SAGE: High-Resolution Collaboration

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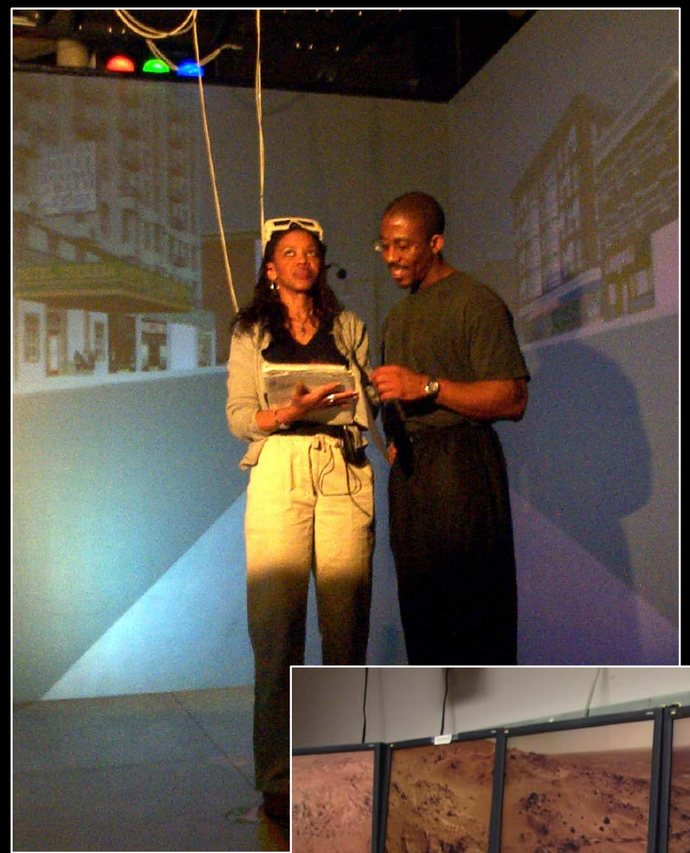
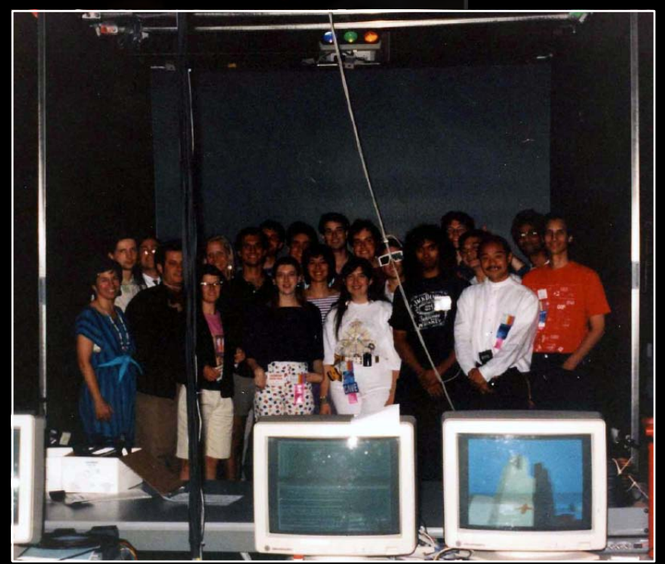
EVL: New Display, Interaction and Collaboration Research





Motivation

- Scale, Complexity, and Collaboration

Motivation

- Problems today are of much larger scale and complexity than ever before
- These and other problems can only be solved through interdisciplinary collaborations
- There is a need to teach students, not just scientists how to collaborate with people from other disciplines

Where we ultimately see things going…
EVL's 100-Megapixel LambdaVision Wall

University of Illinois at Chicago

www.evl.uic.edu

Real World Examples of Managing Scale and Complexity

Will Self, English novelist known for crafting complex narratives with weaving story lines

www.will-self.com/writing-room

Real World Examples of Managing Scale and Complexity

Antarctic Drilling Program
Documenting features is done by hand, on paper

Examples of Managing Scale and Complexity

BMW's Wall of Inspiration

Depicts trends in context of Time, Fashion and Architecture

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BMW's Wall of Inspiration

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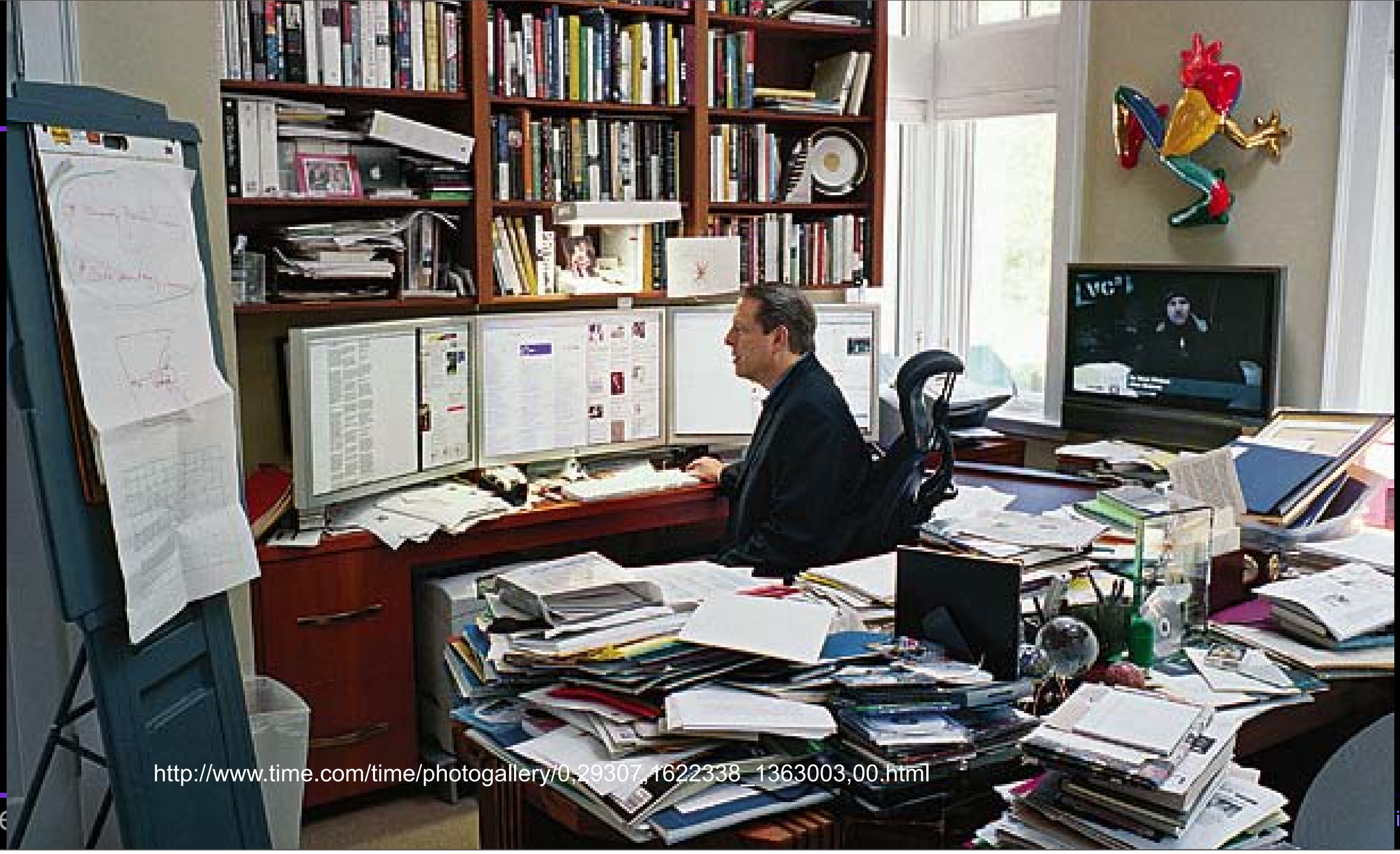
Managing Scale and Complexity in Teams

“War” Rooms / Project Rooms

Another Example

http://www.time.com/time/photogallery/0,29307,1622338_1363003,00.html



http://www.time.com/time/photogallery/0,29307,1622338_1363003,00.html

Is it Just Display Size? Or Does Resolution Matter?

	Small Screen	Big Screen
Low Res	1 doc @ a time Pan & zoom Single user / viewer Single point of control	1 doc @ a time Pan & zoom Multi user / viewer Single point of control or turn taking for multi users
High Res	Multi doc @ a time Reduced pan & zoom Enables detail & context Single user / viewer Single point of control	Multi doc @ a time Reduced pan & zoom Enables detail & context Multi viewer Multi control New modalities of interaction (up close and far away)

Is it Just Display Size? Or Does Resolution Matter?

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Large Scale High Resolution Display Spaces enable users to Externalize and Expand their Working Memory-
A powerful weapon against problems of scale and complexity!

Need for Resolution

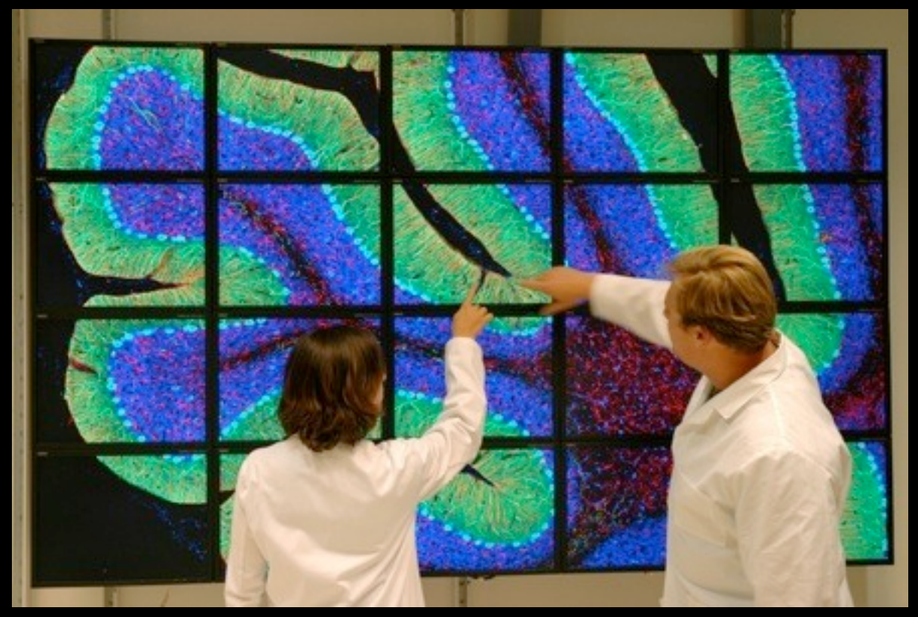
- Need for more resolution !

Scientific Needs: Large Amount of Data and the Ability to Perform Data Fusion

- US Geological Survey
  - National Map Mission
  - 51TB (51,000 GB) of aerial photos
  - 133 cities in US at 1/3 meter resolution
  - 365,000 * 365,000 pixels in each map

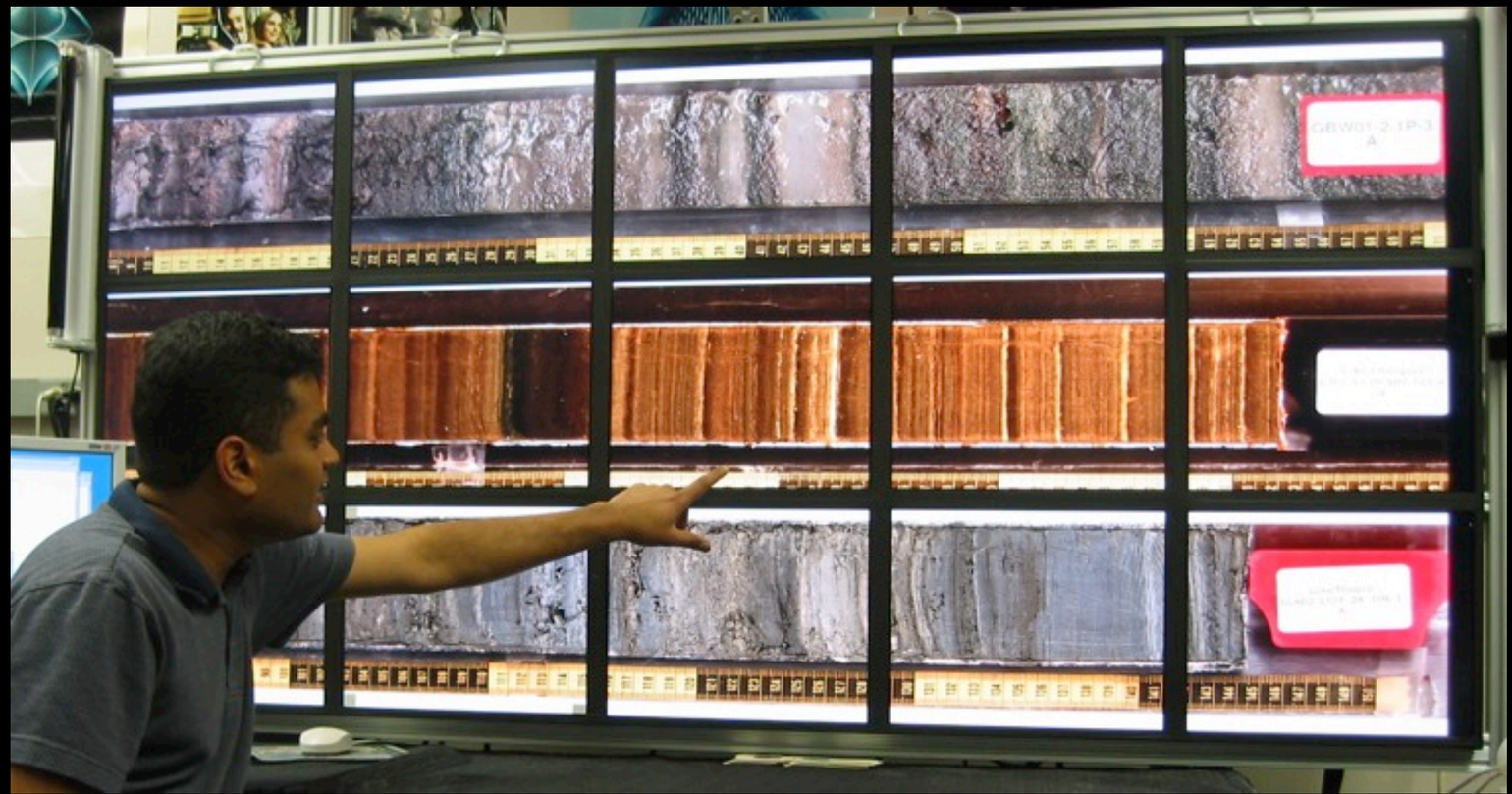
Scientific Needs: Large Amount of Data and the Ability to Perform Data Fusion

