but more recently it has also been used to fund new applied programs, I, for one, believe the applied programs should receive an equal share of this money. This is our investment in the programs of the future, and, in the final analysis, only programs pay the Laboratory's bills.

HECKER: The fact that this Laboratory has the foresight to take a meaningful fraction of its total income and plow it back as discretionary research is fantastic. At many other places the discretionary research money is more like one per cent. We do have an enormous opportunity for internal research. Of course, there has been a lot of upheaval recently about having to write proposals every year for ISRD money.

COLGATE: I think proposals are a darn good idea. I never did have to do them at Livermore. Then at the university I ended up having to write twelve a year. They are never easy, but they are really worth it.

BAKER: They do help people who didn't know what they were doing to think about their work a little more, but on the other side of that coin I think management can really be an obstacle.

COLGATE: Yes, if proposals are not reviewed correctly, you end up with a mess. Most proposals are now judged by the Laboratory management and the Senior Fellows, but this does not always constitute peer review.

HECKER: I agree that we do need more accountability than we used to have. However, one simply cannot set up an environment to do good basic research if proposals are required on a yearly basis. Also, the people making the decisions have become farther and farther away from the people who really know what is going on. I'd like the authority and the responsibility for research programs to rest with the divisions. By all means have an advisory panel of outside peer experts to judge the quality of the research, and if the results aren't good, then fire the division management.

BAKER: I've found that the handing out of Institutional Supporting Research money is based too much on historical factors rather than on quality of research. There is no competition in the true sense, that is, based on demonstrated scientific competence.

HECKER: That problem has been addressed to some extent. Two years ago six working groups were set up to look at areas that were not well represented traditionally, and I know that materials science has been receiving more support recently.

COLGATE: Perhaps the ultimate mechanism is, once again, the individuals. To my mind the Lab is put together of people who have an absurd sense of ego; that is, they have the drive and the motivation to back their own original ideas.

HYMAN: It's true that most projects have started with individuals who were aware that something was about ready to break. They went out and wrote proposals; they got up on their soapboxes; they sold their ideas and started small. Sometimes the ideas fizzled out, but other times they turned into whole divisions.

BAKER: Jerry, what reception do you find to suggestions being made by the Weapons Advanced Concepts people?

LANDT: Very good in general, but there are some people who resist change and don't like to see things at the Laboratory change.

HOWE: I find in the weapons program that you can have a wonderful idea either in software or in hardware, and, fine, they will help you develop it and make the best calculations possible. But then they fail to implement it. Furthermore, we are being urged to develop our own codes rather than just to borrow from Livermore. And in fact we do have several new ones, but I find there is some resistance to changing several hundred thousand lines of a code and putting in the new stuff. The same kind of reluctance appears in the hardware; it takes several years to get a materials idea implemented.

KOLB: Is that a management problem?

Rocky Kolb on Cosmology

"Cosmos" is the Greek word meaning order, and the basic goal of cosmology is to understand the universe on the basis of physical law. By applying physics to what we see in the universe, we endeavor to understand the structure of galaxies and the origin and large-scale structure of the universe.

Within the past five years or so some very interesting and very bold particle physics theories have been hypothesized. They model the physics of incredibly small scales-down to Planck's scale, which is about 10^{-33} centimeter. These theories are extrapolations, but there is some physical basis to them and they imply certain things about the universe. For example, they predict proton decay and the existence of magnetic monopoles. If these predictions are correct, then we now have models of the structure of matter under unbelievably extreme conditions of density and temperature, and we are in a position to study the very, very early universe. By the early universe we used to mean 1 minute or 1 second after the big bang. Now we can talk about 10^{-33} or 10^{-38} or 10^{-40} second because we believe we have a model of the underlying physics with which to do the astrophysics and cosmology.

Some practical questions we might answer are how many magnetic monopoles are expected to be around, what are their properties, and how would one look for them. Another possible insight is understanding the asymmetry of the universe in baryons-that is, why there aren't an equal number of baryons and antibaryons. Unfortunately the big bang is not an experiment that you would want to-or could-duplicate.

