Towards Optimisation of Routine CT Quality Control Analysis

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Mater Misericordiae
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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

ImPACT

Information Leaflet No. 1:
CT Scanner Acceptance Testing

Version 1.02, 18/05/01

CONTENTS:

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.

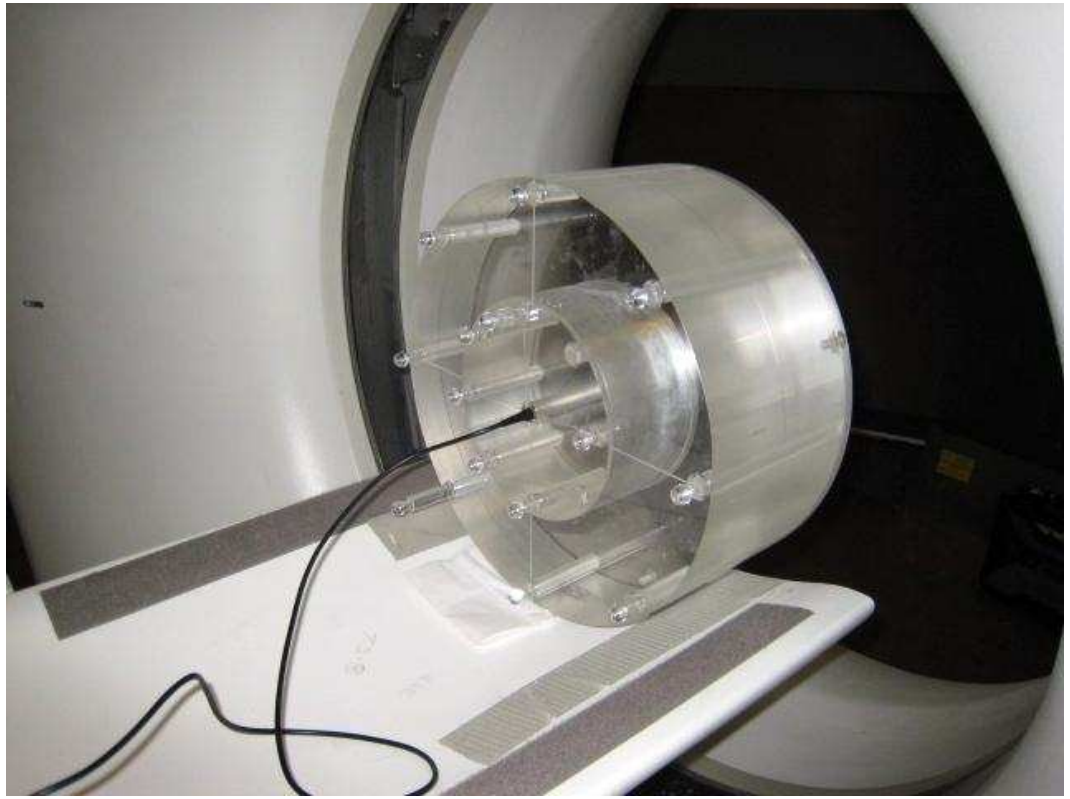
First Hour

- **Dosimetry**
  - **$CTDI_{air}$**
  - **$CTDI_{w}$**

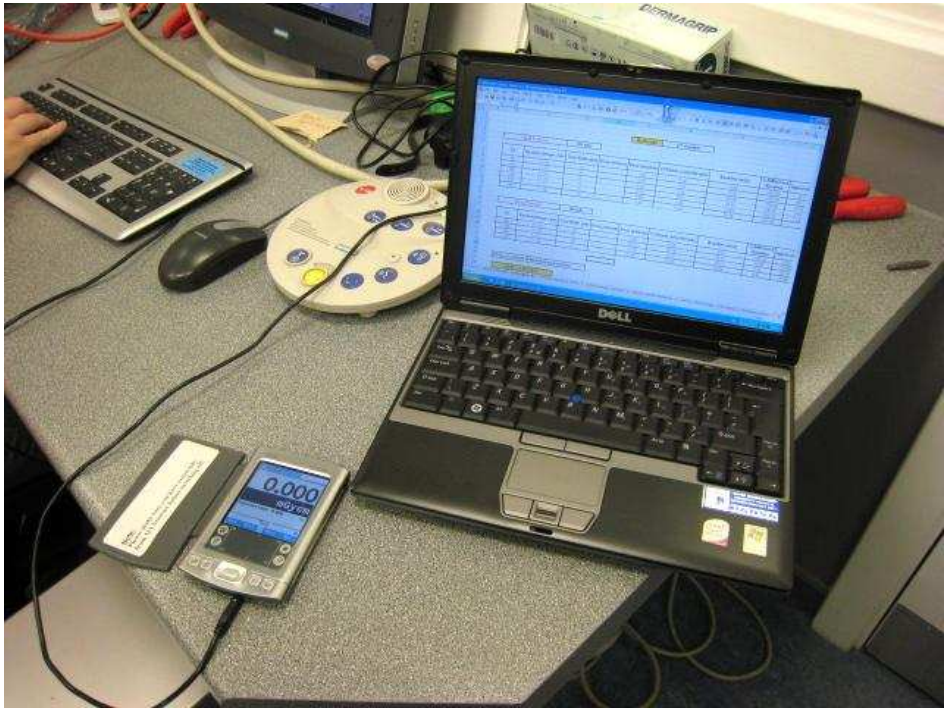
Second Hour

- **Mechanical Accuracy**
- **Image Quality**

Dosimetry – Then:



Dosimetry – Now:



