ERCAP Request #81926 for FY2007

1. Principal Investigator

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3. Senior Investigators	J. Breslau, J.Chen, G.Y. Fu, S.Jardin, W.Park, H.R. Strauss(NYU), L.Sugiyama (MIT)
4. Project Title	3D Extended MHD simulation of fusion plasmas
5. Project Name	mp288
6. Project Class	SciDAC
7. Sponsoring Site	USA: Princeton Plasma Physics Laboratory
8. Science Category	Fusion Energy
9. DOE Office and Program	FES − Fusion SciDAC

10. Is this project funded by the DOE Office of Science?

X

Yes, this project has direct grant support from the DOE Office of Science

Who is your DOE Program Manager?

Mike Crisp, Steve Eckstrand, Curt Bolton, Rostom Dagazian, John Mandrakas

DOE Office of Science Grant Number(s)

DE−AC02−76CH03073

11. Does this project make use of national security information?

Yes X No

If this project is given a NERSC award, I agree to monitor the usage associated with it to ensure that, to the best of my ability to determine, usage is for the project described here.

X Yes No

For continuing projects: I have audited the MPP and/or HPSS usage associated with this project, and to the best of my ability to determine, all usage was for the project specified.

X Yes No

12. Computational Resources Requested

Center	Resource	Alloc Type	Repo	Hours Used 2006	Hours Requested 2007
NERSC	**MPP (Usage Charging)**	DOE Production	mp288	1,688,131	3,000,000

13. Mass Storage Resources Requested

Center	Resource	Alloc Type	Repo	SRUs Used 2006	SRUs Requested 2007
NERSC	**HPSS**	DOE Production	mp288	3,596	5,000

14. Justification for Resources Requested

Based on our experience from the last few years.

We are continuing to add new physics to our codes, increasing their capability. We need to increase resolution. As computers get faster, and the communication networks increase, we are ready to take advantage of this to move from terascale towards petascale applications, as required for ITER simulations.

15. PDSF Repos

16. Project Description

16.1 Project Summary: Provide a brief project description. What will this project accomplish? What is the significance of this work?

The M3D (Multilevel 3D) project consists of a multilevel comprehensive plasma simulation code package, and applications of various levels of the code to increasingly more realistic fusion problems. This is one of the major codes in the field of magnetic fusion energy. It is a substantial component of the funded CEMM SCIDAC project. M3D is capable of describing the nonlinear behavior of large scale instabilities in most every MFE confinement configuration including tokamaks, spherical tokamaks, stellarators, spheromaks, reversed field pinch, and field−reversed configuration. Many phenomena of interest require a plasma description that includes some kinetic effects, and thus the need for the multi−level description.

The current areas of research emphasis by our team are: Neoclassical modes in tokamaks, resistive wall modes in tokamaks, Edge Localized Modes in Tokamaks, the MHD physics of burning plasmas, Stellarator

stochasticity and stability, and some non−fusion applications such as magnetic reconnection in general 3D configurations.

16.2 URL for a relevant web page.

http://w3.pppl.gov/CEMM

17. Accomplishments

The major accomplishments are as follows:

1. Edge Localized Modes in Tokamaks: Together with the NIMROD team, we have carried out the most detailed study of Edge Localized Modes (ELMs) in tokamaks ever undertaken. This has shed much light on the role of different dissipative effects on the nonlinear development of these modes, and the computational resolution requirements. These results satisifed a high−level theory milestone for the Office of Fusion Energy Science. They can be found on the site: http://w3.pppl.gov/CEMM on the "milestones" page. They were also featured in an oral presentation at the IAEA Fusion Energy Conference in Hengdu, China.

2. Sawtooth Instability: We have carried out the most comprehensive study to date of the sawtooth instability (internal reconnection event) in a small tokamak, CDX−U. This also served a code validation function, as the same event was modeled with NIMROD, M3D, and comparison was made to experimental data. We obtained very good agreement. This work was highlighted as an APS/DPP invited talk. It also provided us with information needed to see how these calculations will scale to an ITER sized tokamak.

3. Energetic Particle Modes: We have used the hybrid option of the M3D code to study energetic particle modes in tokamaks, and perform comparison with several experiments. This has led to 5 publications during this period, including an oral presentation at the IAEA conference on fusion energy in Hengdu, China.

