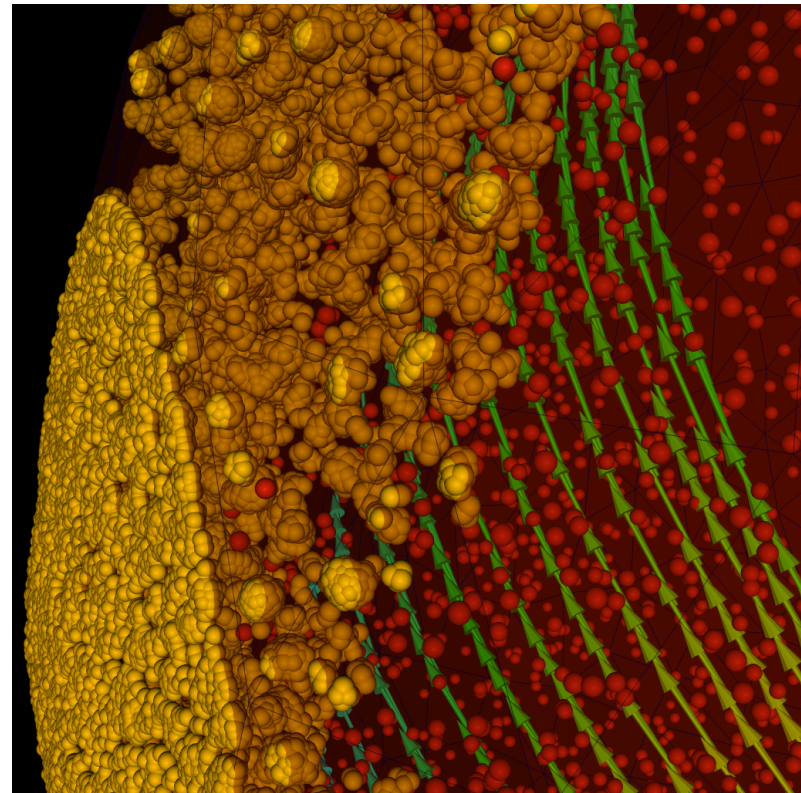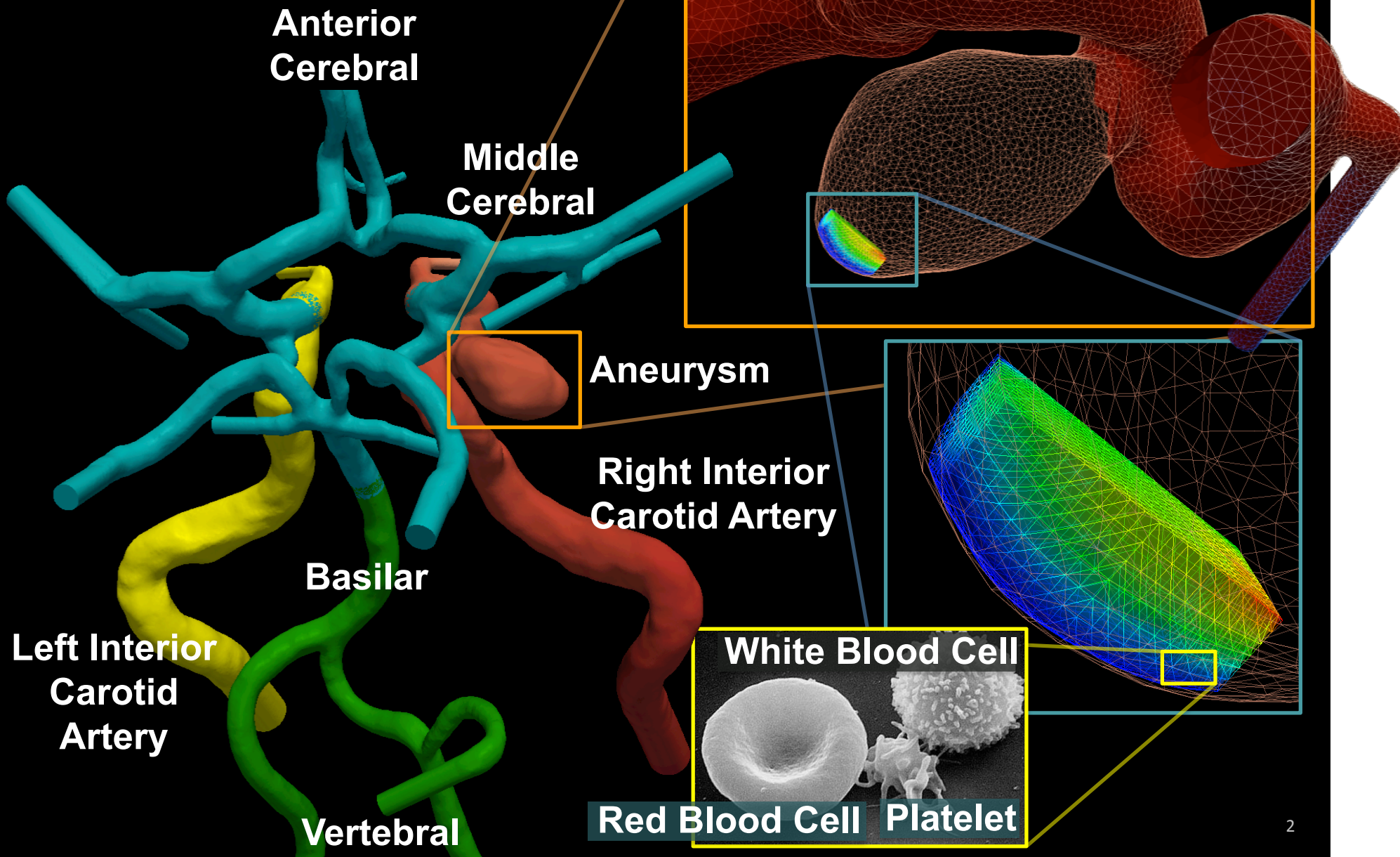# Visualization of Multiscale, Multiphysics Simulation Data: Brain Blood Flow

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Brown University
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Argonne National Laboratory

LDAV 2011
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Providence, Rhode Island

Multiscale Problem:
From O(10cm) to O(1nm)

