Office of Science
Science for America's Future

Fusion Energy Sciences – Fueling the Future

Integrated Simulation and Optimization of Fusion Systems

Presentation to the Fusion Energy Sciences Advisory Committee

Gaithersburg, MD

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Simulation Program Vision

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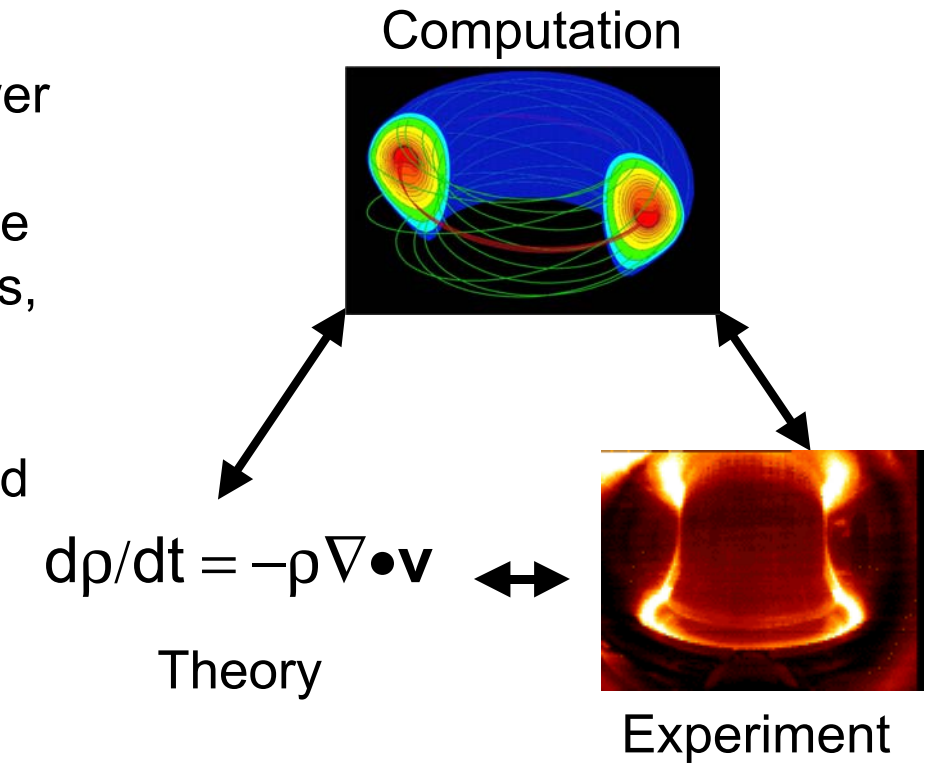
Advanced scientific computing has reached a point where it is on a par with laboratory experiment and mathematical theory as a major tool for scientific discovery.

Major increases in computing power will enable a new generation of simulation codes, based on reliable experimental and theoretical inputs, to lead the way to increased scientific understanding. These in turn will lead to new theoretical and experimental discoveries.



Simulation Program Goals

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Goal 1: Identify and Characterize the Important Fundamental Processes in Fusion Plasmas

Goal 2: Characterize the Complex Interactions that Occur in Fusion Plasmas

Goal 3: Develop the Algorithms and Computational Capabilities Needed to Understand Fusion Plasma Systems and Predict their Behavior

Fusion Computational Efforts

- **The Office of Fusion Energy Sciences is already supporting community efforts to develop some of the components needed for integrated simulation and optimization of fusion systems.**

