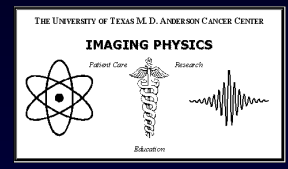
THE UNIVERSITY OF TEXAS
MD ANDERSON
CANCER CENTER
Making Cancer History™



DICOM® Basics for Radiographic and Fluoroscopic Systems

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2004 AAPM Summer School

® DICOM is the registered trademark of the National Electrical Manufacturers Association for its standards publications relating to digital communications of medical information.

DICOM for R&F Systems

- DICOM Basics (Services, Objects, etc)
- DICOM Elements Essential to R/F
- Networking Basics and Connectivity
- Assessing Functionality of DICOM Services on R/F Systems
- Controlling the Quality of R/F Images Using DICOM
- The RFP for R/F Systems

DICOM Basics

Organization

- Services Classes
  - Store
  - Print
  - Query/Retrieve (Q/R)
- Information Objects
  - Modality work lists (MWL)
  - Schedule lists
  - Status updates
  - Images (CT, MR, RF, CR, DX, etc)

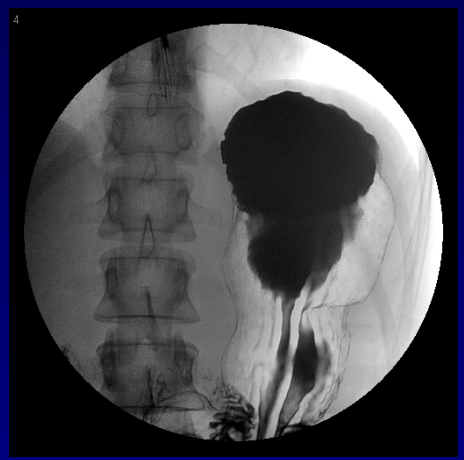
DICOM Basics

- Communication Event: “Instance”
- Service-Object Pair (SOP)
  - Store & RF Image (Store-RF)
  - Print & DX image (Print-DX)
  - Query/Retrieve & MWL (Q/R-MWL)
- Service class Users and Providers
  - Client is user
  - Server is provider

DICOM Basics

Service Class User (SCU)

Object



Service Class Provider (SCP)

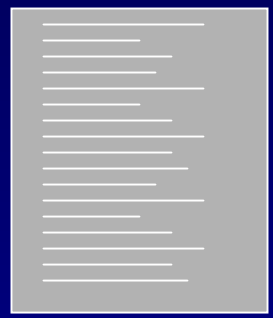
Store-RF SOP

DICOM Basics

SCP

Object

Q/R MWL SOP



Q/R MWL SOP

DICOM Basics

- DICOM
  - Storage Commitment
    - Modality sends number of images in each series
    - PACS responds with failure message if all are not received
  - Performed Procedure Step
    - Modality informs RIS of exam begin/end
    - Problematic for multimodality exams

DICOM Basics

- RFP (Conformance Statement)
  - Supported SOP's (SCU)
    - Store (RF, XF)
    - Print (RF, XF)
    - Q/R Modality Work List
    - Storage Commitment
    - Performed Procedure Step (Optional)

DICOM Elements for R/F

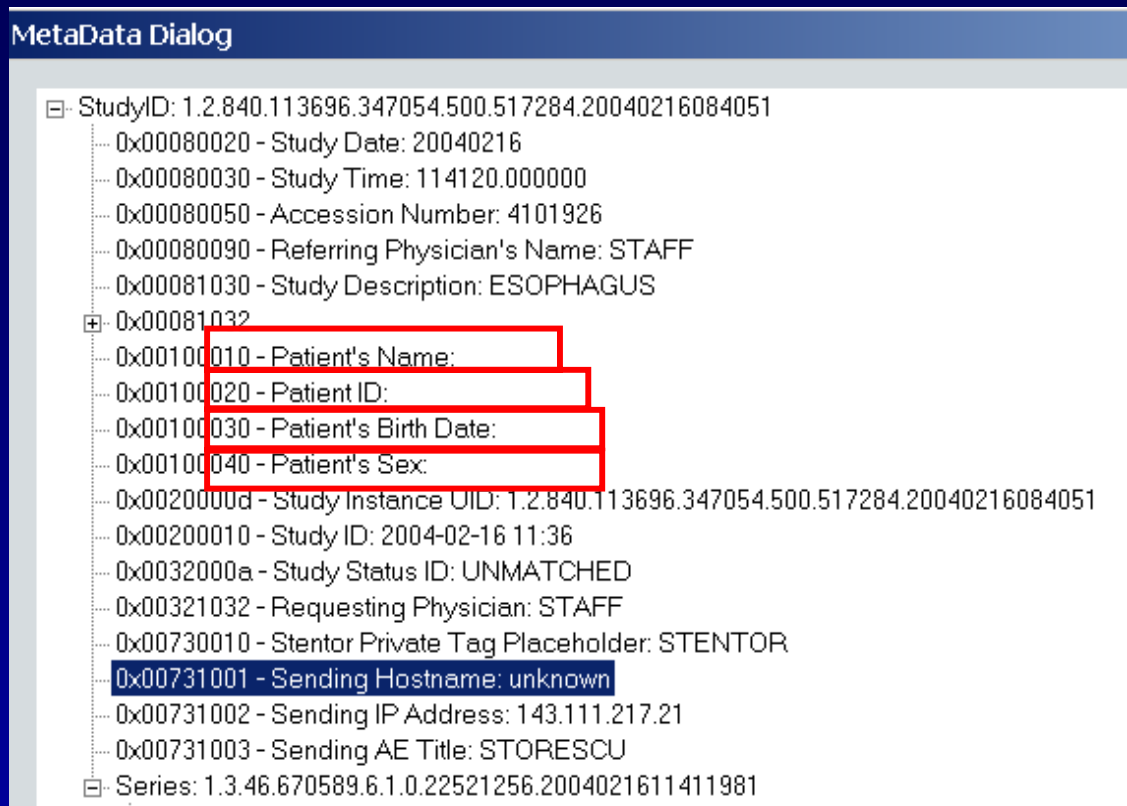
- Viewing DICOM object header information ("Meta Data")
- PACS provides tools for examination
- DICOM "tags" (Group,Element)
  - (0008,1030) Exam description
  - (0010,0010) Patient name
  - (0018,1030) Protocol description
  - (0028,0002) Samples per pixel

DICOM Elements for R/F

- Viewing header information
  - Presentation will depend on viewing tool
  - Layered structure
    - Patient, Study information
      - Consistent across all object types
    - Series, Image information
      - Will depend on type of object

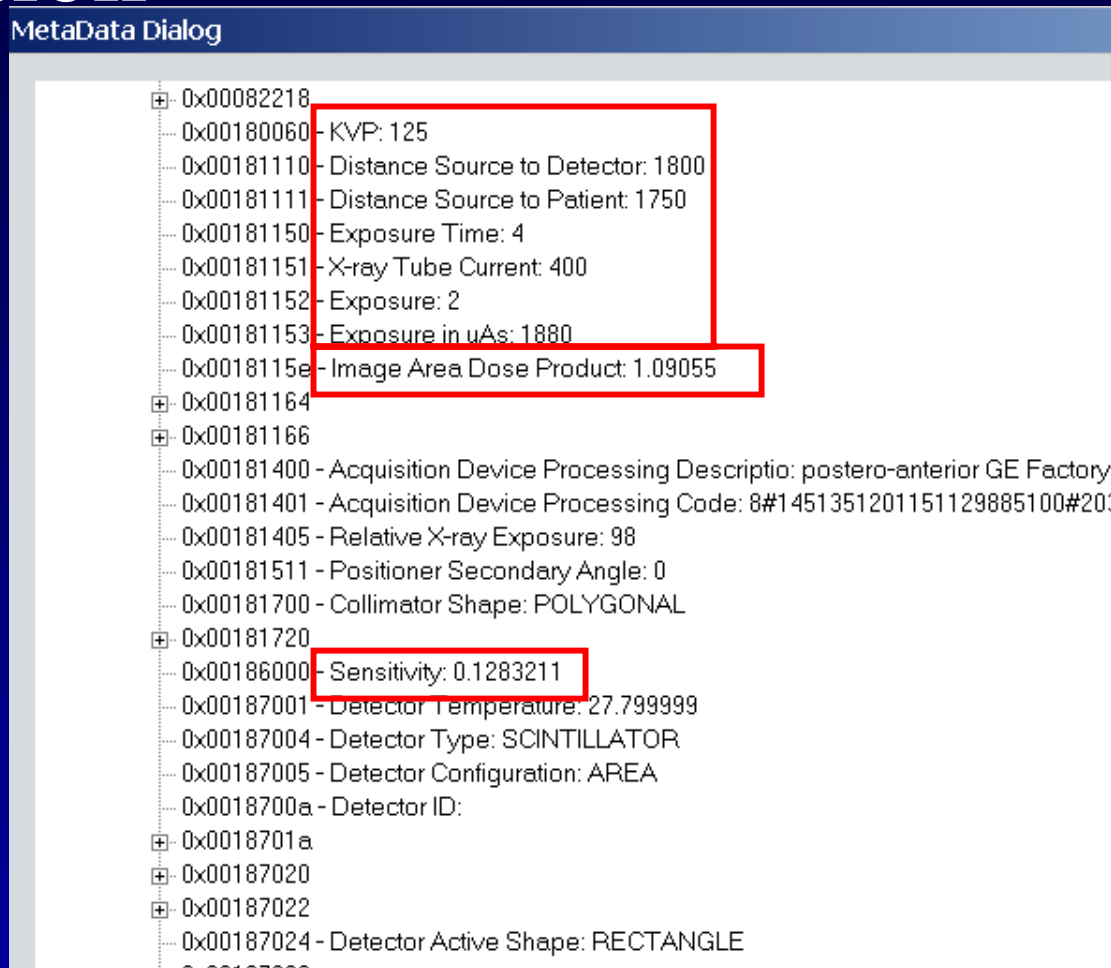
DICOM Elements for R/F

- Patient demographics
  - Patient Name
  - MRN
  - DOB
  - Sex



DICOM Elements for R/F

- Image information
  - Other Modalities (DX, CR, DR, etc)
    - Patient Dose
    - Technique factors
    - Exposure Index
  - Info. is specific to modality type



Basic Networking

All devices must configured for TCP/IP (Transmission Control Protocol / Internet Protocol) communications

- Host name
  - Identification to other machines
- IP Address
  - Internet Protocol address
    - (xxx.xxx.xxx.xxx)
    - xxx – "Octet" (0 – 255)
  - Used by routers to route information packets ("datagrams")

Basic Networking

- IP Address
  - May be fixed or assigned by a server
    - Dynamic Host Configuration Protocol (DHCP)
- Host and IP may be required to communicate
  - "Promiscuous" mode if not required
  - *DHCP is contraindicated for operation with PACS and RIS (non-promiscuous)*

Basic Networking

- Default Gateway
  - Address of traffic control device (“switch”) for the local area network (LAN)

Basic Networking

- Subnet Mask
  - Defines the class of the device's communications (router, gateway or client)
  - Identifies which devices require traffic to be routed through a gateway
    - "Netmask =255.255.255.0" means that any devices on the subnet with the same first three IP's can communicate directly without going through a router ("Class C" operation)

Basic Networking for DICOM

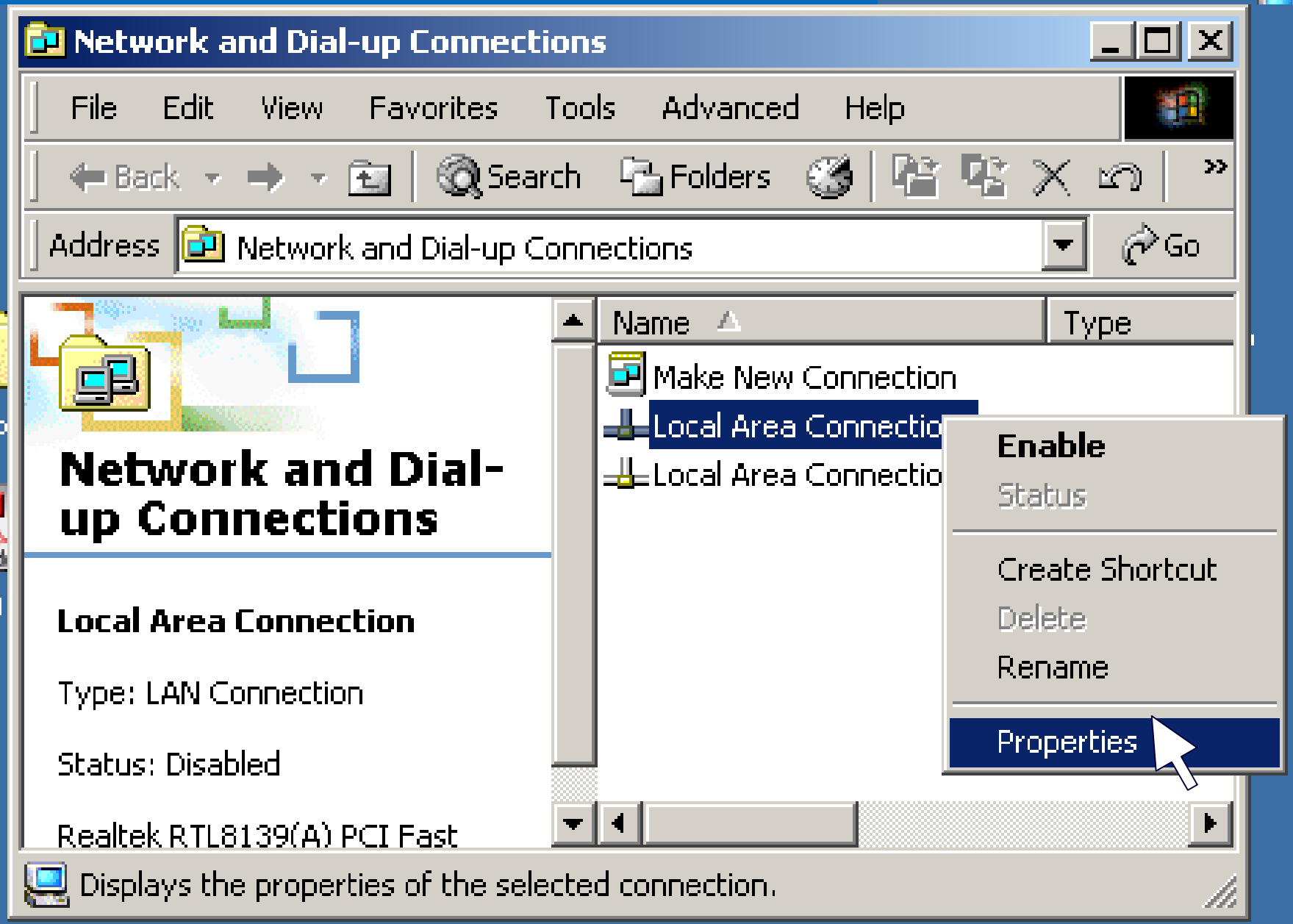
- Port #
  - Logical endpoint for connection
  - Specific to type of activity (104 common for DICOM)
  - Different SC's may use different ports on same device

