Workshop on Parallel Visualization and Graphics

Production Cluster Visualization: Experiences and Challenges

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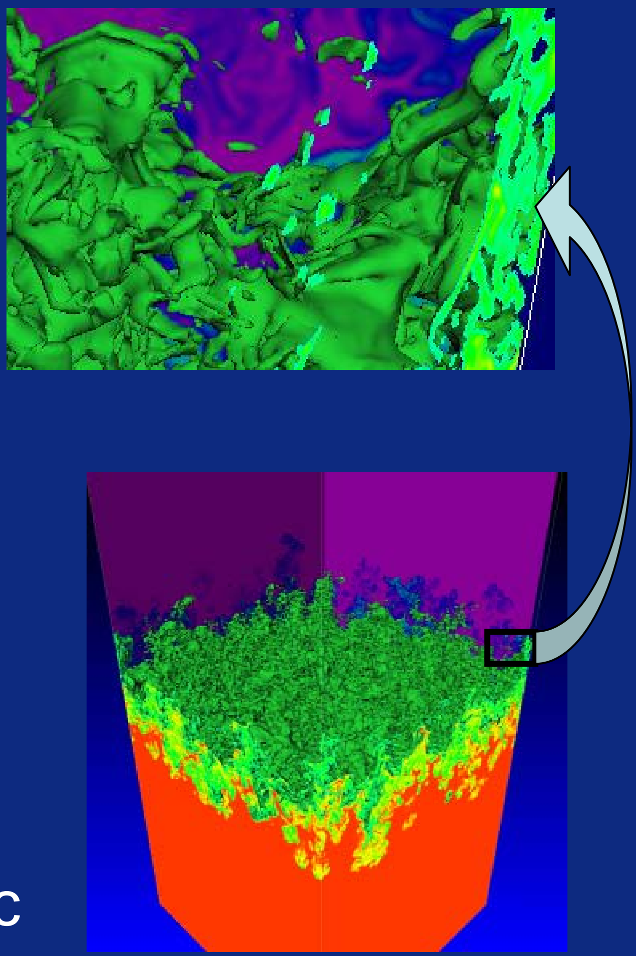
Why COTS Distributed Visualization Clusters?

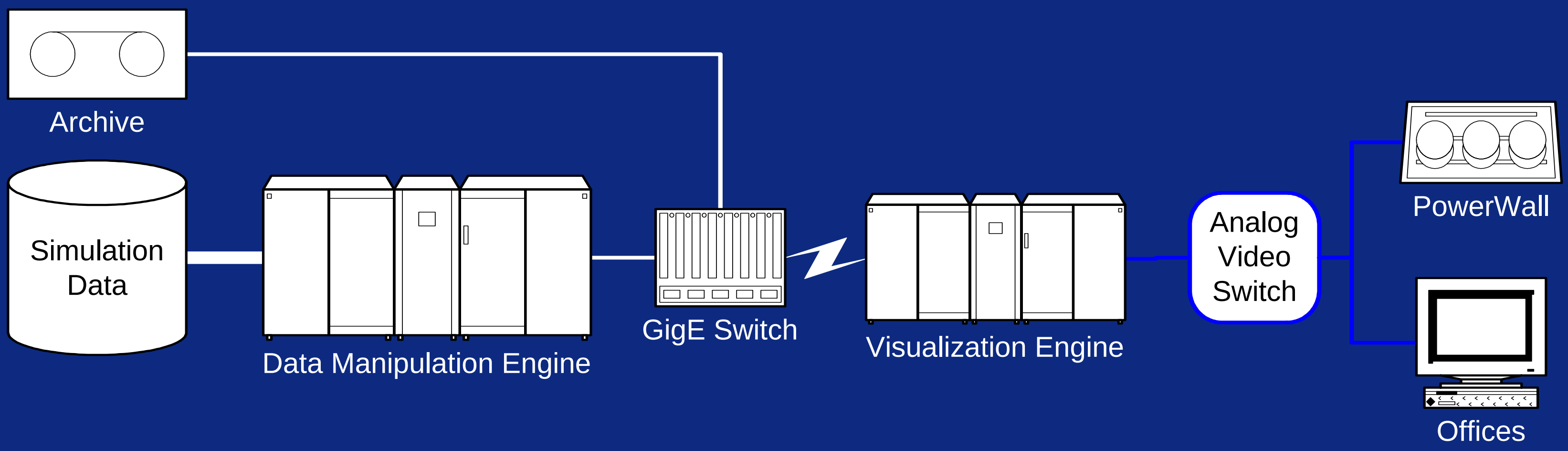
- The realities of extreme dataset sizes (10TB+)
  - Stored with the compute platform
  - Cannot afford to copy the data
  - Co-resident visualization
- Track compute platform trends
  - Distributed infrastructure
  - Commodity hardware trends
  - Cost-effective solutions
- Migration of graphics leadership
  - The PC (Gamers) Desktops
  - Display technologies
    - HDR, resolution, stereo, tiled, etc



