One of the significant discoveries we made was primarily supported by the ONR and involves the development and extensive simulations of an original model that demonstrates the viability of the "lattice-gas" approach to hydrodynamics. Our model overcomes major difficulties of the previous discrete approaches. These difficulties can be traced to discretization artifacts that introduce a violation of the Galilean invariance and spurious energy terms in the equation of state. Some of the work done under Grant No. AFOSR-89-0119 lead us towards this theory (see publication 1). The key new element in our model (see publications 2 and 3) is the proper treatment of the energy degree of freedom (achieved by using particles with different speeds), allowing for true thermal effects. Isotropy and Galilean invariances are recovered by using adjustable direct and inverse collision rates on a projected face-centered hypercubic lattice. Extensive simulation on a Cray-2 computer of periodic shear perturbations and walks to equilibrium document correct Galileo behavior and thermalization effect.
May 1, 1990

Captain Helen R. Tyson  
Air Force Office of Sponsored Research/NM  
Bolling Air Force Base  
Washington, DC 20332

Subject: Grant No AFOSR-89-0119, Final Technical Report

Dear Captain Tyson:

Enclosed please find our final technical report on research done under Grant No AFOSR-89-0119. The last work supported by this grant (listed below as number 7) was in fact completed last week; thus the late date of the present report.

Our research field is best described by the title of our Proposal to AFOSR: “Innovative Uses of Parallel Computers.” It aims to use advanced computers in innovative ways that bypass both the numerical analysis and instabilities of floating point arithmetic. This is achieved with models which are already fully discrete, and thus lend themselves to efficient and exact simulation on digital hardware. The thrust of our effort focussed the design and implementation of models of this type for fluid dynamics (publications 1, 2, and 3). We also investigated general issues of discrete modelling from the viewpoint of statistical mechanics (publication 4), programming (publication 5), and mathematical analysis (publications 6 and 7).

One of the significant discoveries we made was primarily supported by the ONR and involves the development and extensive simulations of an original model that demonstrates the viability of the “lattice-gas” approach to hydrodynamics. Our model overcomes major difficulties of the previous discrete approaches. These difficulties can be traced to discretization artifacts that introduce a violation of the Galilean invariance and spurious energy terms in the equation of state. Some of the work done under Grant No. AFOSR-89-0119 lead us towards this theory (see publication 1). The key new element in our model (see publications 2 and 3) is the proper treatment of the energy degree of freedom (achieved by using particles with different speeds), allowing for true thermal effects. Isotropy and Galilean invariance is recovered by using adjustable direct and inverse collision rates on a projected face centered hypercubic lattice. Ex-
tensive simulation on a Cray-2 computer of periodic shear perturbations and walks to

equilibrium document correct Galileo behavior and thermalization effect.

Publication 4 exhibits a new dynamical exponent in a family a cellular automata
models of growth. This exponent is universal in that it can pertain to a wide class of
phenomena (noise-driven metastability to instability transition). Publications 5 shows
the optimized techniques for programming cellular automata under scalar, vector, and
massively parallel computer architectures.

Publications 6 and 7 are of a more mathematical nature. The former studies lattice
models with methods from the theory of dynamical systems, while the latter investiga-
tes the notion of Boolean derivative as a tool for bridging the discrete and continuum
modelings.

1. Gérard Y. Vichniac, “Cellular Automata Fluids,” in Instabilities and Nonequilib-

2. K. Molvig, P. Donis, R. Miller, and J. Myczkowski, and G. Y. Vichniac, “Multi-
Species Lattice-Gas Hydrodynamics,” in Cellular Automata and the Modeling of
Complex Physical Systems, P. Manneville, N. Boccara, G. Y. Vichniac, and R.
Bidaux, eds. (Springer-Verlag, 1989).


Models of Growth,” in Cellular Automata and the Modeling of Complex Phys-
(Springer-Verlag, 1989).

5. J. Myczkowski and G. Y. Vichniac, “Parallel Programming for Cellular Au-
tomata,” AICA Workshop on Parallel Programming, CINECA, Italy, Proceed-
ings, 1989.

6. G. Y. Vichniac and E. Goles, “Energy and Attractors in Parallel Potts Dynam-


All the above articles acknowledge support from Grant No AFOSR-89-0119. It is our
pleasant duty to acknowledge that the grant also supported in part Dr. Vichniac’s
participation to two meetings, where he delivered the following invited talks:


In the most sincere appreciation,

Gerard Vichniac

cc: Dr. A. Nachman