Parallel Visualization

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***with a little help from my friends**

Parallel Systems Background

- "Node": analogous to a workstation, laptop etc:
  - 1 or more CPUs (or *cores)*
  - Physical resources: memory, I/O devices, graphics etc.

- "Process": An instance of a *program*
  - "Virtualized" resources – notably, memory

- *"Parallel* process"
  - Shared-memory or "Multi-core"
    - 1 process – so 1 memory space
    - >1 "threads of execution" running on >1 cores (OpenMP, pthreads)
    - Requires intra-process synchronization
  - Distributed-memory
    - >1 process
    - Communicate by message-passing (MPI)
    - 1 process / node – *or processes must share physical resources of node*

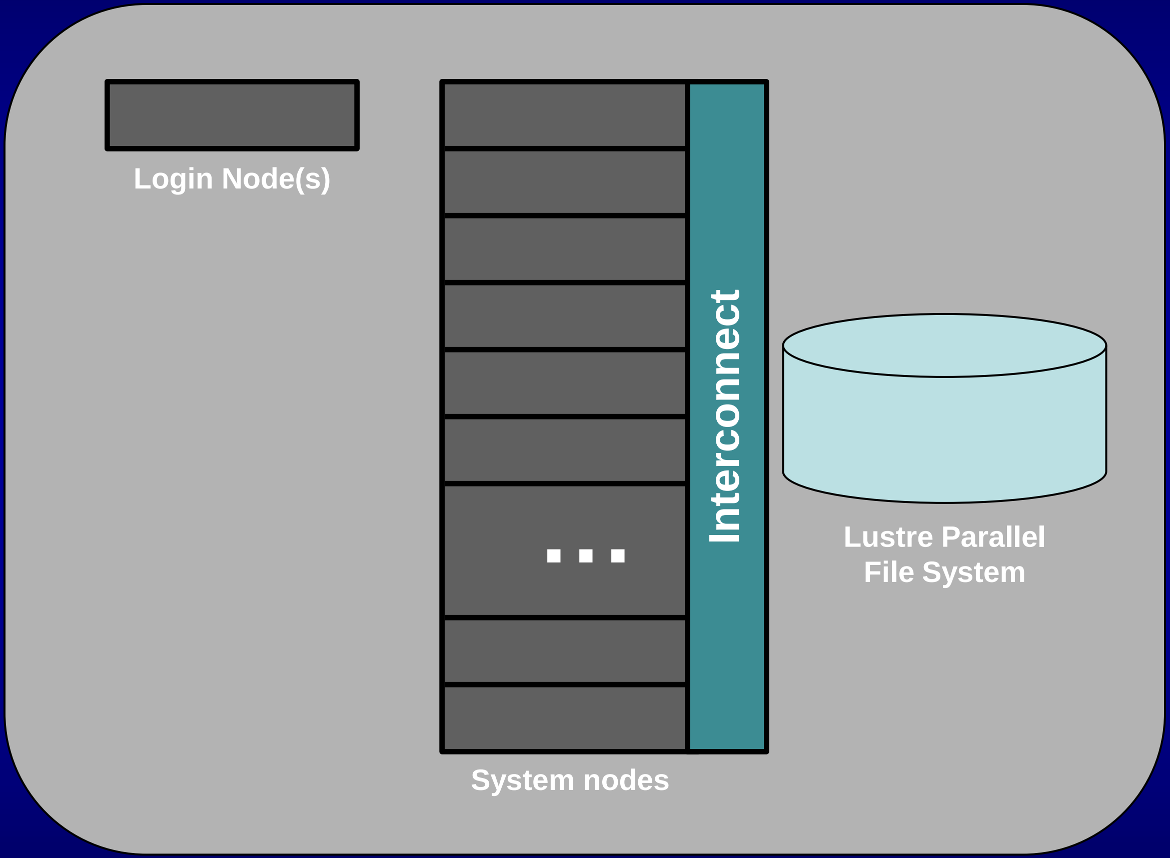
Other approaches:

- Co-Processors
  - Node hosts an accelerator – special processor programmed separately from main processor(s)
  - Program manages parallel execution on accelerator
  - GPGPU, Cell Processor, Cuda (Nvidia), OpenCl
- Hybrids
  - Distributed multi-threaded processes
  - … with accelerators?

Parallel Visualization

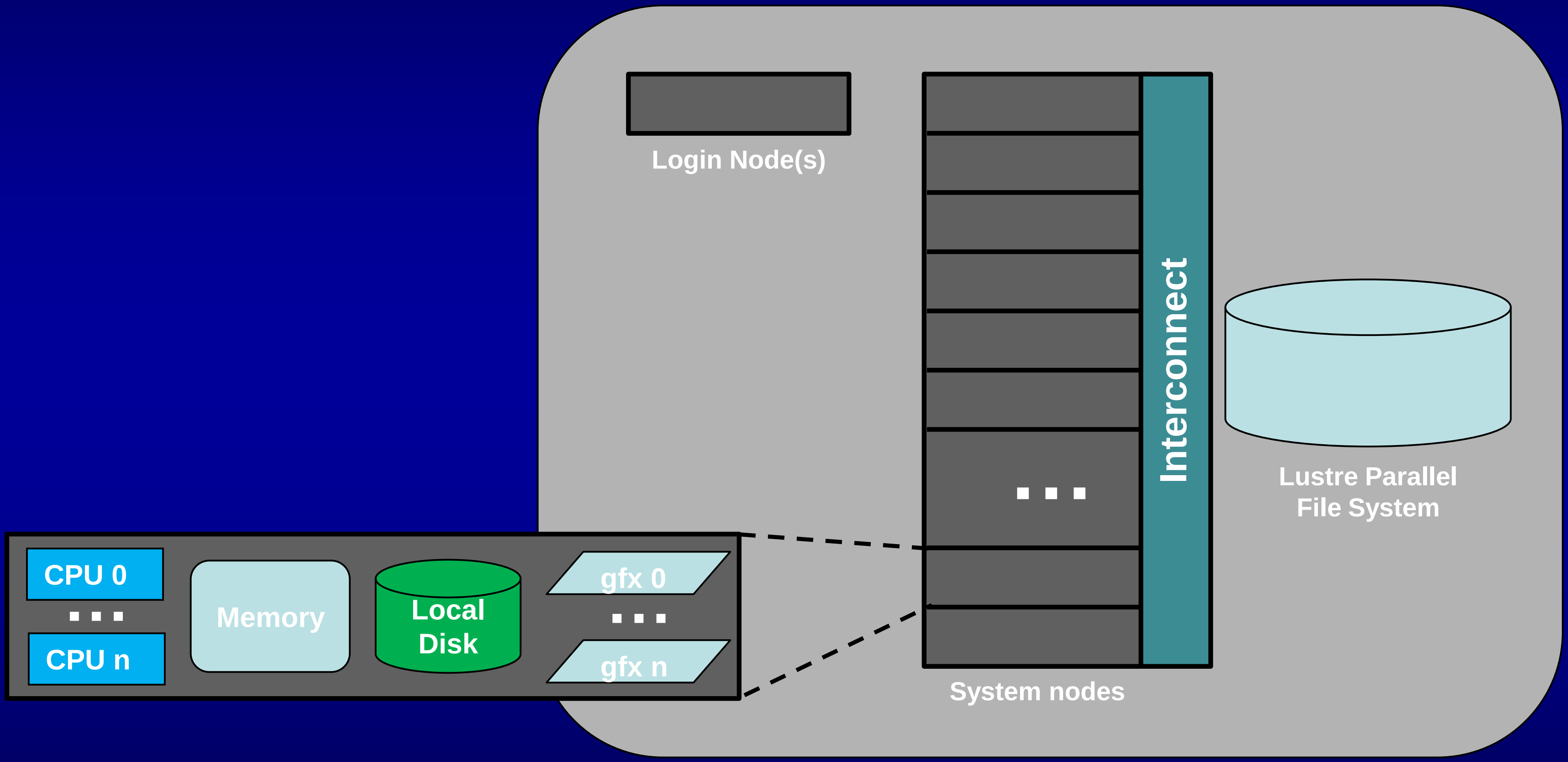
- Why? Performance
  - Processing may be too slow on one CPU
    - Interactive visualization requires real-time frame rates
    - Use lots of CPUs
    - Shared-memory/multicore *or* distributed
  - Data may be too big for available node
    - Virtual memory works, but paging is slow
    - Use lots of nodes to increase physical memory size
    - Big shared-memory/multicore scaling is costly ($/CPU)