Production Visualization Requirements

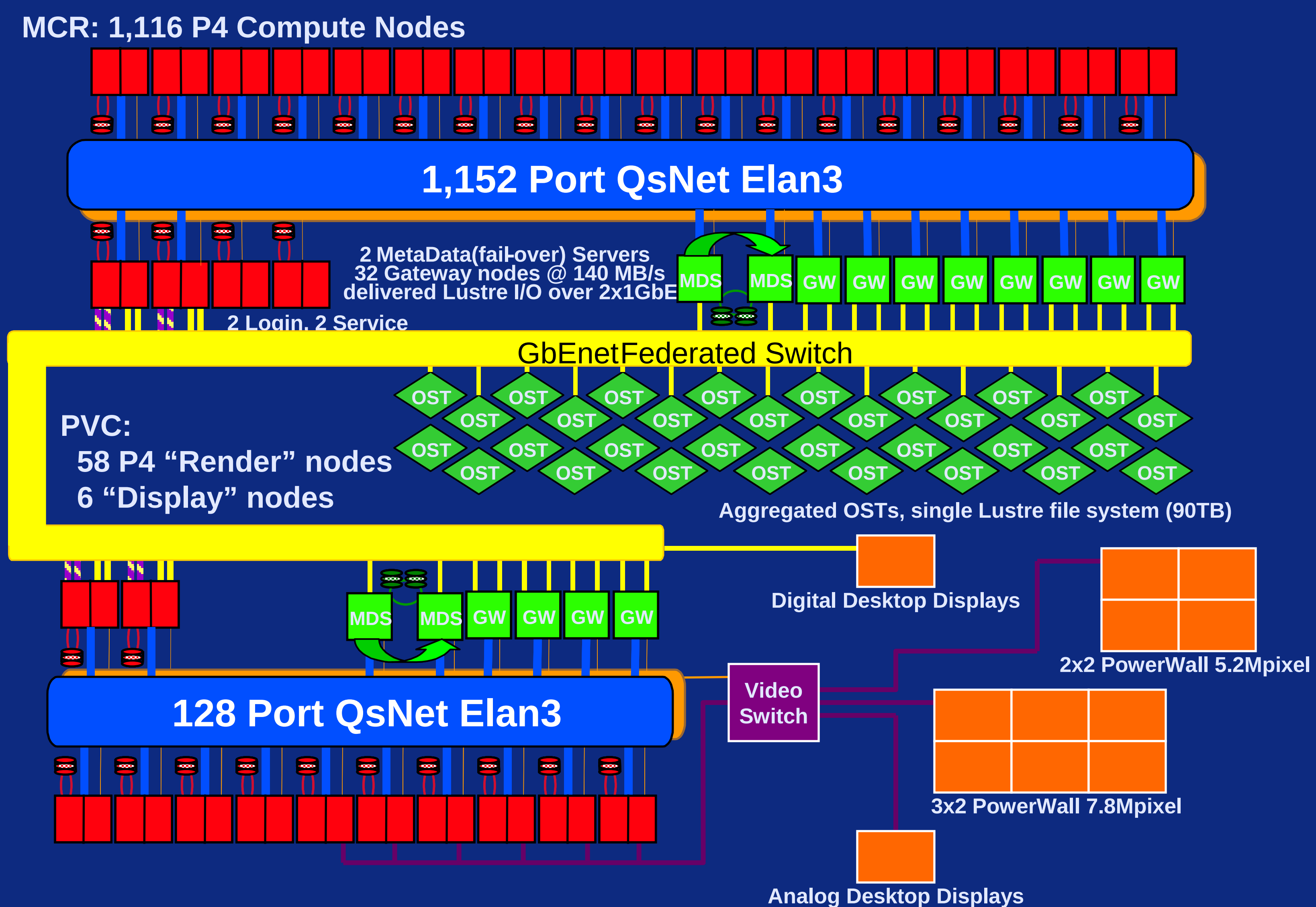
- Unique, aggresive I/O requirements
  - Access patterns/performance
- Generation of graphical primitives
  - Graphics computation: primitive extraction/computation
  - Dataset decomposition (e.g. slabs vs chunks)
- Rendering of primitives
  - Aggregation of multiple rendering engines
- Video displays
  - Routing of digital or video tiles to displays (over distance)
- Interactivity (not a render-farm!)
  - Real-time imagery
  - Interaction devices, human in the loop (latency, prediction issues)
- Scheduling
  - Systems and people