Study of the early universe leaves an interesting unanswered question: why the universe is so old, If you look at the Einstein equations that describe the evolution of the universe, the only time scale that appears is the Planck time, which is about 10^{-45} second. It is rather hard to understand why today, ten billion years, or 10^{60} Planck times, after the big bang, the universe hasn't either recollapsed or expanded to an extent that the gravitational attraction of the matter is irrelevant in the expansion. Today we cannot determine whether the universe will expand forever or eventually recontract, since the kinetic energy of expansion is almost equal and opposite to the gravitational potential energy. This seems to imply that in the initial expansion the kinetic energy balanced the gravitational energy to something like one part in 1056—essentially a zero-energy system. This conundrum has a possible explanation if the universe underwent a strong first-order phase transition. An active field now is phase transitions in the early universe. This is a true interdisciplinary field, bringing in particle physics, general relativity, and statistical mechanics,

Our investigations may also have a number of reciprocal implications for particle physics. It has become fashionable every time a particle physics model is proposed to look for the astrophysical impact of it, You try to see whether the new model does things to the universe that you can't allow. For example, does it lead to too much mass density in the universe? Another example is monopole-catalyzed proton decay, Colgate and I have pointed out that such decay would have a terrible environmental impact on neutron stars. The work we have done leads us to believe that either monopoles do not catalyze proton decay or that monopoles don't exist, which would really be a shame because their existence would have enormous practical implications. ■

HYMAN: It is somewhat a management problem in that the codes have been allowed to grow unstructured for so many years that they have become the unmanageable things they are.

HOWE: It may be an external problem—one caused by whoever is using the weapons.

CRAWFORD: The external response to new ideas probably varies greatly from agency to agency. The Office of Health and Environmental Research, which oversees much of the research in the Life Sciences Division, is quite receptive to new programs.

COLGATE: Other offices of the DOE are also receptive. For example, Rocky has had ISRD support for some time doing far-out research in cosmology relating to conditions in the early universe. But what's really relevant is that last year the Office of High Energy and Nuclear Physics saw tit to pick up part of his funding. Nothing ventured, nothing gained!

SCIENCE: *With regard to external support for new ideas, the Laboratory is encouraging more interactions with industry. How will this affect the Laboratory?*

ROCKWOOD: I would say that a closer union of this Lab and industry would be mutually beneficial. The best single thing that has happened is that the DOE may now allow patent rights to remain with a funding company. Private industry can now put some money into a national lab without losing all rights to patents that emerge from the work. For instance, an industrial organization that wants to get involved in a new venture requiring a group of plasma physicists wouldn't have to hire twenty of their own while they got started. Instead, they could hire our expertise in that area to help them get started—a healthy collaboration.

WHEATLEY: I really think that is right.

ROCKWOOD: I see us starting to make some progress. We have money coming from Westinghouse to help look for a method of enriching certain isotopes that they are interested in as a company. They would have refused to invest this money in us a year ago,

BAKER: The hot dry rock project is a related example. Money is coming from a variety of sources, such as the Japanese government and the German government, as well as our own government.

SCIENCE: *We hire the people and they fund them?*

ROCKWOOD: They hire our people, if you will. They contract to us to do a specific task that saves industry from building up a highly specialized group of people they don't need for the long term.

HYMAN: The kind of basic research a lot of us do is oriented toward the very large problem with very limited applications. Take the supercomputers. There just aren't that many supercomputers out there. Most vendors can't afford to support the effort needed to develop new algorithms and software that push these computers to their limits. Yet it is quite appropriate for us to do that here.

HOWE: I can forsee that industry funding might compete with basic research for a person's time. Since it is near-term support, you are going to have managers saying, "AH right, we want you guys to work on this project for Westinghouse, and you have to put aside your basic research for now."

ROCKWOOD: I think rather that industry will be wanting to use basic research that we have already completed. But I won't say that conflicts will never arise. They'll have to be worked out.

CRAWFORD: If we become closely allied with both universities and private industry, perhaps we will be able to function more as a research and development organization—taking ideas from university programs and assigning teams of researchers well qualified to test the feasibility of such ideas—with the goal of technology transfer to private industry.

SCIENCE: *Gentlemen, it seems that our relationship with industry may undergo a change. What other changes would you like to see*