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School of Manufacturing and Design Engineering
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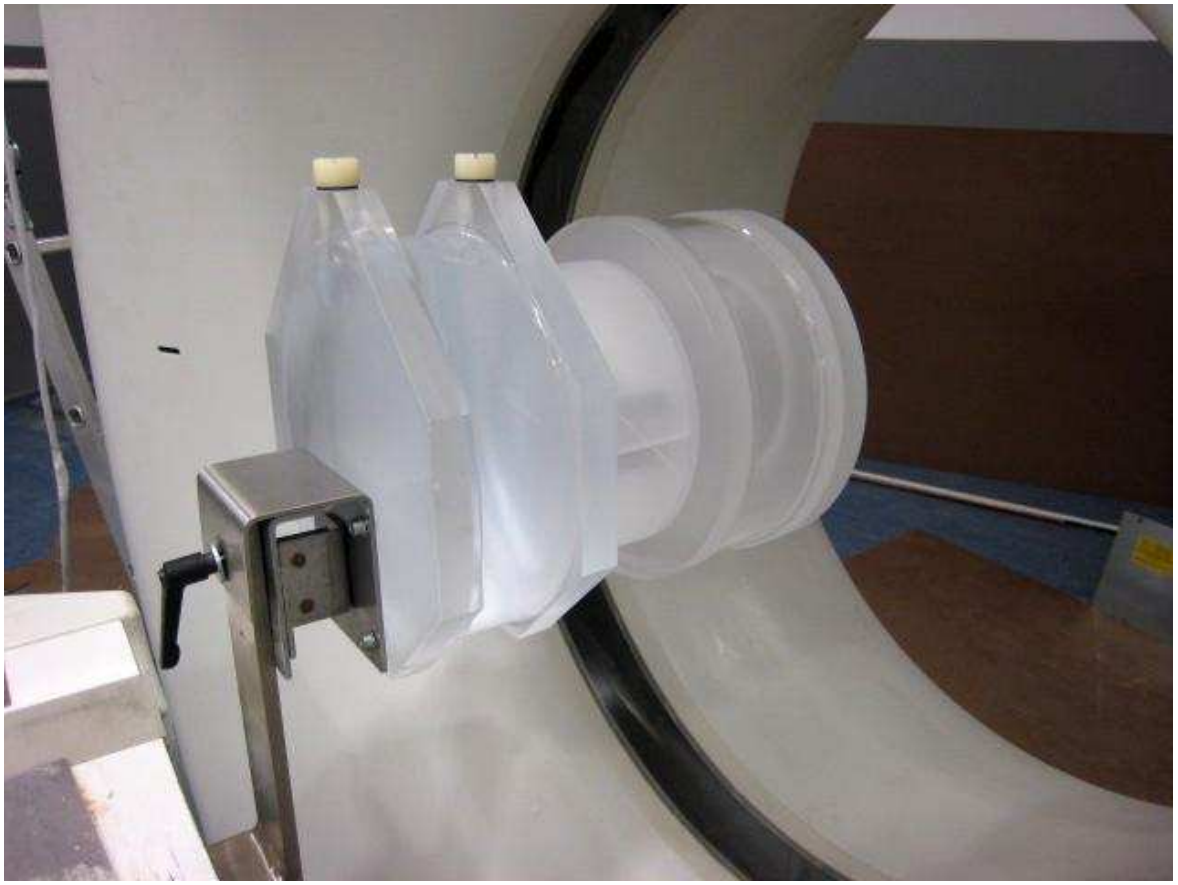
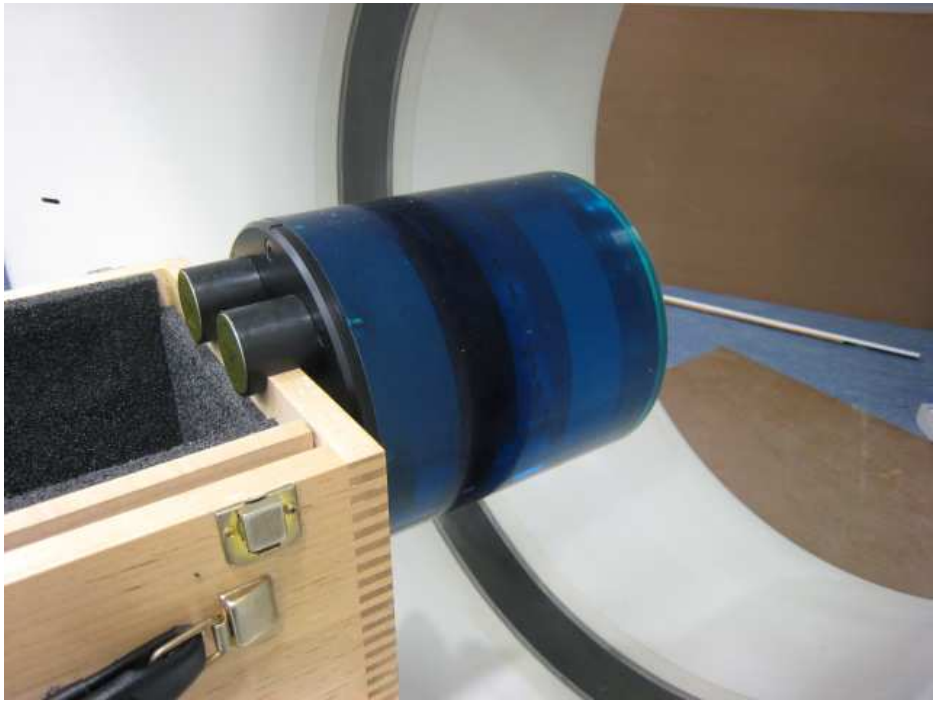
Image Quality – Vendor Phantom