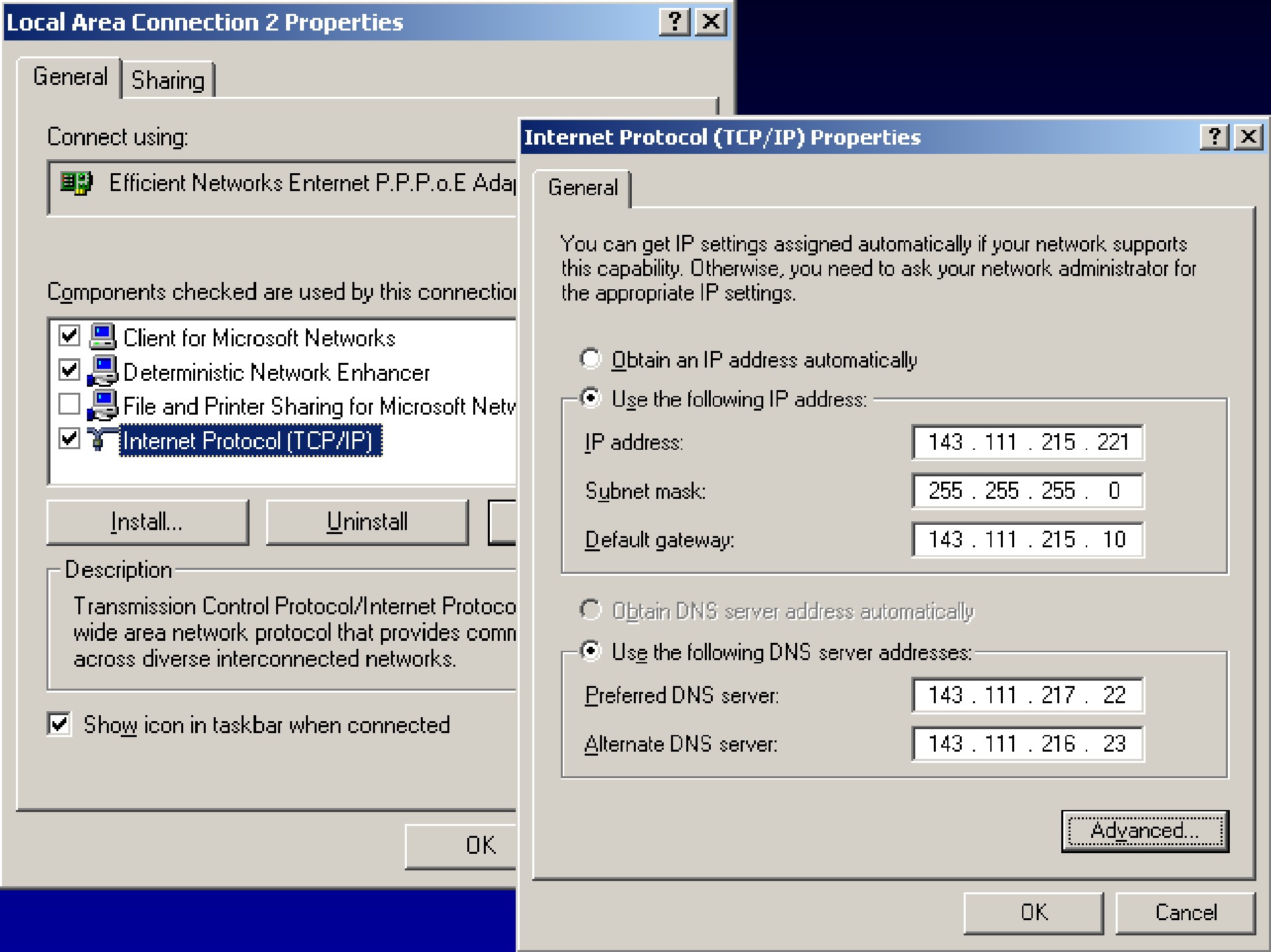
Basic Networking for DICOM

- Application Entity Title ("AE Title" or AET)
  - Unique device name used for a particular DICOM service on a device (like a password)
  - May have several for different service classes ("ct5" for Store, "PR-ct5_SCU" for Print)

Basic Networking for DICOM

- "Host" table
  - List of aliases used by applications
  - IP, AET and Port of all other DICOM devices


Network and Dial-up Connections
File Edit View Favorites Tools Advanced Help
Back Search Folders
Address Network and Dial-up Connections
Go
Network and Dial-up Connections
Local Area Connection
Type: LAN Connection
Status: Disabled
Realtek RTL8139(A) PCI Fast
Name
Type
Make New Connection
Local Area Connectio
Local Area Connectio
Enable
Status
Create Shortcut
Delete
Rename
Properties
Displays the properties of the selected connection.

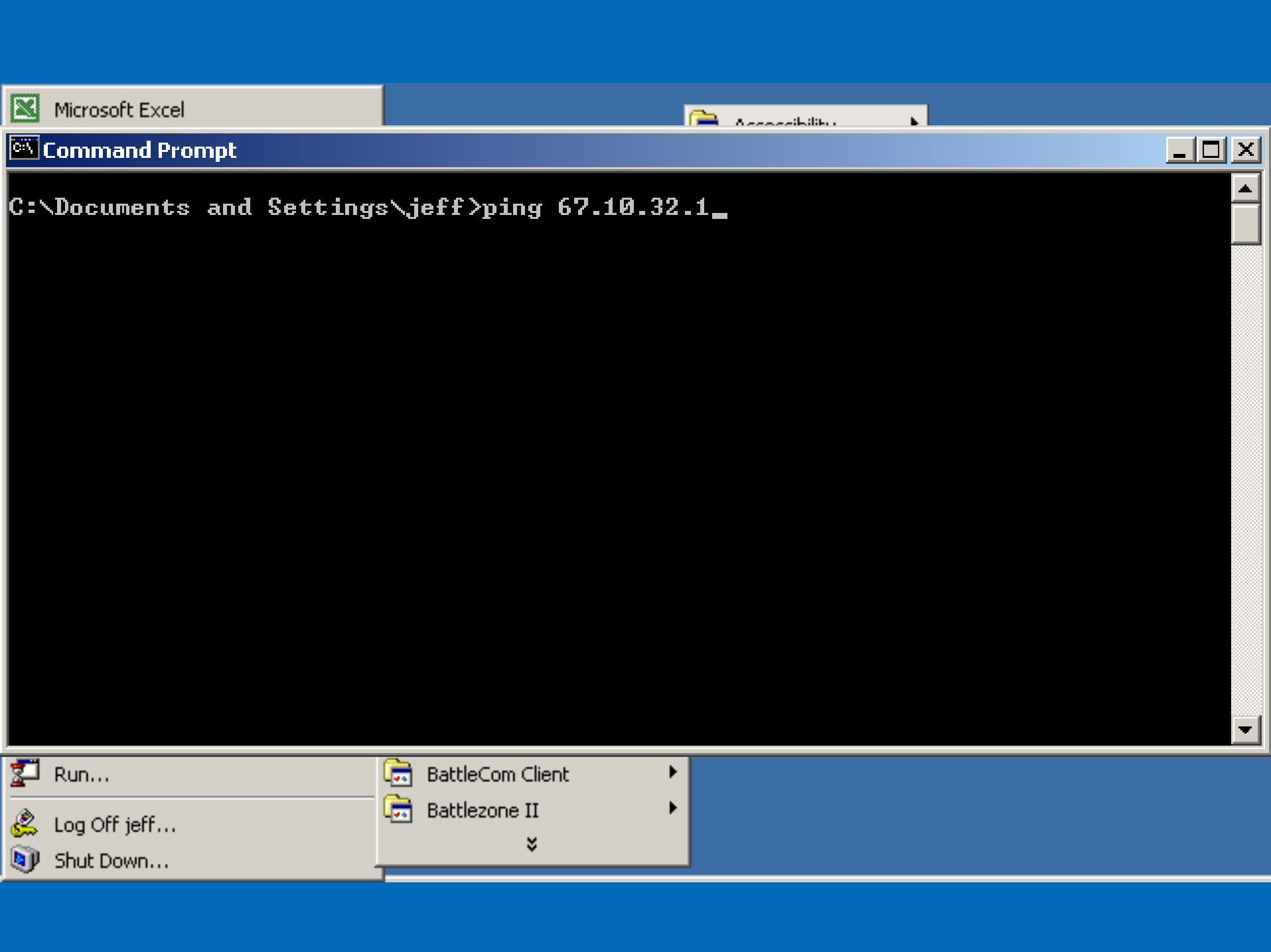

Local Area Connection 2 Properties
General
Sharing
Connect using:
Efficient Networks Enternet P.P.P.o.E Ada
Components checked are used by this connectio
Client for Microsoft Networks
Deterministic Network Enhancer
File and Printer Sharing for Microsoft Netv
Internet Protocol (TCP/IP)
Install...
Uninstall
Description
Transmission Control Protocol/Internet Protoco
wide area network protocol that provides comn
across diverse interconnected networks.
Show icon in taskbar when connected
OK
Internet Protocol (TCP/IP) Properties
General
You can get IP settings assigned automatically if your network supports this capability. Otherwise, you need to ask your network administrator for the appropriate IP settings.
Obtain an IP address automatically
Use the following IP address:
IP address: 143 . 111 . 215 . 221
Subnet mask: 255 . 255 . 255 . 0
Default gateway: 143 . 111 . 215 . 10
Obtain DNS server address automatically
Use the following DNS server addresses:
Preferred DNS server: 143 . 111 . 217 . 22
Alternate DNS server: 143 . 111 . 216 . 23
Advanced...
OK
Cancel

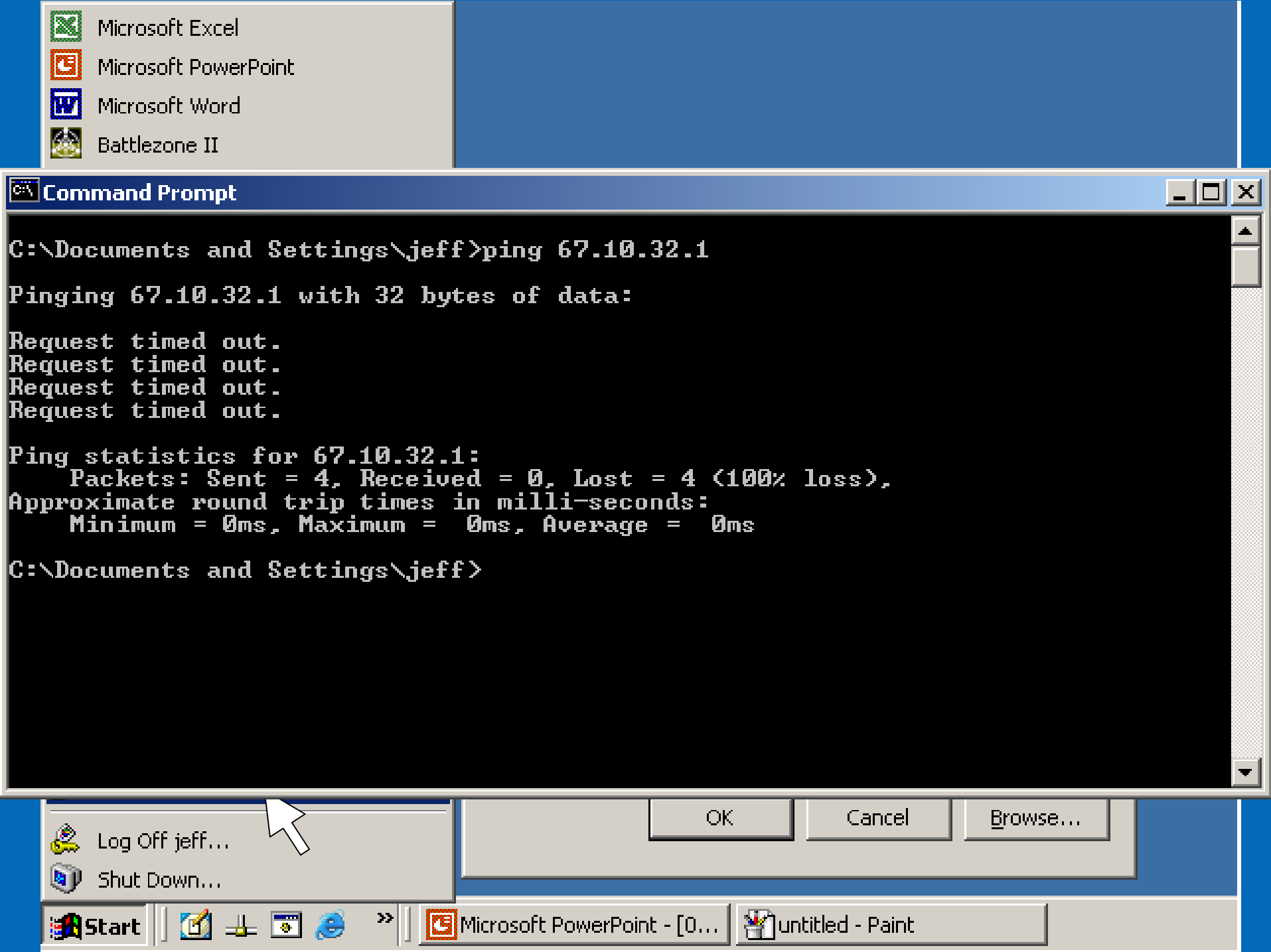
Assessing Functionality

- Elements in the header affect:
  - Patient Identification (RIS)
  - Image Quality (PACS and Print)
  - Hanging Protocols (PACS)
- Functional assessment consists of assuring that the tags are preserved during transmission and are properly applied by the PACS, RIS, and printer.

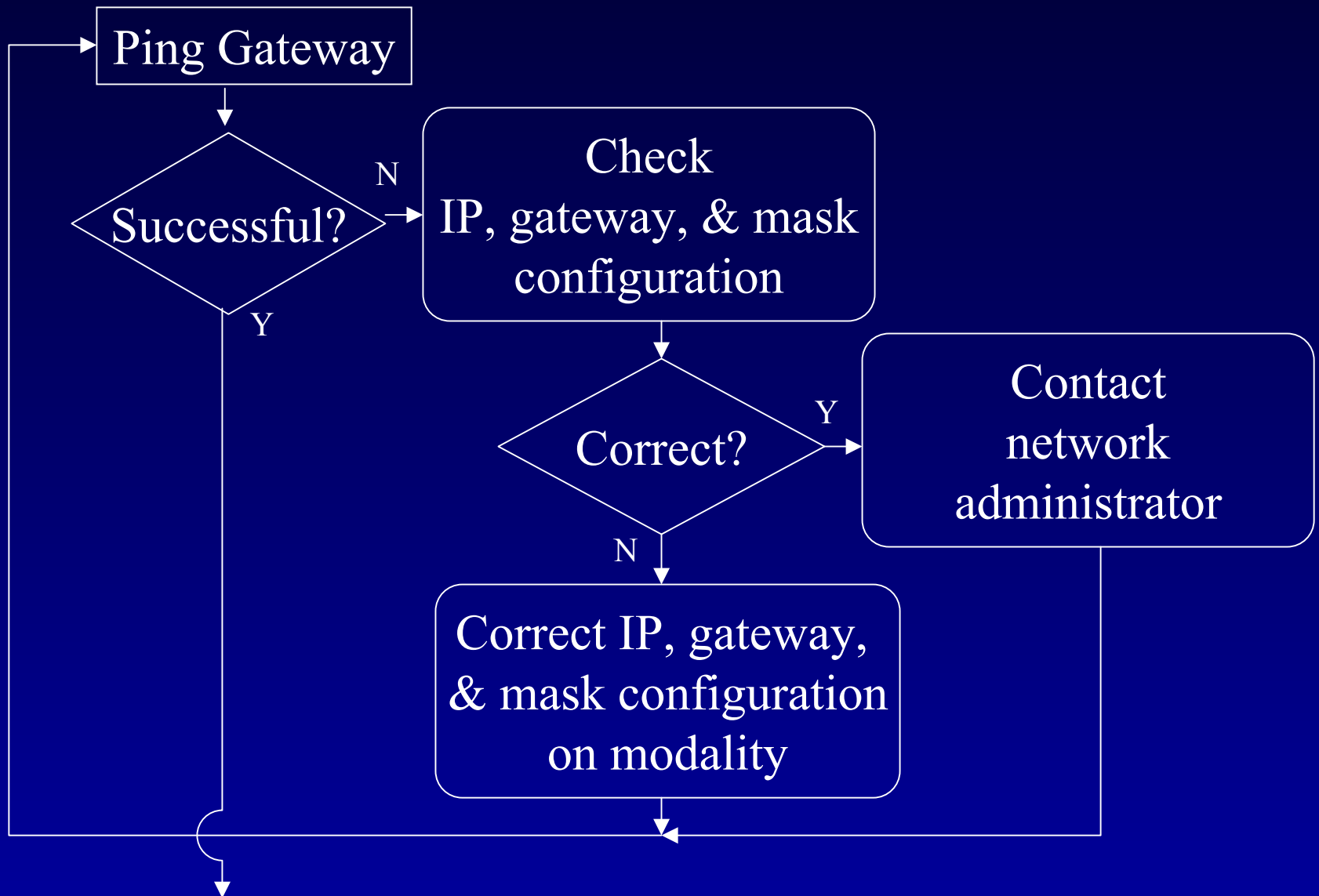
Assessing Functionality

- Network operation
  - Ping
    - Gateway (tests modality and switch configuration)
    - RIS, PACS & Print (tests modality configuration)

