Simulation-Time Ultra Scale Visualization

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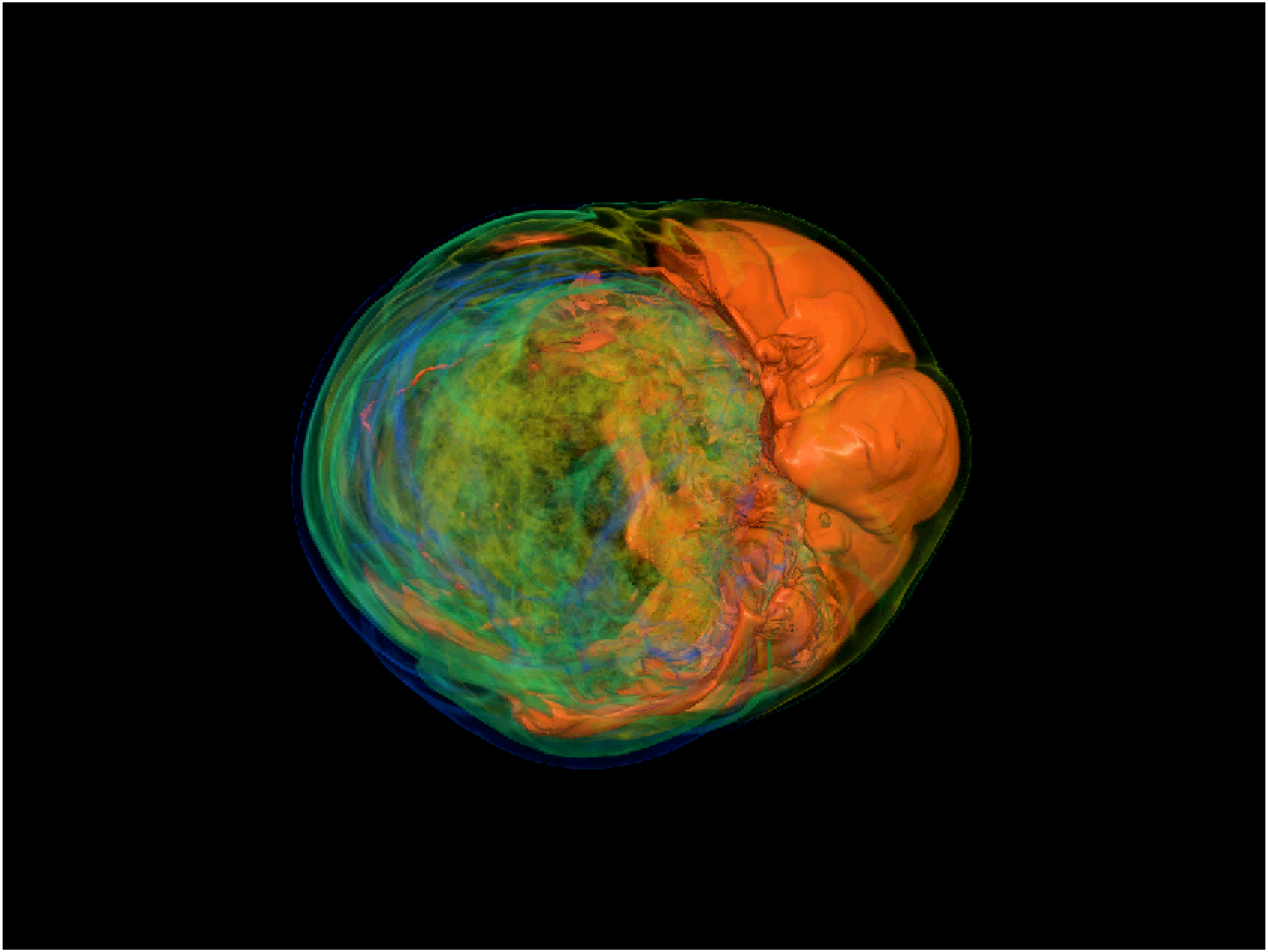
SC06 POWERFUL BEYOND IMAGINATION

NSF

SciDAC Scientific Discovery through Advanced Computing

Outline

- Simulation-Time Visualization
- Parallel Rendering Techniques
- Workshop closing remarks



Rendering Time-Varying Data

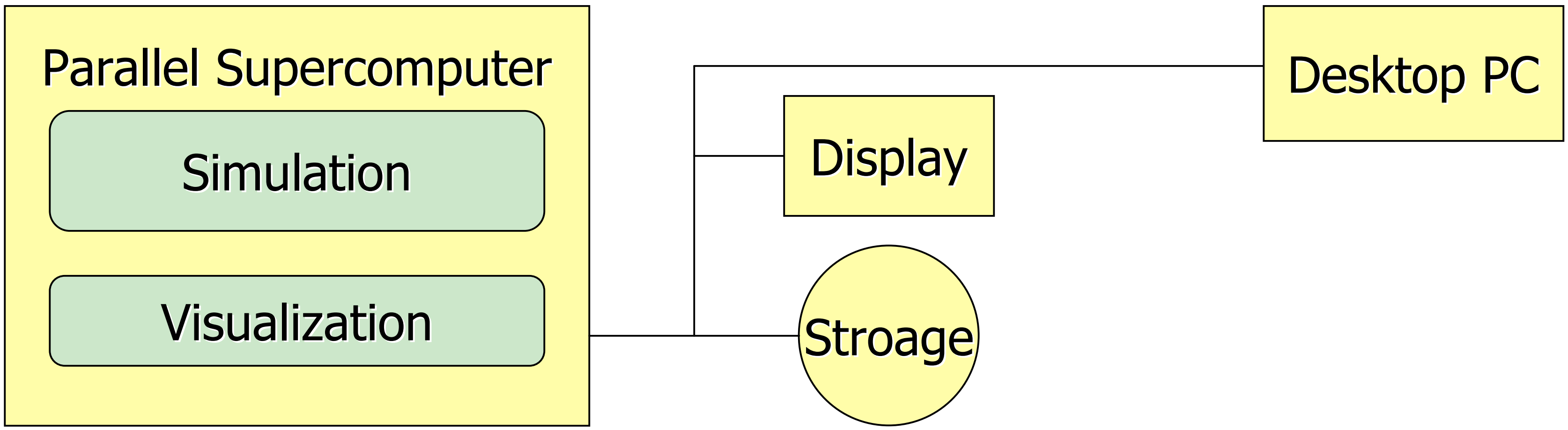
- Hundreds to thousands of time steps
- Hundreds of MB to hundreds of GB per time step
- Terabyes now and petabyte is upcoming

