LBNL Visualization Research Program
High Performance Remote Visualization
Highlights 2005-2007

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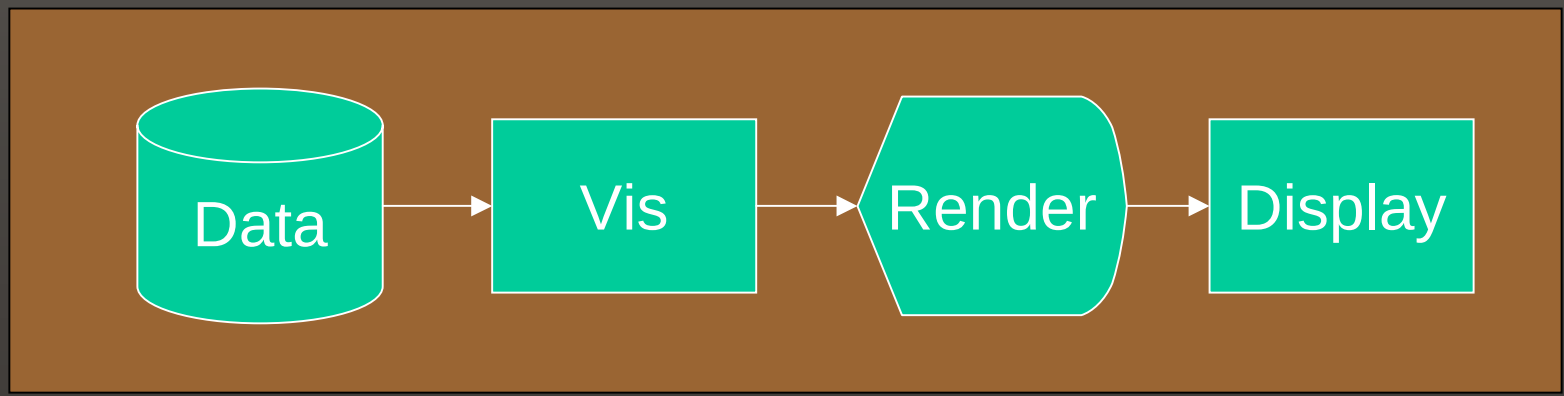
www.vacet.org

Outline

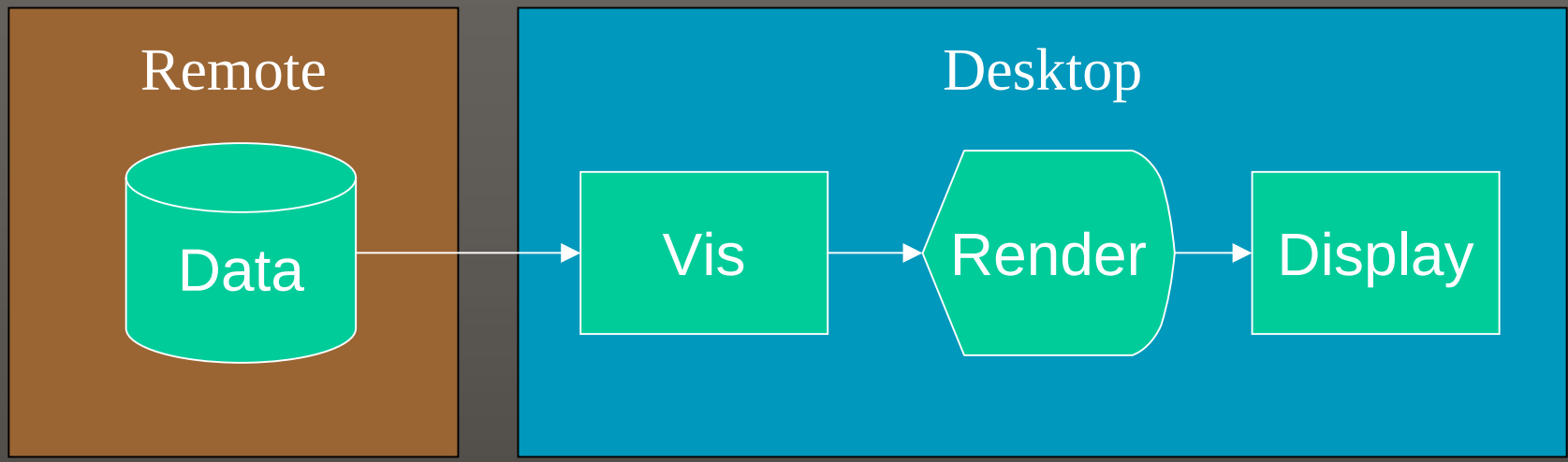
- Remote visualization: definition, approaches.
- MBender: multiresolution remote vis.
- Chromium Renderserver: high performance parallel, hardware-accelerated remote vis.

The Visualization Pipeline

- The Vis pipeline consists of an “assembly line” of components.
- Remote visualization is all about how that pipeline is partitioned between remote and local resources.

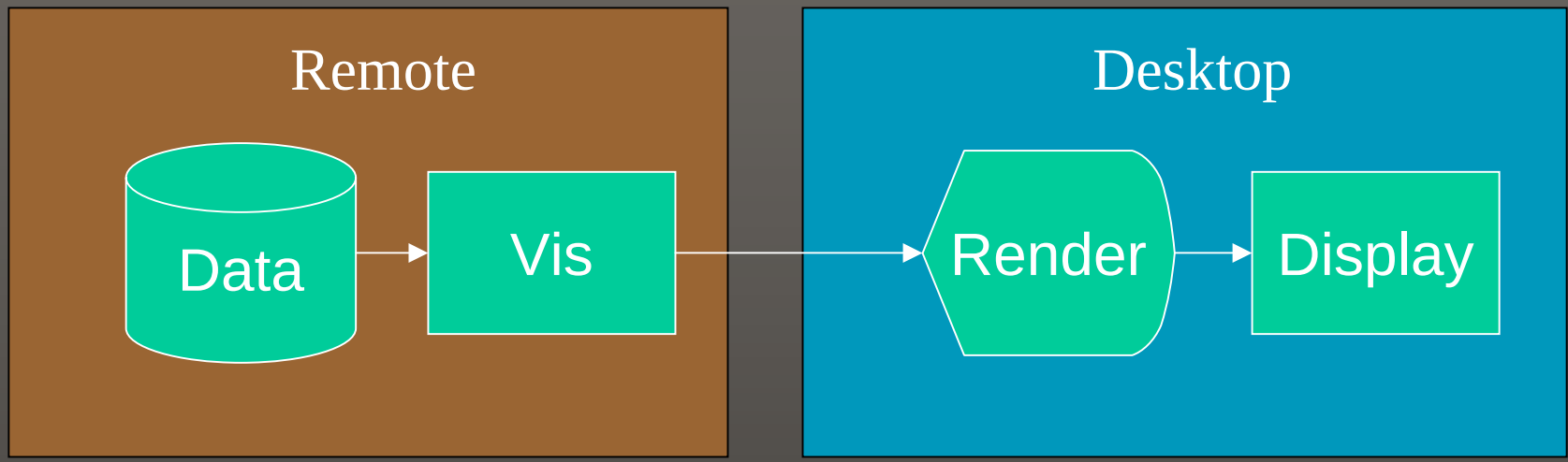


Pipeline Partitioning – Send Data



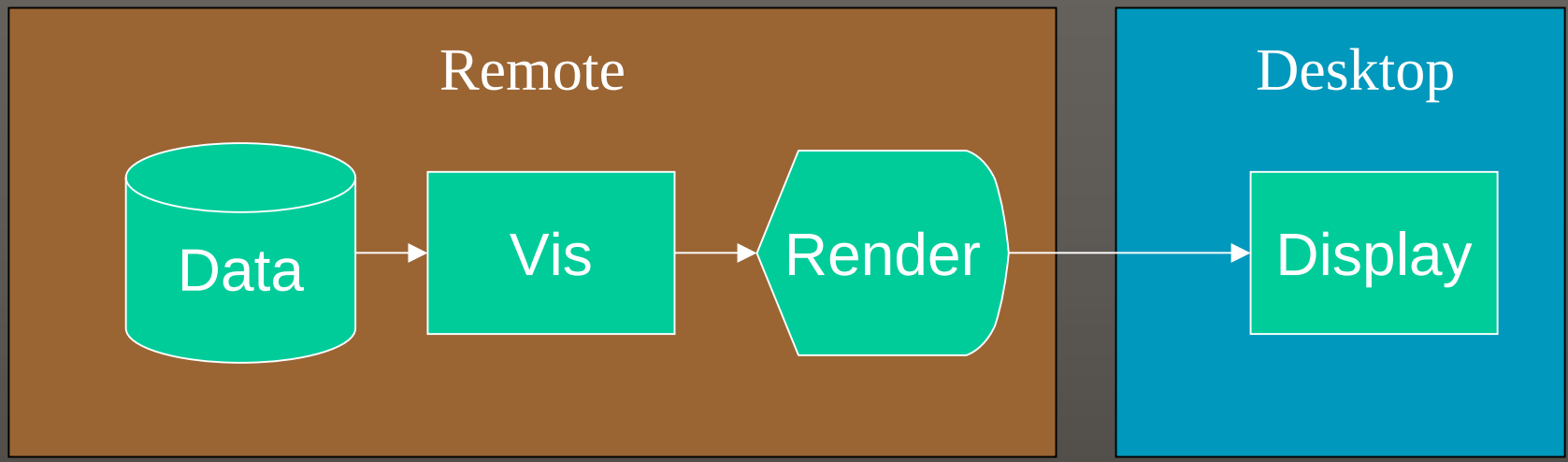
- All visualization, rendering and display happens on “the desktop.”
- Data or data subsets moved between remote and local hosts.