Anterior Cerebral

Middle Cerebral

Aneurysm

Right Interior Carotid Artery

Basilar

Left Interior Carotid Artery

Vertebral

White Blood Cell

Red Blood Cell   Platelet

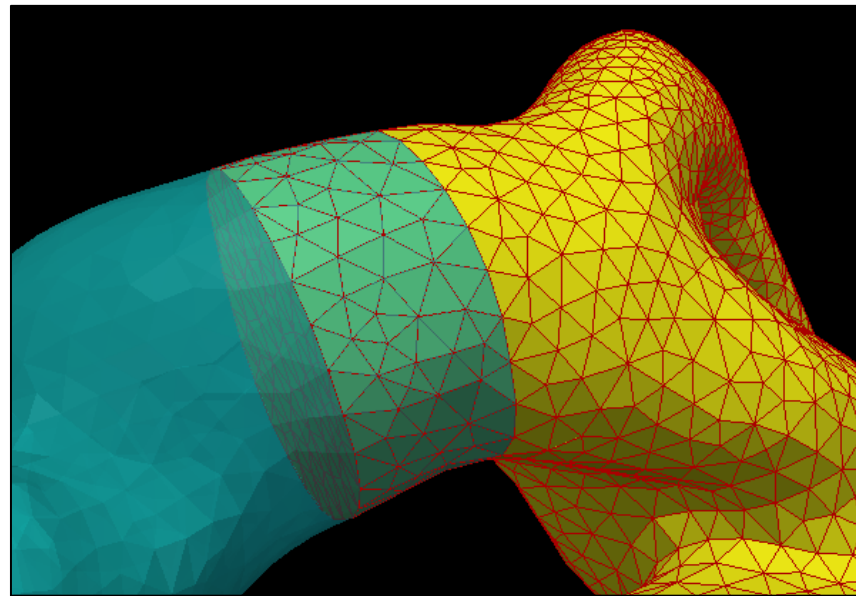# Complex Problem - Big Data

- Complex geometries from patient-specific MRI data

- ~450K spectral elements

- 350+ time steps

- 800 Million particles

- 32 Racks of BG/P (132K processors)

- SC11 Paper: Gordon Bell Finalist
  - L. Grinberg, V. Morozov, D. A. Fedosov, J. A. Insley, M. E. Papka, K. Kumar, and G. E. Karniadakis. *A new computational paradigm in multi- scale simulations: Application to brain blood flow.* In Proceedings of the 2011 ACM/IEEE International Conference for High Performance Computing, Networking, Storage and Analysis, Seattle, WA, 2011.
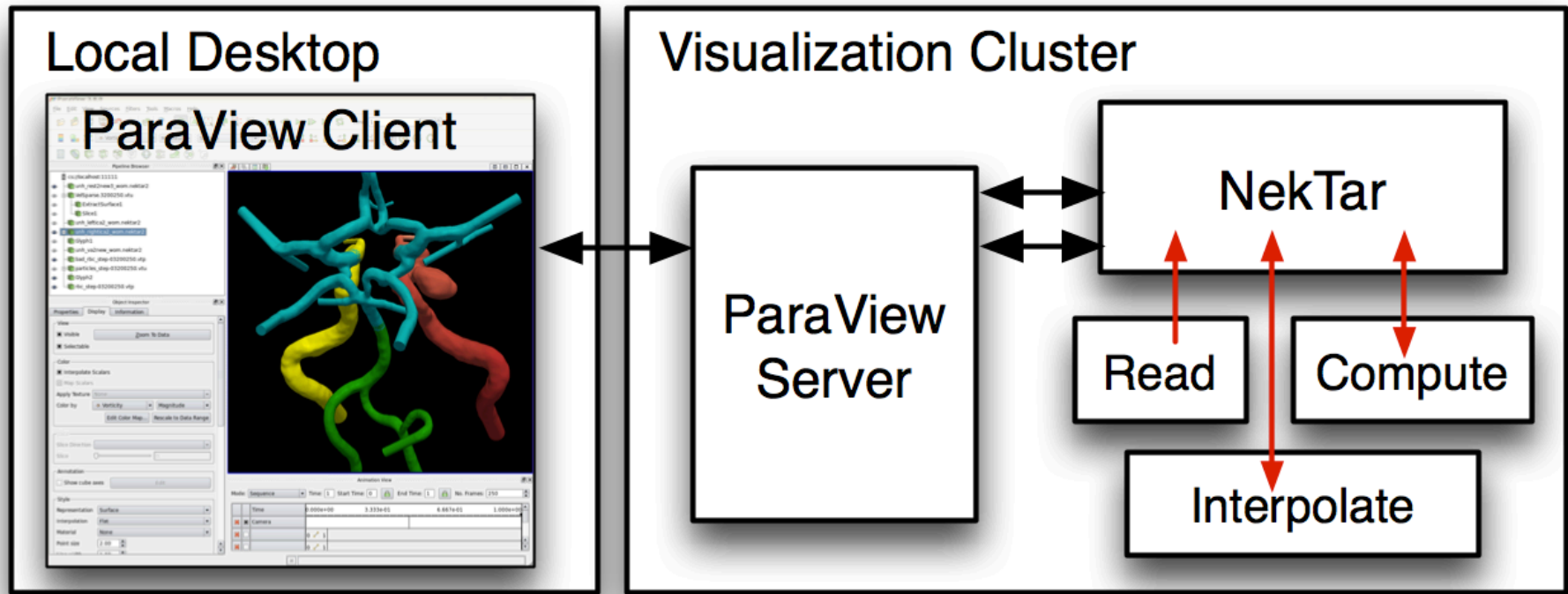
Macroscale Simulation (NekTar)

