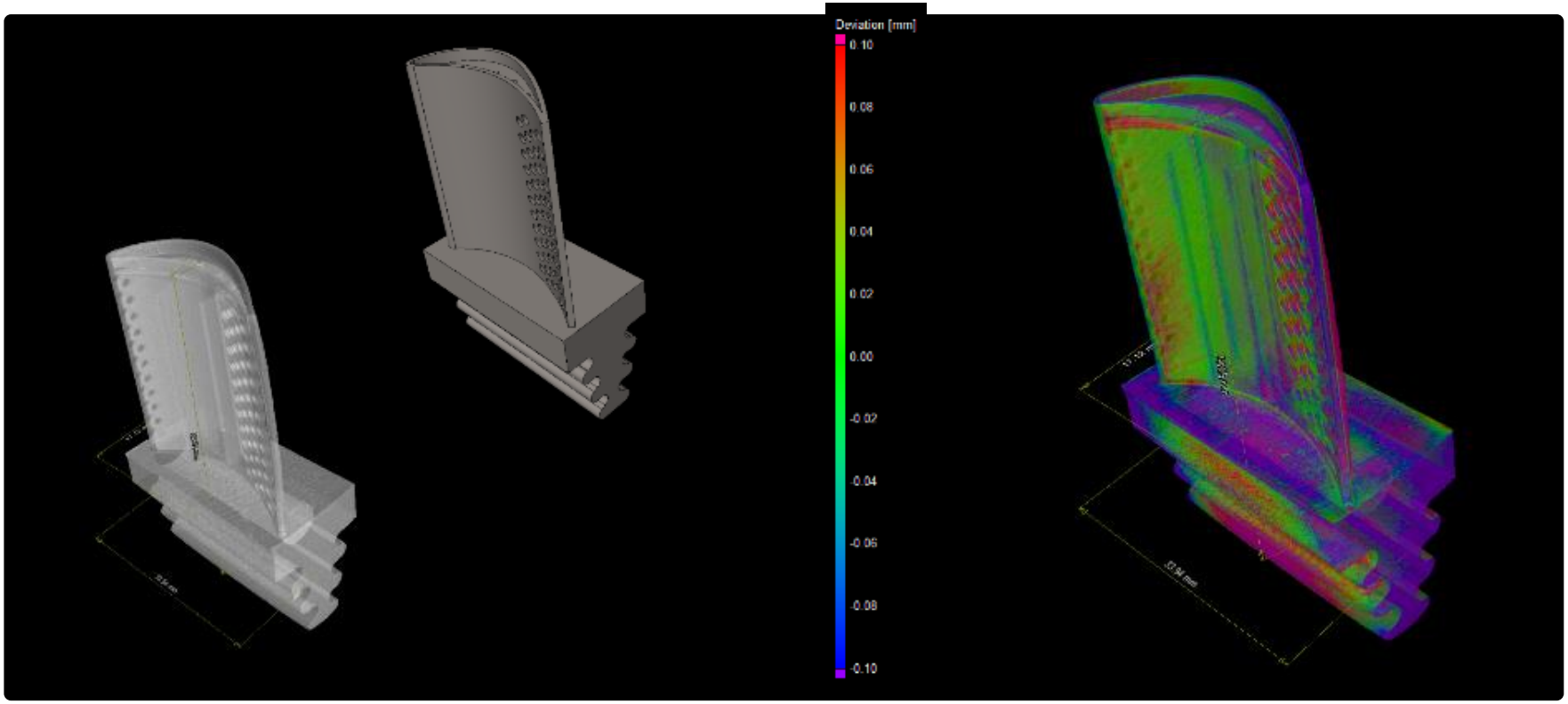




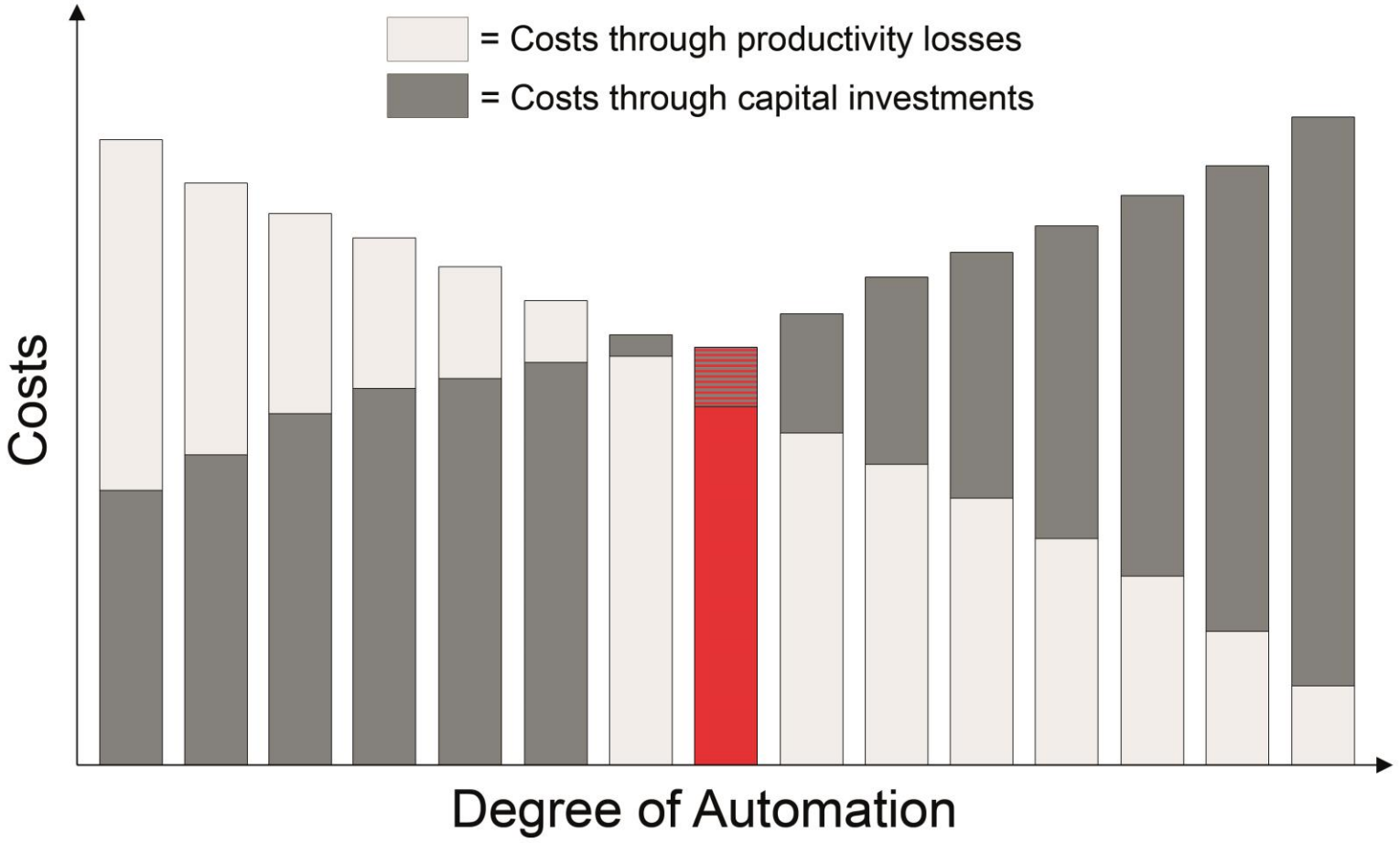
- Statistics and decisions

Material	
Materialvolumen [mm³]	100654.29
Defektvolumen [mm³]	1160.60
Verhältnis Defekte/Gesamtvolumen [%]	1.14

