DICOM, Workstations and PACS

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Overview

- Workstations and the PACS

- New expectations for workstations

- Proprietary, web and standard workstation approaches

- Current and future DICOM services

State of the Art

- DICOM is unequivocally the only standard for modality <-> PACS communication
- Workflow beyond the modality involves:
  - PACS (+/- separate archive)
  - RIS
  - HIS ?
  - EMR/EHR/CPR system
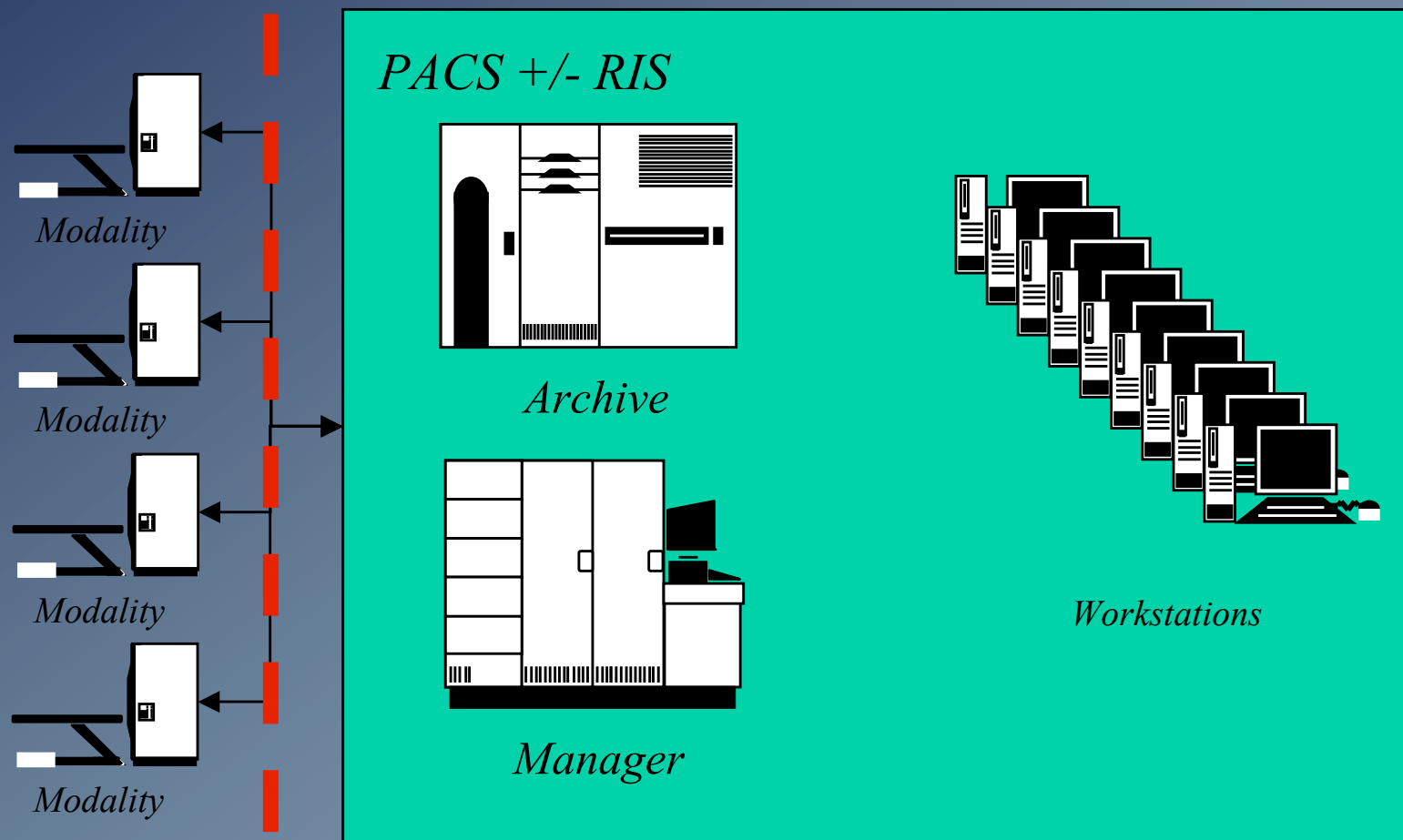- Where do workstations fit in ?