- Temporal browsing using a desktop PC
  - 512^3 or smaller volume data
- Temporal browsing using a cluster or massively parallel supercomputer
  - Data distribution
  - Capacity and processing power
  - Scalability

Techniques

- Data Reduction
  - Spatial and temporal domain encoding
  - multi-resolution representations
  - feature extraction & tracking
- Streaming
- Parallel pipelined rendering
- Parallel I/O
- Simulation-time visualization

Simulation-Time Visualization



- Process data while it is being generated
- Prepare (and reduce) data for visualization and analysis
- All the data are available!
- Transfer the transformed/packed data or images
- Monitor simulation
- Steer visualization and simulation
- But …

Simulation-Time Visualization

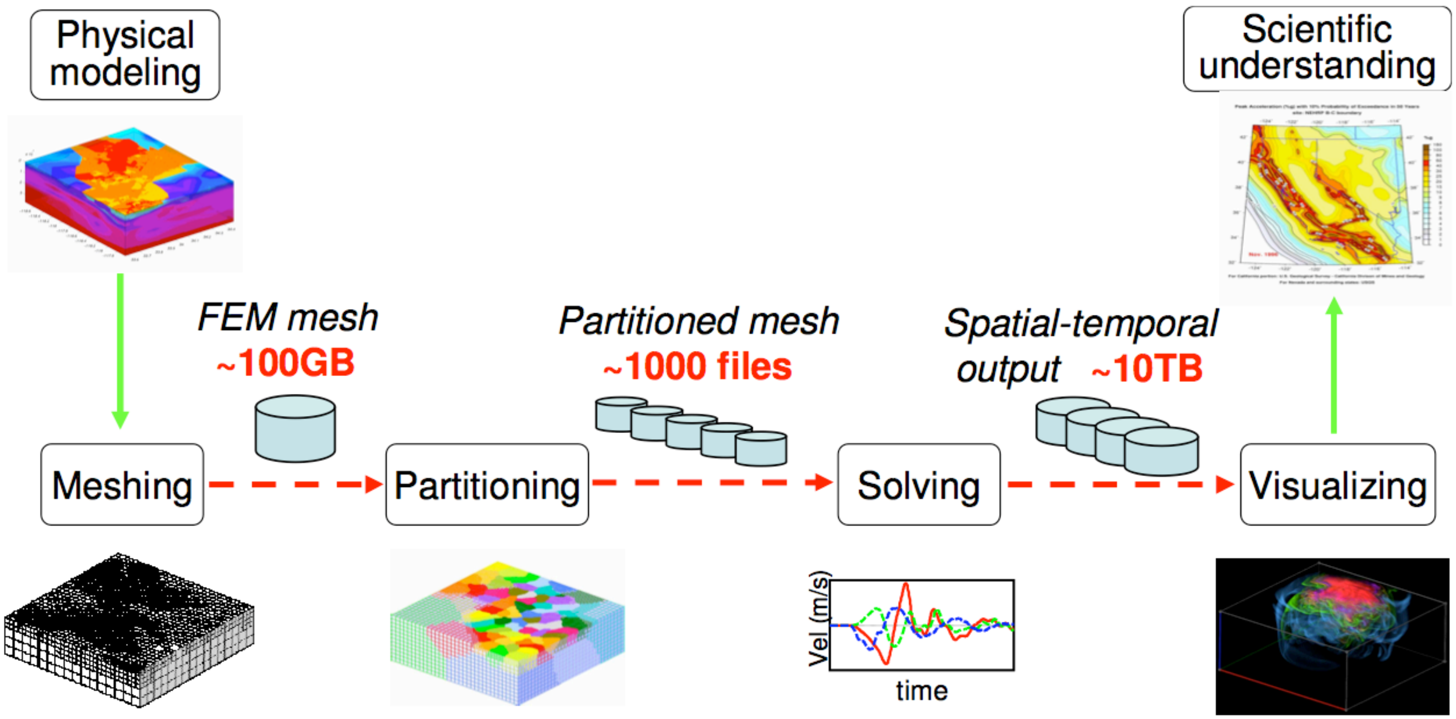
- Supercomputer time is precious
  - The cost of visualization calculations
  - The scalability of the visualization code
- Memory space is limited
  - The storage overhead of visualization calculations
- Domain decomposition and data organization are optimized for the simulation code

- The simulation code must talk to the visualization code
- What to save is not known a priori
  - Exploratory visualization?
  - Accumulated knowledge in routine study
  - Machine learning

Simulation-time visualization is the ultimate solution to the ultra-scale data analysis problem