Pipeline Partitioning – Send Geometry



- All rendering and display happens on the desktop.
- Visualization results – e.g., isosurface triangles – moved across the network.

Pipeline Partitioning – Send Images



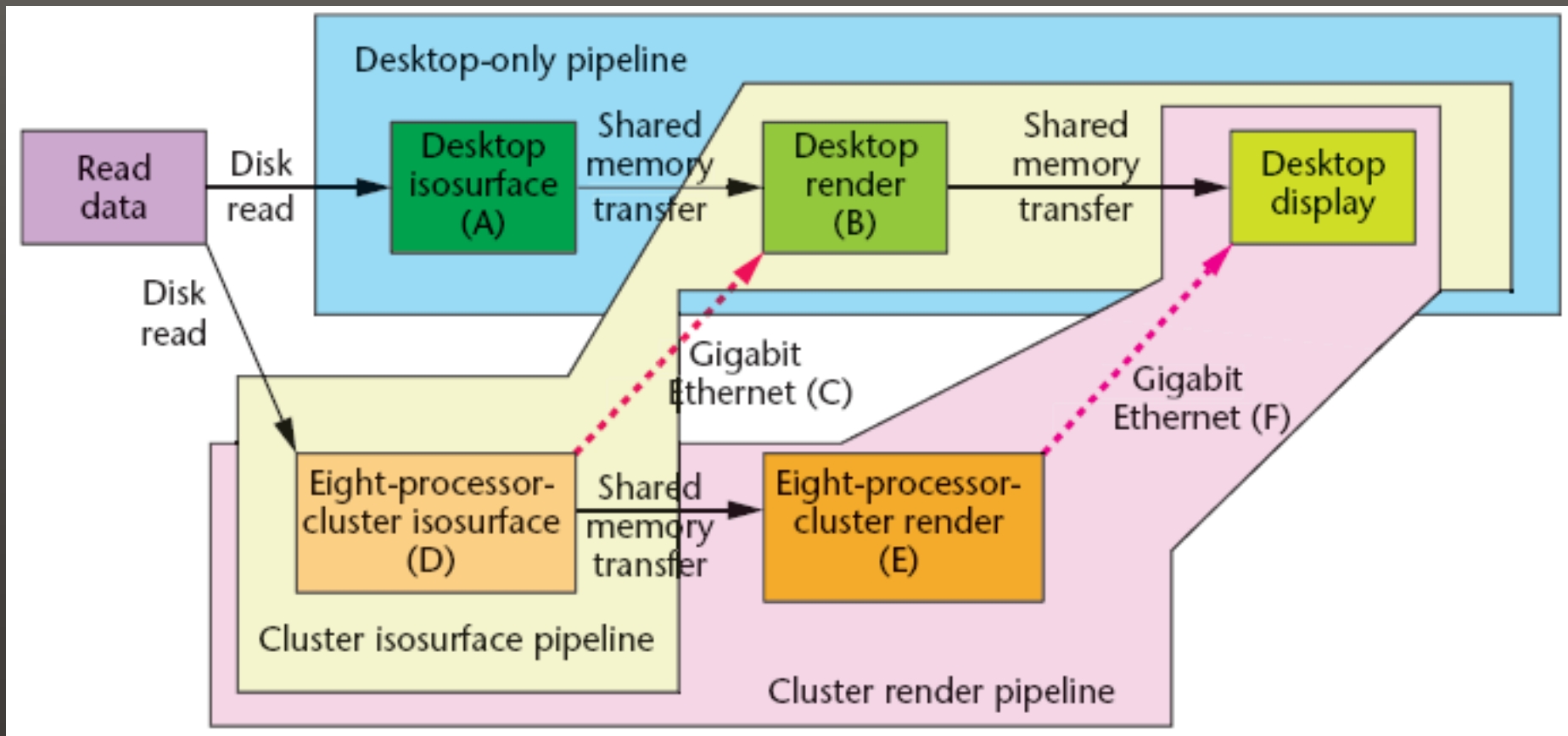
- All data I/O, visualization, and rendering happen on the remote host.
- Only image data moves across the network.

Remote Visualization

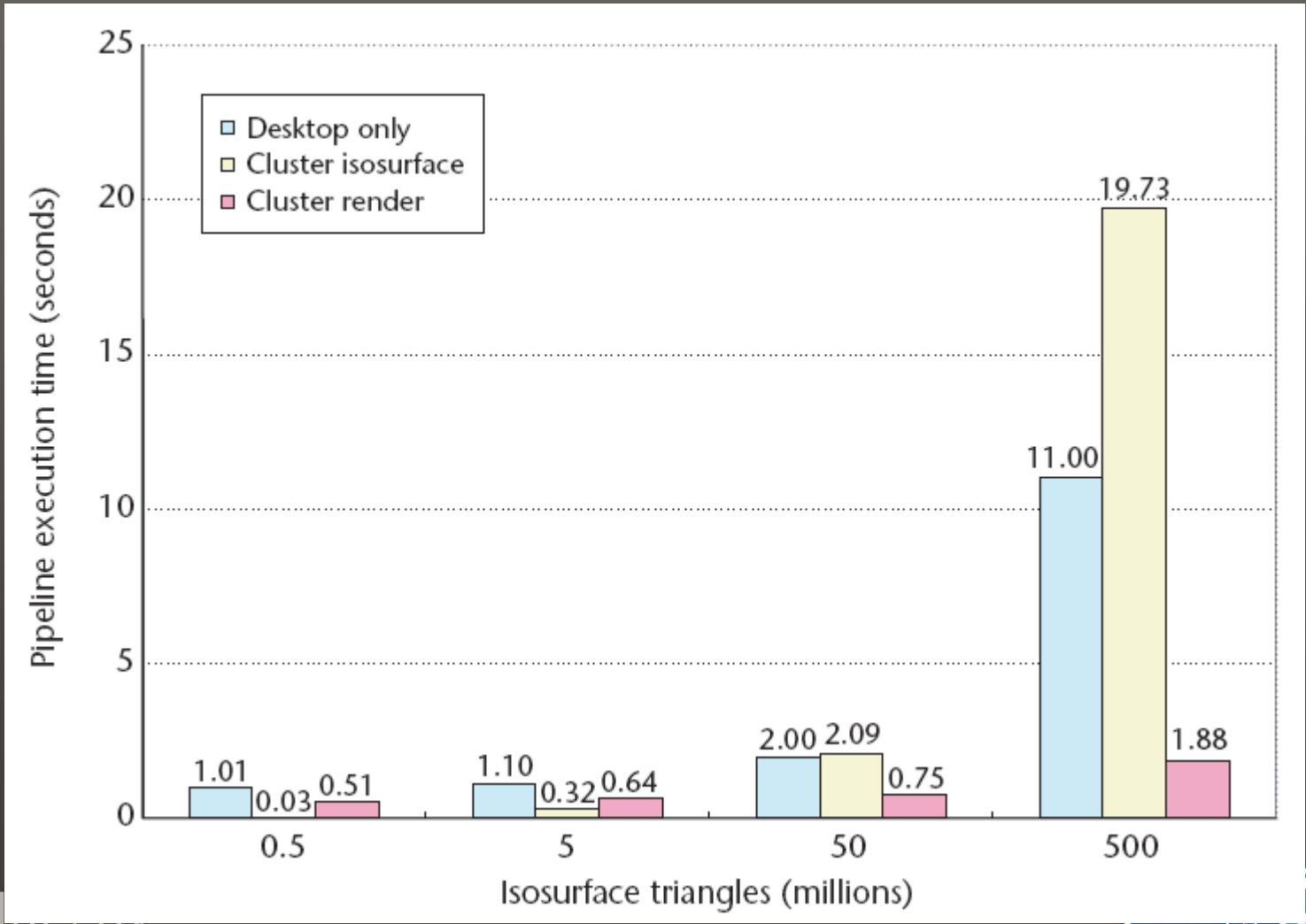
- Which pipeline partitioning works the best?
- Answer(s):
  - It depends on the problem and use model.
  - “Send Images” appears, in general, to be the best option.
- The following slides explain this issue in more detail.

