LANDT: Certainly the Laboratory is aware of its obligation to help the country defend itself and to maintain a balance of technologies. Right now I am assigned to the Weapons Advanced Concepts Program Office, which was begun a year ago to try in a practical way to determine which technologies really make a difference for the national defense so that the country won't throw its money away on the wrong things. The Laboratory management is very interested in addressing this issue, and they have put dollars behind it and people to work on it.

ROCKWOOD: Today the government's method of doing business is very much applied and mission-oriented. Although basic research is also essential to our national security mission, it is often overlooked, and the national laboratories are handcuffed in this area by administrative limitations. People here have to be clever in extracting from their mission-oriented programs good basic results in science. I think Los Alamos has been rather successful at that.

WHEATLEY: Do you think mission orientation is a good thing? As a matter of principle?

ROCKWOOD: Moderation in all things.

BAKER: I think we must tight this trend toward applied work only, toward everything having an immediate payoff. A national laboratory should play as active a role in basic research as any laboratory. The country will suffer in the long run if we don't.

ROCKWOOD: Often the most exciting and fundamentally useful part of a program is not its stated objective but some unplanned spin-off. In the laser isotope separation program, spectroscopists working to explain the spectrum of the octahedral molecule UF_6 discovered that the octahedral symmetry group had originally been analyzed incorrectly and had been wrong in the literature for years. Even a very applied program may yield results of use to basic science.

BAKER: That's certainly been true in space physics. The Vela satellite program to detect nuclear explosions deep in space was a mission-oriented project, and we continue to have test and verification activities. To accomplish that practical goal we had to place instrumentation on the spacecraft to measure the environment. As a result, many properties of the magnetosphere were discovered.

Now the space physics groups are involved in a number of activities on collisionless shock waves, cosmic particle acceleration, the interplay between the solar wind and the earth's magnetic field, and the exploration by the International Sun-Earth Explorer 3 satellite of the night side of the earth.

SCIENCE: *How do you get funds for all these activities?*

BAKER: In a variety of ways. We have been able to obtain reimbursable funding from NASA [National Aeronautics and Space Administration] for some of our projects. But the continuing money from the weapons program gives us more stability than we could ever obtain from reimbursable funding alone. When we get our funding from the DOE [Department of Energy] or from the Laboratory, we are better able to make long-range plans. It's fortunate for us that the Europeans are also participating in many of our scientific satellite programs because the European Space Agency plans much further ahead than NASA does.

HYMAN: There are some problems with diversified funding. The Mathematical Modeling and Analysis Group in the Theoretical Division is almost completely basic research, and we also have been obtaining some support from outside the Laboratory. The largest block grant we have supports only one and one-half staff members. Because our funding comes in such little pieces, we are perpetual job hunters and odd jobbers—always knocking on a different door.

ROCKWOOD: The country hasn't learned how to fund basic science at all. Research doesn't integrate with time. Each administration

Dan Baker on Space Science

The Vela satellite program to detect nuclear explosions in space has led scientists at Los Alamos to satellite exploration of the magnetosphere and of a wide variety of other space phenomena. Some of the instruments aboard such spacecraft have been designed to measure the interplanetary medium and planetary bow shocks, and we are doing theoretical studies in support of these observations. A related study is our work on cosmic particle acceleration. The information about energization of particles at interplanetary shocks may have applicability to shocks of much more cosmic proportions, such as those presumed to exist in supernova remnants.

We are also exploring the interplay between the solar wind [the hot, expanding corona of the sun] and the magnetic field of the earth. This interplay produces the magnetic structure we call the magnetosphere, the tenuous plasma region that makes up the uppermost part of the earth's atmosphere. We are doing computer modeling of the entire magnetosphere and, furthermore, are developing computer network links to many other institutions involved in similar work.

In a more practical vein we are using our advancing technology to do experiments in which we release chemical tracers into the ionsphere or even deeper into the magnetosphere to learn in what way these additives may modify the outer parts of the earth's environment.

