BLUE WATERS

SUSTAINED PETASCALE COMPUTING

# Update on Topology Aware Scheduling (aka TAS)

GREAT LAKES CONSORTIUM
FOR PETASCALE COMPUTATION

Work done in collaboration with

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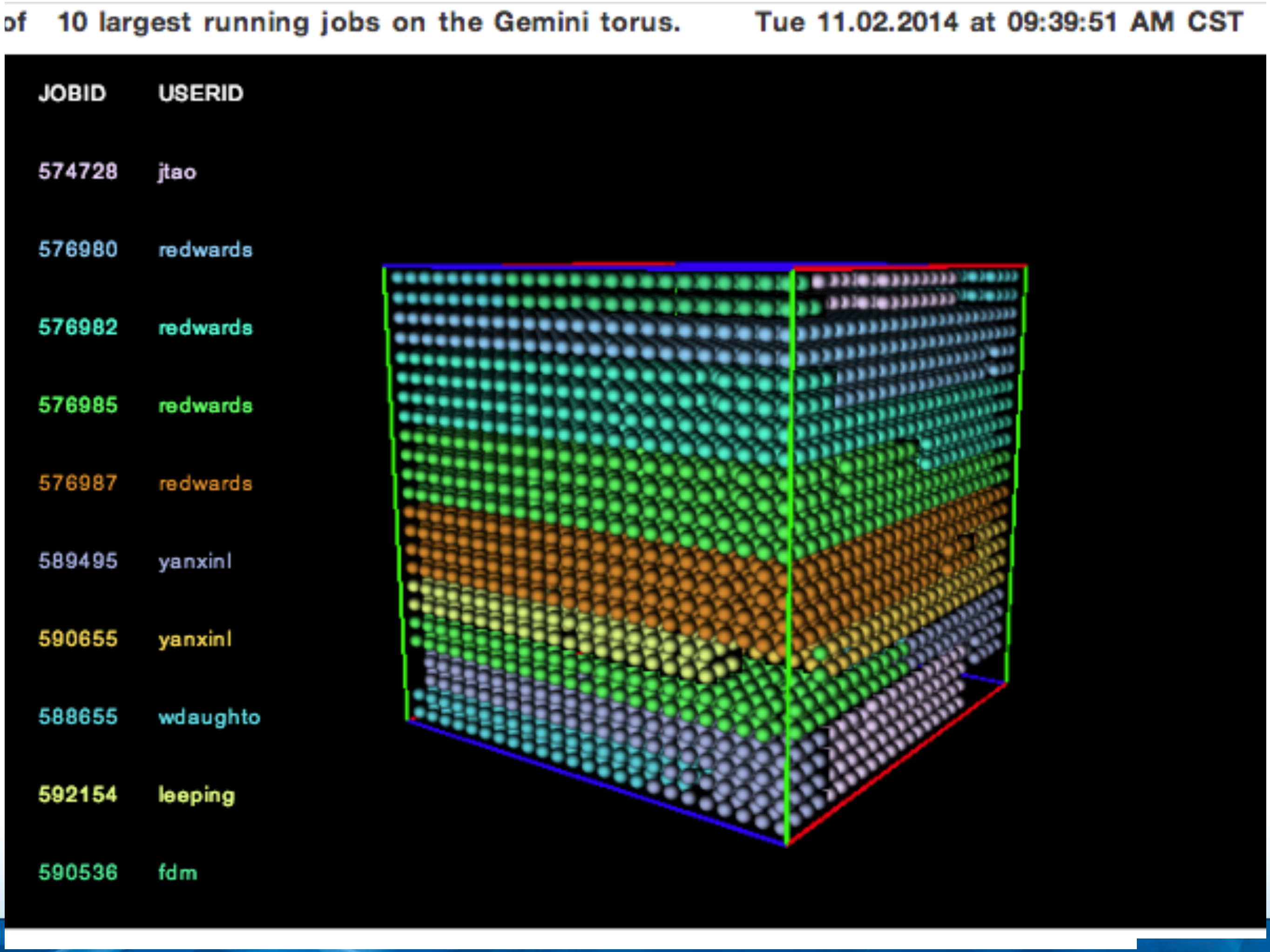
- R. Fiedler
- Adaptive Computing

# When things look good



of 10 largest running jobs on the Gemini torus. Tue 11.02.2014 at 09:39:51 AM CST

| JOBID | USERID |
|---|---|
| 574728 | jtao |
| 576980 | redwards |
| 576982 | redwards |
| 576985 | redwards |
| 576987 | redwards |
| 589495 | yanxinl |
| 590655 | yanxinl |
| 588655 | wdaughto |
| 592154 | leeping |
| 590536 | fdm |

Image credit: Dave Semeraro

# What's the problem?

- Efficient job scheduling on a large torus is not easy.
- Over time (between large jobs, reboots) fragmented allocations appear.
- Fragmentation can lead to degraded and variable application performance.