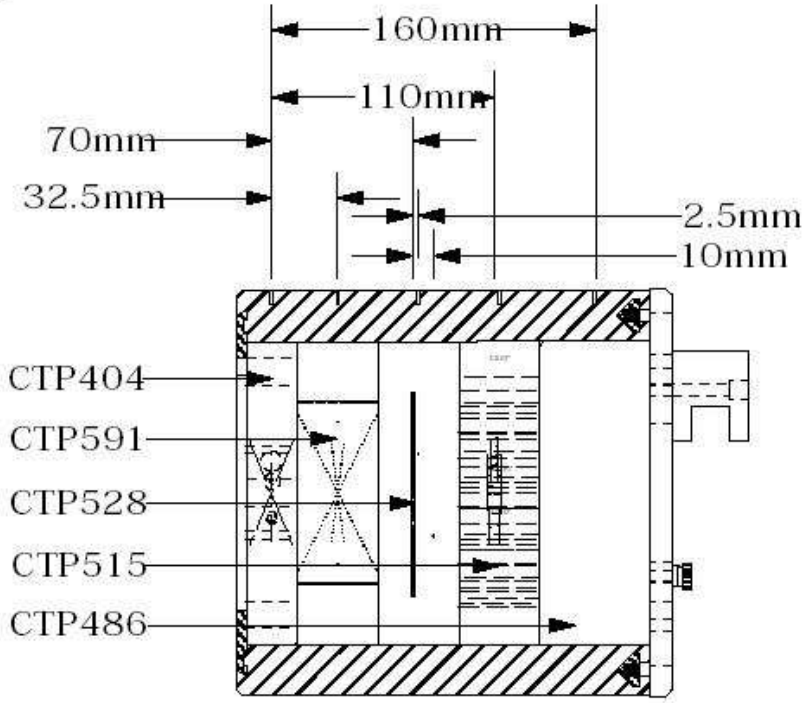


- **Noise**
- **Uniformity**
- **Slice Thickness**

“Be Careful What You Wish For”

Catphan 600

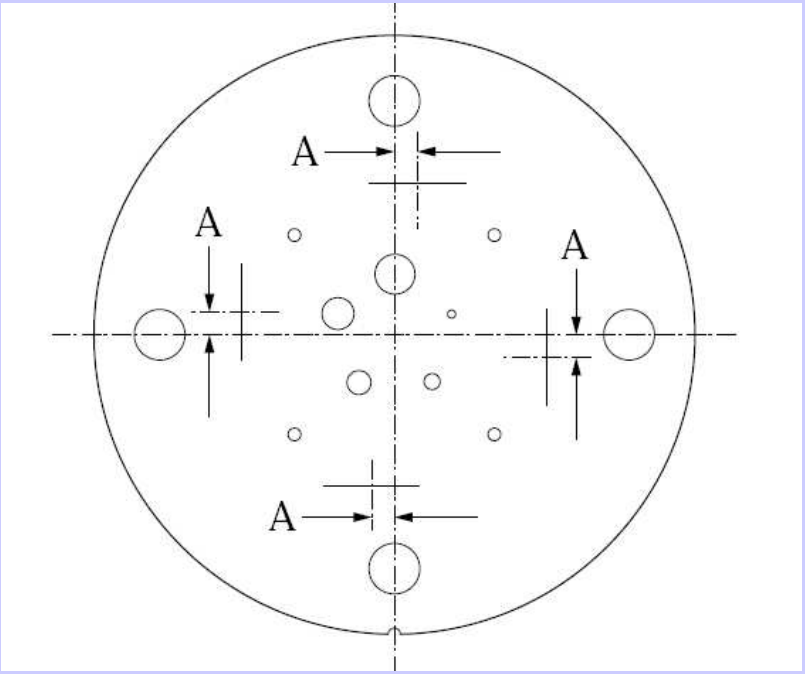


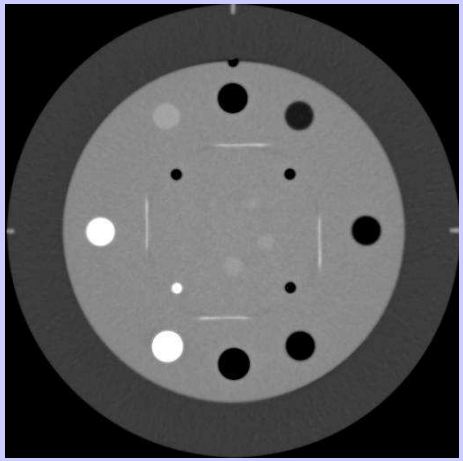


Catphan Protocol

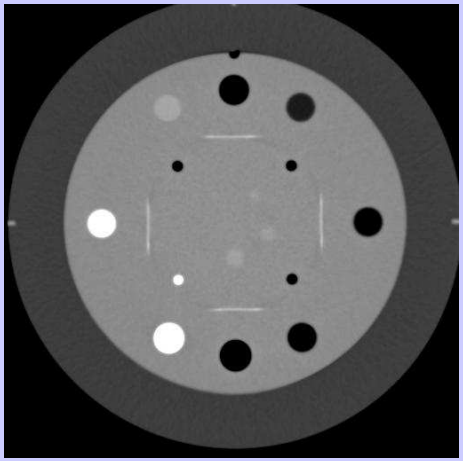
Test	Procedure	kV	mAs	Slice Thick (mm)	Image #	Comments
External Lights Accuracy	External light set-up for **CTP404** (First Module)	120	310	10	1	
Topogram	Lateral	80	200		2	Lateral
Topogram Feed Accuracy	Select from console	120	310	10	3	
Internal Lights Accuracy etc	Manual set-up for **CTP404** (RP)	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**: 2nd 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** 3rd 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** 5th 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