Visualization Environment Architecture



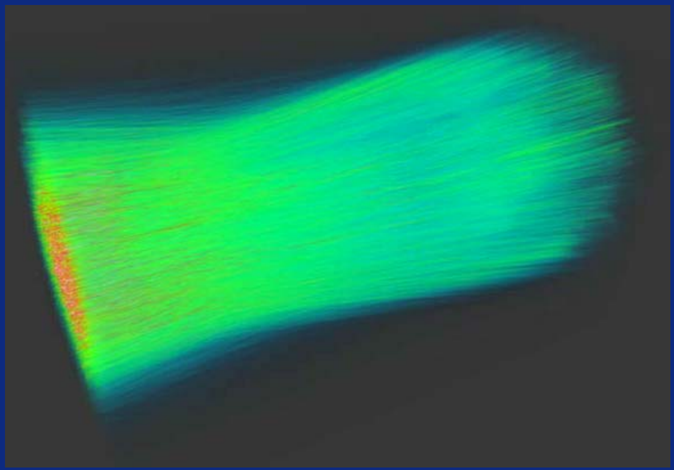
- Raw data on platform disks/archive systems
- Data manipulation engine (direct access to raw data)
- Networking (data/primitives/images)
- Visualization/rendering engine
- Video & remotely rendered image delivery over distance
- Displays (office/PowerWalls)

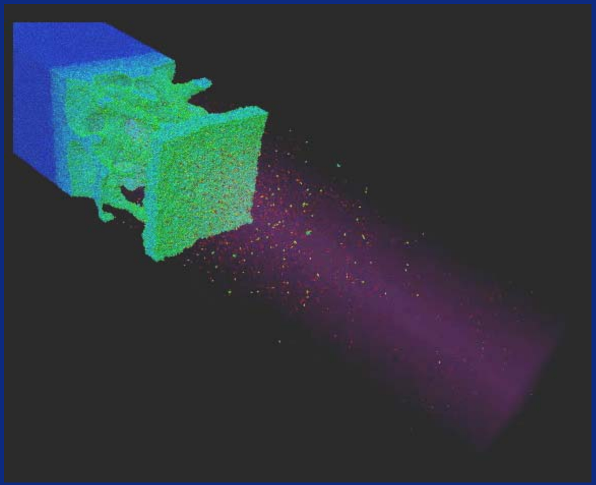
Deployed Environment: MCR & PVC

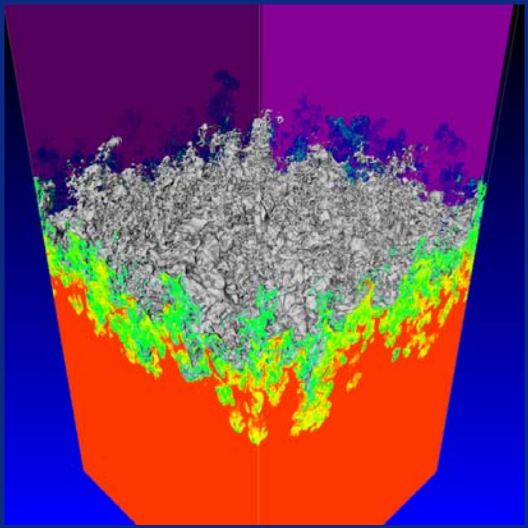


MCR & PVC Success

- MCR+PVC, a prolific tandem…
- Effectively handling multi-TB datasets, many over 10TB
  - Examples: 1152^3 7 variables 1000 timesteps, billion atom
  - Custom data formats: wavelet compression, spacefilling curves
  - Excellent aggregate raw I/O rates (GBs/sec)
- Generating animations: 1/10 the time, 1/5 the resources
- Driving ~8Mpixel PowerWall (3x2)
  - Supporting interaction in a problem solving environment (PSE)

