



Image Master

A General Phantom Analysis Package

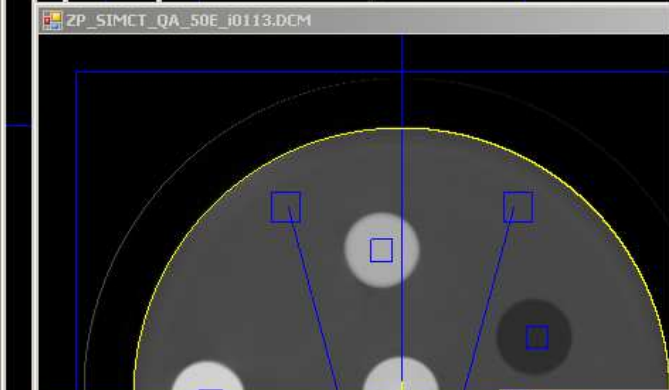
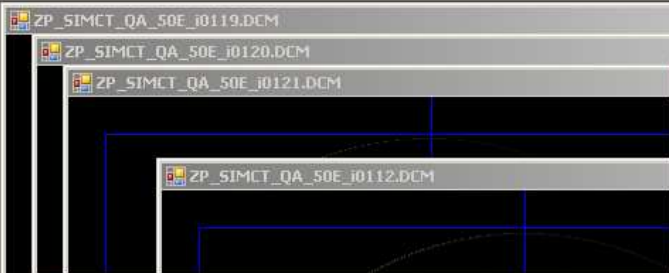
Andrew J Reilly
Edinburgh Cancer Centre

Background...

- Radiotherapy imaging QA
 - Very frequent
 - Quantitative analysis preferred
- All digital imaging modalities
 - CT Scanner, fluoro, DRRs, EPIDs, MRI
- Images being analysed in different ways
 - Dependent upon phantom and modality
- Can we do better?



- Varian Performance Phantom Large
 - Alignment
 - Phantom Centre
 - Geometry
 - Hole 1
 - Hole 2
 - Hole 3
 - Distance: 1-3
 - Distance: 2-3
 - Hole 4
 - Hole 5
 - Distance: 4-5
 - Sensitometry
 - Water
 - Lung
 - Air
 - Soft Bone
 - Resolution
 - MTF
 - Report



Analysis Properties

Main Properties

Do Surface Plot?

Size Y: 15

Size X: 15

Anchor Y: 75

Anchor X: -66

Anchor Relative To: Phantom Centre: Centre of h

Anchor Position: Centre

Coordinate System: Physical_mm

Unique ID: 12

Process Name: MTF

PSF/MTF Report Values: 0.5,0.1

Plot MTF?

Plot PSF?

Analysis Type: All

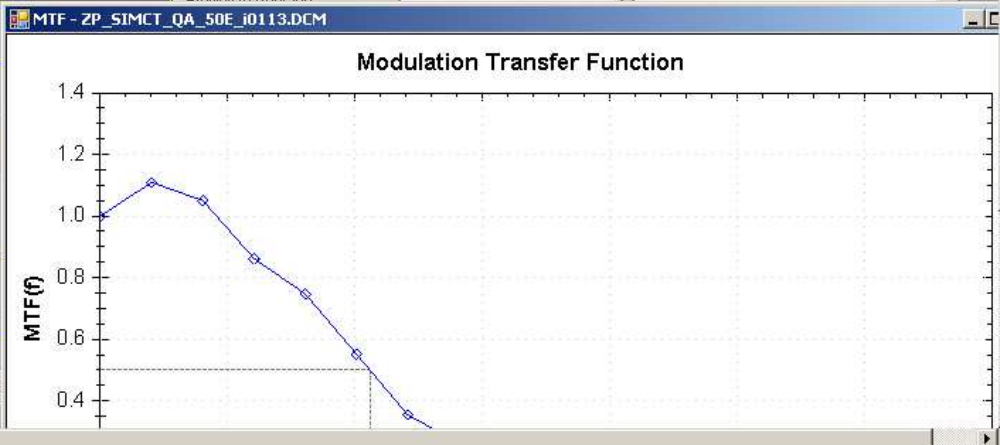
Radius of Point Object (mm): 0.5

Profiles Average

Mean: 1.037E+002
StdDev: 1.684E+001

Freq for 0.5 (/mm): 0.212
Freq for 0.1 (/mm): 0.338

Width at 0.5 (mm): 2.397
Width at 0.1 (mm): 4.187



- ZP_SIMCT_NORMS_50E_i0305.DCM
- ZP_SIMCT_NORMS_50E_i0303.DCM
- ZP_SIMCT_NORMS_50E_i0204.DCM
- ZP_SIMCT_NORMS_50E_i0401.DCM
- ZP_SIMCT_NORMS_50E_i0408.DCM
- ZP_SIMCT_NORMS_50E_i0409.DCM
- ZP_SIMCT_NORMS_50E_i0410.DCM
- ZP_SIMCT_NORMS_50E_i0411.DCM
- ZP_SIMCT_QA_50E_i0102.DCM
- ZP_SIMCT_QA_50E_i0103.DCM
- ZP_SIMCT_QA_50E_i0104.DCM
- ZP_SIMCT_QA_50E_i0105.DCM
- ZP_SIMCT_QA_50E_i0106.DCM
- ZP_SIMCT_QA_50E_i0108.DCM
- ZP_SIMCT_QA_50E_i0109.DCM
- ZP_SIMCT_QA_50E_i0110.DCM
- ZP_SIMCT_QA_50E_i0111.DCM
- ZP_SIMCT_QA_50E_i0112.DCM
- ZP_SIMCT_QA_50E_i0114.DCM
- ZP_SIMCT_QA_50E_i0115.DCM
- ZP_SIMCT_QA_50E_i0119.DCM
- ZP_SIMCT_QA_50E_i0120.DCM
- ZP_SIMCT_QA_50E_i0121.DCM

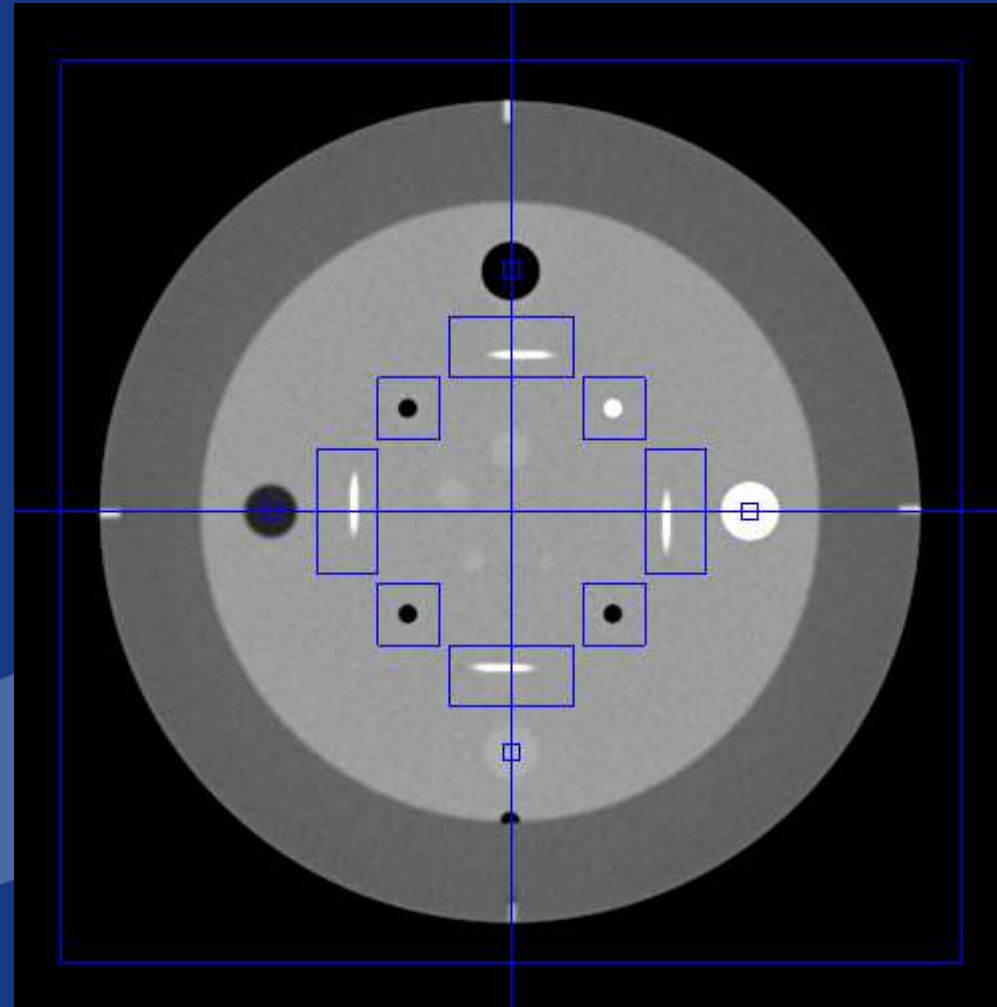
Methodology



- The Generic Phantom
 - All phantoms composed of atomic components
 - e.g. Impulse object, slice thickness ramp
- Develop analysis methods for each component
- User constructs 'analysis tree' for any phantom
- Perform analysis on multiple images
- Report and store results

Catphan 500 Alignment Slice

- [-] Catphan 500 Alignment
 - [-] Phantom Alignment
 - ... Phantom Centre
 - [-] Distances
 - ... Hole 1
 - ... Hole 2
 - ... Hole 3
 - ... Hole 4
 - ... Distance: 1-2
 - ... Distance: 2-3
 - ... Distance: 3-4
 - ... Distance: 4-1
 - [-] Sensitometry
 - ... Air
 - ... LDPE
 - ... Acrylic
 - ... Teflon
 - [-] Ramps
 - ... Ramp: Top
 - ... Ramp: Bottom
 - ... Ramp: RHS
 - ... Ramp: LHS
 - ... Report



Design Decisions

- Availability
 - As cheap as possible!
 - Freely distributable – open-source components
 - Run on desktop or laptop
 - Standalone or network environment
- Language
 - C#, using Visual Studio 2005 Express
 - Use existing libraries / toolkits if possible
- Platform
 - Windows 2000+
- Image Input
 - All standard formats, especially DICOM
 - Open from network, CDROM, USB stick, etc.