Remote Visualization Performance Experiment

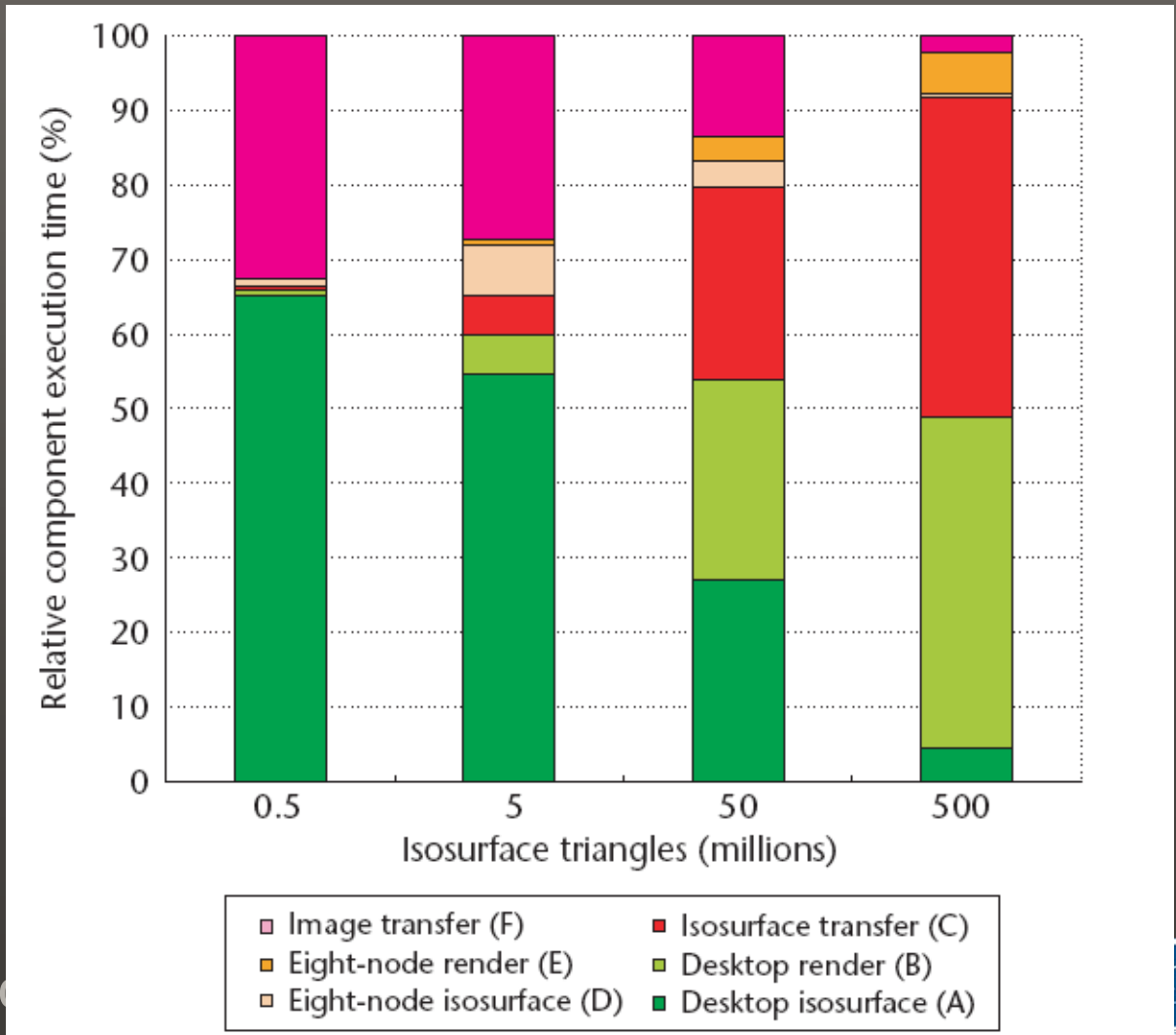
- Three partitions: send data, send geometry, send images.



Absolute Runtime of Three Partitionings



Relative Performance of Three Partitionings



Analysis of Strategies

- Send images (Winner): nearly constant performance regardless of data size. Other advantages (to be discussed).
- Send geometry: performance worsens as data grows larger; implementation difficulties.
  - E.g., isosurface produces ~$O(N^{2/3})$ triangles.
  - Not scalable to larger data, more users, more apps.
- Send data: performance worsens as data grows larger; implementation difficulties.

Two Remote Visualization Projects

- Both based on “send images” partitioning.
- MBender (“Media Bender”)
  - First run the application to generate pre-computed imagery.
  - Later, view/explore multidimensional, multiresolution imagery with web browser.
- Chromium Renderserver
  - Harvest/encode/transmit imagery from hardware-accelerated rendering of parallel vis app to remote viewer(s).

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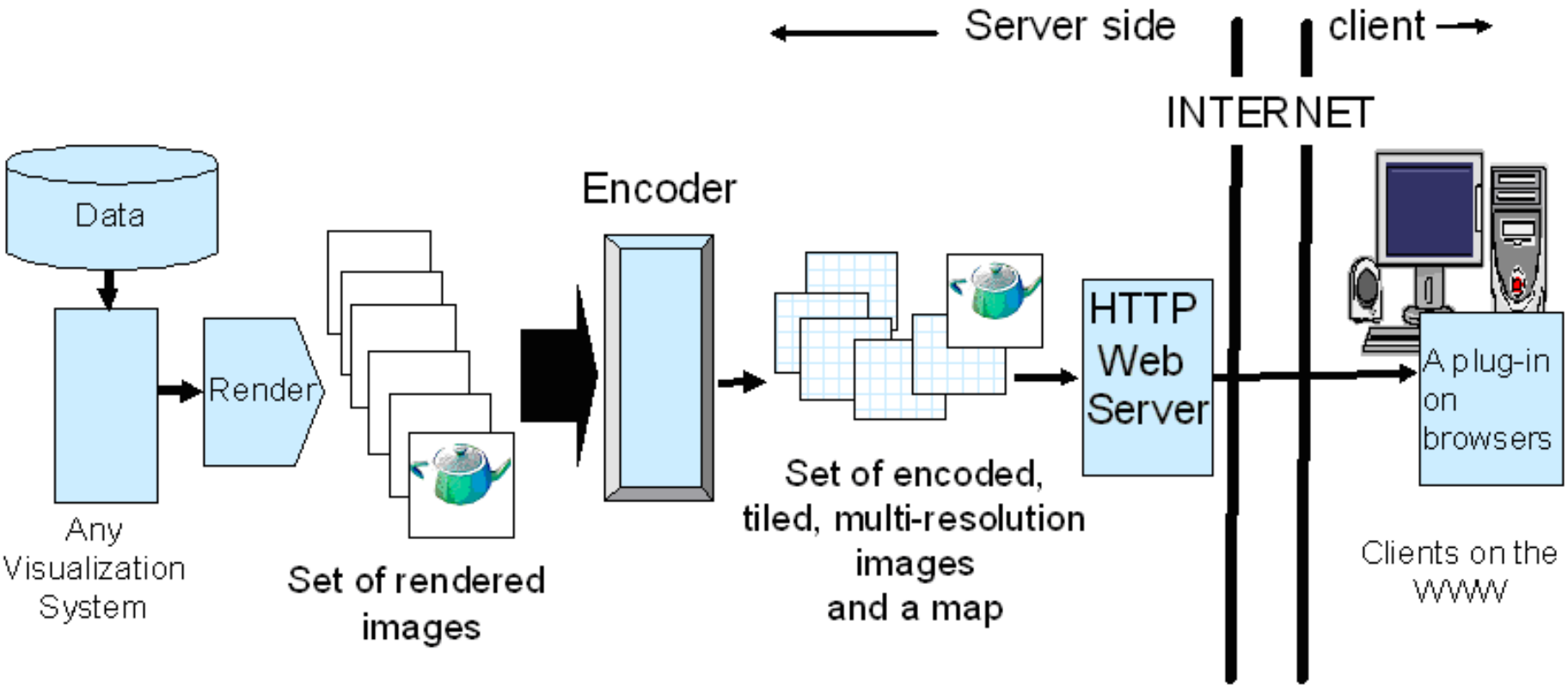
MBender – Basic Idea

- Precompute ordered image sequences
  - Ordering is sampling through vis or rendering space. E.g,. Isocontour level, viewpoint
- Encoding step
  - Produce QuickTime VR Object Movies
  - Produce MBender Catalogue/Map files
- Client-pull, vanilla web server
  - JavaScript implementation – images, web browser
  - QTVR player for QTVR Object movies
  - MBender client for “the full Monty”

MBender Architecture Overview



MBender – Industry-Standard Clients

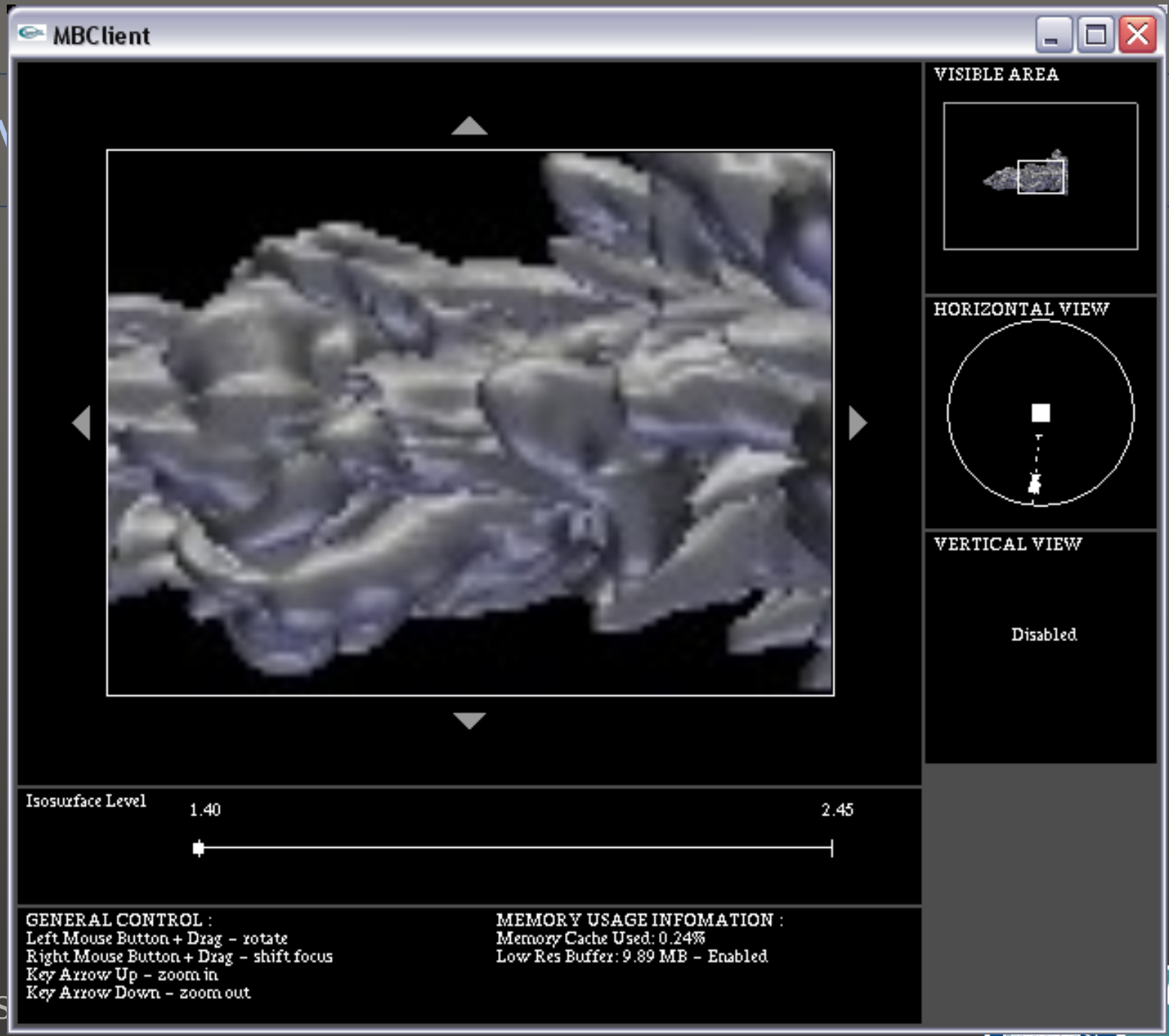
- Apple's QuickTime VR **(example, requires network)**
  - "Inside" looking "out"
  - 3D Navigation
- Apple's QuickTime VR "Object Movies"
  - "Outside" looking "in"
  - **Two-axis + zoom scientific vis example (requires network).**
  - **One-axis + time scientific vis example (requires network).**
- Web Browser/JavaScript example
  - **1D example** (requires network)
  - **2D example** (requires network)