4. New Physics: We have added new physics to our code, in particular the gyroviscous stress, and have used this to demonstrate stabilization of the gravitational instability. Much progress has been made on a new implicit version of M3D using high−order finite elements with C1 continuity. We have developed new highlighly accurate techniques for calculating anisotropic heat conduction with misaligned grids. We have also participated in interpreting some basic physics experiments on magnetic reconnection.

5. Reactor Design: We have applied our codes in a major design study, called ARIES, and also are evaluating the effect of vertical displacement events (VDEs) in ITER and the next generation of tokamak reactors.

18. Relevant Publications

18.1 Refereed Publications: List all refereed publications in the last 12 months based on research using NERSC resources. You may include publications submitted to journals but not publications in preparation.

H.R. Strauss, L. Sugiyama, C.S. Chang, G. Park, S. Ku, W. Park3, J.
Breslau, S. Jardin, "ELM Simulations with M3D," paper TH/P8−6, IAEA Fusion Energy Conference, Hengdu, China, 2006 (to appear in proceedings)

G. Y. Fu, J. A. Breslau, W. Park, S. C. Jardin, J. Chen, "Nonlinear Simulations of Fishbone Instability and Sawteeth in Tokamaks and Spherical Torus", paper EX/7−4Rb, IAEA Fusion Energy Conference, Hengdu, China, 2006 (to appear in proceedings)

J A Breslau, W Park and S C Jardin, "Massively parallel modeling of the sawtooth instability in tokamaks", 2006 J. Phys.: Conf. Ser. 46 97−101

Kramer GJ, Fu GY "Reversed shear Alfven eigenmodes associated with the ellipticity and triangularity Alfven gaps" ,PLASMA PHYSICS AND CONTROLLED FUSION 48 (9): 1285−1295 SEP 2006

Brennan DP, Sugiyama LE "Tearing mode stability in a low−beta plasma with sawteeth", PHYSICS OF PLASMAS 13 (5): Art. No. 052515 MAY 2006

Ferraro NM, Jardin SC "Finite element implementation of Braginskii's gyroviscous stress with application to the gravitational instability"
PHYSICS OF PLASMAS 13 (9): Art. No. 092101 SEP 2006

Fu GY, Park W, Strauss HR, Breslau J, Chen J, Jardin S, Sugiyama LE,
"Global hybrid simulations of energetic particle effects on the n=1 mode in tokamaks: Internal kink and fishbone instability"
PHYSICS OF PLASMAS 13 (5): Art. No. 052517 MAY 2006

Kramer GJ, Nazikian R, Alper B, de Baar M, Berk HL, Fu GY, Gorelenkov NN, McKee G, Pinches SD, Rhodes TL, Sharapov SE, Solomon WM, van Zeeland MA.
"Interpretation of core localized Alfven eigenmodes in DIII−D and Joint European Torus reversed magnetic shear plasmas", PHYSICS OF PLASMAS 13 (5): Art. No. 056104 MAY 2006

Jardin SC, Kessel CE, Mau TK, et al. "Physics basis for the advanced tokamak fusion power plant, ARIES−AT" FUSION ENGINEERING AND DESIGN 80 (1−4): 25−62 JAN 2006

Fredrickson ED, Bell RE, Darrow DS, Fu GY, Gorelenkov NN, LeBlanc BP, Medley SS, Menard JE, Park H, Roquemore AL, Heidbrink WW, Sabbagh SA, Stutman D, Tritz K, Crocker NA, Kubota S, Peebles W, Lee KC, Levinton FM, "Collective fast ion instability−induced losses in national spherical tokamak experiment"
PHYSICS OF PLASMAS 13 (5): Art. No. 056109 MAY 2006

Kessel CE, Mau TK, Jardin SC, et al. "Plasma profile and shape optimization for the advanced tokamak power plant, ARIES−AT" , FUSION ENGINEERING AND DESIGN 80 (1−4): 63−77 JAN 2006

Jardin, S.C; Breslau, J.A. , 2005, Implicit solution of the four−field extended−magnetohydrodynamic equations using high−order high−continuity finite elements. PHYSICS OF PLASMAS 12, 10 pages