- NekTar: Spectral/hp element method (SEM)
  - Non-overlapping elements
  - Multi-patch approach
    - Domain decomposed into overlapping patches
- NekTar Data
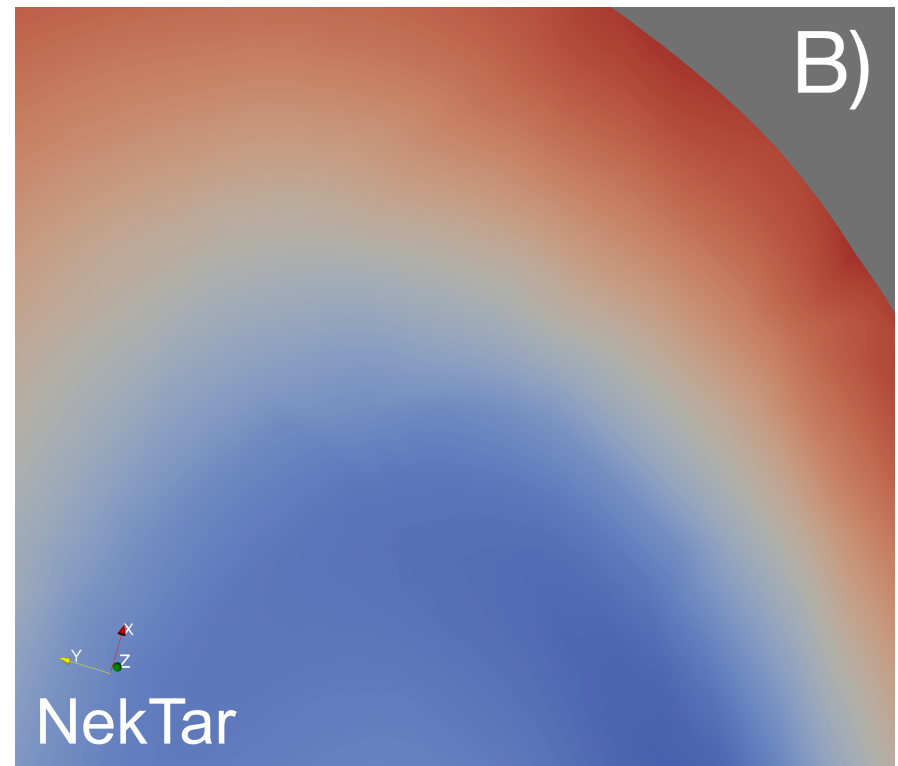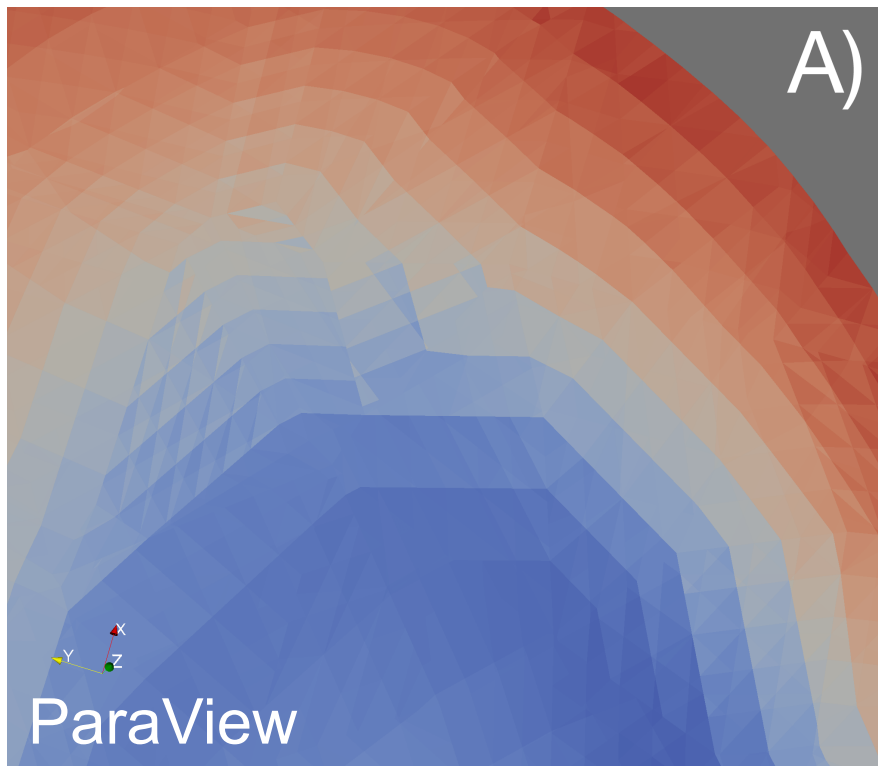 - Saved in Modal space
  - Mesh (geometry)
  - Solution data

NekTar-ParaView Coupling

- NekTar for parallel I/O and computation
- ParaView for parallel visualization and rendering

Processing High-order Spectral Elements

- Data computed with high-order spectral accuracy
  - Grid consistent with simulation resolution

A)

B)