DICOM and the Modality
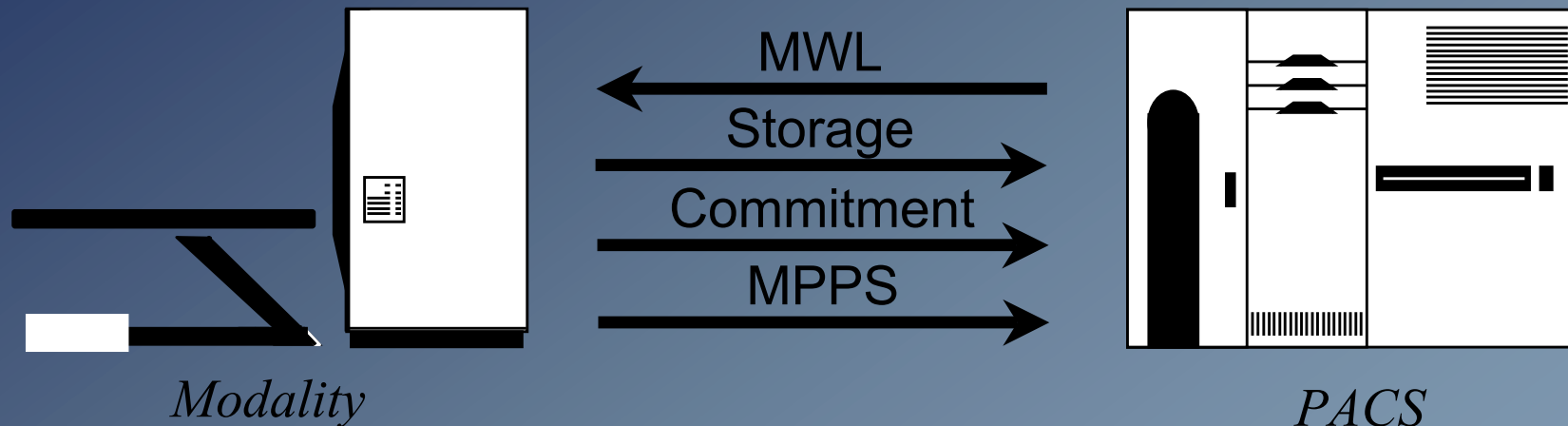
Storage of:
- images
- presentation states (window, group case)
- structured reports (measurements)