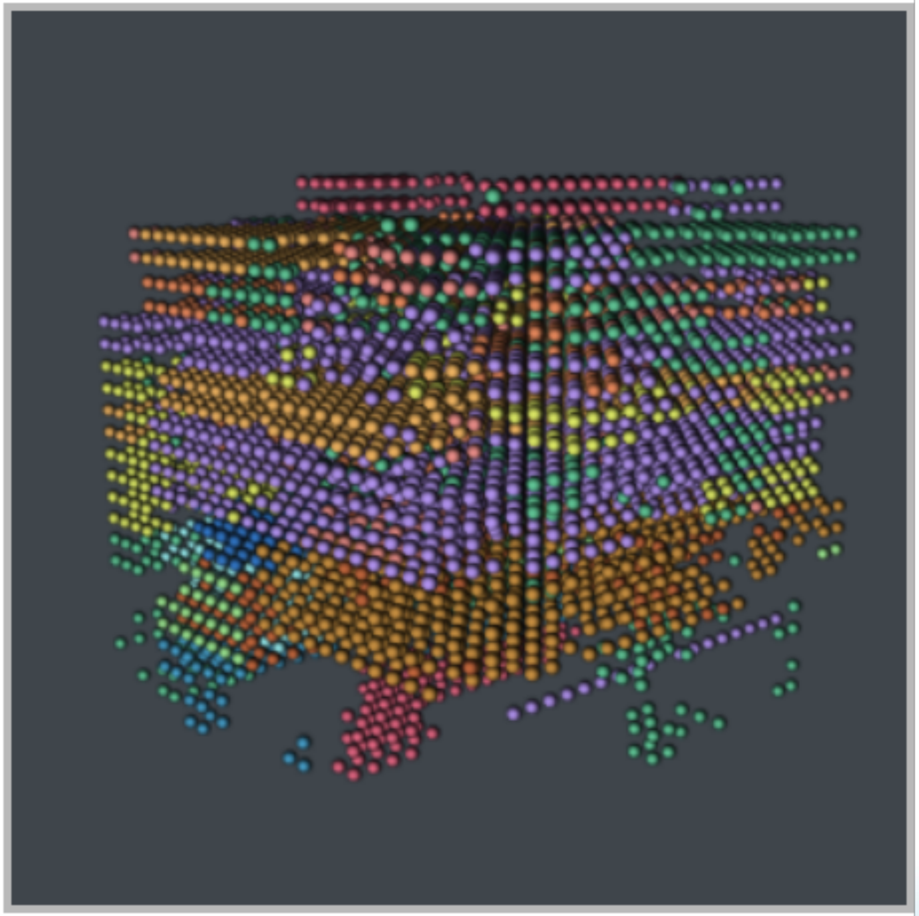
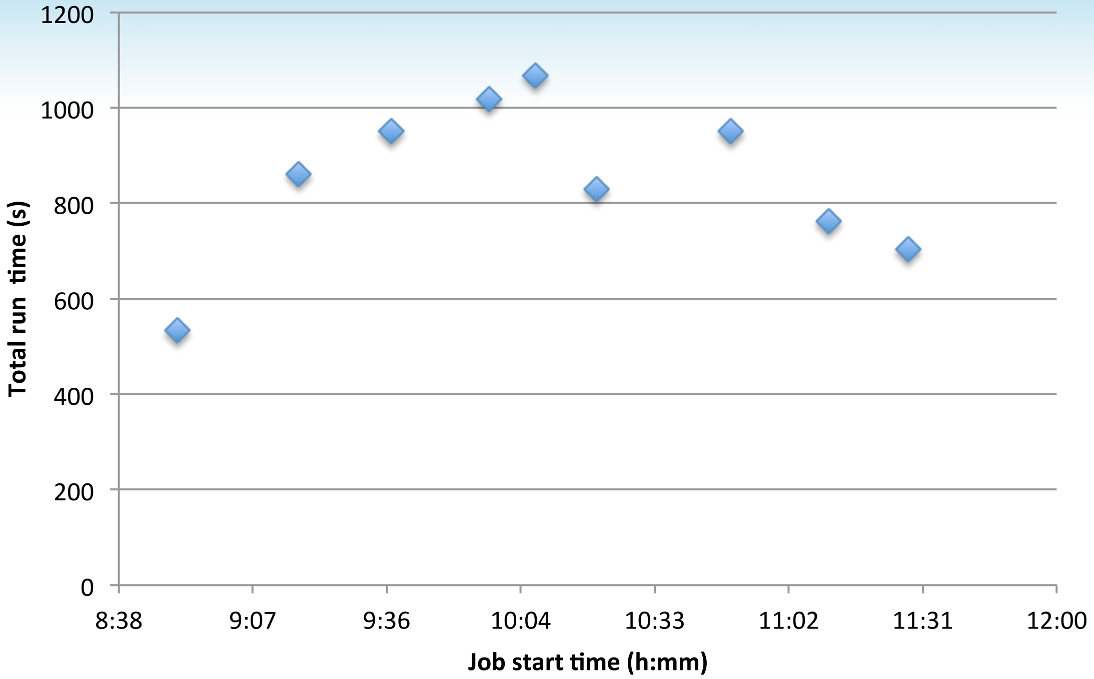


Image credit: Robert Sisneros



- 4,116 XE node jobs run at different times.
- Run to run variability
  - makes it difficult to assign a reasonable wall clock time.
  - has an impact on job throughput.