- NCMIR (Microscopy)
  - Rat Brain Mapping
  - Montage of 43,200 images
  - Each image 4,000 x 4,000 pixels



Scientific Needs: Large Amount of Data and the Ability to Perform Data Fusion

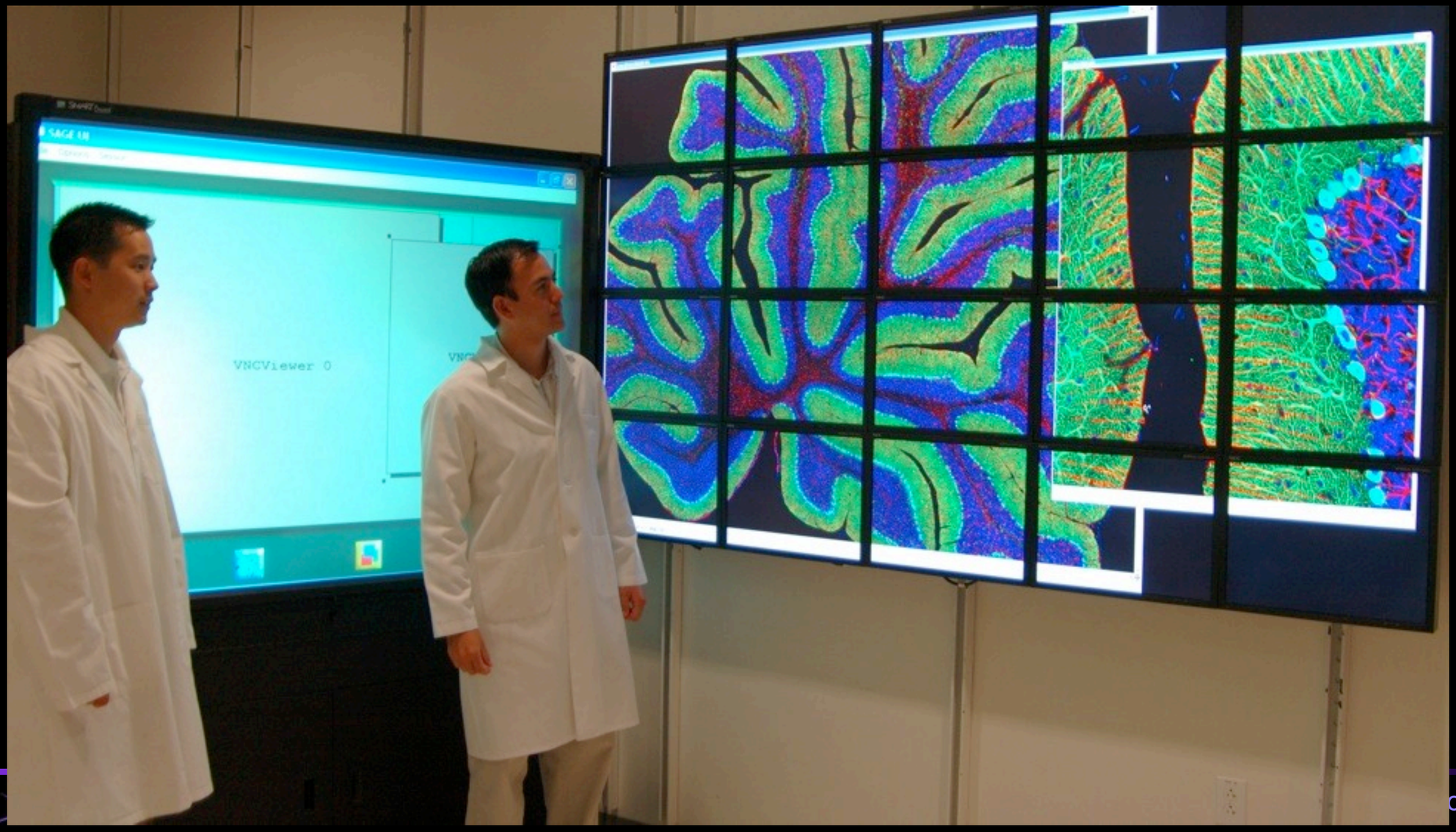
- Core Lab (Geology)
  - –300 km of core samples
  - –scanning at 1200 dpi



Looking for Correlations

- Tiled displays are also good for viewing and manipulating multiple related images at the same time to look for correlations

High Resolution Displays Connected to High Speed Networks are Becoming the Lenses to Cyber-Instruments



- National Center for Microscopy and Imaging Research
- UC San Diego

A Variety of Sizes, Shapes, and Uses

Narrow Borders: ‘Showcase’ at KAUST

Narrow Borders: ‘CyberCommons’ at EVL

Networking

- Need for speed !

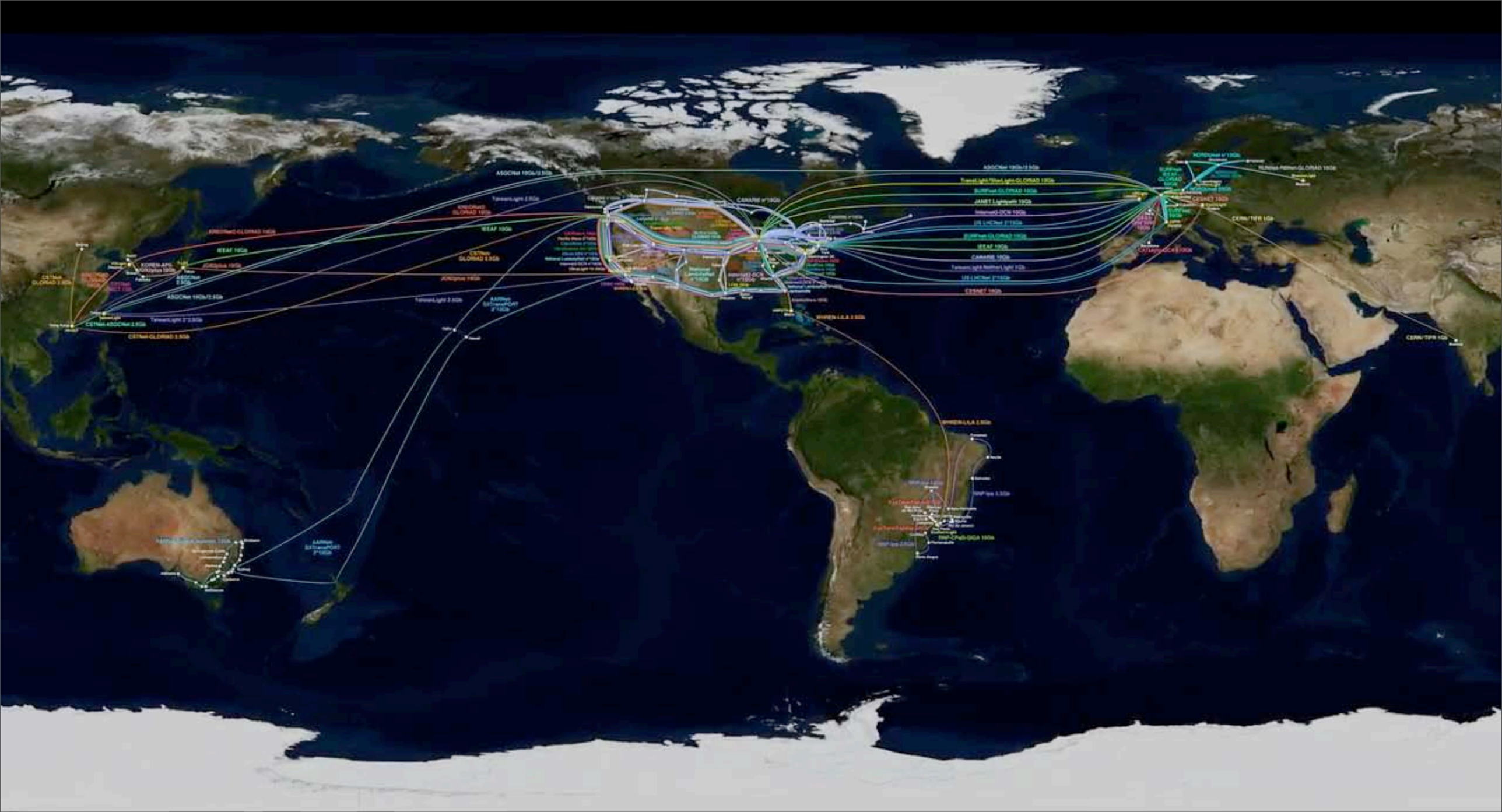
International Network Infrastructure

Global Lambda Integrated Facility

Persistent Optical Networking Infrastructure for
Rapid Distribution of Large Scale Instrumentation Data

Founding Partners: UIC, Northwestern and Argonne National Laboratory

International Network Infrastructure



Wednesday, July 28, 2010

Using High-Speed Networks

- 10 Gbps
  - 10,000x DSL 1Mbps lines
  - over 1GB per second, over 4 TB per hour, ...
- Price
  - 10 Gbps network interface: ~ $500
  - 10 Gbps switch: < $1,000 per port
- High-end desktop computer
  - Can put 4x network interfaces (PCI-express cards)

Pixel Streams at 30fps

	Format	*Bandwidth*
HDV uncompressed	1440x1080 RGB16	~ 700 Mbps
HD video	1920x1080 RGB16	~ 1 Gbps
HD animation	1920x1080 RGB24	~ 1.5 Gbps
HD animation stereo	1920x1080 RGB24	~ 3.0 Gbps
SHD animation	3840x2160 RGB24	~ 6.0 Gbps

Building Tiled Displays

Parallel Approach

- Building cluster computers for graphics
- Combining graphics, networking, storage and compute capabilities to feed content to high-resolution displays
- Exploit consumer-driven off-the-shelf components
- Emergence of wide-area high-speed networks

