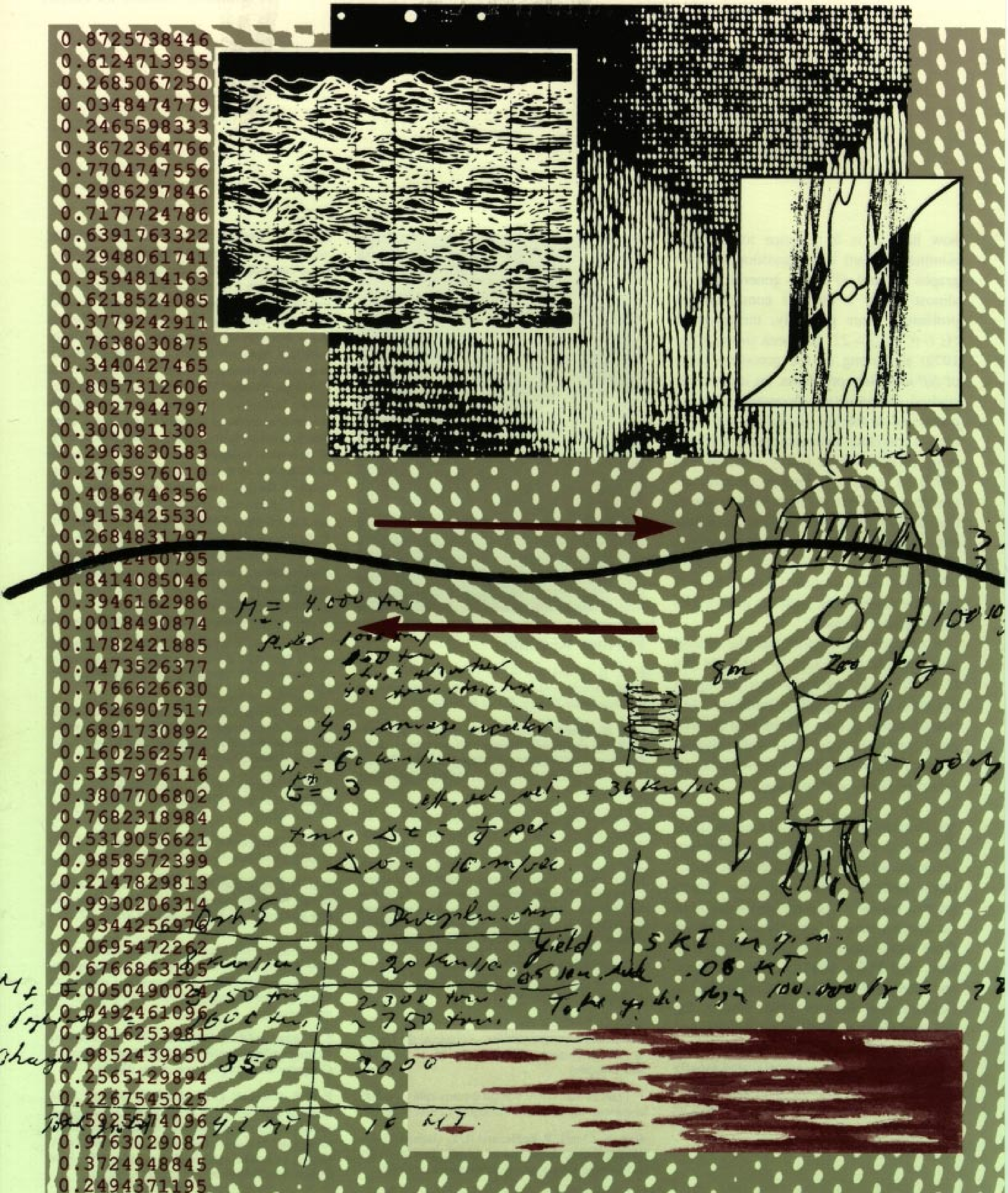
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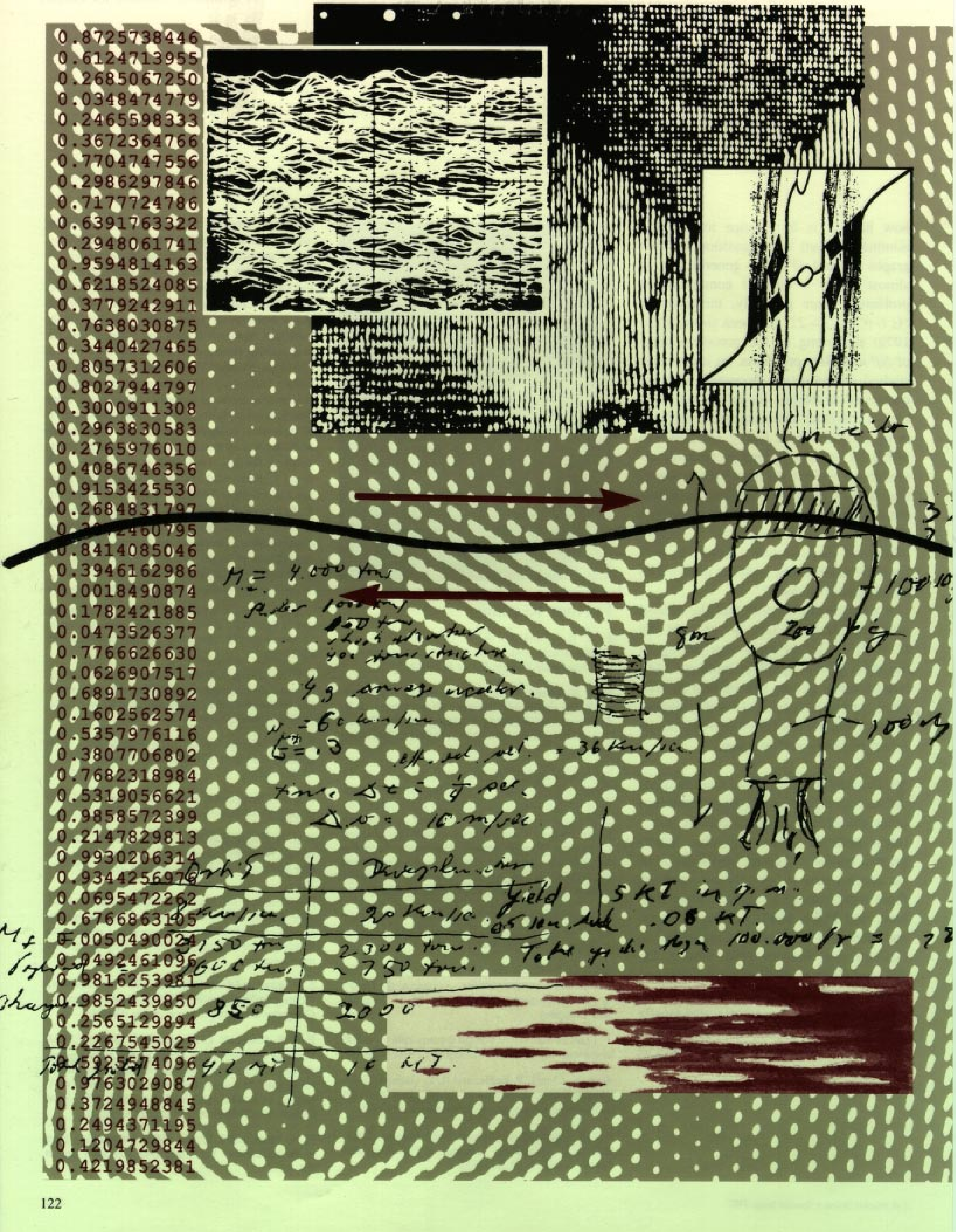
0.4219852381
M = 4.000 tons
400 tons structure
4 g average acceler.
= 60 km/sec
= .3
= 36 km/sec
Δt = 1/4 sec.
Δv = 10 m/sec
8m
200 kg
100 kg
Yield
5 KT
.08 KT
100.000/yr
20 km/sec
2.000 tons
750 tons
850
2000
4.2 MT
10 MT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0.2267545025
0.5925574096
0.9763029087
0.3724948845
0.2494371195
0.1204729844
0.4219852381
M = 4.000 tons
Pusher 1000 tons
00 tons shock absorber
400 tons structure
4 g average acceler.
v = 60 km/sec
ε = .3
eff. exh. vel. = 36 km/sec
time Δt = ¼ sec.
Δv = 10 m/sec
8m
3
100
10
200
g
100 g
Orbit
Interplanetary
Yield
5 KT in orbit
8 km/sec
20 km/sec
.05 ton each
.08 KT
M_f
150 tons
2000 tons
Total yield 100.000/yr = 7
Payload
1600 tons
750 tons
Charges
850
2000
Total yield
4.2 MT
10 MT