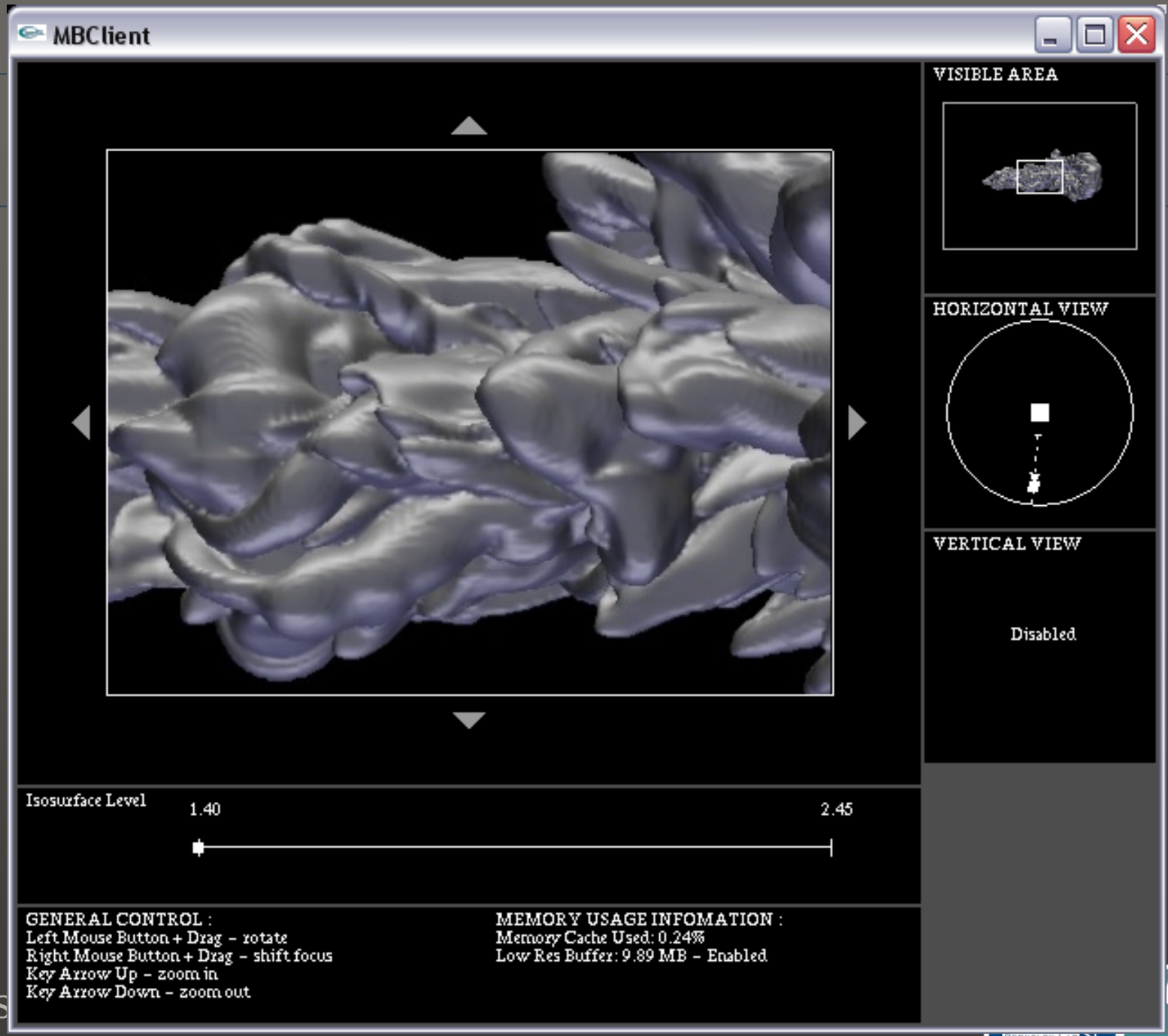
About QTVR, JS Implementations

- Pro's:
  - Industry standard "players": web browser, QT player.
  - Industry standard "formats."
  - All examples served up by "garden variety" web server – no special server-side config required.
  - Rapid, easy exploration of sci-vis results.
- Con's:
  - Fixed image resolution.
  - Not friendly use of bandwidth or memory.
  - Some prep work required before use.
  - Fits many, but not all, remote vis use models.

MBender Motivation

- Overcome limitations of previous approaches:
  - Want support for multiresolution imagery.
  - Want more efficient use of client memory.
  - Want more friendly use of bandwidth.
  - Want support for more browsable dimensions.
    - Visualization parameter space.
    - Rendering parameter space.


MBClient
VISIBLE AREA
HORIZONTAL VIEW
VERTICAL VIEW
Disabled
Isosurface Level
1.40
2.45
GENERAL CONTROL :
Left Mouse Button + Drag – rotate
Right Mouse Button + Drag – shift focus
Key Arrow Up – zoom in
Key Arrow Down – zoom out
MEMORY USAGE INFOMATION :
Memory Cache Used: 0.24%
Low Res Buffer: 9.89 MB – Enabled



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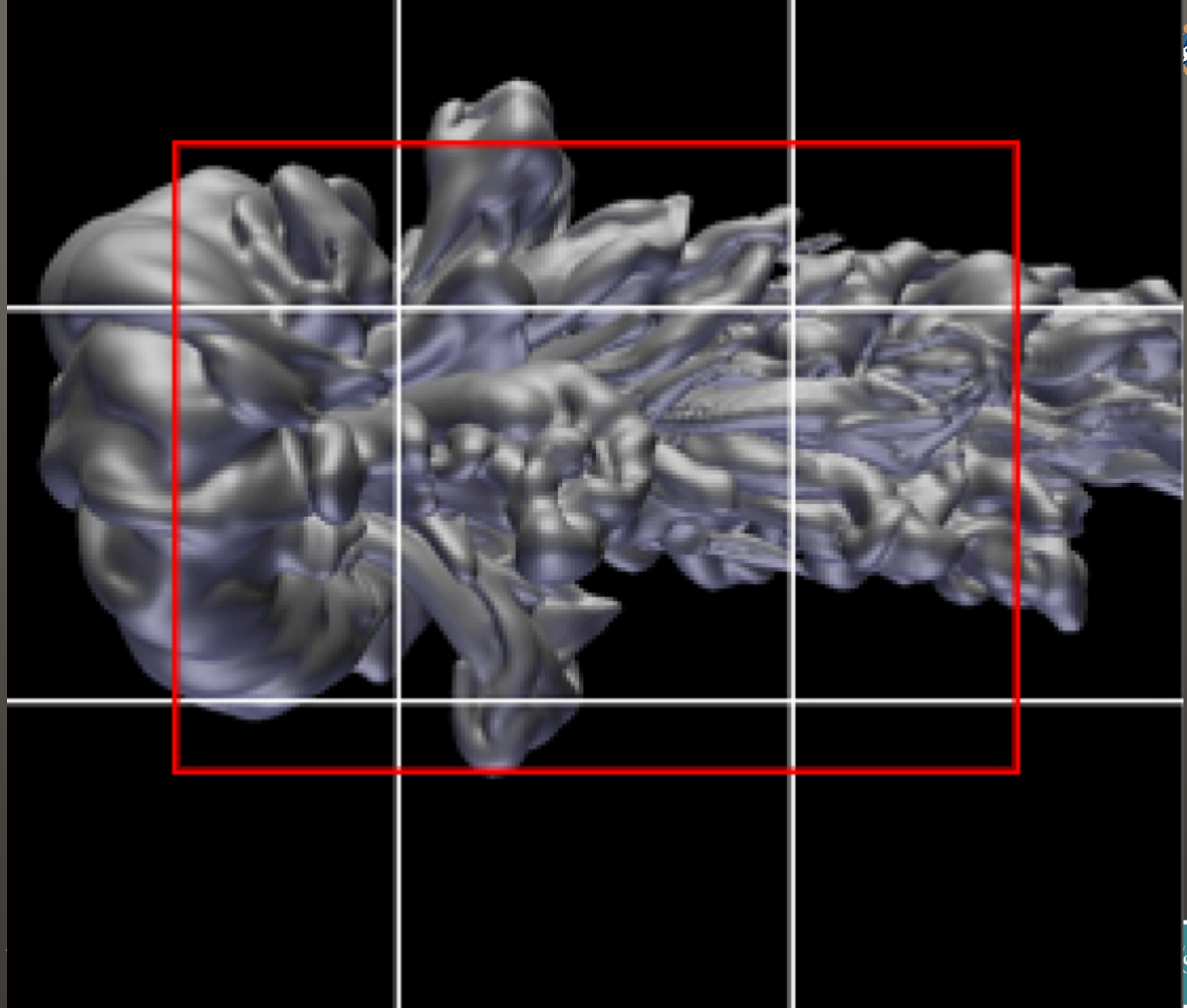
MBender Demonstration