# Blue Waters Torus

- 24x24x24 gemini routers, 2 nodes each
- XE nodes not shown
- XK nodes (red) 15x6x24
- XIO nodes (yellow)
- Links along X & Z dimensions 2x faster than links along Y.

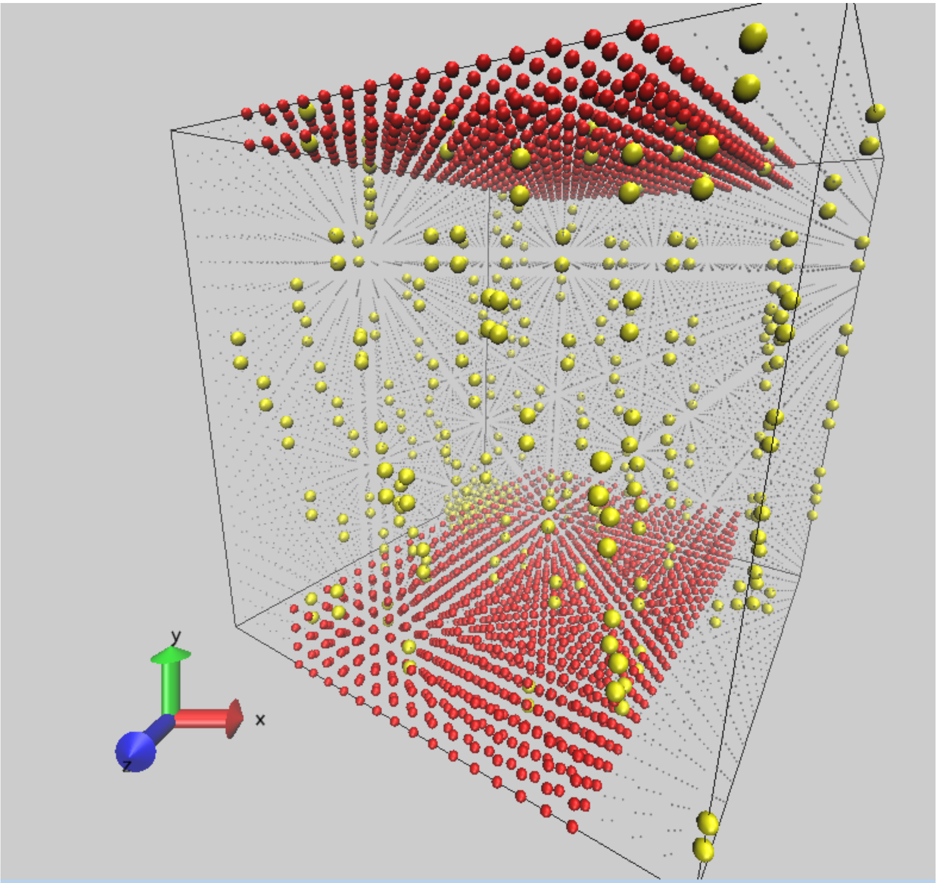
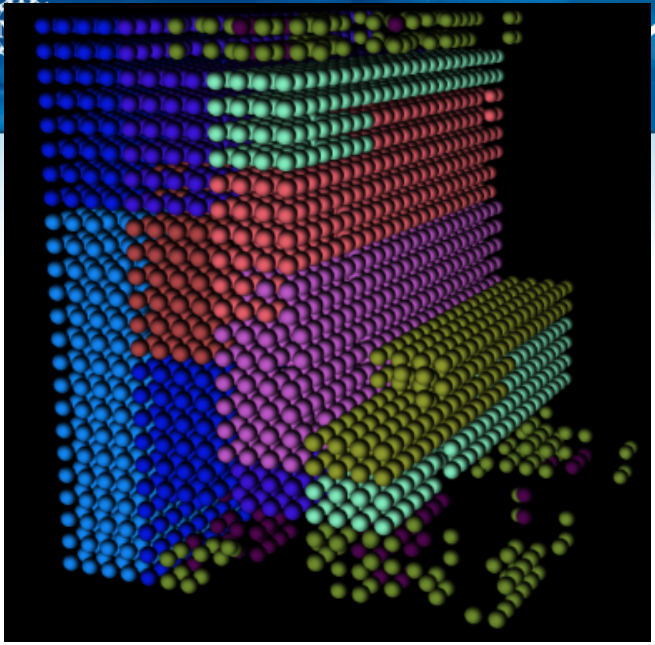