Fusion SciDAC Projects

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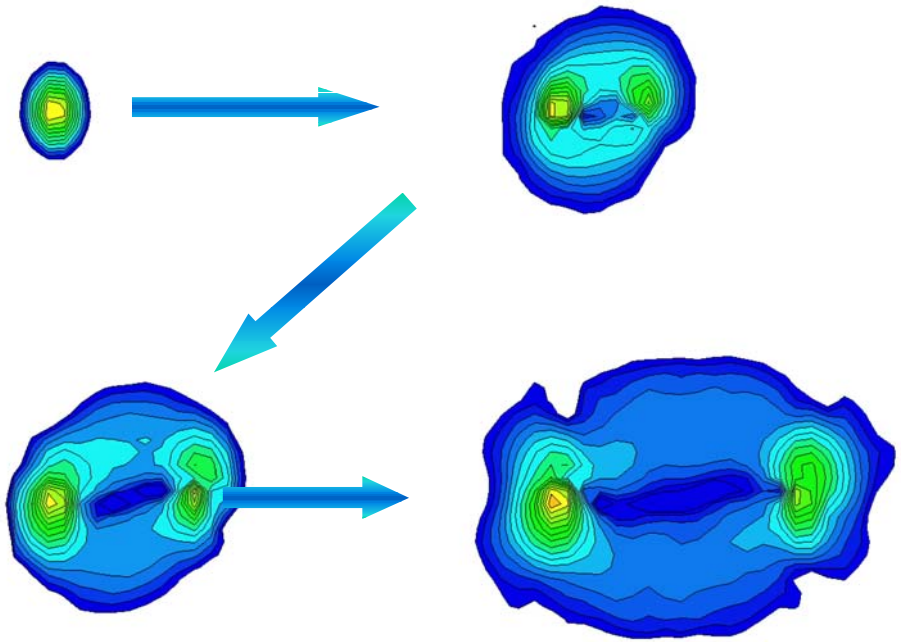
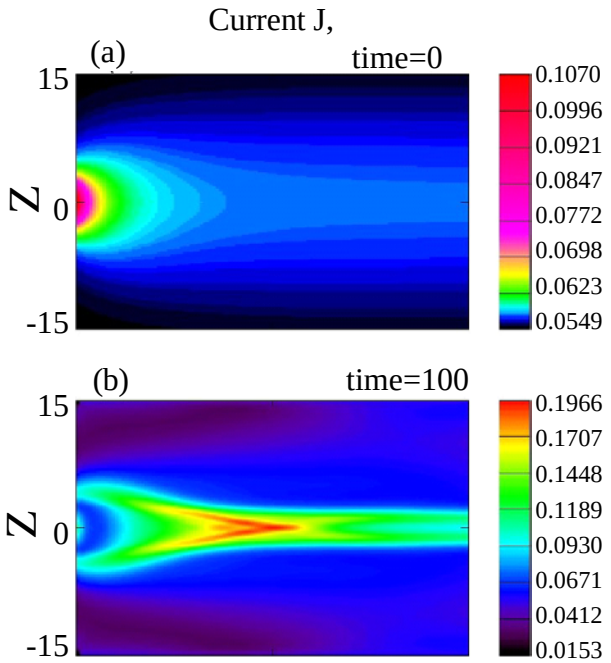
Terascale Atomic Physics

Auburn University
Rollins College
Oak Ridge National Laboratory



Substorm in the Magnetotail



Magnetic Reconnection Code

University of Iowa
University of Chicago
University of Texas

Fusion SciDAC Projects

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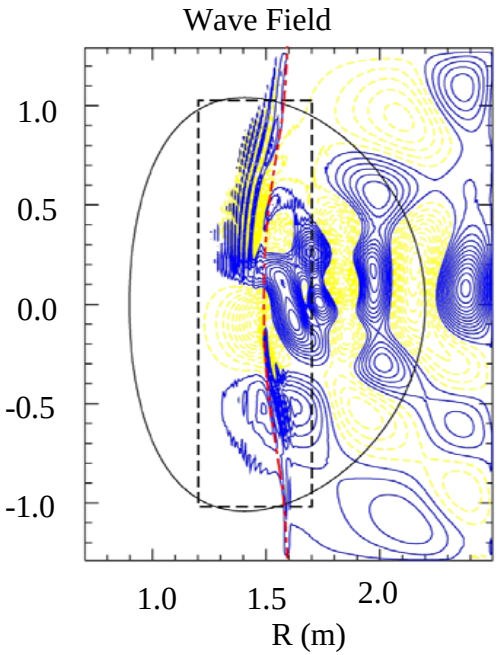
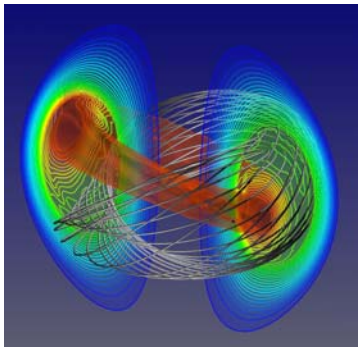
Computation of Wave Plasma Interactions

ORNL, PPPL, MIT, Lodestar, CompX



Extended MHD Modeling

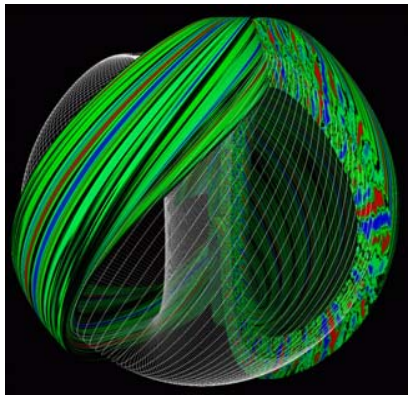


N=1 Plasma Instability

PPPL, SAIC,
U. Wisconsin, NYU,
U. Colorado, MIT,
Utah State U., GA,
LANL, U. Texas