TACC Parallel Visualization Systems



Spur or Longhorn

TACC Parallel Visualization Systems



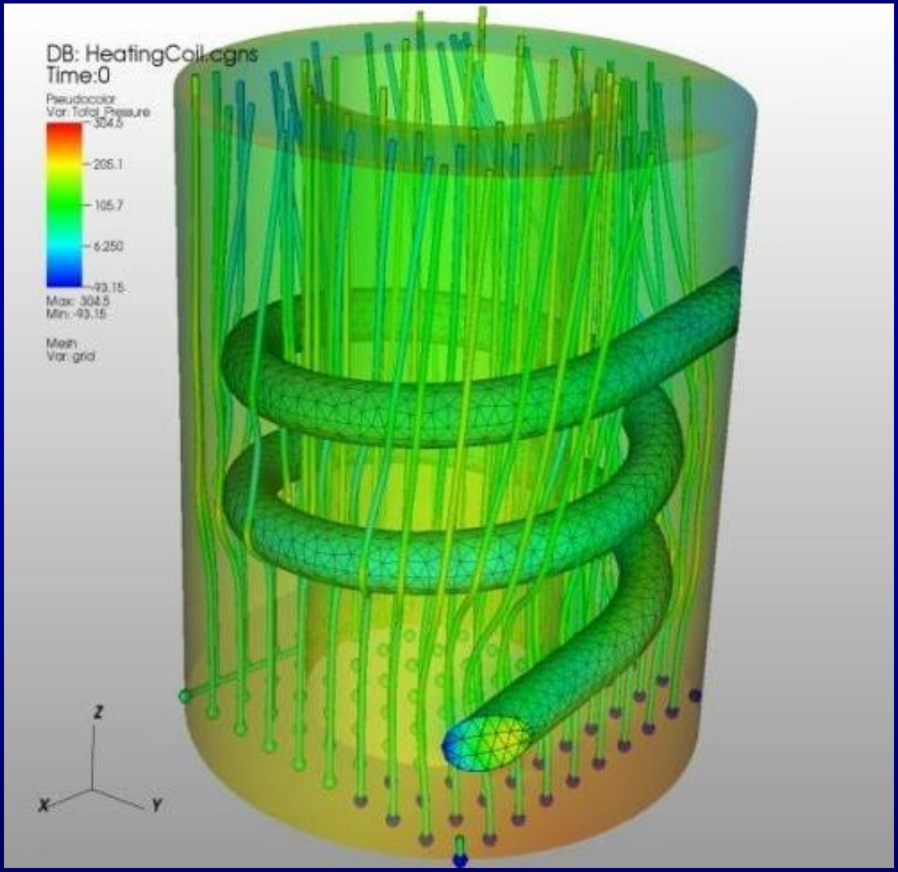
Spur or Longhorn

TACC Parallel Visualization Systems

- Spur
  - 8 nodes
  - 16 cores per node (128 total)
  - 4 GPUs per node (32 total)
  - DDR (dual data rate) Infiniband interconnect

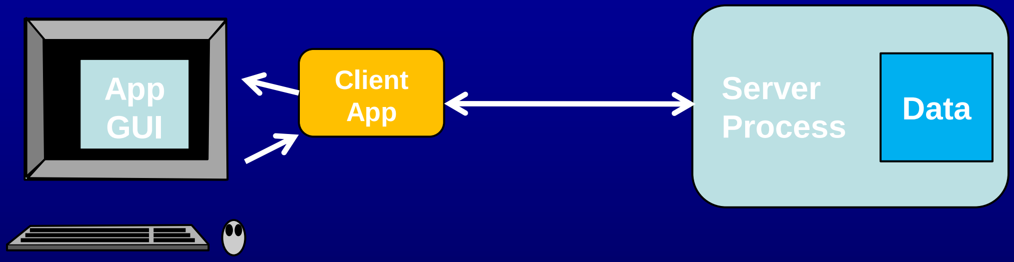
- Longhorn
  - 256 nodes
  - 8 cores per node (2048 total)
  - 2 GPUs per node (512 total)
  - QDR (quad data rate) Infiniband interconnect

Visualization In Parallel



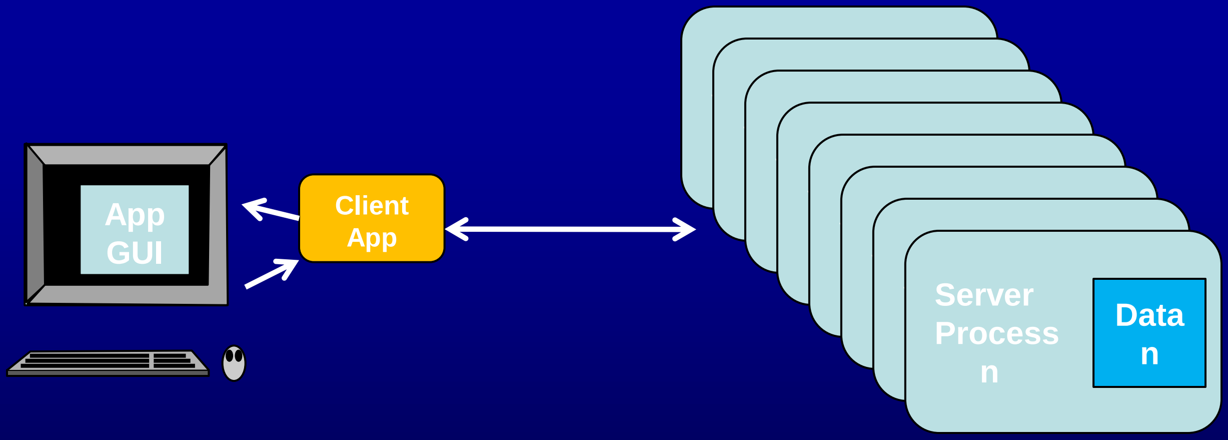
Parallel Visualization Apps At TACC

- Ensight Gold, Paraview and VisIT
- (I don’t know much about Ensight, we’ll focus on ParaView and VisIt)
- PV and Visit are very similar in many ways:
  - Based on VTK
  - Client/Server Architecture