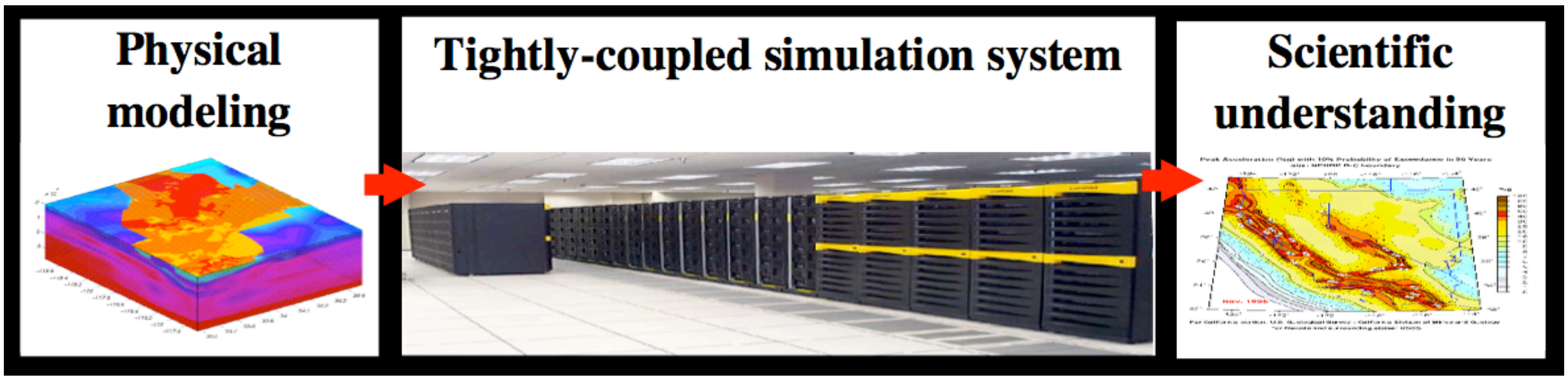
- All the data are there
- We can reduce data early in the scientific discovery process

Earthquake Ground Motion Simulation and Visualization



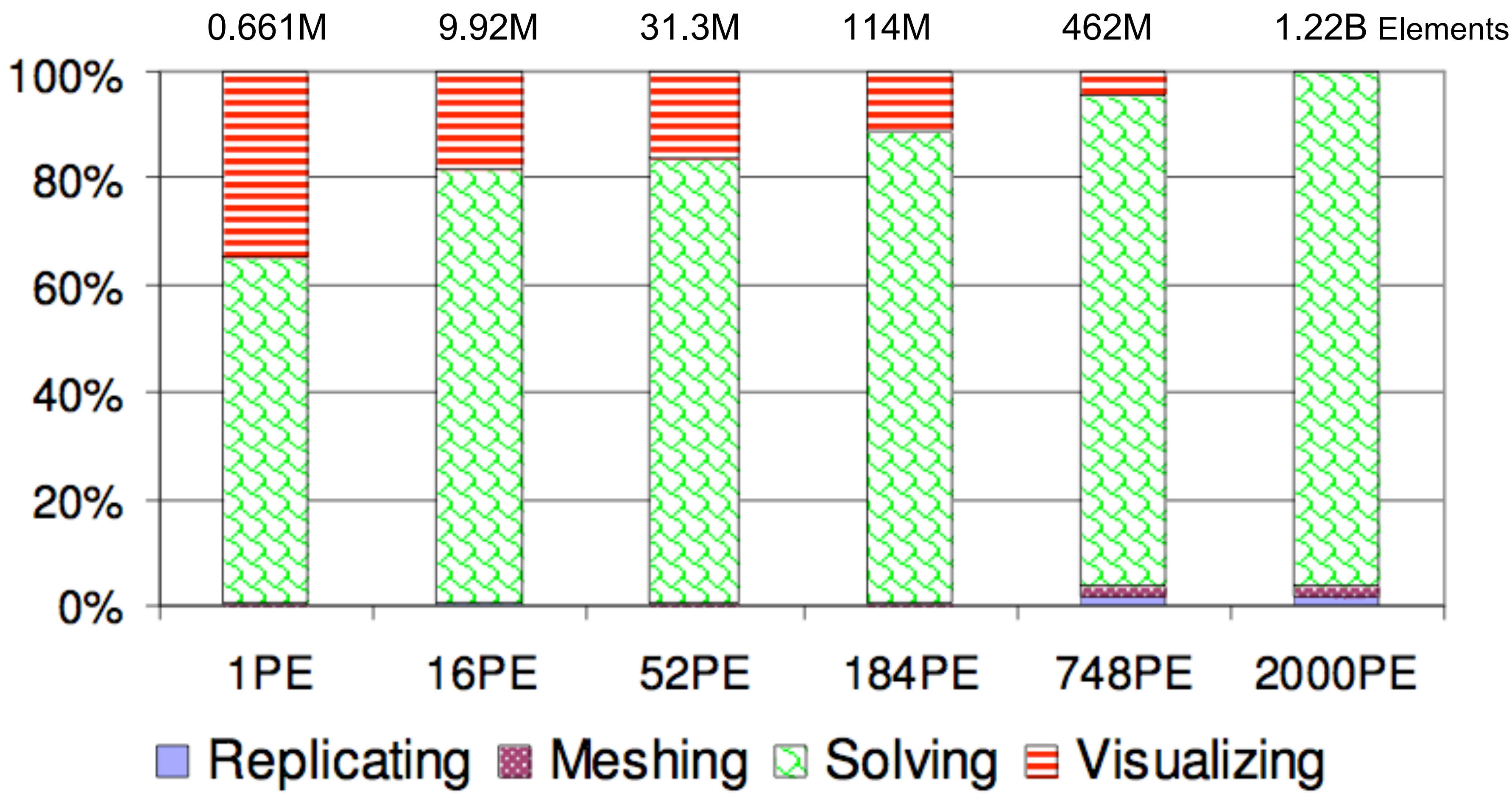
Work done with Tiankai Tu, Jacobo Bielak, Omar Ghattas, and Dave O'Hallaron