PHYSICS

> *"Because of the novel problems which confronted its scientists during the wartime establishment of Los Alamos, the need arose for research and ideas in domains contiguous to its central purpose. This trend continues unabated to the present.*
>
> *Problems of a complexity surpassing anything that had ever existed in technology rendered imperative the development of electronic computing machines and the invention of new theoretical computing methods, There, consultants like von Neumann played an important role in helping enlarge the horizon of the innovations, which required the most abstract ideas derived from the foundations of mathematics as well as from theoretical physics. [These ideas] were and still are invested in new, fruitful ways. . . .*
>
> *In at least two different and separate ways the availability of computing machines has enlarged the scope of mathematical research. it has enabled us . . . to gather through heuristic experiments impressions of the morphological nature of various mathematical concepts such as the behaviour . . . of certain non-linear transformations, the properties of some combinatorial systems and some topological curiosities of seemingly general behaviors. It has also enabled us to throw light on the behaviour of... complicated systems . . . [through] Monte Carlo type experiments and extensive but 'intelligently chosen' brute force approaches, in hydrodynamics for example. "*
>
> **S. Ulam** *1984*

The remarks at left, written to preface Ulam's collected Los Alamos reports, suggest the context, the content, and the import of his influence at Los Alamos. The Los Alamos report on the hydrogen bomb, written with Edward Teller, is certainly of great interest, but classification precludes any discussion beyond that found in "Vita" and "From Above the Fray" in Part I. Weapons development, however, was only one among many Los Alamos projects in which Stan had a hand. In fact the list of his publications at the back of this volume reads in many parts like a history of ideas at Los Alamos. The reports authored by Stan and his many illustrious collaborators on the Monte Carlo method, hydrodynamics, nonlinear transformations, computer studies of nonlinear systems, and other diverse topics, as well as his informal talks and conversations, have left a legacy of ideas and possibilities that are still only partially explored. Stan was present at the opening of the computing era, and together with von Neumann, he understood perhaps better than others its revolutionary potential for exploring complex systems of all kinds.

Nick Metropolis, in "The Beginning of the Monte Carlo Method," describes from firsthand experience the early years of the computer revolution and the invention and first applications of the Monte Carlo method. As the name implies, this method turns *an* iterative process (such as a neutron chain reaction or repeated application of a deterministic transformation) into a game of chance. The computer plays the game over and over again to obtain good estimates of the average (or asymptotic) outcome of the process. In his 1950 paper "Random Processes and Transformations" Ulam outlined a variety of ways in which deterministic problems in mathematics and physics could be converted into equivalent random processes, or games of chance. His vision was prophetic and this method has taken hold in many areas; even particle physicists are applying Monte Carlo techniques to find solutions to complex problems in quantum field theory.

While Metropolis's article and the others on Monte Carlo are basically review, the remaining articles in this section describe current research on nonlinear systems whose inspiration or approach relate back to Stan. In each case computer experiments are used to gain insight into complex behavior.

Turbulence, the chaotic flow we observe in streams and waterfalls, in the oceans, and in the atmosphere, is one of the most difficult problems in nonlinear science. It has defied a fundamental description by mathematicians and physicists for over a hundred years, but its effects must be modeled if we are to achieve success in many technological programs. In this issue two articles deal with attempts to model this phenomenon by computer simulation.

"Instabilities and Turbulence" by Frank Harlow and his collaborators introduces us to the nature of turbulence, describes its disruptive effects in technological applications, and presents a new theory of turbulence transport that strips away the fine-scale details of this complicated phenomenon and comes to grips with its main effects on real physical systems. As Frank mentions in "Early Work in Numerical Hydrodynamics," the approach taken in turbulence transport theory is in line with Ulam's early insight about modeling turbulence—that one needs to model not the detailed shape of the fluid flow but rather the rate of energy flow from large to smaller and smaller length scales.

"Discrete Fluids" by Brosl Hasslacher introduces an alternate and completely novel approach to modeling complex fluid flows. The model is deceptively simple—a set of particles that live on a lattice of discrete points. They hop from point to point at constant speed and when they run into one another they change direction in a way that conserves momentum. That is all there is—but in a miraculous manner still not completely understood this model reproduces the whole spectrum of collective motion in fluids, from smooth to turbulent flow. This lattice gas automaton is a variation of the cellular automata, invented by Ulam and von Neumann. Its behavior embodies one of Ulam's favorite insights—that simple rules are capable of describing arbitrarily complex behavior (maybe even the behavior of the human brain). Although the model is simple, Brosl's three-part article is rich in ideas, suggesting a new paradigm for parallel computing and for modeling many other physical systems usually described by partial differential equations.

At this point the reader may be overwhelmed by the sprawling array of topics and approaches that appear to be part of nonlinear science. Why call it *a* science instead of many different ones? In the remarkably informative overview "Nonlinear Science—From Paradigms to Practicalities" David Campbell pulls together the common features and methodology that link disparate phenomena into a single new discipline. He identifies three major paradigms of this field—solitons and coherent structures, chaos and fractals, and complex configuration and patterns—and then follows through with many examples of physical and mathematical systems in which these paradigms play a significant role. The latter two paradigms have roots in Ulam's work with Stein, discussed in the mathematics section of "The Ulam Legacy," and all three have roots in the FPU problem, Fermi, Pasta, and Ulam's seminal paper on nonlinear systems. (Excerpts of this paper appear toward the end of the physics section).

The FPU results, apart from leading to the discovery of the soliton by Kruskal and Zabusky, were the first indication that the ergodic hypothesis of statistical mechanics may be wrong. In the last paper of this section Adrian Patrascioui, the 1986 Ulam Scholar at the Laboratory's Center for Nonlinear Studies, describes further results in this direction and speculates that a reconsideration of the ergodic hypothesis may lead to profound changes in our understanding of the meaning of quantum mechanics.

The field of nonlinear science is changing our understanding of the world around us. As experimental mathematics uncovers certain universal features of complex deterministic systems, it also brings us face to face with the limits of their predictability.

We hope this section illustrates a remark from Ulam's 1984 preface, that:

". . . a mathematical turn of mind, a mathematical habit of thinking, a way of looking at problems in different subfields [of science] . . . can suggest general insights and not just offer the mere use of techniques."