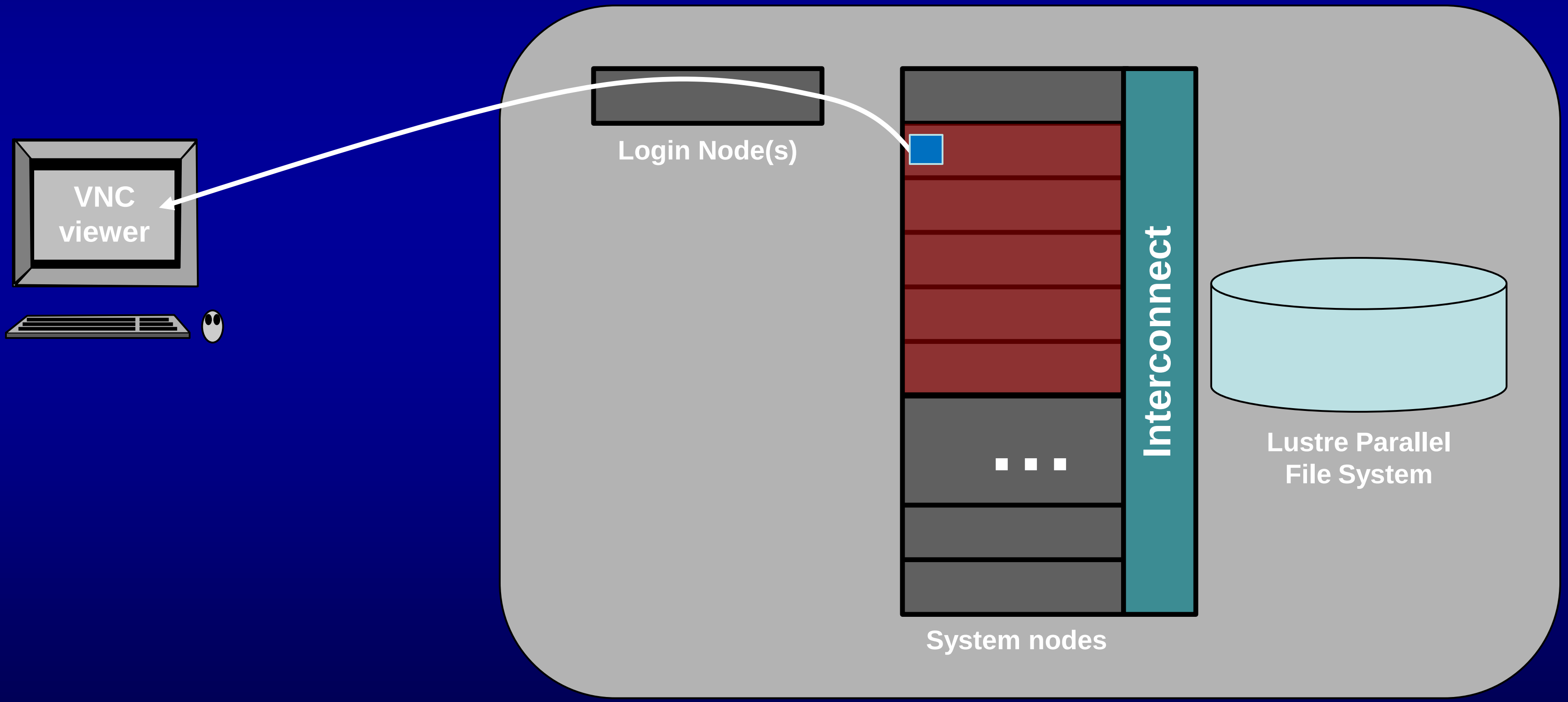
Parallel Visualization Apps At TACC

- Both utilize a distributed, data-parallel serve architecture



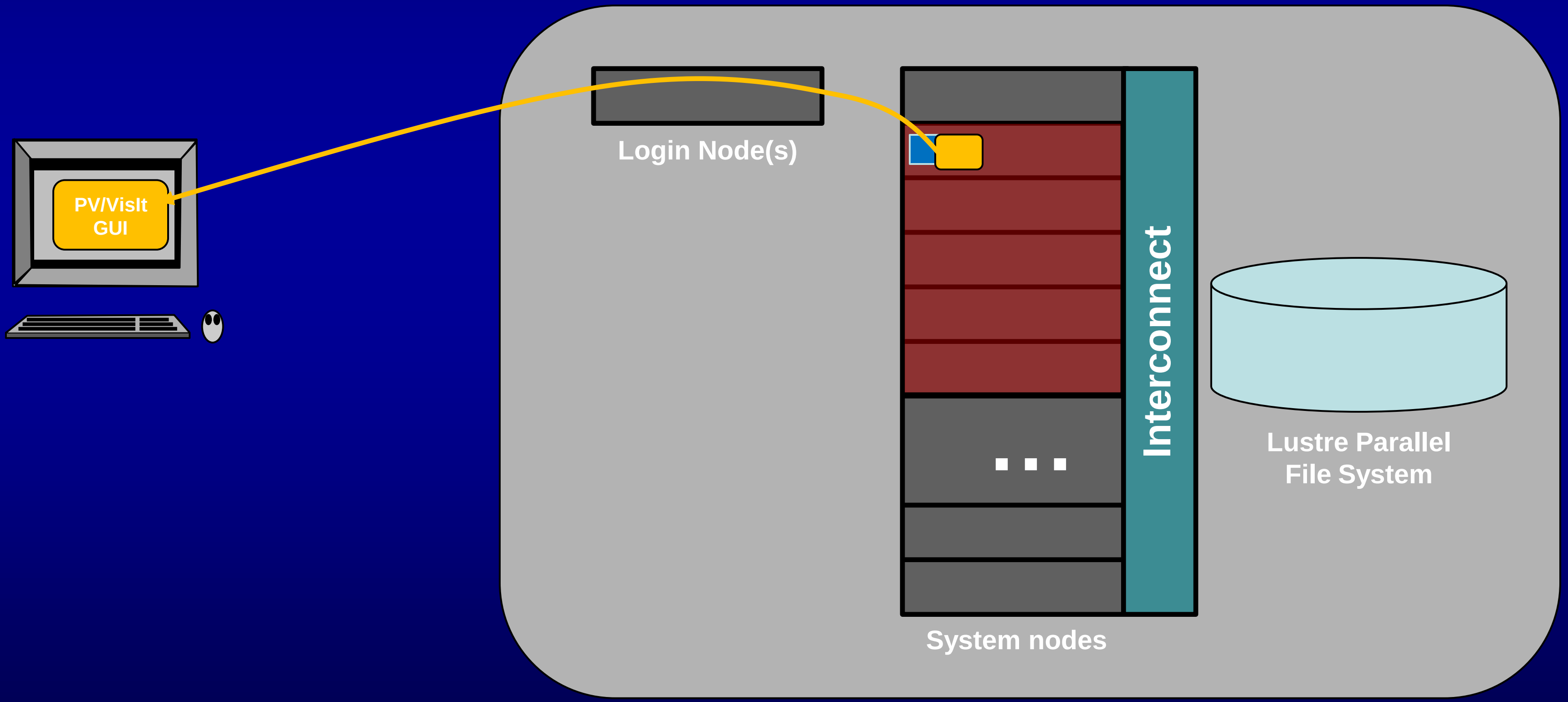
Mapping Parallel PV, VisIt to TACC Visualization Systems

1. Allocate set of nodes on visualization system. This will start a VNC server one one node, which you will connect to (as before)



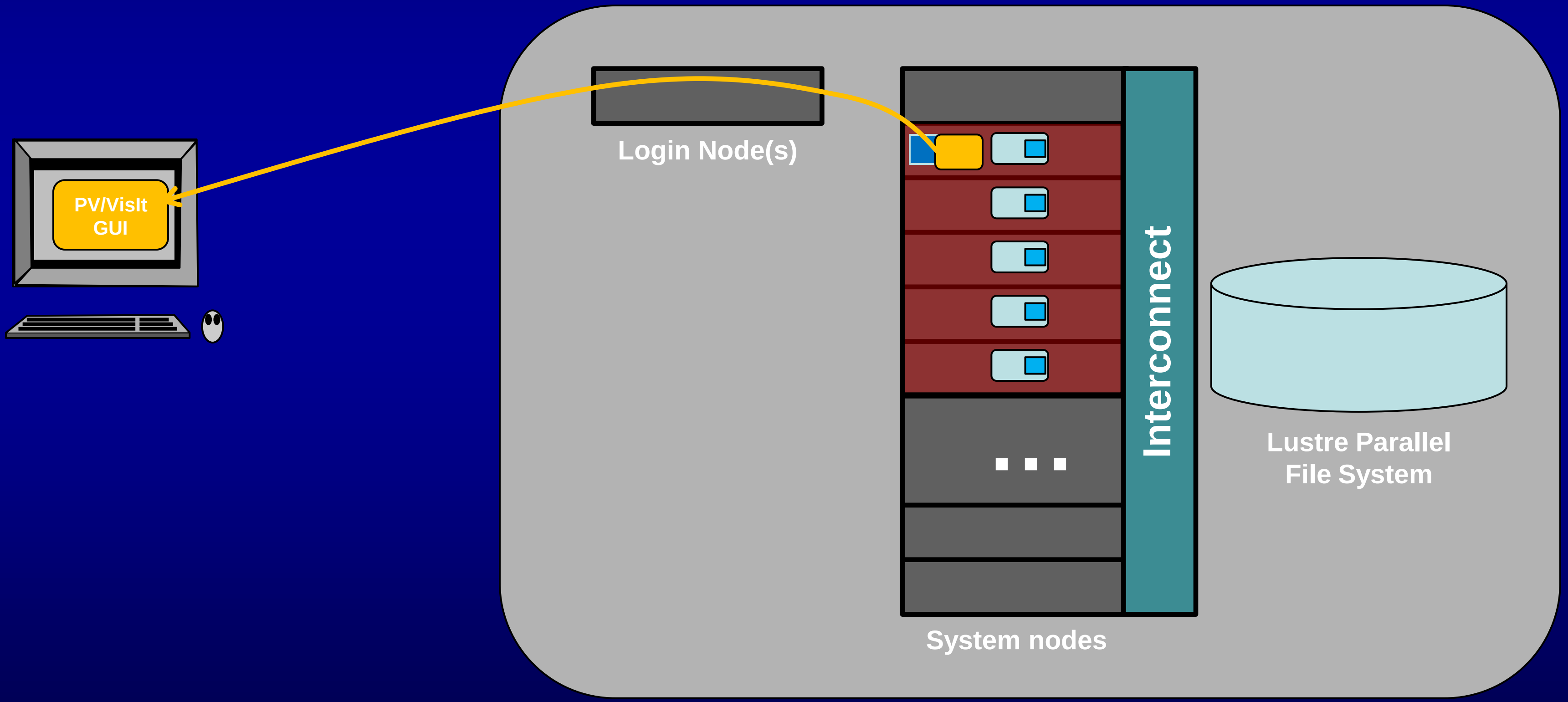
Mapping Parallel PV, VisIt to TACC Visualization Systems