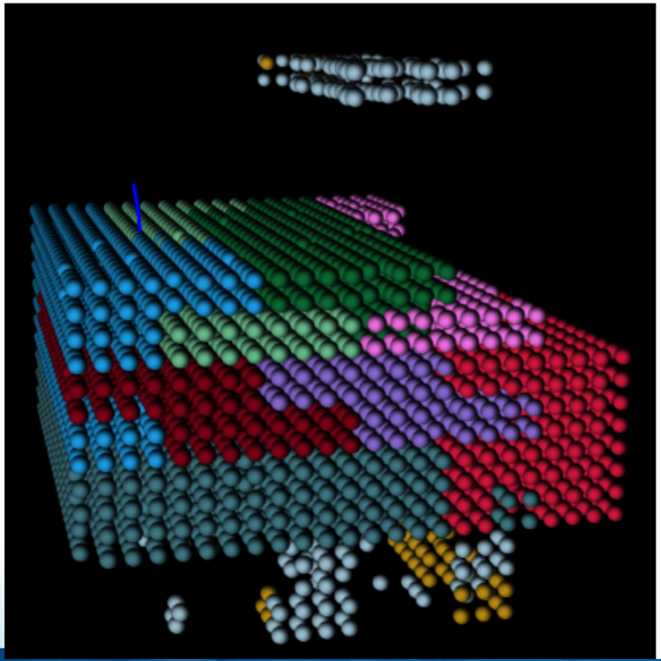
Image credit: VMD

# While waiting for TAS

- Changed default node ordering to favor XZ slabs; improving aggregate interconnect bandwidth and location.
- Workload of MILC, NWCHEM, PSDNS ChaNGa, NAMD, WRF, CESM, DNS_distuf showed average improvements in runtime of 15% to 25%.
- Change does not address job-job interaction.



before



after

- Experimented with pre-defined moab features (explicit node lists) and nodesets of these features.
- Worked well for some teams to improve performance and limit job-job interference.
- Impacted job throughput (having to wait longer for specific sets of nodes).
- Responsiveness of moab adversely affected.

# Impact of topology aware scheduling

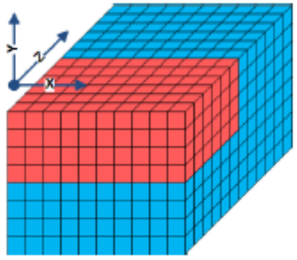
- Important to scientists
  - Reduction in time to solution
  - Reduction of run-to-run variation
  - Get science done
- Important to the project and funder
  - Get Science done
  - System utilization

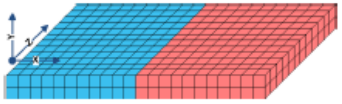
# How to interact with TAS

- Topology aware user specifications
    - #PBS –l geometry=X×Y×Z with some wild cards
    - Application communication characteristics:
        - #PBS –l comm={high|low}[:{high|low}][:{global|local}]
        - “low” or “high” communication intensity.
            - bi-section bandwidth consideration.
        - “low” of “high” communication sensitivity.
            - allow for fragmented node allocations.
        - “global” or “local” as the dominant communication pattern.
    - Cost function for waiting for shape.

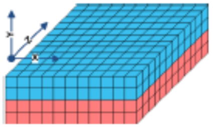
# Workload Tests

- Initial tests limited to allocate convex shapes to lessen internode communication interference on other jobs (dimension ordered routing).
- The scheduler was able to try different rectangular shapes weighted by aggregate bandwidth.

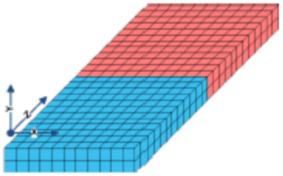




24×2×12



12×4×12



12×2×24

Image credit: Adaptive

# Workload Test

- Synthetic workload composed of several applications
  - MILC, PSDNS, NAMD, NWCHEM, ChaNGa, QMCPACK, DNS_distuf, WRF, SpecFEM3D_globe.
  - Represents a broad range of communication patterns.
  - Numerous representative node counts and scaled run times based on actual Blue Waters production logs.
  - Initial conditions set by stub jobs.
- 1544 jobs (XE and XK) run in two hour window
- Good scheduler responsiveness
- Good utilization

- Top 10 jobs shown.
- XZ slabs favored.
- Some jobs specified X×Y×Z.