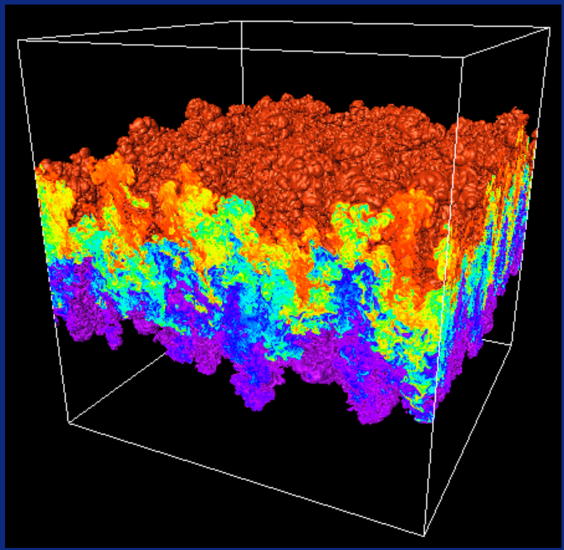






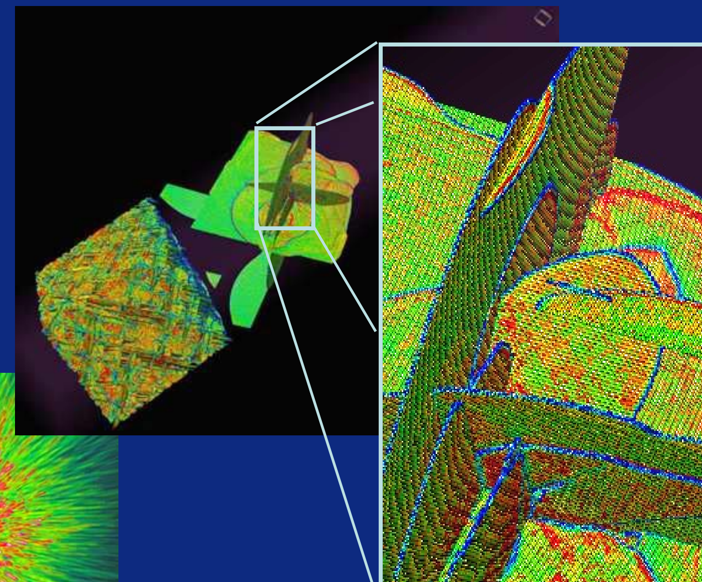
Challenges Remain…

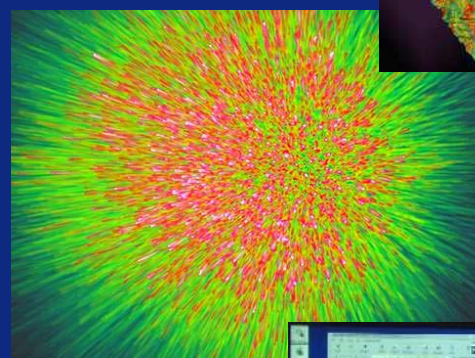
- Fragile system components
- Data access
  - Cluster-wide parallel I/O systems can be fragile
  - Must optimize for viz access patterns
- The impedance mismatch problem
  - Smaller number of nodes for viz
    - Out of core processing
  - Improper data decomposition
- Scheduling complexity
  - Co-scheduling of multiple clusters
  - Combinations of parallel clients, servers, services and displays