2. From that desktop, launch the PV or VisIt Client App



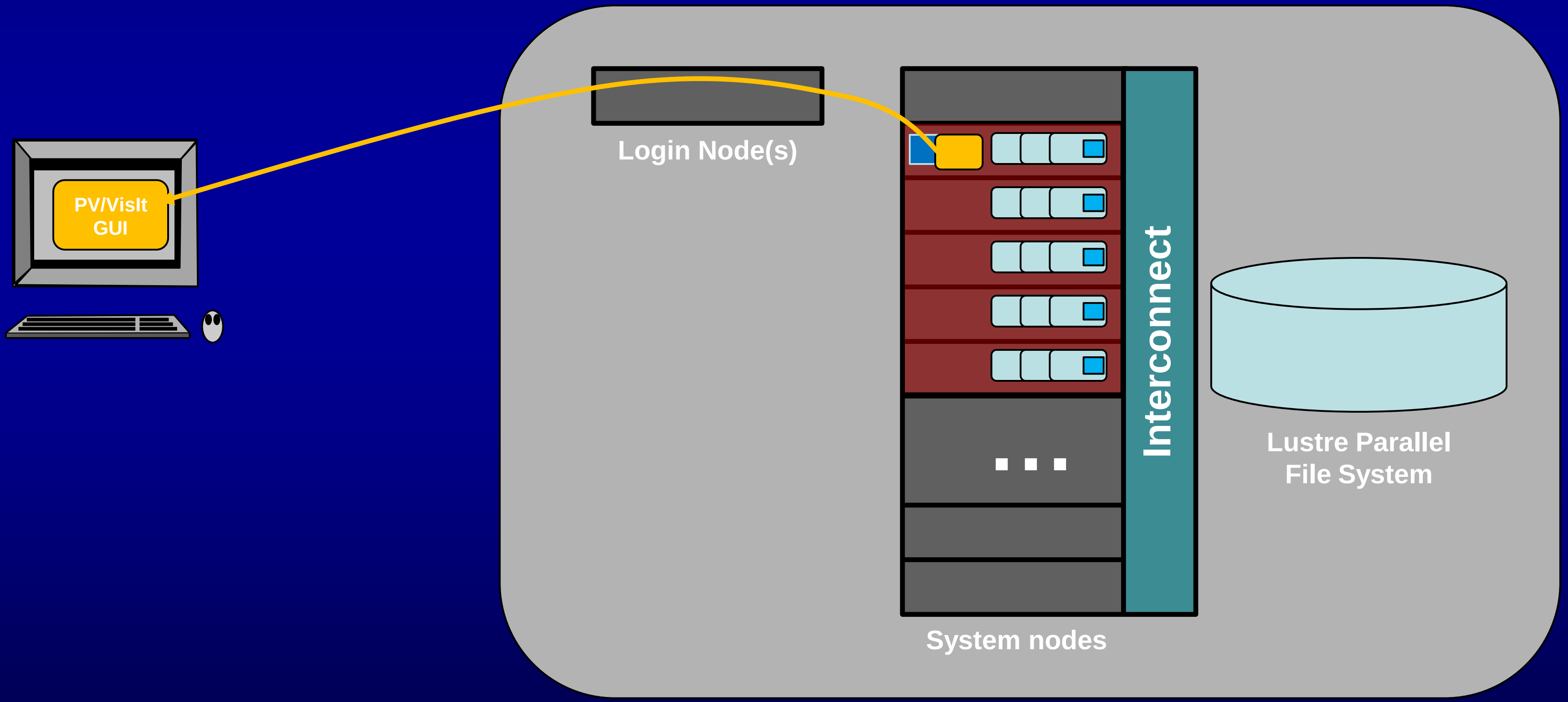
Mapping Parallel PV, VisIt to TACC Visualization Systems

3. Start PV or VisIt Server Processes
   - PV, from command line; VisIt through GUI



Mapping Parallel PV, VisIt to TACC Visualization Systems

4. Multiple processes/node to take advantage of multiple cores/node



Way-ness: The Number of Processes Per Node

Process memory is limited to 1/n of node memory for each of n processes on that node If you need large memory per process, use fewer processes per node

Why would you need to?

- Data is partitioned in large chunks
- Visualization algorithms can expand the data

Way-ness is set up at *allocation time*

- Parallel jobs launched from VNC desktop will adopt the way-ness specified when the VNC server job is launched
- VNC sessions launched through the portal are full-way

Parallel Sessions on Longhorn via the Portal

1. VNC password should already be set
2. Browse to: portal.longhorn.tacc.utexas.edu
3. Select VNC as the session type
4. This time, specify number of nodes = *k,* to get *k* nodes or 8**k* processes
   – *Way-ness will be full – "#slots" will be the number of processes you get*
5. Hit Select and wait a few seconds….
6. Go to the "Rendering" tab and enter your VNC password

* **If you return to the "Resources" page and find your job, you will see it running on 8****k*** **cores.**

Parallel Sessions on Longhorn via qsub

1. VNC password should already be set
2. ssh to longhorn: ssh longhorn.tacc.utexas.edu
3. qsub a VNC session:

qsub [qsub options] /share/sge6.2/default/pe_scripts/job.vnc [vnc options]

Required qsub options:

-P project_type	one of vis, data, gpgpu, or hpc
-q queue	one of normal, long, largemem, devel
-A allocation	if >1 available, choose one
-pe wayness ncores	job size

several more, see the docs

Running Paraview in Parallel

1. Start it as before: in the white xterm,

   module paraview

   vglrun paraview

   Paraview will appear

2. In a second xterm, start the parallel server…

   module paraview

   (csh) env NO_HOSTSORT=1 ibrun tacc_xrun pvserver

   (bash) NO_HOSTSORT=1 ibrun tacc_xrun pvserver

   You will see "Waiting for client…"

Running Parallel Paraview (2)

3. Connect client to server
   a. Click File->Connect to bring up Choose Server dialog
   b. If first time:
      i. Click Add Server
      ii. Set the server configuration name to “manual”
      iii. Click Configure
      iv. From Startup Type select Manual and click Save
   c. Select manual from the list and click Connect

In client xterm, you should see “Waiting for server…”

In server xterm, you should see “Client connected.”

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Running VisIt in Parallel

- Its really easy….

  module load visit

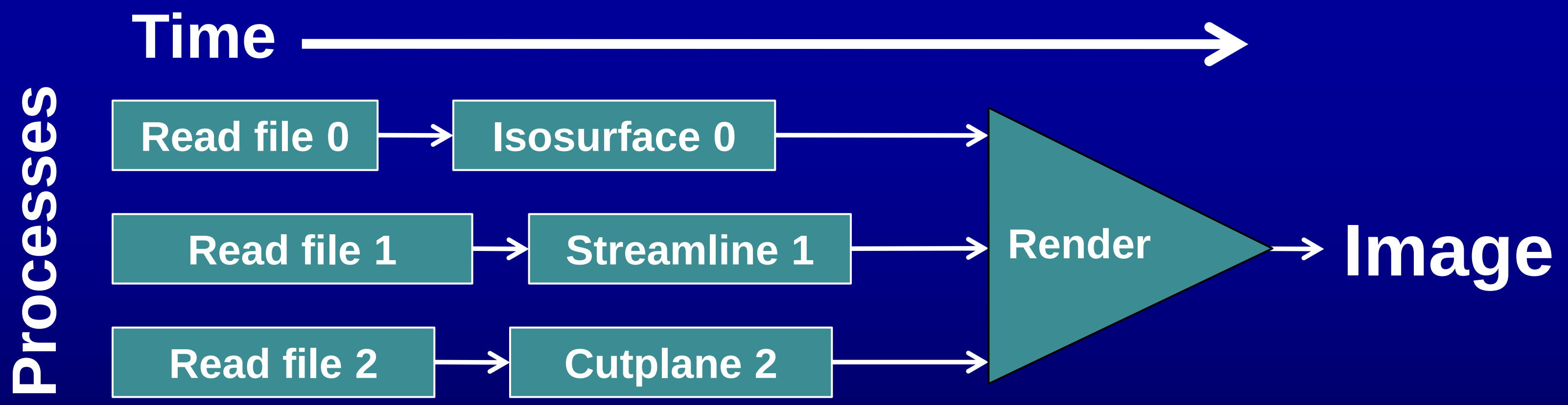
  vglrun visit

Paraview In Parallel

- Demonstrate:
  - Click Sources->Sphere
  - Max out Theta Resolution and Phi Resolution
  - Click Apply
  - ➢ Up comes a white sphere
  - Click Filters->Alphabetical->Process Id Scalars
  - Click Apply
  - ➢ Segments are colored by which process handles them