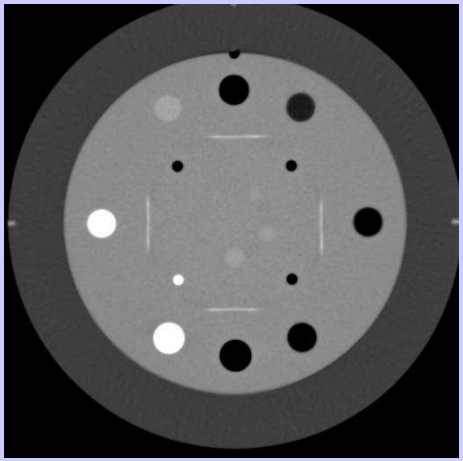




External

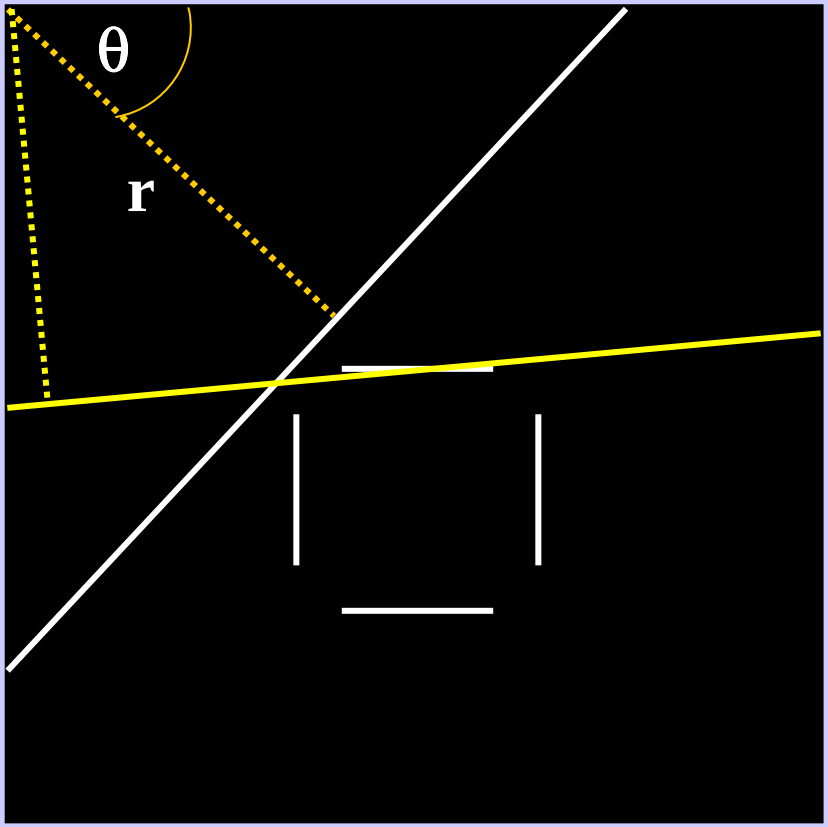


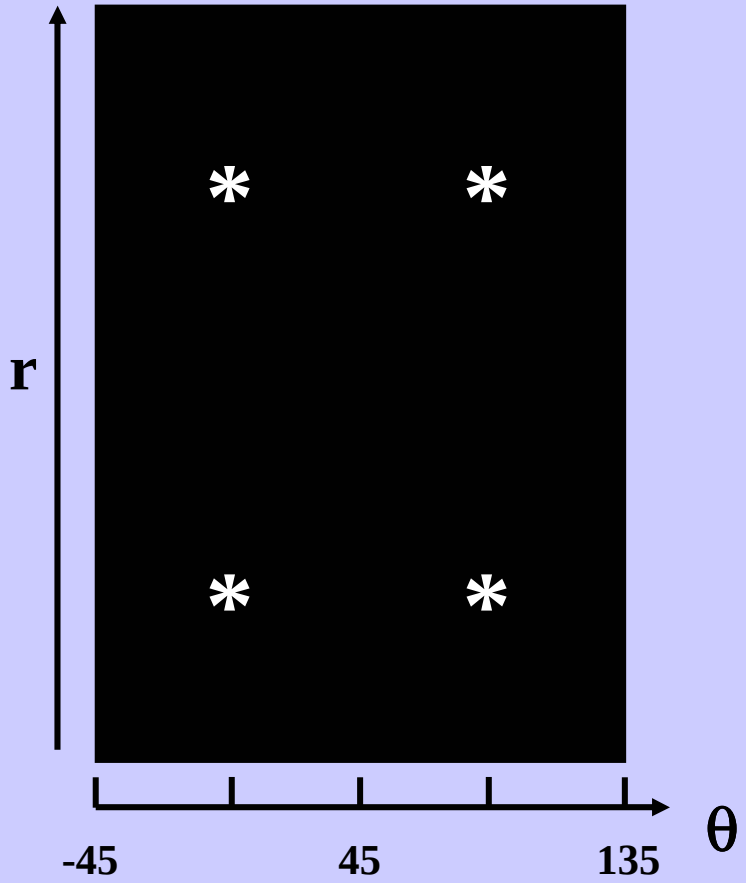
Topogram



Internal

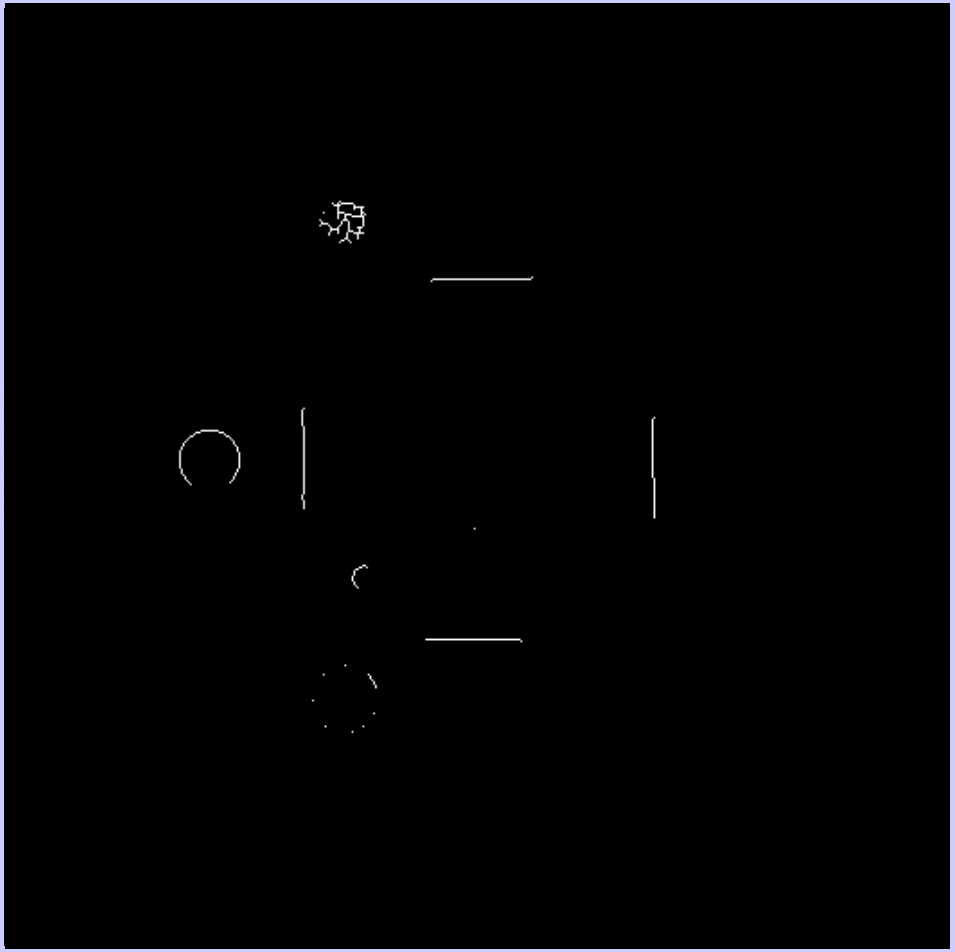
Hough Transform – finding shapes: 3 Matlab routines





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.