DICOM and the PACS

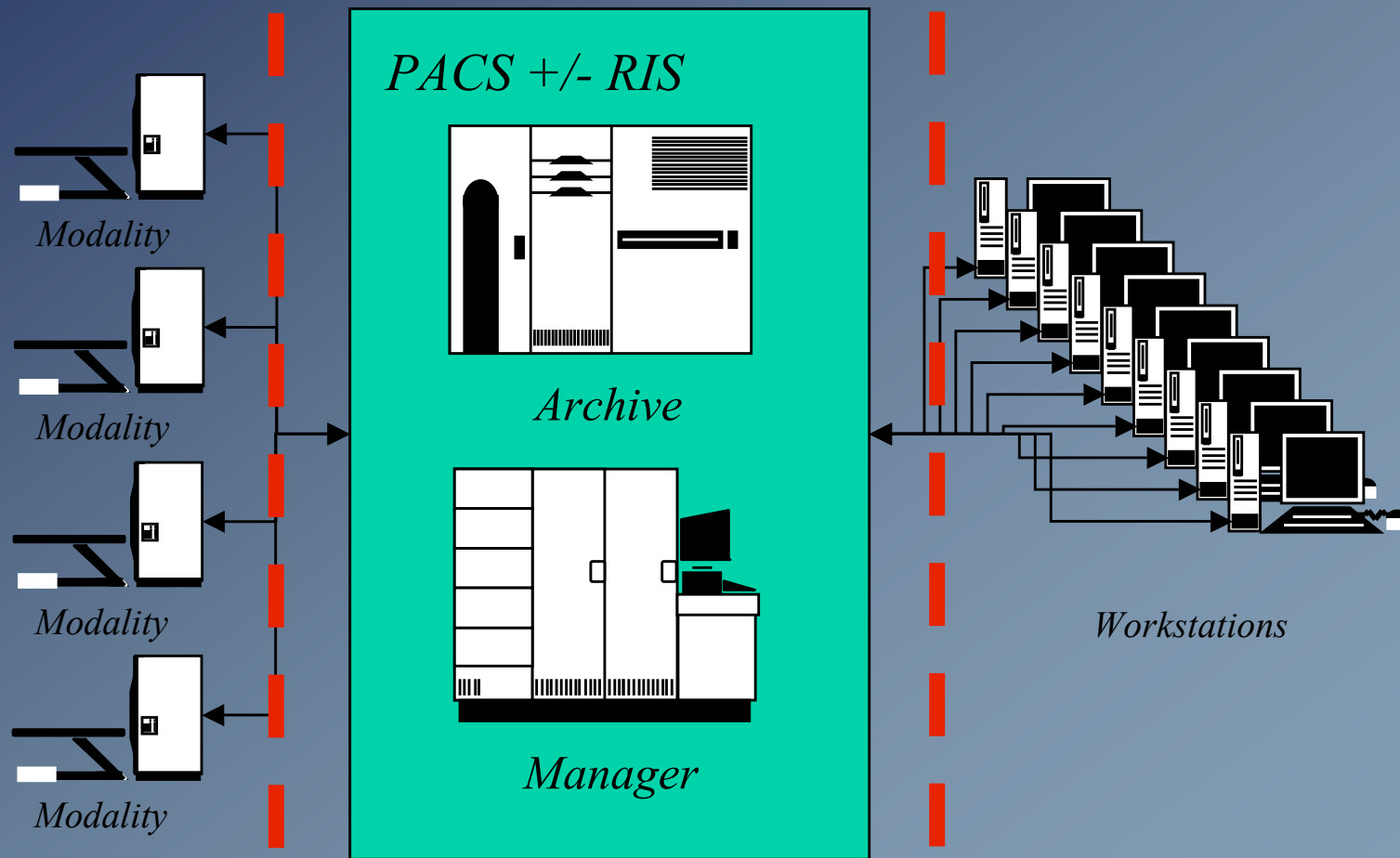Standard Boundary

PACS +/- RIS

Modality

Modality

Modality

Modality

Archive

Manager

Workstations

DICOM and the PACS

Standard Boundary

Standard Boundary

PACS +/- RIS

Archive

Manager

Modality

Modality

Modality

Modality

Workstations

DICOM Workstation

- Is there really any such thing nowadays ?
- Traditional roles
  - Replacements for secondary CT/MR consoles
  - Workstations for 3D and other processing
  - QC and printing workstations
  - All generally "unmanaged" in terms of workflow
- PACS workstations - divergent approaches
  - Proliferation of DICOM workstations, or
  - Proprietary workstations "inside" the PACS
- Regardless, "3rd party" DICOM workstations are now largely treated as "2nd class" citizens !

New Workstation Expectations

- Not just image display and processing
- Layout managers with centrally maintained hanging protocols
  - Should not matter which station a user chooses
- Workflow management
  - Simple filters of all unread images of a particular type in the entire PACS no longer sufficient
  - Productivity expectations dictate the need for centralized control over who does what and when
  - All required inputs (current and relevant prior images, measurements, previous reports) must be made available
- Report creation integration
  - Whether structured or voice recognition or hybrid

New Workstation Challenges

- Are there standards to support the requirements ?
  - DICOM, HL7 v2x and CCOW, web protocols, LDAP, syslog
- Can a single vendor pull this together ?
  - Does the RIS or the PACS own the workflow ?
  - Does the RIS or the PACS own report creation ?
- What about referring physicians' workstation needs ?
  - Will they be satisfied with lesser quality and fewer features ?
- What is realistic in terms of cost ?
- What about additional IT infrastructure needs ?
  - Single sign-on and centralized authentication
  - Centralized software maintenance control
  - Security needs (especially audit trails)

DICOM or Web Distribution ?