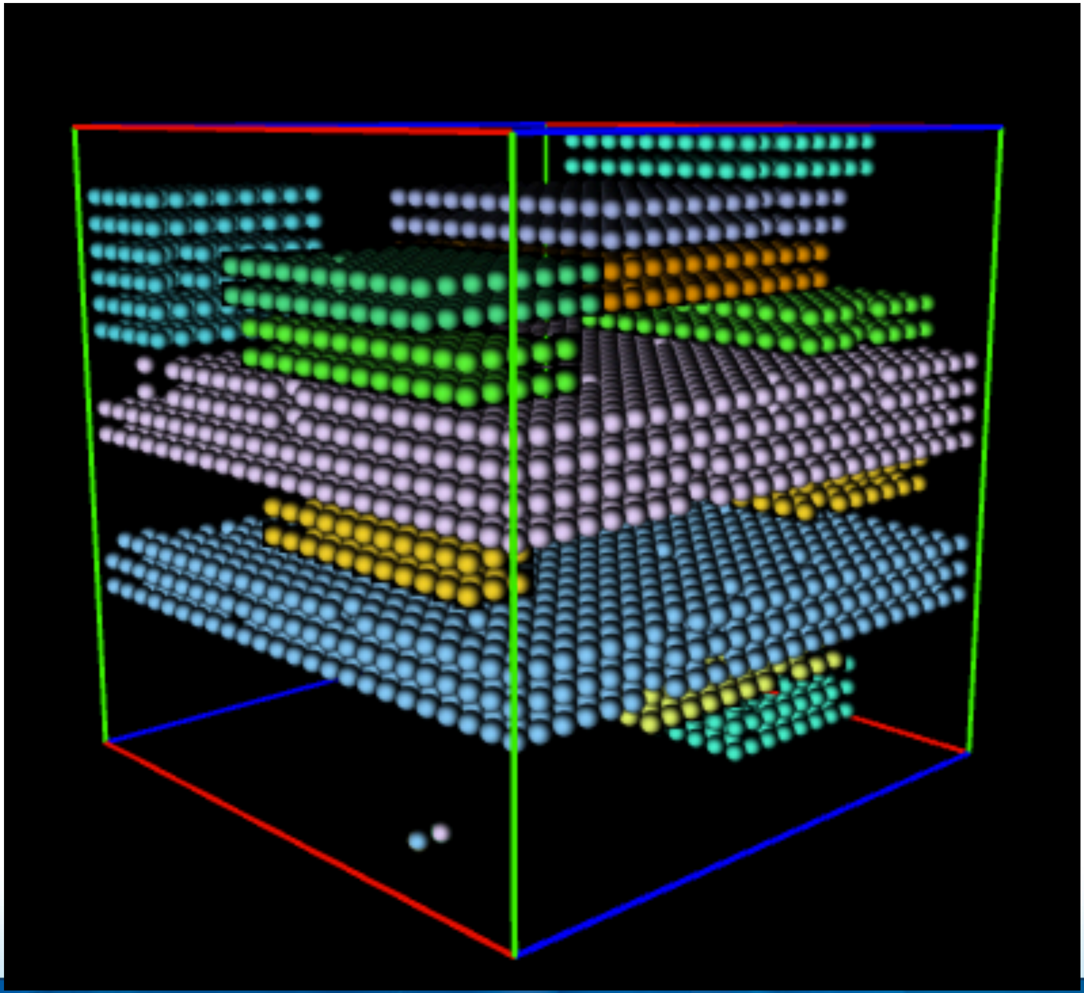
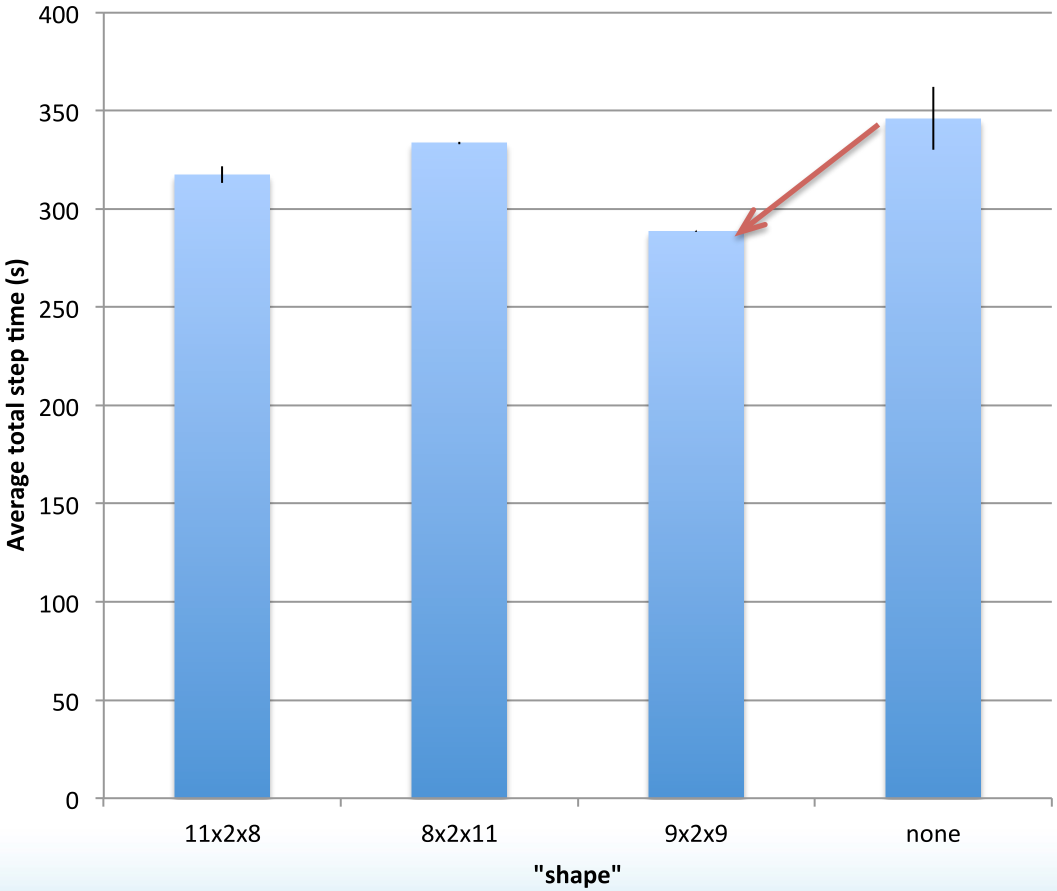


