

Towards Optimisation of Routine CT Quality Control Analysis

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- **600 beds**
- **1 (2) Siemens CTs**
- **Offsite: 2 Siemens
& 1 GE**



Medical Physics & CT

- **No input at all !**
- **Needed for shielding & commissioning etc.**
- **Access: Busy**
- **Value of a physicist in CT?**
- **Flowers & chocolate, bridge-building, hands of friendship etc**
- **Legislation:**
 - high dose, post-service testing**
- **Official access time:**
 - 2 hours per ANNUM**



Information Leaflet No. 1: CT Scanner Acceptance Testing

Version 1.02, 18/05/01

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1. Scope of leaflet

This leaflet is intended as a practical guide to the tests required at the acceptance and commissioning of a CT scanner. It assumes some basic knowledge of CT performance testing but provides additional information, where relevant, regarding multi-slice CT systems. Since there is broad overlap between tests performed at acceptance and commissioning, they are covered jointly here.

The list of tests described here is neither prescriptive nor exhaustive, as less or more could potentially be performed during the acceptance and commissioning of a new scanner. The intention has been to provide an adequate set of measurements to carry out for a routine diagnostic scanner. Some applications, particularly radiotherapy, have specialised requirements from a scanner, and need additional tests to verify them.

The leaflet is intended for direct use within the ionising radiation legislative framework that exists in the UK [1,2], although similar tests are likely to be applicable internationally.

For more detail on all measurement methods discussed here, the reader should refer to [3].

2. General principles of acceptance and commissioning

Acceptance and commissioning tests are performed following the installation of a scanner and after the critical examination has taken place.

Definitions of acceptance and commissioning used here are those given in [4]. In summary, acceptance constitutes the set of tests necessary to demonstrate that the specified requirements in the contract have been met. These include mechanical, electrical and radiation safety tests. Commissioning has two purposes. Firstly, to ensure that the equipment is suitable for clinical use and, secondly, to establish baseline values against which subsequent routine quality control results are to be compared.

Although acceptance and commissioning tests are often performed together, two sets of phantoms and exposure parameters may need to be used, for the reasons given in section 2.1.

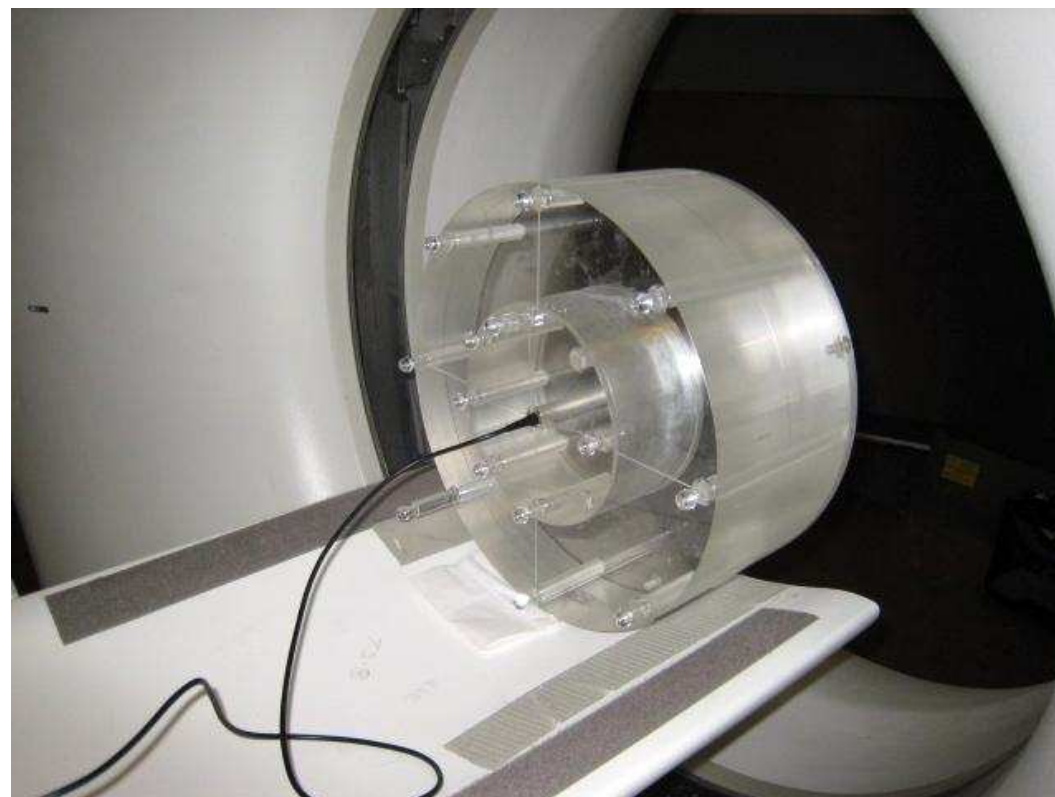
First Hour

- Dosimetry
 - $CTDI_{air}$
 - $CTDI_w$

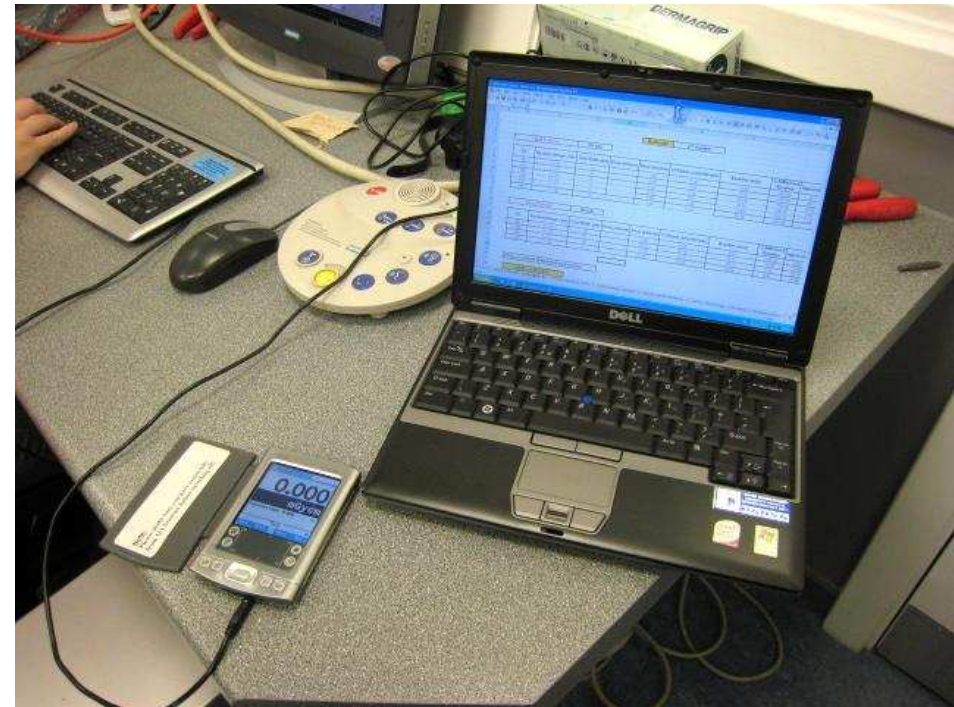
Second Hour

- Mechanical Accuracy
- Image Quality

Dosimetry – Then:



Dosimetry – Now:

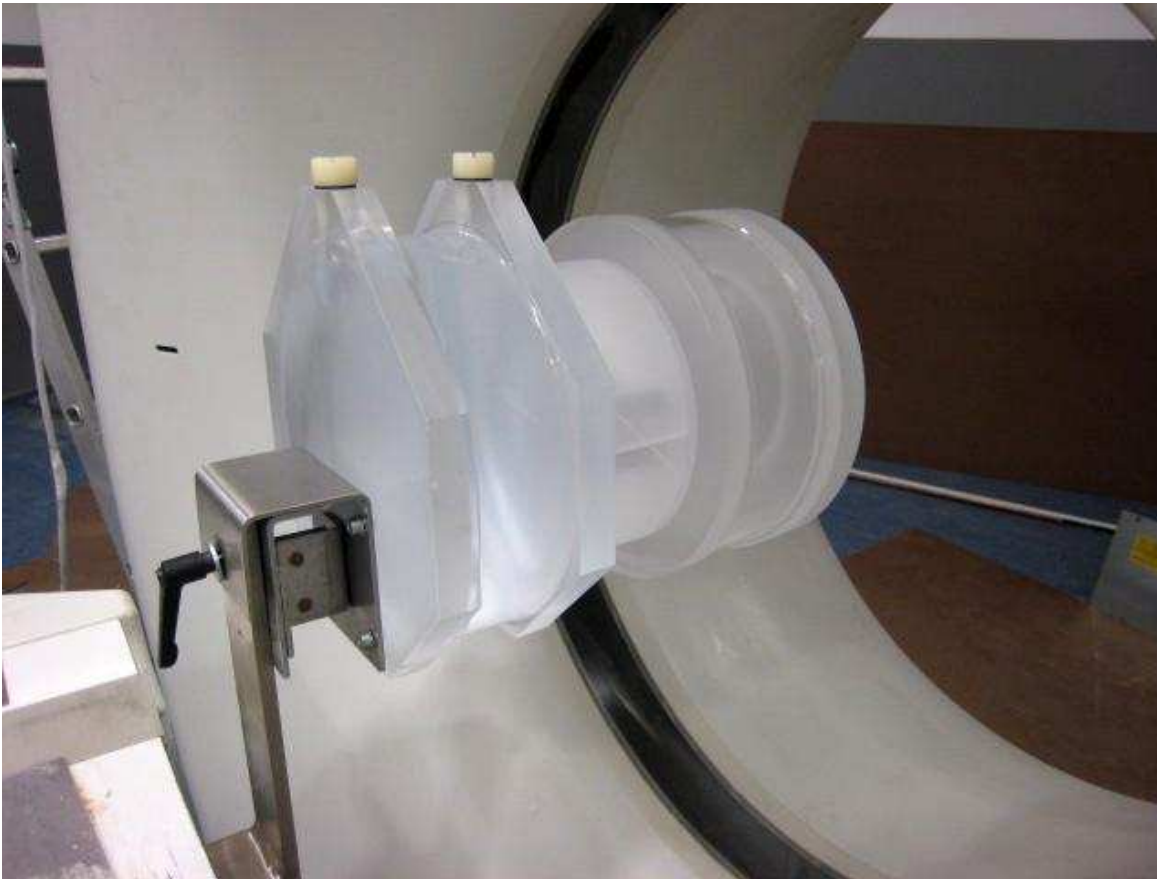


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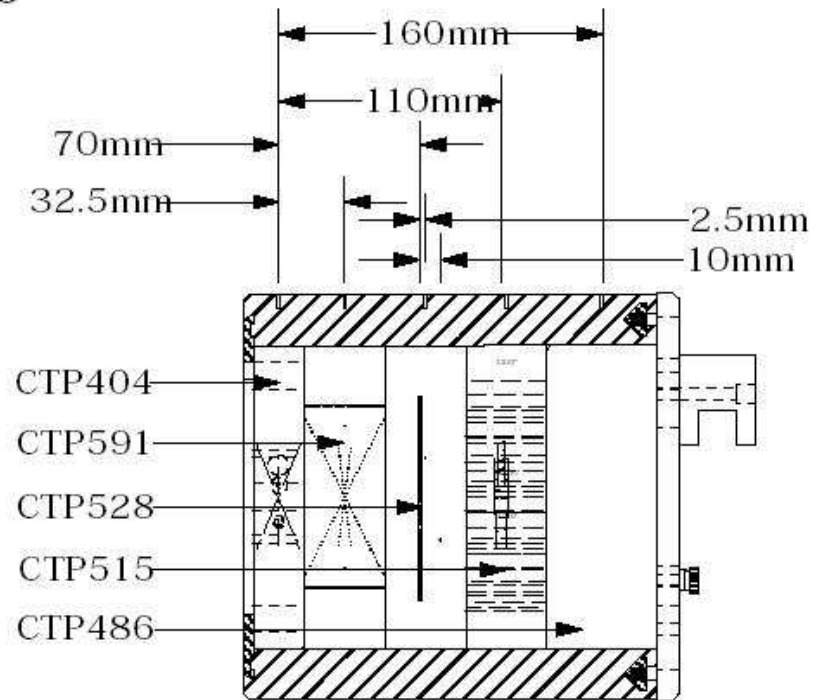
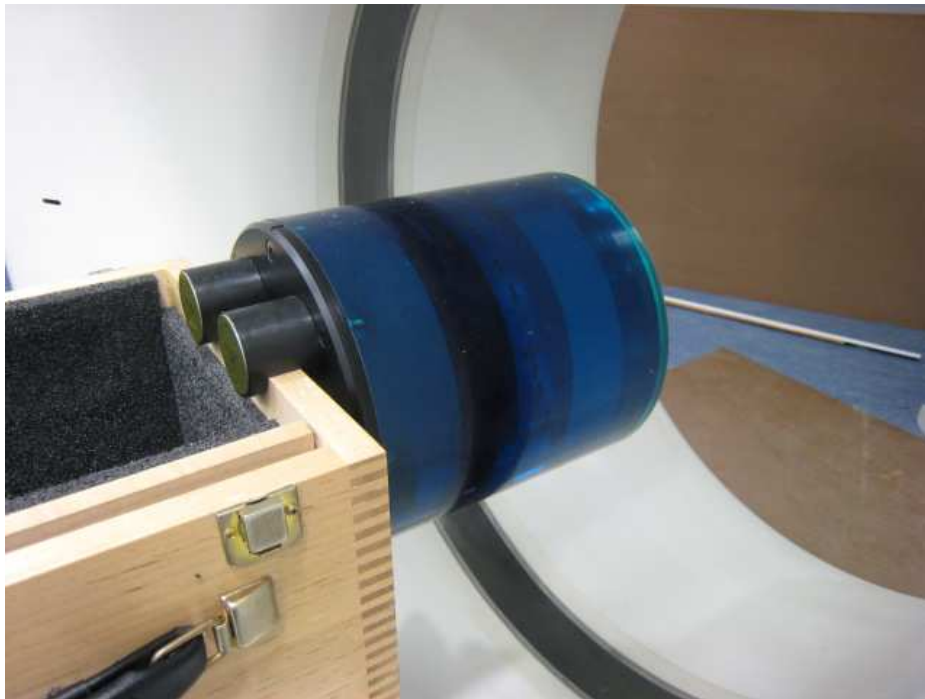
Image Quality – Vendor Phantom