Plasma Microturbulence

LLNL, GA, PPPL, U. Maryland, U. Texas, U. Colorado, UCLA



Turbulent Eddies in Plasma

FUSION NTCC Project

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National Transport Code Collaboration

- Goal of NTCC: Bring about a change in the way fusion modeling codes are constructed and used

- NTCC has demonstrated development of community code using modern software practices
  - Code developed as separate modules by separate institutions
  - Module Library contains portable, reusable, documented modules with clearly defined interfaces

Lehigh, LLNL, TechX Corp, PPPL, GA, ORNL, MIT, University of Texas, Georgia Tech University, UCSD

NATIONAL TRANSPORT CODE COLLABORATION

Computational/Networking Tools

- **The Office of Advanced Scientific Computing Research is already developing and deploying many of the computational and networking tools that will be required for this program.**

OASCR SciDAC Project

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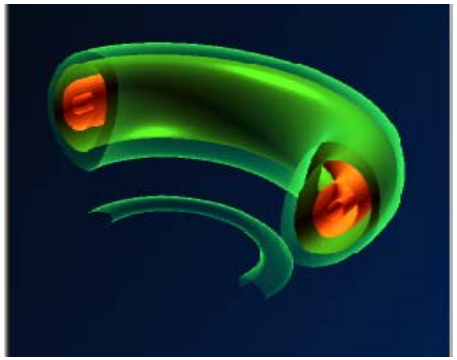
National Fusion Collaboratory

- Advance scientific understanding and innovation in magnetic fusion research by enabling more efficient use of existing experimental facilities and more effective integration of experiment, theory, and modeling

- Enable networked, real-time data analysis and instantaneous communication amongst geographically dispersed teams of experimentalists and theoreticians



Interactive visualization of multiple isosurfaces of time dependent electron temperature data calculated on the Fusion computational Grid [SuperComputing 2001]

GA, ANL, LBNL, MIT, PPPL, Princeton University, University of Utah

The Vision for a DOE Science Grid

Scientific applications use workflow frameworks to coordinate resources and solve complex, multi-disciplinary problems

Grid services provide a uniform view of many diverse resources

Large-scale science and engineering is typically done through the interaction of

- People,
- Heterogeneous computing resources,
- Multiple information systems, and
- Instruments

All of which are geographically and organizationally dispersed.

The overall motivation for “Grids” is to enable the routine interactions of these resources to facilitate this type of large-scale science and engineering.

ESNet provides critical infrastructure

- **Advanced network infrastructure and specialized network services such as adaptive monitoring supporting high performance distributed applications, and Quality-of-Service and bandwidth reservation for building large-scale aggregated systems**
- **Collaboration services such as support for IP multicast based video teleconferencing**
- **Persistent support for directory services that provide naming and location of resources across the Grid and services that enable secure access to these resources**

Charge to FESAC

Fusion Energy Sciences – Fueling the Future

- **Recommend a roadmap for a joint initiative on integrated simulation involving both the Office of Fusion Energy Sciences and the Office of Advanced Scientific Computing Research**

- **Plan for a 5-6 year program at a total funding level of approximately $20M per year**

- **Use experts outside of FESAC, as needed, and consult with the Advanced Scientific Computing Advisory Committee**

Questions for FESAC Subpanel

- What is the current status of integrated computational modeling and simulation?
- What should be the vision for integrated simulation of plasma systems?
- What new theory and applied mathematics are required for simulation and optimization of fusion systems?
- What computer science is required for simulation and optimization of fusion systems?
- What are the computational infrastructure needs for integrated simulation of plasma systems?
- How should integrated simulation codes be validated, and how can they best be used to enable new scientific insights?

Integration Requires Teamwork

Developing an integrated simulation and modeling capability will require an integrated team!

Emphasis of the FY 2003 Budget

Setting aside SNS and the one-time FY2002 projects, there is a 5% increase for science.

- **Science Thrust Areas:**
  - Nanoscale Science, Engineering, and Technology $133M (+$48M)
  - Genomes to Life $45M (+$20M)
  - Climate Change Research Initiative $3M (+$3M)
  - Scientific Discovery Through Advanced Computing (SciDac) $62M (+$5M)
- **More Operating Time and New Instrumentation at User Facilities $1,246M (+$40M)**
- **Improved Infrastructure $43M (+6M)**