End-to-End Tightly Coupled

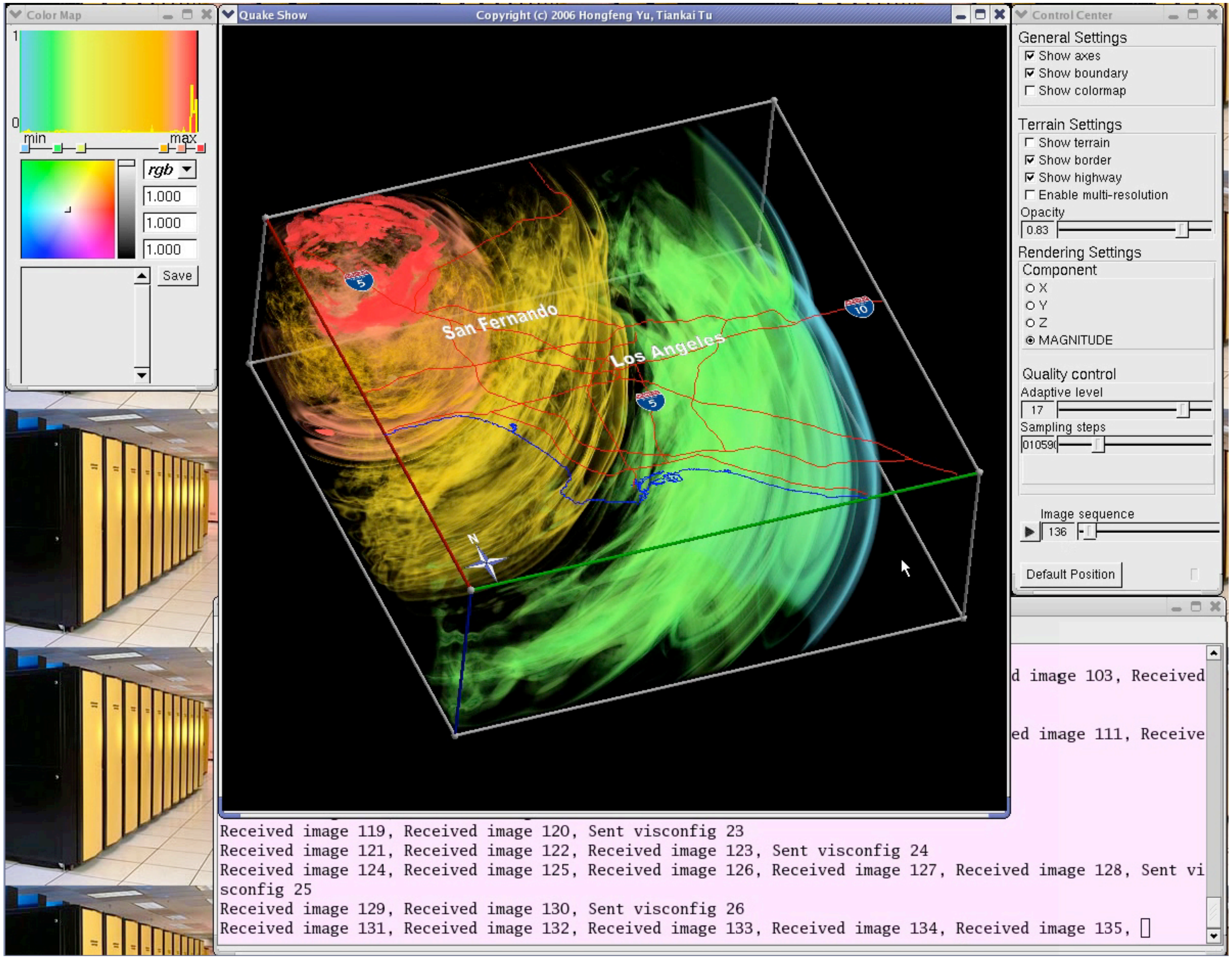


- The main objective is to eliminate scalability bottlenecks
- Run simulation pipelines end-to-end in parallel
- Execute all components on the same processors
- Partitioning favors the solver
- Sustained flops increases as the problem size increases

Simulation-Time Visualization



Simulation-Time Visualization