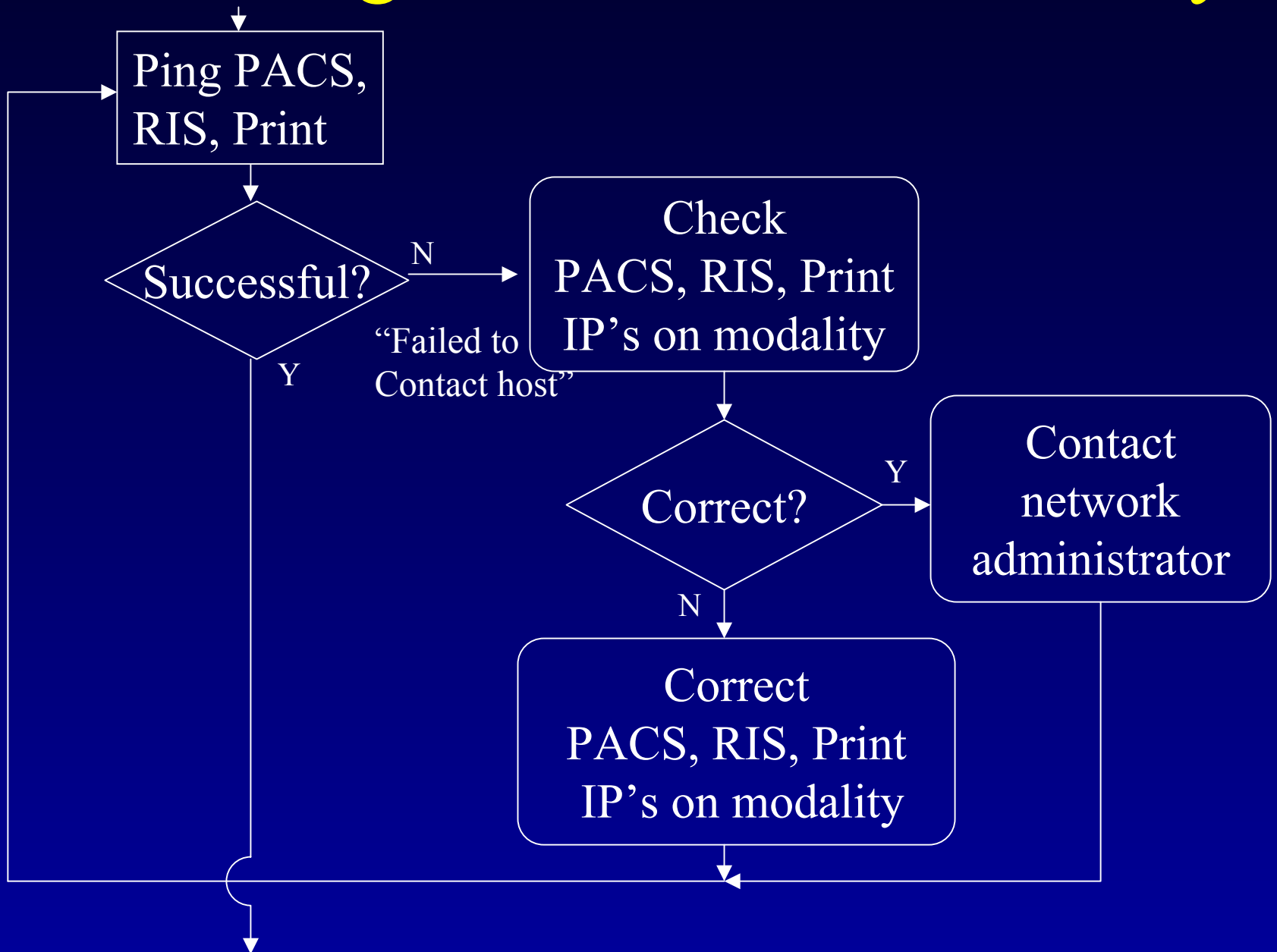

Microsoft Excel
Command Prompt
C:\Documents and Settings\jeff>ping 67.10.32.1
Run...
Log Off jeff...
Shut Down...
BattleCom Client
Battlezone II


Microsoft Excel
Microsoft PowerPoint
Microsoft Word
Battlezone II
Command Prompt
C:\Documents and Settings\jeff>ping 67.10.32.1
Pinging 67.10.32.1 with 32 bytes of data:
Request timed out.
Request timed out.
Request timed out.
Request timed out.
Ping statistics for 67.10.32.1:
Packets: Sent = 4, Received = 0, Lost = 4 (100% loss),
Approximate round trip times in milli-seconds:
Minimum = 0ms, Maximum = 0ms, Average = 0ms
C:\Documents and Settings\jeff>
OK
Cancel
Browse...
Log Off jeff...
Shut Down...
Start
Microsoft PowerPoint - [O...
untitled - Paint

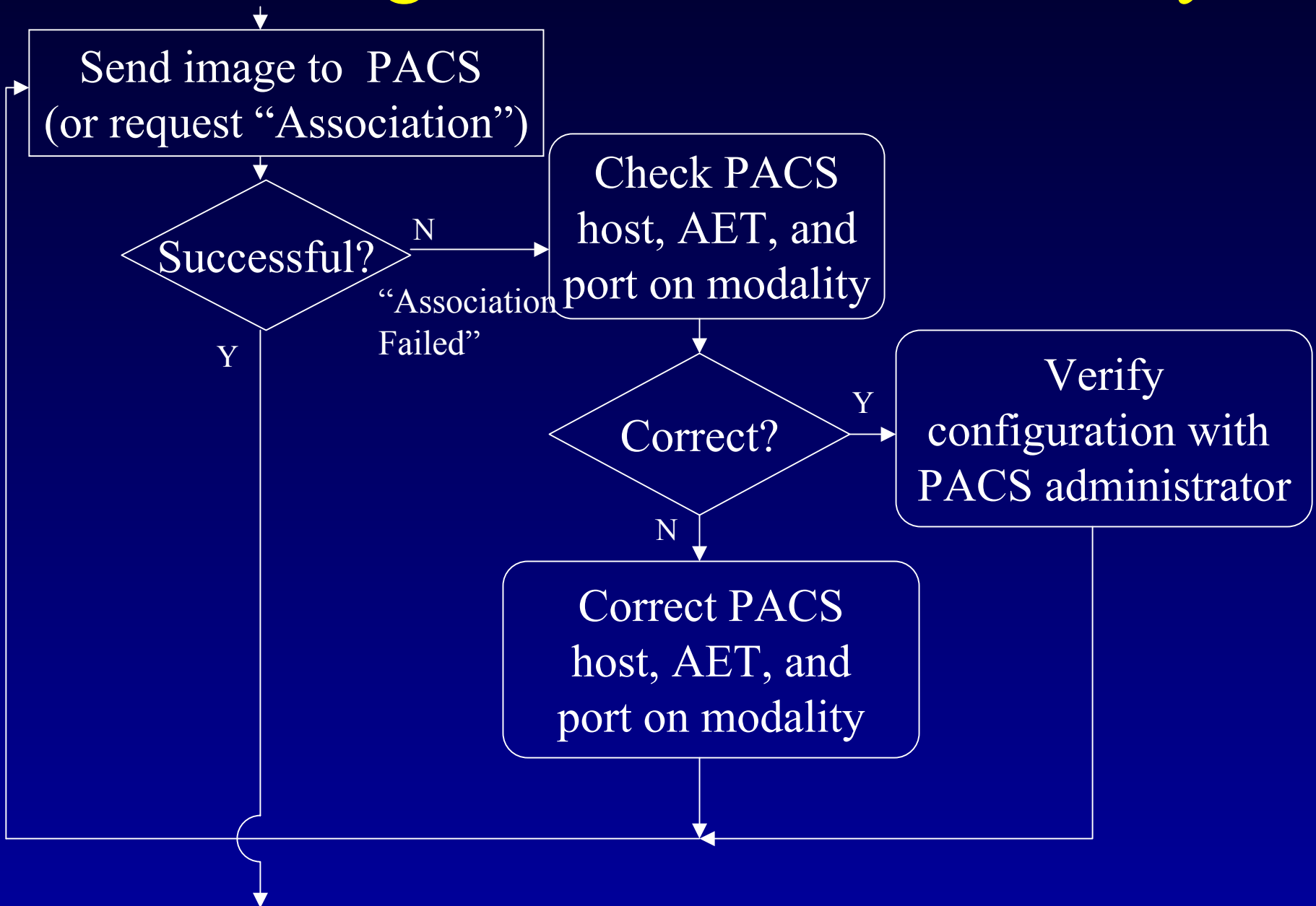
Assessing Network Functionality



Assessing Network Functionality



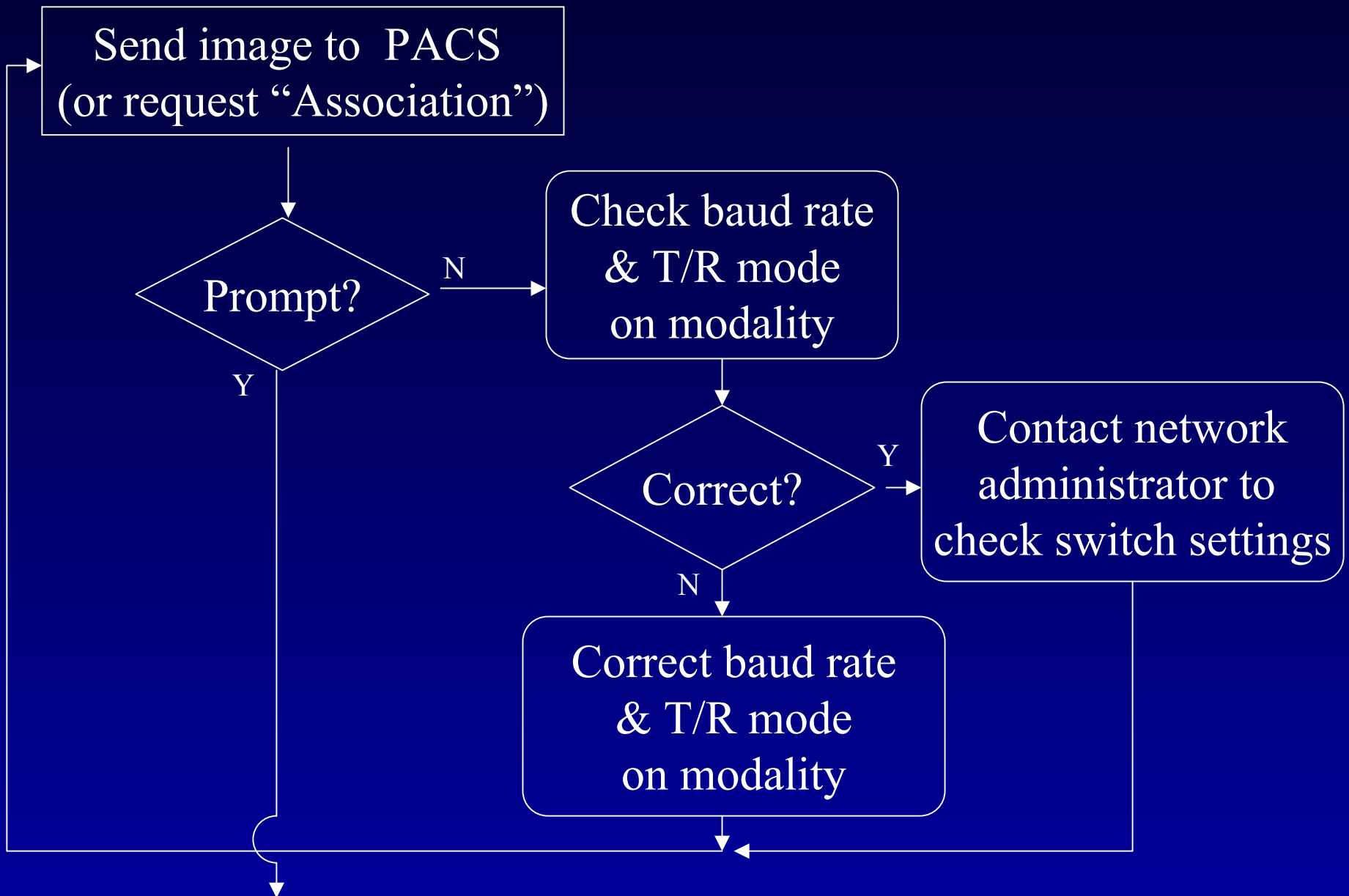
Assessing Network Functionality



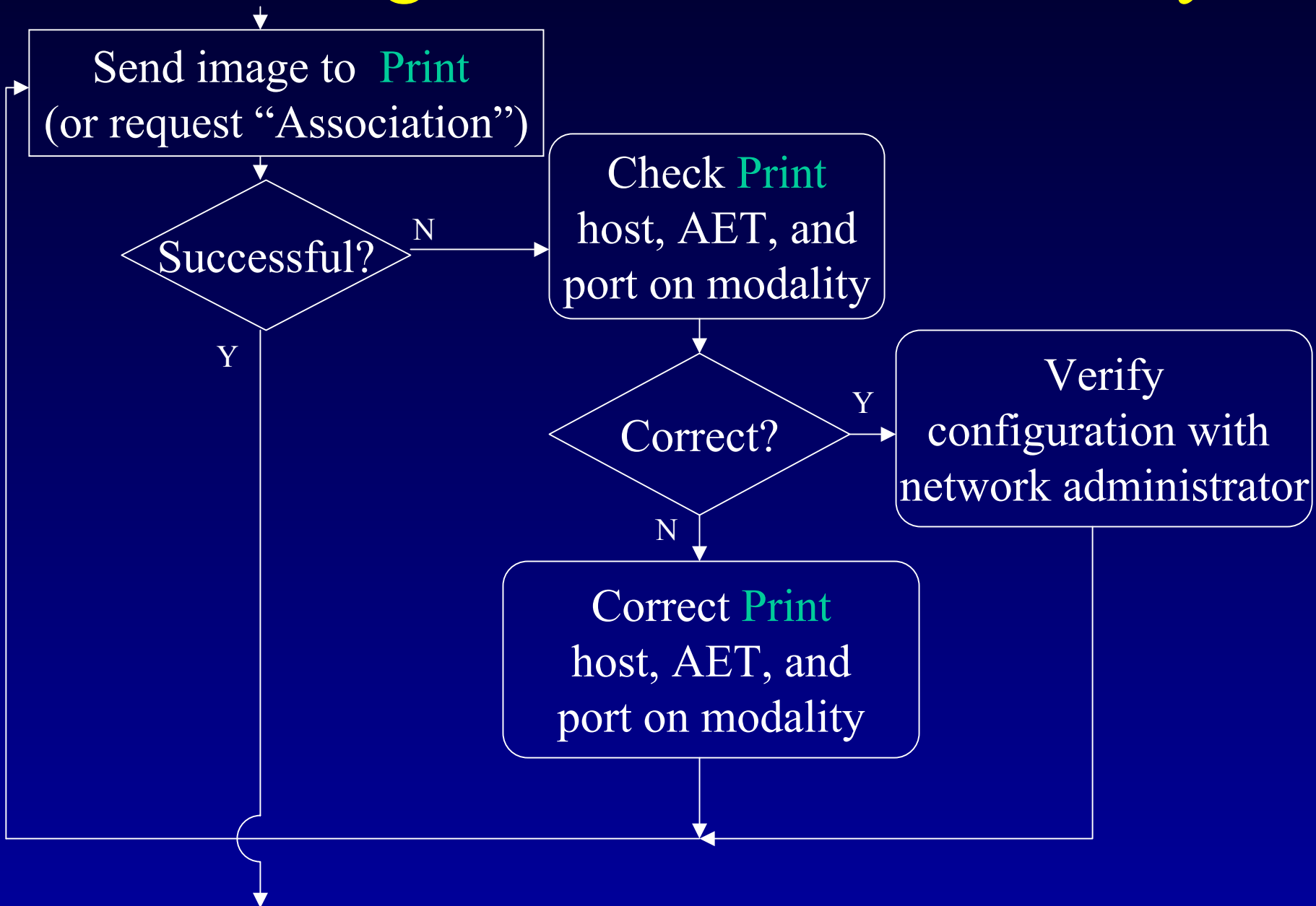
Assessing Functionality

- Transmission speed and duplex operation
  - Speed : Baud rate (ie 10 Mbps or 100 Mbps)
  - Duplex : Transmit/Receive mode
    - Full- (two-way) or half- (one-way only)
  - Must be configured consistently on both gateway and client