- Noise
- Uniformity
- Slice Thickness

“Be Careful What You Wish For”

Catphan 600

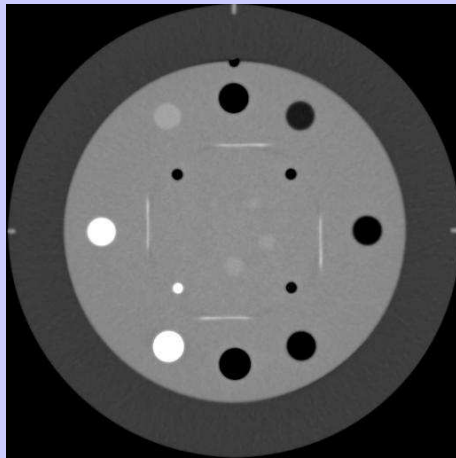
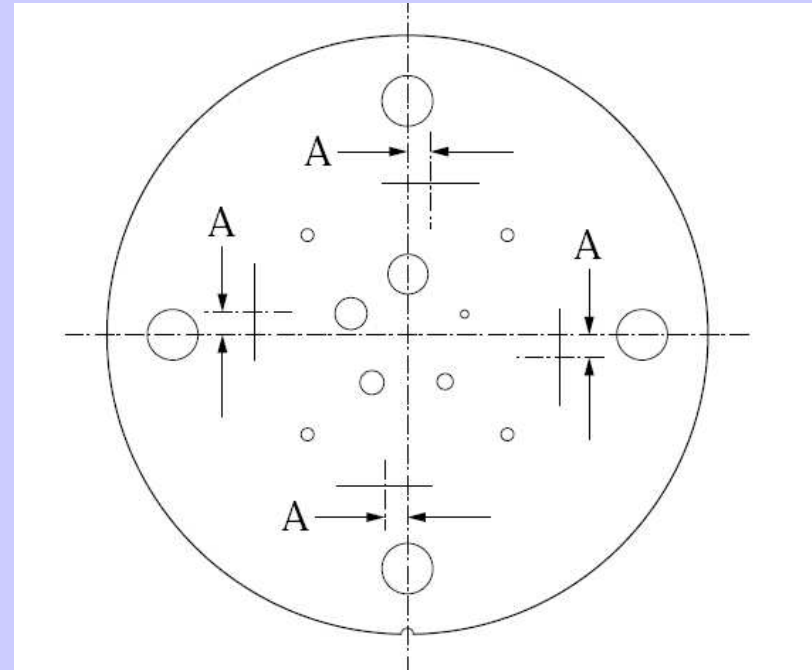


Catphan Protocol

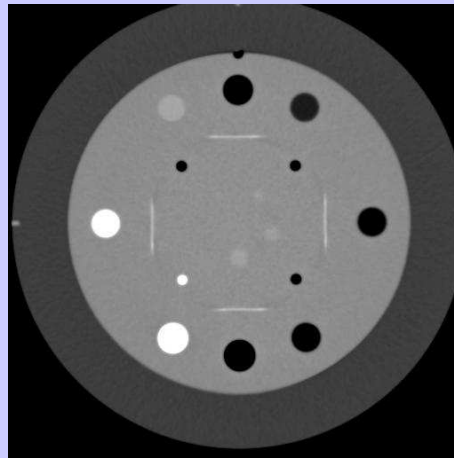
Test	Procedure	kV	mAs	Slice Thick (mm)	Image #	Comments
External Lights Accuracy	External light set-up for CTP404 (First Module)	120	310	10	1	
Topogram	Lateral	80	200		2	Lateral
Topogram Feed Accuracy	Select from console	120	310	10	3	
Internal Lights Accuracy etc	Manual set-up for CTP404 (RP)	120	310	10	4	Feed=0, Cancel Move , Note Reference Position (RP)
Scan Incrementation	+/-5mm from RP	120	310	10	5, 6	Move phantom +/-5mm from RP Cancel Move
Slice Thickness	CTP591 : 2 nd module RP-32.5mm	120	310	5 3	7, 8 9, 10 11,12, 13, 14	St=RP-35 End=RP-30 , St=RP-41.5. End=RP-23.5
Spatial Resolution	CTP528 3 rd Module RP-70	120	310	10 10	15 16	Smooth Filter (H31), Sharp Filter (H60), St=RP-75. End=RP-65 Cancel Move
Noise & Uniformity	CTP486 5 th Module RP-160	120	310	12*1.5 12*0.75	17-28 29-40	Smooth Filter (H31) Cancel Move St=RP-152.5. End=RP-169

• **Alignment Accuracy:**

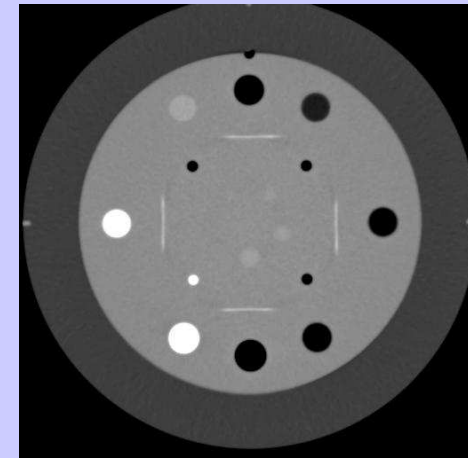
- External lights
- Topogram
- Internal lights