Presentations

1. **Technical paper**

   From Mesh Generation to Scientific Visualization: An End-to-End Approach to Parallel Supercomputing

   2:30pm - 3pm Scalable Systems Software Session

   Tuesday

2. **HPC Analytics Challenge Finalist**

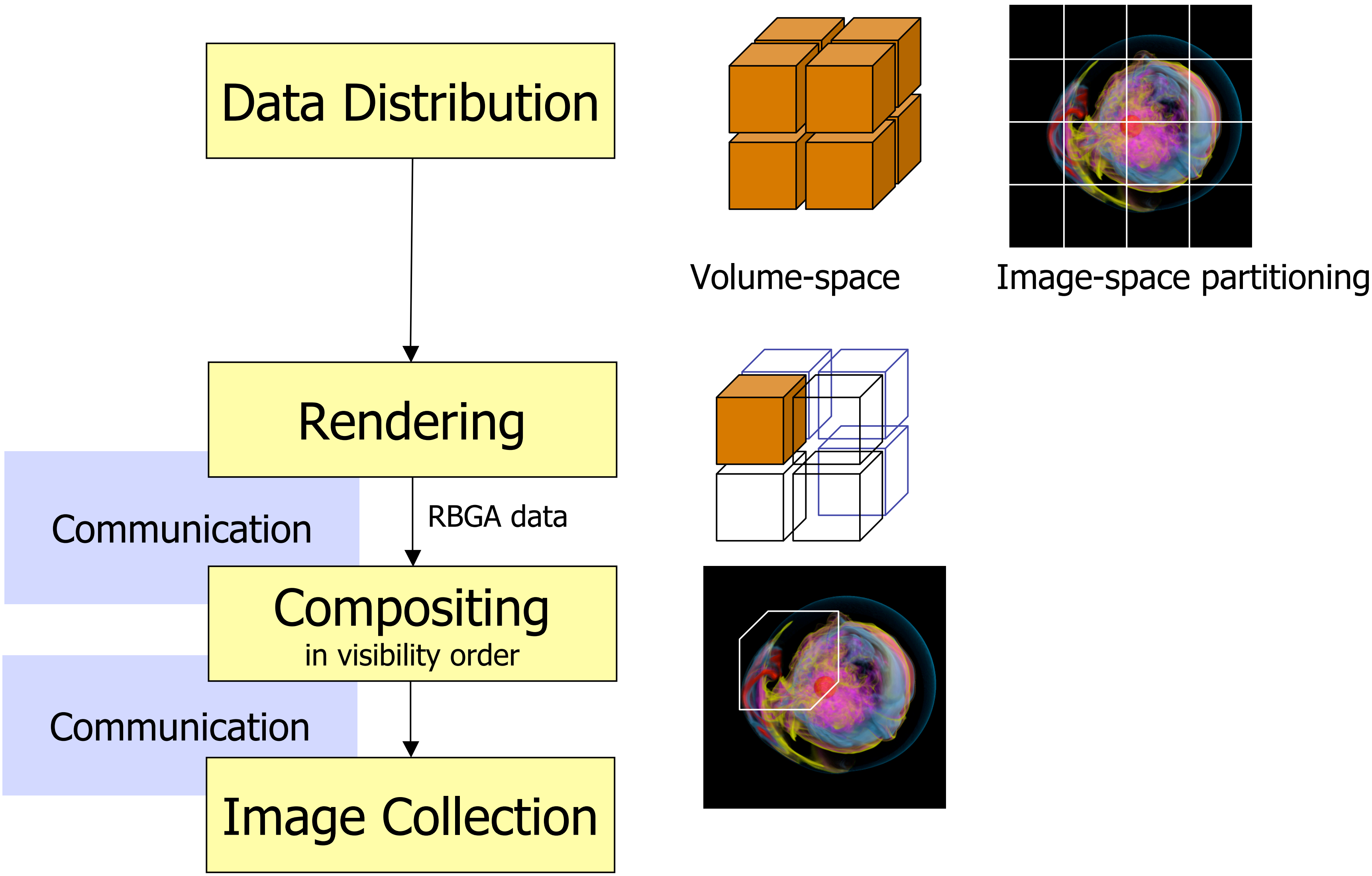
   Remote Runtime Steering of Integrated Terascale Simulation and Visualization