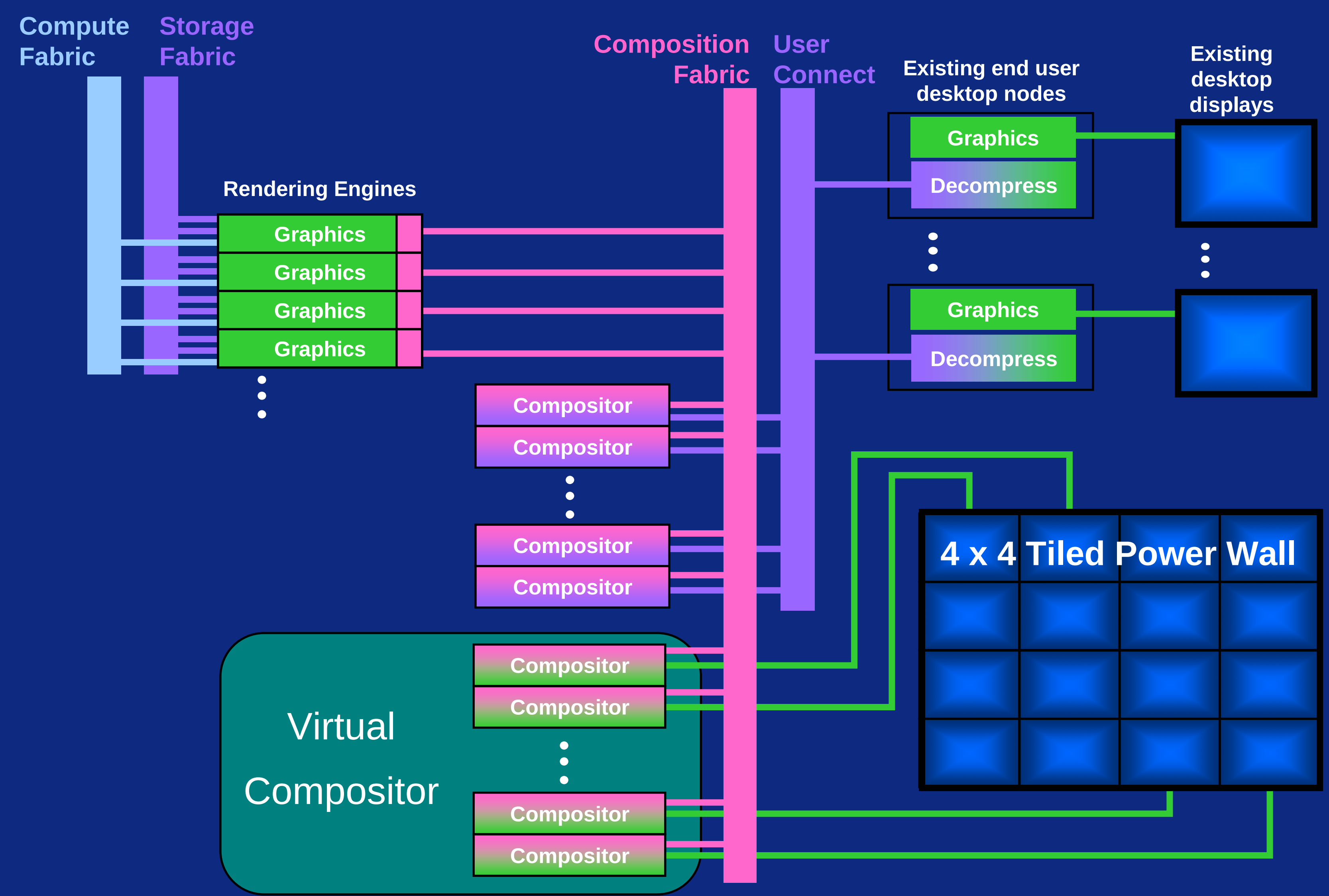
Data Challenges: Large & Complex

- Increased Complexity
  - Increased fidelity
    - Spatial, temporal, higher-order
  - Complex & unique representations
- PSE Integration
  - Multiple data sources
  - Additional context
- Interpretation failure
  - Difficult visual interpretation
    - Artificial polygon limits (90M?)
  - Scalability
    - Failing, global algorithms
    - Fidelity issues



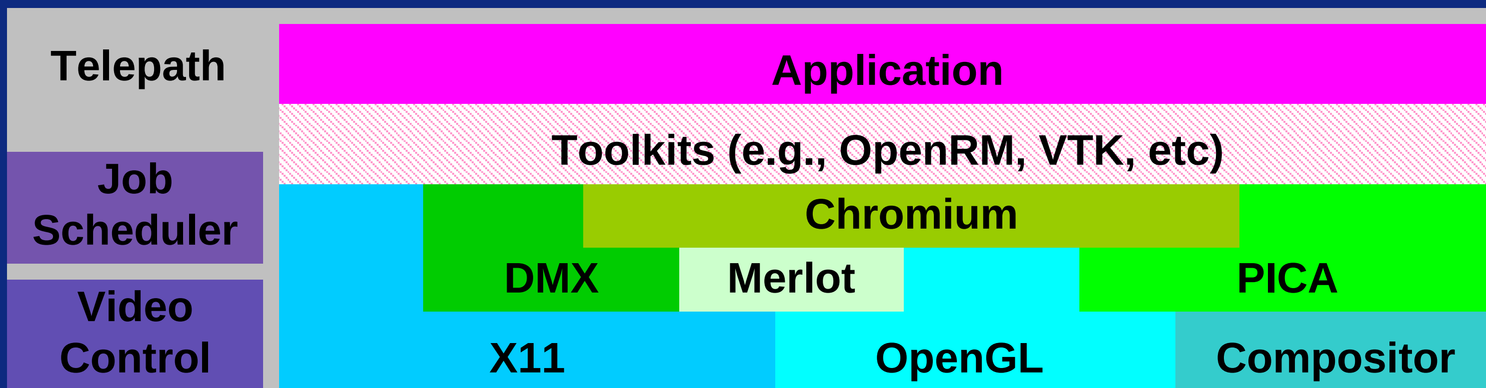


Idealized Visualization Environment



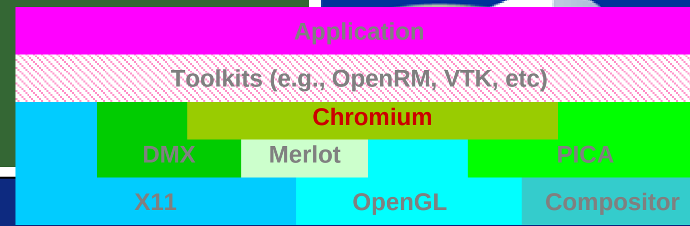
Scalable Visualization Software Stack

- Goal: Provide integrated, distributed parallel services for viz apps. Encourage new apps, increase portability & device transparency.

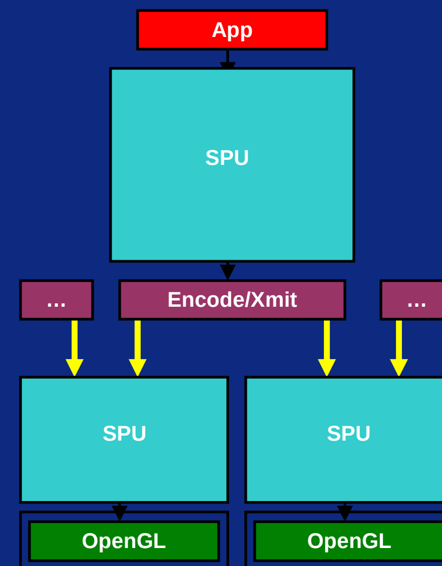


  - Applications: VisIt, ParaView, EnSight, Blockbuster, etc.
  - Toolkits – Parallel visualization algorithms, scene graphs, etc.
  - DMX – Distributed X11 windowing and input devices
  - Chromium – Parallel OpenGL rendering model
  - PICA – Parallel image compositing API
  - Merlot – Digital image delivery infrastructure
  - Telepath – Visualization “session” control and scheduling
  - Core “vendor” services - X11/OpenGL/compositors/NICs/Job control