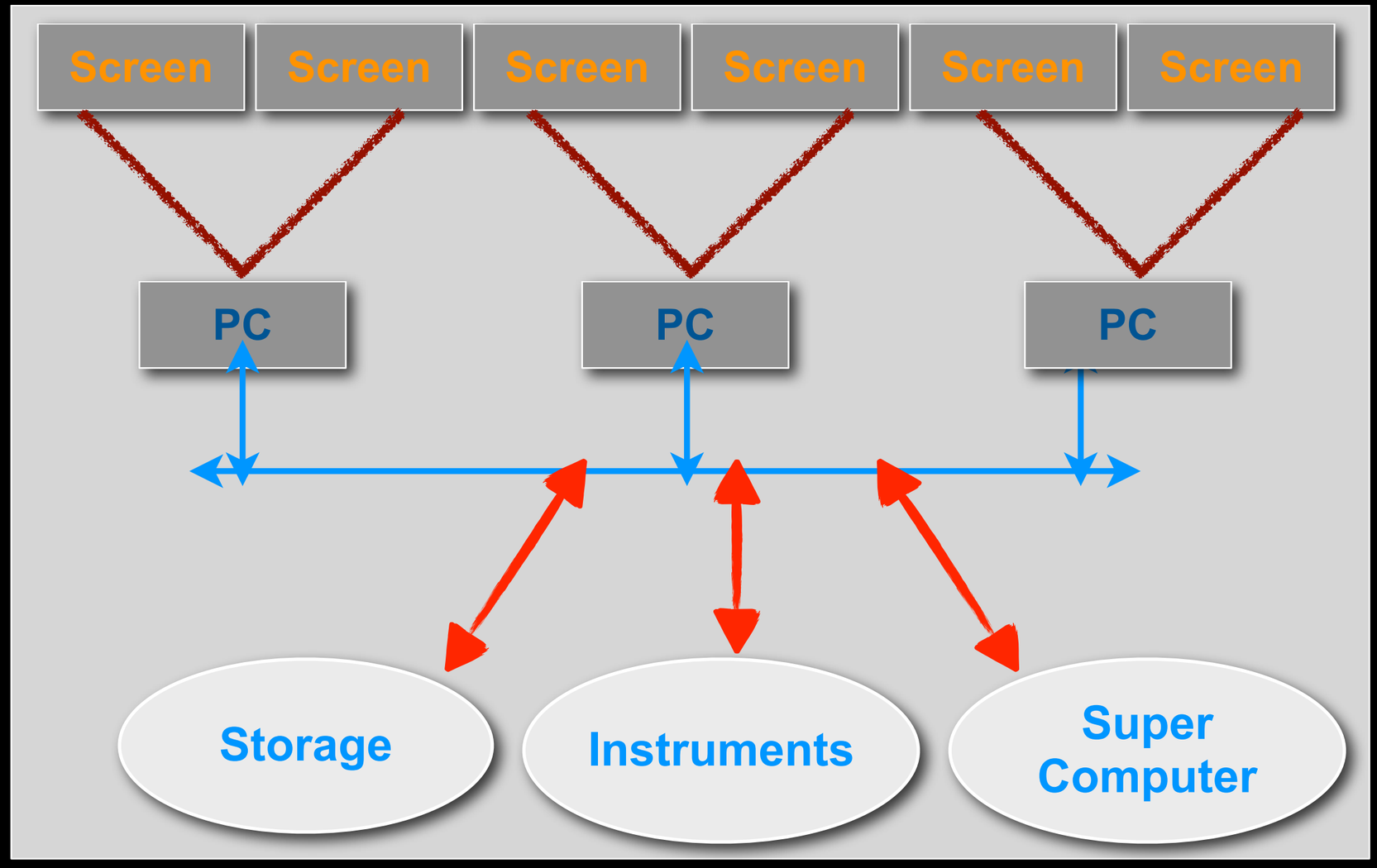
Tiled Displays

Displays

Rendering

Private network

Local and
Wide-area networks



Tiled Displays

- Typically we are driving 2 displays per node with one graphics card
- Why so many cluster nodes?
  - Balance GPU, CPU, Bandwidth
- You can put several graphics cards into each computer
- Modern PCs can now drive 4x 2560x1600 30” monitors using a pair of GPUs

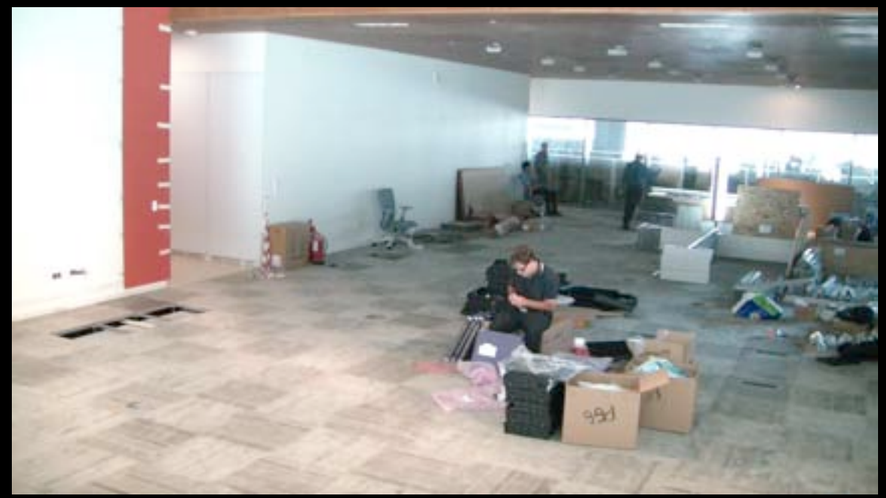
Tiled Displays: Scalable

- Number of nodes (computers) is important
- Managing a single PC with multiple displays as a single large desktop is doable for a Geoscientist, Bioscientist or Astronomer
- Managing a cluster of PCs can be intimidating and requires specialized help

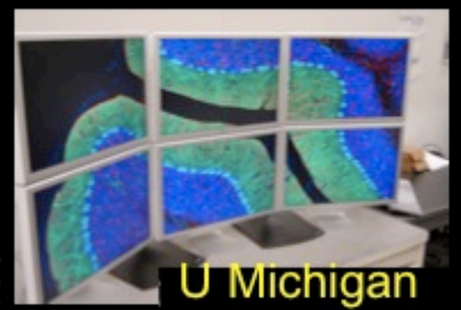
- So we are trying to develop a variety of solutions
  - Personal display for the office
  - Larger shared display in the lab

Building a Wall

- KAUST Wall
  - 40 LCD panels, 10x4 layout
  - 46 inch, 3.5 mm border
  - 1360x768 pixel displays
  - 11-node cluster
  - Intel 64bit dual-quad core
  - NVIDIA GTX 285 graphics cards
  - 10 Gbps network
  - **13600 x 3072 pixels : 41 Megapixels**



Expanding International Community of Users



SAGE community around the world

So What's the Problem?

- Building the display is relatively straightforward but the software side is much harder
  - accessing data
  - rendering the data to the screens
  - juxtaposing multiple related datasets
  - interacting with the data
  - collaborating with others
  - keeping track of the state of the collaboration
  - easily outputting the results of the collaboration to more traditional media

SAGE

SAGE Requirements

- To see heterogeneous high-resolution datasets at a time
- To resize and reposition visualization windows on tiled displays
- To share remote visualization resources
- Collaboration on high-resolution display environment

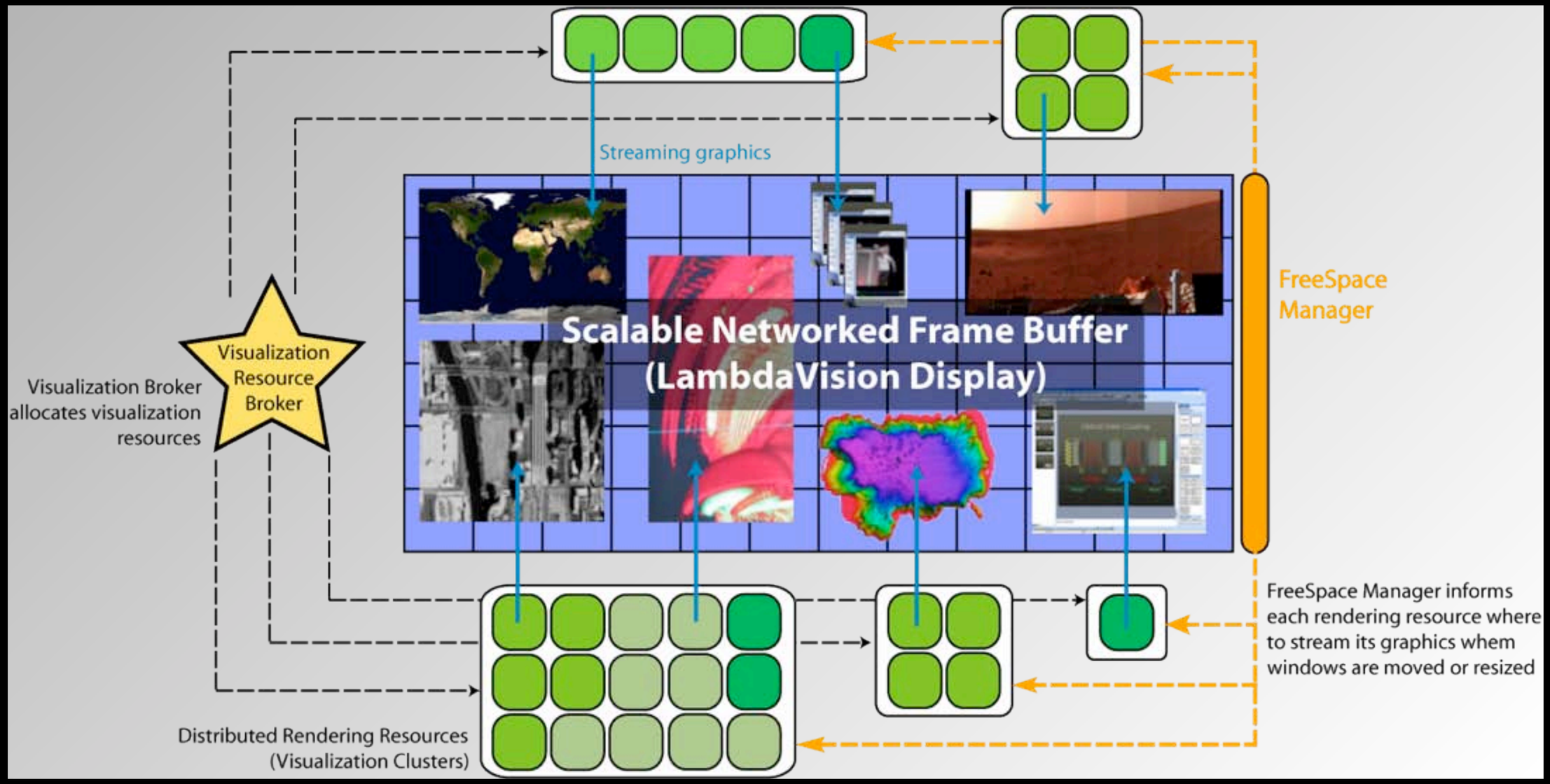
New Approach

- Displays as frame buffers on the network
- Network as a bus between
  - Storage
  - Computing
  - Display resources
- Bridge between network and display
  - Lots of small PCs or a few big ones
  - Gigabit and DVI
- “Ethernet rather than DVI to the display”

SAGE: Scalable Adaptive Graphics Environment

- Imagine
  - Display everywhere
  - Unlimited Bandwidth
- Decoupling rendering and display
- Visualization
  - Scalable in term of data size
  - Scalable in term of resolution

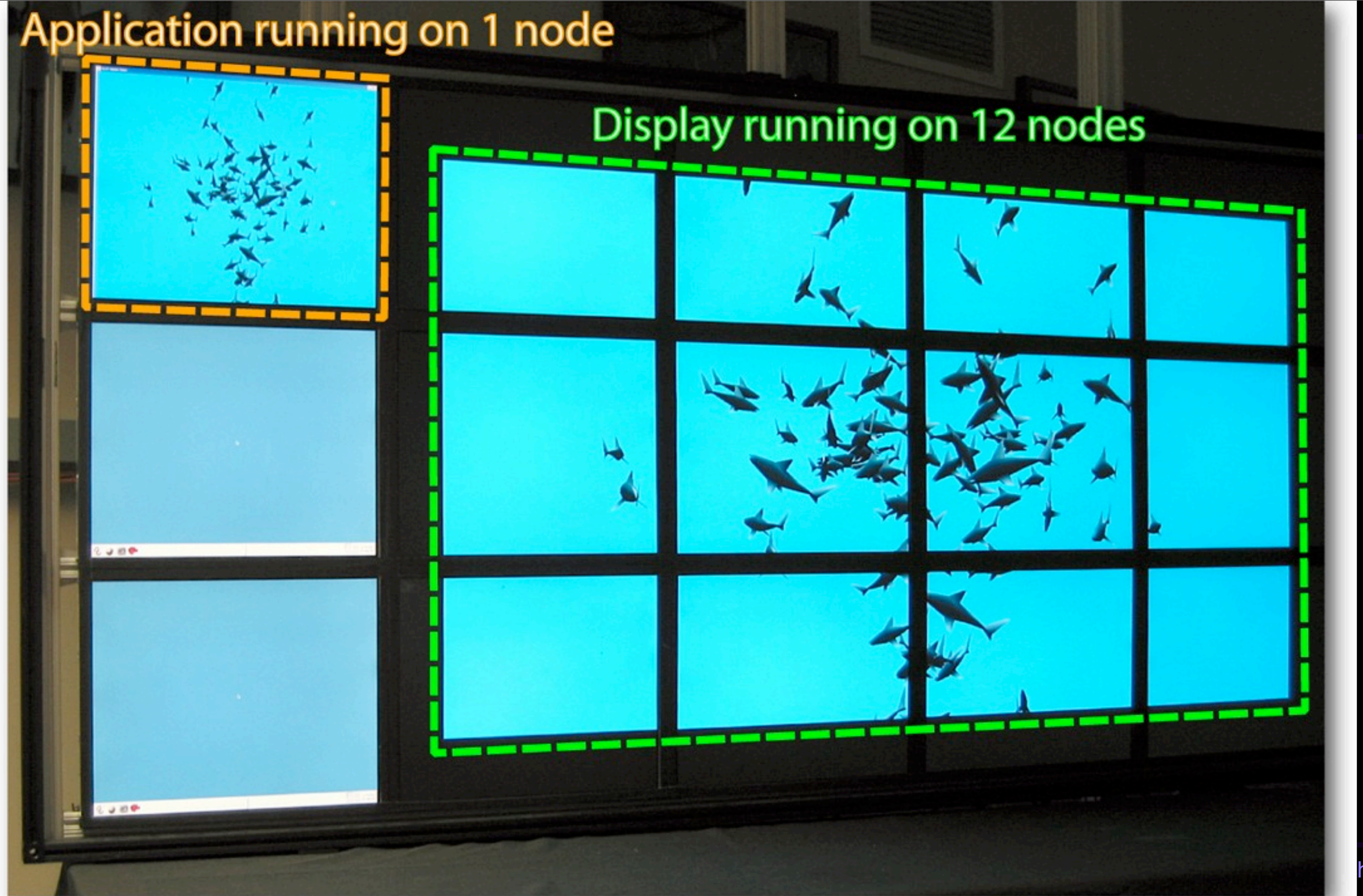
SAGE : to Manage Content on Tiled Displays



SAGE Steps

- Capture the pixels
- Partitioning of the images
- Routing the pixels
- Layout on the display
- User interaction

Result


Application running on 1 node
Display running on 12 nodes

Program a SAGE application

- SAGE object
- Initialization phase
- Streaming phase
- Event processing

Program a SAGE application

- SAGE object:
  - Headers for SAGE
    - **#include "sail.h"**
    - **#include "misc.h"**
  - Pixel buffer
    - **unsigned char *rgbBuffer = NULL;**
  - SAGE information
    - **sail sageInf; // sail object**

Program a SAGE application

- **Initialization phase**
- sageRect imageMap;
- imageMap.left = 0.0;
- imageMap.right = 1.0;
- imageMap.bottom = 0.0;
- imageMap.top = 1.0;

- sailConfig scfg;
- scfg.cfgFile = strdup("sage.conf");
- scfg.appName = strdup("atlantis");
- scfg.rank = 0;

- **scfg.resX = 1024;**
- **scfg.resY = 768;**
- scfg.imageMap = imageMap;
- **scfg.pixFmt = TVPIXFMT_888;**
- scfg.rowOrd = BOTTOM_TO_TOP;

- **sageInf.init(scfg);**

Program a SAGE application

- Streaming phase
  - **rgbBuffer = sageInf.getBuffer()**
  - **Copy pixel data into “rgbBuffer”**
  - **sageInf.swapBuffer()**
- That’s it !!