ParaView

NekTar
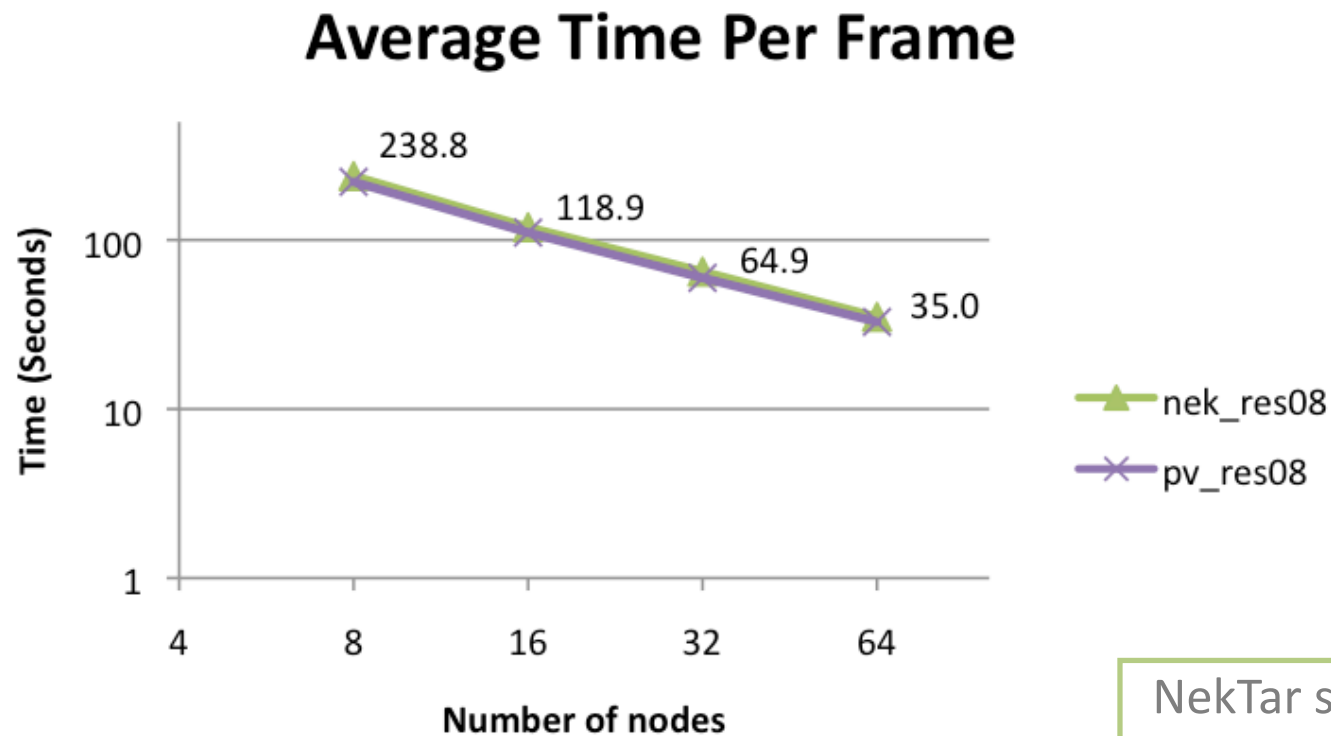
Derived Quantity: Vorticity

NekTar solution more accurate

Processing High-order Spectral Elements

- Data computed with high-order spectral accuracy
  - Grid consistent with simulation resolution
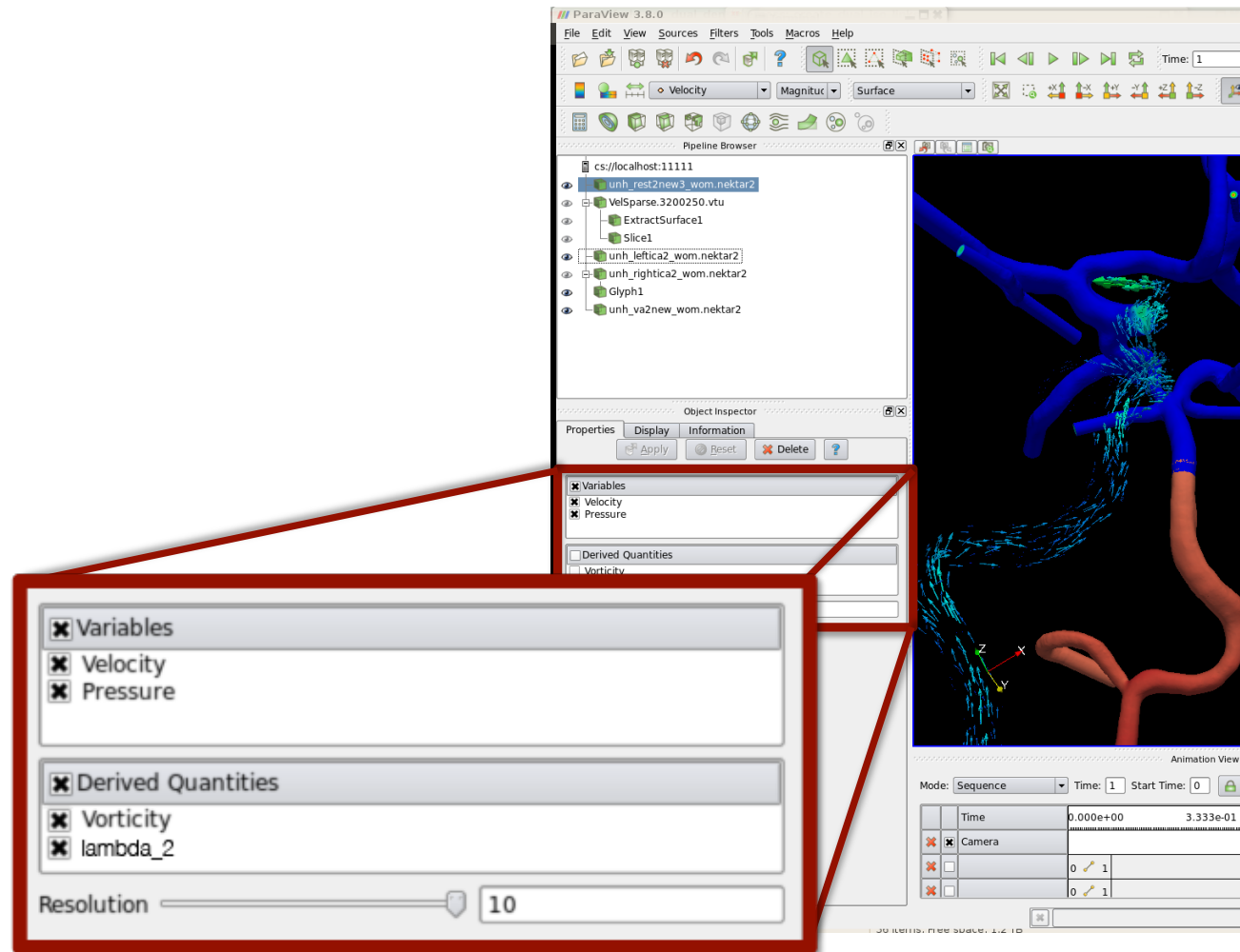- Linear strong scaling performance