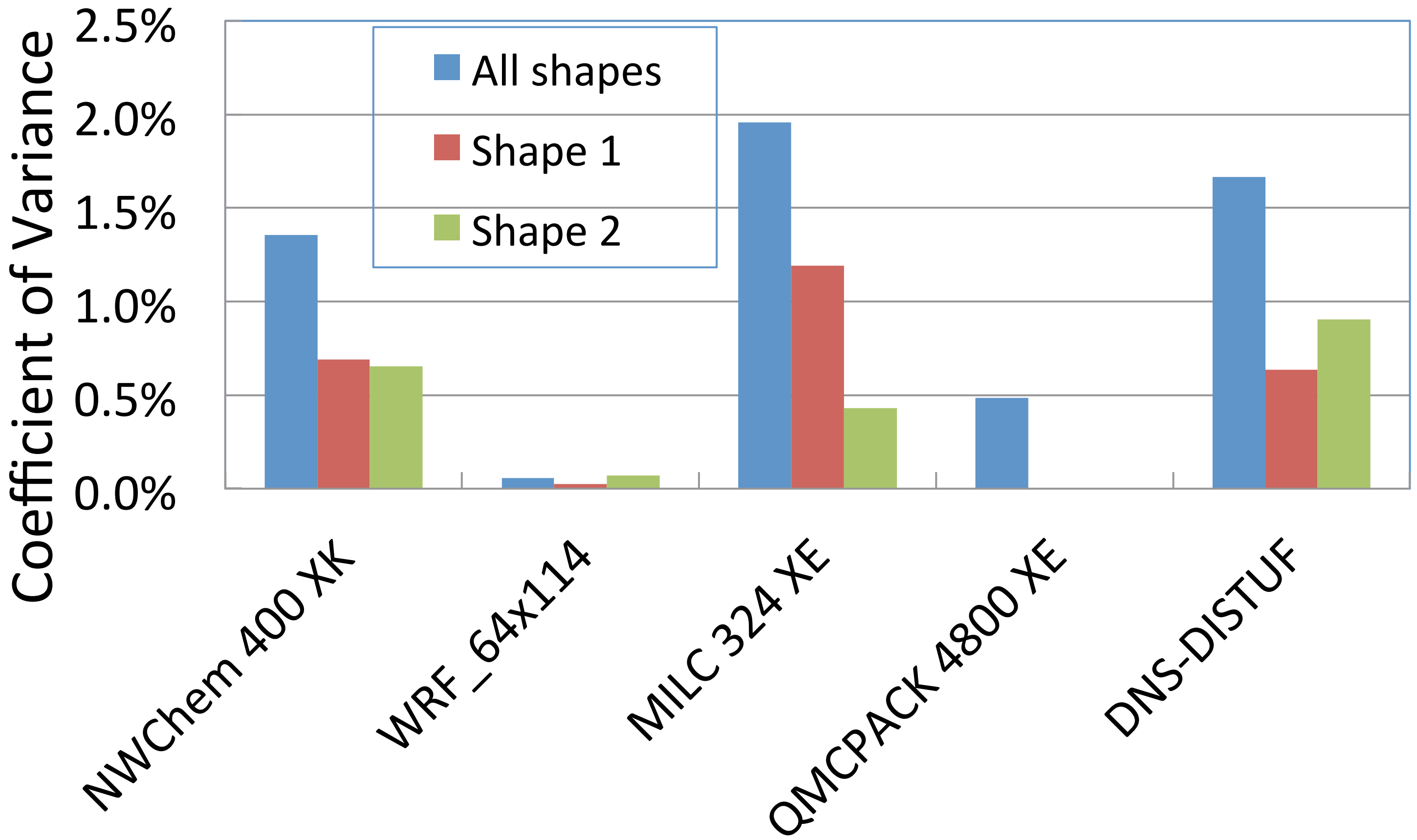
Image credit: Dave Semeraro

# Preliminary Workload Test Results

- 324 nodes - MILC
- 3 shapes used in workload testing.
- “none” collected in batch
- 17% reduction in average runtime
- 10x reduction in CoV.
- Larger impact at larger scales.