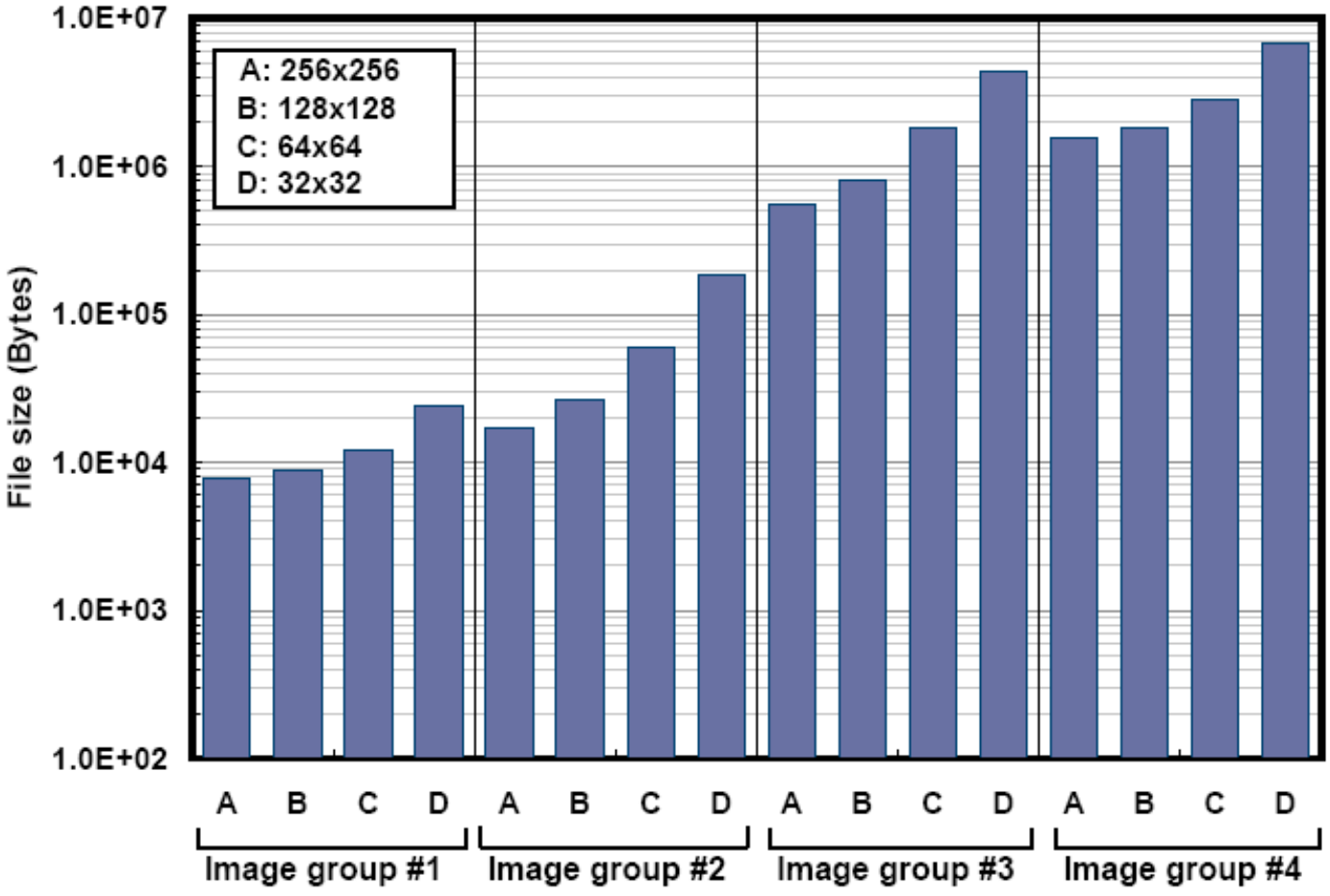
- Demo (requires network)

MBender – Performance Modeling

- Tile Size
  - Server-side storage requirements
  - Client download speed
- Multi-threaded client
  - Overlap I/O, rendering
- Client prefetching algorithm