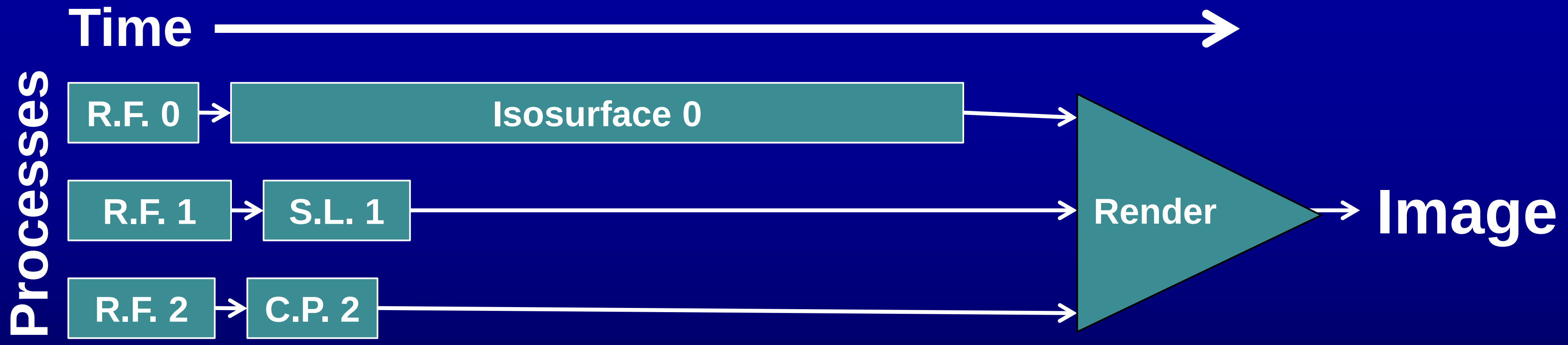
Parallel Visualization Algorithms #1: Task Parallelism

- Divide the overall workflow into tasks that can happen independently and, hence, concurrently
- Likely does not scale well
- Rendering may itself be parallel



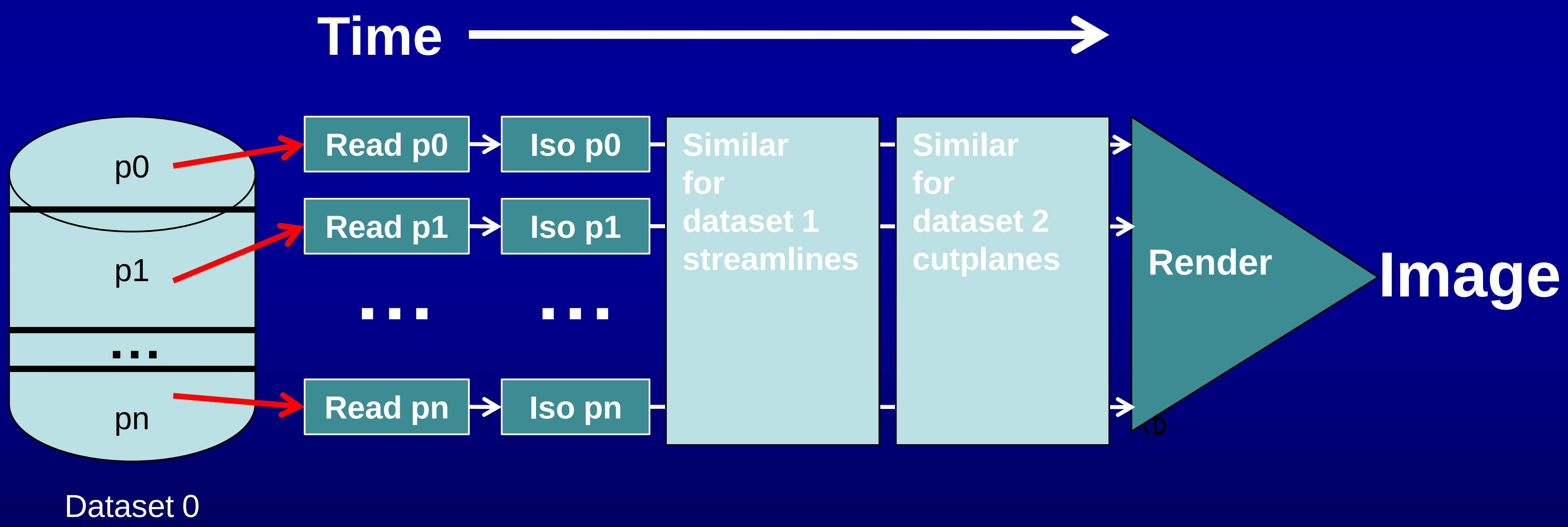
Parallel Visualization Algorithms #1: Task Parallelism

- Often does not scale well
  - Too few independent paths
  - Suppose Isosurface predominates:



Parallel Visualization Algorithms #2: Data Parallelism

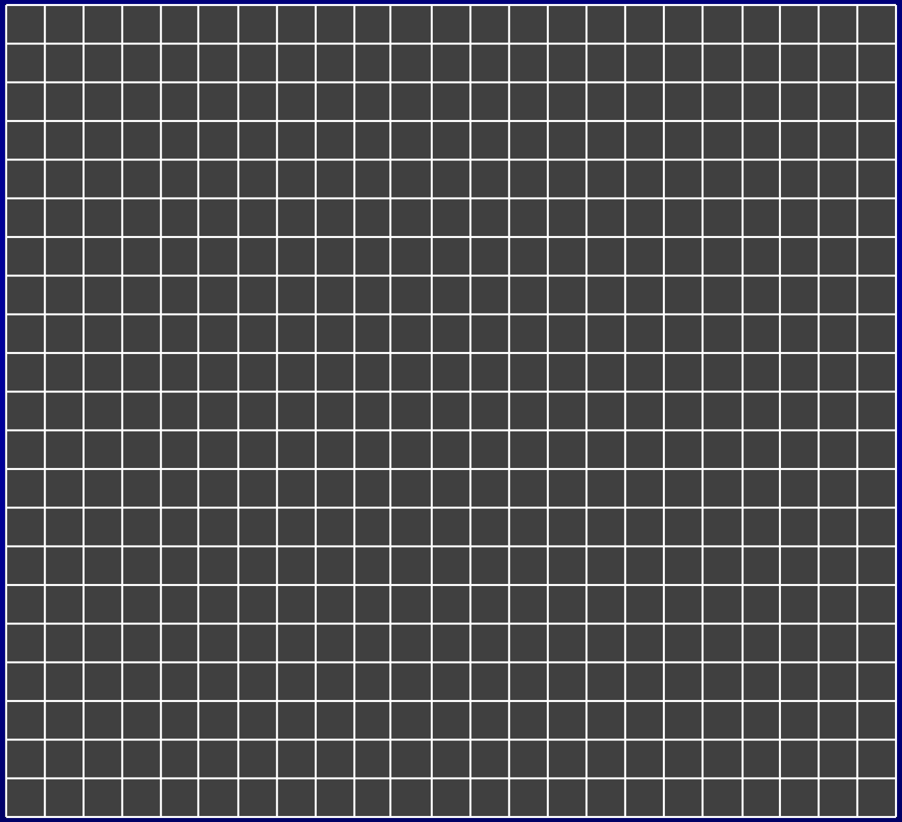
– Data set is partitioned among the processes and all processes execute same operations on the data.
– Scales well as long as the data and operations can be decomposed.



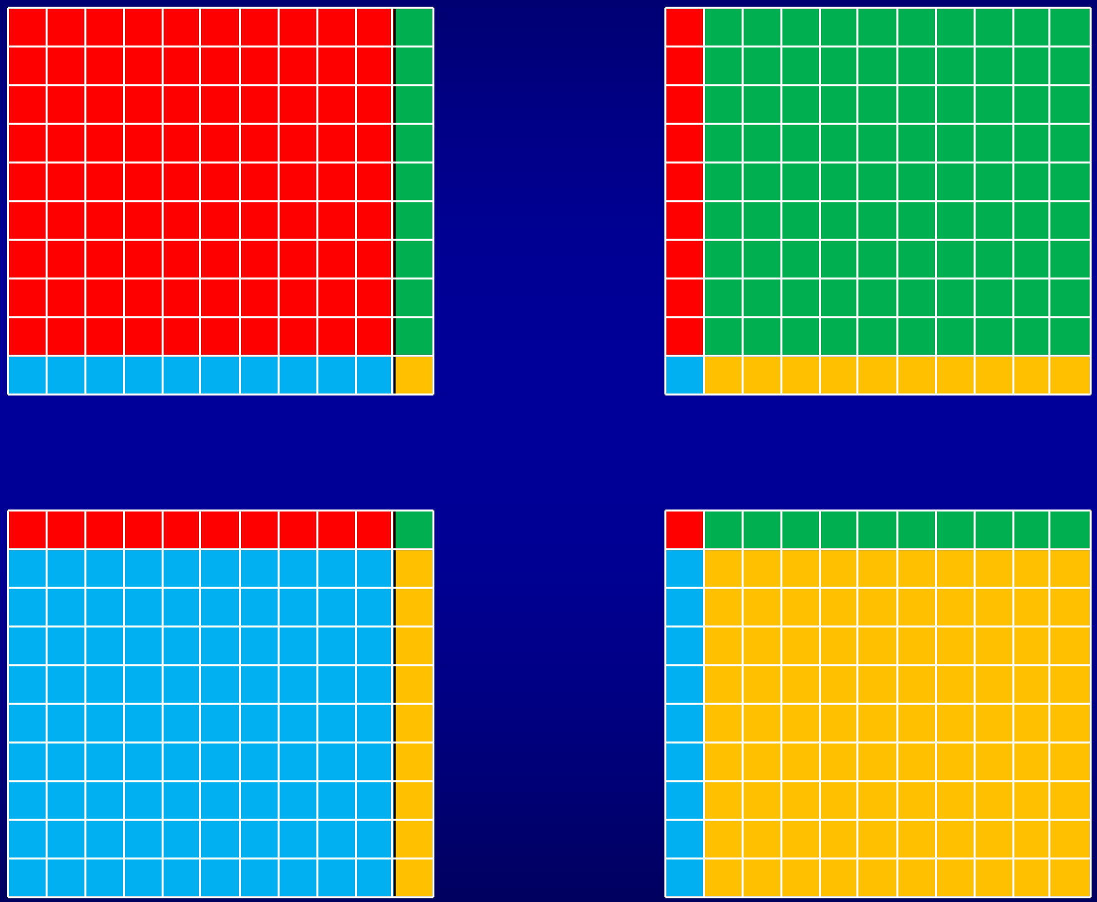
Parallel Visualization Algorithms #2: Data Parallelism