Core Components



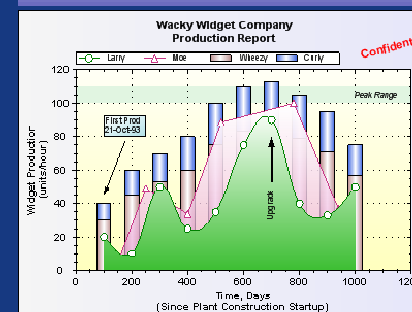
www.r-project.org

SourceGrid



www.devage.com

ZedGraph



zedgraph.org



itext.ugent.be



www.mydicom.net

(Only commercial component)



www.postgresql.org

Distribution

- Freely distributable... although only limited numbers to begin with!
 - Still bugs
 - Support on 'best-effort' basis
- Cannot release full source-code due to DICOM.NET licensing
- Intend to implement plug and play image processing / analysis modules

Features

- Comprehensive Catphan 500 / 600 analysis
- Suitable for other phantoms and modalities
- Flexible user-customisation of analysis tree
- Flexible reporting framework
- Testing of result values
- Storage to database or Excel file
- DICOM Browser

DICOM Browser

Search Directory: F:\TestImages\Sim-VPU

Browse

Search Recursively

Patient Studies

| Date | Patient ID | Patient Name | Series | RT Plans | RT Structs |
|---------------------|------------------|------------------------|--------|----------|------------|
| 06/02/2003 16:42:49 | ZP_SIMCT_QA_5... | ZP_SIMCT_QA_50E^AJR | 22 | 0 | 0 |
| 06/08/2003 16:21:19 | ZP_SIMCT_NOR... | ZP_SIMCT_NORMS_50E^AJR | 11 | 0 | 0 |
| | | | | | |
| | | | | | |
| | | | | | |

Update Study List

Delete Study

Series

| Num | Date / Time | Modality | Description | Protocol | Images | Start Pos | End Pos |
|-----|---------------------|----------|-------------|----------|--------|-----------|---------|
| 2 | 06/03/2003 16:46:34 | CT | | UNKNOWN | 1 | 0 | 0 |
| 5 | 24/07/2003 15:51:58 | CT | | UNKNOWN | 1 | 0 | 0 |
| 11 | 20/11/2003 16:28:24 | CT | | UNKNOWN | 1 | 0 | 0 |
| 12 | 15/01/2004 17:34:19 | CT | | UNKNOWN | 1 | 0 | 0 |
| 13 | 28/01/2004 15:12:10 | CT | | UNKNOWN | 1 | 0 | 0 |
| 14 | 12/02/2004 16:02:18 | CT | | UNKNOWN | 1 | 0 | 0 |
| 15 | 25/02/2004 17:11:04 | CT | | UNKNOWN | 1 | 0 | 0 |

Images

| Num | Pos | Thick |
|-----|-----|-------|
| 1 | 0 | 10.5 |
| | | |
| | | |
| | | |

RT Plans

| Num | Date / Time | Name | Label | Clinician | Iso X | Iso Y | Iso Z |
|-----|-------------|------|-------|-----------|-------|-------|-------|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

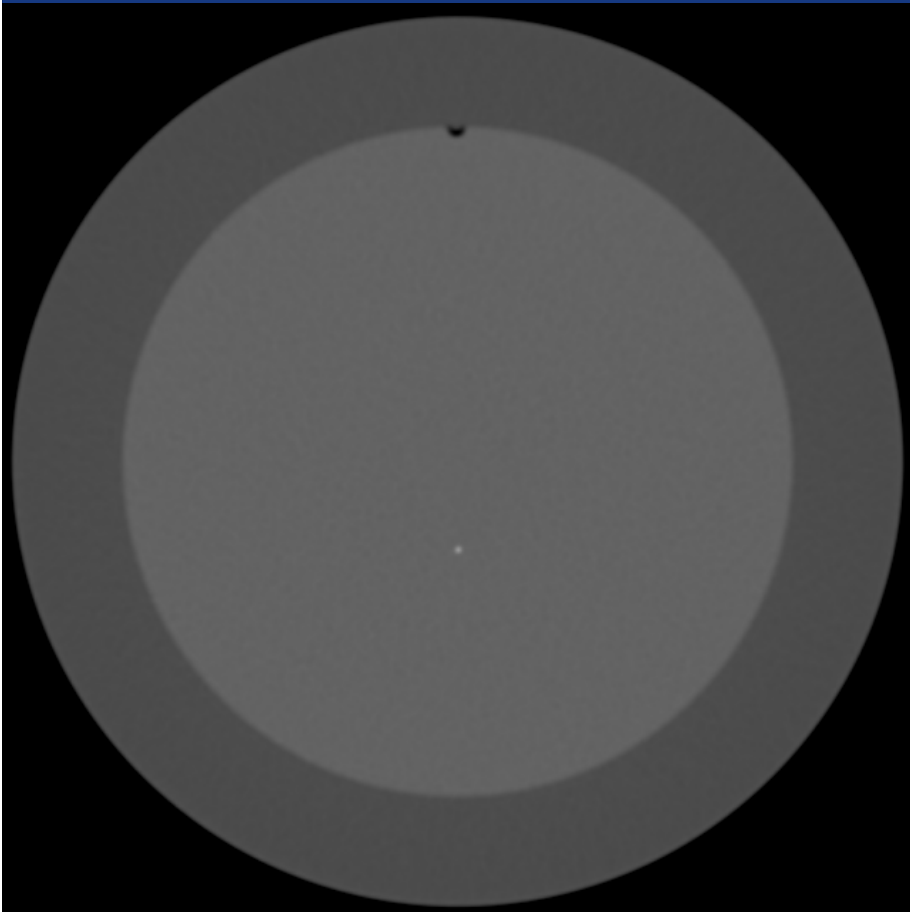
RT Structures

| Num | Date / Time | Name | Label | Clinician | Structures |
|-----|-------------|------|-------|-----------|------------|
| | | | | | |
| | | | | | |
| | | | | | |
| | | | | | |