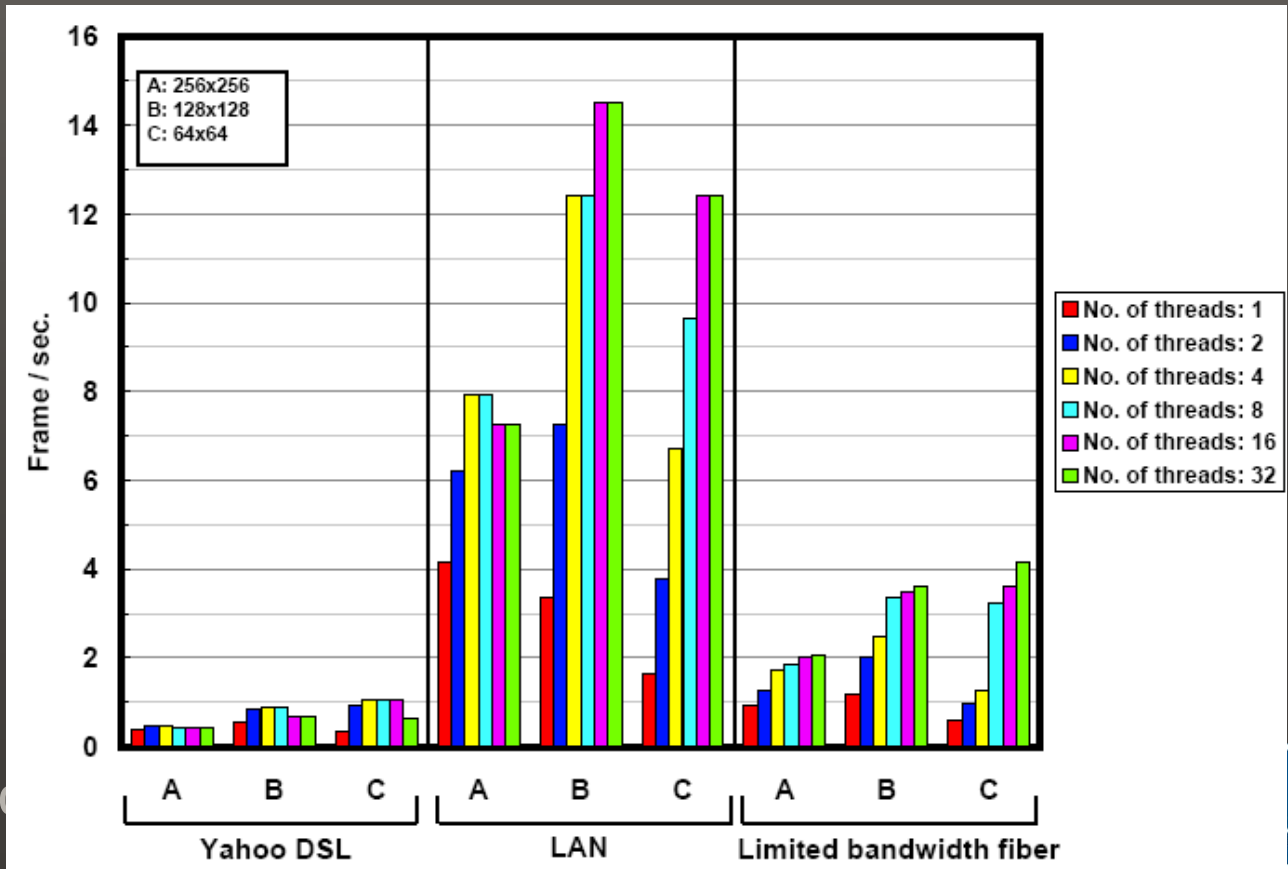


Tile Size – Server-side Storage



Tile Size – Client Download Rate

- 128x128 overall winner across all networks, degrees of I/O parallelism

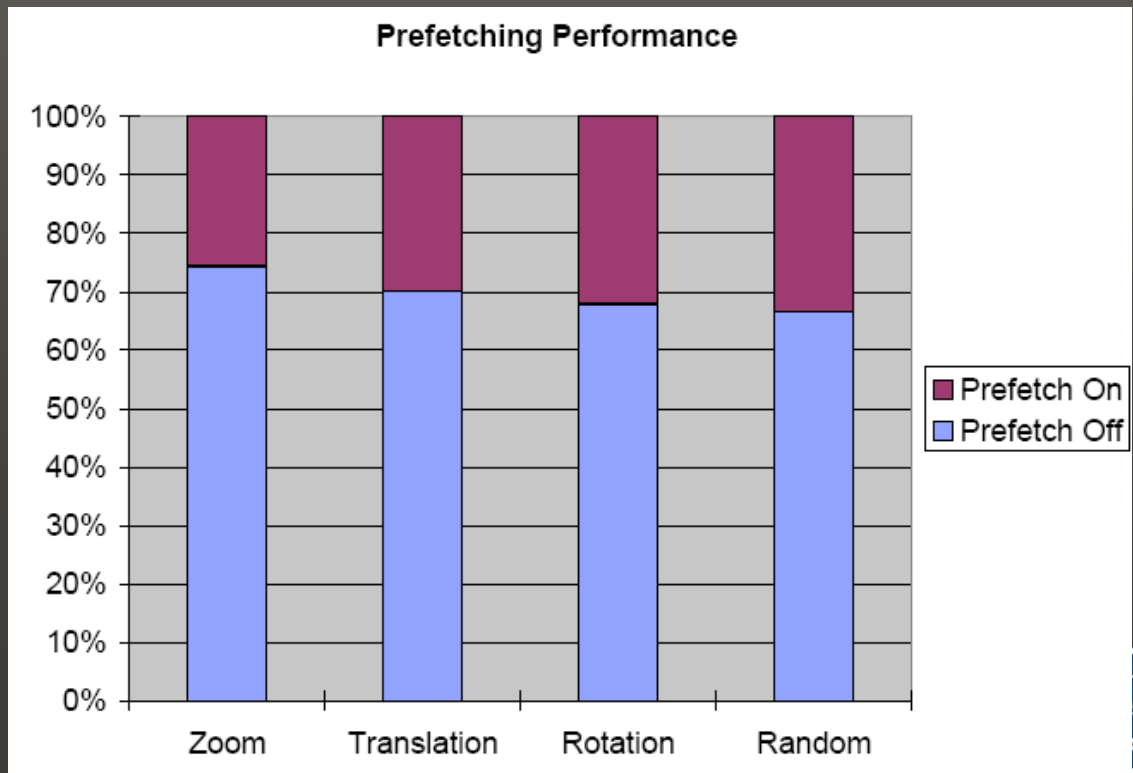


Prefetching Algorithm

- Objective: predict which frames a user will want to see and download them ahead of time.
- Client does navigation through *n*-dimensional parameter space.
- Present client supports 4-d navigation:
  - Pan (left/right/up/down)
  - Rotate (azimuth/pitch)
  - Zoom
  - Data browsing
- Different prefetch algorithm depending upon navigation use mode.

Prefetching Performance Improvement

- Test shows “delay time” – time client spends waiting for images to satisfy view.
- Prefetch produces 2x-3x improvement.

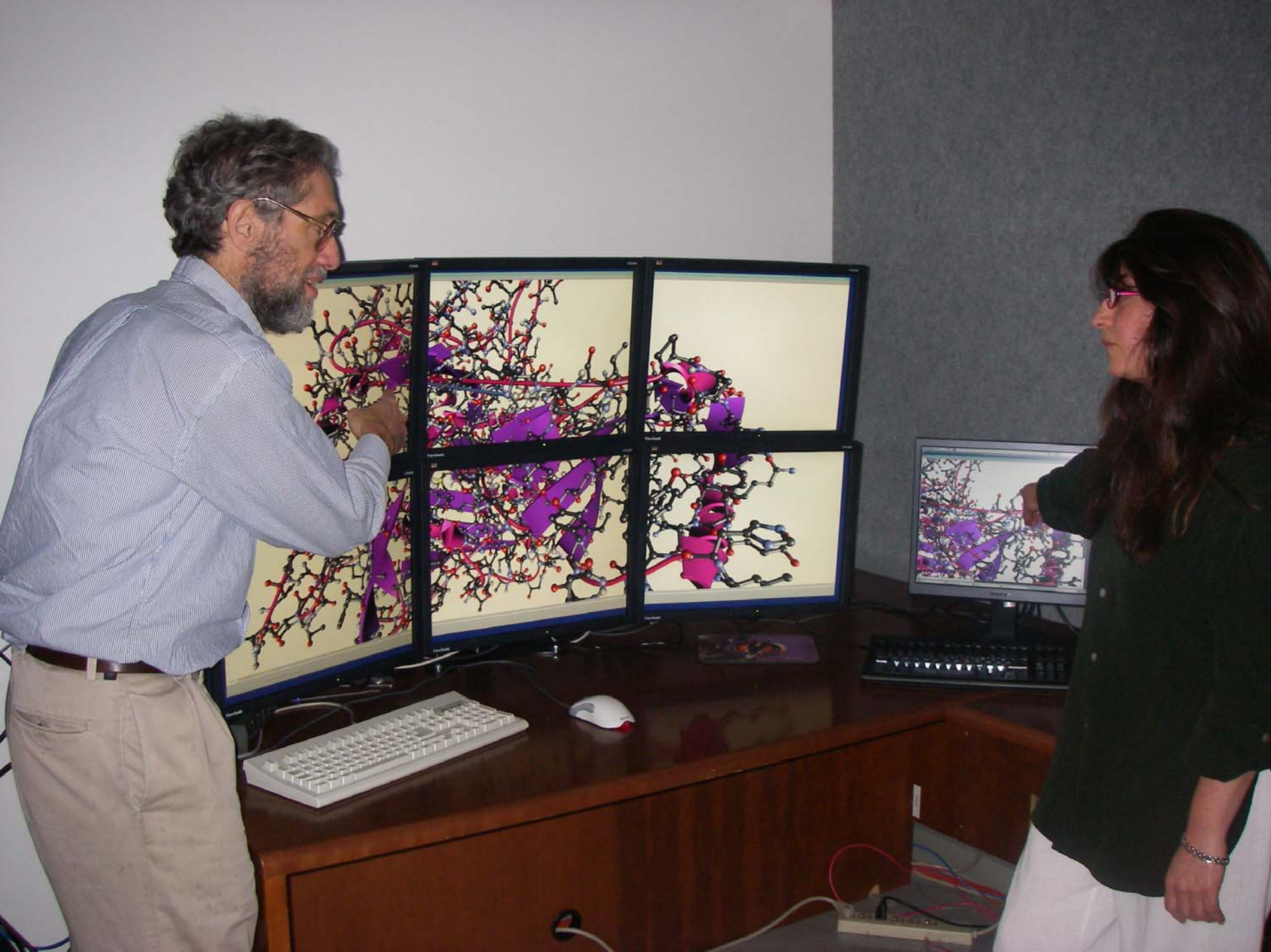


MBender – Post-Game Show

- Great idea, works well.
  - Serve up all images through a vanilla web server.
  - No expensive, complex server-side machinery
- Huge potential use: precompute complex, expensive vis, store images for later use.
- Provides illusion of unconstrained navigation
  - But without the bother of manually running the vis application.
- Supports two of three common visualization use modalities.
- Some challenges: lots of image files!
  - 36 horizontal x 18 vertical views: 648 images
  - Multiply by time, by vis parameter, by rendering parameter, pretty soon have *a lot* of images.

Chromium Render Server

- Focus on remote delivery of imagery produced by vis applications.
- Special focus on support for distributed-memory parallel, hardware-accelerated graphics applications.
- Our general solution suitable for use by literally *any* application that uses Xlib/OpenGL (all apps, basically).
- Supports all common visualization use modalities.