Program a SAGE application

- Event processing

```
sageMessage msg;
if (sageInf.checkMsg(msg, false) > 0) {
        switch (msg.getCode()) {
                case APP_QUIT : {
                        exit(1);
                        break;
                }
        }
}
```

SAGE Applications

- ImageViewer
- VNC
- Movie players: mplayer and VLC
- JuxtaView and MagicCartpet
- Bitplayer: HD animation
- HD: Live HD video
- ... develop your own...

SAGE Applications

- ImageViewer
  - –Reads most of the common image file formats (JPEG, PNG, TIFFF, ...)
  - –“Drag and drop” feature from SAGE UI
  - –Works for small and moderate file sizes
  - –Can start many instances (lightweight)

SAGE Applications

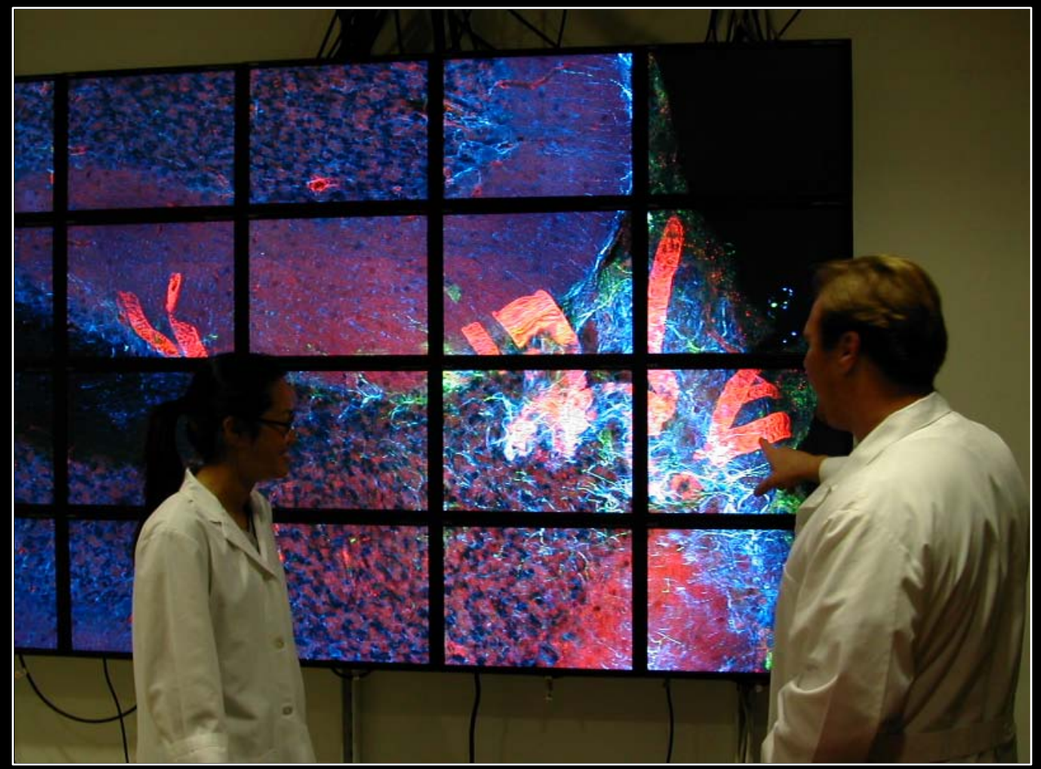
- **VNC**
  - –Remote desktop / desktop sharing tool
  - –Compatible with standard VNC server
  - –Share you Windows, Linux, or MacOSX desktop
  - –Can be launched from SAGE UI
  - –First step towards collaboration

SAGE Applications

- **Movie players: mplayer and VLC**
  - –Plugins for Linux movie players
  - –Display modules only added
  - –Plays most of the movie formats (mpeg, mp4, mov, avi, ...)
  - –Managed by the SAGE UI
  - –Can start several instances

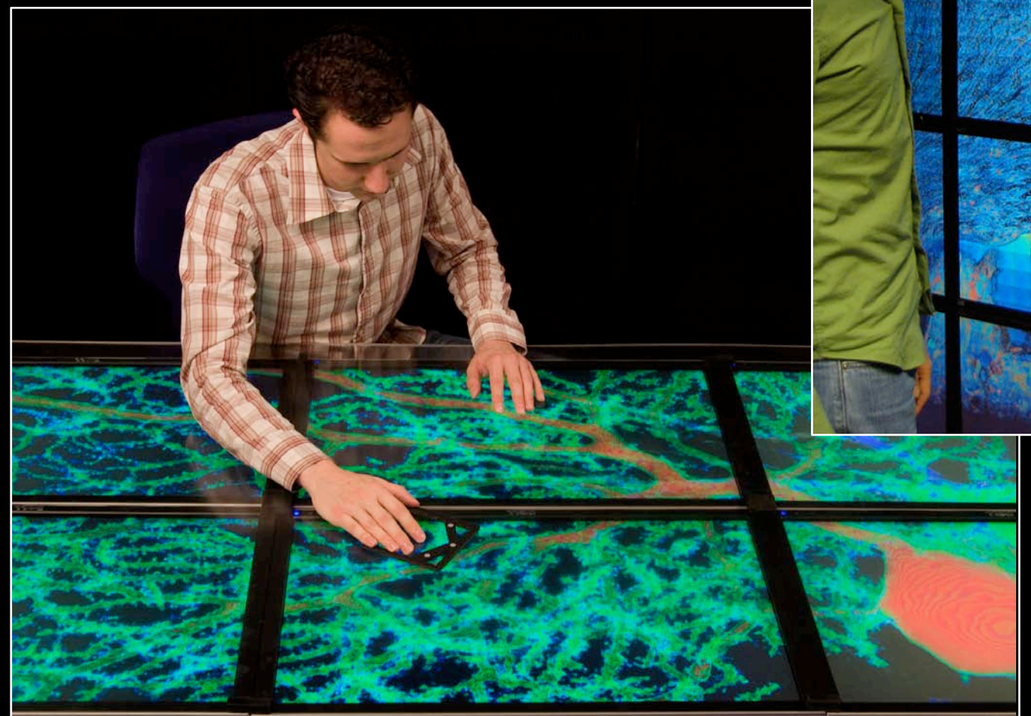
SAGE Applications

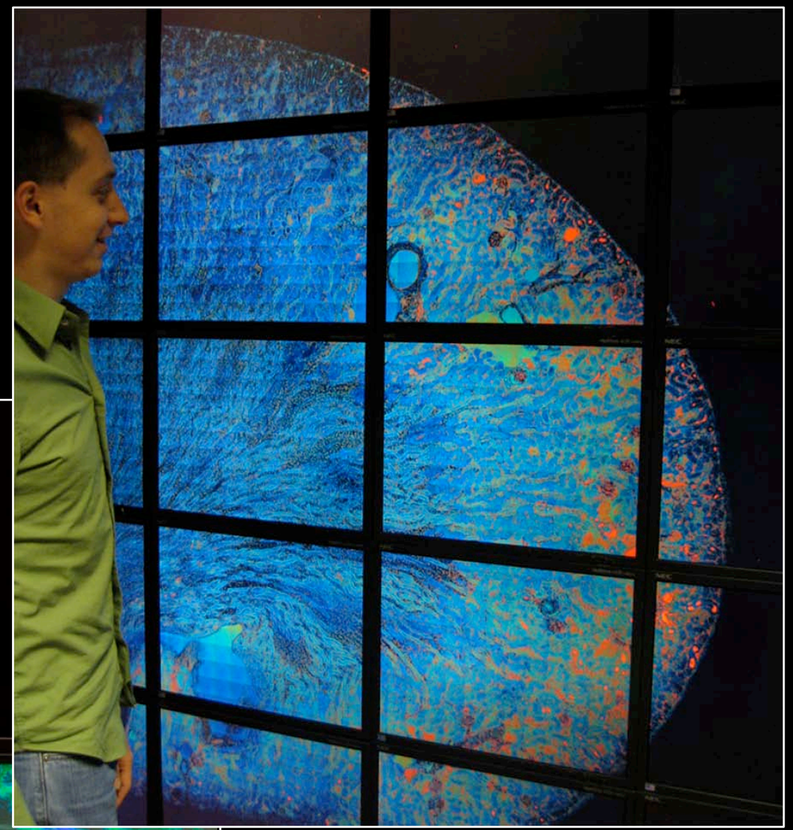
- **JuxtaView and MagicCartpet**
  - –High-resolution image viewer
  - –Works with large mosaic of images
    - ex: aerial photograpy or microscopy
  - –Parallel applications
  - –Juxtaview: software rendering
  - –MagicCarpet: hardware rendering



SAGE Applications

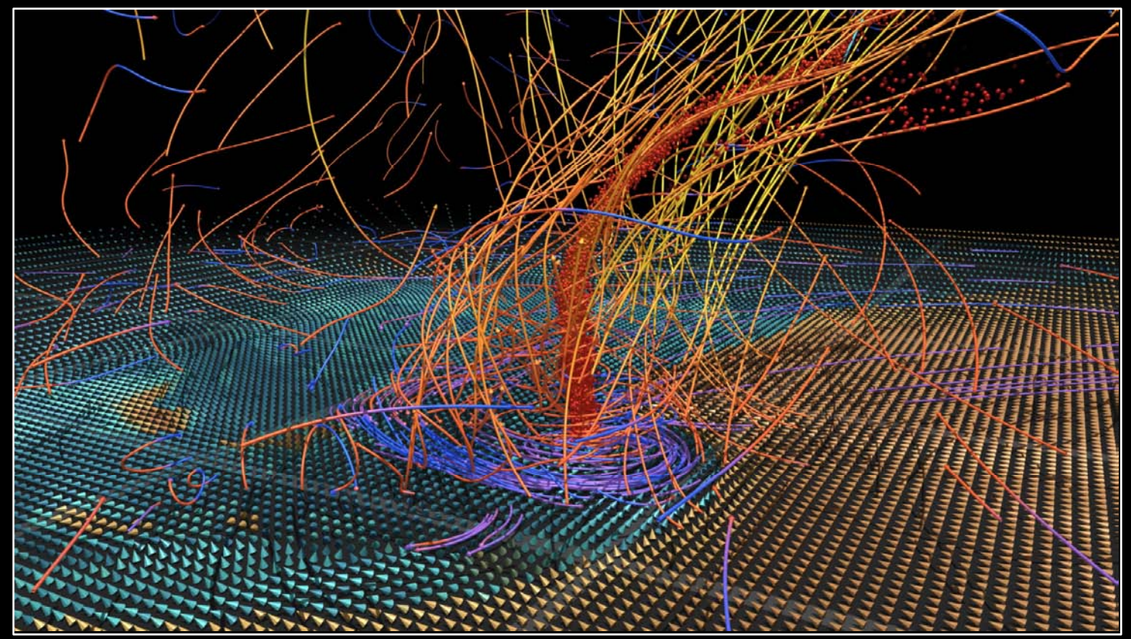
- **Volume rendering**
  - –Large microscopy volumes
  - –Out-of-core block-based I/O
  - –Hardware rendering
  - –VTK-based





SAGE Applications

- **Bitplayer: HD animation**
  - –Developed by NCSA initially
  - –Read uncompressed animations
    - read frame by frame
  - –No size limitation
    - HD 1920x1080
    - 4K SHD, 3840x2160
  - –Very demanding for the storage performance