- What is "web-based PACS" anyway ?
- Web browsers do not natively:
  - Support DICOM images
  - Support other than 8 bit per channel RGB images
  - Support windowing
  - Support 3D rendering or MPR
  - Support annotation of images, measurement, etc.
- So, display of images in web browser requires
  - Plug-in
  - Applet
  - Local application distributed/triggered by web browser
- Navigation & workflow using server-generated pages

Web Browsers & Image Transfer

- Assume plug-in/applet/application installed
- Still need to get pixels for display
- Possibilities include:
  - DICOM transfer (C-MOVE or C-GET/C-STORE)
  - Other transfer of DICOM object (WADO/HTTP)
  - Other standard protocol (JPEG/HTTP, J2K/JPIP)
  - Proprietary protocol
- Regardless, unless DICOM or WADO used, this is a proprietary solution
- Client and server are tightly coupled in a proprietary manner

Proprietary Web Disadvantages

- Depend on the vendor to add a feature
  - display, navigation, workflow, layout/hanging reporting …
- Non-standard image transfer protocol
  - cannot swap client-side applet/plug-in for another
- Non-standard navigation and workflow
  - even if applet/plug-in uses DICOM protocol or objects, display is entirely passive
- Browser environment may limit capability/appearance

A "web-based" PACS is just as proprietary and just as tightly coupled as a traditional monolithic PACS !

Proprietary/Web Advantages

- Vendor has total control of client and server
  - whatever features are present are likely to work very well and be well tested
- Centralized control of distribution of client
  - client can always be the most recent applet/plug-in
- Potentially lower cost of development
  - Use of consumer protocols
  - Use of off-the-shelf (OTS) tools
- Optimization of image transfer for performance
  - Customized transfer suited to the environment or application
  - "Dynamic transfer syntax" of Chang/Stentor
- Greater acceptance by conventional IT staff (port 80)

Real vs. Perceived Benefits

- Lowering ownership costs
  - Use of the web, or the use of OTS PC hardware ("software PACS workstations") ?

- Centralized maintenance
  - Web-distribution of software does support thick client applications (e.g. Java Web Start)
  - Still need security/OS/Virus updates separately anyway, so central imaging of desktops may be necessary regardless