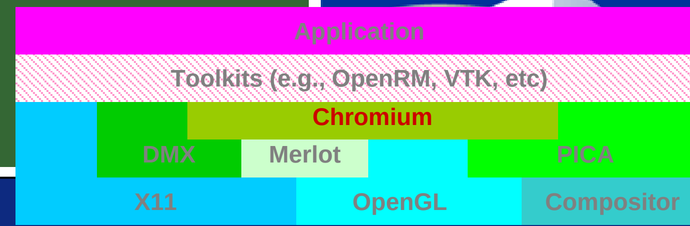
Distributed GL: Chromium



- Distributed OpenGL rendering pipeline. Provides a parallel OpenGL interface for an N to M rendering infrastructure based on a graphics stream processing model.
- The Stream Processing Unit (SPU)
  - “Filter” view OpenGL
  - SPU interface is the OpenGL API
    - Render, modify, absorb…
  - Allows direct OpenGL rendering
  - Supports SPU inheritance
  - Application “translucent”
- Development:
  - chromium.sourceforge.net
  - RedHat/Tungsten Graphics ASCI PathForward
  - Stanford, University of Virginia
  - Stereo, Fragment/Vertex pgms, CRUT, dynamic caching



Distributed GL: Chromium



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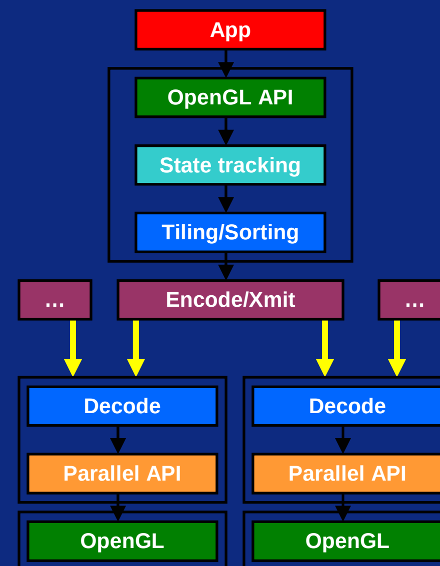
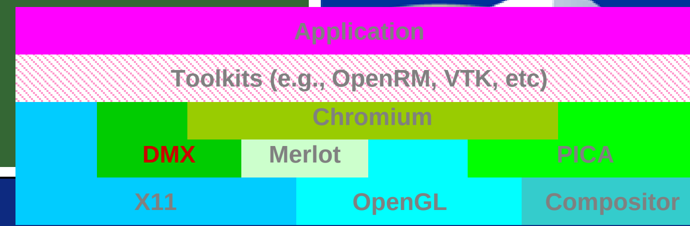
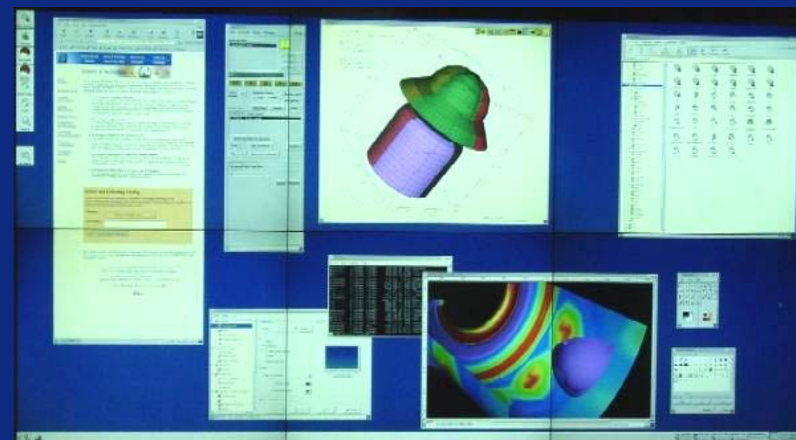