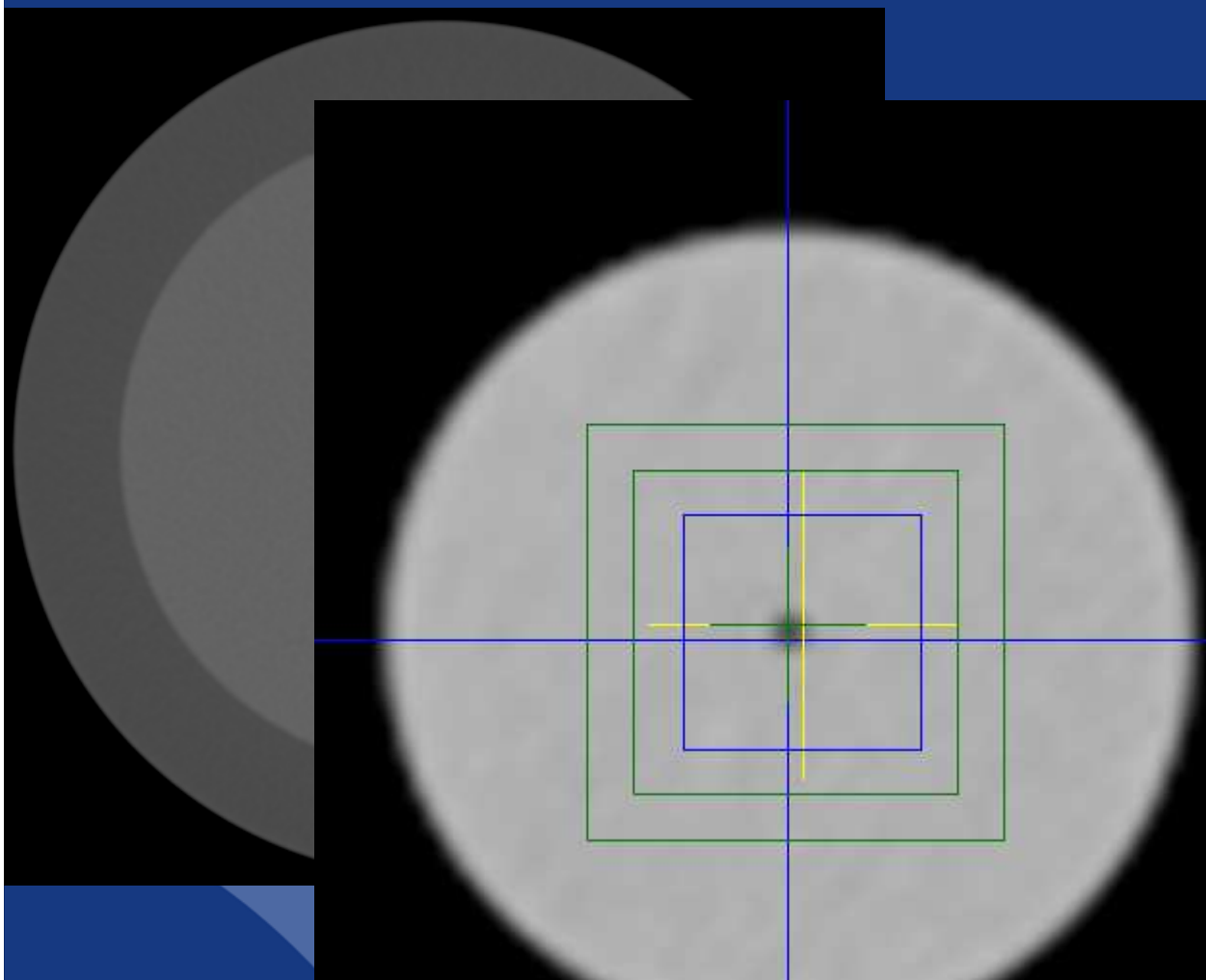
Load Data

Cancel

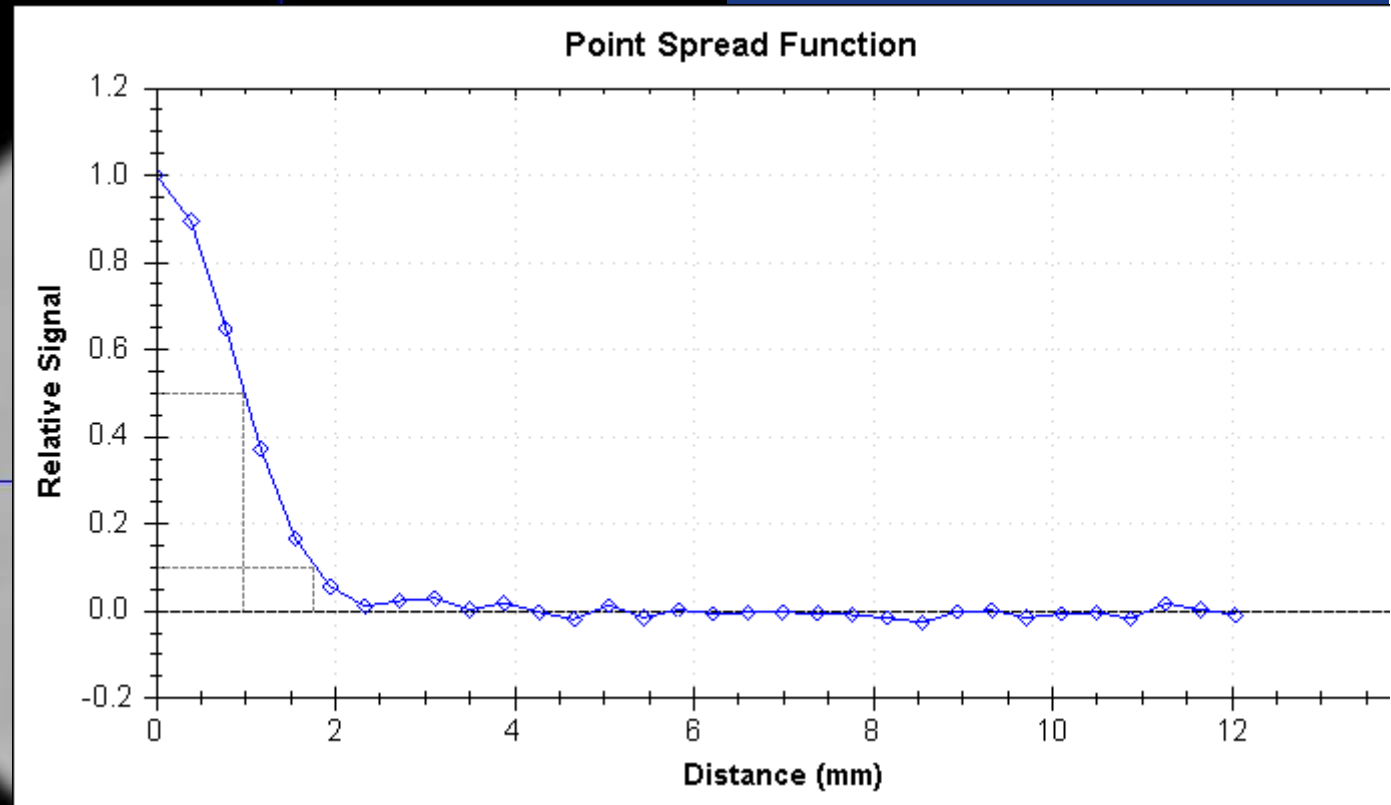
Analysis Examples: Impulse Object



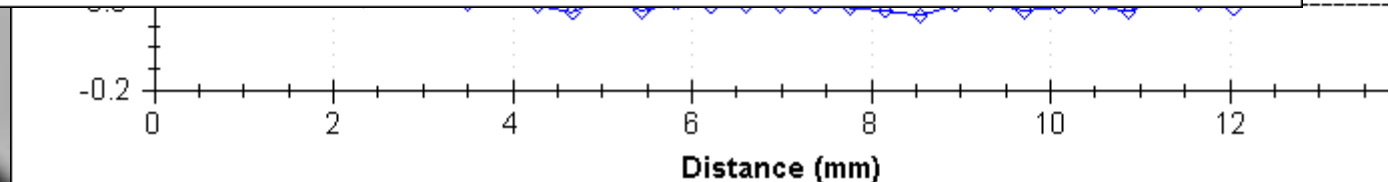
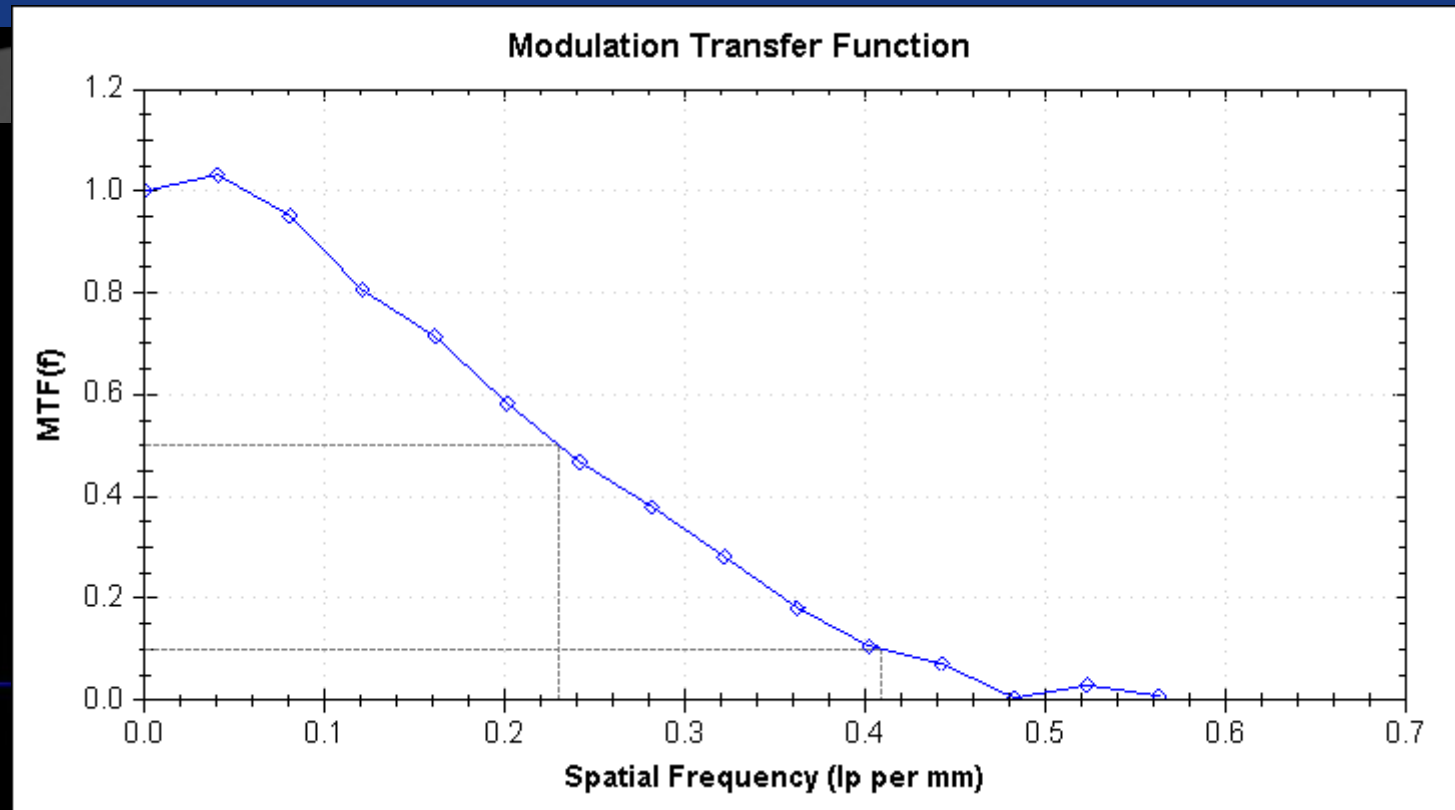
Analysis Examples: Impulse Object