   1:30pm - 2pm Analytics Challenge

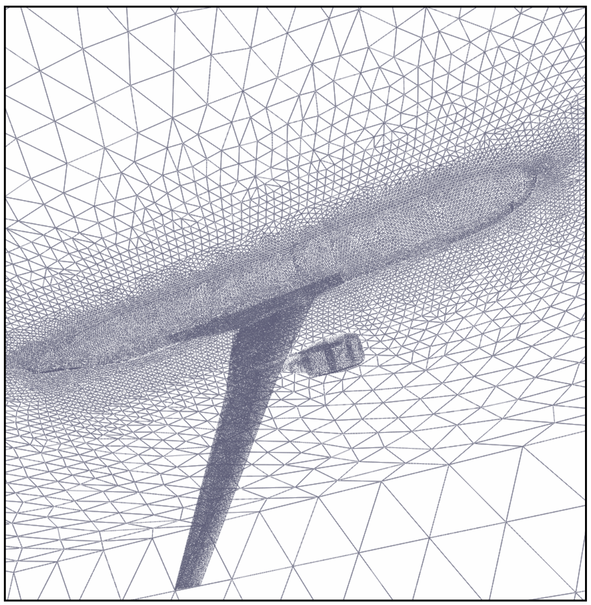
   Tuesday

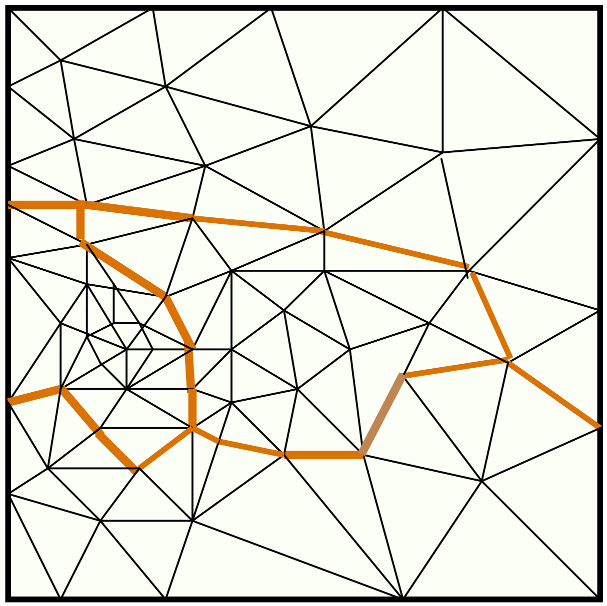
Parallel Rendering

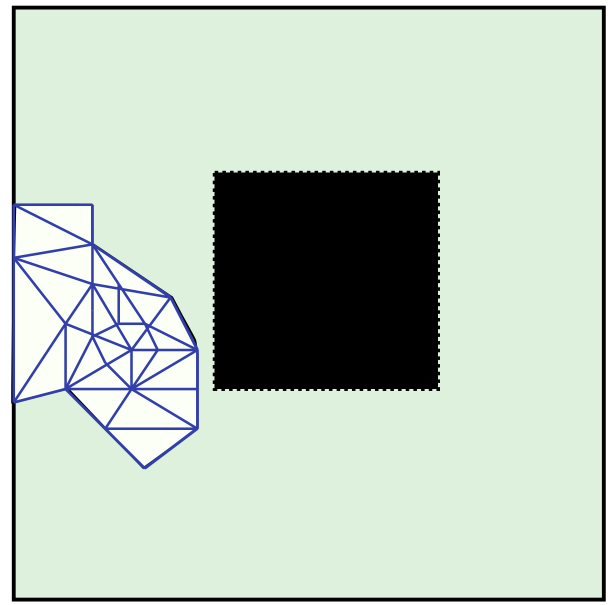
Parallel Volume Rendering



Load Balancing Problem





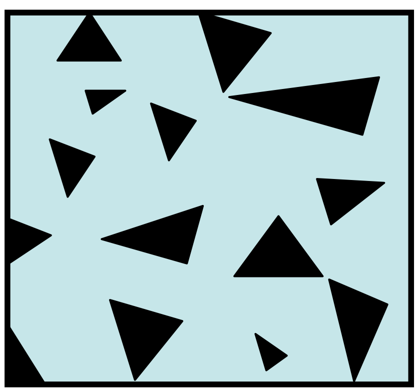


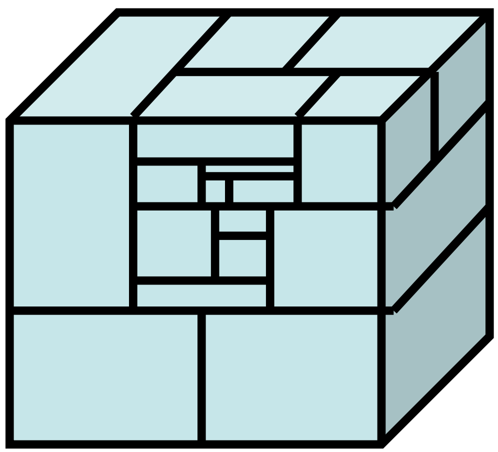
Parallel Rendering of Large Unstructured Grid Data

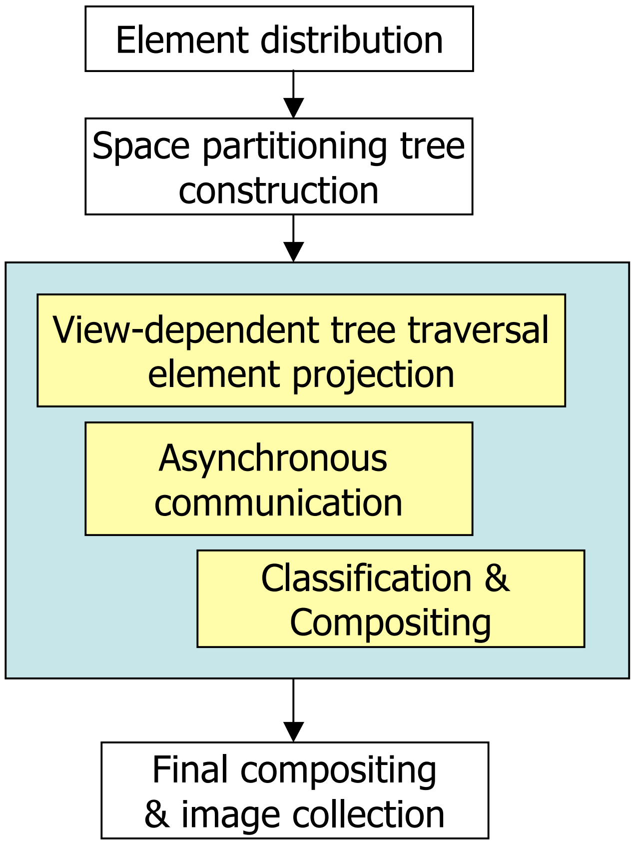
1. Domain decomposition according to a static load balancing scheme used by the renderer
   - Can load be balanced?
   - PRS 1997
2. Domain decomposition used by the simulation
   - Load balancing?
   - PGV 2006

Scalable Rendering Design I

- Random distribution of elements
- 3D space partition tree guiding the rendering
- Early compositing for each projected region
- low sorting cost and memory requirement
- Overlapping rendering and communication
- 75-90% efficiency using up to 512 processors
- Rendering 18 million cells