J. Chen, S. C. Jardin, and H.R. Strauss, "Solving Anisotropic Transport Equations on Misaligned Grids", Springer−Verlag, Lecture Notes in Computer Science, 3516, pp. 1076−1079, 2005

Paccagnella R, Cavinato M, Bolzonella T, Ortolani S, Pautasso G, Schneider W, Lukash V, Khayrutdinov R, Strauss HR , "Vertical displacement events simulations for tokamak plasmas" Paccagnella R, Cavinato M, Bolzonella T, Ortolani S, Pautasso G, Schneider W, Lukash V, Khayrutdinov R, Strauss HR
Source: FUSION ENGINEERING AND DESIGN 75−9: 589−593 NOV 2005

Yamada M, Ren Y, Ji H, Breslau J, Gerhardt S, Kulsrud R, Kuritsyn A "Experimental study of two−fluid effects on magnetic reconnection in a laboratory plasma with variable collisionality" ,PHYSICS OF PLASMAS 13 (5): Art. No. 052119 MAY 2006

18.2 Other Publications: List up to 5 other relevant publications in the last 12 months, also based on research using NERSC resources.

J Chen, J Breslau, G Fu, S Jardin, W Park, "New Applications of Dynamic Relaxation in Advanced Scientific Computing", proceedings of ISICS'06 Conference held at Dalian, China, Aug 15−18, 2006:

In addition, our group has over 10 abstracts that relied on NERSC computing at the annual American Physical Society, Division of Plasma Physics meeting to be held in Philadelphia, PA, the week of October 30, 2006, including 1 invited paper: J. Breslau, "Massively parallel modeling of the sawtooth instability in a small tokamak"

19.1 Code and Application Descriptions

Code Name	Description	Machines	Algorithms	Languages	Libraries	Other Software
M3D	The code integrates the 3D Extended MHD equations in time. It uses finite elements in the poloidal plane, and finite differences in the toroidal direction. There is also an option to use particle−in−cell techniques to represent some or all of the ions. The code treats some terms implicitly, and others explicity. Every time step there are 10 poissons equations that need to be solved on each poloidal plane.		Unstructured Mesh, Iterative Solver, particle methods, multigrid, sparse linear algebra	c, fortran90, MPI, openMP	hdf5, netcdf, petsc	We use an AVS post−processor, mostly locally at PPPL.
M3D−C1	This is a new, implicit code, to integrate the Extended MHD equations. It uses high−continuity, high order finite elements to generate a sparse matrix, which is then solved using SuperLU−Dist.	bassi	Unstructured Mesh, Adaptive Mesh, direct solver, sparse linear algebra	fortran90, MPI	hdf5, netcdf, NCAR, superlu	

Code Name	Checkpoint	Performance Limits	Performance Comments	Planned Code Enhancements
M3D	Y	Algorithm Scaling, Small problem size		We are exploring ways to make the code scale better, use larger timesteps, and be more efficient.
M3D−C1	Y	Algorithm Scaling, memory size	The code is presently 2D, but we are extending it to 3D.	The code is presently 2D, but we are extending it to 3D.

19.2 Code and Application Performance

Code Name	Machine	# of Procs	Total Gflops	Total Memory (Gbytes)	How info was collected/comments
M3D	seaborg	784	21	700	IPMv0.918
M3D−C1	bassi	8	27		superlu diagnostic (X.Li)
M3D−C1	bassi	128	112		superlu diagnostic (X.Li)

20. Storage Required on Computational Systems

The present block quotas for the home directories are sufficient, although it would be useful if the inode quota could be raised from 15000 to 30000 to allow maintaining several working copies of our source code simultaneously.

Our codes do not use large amounts of scratch space.

21. Data Intensive / HPSS Project Requirements

no

22. Networking

the current network bandwidth between PPPL and NERSC is sufficient for our present mode of operation

23. Other HPC Support

The M3D project also uses some on the local PC clusters available to us at PPPL. The amount of time we can get on these machines is severely limited, but we sometimes find them usefull if they are lightly loaded, especially for short interactive runs.

We also have time at the ORNL center, but because of some reliability problems, our users tend to favor the NERSC facilities.

24. Additional Information

25. Feedback and Project Requirements

26. Current Request Status

X
Not Finished: This request is not yet ready for review.

Finished: This request is finished and ready for review.