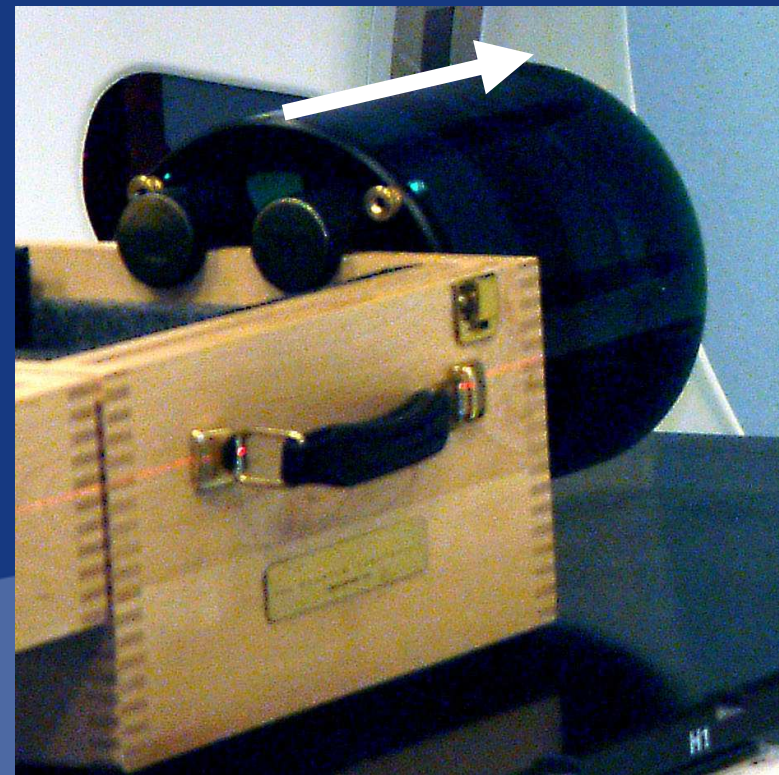
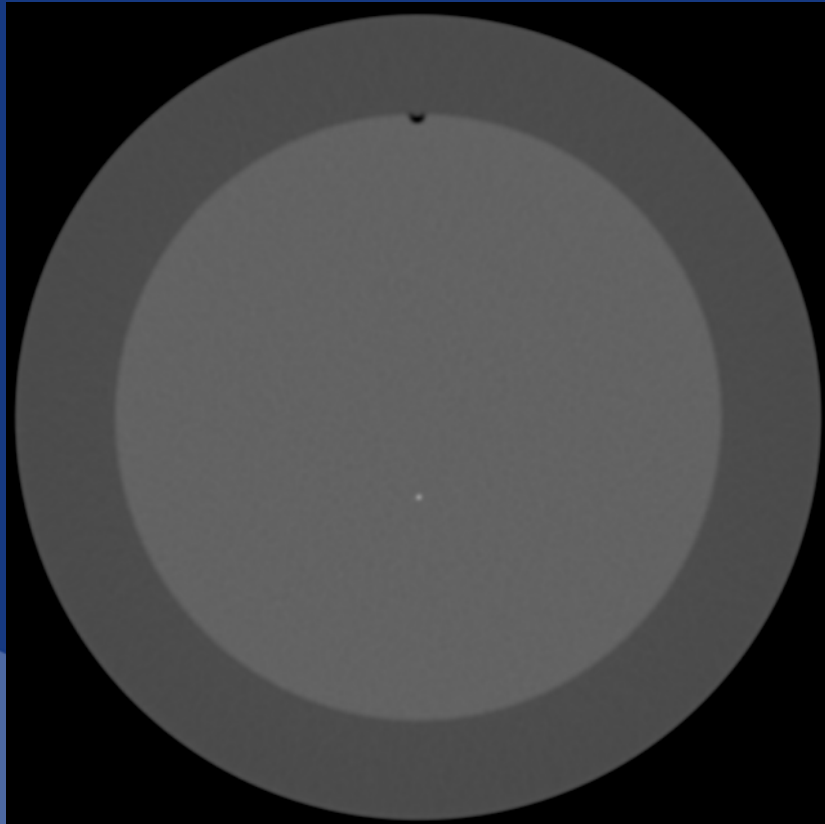
Analysis Examples: Impulse Object