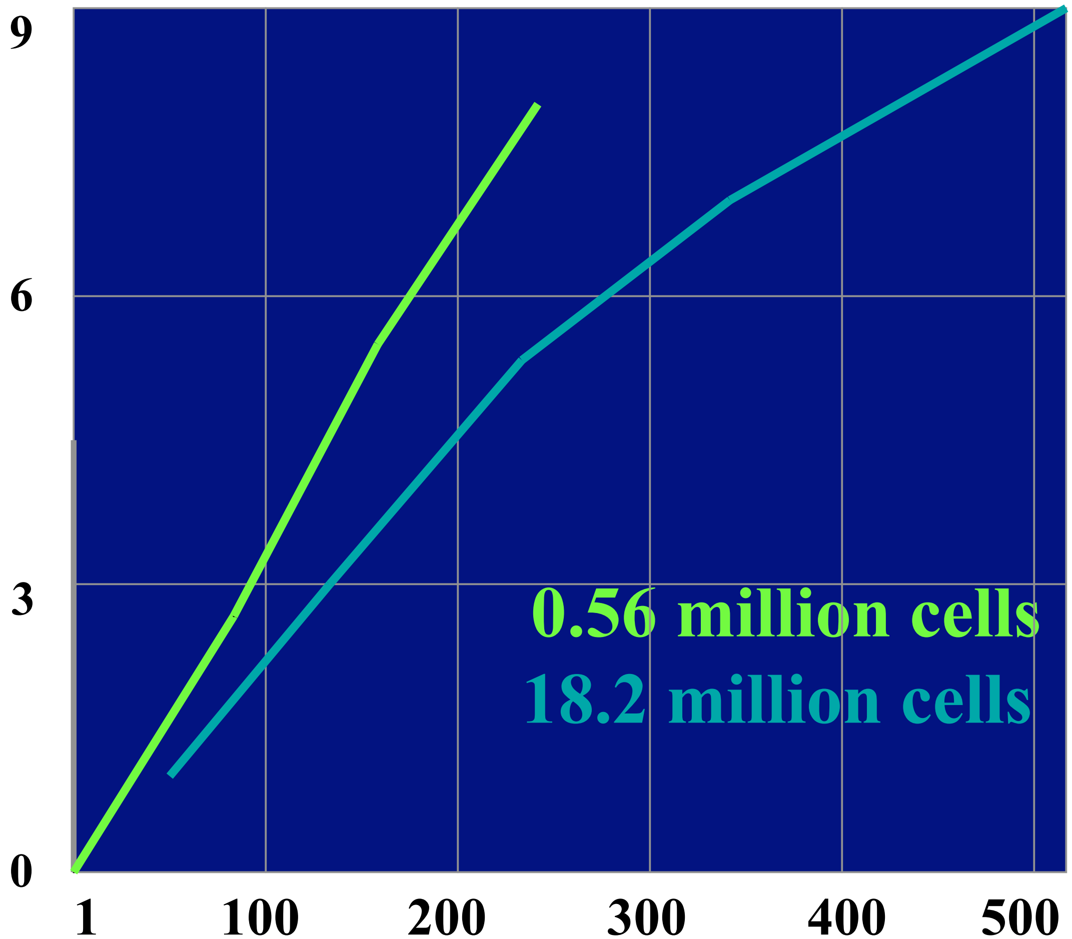


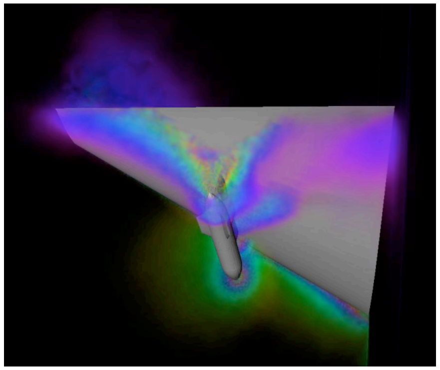


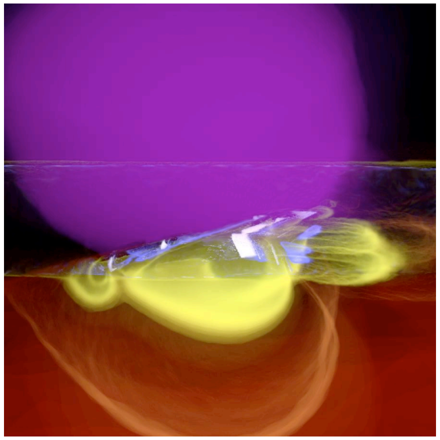


Test Results

Cray/SGI T3E

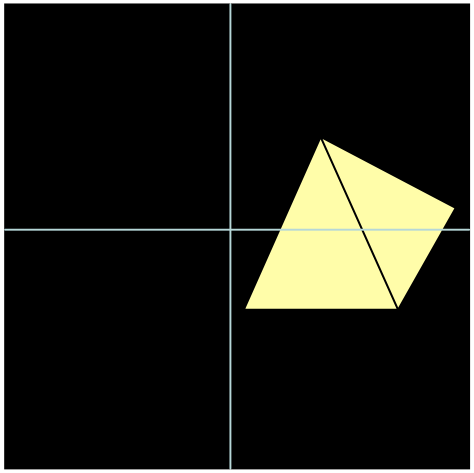


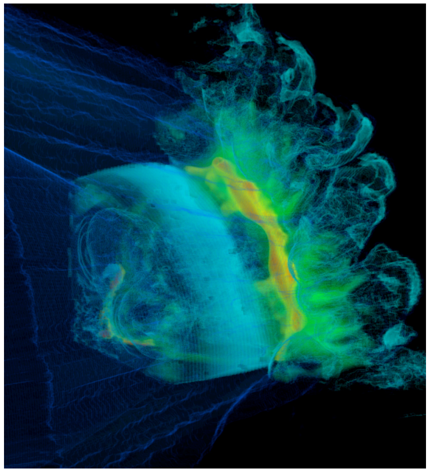




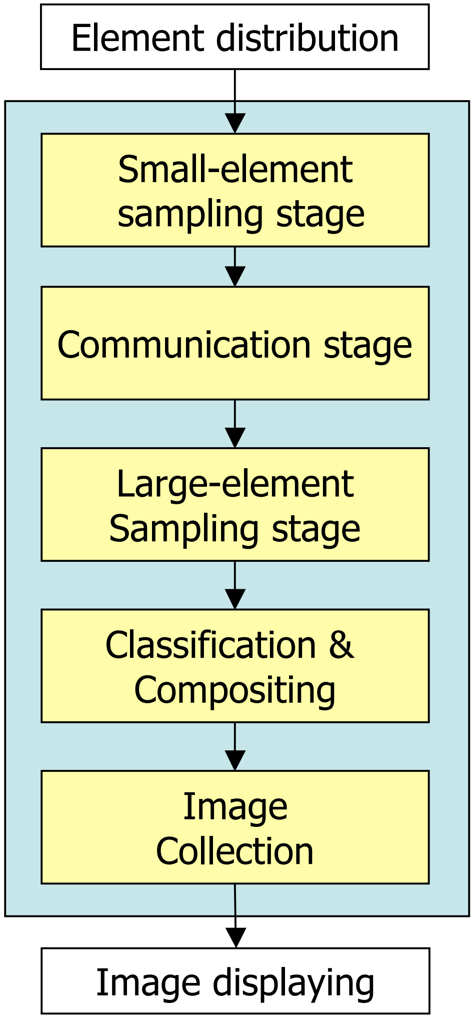
Scalable Rendering Design II

- The same domain decomposition used by the simulation code
- **Rendering of large elements is deferred**
- Minimal communication cost
- Rendering of large elements are redistributed among processors according to the image space partitioning.
- 80-95% efficiency using up to 400 processors
- rendering up to 27 billion elements