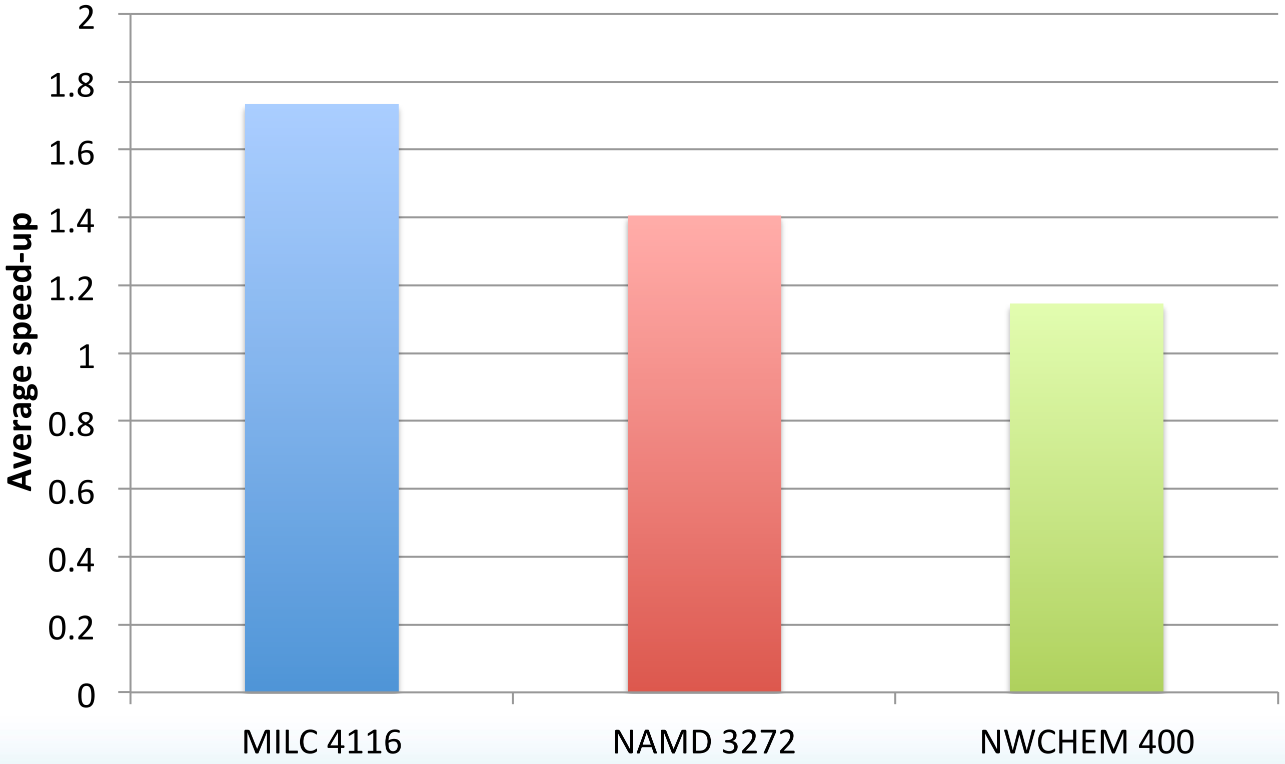
# Preliminary Workload Test Results



- Worst  Application run time CoV is less than 2%
- Worst ‘Per Shape’ Application CoV is less than 1.25%

# Preliminary Workload Test Results

- Speed-up from using topology aware scheduling



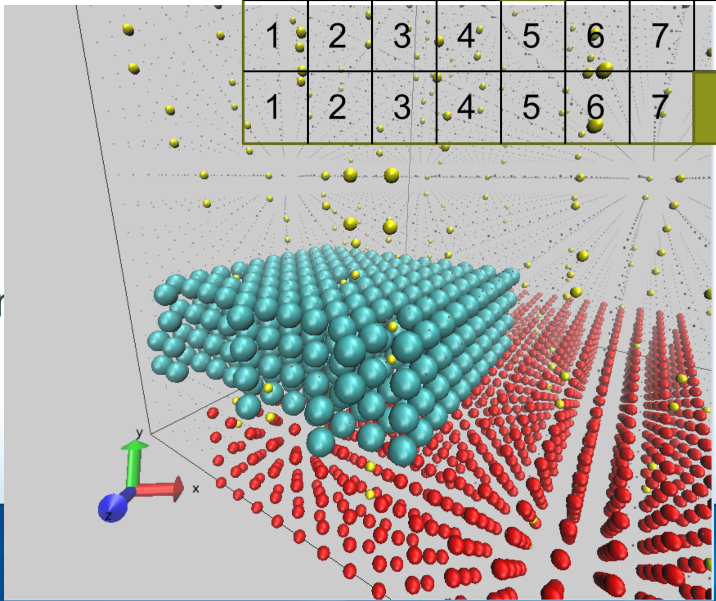
# Node Selection and Task Layout

- Most codes will need to consider MPI rank ordering to take full advantage of nodes provided by topology aware scheduler.
- Topoaware: Provides task mapping for 2, 3, & 4D Cartesian grid virtual topologies.
  - Developed by Bob Fiedler, Cray.
  - In each z-pencil, extends set of selected geminis along z if needed to skip unavailable nodes
  - Determines multiple valid layouts and evaluates layout quality
  - Allows unbalanced layouts
    - Nodes on prism boundaries may have fewer tasks
    - Enables more good layouts for more virtual topology sizes
  - Scheduler ensures allocation has desired gemir count in each z-pencil

z

x

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | ■ |
| ■ | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | ■ | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 1 | 2 | ■ | 3 | 4 | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | ■ | 5 | 6 | 7 | 8 |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | ■ | 8 |



# Topaware tests: Halo exchange

- Virtual topology: 32x32x32
- 10x improvement possible.
- Hop count not the only story.
- Reduction in congestion and improved bandwidth important.
- grid_order provided by Cray to order communication between nearest neighbors in a grid.