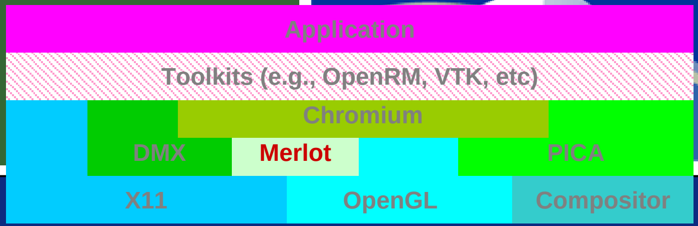
Parallel X11 Server: DMX



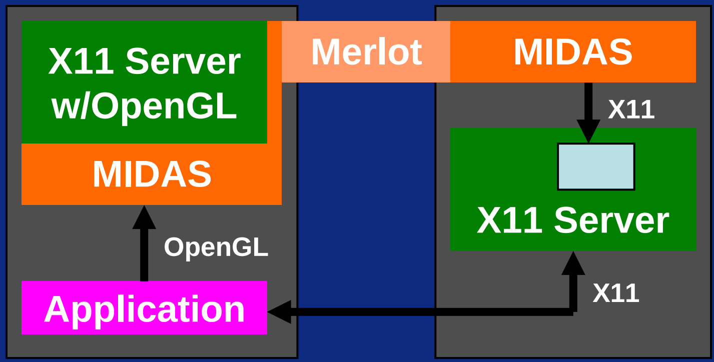
- Distributed multi-headed X server: DMX
- Aggregates X11 servers
  - "Server of servers" for X11
  - Single X server interface
- Accelerated graphics
  - 2D via accelerated X server
    - Common extensions as well
  - Back-side APIs for direct, local X11 server access
  - OpenGL via ProxyGL/GLX (from SGI) or via Chromium SPU
- Development:
  - dmx.sourceforge.net
  - RedHat ASCI PathForward contract
  - Integrated with XFree86



Remote Delivery: Merlot

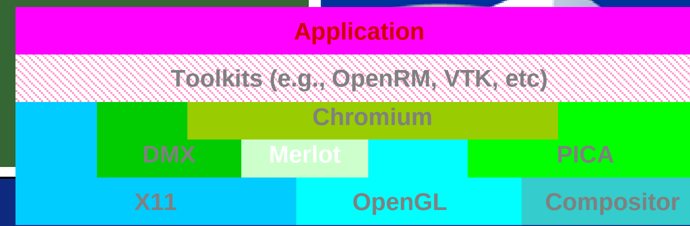


- Merlot is a framework for digital image delivery
  - Transport layer abstraction, Codec interfaces, Device transparency
- MIDAS: Merlot Image Delivery Application Service
  - Indirect OpenGL rendering services for X11 environment
  - Indirect window management
  - Image stream transport

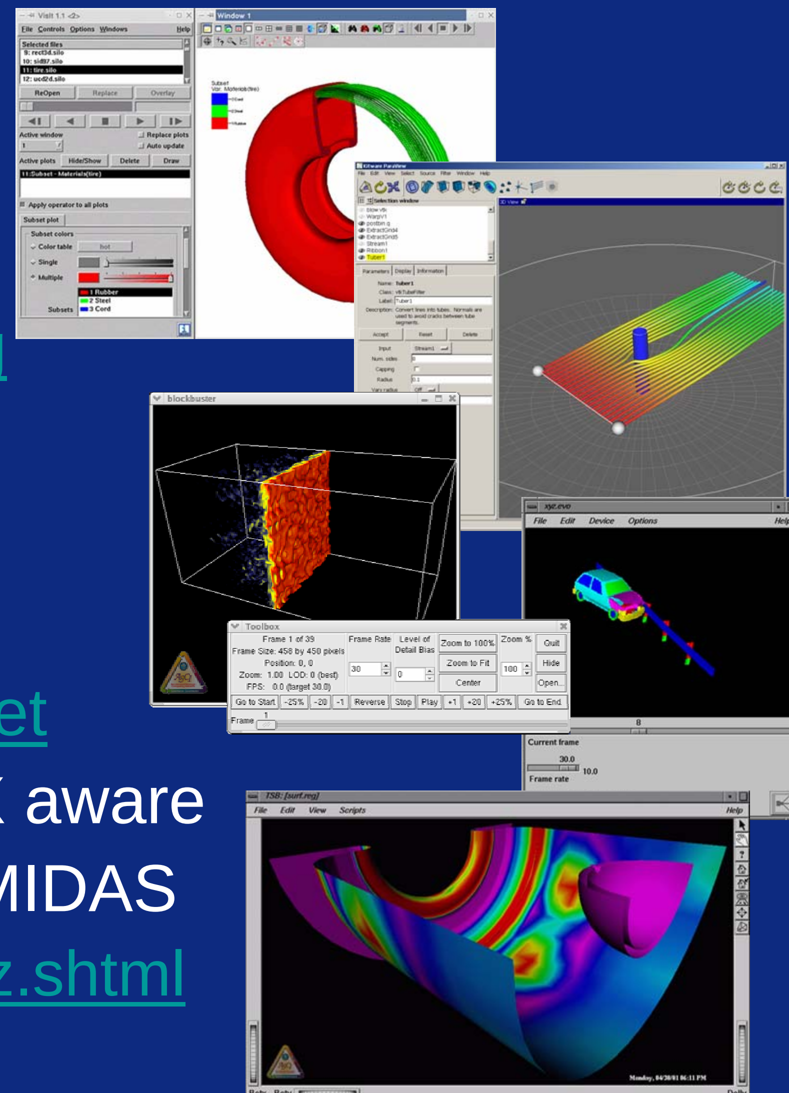


- Development:
  - Alpha released as OpenSource
  - More apps and experimental hardware support