Average Time Per Frame
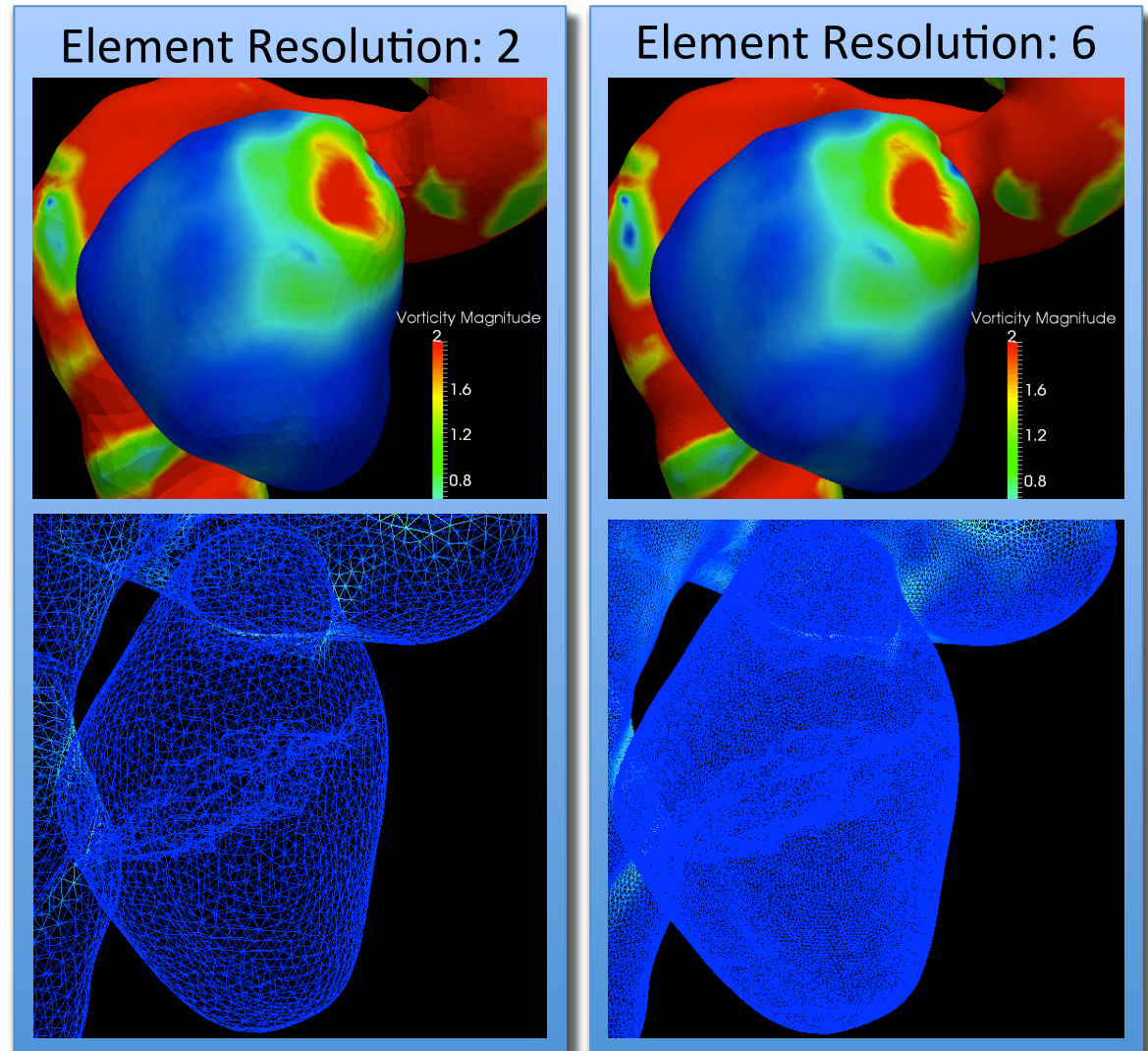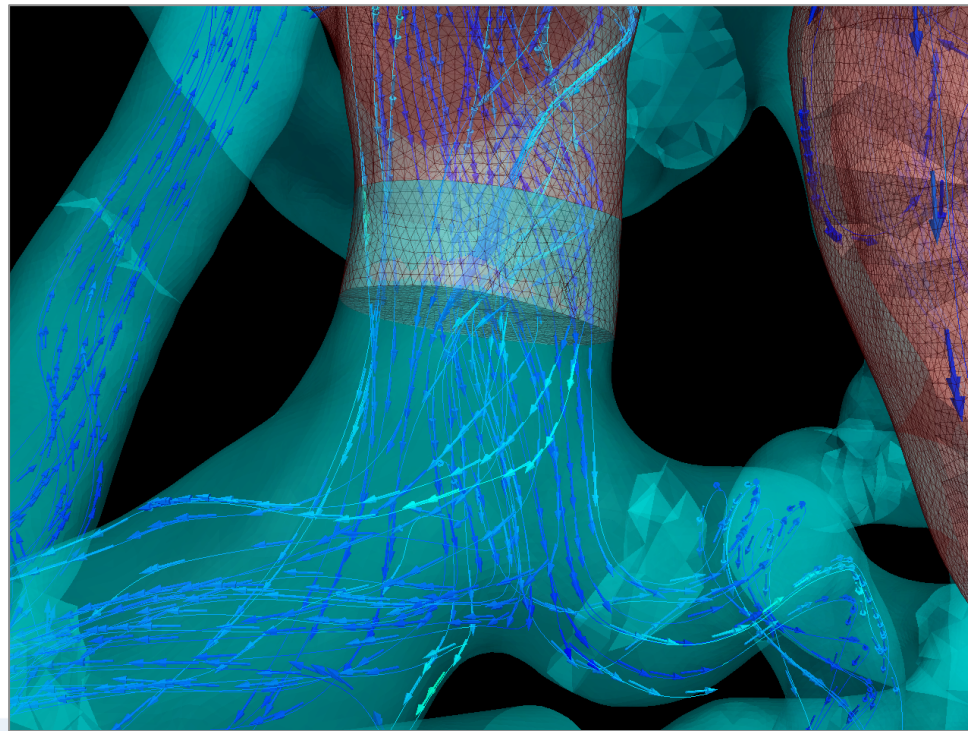