Analysis Examples: Impulse Object

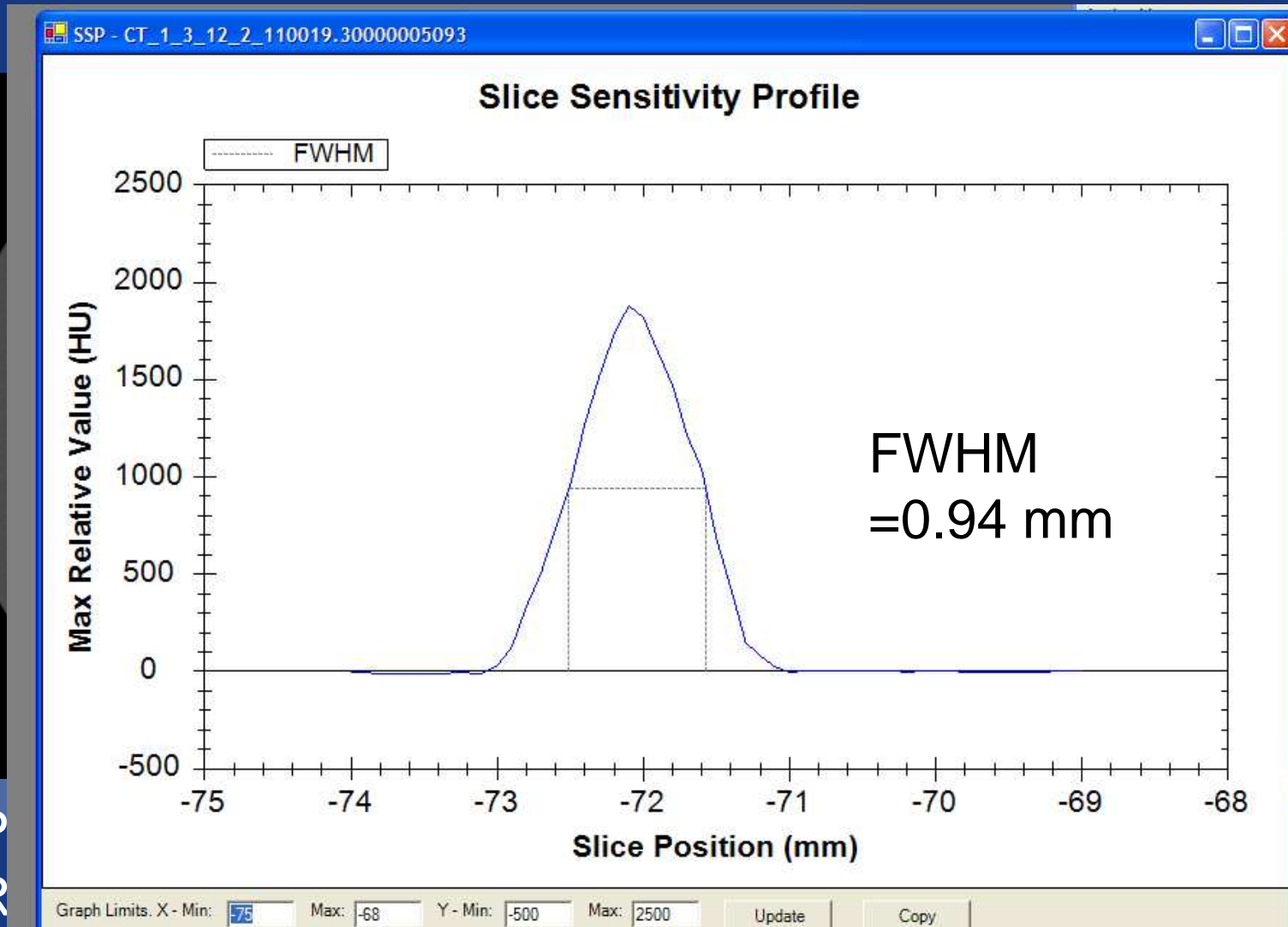


Analysis Example: Helical Slice Sensitivity Profile



- Plot max pixel value as a function of Z Position
- Report FWHM

Analysis Example: Helical Slice Sensitivity Profile

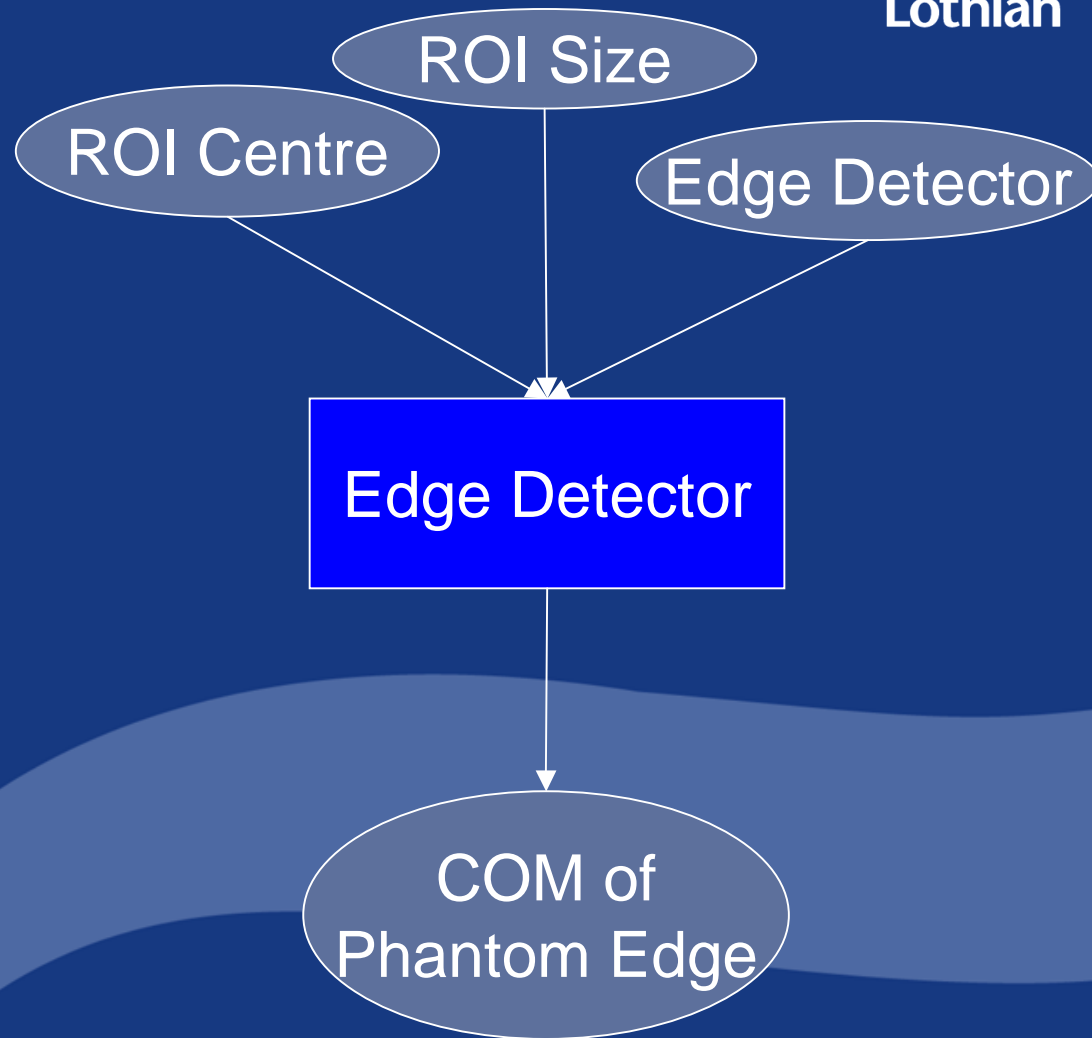


Other Analysis Modules

- General ROI
- Edge detection – find centre of phantom
- Edge analysis -> Angles, LSF, MTF
- Distance measurements
- Bar pattern analysis -> MTF
- Uniformity analysis -> Profiles, indices
- Contrast
- CNR
- NNPS
- DQE

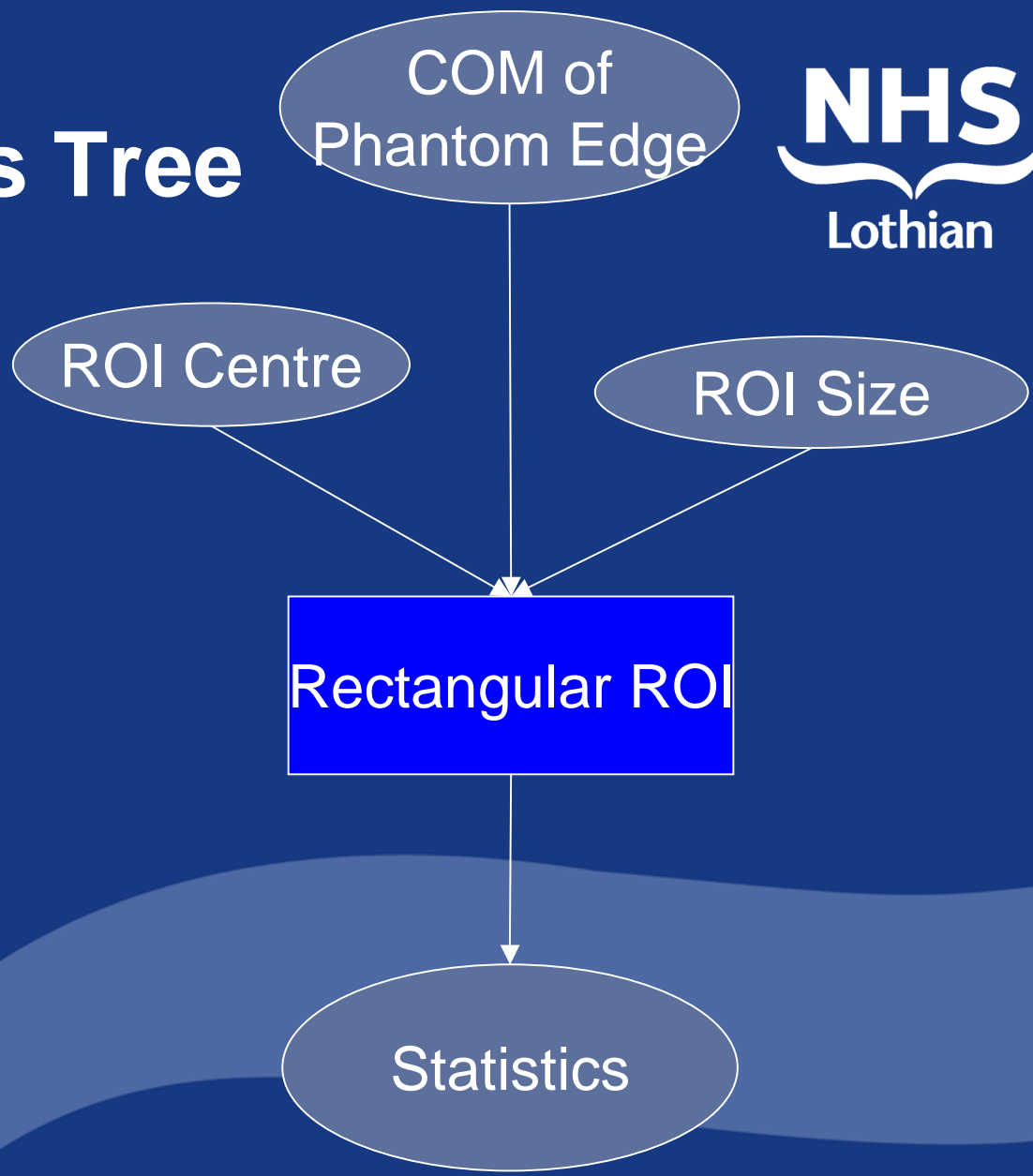
The Analysis Tree

- [-] Catphan 500 Alignment
 - [-] Phantom Alignment
 - Phantom Centre
 - [-] Distances
 - Hole 1
 - Hole 2
 - Hole 3
 - Hole 4
 - Distance: 1-2
 - Distance: 2-3
 - Distance: 3-4
 - Distance: 4-1
 - [-] Sensitometry
 - Air
 - LDPE
 - Acrylic
 - Teflon
 - [-] Ramps
 - Ramp: Top
 - Ramp: Bottom
 - Ramp: RHS
 - Ramp: LHS
 - Report



The Analysis Tree

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The Analysis Tree

COM of Phantom Edge



- [-] Catphan 500 Alignment
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 - ... Ramp: LHS
 - ... Report

RC

Analysis Properties

Main Properties

Do Surface Plot?

Size Y: 15

Size X: 30

Anchor Y: -40

Anchor X: 0

Anchor Relative To: Phantom Centre: Centre of h

Anchor Position: Centre

Coordinate System: Physical_mm

Unique ID: 23

Process Name: Ramp: Top

Plot Profile?

Calculate FWHM?

Background Correct?

Profile Direction: Horizontal

Profiles to Average: 3

Background Annulus Width: 3

Point for Analysis: Max

Ramp Angle (°): 23

Process Type: Ramp Analysis

Mean: 1.018E+002
StdDev: 4.755E+001
Max Value: 139.053571428571, At index 29 (0 mm)
FWHM: 4.96 mm from -2.7 mm to 2.3 mm

Buttons: Apply, Refresh, Details..., Run Process

Reporting Framework

Report Generator

Type: ID: Name: Report Title:

Results to Include

- Distance: 2-3
 - Distance Physical
 - Distance Pixels
- Distance: 3-4
 - Distance Physical
 - Distance Pixels
- Distance: 4-1
 - Distance Physical
 - Distance Pixels

Scientific Notation Decimal Places:

Tests on Results

| Name | Value | Applicability |
|--------------|-------|---------------|
| Within range | 49,51 | All |

Image Information

Include Copy of Image

- 4395118
- ACCESSION_NUMBER
- ACQUISITION_DATE
- ACQUISITION_NUMBER
- ACQUISITION_TIME
- BITS_ALLOCATED
- BITS_STORED
- COLUMNS
- CONTENT_DATE
- CONTENT_DATETIME

Friendly Name:

Comments

Summary Fields

Scientific Notation Decimal Places:

Report Output

- Word Doc
- PDF
- HTML

Data Storage

None

CSV File

File Name:

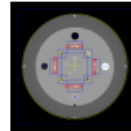
Database

Data Store:

Table:

Catphan 500 Alignment Slice

CONTENT_DATE TIME: 29/09/2006 12:15:43
DEVICE_SERIAL_NUMBER: 0000287.0035138
EXPOSURE_TIME: 1500
INSTITUTION_NAME: EDINBURGH CANCER CENTRE
KVP: 120
MANUFACTURER: GE MEDICAL SYSTEMS
MANUFACTURERS_MODEL_NAME: Speed
ME:
PATIENT_ID: xp_cat_060929
PATIENTS_NAME: xp_cat_060929
SLICE_LOCATION: +0.00
SLICE_THICKNESS: 5.0
X_RAY_TUBE_CURRENT: 200
Z_POS: 0



Phantom Alignment

| | COM - X (mm) | COM - Y (mm) |
|----------------|--------------|--------------|
| Phantom Centre | -0.51 | -0.26 |

Distances

| | Distance Physical |
|----------------|--------------------|
| Distance: 1-2 | 50.17 |
| Distance: 2-3 | 50.09 |
| Distance: 3-4 | 50.03 |
| Distance: 4-1 | 50.11 |
| Average | 50.10 |
| Std Dev | 0.05 (0.1%) |

Sensitometry

| | Mean Value | Standard Deviation |
|----------------|--------------------------|--------------------|
| Air | -989.05 | 3.59 |
| LDPE | 954.32 | 3.50 |
| Acrylic | 116.80 | 2.82 |
| Teflon | -100.18 | 3.08 |
| Average | -4.53 | 3.25 |
| Std Dev | 691.47 (15271.8%) | 0.31 (9.7%) |

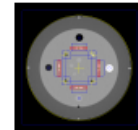
Ramps

| | FWHM |
|--------------|------|
| Ramp: Top | 4.86 |
| Ramp: Bottom | 4.89 |
| Ramp: RHS | 4.92 |

| | FWHM |
|----------------|--------------------|
| Ramp: LHS | 4.90 |
| Average | 4.89 |
| Std Dev | 0.02 (0.5%) |

Catphan 500 Alignment Slice

CONTENT_DATE TIME: 25/09/2006 18:55:21
DEVICE_SERIAL_NUMBER: 0000287.0035138
EXPOSURE_TIME: 1500
INSTITUTION_NAME: EDINBURGH CANCER CENTRE
KVP: 120
MANUFACTURER: GE MEDICAL SYSTEMS
MANUFACTURERS_MODEL_NAME: Speed
ME:
PATIENT_ID: xp_cat_060925
PATIENTS_NAME: xp_cat_060925
SLICE_LOCATION: +0.00
SLICE_THICKNESS: 5.0
X_RAY_TUBE_CURRENT: 200
Z_POS: 0



Phantom Alignment

| | COM - X (mm) | COM - Y (mm) |
|----------------|--------------|--------------|
| Phantom Centre | -0.58 | 0.79 |

Distances

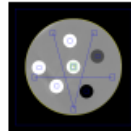
| | Distance Physical |
|----------------|--------------------|
| Distance: 1-2 | 50.07 |
| Distance: 2-3 | 50.29 |
| Distance: 3-4 | 50.13 |
| Distance: 4-1 | 50.11 |
| Average | 50.15 |
| Std Dev | 0.08 (0.2%) |

Sensitometry

| | Mean Value | Standard Deviation |
|----------------|--------------------------|--------------------|
| Air | -987.47 | 2.93 |
| LDPE | 955.92 | 2.91 |
| Acrylic | 116.94 | 2.91 |
| Teflon | -96.89 | 3.42 |
| Average | -2.87 | 3.04 |
| Std Dev | 691.36 (24050.9%) | 0.22 (7.1%) |

Large Varian Performance Phantom

CONTENT_DATE TIME: 27/10/2006 13:30:49
DEVICE_SERIAL_NUMBER: 0000287.0035138
INSTANCE_NUMBER: 3
KVP: 120
MANUFACTURER: GE MEDICAL SYSTEMS
MANUFACTURERS_MODEL_NAME: Speed
ME:
PATIENT_ID: xp_perLC_061027
PATIENTS_NAME: xp_perLC_061027
SLICE_LOCATION: +0.00
SLICE_THICKNESS: 3.0
TABLE_HEIGHT: -50
X_RAY_TUBE_CURRENT: 200
Z_POS: 0



Alignment

| | COM - X (mm) | COM - Y (mm) |
|----------------|--------------|--------------|
| Phantom Centre | 0.95 | -0.49 |

Geometry

| Object | Analysis | Expected Result | Result | Test Result |
|---------------|-------------------|----------------------|--------|-------------|
| Distance: 1-3 | Distance Physical | Within range 298,302 | 301.57 | PASS |
| Distance: 2-3 | Distance Physical | Within range 298,302 | 300.82 | PASS |
| Distance: 4-5 | Distance Physical | Within range 298,302 | 300.78 | PASS |

Sensitometry

| Object | Analysis | Expected Result | Result | Test Result |
|-----------|--------------------|-------------------------|---------|-------------|
| Water | Mean Value | Within range -5,5 | -2.80 | PASS |
| Water | Standard Deviation | | 4.23 | |
| Lung | Mean Value | Within range -742,-722 | -732.72 | PASS |
| Lung | Standard Deviation | | 3.40 | |
| Air | Mean Value | Within range -1005,-995 | -996.30 | PASS |
| Air | Standard Deviation | | 3.03 | |
| Hard Bone | Mean Value | Within range 1290,1310 | 1298.80 | PASS |
| Hard Bone | Standard Deviation | | 10.78 | |
| Soft Bone | Mean Value | Within range 179,199 | 184.40 | PASS |
| Soft Bone | Standard Deviation | | 7.87 | |

Resolution

| Object | Analysis | Expected Result | Result | Test Result |
|--------|----------|------------------------|--------|-------------|
| MTF | ISO | Within range 0.18,0.22 | 0.23 | FAIL |

MTF - MTF Graph

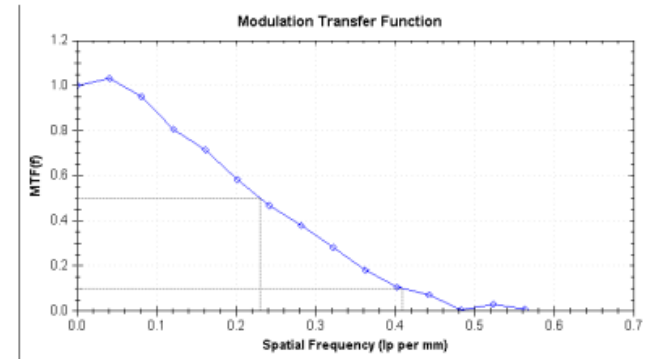


Image Number: 04

Report Generated: 15/11/2004 14:29:43

Storage Options

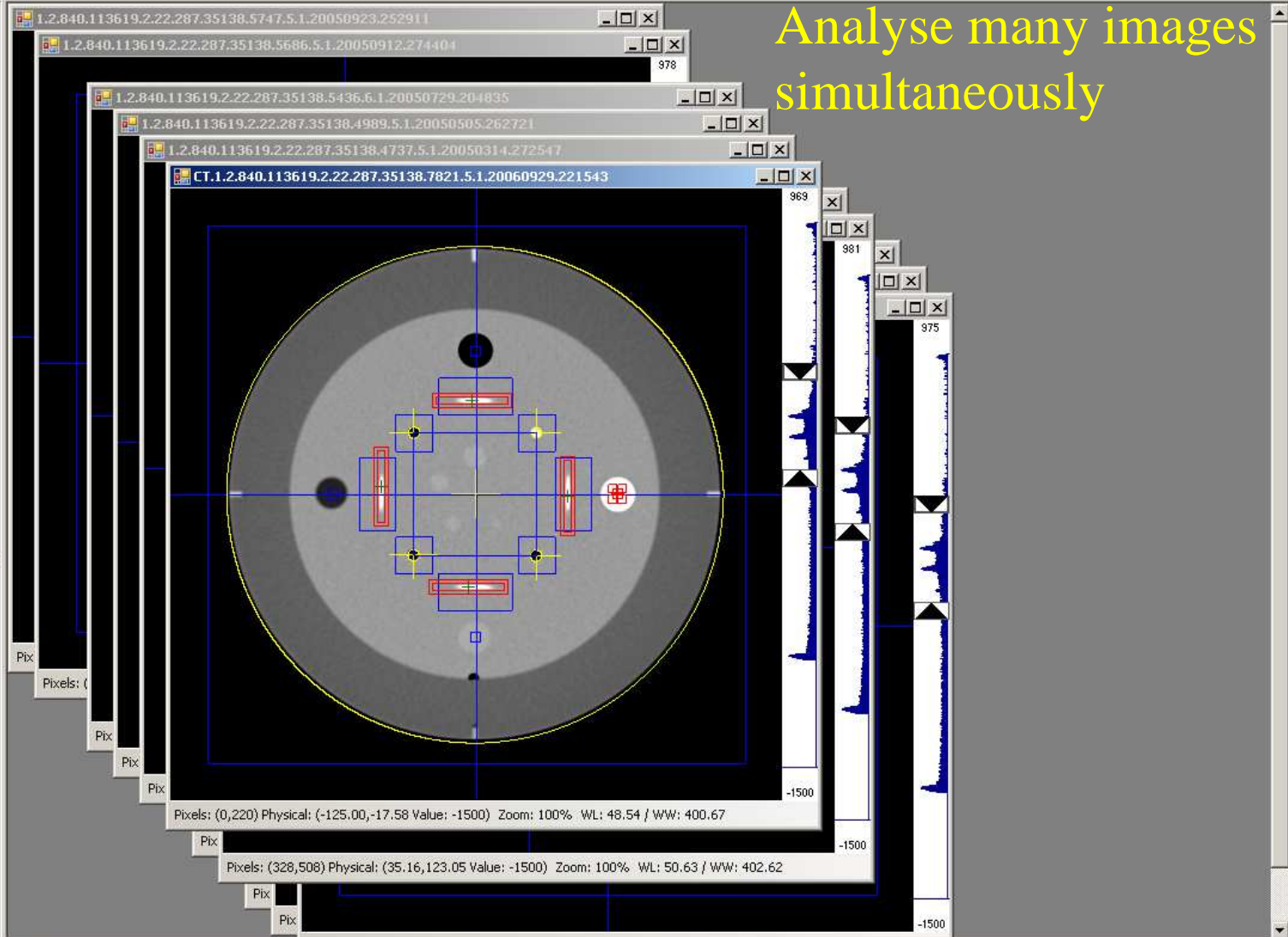
- CSV File
 - Opens easily in Excel
- PostgreSQL database
 - Can be queried by Access or Excel
 - Good for central storage of many tables
 - Better for number crunching