External

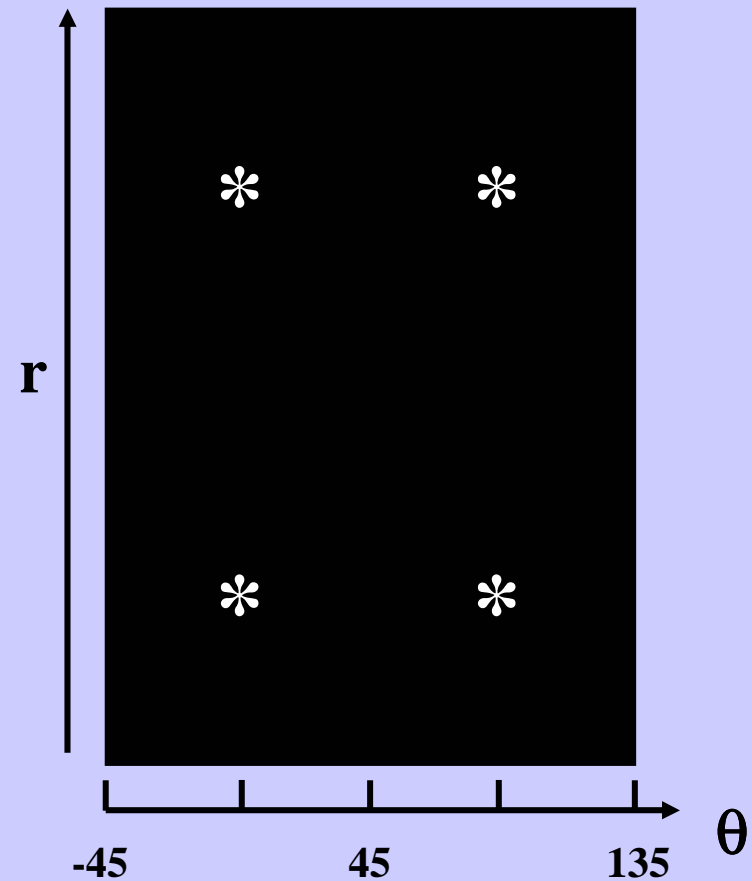
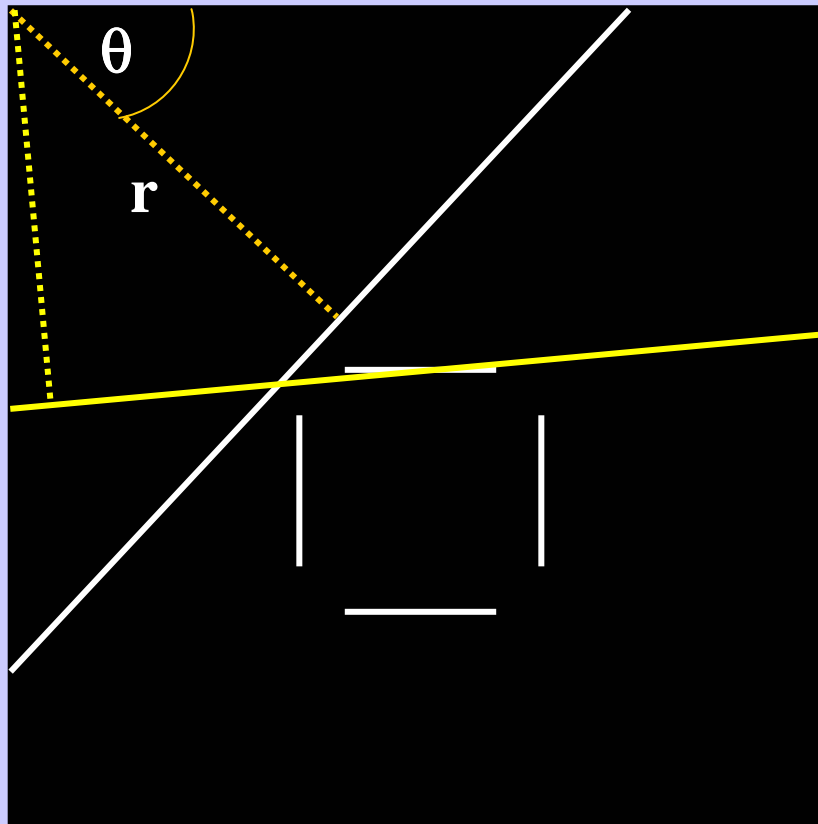