NekTar solution more accurate

Plug-in Controls

- Select variables

- Interactively set data resolution
  - No need to re-read mesh data from disk

- Time varying data
  - Only new data read from disk, not geometry

- Data caching

Plug-in Controls

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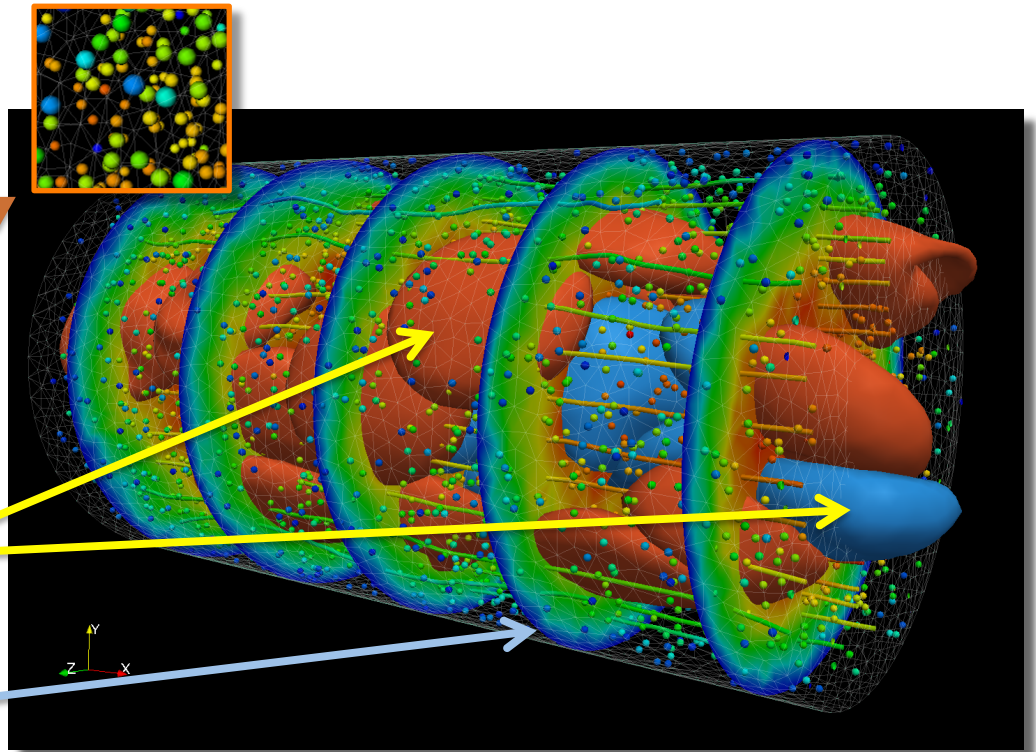- Data caching

Data Validation

- Multiple patches
  - Interfaces between patches
- Separately control resolution
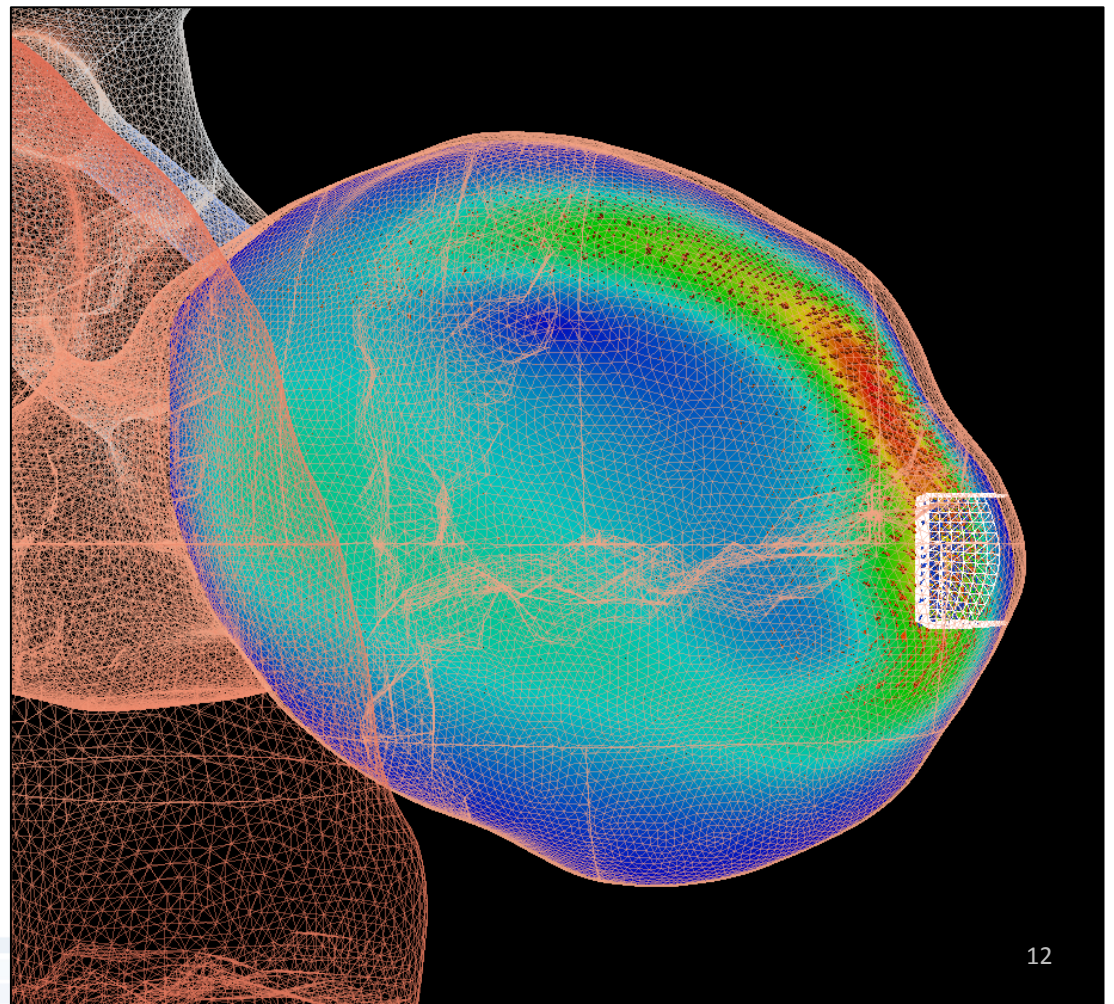 - More focus in regions of greater interest

Microscale Simulation (DPD-LAMMPS)