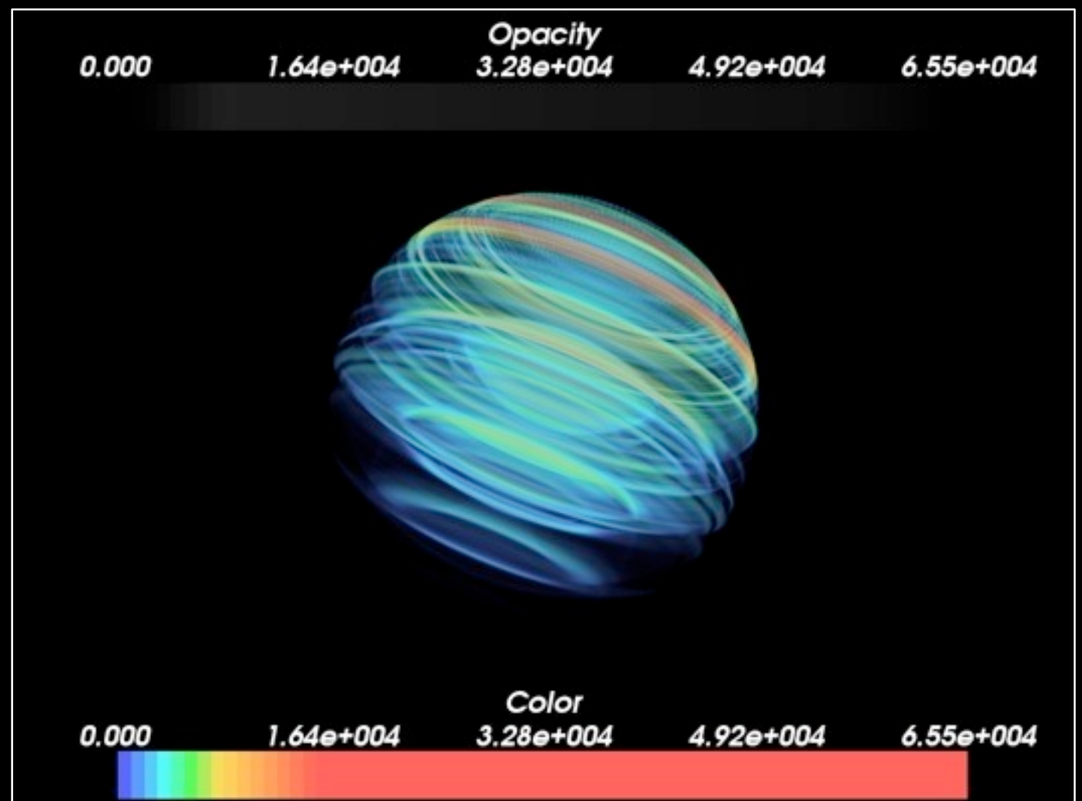


SAGE Applications

- **Live HD video**
  - Streams live HD video from HDMI camera
  - 1920x1080 resolution
  - YUV 422 sampling
  - YUV transport pixel format: 16bits per pixels
  - Streams also audio

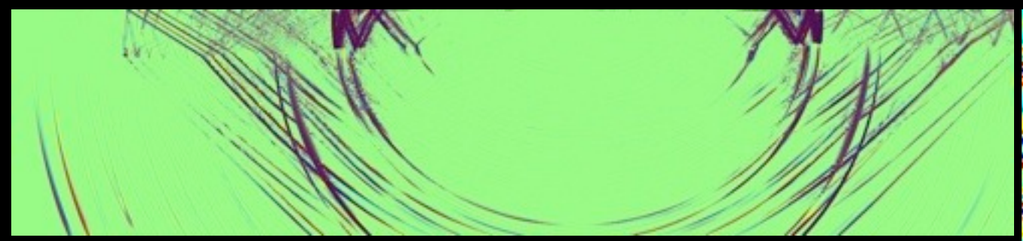
Scenario 1: Visualize the output

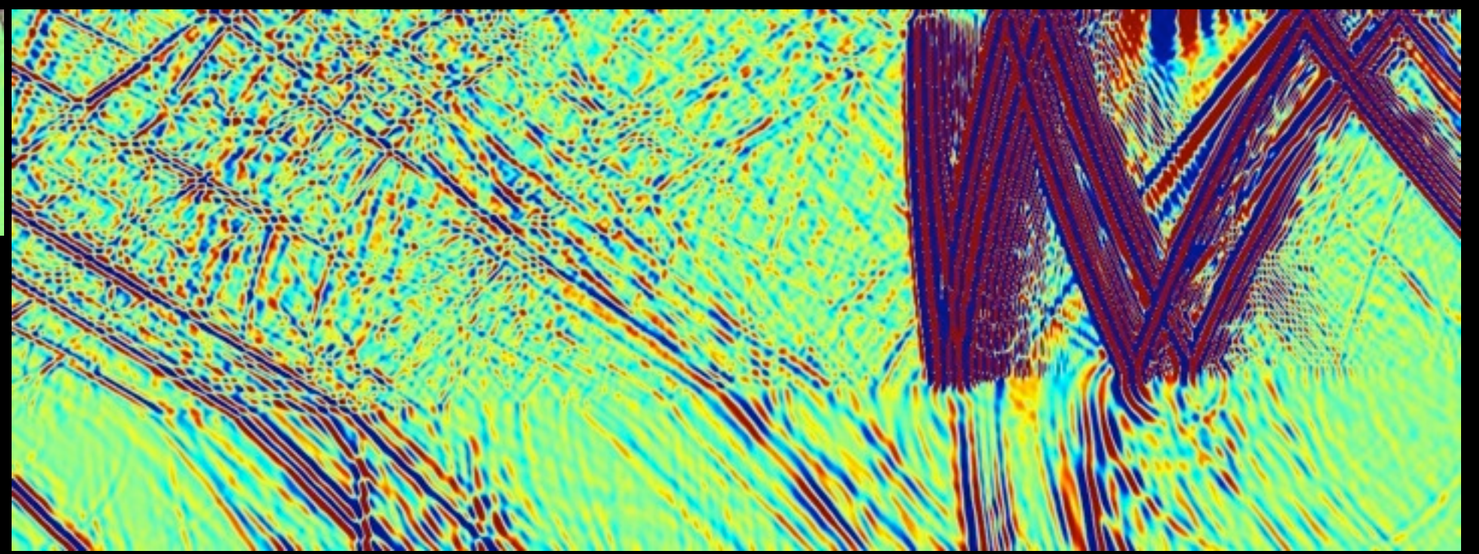
- Images, animations, or videos produced at one site
- Load
  - Images: ‘imageviewer’ application
  - Movies: ‘mplayer’ / VLC plugin
  - Animation: `bitplayer’ NCSA format
- Stream
- Display



Example: SDSC/Geon

- Images at 8874x2000 pixels, 400 frames
- Movies of X and Z ground velocities from an earthquake simulation





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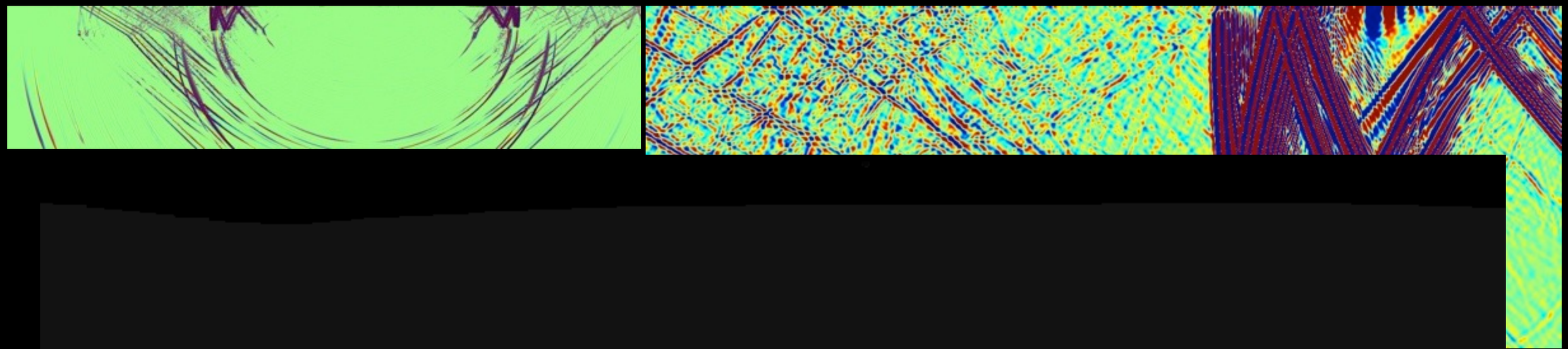


Scenario 2: OpenGL application

- OpenGL hardware rendering application
- Capture pixels
  - Dynamic loading of a new OpenGL library
    - No application modification
    - à la Chromium
  - Or small source code addition (glReadPixels)
- Stream
- Display

Scenario 3: Application modification

- Application produces pixel buffers
- Stream
- Display

Initialization

```
sailConfig scfg;
scfg.cfgFile = "sage.conf";
scfg.appName = "myapp”;
scfg.resX = 1024;
scfg.resY = 768;
scfg.colorDepth = 24;
scfg.pixFmt = TVPIXFMT_888;
scfg.rowOrd = TOP_TO_BOTTOM;
sageInf.init(scfg);
```

Streaming

```
rgbBuffer = sageInf.getBuffer();
memcpy(rgbBuffer, data, size);
sageInf.swapBuffer();
```

Case Study: Paraview - SAGE integration

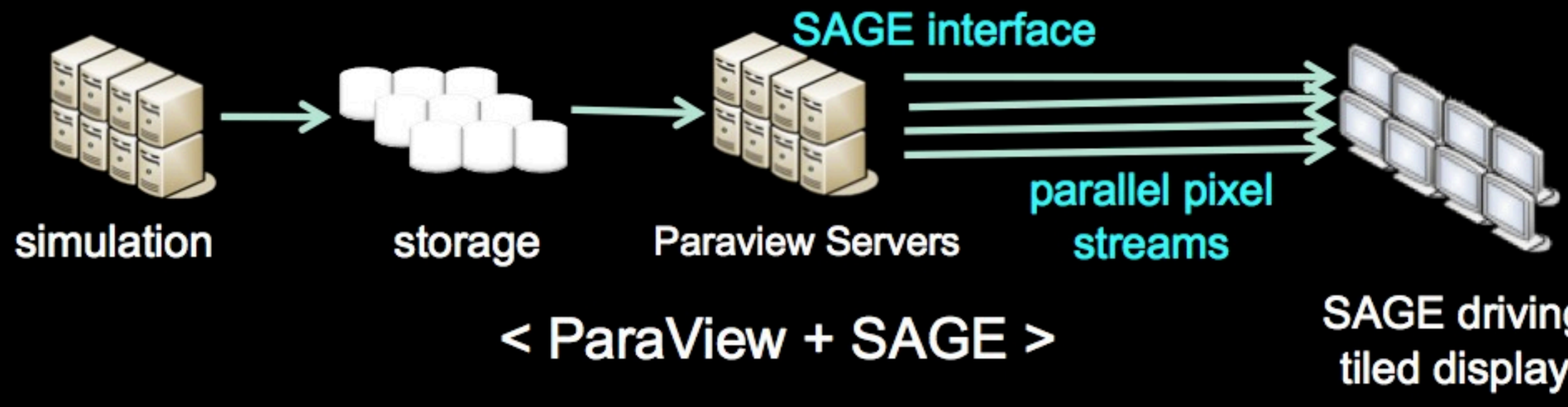
- Work led by Byungil Jeong
  - Texas Advanced Computing Center, University of Texas, Austin

- Contribution from Sungwon Nam
  - Electronic Visualization Laboratory, University of Illinois, Chicago

ParaView and SAGE

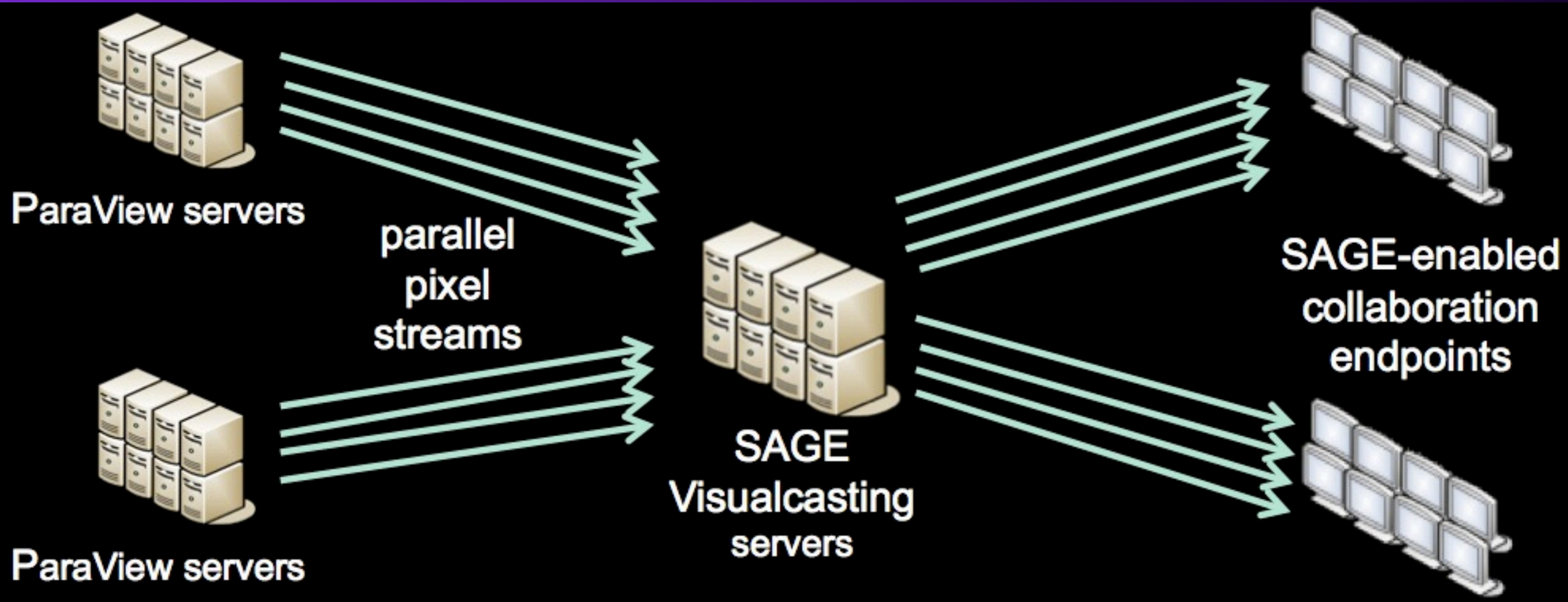
- ParaView
  - Well fit to the cyber-infrastructure model
  - Designed for large-scale parallel visualization
- SAGE
  - Assuming ultra-speed network (at least gigabits per second)
  - High-resolution display helps scientific discovery
  - Enable remote visualization on ultra-resolution tiled display
  - Allow users to juxtapose multiple high-resolution visualizations
- ParaView and SAGE integration
  - Enable remote visualization of multiple large-scale data-sets in ultra-resolution display environments