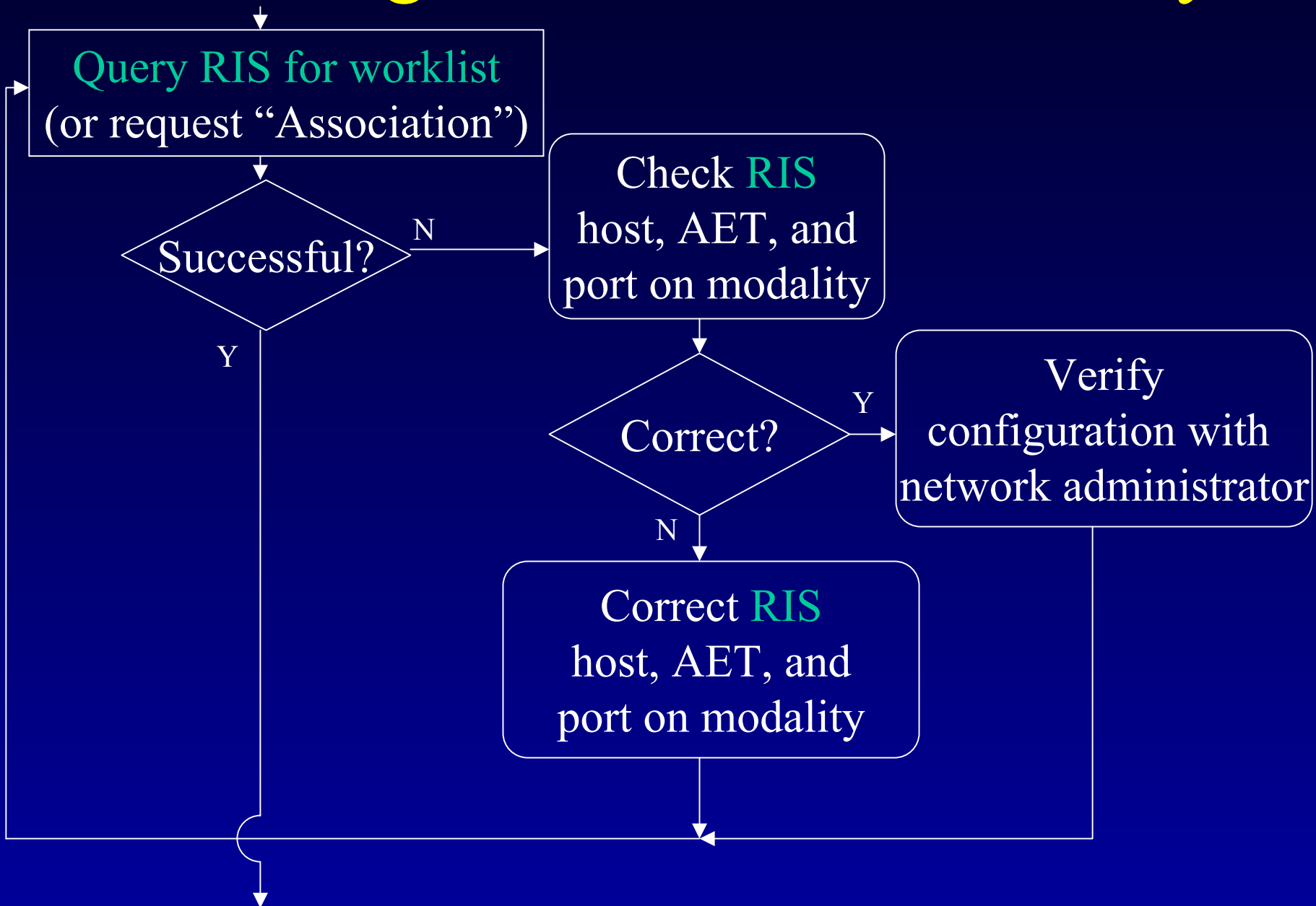
Assessing Network Functionality



Assessing Network Functionality



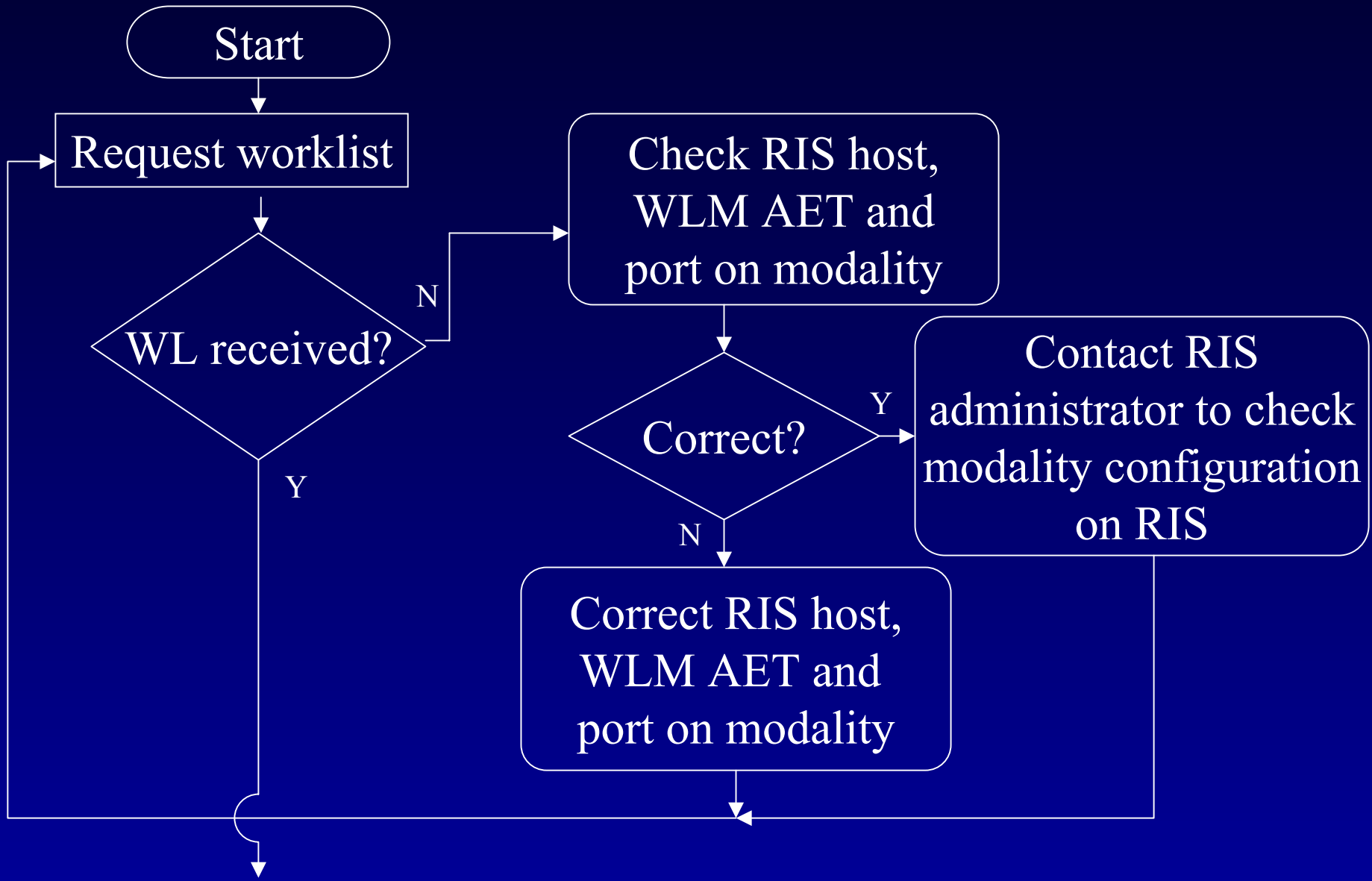
Assessing Network Functionality



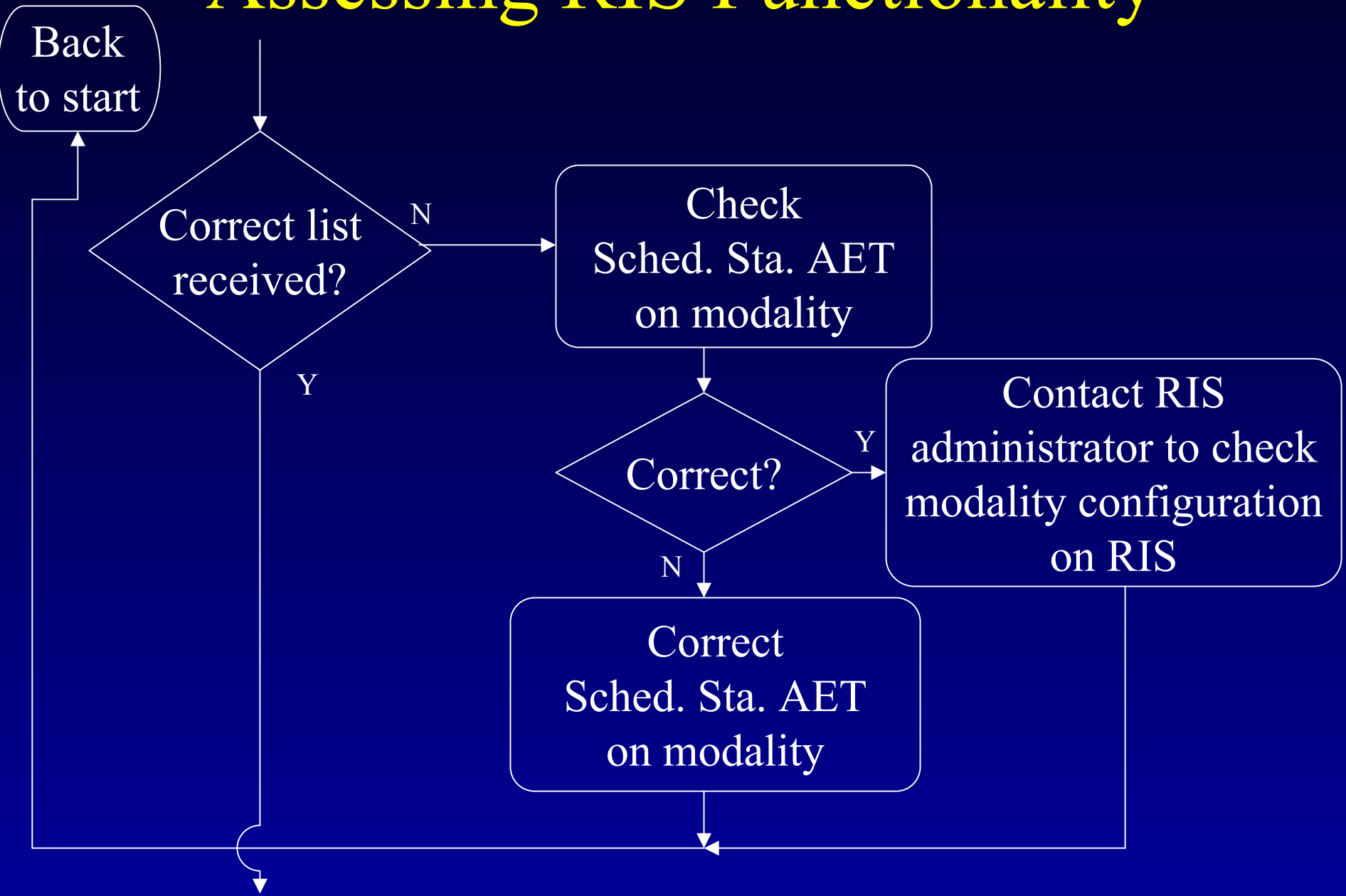
Assessing Functionality

- With RIS
  - Configure RIS with Host name, IP, AET, port #, and object type for the modality
  - RIS responds with appropriate list of scheduled exams
    - For the device
    - For a time interval

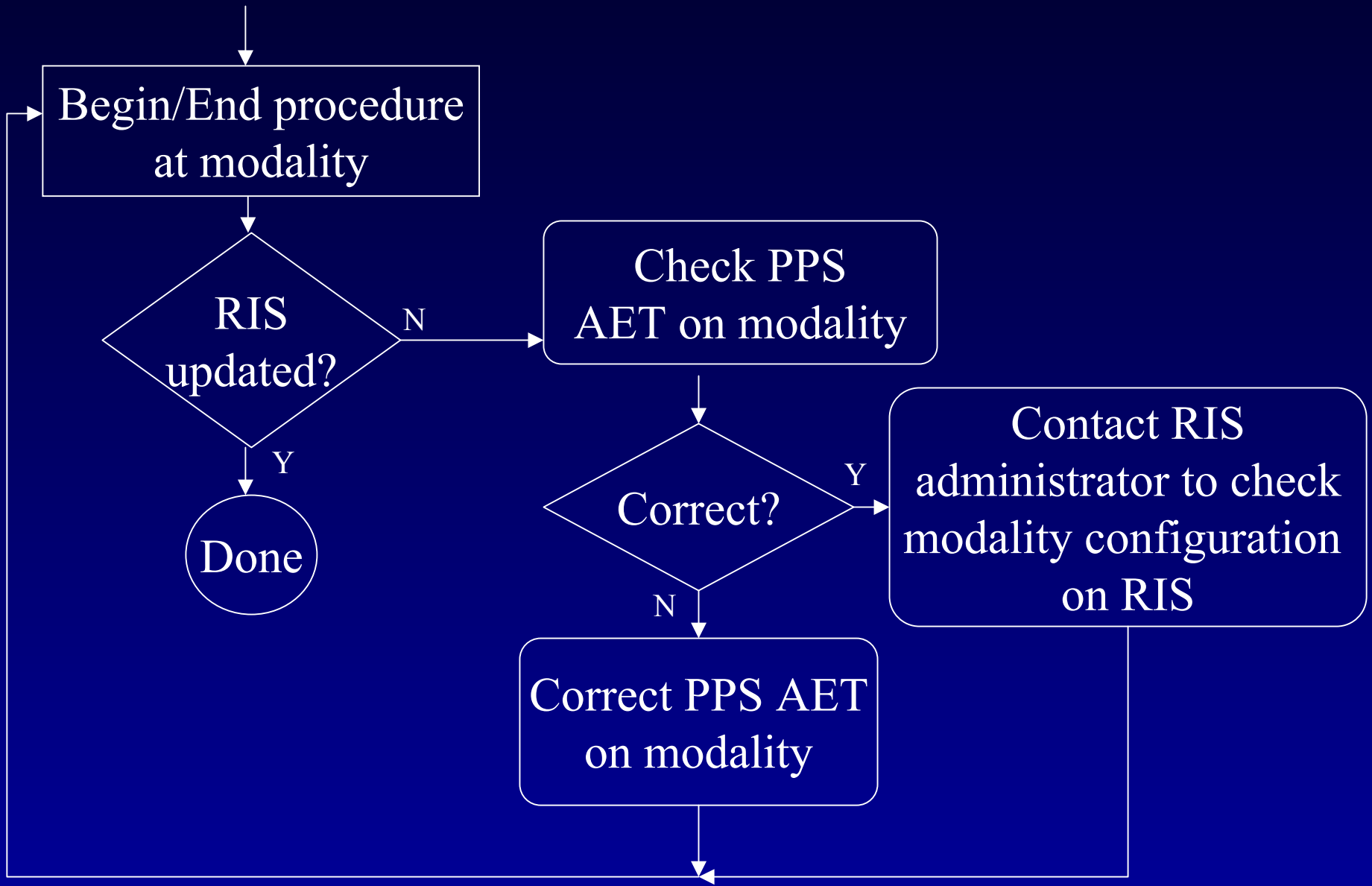
Assessing RIS Functionality



Assessing RIS Functionality



Assessing RIS Functionality

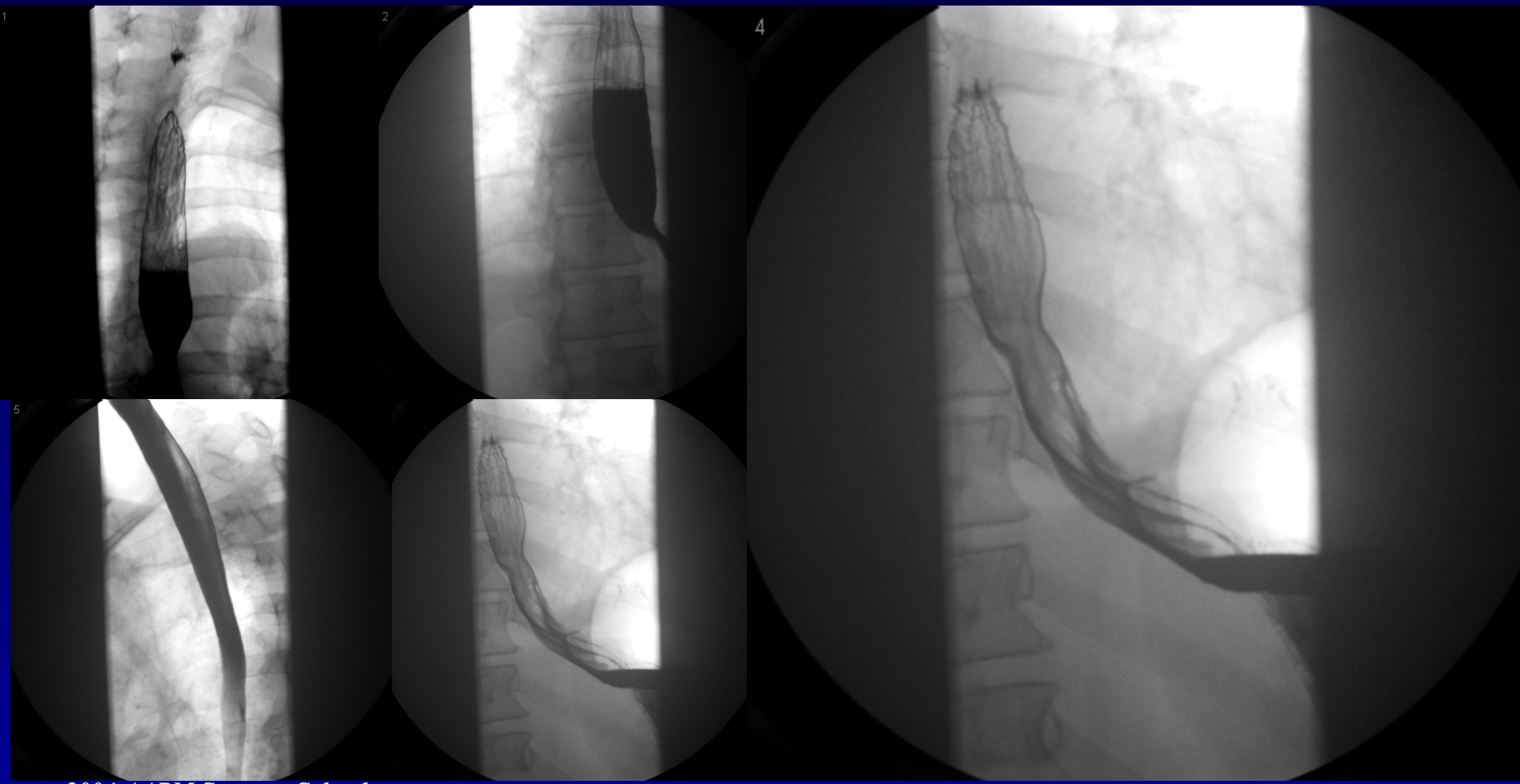


Assessing Functionality

With PACS

- PACS configuration
  - Modality host, AET, IP, and port
- Check:
  - Correct Patient and study demographics
  - Series and Study descriptions (Hanging protocols)
    - Extract from study name from RIS, if possible

