ing, everyone had his own favorite procedure for these elementary functions, but gradually the better ones were included in the mathematics program library. In the '60s and '70s higher level routines for solving linear systems of equations, integrating ordinary differential equations, handling one-dimensional interpolation, and other moderately complicated procedures were developed and included in the computer library. But then in the late '70s the trend slowed down and in some cases stopped. Right now we have no appreciable effort developing the next generation of mathematics support software. If such a group existed, it would be writing even higher level routines: multidimensional interpolation and differentiation programs, grid generation and adaptive mesh routines that adjust the solution algorithm to the boundary of the problem and the structure of the solution, routines to help solve large systems of sparse nonlinear equations, and routines to incorporate the boundary conditions into a discrete approximation of the physics model,

For this new software to be successful, it must be compatible with existing techniques and be simple enough that in a trial run potential users can observe tangibly better results than with existing methods. The software packages that are most readily accepted are those that behave like the existing ones—only work better.

Industries and most universities that develop new software are too far removed from the production code programmers to interact with them and obtain the essential feedback. Also, the production codes are run on the most powerful computers available and those writing the software must have access to these machines. This means that we at the national computing centers should be writing the next generation of high-level mathematics support routines to be used in our production codes. At the same time we really should be getting together more with the scientists in industry and universities who are writing mathematics software. This means having a much more active visitor program in math software development and providing easy, long-distance access to our supercomputers.

CRAWFORD: I agree that we should forge ahead in our computer work, both the hardware and the software. Our national security will depend partly on our ability to lead the supercomputer field.

HYMAN: We need a coordinated effort like Japan's. Japan already dominates in applying robotics in industry. Through its Ministry of International Trade and Industry, it has identified other projects it plans to complete by 1990. One project is a high-speed computer whose capability is at least ten times that of the Cray-1. Another is a fifth-generation computer that will implement artificial intelligence—the number of inferences per second would be a hundred to a thousand times current technology. Losing our technological edge in these areas would have serious repercussions on both our economic and our national security.

CRAWFORD: I would like to insert another note of warning. Recombinant DNA techniques are ridiculously simple to master. The United States could suffer from foreign nations or even terrorist groups employing biological or chemical weapons. Our Laboratory is an ideal place—we have both physical isolation and classified research ability—to establish a defense program against such agents. Biological and chemical agents can and will be used by those with a cause, however ill conceived. Countermeasures like specific antitoxins are within reach of our present capability. The nation should move forward in preparing these defenses.

LANDT: To close this discussion, I would like to spend a minute or two talking about future defense. Historically this Lab has developed the nuclear side, but now we should try to get people to think about the other side, the nonnuclear. There is an antinuclear movement in this country and the world. Advances in electronics are going to permit some conventional munitions to have the same military impact as nuclear ones, and we should take advantage of that. These are some of the things the Weapons Advanced Concepts people are thinking about.

ROCKWOOD: I also believe the Laboratory should be expanding into nonnuclear weapons for defense. It appears that the nuclear age has, if you will, made the world "safe" for conventional warfare. Conflicts such as the kind in Vietnam, the Falkland Islands, and the Middle East seem those most likely to occur, and the ever-increasing role of high-technology weapons in those conflicts is a matter of which we must be cognizant. We are a nation that aspires to defend itself not by massive uses of people, but as much as possible by the use of high technology—and that means us here at Los Alamos. ■

The Participants

DAN BAKER: I got my Ph.D. at the University of Iowa with Jim Van Allen in 1974 and then went to Caltech as a Research Fellow in the Physics Division, While there I collaborated over a period of a couple of years with people from Los Alamos. In 1977 I came to Los Alamos for a job interview and was impressed with the interests and abilities of the people I encountered. I decided to join a group in the Physics Division involved in high-altitude physics, where I then worked for two or three years on satellite instrumentation and data interpretation. Since October of '81 I've been Leader of the Space Plasma Physics Group in the Earth and Space Sciences Division, which, I might add, is better known simply as Heaven and Earth Division.

STIRLING COLGATE: I came to Los Alamos primarily because the then Director of the Laboratory, Harold Agnew, and the then Leader of the Theoretical Division, Peter Carruthers, persuaded me to come. I had been a staff physicist at Lawrence Livermore Laboratory for twelve years and then President of New Mexico Tech for ten years. I realized that the type of research I knew best would utilize the facilities of a major national laboratory. My work in inertial fusion continues, and the ability to do astrophysics, atmospheric research, and tectonic engineering in an environment where my advice is respected and my research work is encouraged is a privilege beyond measure. In addition, becoming recognized as a theoretical physicist after initially being an engineer in the Merchant Marine and then being an experimental physicist for many years is a very great privilege, indeed. Explosions turn me on—from firecrackers to testing nuclear bombs at Eniwetok, from using the Lab's codes to calculate supernova explosions to preventing volcanic ones. Our universe started with an explosion, is tilled with explosions, and by far the most extraordinary and singular one is the explosion of intelligent life.

BRIAN CRAWFORD: I was actively recruited by the Laboratory while I was completing work for my Ph.D. at Johns Hopkins University. The Genetics Group of the Life Sciences Division needed someone to investigate the basic mechanisms by which ionizing radiation, chemicals, or other agents cause gene mutation and/or malignant transformation in cells. I had the specific skills required because my thesis had involved study of the genetic mechanisms of chemical carcinogenesis. I was encouraged to apply for one of the Laboratory's Oppenheimer Fellowships, which I received in time to begin work in the summer of 1981. Since I came, I have been applying recombinant DNA methods to research on the genetic events underlying carcinogenesis. What attracts me to this Lab are its advanced facilities and, above all, its cooperative atmosphere—theoreticians are working closely with biophysicists and biochemists in very sophisticated studies.