- *Generally* scales well if:
  - Tasks are amenable to data-parallelism
    - Many are (isosurfaces etc.)
    - A few just aren't (streamlines!)
  - Work is evenly distributed over partitions
  - Alternative is to have >>partitions than processors for load-balancing
- Inter-Partition Boundaries In Distributed Implementations
  - Some applications require neighborhood information to get right answer
  - Requires access to data assigned to neighboring partitions (called ghost zones)
  - Overhead increases with number of partitions

Partitioning for Data-Parallelism

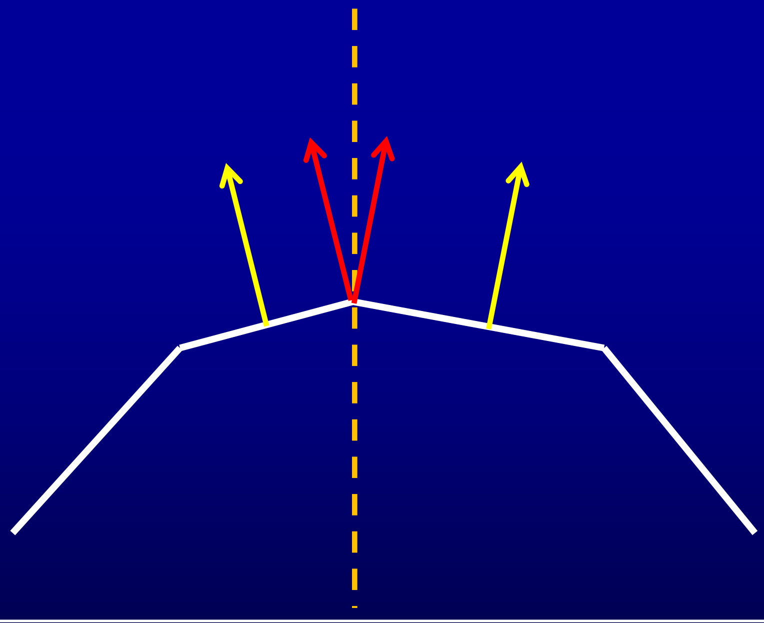


Partitioning for Data-Parallelism



Aside: Why Ghost Zones?

- What happens when the incident triangles lie in different partitions?   A discontinuity – and the eye is designed to pick it up

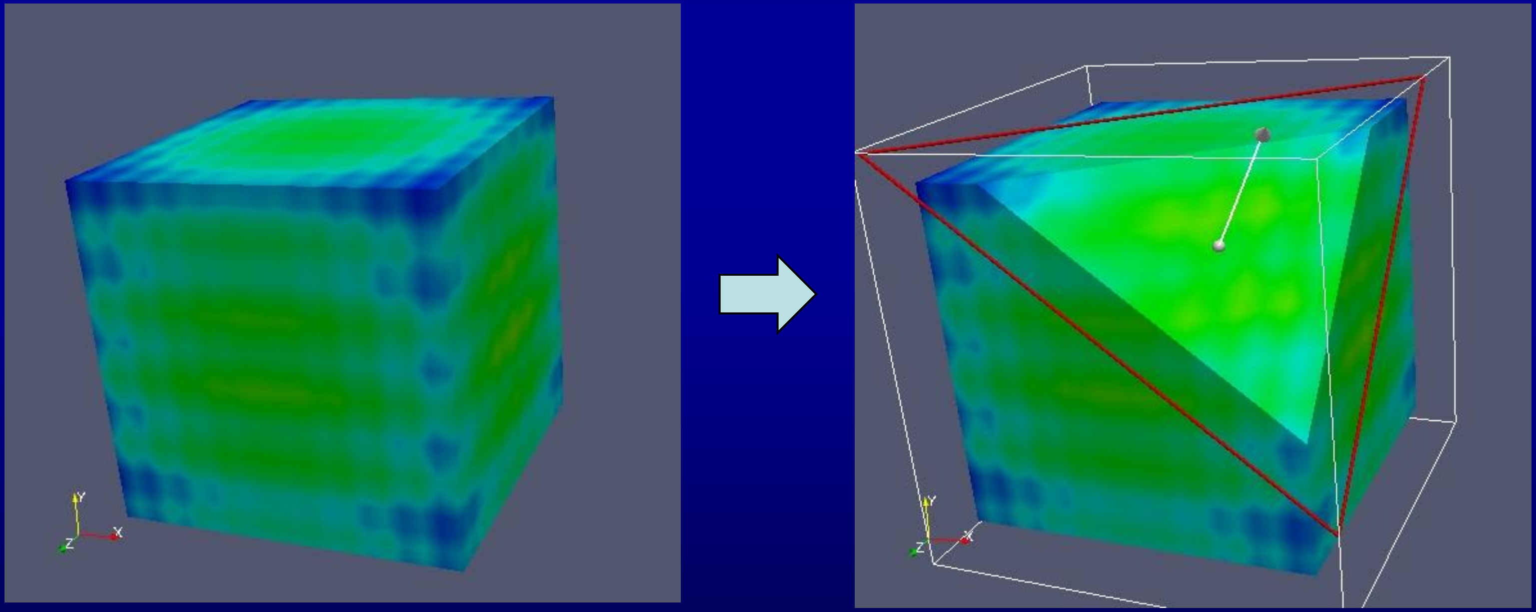


Performance Issues

- Memory Utilization
- Parallel Data Management
  - Supporting parallel compute
  - Supporting parallel I/O
- Non-data parallel algorithms
- Parallel rendering overhead

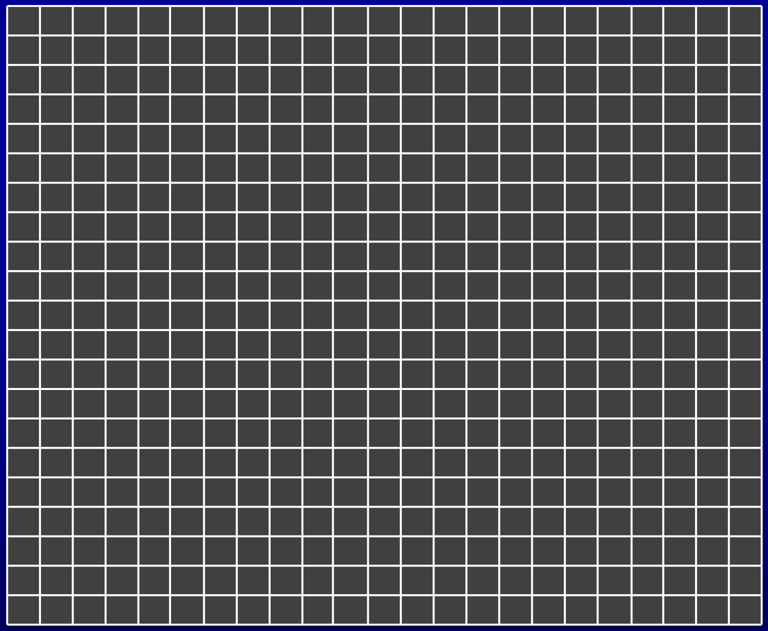
Memory Utilization

- Some visualization techniques cause memory use to skyrocket!