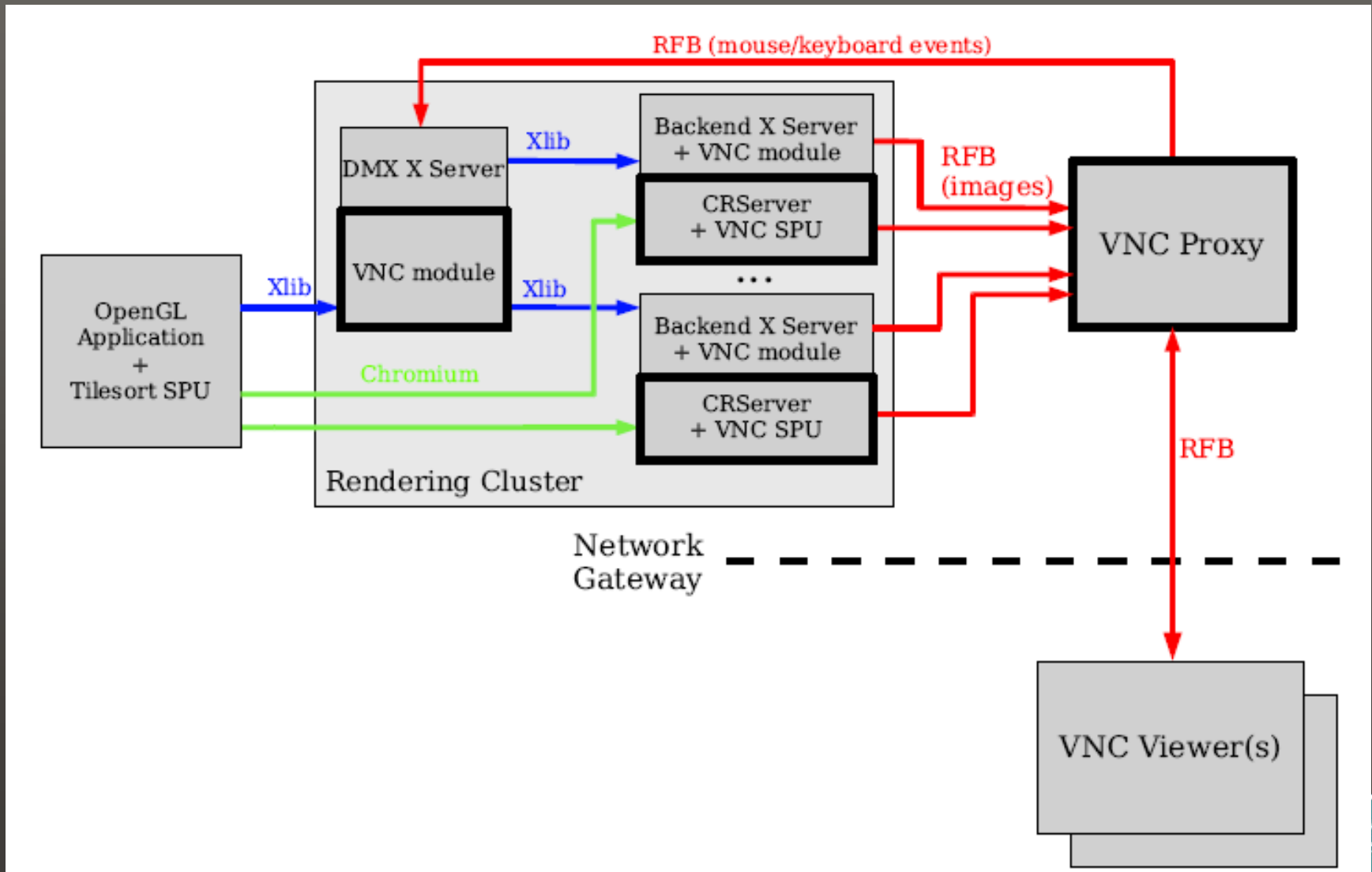
Prior Work

- Send-images approaches
  - Virtual Network Computing – VNC (Industry standard, no OpenGL support)
  - SGI's VizServer (comm., RIP)
  - IBM's Deep Computing Visualization (comm.)
  - ThinAnywhere (comm.)
  - HP's Remote Graphics Software (comm.)
- Send-images/send-geom hybrid
  - VirtualGL
- Send geometry
  - CEI's Ensight Gold Server-of-Servers

CRRS Approach

- Communication protocol: extend VNC
  - Ubiquitous viewer
  - Well-understood protocol
  - Open Source
- Rendering Infrastructure: extend Chromium
  - Solid base for distributed memory, h/w accelerated graphics
  - Open Source

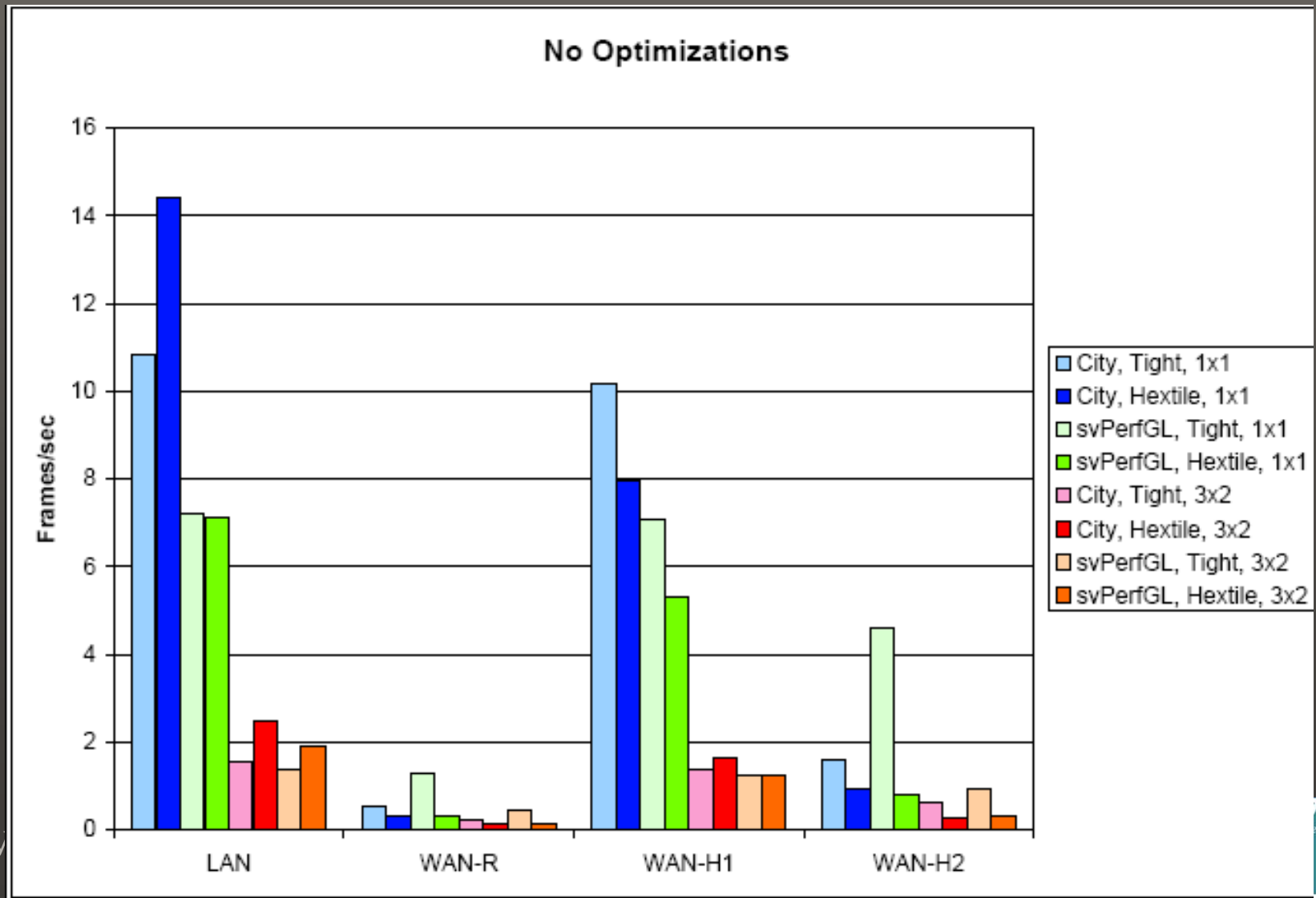
CRRS Architecture



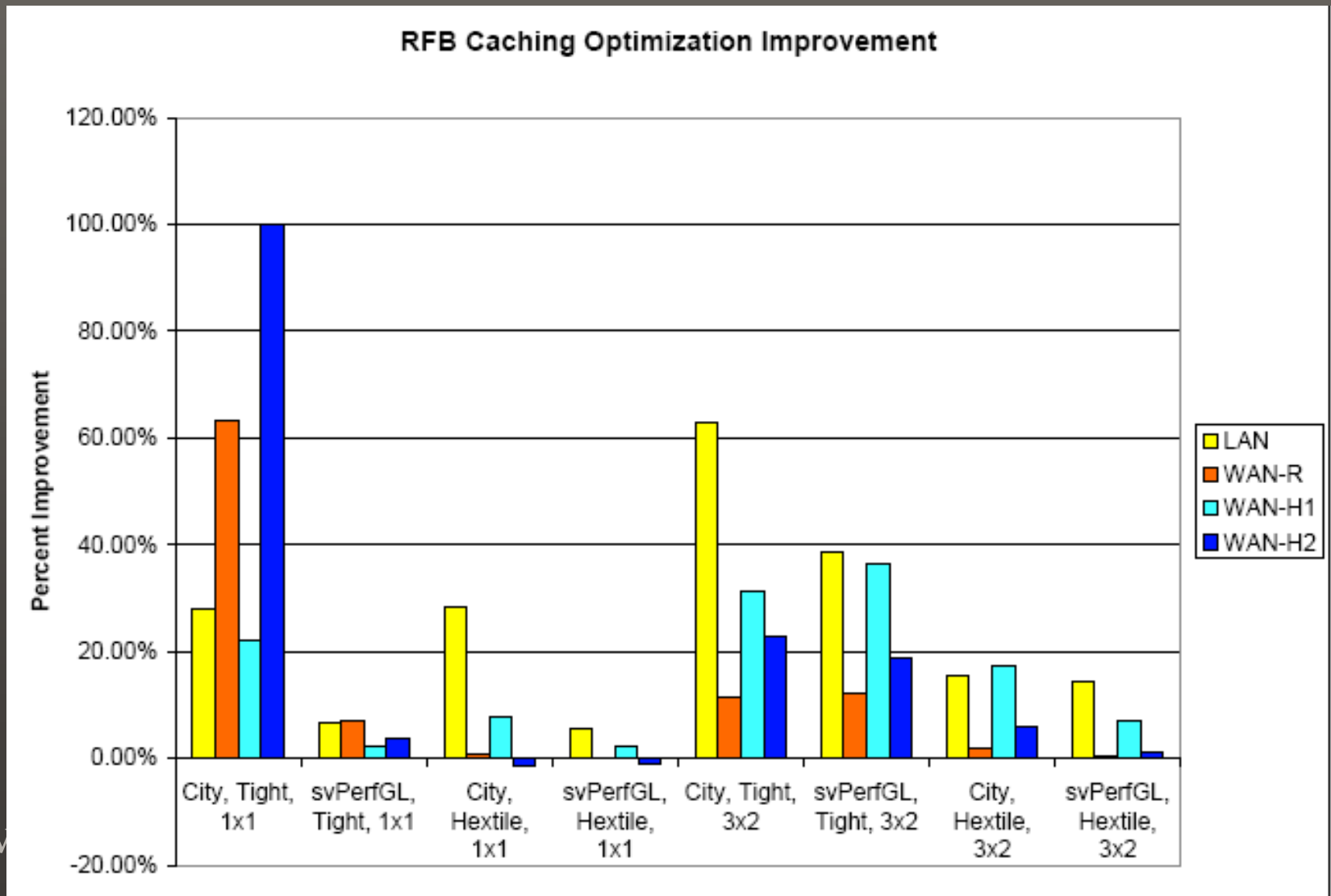
CRRS Optimizations

- RFB Caching
  - Avoid re-encoding images at the VNC Proxy
- Bounding box tracking
  - Limit RFB Updates to regions of OpenGL window that have changed since the last frame
- Double-buffering
  - Overlap rendering with encoding/transmission
- Frame synchronization
  - Synchronize parallel rendering streams