ParaView and SAGE Integration



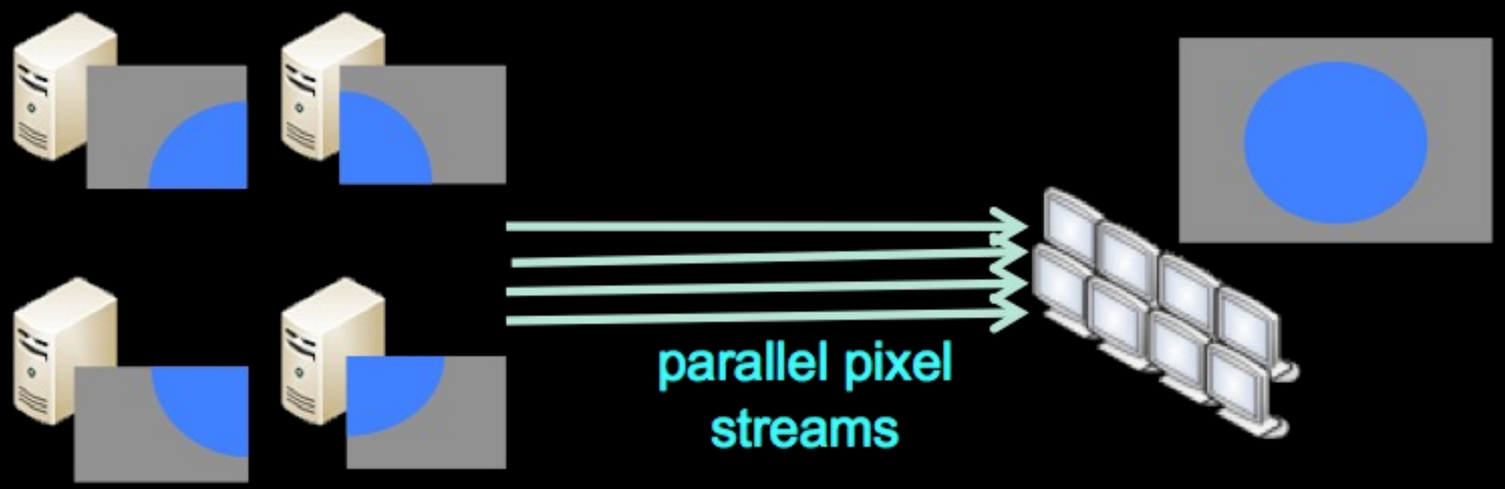
- ParaView servers visualize large-scale data in parallel
- Resulting imagery generated on each server is composited and streamed as a single image to the client (ParaView only)
- SAGE interface captures the pixel data from each server and streams in parallel

Benefits of the Integration



- Juxtapose multiple remote ultra-resolution visualizations
- Distribute the visualizations to multiple tiled displays at collaboration endpoints

SAGE Interface in ParaView



- ParaView tiled-display mode
  - ParaView servers do sort-last rendering and compositing for each tile
- Integrated inside “vtkIceTRenderManager” class
  - IceT compositing library
  - Minimal changes
  - Get tilling info, copy pixels, pass buffer to SAGE

ParaView across the US

Remote Rendering and Parallel Pixel Streaming with ParaView + SAGE

Sungwon Nam
November 13, 2009

Electronic Visualization Laboratory
University of Illinois at Chicago

www.evl.uic.edu

Experimental Environment

- Render nodes
  - TACC Spur vis nodes (16CPU cores, 4GPUs, and 128GB RAM per node).
- Display nodes
  - EVL LambdaVision driven by Yorda cluster
  - Each node has AMD Opteron 2Ghz, 4GB RAM, Nvidia Quardo graphics.
  - Each display node has two 1600x1200 LCD monitors
- Network route
  - 10Gbps National Lambda Rail (CaveWave) via San Diego

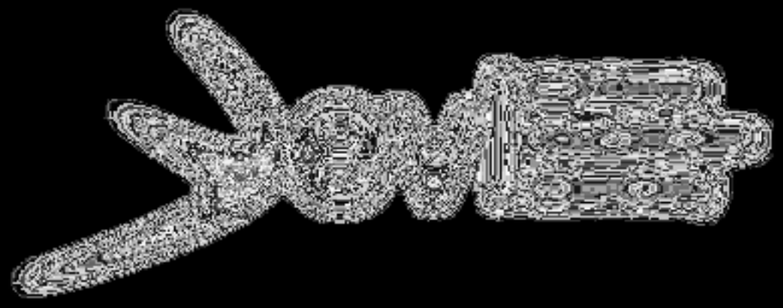
ParaView-SAGE within the lab

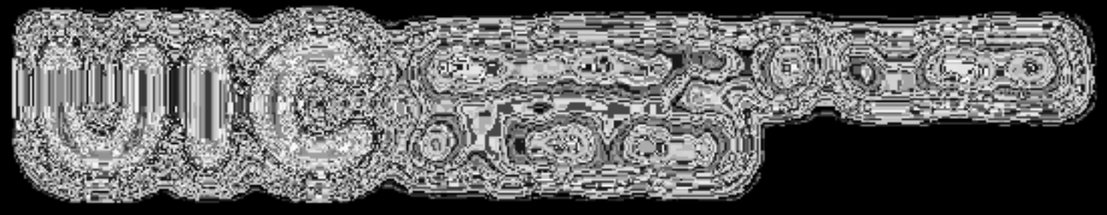
Paraview-SAGE Integration

July 2010

Paraview–SAGE Integration

July 2010





Use cases

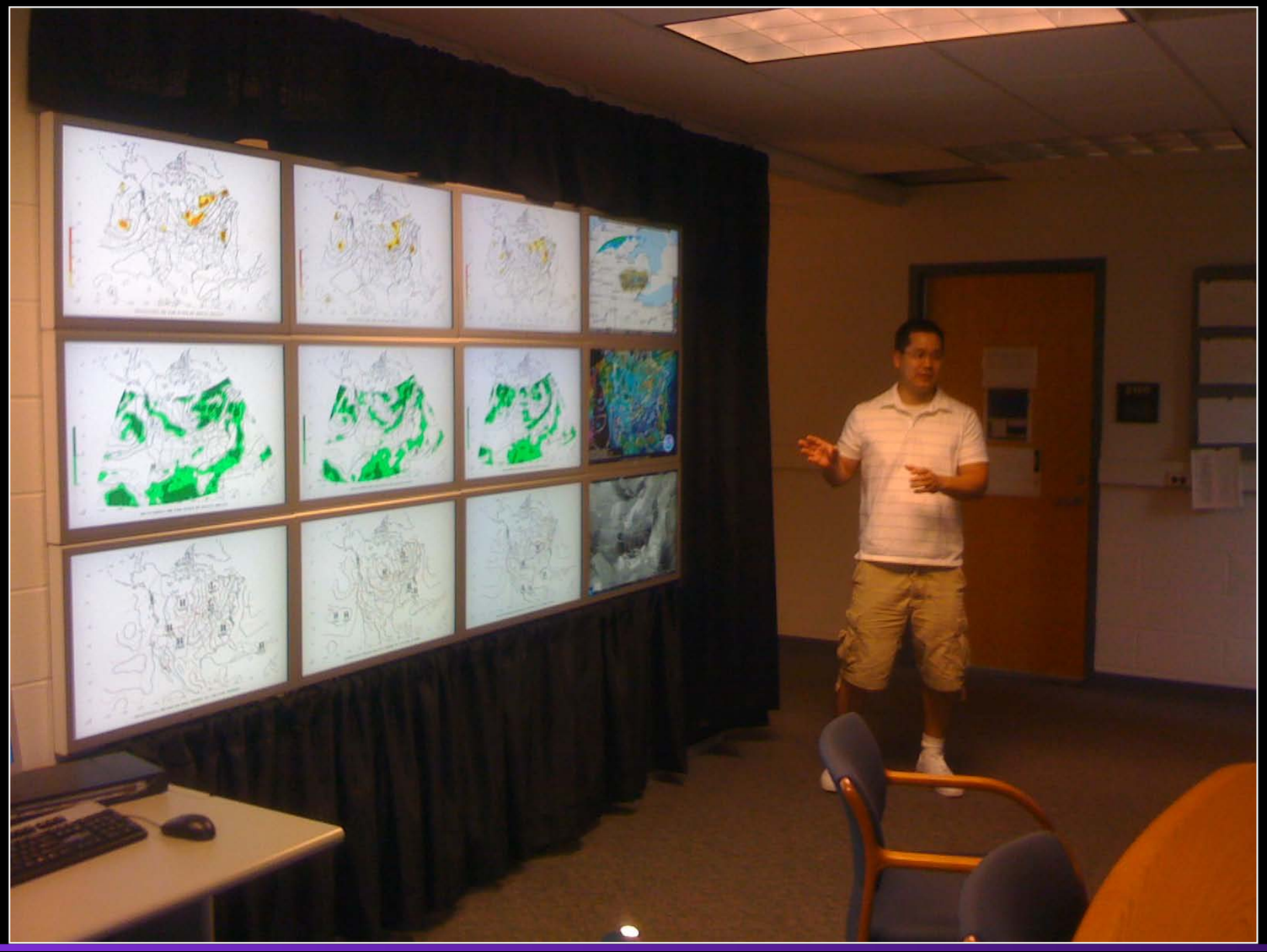
- Using tiled displays for science and education