Memory Utilization

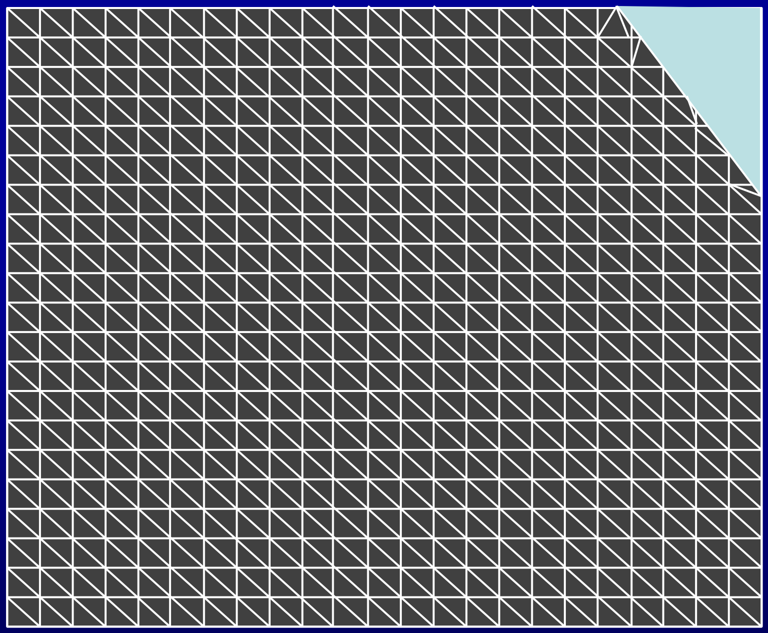
- Regular grids



- Grid and mesh are specified by:
  - (xyz) origin
  - (dx,dy,dz) delta vectors
  - (nx,ny,nz) counts
- Requires diddly-squat memory

Memory Utilization

- Chop off the corner -> Unstructured Grids

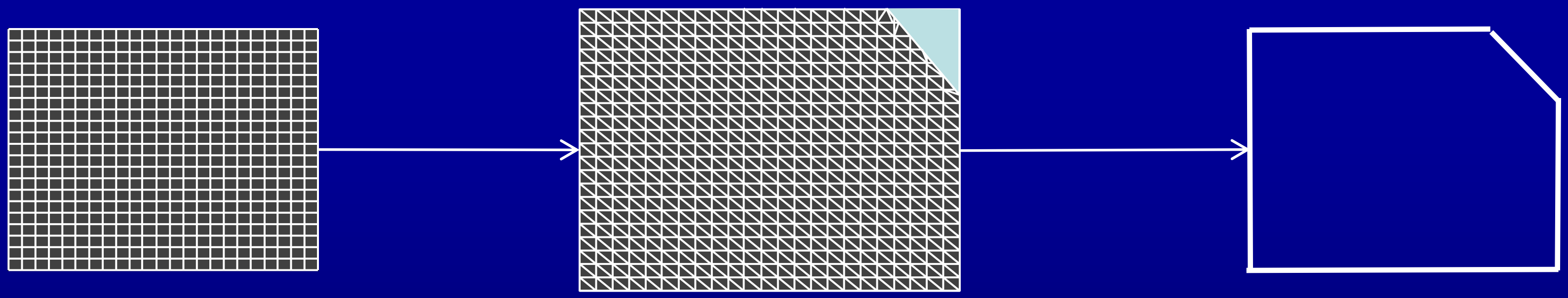


- **Specified by:**
  - **Explicit list of vertices**
  - **Explicit list of triangles (2D)**

