Final Report to DOE, July 12, 2000

Project Title: ***Bifurcation, Geometric Phases and Control in Hamiltonian Systems and Fluid Dynamics***
Project FG03-95-ER25251 UC. BERKELEY
Dates: July 1, 1995–June 30, 1999

1 Principal Investigators

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2 Principal Project Personnel

Jerrold E. Marsden
A. Role in the project. Principal Investigator/Researcher

B. Principal Areas of Research and Expertise. Mechanics, dynamics, bifurcation theory and control theory.

C. Percentage of time. Approximately 15%.

D. Education. BSc, Toronto, 1965, PhD Princeton, 1968

E. Employment History. University of California, Berkeley, 1968--present, Professor, Control and Dynamical Systems, Caltech, 1995--present.

F. Relevant Professional Societies and Honors. Editor for Springer's Applied Mathematical Sciences Series, Member, AMS, SIAM, APS, IEEE; Gravity Research Foundation prize, 1973, Carnegie Fellowship, 1977, Killam Scholar, 1979, Wiener Prize, 1990, Humboldt Prize, 1991, Fairchild Scholar, 1992, Plenary Lecture, ICIAM, Hamburg, 1995.

Edgar Knobloch
A. Role in the project. Principal Investigator/Researcher

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B. Principal Areas of Research and Expertise. Applied Dynamics, Fluid Dynamics, Bifurcation Theory.

C. Percentage of time. Approximately 15%.

D. Education. BA, Cambridge, 1974, PhD, Harvard, 1978

E. Employment History. Junior Fellow, Harvard Society of Fellows, 1978-1980, University of California, Berkeley, 1978–present.

F. Relevant Professional Societies and Honors. Editorial Board of Nonlinearity, and of Fluid Dynamics Research. Member, APS. Alfred P. Sloan Research Fellow 1980–84. Sc.D., University of Cambridge, 1994, JILA Visiting Fellow, 1996.

3 Additional Project Personnel

Project personnel during the duration of the grant were described in the annual progress reports. During the final year no additional personnel were supported due to lack of funds.

Collaborators at other Universities were not supported by these funds, but include Anthony Bloch, Gerhard Dangelmayr, J. Hettel, Darryl Holm, Keith Julien, Vivien Kirk, P.S. Krishnaprasad, Hans-Peter Kruse, Adam Landsberg, Jeff Moehlis, Robert Pierce, Michael Proctor, Tudor Ratiu, Genevieve Raugel, Jürgen Scheurle, Mary Silber, Steve Tobias and Juri Toomre.

4 Project Overview

The following papers (in addition to those appearing in the annual progress reports) wrapped up the project:

1. Kirk, V., J. E. Marsden and M. Silber, Branches of stable three-tori using Hamiltonian methods in Hopf bifurcation on a rhombic lattice, Dyn. and Stab. of Systems, vol. 11 (1996) pp. 267-302.

2. Kruse, H. P., A. Mahalov and J. E. Marsden, On the Hamiltonian structure and three-dimensional instabilities of rotating liquid bridges, Fluid Dyn. Research, vol. 24 (1999) pp. 37-59.

3. Marsden, Ratiu and Raugel continue their work on shallow water approximations of the Euler equations, especially those on the two sphere. Some of the results were announced in the paper of Marsden, Ratiu, and Raugel [1995], "Équations d'Euler dans une coque sphérique mince (Euler equations on a

thin spherical shell)", *C.R. Acad. Sci. Paris* **321**, 1201-1206. Considerable progress has been made on the longer version of this paper during a visit of Marsden and Ratiu to Paris in 1999.

4. Zenkov, D. V., A. M. Bloch and J. E. Marsden, The Energy Momentum Method for the Stability of Nonholonomic Systems, Dyn. Stab. of Systems, vol. 13 (1998) pp. 123-166.

5. Julien, Keith; Knobloch, Edgar; Tobias, Steve Strongly nonlinear magneto-convection in three dimensions. Phys. D 128 (1999), no. 2-4, 105–129.

6. Julien, Keith; Knobloch, Edgar Fully nonlinear three-dimensional convection in a rapidly rotating layer. Phys. Fluids 11 (1999), no. 6, 1469–1483.

7. Marsden, J. E. and J. M. Wendlandt, Mechanical systems with symmetry, variational principles and integration algorithms in: Current and Future Directions in Applied Mathematics, Birkhuser (1997) pp. 219-261.

8. Koon, W. S. and J. E. Marsden, The Poisson reduction of nonholonomic mechanical systems, Reports on Math. Phys., vol. 42 (1998) pp. 101-134.

Significance and Relevance. We studied stability, bifurcation and dynamics problems in fluid mechanics which are topics of fundamental scientific importance. Considerable progress on these topics was made during the duration of the grant with numerous publications produced. In addition, the topic of variational integrators was begun which has led (after the grant closed) to significant breakthroughs in integration algorithms of a multisymplectic nature for elasticity, fluid mechanics and satellite dynamics. Application of these algorithms to the simulation of atmospheric, oceanographic and turbulent flows is currently underway. Support of DOE during the formative stage of these algorithms was an important part of this development.