UIC Research Meeting

UIC Research Meeting

UIC Anatomy Class

University of Michigan
Atmospheric Sciences Department



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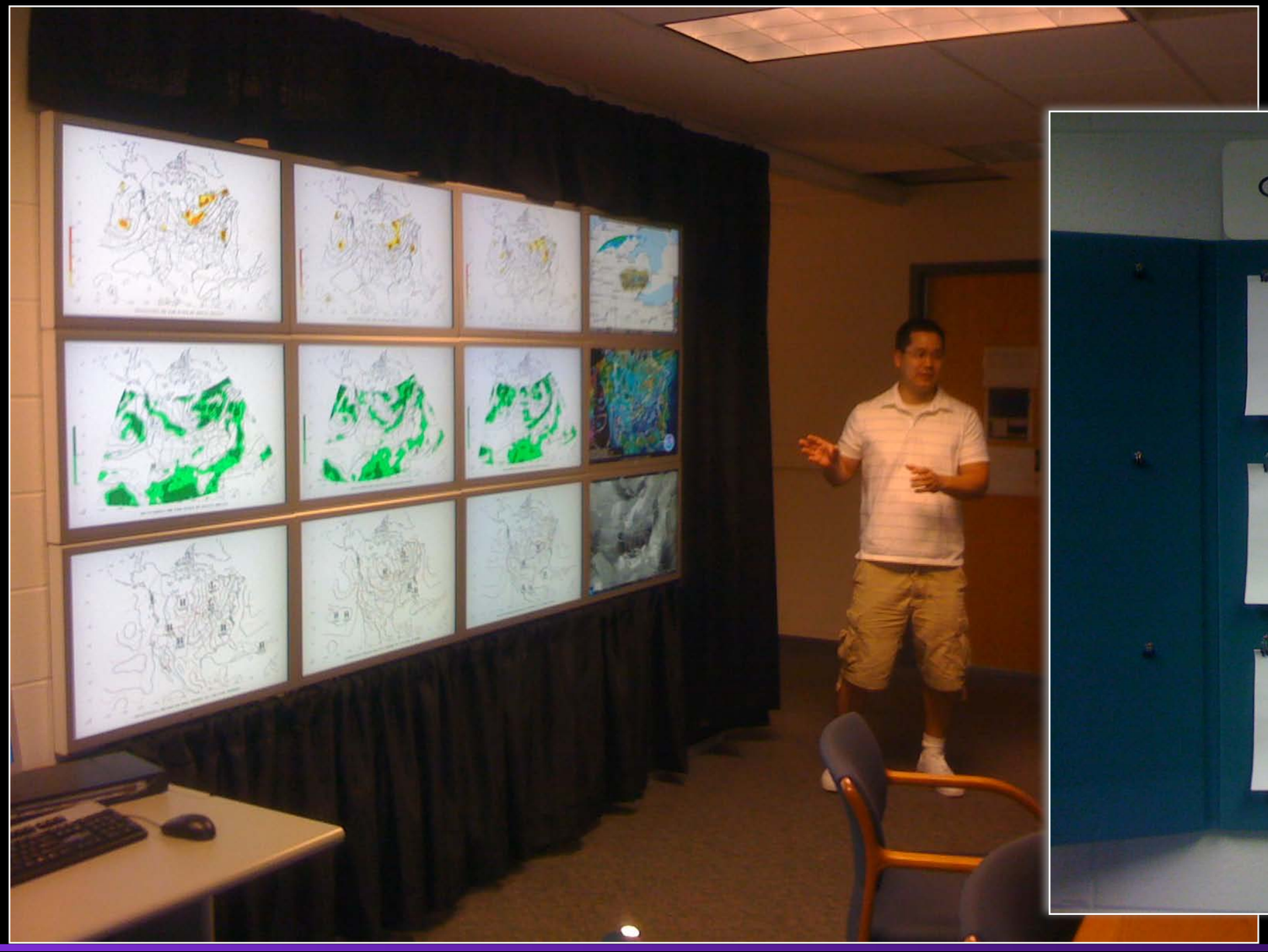
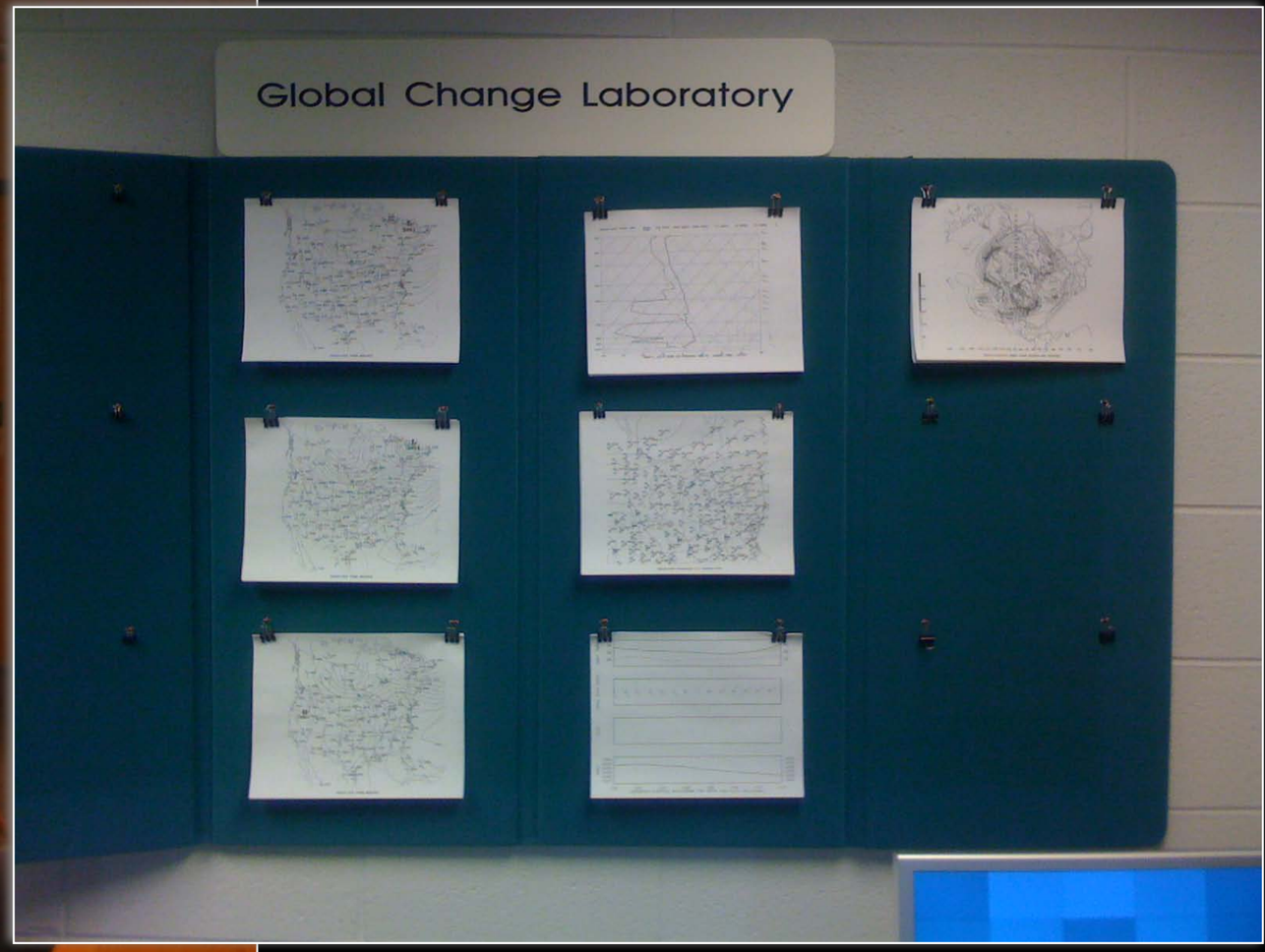




Sharp Labs of America

Chairman of Sharp

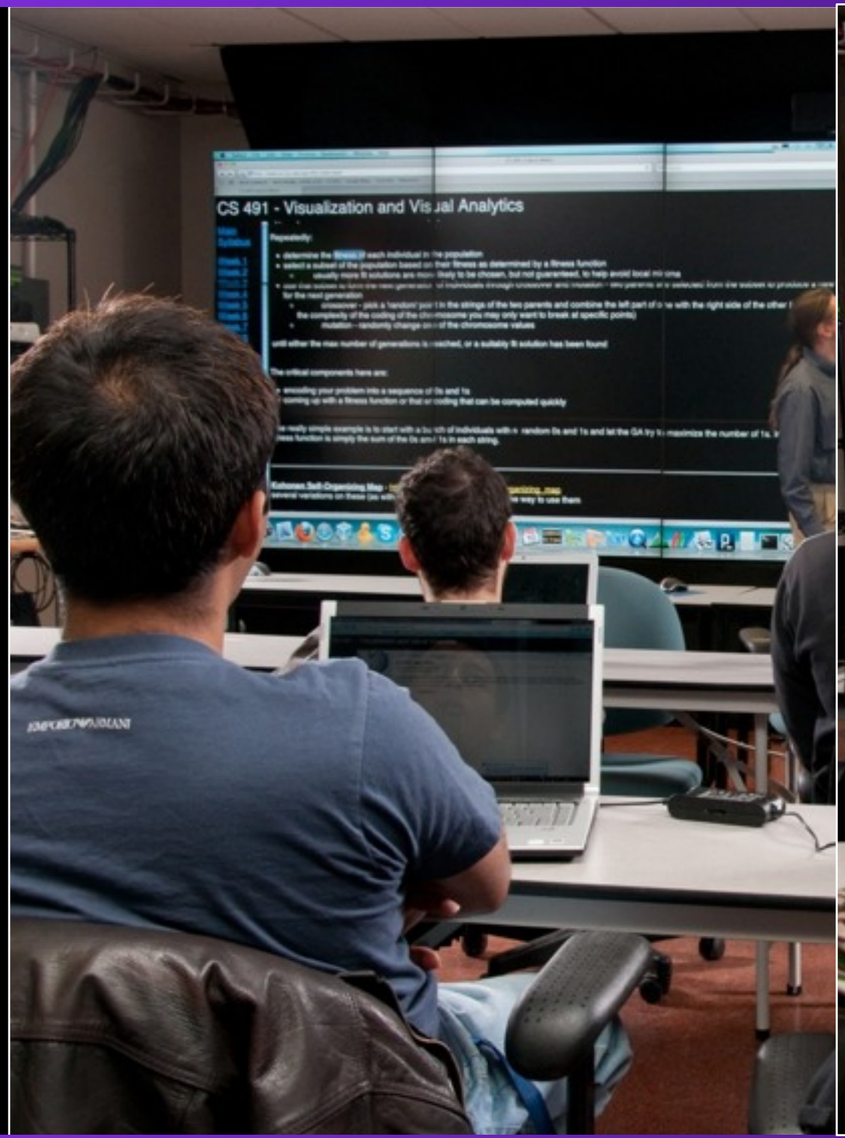
> “In ten years' time entire walls could be screens”
>
> Forbes, June 4, 2007

Virtual School in Petascale Computing

Virtual School in Petascale Computing

Visual Analytics Class at UIC

Visual Analytics Class at UIC



Collaboration

- Distance collaboration over high-speed networks

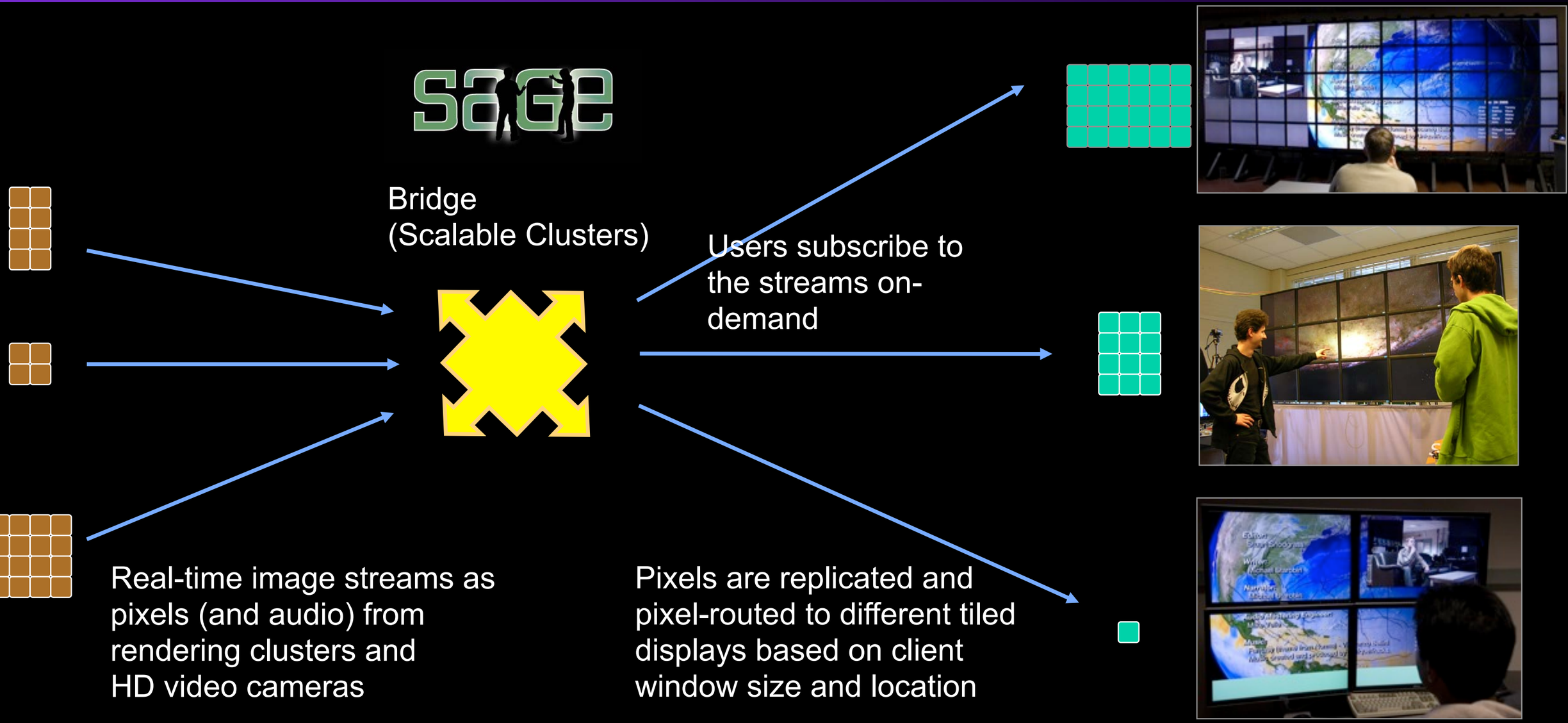
Scalable VisualCasting for Global Ultra-Definition Collaborative Visualization

- **Motivation:**
  - In time critical situations, high-definition video and ultra-high resolution visualizations need to be distributed in real-time to many collaborating sites to facilitate joint analysis and decision making.
  - Immersive war room environments with potential resolutions on the order of hundreds of megapixels require “multicasting” of visualizations at tens of gigabits per second.
  - This is not possible with current generation of war room technology & telco equipment.