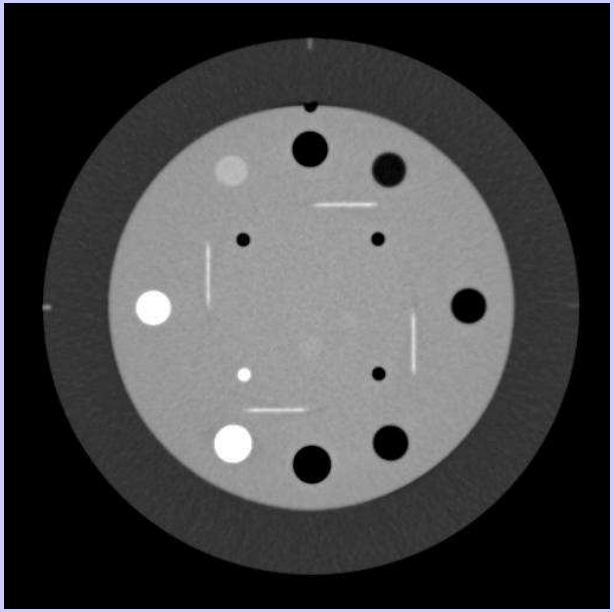
Scan Incrementation

- **Purpose:**

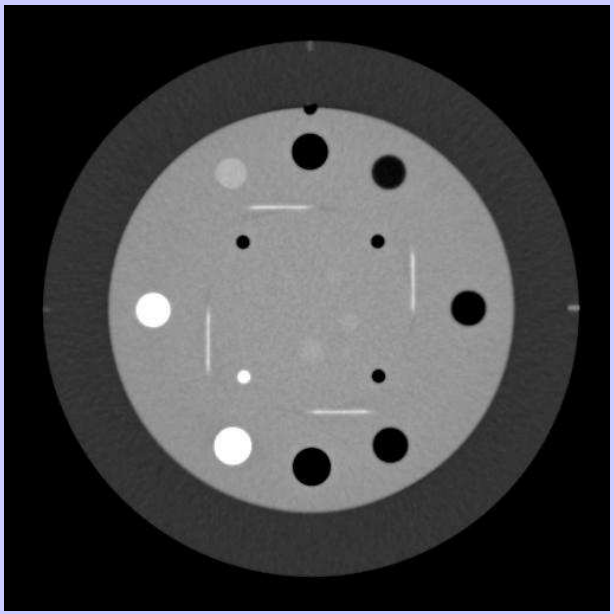
Test accuracy of scan displacements.

  - 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.
    - Tan(23)=0.42!