- Lowering development costs
  - Bulk of the development and testing is at the application level in terms of features, not at the toolkit or protocol level
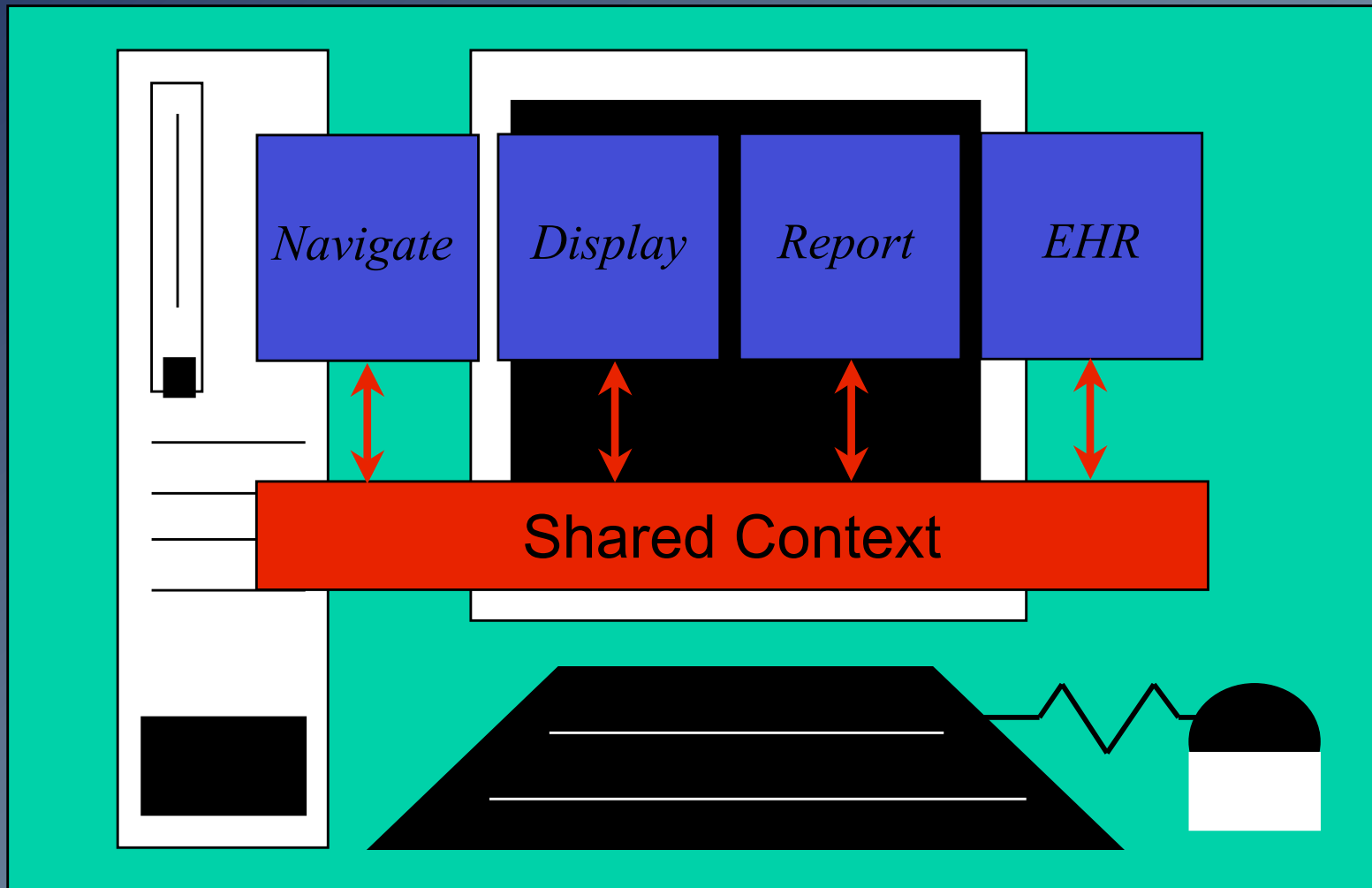
Towards a Standard Workstation

- Already in DICOM, HL7, CCOW and IHE
  - Image, grayscale presentation, key object, measurement and report transfer
  - Workflow management (GP-SPS and GP-PPS)
  - On-demand fetching (query/retrieval)
  - Infrastructure and security issues (audit message)
  - Desktop application integration
- Gaps in the standards are few
  - Hanging protocols and structured display
  - More advanced presentation states (color, fusion, 3D)
  - Voice recognition integration
- Real challenges are in the efficient implementation

Carving out the Workstation

PACS +/- RIS

Worklist (GP-SPS)

Retrieve (Move)

Inputs (Store)

Status (GP-PPS)