Topogram



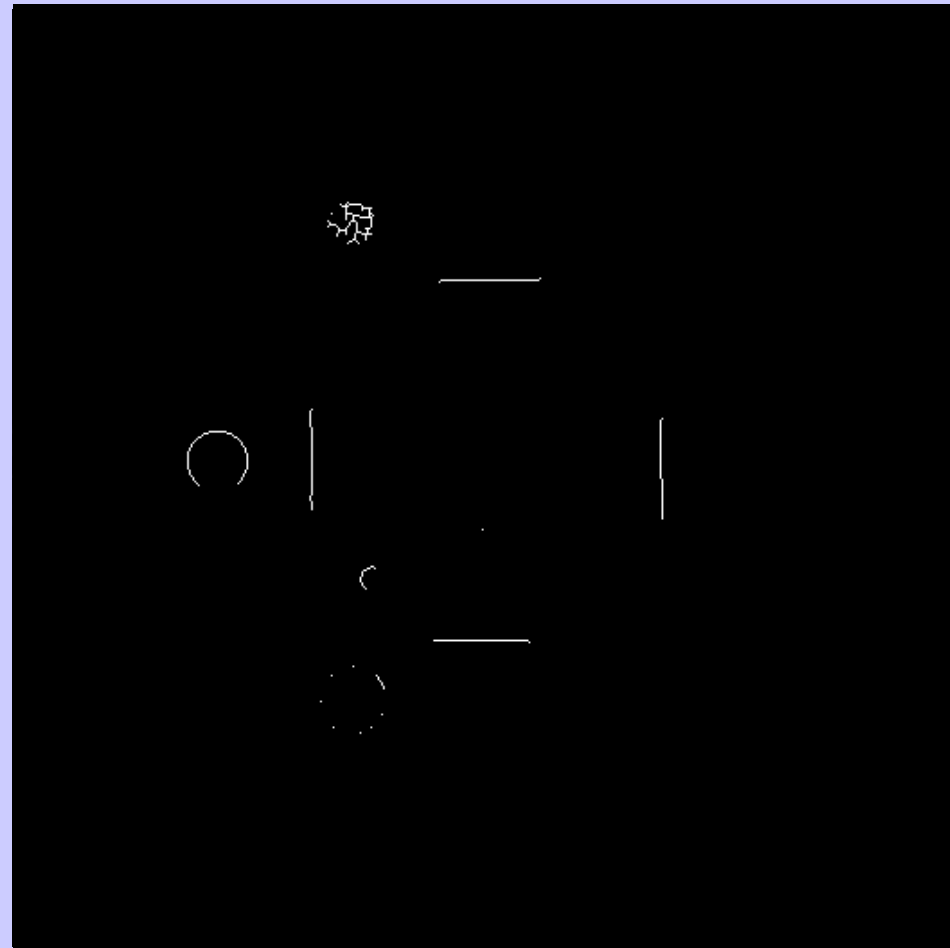
Internal

Hough Transform – finding shapes: 3 Matlab routines



Patient Alignment System Check

- Detection of four lines:
 - Threshold.
 - Thinning.
 - Eccentricity value.
 - Line => Ecc.=1
 - Matlab function:
 - Bwboundaries.
 - X & Y line coordinates.
 - Mean values = midpoints.

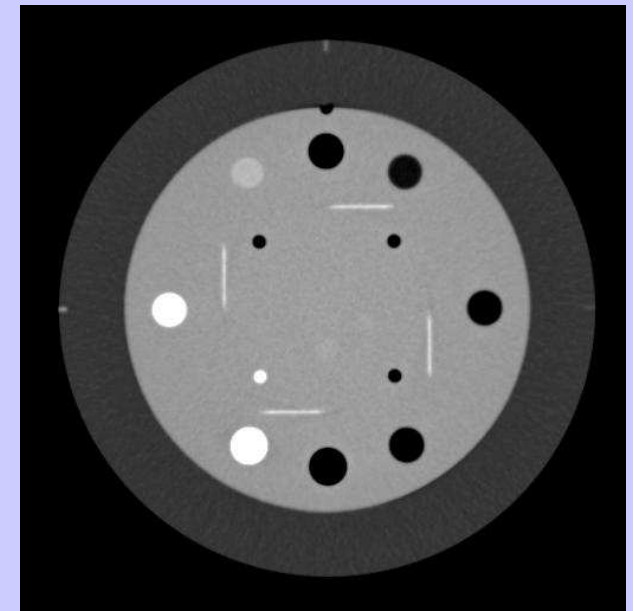


Scan Incrementation

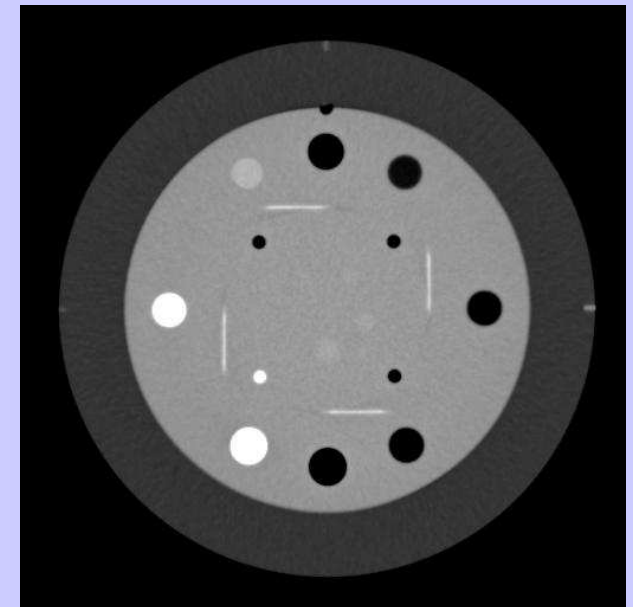
- **Purpose:**

Test accuracy of scan displacements.

- Find the midpoint.
- The position for that point; (L1).
- Proceed as above for the second image;(L2).
- **Scan Incrementation=|0.42(L1-L2)|**
 - The ramps have slope:
23 degrees.
 - The projection on X-Y plane is
calculated with the tangent.
 - $\text{Tan}(23)=0.42!$