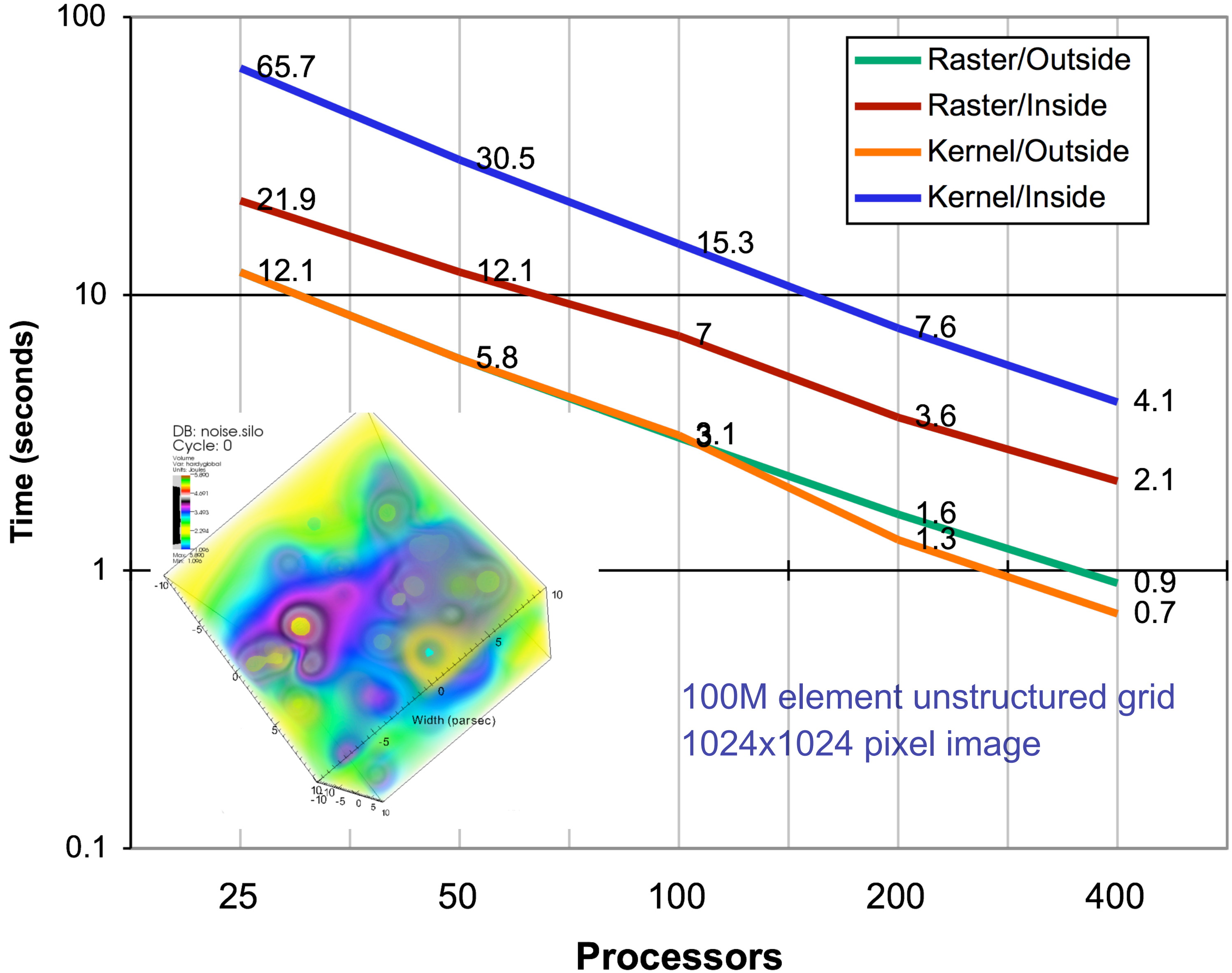




Blast wave over a reinforced concrete



Scalability Study



Summary

- Terascale visualization capabilities have been developed but are not generally accessible
- Petascale computing is coming!
- Parallel visualization must address every stage of the visualization pipeline
- Simulation-time visualization is feasible and attractive
- GPU computing creates both new opportunities and new challenges
- The Institute for Ultra Scale Visualization will lead the effort to create technologies meeting the next generation visualization challenges

Institute for Ultra Scale Visualization

Research

- Time-Varying Data Visualization
- Multivariate Data Visualization
- Irregular/Unstructured Grid Data Visualization

  (J. Huang, K.-L. Ma, N. Max, H.-W. Shen)
- Parallel Rendering Framework and API
- Parallel I/O Support for Visualization
- Multi-GPU Support for Visualization
- ParaView Extensions for Ultra Scale Visualization

  (G. Humphreys, K. Moreland, J. Owens, R. Ross)

Education

http://IUSV.org ma@cs.ucdavis.edu

Workshop Program

• Opening	08:10 - 08:30am
• State of the Art	08:30 - 10:00am
• Coffee Break	10:00-10:30am
• Case Studies	10:30-12:00pm
• Lunch Break	12:00-01:30pm
• The Future I	01:30-03:00pm
• Coffee Break	03:00-03:30pm
• The Future II	03:30-05:00pm

State of the Art

- *VisIt Visualization Tool*, Hank Childs, Lawrence Livermore National Laboratory
- *ParaView - Parallel Visualization Application*, Kenneth Moreland, Sandia National Laboratories
- *VAPOR*, John Clyne, National Center for Atmospheric Research

Case Studies

- *Leadership End-to-End Computing*, Scott Klasky, Oak Ridge National Laboratory
- *Petascale Visualization on BGL,* Michael Papka, Argonne National Laboratory
- *Quantitative and Comparative Visualization Applied to Cosmological Simulations*, James Ahrens, Los Alamos National Laboratory

The Future

- *Query-Driven Visualization of Large Data Sets*, Wes Bethel, Lawrence Berkeley National Laboratory
- *Large Data Visualization using Shared Distributed Resources,* Jian Huang, University of Tennessee, Knoxville
- *Navigating Large Data Scalar Volume Data*, Han-Wei Shen, Ohio State University
- *Feature Extraction and Tracking Methods*, Deborah Silver, Rutgers, the State University of New Jersey
- *Topology-Based Analysis of Large Scale Data,* Valerio Pascucci, Lawrence Livermore National Laboratory
- *Massively Parallel Visualization,* Kwan-Liu Ma, University of California at Davis

Acknowledgments

- SC06 Workshop Co-Chairs and Committee
  - Mary Thomas
  - Radha Nandkumar
- NSF ITR program
- DOE SciDAC program

Comments/Questions?

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