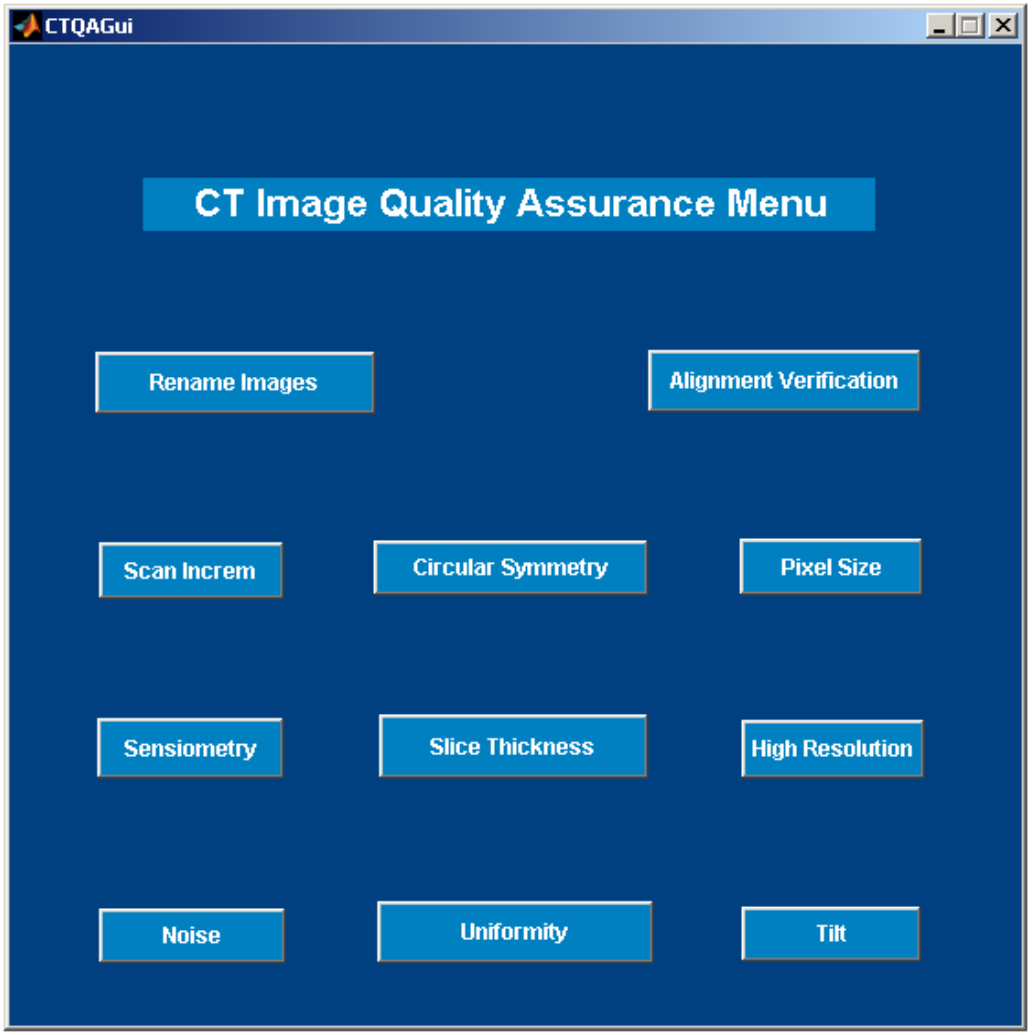
Ref + 5 *mm*



Ref - 5 *mm*

CT Image Analysis

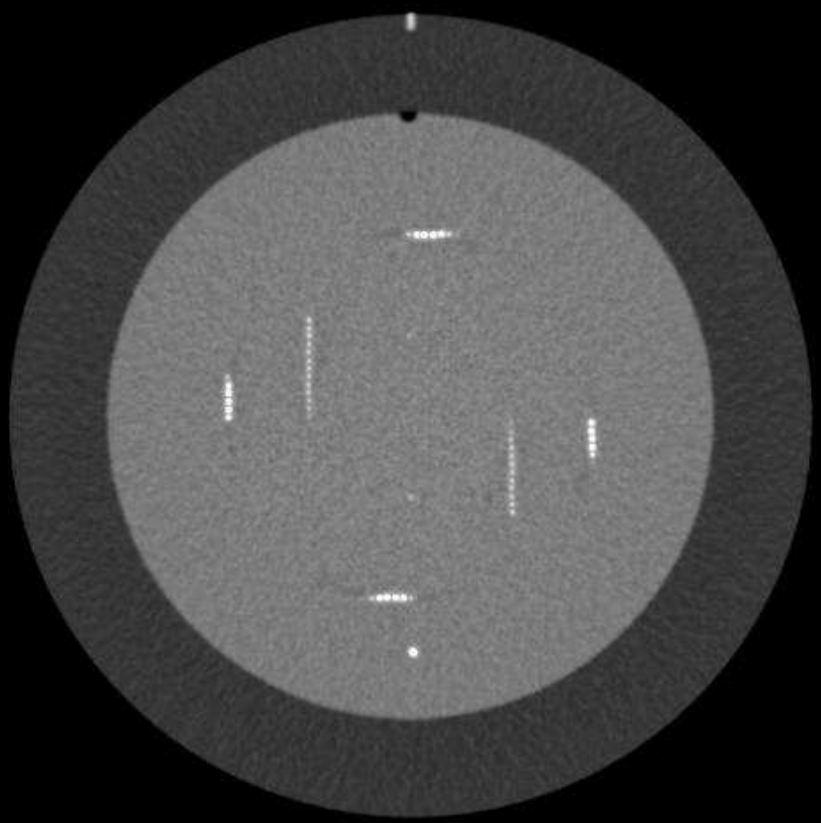
- **Suite of programs developed in Matlab**
- **GUI Graphical User Interface**
- **Results exported directly to Excel**
- **Image Identification !!**
  - Manual:
    - Slice Thickness.
    - Spatial Resolution
  - Automatic
    - Slice position accuracy
    - Scan incrementation
    - Circular Symmetry.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