The screenshot shows a software interface with several panels. The 'Image Information' panel on the left has a list of fields with checkboxes, including 'CONTENT_DATETIME' which is checked. Below it is a 'Friendly Name' field containing 'CONTENT_DATETIME'. The 'Comments' panel is empty. The 'Summary Fields' panel has a 'Scientific Notation' checkbox and a 'Decimal Places' field set to '2'. The 'Report Output' panel has radio buttons for 'Word Doc', 'PDF', and 'HTML'. The 'Data Storage' panel, highlighted with a red border, has radio buttons for 'None', 'CSV File', and 'Database'. 'CSV File' is selected. Below it is a 'File Name' field containing 'F:\ImageMaster\results' and a 'Select' button. There is also a 'Data Store' dropdown menu and a 'Table' field with a 'Create' button. At the bottom of the 'Data Storage' panel is a 'Store Now' button.



- Catphan 500 Alignment
 - Phantom Alignment
 - Phantom Centre
 - Distances
 - Hole 1
 - Hole 2
 - Hole 3
 - Hole 4
 - Distance: 1-2
 - Distance: 2-3
 - Distance: 3-4
 - Distance: 4-1
 - Sensitometry
 - Air
 - LDPE
 - Acrylic
 - Teflon
 - Ramps
 - Ramp: Top
 - Ramp: Bottom
 - Ramp: RHS
 - Ramp: LHS
 - Report

Analyse many images simultaneously

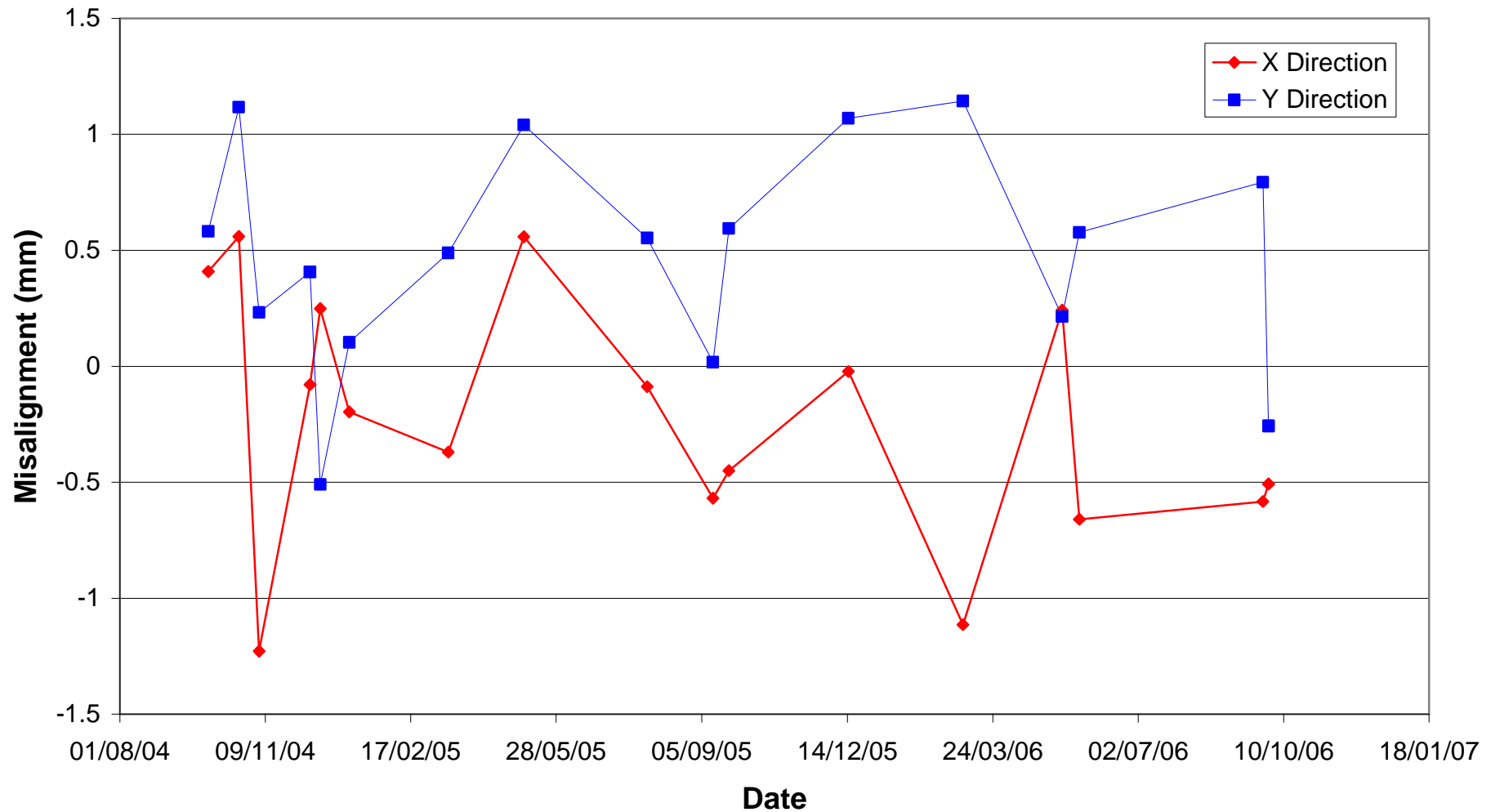


- CT.1.2.840.113619.2.22.287.35138.7821.5.1.20060929.221543
- CT.1.2.840.113619.2.22.287.35138.7789.5.1.20060925.295521
- CT.1.2.840.113619.2.22.287.35138.7045.6.1.20060522.234241
- 1.2.840.113619.2.22.287.35138.6979.5.1.20060510.274812
- 1.2.840.113619.2.22.287.35138.6617.5.1.20060303.224803
- 1.2.840.113619.2.22.287.35138.6227.5.1.20051214.271647
- 1.2.840.113619.2.22.287.35138.5686.5.1.20050912.274404
- 1.2.840.113619.2.22.287.35138.5436.6.1.20050729.204835
- 1.2.840.113619.2.22.287.35138.4989.5.1.20050505.262721
- 1.2.840.113619.2.22.287.35138.4413.5.1.20050105.270741
- 1.2.840.113619.2.22.287.35138.4348.5.1.20041216.264412
- 1.2.840.113619.2.22.287.35138.4309.5.1.20041209.271605
- 1.2.840.113619.2.22.287.35138.4066.5.1.20041021.280547
- 1.2.840.113619.2.22.287.35138.3952.5.1.20040930.274110