Assessing Functionality



Assessing Functionality

With PACS (cont'd)

- Presentation State (electronic masks, image flip, image rotate, image reversal, annotations and LUT's)
- Detector exposure indices (Pt. dose and noise)
- Patient dose indicator accuracy
- Pixel spacing (measurements in mm, not pixels)

Image Quality (PACS)

- If PACS workstation is designed to post-process raw images,
  - Verify post-processing parameters are present in header
  - Verify post-processing parameters are applied properly by workstation

Image Quality (PACS)

- Check header on PACS to verify:
  - Widow width (0028,1050)
  - Window level or center (0028,1051)
- Check that PACS applies modality WW and WL
- Turn off "Modality Gamma" on PACS

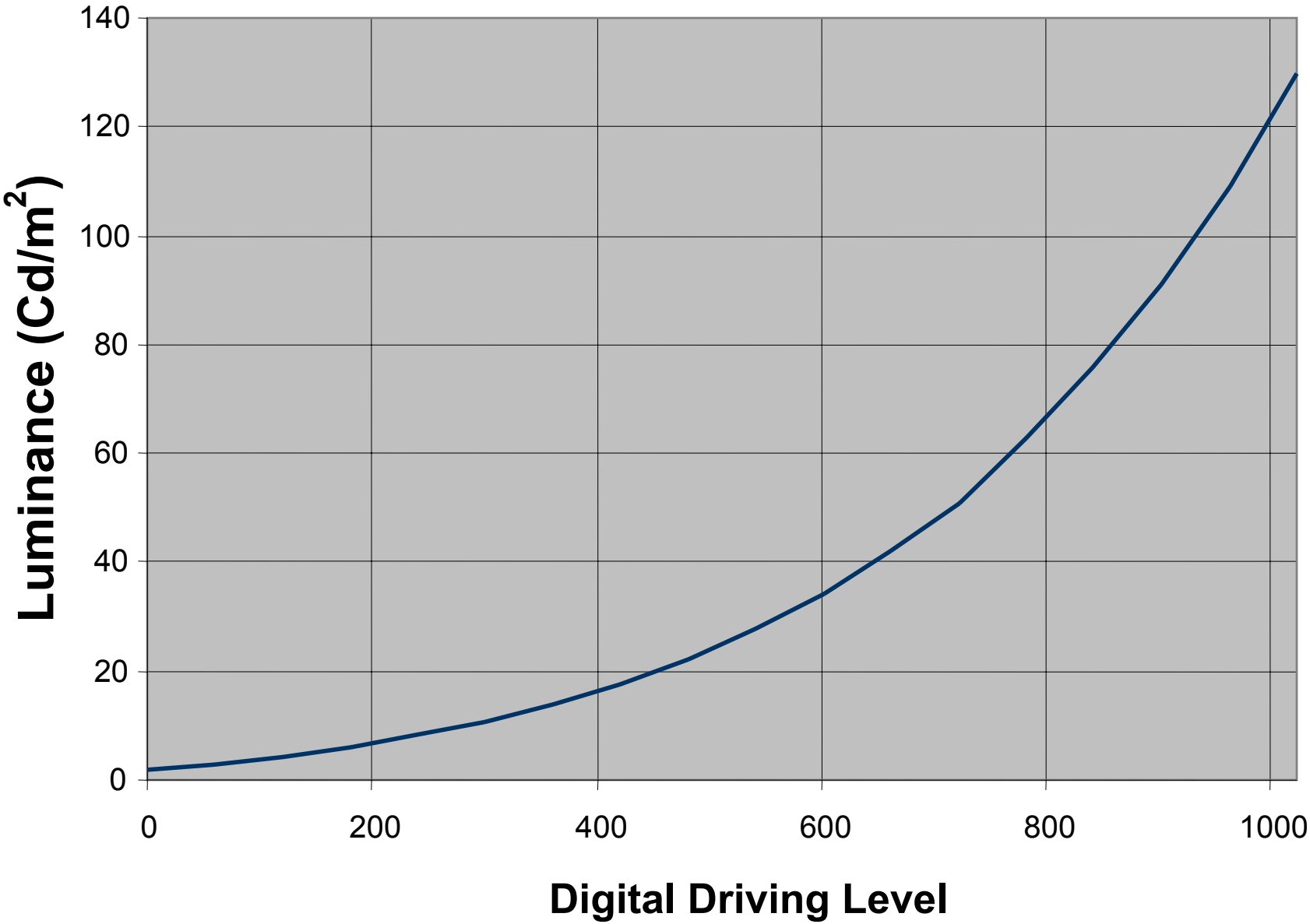
Image Quality (PACS)

- LUT
  - Rescale Type (0028,0054) = "US"
  - Rescale Slope (0028,0053)
  - Rescale Intercept (0028,0052)
- Apply W/L in DICOM tags at modality to set filters appropriately

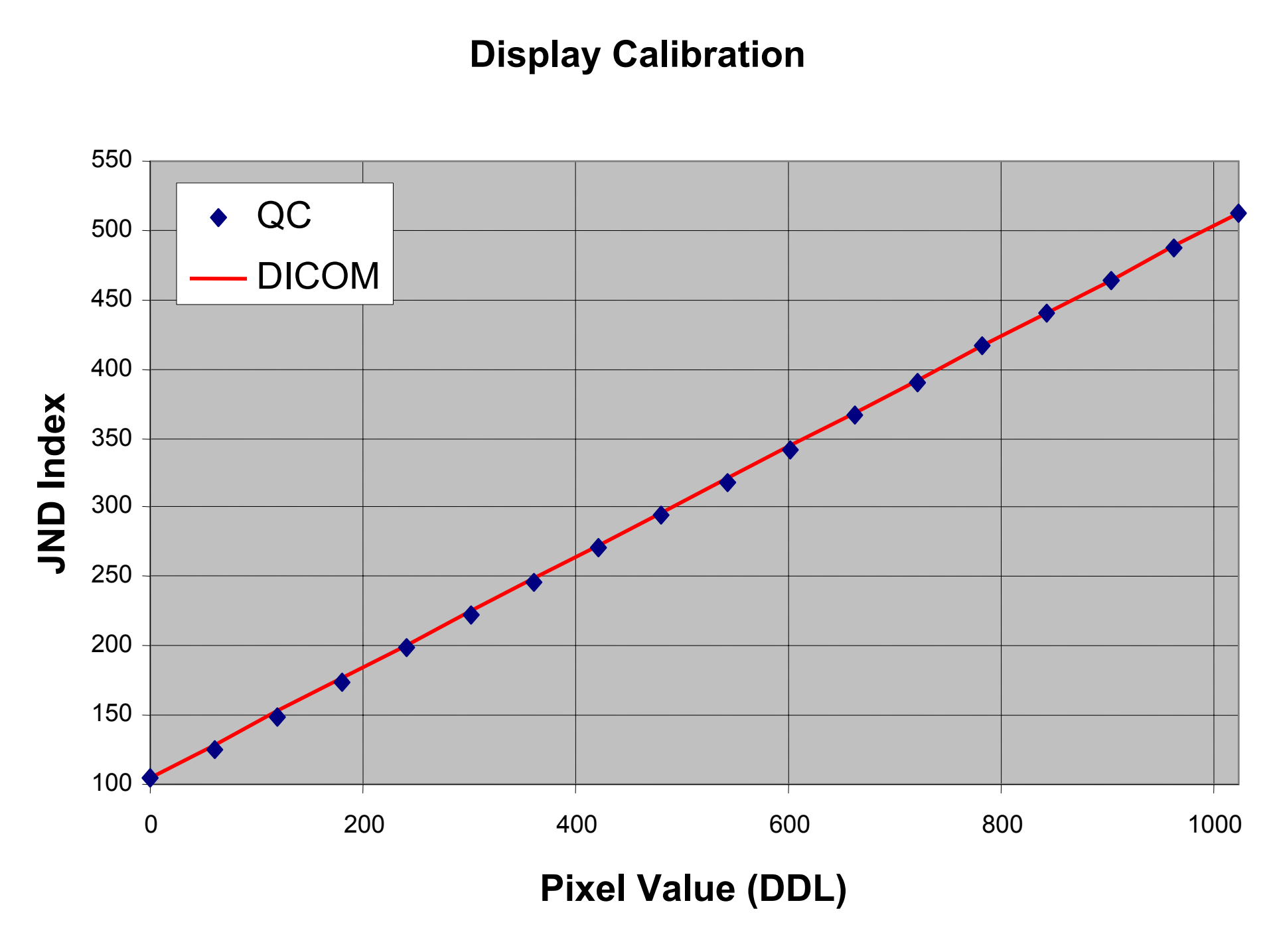
Image Quality (PACS)

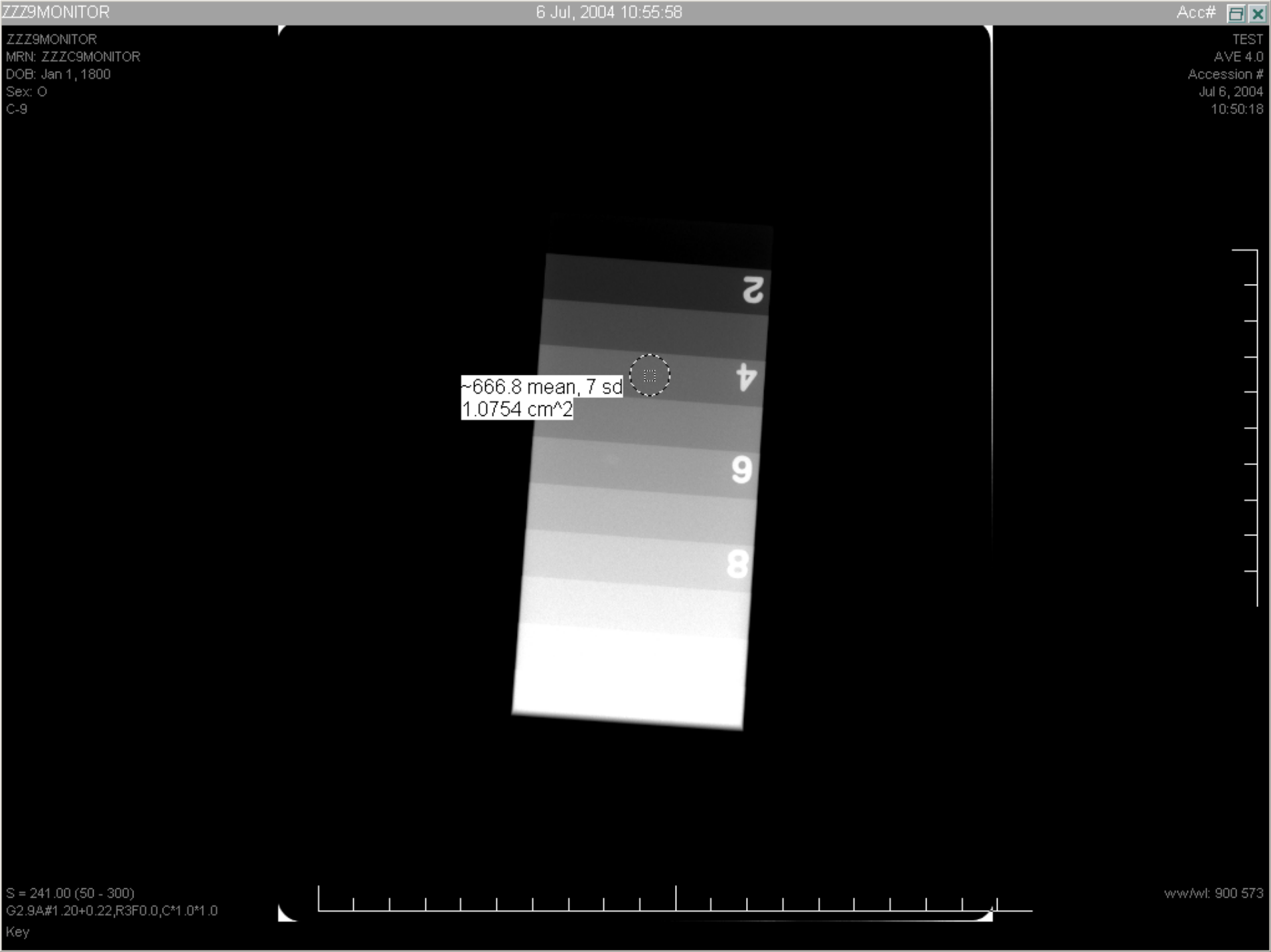
- Compare LUT on QC monitor to PS 3.14
  - Measure steps on the QC monitor with a photometer (See TG18)
  - Calculate JND's at min and max L for the monitor (PS 3.14, Table B1)
  - Calculate target JND's at each step assuming a linear increase with pixel value
  - Calculate JND's at each step from measured values
  - Calculate % of total JND range at each step
  - Compare to DICOM at each step