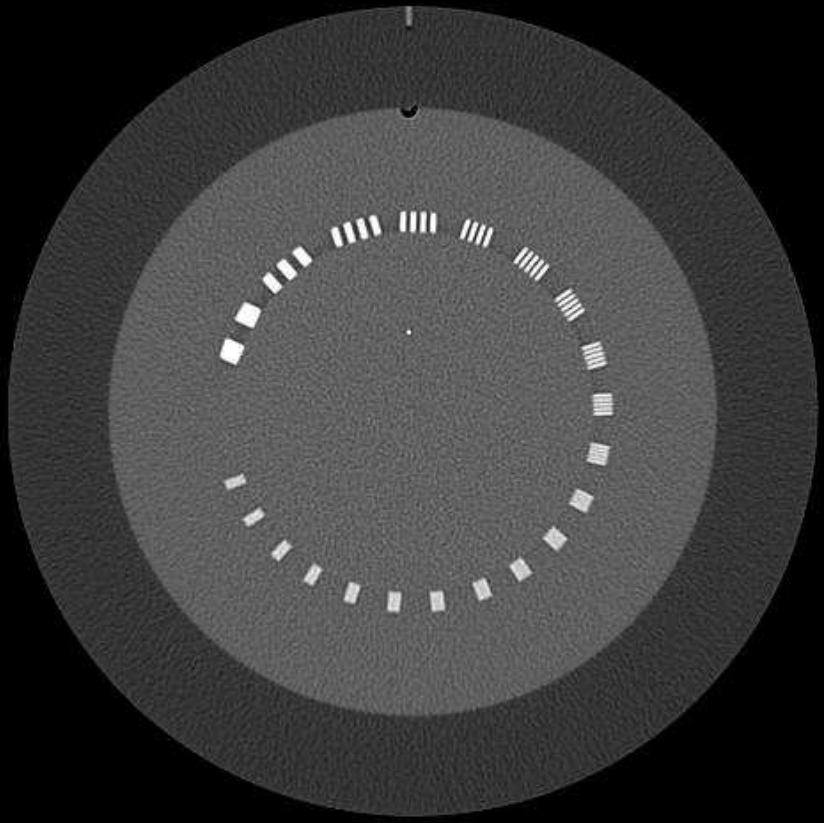


Slice Thickness & Spatial Resolution

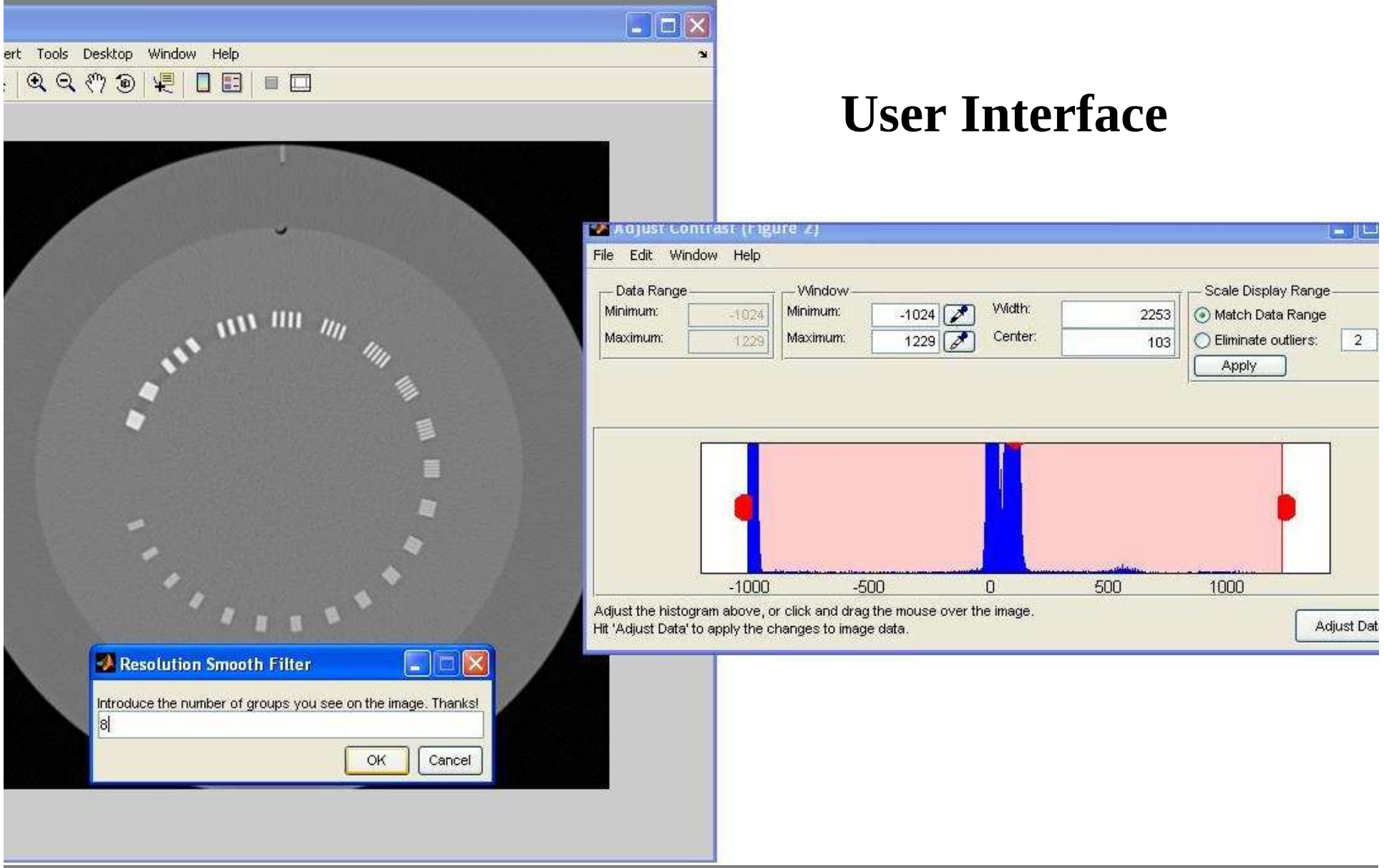
Manual: Window & Level

Score exported to Excel

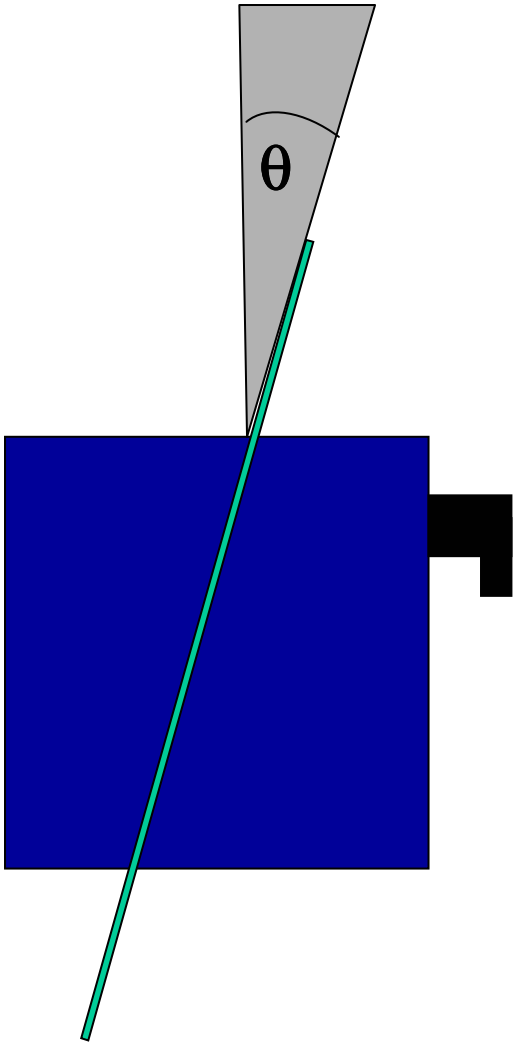




User Interface



Gantry Tilt

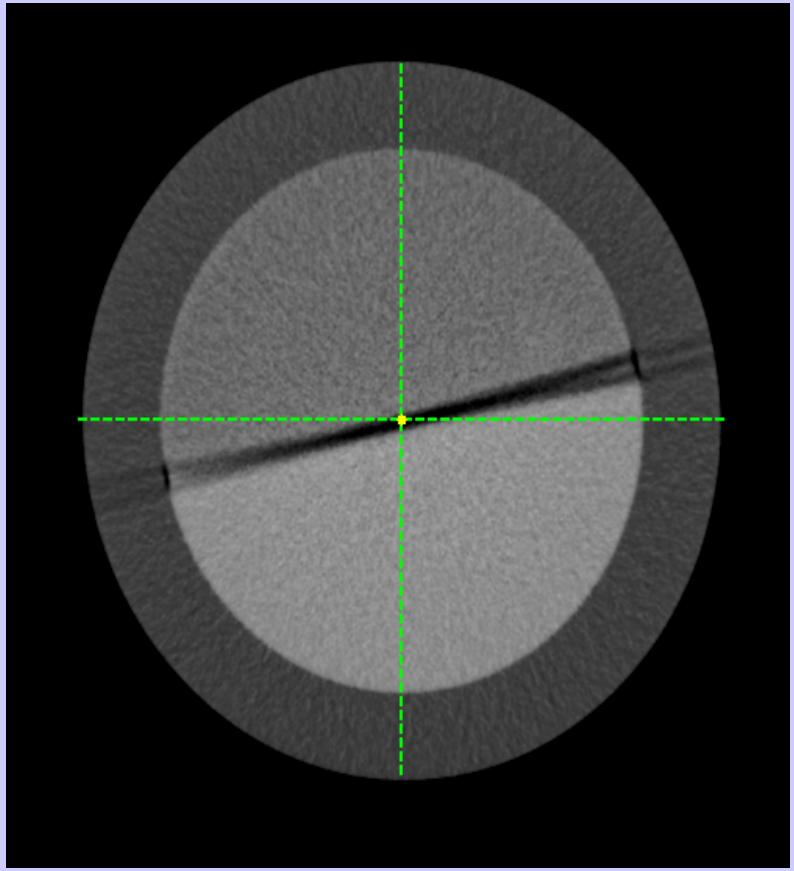


Gantry Tilt

- **Tilt Angle:**

$$\theta = \text{aCos}\left(\frac{\text{Major\_Axis}}{\text{Minor\_Axis}}\right)$$

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



Final Report – Excel

Mater Misericordiae University Hospital

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

Sensiometry

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

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

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		

Dosimetry

