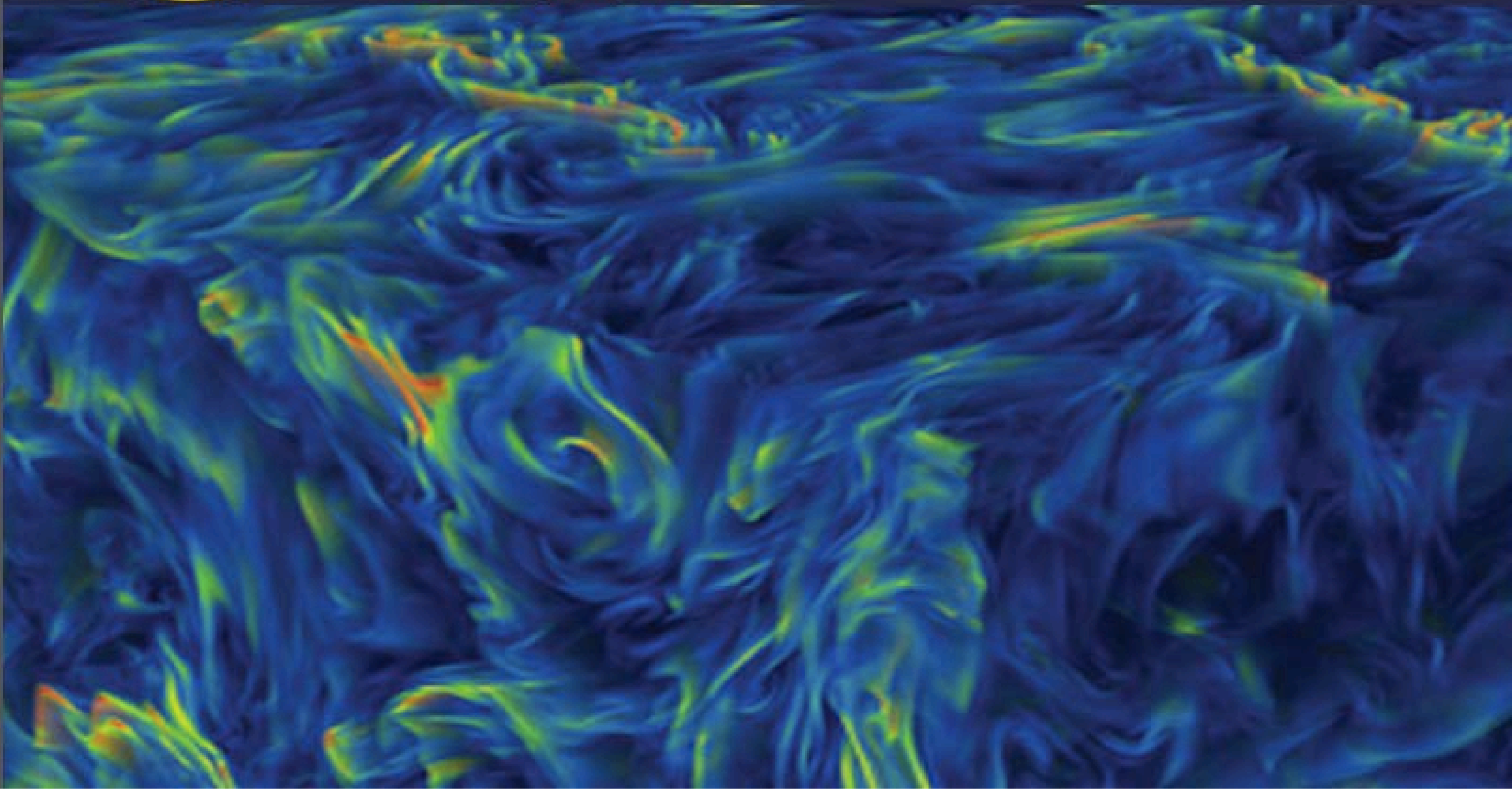
Top Ten Exascale Research Challenges

DOE ASCAC Subcommittee Report

February 10, 2014



1. Energy Efficiency

The goal is to achieve exascale using 20 MW of power, yet existing circuits consume an order of magnitude too much power to meet this goal. Without much more energy-efficient circuits, architecture, power conversion, power delivery and cooling technologies, the total cost of ownership for exascale systems could be 10 times higher than today.

2. Interconnect technology

The performance of the interconnect is key to extracting the full computational capability of a computing system. Without a high performance, energy-efficient interconnect, an exascale system would be more like the millions of individual computers in a data center, rather than a supercomputer.

3. Memory technology

Many new memory technologies are emerging, including stacked memory, non-volatile memory, and processor-in-memory. All of these need to be evaluated for use in an exascale system. Minimizing data movement to this memory and making it more energy efficient are critical to developing a viable exascale system. Science requirements for the amount of memory will be a significant driver of overall system cost.

4. Scalable system software

Present system software was not designed to handle the exponentially growing scale of leadership-class systems. Overall management of the power and resilience of the millions of nodes in an exascale system will be the responsibility of the system software.

5. Programming systems

The present CSP model doesn’t include resilience and puts all the burden of locality and parallelization on the application developers. Exascale systems will have billion-way parallelism, and frequent faults. More expressive programming models are needed that can deal with this behavior and simplify the developer’s efforts.

6. Data management

There is an explosion in both the amount and complexity of the data being generated by experiments and simulations. Without significant improvements in data management, the answers in the data will never be found.

7. Exascale algorithms

There are many thousands of man-years invested in the scientific and engineering codes now in use. Changing them to run with billion-way parallelism will require redesigning, or even reinventing, the algorithms used in them, and potentially reformulating the science problems. Understanding how to do these things efficiently and effectively will be key to solving mission-critical science problems at exascale.

8. Algorithms for discovery, design, and decision

It is anticipated that the need for methods and software to efficiently carry out uncertainty quantification and optimization on complex multi-physics problems will be a key need at exascale

9. Resilience and correctness

Programming tools, compilers, debuggers, and performance enhancement tools will all play a big part in how productive a scientist is when working with an exascale system. Without increasing programming productivity, an application may run in a few hours or days at exascale, but it may take months for the scientist to get it ready to run.

10. Scientific productivity

Programming tools, compilers, debuggers, and performance enhance- ment tools will all play a big part in how productive a scientist is when working with an exascale system. Without increasing programming productivity, an application may run in a few hours or days at exascale, but it may take months for the scientist to get it ready to run.

Findings & Recommendations

Findings

1. Exascale computing is critical for executing the DOE mission.
2. U.S. national leadership is at risk

Findings, con’t

3. The U.S. has the technical foundation to create exascale systems
4. An evolutionary approach to achieving exascale will not be adequate.
5. The U.S. government’s continuous leadership and investment are required to create exascale systems

Recommendations

1. DOE should invest in a program of continuous advancement in HPC
2. DOE should invest in the U.S. industrial base to catalyze the foundation for exascale systems

Recommendations, con’t

3. DOE should invest in exascale mathematics and system software responsive to DOE missions and other U.S. government requirements.
4. DOE should create an Open Exascale System Design Framework to enable cooperative hardware and software advancement.