CT Simulator Alignment



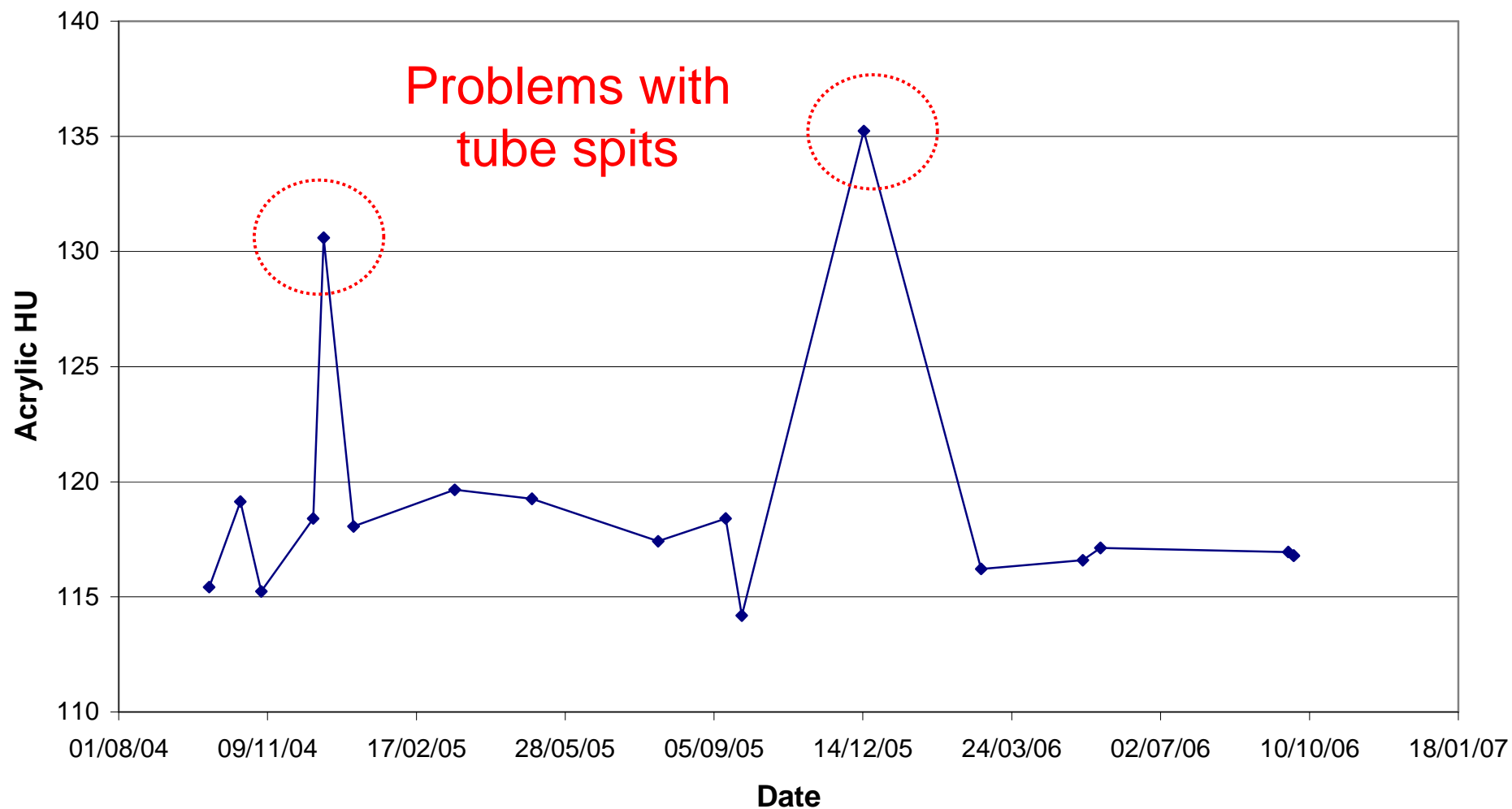
Phantom Alignment Time-Trend



Sensitometry Trends

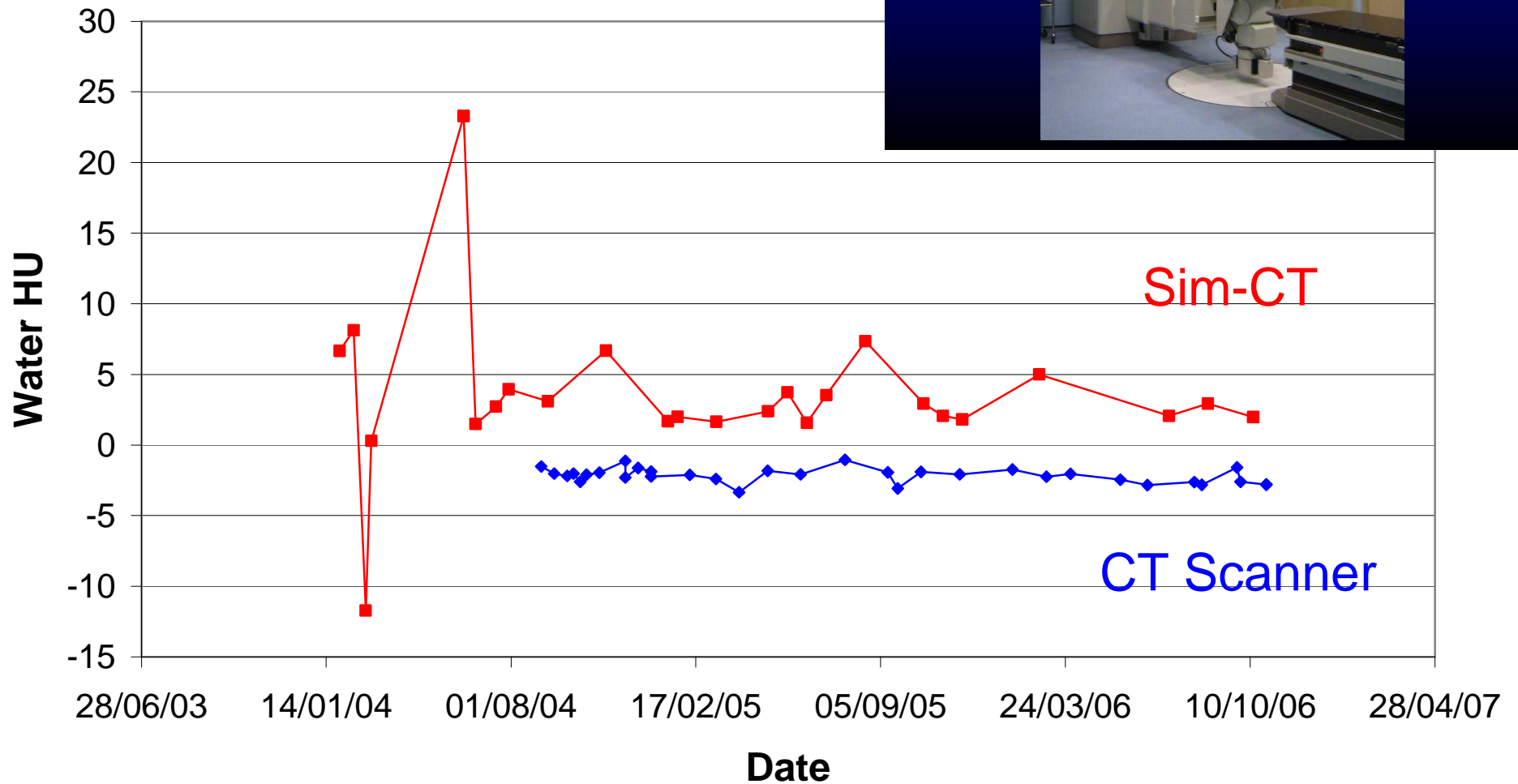
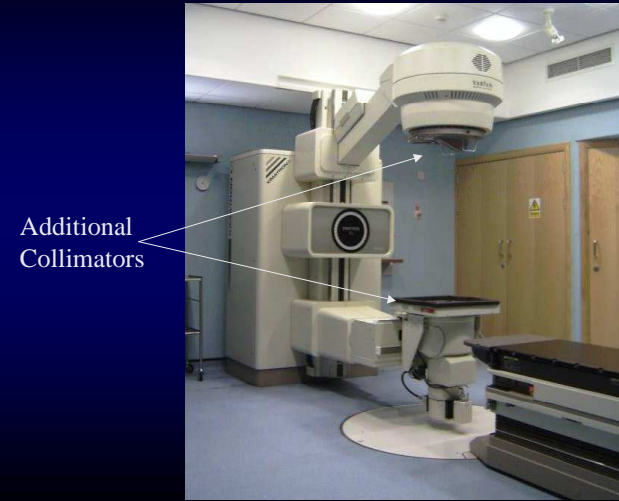


Acrylic Sensitometry



CT Scanner vs Sim-CT

Sim-CT Hardware



Other Modalities: Electronic Portal Imaging



Image Master v0.4 - 15/11/2006

File Edit View Process Analysis Generate Tools Test Windows Help

Process Group

- Uniform_1
- Uniform_2
- Region_1
- Region_2
- Region_3
- Region_4
- Region_5
- Droegre_MTF
- Report

SPI00026.dcm

Droegre MTF Analysis

Number of ROIs: 5

| | | | | |
|---|--------------------|------|------------------|---------------------|
| 1 | Region_5: ROIStats | 0.1 | Uniform Region 1 | Uniform_1: ROIStats |
| 2 | Region_4: ROIStats | 0.2 | Uniform Region 1 | Uniform_2: ROIStats |
| 3 | Region_3: ROIStats | 0.25 | Noise Region | Uniform_2: ROIStats |
| 4 | Region_2: ROIStats | 0.45 | | |
| 5 | Region_1: ROIStats | 0.76 | | |

Frequencies to Determine: 0.5

Correct for Noise

Plot Graph

Freq for 0.5 (/mm): 0.345

MTF - SPI00026.dcm

Modulation Transfer Function

| Spatial Frequency (lp per mm) | MTF(0) |
|-------------------------------|--------|
| 0.0 | 1.0 |
| 0.1 | 0.75 |
| 0.2 | 0.65 |
| 0.3 | 0.55 |
| 0.4 | 0.48 |
| 0.5 | 0.42 |
| 0.6 | 0.36 |
| 0.7 | 0.30 |
| 0.8 | 0.25 |

Graph Limits. X - Min: 0 Max: 0.9 Y - Min: 0 Max: 1.2 Update Copy Log Y

Pixel: (476,23) Physical: (123.20,-94.64 Value: -3443) Zoom: 100% WL: -2448

Pixel: (336,501) Physical: (39.06,119.63 Value: -1500) Zoom: 100% WL: 44.78 / W

NR 6
RTE
LIH
R
W 10
15.0
10:5

Conclusions and the Future



- Developed general analysis framework, applicable to CT and other modalities
- Package is flexible without requiring additional programming
- Reporting, testing and storage functionality
- Currently in routine use in ECC

- Plug and play analysis framework to be developed
- Bugs need fixed!