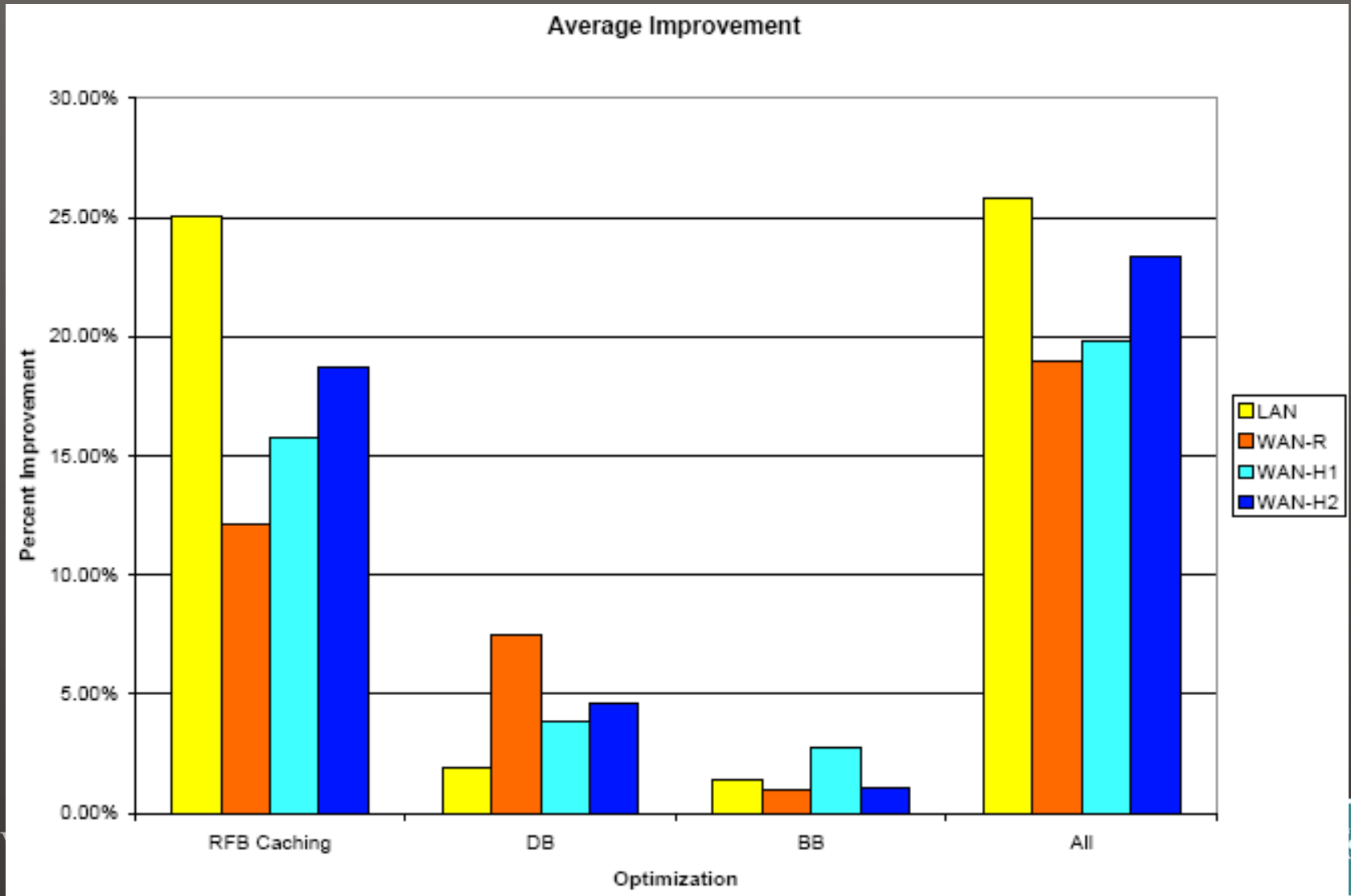
CRRS Baseline Performance



CRRS Performance w/RFB Caching



CRRS Performance w/Optimizations

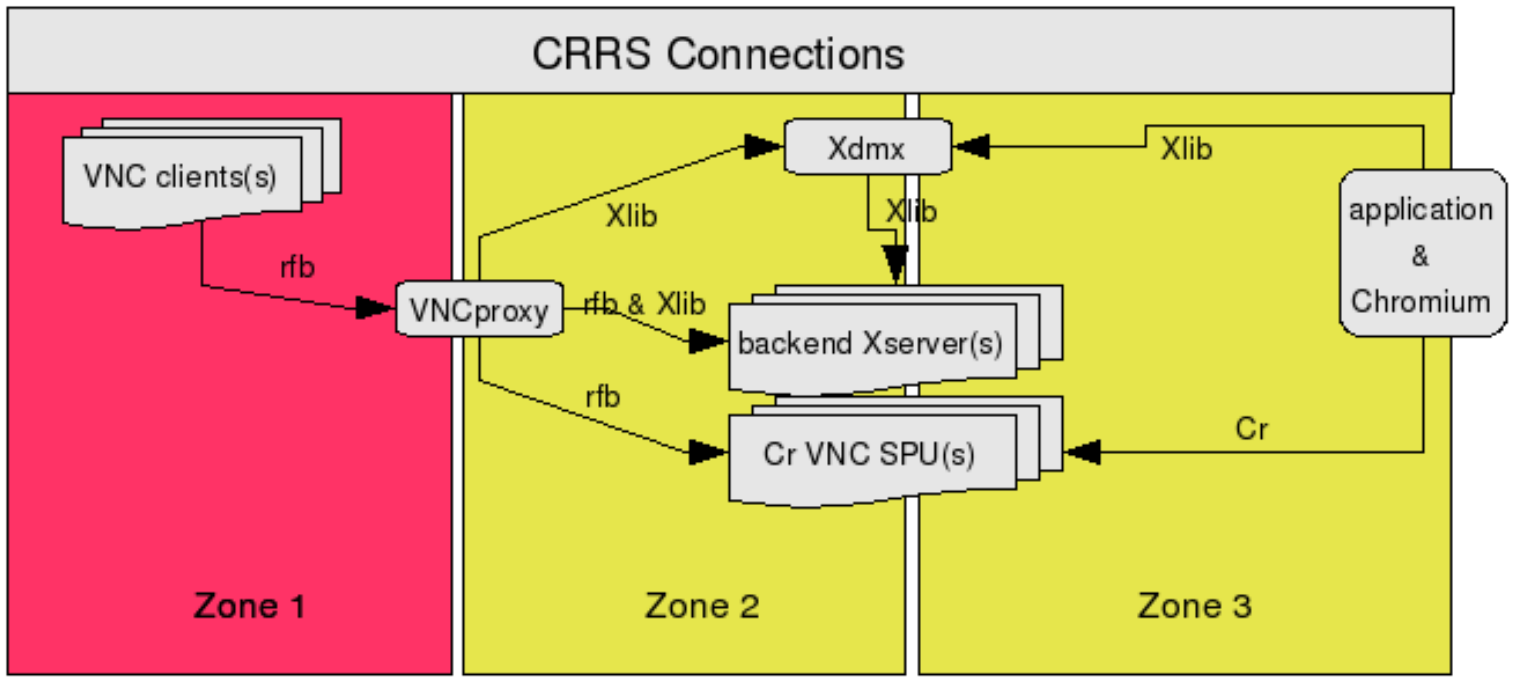


CRRS Feature/Capability Summary

- Remote visualization capability
  - Support for virtually any application
  - Including hardware-accelerated rendering
  - Supports multiple, collaborative participants (VNC)
  - Ubiquitous client application (VNC)
  - Completely Open Source (vncproxy.sf.net)
  - Deployment activities at LBNL, ORNL.
    - Security considerations (next slide)

CRRS Security

- Zone 1 – open internet
- Zone 3 – intracluster fabric
- Zone 2 – intracenter fabric



The CRRS Team

- Tungsten Graphics, Inc.
  - SBIR Small Business
- Lab participants: LLNL, ORNL, LBNL
- Peer-reviewed journal publication: IEEE Transactions on Visualization and Computer Graphics, May/June 2008.

The End – Remote Visualization

- Send images holds the most promise
- Two projects that deliver results
  - Both garner peer-reviewed journal pubs in IEEE Transactions on Visualization and Computer Graphics
- Open source software release
- CRRS being deployed for production use at LBNL/NERSC and ORNL/CCS.