Ref + 5 mm



Ref - 5 mm



CT Image Analysis

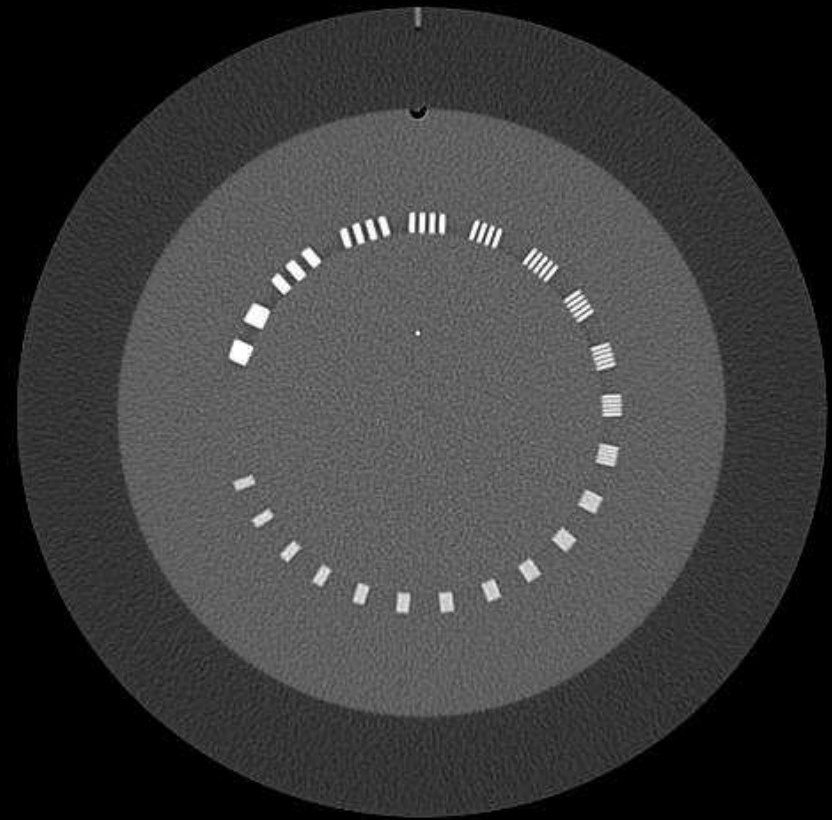
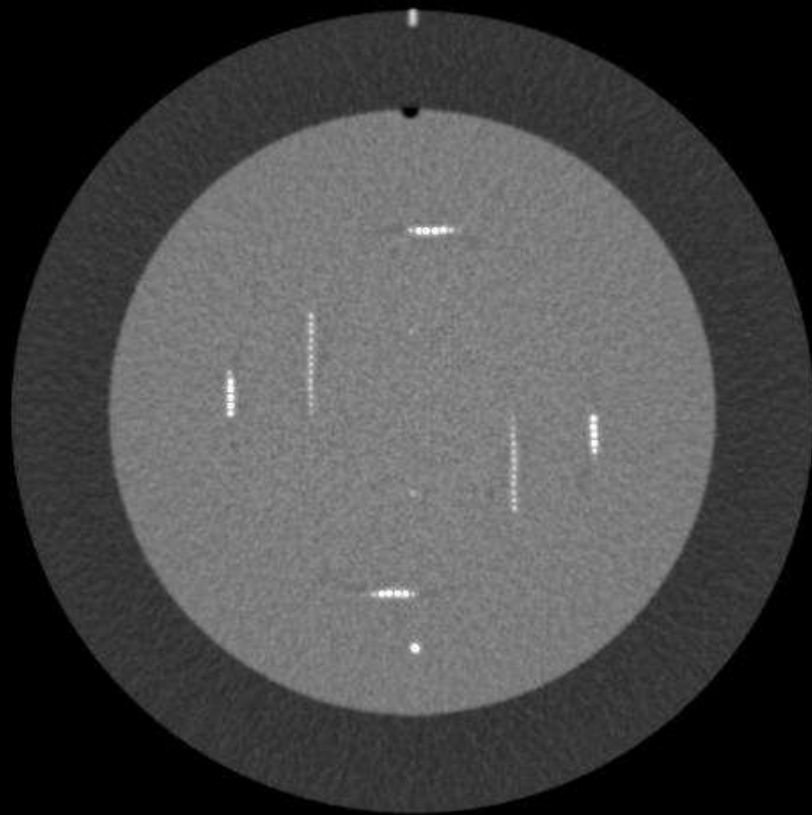
- Suite of programs developed in Matlab
- GUI Graphical User Interface
- Results exported directly to Excel
- Image Identification !!
 - Manual:
 - Slice Thickness.
 - Spatial Resolution
 - Automatic
 - Slice position accuracy
 - Scan incrementation
 - Circular Symmetry.
 - Pixel Size Verification.
 - Sensitometry.
 - Noise & Uniformity.
 - Gantry Tilt



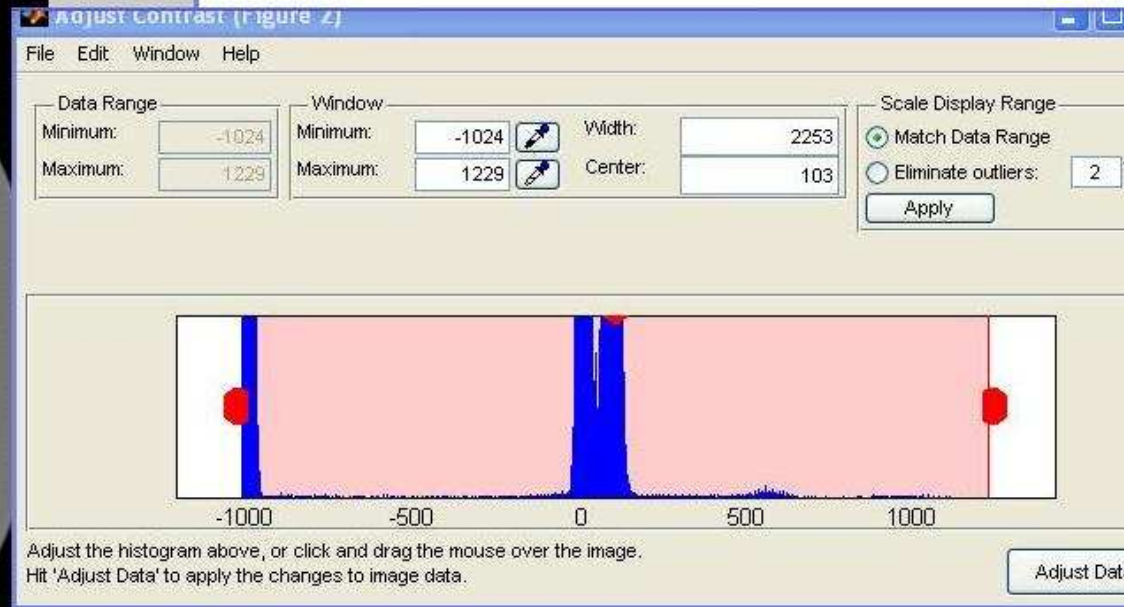
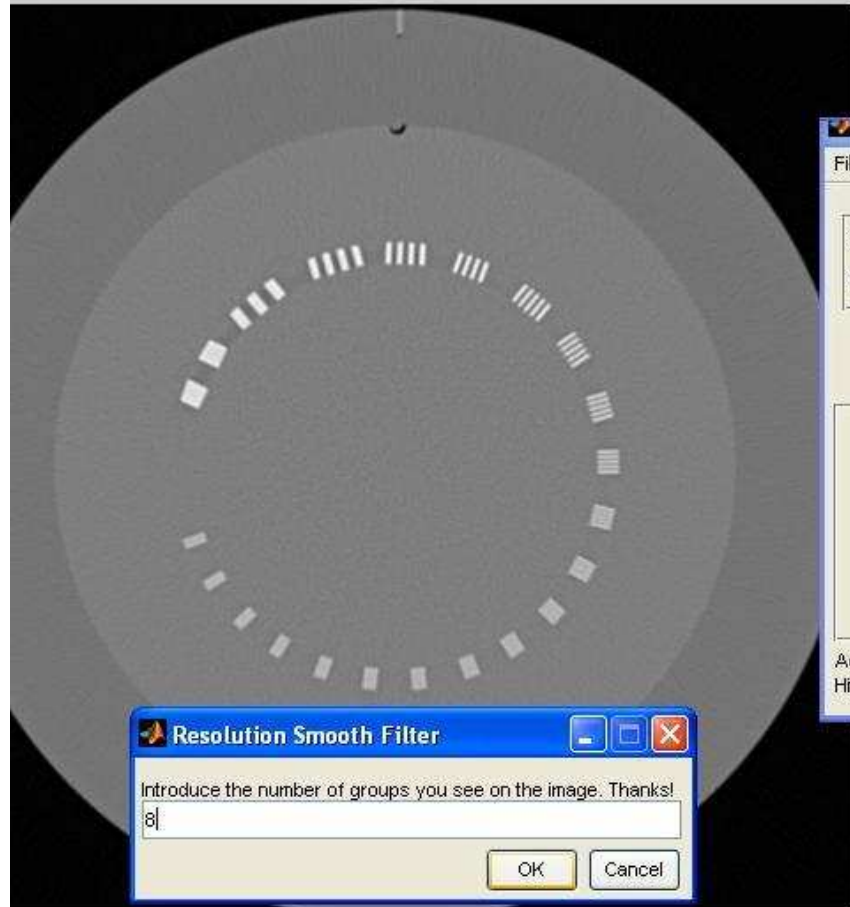
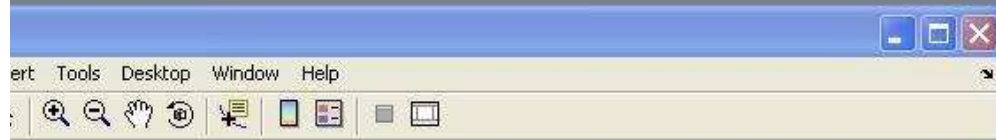
Slice Thickness & Spatial Resolution