•Memory use can go up *many* times

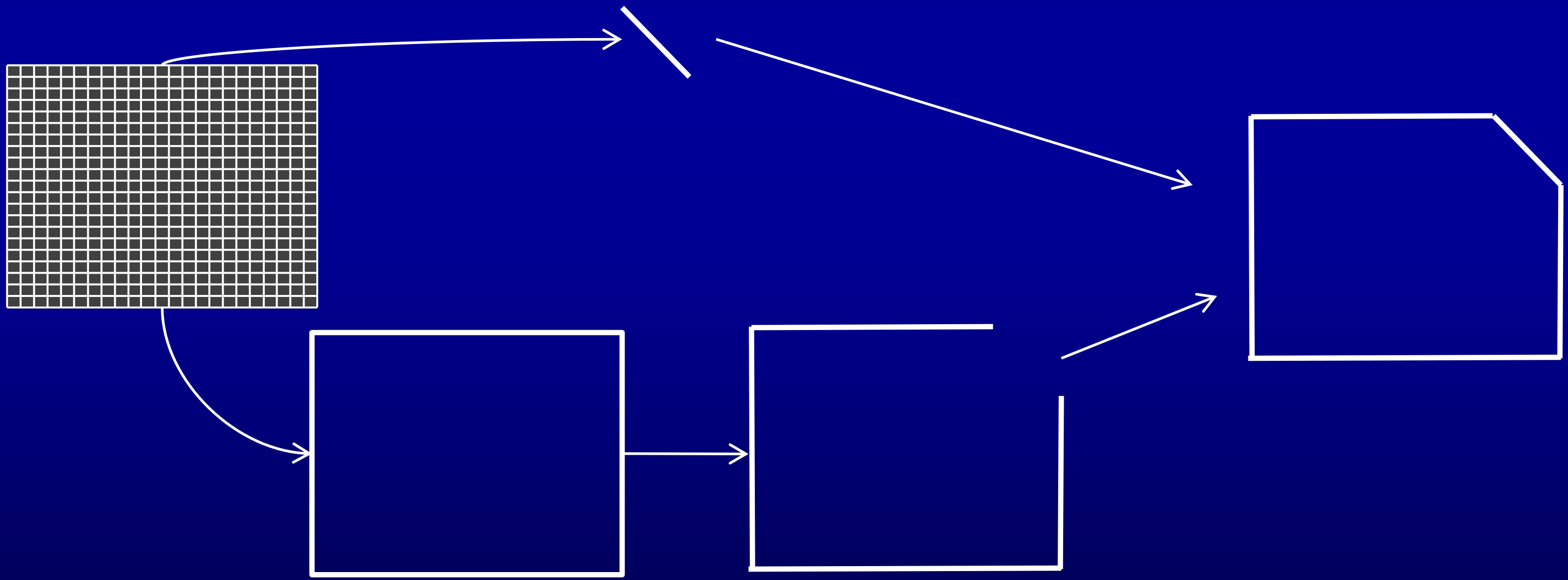
Memory Utilization

- Bad solution: Clip volume, extract bundary

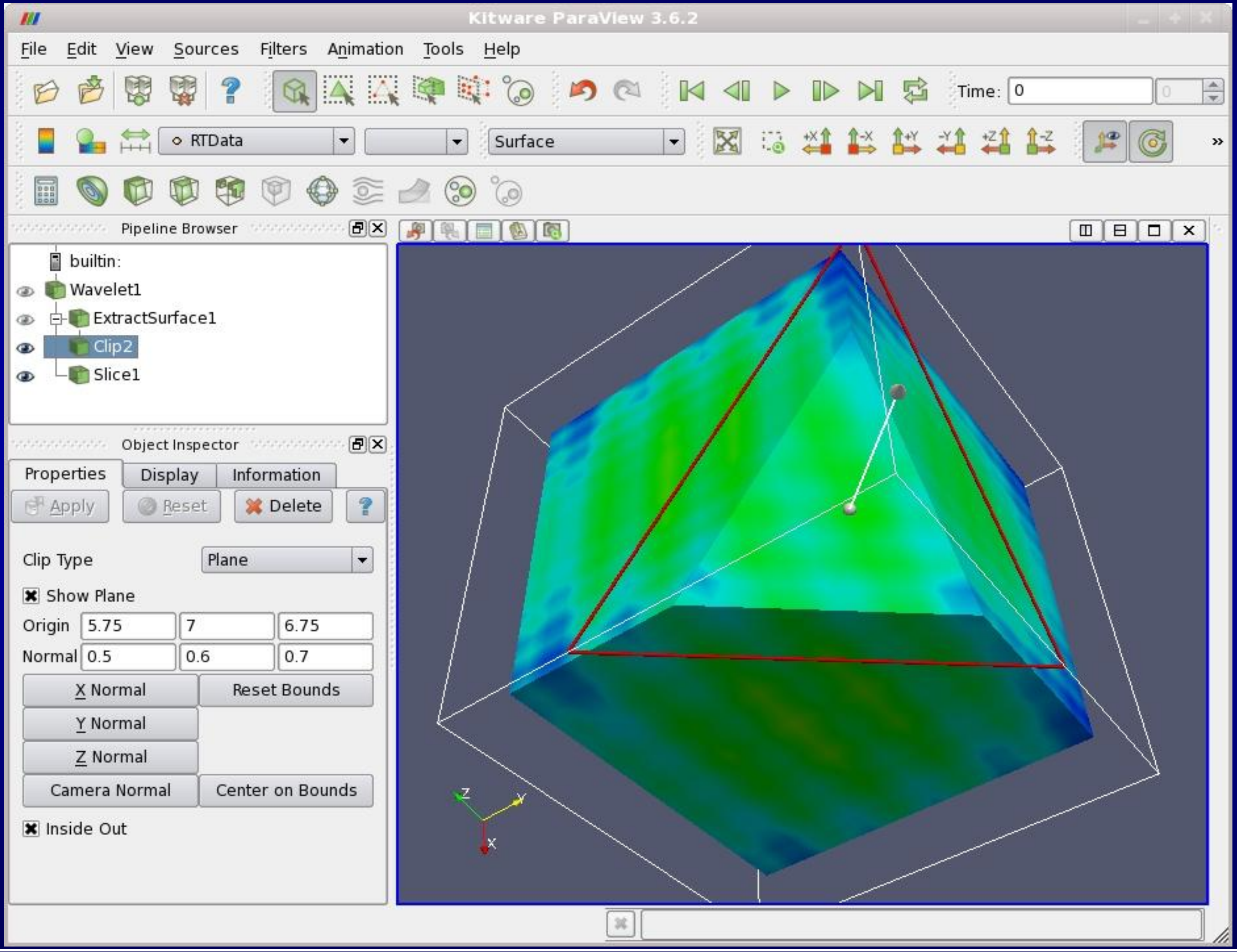


Memory Utilization

- Better Solution: extract the boundary and chop, add in cap



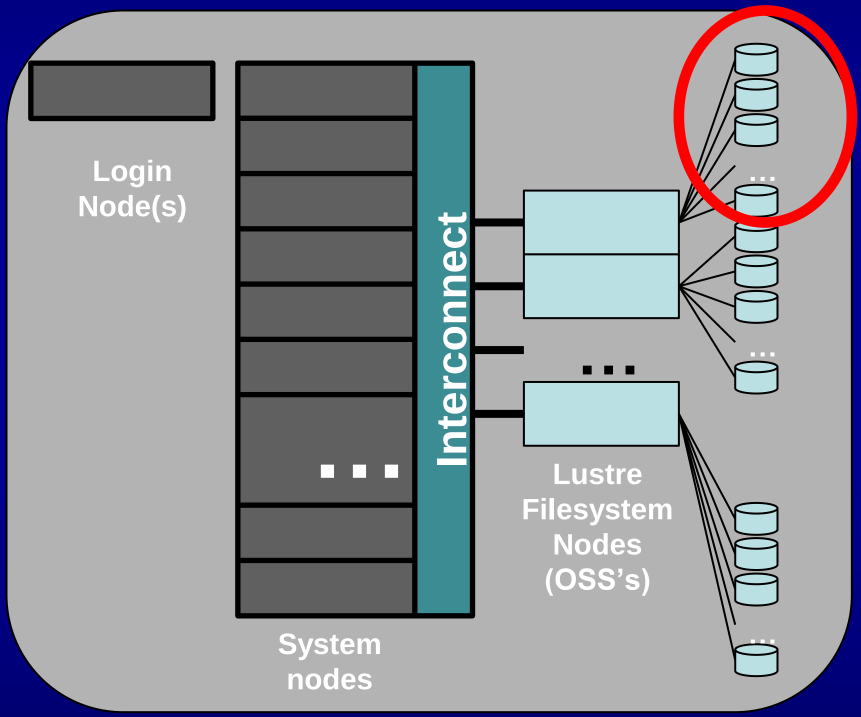
In Paraview


Kitware ParaView 3.6.2
File
Edit
View
Sources
Filters
Animation
Tools
Help
Time: 0
RTData
Surface
Pipeline Browser
builtin:
Wavelet1
ExtractSurface1
Clip2
Slice1
Object Inspector
Properties
Display
Information
Apply
Reset
Delete
Clip Type
Plane
Show Plane
Origin 5.75 7 6.75
Normal 0.5 0.6 0.7
X Normal
Reset Bounds
Y Normal
Z Normal
Camera Normal
Center on Bounds
Inside Out

Parallel Data Management

- *Data must be distributed* across parallel processes to take advantage of resources
- How does it get there?
  - *Some* PV and VisIt readers import in parallel
    - *Explicit* parallel formats use separate files for partitions (.pvti, global.silo)
    - *Implicit* parallel formats – parallel processes figure out what they need – (.vti, brick-of-values)
  - Some may *seem* to import in parallel
    - Actually, import serially and then distribute
    - Bad bad bad – 1 process needs enough memory for entire dataset *plus* additional space for partitioning
  - And some just don't
    - … and leave it to you (D3 filter in Paraview)
    - See Bad bad bad above

TACC Parallel I/O Numbers



Number of disks per server:
- **2 Logical Units (LUNs)**
- **6(+1 redundant) disks/LUN**

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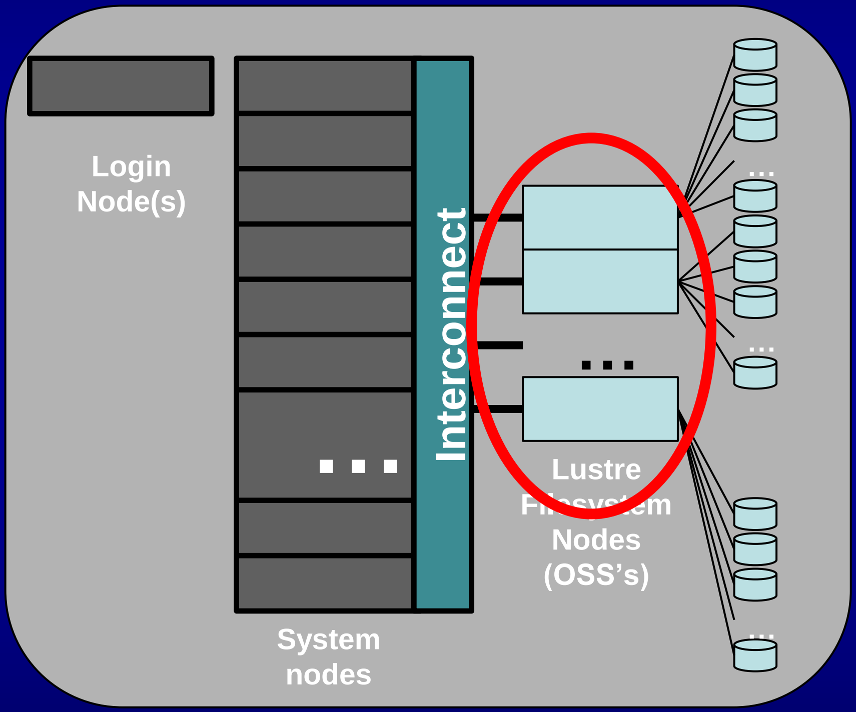
TACC Parallel I/O Numbers



Filesystem Servers (OSS nodes)

- **Spur has 50, SDR IB connect**
- **Longhorn 12, QDR IB connect**

Lustre File System

- No files are local
  - any process can access any file, or any *part* of a file
- Files are served across network
  - Bandwidth into node across interconnect >> bandwidth from a few local disks
- Multiple pinch-points remain
  - Total number of disks (~30-40 MB/sec per disk)
  - Total number of file servers (IB connectivity)
- *Layout* of files becomes important
  - File striping across disks in each file server
  - File striping *across file servers*

Luster OSS Striping

- Stripe across >1 OSS node for performance (and capacity) with diminishing (negative) returns
  - Spur defaults to 4, Longhorn to 2
- Striping is under user control
  - lfs getstripe *file*
    - see *lmm_stripe_count* for current striping
  - lfs getstripe *dir*
    - *stripe_count* will be applied to all files written to that dir
  - lfs setstripe dir
    - Set the stripe count to apply to all files written to that dir

Finally, Some Things Just Don't Lend Themselves To Parallel Execution

- Streamlines!
  - Not data-parallel
  - Partial streamlines must be passed from processor to processor as the streamline moves from partition to partition
  - No more parallelism available than the number of streamlines!
  - If >1 streamlines pass through the same partition, you may not even get that

Rendering

- Got lots of triangles spread out over nodes
- 2 rendering solutions
  - 1. Gather triangles onto one node, render there
    - Best when there's not a lot of data to render
  - 2. Render triangles in place, gather and Z-composite the results
    - Best when there *is* a lot of data to render
    - Overhead is *almost* independent of data size
- VisIt and Paraview both do it both ways
  - User controls threshold

Summary

- Paraview and VisIt are designed to look the same whether serial or parallel
- You can’t completely ignore the realities
  - Choose your file formats well!
  - Consider file system realities!
  - Watch out for memory explosion!