| Placement | Iter time (ms) | Max hops |
|---|---:|---:|
| Default 8x8x8 | 11.315 | 9 |
| Grid_order 8x8x8 | 7.722 | 16 |
| Topaware 8x8x8 | 2.771 | 2 |
| Topaware 11x6x11 (unbalanced) | 1.287 | 2 |
| Topaware 11x8x8 (unbalanced) | 1.147 | 2 |
| Topaware 8x8x11 (unbalanced) | 1.214 | 2 |
| Topaware 11x7x8 (unbalanced) | 1.782 | 2 |
| Topaware 8x7x11 (unbalanced) | 1.737 | 2 |
| Topaware 11x8x7 (unbalanced) | 1.580 | 2 |
| Topaware 7x8x11 (unbalanced) | 1.690 | 2 |

# Topaware tests: MILC

- MILC
  - Virtual topology 21x2x21x24
  - 1764 nodes, 12 tasks each
  - 21x2x21 geminis
  - 2.2x faster with Topaware than with grid_order –c 2,2,2,2 on same nodes
  - grid_order can provide 2x over not using grid_order.
  - See Topology Consideration talk at December 2013 workshop.

| Placement | Run Time (10 iterations) |
|---|---|
| Grid_order | 254.0 |
| Topaware | 116.4 |

# Conclusions and Next Steps

- From initial tests with topology aware scheduling we see
  - improvements in overall performance and run-to-run variability
  - promising utilization numbers
- Further tests coming and then deployment.

- What we like to see on Blue Waters …

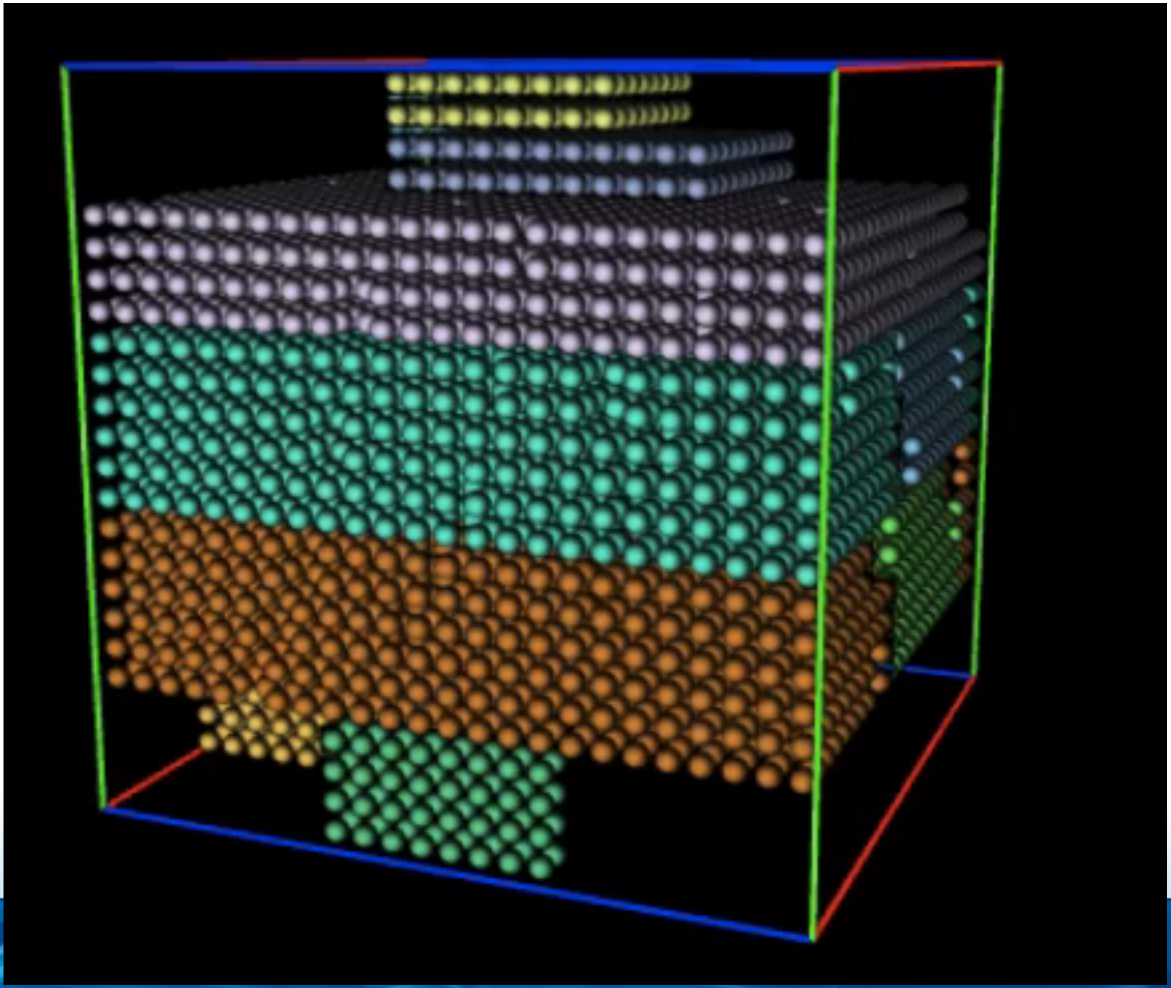


Image credit: Dave Semeraro