Display Calibration

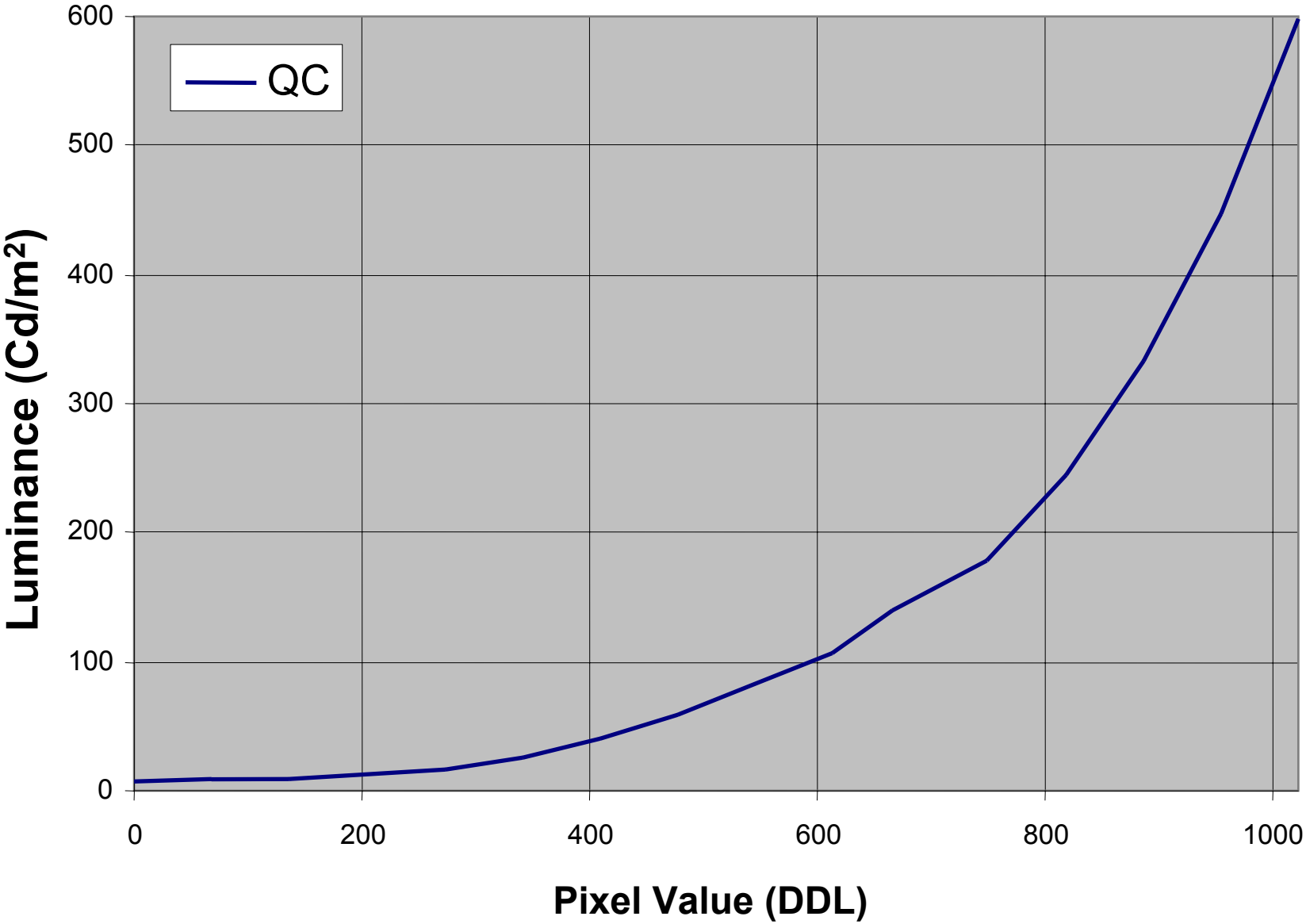


	Luminance	JND Index		% JND		
ddl	QC	QC	DICOM	QC	DICOM	Error
1023	130	512	512	100%	100%	
963.0	109.0	488	488	94%	94%	0%
903.0	91.2	464	464	88%	88%	0%
842.0	75.9	440	440	82%	82%	0%
782.0	63.0	416	416	76%	76%	0%
722.0	51.0	390	392	70%	71%	-1%
662.0	41.9	366	368	64%	65%	-1%
602.0	34.2	342	345	58%	59%	-1%
542.0	27.6	318	321	52%	53%	-1%
481.0	22.2	294	296	47%	47%	0%
421.0	17.7	271	273	41%	41%	0%
361.0	13.7	246	249	35%	35%	-1%
301.0	10.7	223	225	29%	29%	0%
241.0	8.1	199	201	23%	24%	-1%
181.0	5.9	174	177	17%	18%	-1%
120.0	4.2	149	153	11%	12%	-1%
60.0	2.9	125	129	5%	6%	-1%
0.0	2.04	105	105	0%	0%	

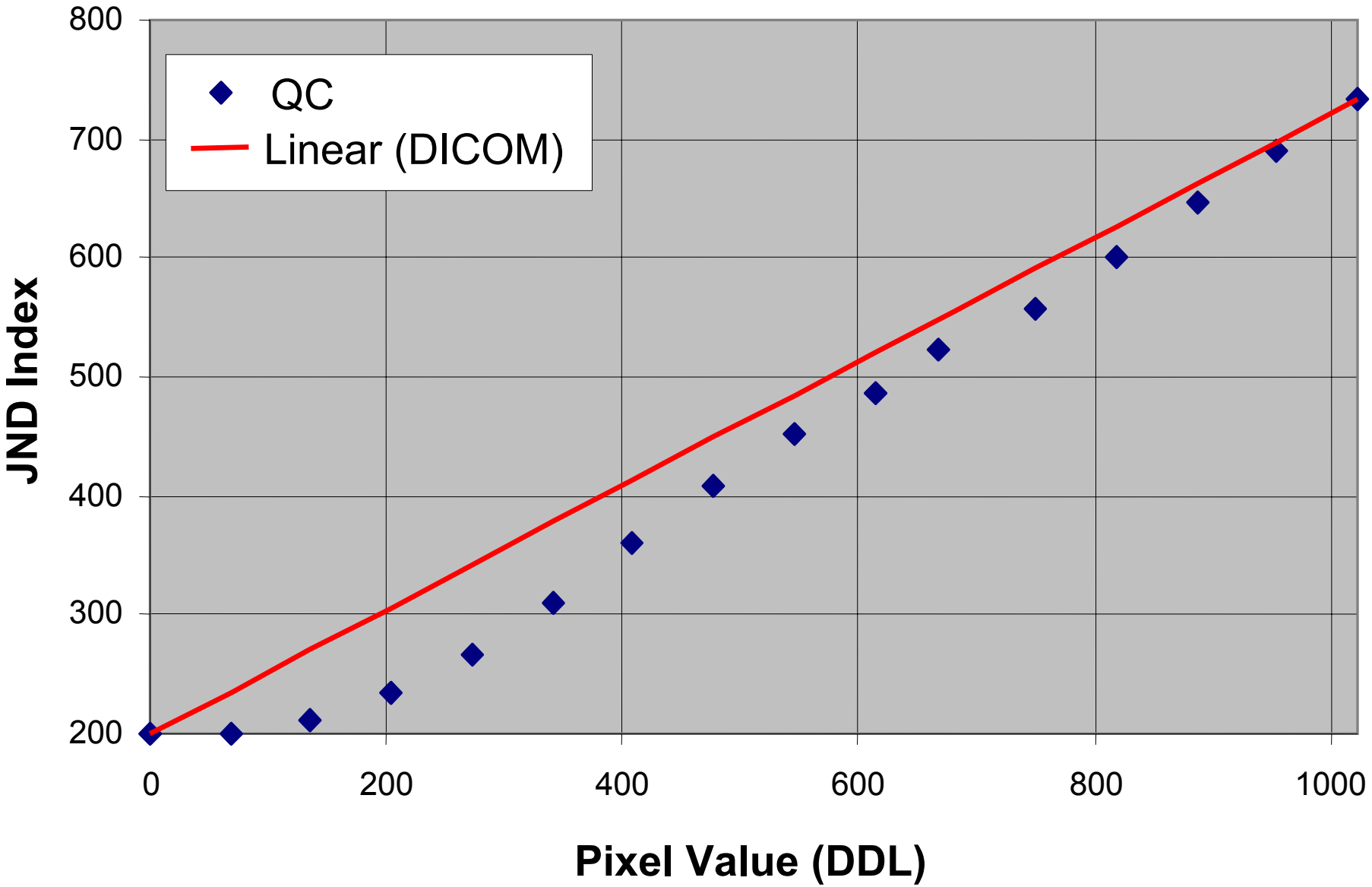

Display Calibration
QC
DICOM
JND Index
550
500
450
400
350
300
250
200
150
100
0
200
400
600
800
1000
Pixel Value (DDL)


ZZZ9MONITOR
6 Jul, 2004 10:55:58
Acc#
ZZZ9MONITOR
MRN: ZZZC9MONITOR
DOB: Jan 1, 1800
Sex: O
C-9
TEST
AVE 4.0
Accession #
Jul 6, 2004
10:50:18
2
4
9
8
~666.8 mean, 7 sd
1.0754 cm^2
S = 241.00 (50 - 300)
G2.9A#1.20+0.22,R3F0.0,C*1.0*1.0
Key
ww/wl: 900 573

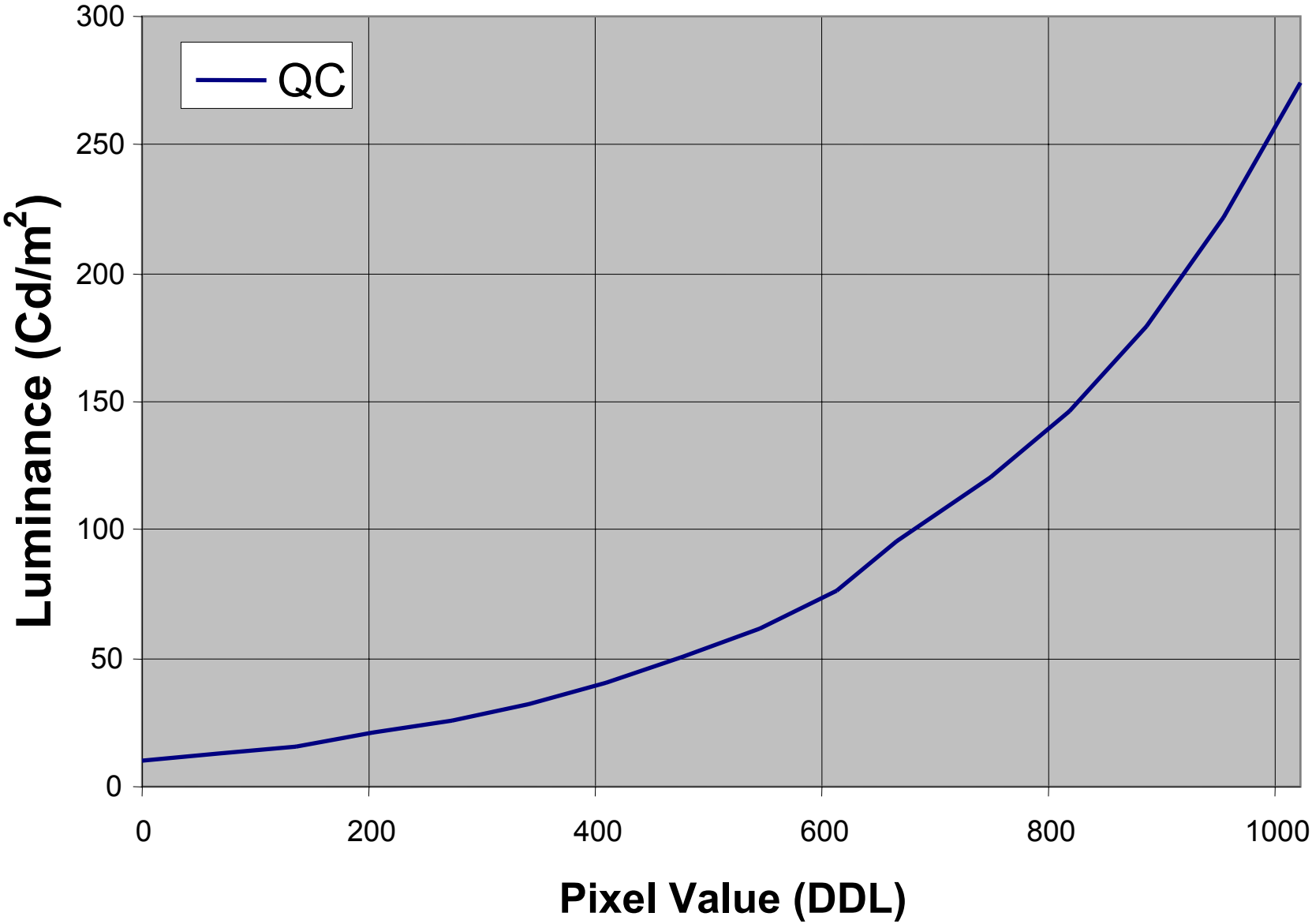
Display Calibration



Display Calibration



Display Calibration



Display Calibration

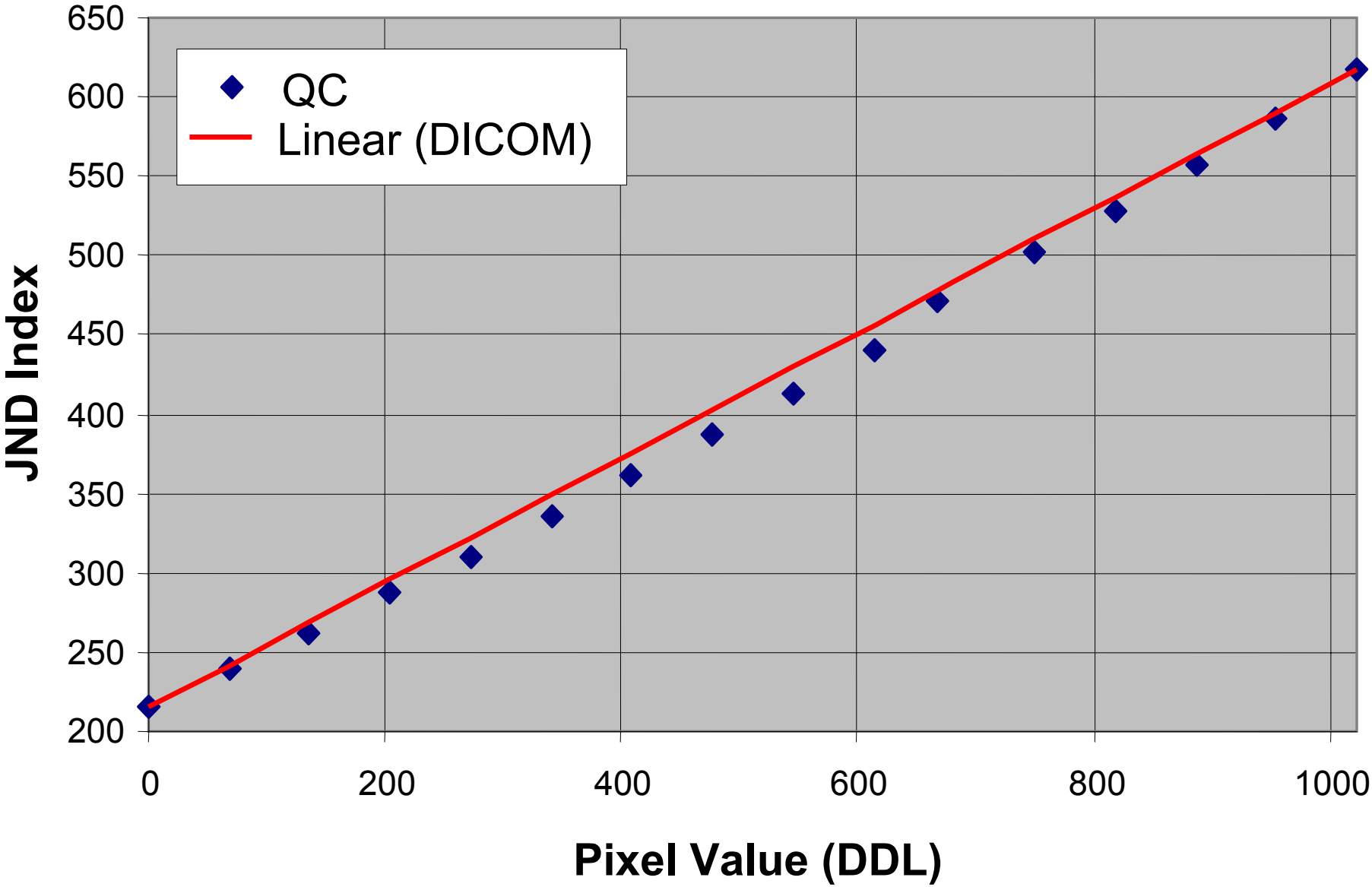


Image Quality (PACS)

- Calibrated QC monitors are rare
  - Include requirement for calibration to the Barten standard in DICOM PS 3.14 in the RFP
  - Pressure vendors to comply (With-hold final payment until requirement is fulfilled?)