Manual: Window & Level

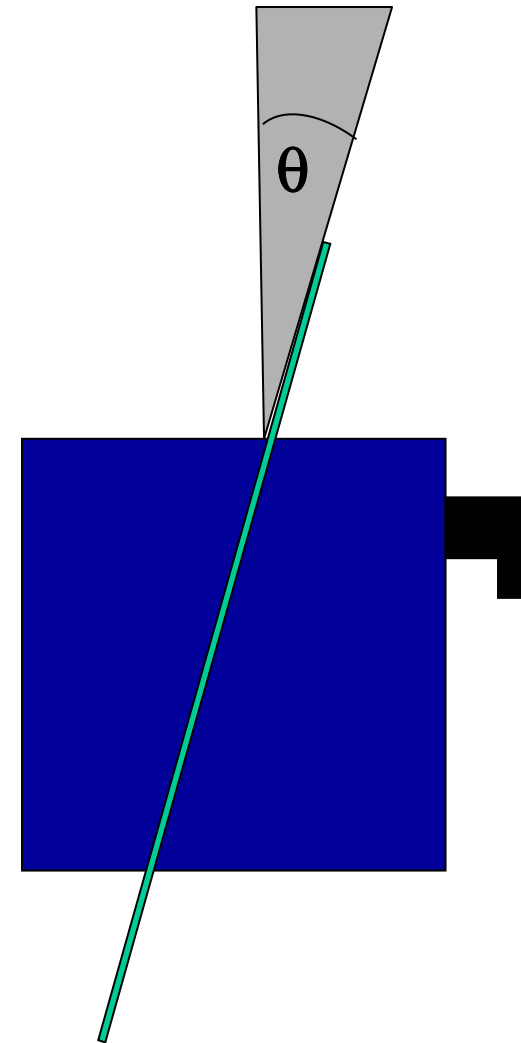
Score exported to Excel



User Interface



Gantry Tilt

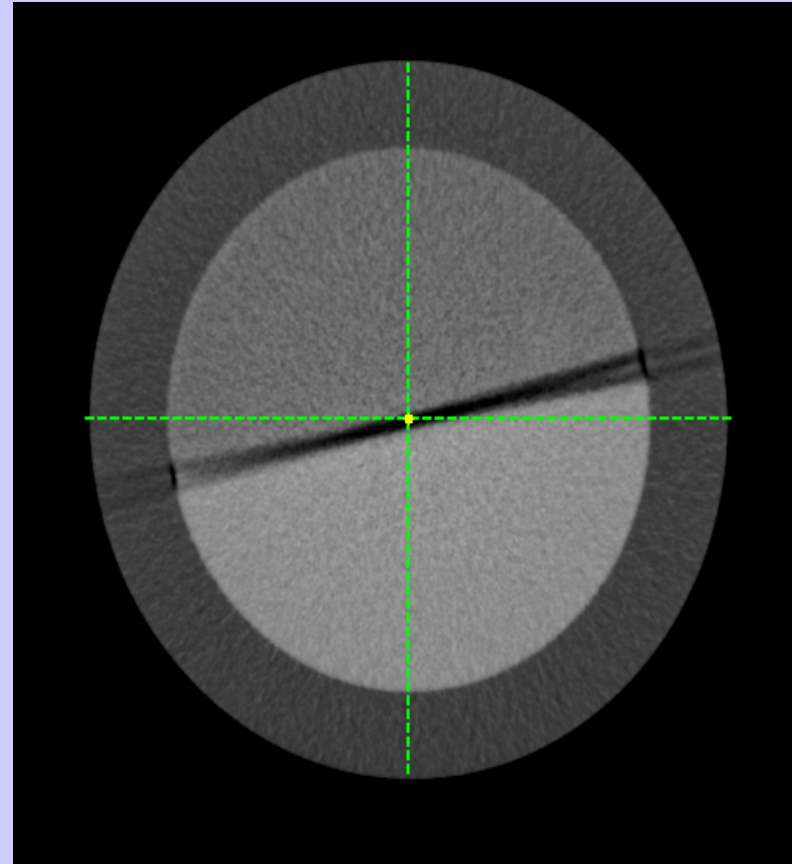


Gantry Tilt

- **Tilt Angle:**

$$\theta = \arccos\left(\frac{\text{Major_Axis}}{\text{Minor_Axis}}\right)$$

- **Increase FOV**
- **Body protocol**
- **Thin slice.**
- **Set-up!**
 - **Minor & Major axes.**
 - **Positive/negative angle ?**



Final Report – Excel



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Sensitometry

Material	Meas. Mean (HU)	Calc. HU	Exp. Mean (HU)	Difference (HU)	Results
Delrin	338.0	274	340	-0.6	Pass
Teflon	955.1	862	990	-3.5	Pass
PMP	-198.3	2.26	-200	-0.9	Pass
LDPE	-105.4	-91	-100	5.4	Pass
Polystyrene	-46.9	-107	-35	34.1	FAIL
Acrylic	117.4	127	120	-2.1	Pass
Air	-1000.0	-1000	-1000	0.0	Pass

Centre		System	BrightSpeed
Test Date	26/02/2009	Manufacturer	GE MEDICAL SYSTEMS
Assessors	Zahara Martin	Serial Number	
Meter	Barracuda	Detector	
Calibration Date			