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

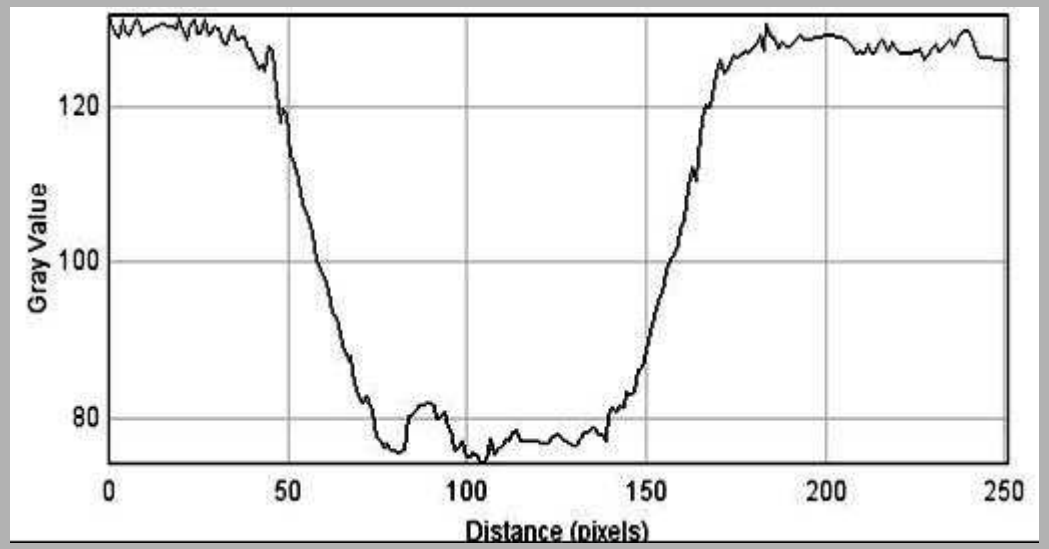
Mechanical Accuracy

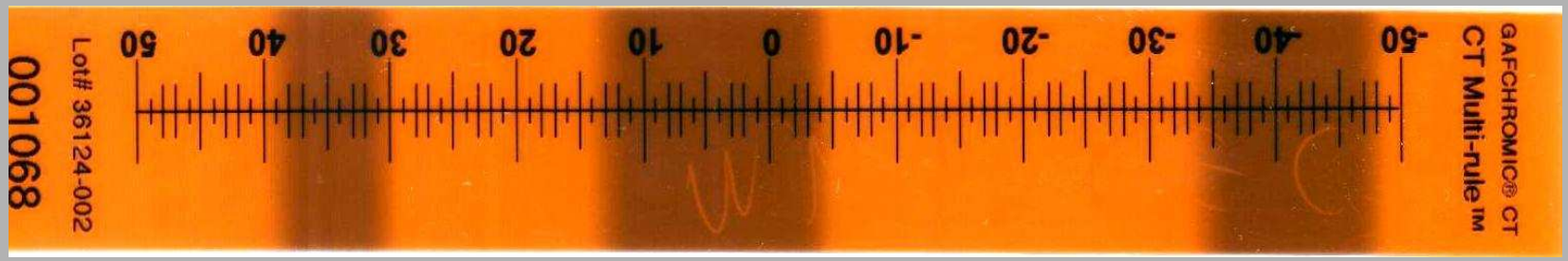
	Measured	Difference	Tolerance	Ref	Result	Comments
Slice Thick. (mm) *CTP 591*	10.0	0.0	Base. ± 20% or ± 1mm, whichever is greater	*4*	Pass	
Irradiated Slice Thick. (mm)	21.0	-2.0	Base. ± 20% or ± 1mm, whichever is greater	*4*		
Scan Incr. (mm) *CTP 404*	9.8	-0.2	± 2mm	*6*	Pass	
Tilt (°)	19.9	0.1	± 3°	*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	
Sensiometry (HU) *CTP 404*	-36.1	3	Water: Base.± 5 HU Other materials: Base. ± HU	*4*	Pass	

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 ≈ 30 Minutes (in CT room)**
- **Helical tests ?**
- **Feedback: pkenny@mater.ie**
- **Other CT Image Analysis systems ?**