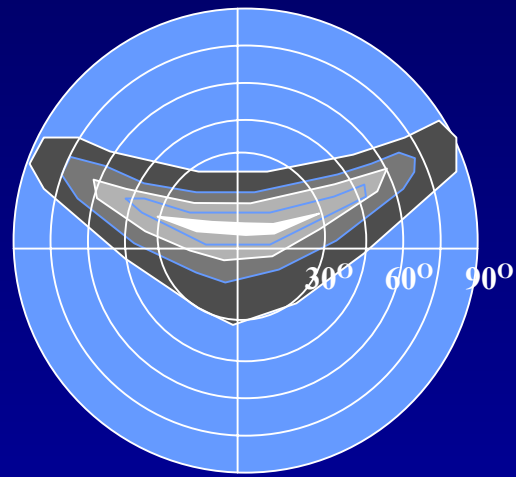
Image Quality (PACS)

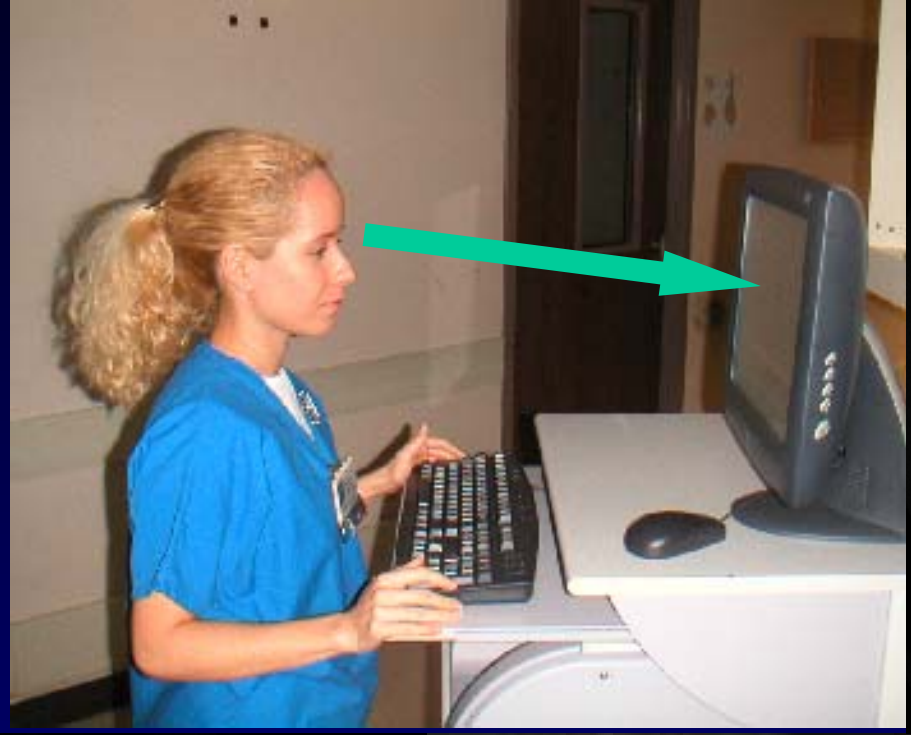
- In the event of mismatch (> $\pm$10%)
  - QC console monitor may not be calibrated to same LUT as PACS
    - Require calibration in RFP
    - Install DICOM calibration software yourself
  - Information displayed on the QC console monitor may be filtered (W/L or LUT)
  - Information sent to PACS is ignored
    - May be incorrectly formatted (value representation)
    - PACS may improperly handle information

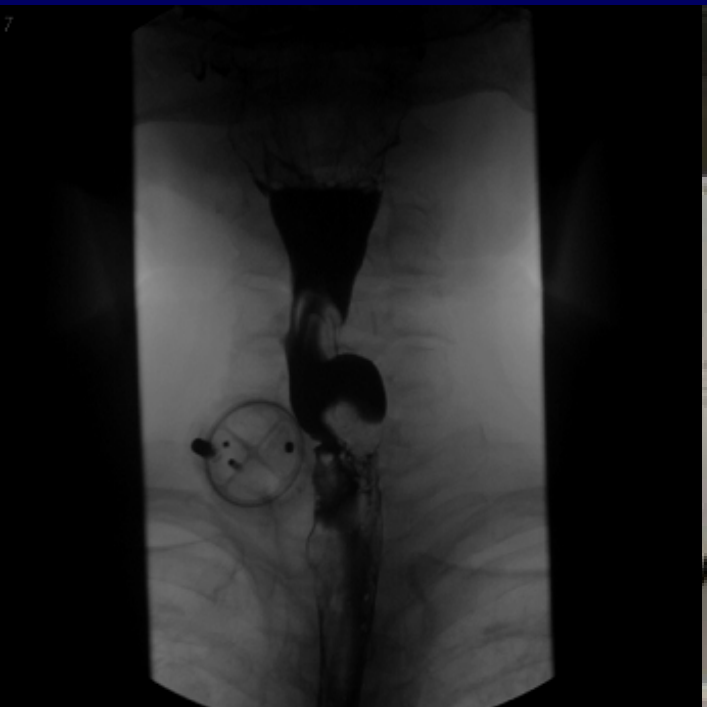
Image Quality: (PACS)

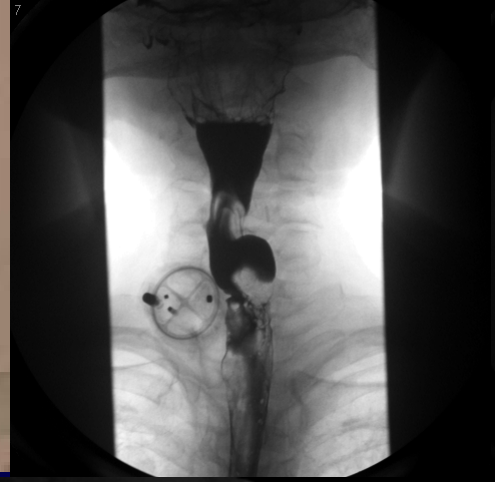
Viewing-angle dependence of brightness and contrast

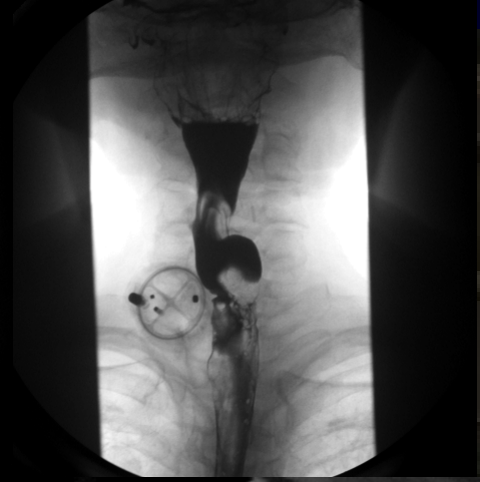
- Asymmetries in molecular orientation within the LC layer
- Some (expensive) LCD monitors correct for this:
  - Birefringent filter layers
  - Multidomain Pixels
  - In-Plane Switching
  - Combinations of above

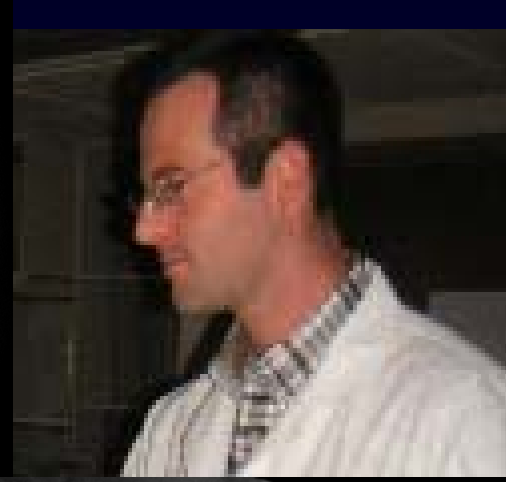


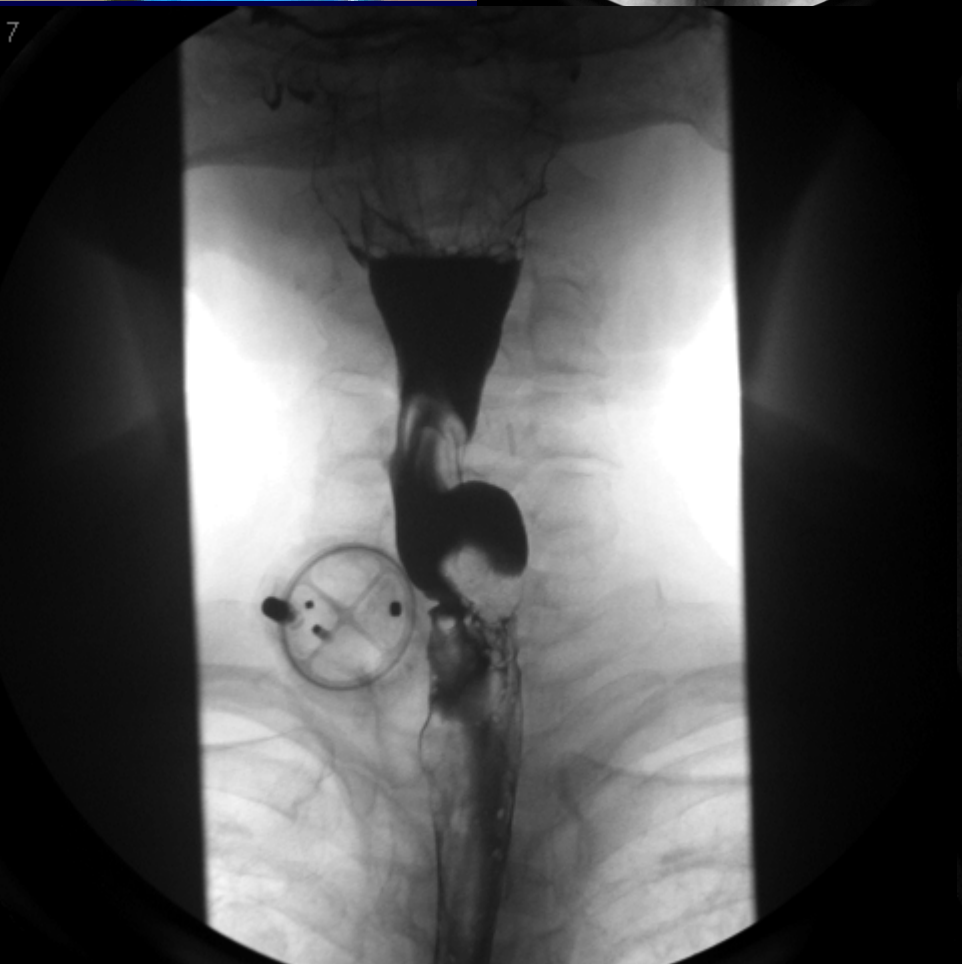












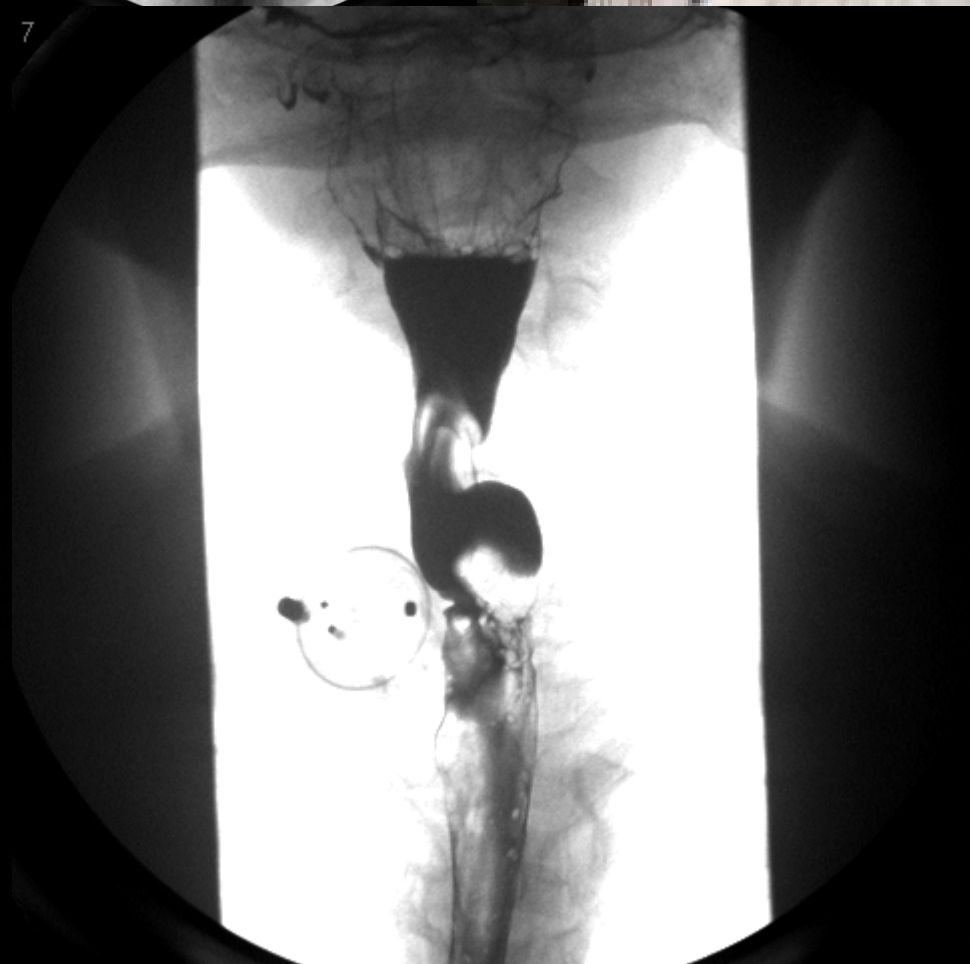


Image Quality (PACS)

- QC Console (display and graphics card)
  - Should match PACS calibration (within $\pm$10%)
    - Preferably Barten
  - 100:1 Contrast Ratio
  - Resolution (at least 1280x1024)
  - Off-axis contrast within $\pm$10% of center to $\pm 15^{O}$ (horizontal) and $\pm 30^{O}$ (vertical)
  - ***NO*** room light sensors
- Require all in RFP

Image Quality (PACS)

- Some systems are not designed to display on GSDF-compliant monitors
  - Adjust post-processing accordingly
  - Specify PACS system in RFP and require post-processing designed to display correctly with the PACS display LUT.

Assessing Functionality (Hard Copy)

- Printer configuration:
  - –Printer must apply appropriate LUT, D_{min}, D_{max}, sharpness, interpolation and media type to be used
  - –Modality IP, Host, port, AET on print server
- Evaluate image quality

Image Quality (Hard Copy)

- Elements that Control Image Appearance on Printers
  - D_{min}/D_{max} - must be identical on both modality and printer
    - May be omitted - use printer default
  - Addressable area (# rows and columns) on modality for "true-size" print
  - Margins and image box separation

Image Quality (Hard Copy)

- Elements that Control Image Appearance on Printers
  - Sharpness filter ("Inverse Smoothness" filter) – Smooth, Medium, Sharp
    - Some printers apply edge enhancement
  - Magnification (Interpolation algorithm – Replicate, Bilinear, or Cubic)
  - Media (Blue, Clear, Portrait, Landscape, etc)

Image Quality (Hard Copy)

- Elements that Control Image Appearance on Printers
  - LUT
    - Responsibility for Barten LUT - Printer or Modality?
      - Set printer to linear LUT if modality applies GSDF
      - Set printer to GSDF if modality sends linear LUT
    - May require custom LUT to match modality filter

Image Quality (Hard Copy)

- Elements that Control Image Appearance on Printers
  - Presentation State
    - LUT in a tag to be applied by printer
    - Not yet supported by most modalities
    - Evaluate if supported

Image Quality (Hard Copy)

- Send a digital step tablet image (one-on-one)
  - W/L settings
  - Measure OD's of step tablet