- Modified version of LAMMPS

- Two types of data
  - Atomistic (particle) data
    - Plasma
    - Red Blood Cells (RBC)
    - Platelets
  - Field data
    - Ensemble average solution
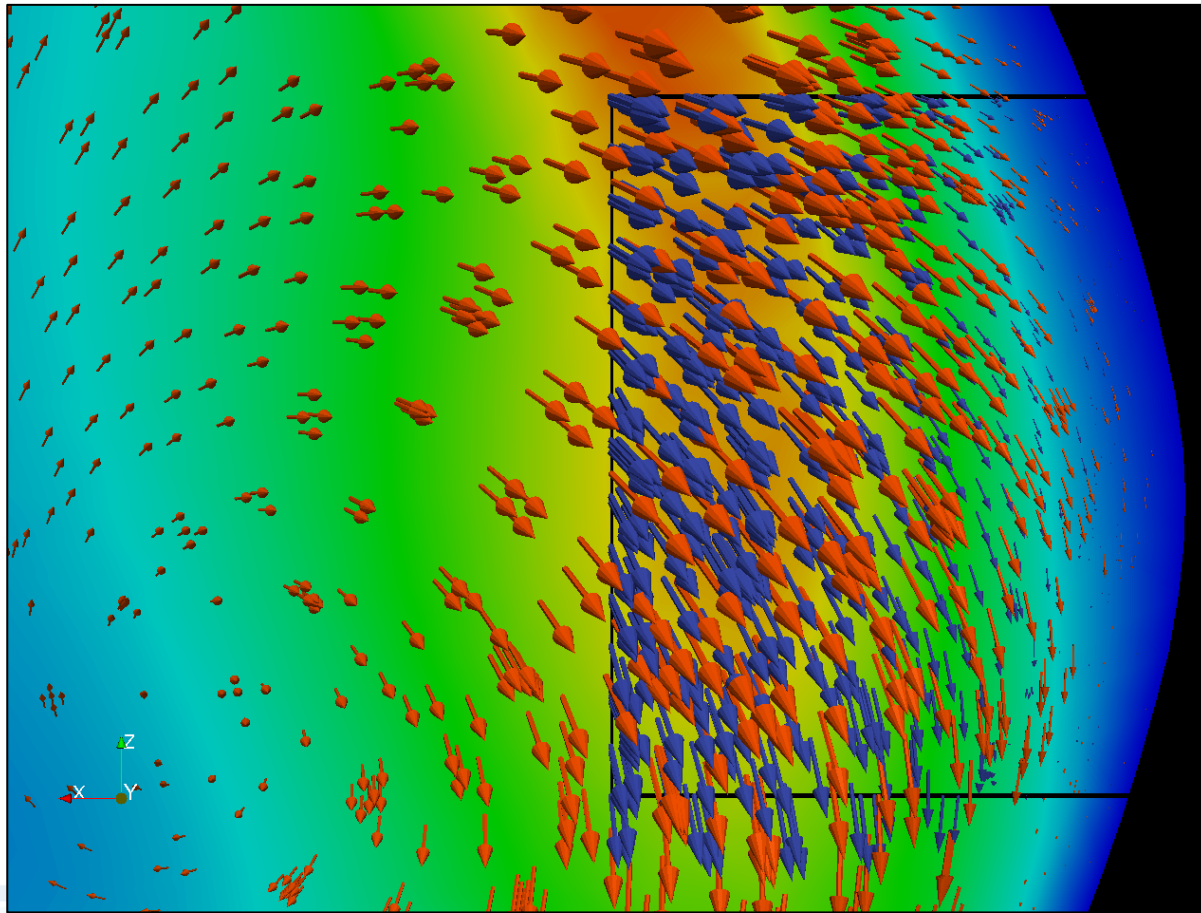   - Window Proper Orthogonal Decomposition (WPOD)

Integrated Visualization

- Used for verification
  - Field data from NekTar and DPD-LAMMPS
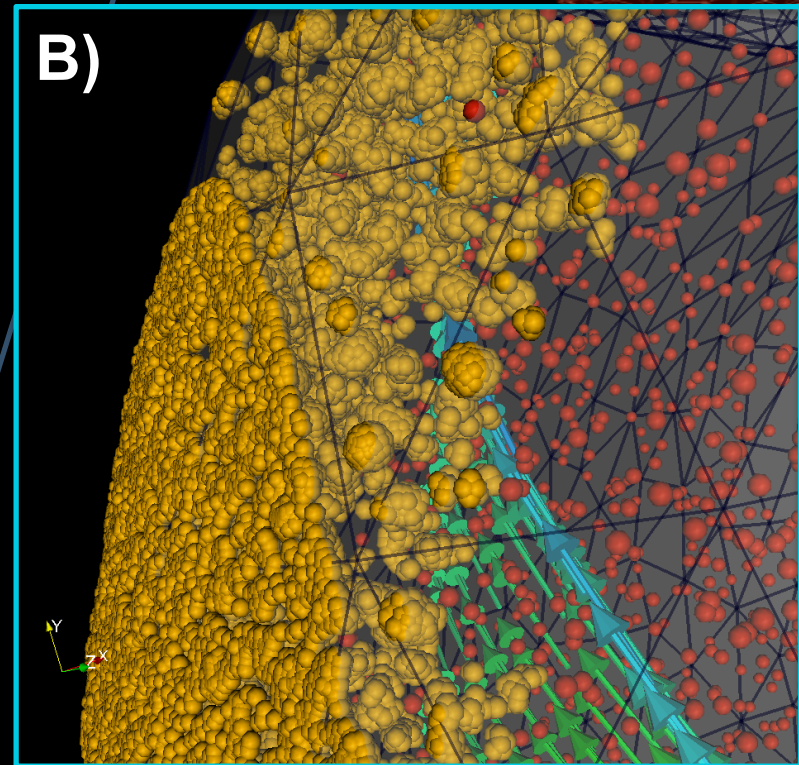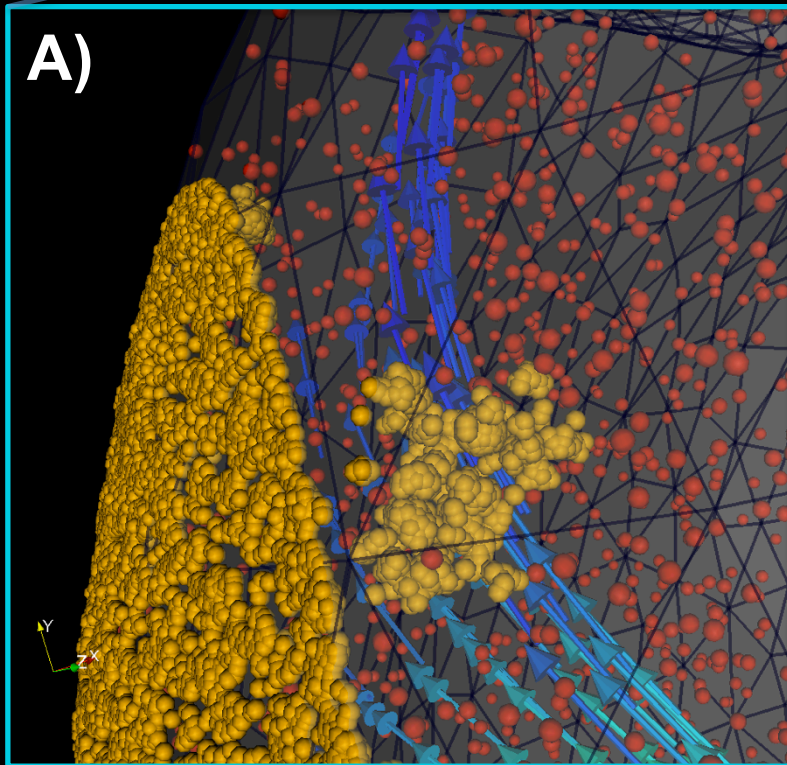
Integrated Visualization