Compute Tomography



Commercial justification



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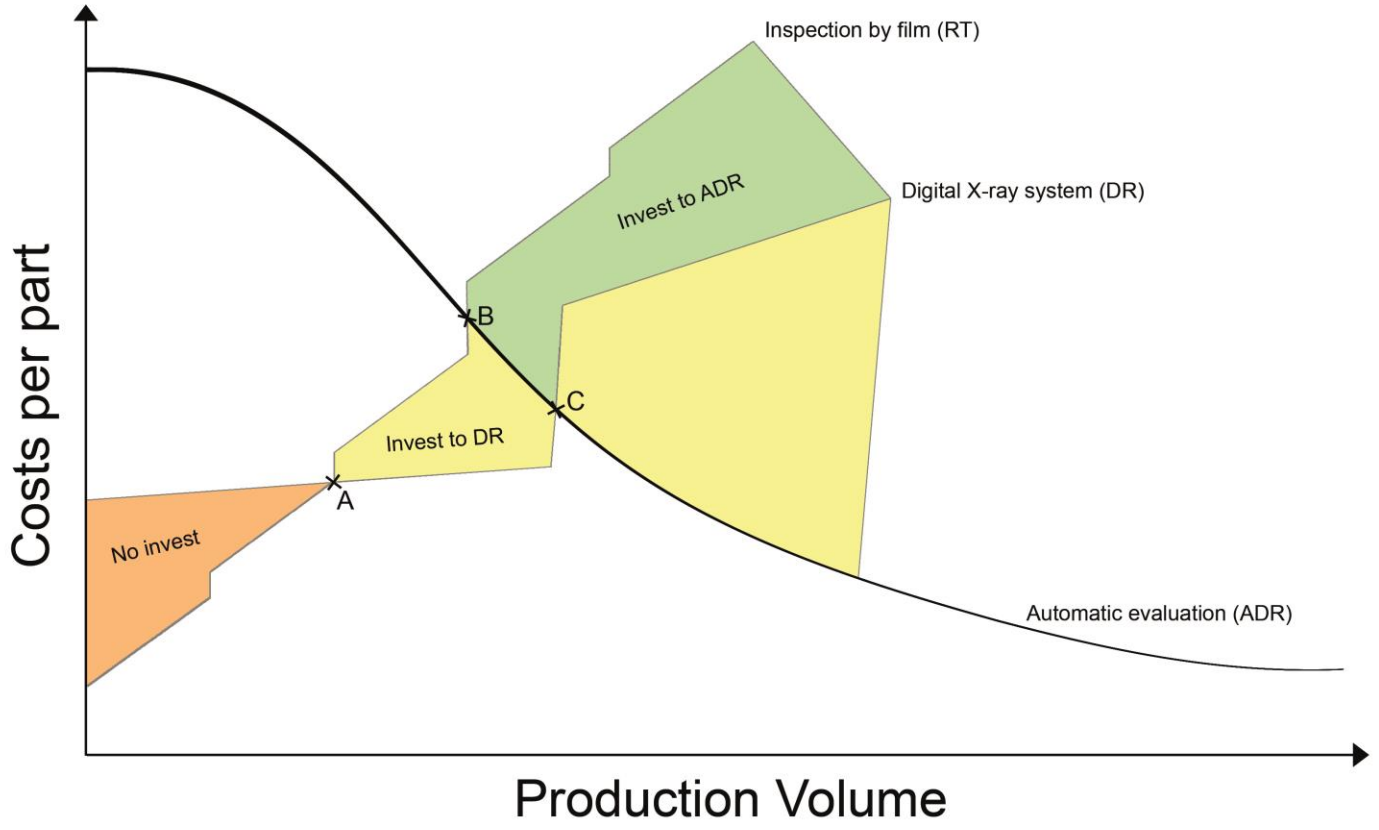

Thanks for your attention

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