Outputs (Store)
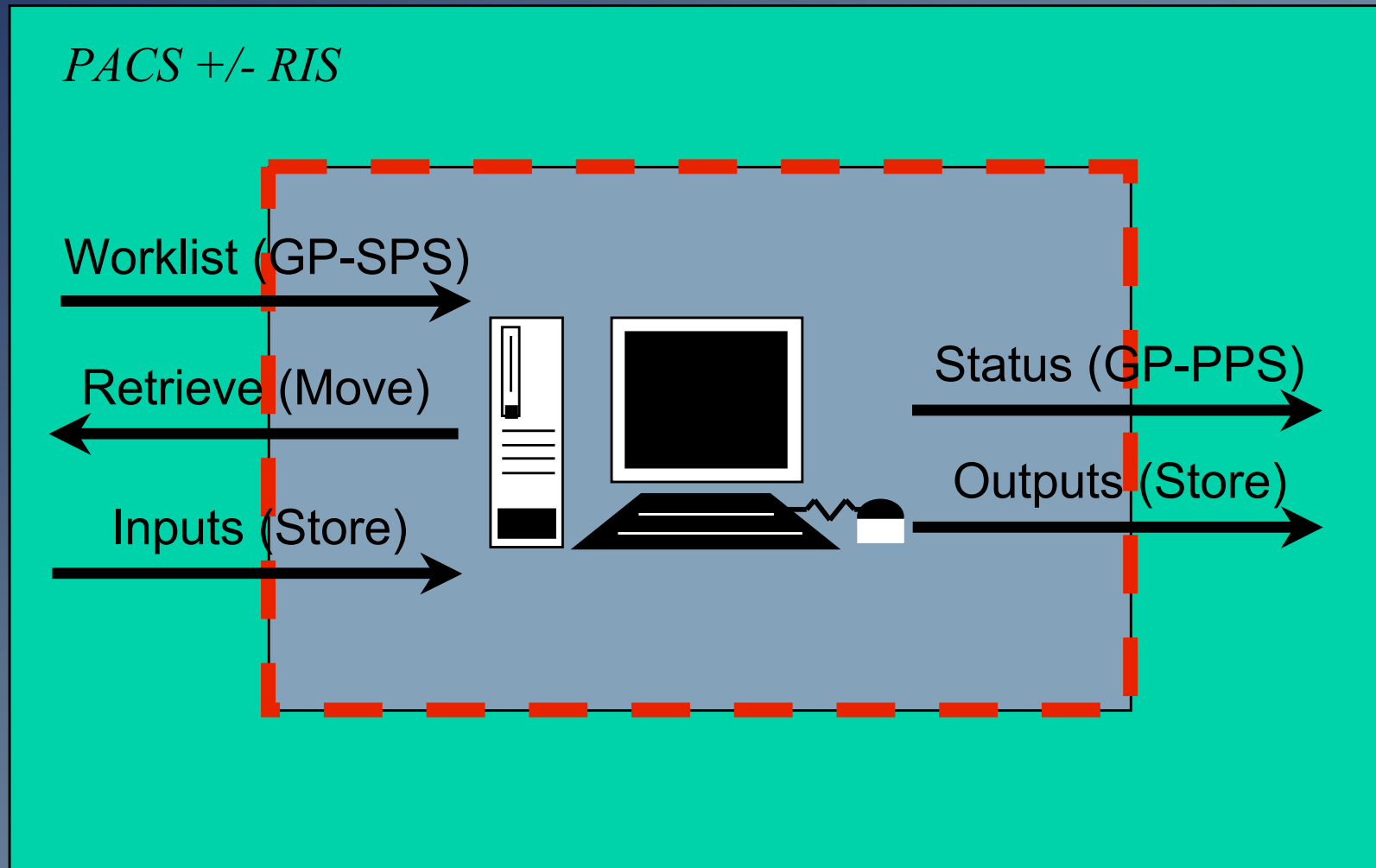
Standards Within the Workstation

Performance Anxiety (I)

- Some say DICOM is inherently "slow" or "chatty"
- Can be, if poorly implemented and not properly tuned
- Some implementers make no effort to optimize for the deployment environment & underlying TCP stack
- Consider different bandwidth/latency/fragmentation
  - LAN with switched 10/100/1000 Ethernet
  - WAN over cable or DSL
  - Dial-up modem
  - Satellite
  - Internet 2
- Key factor is Bandwidth Delay Product (BDP)
- DICOM can approach the speed of raw sockets, just as ftp and http can, if properly implemented

Performance Anxiety (II)

- *Don't* open a new association for each image
  - Avoids TCP/IP connection establishment delay
  - Avoids association negotiation
  - Consider maintaining an open pool of associations with timeouts
- *Don't* negotiate more SOP Classes/Transfer Syntaxes than you need to transfer
- *Don't* delay DICOM primitive acknowledgement (C-STORE response) (especially on high BDP connections)
- *Do* use multiple simultaneous associations or asynchronous operations to reduce impact of delayed DICOM primitive acknowledgement
- *Do* tune the TCP send and receive buffer sizes in the OS (e.g. Windows defaults are historically ridiculously low)
- *Do* choose a reasonably large DICOM maximum PDU size, but do not expect miracles
- *Do* avoid buffer copying and user/kernel context switches, try memory-mapped files, and work around fragmentation overhead with scatter/gather buffers

Performance Anxiety (III)