Dosimetry

	Protocol	Measured	Tolerance	Ref	Result	Comments
CTDI ₁₀₀ in Air @ 100 mAs & 10 mm	Head Protocol @ 120 kV	27.9	Baseline ± 15%	4	Pass	
	Body Protocol @ 120 kV	33.5			Fail	
CTDI ₁₀₀ in Perspex @ 100 mAs & 10 mm	Head Protocol @ 120kV	21.3	Baseline ± 15%	4	Pass	
	Body Protocol @ 120 kV	10.1			Pass	

Spatial Linearity of the Pixel Size Verification

Top Dots				
# of Pixels	Distance (mm)	Meas. Pixels/mm	Nominal Pixels/mm	Results
114	50	2.28	2.28	Pass
Bottom Dots				
# of Pixels	Distance (mm)	Meas. Pixels/mm	Nominal Pixels/mm	Results
114	50	2.28	2.28	Pass

Mechanical Accuracy

	Measured	Difference	Tolerance	Ref	Result	Comments
Slice Thick. (mm) CTP 591	10.0	0.0	Base. ± 20% or ± 1mm, whichever is greater	4	Pass	
Irradiated Slice Thick. (mm)	21.0	-2.0	Base. ± 20% or ± 1mm, whichever is greater	4		
Scan Incr. (mm) CTP 404	9.8	-0.2	± 2mm	6	Pass	
Tilt (°)	19.9	0.1	± 3°	6	Pass	

Image Performance

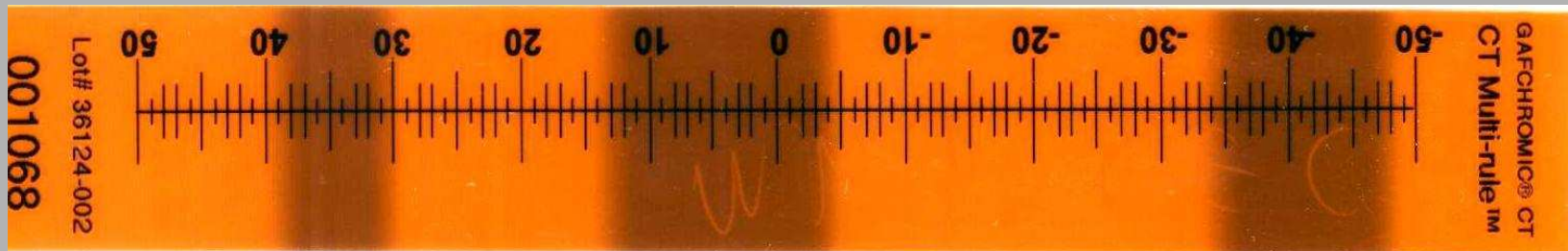
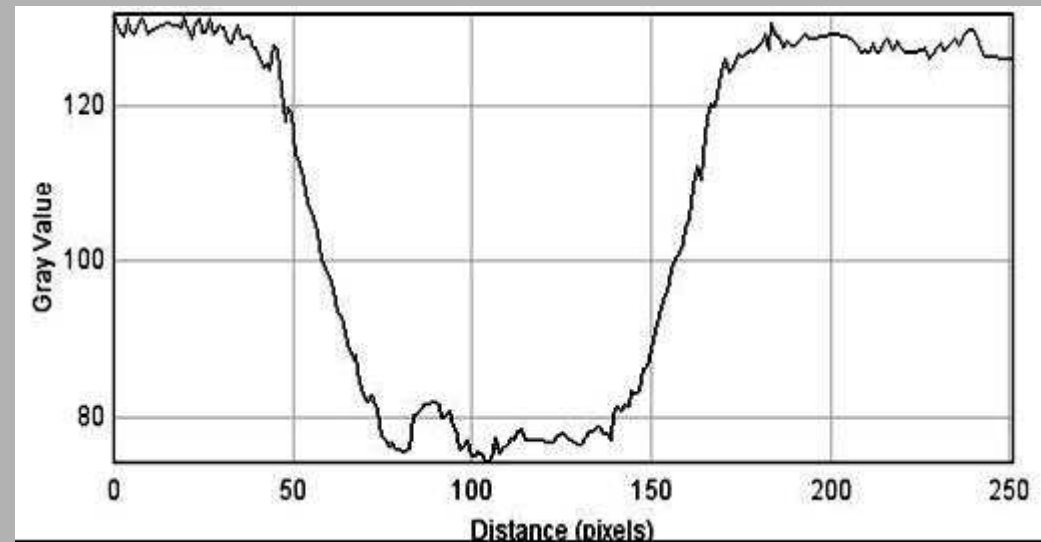
	Measured	Difference	Tolerance	Ref	Result	Comments
Patient Align. System (mm) CTP 404	1	-1.2	± 2mm	4	Pass	
Circular Symmetry (mm) CTP 404	51	0.5	± 2mm	50 mm	Pass	± 2mm guidance
	149	-0.8		150 mm	Pass	
Pixel Size Verification (mm/pixel) CTP 404	2.0	0.0	± 1mm/pixel		Pass	± 1 mm/pixel guidance
High Resolution CTP 528	7	0	Baseline ± 20%	4	Pass	Smooth Filter
	0	0			Sharp Filter	
Uniformity (HU) CTP 486	11.6	-0.56	± 20 HU	4	Pass	Max. Dev. from Centre
Noise (HU) CTP 486	3.7	0.1	Baseline ± 10 % Inter-slice variation: Mean ± 10%	4	Pass	
Sensitometry (HU) CTP 404	-36.1	3	Water: Base. ± 5 HU Other materials: Base. ± HU	4	Pass	

Scan Incrementation

	Meas. Scan Inc. (mm)	Set Scan Inc. (mm)	Results
	9.78	10	Pass
	9.97	10	Pass
	10.34	10	Pass
	10.15	10	Pass
Average	10.15		
St.Deviation	0.24		

Radiation Dose Profile

Currently manual, but



Conclusions

- **The results of the analysis are automatically written from MATLAB into a pre-designed Excel spreadsheet in report format for both CT and MR.**
- **These cumbersome and relatively uncommon QC protocols involving image analysis have been highly automated, thereby significantly decreasing processing time and the amount of time it takes to complete the final report following testing.**

Conclusions

- **Challenged to improve our efficiency:**
- **Current Catphan protocol automated**
- **Gained \approx 30 Minutes (in CT room)**
- **Helical tests ?**
- **Feedback: pkenny@mater.ie**
- **Other CT Image Analysis systems ?**