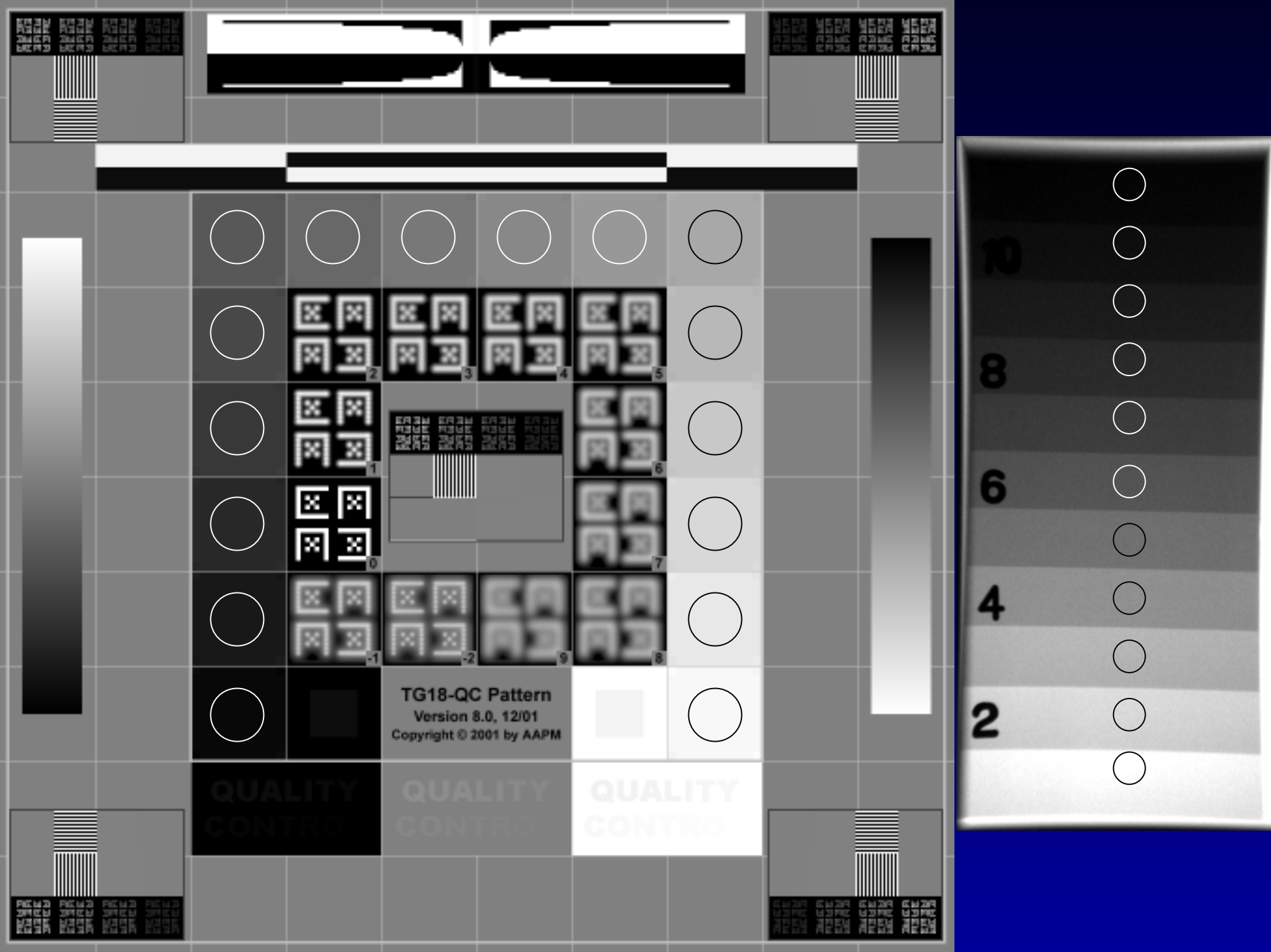

TG18-QC Pattern
Version 8.0, 12/01
Copyright © 2001 by AAPM
QUALITY CONTROL
QUALITY CONTROL
QUALITY CONTROL
10
8
6
4
2

Image Quality (Hard Copy)

- Calculate the transmitted luminance from a standard viewbox (~3000 Cd/m^2)
- Convert to JND indices (DICOM PS 3.14)
- Calculate the %JND at each step
- Compare to the %JND at each step of the PACS monitors
- Should be within $\pm$10%

p	Film		JND		%JND		Error
	OD	L	Film	DICOM	Film	DICOM	
0	0.16	1867.9	906	906	100%	100%	
68	0.28	1417	864	854	95%	93%	1%
136	0.42	1026.5	814	802	88%	87%	2%
205	0.56	743.64	766	749	82%	80%	2%
273	0.69	551.27	721	697	76%	73%	3%
341	0.82	408.66	676	644	71%	67%	4%
409	0.95	302.94	632	592	65%	60%	5%
477	1.09	219.46	585	540	59%	53%	6%
546	1.24	155.37	537	487	53%	47%	6%
614	1.39	109.99	489	435	47%	40%	7%
682	1.56	74.364	437	383	40%	33%	7%
750	1.72	51.447	391	330	34%	27%	8%
818	1.89	34.783	344	278	28%	20%	8%
887	2.13	20.015	284	225	21%	13%	7%
955	2.47	9.1488	209	173	11%	7%	5%
1023	3.00	2.7	121	121	0%	0%	

Hard Copy Calibration

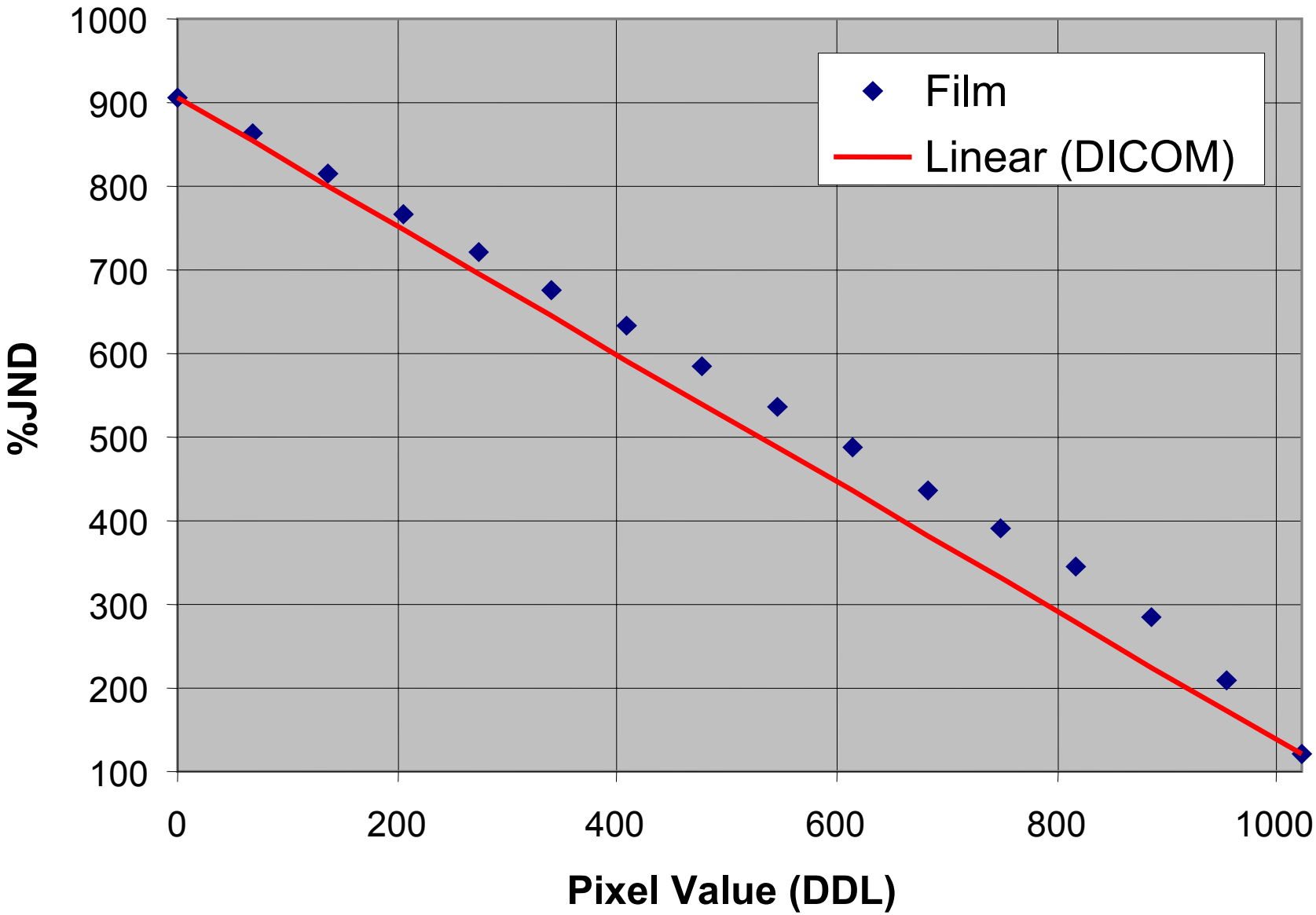


Image Quality (Hard Copy)

- Measure density uniformity (5 places)
- Measure distortion (regionally and globally)

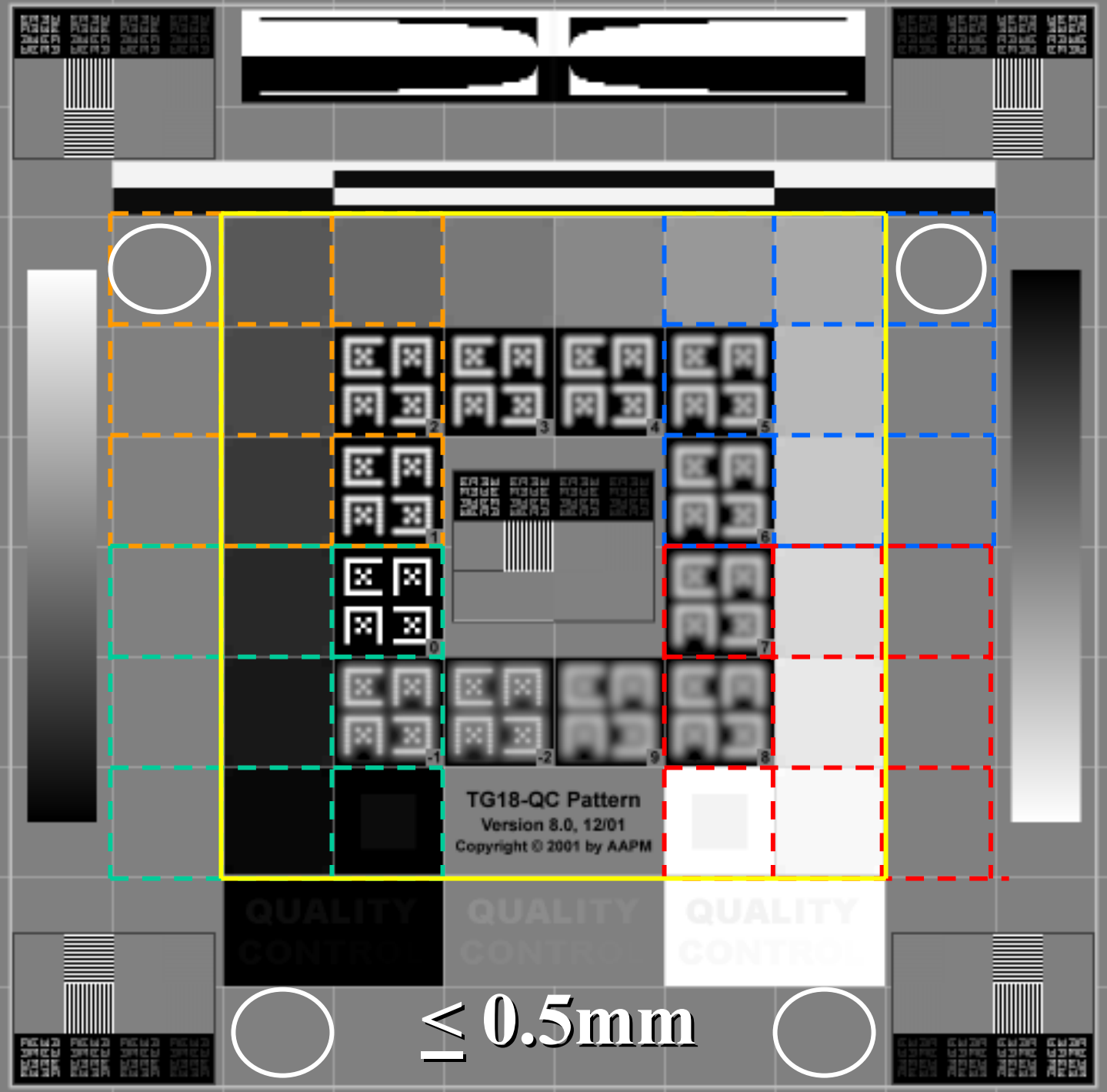
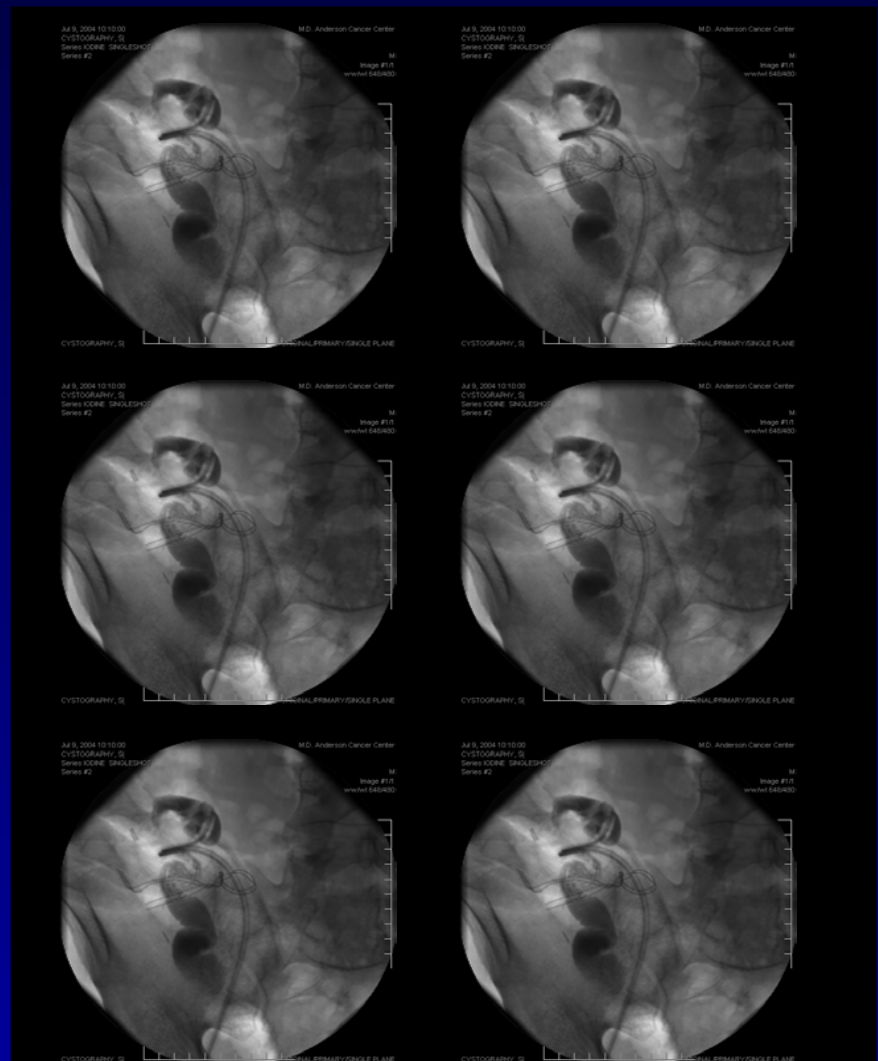

TG18-QC Pattern
Version 8.0, 12/01
Copyright © 2001 by AAPM
QUALITY CONTROL
QUALITY CONTROL
QUALITY CONTROL
≤ 0.5mm

Image Quality (Hard Copy)

- Examine sharpness of alpha-numeric characters



Summary – RFP (Modality)

- Basic Networking
  - Access to all passwords for network and DICOM re-configuration.
  - Training and manuals necessary to support reconfiguration.
  - *Network and DICOM configuration parameters should be password protected!!!*

Summary – RFP (Modality)

- DICOM
  - Supported SOP's (SCU)
    - Store (RF, DX, XF)
      - CR devices should support DX objects, not CR
    - Manual send or Auto send (user selectable)
      - Print (RF, DX, XF)

Summary – RFP (Modality)

- DICOM
  - Q/R Modality Work List
    - Query by Accession Number, Date, ID, or Name
    - Ad hoc and periodic
  - Storage Commitment

Summary – RFP (Modality)

- DICOM
  - Support for Secondary Capture ("Screen grab")
  - Send Queue Stop, Clear, Restart
  - Multiple simultaneous print destinations
  - Performed Procedure Step (Optional)

Image Quality (Modality)

- QC Console (display and graphics card)
  - Calibration matches PACS within $\pm$10% (preferably DICOM PS3.14 GSDF)
  - 100:1 Contrast Ratio (L_{max}/L_{min})
  - Resolution at least 1200x1600 pixels
  - Off-axis contrast within $\pm$10% of center to $\pm 15^{O}$ (horizontal) and $\pm 30^{O}$ (vertical)
  - ***NO*** room light sensors

Summary – RFP (Modality)

- Other
  - Manipulation of header information content
    - Interoperability with PACS
      - Tag information formatted, parsed
  - Private Tags (non-standard information)

Summary – RFP (Modality)

- Other:
  - Multi-frame objects
    - Integration of multiple single-frame series into one multi-frame object (for stack-mode viewing)
  - Support for overlay data (not "burned" in)
  - Re-open exam and add images