- Consider lossless compression
  - can be progressive to lossless for intermediate updates, with no extra bits sent (embedded)
  - tradeoff between reduction in transfer time (fewer bits) vs. additional decompression time on client
  - server-side compression avoided if already stored in (same) compressed form; also reduces disk bandwidth required
- Not uncommon in proprietary PACS
- Uncommon in pure DICOM workstations/archives
- Choose transfer syntax with fastest possible and least resource intensive decompression times
- Compare JPEG lossless, JPEG-LS and J2K in this regard

Size as a Confounding Factor

- Does the client PC really have the power for on demand
  - 3D volume or surface rendering
  - re-sampling to create non-orthogonal MPRs
  - re-sampling to displayed pre-registered studies
  - local registration of prior studies or different modalities for fused display or locked navigation for longitudinal comparison or lesion tracking and measurement
- Does transferring a huge isotropic voxel volume data set to the client PC even make sense ?
  - worklist-driven next-case-anticipated pre-fetching can eliminate the perceived delay but not the bandwidth consumption
  - on-demand responsiveness dictates significant disk and network bandwidth allocation
- Is a need arising for a standard for interactive command and control of a rendering server ?

What is DICOM Doing ?

- Supporting and maintaining SOP Classes in support of workflows and use-cases defined by IHE
  - especially GP-SPS, GP-PPS, presentation state and SR-related
- Defining new objects to support extremely large data sets
  - CT/MR/XA multiframe, ND object
  - May or may not simplify/accelerate transfer
  - Certainly facilitates access to information organized into patterns suitable for presentation and processing
  - Spatial registration and fiducials objects
- Addressing presentation and display consistency management
- Considering new pixel transfer mechanisms

DICOM Presentation Services (I)

- GSPS (standard)
  - Applies to 1-n frames of a grayscale image
  - Essentially 2D
  - Spatial transformations
  - Grayscale pipeline with calibrated output
- Color PS (early draft)
  - Again 2D, GSPS applied to color +/- consistency

DICOM Presentation Services (II)

- Hanging Protocols (pre-letter ballot)
  - How to arrange and display an abstract class of images, rather than concrete instances thereof
  - Allows for general concepts such as MPR, without specific parameters
  - Centralized storage of user-specific protocols
- Structured display (proposal)
  - How to lay out a concrete set of instances
 - For example, to capture a predefined state

Presentation Services - Gaps

- For these sources of images (data)
  - Existing single frame CT/MR/PET slices
  - Multi-frame NM/CT/MR volumes
  - Proposed ND object
- Need:
  - Two overlapped fused 2D images (other blending variants)
  - Specified MPR or MIP or Volume Rendering
    - View position, cut planes, illumination
    - Segmentation, thresholds, fly-through paths
  - Selection of dimensions/channels (space, time, acquisition characteristic)
  - 3D fusion (e.g. make use of Sup 73 registration object)