SIG HECKER: I grew up in Austria but moved to Cleveland when I was thirteen. Indeed, I had never been west of Toledo until I came here as a summer graduate student in 1965. My visit was brought about by a gentleman from the Laboratory's recruiting office who showed me a brochure containing lovely photos of New Mexico mountains. Once here I liked the marriage of basic science and applied technology at the Laboratory. After receiving my Ph.D. from Case Institute of Technology, now Case Western Reserve University, I returned to Los Alamos as a postdoc in 1968, attracted by the excellent funding and the chance to do basic research in metal deformation. In 1973 I came as a staff member after three years in the Physics Department of General Motors. I've worked ever since in materials science, principally in plutonium metallurgy and in actinides, although I've worked on a number of projects related to the space power and basic energy programs. Two years ago I joined the Division Office of what is now the Materials Science and Technology Division.

STEVEN HOWE: I'm another of those students who keep turning up. I started coming here as a summer student in 1975 and did that for the next two years. Then in January '78 I came to do my thesis research at the Weapons Neutron Research Facility at LAMPF. After receiving my degree from Kansas State University, I spent a year at Kernforschung Zentrum in Karlsruhe and then returned as a staff member in September '81. I'm in the Thermonuclear Applications Group in the Applied Theoretical Physics Division.

JAMES (MAC) HYMAN: I was indirectly introduced to Livermore and Los Alamos at the same time. I was interviewed for my graduate fellowship, a Hertz Fellowship, by someone from Livermore, and he asked, "What are you doing this summer?" I worked that summer at Livermore, and it was the first time I saw mathematicians and physicists working in close coordination with experimentalists. It was just great—except the temperature was 115 degrees. My boss at Livermore had been here during the war, and he said, "Where you really want to go next is Los Alamos." So I did, and it evolved into a full-time job after I got my degree from the Courant Institute. I work on numerical methods and software for large systems of differential equations, equations that model the physics experiments. It's partly physics, partly computer science, and mostly mathematics.

EDWARD (ROCKY) KOLB: I received my Ph.D. at the University of Texas in '78. I interviewed here for a postdoc position, but I went to Caltech instead. Then I came here as an Oppenheimer Fellow rather than going to a university, because here I could spend 100 per cent of my time doing research rather than teaching and sitting on committees. I was attracted by the people I would have a chance to work with. It was really the people who brought me here. I did my Ph.D. in elementary particle theory, and now I'm into cosmology and astrophysics, high-energy astrophysics. I'm in the Theoretical Astrophysics Group and I work closely with the Elementary Particles and Field Theory Group, an overlap that's possible here for someone not in a traditional discipline. At universities people seem more locked into compartments: there's one person in nuclear physics, one person in atomic physics, and so forth, and it's not easy to move into new fields. Here at Los Alamos you can move quickly into exciting fields as they open up.

JEREMY LANDT: The country in the western part of my home state of South Dakota is very much like the country here, so perhaps that was a factor in my initial attraction to Los Alamos. I came here in 1967 as a summer graduate student and liked the facilities and the people. When I completed my research work at Stanford, there weren't too many jobs available at Los Alamos in the areas I had studied—radiopropagation, electromagnetic theory, and that kind of thing. But there were at Livermore, so I spent a few very enjoyable years there. But I got tired of all the people and the hassle, and when something opened up here, I applied and came back in 1975. Except for the past year, my stint here has been spent in the Electronics Division. I have worked on electronic identification systems, EMP calculations, application of radar and other electronic techniques to mapping underground fractures for the hot dry rock project, plus a little nuclear magnetic resonance work, so I have dabbled in this and that. At present I'm working in the Weapons Advanced Concepts Program Office. We're supposed to be looking at wonderful new things; we're finding lots of wonderful old things that other people have thought of.

STEVE ROCKWOOD: After finishing my doctorate at Caltech in 1969, I went into the Air Force as my obligation to the country during the Vietnam era and spent two years at the Air Force Weapons Lab. There I got into laser activities, a field entirely different from my graduate work. I came to Los Alamos in 1972 principally because the laser programs then being started at the Laboratory and the people here were stimulating, It is an exciting area to work in. A secondary consideration would have to be the New Mexico environment. My own personal way of working has been to change fields frequently, although always within physics. I started out at the Laboratory as a theorist in T Division and then became part of the fledgling isotope separation program and was Leader of the Laser Development Group until 1980. Then I took over my present job as Deputy Associate Director for Inertial Fusion. To me the main attraction of the Laboratory, in contrast to universities, is its ability to pull together the resources to do a large multidisciplinary program and move on it quickly.

JOHN WHEATLEY: I received my doctorate from the University of Pittsburgh in 1952 and came here just recently, after stints at the University of Illinois and the University of California, San Diego, because I saw the opportunity to do both the basic physics research that is my main line of work and also what I call fundamental technology. That combination is highly regarded here, while in my previous university careers I always felt I had to sneak my interest in technology in the back door. After all, instruction through basic research, not development of technology, is the principal function of a university. Also, I perceive a very substantial increase in my effective mass here because the Lab has many more people interested in my field, which is thermal physics and condensed-matter physics.