Proposed Solution

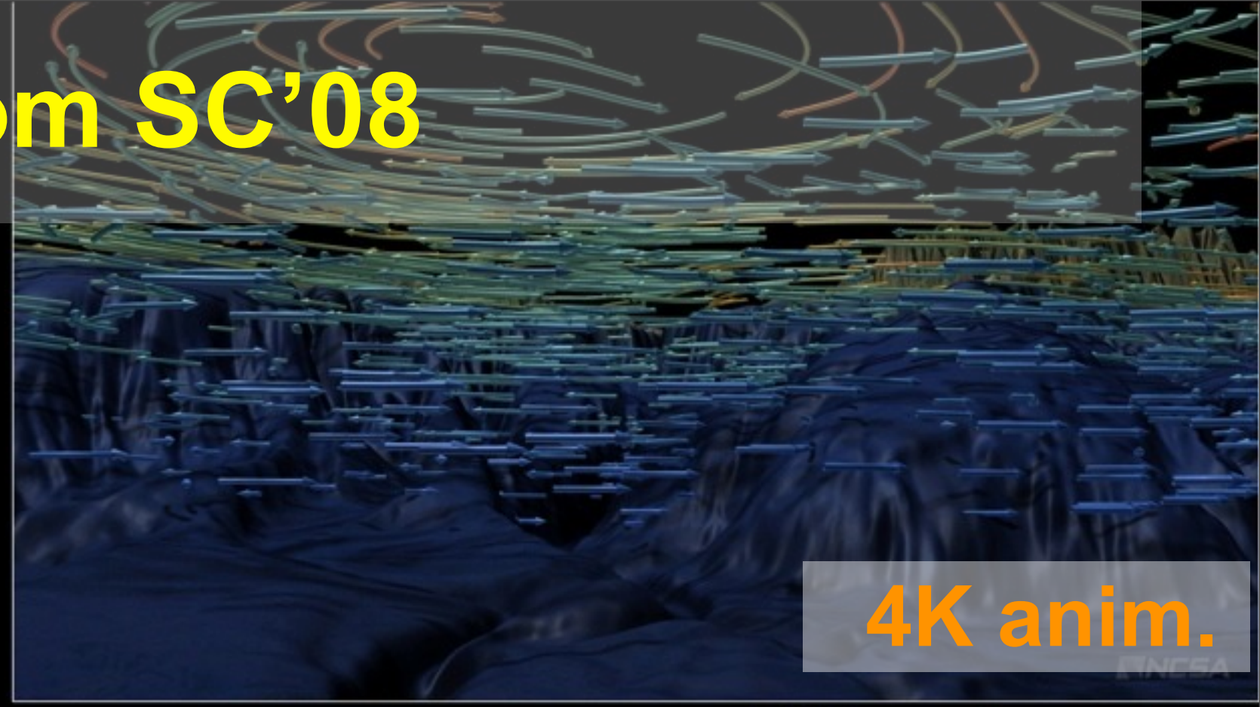
- A fundamental requirement of high-resolution collaborative visualization systems is multicast of visualization.
- Visualcasting: scalable real-time image multicasting service in ultra-high resolution display environment.
- SAGE Bridge: A high-speed bridging system which distributes pixel data received from rendering clusters to each end-point.
- It is deployed on a high-performance PC cluster equipped with 10gigabit network interfaces.

How Visualcasting Works



a View from SC'08

Michigan



4K anim.

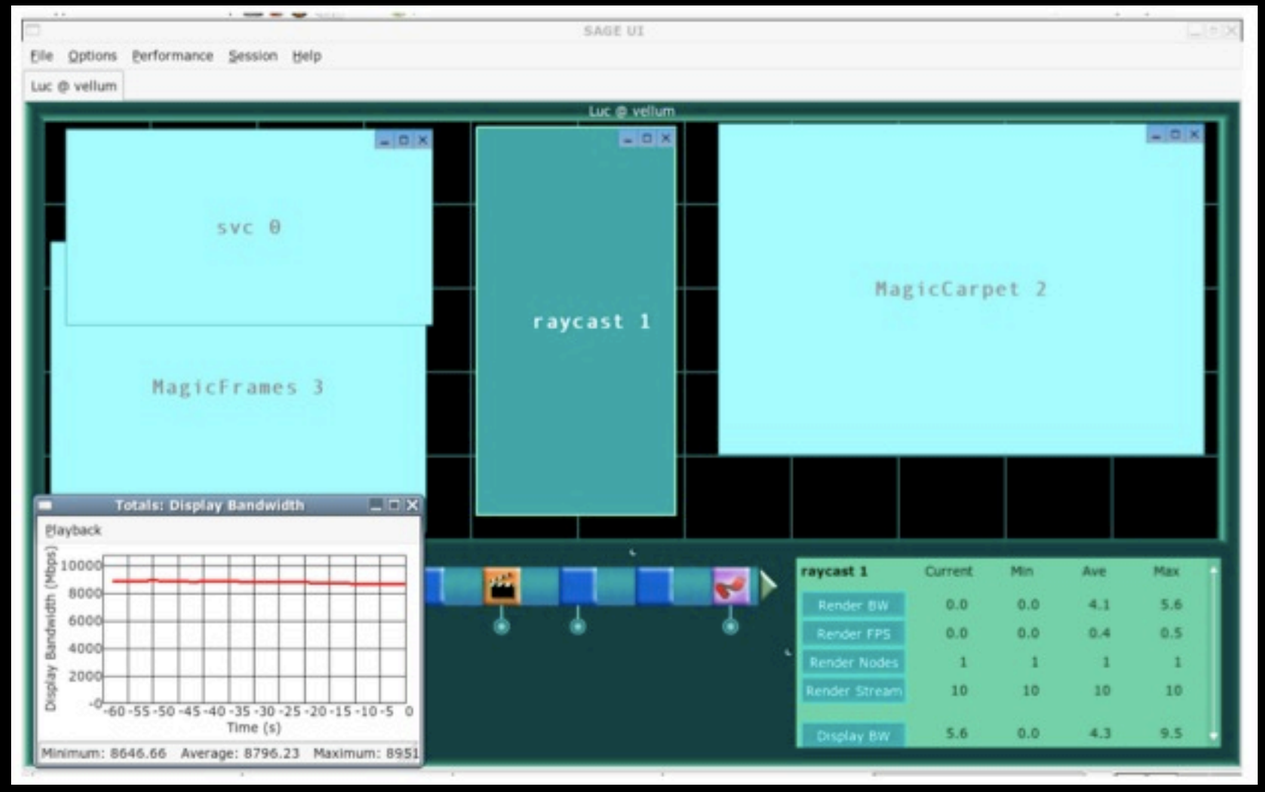
Chicago

Czech R.

Interaction

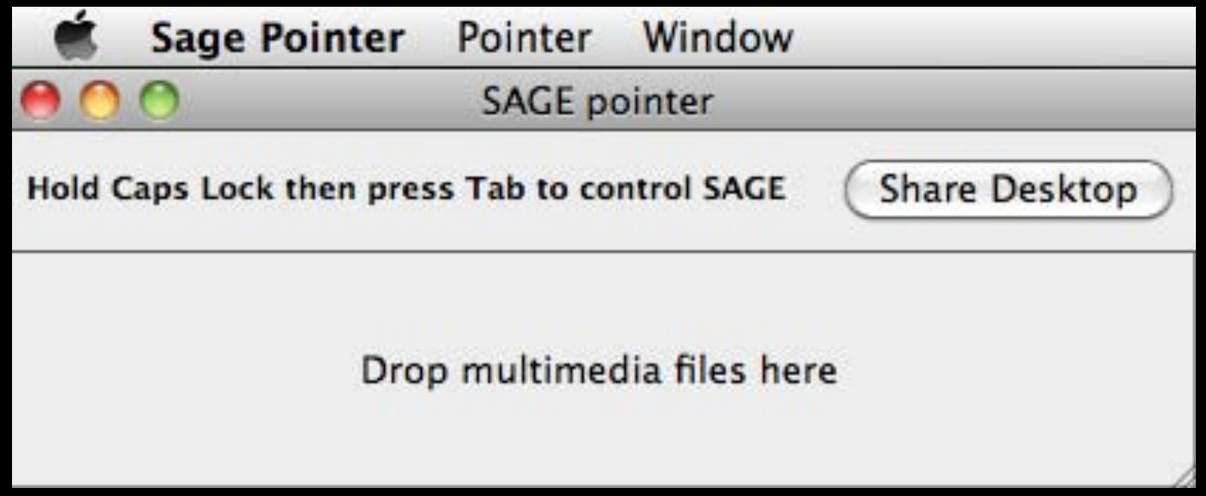
SAGE User Interface

- Creation of a simple user interface that provides interaction with SAGE
- SAGE UI:
  - All of the SAGE applications appear in the launcher area
  - Operations: resize, move, z-ordering, start, kill
- Application performance monitoring information

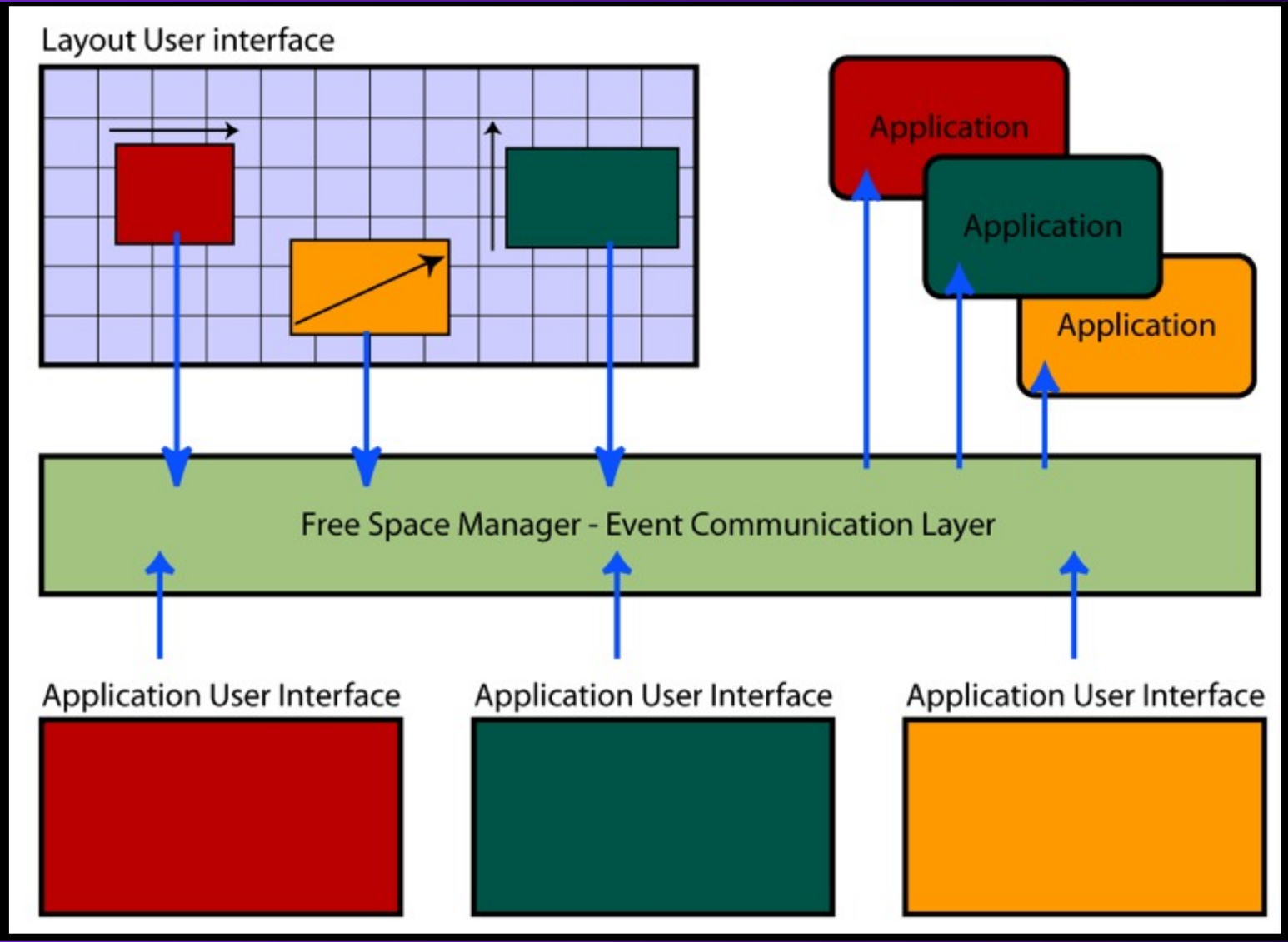


Personal Interaction

- Small application for every laptop user
- Capture keyboard and mouse events
- Enable desktop sharing through VNC
- Drag-and-drop of multimedia files onto the display
  - from desktop or web broswer
  - pictures, videos, PDFs



Application Model



SAGE Widgets

- Applications can define UI widgets
- Overlaid on application window
- Used for direct interaction on the wall
- Shared by all the users

- File browser for pictures, videos, PDFs

- Automatic layout of content
  - grid, tiles, free form

Direct Manipulation

Direct Wall Interaction in SAGE

Ratko Jagodic

November 17, 2009

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Closing Remarks

- Tiled displays bring resolution and size with detail and context
- SAGE enables users to couple displays to powerful visualization resources enabling high-performance visualization and collaboration
- SAGE is deployed around the world all with a variety of tiled display configurations
- Visualcasting enables a persistent collaborative infrastructure for global scientific collaboration

Closing Remarks

- For more info:
  - www.sagecommons.org
  - www.evl.uic.edu
  - renambot@uic.edu

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