Applications



- Full-featured visualization
  - VisIt: www.llnl.gov/visit
    - VTK, client-server model
  - ParaView: www.paraview.org
    - Parallel VTK viz tool
- Specialty applications
  - Blockbuster
    - blockbuster.sourceforge.net
    - Scalable animations, DMX aware
  - TeraScale Browser/Xmovie/MIDAS
    - www.llnl.gov/icc/sdd/img/viz.shtml

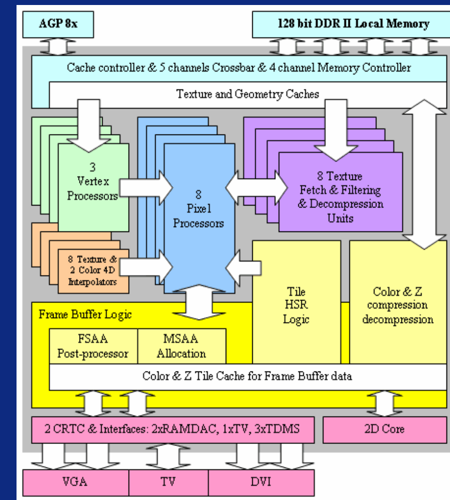


The Road Ahead

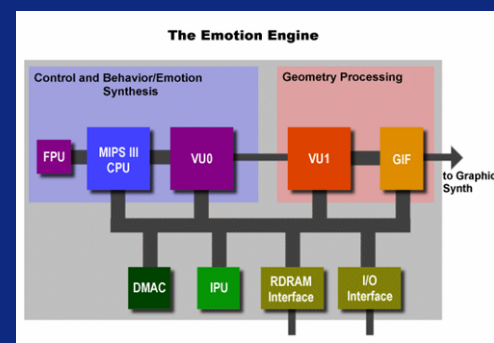
- Improved data understanding and exploitation
  - Basic interactivity is pretty much a done deal
    - Plenty of workable, scalable approaches
  - Picking up to temporal (or other dimensional) challenge
  - Topological based representations
  - How far do we follow the terabyte to gigapixel path?
- Imminent progress
  - Bandwidth increases everywhere: Buses, interconnects, etc
  - Dedicated compositing hardware
  - Second generation digital video technologies: 10gigE, IB, etc
- On the near horizon…
  - Managing software longevity, software & hardware complexity
  - High dynamic range: data to rendering to display
  - The extreme FLOP approach

The NV30 and the Sony Playstation 3

- The nVidia NV30 Architecture
  - 256MB+ RAM, 96 32bit IEEE FP units @ 500Mhz
  - “Assembly language” for custom operations
  - Streaming internal infrastructure
- The PlayStation3 (patent application)
  - Core component is a cell
    - 1 “PowerPC” CPU + 8 APUs (“vectorial” cpus)
    - 4GHz, 128K RAM, 256GFLOP/cell
    - Building block for multimedia framework
  - Multiple cells
    - Four cell architecture (1TFLOP)
    - Central 64MB memory
    - Switched 1024 bit bus, optical links?
- Effective streaming data access?
- New rendering abstractions (are polygons dead?)



nVidia NV30



Sony PS2 “Emotion” Engine

The Streaming Programming model

- Streaming exposes concurrency and latency at the system level as part of the programming target
- Data moves through the system: exposed concurrency
  - Avoid global communication: prefer implicit models (e.g. Cr)
- Memory model: exposed latency/bandwidth
  - Scalable, must support very small footprints
  - Distributed, implicit flow between each operation
- A working model:
  - Computational elements + caching and bandwidth constraints
  - External “oracle” for system characterization and realization
- Goals:
  - Optimally trade off computation for critical bandwidth
  - Leverage traditionally “hidden” programmable elements

Next Generation Streaming Cluster…

- Modified visualization algorithms
  - Cache oblivious: local, at the expense of computation
  - “Non-graphical” algorithms, moving away from polygon primitives
  - Digital, high dynamic range imagery from generation to display
- Computation and memory caches everywhere
  - NICs, Drive controllers, Switches, TFLOP GPUs + PCI express
  - Utilizing them may require a disruptive programming shift
    - Exposed data staging and streaming issues
- What are the appropriate abstractions?
  - New languages with higher levels of abstractions?
    - Run-time “realization”, dynamic compilation and scheduling
  - Glue languages: e.g. “shader” languages?
  - Graphics or other API extensions/encapsulation?
  - How do we preserve our largest investments, people & software?

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