Still another project is attempting to use an existing satelite in a different and innovative way. The International Sun-Earth Explorer 3 [ISEE-3] spacecraft has been orbiting at the L-I

point on the sunward side of the earth for about four years. The L-1 point, the sun-earth Lagrangian point, can be thought of as an imaginary center of mass around which the satellite has been traveling in a large looping orbit. Now this satellite has been moved into the earth's distant magnetotail and is orbiting well downstream on the night side of the earth. It will be the first spacecraft to explore that region in space. To accomplish the move, the satellite's gas-jet thruster, which ordinarily performs minor station-keeping orbital adjustments, was used to move the craft in such a way that it encountered the moon's gravitational pull and got a lunar gravitational assist to kick it deep into the magnetotail. It is not in a stationary orbit, and thus the lunar encounters must occur every one to three months in order to keep the satellite deep in the magnetotail. Eventually another lunar push will occur, and ISEE-3 will go on to intercept a comet. This will be the first time that any spacecraft has gotten close to a cometary body.

Bob Farquhar, a very creative guy at NASA who seemingly can move any satellite anywhere you want using any other celestial object, helped with the ISEE-3 project and has also helped to plan what is called the International Solar-Polar Mission. Because we don't have enough energy in most launch vehicles to get significantly out of the ecliptic plane [the plane of the earth's orbit], we are sending a satellite out to Jupiter to get a large gravitational kick from that massive planet. The spacecraft will then move above the ecliptic plane and travel high over the sun's pole, another previously unexplored region. ●

comes in and has a new policy. Basic science suffers more from these oscillations than it would from a low level of sustained funding. And I believe Los Alamos suffers more from funding oscillations and changes in direction than other national laboratories. Our normal attrition rate is about 4 per cent per year. Any change in direction by more than that amount involves moving people around. People's skills are not always totally applicable to a different program, and those who are not absorbed by other parts of the Laboratory are not absorbed by the town at all. It is this very closed environment, which drastically constrains our flexibility, that I see as a major problem for the Laboratory. It always has been so.

Returning to the question of the funding of basic research, I feel that, although the government can't just pour out money and expect nothing in return except good intentions, the funding "pendulum" has swung too far toward applied activities.

WHEATLEY: Some of you would say that Los Alamos ought as a matter of principle to devote some fraction of its work to purely unqualified basic science, the sole motive being to understand things better and to develop knowledge or whatever-to have fun, really. I would like to suggest that perhaps that's not true. Perhaps it is our responsibility to articulate the possible relationship between our work and some appropriate mission of this Laboratory. I am not thinking of explicit applications, necessarily. Let me give you a personal example. I think that it is appropriate that my work in thermal and condensed-matter physics should feed into thermal technology. broadly defined, that is to say, into technologies that involve the concepts of energy, work, heat, temperature, and so on.

Right now I am working on heat engines. I had set myself a semipractical problem that no one in industry would define as practical of course—but it was. It had to do with producing cold very simply. I had an idea for doing that with acoustics, so I started playing around with the idea, developing it, and soon—meaning one year later—I found that what I was doing seemed to me to have very broad implications. Now I have put possible applications off to one side, and I am looking strictly at the basic science. at the fundamentals of it. I think I have identified what I regard as a new principle applying to heat engines in a very general sense. I do feel a responsibility ultimately to be able to draw a connection between the basic scientific work I do and some technology.

KOLB: I don't feel that way at all, There is a real necessity for nonmission. For fifteen years people have been looking at magnetic monopoles, intensively, just for pleasure, and for the past five or six years have been studying grand unified gauge theories—same motivation. Recently, Rubakov in Russia and Callan at Princeton have proposed that monopoles can catalyze proton decay, can just completely convert the rest mass of protons into energy. It will be another five years before it's worked out. Now something like that would have a tremendous payoff. would be comparable to Otto Hahn's discovery of fission. But it never could happen in a mission-oriented environment. No one told these people they should study monopole structure because it might have important applications. And no government agency has told me I should be studying them, either.

WHEATLEY: I'm not waiting to be told what I should do, either. For instance, I would feel perfectly tine studying spin-polarized hydrogen, a project in which 1 am very interested. Nor can I tell you what gadget that might be used in, but I do see that it is part of the foundation for thermal physics and that we ought to understand it.

KOLB: I don't choose research projects by wondering if they will have any impact on technology.

BAKER: Aren't you thinking of beam weapons systems using