- Used for verification
  - Field data from NekTar and DPD-LAMMPS

Right Interior Carotid Artery

Aneurysm

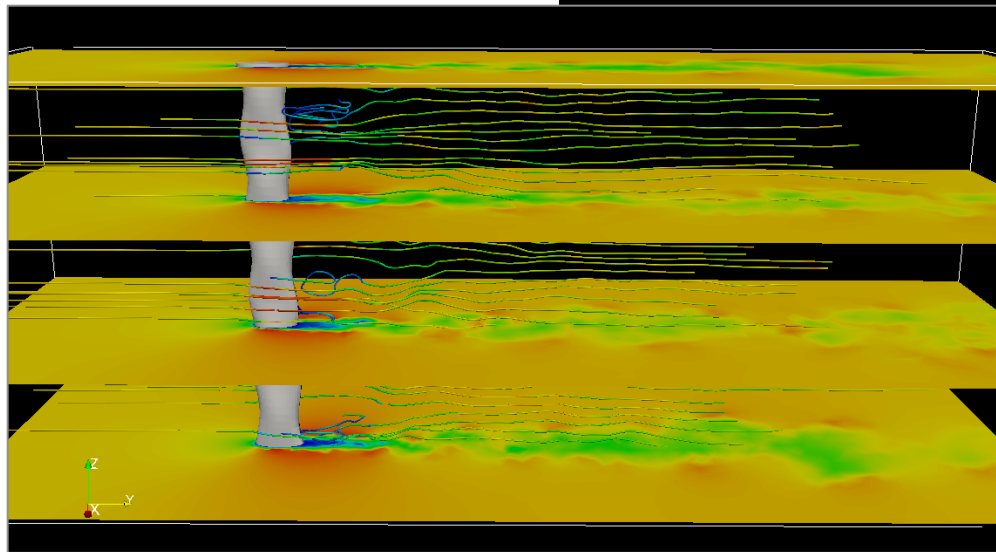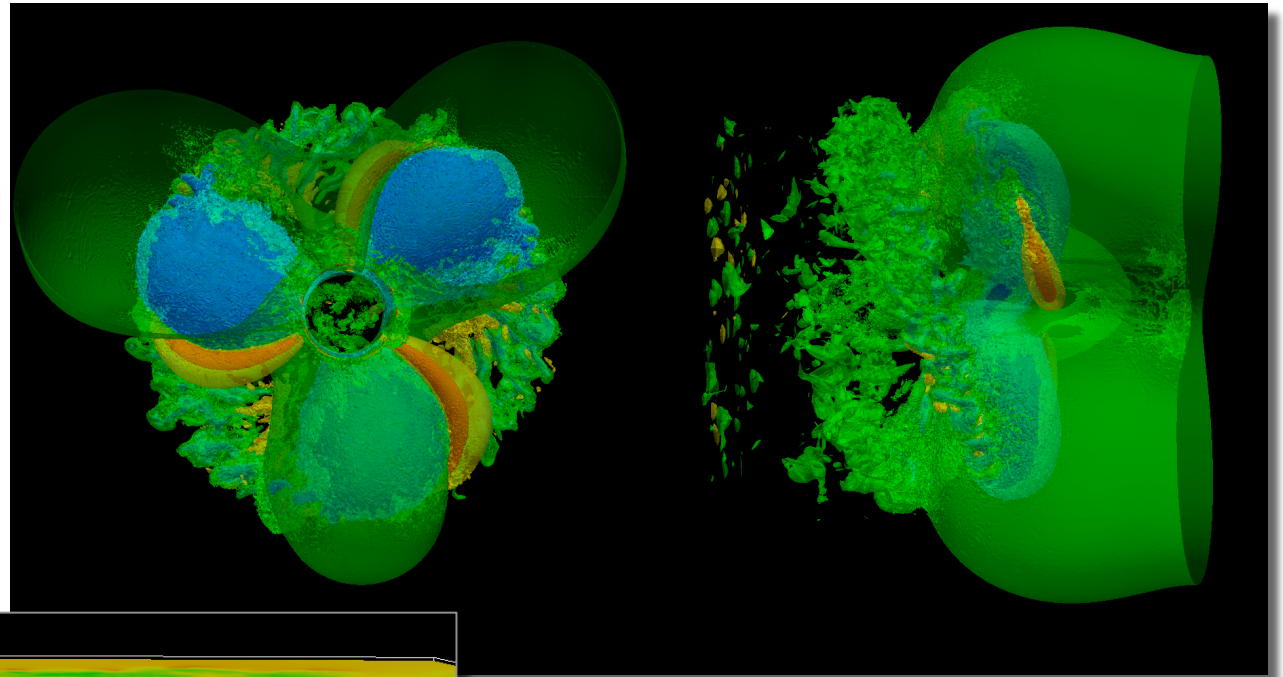Platelet Aggregation

A)

B)

Conclusions

- Multiscale will become increasingly important
  - Appropriate tools for visualization will be critical
- Work closely with scientists
  - Cyclical process – learn from each other what is important and possible (and not possible)
- Co-processing a next step
  - Reduce I/O requirements
  - Leverage infrastructure
  - Shorten time to discovery

Additional Applications of NekTar

- Air flow

- Water flow

- Heat transfer

Thanks

- George Karniadakis and Dmitry Fedosov, Brown University

- Visualization Group, Mathematics and Computer Science Division, Argonne National Laboratory