Orthogonal Dimensions of Presentation

- Mapping data (e.g. set of frames) to a tile
  - different modalities (CT, PET)
  - different signals (US, Doppler velocity)
  - re-sampling (e.g. MPR)
- How to layout tiles
  - how many
  - what in which
- Abstract vs. concrete
  - Protocols - about a class of instances
  - State - about specific instances
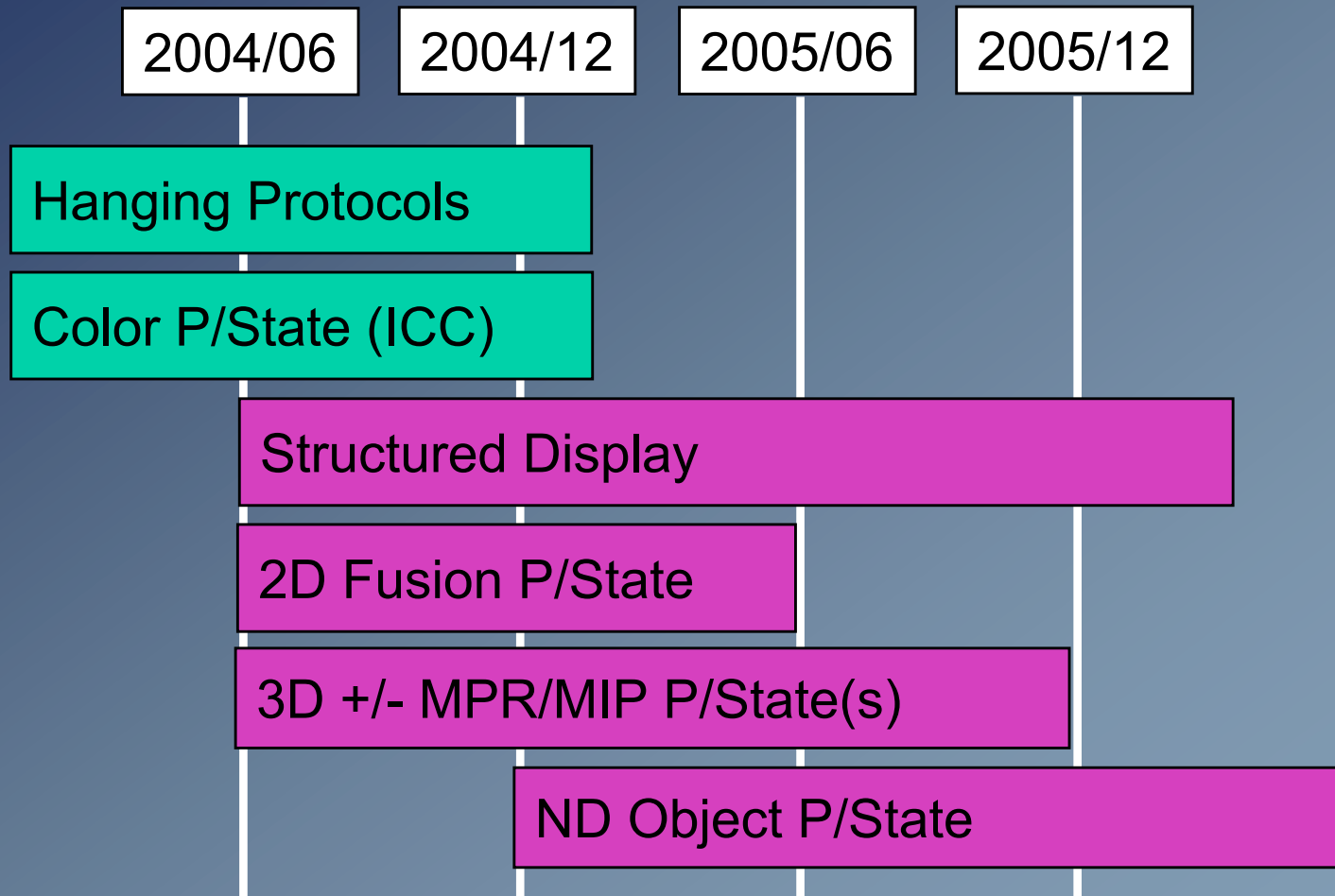
Dependencies

- Images (and other data)
  - Single and multi-frame objects exist
  - ND object is work in progress
- Spatial registration
  - Affine transformation of frames of reference now standard (Sup 73)
- Segmented images
  - Pre-requisite for specifying surface rendering
- "Single-tile" GSPS and CSPS
  - Referenced by proposed structured display instances

New Pixel Transfer Mechanisms

- New "conventional" Transfer Syntaxes have already been added for JPEG-LS and JPEG 2000

- JPEG 2000 Interactive Protocol (JPIP)
  - opportunity to selectively transfer only necessary bits for a particular purpose
  - opportunity to leverage potentially popular consumer industry standard

- Currently a DICOM WG 4 work item (since Nov 2001) awaiting standardization by JTC1/SC29/WG1

- Will entail separating the C-STORE of the non-pixel data from retrieval of the pixel data bit stream to achieve interactivity

Summary

- The ball is in the user's court
- Sufficient standards are already in place to factor the workstation out of the turn-key PACS to mitigate "single vendor tyranny" and allow choice of best of breed
- Challenge is to the users to insist that the vendors deliver this capability, and the vendors to implement the standards effectively
- DICOM, IHE, SCAR and other organizations continue to work on additional details to meet the anticipated challenges of the growing data set size